Appendix 2-C
HBPP Groundwater Monitoring Summary

HBPP Groundwater Monitoring Summary

Well/Quarter	Gross Beta	H-3	Sr-90	Gross Alpha	Am-241	Co-60	Cs-137
1C-MW-07/ 2nd 2009	13.4 pCi/L	<MDC	<MDC	10.5 pCi/L	<MDC	<MDC	<MDC
RCW-CS-1/ 2nd 2009	19.4 pCi/L	<MDC	<MDC	<MDC	<MDC	<MDC	<MDC
1EW-MW-12/ 2nd 2009	5.59 pCi/L	<MDC	<MDC	4.82 pCi/L	<MDC	<MDC	<MDC
5G-MW-03/ 2nd 2009	3.59 pCi/L	<MDC	<MDC	<MDC	<MDC	<MDC	<MDC
RCW-CS-5/ 2nd 2009	<MDC	<MDC	<MDC	<MDC	<MDC	<MDC	<MDC
MW-1/ 2nd 2009	5.19 pCi/L	<MDC	<MDC	<MDC	<MDC	<MDC	<MDC
1C-MW-08/ 2nd 2009	5.32 pCi/L	<MDC	<MDC	<MDC	<MDC	<MDC	<MDC
RCW-CS-4/ 2nd 2009	5.92 pCi/L	<MDC	<MDC	<MDC	<MDC	<MDC	<MDC
MW-2/ 2nd 2009	3.60 pCi/L	<MDC	<MDC	<MDC	<MDC	<MDC	<MDC
MW-6/ 2nd 2009	<MDC	<MDC	<MDC	<MDC	<MDC	<MDC	<MDC
RCW-CS-2/ 2nd 2009	<MDC	<MDC	<MDC	<MDC	<MDC	<MDC	<MDC
MW-4/ 2nd 2009	6.93 pCi/L	<MDC	0.59 pCi/L	<MDC	<MDC	<MDC	<MDC
MW-11/ 2nd 2009	6.00 pCi/L	<MDC	<MDC	<MDC	<MDC	<MDC	<MDC
RCW-CS-3/ 2nd 2009	<MDC	<MDC	<MDC	<MDC	<MDC	<MDC	<MDC
1E-MW-13/ 2nd 2009	2.67 pCi/L	<MDC	<MDC	<MDC	<MDC	<MDC	<MDC
SFP-1/ 2nd 2009	4.30 pCi/L	<MDC	<MDC	<MDC	<MDC	<MDC	<MDC
RCW-SFP-2/ 2nd 2009	4.83 pCi/L	<MDC	<MDC	<MDC	<MDC	<MDC	<MDC
1H-MW-02/ 2nd 2009	N/A	<MDC	N/A	N/A	N/A	N/A	N/A
RCW-CS-2/ 3rd 2009	11.0 pCi/L	<MDC	<MDC	<MDC	<MDC	<MDC	<MDC
MW-4/ 3rd 2009	9.19 pCi/L	<MDC	<MDC	<MDC	<MDC	<MDC	<MDC
MW-1/ 3rd 2009	12.6 pCi/L	<MDC	<MDC	<MDC	<MDC	<MDC	<MDC
SFP-1/ 3rd 2009	5.78 pCi/L	<MDC	<MDC	<MDC	<MDC	<MDC	<MDC
MW-11/ 3rd 2009	8.88 pCi/L	<MDC	<MDC	<MDC	<MDC	<MDC	<MDC
1E-MW-13/ 3rd 2009	<MDC	<MDC	<MDC	<MDC	<MDC	<MDC	<MDC
RCW-SFP-2/ 3rd 2009	4.86 pCi/L	<MDC	<MDC	<MDC	<MDC	<MDC	<MDC

Well/Quarter	Gross Beta	H-3	Sr-90	Gross Alpha	Am-241	Co-60	Cs-137
1C-MCW-8/ 3rd 2009	5.57 pCi/L	<MDC	<MDC	<MDC	<MDC	<MDC	<MDC
RCW-CS-1/ 3rd 2009	28.1 pCi/L	<MDC	<MDC	80.6 pCi/L	<MDC	<MDC	<MDC
1C-MW-07/ 3rd 2009	13.7 pCi/L	<MDC	<MDC	7.09 pCi/L	<MDC	<MDC	<MDC
5G-MW-03/ 3rd 2009	4.19 pCi/L	<MDC	<MDC	2.87 pCi/L	<MDC	<MDC	<MDC
RCW-CS-5/ 3rd 2009	3.55 pCi/L	<MDC	<MDC	2.62 pCi/L	<MDC	<MDC	<MDC
1E-MW-12/ 3rd 2009	15.5 pCi/L	<MDC	<MDC	11.1 pCi/L	<MDC	<MDC	<MDC
RCW-CS-3/ 3rd 2009	3.63 pCi/L	<MDC	<MDC	<MDC	<MDC	<MDC	<MDC
RCW-CS-4/ 3rd 2009	<MDC	<MDC	<MDC	<MDC	<MDC	<MDC	<MDC
MW-2/ 3rd 2009	6.83 pCi/L	<MDC	<MDC	<MDC	<MDC	<MDC	<MDC
MW-6/ 3rd 2009	<MDC	<MDC	<MDC	<MDC	<MDC	<MDC	<MDC
RCW-CS-2/ 4th 2009	7.19 pCi/L	<MDC	<MDC	<MDC	<MDC	<MDC	<MDC
MW-4/ 4th 2009	7.25 pCi/L	<MDC	<MDC	<MDC	<MDC	<MDC	<MDC
MW-1/ 4th 2009	8.30 pCi/L	<MDC	<MDC	<MDC	<MDC	<MDC	<MDC
RCW-SFP-1/ 4th 2009	<MDC	<MDC	<MDC	<MDC	<MDC	<MDC	<MDC
MW-11/ 4th 2009	6.99 pCi/L	<MDC	<MDC	<MDC	<MDC	<MDC	<MDC
1E-MW-13/ 4th 2009	<MDC	<MDC	<MDC	<MDC	<MDC	<MDC	<MDC
RCW-SFP-2/ 4th 2009	41.4 pCi/L	<MDC	<MDC	<MDC	<MDC	<MDC	<MDC
1C-MCW-08/ 4th 2009	3.50 pCi/L	<MDC	<MDC	2.22 pCi/L	<MDC	<MDC	<MDC
RCW-CS-1/ 4th 2009	<MDC	<MDC	<MDC	<MDC	<MDC	<MDC	<MDC
MW-2/ 4th 2009	4.08 pCi/L	<MDC	<MDC	<MDC	<MDC	<MDC	<MDC
MW-6/ 4th 2009	3.19 pCi/L	952 pCi/L	<MDC	<MDC	<MDC	<MDC	<MDC
RCW-CS-5/ 4th 2009	6.73 pCi/L	<MDC	<MDC	<MDC	<MDC	<MDC	<MDC
1E-MW-12/ 4th 2009	14.3 pCi/L	<MDC	<MDC	<MDC	<MDC	<MDC	<MDC
RCW-CS-3/ 4th 2009	<MDC	<MDC	<MDC	<MDC	<MDC	<MDC	<MDC
RCW-CS-4/ 4th 2009	5.24 pCi/L	<MDC	<MDC	<MDC	<MDC	<MDC	<MDC
MW-1/ 1st 2010	4.54 pCi/L	<MDC	<MDC	<MDC	<MDC	<MDC	<MDC

Well/Quarter	Gross Beta	H-3	Sr-90	Gross Alpha	Am-241	Co-60	Cs-137
MW-2/ 1st 2010	7.64 pCi/L	<MDC	<MDC	<MDC	<MDC	<MDC	<MDC
MW-4/ 1st 2010	13.2 pCi/L	<MDC	<MDC	8.35 pCi/L	<MDC	<MDC	<MDC
MW-6/ 1st 2010	<MDC	<MDC	<MDC	<MDC	<MDC	<MDC	<MDC
MW-11/ 1st 2010	<MDC	<MDC	<MDC	<MDC	<MDC	<MDC	<MDC
RCW-CS-1/ 1st 2010	9.02 pCi/L	<MDC	<MDC	29.7 pCi/L	<MDC	<MDC	<MDC
RCW-CS-2/ 1st 2010	10.2 pCi/L	<MDC	<MDC	<MDC	<MDC	<MDC	<MDC
RCW-CS-3/ 1st 2010	<MDC	<MDC	<MDC	<MDC	<MDC	<MDC	<MDC
RCW-CS-4/ 1st 2010	<MDC	<MDC	<MDC	<MDC	<MDC	<MDC	<MDC
RCW-CS-5/ 1st 2010	<MDC	<MDC	<MDC	<MDC	<MDC	<MDC	<MDC
RCW-SFP-1/ 1st 2010	<MDC	<MDC	<MDC	<MDC	<MDC	<MDC	<MDC
1E-MW-12/ 1st 2010	<MDC	<MDC	<MDC	<MDC	<MDC	<MDC	<MDC
1E-MW-13/ 1st 2010	<MDC	<MDC	<MDC	<MDC	<MDC	<MDC	<MDC
RCW-SFP-2/ 1st 2010	<MDC	<MDC	<MDC	<MDC	<MDC	<MDC	<MDC
1C-MW-08/ 1st 2010	2.82 pCi/L	<MDC	<MDC	<MDC	<MDC	<MDC	<MDC
1C-MW-07/ 1st 2010	<MDC	<MDC	<MDC	<MDC	<MDC	<MDC	<MDC
MW-1/ 2nd 2010	<MDC	<MDC	<MDC	<MDC	<MDC	<MDC	<MDC
MW-2/ 2nd 2010	3.85 pCi/L	<MDC	<MDC	<MDC	<MDC	<MDC	<MDC
MW-4/ 2nd 2010	12.6 pCi/L	N/A	<MDC	9.19 pCi/L	<MDC	<MDC	<MDC
MW-6/ 2nd 2010	<MDC	<MDC	<MDC	<MDC	<MDC	<MDC	<MDC
MW-11/ 2nd 2010	7.09 pCi/L	N/A	<MDC	<MDC	<MDC	<MDC	<MDC
RCW-CS-1/ 2nd 2010	17.8 pCi/L	<MDC	<MDC	<MDC	<MDC	<MDC	<MDC
RCW-CS-2/ 2nd 2010	31.4 pCi/L	N/A	<MDC	27.4 pCi/L	<MDC	<MDC	<MDC
RCW-CS-3/ 2nd 2010	<MDC	<MDC	<MDC	<MDC	<MDC	<MDC	<MDC
RCW-CS-4/ 2nd 2010	5.19 pCi/L	<MDC	<MDC	<MDC	<MDC	<MDC	<MDC
RCW-CS-5/ 2nd 2010	<MDC	<MDC	<MDC	<MDC	<MDC	<MDC	<MDC
RCW-SFP-1/ 2nd 2010	<MDC	<MDC	<MDC	<MDC	<MDC	<MDC	<MDC

Well/Quarter	Gross Beta	H-3	Sr-90	Gross Alpha	Am-241	Co-60	Cs-137
1E-MW-12/ 2nd 2010	<MDC	<MDC	<MDC	<MDC	<MDC	<MDC	<MDC
1E-MW-13/ 2nd 2010	2.98 pCi/L	<MDC	<MDC	<MDC	<MDC	<MDC	<MDC
RCW-SFP-2/ 2nd 2010	<MDC	N/A	<MDC	<MDC	<MDC	<MDC	<MDC
1C-MW-08/ 2nd 2010	2.87 pCi/L	<MDC	<MDC	<MDC	<MDC	<MDC	<MDC
1C-MW-07/ 2nd 2010	2.97 pCi/L	<MDC	<MDC	<MDC	<MDC	<MDC	<MDC
MW-1/ 3rd 2010	<MDC	<MDC	<MDC	<MDC	<MDC	<MDC	<MDC
MW-2/ 3rd 2010	<MDC	<MDC	<MDC	<MDC	<MDC	<MDC	<MDC
MW-4/ 3rd 2010	6.41 pCi/L	<MDC	<MDC	<MDC	<MDC	<MDC	<MDC
MW-6/ 3rd 2010	<MDC	<MDC	<MDC	<MDC	<MDC	<MDC	<MDC
MW-11/ 3rd 2010	<MDC	<MDC	<MDC	<MDC	<MDC	<MDC	<MDC
RCW-CS-1/ 3rd 2010	<MDC	<MDC	<MDC	<MDC	<MDC	<MDC	<MDC
RCW-CS-2/ 3rd 2010	<MDC	<MDC	<MDC	<MDC	<MDC	<MDC	<MDC
RCW-CS-3/ 3rd 2010	<MDC	<MDC	<MDC	<MDC	<MDC	<MDC	<MDC
RCW-CS-4/ 3rd 2010	10.8 pCi/L	<MDC	<MDC	<MDC	<MDC	<MDC	<MDC
RCW-CS-5/ 3rd 2010	<MDC	<MDC	<MDC	<MDC	<MDC	<MDC	<MDC
RCW-SFP-1/ 3rd 2010	<MDC	<MDC	<MDC	<MDC	<MDC	<MDC	<MDC
RCW-SFP-2/ 3rd 2010	<MDC	<MDC	<MDC	<MDC	<MDC	<MDC	<MDC
1C-MW-07/ 3rd 2010	7.32 pCi/L	<MDC	<MDC	<MDC	<MDC	<MDC	<MDC
1C-MW-08/ 3rd 2010	8.65 pCi/L	<MDC	<MDC	<MDC	<MDC	<MDC	<MDC
1E-MW-12/ 3rd 2010	86.0 pCi/L	<MDC	<MDC	103 pCi/L	<MDC	<MDC	<MDC
1E-MW-13/ 3rd 2010	<MDC	<MDC	<MDC	<MDC	<MDC	<MDC	<MDC
MW-1/ 4th 2010	<MDC	<MDC	<MDC	<MDC	<MDC	<MDC	<MDC
MW-2/ 4th 2010	<MDC	<MDC	<MDC	<MDC	<MDC	<MDC	<MDC
MW-4/ 4th 2010	3.92 pCi/L	<MDC	<MDC	<MDC	<MDC	<MDC	<MDC
MW-6/ 4th 2010	<MDC	<MDC	<MDC	<MDC	<MDC	<MDC	<MDC
MW-11/ 4th 2010	<MDC	<MDC	<MDC	<MDC	<MDC	<MDC	<MDC

Well/Quarter	Gross Beta	H-3	Sr-90	Gross Alpha	Am-241	Co-60	Cs-137
RCW-CS-1/ 4th 2010	18.6 pCi/L	<MDC	<MDC	<MDC	<MDC	<MDC	<MDC
RCW-CS-2/ 4th 2010	17.2 pCi/L	<MDC	<MDC	4.85 pCi/L	<MDC	<MDC	<MDC
RCW-CS-3/ 4th 2010	5.13 pCi/L	<MDC	<MDC	<MDC	<MDC	<MDC	<MDC
RCW-CS-4/ 4th 2010	<MDC	<MDC	<MDC	<MDC	<MDC	<MDC	<MDC
RCW-CS-5/ 4th 2010	<MDC	<MDC	<MDC	<MDC	<MDC	<MDC	<MDC
RCW-SFP-1/ 4th 2010	<MDC	<MDC	<MDC	<MDC	<MDC	<MDC	<MDC
RCW-SFP-2/ 4th 2010	6.33 pCi/L	<MDC	<MDC	<MDC	<MDC	<MDC	<MDC
1C-MW-07/ 4th 2010	3.28 pCi/L	<MDC	<MDC	<MDC	<MDC	<MDC	<MDC
1C-MW-08/ 4th 2010	11.5 pCi/L	<MDC	<MDC	8.71 pCi/L	<MDC	<MDC	<MDC
1E-MW-12/ 4th 2010	9.32 pCi/L	<MDC	<MDC	<MDC	<MDC	<MDC	<MDC
1E-MW-13/ 4th 2010	<MDC	<MDC	<MDC	<MDC	<MDC	<MDC	<MDC

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TABLES

No table of figures entries found.

3 IDENTIFICATION OF REMAINING DECOMMISSIONING ACTIVITIES

3.1 Introduction

In accordance with 10 CFR 50.82(a)(9)(ii)(B), the License Termination Plan (LTP) must identify the major remaining dismantlement and decontamination activities. This chapter was written following the guidance of NUREG-1700, "Standard Review Plan for Evaluating Nuclear Power Reactor License Termination Plans," (Reference 3-1) and Regulatory Guide 1.179, "Standard Format and Content of License Termination Plans for Nuclear Power Reactors," (Reference 3-2) and will discuss those remaining dismantlement activities as of April 12, 2013. Information is presented to demonstrate that these activities will be performed in accordance with 10 CFR 50 and will not be detrimental to the common defense and security or to the health and safety of the public pursuant to 10 CFR 50.82(a) (10). Information that demonstrates that these activities will not have a significant effect on the quality of the environment is provided in LTP Chapter 8, Supplement to the Environmental Report.

The information includes those areas and equipment in need of further remediation, and an estimate of radiological conditions that may be encountered. Included are estimates of associated occupational radiation dose and projected volumes of radioactive waste. Humboldt Bay Power Plant (HBPP's) primary goals are to decommission HBPP safely and successfully terminate the HBPP license. HBPP will decontaminate and dismantle HBPP in accordance with the DECON alternative, as described in NUREG-0586, "Final Generic Environmental Impact Statement" (GEIS) (Reference 3-3). Completion of the DECON option is contingent upon access to one or more low-level waste (LLW) disposal sites. Currently, HBPP has access to the disposal facilities in Utah, Texas, and Idaho.

HBPP is currently conducting decontamination and dismantlement (D&D) activities at the HBPP site in accordance with HBPP procedures and approved work packages. Decommissioning activities are being coordinated with the appropriate federal and state regulatory agencies.

Decommissioning activities at HBPP are conducted in accordance with the HBPP PSDAR, Radiation Protection Program, written work plans, existing 10 CFR Part 50 license, and the requirements of 10 CFR 50.82(a)(6) and 10 CFR 50.82(a)(7). If an activity requires prior NRC approval under 10 CFR 50.59(c)(2) or a change to the HBPP Technical Specifications or license, a submittal will be provided to the NRC for review and approval prior to implementation of the activity in question.

The activities listed in Section 3.3, "Future Decommissioning Activities," include activities up to future release of the site. This section provides an overview of the major remaining decommissioning activities.

Information related to the remaining D&D tasks is provided in Section 3.4. This information includes an estimate of the quantity of radioactive material to be disposed in accordance with 10 CFR 20.2001, a description of proposed control mechanisms to ensure areas are not recontaminated, estimates of occupational exposures, and characterization of radiological conditions to be encountered and the types and quantities of radioactive waste. This information supports the assessment of impacts considered in other sections of the LTP and provides sufficient detail to identify inspections or technical resources needed during the remaining dismantlement activities. Many of these dismantlement tasks require coordination with other federal, state, or local regulatory agencies or groups.

The dismantlement activities described in Section 3.3 provide the NRC the information to support site release and future license termination pursuant to 10 CFR 50.82(a)(11)(i). Therefore, this section was written in order to indicate clearly each major dismantlement activity that remains to be completed prior to qualifying for license termination. The final state of the HBPP site will be an electrical production facility for approximately 30 years (as defined in Chapter 1). The impact of decommissioning activities performed will be to reduce residual radioactivity to a level of 25 mrem/year and as low as reasonably achievable (ALARA) from all potential pathways to the average member of the critical group (Resident Farmer).

3.2 Completed Decommissioning Activities and Tasks

3.2.1 *Spent Fuel Storage*

The Humboldt Bay Independent Spent Fuel Storage Installation (ISFSI) was loaded with five Hi-Star HB casks between August 2008 and December 2008 containing all the spent nuclear fuel stored onsite at the HBPP, licensed under a 10 CFR 72 Site Specific License. This removed all spent fuel assemblies from the spent fuel pool. A sixth Hi-Star cask is being constructed for eventual use in storing the Greater Than Class C (GTCC) waste that includes items from ongoing dismantlement activities of the reactor vessel. The GTCC waste will be placed in the ISFSI for temporary storage and eventually transferred to a national permanent repository along with the spent fuel.

3.2.2 *Spent Fuel Pool Activities*

The spent fuel racks have been removed.

3.2.3 *Reactor Building*

- The drywell shield plugs as well as the drywell head have been removed
- Reactor and drywell heads have been shipped
- The reactor internals have been removed

3.2.4 *Liquid Radwaste (LRW) Building*

Currently, the evaporator and miscellaneous tanks have been removed.

3.2.5 *Turbine Building*

The following activities have been completed in the Turbine Building:

- Main Turbine removal
- Condenser removal
- Steam, feedwater, and seal oil piping removal

3.2.6 *Miscellaneous Structures*

The following miscellaneous structures activities have been completed:

- Aboveground portions of Fossil Units 1 and 2 have been demolished and removed.
- Mobil Emergency Power Plant Stations (MEPPs) 1 and 2 have been removed from site.
- All fuel oil tanks associated with Units 1 and 2 have been demolished and removed.
- A section of the circulation water piping has been removed.
- A majority of the ventilation stack has been demolished and removed.

3.3 Future Decommissioning Activities

3.3.1 *Remaining Component Removal*

The following table lists the remaining major activities associated with the decommissioning of HBPP and their projected completion date:

Table3-1 Major Remaining Activities and Completion Dates

Activity	Projected Completion Date
Reactor vessel removal	Mid 2014
Reactor Building above grade removal	Late 2015
Spent Fuel Pool removal	Mid 2016
Caisson removal	Mid 2018
LRW Building removal	Mid 2014
Turbine Building removal	Mid 2013
Waste Buildings and vaults removal	Mid 2014
Slurry Wall installation	Mid 2014
GTCC waste moved to ISFSI	Late 2013
Intake Canal dredging/remediation	Mid 2015
Discharge Canal dredging/ remediation	Mid 2015
Site restoration	Late 2018
Final Status Survey (FSS) activities	Late 2019

3.3.2 *Control Mechanisms to Ensure No Recontamination*

Due to the large scope of remaining structures and systems to be decontaminated and the need for some FSS activities to be performed in parallel with dismantlement activities, a systematic approach to controlling areas is established. Upon commencement of the FSS for survey areas where there is a potential for recontamination, implementation of one or more of the following control measures will be implemented:

- Personnel training
- Installation of barriers to control access to surveyed areas
- Installation of barriers to prevent the migration of contamination from adjacent areas
- Installation of postings requiring personnel to perform contamination monitoring prior to surveyed area access
- Locking entrances to surveyed areas of the facility
- Installation of tamper-evident labels or seals
- Upon completion of FSS, the area will be placed under periodic routine surveillance survey by the FSS department to ensure no recontamination occurs. If recontamination is identified, an investigation will be initiated that could result in corrective actions up to and including reperformance of the FSS for that area.

3.4 Occupational Exposure

Table 3-2 provides HBPP cumulative site dose and estimates for the decommissioning project. These estimates were developed to provide site management ALARA goals. The goals are verified by summation of actual site dose, as determined by appropriate dosimetry. Exposure estimates are a compilation of radiation work permit estimates for the period. The total nuclear worker exposure during decommissioning is currently estimated to be less than 154 person-rem. This estimate is significantly below the 1,874 person-rem estimate of the GEIS for immediate dismantlement and below the ten-year SAFSTOR estimate of 834 person-rem.

Table3-2 HBPP Cumulative Site Dose

Year	Exposure (person-rem)
2009	0.631
2010	7.691
2011	6.709
2012	13.5
2013-2018	125*

*estimated exposure

3.4.1 *Public Exposure*

Continued application of HBPP's current and future Radiation Protection and Radiological Effluent Programs ensures public protection in accordance with 10 CFR 20 and 10 CFR 50, Appendix I. Sections 3.4.4 and 3.4.5 conclude that the public exposure as a result of decommissioning activities is bounded by the evaluation in the GEIS, which concludes the impact is small.

3.4.2 *Estimate of Quantity of Radioactive Material to be Shipped for Disposal.*

HBPP has shipped for radioactive disposal approximately 2,220 cubic meters (m^3) (78,399 cubic feet [ft^3]) of waste through December 31, 2011. The estimate of remaining waste is 62,031 m^3 (2,190,604 ft^3), most of which is very low activity soils, sediments, and concrete debris. This volume of waste exceeds the NUREG-0586 volume for the reference boiling water reactor of 18,343 m^3 (647,777 ft^3). The additional waste generated is mainly due to the removal of the caisson and the removal of low-level sediments in the Discharge Canal. An environmental impact assessment due to the additional volume of waste generated is provided in Chapter 8 of the LTP.

3.4.3 *Solid Waste Activity and Volume*

HBPP's Annual Radioactive Effluent Release Report (Reference 3-4, 3-5 and 3-6), required by Section 3.7.3 of the Humboldt Bay Power Plant Unit 3 SAFSTOR Quality Assurance Plan, includes a report on solid waste activity and volumes. This report is submitted annually. A summary of solid waste disposal for 2009 through 2011, with an estimate for the remainder of the project is provided in Table 3-3. Future updates may be obtained from HBPP for inspection.

Table3-3 Solid Waste Effluent Release Report Summary

Year	Volume (m^3)	Total Curies
2009	252.8	0.101
2010	1312	1.12
2011	654.73	3.661
2012-2019	62,031*	3335*

* Estimated values

3.4.4 *Liquid Waste Activity and Volume*

HBPP also reports, in the Annual Radioactive Effluent Release Report, data on liquid waste discharged in effluents from the facility. The set of data provided in Table 3-4 provides a compilation of this information. The following text summarizes the liquid waste effluent release reports for 2009 through 2011. Liquid effluent release data were not available for 2013 at the time of this LTP submittal; future updates may be obtained from HBPP for inspection. Releases for 2013 are expected to be similar to 2010 releases, a small fraction of the limits. Liquid radioactive discharges are expected to cease in 2014.

Table3-4 Liquid Waste Effluent Releases

Year	Tritium Release (Ci)	Dissolved and Entrained Gas Release (Ci)	Alpha Release (Ci)	Other Fission and Activation Release (Ci)	Volume (Liters)	Volume of Dilution Water (Liters)
2009	2.74E-03	0	2.29E-06	5.08E-04	1.01E+05	7.23E+10
2010	1.88E-03	0	1.06E-05	5.39E-03	2.72E+05	7.57E+10
2011	7.66E-04	0	4.60E-06	4.48E-03	2.47E+05	1.04E+09
2012	3.15E-03	0	2.01E-06	1.92E-03	4.00E+05	1.93E+09
2013*	1.88E-03*	0*	1.06E-05*	5.39E-03*	2.72E+05*	7.57E+10*
2014**	0*	0*	0*	0*	0*	N/A*
2015	0*	0*	0*	0*	0*	N/A*
2016	0*	0*	0*	0*	0*	N/A*
2017	0*	0*	0*	0*	0*	N/A*
2018	0*	0*	0*	0*	0*	N/A*

*Estimated values
**Any wastewater will be shipped off-site and some low level activity will be likely discharged through the Ground Water Treatment System and will be monitored and accounted for as a discharge.

Radiation doses for the maximally exposed individuals both actual and projected due to liquid waste effluent releases are 0.07 mrem for the decommissioning period, which is bounded by the evaluation in the GEIS (less than 0.1 person-rem).

3.4.5 *Gaseous Waste Activity and Volume*

HBPP also reports, in the Annual Radioactive Effluent Release Report, data on gaseous waste. The set of data provided in Table 3-5 provides a compilation of this information. A summary of the gaseous waste effluent release reports for 2009 through 2011 with an estimate for the remainder of the project follows.

Table3-5 Gaseous Waste Effluent Releases

Year	Fission and Activation Gas Release (Ci)	Iodines (Ci)	Particulates (Ci)
2009	<MDA	<MDA	4.99E-09
2010	<MDA	<MDA	1.72E-07
2011	<MDA	<MDA	4.71E-08
2012	<MDA	<MDA	7.00E-08
2013*	<MDA	<MDA	<1.72E-07
2014*	<MDA	<MDA	<1.72E-07
2015*	<MDA	<MDA	<1.72E-07
2016*	<MDA	<MDA	<1.72E-07
2017*	<MDA	<MDA	<1.72E-07
2018*	<MDA	<MDA	<1.72E-07
2019*	<MDA	<MDA	<1.72E-07

* Estimated values

Radiation doses for the maximally exposed individuals both actual and projected due to gaseous waste effluent releases are 0.00 mrem (total body-teen age group) and 0.00 mrem (bone-teen age group), which is bounded by the evaluation in the GEIS (less than 0.1 person-rem).

3.5 Site Description after License Release

Currently, the Count Room Building, Waste Management Building, Security buildings, Administration buildings, Training building, ISFSI, and Humboldt Bay Generating Station (HBGS) are the only structures scheduled to remain onsite at the time of license termination. All other above-grade structures will have been removed and the site will have been graded.

3.6 Coordination with Outside Entities

The decommissioning and termination of HBPP's 10 CFR 50 license involves, among others, the US NRC, several State of California regulatory agencies, US Army Corp of Engineers, and the US Department of Transportation.

Chapter 8, "Supplement to the Environmental Report," discusses some of the related requirements.

3.7 References

3-1 U.S. Nuclear Regulatory Commission NUREG-1700, "Standard Review Plan for Evaluating Nuclear Power Reactor License Termination Plans," April 2000

3-2 U.S. Nuclear Regulatory Commission Regulatory Guide 1.179, "Standard Format and Content of License Termination Plans for Nuclear Power Reactors," January 1999

3-3 U.S. Nuclear Regulatory Commission NUREG-0586, "Final Generic Environmental Impact Statement (GEIS) on Decommissioning of Nuclear Facilities," October 2002, Supplement 1

3-4 HBPP Annual Radioactive Effluent Release Report, March 30, 2010

3-5 HBPP Annual Radioactive Effluent Release Report, March 31, 2011

3-6 HBPP Annual Radioactive Effluent Release Report, March 30, 2012

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TABLES

4 SITE REMEDIATION PLAN

4.1 Remediation Actions and ALARA Evaluations

This chapter of the License Termination Plan (LTP) describes various remediation and decontamination actions that may be used during the decommissioning of Humboldt Bay Power Plant (HBPP), Unit 3. Additionally described are the methods used to reduce residual contamination to levels that comply with the NRC's annual dose limit of 25 mrem, and as low as reasonably achievable (ALARA). Finally, the Radiation Protection Program requirements for the remediation are also 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. Activities performed solely to accommodate Final Status Survey (FSS) measurements (e.g., wiping down of surfaces, shaving concrete to allow for proper instrument probe geometries) will not be evaluated for ALARA.

4.2.1 *Structures*

Following the removal of designated equipment and components, structures will be surveyed as necessary, and contaminated materials will be remediated or removed and disposed as radioactive waste. Contaminated structural surfaces that will remain onsite after license termination will be remediated to levels that will meet the established radiological criteria provided in Chapter 6. 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 intended for concrete surfaces. Concrete removal, if required, 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*

As stated above, the principal remediation methods expected to be used for removing contaminants from concrete surfaces are 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 inch at a rate of about 20 ft^2 per hour. The scabbling pistons (feet) are contained in a closed-capture attachment 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 closed-capture attachment 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 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 other scabbling methods. Use of needle guns for removing and chipping 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 overspray. 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 Derived Concentration Guideline Levels (DCGL) levels, ALARA evaluations are performed. Washing and wiping techniques used as housekeeping or good practice measures will not be evaluated. Examples of washing and wiping activities for which ALARA evaluations would be performed include the following:

- Decontamination of structural materials, metals, or media for which decontamination reagents may be required

- Structure areas that do not provide sufficient access for use of other decontamination equipment such as pressure washing

4.2.1.7 *Grit Blasting*

Most contaminated piping will be removed and disposed 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 Concrete*

Activated concrete will be evaluated and remediated or removed, as necessary.

4.2.1.9 *Additional Remedial Actions*

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

4.2.2 *Soil*

Soil contamination above the site specific DCGL that is removed will be disposed 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 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). Chapter 5 discusses soil sampling and survey methods. Soil remediation equipment will include, but not be limited to, shovels, backhoe, and trackhoe 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, work package instructions will augment the previous guidance and procedural requirements to ensure adequate erosion, sediment, and air emission controls during soil remediation.

Characterization data available to date indicates that no remediation of surface or ground waters will be required at HBPP to meet the site release criteria.

4.3 Remediation Activities Impact on the Radiation Protection Program

The Radiation Protection Program used for decommissioning is similar to the program in place during power operation. During power and SAFSTOR 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. Remediation activities have had an impact on the HBPP Radiation Protection Program, given that alpha contamination is present on the interior surfaces of Unit 3 systems and components. Subsequent challenges to the program due to the alpha are:

- Alpha monitoring is required in the ventilation system
- Alpha contaminated surfaces require application of a fixative prior to dismantling the system or component
- Mechanical cutting is the only current method allowed on alpha contaminated material removal, causing challenges in the exposure control to personnel

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 to be remediated by washing and wiping. These techniques have been used successfully in the decommissioning process. Wiping with a 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 remediate lightly contaminated structural surfaces during remediation actions. Scabbling or other surface removal techniques will reduce high levels of contamination on contaminated concrete. Mechanical or diamond wire cutting will be used to section the reactor vessel. 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 existing Radiation Protection Program is adequate to control the radiological aspects of remediation work safely.

4.4 ALARA Evaluation

In order to terminate the NRC 10 CFR 50 license, HBPP must demonstrate that the dose criteria in 10 CFR 20, Subpart E, have been met, and should demonstrate whether it is feasible to further reduce the levels of residual activity to below those necessary to meet the dose criteria (i.e., to levels that are ALARA). For the HBPP decommissioning, the ALARA cleanup levels are established at one of two levels; a predefined generic ALARA screening, or a survey unit-specific ALARA evaluation. In either case, an ALARA action level (AL) is applied.

The AL corresponds to a residual activity concentration at which the averted radiation dose converted into dollars is equal to the costs of remediation. An ALARA analysis ensures that the efforts to remove residual contamination are commensurate with the risk that exists from leaving the contamination in place. "Reasonably achievable" is judged by considering the state of technology and the economics of improvements in relation to all the benefits from these improvements. However, a comprehensive consideration of risks and benefits will include risks from nonradiological hazards. An action taken to reduce radiation risks should not result in a significantly larger risk from the other hazards.

NUREG-1757, "Consolidated NMSS Decommissioning Guidance," (Reference 4-3) recognizes that remediation of soils beyond the DCGLs is not likely to be cost-beneficial due to the high costs of waste disposal. For HBPP, if remediation of soils beyond the DCGL is determined not to be cost-beneficial, then residual activity in soils that meet the DCGL will be considered ALARA. Similarly, if residual radioactivity on remaining structures is below a predetermined generic ALARA screening level or a unit specific level, then the levels associated with the structure will be considered ALARA. The methodology and equations used are consistent with those provided in Volume 2 of NUREG-1757. Copies of ALARA evaluations will be included in the FSS Report for each survey area.

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.

4.5.1 *Calculation of Total Cost*

When performing a fairly simple evaluation, the costs generally include the monetary costs of: (1) the remediation action being evaluated, (2) transportation and disposal of the waste generated by the action, (3) workplace accidents that occur because of the remediation action, (4) traffic fatalities resulting from transporting the waste generated by the action, (5) doses received by workers performing the remediation action, and (6) doses to the public from excavation, transport, and disposal of the waste. Other costs that are appropriate for the specific case may also be included. Values of some standard parameters are contained in Table 4-1.

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, Volume 2, Appendix N:

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

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 dose received by workers performing the remediation action and transporting waste to the disposal facility

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

$Cost_{other}$ = other costs as appropriate for the particular situation

4.5.1.1 *Remedial Action Costs*

Calculations of the incremental remedial action costs include the standard manpower and mechanical costs. Lower concentrations may change sampling/survey requirements. Increased survey costs can be considered in the remedial action (e.g., confined spaces, difficult to access areas, ceilings and walls above six feet) and will raise standard remediation costs due to the increase in man-hours, but note that these are the incremental costs of surveying below the dose limit.

4.5.1.2 *Transport and Disposal of the Waste*

The cost of waste transport and disposal ($Cost_{WD}$) may be evaluated according to Equation N-4 of NUREG-1757, Volume 2, Appendix N:

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

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 $\$/m^3$

4.5.1.3 *Nonradiological Risks*

The cost of nonradiological workplace accidents ($Cost_{ACC}$) may be evaluated using Equation N-5 of NUREG-1757, Volume 2, Appendix N:

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

Where:

\$3,000,000 = monetary value of a fatality equivalent to \$2,000 Person-Rem (see Pages 11-12 of "Reassessment of NCR's Dollar per Person-Rem Conversion Factor Policy," NUREG-1530, December 1995) (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

4.5.1.4 *Transportation Risks*

The cost of traffic fatalities incurred during the transportation of waste ($Cost_{TF}$) may be evaluated using Equation N-6 of NUREG-1757, Volume 2, Appendix N:

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

Where:

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

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

D_T = distance traveled in km

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

4.5.1.5 *Worker Dose Estimates*

The cost of the remediation worker dose ($Cost_{WDose}$) may be evaluated using Equation N-7 of NUREG-1757, Volume 2, Appendix N:

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

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

4.5.1.6 *Loss of Economic Use of Property*

A cost in the "other" category could include the fair market rental value or economic use for the site during the time the additional remediation work is being performed.

4.5.1.7 *Parameters*

For performing these calculations, acceptable values for some of the parameters are shown in Table 4-1 below:

Table 4-1 Parameter Values for use in ALARA Analysis

Parameter	Value	Reference and Comments
Workplace accident fatality rate, F_W	4.2×10^{-8}/hr	NUREG–1496, "Final Generic Environmental Impact Statement in Support of Rulemaking on Radiological Criteria for License Termination of NRC-Licensed Nuclear Facilities," and NUREG–1496, July 1997, Volume 2, Appendix B, Table A.1 (Reference 4-2)
Transportation fatality rate, F_T	Trucks: 3.8×10^{-8}/km	NUREG–1496, Volume 2, Appendix B, Table A.1
Dollars per person-rem	$2,000	NUREG/BR–0058 (Reference 4-8)
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
Number of years of exposure, N	Buildings: 70 years Soil: 1000 year	NUREG–1496, Volume 2, Appendix B, Table A.1
Population density, P_D	Building: 0.007 Land: 0.0001	HBPP Site-Specific Sensitivity Analysis
Excavation, monitoring, packaging, and handling soil	1.62 person-hours/m^3 of soil	NUREG–1496, Volume 2, Appendix B, Table A.1
Waste shipments volume	Truck: 13.6 m^3/shipment	NUREG–1496, Volume 2, Appendix B, Table A.1

4.5.2 *Calculation of Benefits*

In the simplest form of the analysis, the only benefit estimated from a reduction in the level of residual radioactivity is the monetary value of the collective averted dose to future occupants of the site. For buildings, the collective averted dose from residual radioactivity is based on the Occupational Scenario. For land, the averted dose is based on the Resident Farmer Scenario. In general, the ALARA analysis should use the same critical group scenario that is used for the compliance calculation.

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 a monetary value using Equation N-1 of NUREG-1757, Volume 2, Appendix N:

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

Where:

B_{AD}	=	benefit from an averted dose for a remediation action, in current U.S. dollars
\$2,000	=	value in dollars of a person-rem averted (see NUREG/BR-0058, "Regulatory Analysis Guidelines of the U.S. Nuclear Regulatory Commission," Revision 4, 2004)
$PW(AD_{collective})$	=	present worth of a future collective averted dose

An acceptable value for a collective dose is \$2000 per person-rem averted, discounted for a dose averted in the future (see Section 4.3.3 of "Regulatory Analysis Guidelines of the U.S. Nuclear Regulatory Commission," NUREG/BR-0058, Revision 4, 2004). For doses averted within the first 100 years, a discount rate of 7 percent should be used. For doses averted beyond 100 years, a 3 percent discount rate should be used.

The present worth of the future collective averted dose can be estimated from Equation N-2 of NUREG-1757, Volume 2, Appendix N, for relatively simple situations:

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

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 DCGL 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 0.25 mSv/y (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

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

The present worth of the benefit calculated by Equation N-2 assumes that the peak dose occurs in the first year. This is usually true for the Building Occupancy Scenario, but not always true for the Residential Scenario where the peak dose can occur in later years. When the peak dose occurs in later years, Equation N-2 would overestimate the benefit. A more exact calculation may be used that avoids this overestimation of the benefit of remediation by calculating the dose during each year of the evaluation period and then calculating the present worth of each year's dose.

The $DCGL_W$ used should be the same as the $DCGL_W$ used to show compliance with the 25 mrem/y dose limit. The population density, P_D, should be based on the dose scenario used to demonstrate compliance with the dose limit. Thus, for buildings, the estimate P_D for the Occupational Scenario should be used. For soil, P_D should be based on the Resident Farmer Scenario. 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.

If more than one radionuclide is present, the total benefit from a collective averted dose, B_{AD} is the sum of the collective averted dose for each radionuclide. When multiple radionuclides have a fixed concentration, residual radioactivity below the dose criteria is normally demonstrated by measuring one radionuclide and comparing its concentration to a $DCGL_W$ that has been calculated to account for the dose from the other radionuclides. In this case, the adjusted $DCGL_W$ may be used with the concentration of the radionuclide being measured. The other case is where the ratio of the radionuclide concentrations is not fixed, but varies from location to location within a survey unit; this benefit is the sum of the collective averted dose from each.

4.5.3 *Residual Radioactivity Levels that 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 N-2, the ratio of the concentration *(Conc)* to the $DCGL_W$ can be determined by using Equation N-8 of NUREG-1757, Volume 2, Appendix N below:

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

All the items in Equation N-8 are as previously defined. Since P_D, N, λ and r are constants that have generic values for all locations on the site for each scenario, HBPP only needs to determine the total cost, $Cost_T$, and the effectiveness, F, for a specific remediation action for a specific area. If the concentration at a location exceeds *Conc*, it may be cost effective to remediate the location by a method whose total cost is $Cost_T$. Note that the concentration, *Conc,* which is ALARA, can be higher or lower (more or less stringent) than the $DCGL_W$, although the $DCGL_W$ must be met in order to meet the criteria for license termination.

4.6 Radionuclides Considered for ALARA Calculations

As discussed in Chapter 6, the site-specific suite of radionuclides identified for use at HBPP contains 22 radionuclides. Only two of these radionuclides have been identified above minimum detectable concentration (MDC) levels in soil samples and structural surface samples. For purposes of the ALARA calculations, only Cs-137 and Co-60 are used along with their associated DCGL values.

4.7 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-1496, Volume 2, "Generic Environmental Impact Statement in Support of Rulemaking on Radiological Criteria for License Termination of NRC-Licensed Nuclear Facilities," July 1997

4-3 U.S. Nuclear Regulatory Commission, NUREG-1757, Volume 2, Final Report, "Consolidated NMSS Decommissioning Guidance-Characterization, Survey, and Determination of Radiological Criteria," September 2003

4-4 U.S. Nuclear Regulatory Commission, NUREG/CR-5884, Volume 2, "Revised Analyses of Decommissioning for the Reference Pressurized Water Reactor Power Station," November 1995

4-5 U.S. Nuclear Regulatory Commission, NUREG/CR-5884, Volume 1, "Revised Analyses of Decommissioning for the Reference Pressurized Water Reactor Power Station," November, 1995

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

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5 FINAL STATUS SURVEY PLAN

5.1 Introduction to the Final Status Survey Plan

The Humboldt Bay Power Plant (HBPP), Unit 3, Final Status Survey (FSS) Plan has been prepared using the applicable regulatory and industry guidance. Survey results are documented by survey unit in corresponding survey packages.

5.1.1 *Purpose*

The FSS Plan describes the final survey process used to demonstrate that the HBPP facility and site comply with radiological criteria for unrestricted use specified in 10 CFR 20.1402 (i.e., annual dose limit of 25 millirem as well as ensure dose will be As Low As Reasonably Achievable (ALARA) for all dose pathways). Nuclear Regulatory Commission (NRC) regulations applicable to radiation surveys are found in 10 CFR 50.82(a)(9)(ii)(D), 10 CFR 50.82(11)(ii), and 10 CFR 20.1501(a) and (b).

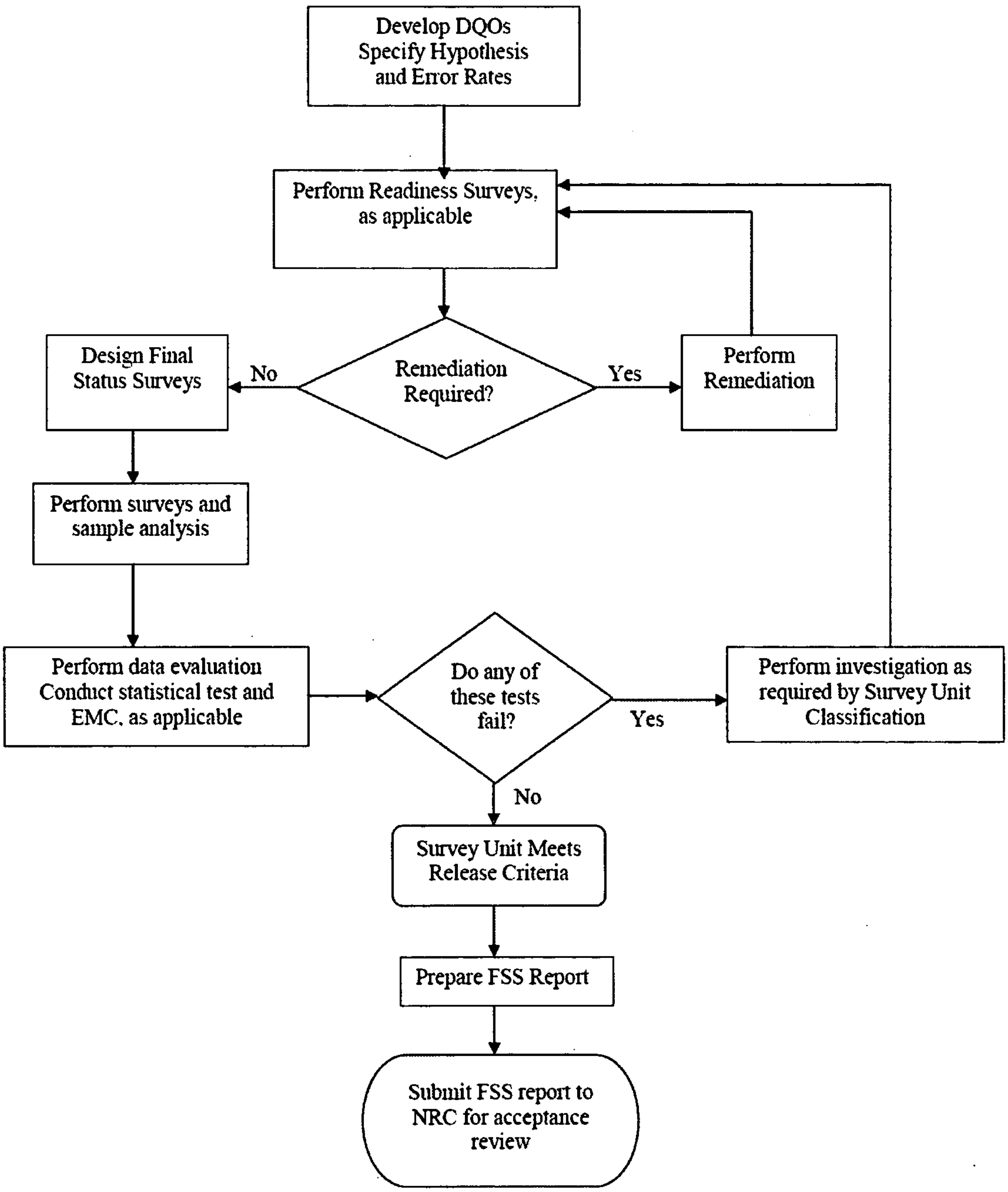
5.1.2 *Scope*

PG&E intends to release site land from the 10 CFR 50 license. An Independent Spent Fuel Storage Installation (ISFSI) located on the site is licensed under 10 CFR 72 and will be released from the 10 CFR 50 license per this release plan. This Plan addresses only facilities and land areas that are identified as contaminated or potentially contaminated (affected) resulting from activities associated with commercial nuclear plant operation.

5.1.3 *Final Status Survey Preparation and Implementation Overview*

The FSS Plan contained in this chapter will be used as the basis for developing FSS procedures and applying existing procedures to the FSS process (Figure 5-1). Section 5.1.4 contains a list of regulatory documents used in preparing the FSS Plan. Quality Assurance requirements, which are outlined in Section 5.8, apply to activities associated with FSS. An FSS Package will be produced for each survey unit; the survey package is a collection of documentation detailing survey design, survey implementation, and data evaluation for the FSS. The following sections describe specific elements of the organization, preparation, and implementation of the HBPP FSS. All processes associated with final status surveys will be conducted in accordance with approved site procedures.

Figure 5-1 FSS Process Overview



5.1.3.1 *FSS Organization*

The general FSS organization will consist of the HBPP Site Closure Manager, the FSS Supervisor, FSS Engineers, and technicians. Since the License Termination organization has not been fully implemented at the time of License Termination Plan (LTP) development, it is expected that specific job titles may vary over the period of project execution. These titles are used within this document to describe various functional areas of responsibility. Section 5.8.1.1 outlines the basic responsibilities and functions of the FSS organization.

5.1.3.2 *Survey Preparation*

Survey preparation is the first step in the FSS process and occurs after any necessary remediation has been completed. In areas where remediation is required, a remediation survey or equivalent evaluation will be performed to confirm that remediation was successful prior to initiating FSS activities. Remediation surveys, turnover surveys, or equivalent evaluation for areas not requiring remediation may be performed using the same process and controls as FSS so that data from these surveys may be used as part of the FSS data. In order for survey data to be used for FSS, it will be designed and collected in compliance with approved procedures and in accordance with Sections 5.3 through 5.5, or as specified by License Amendment Request (LAR). Additionally, the area will be controlled in accordance and implemented via approved procedures. Any surveys performed prior to the NRC approval of the LTP are understood to have been performed "at risk." Survey design and the data collected will be carefully evaluated to ensure the intent of the LTP and associated procedures were met before using the data. Following turnover/remediation surveys (if required) or post-remediation evaluation, the FSS is performed. Areas to be surveyed are isolated and/or controlled to ensure that radioactive material is not reintroduced into the area from ongoing activities nearby and to maintain the "as left" condition of the area. Section 5.2 addresses specific survey preparation requirements and considerations. All tools and equipment that would impede the survey must be removed, the area must be free of obstructions to the survey, and the area must be in a condition that will allow FSS activities.

Routine access, material storage, and worker transit through the area are not allowed, unless authorized by the FSS Supervisor, or designee. An inspection of the area is conducted by FSS personnel to ensure that work is complete and the area is ready for final status survey. Approved procedures provide isolation and control measures until the area is released for unrestricted use.

5.1.3.3 *Survey Design*

The survey design process establishes the methods and performance criteria used to conduct the survey. Survey design assumptions are documented in Survey Packages for each survey unit in accordance with approved procedures. The site land, structures, and systems[1] are organized into survey areas and classified by contamination potential as Class 1, Class 2, Class 3, or non-impacted in accordance with Section 5.2.2. See Chapter 2 for illustrative representations of the HBPP survey areas. Survey unit size is based on the assumptions in the dose assessment models in accordance with the guidance provided in NUREG-1757, Volume 2, "Consolidated NMSS Decommissioning Guidance - Characterization, Survey, and Determination of Radiological Criteria, Final Report." The percent coverage for scan surveys is determined in accordance with Section 5.3.2. The number and location of structure surface measurements (and structure volumetric samples, if required) and soil samples are established in accordance with Sections 5.3.3 and 5.3.5. Investigation levels are established in accordance with Section 5.3.6. A survey map is prepared for each survey unit and a reference grid is superimposed on the map to allow use of an (x, y) coordinate system. Random numbers between 0 and 1 are generated, which are then multiplied by the maximum x and y axis values of the sample grid. This provides coordinates for each random sample location, or a random start location for a systematic grid, as appropriate. Grid

[1] embedded and buried piping/conduit are the principal potentially contaminated systems that will remain after decommissioning

points may be automatically designated on the map, with grid locations, if generated, using Visual Sample Plan (VSP) software. The measurement/sample locations are plotted on the map. Each measurement/sample location is assigned a unique identification code, which identifies the measurement/sample by survey area, survey unit, and sequential number. The appropriate instruments and detectors, instrument operating modes, and survey methods used to collect and analyze data are also specified. Replicate measurements are performed as part of the quality process established to identify, assess, and control errors and uncertainty associated with sampling, survey, or analytical activities. This quality control process, described in Section 5.8.1, provides assurance that the survey data meet the accuracy and reliability requirements necessary to support the decision to release or not release a survey unit. Written survey instructions that incorporate the requirements set forth in the survey design and direction are provided, as applicable to survey design, for selection of instruments, count times, instrument modes, survey methods, required documentation, investigation set points, investigative actions, background requirements, and other appropriate instructions. In conjunction with the survey instructions, survey data forms may be prepared to assist in survey documentation as well as using the data-logging capabilities of the instruments. The survey design is reviewed and quality verification steps applied to ensure that appropriate instruments, survey methods, and sample locations have been properly identified. A two-tiered review process will be used with a review by a peer Engineer and a review and approval by the FSS Supervisor, or designee.

5.1.3.4 *Survey Data Collection*

After preparation of a survey package, the FSS data are collected. Trained and qualified personnel will perform the necessary measurements using calibrated instruments in accordance with approved procedures and instructions contained in the survey package. Section 5.5 addresses FSS data collection requirements. Survey areas and/or locations are identified by gridding, markings, or flags as appropriate. A FSS Engineer, or qualified designee, performs a pre-survey briefing with the survey technicians during which the survey instructions are reviewed and additional survey unit considerations are discussed (e.g., safety). The technicians gather instruments and equipment as indicated and perform surveys in accordance with the appropriate procedures and survey package specifications. Technicians are responsible for documenting survey results and maintaining custody of samples and instrumentation. At the completion of surveys, technicians return instruments and prepare samples for analysis. Survey instruments provided to the technicians are prepared in accordance with approved site procedures and the survey instructions. Instrument calibration, except for onsite lab instrumentation, is performed either onsite or by an offsite vendor and performance checks are conducted in accordance with applicable site procedures. Data are reviewed to flag any measurements that exceed investigation criteria so that appropriate investigation surveys can be performed and any required remediation can be planned and performed as necessary. Corrective action documents will be initiated as necessary to document problems and to implement appropriate corrective actions.

If a survey unit has been selected to receive a Quality Control (QC) survey (replicate surveys, etc.), a QC survey package is developed and implemented. QC measurement results are compared to the original measurement results. If QC results do not reach the same conclusion as the original survey, an investigation is then performed. Section 5.8 provides additional detail regarding QC survey requirements.

5.1.3.5 *Data-Assessment*

Survey data assessment is performed to verify that the data are sufficient to demonstrate that the survey unit meets the unrestricted use criterion. Statistical analyses are performed on the data and compared to predetermined investigation levels (see Section 5.3.6). Depending on the results of the data assessment and any required investigation, the survey unit may either be released or require further remediation, reclassification, and/or resurvey. Assumptions and requirements in the survey package are reviewed for applicability and completeness; additional data needs are identified during this review. Specific data assessment requirements are contained in Section 5.6. A review is performed of survey data and sample counting reports to verify completeness, legibility, and compliance with survey design and associated instructions. As directed by the FSS supervisor, or designee, the following types of activities may be performed:

- Convert data to reporting units
- Calculate mean, median and range of the data set
- Review the data for values that vary more than three standard deviations from the data mean
- Calculate the standard deviation of the data set
- Calculate Minimum Detectable Concentration (MDC) for each survey type performed
- Create posting, frequency and quartile plots for visual interpretation of data

Computer programs may be used for these activities if they have been approved by the Site Closure Manager, or designee. FSS personnel include data quality verifications in their evaluations of statistical calculations. Integrity and usefulness of the data set and the need for further data or investigation are also included in the evaluations. The Site Closure Manager, or designee, will review the data for statistical evaluation. The results of the data evaluation are documented and filed in the survey package.

5.1.3.6 *Final Status Survey Package Completion*

Survey results are documented by survey unit in corresponding survey packages. The data are reviewed, analyzed, and processed and the results documented in the FSS Package. This documentation file provides a record of the information necessary to support the decision to release the survey units for unrestricted use. The FSS Reports will be prepared to provide the necessary data and analyses from FSS packages for submittal to the NRC. Section 5.7 addresses reporting of survey results and conclusions.

5.1.4 *Regulatory Requirements and Industry Guidance*

This FSS Plan has been developed using the guidance contained in the following documents:

- NUREG-1575, "Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM)", Revision 1, August 2000
- NUREG-1505, "A Nonparametric Statistical Methodology for the Design and Analysis of Final Status Decommissioning Surveys," Revision 1, June 1998
- NUREG-1507, "Minimum Detectable Concentrations With Typical Radiation Survey Instruments for Various Contaminants and Field Conditions," June 1998
- NUREG-1700, "Standard Review Plan for Evaluating Nuclear Power Reactor License Termination Plans," Revision 1, April 2003
- NUREG-1757, Volume 2, "Consolidated NMSS Decommissioning Guidance Characterization, Survey, and Determination of Radiological Criteria, Final Report", Revision 1, September 2006
- Regulatory Guide 1.179, "Standard Format and Content of License Termination Plans for Nuclear Power Reactors," Revision 1, June 2011

Other documents used in the preparation of this plan are listed in Section 5.9. PG&E anticipates the NRC may choose to conduct confirmatory measurements during HBPP FSS activities. The NRC may take confirmatory measurements to make a determination the FSS and associated documentation demonstrate that the site is suitable for release in accordance with the criteria established in 10 CFR 20 subpart E.

5.2 Development of Survey Plan

5.2.1 *Radiological Status*

The following sections provide a summary of site characterization and dose modeling results applicable to development of the HBPP FSS Plan.

5.2.1.1 *Identification of Radiological Contaminants*

A site-specific suite of radionuclides potentially present at HBPP has been developed. This suite contains 22 radionuclides that are potentially present in HBPP environs, structures, and systems/components. Development of this site-specific suite of radionuclides is described in Chapter 6, "Compliance with the Radiological Criteria for License Termination," Section 6.2. PG&E has conducted radiological characterization of the site property to identify and document residual contamination resulting from nuclear plant operation, SAFSTOR operations and decommissioning activities. The effort included reviews of historical information as well as physical measurements of onsite soils, structures, and systems during scoping and characterization surveys. Chapter 2, Site Characterization, contains a detailed discussion of this effort.

5.2.1.2 *Dose Modeling Summary*

Dose models allow the translation of residual radioactivity levels into potential radiation doses to the public. For the HBPP site, dose models have been developed based on the guidance found in NUREG/CR-5512, Volumes 1, 2, and 3. The conceptual model reflects the anticipated site conditions at the time of unrestricted release. The dose modeling approach for the HBPP site is consistent with the information for site specific modeling provided in Appendix I of NUREG-1757, including source term abstraction and scenarios, pathways, and critical groups.

There are three defining factors for a dose model: (1) the scenario, (2) the critical group, and (3) the exposure pathways. The scenarios described in NUREG/CR-5512, Volume 1, address the major exposure pathways of direct exposure to penetrating radiation and inhalation and ingestion of radioactive materials. The scenarios also identify the critical group, which is defined as the group of individuals reasonably expected to receive the greatest exposure to residual radioactivity within the assumptions of a particular scenario. The design for scenarios and the site-specific modeling provide reasonable and conservative estimates of the potential doses associated with residual radioactivity.

The dose models supporting the building surface and soil Derived Concentration Guideline Levels (DCGLs) were developed using the approach outlined previously. The scenarios described in NUREG/CR-5512, Volume 1, were selected for the HBPP site to estimate potential radiation doses from radioactive material in buildings based on (Building Occupancy Scenario) and soil (Resident Farmer Scenario).

Table 5-1 provides a list of significant radionuclides that may be present in onsite soils and on structural surfaces along with their corresponding single nuclide DCGL values derived in Chapter 6.

Table 5-1 DCGLs by Radionuclide and Medium Type

Nuclide	Building Surface (dpm/100 cm^2)	Soils (pCi/g)
	25 mrem/y DCGL	**25mrem/y DCGL**
Am-241	3.02E+03	2.58E+01
C-14	7.03E+06	6.30E+00
Cm-243	4.37E+03	2.90E+01
Cm-244	5.56E+03	4.81E+01
Cm-245	2.24E+03	1.78E+01
Cm-246	2.72E+03	2.58E+01
Co-60	1.36E+04	3.82E+00
Cs-137	4.66E+04	7.93E+00
Eu-152	2.75E+04	1.01E+01
Eu-154	2.58E+04	9.40E+00
H-3	1.84E+08	6.86E+02
I-129	4.96E+04	4.83E+00
Nb-94	1.94E+04	7.13E+00
Ni-59	6.33E+07	1.97E+03
Ni-63	2.43E+07	7.24E+02
Np-237	2.44E+03	1.11E+00
Pu-238	3.47E+03	2.97E+01
Pu-239	3.12E+03	2.67E+01

Nuclide	Building Surface (dpm/100 cm^2)	Soils (pCi/g)
	25 mrem/y DCGL	25mrem/y DCGL
Pu-240	3.12E+03	2.67E+01
Pu-241	1.45E+05	8.61E+02
Sr-90	9.72E+04	1.51E+00
Tc-99	9.64E+06	1.24E+01

5.2.1.3 *Surrogate Ratio DCGLs*

Generally, surrogate ratio DCGLs are developed and applied to land areas and materials with volumetric residual radioactivity where constant radionuclide concentration ratios can be demonstrated to exist. They are derived using pre-remediation site characterization data collected prior to the FSS. The established ratio among the radionuclide concentrations allows the concentration of every radionuclide to be expressed in terms of any one of them. Likewise, a surrogate ratio DCGL allows the DCGLs specific to Hard-to-Detect (HTD) radionuclides in a mixture to be expressed in terms of a single radionuclide that is more readily measurable. The measured radionuclide is called the surrogate radionuclide. Cs-137 is expected to be the surrogate radionuclide for HBPP. A sufficient number of measurements, representative of the area of interest, are taken to establish a consistent ratio of radionuclide concentrations. The number of measurements needed to determine the ratio is based on the chemical, physical, and radiological characteristics of the radionuclides and the site. Measurements from different media types will not be mixed to derive the ratio. The surrogate ratio is acceptable if the mean values for individual samples for a given media are within two standard deviations of the overall mean value for the media. Once an appropriate surrogate ratio is determined, the DCGL of the measured radionuclide is modified to account for the represented radionuclide according to the following Equation 5-1 (MARSSIM Equation 4-1):

$$DCGL_{SR} = DCGL_{SUR} \times \frac{DCGL_{REP}}{[(C_{REP} \div C_{SUR})(DCGL_{SUR})] + DCGL_{REP}}$$

Equation 5-1

where:

$DCGL_{SR}$ = modified DCGL for surrogate ratio

$DCGL_{SUR}$ = DCGL for surrogate radionuclide

$DCGL_{REP}$ = DCGL for represented radionuclide

C_{REP} = Concentration of represented radionuclide

C_{SUR} = Concentration of surrogate radionuclide

When a surrogate ratio is established using data collected prior to remediation, post-remediation or FSS measurements will be reviewed to ensure that the established ratios are still appropriate. The surrogate ratio DCGL will be evaluated using the HBPP data quality objectives (DQOs) and modified, if necessary. Professional judgment is used to determine consistency.

5.2.1.4 *Gross Activity DCGLs*

As a rule, gross activity DCGLs ($DCGL_{GA}$) are developed and applied to structures and plant systems with surface residual radioactivity where multiple radionuclides are present at concentrations that exceed 10 percent of their respective DCGLs. The $DCGL_{GA}$ is determined in a manner similar to surrogate DCGLs, taking into account nuclide detectability to enable field measurement of gross activity, rather than the determination of individual radionuclide activity, for comparison to the radionuclide specific DCGL. The $DCGL_{GA}$, for surfaces with multiple radionuclides is calculated using the following Equation 5-2 (MARSSIM, Equation 4-4):

$$DCGL_{GA} = \frac{1}{\frac{f_1}{DCGL_1} + \frac{f_2}{DCGL_2} + \cdots \frac{f_n}{DCGL_n}}$$

Equation 5-2

where:

fn = fraction of the total activity contributed by radionuclide n

$DCGLn$ = DCGL for radionuclide n

Different radionuclides or radionuclide combinations may exist on different portions of the site and require the calculation of one or more site-specific $DCGL_{GA}$. $DCGL_{GA}$ are calculated using the relative nuclide fractions determined from samples of building surface or plant system material, as appropriate, prior to remediation. For areas where the radionuclide distribution has not been determined, the most conservative distribution resulting in the lowest DCGL of those specified areas will be used. The distributions are based on the radionuclides identified in samples collected from the specific areas prior to FSS. If new radionuclide distribution data are obtained and determined to be more appropriate for use, the $DCGL_{GA}$ may be reevaluated and altered during the course of the FSS; however, the single nuclide DCGLs will not be revised without NRC approval.

5.2.2 *Classification of Areas*

Prior to beginning the FSS, a characterization of the radiological status and historical review of the site was performed. Additional data may be collected and evaluated throughout the decommissioning. The methods and results from site characterization are described in Chapter 2. Based on the characterization results, the structures and open land areas were classified following the guidance in Appendix A, of NUREG-1757, Volume 2 and Section 4.4 of NUREG-1575. Area classification ensures that the number of measurements and the scan coverage is commensurate with the potential for residual contamination to exceed the unrestricted use criteria. Initial classification of site areas is based on historical information and site scoping and characterization data. Data from operational surveys performed in support of decommissioning, routine surveillance, or any other applicable survey data may be used to change the initial classification of an area up to the time of commencement of the FSS for that area as long as the classification reflects the levels of residual radioactivity that existed prior to remediation. Once the FSS of a given survey unit begins, the basis for any reclassification will be documented, requiring a redesign of the survey unit package, if required (e.g., a Class 3 to a Class 2) and the initiation of a new survey using the redesigned survey unit package. If during the conduct of a FSS, sufficient evidence is accumulated to warrant an investigation and reclassification of the survey unit, in accordance with Section 5.3.6, the FSS may be terminated without completing the current survey unit package.

5.2.2.1 *Non-Impacted Areas*

Non-impacted areas have no reasonable potential for residual contamination because there was no demonstrable impact from site operations. These areas are not required to be surveyed beyond what has already been completed as a part of the Historical Site Assessment (HSA) as described in Chapter 2, or scoping/site characterization surveys performed to confirm the area's non-impacted classification.

5.2.2.2 *Impacted Areas*

Impacted areas may contain residual radioactivity from licensed activities. Based on the levels of residual radioactivity present, impacted areas are further divided into Class 1, Class 2, or Class 3 designations. The following definitions are from NUREG-1757, Volume 2, Page A2.

- Class 1 Areas: are impacted areas that are expected to have concentrations of residual radioactivity that exceed the *DCGL*
- Class 2 Areas: are impacted areas that are not likely to have concentrations of residual radioactivity that exceed the *DCGL*
- Class 3 Areas: areas are impacted areas that have a low probability of containing residual radioactivity

If the available information is not sufficient to designate an area as a particular class, the area will either be classified as Class 1 or be further characterized. Areas that are considered to be on the borderline between classes will receive the more restrictive classification.

5.2.2.3 *Initial Classification of Structural Surfaces and Land Areas*

All land areas and structural surfaces to remain after decommissioning were assigned an initial classification. Characterization was performed and reported by initial survey area designation. The area designations developed for the characterization process were used, for the most part, to delineate and classify areas for FSS. This allows characterization data to be efficiently used for final survey area classification and for estimating the sigma value for sample size determination. For operational efficiency, each of the final survey areas listed in Table 5-2 may be subdivided into multiple survey units. The classification of all subdivided survey units will be the same as indicated in Table 5-2, unless reclassified in accordance with this LTP. No individual survey unit will have more than one classification. Areas within the Restricted Area (RA) will require further characterization once demolition activities are in progress. These areas are classified as Class 1 areas and will remain Class 1 areas. Chapter 2 provides the data for the information provided in Table 5-2.

Table 5-2 Survey Area Summary

Survey Area Designator	Name/Building	Total Area Footprint m^2	Classification	σ pCi/g	Mean pCi/g
NOL01	Open land area (inside RA)	7617	1	5.15	2.68
OOL01	Discharge canal south	2471	1	8.55	8.73
OOL02	Intake canal east	628	1	11.48	9.42
OOL03	Open Land Area Outside the RA	1989	1	1.01	0.77
OOL04	Sump Drain Line Land Area	458	1	7.70	11.25
OOL05	Discharge Canal North	556	2	0.90	1.22
OOL06	Intake Center	2047	2	0.04	0.20
OOL07	NOL01 Boundary East	8326	2	0.25	0.27
OOL08	NOL01 Boundary West	6837	2	0.20	0.27
OOL09	Haz. Waste Area	1032	2	1.19	0.48
OOL10	Remainder of Land Area	235,191	3	0.18	0.38
OOL11	Intake West	2470	3	0.08	0.08
OFA	Office Annex	270	3	85*	428*
ISF01	ISFSI Area	5540	3	0.08	0.13

Survey Area Designator	Name/Building	Total Area Footprint m^2	Classification	σ pCi/g	Mean pCi/g
TRB	Training Bldg.	40	3	118*	314*
SEC	Security Bldg.	49	3	101*	326*
MOB	Main Office Bldg.	409	3	89*	348*
CRB	Count Room Bldg.	372	1	TBD**	TBD**
WMB	Waste Management Building	***	1	***	***

* Units are in dpm/100 cm^2
** The building is in use and will require further characterization
*** Building to be constructed. Data will be available once constructed

5.2.2.4 *Changes in Classification*

Initial classification of site areas is based on historical information, scoping surveys, and site characterization data. Data from operational surveys performed in support of decommissioning, routine surveillance, and any other applicable survey data may be used to change the initial classification of an area up to the time of commencement of the FSS for that area as long as the classification reflects the levels of residual radioactivity that existed prior to remediation. Units within initial survey areas may be upgraded in classification due to future requirements for lay down and storage areas during demolition activities or incorrect initial classification. If during FSS, sufficient evidence is accumulated to warrant an investigation and reclassification of the survey unit in accordance with Section 5.3.6, the survey may be terminated without completing the current survey unit package.

5.2.3 *Establishing Survey Units*

The survey units contained within the survey areas are divisions that have similar characteristics and contamination levels. Survey units are assigned only one classification. The site is surveyed and evaluated on a survey unit basis. The site is released on a survey area basis (i.e., through survey area FSS reports).

5.2.3.1 *Survey Unit Size*

Survey unit sizes will be selected based on area classification, survey execution logistics, and applicable regulatory guidance documents. Typical survey unit sizes for structural surfaces and open land area soil are listed in Table 5-3. Survey unit sizes are consistent with

NUREG-1575. Class 1 and 2 areas provided in Table 5-2 may be further subdivided into smaller areas to meet the guidelines present in Table 5-3. If survey unit areas larger than the sizes in Table 5-3 are used, a technical evaluation will be presented in the FSS Package for the specific survey unit justifying the survey unit size.

Table 5-3 Suggested Survey Unit Sizes

Class	Structural Surfaces*	Open Land Soil Area
1	100 m^2	2000 m^2
2	100 to 1000 m^2	2000 to 10000 m^2
3	No Limit	No Limit

* Based on floor area

5.2.3.2 *Reference Coordinate System for Open Land Areas (Reference Grid)*

A reference coordinate system is used for impacted areas to facilitate the identification of sample points within the survey unit. The reference coordinate system is basically an X-Y plot of the site area referenced to a fixed structure(s) on the site (e.g., the corner of a building) or by the utilization of a Global Positioning System (GPS) referenced to the State of California Mercator projections. The metadata used is North American Datum (NAD) 83, California Zone 1. Elevations are in North American Vertical Datum (NAVD) 88. Once the reference points are established, grids may be overlaid parallel to lines of latitude and longitude.

5.2.4 *Access Control Measures*

5.2.4.1 *Turnover*

Due to the scope of decommissioning activities, it is anticipated that some surveys will be performed in parallel with dismantlement activities. This will require a systematic approach be established to turnover of the areas. Prior to acceptance of a survey unit for FSS, the following conditions must be satisfied in accordance with applicable procedures:

- Decommissioning activities having the potential to contaminate a survey unit shall be complete or measures taken to eliminate such potential.
- Tools and equipment that would impede the FSS of the survey must be removed, and housekeeping and cleanup shall be complete.
- Decontamination activities in the area shall be complete.
- Access control or other measures to prevent recontamination must be implemented.
- Turnover or remediation surveys may be performed and documented to the same standards as FSS, so that data can be used for the FSS.

5.2.4.2 *Walkdown*

The principal objective of the walkdown is to assess the physical scope of the survey unit. The walkdown ensures that the area has been left in the necessary configuration for FSS or that any further work has been identified. The walkdown provides detailed physical information for survey design. Details such as structural interferences or areas requiring special survey techniques can be determined. Specific requirements will be identified for accessing the survey area and obtaining support functions necessary to conduct FSSs, such as interference removal or dewatering. Industrial safety and environmental concerns will also be identified during this walkdown.

5.2.4.3 *Transfer of Control*

Once a walkdown has been performed and the turnover requirements have been met, access control to the area is transferred from the HBPP Radiation Protection (RP) Department to the FSS group. Access control and isolation methods are described in the following subsection.

5.2.4.4 *Isolation and Control Measures*

Since all site decommissioning activities will not be completed prior to the start of the FSS, measures will be implemented to protect survey units from contamination during and subsequent to the FSS. Decommissioning activities creating a potential for the spread of contamination will be completed within each survey unit prior to the FSS. Additionally, decommissioning activities that create a potential for the spread of contamination to adjacent areas will be evaluated and controlled. Upon commencement of the FSS for survey units where there is a potential for recontamination, implementation of a combination of the following control measures will be required as needed for appropriate area control:

- Personnel training
- Installation of barriers to control access to surveyed areas
- Installation of barriers to prevent the migration of contamination from adjacent or overhead areas from water runoff, etc.
- Installation of postings requiring contamination monitoring prior to surveyed area access
- Locking entrances to surveyed areas of the facility
- Installation of tamper-evident devices at entrance points
- Periodic surveillance/inspection to monitor and verify adequacy of isolation and control measures
- Installation of postings restricting the introduction of radioactive materials into the area

Periodic surveillances/inspections will not be required for open land areas that are not normally occupied and are unlikely to be impacted by decommissioning activities. If the periodic surveillance/inspection indicates that the adequacy of isolation and control measures has been compromised with the potential for recontamination of the area, post-FSS radiation survey locations will be selectively determined for survey, based on technical or site-specific knowledge and current conditions present in or near the survey area. The selected locations will be surveyed using the same instruments and techniques used for the FSS, and the results will be compared with those obtained during the FSS to determine whether the area had been recontaminated. The primary function of these surveys is to detect the potential migration of contaminants from decommissioning activities taking place in adjacent areas.

5.3 Survey Design and Data Quality Objectives

This section describes the methods and data required to determine the number and location of measurements or samples in each survey unit and the coverage fraction for scan surveys. The design activities described in this section will be documented in a survey package for each survey unit. Survey design considers the following:

- Type I and II Errors
- Scan Survey Coverage
- Sample Size Determination
- Instrumentation and Required Minimum Detectable Concentrations MDCs
- Sample Location
- DCGL and $DCGL_{EMC}$ ($DCGL_{EMC}$ is defined in Section 5.3.6.3)

5.3.1 *Data Quality Objectives (DQOs)*

The appropriate design for a given survey area is developed using the DQO process as outlined in MARSSIM, Appendix D. These seven steps are:

1. State the problem
2. Identify the decision
3. Identify inputs to the decision
4. Define the study boundaries
5. Develop a decision rule
6. Specify limits on decision errors
7. Optimize the design for obtaining data

The DQO process will be used for designing and conducting all final status surveys at HBPP. Each survey package will contain the appropriate information, statistical parameters, and contingencies to support the DQO process.

5.3.2 *Scan Survey Coverage*

The area covered by scan measurement is based on the survey unit classification as described in NUREG-1757, and as shown in Table 5-4. The accessible area scan required of Class 1 survey units will be 100 percent. For Class 2 survey units, the emphasis will be placed on scanning the higher risk areas such as soils, floors, and lower walls. Scanning percentage of Class 3 survey units will be performed on likely areas of contamination based on the judgment of the FSS Engineer. The FSS Engineer has the discretion to increase the scan coverage beyond 10 percent, if desired.

Table 5-4 Scan Survey Coverage Requirements

	Class 1	Class 2	Class 3
Scan Coverage	100%	10-100 %*	Judgmental (1-10%)

* For Class 2 Survey Units, the amount of scan coverage will be proportional to the potential for finding areas of elevated activity or areas close to the release criterion in accordance with MARSSIM Section 5.5.3. Accordingly, HBPP will use historical information and the results of individual measurements collected during characterization to correlate this activity potential to scan coverage levels.

5.3.3 *Sample Size Determination*

NUREG-1757, Volume 2, Appendix A, describes the process for determining the number of survey measurements necessary to ensure a data set sufficient for statistical analysis. Sample size is based on the relative shift, the Type I and II errors, standard deviation, and the specific statistical test used to evaluate the data.

5.3.3.1 *Determining Which Statistical Test Will Be Used*

Appropriate tests will be used for the statistical evaluation of survey data. Tests such as the Sign Test and Wilcoxon Rank Sum (WRS) Test will be implemented using unity rules, surrogate methodologies, or combinations of unity rules and surrogate methodologies, as applicable, as described in MARSSIM and NUREG-1505 chapters 11 and 12. If the contaminant is not in the background or constitutes a small fraction of the DCGL, the Sign Test will be used. If background is a significant fraction of the DCGL, the WRS Test will be used.

5.3.3.2 *Establishing Decision Errors*

The probability of making decision errors is controlled by hypothesis testing. The survey results will be used to select between one condition of the environment (the null hypothesis) or an alternate condition (the alternative hypothesis). These hypotheses, chosen for MARSSIM Scenario A, are defined as follows:

- Null Hypothesis (H_0): The survey unit does not meet the release criteria.

- Alternate Hypothesis (H_a): The survey unit does meet the release criteria.

HBPP will use the Null Hypothesis concept in the design of all final status surveys.

A Type I decision error would result in the release of a survey unit containing average residual radioactivity above the release criteria. The Type I decision error occurs when the Null Hypothesis is rejected when it is true. The probability of making this error is designated as "α." A Type II decision error would result in the failure to release a survey unit when the average residual radioactivity is below the release criteria. This occurs when the Null Hypothesis is accepted when it is not true. The probability of making this error is designated as "β." Appendix E of NUREG-1757, Volume 2, recommends using a Type I error probability (α) of 0.05 and states that any value for the Type II error probability (β) is acceptable. Following the NUREG-1757, Volume 2, guidance, α will be set at 0.05. A β of 0.05 will be selected initially, based on site-specific considerations. The β may be modified, as necessary, after weighing the resulting change in the number of required survey measurements against the risk of unnecessarily investigating and/or remediating survey units that are truly below the release criteria.

5.3.3.3 *Relative Shift*

The relative shift (Δ / σ) is calculated. Delta (Δ) is equal to the $DCGL_W$ minus the Lower Boundary of the Gray Region (LBGR). Calculation of sigma (σ) is discussed in Section 5.3.3.3.2 and initial values are provided in Table 5-2. The sigma values used for the relative shift calculation may be recalculated based on the most current data obtained from post remediation or post-demolition surveys or from background reference areas, as appropriate. The LBGR is initially set at 0.5 times the *DCGL*, but may be adjusted to obtain an optimal value, normally between 1 and 3 for the relative shift.

5.3.3.3.1 Lower Boundary of the Gray Region

The LBGR is the point at which the Type II (β) error applies. The default value of the LBGR is set initially at 0.5 times the DCGL. If the relative shift is greater than 3, then the number of data points, N, listed for the relative shift values of 3 from Table 5-5 or Table 5-3 in MARSSIM, will normally be used as the minimum sample size. If the minimum sample size results in a sample density less than the required minimum density, the sample size will be increased accordingly.

5.3.3.3.2 Standard Deviation (Sigma)

Sigma values (estimate of the standard deviation of the measured values in a survey unit and/or reference area) were initially calculated from characterization data. These sigma values can be used in FSS design or more current post-remediation sigma values can be used. The use of the sigma values from the characterization data will be conservative for the sample size determination since the post-remediation sigma values are expected to be smaller.

5.3.3.3.3 Wilcoxon Rank Sum (WRS) Test Sample Size

The number of data points, N, to be obtained from each reference area or survey unit are determined using Table 5-3 in MARSSIM. This table includes the recommended 20 percent adjustment to ensure an adequate sample size.

5.3.3.3.4 Sign Test Sample Size

The number of data points is determined from Table 5-5 in MARSSIM for application of the Sign Test. This table includes the recommended 20 percent adjustment to ensure an adequate sample size.

5.3.3.3.5 Elevated Measurement Comparison Sample Size Adjustment

If the Scan MDC is greater than the $DCGL_W$, the sample size will be calculated using Equation 5-3 (NUREG-1757, Equation A-8) provided below. If N_{EMC} exceeds the statistically determined sample size *(N)*, N_{EMC} will replace *N*.

$$N_{EMC} = \frac{A}{A_{EMC}}$$

Equation 5-3

where:

N_{EMC} = the elevated measurement comparison sample size

A = the survey unit area

A_{EMC} = the area corresponding to the area factor calculated using the MDC concentration

5.3.4 *Background Reference Area*

Background reference area measurements are required when the WRS test is used, and background subtraction may be used with the Sign Test under certain conditions such as those described in Chapter 12 of NUREG-1505. Reference area measurements, if needed, will be collected using the methods and procedures required for Class 3 final survey units. For soil, reference areas will have a soil type as similar to the soil type in the survey unit as possible. When there is a reasonable choice of possible soil reference areas with similar soil types, consideration will be given to selecting reference areas that are most similar in terms of other physical, chemical, geological, and biological characteristics. For structure survey units that contain a variety of materials with markedly different backgrounds, a reference area will be selected containing similar materials. If one material is predominant, or if there is not a large variation in background among materials, a background from a reference area containing a single material is appropriate when it is demonstrated that the selected reference area will not result in underestimating the residual radioactivity in the survey unit.

It is understood that background reference areas should have physical characteristics (including soil type and rock formation) similar to the site and shall not contain areas contaminated by site activities. Offsite areas (outside the HBPP Owner Controlled Area) should be chosen to serve as background reference areas.

Should significant variations in background reference areas be encountered, appropriate evaluations will be performed to define the background concentration. As noted in NUREG-1757, Appendix A, Section A.3.4, the Kruskal-Wallis test can be conducted in such circumstances to determine that there are no significant differences in the mean background concentrations among potential reference areas. HBPP will consider this and other statistical guidance in the evaluation of apparent significant variations in background reference areas.

If material background subtraction is performed, the sigma value used will account for the variability of the material background.

5.3.5 *Reference Grid and Sample Location*

Sample location is a function of the number of measurements required, the survey unit classification, and the contaminant variability.

5.3.5.1 *Reference Grid*

The reference grid is primarily used for reference purposes and is illustrated on sample maps. Physical marking of the reference grid lines in the survey unit will be performed only when necessary. For the sample grid in Class 1 and Class 2 survey units, a randomly selected sample start point will be identified. Beginning at the random starting coordinate, a row of points is identified, parallel to the X-axis, at intervals of L, the grid spacing. A second row of points is then developed, parallel to the first row, at a distance of 0.866 x L from the first row. The sample and reference grids are illustrated on sample maps and may be physically marked in the field. For Class 3 survey units, all sample locations are randomly selected, based on the reference grid point(s). GPS instruments will be used in open land areas to determine reference or sample grid locations within the survey area. Locations within a survey area also may be tied to a United States Geological Survey (USGS) survey benchmark site. Digital cameras may be employed to provide a record of survey locations within the survey unit and will be used extensively at HBPP.

5.3.5.2 *Measurement Locations*

Measurement locations within the survey unit are clearly identified and documented for the purpose of reproducibility. Actual measurement locations are identified by tags, labels, flags, stakes, paint marks, geopositioning units, or photographic records. An identification code matches a survey location to a particular survey unit.

Sample points for Class 1 and Class 2 survey units are positioned in a systematic pattern or grid throughout the survey unit by first randomly selecting a start point coordinate. A random number generator is used to determine the start point of the grid pattern. The grid spacing, L, is a function of the area of the survey unit as shown in Equation 5-4 (MARSSIM Equation 5-5) for a triangular grid:

$$L = \sqrt{\frac{A}{0.866\, n_{EA}}}$$

Equation 5-4

Where:

A = Area of the survey unit

n_{EA} = Calculated number of survey locations

Beginning at the random starting coordinate, a row of points is identified, parallel to the X-axis, at intervals of L. A second row of points is then developed, parallel to the first row, at a distance of 0.866 x L from the first row.

Software may be used to generate grid patterns and sample/measurement locations (i.e., Visual Sample Plan (VSP)).

Random measurement patterns are used for Class 3 survey units. Sample location coordinates (*x* and *y*) are randomly picked using a random number generator or VSP.

Measurement locations selected using either a random selection process or a randomly started systematic pattern that do not fall within the survey unit or that cannot be surveyed due to site conditions are replaced with other measurement locations as determined by the FSS Supervisor, FSS Engineer, or designee.

5.3.6 *Investigation Levels and Elevated Areas Test*

During survey unit measurements, levels of radioactivity may be identified that warrant investigation. Depending on the results of the investigation, the survey unit may require no action, remediation, and/or reclassification and resurvey. The following subsections describe investigation process and investigation levels.

5.3.6.1 *Investigation Process*

During the survey process, locations with potential residual activity exceeding investigation levels are documented and marked for further investigation. The elevated survey measurement is verified by resurvey. For Class 1 areas, size and average activity level in the elevated area is acceptable if it complies with the area factors and other criteria that may apply to evaluation of the DCGL for elevated measurements $DCGL_{EMC}$. As discussed in Section 5.3.6.3, the $DCGL_{EMC}$ is applicable only for Class 1 areas. If any location within a Class 2 area exceeds the DCGL, scanning coverage in the vicinity is increased in order to determine the extent and level of the elevated reading(s) and the area is evaluated for reclassification. If the elevated reading occurs in a Class 3 area, the scanning coverage is increased and the area is evaluated for reclassification and resurvey under the criteria of the new classification. All survey unit investigations will be conducted in accordance with the applicable FSS DQOs.

Investigations should address the following items:

- The assumptions made in the survey unit classification
- The most likely or known cause of the contamination
- The effects of summing multiple areas with elevated activity within the survey unit

Depending on the results of the investigation, a portion of the survey unit may be reclassified or combined with an adjacent area with similar characteristics if there is sufficient justification. Either action would result in resurvey of the (new) area(s). The results of the investigation process are documented in the survey package. Section 5.6 provides additional discussion regarding potential reclassification of the survey unit.

5.3.6.2 *Investigation Levels*

Technicians will respond to all instrument indications of elevated activity while surveying. Upon receiving an indication, the technician will stop and resurvey the last square meter of area surveyed to verify the increase. Technicians are cautioned, in training, about the importance of the verification survey and are given specific direction in the procedure as to survey extent and scan speed. If the indication is verified, the technician will mark the area with a flag or other appropriate means. Each area marked will be addressed in an investigation survey instruction prepared for the survey unit. The instruction will specify the required actions, such as a rescan of the area, direct measurements, and collection of a soil sample (for land surveys). Each investigation will be evaluated and reported in the FSS survey area report. Investigation levels are shown in Table 5-5.

Table 5-5 Investigation Levels

Classification	Scan Investigation Levels	Direct Investigation Levels
Class 1	> $DCGL_{EMC}$	$>DCGL_{EMC}$ or $>DCGL_W$ and > a statistical parameter-based value
Class 2	$>DCGL_W$ or $>MDC_{SCAN}$ if MDC_{SCAN} is greater than $DCGL_W$	> $DCGL_W$
Class 3	Detectable over Background	> 0.5 $DCGL_W$

In Class 1 areas, the size and average activity level in the elevated area is determined to demonstrate compliance with the area factors. If any location in a Class 2 area exceeds the DCGL, scanning coverage in the vicinity is increased in order to determine the extent and level of the elevated reading(s). If the elevated reading occurs in a Class 3 area, the scanning coverage is increased and reclassification of the area should be considered.

5.3.6.3 *Elevated Measurement Comparison (EMC)*

5.3.6.3.1 Open Land Areas and Structural Surfaces

The elevated measurement comparison is applied to Class 1 survey units when one or more verified scan or static measurement exceeds the investigation level. As stated in MARSSIM, the EMC is intended to flag potential failures in the remediation process and should not be considered the primary means to identify whether or not a survey unit meets the release criterion. The EMC provides assurance that unusually large measurements receive the proper attention and that any area having the potential for significant dose contribution is identified. Locations identified by scan methodology or soil sample analyses measurements with levels of residual radioactivity that exceed the $DCGL_{EMC}$ are subject to additional surveys to determine compliance with the elevated measurement criteria. The size of the area containing the elevated residual radioactivity and the average level of residual activity within the area are determined. The average level of activity is compared to the $DCGL_W$ based on the actual area of elevated activity. An a priori $DCGL_{EMC}$ for the area between direct measurements (the likely size of an elevated area) is established during the survey design and is calculated as follows:

$$DCGL_{EMC} = Area\ Factor \times DCGL_W$$

Equation 5-5

The area factor is the multiple of the $DCGL_W$ that is permitted in the area of elevated residual radioactivity without remediation. The area factor is related to the size of the area over which the elevated activity is distributed. The actual area is generally bordered by levels of residual radioactivity below the $DCGL_W$ and its size is determined during the investigation process. Area factor calculations are described in Section 6.6 and summarized in Tables 5-6 and 5-7. The actual area of elevated activity is determined by investigation surveys and the area factor is adjusted for the actual area of elevated activity. The product of the adjusted area factor and the $DCGL_W$ determines the a posteriori $DCGL_{EMC}$. Additional measurements are made to determine the average activity of the elevated area, if necessary. If the $DCGL_{EMC}$ is exceeded, the area is remediated and resurveyed. The results of the elevated area investigations in a given survey unit that are below the $DCGL_{EMC}$ limit are evaluated using Equation 5-6. If more than one elevated area is identified in a given survey unit, the unity rule with Equation 5-6 is used to determine compliance. If the formula value is less than unity, no further elevated area testing is required and the EMC test is satisfied.

Table 5-6 Soil Area Factors

Radionuclide of Concern (ROC)	Area Factor for Area Contaminated Zone (m²):							
	2000	1000	500	100	50	10	5	1
Am-241	1.0E+00	1.0E+00	2.0E+00	8.7E+00	1.6E+01	4.9E+01	7.7E+01	1.9E+02
C-14	1.0E+00	1.5E+00	4.0E+00	4.2E+01	1.1E+02	1.0E+03	2.5E+03	1.8E+04
Cm-243	1.0E+00	1.0E+00	1.6E+00	3.4E+00	4.3E+00	7.3E+00	1.1E+01	3.2E+01
Cm-244	1.0E+00	1.0E+00	2.0E+00	9.7E+00	1.9E+01	7.6E+01	1.2E+02	2.8E+02
Cm-245	1.0E+00	1.0E+00	1.9E+00	6.2E+00	9.2E+00	1.9E+01	3.0E+01	8.1E+01
Cm-246	1.0E+00	1.0E+00	2.0E+00	9.7E+00	1.9E+01	7.6E+01	1.3E+02	2.8E+02
Co-60	1.0E+00	1.0E+00	1.1E+00	1.3E+00	1.4E+00	2.2E+00	3.3E+00	1.0E+01
Cs-137	1.0E+00	1.0E+00	1.3E+00	1.7E+00	1.9E+00	3.0E+00	4.5E+00	1.4E+01
Eu-152	1.0E+00	1.0E+00	1.0E+00	1.1E+00	1.3E+00	2.0E+00	3.0E+00	9.1E+00
Eu-154	1.0E+00	1.0E+00	1.0E+00	1.2E+00	1.3E+00	2.0E+00	3.0E+00	9.2E+00
H-3	1.0E+00	1.1E+00	2.1E+00	1.0E+01	2.1E+01	1.0E+02	2.0E+02	9.3E+02
I-129	1.0E+00	1.1E+00	2.2E+00	1.1E+01	2.2E+01	9.9E+01	1.9E+02	8.3E+02
Nb-94	1.0E+00	1.0E+00	1.0E+00	1.2E+00	1.3E+00	2.0E+00	3.0E+00	9.0E+00
Ni-59	1.0E+00	1.2E+00	2.3E+00	1.2E+01	2.3E+01	1.2E+02	2.3E+02	1.2E+03
Ni-63	1.0E+00	1.2E+00	2.3E+00	1.2E+01	2.3E+01	1.2E+02	2.3E+02	1.2E+03
Np-237	1.0E+00	1.0E+00	2.0E+00	9.0E+00	1.6E+01	5.6E+01	9.8E+01	3.5E+02
Pu-238	1.0E+00	1.0E+00	2.0E+00	9.7E+00	1.9E+01	7.6E+01	1.3E+02	2.8E+02
Pu-239	1.0E+00	1.0E+00	2.0E+00	9.7E+00	1.9E+01	7.6E+01	1.3E+02	2.9E+02
Pu-240	1.0E+00	1.0E+00	2.0E+00	9.7E+00	1.9E+01	7.6E+01	1.3E+02	2.9E+02
Pu-241	1.0E+00	1.0E+00	2.0E+00	8.8E+00	1.6E+01	4.9E+01	7.8E+01	1.9E+02
Sr-90	1.0E+00	1.0E+00	2.0E+00	1.0E+01	2.0E+01	9.9E+01	2.0E+02	9.6E+02
Tc-99	1.0E+00	1.0E+00	2.0E+00	1.0E+01	2.0E+01	1.0E+02	2.0E+02	1.0E+03

Table 5-7 Building Surfaces Area Factors

	Area Factor Value:										
(m^2)	Am-241	C-14	Cm-243	Cm-244	Cm-245	Cm-246	Co-60	Cs-137	Eu-152	Eu-154	H-3
1	9.7E+01	9.7E+01	8.9E+01	1.0E+02	3.9E+01	6.4E+01	1.3E+01	1.5E+01	1.3E+01	1.3E+01	1.0E+02
2	4.9E+01	4.9E+01	4.5E+01	5.0E+01	2.1E+01	3.3E+01	7.2E+00	8.2E+00	7.2E+00	7.2E+00	5.0E+01
3	3.3E+01	3.3E+01	3.0E+01	3.3E+01	1.5E+01	2.3E+01	5.3E+00	6.0E+00	5.3E+00	5.3E+00	3.3E+01
4	2.5E+01	2.4E+01	2.3E+01	2.5E+01	1.2E+01	1.8E+01	4.3E+00	4.9E+00	4.3E+00	4.3E+00	2.5E+01
5	2.0E+01	2.0E+01	1.9E+01	2.0E+01	9.9E+00	1.5E+01	3.7E+00	4.2E+00	3.7E+00	3.7E+00	2.0E+01
6	1.6E+01	1.6E+01	1.6E+01	1.7E+01	8.6E+00	1.2E+01	3.3E+00	3.8E+00	3.3E+00	3.3E+00	1.7E+01
8	1.2E+01	1.2E+01	1.2E+01	1.2E+01	6.9E+00	9.7E+00	2.8E+00	3.2E+00	2.8E+00	2.8E+00	1.2E+01
10	9.9E+00	9.9E+00	9.5E+00	1.0E+01	5.9E+00	8.0E+00	2.5E+00	2.8E+00	2.5E+00	2.5E+00	1.0E+01
50	2.0E+00	2.0E+00	2.0E+00	2.0E+00	1.8E+00	1.9E+00	1.2E+00	1.3E+00	1.2E+00	1.2E+00	2.0E+00
100	1.0E+00	1.0E+00	1.0E+00	1.0E+00	1.0E+00	1.0E+00	1.0E+00	1.0E+00	1.0E+00	1.0E+00	1.0E+00
	Area Factor Value:										
(m^2)	I-129	Nb-94	Ni-59	Ni-63	Np-237	Pu-238	Pu-239	Pu-240	Pu-241	Sr-90	Tc-99
1	6.5E+01	1.3E+01	1.0E+02	1.0E+02	8.9E+01	1.0E+02	1.0E+02	1.0E+02	9.8E+01	9.0E+01	8.7E+01
2	3.4E+01	7.2E+00	5.0E+01	5.0E+01	4.5E+01	5.0E+01	5.0E+01	5.0E+01	4.9E+01	4.5E+01	4.4E+01
3	2.3E+01	5.3E+00	3.3E+01	3.3E+01	3.0E+01	3.3E+01	3.3E+01	3.3E+01	3.3E+01	3.0E+01	3.0E+01
4	1.8E+01	4.3E+00	2.5E+01	2.5E+01	2.3E+01	2.5E+01	2.5E+01	2.5E+01	2.5E+01	2.3E+01	2.3E+01
5	1.5E+01	3.7E+00	2.0E+01	2.0E+01	1.8E+01	2.0E+01	2.0E+01	2.0E+01	2.0E+01	1.9E+01	1.8E+01
6	1.3E+01	3.3E+00	1.7E+01	1.7E+01	1.6E+01	1.7E+01	1.7E+01	1.7E+01	1.7E+01	1.6E+01	1.5E+01
8	9.7E+00	2.8E+00	1.3E+01	1.2E+01	1.2E+01	1.3E+01	1.2E+01	1.2E+01	1.2E+01	1.2E+01	1.2E+01
10	8.0E+00	2.5E+00	1.0E+01	1.0E+01	9.4E+00	1.0E+01	1.0E+01	1.0E+01	9.9E+00	9.5E+00	9.4E+00
50	1.9E+00	1.2E+00	2.0E+00	2.0E+00	2.0E+00	2.0E+00	2.0E+00	2.0E+00	2.0E+00	2.0E+00	2.0E+00
100	1.0E+00	1.0E+00	1.0E+00	1.0E+00	1.0E+00	1.0E+00	1.0E+00	1.0E+00	1.0E+00	1.0E+00	1.0E+00

Equation 5-6 applies to a single radionuclide contaminant. When multiple radionuclides are present, the calculation in Equation 5-6 is made with a unitized DCGL.

$$\frac{\delta}{DCGL_W} + \frac{(Conc_{AVE} - \delta)}{(Area\ Factor)(DCGL_W)} < 1$$

Equation 5-6

where:

δ = Estimate of average concentration of residual radioactivity, and

$Conc_{AVE}$ = average concentration in elevated area.

If more than one elevated area exists in the survey unit, a separate term will be included for each in Equation 5-6 (refer to Section 5.6.2.2).

5.3.6.3.2 *Embedded/Buried Piping*

DCGLs for HBPP embedded and buried piping will be in accordance with HBPP Technical Basis Documents (TBDs). The HBPP embedded/buried piping DCGL TBD will be submitted to NRC for approval prior to implementation.

5.3.6.4 *Remediation and Reclassification*

As shown in Table 5-8, Class 1 areas of elevated residual activity above the $DCGL_{EMC}$ are remediated to reduce the residual radioactivity to acceptable levels. Based on survey data, it may be necessary to remediate an entire survey unit or only a portion of it. If an individual survey measurement (scan or direct measurement) in a Class 2 survey unit exceeds the $DCGL_W$, the survey unit or a portion of it may be evaluated for a change of classification to a Class 1 survey unit and the survey redesigned and reperformed accordingly. If an individual survey measurement in a Class 3 survey unit exceeds 0.5 $DCGL_W$, the survey unit, or portion of a survey unit, will be evaluated, and if necessary, reclassified to a Class 2 survey unit and the survey redesigned and reperformed accordingly.

Table 5-8 Investigative Actions for Individual Survey Units

Area Classification	Action if Investigation Results exceed:		
	$DCGL_{EMC}$	$DCGL_W$	0.5 $DCGL_W$
Class 1	Remediate and resurvey as necessary	Acceptable*	N/A
Class 2	Remediate, reclassify portions as necessary, and investigate**	Reclassify portions as necessary and investigate**	N/A
Class 3	Remediate, reclassify portions as necessary, and investigate**	Reclassify portions as necessary, increase scan coverage, and investigate**	Reclassify portions as necessary and resurvey, increase scan coverage

* For individual measurements above DCGL, the Sign Test will be conducted on the survey unit and an EMC evaluation performed.

** Requires an investigation of the initial classification process and a survey unit evaluation of sufficient intensity to satisfy the requirements of new classification status.

5.3.6.5 *Resurvey*

Following an investigation, if a survey unit is reclassified to a more restrictive classification or if remediation activities were performed, a resurvey is performed in accordance with approved procedures. If a Class 2 area had contamination greater than the $DCGL_W$, the area should be reclassified to a Class 1 area. If the average value of Class 2 direct survey measurements was less than the $DCGL_W$, the Scan MDC was sensitive enough to detect the $DCGL_{EMC}$ and there were no areas greater than the $DCGL_{EMC}$, the survey redesign may be limited to obtaining a 100 percent scan without having to reperform the static measurements or soil sample analyses. This condition assumes that the sample density meets the requirements for a Class 1 area.

5.4 Survey Methods and Instrumentation

5.4.1 *Survey Measurement Methods*

Survey measurements and sample collection are performed by personnel trained and qualified in accordance with the applicable HBPP procedures. The techniques for performing survey measurements or collecting samples are specified in approved HBPP procedures. FSS measurements include surface scans, direct surface measurements, and gamma spectroscopy of volumetric materials. Advanced Survey Technologies, not specifically described in this LTP also may be used for final status surveys. If so, HBPP will give NRC 30 days notice to provide an opportunity to review the associated basis document that will be provided on the Advanced Survey Technology(s). Onsite, as well as offsite, laboratory facilities are used for gamma spectroscopy, liquid scintillation, and gas proportional counting in accordance with applicable procedures. "Approved" off-site facilities "as required by Section 5.8" are used as necessary. No matter which facilities are used, analytical methods will be administratively established to detect levels of radioactivity at 10 percent to 50 percent of the DCGL value.

5.4.2 *Structures*

Structures will receive scan surveys, direct measurements, and, when necessary, volumetric sampling.

5.4.2.1 *Scan Surveys*

Scanning is performed in order to locate small elevated areas of residual activity above the investigation level. Structures are scanned for beta/gamma radiation with appropriate instruments such as those listed in Table 5-9. The measurements will typically be performed at a distance of 1 cm or less from the surface and at a nominal scan speed of 5 cm/sec for hand-held instruments. Adjustments to scan speed and distance may be made in accordance with approved technical guidance.

5.4.2.2 *Direct Measurements*

Direct measurements are performed to detect surface activity levels. Direct measurements are conducted by placing the detector on or very near the surface to be counted and acquiring data over a predetermined count time. A count time of one minute is typically used for HBPP surface measurements and generally provides detection levels well below the DCGL (the count time may be varied provided the required detection level is achieved).

5.4.2.3 *Concrete with Activated Radionuclides*

Activated concrete that does not meet FFS criteria at HBPP will be removed and shipped to a suitable burial site.

5.4.2.4 *Volumetric Concrete Measurements*

Volumetric sampling of contaminated concrete, as opposed to direct measurements, may be necessary if the efficiency or uncertainty of the gross beta measurements is too high.

In this case, the surface layer is removed from the known area by using a commercial stripping agent (coated surfaces) or by physically abrading the surface. The removed coating material is analyzed for activity content and the level converted to appropriate units (i.e., dpm/100 cm^2) for comparison with surface activity DCGLs. Direct measurements can then be performed on the underlying surface after removal of the coating.

The thickness of the layer of building surface to be removed as a sample should be consistent with the development of the HBPP site model and the DCGLs (i.e., less than 10 mm in depth).

5.4.2.5 *Soils*

Soil will receive scan surveys at the coverage level described in Table 5-4 and volumetric samples will be taken at designated locations. Surface soil samples will normally be taken at a depth of 0 to 15 cm. Samples will be collected and prepared in accordance with approved procedures.

5.4.2.5.1 **Scans**

Open land areas are scanned for gamma emitting nuclides. The gamma emitters are used as surrogates for the HTD radionuclides. Sodium iodide detectors are typically used for scanning. For detectors such as the Ludlum 44-10, the detector is held within 2.5 to 7.5 cm off the ground surface and is moved at a speed of 0.5 m/sec, traversing each square meter three times. The area covered by scan measurements is based on the survey unit classification, as described in Section 5.3.2.

5.4.2.5.2 *Volumetric Samples*

Soil materials are analyzed by gamma spectroscopy. Soil samples of approximately 1,500 grams are normally collected from the surface layer (top 15 cm). Sample preparation includes removing extraneous material, homogenizing, and drying the soil for gamma isotopic analysis. Separate containers are used for each sample and each container is moved through the analysis process following site procedures. Samples are split, when required, by the HBPP Quality Assurance Project Plan (QAPP). If a survey area has already been excavated and remediated to the soil DCGL, this area will be treated as surface soil, and the FSS will be performed on the excavated area. Soil samples will be collected to depths at which there is high confidence that deeper samples will not result in higher concentrations. Alternatively, a sodium-iodide detector or in situ object counting system (ISOCS) of sufficient sensitivity to detect DCGL concentrations may be used to identify the presence or absence of subsurface contamination (i.e. greater than 15 cm in depth), and the extent of such contamination. If the detector identifies the presence of contamination at a significant fraction of the DCGL (as referenced in Table 5-5), confirmatory investigation and analyses of soil samples of the suspect areas will be performed. All subsurface sampling will be performed in accordance with the guidance in Section G.2.1 of NUREG- 1757, Volume 2. The sample size for subsurface samples will be determined using the same methods described for surface soil. Per NUREG-1757, Volume 2, scanning is not applicable to subsurface areas; however, HBPP FSS will employ scanning techniques commensurate with the survey unit classification. Scanning subsurface soils, where accessible as an excavated surface, will be used for characterization data.

5.4.3 *Specific Survey Area Considerations*

5.4.3.1 *Pavement-Covered Areas and Shallow Concrete Slabs*

Survey of paved areas will be required along the roadways providing ingress and egress to HBPP. The survey design of paved/concrete areas will be based on soil survey unit sizes since they are outdoor areas where the exposure scenario is most similar to direct radiation from surface soil. The applicable DCGL will be the soil DCGL. Scan and static gamma and beta-gamma surveys are determined by the survey unit design. Samples will be obtained of not only the asphalt/concrete, but of the soil present under the asphalt/concrete. Paved areas may be separate survey units or they may be incorporated into surveys of adjacent open land areas of like classification.

5.4.3.2 *Bulk Materials*

Excavated soil may be reused onsite. Prior to reuse, excavated soil will be characterized to determine its suitability. Any surface scanning or volumetric analyses will be directly compared with DCGL values. Controls will be instituted to prevent mixing of soils from more restrictive survey area classifications (e.g., Class 2 material could be used in either Class 1 or 2 areas and Class 1 material could only be used in Class 1 areas). Soils satisfying the criteria for unrestricted release may be stockpiled for use as HBPP onsite backfill material.

5.4.3.3 *Embedded Piping and Buried Piping*

Embedded and buried piping may remain after decommissioning HBPP. Separate FSS survey plans will be developed for embedded/buried piping, which will include survey unit DQOs. These FSS plans will include the following items:

- radionuclides of interest and chosen surrogate
- levels and distribution of contamination
- internal surface condition of the piping
- internal residues and sediments and their radiation attenuation properties
- removable and fixed surface contamination

- instrument sensitivity and related scan and fixed minimum detectable concentrations
- piping geometry and presence of internally inaccessible areas/sections
- instrument calibration

Accessible internal surfaces are surveyed the same as other structural surfaces. Scale and sediment samples will be obtained, if appropriate, as well as smears and wipes to assist in the identification of the total radionuclide deposits within the piping. The activity of the internal surfaces will be compared to the building surface DCGLs, which is a conservative measure. If the amount of activity observed on the internal surfaces is so great as to fail a survey unit, specialized embedded piping DCGLs will be developed in a technical basis document. Some buried piping, storm drains, sewer systems, plumbing and floor drains may be free released or assessed. All remaining embedded and buried piping will be grouted after surveying unless it is to be used as an active system (e.g., drainage piping).

5.4.3.4 *Cracks, Crevices, Wall-to-Floor Interfaces, and Small Holes*

Surface contamination on irregular structure surfaces (e.g., cracks, crevices, and holes) is difficult to survey directly. Where no remediation has occurred and residual activity has not been detected above background, these surface blemishes may be assumed to have the same level of residual activity as that found on adjacent surfaces. The accessible surfaces are surveyed in the same manner as other structural surfaces and no special corrections or adjustments are required. In situations where remediation has taken place or where residual activity has been detected above background, a representative sample of the contamination within the crack or crevice may be obtained or an adjustment for instrument efficiency may be made. If an instrument efficiency adjustment cannot be justified based on the depth of contamination or other geometry factors, volumetric samples will be collected. As an alternative method, radionuclide specific analysis, coupled with application of the unity rule, may be used. Volumetric samples analyzed by gamma spectroscopy will detect the presence of radioactivity below the surface.

Typically, such sampling is performed following removal of paint and other surface coatings during remediation. After analysis, the data may be converted to equivalent surface activity. The accessible surfaces on irregular structure surfaces are surveyed in the same manner as other structure surfaces except that they are included in areas receiving judgmental scans when scanning is performed over less than 100 percent of the area.

5.4.3.5 *Paint Covered Surfaces*

Painted surfaces will be evaluated prior to the start of the FSS for that survey unit. In the event of suspected activity beneath painted surfaces, the coating will be removed prior to performing the survey. No special consideration will be given to wall or ceiling areas painted before plant startup and which have not been subjected to repeated exposure to materials that would have penetrated the painted surface. If the thickness of the coating can be determined with certainty, then a source efficiency correction may be applied to the measurement as described in NUREG-1507.

5.4.3.6 *Exterior Surfaces of Building Foundations*

Exterior surfaces of below-grade foundations will be evaluated using the historical site assessment and other pertinent records to determine the potential for sub-surface contamination on the exterior surfaces of below-grade foundations. One method available to evaluate the exterior surfaces is the use of core bores through foundation or walls and the taking of soil samples at locations having a high potential for the accumulation and migration of radioactive contamination to sub-surface soils. These biased locations for soil and concrete assessment could include stress cracks, floor and wall interfaces, penetrations through walls and floors for piping, run-off from exterior walls, and leaks or spills in adjacent outside areas, etc. If the soil is found to be free of residual radioactivity at the biased locations, it will be assumed that the exterior surface of the foundation is also free of residual activity. Otherwise, additional sampling may be necessary to determine the extent of decontamination and remediation efforts. Another method available for evaluating the exterior surfaces of below-grade foundations is gamma well logging. Soil in biased locations next to the exterior of the buildings may be evaluated using this technique. This technique can provide for rapid isotopic analysis of soils without sampling.

5.4.3.7 *Groundwater*

Assessments of any residual activity in groundwater at HBPP will be via groundwater monitoring wells. The monitoring wells installed at the site will monitor groundwater at both deep and shallow depths. Section 2.2.2 describes the groundwater monitoring conducted.

The data collected from the monitoring wells will be used to ensure that the concentration of well water available, based upon the well supply requirements assumed in Section 6 for the resident farmer (i.e., resident farmer's well), is below the U.S. Environmental Protection Agency (EPA) maximum contaminant levels (MCLs) (e.g., 20,000 pCi/l for H-3). This will ensure that the dose contribution from groundwater is a small fraction of the limit in 10 CFR 20.1402.

5.4.4 *Instrumentation*

Radiation detection and measurement instrumentation for the FSS is selected to provide both reliable operation and adequate sensitivity to detect the radionuclides identified at the site at levels sufficiently below the DCGL. Detector selection is based on detection sensitivity, operating characteristics, and expected performance in the field. The instrumentation will, to the extent practicable, use data logging. Commercially available portable and laboratory instruments and detectors typically are used to perform the three basic survey measurements: (1) surface scanning, (2) direct surface contamination measurements, (3) and spectroscopy of soil and other bulk materials, such as concrete.

HBPP procedures control the issuance and use of instrumentation. Records supporting the instrumentation program are maintained in accordance with HBPP procedures.

5.4.4.1 *Instrument Selection*

Radiation detection and measurement instrumentation is selected based on the type and quantity of the radiation to be measured. The instruments used for direct measurements are capable of detecting the radiation of concern below the applicable DCGL. MDCs of less than 50 percent of the DCGL allow detection of residual activity in Class 3 survey units at an investigation level of 0.5 times the DCGL. Instruments used for scan measurements in Class 1 areas are required to be capable of detecting radioactive material at the $DCGL_{EMC}$. Instrumentation currently proposed for use in the HBPP FSS is listed in Table 5-9. Instrument MDCs are discussed in Section 5.4.3.4 and nominal MDC values are listed in Table 5-10. Other measurement instruments or techniques may be used. The acceptability of any alternate technologies for use in the FSS Program will be justified in a technical basis evaluation document. Technical basis evaluations for Advanced Survey Technologies will be provided for NRC review 30 days prior to use. An instrument technical analysis will include the following:

- Description of the conditions under which the method would be used
- Description of the measurement method, instrumentation, and criteria
- Justification that the technique would provide the required sensitivity for the given survey unit classification in accordance with Table 5-10
- Demonstration that the instrument provides sufficient sensitivity for measurement below the release criteria with Type I error equivalent to 5 percent or less

Table 5-9 Typical FSS Instrumentation

Measurement Type	Detector Type	Effective Detector Area and Window Density	Instrument and Model	Detector Model
Alpha Scan	Gas-flow Proportional	126 cm^2 0.8 mg/cm^3 Aluminized Mylar	Ludlum 2350-1	Ludlum 43-68
Beta-gamma static and scan	Gas-flow Proportional	126 cm^2 0.8 mg/cm^3 Aluminized Mylar	Ludlum 2350-1	Ludlum 43-68
Beta-gamma scan	Gas-flow Proportional	584 cm^2 0.8 mg/cm^3 Aluminized Mylar	Ludlum 2350-1	Ludlum 43-37

Measurement Type	Detector Type	Effective Detector Area and Window Density	Instrument and Model	Detector Model
Gamma scan	Scintillation	2" diameter x 2" length NaI	Ludlum 2350-1	Ludlum 44-10
Soil, structure surface and bulk material	High purity germanium	N/A	Canberra and off site Laboratory	N/A

Table 5-10 Typical FSS Detection Sensitivities

Instruments and Detectors	Radiation	Background Count Time (minutes)	Background (cpm)	Instrument Efficiency (2pi)	Count Time (minutes)	Static MDC (dpm/100 cm^2)	Scan MDC (dpm/100 cm^2)
Model 43-68	Alpha	1	2	0.1500	5	61	N/A
Model 43-68	Beta-Gamma	1	300	0.3200	1	920	13291
Model 43-37	Beta-Gamma	1	600	0.2800	1	320	7267
Model 4410	Gamma	1	4000	0.0350	0.04	N/A	See Table 5-13 for E_i
HPGe	Gamma	Up to 60	N/A	0.40 Relative	10-60	0.15	N/A
Tennelec Low Bkg. Counter	Alpha Beta	20 20	0.175 3.9	0.348 0.377	3 3	<11 <16	N/A N/A

5.4.4.2 *Calibration and Maintenance*

Instruments and detectors are calibrated by HBPP for the radiation types and energies of interest at the site. Approved suppliers will calibrate instruments, as necessary that will be utilized for analysis under their approved Quality Assurance Program as described in Section 5.8. Calibration may also be performed in accordance with approved procedures at HBPP or Diablo Canyon Power Plant (DCPP). The calibration source for beta survey instruments is Cs-137, because the average beta energies approximate the beta energy of the radionuclides found on surfaces at HBPP. The alpha calibration source is Am-241 that has an appropriate alpha energy for plant-specific alpha emitting nuclides. Gamma scintillation detectors are calibrated using Cs-137. Radioactive sources used for calibration are traceable to the National Institute of Standards and Technology (NIST). When characterized High Purity Germanium (HPGe) detectors are used, using approved procedures, suitable NIST-traceable sources are used for onsite calibration, and the software is set up appropriately for the desired geometry.

5.4.4.3 *Response Checks*

Instrumentation response checks are conducted to ensure proper field survey instrument response and operation. An acceptable response for field instrumentation is an instrument reading within plus or minus 20 percent of the established check source value as documented on a control chart. Response checks are performed daily before instrument use and again at the end of use. Check sources contain the same type of radiation of that being measured in the field and are held in fixed geometry jigs for reproducibility. If an instrument fails a response check, it is tagged "Out of Service" to prevent inadvertent use and is removed from service until the problem is corrected in accordance with applicable HBPP procedures. Measurements made between the last acceptable check and the failed check will be evaluated to determine if they should remain in the data set.

5.4.4.4 *Minimum Detectable Concentration*

The MDC is determined for the instruments and techniques used for final status surveys (Table 5-9). The MDC is the concentration of radioactivity that an instrument can be expected to detect 95 percent of the time.

5.4.4.4.1 Static MDC for Structure Surfaces

For static (direct) surface measurements, with conventional detectors, such as those listed in Table 5-9, the MDC is calculated by Equation 5-7 as follows:

$$MDC_{static} = \frac{3 + 4.65\sqrt{B}}{(K)(t)}$$

Equation 5-7

where:

3 = Poisson probability sum for α and β squared and corrected to 3 (Brodsky 1992)

MDCstatic = minimum detectable concentration for direct counting (dpm/100 cm^2)

B = number of background counts during the count interval t

t = count interval (for paired observations of sample and blank, usually 1 minute)

K = calibration constant (counts/min per dpm/100 cm^2) The value of *K* includes correction factors for efficiency (e_i and e_s). The value of e_s is dependent on the material type. Corrections for radionuclide absorption have been made.

5.4.4.4.2 Structural Surface Beta-Gamma Scan MDCs

Following the guidance of Sections 6.7 and 6.8 of NUREG- 1507, MDCs for surface scans of structural surfaces for beta and gamma emitters will be computed by Equation 5-8. For determining Scan MDCs, a rate of 95 percent of correct detections is required and a rate of 60 percent of false positives is determined to be acceptable; therefore, a sensitivity index value of 1.38 was selected from Table 6.1 of NUREG-1507 and Equation 5-7 becomes:

$$MDC_{structural\ surface\ scan}(dpm/cm^2) = \frac{1.38\sqrt{B}}{\sqrt{p}\, e_i e_s \left(\frac{A}{100}\right) t}$$

Equation 5-8

where:

B = number of background counts during the count interval t

p = surveyor efficiency

e_i = instrument efficiency (2π) for the emitted radiation (cpm per dpm)

e_s = source efficiency (intensity) in emissions per disintegration

A = sensitive area of the detector (cm^2)

t = time interval of the observation while the probe passes over the source (minutes)

The numerator in Equation 5-8 represents the minimum detectable count rate that the observer would "see" at the performance level represented by the sensitivity index. The surveyor efficiency (p) will be taken to be 0.5, as recommended by Section 6.7.1 of NUREG-1507. The factor of 100 corrects for probe areas that are not 100 cm^2. In the case of a scan measurement, the counting interval is the time the probe is actually over the source of radioactivity. This time depends on scan speed, the size of the source, and the fraction of the detector's sensitive area that passes over the source, with the latter depending on the direction of probe travel. The source efficiency term (e_s) in Equation 5-8 may be adjusted to account for effects such as self absorption, as appropriate.

5.4.4.4.3 *Total Efficiency (e_t) and Source Efficiency (e_s) for Concrete Contamination*

The source term inventory on contaminated concrete appears to be primarily located within the top few millimeters of the concrete surface.

The practical application of choosing the proper instrument efficiency may be determined by averaging the surface variation (peaks and valleys narrower than the length of the detector) and adding 0.5 centimeter, the spacing that should be maintained between the detector and the highest peaks of the surface. Selection of the source to detector distance is based on Table 5-11 that best reflects the predetermined geometry.

Table 5-11 Source to Detector Distance Effects on Instrument Efficiencies for α/β Emitters

Source to Detector Distance (cm)	Instrument Efficiency ei	
	Cs-137 Distributed	Am-241 Distributed
Contact	(1) (2π eff)	(1)(2π eff)
0.5	(0.894)(2π eff)	(0.833)(2π eff)
1.0	(0.816)(2π eff)	(0.724)(2π eff)
2	(0.659)(2π eff)	(0.362) (2π eff)

Source efficiency (e_s) reflects the physical characteristics of the surface and any surface coatings. The source efficiency is the ratio between the number of particles emerging from surface and the total of particles released within the source. The source efficiency accounts for attenuation and backscatter. Source efficiency (e_s) is nominally 0.5 (no self-absorption/attenuation, no backscatter). Backscatter increases the value, self-absorption decreases the value. Source efficiencies may either be derived empirically or simply selected from the guidance contained in International Organization for Standardization (ISO) 7503-1 (Reference 5-8). ISO 7503-1 takes a conservative approach by recommending the use of factors to correct for alpha and beta self-absorption/attenuation when determining surface activity. However, this approach may prove to be too conservative for radionuclides with max beta energies that are marginally lower than 0.400 MeV, such as Co-60 with a βmax of 0.3 18 MeV. In this situation, it may be more appropriate to determine the source efficiency by considering the energies of other beta emitting radionuclides. Using this approach, it is possible to determine weighted average source efficiency. For example, a source efficiency of 0.375 may be calculated based on a 50/50 mix of Co-60 and Cs-137. The source efficiencies for Co-60 and Cs-137 are 0.25 and 0.5 respectively, since the radionuclide fraction for Co-60 and Cs-137 is 50 percent for each, the weighted average source efficiency for the mix may be calculated in the following manner:

$$(.25)(.50) + (.50)(.50) = 0.375$$

Table 5-12 lists the ISO 7503-1 source efficiencies.

Table 5-12 Source Efficiencies as Listed in ISO 7503-1

	>.400 Mev_{max}	**<.400 Mev_{max}**
Beta Emitters	$e_s = 0.50$	$e_s = 0.25$
Alpha Emitters	$e_s = 0.25$	$e_s = 0.25$

The total efficiency for any given condition can now be calculated from the product of the instrument efficiency e_i and the source efficiency e_s.

$$e_{total} = (e_i)\,(e_s)$$

Equation 5-9

where:

e_{total} = Total efficiency
e_i = Instrument efficiency
e_s = Source efficiency

5.4.4.4.4 Structural Surfaces Alpha Scan MDCs

In cases where alpha scan surveys are required, MDCs must be quantified differently from those for beta-gamma surveys because the background count rate from a typical alpha survey instrument is nearly zero (1 to 3 counts per minute, typically). Since the time that an area of alpha activity is under the probe varies and the background count rates of alpha survey instruments is so low, it is not practical to determine a fixed MDC for scanning. Instead, it is more useful to determine the probability of detecting an area of contamination at a predetermined DCGL for given scan rates. For alpha survey instrumentation with a background around 1 to 3 counts per minute, a single count will give a surveyor sufficient cause to stop and investigate further. Thus, the probability of detecting given levels of alpha emitting radionuclides can be calculated by use of Poisson summation statistics (see MARSSIM Section 6.7.22 and Appendix J for details). Doing so, one finds that the probability of detecting an area of alpha activity of 300 dpm/100 cm^2 at a scan rate of 3 cm per second (roughly 1 inch per second) is 90 percent if the probe dimension in the direction of the scan is 10 cm. If the probe dimension in the scan direction is halved to 5 cm, the detection probability is still 70 percent. Choosing appropriate values for surveyor efficiency, instrument and surface efficiencies will yield MDCs for alpha surveys for structure surfaces. If for some reason lower MDCs are desired, then scan speeds may be adjusted, within practicable limits, via the methods of Section 6.7.2.2 and Appendix J of MARSSIM.

5.4.4.4.5 Open Land Area Gamma Scan MDCs

In addition to the minimum detectable count rate (MDCR) and detector characteristics, the Scan MDC (in pCi/g) for land areas is based on extent of the elevated area, depth of the elevated area, and the radionuclide (i.e., energy and yield of gamma emissions). If one assumes constant parameters for each of these variables, with the exception of the specific radionuclide in question, the Scan MDC may be reduced to a function of the radionuclide alone. The evaluation of open land areas requires a detection methodology of sufficient sensitivity for the identification of small areas of potentially elevated activity. Scan measurements are performed by passing a 2 inch by 2 inch NaI (Tl) gamma scintillation detector in gross count rate mode across the land surface under investigation. The centerline of the detector is maintained at a source-to-detector distance of approximately 6 cm and moved from side to side in a 1 meter wide pattern at a rate of 0.5 m/sec. This serpentine scan pattern is designed to cross each survey cell (one square meter [1 m^2]) a minimum of three times in approximately 10 seconds with a maximum separation of less than 150 cm between one pass. The audible signal is monitored for detectable increases in count rate. An observed count rate increase results in further investigation to verify findings and define the level and extent of residual radioactivity. This method represents the Stage 1 and Stage 2 surface scanning process for land areas defined in NUREG-1507 and is the basis for calculation of the scanning detection sensitivity (Scan MDC). The sensitivity is only slightly affected by the relative amounts of Cs-137 and Co-60 in the soil, giving typical Scan MDC values in the range of 5 to 6 pCi/g for instrument backgrounds of 8,000 to 10,000 cpm. Alternative methods of sufficient sensitivity for the identification of small areas of elevated radioactivity may be used where appropriate.

An a priori determination of scanning sensitivity is performed to ensure that the measurement system is able to detect concentrations of radioactivity at levels below the regulatory release limit. Expressed in terms of scan MDC, this sensitivity is the lowest concentration of radioactivity for a given background that the measurement system is able to detect at specified performance level and surveyor efficiency.

The Scan MDC value (in pCi/g) for open land area surface scanning with a desired performance level of 95 percent correct detections and 60 percent false positive rate, the sensitivity index has a value of 1.38, resulting in the following MDCR:

$$MDCR = 1.38\sqrt{b_i} \times \left(\frac{60\ sec}{1\ min}\right)$$

Equation 5-10

where:

b_i = background counts in the observation interval

Introducing the human factor performance element of surveyor efficiency, the surveyor minimum detectable count rate becomes:

$$MDCR_{surveyor} = \frac{MDCR}{\sqrt{p}}$$

Equation 5-11

Where:

$MDCR_{surveyor}$ = Minimum detectable surveyor count rate (cpm), and

p = Surveyor efficiency = *0.5*

A corresponding minimum detectable exposure rate can be determined for a specified detector and radionuclide by dividing the $MDCR_{surveyor}$ value by the detector manufacturer's count rate to exposure rate ratio (cpm per μR/h) to give a minimum detectable exposure rate in units of μR/h. The minimum detectable exposure rate then is used to determine the minimum detectable radionuclide concentration (i.e., the Scan MDC) by modeling a specified small area of elevated activity using MicroShield™ to yield a conversion factor (E_i) of cpm per pCi/g. The minimum detectable exposure rate is then divided by the MicroShield™ conversion factor to give a Scan MDC in units of pCi/g.
Table 5-13 provides the E_i for HBPP predominant gamma emitting radionuclides as determined by HBPP Technical Basis Documents (TBD) *Instrument Efficiency Determination for use in Minimum Detectable*

Concentration Calculations in Support of the Final Status Survey at HBPP.

Table 5-13 Efficiency for Photon Emitting Isotopes

Isotope	E_i (cpm/pCi/g)
Co-60	315
Nb-94	387
Cs-137	202
Eu-152	419
Eu-154	230

5.4.4.4.6 HPGe Spectrometer Analysis

The onsite chemistry laboratory maintains gamma isotopic spectrometers that are calibrated to various sample geometries, including one liter Marinelli geometry for soil analysis. These systems are calibrated using a National Institute of Standards and Technology (NIST) traceable mixed gamma source using approved procedures. The detectors are manufactured by Canberra Industries. Approved off-site laboratories may also be used to perform gamma analyses.

Laboratory counting system count times are set to meet a maximum MDC of 10 percent of the DCGL for HBPP radionuclides.

5.4.4.4.7 Pipe Survey Instrumentation

Accessible portions of any remaining embedded piping will be surveyed to ensure residual remaining activity is less than the DCGL. Pipe survey instruments proposed for use at HBPP are scintillation detectors and/or Geiger-Mueller (GM) arrays. Pipe survey instruments proposed for use will have a level of sensitivity adequate to detect residual activity below the embedded piping DCGLs.

5.5 Data Collection and Processing

This section describes data collection, review, validation, and record keeping requirements for final status surveys.

5.5.1 *Sample Handling and Record Keeping*

A chain-of-custody (COC) record will accompany each sample from the collection point through obtaining the final results to ensure the validity of the sample data. COC records are controlled and maintained in accordance with applicable procedures.

Each survey unit has an associated document package that covers the design and field implementation of the survey requirements. Survey unit records are considered quality records.

5.5.2 *Data Management*

Survey data are collected from several sources during the data life cycle and are evaluated for validity throughout the survey process. QC replicate measurements are not used as FSS data. Measurements performed during turnover and investigation surveys can be used as FSS data if they were performed according to the same requirements as the FSS data, as follows:

- Survey data shall reflect the as-left survey unit condition (i.e., no further remediation required).
- The application of isolation measures to the survey unit to prevent recontamination and to maintain final configuration are in effect.
- The data collection and design were in accordance with FSS methods and procedures (e.g., Scan MDC, investigation levels, survey data point number and location, statistical tests, and EMC tests or as specified by the LAR submitted for the HBGS).

Measurement results stored as final status survey data constitute the final survey of record and are included in the data set for each survey unit used for determining compliance with the site release criteria. Measurements are recorded in units appropriate for comparison to the applicable DCGL. Numerical values, even negative numbers, are recorded. Measurement records include, at a minimum, the surveyor's name, the location of the measurement, the instrument used, measurement results, the date and time of the measurement, any surveyor comments, and records of applicable reviews.

5.5.3 *Data Verification and Validation*

The FSS data are reviewed prior to data assessment to ensure that they are complete, fully documented, and technically acceptable.

The review criteria for data acceptability will include at a minimum, the following items:

- The instrumentation MDC for fixed or volumetric measurements was below the $DCGL_W$ or if not, it was below the $DCGL_{EMC}$ for Class 1, below the $DCGL_W$ for Class 2, and below 0.5 $DCGL_W$ for Class 3 survey units.
- The instrument calibration was current and traceable to NIST standards.
- The field instruments were source checked with satisfactory results before and after use each day data were collected or data were evaluated accordance with Section 5.4.4.3.
- The MDCs and assumptions used to develop them were appropriate for the instruments and techniques used to perform the survey.
- The survey methods used to collect data were appropriate for the types of radiation involved and for the media being surveyed.
- "Special methods" for data collection were properly applied to the survey unit under review. These special methods are described in this LTP section or will be the subject of an NRC notice of opportunity for review.
- The sample was controlled from the point of sample collection to the point of obtaining results.
- The data set is comprised of qualified measurement results collected in accordance with the survey design, which accurately reflects the radiological status of the facility.
- The data have been properly recorded.

If the data review criteria were not met, the discrepancy will be reviewed and the decision to accept or reject the data will be documented, reviewed, and approved by the FSS Supervisor.

5.5.4 *Graphical Data Review*

Survey data will be graphed to identify patterns, relationships, or possible anomalies that might not be apparent using other methods of review. A posting plot and a frequency plot will be made. Other special graphical representations of the data set will be made as the need dictates. The FSS Supervisor will review all data for acceptance.

5.5.4.1 *Posting Plots*

Posting plots will be used to identify spatial variability in the data. The posting plot consists of the survey unit map with the numerical data shown at the location from which it was obtained. Posting plots can reveal areas of elevated radioactivity or local areas in which the DCGL is exceeded. Posting plots can be generated for background reference areas to point out spatial trends that might adversely affect the use of the data. Anomalies in the background data may be the result of residual, undetected activity, or may just reflect background variability.

5.5.4.2 *Frequency Plots*

Frequency plots will be used to examine the general shape of the data distribution. Frequency plots are basically bar charts showing data points within a given range of values. Frequency plots reveal such things as skewness and bimodality (having two peaks). Skewness may be the result of a few areas of elevated activity or may be the result of very little activity present in the survey unit such as a log-normal data distribution. Multiple peaks (bi-modal, tri-modal, etc.) in the data may indicate the presence of isolated areas of residual radioactivity or background variability due to soil types or differing materials of construction. Variability may also indicate the need to match background reference areas to survey units more carefully or to subdivide the survey unit by material or soil type.

5.5.4.3 *Contour and 3-D Surface Plots*

Contour and 3-D surface plots may be used to represent graphically a trend in collected survey data. This can be an aid in visualizing the location of activity outside the area that affects the collected data. Contour and 3-D surface plots typically require that a plotting algorithm be applied to interpolate data at a predetermined frequency.

5.6 Data Assessment and Compliance

An assessment is performed on the FSS data to ensure that they are adequate to support the determination to release the survey unit. Simple assessment methods such as comparing the survey data to the DCGL or comparing the mean value to the DCGL are first performed. The statistical tests are then applied, as necessary, to the final data set and conclusions are made as to whether the survey unit meets the site release criterion.

5.6.1 *Data Assessment Including Statistical Analysis*

The results of the survey measurements are evaluated to determine whether the survey unit meets the release criteria. In some cases, the determination can be made without performing complex, statistical analyses.

5.6.1.1 *Interpretation of Sample Measurement Results*

An assessment of the measurement results is used to determine quickly whether the survey unit passes or fails the release criteria or whether one of the statistical analyses must be performed. The evaluation matrices are presented in Tables 5-14 and 5-15.

Table 5-14 Interpretation of Sample Measurements When the WRS Test is Used

Measurement Results	Conclusion
Difference between maximum survey unit concentration and minimum reference area concentration is less than $DCGL_W$	Survey Unit meets the release criteria
Difference of survey unit average concentration and reference average concentrations greater than $DCGL_W$	Survey Unit fails
Difference between any survey unit concentration and any reference area concentration is greater than $DCGL_W$. A difference of survey unit average concentration and reference area average concentration is less than $DCGL_W$	Conduct WRS test and elevated measurements test

Table 5-15 Interpretation of Sample Measurements When the Sign Test is Used

Measurement Results	Conclusion
All concentrations less than $DCGL_W$	Survey Unit meets the release criteria
Average concentration greater than $DCGL_W$	Survey Unit fails
Any concentration greater than $DCGL_W$ and average concentration less than $DCGL_W$	Conduct Sign test and elevated measurements test

When required, one of four nonparametric statistical tests will be performed on the survey data:

1. WRS Test

2. Sign Test
3. WRS Test Unity Rule
4. Sign Test Unity Rule

In addition, survey data are evaluated against the EMC criteria as previously described in Section 5.3.6.3 and as required by NUREG-1757, Volume 2. The statistical test is based on the null hypothesis (H_0) that the residual radioactivity in the survey unit exceeds the DCGL. There must be sufficient survey data at or below the DCGL to reject the null hypothesis and conclude the survey unit meets the site release criterion for dose. Statistical analyses are performed using a specially designed software package or, if necessary, using hand calculations.

5.6.1.2 *Wilcoxon Rank Sum Test*

The WRS test, or WRS Unity Rule (NUREG-1505, Chapter 11), may be used when the radionuclide of concern is present in the background or measurements are used that are not radionuclide-specific. In addition, this test is valid only when "less than" measurement results do not exceed 40 percent of the data set.

The WRS test is applied as follows:

1. The background reference area measurements are adjusted by adding the $DCGL_W$ to each background reference area measurement, X_i; (i.e., $Z_i = X_i$ + DCGL).
2. The number of adjusted background reference area measurements, m, and the number of survey unit measurements, n, are summed to obtain N, (N =m + n).
3. The measurements are pooled and ranked in order of increasing size from 1 to N. If several measurements have the same value, they are assigned the average rank of that group of measurements.
4. The ranks of the adjusted background reference area measurements are summed to obtain Wr.
5. The value of Wr, is compared with the critical value in Table I.4 of MARSSIM. If Wr, is greater than the critical value, the survey unit meets the site release dose criterion. If Wr, is less than or equal to the critical value, the survey unit fails to meet the criterion.

5.6.1.3 *Sign Test*

The Sign Test and Sign Test Unity Rule are one-sample statistical tests used for situations in which the radionuclide of concern is not present in background, or is present at acceptable low fractions compared to the $DCGL_W$. If present in background, the gross measurement is assumed to be entirely from plant activities. This option is used when it can be reasonably expected that including the background concentration will not affect the outcome of the Sign test. The advantage of using the Sign Test is that a background reference area is not necessary. The Sign Test is conducted as follows:

1. The survey unit measurements, X_i, i = 1, 2, 3,...N; where N = the number of measurements, are listed.
2. X_i is subtracted from the $DCGL_W$ to obtain the difference $D_i = DCGL_W - X_i$, where i = 1, 2, 3,..., N.
3. Differences where the value is exactly zero are discarded and N is reduced by the number of such zero measurements.
4. The number of positive differences is counted. The result is the test statistic S+.

   Note: A positive difference corresponds to a measurement below the $DCGL_W$ and contributes evidence that the survey unit meets the site release criterion.

5. The value of S+ is compared to the critical value given in Table I.3 of MARSSIM. The table contains critical values for given values of N and α. The value of α is set at 0.05 during survey design. If S+ is greater than the critical value given in the table, the survey unit meets the site release criterion. If S+ is less than or equal to the critical value, the survey unit fails to meet the release criterion.

5.6.2 *Unity Rule*

5.6.2.1 *Multiple Radionuclide Evaluations*

The Cs-137 to Co-60 (or other gamma nuclide) ratio will vary in the final survey soil samples, and this will be accounted for using a "unity rule" approach as described in NUREG-1505, Chapter 11. Unity Rule Equivalents will be calculated for each measurement result using the surrogate adjusted Cs-137 DCGL and the Co-60 DCGL, as shown in the following Equation 5-12.

$$Unity\ Rule\ Equivalent \leq 1 = \frac{Cs-137}{DCGL_{Cs-137s}} + \frac{Co-60}{DCGL_{Co-60}} + \cdots + \frac{R_n}{DCGL_n}$$

Equation 5-12

where:

Cs-137 and Co-60 are the gamma results

$DCGL_{Cs\text{-}137\,s}$ = the surrogate Cs-137, DCGL, as applicable

$DCGL_{Co\text{-}60}$ = the Co-60 DCGL

R_n = any other identified gamma emitting radionuclide

$DCGL_n$ = the DCGL for radionuclide N

The unity rule equivalent results will be used to demonstrate compliance, assuming the DCGL is equal to 1.0 using the criteria listed in Tables 5-14 and 5-15. If the application of the WRS or Sign Test is necessary, these tests will be applied using the unity rule equivalent results and assuming that the DCGL is equal to 1.0. An example of a WRS test using the unity rule is provided in NUREG-1505, Page 11-3; Section 11.4 (If the WRS Test was used, or background subtraction was used in conjunction with the Sign Test, background concentrations also would be converted to Unity Rule Equivalents prior to performing test). The Sign Test will be used without background subtraction if background Cs-137 is not considered a significant fraction of the DCGL.

Note that the surrogate Cs-137 DCGL will be used for both the statistical tests and comparisons with the criteria in Tables 5-13 and 5-14. The same general surrogate and unity rule methods described previously for soil would be applied to other materials, such as activated concrete, where sample gamma spectroscopy is used for final survey as opposed to gross beta measurements.

5.6.2.2 *Elevated Measurement Comparison Evaluations*

During final surveys, areas of elevated activity may be detected and they must be evaluated both individually and in total to ensure compliance with the release criteria. Each elevated area is compared to the specific $DCGL_{EMC}$ value calculated for the size of the specific elevated area. If the individual elevated area passes, then the elevated areas are combined and evaluated under the unity rule.

The average activity of each elevated area is determined as well as the average value for the survey unit. The survey unit average value is divided by the $DCGL_W$, the survey unit average value is subtracted from the elevated area average activity value, and the result is divided by the elevated area $DCGL_{EMC}$. Each elevated area net average activity is evaluated against its $DCGL_{EMC}$. The fractions are summed and the result must be less than unity for the survey unit to pass. This is summarized in Equation 5-13.

$$\frac{\delta}{DCGL} + \frac{\bar{C}_{elevated} - \delta}{(Area\ Factor) \times DCGL} < 1$$

Equation 5-13

Where:

δ = average concentration outside the elevated area

$\bar{C}_{elevated}$ = average concentration in the elevated area

A separate term will be used in the equation for each elevated area identified in a survey unit.

5.6.3 *Data Conclusions*

The results of the statistical tests, including application of the EMC, allow one of two conclusions to be made. The first conclusion is that the survey unit meets the site release dose criterion. The data provide statistically significant evidence that the level of residual radioactivity in the survey unit does not exceed the release criterion. The decision to release the survey unit is made with sufficient confidence and without further analysis. The second conclusion that can be made is that the survey unit fails to meet the release criterion. The data are not conclusive in showing that the residual radioactivity is less than the release criterion. The data are analyzed further to determine the reason for the failure.

Possible reasons include the following:

- The average residual radioactivity exceeds the $DCGL_W$.
- The average residual radioactivity is less than the $DCGL_W$; however, the survey unit fails the elevated measurement comparison.
- The survey design or implementation was insufficient to demonstrate compliance for unrestricted release.
- The test did not have sufficient power to reject the null hypothesis (i.e., the result is due to random statistical fluctuation).

The power of the statistical test is a function of the number of measurements made and the standard deviation in measurement data. The power is determined from $1-\beta$ where β is the value for Type II errors. A retrospective power analysis may be performed using the methods described in Appendix I.9 of MARSSIM.

If the power of the test is insufficient due to the number of measurements, additional samples may be collected as directed by procedure. A greater number of measurements increase the probability of passing if the survey unit actually meets the release criterion. Retrospective power analyses will be developed for each HBPP survey unit, regardless if the unit passes FSS criteria or not.

If failure was due to the presence of residual radioactivity in excess of the release criterion, the survey unit shall be remediated and as necessary, reclassified. Survey unit failure due to inadequate design or implementation shall require investigation and reinitiation of the FSS process.

5.6.4 *Compliance*

The FSS is designed to demonstrate licensed radioactive materials have been removed from the HBPP site to the extent that remaining residual radioactivity is below the radiological criteria for unrestricted release. The site-specific radiological criteria presented in this plan demonstrate compliance with the criteria of 10 CFR 20.1402. If the measurement results pass the requirements of Section 5.6.1 and 5.6.1.2, and the elevated areas evaluated per Section 5.6.2.2 pass the elevated measurement comparison, the survey unit is suitable for unrestricted release. If survey measurements do not meet the criteria specified in Table 5-5, an investigation will be performed. Investigations will include an evaluation of survey design, instrumentation use, and calculations, as necessary. Investigations of this nature will be documented in accordance with the HBPP FSS QA Plan.

5.7 Final Status Survey Reporting Format

Survey results and a brief operating history are documented in the FSS Report. Other reports may be generated as requested by NRC.

5.7.1 *Operating History*

A brief operational history including relevant operational and decommissioning data is compiled. The purpose of the historical information is to provide additional, substantive data that form a portion of the basis for the survey unit classification, and hence, the level of intensity of the FSS. The historical information includes operating history that could affect radiological status, summarized scoping and site characterization data, and other relevant information as deemed necessary.

5.7.2 *Final Status Survey Report*

Survey results will be described in a written report for each survey area and submitted to the NRC. Upon completion of each survey area the FSS report provides a summary of the survey results and the overall conclusions that demonstrate that the HBPP site meets the radiological criteria for unrestricted use. Information such as the number and type of measurements, basic statistical quantities, and statistical analysis results are included in the report. The level of detail is sufficient to describe clearly the FSS program and to certify the results. The format of the final report will contain, as a minimum, the following topics:

- Overview of the results
- Discussion of changes to FSS
- FSS Methodology
  - Survey unit sample size
  - Justification for sample size
- FSS Results
  - Number of measurements taken
  - Survey maps
  - Sample concentrations

  - Statistical evaluations
  - Judgmental and miscellaneous data sets
- Anomalous data
- Conclusion for each survey unit
- Any changes from initial assumptions on extent of residual activity

5.7.3 *Other Reports*

Other reports relating to FSS activities may be prepared and submitted as necessary.

5.8 Final Status Survey Program Quality (QAPP)

Quality is built in to each phase of the FSS Program and measures must be taken during the execution of the plan to determine whether the expected level of quality is being achieved. The FSS Program will ensure that the site will be surveyed, evaluated, and determined to be acceptable for unrestricted release if the residual activity results in an annual TEDE to the average member of the critical group of 25 mrem/year or less for all pathways and is ALARA. The following sections provide a description of applicable HBPP quality programs and specific quality elements of the FSS Program.

5.8.1 *FSS Quality Assurance Project Plan*

The objective of the FSS QAPP is to ensure the survey data collected are of the type and quality needed to demonstrate with sufficient confidence the site is suitable for unrestricted release. The objective is met through use of the DQO process for FSS design, analysis, and evaluation. The plan ensures the following items are accomplished:

- The elements of the FSS plan are implemented in accordance with approved procedures and survey instructions.
- Surveys are conducted by trained personnel using calibrated instrumentation.
- The quality of the data collected is adequate.
- All phases of package design and survey are properly reviewed, with management oversight provided.
- Corrective actions, when identified, are implemented in a timely manner and are determined to be effective.

The following sections describe the basic elements of the FSS QAPP.

5.8.1.1 *Project Management and Organization*

Compliance with the QAPP and the LTP shall be the responsibility of all personnel involved with FSS activities. The HBPP staff performs the following specific responsibilities. Outside vendors may also be contracted to perform specific review activities such as the following:

- Perform surveillance of the implementation of the FSS
- Performing periodic audits of the FSS program
- Perform conformance reviews of selected FSS implementing procedures
- Perform conformance reviews of selected FSS reports

The HBPP FSS Organization is responsible for the quality of those activities necessary to achieve a final status of unrestricted use for the HBPP site.

The following are key FSS positions. The responsibilities for the key positions are described in HBAP C-225, "Final Status Survey Program," and responsibilities may be assigned to a designee as appropriate.

- HBPP Site Closure Manager
- FSS Supervisor
- FSS Engineers
- FSS Foreman

Figure 5-2 provides an organizational chart of the projected HBPP License Termination Organization.

5.8.1.2 *Program Controls*

Program Controls shall be established for performing specific FSS activities. Activities will be accomplished using suitable instructions, procedures, and drawings that incorporate appropriate regulatory and industry guidance.

Personnel conducting activities shall be appropriately trained and qualified. Training, qualification, and any appropriate maintenance of proficiency requirements shall be defined in administrative procedures or instructions. Professional resumes, other verifiable credentials, and/or discrete certification packages, as applicable, shall be used to document personnel qualifications.

5.8.1.3 *Design Controls*

Design control requirements are established to ensure that the applicable regulatory bases, codes, technical standards, and quality standards are identified in the FSS. Design controls also include independent verification and design interface control. These design controls will be implemented to determine the DCGLs, MDCs, area factors, and other DQO and FSS elements.

5.8.1.4 *Procurement Document Control*

Procurement documents related to the FSS shall be prepared in accordance with approved procedures and instructions. These procedures and instructions shall contain provisions to ensure that procurement documents include or reference applicable regulatory requirements and any other requirement necessary to guarantee adequate quality for the purchased service, equipment, or material.

5.8.1.5 *Instructions, Procedures, and Drawings*

The performance of the FSS will require procedures for personnel training, survey implementation, data collection, COC, instrument calibration and maintenance, verification, and record storage. These procedures will ensure compliance with the LTP and will meet applicable quality requirements. These quality requirements include the development and approval in accordance with the site controls.

5.8.1.6 *Document Control*

Instructions, Procedures, and Drawings shall be controlled as described in approved procedures or instructions. Controlled copies shall be available for use by personnel performing activities affecting the FSS Program. These controls shall ensure that only current information is issued and used. The results of the FSS will be retained at least for the duration of the 10 CFR 50 facility license.

5.8.1.7 *Control of Purchased Material, Items, and Services*

Vendors may be used for the performance of the FSS and laboratory activities. Quality related services, such as laboratory analysis, are procured from qualified vendors whose internal QA program is subject to approval in accordance with approved procedures. Additionally, audits and surveillances of these contractors should be performed to provide an adequate level of assurance that the quality activities are being effectively performed and conform to the requirements of the procurement document.

5.8.1.8 *Control of Special Processes*

Procedures will be developed to implement any special processes that may be used in support of FSS implementation. The special processes used will be validated and implemented by trained, qualified individuals using approved procedures.

5.8.1.9 *Inspections*

Inspections and verification activities will be delineated in implementing procedures. These programs and procedures will be used to verify that sampling and surveying protocols are appropriately performed. Appropriate members of the line organization that are qualified, or an independent organization as described in administrative procedures, may perform these inspections.

5.8.1.10 *Control of Measuring and Test Equipment*

Approved procedures will be developed for the control, use, calibration, and testing of the equipment used for the FSS, including both laboratory and field use equipment. These procedures will ensure confidence in the data obtained. Instrument calibrations will be performed periodically in accordance with appropriate industry standards.

5.8.1.11 *Handling, Storage and Shipping*

Some of the material samples will be transported to offsite laboratories for analysis. The process for controlling this material will be sufficient to ensure that a COC is maintained. Measures shall be established to ensure that samples are received, handled, stored, packaged, and shipped in accordance with approved procedures or instructions. These procedures or instructions shall be responsive to applicable industry or manufacturer's requirements and include controls for "shelf life" of sensitive products. Additionally, protocols must be established to ensure there is no cross-contamination between samples and sample packaging. Appropriate controls will be defined in administrative procedures to ensure that sample integrity is maintained.

5.8.1.12 *Control of Nonconformance*

During the performance of the FSS, nonconforming conditions may be identified with equipment or services. The data associated with the nonconforming condition will be controlled until such time that it is accepted, rejected, or reworked in accordance with an appropriate procedure. Nonconforming equipment will not be used until conformance with applicable requirements has been established.

5.8.1.13 *Corrective Action Program*

The existing HBPP Corrective Action Program will be used for the FSS Program to ensure conditions adverse to quality are promptly identified and corrected.

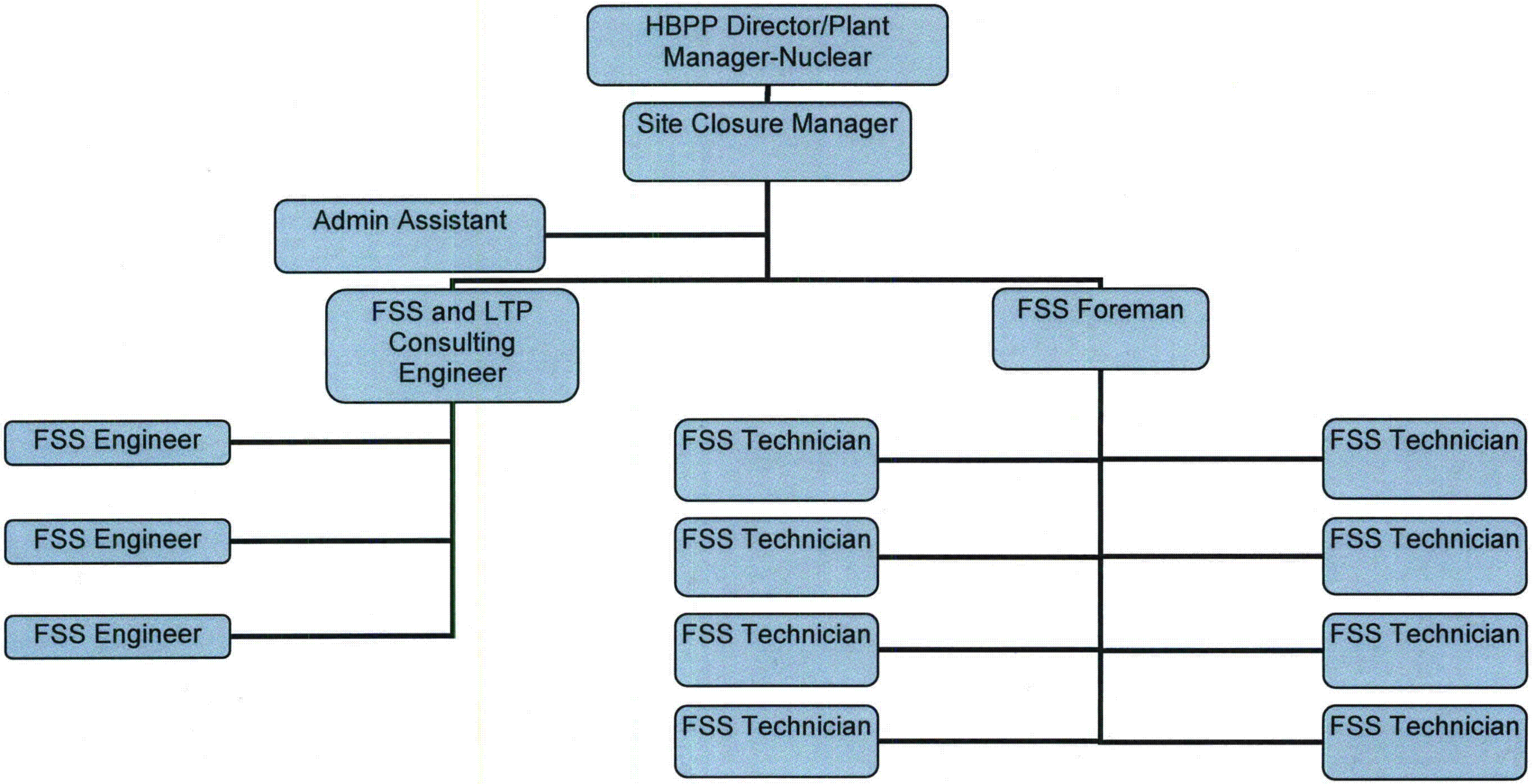
5.8.1.14 *Records*

Measures have been established that ensure that FSS records are maintained as quality records. These measures also include procedures by which the records are reviewed and approved, and procedures that ensure the records can be retrieved within a reasonable period. The controls shall also provide for the protection of the records to ensure they are not lost or subject to degradation over time.

5.8.1.15 *Audits*

Audits of FSS activities will be performed periodically, in accordance with approved procedures or instructions, to verify the implementation of quality activities.

Figure 5-2 Projected HBPP FSS Organizational Chart



5.9 References

5-1 U.S. Nuclear Regulatory Commission NUREG-1757, Volume 2, "Consolidated NMSS Decommissioning Guidance - Characterization, Survey, and Determination of Radiological Criteria, Final Report," September 2003.

5-2 U.S. Nuclear Regulatory Commission NUREG-1575, Revision 1, "Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM)," August 2000.

5-3 U.S. Nuclear Regulatory Commission NUREG-1505, Revision 1, "A Nonparametric Statistical Methodology for the Design and Analysis of Final Status Decommissioning Surveys," June 1998 Draft.

5-4 U.S. Nuclear Regulatory Commission NUREG-1507, "Minimum Detectable Concentrations with Typical Radiation Survey Instruments for Various Contaminants and Field Conditions," June 1998

5-5 U.S. Nuclear Regulatory Commission NUREG-1700, Revision 1, "Standard Review Plan for Evaluating Nuclear Power Reactor License Termination Plans," April 2003

5-6 U.S. Nuclear Regulatory Commission Regulatory Guide 1.179, "Standard Format and Content of License Termination Plans for Nuclear Power Reactors," January 1999

5-7 U.S. Nuclear Regulatory Commission NUREG/CR-5512, Volume 1, Final Report, 1992

5-8 International Organization for Standardization, ISO 7503-1, "Evaluation of Surface Contamination - Part 1: Beta Emitters and Alpha Emitters (first edition)," 1988

5-9 Brodsky, A, 1992 "Exact Calculation of Probabilities of False Positives and False Negatives for Low Background Counting" Health Physics 63(2): 198-204

5-10 HBPP TBD, *Instrument Efficiency Determination for use in Minimum Detectable Concentration Calculations in Support of the Final Status Survey at HBPP,* Revision 0

5-11 HBPP TBD, "*Radiological Selection for DCGL Development,*" Revision 0

5-12 Applicable Site Procedures for FSS:

- HBAP C-225, "Final Status Survey (FSS) Program," Revision 0
- HBAP C-202, "FSS Quality Assurance Program Procedure (QAPP)," Revision 0
- RCP FSS-8, "Collection of Site Characterization and FSS Samples," Revision 1
- RCP FSS-7, "Determination of the Number and Locations of FSS Samples," Rev. 0
- RCP FSS-4, "Isolation and Control of Areas for FSS," Revision 0A
- RCP FSS-1, "Survey Unit Classification," Revision 0
- RCP FSS-2, "Preparation of FSS Survey Plans," Revision 0
- RCP-FSS-15, "Statistical Tests," Revision 0
- RCP FSS-13, "Area Surveillance Following FSS," Revision 0
- RCP FSS-14, "Data Quality Assessment," Revision 0
- RCP FSS-17, "Preparation of FSS Reports," Revision 0
- RCP FSS-11, "Split Sample Assessment for Final Status Survey," Revision 0
- RCP FSS-18, "Computer Determination of the Number and Location of FSS Samples and Measurements," Revision 0
- RCP FSS-3, "FSS Background Assessment," Revision 0
- RCP FSS-16, "ALARA Evaluations for Final Status Survey Areas," Revision 0

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6. COMPLIANCE WITH THE RADIOLOGICAL CRITERIA FOR LICENSE TERMINATION

6.1. Site Release Criteria

6.1.1. Radiological Criteria for Unrestricted Use

The site release criteria for the Humboldt Bay Power Plant (HBPP), Unit 3, site are the NRC's radiological criteria for unrestricted use established in 10 CFR 20.1402 (Reference 6-1):

- **Dose Criterion**: The residual radioactivity that is distinguishable from background radiation results in a Total Effective Dose Equivalent (TEDE) to an average member of the critical group that does not exceed 25 mrem/yr, including that from groundwater sources; and
- **ALARA Criterion**: The residual radioactivity has been reduced to levels that are As Low As Reasonably Achievable (ALARA).

"Background radiation" in the previous criteria means radiation from cosmic sources, natural occurring radioactive material (including radon, except as a decay product of source or special nuclear material), and global fallout as it exists in the environment from the testing of nuclear explosive devices or from past nuclear accidents such as Chernobyl. All of these sources of radiation contribute to background radiation and are not under control of the licensee. Background radiation does not include radiation from source, byproduct, or special nuclear materials regulated by the commission.

6.1.2. Conditions Satisfying the Site Release Criteria

Derived concentration guideline levels (DCGLs) are radionuclide-specific activity concentrations that correspond to release criteria described in Section 6.1.1. DCGL values are derived from activity-dose relationships through the analysis of various exposure pathway scenarios. Section 6.2.3 discusses the potential radionuclides of concern for the HBPP site.

DCGL values for assessing residual radioactivity on building surfaces and in site soil have been calculated for each potential radionuclide of concern. The DCGLs form the basis for the following conditions which, when met, satisfy the site release criteria as prescribed in 10 CFR 20.1402:

- The average residual radioactivity above background is less than or equal to the DCGL. For mixtures of radionuclides, the sum of the fractions of the contaminant's concentration over the contaminant's DCGL must be less than or equal to one.

- Individual measurements representing small areas of residual radioactivity that exceed the DCGL, but do not exceed the elevated measurement comparison DCGL ($DCGL_{EMC}$).
- Where one or more individual measurements exceed the DCGL, but the average residual radioactivity passes the Wilcoxon Rank Sum or Sign statistical test.
- Remediation of contaminated areas is performed where ALARA considerations require that levels of residual radioactivity be below DCGLs.

The methods in Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM) (Reference 6-2) and the DCGLs may not be appropriate for nonstructural components. For those nonstructural components and systems to which MARSSIM does not apply, the current "no detectable" criteria, consistent with IE Circular 81-07, (Reference 6-17) and/or the Multi-Agency Radiation Survey and Assessment of Materials and Equipment Manual (MARSAME) (Reference 6-3) protocol will be applied to disposition these items. Similarly, the DCGLs are not appropriate for assessing embedded piping.

6.2. Dose Modeling Approach

6.2.1. Overview

Dose models allow the translation of residual radioactivity levels into potential radiation doses to the public. For the Humboldt Bay site, dose models have been developed based on the guidance found in NUREG/CR-5512 (Reference 6-4), Volumes 1, 2, and 3. The conceptual model reflects the anticipated site conditions at the time of license termination. The dose modeling approach for the Humboldt Bay site is consistent with the information for site-specific modeling provided in Appendix I of NUREG-1757 (Reference 6-6), including source term abstraction and scenarios, pathways, and critical groups.

There are three defining factors for a dose model: (1) the scenario, (2) the critical group, (3) and the exposure pathways. The scenarios described in NUREG/CR-5512, Volume 1, address the major exposure pathways of direct exposure to penetrating radiation and inhalation and ingestion of radioactive materials. The scenarios also identify the critical group, which is defined as the group of individuals reasonably expected to receive the greatest exposure to residual radioactivity within the assumptions of a particular scenario. The design for scenarios and the site-specific modeling provide reasonable and conservative estimates of the potential doses associated with residual radioactivity.

The dose models supporting the building surface and soil DCGLs were developed using the approach outlined previously. The scenarios described in NUREG/CR-5512, Volume 1, were selected for the Humboldt Bay site to estimate potential radiation doses from radioactive material in buildings (Building Occupancy Scenario) and soil (Resident Farmer Scenario).

6.2.2. Site Conceptual Model

The site conceptual model (SCM) for the HBPP facility is the relationship between the sources of residual radioactivity, the areas where the sources are located, transport mechanisms, exposure routes, and the receptor (i.e., hypothetically exposed human). The SCM describes how residual radioactivity at the site might enter into the environment, how it moves around within the environment, and the routes used to expose humans. The SCM has three fundamental components that are needed to calculate (or model) the potential future dose to a receptor on or near the decommissioned facility. The first component is the physical characteristic(s) of the site. The second is the source term itself. The third is the range of realistic (plausible) human exposure scenarios that are described by factors that are associated with human behavior and metabolic processes. Each of these fundamental components is described in the following subsections.

6.2.2.1 Geology

Figures 6-1 and 6-2 provides the HBPP site location and the HBPP boundary respectively. The HBPP at Buhne Point is at the northern margin of the northeast-trending Eel River Geosyncline. Deposits in the geosynclines range in age from Cretaceous to Recent. Consolidated bedrock is overlain by approximately 3,000 to 4,000 ft of unconsolidated clay, silt, sand, and gravel in the

Eel River-Humboldt Bay area. The bedrock consists of the Franciscan assemblage; Yager Formation; and the Pullen, Eel River, Rio Dell, and Scotia Bluffs formations of the Wildcat Group. The unconsolidated sediments contain most of the groundwater in the region and are divided into dune sand, alluvium, terrace deposits, the Hookton Formation, and the Carlotta Formation of the upper Wildcat Group.

6.2.2.2 *Site Stratigraphy*

The HBPP site is underlain by sediments of the Hookton Formation. Borehole data indicate that to a depth of approximately 15-35 feet, the strata are compact clay, clayey sands, and clayey silt. Below this layer lies a sand body that becomes gravelly with depth, containing pea to cobble sized gravels in thin discontinuous lenses. The sand extends to a depth of approximately 110 feet; however, it is divided into two relatively clean sections by a clayey zone (2^{nd} Bay Clay). The Lower Hookton Formation encounters the Wildcat Group at a depth of approximately 1,100 feet. The lower unit of the Hookton Formation consists of laterally persistent beds of alternating sand, silty sand, gravel, gravelly sand, silty clay, and clay. Figure 6-3 illustrates the various zones.

Figure 6-1 HBPP Site Location

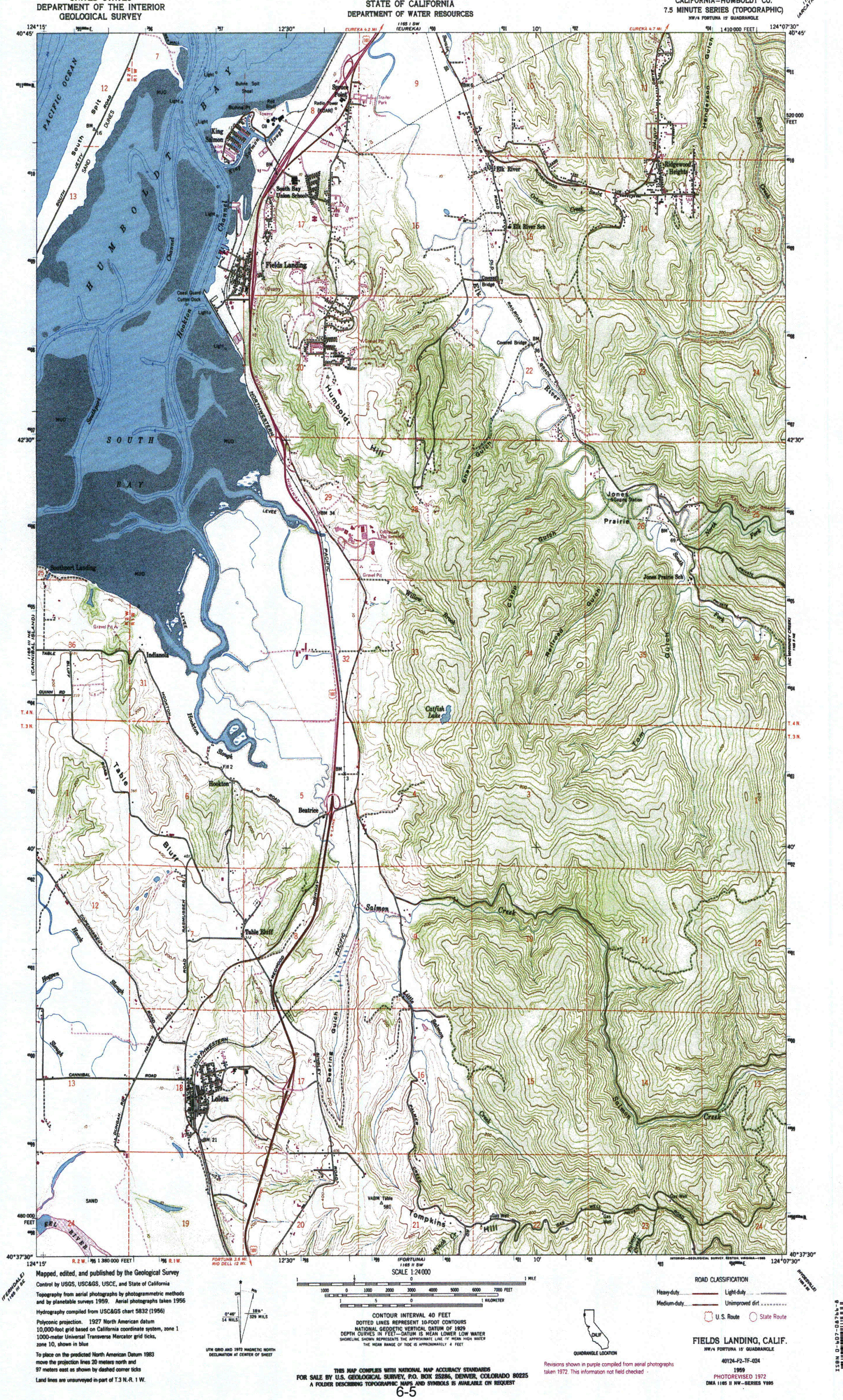


Figure 6- 2 Aerial View of HBPP With Site Boundary

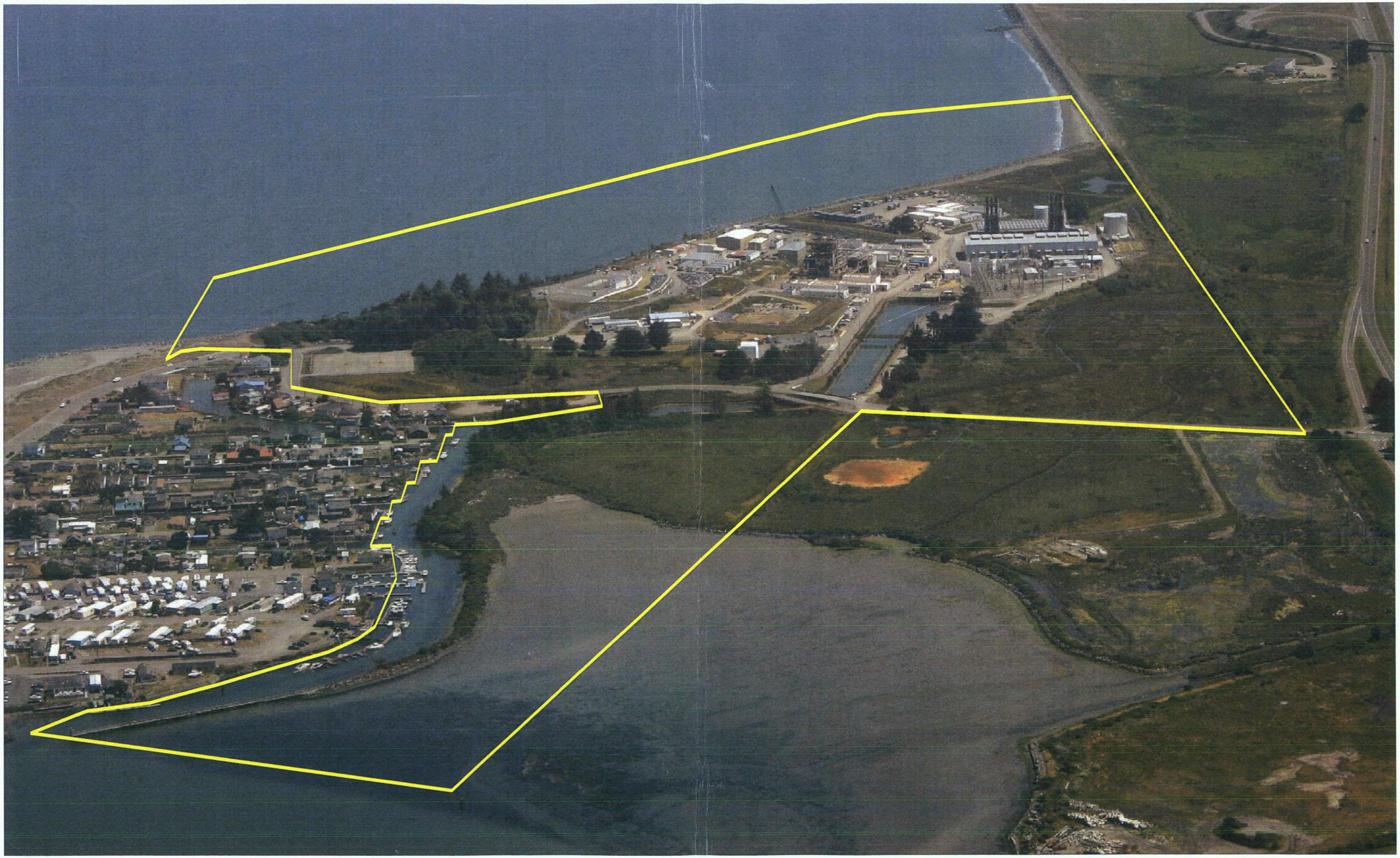
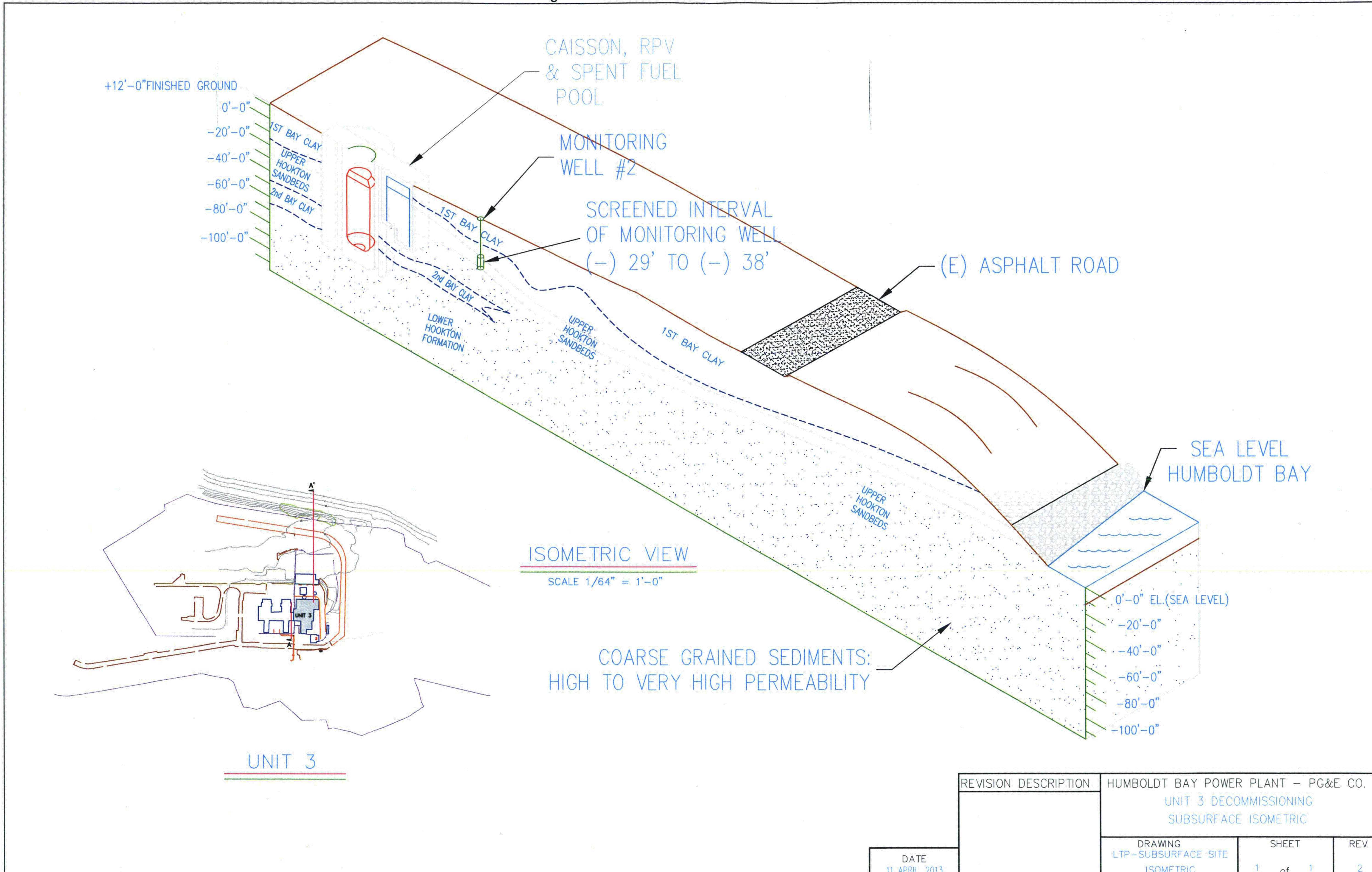


Figure 6-3 Cross-section of HBPP Subsurface



6.2.2.3 *Groundwater Hydrology*

Groundwater in the Eel River-Humboldt Bay area is contained primarily in the loosely unconsolidated sediments of the dune sand, alluvium, and terrace deposits and the poorly consolidated sediments of the Hookton and Carlotta formations. HBPP is underlain by a portion of the Hookton aquifer, consisting of a predominately sand and gravel unit in the alluvium extending from about elevation minus 8 feet Mean Sea Level (MSL) to about elevation minus 100 feet MSL.

Underlying HBPP are three distinct water bearing zones:

1. Zone of Perched Groundwater in the Upper Hookton silt and clay beds; unconfined aquifer perched within the upper silt and clay beds of the First Bay Clay
2. Upper Hookton Aquifer; confined to semiconfined aquifer within the Upper Hookton Sand Beds between the First and Second Bay Clay
3. Aquifer between Unit F and Second Bay Clay; confined to semiconfined aquifer within the Lower Hookton, between the Second Bay Clay and Unit F Clay

Groundwater closest to the surface beneath HBPP is encountered in the interbedded fine grained deposits of the First Bay Clay, which extend to depths ranging from 16 to 28 feet below grade surface (BGS). Water in this unconfined aquifer is trapped within multiple intermixed sand and silt beds and is considered "perched."

The upper part of the Hookton aquifer zone is in relatively clean sand approximately 30 feet thick. The upper aquifer and lower aquifer are separated by a clayey zone. Wells in the aquifer have shown that the groundwater fluctuates with tidal cycles. Calculated tidal efficiencies have ranged from 46 percent for a well approximately 235 feet from the bay to 26 percent for a well approximately 605 feet from the bay. Permeability data for the shallow sand at the site present permeabilities of 3×10^{-3} to 1×10^{-2} cm/sec (3,100 ft/yr to 10,400 ft/yr) using data on tidal efficiency and tidal lag times from five monitoring wells.

6.2.2.4 *Groundwater Recharge, Flow and Discharge*

The Eel River Valley alluvial aquifer contours indicate that groundwater flows west, down the valley, toward the coast. Groundwater levels and flow direction at HBPP are influenced by topography, proximity to Humboldt Bay, tidal influence, seasonal variations, and heterogeneity in soil stratigraphy. While the flow of groundwater is predominately west to northwest, toward the bay, during rising tides the flow turns easterly. During wet winter months when the aquifer discharge is likely to be greater, the flow reversal is subdued with the predominant flow direction toward the bay. Additionally, during this time of the year, the alluvial aquifer is flushed by the high flows attributed to runoff. A downward vertical gradient exists within the first water bearing zone and between the first and second water bearing zones. Recharge to the alluvium deposits is by direct infiltration of precipitation, seepage from rivers and streams, and to some extent, by lateral seepage from the Hookton and Carlotta formations. Groundwater is discharged from the alluvium by seepage into tidal estuaries and Humboldt Bay, by evapotranspiration and by pumping. The maximum discharge by tidal seepage occurs at the low tidal cycle. Recharge to the Hookton and Carlotta aquifers is primarily through deep percolation of rainfall on the outcrop areas and subsequent lateral flow beneath the confining beds. Recharge potential at HBPP is low, due to the 15 to 35 feet of silt and clay at the surface. Discharge occurs primarily by seepage into the sea.

6.2.2.5 *Open Land Area Source Term*

The open land area source term for HBPP is the concentration of radioactivity that will be allowed to remain in the soils after remediation is complete. That concentration is bounded by an upper limit on radiation dose potential of 25 millirem TEDE. Chapter 2 describes the current characterization of the HBPP site by providing Survey Area by Survey Area concentrations of activity. The highest concentrations presently found on the HBPP site are found in Survey Areas NOL01 (the area within the Restricted Area (RA) boundary) and to a lesser degree in Survey Area OOL03 (the area north of Units 1 and 2).

Contaminations in these areas are primarily due to unplanned events that have deposited contamination on the area surfaces. Contamination levels in these areas have shown that the contamination has migrated downward into the subsoil at depths up to 12 feet. The predominant radionuclides present are Cs-137 and Co-60.

Areas of significance at HBPP are as follows:

- Discharge Canal - Activity levels are greater in the first 90 percent lengthwise from the point where Unit 3 discharges into the canal. Activity levels in the headworks (southern end) portion average 8.7 and 1.0 pCi/g Cs-137 and Co-60, respectively, with the highest levels of 42.24 and 2.94 pCi/g, respectively. Levels taper off in the final 10 percent of the canal before entering the bay to an average of 1.2 and 0.2 pCi/g Cs-137 and Co-60, respectively. Activity levels appear to be confined to the top 2 feet of the sediment.
- Intake Canal - Activity levels are at their highest at the eastern end with the average concentration of 9.42 and 0.38 pCi/g Cs-137 and Co-60, respectively.
- RA Area - As seen in Table 2-4 of Chapter 2, activity in the soils within the RA vary considerably. Generally, levels of contamination in the first 0.5 foot from the surface average approximately 1 pCi/g Cs-137 and 0.12 pCi/g Co-60. However, areas where events have occurred demonstrate considerably greater contamination with levels as high as 30 pCi/g Cs-137, not only at the surface but at depths to 12 feet, or greater where levels of 3.5 pCi/g Cs-137 have been found.
- North Yard Drain Area - Activity levels where events have occurred range from 1 to 23.7 pCi/g Cs-137 and 0.06 to 0.48 pCi/g Co-60. The depth of activity is not as great as inside the RA; however, contamination is found at depths up to 4 feet.

6.2.2.6 *Building Surface Area Source Term*

The building surface area source term is composed of the contributions from activity present on the HBPP structure surfaces from primarily Cs-137. Few structures will remain at the time of license termination. The remaining structures were minimally impacted by Unit 3 operations. The primary impact was through the wet and dry deposition of activity due to stack releases. The residual activity, if present on the building surfaces, is fixed in nature and characterization data indicate levels of 213 to 1,126 dpm/100 cm^2. The average level of activity present on building surfaces is 411 dpm/100 cm^2 with a standard deviation of 182 dpm/100 cm^2. The activity is predominately located on the roofs of the structures.

Areas where the potential exists for contaminants to migrate to subsurface locations (e.g., caisson) will undergo strict evaluations and, if a pathway is determined to exist from the inner surfaces to the soils beyond the structure, samples will be gathered to assess the extent of activity in these areas.

6.2.3. Potential Radionuclides of Concern

As part of the source-term extraction process, an analysis was performed in HBPP Technical Basis Document, "Radiological Selection for DCGL Development, Revision 0" (Reference 6-5) to identify a suite of radionuclides that could potentially be present on remaining site structural surfaces, in site soils, and in groundwater following completion of decommissioning activities. This document was developed using the HBPP Historical Site Assessment (HSA) (Reference 6-18) and the regulatory documents identified in the HSA. The HBPP HSA identified a suite of radionuclides that were the primary contaminants of concern for the HBPP site. The suite included Am-241, Cm-244, Co 60, Cs-137, Fe-55, Mn-54, Ni-63, Pu-238, Pu-239, Pu-240, and Sr-90. This suite was appropriate for the preliminary development of site-specific DCGLs.

Additional potential radionuclides were evaluated from NUREG/CR-3474 "Long-Lived Activation Products in Reactor Materials," (Reference 6-15) and NUREG/CR-4289 "Residual Radionuclide Contamination Within and Around Commercial Nuclear Power Plants" (Reference 6-16).

Radionuclides identified in NUREG/CR-3474 Table 5.14, Activity Inventory of Boiling Water Reactor (BWR) Internals at Shutdown, along with their half-lives in years and their decay modes, are provided in Table 6–1.

Table 6-1 NUREG/CR-3474 Identified Activation Product Radionuclides

Radionuclide	Half Life (Years)	Decay Mode
Ag-108m	4.18E+02	IT
Ag-110m	6.84E-01	β^-, γ
Ar-39	2.69E+02	β^-
Ba-133	1.05E+01	γ
C-14	5.73E+03	β^-
Ca-41	1.03E+05	β^+, γ
Ce-141	8.90E-02	β^-, γ
Cl-36	3.01E+05	β^-
Co-58	1.94E-01	β^+, γ
Co-60	5.27E+00	β^-, γ
Cr-51	7.58E-02	γ
Cs-134	2.06E+00	β^-, γ
Cs-135	2.30E+06	β^-
Cs-137	3.02E+01	β^-
Eu-152	1.36E+01	β^-, γ
Eu-154	8.80E+00	β^-, γ
Eu-155	4.96E+00	β^-, γ
Fe-55	2.70E+00	γ
Fe-59	1.22E-01	β^-
H-3	1.23E+01	β^-
Hf-178m	3.00E+01	IT
Ho-166m	1.20E+03	β^-, γ
I-129	1.57E+07	β^-, γ
Kr-81	2.10E+05	γ
Kr-85	1.07E+01	β^-, γ
Mn-53	3.70E+06	γ
Mn-54	8.56E-01	Γ, β^+
Mo-93	4.00E+03	γ
Nb-92m	2.78E-02	Γ, β^+
Nb-94	2.03E+04	β^-, γ
Ni-59	7.50E+04	Γ, β^+
Ni-63	1.00E+02	β^-
Pb-205	1.51E+07	γ
Pm-145	1.77E+01	γ
Pu-239	2.41E+04	α, γ
Sb-124	1.65E-01	β^-, γ
Sc-46	2.29E-01	β^-, γ
Se-79	1.13E+06	β^-
Sm-146	1.00E+08	α
Sm-151	9.30E+01	β^-, γ
Sn-121m	5.00E+00	β^-, γ
Sr-90	2.86E+01	β^-
Tb-158	1.50E+02	β^-, γ, β^+
Tc-99	2.13E+05	β^-, γ
U-233	1.59E+05	α, γ
Zn-65	6.69E-01	β^+, γ
Zr-93	1.53E+06	β^-

α – Alpha decay
β- – Beta decay
β+ – Positron decay
γ – Gamma decay
IT – Isomeric transition

Radionuclides identified in NUREG/CR-4289 along with their half-lives in years and their decay modes, are provided in Table 6–2.

With the exception of Co-60, radionuclides with half-lives less than 5.4 years identified in NUREG/CR-4289 were discounted and not included in the list provided in Table 6–2. Based on the period from final shutdown of HBPP to the originally anticipated completion of license termination in 2016, it is highly unlikely that any activity from radionuclides with half-lives less than 5.4 years would remain significant. Although Co-60 has a half-life of 5.27 years, the HBPP HSA reported a September 1, 2006, inventory of 672.3 Ci of Co-60. Assuming a July 1, 2016, (estimated date at the TBD development) license termination, the Co-60 inventory at that time would still be approximately 172 Ci. Therefore, it is appropriate to retain Co-60 in the list of potential radionuclides.

Table 6-2 Radionuclides Identified in NUREG/CR-4289

Radionuclide	Half Life (Years)	Decay Mode
Am-241	4.32E+02	α, γ
C-14	5.73E+03	β-
Cm-244	1.81E+01	α, γ
Co-60	5.27E+00	β-, γ
Cs-137	3.02E+01	β-
Eu-152	1.36E+01	β-, γ
Eu-154	8.80E+00	β-, γ
H-3	1.23E+01	β-
I-129	1.57E+07	β-, γ
Nb-94	2.03E+04	β-, γ
Ni-59	7.50E+04	β^{+},γ
Ni-63	1.00E+02	β-
Np-237	2.14E+6	α, γ
Pu-238	8.78E+01	α, γ
Pu-239	2.41E+04	α, γ
Pu-240	6.60E+03	α, γ
Sr-90	2. 86E+01	β-
Tc-99	2.13E+05	β-, γ

α – Alpha decay
β- – Beta decay
γ – Gamma decay

6.2.4. Discounting insignificant radionuclides

Since Tables 6–1 and 6–2 include trace elements that are not likely to be found in site area soils or on surfaces, due to their low abundance and/or short half-lives, an evaluation of radionuclides that may be discounted as being of potential importance was performed. The total inventory for each radionuclide was determined from generic activity inventories provided in Table 5.14 and Table 5.15 of NUREG/CR-3474. From this information, the percentage of total inventory for each radionuclide was calculated. The results of this evaluation are provided in Table 6–3.

Table 6-3 Evaluation of NUREG/CR-3474 Total Activity Fractions (Reactor Vessel)

Radionuclide	Activity - Ci				Percent Total	Less than 0.1%?
	Shroud	Vessel Cladding	Vessel Walls	Total Activity		
Ag-108m	2.18E-01	1.79E-01	7.39E-06	6.41E-05	2.67E-04	Yes
Ar-39	2.68E-01	2.43E-01	2.73E-05	1.00E-03	3.64E-04	Yes
Ba-133	1.00E+01	9.24E-01	3.23E-05	2.03E-04	1.38E-03	Yes
C-14	1.03E+02	1.03E+02	2.79E-03	1.19E-02	1.53E-01	No
Ca-41	2.00E-02	2.00E-02	5.20E-07	2.00E-06	2.98E-05	Yes
Cl-36	2.24E+00	2.24E+00	5.70E-05	1.43E-04	3.34E-03	Yes
Co-60	4.50E+05	3.91E+03	1.20E-01	8.30E-01	5.83E+00	No
Cs-134	3.37E+01	1.80E-04	5.23E-09	1.87E-08	2.68E-07	Yes
Cs-135	3.80E-04	3.80E-04	3.67E-10	2.46E-09	5.67E-07	Yes
Cs-137	2.11E+00	9.22E-01	8.74E-06	6.03E-05	1.37E-03	Yes*
Eu-152	2.09E-02	4.91E-08	6.12E-04	2.70E-03	4.94E-06	Yes*
Eu-154	1.28E+01	7.46E-01	2.68E-05	2.62E-04	1.11E-03	Yes*
Eu-155	5.06E+00	3.27E-02	1.10E-07	1.21E-06	4.87E-05	Yes
Fe-55	9.29E+05	8.81E+01	2.24E-03	1.08E-02	1.31E-01	No
H-3	1.83E+02	2.40E+01	1.83E-03	7.98E-03	3.57E-02	Yes*
Hf-178m	5.21E-01	2.26E-01	1.87E-05	3.08E-04	3.37E-04	Yes
Ho-166m	3.93E-01	3.85E-01	1.08E-05	1.56E-04	5.74E-04	Yes
I-129	5.90E-07	5.90E-07	4.40E-12	1.88E-12	8.80E-10	Yes*
Kr-81	2.24E-04	2.24E-04	5.40E-12	3.04E-11	3.34E-07	Yes
Kr-85	8.15E-01	7.87E-02	4.83E-07	2.12E-06	1.17E-04	Yes
Mn-53	6.51E-03	6.50E-03	8.00E-07	1.00E-05	9.71E-06	Yes
Mn-54	1.17E+04	2.39E-09	2.33E-13	2.60E-12	3.58E-12	Yes
Mo-93	1.08E+00	8.51E-04	3.47E-08	6.27E-07	1.27E-06	Yes
Nb-92m	6.36E-07	6.33E-07	2.20E-10	2.90E-09	9.49E-10	Yes
Nb-94	8.86E-01	8.85E-01	2.80E-05	7.19E-05	1.32E-03	Yes*
Ni-59	6.04E+02	6.04E+02	1.80E-02	8.00E-02	9.01E-01	No
Ni-63	8.00E+04	6.23E+04	1.79E+00	7.44E+00	9.29E+01	No
Pb-205	4.00E-06	4.00E-06	2.58E-10	3.04E-09	5.97E-09	Yes
Pm-145	4.40E-03	1.07E-03	3.16E-08	2.29E-08	1.60E-06	Yes
Pu-239	3.81E-02	3.80E-02	3.00E-06	6.79E-05	5.67E-05	Yes*
Se-79	1.40E-03	1.40E-03	9.80E-08	1.00E-06	2.09E-06	Yes
Sm-146	4.08E-10	4.07E-10	4.50E-14	6.20E-13	6.08E-13	Yes
Sm-151	5.32E-02	4.05E-02	1.38E-05	1.11E-04	6.06E-05	Yes
Sn-121m	1.07E-02	7.19E-05	6.72E-09	9.41E-08	1.07E-07	Yes
Sr-90	2.11E+00	8.80E-01	5.84E-06	2.54E-05	1.31E-03	Yes*

Radionuclide	Activity - Ci				Percent Total	Less than 0.1%?
	Shroud	Vessel Cladding	Vessel Walls	Total Activity		
Tb-158	5.31E-03	4.49E-03	5.34E-07	6.77E-06	6.70E-06	Yes
Tc-99	2.10E-01	2.10E-01	9.00E-06	1.59E-04	3.13E-04	Yes*
U-233	2.25E-03	2.25E-03	1.30E-07	2.00E-06	3.36E-06	Yes
Zn-65	1.55E+03	9.00E-14	2.38E-18	1.68E-18	1.34E-16	Yes
Zr-93	1.41E-04	1.41E-04	6.90E-09	8.10E-08	2.10E-07	Yes
Total	6.70E+04	1.94E+00	8.38E+00	6.70E+04	1.00E+02	
Total percent of activity discounted					6.57E-03	

* Radionuclides meet the criteria of contributing less than 0.1 percent of the total activity but cannot be discounted because they have other methods of production in addition to activation of reactor components and/or have been observed in 10 CFR 61 waste stream analyses or site characterization samples.

Based on the previous evaluation, it was determined that individual radionuclides that contributed less than 0.1 percent of the total activity could potentially be discounted, providing that dose contributed by the sum of the those radionuclides does not exceed 1 percent of the total calculated dose. The total percentage of activity attributed to radionuclides that meet these criteria amounts to 0.007 percent.

6.2.5. Site-Specific Suite of Radionuclides

Table 6-4 represents a list of radionuclides potentially present at HBPP, based on applying the described screening criteria to the combined list of potential radionuclides from regulatory guidance contained in NUREG/CR-3474 and NUREG/CR-4289 and historical 10 CFR 61 analyses.

Table 6-4 HBPP Site Specific Suite of Nuclides

Radionuclide	Half Life (Years)	Decay Mode
*Cm-243/244	1.81E+01	α, γ
*Cm-245/246	4.75E+03	α, γ
Am-241	4.32E+02	α, γ
C-14	5.73E+03	β-
Co-60	5.27E+00	β-, γ
Cs-137	3.02E+01	β-
Eu-152	1.36E+01	β-, γ
Eu-154	8.80E+00	β-, γ
H-3	1.23E+01	β-
I-129	1.57E+07	β-, γ
Nb-94	2.03E+04	β-, γ
Ni-59	7.50E+04	γ
Ni-63	1.00E+02	β-
Np-237	2.14E+06	α, γ
Pu-238	8.78E+01	α, γ

Radionuclide	Half Life (Years)	Decay Mode
Pu-239	2.41E+04	α, γ
Pu-240	6.60E+03	α, γ
Pu-241	1.44E+01	β-
Sr-90	2. 86E+01	β-
Tc-99	2.13E+05	β-, γ

*Listed half-life is the shortest half-life for the radionuclides in the pair
α – Alpha Decay
β – Beta Decay
γ – Gamma Decay

6.2.6. Resident Farmer Scenario for Surface and Subsurface Soil Exposure

6.2.6.1 Resident Farmer Scenario Justification

PG&E has no plans to release all or part of the facility for ownership by members of the public. Although the public does have access to portions of the site via the coastal walkway, there is no ready access to the majority of the site. The HBPP switchyard has been in continual use, and the site continues to be an important center of electrical supply from the Humboldt Bay Generating Station (HBGS).

It is unlikely that the HBPP site will be used for any purpose other than an industrial site; however, HBPP has chosen the conservative approach of remediating and surveying to the Resident Farmer Scenario at license termination to allow for other uses following the expected 30-year life of the HBGS, which would be in 2040.

6.2.6.2 Critical Group for Surface Exposure

The average member of the critical group was determined to be the resident farmer who lives on the Humboldt Bay site following decommissioning, grows all or a portion of his/her diet onsite, and uses the water from a groundwater source on the site for drinking water and irrigation. The dose from residual radioactivity in soil is evaluated for the critical receptor as required by 10 CFR 20, Subpart E, and described in Appendix I to NUREG -1757.

6.2.6.3 Conceptual Model and Site-Specific Exposure Pathways

The conceptual model for this scenario is a residential farming family that lives onsite, raises crops and livestock for consumption, and drinks water from an onsite ground water source.

It is unlikely that any other set of plausible human activities that would result in a dose exceeding that calculated for the hypothetical resident farmer could occur on the Humboldt Bay site. It is more likely that the behavior of future occupants would result in a lower dose. For example, it is more likely that the Humboldt Bay site will be reused for industrial purposes rather than a site for a residential farmer. The hypothetical dose from residual contamination in the soil to an individual in these settings would be less than for a resident farmer because such an individual would not reside on the site and ingest food grown onsite. Therefore, the use of the resident farmer as the average member of the critical group is both conservative and bounding for the calculation of soil DCGLs. The following bullets list the potential exposure pathways that apply to the resident farmer, based upon those in NUREG/CR-5512, Volume 1:

- Direct exposure to external radiation from residual radioactivity
- Internal dose from inhalation of airborne radionuclides
- Internal dose from ingestion of the following items:
    - Plant foods grown in media containing residual radioactivity and irrigated with water containing residual radioactivity
    - Meat and milk from livestock fed with fodder grown in soil containing residual radioactivity and water containing residual radioactivity
    - Drinking water (containing residual radioactivity) from a well
    - Fish from a pond containing residual radioactivity
    - Soil containing residual radioactivity

6.2.7. Building Occupancy Scenario for Building Occupancy Exposure

6.2.7.1 Building Occupancy Scenario Justification

The Building Occupancy Scenario is described in NUREG/CR-5512, Volume 1. Modeling of this scenario provides an estimate of human radiation exposure to residual radioactivity on surfaces inside standing buildings and permits the determination of DCGLs for building surfaces. This scenario was selected as the modeling basis for building surface DCGLs.

The justification for the Soils Scenario (Section 6.2.6.1) also applies to the Building Surface Scenario.

6.2.7.2 Critical Group for Structural Surface Exposure

The average member of the critical group is defined as an adult individual engaging in work within the buildings following decommissioning of the site. The person occupies and carries out light to moderate work activities inside the building for a full year of employment. The breathing rate applied in the sensitivity analysis was appropriate for light to moderate activity. For conservatism, a higher breathing rate (appropriate for moderate to heavy activity) was used in the development of the building surface DCGLs. The dose to the individual from residual radioactivity on building surfaces is evaluated as required by 10 CFR 20, Subpart E, and described in Appendix I to NUREG -1757.

6.2.7.3 Conceptual Model and Site-Specific Exposure Pathways

The conceptual model is a Humboldt Bay worker who occupies the building as a routine work area and performs light to moderate renovation activities for a full employment year, receiving radiation exposure via the following potential exposure pathways:

- Direct exposure to external radiation from the following sources:
    - Material deposited on the room surfaces (i.e., walls, floor, and ceiling)
    - Submersion in airborne dust
- Internal dose from inhalation of airborne radionuclides

- Internal dose from inadvertent ingestion of radionuclides

In the development of building surface DCGL values, the Building Occupancy Scenario modeled for the Humboldt Bay site accounted for moderate to heavy renovation activities carried out inside Humboldt Bay site buildings through use of conservative input for breathing rate and inadvertent ingestion of surface contamination. This approach produced reasonably conservative estimates of annual doses associated with contaminated building surfaces.

6.3. Computational Model Used for Dose Calculations

6.3.1. Impacted Area Soils

The computer code RESidual RADioactive materials (RESRAD) v6.3, followed by v6.4 after its release during the winter of 2007, was selected to perform site-specific dose modeling of impacted area soils because of the ability to model subsurface soil contamination contained within the code. Argonne National Laboratory (ANL) developed the RESRAD computer code under the sponsorship of the U.S. Department of Energy (DOE). The code has been used widely by DOE and its contractors, the U.S. NRC, U.S. Environmental Protection Agency (EPA), U.S. Army Corps of Engineers, industrial firms, universities, and foreign government agencies and institutions. This code is a pathway analysis model designed to evaluate potential radiological doses to an average member of the specific critical group.

The NRC has adopted a risk-informed approach in assessing impacts on the health and safety of the public from radioactive contamination remaining at decommissioned sites. Therefore, the NRC tasked ANL to develop parameter distribution functions and parametric analysis for RESRAD for conducting probabilistic dose analysis. As part of this effort, external modules equipped with probabilistic sampling and analytical capabilities were developed for the RESRAD code. The modules also are equipped with user-friendly input/output interface features to accommodate numerous parameter distribution functions and to fulfill results display requirements.

The RESRAD database includes inhalation and ingestion dose conversion factors from the EPA's Federal Guidance Report (FGR) No. 11, direct external exposure dose conversion factors from FGR No. 12, and radionuclide half-lives from International

Commission on Radiological Protection Publication 38 (References 6-7, 6-8 and 6-9, respectively).

6.3.2. Impacted Structural Surfaces and Bulk Material

RESRAD-BUILD v3.3 was selected to perform site-specific dose modeling of impacted structural surfaces and bulk material. RESRAD-BUILD is a computer code designed to evaluate the radiation doses from RESidual RADioactivity in BUILDings. The RESRAD-BUILD code was developed by ANL under sponsorship of the DOE and other federal agencies.

The RESRAD-BUILD computer code is a pathway analysis model designed to evaluate the potential radiological dose incurred by an individual who works or lives in a building contaminated with radioactive material. The transport of radioactive material within the building from one compartment to another is calculated with an indoor air quality model. The air quality model considers the transport of radioactive dust particulates and radon progeny due to air exchange, deposition and resuspension, and radioactive decay and ingrowth.

Seven exposure pathways are considered in the RESRAD-BUILD code:

(1) external exposure directly from the source

(2) external exposure from materials deposited on the floor

(3) external exposure due to air submersion

(4) inhalation of airborne radioactive particulates

(5) inhalation of aerosol indoor radon progeny (in the case of the presence of radon predecessors) and tritiated water vapor (the radon pathway was turned off because the NRC does not regulate dose received from radon and progeny)

(6) inadvertent ingestion of radioactive material directly from the source

(7) ingestion of materials deposited on the surfaces of the building compartments

Various exposure scenarios may be modeled with the RESRAD-BUILD code. These include, but are not limited to, office worker, renovation worker, building visitor, and residency scenarios. Both deterministic and probabilistic dose analyses can be performed with RESRAD-BUILD, and the results can be shown in both text and graphic reports.

6.4. Derived Concentration Guideline Levels

6.4.1. Computer Code Selection

The RESRAD Family of Codes has been selected for use in determining DCGL values at the Humboldt Bay site. The RESRAD computer codes are pathway-analysis models developed at ANL. This family of computer codes includes RESRAD-BUILD, used to analyze pathways associated with buildings, and RESRAD, used to analyze pathways associated with soil.

The RESRAD-BUILD computer code is a pathway analysis model designed to evaluate the potential radiological dose incurred by an individual who works in a building contaminated with radioactive material. Version 3.5 of the RESRAD-BUILD computer code was used in this analysis to consider four primary exposure pathways to occupants of a building:

- External exposure directly from the sources (walls, floors, and ceilings)
- External exposure due to air submersion
- Inhalation of airborne radioactive particulates
- Inadvertent ingestion of radioactive material directly from the sources

As with the RESRAD-BUILD code, the RESRAD computer code was developed by ANL as a multifunctional tool to assist in developing radiological criteria for unrestricted release and assessing the dose or risk associated with residual radioactive material. The RESRAD computer code is a pathway analysis model designed to evaluate the potential radiological dose associated with residual radioactive material in land areas. Version 6.5 of the RESRAD computer code was used in this analysis to consider three major exposure pathways to a resident farmer:

- Direct exposure to external radiation from soil containing residual radioactivity
- Internal exposure from inhalation of airborne radionuclides
- Internal exposure from ingestion of radionuclides

Both the RESRAD-BUILD and the RESRAD computer codes incorporate probabilistic modules that permit the user to perform a sensitivity analysis to identify those parameters that have the greatest impact on dose. In addition, the probabilistic modules allow the evaluation of dose as a function of parameter distributions. Information on the use of these codes and their applications are outlined in NUREG/CRs-6676, -6692, -6697, -6755 (References 6-20, 6-21, 6-10, and 6-12 respectively) and the Users Manual for RESRAD, Version 6.0 (Reference 6-22).

6.4.2. Sensitivity Analysis

6.4.2.1 Input Parameter Selection Process

The dose and conceptual models are quantified by a set of input parameters. Probabilistic modules that allow the evaluation of dose as a function of parameter distributions are incorporated within RESRAD-BUILD Version 3.5 and RESRAD Version 6.5. A schematic flow diagram of the parameter selection process is provided in Figure 6-4.

6.4.2.2 Classification (Type)

The input parameters were classified as behavioral, metabolic, or physical, consistent with NUREG/CR-6697. Behavioral parameters depend on the behavior of the receptor and the scenario definition. Metabolic parameters represent the metabolic characteristics of the receptor and are independent of the scenario definition. Physical parameters are those parameters that do not change with changes to the receptor.

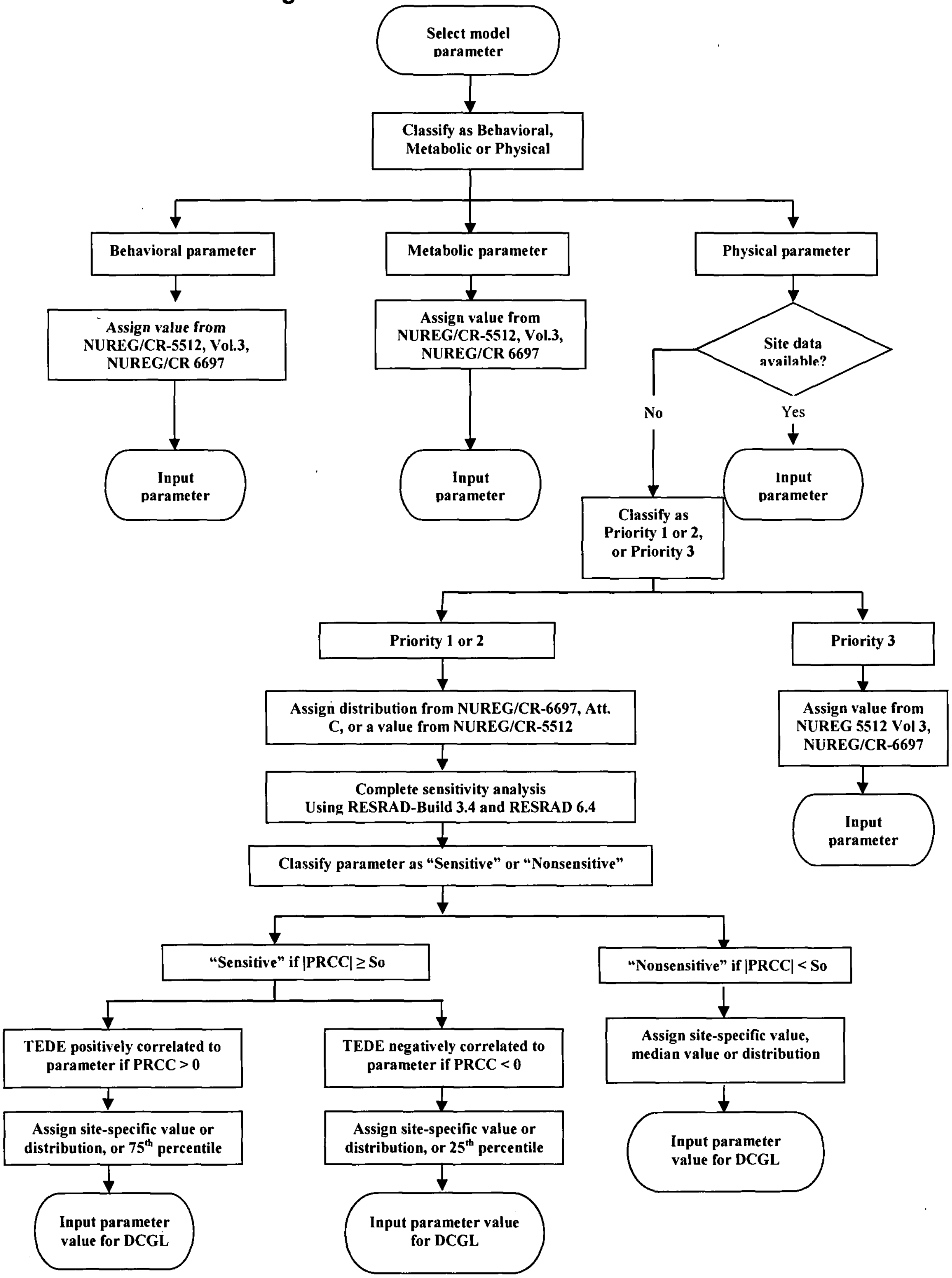
6.4.2.3 Prioritization

The parameters were prioritized in order of importance consistent with NUREG/CR-6697. Prioritization was based on the following items:

- The relevance of the parameter in dose calculations
- The variability of the dose as a result of changes in the parameter value
- The parameter type
- The availability of parameter-specific data

Priority 1 parameters are considered high priority; Priority 2 parameters are considered medium priority; and Priority 3 parameters are considered low priority.

Figure 6-4 Parameter Selection Process



6.4.2.4 Treatment

The parameters were treated as either deterministic or stochastic, depending on parameter type, priority, availability of site-specific data, and the relevance of the parameter in dose calculations. The deterministic modules of the code use a single value for input parameters and generate a single value for dose. The probabilistic modules of the code use probability distributions for stochastic input parameters and generate a range of doses.

The behavioral and metabolic parameters are treated as deterministic and were assigned values from NUREG/CR-5512, Volume 3, NUREG/CR-6697, or the applicable code's default library. Physical parameters for which site-specific data are available were also treated as deterministic.

The remaining physical parameters, for which no site-specific data are available to quantify, are classified as either Priority 1, 2, or 3. Priority 1 and 2 parameters are treated as stochastic and are assigned a probability distribution from NUREG/CR-6697 (Reference 6-10). The Priority 3 physical parameters are treated as deterministic and are assigned values from NUREG/CR-5512, Volume 3, NUREG/CR-6697, or the applicable code's default library.

6.4.2.5 Sensitivity Criteria

In order to determine values for parameters not already assigned a value, a sensitivity analysis was performed to determine which of the stochastic parameters have an influence on the resulting dose and associated DCGLs. The analyses were performed using the probabilistic modules of RESRAD-Build, Version 3.5, and RESRAD, Version 6.5.

The stochastic parameters identified in the preceding paragraphs were generally assigned distribution types and corresponding distribution statistical parameters from NUREG/CR-6697, Attachment C. Sensitivity analyses were performed on the stochastic parameters using the assigned distributions. To perform the sensitivity analysis, the following information was required:

- **Sample Specifications:** The analyses were run using 300 observations for building surfaces, 2,000 observations for soils, and 1 repetition for both scenarios. The Latin Hypercube Sampling (LHS) technique was used to sample the probability distributions for each of the stochastic input parameters. The correlated or uncorrelated grouping option was used to preserve the prescribed correlation. Correlation coefficients were assigned to correlated parameters.
- **Sensitivity Indicator:** Sensitivity analyses were performed for each of the radionuclides. The Partial Rank Correlation Coefficient (PRCC) for the peak of the mean dose was used as a measure of the sensitivity of each parameter.
- **Sensitivity Thresholds:** For the building occupancy scenario, a parameter was identified as sensitive if the absolute value of its PRCC (|PRCC|) was greater than or equal to 0.10 and nonsensitive if the |PRCC| value was less than 0.10. For the Resident Farmer Scenario, a parameter was identified as sensitive if the |PRCC| was greater than or equal to 0.25 and nonsensitive if the |PRCC| value was less than 0.25. These sensitivity thresholds (So) were selected based on the guidance included in NUREG/CR-6676 and NUREG/CR-6692.

6.4.2.6 *Parameter Value Assignment for DCGL Determination*

As discussed previously, behavioral and metabolic parameters were assigned values from NUREG/CR-5512 Volume 3, NUREG/CR-6697, or NUREG/CR-6755. When available, site data served as input for physical parameters. For Priority 3 physical parameters without site data, values from NUREG/CR-5512, Volume 3, or NUREG/CR-6697 were used.

Priorities 1 and 2 physical parameters were assigned values as follows:

- Priorities 1 and 2 physical parameters shown to be sensitive were assigned conservative values:
  - A site-specific value, or
  - The 25th or 75th percentile value of the distribution was used, respectively, depending on whether the parameter was positively or negatively correlated with dose. Use of 25th and 75th

percentiles values provides assurance that the DCGL calculations take into account the uncertainties associated with the sensitive input parameters.

- Priorities 1 and 2 physical parameters shown to be nonsensitive were assigned:
  - A distribution or site-specific value, or
  - The median value of the distribution

6.4.3. Code Output and Calculation of DCGL

RESRAD-BUILD code determines an average annual dose at the time of the peak dose in mrem/yr, whereas RESRAD code determines an annual peak of the mean dose in mrem/yr. By specifying a unit radionuclide concentration (i.e., 1 pCi/m^2 in RESRAD-BUILD or 1 pCi/g in RESRAD) to be used in conjunction with the parameters values determined by the process described previously, both codes produce a dose conversion factor (DCF). The DCF from RESRAD-BUILD is in units of mrem/yr per pCi/m^2 and the DCF from RESRAD is in units of mrem/yr per pCi/g. As suggested in NUREG-1757, DCFs based upon peak mean doses were used to calculate DCGLs with units of dpm/100 cm^2 for building surfaces and pCi/g for soil. The Humboldt Bay DCGLs correspond to the site release criterion, 25 mrem/y, and were calculated using the following equations:

For building surfaces,

$$DCGL(pCi/m^2) = \frac{25 mrem/y}{DCF\ mrem/yr / pCi/m^2}$$

Equation 6-1

$$DCGL(dpm/cm^2) = DCGL(pCi/m^2) \times 2.22 dpm/pCi \times (1m/100cm)^2$$

Equation 6-2

$$DCGL(dpm/100cm^2) = DCGL(pCi/m^2) \times 2.22 dpm/pCi \times (1m/100cm)^2 \times 100$$

Equation 6-3

For soil,

$$DCGL(pCi/g) = \frac{25mrem/y}{DCFmrem/y/pCi/g}$$

Equation 6-4

6.4.4. Calculation of Building Surface DCGL

6.4.4.1 Dose Model

The dose model used to calculate the building surface DCGLs is based upon the Building Occupancy Scenario as defined in NUREG/CR-5512, Volumes 1, 2, 3, and NUREG-1757. The scenario assumes that the critical group consists of workers performing routine work activities in the building following license termination.

6.4.4.2 Conceptual Model

The conceptual model was based on site characteristics expected at the time of license termination. The model is composed of a room representative of rooms inside Humboldt Bay buildings expected to remain at the site. The model room was selected for the following reasons:

- Very little, if any, remediation will be required in this area and, therefore, will be most suited for occupancy
- The room is slated to be occupied by administrative personnel on the most continuous basis (i.e., will not leave to perform "rounds" or maintenance)

The four walls, floor, and ceiling of the room are assumed to be uniformly contaminated to equal levels. This is a conservative assumption as normally the amount of contamination on room walls and ceiling is less than that on the floor and would be expected to decrease as the distance from the floor increases.

6.4.4.3 Parameter Value Assignment

Appendix A provides the details for the determination of the room dimensions and the bases for other site-specific parameters affecting the modeling for building surfaces DCGLs. The values and distributions assigned to all parameters for the sensitivity analyses and the bases for assigning such values and distributions are summarized in

Appendix B. The time in which the maximum dose occurred was taken into account in the sensitivity analyses.

6.4.4.4 Sensitivity Analysis

The results of the sensitivity analysis performed for RESRAD-BUILD input parameters are provided in Appendix C.

6.4.4.5 DCGL Determination

The DCGL determination was performed using RESRAD-BUILD, Version 3.5. The input values, including the 25th and 75th percentile values for sensitive input parameters, are summarized in Appendix D. The resulting DCFs, based upon the average dose during the year that the maximum dose occurs, are provided in Appendix E. These DCGL values, which represent an annual dose of 25 mrem, were calculated using Equations 6-1 through 6-3. They are shown in Table 6-5 and provided in Appendix E.

6.4.5. Calculation of Soil DCGL

6.4.5.1 Dose Model

The DCGLs for soil were calculated using the resident farmer scenario. The residual radioactive materials were assumed to be contained in a soil layer on the property that can be used for residential and light farming activities. The average member of the critical group is the resident farmer that lives on the plant site, grows all of his/her diet onsite, and drinks water from a groundwater source onsite.

6.4.5.2 Conceptual Model

The conceptual model used in the code was based on the site characteristics expected at the time of release of the site. The model is composed of a contaminated zone underlain by an unsaturated zone underlain by a saturated zone. The contaminated zone is assumed to be at the ground surface with no cover material and the groundwater is initially uncontaminated. The model as described is consistent with that described in the RESRAD User's Manual.

6.4.5.3 *Parameter Value Assignment*

The evaluation of site/regional data and the justification of values assigned to the site-specific parameters are provided in Appendix F. The values/distributions assigned to all parameters for the sensitivity analyses and the basis for assigning such values/distributions are summarized in Appendix G.

6.4.5.4 *Sensitivity Analysis*

The results of the sensitivity analysis performed for RESRAD input parameters are provided in Appendix H.

6.4.5.5 *DCGL Determination*

The DCGL determination was performed using RESRAD Version 6.5. The input values, including the 25^{th} and 75^{th} percentile values for sensitive input parameters, are summarized in Appendix I. The resulting DCFs, based upon the peak of the mean doses, are provided in Appendix J. The DCGLs, which represent an annual dose equal to 25 mrem, were calculated using Equation 6-4. The DCGL values are shown in Table 6-5 and provided in Appendix J.

Table 6-5 DCGLs by Radionuclide and Medium Type

Nuclide	Building Surface DCGL (dpm/100 cm^2)	Soil DCGL (pCi/g)
Am-241	3.0E+03	2.5E+01
C-14	7.0E+06	6.3E+00
Cm-243	4.3E+03	2.9E+01
Cm-244	5.5E+03	4.8E+01
Cm-245	2.2E+03	1.7E+01
Cm-246	2.7E+03	2.5E+01
Co-60	1.3E+04	3.8E+00
Cs-137	4.6E+04	7.9E+00
Eu-152	2.7E+04	1.0E+01
Eu-154	2.5E+04	9.4E+00
H-3	1.8E+08	6.8E+02
I-129	4.9E+04	4.8E+00
Nb-94	1.9E+04	7.1E+00
Ni-59	6.3E+07	1.9E+03
Ni-63	2.4E+07	7.2E+02
Np-237	2.4E+03	1.1E+00
Pu-238	3.4E+03	2.9E+01
Pu-239	3.1E+03	2.6E+01
Pu-240	3.1E+03	2.6E+01
Pu-241	1.4E+05	8.6E+02

Nuclide	Building Surface DCGL (dpm/100 cm^2)	Soil DCGL (pCi/g)
Sr-90	9.7E+04	1.5E+00
Tc-99	9.6E+06	1.2E+01

6.5. Area Factors

6.5.1. Calculation of Area Factors

Area factors (AFs) for both building surface DCGLs and soil DCGLs may be required during final status survey activities. AF values are calculated in a step process. First, the total doses from all pathways are calculated for each radionuclide and for each area of contamination. Then, the AF values are determined from the ratio of the dose for the base case to the dose for each smaller area evaluated.

6.5.2. Calculation of Area Factors for the Building Surfaces

For the building occupancy scenario, an approach different from that used for the building surface DCGLs was applied in the computation of the area factors used to establish the $DCGL_{EMC}$. While the $DCGL_W$ is the average concentration over the entire surface area of the Humboldt Bay representative room, the $DCGL_{EMC}$ should reflect the exposure an occupant would receive from an area of elevated activity having dimensions that are much smaller than the total interior area of the room. The total surface area of contaminated sources for the Humboldt Bay representative room is 118 m^2, which includes the floor, four walls, and ceiling. The calculation of AFs assumed activity on a single surface that did not exceed 100 m^2. Elevated measurement comparisons (i.e., assessments of residual activity greater than the DCGL value) will occur only in Class 1 areas. Contamination levels exceeding DCGL values (or for a radionuclide mixture, a sum of the fraction exceeding one) are not expected in Class 2 or Class 3 survey units and, if found, would result in reclassification of the entire area (or a portion of the area) to Class 1. Accordingly, the recommended limit to the size of a Class 1 structure, 100 m^2, given in MARSSIM, was established as the upper bound (or base case) for sizes used to develop AFs for building surfaces.

The total doses for various areas of the contaminated source are calculated using RESRAD-BUILD Version 3.5. The model used in RESRAD-BUILD is similar to that used in the model for calculating building surface $DCGL_W$ values. However, only one source is modeled, instead of the five sources considered in calculating the building surface $DCGL_w$ values. The receptor is located at the source midpoint at a distance of 1 meter away. All other input parameters and assumed active exposure pathways are the same as those used in the calculations for building surface DCGLs and are presented in Appendix K. Appendix L presents the radionuclide-specific area factors.

6.5.3. Calculation of Area Factors for the Soils

Area factors for the resident farmer are calculated using the RESRAD 6.5 computer code using the input parameters from the original soils analysis and a unit activity of 1 pCi/g. As the contaminated area decreases, some members of the set of ingestion pathway input parameters referred to as Contamination Fractions, also decrease, using the equations in the RESRAD Users Manual. A Contamination Fraction indicates the fraction of a person's total diet that is obtained from the contaminated area. As the contaminated area decreases below a certain size, it is reasonable to assume that the fraction of the person's total diet from the contaminated area will also decrease proportionately.

The contaminated fractions for drinking water, livestock water, irrigation water, and aquatic food are not allowed to decrease as the size of the contaminated zone decreases. Use of a value equal to 1.0 incorporates the assumption that all water used by the resident farmer comes from the site (i.e., residential well), regardless of the size of the contaminated area.

Adjustments to the contaminated fractions for plants, meat, and milk are made using equations from the RESRAD User's Manual. Values of the multiplier are listed in Appendix M as a function of the size of the contaminated zone. Appendix M provides contaminated fraction values as a function of the area of the contaminated zone.

The fraction of household water remains set at 1.0 for all sizes of contaminated zones, which is consistent with the RESRAD code input screen that does not allow deviation from the default value of 1.0.

As with buildings, elevated measurement comparisons (i.e., assessments of residual activity greater than the DCGL value) will occur only in Class 1 survey units. Contamination levels exceeding DCGL values (or for a radionuclide mixture, a sum of the fraction exceeding one) are not expected in Class 2 or Class 3 open land areas and, if found, would result in reclassification of the entire area (or a portion of the area) to a Class 1 open land survey unit. Accordingly, the recommended limit to the size of a Class 1 open land survey unit, 2,000 m^2 given in MARSSIM, was established as the upper bound (or base case) for sizes used to develop AFs for the soil DCGLs.

The total doses corresponding to the various areas of the contaminated zone are calculated using the input parameter values listed in Appendix M. Appendix N provides the soil AF values by radionuclide and area. Table 6-6 provides building surface area factors and Table 6-7 provides soil area factors.

Table 6-6 Building Surface Area Factors

	Area Factor Value:										
(m²)	Am-241	C-14	Cm-243	Cm-244	Cm-245	Cm-246	Co-60	Cs-137	Eu-152	Eu-154	H-3
1	9.7E+01	9.7E+01	8.9E+01	1.0E+02	3.9E+01	6.4E+01	1.3E+01	1.5E+01	1.3E+01	1.3E+01	1.0E+02
2	4.9E+01	4.9E+01	4.5E+01	5.0E+01	2.1E+01	3.3E+01	7.2E+00	8.2E+00	7.2E+00	7.2E+00	5.0E+01
3	3.3E+01	3.3E+01	3.0E+01	3.3E+01	1.5E+01	2.3E+01	5.3E+00	6.0E+00	5.3E+00	5.3E+00	3.3E+01
4	2.5E+01	2.4E+01	2.3E+01	2.5E+01	1.2E+01	1.8E+01	4.3E+00	4.9E+00	4.3E+00	4.3E+00	2.5E+01
5	2.0E+01	2.0E+01	1.9E+01	2.0E+01	9.9E+00	1.5E+01	3.7E+00	4.2E+00	3.7E+00	3.7E+00	2.0E+01
6	1.6E+01	1.6E+01	1.6E+01	1.7E+01	8.6E+00	1.2E+01	3.3E+00	3.8E+00	3.3E+00	3.3E+00	1.7E+01
8	1.2E+01	1.2E+01	1.2E+01	1.2E+01	6.9E+00	9.7E+00	2.8E+00	3.2E+00	2.8E+00	2.8E+00	1.2E+01
10	9.9E+00	9.9E+00	9.5E+00	1.0E+01	5.9E+00	8.0E+00	2.5E+00	2.8E+00	2.5E+00	2.5E+00	1.0E+01
50	2.0E+00	2.0E+00	2.0E+00	2.0E+00	1.8E+00	1.9E+00	1.2E+00	1.3E+00	1.2E+00	1.2E+00	2.0E+00
100	1.0E+00	1.0E+00	1.0E+00	1.0E+00	1.0E+00	1.0E+00	1.0E+00	1.0E+00	1.0E+00	1.0E+00	1.0E+00
	Area Factor Value:										
(m²)	I-129	Nb-94	Ni-59	Ni-63	Np-237	Pu-238	Pu-239	Pu-240	Pu-241	Sr-90	Tc-99
1	6.5E+01	1.3E+01	1.0E+02	1.0E+02	8.9E+01	1.0E+02	1.0E+02	1.0E+02	9.8E+01	9.0E+01	8.7E+01
2	3.4E+01	7.2E+00	5.0E+01	5.0E+01	4.5E+01	5.0E+01	5.0E+01	5.0E+01	4.9E+01	4.5E+01	4.4E+01
3	2.3E+01	5.3E+00	3.3E+01	3.3E+01	3.0E+01	3.3E+01	3.3E+01	3.3E+01	3.3E+01	3.0E+01	3.0E+01
4	1.8E+01	4.3E+00	2.5E+01	2.5E+01	2.3E+01	2.5E+01	2.5E+01	2.5E+01	2.5E+01	2.3E+01	2.3E+01
5	1.5E+01	3.7E+00	2.0E+01	2.0E+01	1.8E+01	2.0E+01	2.0E+01	2.0E+01	2.0E+01	1.9E+01	1.8E+01
6	1.3E+01	3.3E+00	1.7E+01	1.7E+01	1.6E+01	1.7E+01	1.7E+01	1.7E+01	1.7E+01	1.6E+01	1.5E+01
8	9.7E+00	2.8E+00	1.3E+01	1.2E+01	1.2E+01	1.3E+01	1.2E+01	1.2E+01	1.2E+01	1.2E+01	1.2E+01
10	8.0E+00	2.5E+00	1.0E+01	1.0E+01	9.4E+00	1.0E+01	1.0E+01	1.0E+01	9.9E+00	9.5E+00	9.4E+00
50	1.9E+00	1.2E+00	2.0E+00	2.0E+00	2.0E+00	2.0E+00	2.0E+00	2.0E+00	2.0E+00	2.0E+00	2.0E+00
100	1.0E+00	1.0E+00	1.0E+00	1.0E+00	1.0E+00	1.0E+00	1.0E+00	1.0E+00	1.0E+00	1.0E+00	1.0E+00

Table 6-7 Area Factors for Soils

ROC	Area Factor for Area Contaminated Zone (m^2):							
	2000	1000	500	100	50	10	5	1
Am-241	1.0E+00	1.0E+00	2.0E+00	8.7E+00	1.6E+01	4.9E+01	7.7E+01	1.9E+02
C-14	1.0E+00	1.5E+00	4.0E+00	4.2E+01	1.1E+02	1.0E+03	2.5E+03	1.8E+04
Cm-243	1.0E+00	1.0E+00	1.6E+00	3.4E+00	4.3E+00	7.3E+00	1.1E+01	3.2E+01
Cm-244	1.0E+00	1.0E+00	2.0E+00	9.7E+00	1.9E+01	7.6E+01	1.2E+02	2.8E+02
Cm-245	1.0E+00	1.0E+00	1.9E+00	6.2E+00	9.2E+00	1.9E+01	3.0E+01	8.1E+01
Cm-246	1.0E+00	1.0E+00	2.0E+00	9.7E+00	1.9E+01	7.6E+01	1.3E+02	2.8E+02
Co-60	1.0E+00	1.0E+00	1.1E+00	1.3E+00	1.4E+00	2.2E+00	3.3E+00	1.0E+01
Cs-137	1.0E+00	1.0E+00	1.3E+00	1.7E+00	1.9E+00	3.0E+00	4.5E+00	1.4E+01
Eu-152	1.0E+00	1.0E+00	1.0E+00	1.1E+00	1.3E+00	2.0E+00	3.0E+00	9.1E+00
Eu-154	1.0E+00	1.0E+00	1.0E+00	1.2E+00	1.3E+00	2.0E+00	3.0E+00	9.2E+00
H-3	1.0E+00	1.1E+00	2.1E+00	1.0E+01	2.1E+01	1.0E+02	2.0E+02	9.3E+02
I-129	1.0E+00	1.1E+00	2.2E+00	1.1E+01	2.2E+01	9.9E+01	1.9E+02	8.3E+02
Nb-94	1.0E+00	1.0E+00	1.0E+00	1.2E+00	1.3E+00	2.0E+00	3.0E+00	9.0E+00
Ni-59	1.0E+00	1.2E+00	2.3E+00	1.2E+01	2.3E+01	1.2E+02	2.3E+02	1.2E+03
Ni-63	1.0E+00	1.2E+00	2.3E+00	1.2E+01	2.3E+01	1.2E+02	2.3E+02	1.2E+03
Np-237	1.0E+00	1.0E+00	2.0E+00	9.0E+00	1.6E+01	5.6E+01	9.8E+01	3.5E+02
Pu-238	1.0E+00	1.0E+00	2.0E+00	9.7E+00	1.9E+01	7.6E+01	1.3E+02	2.8E+02
Pu-239	1.0E+00	1.0E+00	2.0E+00	9.7E+00	1.9E+01	7.6E+01	1.3E+02	2.9E+02
Pu-240	1.0E+00	1.0E+00	2.0E+00	9.7E+00	1.9E+01	7.6E+01	1.3E+02	2.9E+02
Pu-241	1.0E+00	1.0E+00	2.0E+00	8.8E+00	1.6E+01	4.9E+01	7.8E+01	1.9E+02
Sr-90	1.0E+00	1.0E+00	2.0E+00	1.0E+01	2.0E+01	9.9E+01	2.0E+02	9.6E+02
Tc-99	1.0E+00	1.0E+00	2.0E+00	1.0E+01	2.0E+01	1.0E+02	2.0E+02	1.0E+03

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6-21 NUREG/CR-6692, "Probabilistic Modules for the RESRAD and RESRAD-BUILD Computer Codes," November 2000

6-22 ANL/EAD-4, Users Manual for RESRAD Version 6.0, Yu, C. et al., July 2001

Appendix A
Basis for Site-Specific Parameter Values; Building Surfaces

Site-specific information was used when available as the basis for the RESRAD-BUILD input parameter discussed below. NUREG/CR-6755, which documents the calculations of site-specific parameter values, provides the information presented below.

1. Room Dimensions.

The model room was selected as a representative room for the Humboldt Bay site buildings and was used as the modeling basis for the building surfaces DCGLs. Table A-1 shows the dimensions, unit conversion, and the area associated with each source (i.e., floor, walls, and ceiling) for the modeled room.

Table A-1: Representative Room for Humboldt Bay Site

Source No.	Description	Recorded Dimension (ft)[a]	m[b]	m^2
1	floor	N/A		47.77
2	north wall	27.8	8.47	21.09
3	east wall	18.5	5.64	14.04
4	south wall	27.8	8.47	21.09
5	west wall	18.5	5.64	14.04
	wall height	8.17	2.49	
			total source area:	118.03

[a] Recorded length and width dimensions for representative room.

[b] Feet to meter conversion factor: 1ft = 0.3048m.

The wall length and height dimensions defined the room model and the location of the receptor.

2. Source Configuration.

NUREG/CR-6755, Section 4.0, describes three principal assumptions inherent in the building scenario: a fixed room area, uniform surface contamination, and the receptor location at the center of the floor at a height of 1 meter. The room dimensions in Table A-1 were used as the configuration bases for the source and the receptor locations. The RESRAD-BUILD input parameters for receptor location and the centers of sources are provided in Table A-2.

Table A-2: Location of Center of Sources and Receptor

Source No.	Source Description	Location of Center of Source (m)		
		X-axis	Y-axis	Z-axis
1	floor	4.24	2.82	0.00
2	north wall	4.24	0.00	1.25
3	east wall	0.00	2.82	1.25
4	south wall	4.24	5.64	1.25
5	west wall	8.47	2.82	1.25
6	ceiling	4.24	2.82	2.49

3. Direct Ingestion Rate.

The RESRAD-BUILD source-specific input parameter, Direct Ingestion Rate, is the direct ingestion rate of the source by any receptor in the room. Direct ingestion represents the fraction of the source ingested per hour. NUREG/CR-5512, Volume 3, defines the average ingestion rate of 1.1E-4 m^2/h as representative for the average individual in an industrial setting. The Direct Ingestion Rate for use in the Building Occupancy Scenario was calculated based on the total room surface area (i.e., source area). The surface area is equal to the sum of the surface area of four walls, plus the surface areas of the floor and ceiling (118.03 m^2, as shown in Table A-1).

Direct Ingestion Rate = Average Ingestion Rate/Source Area
= (1.1E-04 m^2/h)/(118.03 m^2)
= 9.32E-7 h^{-1}

Appendix B
Input Parameter Values for Sensitivity Analysis: Building Surfaces

RESRAD-Build Input Parameter Values for Sensitivity Analysis									
Parameter	Type[a]	Priority[b]	Treat-ment[c]	Value or Distribution	Value/Distribution Reference Source	Distribution's Statistical Parameters[d]			
						1	2	3	4
Exposure Duration (d)	B	3	D	365.25	NUREG/CR-5512, Vol.3,section 5.2.1	NR[e]	NR	NR	NR
Indoor Fraction	B	2	D	0.267	NUREG/CR-5512, Vol.3,section 5.2.2.4	NR	NR	NR	NR
Evaluation Time (y)	P	3	D	1 or multiple (e.g., 1,10, 50, 100)	T=1 corresponds to dose over the 1st year	NR	NR	NR	NR
Number of Rooms	P	3	D	1	NUREG/CR-5512	NR	NR	NR	NR
Deposition Velocity (m/s)	P	2	S	Loguniform	NUREG/CR-6755, Section 3.3; NUREG/CR-6697, Att.C, section 7.5	2.70E-06	2.70E-03	-	-
Resuspension Rate (s^{-1})	P	1	S	Loguniform	NUREG/CR-6755, Section 3.1	2.5E-11	1.3E-5	-	-
Air Exchange Rate for Room (h^{-1})	B	2	S	Truncated Lognormal	NUREG/CR-6755, Section 3.2	0.4187	0.88	0.001	0.999
Room Area (m^2)	P	2	D	47.77	Site-specific data for representative room (General Office Building)	NR	NR	NR	NR
Room Height (m)	P	2	D	2.49	Site-specific data for representative room (General Office Building)	NR	NR	NR	NR
Time Fraction	B	3	D	1	NUREG/CR-5512	NR	NR	NR	NR
Inhalation Rate (m^3/d)	M	2	D	33.6	NUREG/CR-5512, vol. 3, section 5.3.4	NR	NR	NR	NR
Indirect Ingestion Rate (m^2/h)	B	2	D	0.0001	NUREG/CR-5512	NR	NR	NR	NR
Receptor Location (x-, y-, z-axis)	B	3	D	4.24, 2.82,1.0	NUREG/CR-5512; center of room based on site-specific room dimensions	NR	NR	NR	NR
Shielding Thickness (cm)	P	2	D	0	Site-specific model-no shielding assumed	NR	NR	NR	NR
Shielding Density (g/cm^3)	P	1	D	0	Site-specific model-no shielding assumed	NR	NR	NR	NR
Shielding Material	P	3	D	None	Site-specific model-no shielding assumed	NR	NR	NR	NR

RESRAD-Build Input Parameter Values for Sensitivity Analysis									
Parameter	Type[a]	Priority[b]	Treat-ment[c]	Value or Distribution	Value/Distribution Reference Source	Distribution's Statistical Parameters[d]			
						1	2	3	4
Number of Sources	P	3	D	6	Site-specific modeling (includes floor, 4 walls, and ceiling)				
External Dose Conversion Factor, (mrem/y per pCi/cm^2)	M	3	D	RESRAD-Build Dose Conversion Library	FGR12				
Air Submersion Dose Conversion Factor, (mrem/y per pCi/m^3)	M	3	D	RESRAD-Build Dose Conversion Library	FGR12				
Inhalation Dose Conversion Factor, (mrem/pCi)	M	3	D	RESRAD-Build Dose Conversion Library	FGR11				
Ingestionl Dose Conversion Factor, (mrem/pCi)	M	3	D	RESRAD-Build Dose Conversion Library	FGR11				
Source 1: Floor									
Type	P	3	D	area	NUREG/CR-5512				
Direction	P	3	D	Z	NUREG/CR-5512				
Location of Center of Source: x,y,z (m)	P	3	D	4.24, 2.82, 0.0	site-specific data based on dimensions for representative room				
Source length X-axis (m)	P	2	D	8.47	site-specific data based on dimensions for representative room				
Source length Y-axis (m)	P	2	D	5.64	site-specific data based on dimensions for representative room				
Area (m^2)	P	2	D	---	Source length inputs used				
Air Fraction for H-3	B	2	D	1.0	NUREG/CR-6697, Att. C Section 8.6				
Air Fraction (all nuclides other than H-3)	B	2	D	0.07	NUREG/CR-6697, Att. C Section 8.6				
Direct Ingestion (h^{-1})	B	2	D	9.32E-7	NUREG/CR6755, A.3.3				
Removable Fraction	P	1	D	0.1	NUREG/CR-6755, section 3.5				
Time for Source Removal (d)	P	2	S	Triangular	NUREG/CR-6755, Section 3.6; NUREG/CR-6697, Att.C, 8.8	1,000	100,000	10,000	-
Radionuclide Concentration (pCi/m^2)	P	2	D	1.0	-	-	-	-	-

RESRAD-Build Input Parameter Values for Sensitivity Analysis									
Parameter	Type[a]	Priority[b]	Treat-ment[c]	Value or Distribution	Value/Distribution Reference Source	Distribution's Statistical Parameters[d]			
						1	2	3	4
Source 2: North Wall									
Type	P	3	D	Area	NUREG/CR-5512				
Direction	P	3	D	Y	NUREG/CR-5512				
Location of Center of Source: x,y,z (m)	P	3	D	4.24, 0.0, 1.25	site-specific data based on dimensions for representative room				
Source length X-axis (m)	P	2	D	8.47	site-specific data based on dimensions for representative room				
Source length Z-axis (m)	P	2	D	2.49	site-specific data based on dimensions for representative room				
Area (m^2)	P	2	D	---	Source length inputs used				
Air Fraction for H-3	B	2	D	1.0	NUREG/CR-6697, Att. C Section 8.6				
Air Fraction (all nuclides other than H-3)	B	2	D	0.07	NUREG/CR-6697, Att. C Section 8.6				
Direct Ingestion (h^{-1})	B	2	D	9.32E-7	NUREG/CR6755, A.3.3				
Removable Fraction	P	1	D	0.1	NUREG/CR-6755, section 3.5				
Time for Source Removal (d)	P	2	S	Triangular	NUREG/CR-6755, Section 3.6; NUREG/CR-6697, Att.C, 8.8	1,000	100,000	10,000	-
Radionuclide Concentration (pCi/m^2)	P	2	D	1.0	-	-	-	-	-
Source 3: East Wall									
Type	P	3	D	Area	NUREG/CR-5512				
Direction	P	3	D	X	NUREG/CR-5512				
Location of Center of Source: x,y,z (m)	P	3	D	0.00, 2.82, 1.25	site-specific data based on dimensions for representative room				
Source length Y-axis (m)	P	2	D	5.64	site-specific data based on dimensions for representative room				

RESRAD-Build Input Parameter Values for Sensitivity Analysis									
Parameter	Type[a]	Priority[b]	Treat-ment[c]	Value or Distribution	Value/Distribution Reference Source	Distribution's Statistical Parameters[d]			
						1	2	3	4
Source length Z-axis (m)	P	2	D	2.49	site-specific data based on dimensions for representative room				
Area (m^2)	P	2	D	---	Source length inputs used				
Air Fraction for H-3	B	2	D	1.0	NUREG/CR-6697, Att. C, Section 8.6				
Air Fraction (all nuclides other than H-3)	B	2	D	0.07	NUREG/CR-6697, Att. C, Section 8.6				
Direct Ingestion (h^{-1})	B	2	D	9.32E-7	NUREG/CR6755, A.3.3				
Removable Fraction	P	1	D	0.1	NUREG-1727, Table C.7.1; NUREG/CR-6755, section 3.5				
Time for Source Removal (d)	P	2	S	Triangular	NUREG/CR-6755, Section 3.6; NUREG/CR-6697, Att.C, 8.8	1,000	100,000	10,000	-
Radionuclide Concentration (pCi/m^2)	P	2	D	1.0	-	-	-	-	-
Source 4: South Wall									
Type	P	3	D	area	NUREG/CR-5512				
Direction	P	3	D	Y	NUREG/CR-5512				
Location of Center of Source: x,y,z (m)	P	3	D	4.24, 5.64, 1.25	site-specific data based on dimensions for representative room				
Source length X-axis (m)	P	2	D	8.47	site-specific data based on dimensions for representative room				
Source length Z-axis (m)	P	2	D	2.49	site-specific data based on dimensions for representative room				
Area (m^2)	P	2	D	---	Source length inputs used				
Air Fraction for H-3	B	2	D	1.0	NUREG/CR-6697, Att. C Section 8.6				
Air Fraction (all nuclides other than H-3)	B	2	D	0.07	NUREG/CR-6697, Att. C Section 8.6				
Direct Ingestion (h^{-1})	B	2	D	9.32E-7	NUREG/CR6755, A.3.3				

RESRAD-Build Input Parameter Values for Sensitivity Analysis									
Parameter	Type[a]	Priority[b]	Treat-ment[c]	Value or Distribution	Value/Distribution Reference Source	Distribution's Statistical Parameters[d]			
						1	2	3	4
Removable Fraction	P	1	D	0.1	NUREG/CR-6755, section 3.5				
Time for Source Removal (d)	P	2	S	Triangular	NUREG/CR-6755, Section 3.6; NUREG/CR-6697, Att.C, 8.8	1,000	100,000	10,000	-
Radionuclide Concentration (pCi/m^2)	P	2	D	1.0	-	-	-	-	-
Source 5: West Wall									
Type	P	3	D	area	NUREG/CR-5512				
Direction	P	3	D	X	NUREG/CR-5512				
Location of Center of Source: x,y,z (m)	P	3	D	8.47, 2.82, 1.25	site-specific data based on dimensions for representative room				
Source length Y-axis (m)	P	2	D	5.64	site-specific data based on dimensions for representative room				
Source length Z-axis (m)	P	2	D	2.49	site-specific data based on dimensions for representative room				
Area (m^2)	P	2	D	---	Source length inputs used				
Air Fraction for H-3	B	2	D	1.0	NUREG/CR-6697, Att. C Section 8.6				
Air Fraction (all nuclides other than H-3)	B	2	D	0.07	NUREG/CR-6697, Att. C Section 8.6				
Direct Ingestion (h^{-1})	B	2	D	9.32E-7	NUREG/CR6755, A.3.3				
Removable Fraction	P	1	D	0.1	NUREG-1727, Table C.7.1; NUREG/CR-6755, section 3.5				
Time for Source Removal (d)	P	2	S	Triangular	NUREG/CR-6755, Section 3.6; NUREG/CR-6697, Att.C, 8.8	1,000	100,000	10,000	-
Radionuclide Concentration (pCi/m^2)	P	2	D	1.0	-	-	-	-	-
Source 6: Ceiling									
Type	P	3	D	area	NUREG/CR-5512				
Direction	P	3	D	Z	NUREG/CR-5512				

RESRAD-Build Input Parameter Values for Sensitivity Analysis									
Parameter	Type[a]	Priority[b]	Treat-ment[c]	Value or Distribution	Value/Distribution Reference Source	Distribution's Statistical Parameters[d]			
						1	2	3	4
Location of Center of Source: x,y,z (m)	P	3	D	4.24, 2.82, 2.49	site-specific data based on dimensions for representative room				
Source length X-axis (m)	P	2	D	8.47	site-specific data based on dimensions for representative room				
Source length Y-axis (m)	P	2	D	5.64	site-specific data based on dimensions for representative room				
Area (m^2)	P	2	D	---	Source length inputs used				
Air Fraction for H-3	B	2	D	1.0	NUREG/CR-6697, Att. C Section 8.6				
Air Fraction (all nuclides other than H-3)	B	2	D	0.07	NUREG/CR-6697, Att. C Section 8.6				
Direct Ingestion (h^{-1})	B	2	D	9.32E-7	NUREG/CR6755, A.3.3				
Removable Fraction	P	1	D	0.1	NUREG-1727, Table C.7.1; NUREG/CR-6755, section 3.5				
Time for Source Removal (d)	P	2	S	Triangular	NUREG/CR-6755, Section 3.6; NUREG/CR-6697, Att.C, 8.8	1,000	100,000	10,000	-
Radionuclide Concentration (pCi/m^2)	P	2	D	1.0	-	-	-	-	-

[a] P = physical, B = behavioral, M = metabolic
[b] 1 = high-priority parameter, 2 = medium-priority parameter, 3 = low-priority parameter
[c] D = deterministic, S = stochastic
[d] Distribution Statistical Parameters:
Loguniform: 1= minimum, 2 = maximum
Triangular: 1 = minimum, 2 = maximum, 3 = most likely
[e] NR = none recommended
Input Rank Correlation Coefficients:
Resuspension Rate and Deposition Velocity = 0.9
Time for source removal (correlation set between sources) = 0.9

Appendix C
Results of Sensitivity Analysis: Building Surfaces

Table C-1: *Results of Sensitivity Analysis: Building Surface*

Radionuclide	LAMBDAT[a]	RFO[b] (source #)	UD[c] (source #)	DKSUS[d] (source #)
Am-241	-0.96 (1) -0.97 (2, 3, 4, 5, 6)	-0.71 (1, 4) -0.70 (2, 6) -0.69 (3, 5)	NS[e] (1, 2, 3, 4, 5, 6)	NS (1, 2, 3, 4, 5, 6)
C-14	-0.64 (1, 3, 6) -0.62 (2, 4) -0.63 (5)	0.43 (1) 0.39 (2) 0.36 (3) 0.46 (4) 0.41 (5) 0.31 (6)	0.27 (1, 2, 6) 0.28 (3, 5) 0.30 (4)	-0.50 (1, 2, 3, 6) -0.51 (4) -0.52 (5)
Cm-243	-0.96 (1) -0.97 (2, 3, 4, 5, 6)	-0.71 (1, 2, 4) -0.69 (3, 5, 6)	NS (1, 2, 3, 4, 5, 6)	NS (1, 2, 3, 4, 5, 6)
Cm-244	-0.96 (1) -0.97 (2, 3, 4, 5, 6)	-0.71 (1, 2, 4) -0.69 (3, 5, 6)	NS (1, 2, 3, 4, 5, 6)	NS (1, 2, 3, 4, 5, 6)
Cm-245	-0.96 (1) -0.97 (2, 3, 4, 5, 6)	-0.71 (1, 4) -0.70 (2) -0.68 (5) -0.69 (3, 6)	NS (1, 2, 3, 4, 5, 6)	NS (1, 2, 3, 4, 5) -0.11 (6)
Cm-246	-0.96 (1) -0.97 (2, 3, 4, 5, 6)	-0.71 (1, 4) -0.70 (2, 6) -0.69 (3) -0.68 (5)	NS (1, 2, 3, 4, 5, 6)	NS (1, 2, 3, 4, 5) -0.11 (6)
Co-60	-0.45 (1) -0.73 (2) -0.71 (3) -0.76 (4) -0.72 (5) -0.37 (6)	0.56 (1) 0.41 (2) 0.23 (3) 0.46 (4) 0.35 (5) 0.73 (6)	NS (1, 2, 3) 0.13 (4) 0.11 (5) 0.12 (6)	NS (1, 2, 3) -0.14 (4) -0.13 (5) -0.50 (6)
Cs-137	-0.46 (1) -0.40 (2) -0.59 (3) -0.41 (4) -0.57 (5) -0.52 (6)	0.69 (1) 0.57 (2) 0.66 (3) 0.54 (4) 0.69 (5) 0.63 (6)	0.36 (1) 0.23 (2) 0.41 (3) 0.27 (4) 0.37 (5) 0.35 (6)	-0.44 (1) -0.27 (2) -0.48 (3) -0.33 (4) -0.44 (5) -0.42 (6)
Eu-152	-0.80 (1) -0.83 (2) -0.94 (3, 5) -0.83 (4) -0.84 (6)	0.49 (1) 0.13 (2) NS (3, 5) -0.43 (4) 0.44 (6)	NS (1, 2, 4, 6) 0.23 (3) 0.19 (5)	-0.12 (1) -0.13 (2) -0.24 (3) NS (4, 6) -0.22 (5)

Radionuclide	LAMBDAT[a]	RFO[b] (source #)	UD[c] (source #)	DKSUS[d] (source #)
Eu-154	-0.83 (1) -0.87 (2, 4, 6) -0.95 (3, 5)	0.48 (1) 0.12 (2) NS (3, 5) 0.11 (4) 0.33 (6)	NS (1, 2, 4, 6) 0.19 (3) 0.15 (5)	NS (1, 2, 4, 6) -0.20 (3) -0.16 (5)
H-3	-0.94 (1, 6) -0.95 (2, 3, 4, 5)	-0.45 (1) -0.49 (2) -0.41 (3) -0.55 (4) -0.42 (5) -0.47 (6)	0.48 (1) 0.51 (2) 0.45 (3) 0.46 (4) 0.47 (5) 0.49 (6)	-0.53 (1, 4, 5) -0.57 (2) -0.52 (3) -0.55 (6)
I-129	-0.58 (1, 3) -0.54 (2) -0.56 (4, 5) -0.57 (6)	0.48 (1) 0.43 (2, 5) 0.39 (3) 0.49 (4) 0.37 (6)	0.29 (1, 6) 0.28 (2) 0.30 (3, 5) 0.31 (4)	-0.54 (1, 3, 4, 5, 6) -0.52 (2)
Nb-94	-0.76 (1) -0.90 (2, 4) -0.94 (3, 5) -0.88 (6)	0.30 (1) NS (2, 4) -0.12 (3) -0.20 (5) 0.16 (6)	0.19 (1) 0.30 (2) 0.33 (3) 0.26 (4) 0.32 (5) 0.20 (6)	-0.31 (1) -0.44 (2) -0.49 (3) -0.40 (4) -0.48 (5) -0.36 (6)
Ni-59	-0.95 (1, 2, 3, 4, 5, 6)	-0.27 (1) -0.28 (2, 4, 5) -0.22 (3) -0.35 (6)	0.27 (1, 4, 5, 6) 0.29 (2) 0.26 (3)	-0.37 (1, 4) -0.41 (2) -0.38 (3) -0.39 (5, 6)
Ni-63	-0.95 (1, 2, 4, 5, 6) -0.96 (3)	-0.16 (1) -0.21 (2) -0.14 (3) -0.22 (4) -0.18 (5) -0.25 (6)	0.26 (1, 6) 0.29 (2) 0.27 (3) 0.25 (4, 5)	-0.28 (1, 5) -0.33 (2) -0.30 (3) -0.29 (4, 5) -0.31 (6)
Np-237	-0.96 (1) -0.97 (2, 3, 4, 5, 6)	-0.71 (1, 4) -0.70 (2) -0.69 (3, 5, 6)	NS (1, 2, 3, 4, 5, 6)	NS (1, 2, 3, 4, 5, 6)
Pu-238	-0.96 (1) -0.97 (2, 3, 4, 5, 6)	-0.71 (1) -0.70 (2) -0.69 (3, 5, 6) -0.72 (4)	NS (1, 2, 3, 4, 5, 6)	NS (1, 2, 3, 4, 5, 6)
Pu-239	-0.96 (1) -0.97 (2, 3, 4, 5, 6)	-0.71 (1, 4) -0.70 (2, 6) -0.69 (3) -0.68 (5)	NS (1, 2, 3, 4, 5, 6)	NS (1, 2, 3, 4, 5, 6)

Radionuclide	LAMBDAT[a]	RFO[b] (source #)	UD[c] (source #)	DKSUS[d] (source #)
Pu-240	-0.96 (1) -0.97 (2, 3, 4, 5, 6)	-0.71 (1, 4) -0.70 (2, 6) -0.69 (3) -0.68 (5)	NS (1, 2, 3, 4, 5, 6)	NS (1, 2, 3, 4, 5, 6)
Pu-241	-0.96 (1) -0.97 (2, 3, 4, 5, 6)	-0.71 (1, 2, 4) -0.69 (3, 5, 6)	NS (1, 2, 3, 4, 5, 6)	NS (1, 2, 3, 4, 5, 6)
Sr-90	-0.95 (1, 2, 3, 4, 5, 6)	NS (1, 2, 3, 4, 5, 6)	0.22 (1) 0.23 (2) 0.24 (3) 0.19 (4) 0.21 (5) 0.18 (6)	-0.22 (1, 4, 6) -0.26 (2) -0.25 (3) -0.23 (5)
Tc-99	-0.90 (1, 3, 4, 5, 6) -0.91 (2)	NS (1, 2, 6) 0.15 (3) 0.13 (4) 0.11 (5)	0.27 (1, 4) 0.29 (2) 0.28 (3, 5) 0.25 (6)	-0.45 (1, 5) -0.46 (2) -0.44 (3, 4) -0.43 (6)

[a] LAMBDAT = building air exchange rate
[b] RFO(#) = source removal time (for source number)
[c] UD = deposition velocity
[d] DKSUS = resuspension rate
[e] NS = not sensitive

Appendix D
Input Parameter Values for DCGL Determination: Building Surfaces

RESRAD-Build Input Parameter Values for DCGLs					
Parameter	**Type[a]**	**Nuclide**	**Treatment[b]**	**Value/Distribution**	**Value Reference Source**
Exposure Duration (d)	B	All	D	365.25	NUREG/CR-5512, Vol.3,section 5.2.1
Indoor Fraction	B	All	D	0.267	NUREG/CR-5512, Vol.3,section 5.2.2.9
Evaluation Time (y)	P	All	D	1, 5 (1, 5, 10, 25, 50, 100 for Pu-241)	Use of 1y provides doses at t=0y and t=1y; multiple input applied to verify time of peak dose
Number of Rooms	P	All	D	1	NUREG/CR-5512
Deposition Velocity (m/s)	P	Am-241, Cm-243, Cm-244, Cm-245, Cm-246, Np-237, Pu-238, Pu-239, Pu-240, and Pu-241	D	1.5179E-05	25[th] percentile value
		C-14, Co-60, Cs-137, Eu-152, Eu-154, H-3, I-129, Nb-94, Ni-59, Ni-63, Sr-90, and Tc-99	D	4.78217E-04	75[th] percentile value
Resuspension Rate (s^{-1})	P	Am-241, Cm-243, Cm-244, Np-237, Pu-238, Pu-239, Pu-240, and Pu-241	D	1.79444E-08	50[th] percentile value
		C-14, Cm-245, Cm-246, Co-60, Cs-137, Eu-152, Eu-154, H-3, I-129, Nb-94, Ni-59, Ni-63, Sr-90, and Tc-99	D	6.70403E-10	25[th] percentile value
Air Exchange Rate for Room (h^{-1})	P	All	D	8.35789E-01	25[th] percentile value
Room Area (m^2)	P	All	D	47.77	Humboldt Bay-specific data (General Office Building)
Room Height (m)	P	All	D	2.49	Humboldt Bay-specific data (General Office Building)
Time Fraction	B	All	D	1	NUREG/CR-5512
Inhalation Rate (m^3/d)	M	All	D	45.6	Conservative inhalation rate for moderate to heavy activities - NUREG/CR-6697, Attachment C, section 5.1; NUREG/CR-5512, vol. 3, section 5.3.4
Indirect Ingestion Rate (m^2/h)	B	All	D	0.0001	NUREG/CR6755
Receptor Location	B	All	D	4.24, 2.82,1.0	NUREG/CR-5512; site-specific room dimensions (General Office Building)
Shielding Thickness (cm)	P	All	D	0	Site-specific model-no shielding assumed
Shielding Density (g/cm^3)	P	All	D	2.4	RESRAD-Build default value for concrete – not used in DCGL calculations
Shielding Material	P	All	D	concrete	Default input – not used in DCGL calculations
Number of Sources	P	All		6	Modeling for representative room (includes floor, 4 walls, and ceiling)

RESRAD-Build Input Parameter Values for DCGLs					
Parameter	Type[a]	Nuclide	Treatment[b]	Value/Distribution	Value Reference Source
External Dose Conversion Factor, (mrem/y per pCi/cm^2)	M	All	D	RESRAD-Build default	FGR12
Air Submersion Dose Conversion Factor, (mrem/y per pCi/m^3)	M	All	D	RESRAD-Build default	FGR12
Inhalation Dose Conversion Factor, (mrem/pCi)	M	All	D	RESRAD-Build default	FGR11
Ingestionl Dose Conversion Factor, (mrem/pCi)	M	All	D	RESRAD-Build default	FGR11
Source 1: Floor					
Type	P	All		area	NUREG/CR-5512
Direction	P	All		Z	NUREG/CR-5512
Location of Center of Source: x,y,z (m)	P	All	D	4.24, 2.82, 0.0	site-specific data – center of floor based on dimensions for General Office Building room
Source length X-axis (m)	P	All	D	8.47	site-specific data based on dimensions for General Office Building room
Source length Y-axis (m)	P	All	D	5.64	site-specific data based on dimensions for General Office Building room
Area (m^2)	P	All	D	---	Source length inputs used
Air Fraction	B	H-3 All others	D	1.0 0.07	NUREG/CR-6697, Att. C Section 8.6
Direct Ingestion (h^{-1})	B	All	D	9.32E-7	NUREG/CR6755, A.3.3
Removable Fraction	P	All	D	0.1	NUREG-1727, Table C.7.1; NUREG/CR-6755, section 3.5
Time for Source Removal (d)	P	C-14, Co-60, Cs-137, Eu-152, Eu-154, I-129, and Nb-94	D	52695.2	75th percentile value
		Sr-90 and Tc-99	D	33056.9	50th percentile value
		Am-241, Cm-243, Cm-244, Cm-245, Cm-246, H-3, Ni-59, Ni-63, Np-237, Pu-238, Pu-239, Pu-240, and Pu-241	D	18249.3	25Th percentile value
Radionuclide Concentration (pCi/m^2)	P	All	D	1.0	-
Source 2: North Wall					
Type	P	3		Area	NUREG/CR-5512

RESRAD-Build Input Parameter Values for DCGLs					
Parameter	**Type[a]**	**Nuclide**	**Treatment[b]**	**Value/Distribution**	**Value Reference Source**
Direction	P	3		X	NUREG/CR-5512
Location of Center of Source: x,y,z (m)	P	3	D	4.24, 0.0, 1.25	site-specific data – center of floor based on dimensions for General Office Building room
Source length Y-axis (m)	P	2	D	8.47	site-specific data based on dimensions for General Office Building room
Source length Z-axis (m)	P	2	D	2.49	site-specific data based on dimensions for General Office Building room
Area (m^2)	P	2	D	---	Source length inputs used
Air Fraction	B	H-3 All others	D	1.0 0.07	NUREG/CR-6697, Att. C Section 8.6
Direct Ingestion (h^{-1})	B	2	D	9.32E-7	NUREG/CR6755, A.3.3
Removable Fraction	P	1	D	0.1	NUREG-1727, Table C.7.1; NUREG/CR-6755, section 3.5
Time for Source Removal (d)	P	C-14, Co-60, Cs-137, Eu-152, Eu-154, and I-129	D	52718.8	75[th] percentile value
		Nb-94, Sr-90, and Tc-99	D	33202.9	50[th] percentile value
		Am-241, Cm-243, Cm-244, Cm-245, Cm-246, H-3, Ni-59, Ni-63, Np-237, Pu-238, Pu-239, Pu-240, and Pu-241	D	18230.1	25[Th] percentile value
Radionuclide Concentration (pCi/m^2)	P	2	D	1.0	-
Source 3: East Wall					
Type	P	3		Area	NUREG/CR-5512
Direction	P	3		Y	NUREG/CR-5512
Location of Center of Source: x,y,z (m)	P	3	D	0.00, 2.82, 1.25	site-specific data – center of floor based on dimensions for General Office Building room
Source length X-axis (m)	P	2	D	5.64	site-specific data based on dimensions for General Office Building room
Source length Z-axis (m)	P	2	D	2.49	site-specific data based on dimensions for General Office Building room
Area (m^2)	P	2	D	---	Source length inputs used

RESRAD-Build Input Parameter Values for DCGLs					
Parameter	Type[a]	Nuclide	Treatment[b]	Value/Distribution	Value Reference Source
Air Fraction	B	H-3 All others	D	1.0 0.07	NUREG/CR-6697, Att. C Section 8.6
Direct Ingestion (h^{-1})	B	2	D	9.32E-7	NUREG/CR6755, A.3.3
Removable Fraction	P	1	D	0.1	NUREG-1727, Table C.7.1; NUREG/CR-6755, section 3.5
Time for Source Removal (d)	P	C-14, Co-60, Cs-137, I-129, and Tc-99	D	52775.6	75th percentile value
		Eu-152, Eu-154, and Sr-90	D	33048.9	50th percentile value
		Am-241, Cm-243, Cm-244, Cm-245, Cm-246, H-3, Nb-94, Ni-59, Ni-63, Np-237, Pu-238, Pu-239, Pu-240, and Pu-241	D	18130.2	25Th percentile value
Radionuclide Concentration (pCi/m^2)	P	2	D	1.0	-
Source 4: South Wall					
Type	P	3		area	NUREG/CR-5512
Direction	P	3		X	NUREG/CR-5512
Location of Center of Source: x,y,z (m)	P	3	D	4.24, 5.64, 1.25	site-specific data – center of floor based on dimensions for General Office Building room
Source length Y-axis (m)	P	2	D	8.47	site-specific data based on dimensions for General Office Building room
Source length Z-axis (m)	P	2	D	2.49	site-specific data based on dimensions for General Office Building room
Area (m^2)	P	2	D	---	Source length inputs used
Air Fraction	B	H-3 All others	D	1.0 0.07	NUREG/CR-6697, Att. C Section 8.6
Direct Ingestion (h^{-1})	B	2	D	9.32E-7	NUREG/CR6755, A.3.3
Removable Fraction	P	1	D	0.1	NUREG-1727, Table C.7.1; NUREG/CR-6755, section 3.5

RESRAD-Build Input Parameter Values for DCGLs					
Parameter	Type[a]	Nuclide	Treatment[b]	Value/Distribution	Value Reference Source
Time for Source Removal (d)	P	C-14, Co-60, Cs-137, Eu-154, I-129, and Tc-99	D	52726.9	75[th] percentile value
		Nb-94 and Sr-90	D	33041.0	50[th] percentile value
		Am-241, Cm-243, Cm-244, Cm-245, Cm-246, Eu-152, H-3, Ni-59, Ni-63, Np-237, Pu-238, Pu-239, Pu-240, and Pu-241	D	18207.1	25[Th] percentile value
Radionuclide Concentration (pCi/m^2)	P	2	D	1.0	-
Source 5: West Wall					
Type	P	3		area	NUREG/CR-5512
Direction	P	3		Y	NUREG/CR-5512
Location of Center of Source: x,y,z (m)	P	3	D	8.47, 2.82, 1.25	site-specific data – center of floor based on dimensions for General Office Building room
Source length X-axis (m)	P	2	D	5.64	site-specific data based on dimensions for General Office Building room
Source length Z-axis (m)	P	2	D	2.49	site-specific data based on dimensions for General Office Building room
Area (m^2)	P	2	D	---	Source length inputs used
Air Fraction	B	H-3 All others	D	1.0 0.07	NUREG/CR-6697, Att. C Section 8.6
Direct Ingestion (h^{-1})	B	2	D	9.32E-7	NUREG/CR6755, A.3.3
Removable Fraction	P	1	D	0.1	NUREG-1727, Table C.7.1; NUREG/CR-6755, section 3.5
Time for Source Removal (d)	P	C-14, Co-60, Cs-137, I-129, and Tc-99	D	52713.2	75[th] percentile value
		Eu-152, Eu-154, and Sr-90	D	33108.5	50[th] percentile value
		Am-241, Cm-243, Cm-244, Cm-245, Cm-246, H-3, Nb-94, Ni-59, Ni-63, Np-237, Pu-238, Pu-239, Pu-240, and Pu-241	D	18094.8	25[Th] percentile value
Radionuclide Concentration (pCi/m^2)	P	2	D	1.0	-

RESRAD-Build Input Parameter Values for DCGLs					
Parameter	**Type[a]**	**Nuclide**	**Treatment[b]**	**Value/Distribution**	**Value Reference Source**
Source 6: Ceiling					
Type	P	3		area	NUREG/CR-5512
Direction	P	3		Y	NUREG/CR-5512
Location of Center of Source: x,y,z (m)	P	3	D	4.24, 2.82, 2.49	site-specific data – center of floor based on dimensions for General Office Building room
Source length X-axis (m)	P	2	D	8.47	site-specific data based on dimensions for General Office Building room
Source length Z-axis (m)	P	2	D	5.64	site-specific data based on dimensions for General Office Building room
Area (m^2)	P	2	D	---	Source length inputs used
Air Fraction	B	H-3 All others	D	1.0 0.07	NUREG/CR-6697, Att. C Section 8.6
Direct Ingestion (h^{-1})	B	2	D	9.32E-7	NUREG/CR6755, A.3.3
Removable Fraction	P	1	D	0.1	NUREG-1727, Table C.7.1; NUREG/CR-6755, section 3.5
Time for Source Removal (d)	P	C-14, Co-60, Cs-137, Eu-152, Eu-154, I-129, and Nb-94	D	52622.2	75th percentile value
		Sr-90 and Tc-99	D	33050.0	50th percentile value
		Am-241, Cm-243, Cm-244, Cm-245, Cm-246, H-3, Ni-59, Ni-63, Np-237, Pu-238, Pu-239, Pu-240, and Pu-241	D	18246.6	25Th percentile value
Radionuclide Concentration (pCi/m^2)	P	2	D	1.0	-

[a] P = physical, B = behavioral, M = metabolic; (see NUREG/CR-6697, Attachment B, Table 4.)
[b] D = deterministic
[c] Triangular with defining values for distribution: minimum = 1,000, maximum = 100,000, and most likely = 10,000.

Appendix E
Building Surface DCGL Results

Table E-1: *Building Surface DCGL Results*

Nuclide	DCGL Value Development: CF (mrem/y per pCi/m^2)	$DCGL_{25}$ (pCi/m^2)	$DCGL_W$ (dpm/100 cm^2)
Am-241	1.84E-04	1.36E+05	3.02E+03
C-14	7.90E-08	3.16E+08	7.03E+06
Cm-243	1.27E-04	1.97E+05	4.37E+03
Cm-244	9.98E-05	2.51E+05	5.56E+03
Cm-245	2.48E-04	1.01E+05	2.24E+03
Cm-246	2.04E-04	1.23E+05	2.72E+03
Co-60	4.09E-05	6.11E+05	1.36E+04
Cs-137	1.19E-05	2.10E+06	4.66E+04
Eu-152	2.02E-05	1.24E+06	2.75E+04
Eu-154	2.15E-05	1.16E+06	2.58E+04
H-3	3.01E-09	8.31E+09	1.84E+08
I-129	1.12E-05	2.23E+06	4.96E+04
Nb-94	2.86E-05	8.74E+05	1.94E+04
Ni-59	8.77E-09	2.85E+09	6.33E+07
Ni-63	2.28E-08	1.10E+09	2.43E+07
Np-237	2.27E-04	1.10E+05	2.44E+03
Pu-238	1.60E-04	1.56E+05	3.47E+03
Pu-239	1.78E-04	1.40E+05	3.12E+03
Pu-240	1.78E-04	1.40E+05	3.12E+03
Pu-241	3.83E-06	6.53E+06	1.45E+05
Sr-90	5.71E-06	4.38E+06	9.72E+04
Tc-99	5.76E-08	4.34E+08	9.64E+06

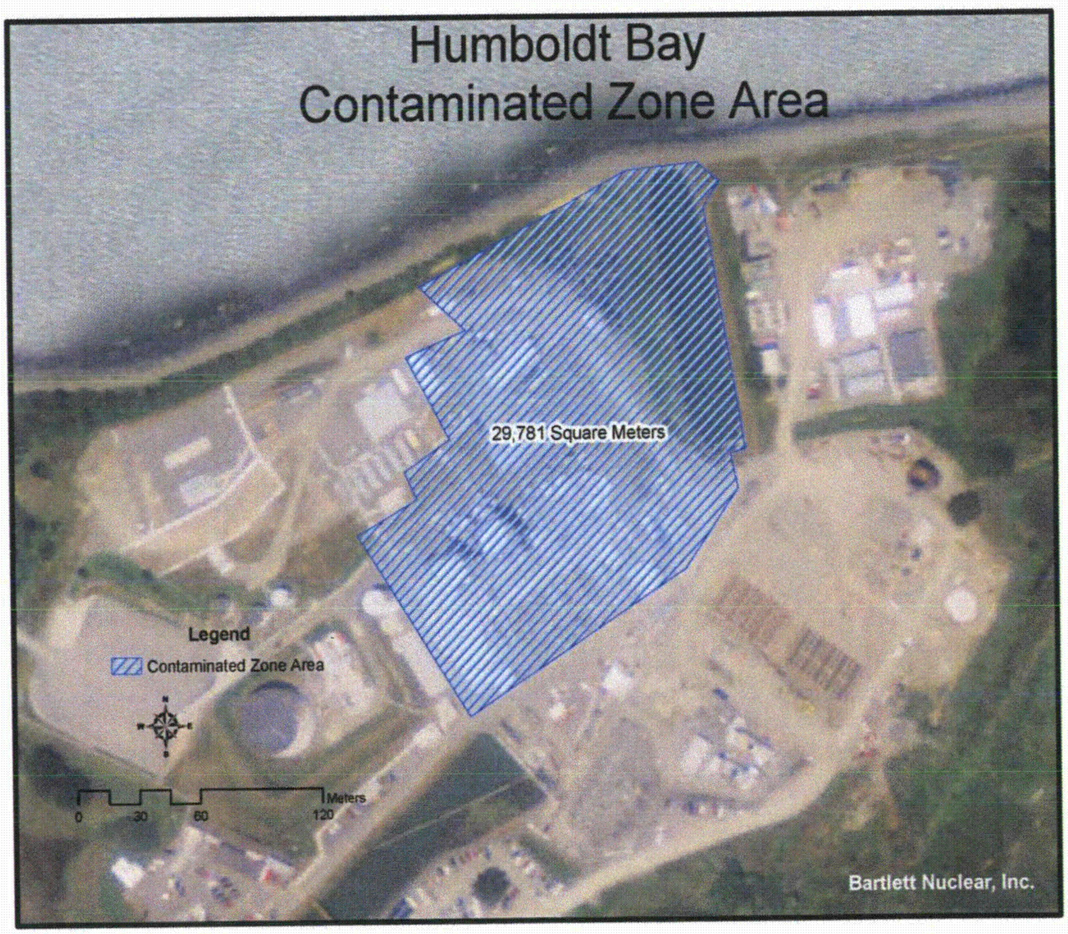
Appendix F
Basis for Site-Specific Parameters Values: Soil

Site-specific information was used when available as the basis for the RESRAD input parameter discussed below. Reference 11, which documents the calculations of site-specific parameter values, provides the information presented below.

1. Area of the Contaminated Zone

Figure F-1, Area of the Contaminated Zone, was generated with AutoCAD. The size of the contaminated zone is based on the largest contiguous MARSSIM Class 1 and Class 2 at the Humboldt Bay site and includes the Protected Area and adjacent impacted areas. That area, 29,781 m^2, was then rounded to the nearest thousand. For modeling purposes, the size of the Humboldt Bay contaminated zone is 30,000 m^2.

Figure F-1: Area of Contaminated Zone



2. Length Parallel to Aquifer Flow

The length parallel to the aquifer is defined as is the maximum horizontal distance measured in the contaminated zone, from its up gradient edge to the down gradient edge, along the direction of the groundwater flow in the underlying aquifer. It was assumed that the area of the contaminated zone could be approximated by a circle with an area of 30,000 m^2 (the area of the contaminated zone). The diameter of the circle is suitable as input for the length parallel to the aquifer parameter and is calculated as follows:

$$A = \pi r^2$$

Where A is the area in m^2 and r is the radius in meters.

$$r = \sqrt{\frac{30000}{\Pi}}$$

$$r = 97.7 \text{ m}$$

$$D = 2 \times r = 2 * 97.7$$

$$D = 195 \text{ m}$$

Therefore, the length of parallel is 195 m.

3. Contaminated Zone Erosion Rate

The slope of the contaminated zone was determined using elevations from site contour maps provided in the HSA (Reference 10) to determine the site grades in three directions within the contaminated zone. This determination is summarized below:

Trial	Grade Difference	Approximate Distance between Points[a]	Estimated Slope
A	9.1 m	110 m	8%
B	6.1 m	151 m	4%
C	6.1 m	85 m	7%
		average	6%

[a] Locations of points shown in Figure 3 in Reference 11.

Data from NUREG/CR-6697, Attachment C, Section 3.8, was used to select the appropriate Erosion Rate that corresponds to the Humboldt Bay site slope of 6 percent.

4. Soil Type

Contaminated Zone: The thickness of the contaminated zone was determined from characterization soil sample data provided in the HSA (Reference 10). Plant-related radioactivity was detected in surface soil samples (6 inches or less in depth) and in a sub-surface sample collected at a depth of 11.5 feet. To account for the uncertainty of thickness of the contaminated zone, a uniform distribution was established using a minimum thickness equal to 6 inches and a maximum thickness equal to 11.5 feet.

Well installation logs for 22 groundwater monitoring wells were reviewed for soil type descriptions to a depth of 11.5 ft to determined a representative soil type for the contaminated zone. The soil type descriptions and the USCS codes recorded on the well logs were then compared to the soil categories listed Tables 3.1-1 and 3.2-1 in Attachment

C to NUREG/CR-6697. Soil descriptions recorded in the "Lithologic Description" section of the logs served as the primary factor for selecting a RESRAD soil type category from the surface to a depth. When those descriptions did not match one of the soil types given in Attachment C to NUREG/CR-6697, the USCS code was used. Soil type selection focused on two soil characteristics: density and total porosity. These characteristics were weighted by depth and overall averages determined. The soil type for the contaminated zone was selected based on matching the overall average density and total porosity to the soil types given in Tables 3.1-1 and 3.2-1 in Attachment C to NUREG/CR-6697.

Based on that approach, "clay loam" was selected from the soil type provided in NUREG/CR-6697 as reasonably representative soil type for the contaminated zone. The "clay loam" soil classification was used as the basis for selecting input for other soil type-dependent parameters, such as hydraulic conductivity and the RESRAD soil-b parameter.

Unsaturated zone: The thickness of the unsaturated zone was determined from 2009 groundwater monitoring data, which showed a minimum depth to groundwater equal to approximately 4.9 feet and a maximum depth equal to approximately 27 feet. To account for the uncertainty of thickness of the unsaturated zone, a uniform distribution was established using a minimum thickness equal to 0 inches and a maximum thickness equal to 26.5 feet.

Using the same approach as that used to determine the soil type for the contaminated zone; "clay loam" was selected as reasonably representative soil type for the unsaturated zone. "Clay loam" was selected from the soil type provided in NUREG/CR-6697 as reasonably representative soil type for the unsaturated zone. The "clay loam" soil classification was used as the basis for selecting input for other soil type-dependent parameters, such as effective porosity, hydraulic conductivity, and the RESRAD soil-b parameter.

Saturated zone: Using the same approach as that used to determine the soil type for the contaminated and unsaturated zones; "silty clay loam" was selected as reasonably representative soil type for the saturated zone. The "silty clay loam" soil classification was used as the basis for selecting input for other soil type-dependent parameters, such as effective porosity, hydraulic conductivity, and the RESRAD soil-b parameter.

5. Field Capacity:

Field capacity defines the relationship of field capacity (residual water content) to effective porosity. The field capacity is the ratio of the volume of water retained in the soil sample, after all drainage has ceased, to the total volume of the soil sample. Equation 4.4 in *Data Collection Handbook to Support Modeling the Impacts of Radioactive Material in Soil* (ANL/EAIS-8, U.S. Department of Energy – Argonne National Laboratory, April 1993) relates total and effective porosities to field capacity as follows:

$$\text{Effective Porosity} = \text{Total Porosity} - \text{Field Capacity}$$

Rearranging this equation:

$$\text{Field Capacity} = \text{Total Porosity} - \text{Effective Porosity}$$

For the Contaminated and Unsaturated Zones, the mean total porosity for clay loam soil is of 0.41 and the mean effective porosity is 0.315. Therefore the field capacity for these two zones is approximately 0.095

For the Saturated Zone, the mean total porosity for silty clay loam soil is of 0.43 and the mean effective porosity is 0.342. Therefore the field capacity for this zone is approximately 0.088.

6. Irrigation Rate (Evapotranspiration and Runoff Coefficients)

Attachment C to NUREG/CR-6697 discusses the Irrigation Rate in terms of the Evapotranspiration Coefficient, and provides the following equation for the Evapotranspiration Coefficient:

$$Ce = (ETr)/(1-Cr)(Pr) + IRr$$

Where: ETr = the Evapotransporation Rate (m/y) = 0.61 (Humboldt Bay SAFSTOR Environmental Report, July 1984)
Pr = the Precipitation Rate (m/y) = 0.91 (Humboldt Bay SAFSTOR Environmental Report, July 1984)
IRr = the Irrigation Rate (m/y) and
Cr = the Runoff Coefficient.

The *Data Collection Handbook to Support Modeling the Impacts of Radioactive Material in Soil* (ANL/EAIS-8, U.S. Department of Energy – Argonne National Laboratory, April 1993) provides the equation below to calculate the Runoff Coefficient, Cr, for an agricultural environment and also provides values for the terms c_1, c_2, and c_3.

$$C_r = 1 - c_1 - c_2 - c_3$$

c_1 = 0.2 for rolling land with an average slope between 4.6 to 6.1 m/mi. (assumed representative for the Humboldt Bay site)

c_2 = 0.2 for intermediate combinations of clay and loam

c_3 = 0.1 for cultivated lands (consistent with the resident farmer scenario).

$$Cr = 1 - 0.2 - 0.2 - 0.1 = 0.5$$

NUREG/CR-6697, Attachment C, Section 4.3 defines the Evapotranspiration Coefficient, Ce, as the ratio of the total volume of water (a combination of evaporation from soil surfaces and transpiration from vegetation) transferred to the atmosphere to the total volume of water available within the root zone of the soil. The NUREG/CR recommends the use of a uniform distribution with minimum and maximum values for Ce equal to 0.5 and 0.75, respectively, and with 0.625 as median.

Rearranging this equation above, the Irrigation Rate can be expressed as:

$$IRr = (ETr/Ce)-(1-Cr)(Pr)$$

The input values for the variables in the equation above follow:

Variable	Use of Min Ce Value	Use of Max Ce Value
ETr (m/y)	0.61	0.61
Pr (m/y)	0.91	0.91
Cr	0.5	0.5
Ce	0.5	0.75
IRr (m/y)	0.77	0.36

The irrigation rate equation yields a minimum IRr value equal to 0.36 and a maximum IRr value equal to 0.77 m/y. A uniform distribution with minimum and maximum value equal to 0.36 and 0.77, respectively, and a median equal to 0.56 was assigned as input for this parameter.

7. Well Pumping Rate

Well Pumping Rate: Attachment C to NUREG/CR-6697 states that "A site-specific input distribution for well pumping rate can be determined as the sum of individual water needs." The household use component as determined from the domestic use data is summarized below.

Water Use Component (family of four)	Median	Minimum	Maximum
Household* (m^3/y)	374	374	374
Livestock (m^3/y)	76.7	76.7	76.7
Contaminated fraction for Irrigation	*1*	*1*	*1*
f_p = 1 (assumes irrigation of the entire area)			
Irrigation rate I_r (m/y)	*0.56*	*0.36*	*0.76*
Irrigation water (m^3/y) $f_p \times I_r \times 2000$	1120	720	1520
Drinking Water (m^3/y)	2.04	2.04	2.04
Total for Family of Four (m^3/y)	1573	1173	1973

* Household Use: Domestic Water Use for family of four, 376 m^3/y, minus the drinking water component, 1.91 m^3/y, or approximately 374 m^3/y.
Domestic water use based on 272 gallons per day per family and drinking water based on use of 511 L/y per individual.
Conversion: 272 gal/day * 3.79E-3 gal/m^3 * 365.25day/y = 376 m^3/y
511 L/y-Ind * 4 Ind * 1m^3/1000L = 2.04 m^3/y.

A uniform distribution with a minimum value equal to 1173 m3/y, a maximum value equal to 1973 m^3/y, and a median value equal to 1573 m^3/y was assigned as input for the Well Pump Rate parameter.

Appendix G
Input Parameter Values for Sensitivity Analysis: Soil

RESRAD Input Parameter Values for Sensitivity Analysis										
Parameter (unit)	Type	Priority	Treatment	Value/Distribution	Basis	Distribution's Statistical Parameters[d]				
						1	2	3	4	Mean/ Median
Soil Concentrations										
Basic radiation dose limit (mrem/y)		3	D	25	10 CFR 20.1402 (Ref. x)	NR	NR	NR	NR	
Initial principal radionuclide (pCi/g)	P	2	D	1	Unit Value	NR	NR	NR	NR	
Distribution coefficients (contaminated, unsaturated, and saturated zones) (cm^3/g)										
Ac-227 (daughter for Cm-243 and Pu-239)	P	1	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	6.72	3.22	0.001	0.999	825
Am-241 (also daughter for Cm-245 and Pu-241)	P	1	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	7.28	3.15	0.001	0.999	1445
Am-243 (daughter for Cm-243)	P	1	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	7.28	3.15	0.001	0.999	1445
C-14	P	1	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	2.4	3.22	0.001	0.999	11
Cm-243	P	1	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	8.82	1.82	0.001	0.999	6761
Cm-244	P	1	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	8.82	1.82	0.001	0.999	6761
Cm-245	P	1	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	8.82	1.82	0.001	0.999	6761
Cm-246	P	1	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	8.82	1.82	0.001	0.999	6761
Co-60	P	1	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	5.46	2.53	0.001	0.999	235
Cs-137	P	1	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	6.1	2.33	0.001	0.999	446
Eu-152	P	1	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	6.72	3.22	0.001	0.999	825
Eu-154	P	1	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	6.72	3.22	0.001	0.999	825
Gd-152 (daughter for Eu-152)	P	1	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	6.72	3.22	0.001	0.999	825
H-3	P	1	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-2.81	0.5	0.001	0.999	0.06
I-129	P	1	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	1.52	2.19	0.001	0.999	4.6
Nb-94	P	1	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	5.94	3.22	0.001	0.999	380
Ni-59	P	1	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	6.05	1.46	0.001	0.999	424
Ni-63	P	1	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	6.05	1.46	0.001	0.999	424
Np-237 (also daughter for Am-241, Cm-245, and Pu-241)	P	1	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	2.84	2.25	0.001	0.999	17
Pa-231 (daughter for Cm-243 and Pu-239)	P	1	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	5.94	3.22	0.001	0.999	380
Po-210 (daughter for Cm-246)	P	1	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	5.20	1.68	0.001	0.999	181
Pb-210 (daughter for Cm-246 and Pu-238)	P	1	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	7.78	2.76	0.001	0.999	2392
Pu-238	P	1	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	6.86	1.89	0.001	0.999	953
Pu-239 (also daughter for Cm-243)	P	1	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	6.86	1.89	0.001	0.999	953

RESRAD Input Parameter Values for Sensitivity Analysis										
Parameter (unit)	Type	Priority	Treatment	Value/Distribution	Basis	Distribution's Statistical Parameters[d]				
						1	2	3	4	Mean/ Median
Pu-240 (also daughter for Cm-244)	P	1	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	6.86	1.89	0.001	0.999	953
Pu-241 (also daughter for Cm-245)	P	1	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	6.86	1.89	0.001	0.999	953
Pu-242 (daughter for Cm-246)	P	1	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	6.86	1.89	0.001	0.999	953
Ra-226 (daughter for Cm-246 and Pu-238)	P	1	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	8.17	1.7	0.001	0.999	3533
Ra-228 (daughter for Cm-244 and Pu-240)	P	1	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	8.17	1.7	0.001	0.999	3533
Sr-90	P	1	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	3.45	2.12	0.001	0.999	32
Tc-99	P	1	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-0.67	3.16	0.001	0.999	0.51
Th-228 (daughter for Cm-244 and Pu-240)	P	1	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	8.68	3.62	0.001	0.999	5884
Th-229 (daughter for Am-241, Cm-245, Np-237, and Pu-241)	P	1	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	8.68	3.62	0.001	0.999	5884
Th-230 (daughter for Cm-246 and Pu-238)	P	1	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	8.68	3.62	0.001	0.999	5884
Th-232 (daughter for Cm-244 and Pu-240)	P	1	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	8.68	3.62	0.001	0.999	5884
U-233 (daughter for Am-241, Cm-245, Np-237, and Pu-241)	P	1	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	4.84	3.13	0.001	0.999	126
U-234 (daughter for Cm-246 and Pu-238)	P	1	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	4.84	3.13	0.001	0.999	126
U-235 (daughter for Cm-243 and Pu-239)	P	1	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	4.84	3.13	0.001	0.999	126
U-236 (daughter for Cm-244 and Pu-240)	P	1	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	4.84	3.13	0.001	0.999	126
U-238 (daughter for Cm-246)	P	1	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	4.84	3.13	0.001	0.999	126
Initial concentration of radionuclides present in groundwater (pCi/l)	P	3	D	0	Ground water initially uncontaminated for this scenario	NR	NR	NR	NR	
Calculation Times										
Time since placement of material (y)	P	3	D	0		NR	NR	NR	NR	
Time for calculations (y)	P	3	D	0, 1, 3, 10, 30, 100, 300, 1000	RESRAD Default	NR	NR	NR	NR	
Contaminated Zone										
Area of contaminated zone (m^2)	P	2	D	30,000	Site-specific: largest contiguous class 1/class 2 area (rounded to nearest thousands)	NR	NR	NR	NR	

RESRAD Input Parameter Values for Sensitivity Analysis										
Parameter (unit)	Type	Priority	Treatment	Value/Distribution	Basis	Distribution's Statistical Parameters[d]				
						1	2	3	4	Mean/ Median
Thickness of contaminated zone (m)	P	2	S	Uniform	Site-specific; equal to depth of soil mixing layer (0.15m) and max depth of subsurface sample yielding detectable plant-related radioactivity (11.5 ft, LTP chap 2, Table 2-4)	0.15	3.51			1.83
Length parallel to aquifer flow (m)	P	2	D	195	Site-specific - diameter of circle with an area of 30,000 m^2	NR	NR	NR	NR	
Contaminated fraction below water table	P	2	D	0	Ground water initially uncontaminated for this scenario	NR	NR	NR	NR	
Cover and Contaminated Zone Hydrological Data										
Cover depth (m)	P	2	D	0	Site-specific - no cover assumed	NR	NR	NR	NR	
Density of contaminated zone (g/cm^3)	P	1	S	Bounded Normal	NUREG 6697 dist for site soil type - clay loam	1.5635	0.2385	0.827	2.3	1.5635
Contaminated zone erosion rate (m/y)	P	2	D	2.2E-3	Calculated value based on site-specific slope of 6%	NR	NR	NR	NR	
Contaminated zone total porosity	P	2	S	Bounded Normal	NUREG 6697 dist for site soil type - clay loam	0.41	0.09	0.1319	0.6881	0.41
Contaminated zone field capacity	P	3	D	0.095	Site-specific value calculated in step 6.4	NR	NR	NR	NR	0.095
Contaminated zone hydraulic conductivity (m/y)	P	2	S	Bounded Log Normal n	NUREG 6697 dist for site soil type - clay loam	1.36	2.17	0.00478	3190	3.90
Contaminated zone b parameter	P	2	S	Bounded Log Normal n	NUREG 6697 dist for site soil type - clay loam	1.73	0.323	2.08	15.3	5.6
Humidity in air (g/m^3)	P	3	D	8.2	Regional value for northern CA as represented by San Francisco	NR	NR	NR	NR	
Evapotranspiration coefficient	P	2	S	Uniform	NUREG/CR-6697 Att. C, Ref. 4	0.5	0.75	NR	NR	0.625
Average annual wind speed (m/s)	P	2	D	3.04	Site-specific value (from NCDC website)	NR	NR	NR	NR	

RESRAD Input Parameter Values for Sensitivity Analysis

Parameter (unit)	Type	Priority	Treatment	Value/Distribution	Basis	Distribution's Statistical Parameters[d]				
						1	2	3	4	Mean/ Median
Precipitation (m/y)	P	2	D	0.91	Site-specific value from HB SAFSTOR Environmental Report, section 4.1.1	NR	NR	NR	NR	
Irrigation (m/y)	B	3	S	Uniform	NUREG/CR-6697, Att C methodology	0.36	0.76	NR	NR	0.56
Irrigation mode	B	3	D	Overhead	Overhead irrigation is common practice in U. S.	NR	NR	NR	NR	
Runoff coefficient	P	2	D	0.5	Site-specific value; NUREG/CR-6697, Att. C section 4.2 methodology	NR	NR	NR	NR	
Watershed area for nearby stream or pond (m^2)	P	3	D	2.52E+07	Site-specific value from (HB SAFSTOR Environmental Report)	NR	NR	NR	NR	
Accuracy for water/soil computations	-	3	D	1.00E-03	RESRAD Default	NR	NR	NR	NR	
Saturated Zone Hydrological Data										
Density of saturated zone (g/cm^3)	P	1	S	Bounded Normal	NUREG 6697 dist for site soil type - silty clay loam	1.5105	0.1855	0.937	2.084	1.5105
Saturated zone total porosity	P	1	S	Bounded Normal	NUREG 6697 dist for site soil type - silty clay loam	0.43	0.0699	0.214	0.646	0.43
Saturated zone effective porosity	P	1	S	Bounded Normal	NUREG 6697 dist for site soil type - silty clay loam	0.342	0.0705	0.124	0.56	0.342
Saturated zone field capacity	P	3	D	0.088	Site-specific value calculated in step 6.4	NR	NR	NR	NR	0.088
Saturated zone hydraulic conductivity (m/y)	P	1	S	Bounded Log Normal n	NUREG 6697 dist for site soil type - silty clay loam	0.362	1.59	0.0106	195	1.44
Saturated zone hydraulic gradient	P	2	D	0.002	Site-specific value determined using method described in NUREG/CR-6697, App. C (step 6.5)	NR	NR	NR	NR	
Saturated zone b parameter	P	2	S	Bounded Log Normal n	NUREG 6697 dist for site soil type - silty clay loam	1.96	0.265	3.02	15.5	7.1
Water table drop rate (m/y)	P	3	D	1.00E-03	RESRAD User Manual	NR	NR	NR	NR	
Well pump intake depth (m below water table)	P	2	S	Triangular	NUREG/CR-6697, Att. C	6	10	30		10
Model: Nondispersion (ND) or Mass-Balance (MB)	P	3	D	ND	ND model recommended for contaminant areas > 1,000 m^2	NR	NR	NR	NR	

RESRAD Input Parameter Values for Sensitivity Analysis										
Parameter (unit)	Type	Priority	Treatment	Value/Distribution	Basis	Distribution's Statistical Parameters[d]				
						1	2	3	4	Mean/ Median
Well pumping rate (m^3/y)	P	2	S	Uniform	Min, Max, median value based on site irrigation and area and calculated according to NUREG/CR-6697, Att. C section 3.10 method. (see step 6.13)	1173	1973			1573
Unsaturated Zone Hydrological Data										
Number of unsaturated zone strata	P	3	D	1	Site-specific value	NR	NR	NR	NR	
Unsat. zone thickness (m)	P	2	S	Uniform	Site-specific distribution base on thickness of CZ and groundwater elevations	0.00	8.08			4.04
Unsat. zone soil density (g/cm^3)	P	1	S	Bounded Normal	NUREG 6697 dist for site soil type - clay loam	1.5635	0.2385	0.827	2.3	1.5635
Unsat. zone total porosity	P	2	S	Bounded Normal	NUREG 6697 dist for site soil type - clay loam	0.41	0.09	0.1319	0.6881	0.41
Unsat. zone effective porosity	P	1	S	Bounded Normal	NUREG 6697 dist for site soil type - clay loam	0.315	0.0905	0.0349	0.594	0.315
Unsat. zone field capacity	P	3	D	0.095	Site-specific value calculated using Equation 4.4 from Ref	NR	NR	NR	NR	0.095
Unsat. zone hydraulic conductivity (m/y)	P	1	S	Bounded Log Normal n	NUREG 6697 dist for site soil type - clay loam	1.36	2.17	0.00478	3190	3.90
Unsat. zone soil-specific b parameter	P	2	S	Bounded Log Normal n	NUREG 6697 dist for site soil type - clay loam	1.73	0.323	2.08	15.3	5.6
Occupancy										
Inhalation rate (m^3/y)	B	3	D	8400	NUREG/CR-6697, Att C	NR	NR	NR	NR	
Mass loading for inhalation (g/m^3)	P	2	S	Continuous linear	NUREG/CR-6697, Att. C					2.33E-05
Exposure duration	B	3	D	30	*User's Manual for RESRAD Version 6*; parameter value not used in dose calculation	NR	NR	NR	NR	
Indoor dust filtration factor	P	2	S	Uniform	NUREG/CR-6697, Att. C	0.15	0.95			0.55
Shielding factor, external gamma	P	2	S	Bounded lognormal-n	NUREG/CR-6697, Att. C	-1.3	0.59	0.044	1	0.2725
Fraction of time spent indoors	B	3	D	0.6571	NUREG/CR-5512, Vol. 3 Table 6.87	NR	NR	NR	NR	

RESRAD Input Parameter Values for Sensitivity Analysis										
Parameter (unit)	Type	Priority	Treatment	Value/Distribution	Basis	Distribution's Statistical Parameters[d]				
						1	2	3	4	Mean/ Median
Fraction of time spent outdoors (on site)	B	3	D	0.1181	NUREG/CR-5512, Vol. 3 Table 6.87 (outdoors + gardening)	NR	NR	NR	NR	
Shape factor flag, external gamma	P	3	D	Circular	Circular contaminated zone assumed for modeling purposes	NR	NR	NR	NR	
Ingestion, Dietary										
Fruits, vegetables, grain consumption (kg/y)	B	2	D	112	NUREG/CR-5512, Vol. 3 (other vegetables + fruits + grain)	NR	NR	NR	NR	
Leafy vegetable consumption (kg/y)	B	3	D	21.4	NUREG/CR-5512, Vol. 3	NR	NR	NR	NR	
Milk consumption (L/y)	B	2	D	233	NUREG/CR-5512, Vol. 3	NR	NR	NR	NR	
Meat and poultry consumption (kg/y)	B	3	D	65.1	NUREG/CR5512, Vol. 3 (beef + poultry)	NR	NR	NR	NR	
Fish consumption (kg/y)	B	3	D	20.6	NUREG/CR-5512, Vol. 3	NR	NR	NR	NR	
Other seafood consumption (kg/y)	B	3	D	0.9	*User's Manual for RESRAD Version 6*, Appendix D	NR	NR	NR	NR	
Soil ingestion rate (g/y)	B	2	D	18.26	NUREG/CR-5512, Vol. 3	NR	NR	NR	NR	
Drinking water intake (L/y)	B	2	D	511	NUREG/CR-5512, Vol. 3 Table 6.87 (Ref. 2)	NR	NR	NR	NR	
Contamination fraction of drinking water	P	3	D	1	All water assumed contaminated	NR	NR	NR	NR	
Contamination fraction of household water (if used)	P	3		NA						
Contamination fraction of livestock water	P	3	D	1	All water assumed contaminated	NR	NR	NR	NR	
Contamination fraction of irrigation water	P	3	D	1	Alll water assumed contaminate	NR	NR	NR	NR	
Contamination fraction of aquatic food	P	2	D	1	NUREG/CR-5512, Vol. 3	NR	NR	NR	NR	
Contamination fraction of plant food	P	3	D	1	NUREG/CR-5512, Vol. 3	NR	NR	NR	NR	
Contamination fraction of meat	P	3	D	1	NUREG/CR-5512, Vol. 3	NR	NR	NR	NR	
Contamination fraction of milk	P	3	D	1	NUREG/CR-5512, Vol. 3	NR	NR	NR	NR	
Ingestion, Non-Dietary										

RESRAD Input Parameter Values for Sensitivity Analysis										
Parameter (unit)	Type	Priority	Treatment	Value/Distribution	Basis	Distribution's Statistical Parameters[d]				
						1	2	3	4	Mean/ Median
Livestock fodder intake for meat (kg/day)	M	3	D	27.1	NUREG/CR5512, Vol. 3 Table 6.87, beef cattle + poultry + layer hen	NR	NR	NR	NR	
Livestock fodder intake for milk (kg/day)	M	3	D	63.2	NUREG/CR5512, Vol. 3 Table 6.87, forage + grain + hay	NR	NR	NR	NR	
Livestock water intake for meat (L/day)	M	3	D	50.6	NUREG/CR5512, Vol. 3 Table 6.87, beef cattle + poultry + layer hen	NR	NR	NR	NR	
Livestock water intake for milk (L/day)	M	3	D	60	NUREG/CR5512, Vol. 3 Table 6.87	NR	NR	NR	NR	
Livestock soil intake (kg/day)	M	3	D	0.5	*User's Manual for RESRAD Version 6*, Appendix L	NR	NR	NR	NR	
Mass loading for foliar deposition (g/m^3)	P	3	D	4.00E-04	NUREG/CR-5512, Vol. 3 Table 6.87, gardening	NR	NR	NR	NR	
Depth of soil mixing layer (m)	P	2	S	Triangular	NUREG/CR-6697, Att. C	0	0.15	0.6		0.23
Depth of roots (m)	P	1	S	Uniform	Min. from NUREG/CR-6697, Att. C (Ref. 4)	0.3	4.0			2.15
Drinking water fraction from ground water	P	3	D	1	All water assumed to be supplied from groundwater	NR	NR	NR	NR	
Household water fraction from ground water (if used)	P	3		NA						
Livestock water fraction from ground water	P	3	D	1	All water assumed to be supplied from groundwater	NR	NR	NR	NR	
Irrigation fraction from ground water	P	3	D	1	All water assumed to be supplied from groundwater	NR	NR	NR	NR	
Wet weight crop yield for Non-Leafy (kg/m^2)	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	0.56	0.48	0.001	0.999	1.75
Wet weight crop yield for Leafy (kg/m^2)	P	3	D	2.88921	NUREG/CR-5512, Vol. 3 Table 6.87	NR	NR	NR	NR	
Wet weight crop yield for Fodder (kg/m^2)	P	3	D	1.8868	NUREG/CR-5512, Vol. 3 Table 6.87	NR	NR	NR	NR	
Growing Season for Non-Leafy (y)	P	3	D	0.246	NUREG/CR-5512, Vol. 3 Table 6.87	NR	NR	NR	NR	
Growing Season for Leafy (y)	P	3	D	0.123	NUREG/CR-5512, Vol. 3 Table 6.87	NR	NR	NR	NR	

RESRAD Input Parameter Values for Sensitivity Analysis										
Parameter (unit)	Type	Priority	Treatment	Value/Distribution	Basis	Distribution's Statistical Parameters[d]				
						1	2	3	4	Mean/ Median
Growing Season for Fodder (y)	P	3	D	0.082	NUREG/CR-5512, Vol. 3 Table 6.87	NR	NR	NR	NR	
Translocation Factor for Non-Leafy	P	3	D	0.1	NUREG/CR-5512, Vol. 3 Table 6.87	NR	NR	NR	NR	
Translocation Factor for Leafy	P	3	D	1	NUREG/CR-5512, Vol. 3 Table 6.87	NR	NR	NR	NR	
Translocation Factor for Fodder	P	3	D	1	NUREG/CR-5512, Vol. 3 Table 6.87	NR	NR	NR	NR	
Weathering Removal Constant for Vegetation (1/y)	P	2	S	Triangular	NUREG/CR-6697, Att. C	5.1	18	84		33
Wet Foliar Interception Fraction for Non-Leafy	P	3	D	0.35	NUREG/CR-5512, Vol. 3 Table 6.87	NR	NR	NR	NR	
Wet Foliar Interception Fraction for Leafy	P	2	S	Triangular	NUREG/CR-6697, Att. C	0.06	0.67	0.95		0.58
Wet Foliar Interception Fraction for Fodder	P	3	D	0.35	NUREG/CR-5512, Vol. 3 Table 6.87	NR	NR	NR	NR	
Dry Foliar Interception Fraction for Non-Leafy	P	3	D	0.35	NUREG/CR-5512, Vol. 3 Table 6.87	NR	NR	NR	NR	
Dry Foliar Interception Fraction for Leafy	P	3	D	0.35	NUREG/CR-5512, Vol. 3	NR	NR	NR	NR	
Dry Foliar Interception Fraction for Fodder	P	3	D	0.35	NUREG/CR-5512, Vol. 3	NR	NR	NR	NR	
Storage times of contaminated foodstuffs (days):										
Fruits, non-leafy vegetables, and grain	B	3	D	14	NUREG/CR-5512, Vol. 3 Table 6.87	NR	NR	NR	NR	
Leafy vegetables	B	3	D	1	NUREG/CR-5512, Vol. 3 Table 6.87	NR	NR	NR	NR	
Milk	B	3	D	1	NUREG/CR-5512, Vol. 3 Table 6.87	NR	NR	NR	NR	
Meat and poultry	B	3	D	20	NUREG/CR-5512, Vol. 3 Table 6.87 (holdup period for beef)	NR	NR	NR	NR	
Fish	B	3	D	7	*User's Manual for RESRAD Version 6*, Appendix D	NR	NR	NR	NR	
Crustacea and mollusks	B	3	D	7	*User's Manual for RESRAD Version 6*, Appendix D	NR	NR	NR	NR	

RESRAD Input Parameter Values for Sensitivity Analysis										
Parameter (unit)	Type	Priority	Treatment	Value/Distribution	Basis	Distribution's Statistical Parameters[d]				
						1	2	3	4	Mean/ Median
Well water	B	3	D	1	*User's Manual for RESRAD Version 6*, Appendix D	NR	NR	NR	NR	
Surface water	B	3	D	1	*User's Manual for RESRAD Version 6*, Appendix D	NR	NR	NR	NR	
Livestock fodder	B	3	D	45	*User's Manual for RESRAD Version 6*, Appendix D	NR	NR	NR	NR	
Special Radionuclides (C-14)										
C-12 concentration in water (g/cm^3)	P	3	D	2.00E-05	*User's Manual for RESRAD Version 6*, Appendix L	NR	NR	NR	NR	
C-12 concentration in contaminated soil (g/g)	P	3	D	3.00E-02	*User's Manual for RESRAD Version 6*, Appendix L	NR	NR	NR	NR	
Fraction of vegetation carbon from soil	P	3	D	2.00E-02	*User's Manual for RESRAD Version 6*, Appendix L	NR	NR	NR	NR	
Fraction of vegetation carbon from air	P	3	D	9.80E-01	*User's Manual for RESRAD Version 6*, Appendix L	NR	NR	NR	NR	
C-14 evasion layer thickness in soil (m)	P	2	S	Triangular	NUREG/CR-6697, Att. C	0.2	0.3	0.6		0.3
C-14 evasion flux rate from soil (1/sec)	P	3	D	7.00E-07	*User's Manual for RESRAD Version 6*, Appendix L	NR	NR	NR	NR	
C-12 evasion flux rate from soil (1/sec)	P	3	D	1.00E-10	*User's Manual for RESRAD Version 6*, Appendix L	NR	NR	NR	NR	
Fraction of grain in beef cattle feed	B	3	D	0.2500	NUREG/CR-6697, Att. B	NR	NR	NR	NR	
Fraction of grain in milk cow feed	B	3	D	0.1000	NUREG/CR-6697, Att. B	NR	NR	NR	NR	
Dose Conversion Factors (Inhalation mrem/pCi)										
Ac-227	M	3	D	6.70E+00	FGR11 (RESRAD Dose Conversion Library)	NR	NR	NR	NR	
Am-241	M	3	D	4.44E-01	FGR11	NR	NR	NR	NR	
Am-243	M	3	D	4.40E-01	FGR11	NR	NR	NR	NR	
C-14	M	3	D	2.09E-06	FGR11	NR	NR	NR	NR	

RESRAD Input Parameter Values for Sensitivity Analysis										
Parameter (unit)	Type	Priority	Treatment	Value/Distribution	Basis	Distribution's Statistical Parameters[d]				
						1	2	3	4	Mean/ Median
Cm-243	M	3	D	3.07E-01	FGR11	NR	NR	NR	NR	
Cm-244	M	3	D	2.48E-01	FGR11	NR	NR	NR	NR	
Cm-245	M	3	D	4.55E-01	FGR11	NR	NR	NR	NR	
Cm-246	M	3	D	4.51E-01	FGR11	NR	NR	NR	NR	
Co-60	M	3	D	2.19E-04	FGR11	NR	NR	NR	NR	
Cs-137	M	3	D	3.19E-05	FGR11	NR	NR	NR	NR	
Eu-152	M	3	D	2.21E-04	FGR11	NR	NR	NR	NR	
Eu-154	M	3	D	2.86E-04	FGR11	NR	NR	NR	NR	
Gd-152	M	3	D	2.43E-01	FGR11	NR	NR	NR	NR	
H-3	M	3	D	6.40E-08	FGR11	NR	NR	NR	NR	
I-129	M	3	D	1.74E-04	FGR11	NR	NR	NR	NR	
Nb-94	M	3	D	4.14E-04	FGR11	NR	NR	NR	NR	
Ni-59	M	3	D	2.70E-06	FGR11	NR	NR	NR	NR	
Ni-63	M	3	D	6.29E-06	FGR11	NR	NR	NR	NR	
Np-237	M	3	D	5.40E-01	FGR11	NR	NR	NR	NR	
Pa-231	M	3	D	1.28E+00	FGR11	NR	NR	NR	NR	
Pb-210	M	3	D	1.36E-02	FGR11	NR	NR	NR	NR	
Po-210	M	3	D	9.40E-03	FGR11	NR	NR	NR	NR	
Pu-238	M	3	D	3.92E-01	FGR11	NR	NR	NR	NR	
Pu-239	M	3	D	4.29E-01	FGR11	NR	NR	NR	NR	
Pu-240	M	3	D	4.29E-01	FGR11	NR	NR	NR	NR	
Pu-241	M	3	D	8.25E-03	FGR11	NR	NR	NR	NR	
Pu-242	M	3	D	4.11E-01	FGR11	NR	NR	NR	NR	
Ra-226	M	3	D	8.58E-03	FGR11	NR	NR	NR	NR	
Ra-228	M	3	D	4.77E-03	FGR11	NR	NR	NR	NR	
Sr-90	M	3	D	1.30E-03	FGR11	NR	NR	NR	NR	
Tc-99	M	3	D	8.32E-06	FGR11	NR	NR	NR	NR	
Th-228	M	3	D	3.42E-01	FGR11	NR	NR	NR	NR	
Th-229	M	3	D	2.15E+00	FGR11	NR	NR	NR	NR	
Th-230	M	3	D	3.26E-01	FGR11	NR	NR	NR	NR	

RESRAD Input Parameter Values for Sensitivity Analysis										
Parameter (unit)	Type	Priority	Treatment	Value/Distribution	Basis	Distribution's Statistical Parameters[d]				
						1	2	3	4	Mean/ Median
Th232	M	3	D	1.64e+00	FGR11	NR	NR	NR	NR	
U-233	M	3	D	1.35E-01	FGR11	NR	NR	NR	NR	
U-234	M	3	D	1.32E-01	FGR11	NR	NR	NR	NR	
U-235	M	3	D	1.23E-01	FGR11	NR	NR	NR	NR	
U-236	M	3	D	1.25E-01	FGR11	NR	NR	NR	NR	
U-238	M	3	D	1.18E-01	FGR11	NR	NR	NR	NR	
Dose Conversion Factors (Ingestion mrem/pCi)										
Ac-227	M	3	D	1.41E-02	FGR11 (RESRAD Dose Conversion Library)	NR	NR	NR	NR	
Am-241	M	3	D	3.64E-03	FGR11	NR	NR	NR	NR	
Am-243	M	3	D	3.62E-03	FGR11	NR	NR	NR	NR	
C-14	M	3	D	2.09E-06	FGR11	NR	NR	NR	NR	
Cm-243	M	3	D	2.51E-03	FGR11	NR	NR	NR	NR	
Cm-244	M	3	D	2.02E-03	FGR11	NR	NR	NR	NR	
Cm-245	M	3	D	3.74E-03	FGR11	NR	NR	NR	NR	
Cm-246	M	3	D	3.70E-03	FGR11	NR	NR	NR	NR	
Co-60	M	3	D	2.69E-05	FGR11	NR	NR	NR	NR	
Cs-137	M	3	D	5.00E-05	FGR11	NR	NR	NR	NR	
Eu-152	M	3	D	6.48E-06	FGR11	NR	NR	NR	NR	
Eu-154	M	3	D	9.55E-06	FGR11	NR	NR	NR	NR	
Gd-152	M	3	D	1.61E-04	FGR11	NR	NR	NR	NR	
H-3	M	3	D	6.40E-08	FGR11	NR	NR	NR	NR	
I-129	M	3	D	2.76E-04	FGR11	NR	NR	NR	NR	
Nb-94	M	3	D	7.14E-06	FGR11	NR	NR	NR	NR	
Ni-59	M	3	D	2.10E-07	FGR11	NR	NR	NR	NR	
Ni-63	M	3	D	5.77E-07	FGR11	NR	NR	NR	NR	
Np-237	M	3	D	4.44E-03	FGR11	NR	NR	NR	NR	
Pa-231	M	3	D	1.06E-02	FGR11	NR	NR	NR	NR	
Pb-210	M	3	D	5.37E-03	FGR11	NR	NR	NR	NR	
Pb-210	M	3	D	1.90E-03	FGR11	NR	NR	NR	NR	
Pu-238	M	3	D	3.20E-03	FGR11	NR	NR	NR	NR	

RESRAD Input Parameter Values for Sensitivity Analysis										
Parameter (unit)	Type	Priority	Treatment	Value/Distribution	Basis	Distribution's Statistical Parameters[d]				
						1	2	3	4	Mean/ Median
Pu-239	M	3	D	3.54E-03	FGR11	NR	NR	NR	NR	
Pu-240	M	3	D	3.54E-03	FGR11	NR	NR	NR	NR	
Pu-241	M	3	D	6.84E-05	FGR11	NR	NR	NR	NR	
Pu-242	M	3	D	3.36E-03	FGR11	NR	NR	NR	NR	
Ra-226	M	3	D	1.32E-03	FGR11	NR	NR	NR	NR	
Ra-228	M	3	D	1.44E-03	FGR11	NR	NR	NR	NR	
Sr-90	M	3	D	1.42E-04	FGR11	NR	NR	NR	NR	
Tc-99	M	3	D	1.46E-06	FGR11	NR	NR	NR	NR	
Th-228	M	3	D	3.96E-04	FGR11	NR	NR	NR	NR	
Th-229	M	3	D	3.53E-03	FGR11	NR	NR	NR	NR	
Th-230	M	3	D	5.48E-04	FGR11	NR	NR	NR	NR	
Th-232	M	3	D	2.73E-03	FGR11	NR	NR	NR	NR	
U-233	M	3	D	2.89E-04	FGR11	NR	NR	NR	NR	
U-234	M	3	D	2.83E-04	FGR11	NR	NR	NR	NR	
U-235	M	3	D	2.66E-04	FGR11	NR	NR	NR	NR	
U-236	M	3	D	2.69E-04	FGR11	NR	NR	NR	NR	
U-238	M	3	D	2.55E-04	FGR11	NR	NR	NR	NR	
Plant Transfer Factors (pCi/g plant)/(pCi/g soil)										
Ac-227	P	1	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-6.91	1.1	0.001	0.999	1.0E-03
Am-241	P	1	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-6.91	0.9	0.001	0.999	1.0E-03
Am-243	P	1	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-6.91	0.9	0.001	0.999	1.0E-03
C-14	P	1	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-0.36	0.9	0.001	0.999	7.0E-01
Cm-243	P	1	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-6.91	0.9	0.001	0.999	1.0E-03
Cm-244	P	1	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-6.91	0.9	0.001	0.999	1.0E-03
Cm-245	P	1	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-6.91	0.9	0.001	0.999	1.0E-03
Cm-246	P	1	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-6.91	0.9	0.001	0.999	1.0E-03
Co-60	P	1	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-2.53	0.9	0.001	0.999	8.0E-02
Cs-137	P	1	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-3.22	1.0	0.001	0.999	4.0E-02
Eu-152	P	1	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-6.21	1.1	0.001	0.999	2.0E-03
Eu-154	P	1	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-6.21	1.1	0.001	0.999	2.0E-03
Gd-152	P	1	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-6.21	1.1	0.001	0.999	2.0E-03

RESRAD Input Parameter Values for Sensitivity Analysis										
Parameter (unit)	Type	Priority	Treatment	Value/Distribution	Basis	Distribution's Statistical Parameters[d]				
						1	2	3	4	Mean/ Median
H-3	P	1	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	1.57	1.1	0.001	0.999	4.8E+00
I-129	P	1	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-3.91	0.9	0.001	0.999	2.0E-02
Nb-94	P	1	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-4.61	1.1	0.001	0.999	1.0E-02
Ni-59	P	1	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-3.0	0.9	0.001	0.999	5.0E-02
Ni-63	P	1	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-3.0	0.9	0.001	0.999	5.0E-02
Np-237	P	1	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-3.91	0.9	0.001	0.999	2.0E-02
Pa-231	P	1	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-4.61	1.1	0.001	0.999	1.0E-02
Pb-210	P	1	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-5.52	0.9	0.001	0.999	4.0E-03
Po-210	P	1	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-6.90	0.9	0.001	0.999	1.0E-03
Pu-238	P	1	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-6.91	0.9	0.001	0.999	1.0E-03
Pu-239	P	1	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-6.91	0.9	0.001	0.999	1.0E-03
Pu-240	P	1	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-6.91	0.9	0.001	0.999	1.0E-03
Pu-241	P	1	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-6.91	0.9	0.001	0.999	1.0E-03
Pu-242	P	1	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-6.91	0.9	0.001	0.999	1.0E-03
Ra-226	P	1	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-3.22	0.9	0.001	0.999	4.0E-02
Ra-228	P	1	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-3.22	0.9	0.001	0.999	4.0E-02
Sr-90	P	1	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-1.20	1.0	0.001	0.999	3.0E-01
Tc-99	P	1	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	1.61	0.9	0.001	0.999	5.0E+00
Th-228	P	1	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-6.91	0.9	0.001	0.999	1.0E-03
Th-229	P	1	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-6.91	0.9	0.001	0.999	1.0E-03
Th-230	P	1	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-6.91	0.9	0.001	0.999	1.0E-03
Th-232	P	1	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-6.91	0.9	0.001	0.999	1.0E-03
U-233	P	1	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-6.21	0.9	0.001	0.999	2.0E-03
U-234	P	1	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-6.21	0.9	0.001	0.999	2.0E-03
U-235	P	1	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-6.21	0.9	0.001	0.999	2.0E-03
U-236	P	1	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-6.21	0.9	0.001	0.999	2.0E-03
U-238	P	1	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-6.21	0.9	0.001	0.999	2.0E-03
Meat Transfer Factors (pCi/kg)/(pCi/d)										
Ac-227	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-10.82	1.0	0.001	0.999	2.0E-05
Am-241	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-9.90	0.2	0.001	0.999	5.0E-05
Am-243	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-9.90	0.2	0.001	0.999	5.0E-05

RESRAD Input Parameter Values for Sensitivity Analysis										
Parameter (unit)	Type	Priority	Treatment	Value/Distribution	Basis	Distribution's Statistical Parameters[d]				
						1	2	3	4	Mean/ Median
C-14	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-3.47	1.0	0.001	0.999	3.1E-02
Cm-243	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-10.82	1.0	0.001	0.999	2.0E-05
Cm-244	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-10.82	1.0	0.001	0.999	2.0E-05
Cm-245	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-10.82	1.0	0.001	0.999	2.0E-05
Cm-246	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-10.82	1.0	0.001	0.999	2.0E-05
Co-60	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-3.51	1.0	0.001	0.999	3.0E-02
Cs-137	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-3.00	0.4	0.001	0.999	5.0E-02
Eu-152	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-6.21	1.0	0.001	0.999	2.0E-03
Eu-154	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-6.21	1.0	0.001	0.999	2.0E-03
Gd-152	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-6.21	1.0	0.001	0.999	2.0E-03
H-3	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-4.42	1.0	0.001	0.999	1.2E-02
I-129	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-3.22	0.4	0.001	0.999	4.0E-02
Nb-94	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-13.82	0.9	0.001	0.999	1.0E-06
Ni-59	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-5.30	0.9	0.001	0.999	5.0E-03
Ni-63	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-5.30	0.9	0.001	0.999	5.0E-03
Np-237	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-6.91	0.7	0.001	0.999	1.0E-03
Pa-231	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-12.21	1.0	0.001	0.999	5.0E-06
Po-210	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-5.30	0.7	0.001	0.999	5.0E-03
Pb-210	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-7.13	0.7	0.001	0.999	8.0E-04
Pu-238	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-9.21	0.2	0.001	0.999	1.0E-04
Pu-239	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-9.21	0.2	0.001	0.999	1.0E-04
Pu-240	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-9.21	0.2	0.001	0.999	1.0E-04
Pu-241	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-9.21	0.2	0.001	0.999	1.0E-04
Pu-242	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-9.21	0.2	0.001	0.999	1.0E-04
Ra-226	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-6.91	0.7	0.001	0.999	1.0E-03
Ra-228	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-6.91	0.7	0.001	0.999	1.0E-03
Sr-90	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-4.61	0.4	0.001	0.999	1.0E-02
Tc-99	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-9.21	0.7	0.001	0.999	1.0E-04
Th-228	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-9.21	1.0	0.001	0.999	1.0E-04
Th-229	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-9.21	1.0	0.001	0.999	1.0E-04
Th-230	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-9.21	1.0	0.001	0.999	1.0E-04

RESRAD Input Parameter Values for Sensitivity Analysis										
Parameter (unit)	Type	Priority	Treatment	Value/Distribution	Basis	Distribution's Statistical Parameters[d]				
						1	2	3	4	Mean/ Median
Th-232	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-9.21	1.0	0.001	0.999	1.0E-04
U-233	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-7.13	0.7	0.001	0.999	8.0E-04
U-234	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-7.13	0.7	0.001	0.999	8.0E-04
U-235	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-7.13	0.7	0.001	0.999	8.0E-04
U-236	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-7.13	0.7	0.001	0.999	8.0E-04
U-238	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-7.13	0.7	0.001	0.999	8.0E-04
Milk Transfer Factors (pCi/L)/(pCi/d)										
Ac-227	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-13.12	0.9	0.001	0.999	2.0E-06
Am-241	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-13.12	0.7	0.001	0.999	2.0E-06
Am-243	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-13.12	0.7	0.001	0.999	2.0E-06
C-14	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-4.4	0.9	0.001	0.999	1.2E-02
Cm-243	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-13.12	0.9	0.001	0.999	2.0E-06
Cm-244	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-13.12	0.9	0.001	0.999	2.0E-06
Cm-245	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-13.12	0.9	0.001	0.999	2.0E-06
Cm-246	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-13.12	0.9	0.001	0.999	2.0E-06
Co-60	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-6.21	0.7	0.001	0.999	2.0E-03
Cs-137	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-4.61	0.5	0.001	0.999	1.0E-02
Eu-152	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-9.72	0.9	0.001	0.999	6.0E-05
Eu-154	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-9.72	0.9	0.001	0.999	6.0E-05
Gd-152	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-9.72	0.9	0.001	0.999	6.0E-05
H-3	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-4.6	0.9	0.001	0.999	1.0E-02
I-129	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-4.61	0.5	0.001	0.999	1.0E-03
Nb-94	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-13.12	0.7	0.001	0.999	2.0E-06
Ni-59	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-3.91	0.7	0.001	0.999	2.0E-02
Ni-63	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-3.91	0.7	0.001	0.999	2.0E-02
Np-237	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-11.51	0.7	0.001	0.999	1.0E-05
Pa-231	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-12.21	0.9	0.001	0.999	5.0E-06
Po-210	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-7.82	0.7	0.001	0.999	4.0E-04
Pb-210	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-8.11	0.9	0.001	0.999	3.0E-04
Pu-238	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-13.82	0.5	0.001	0.999	1.0E-06
Pu-239	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-13.82	0.5	0.001	0.999	1.0E-06

RESRAD Input Parameter Values for Sensitivity Analysis										
Parameter (unit)	Type	Priority	Treatment	Value/Distribution	Basis	Distribution's Statistical Parameters[d]				
						1	2	3	4	Mean/ Median
Pu-240	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-13.82	0.5	0.001	0.999	1.0E-06
Pu-241	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-13.82	0.5	0.001	0.999	1.0E-06
Pu-242	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-13.82	0.5	0.001	0.999	1.0E-06
Ra-226	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-6.91	0.5	0.001	0.999	1.0E-03
Ra-228	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-6.91	0.5	0.001	0.999	1.0E-03
Sr-90	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-6.21	0.5	0.001	0.999	2.0E-03
Tc-99	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-6.91	0.7	0.001	0.999	1.0E-03
Th-228	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-12.21	0.9	0.001	0.999	5.0E-06
Th-229	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-12.21	0.9	0.001	0.999	5.0E-06
Th-230	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-12.21	0.9	0.001	0.999	5.0E-06
Th-232	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-12.21	0.9	0.001	0.999	5.0E-06
U-233	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-7.82	0.6	0.001	0.999	4.0E-04
U-234	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-7.82	0.6	0.001	0.999	4.0E-04
U-235	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-7.82	0.6	0.001	0.999	4.0E-04
U-236	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-7.82	0.6	0.001	0.999	4.0E-04
U-238	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-7.82	0.6	0.001	0.999	4.0E-04
Bioaccumulation Factors for Fish ((pCi/kg)/(pCi/L))										
Ac-227	P	2	S	Lognormal-n	NUREG/CR-6697, Att. C	2.7	1.1			1.5E+01
Am-241	P	2	S	Lognormal-n	NUREG/CR-6697, Att. C	3.4	1.1			3.0E+01
Am-243	P	2	S	Lognormal-n	NUREG/CR-6697, Att. C	3.4	1.1			3.0E+01
C-14	P	2	S	Lognormal-n	NUREG/CR-6697, Att. C	10.8	1.1			4.9E+04
Cm-243	P	2	S	Lognormal-n	NUREG/CR-6697, Att. C	3.4	1.1			3.0E+01
Cm-244	P	2	S	Lognormal-n	NUREG/CR-6697, Att. C	3.4	1.1			3.0E+01
Cm-245	P	2	S	Lognormal-n	NUREG/CR-6697, Att. C	3.4	1.1			3.0E+01
Cm-246	P	2	S	Lognormal-n	NUREG/CR-6697, Att. C	3.4	1.1			3.0E+01
Co-60	P	2	S	Lognormal-n	NUREG/CR-6697, Att. C	5.7	1.1			3.0E+02
Cs-137	P	2	S	Lognormal-n	NUREG/CR-6697, Att. C	7.6	0.7			2.0E+03
Eu-152	P	2	S	Lognormal-n	NUREG/CR-6697, Att. C	3.9	1.1			4.9E+01
Eu-154	P	2	S	Lognormal-n	NUREG/CR-6697, Att. C	3.9	1.1			4.9E+01
Gd-152	P	2	S	Lognormal-n	NUREG/CR-6697, Att. C	3.2	1.1			2.5E+01
H-3	P	2	S	Lognormal-n	NUREG/CR-6697, Att. C	0	0.1			1.0E+00

RESRAD Input Parameter Values for Sensitivity Analysis										
Parameter (unit)	Type	Priority	Treatment	Value/Distribution	Basis	Distribution's Statistical Parameters[d]				
						1	2	3	4	Mean/ Median
I-129	P	2	S	Lognormal-n	NUREG/CR-6697, Att. C	3.7	1.1			4.0E+01
Nb-94	P	2	S	Lognormal-n	NUREG/CR-6697, Att. C	5.7	1.1			3.0E+02
Ni-59	P	2	S	Lognormal-n	NUREG/CR-6697, Att. C	4.6	1.1			9.9E+01
Ni-63	P	2	S	Lognormal-n	NUREG/CR-6697, Att. C	4.6	1.1			9.9E+01
Np-237	P	2	S	Lognormal-n	NUREG/CR-6697, Att. C	3.4	1.1			3.0E+01
Pa-231	P	2	S	Lognormal-n	NUREG/CR-6697, Att. C	2.3	1.1			9.9E+00
Po-210	P	2	S	Lognormal-n	NUREG/CR-6697, Att. C	4.6	1.1			1.0E+01
Pb-210	P	2	S	Lognormal-n	NUREG/CR-6697, Att. C	5.7	1.1			3.0E+02
Pu-238	P	2	S	Lognormal-n	NUREG/CR-6697, Att. C	3.4	1.1			3.0E+01
Pu-239	P	2	S	Lognormal-n	NUREG/CR-6697, Att. C	3.4	1.1			3.0E+01
Pu-240	P	2	S	Lognormal-n	NUREG/CR-6697, Att. C	3.4	1.1			3.0E+01
Pu-241	P	2	S	Lognormal-n	NUREG/CR-6697, Att. C	3.4	1.1			3.0E+01
Pu-242	P	2	S	Lognormal-n	NUREG/CR-6697, Att. C	3.4	1.1			3.0E+01
Ra-226	P	2	S	Lognormal-n	NUREG/CR-6697, Att. C	3.9	1.1			4.9E+01
Ra-228	P	2	S	Lognormal-n	NUREG/CR-6697, Att. C	3.9	1.1			4.9E+01
Sr-90	P	2	S	Lognormal-n	NUREG/CR-6697, Att. C	4.1	1.1			6.0E+01
Tc-99	P	2	S	Lognormal-n	NUREG/CR-6697, Att. C	3	1.1			2.0E+01
Th-228	P	2	S	Lognormal-n	NUREG/CR-6697, Att. C	4.6	1.1			9.9E+01
Th-229	P	2	S	Lognormal-n	NUREG/CR-6697, Att. C	4.6	1.1			9.9E+01
Th-230	P	2	S	Lognormal-n	NUREG/CR-6697, Att. C	4.6	1.1			9.9E+01
Th-232	P	2	S	Lognormal-n	NUREG/CR-6697, Att. C	4.6	1.1			9.9E+01
U-233	P	2	S	Lognormal-n	NUREG/CR-6697, Att. C	2.3	1.1			1.0E+01
U-234	P	2	S	Lognormal-n	NUREG/CR-6697, Att. C	2.3	1.1			1.0E+01
U-235	P	2	S	Lognormal-n	NUREG/CR-6697, Att. C	2.3	1.1			1.0E+01
U-236	P	2	S	Lognormal-n	NUREG/CR-6697, Att. C	2.3	1.1			1.0E+01
U-238	P	2	S	Lognormal-n	NUREG/CR-6697, Att. C	2.3	1.1			1.0E+01
Bioaccumulation Factors for Crustacea/ Mollusks ((pCi/kg)/(pCi/L))										
Ac-227	P	3	D	1.00E+03	*User's Manual for RESRAD Version 6*, Appendix D	NR	NR	NR	NR	

RESRAD Input Parameter Values for Sensitivity Analysis										
Parameter (unit)	Type	Priority	Treatment	Value/Distribution	Basis	Distribution's Statistical Parameters[d]				
						1	2	3	4	Mean/ Median
Am-241	P	3	D	1.00E+03	*User's Manual for RESRAD Version 6*, Appendix D	NR	NR	NR	NR	
Am-243	P	3	D	1.00E+03	*User's Manual for RESRAD Version 6*, Appendix D	NR	NR	NR	NR	
C-14	P	3	D	9.10E+03	*User's Manual for RESRAD Version 6*, Appendix D	NR	NR	NR	NR	
Cm-243	P	3	D	1.00E+03	*User's Manual for RESRAD Version 6*, Appendix D	NR	NR	NR	NR	
Cm-244	P	3	D	1.00E+03	*User's Manual for RESRAD Version 6*, Appendix D	NR	NR	NR	NR	
Cm-245	P	3	D	1.00E+03	*User's Manual for RESRAD Version 6*, Appendix D	NR	NR	NR	NR	
Cm-246	P	3	D	1.00E+03	*User's Manual for RESRAD Version 6*, Appendix D	NR	NR	NR	NR	
Co-60	P	3	D	2.00E+02	*User's Manual for RESRAD Version 6*, Appendix D	NR	NR	NR	NR	
Cs-137	P	3	D	1.00E+02	*User's Manual for RESRAD Version 6*, Appendix D	NR	NR	NR	NR	
Eu-152	P	3	D	1.00E+03	*User's Manual for RESRAD Version 6*, Appendix D	NR	NR	NR	NR	
Eu-154	P	3	D	1.00E+03	*User's Manual for RESRAD Version 6*, Appendix D	NR	NR	NR	NR	
Gd-152	P	3	D	1.00E+03	*User's Manual for RESRAD Version 6*, Appendix D	NR	NR	NR	NR	
H-3	P	3	D	1.00E+00	*User's Manual for RESRAD Version 6*, Appendix D	NR	NR	NR	NR	

RESRAD Input Parameter Values for Sensitivity Analysis										
Parameter (unit)	Type	Priority	Treatment	Value/Distribution	Basis	Distribution's Statistical Parameters[d]				
						1	2	3	4	Mean/ Median
I-129	P	3	D	5.00E+00	*User's Manual for RESRAD Version 6*, Appendix D	NR	NR	NR	NR	
Nb-94	P	3	D	1.00E+02	*User's Manual for RESRAD Version 6*, Appendix D	NR	NR	NR	NR	
Ni-59	P	3	D	1.00E+02	*User's Manual for RESRAD Version 6*, Appendix D	NR	NR	NR	NR	
Ni-63	P	3	D	1.00E+02	*User's Manual for RESRAD Version 6*, Appendix D	NR	NR	NR	NR	
Np-237	P	3	D	4.00E+02	*User's Manual for RESRAD Version 6*, Appendix D	NR	NR	NR	NR	
Pa-231	P	3	D	1.10E+02	*User's Manual for RESRAD Version 6*, Appendix D	NR	NR	NR	NR	
Pb-210	P	3	D	1.00E+02	*User's Manual for RESRAD Version 6*, Appendix D	NR	NR	NR	NR	
Po-210	P	S	D	2.0E+04	*User's Manual for RESRAD Version 6*, Appendix D	NR	NR	NR	NR	
Pu-238	P	3	D	1.00E+02	*User's Manual for RESRAD Version 6*, Appendix D	NR	NR	NR	NR	
Pu-239	P	3	D	1.00E+02	*User's Manual for RESRAD Version 6*, Appendix D	NR	NR	NR	NR	
Pu-240	P	3	D	1.00E+02	*User's Manual for RESRAD Version 6*, Appendix D	NR	NR	NR	NR	
Pu-241	P	3	D	1.00E+02	*User's Manual for RESRAD Version 6*, Appendix D	NR	NR	NR	NR	
Pu-242	P	3	D	1.00E+02	*User's Manual for RESRAD Version 6*, Appendix D	NR	NR	NR	NR	

RESRAD Input Parameter Values for Sensitivity Analysis										
Parameter (unit)	Type	Priority	Treatment	Value/Distribution	Basis	Distribution's Statistical Parameters[d]				
						1	2	3	4	Mean/ Median
Ra-226	P	3	D	2.50E+02	*User's Manual for RESRAD Version 6*, Appendix D	NR	NR	NR	NR	
Ra-228	P	3	D	2.50E+02	*User's Manual for RESRAD Version 6*, Appendix D	NR	NR	NR	NR	
Sr-90	P	3	D	1.00E+02	*User's Manual for RESRAD Version 6*, Appendix D	NR	NR	NR	NR	
Tc-99	P	3	D	5.00E+00	*User's Manual for RESRAD Version 6*, Appendix D	NR	NR	NR	NR	
Th-228	P	3	D	5.00E+02	*User's Manual for RESRAD Version 6*, Appendix D	NR	NR	NR	NR	
Th-229	P	3	D	5.00E+02	*User's Manual for RESRAD Version 6*, Appendix D	NR	NR	NR	NR	
Th-230	P	3	D	5.00E+02	*User's Manual for RESRAD Version 6*, Appendix D	NR	NR	NR	NR	
Th-232	P	3	D	5.00E+02	*User's Manual for RESRAD Version 6*, Appendix D	NR	NR	NR	NR	
U-233	P	3	D	6.00E+01	*User's Manual for RESRAD Version 6*, Appendix D	NR	NR	NR	NR	
U-234	P	3	D	6.00E+01	*User's Manual for RESRAD Version 6*, Appendix D	NR	NR	NR	NR	
U-235	P	3	D	6.00E+01	*User's Manual for RESRAD Version 6*, Appendix D	NR	NR	NR	NR	
U-236	P	3	D	6.00E+01	*User's Manual for RESRAD Version 6*, Appendix D	NR	NR	NR	NR	
U-238	P	3	D	6.00E+01	*User's Manual for RESRAD Version 6*, Appendix D	NR	NR	NR	NR	
Graphics Parameters										

RESRAD Input Parameter Values for Sensitivity Analysis										
Parameter (unit)	Type	Priority	Treatment	Value/Distribution	Basis	Distribution's Statistical Parameters[d]				
						1	2	3	4	Mean/ Median
Number of points				32	RESRAD Default	NR	NR	NR	NR	
Spacing				log	RESRAD Default	NR	NR	NR	NR	
Time integration parameters										
Maximum number of points for dose				17	RESRAD Default	NR	NR	NR	NR	

Footnotes:

[a] P = physical, B = behavioral, M = metabolic; (see NUREG/CR-6697, Attachment B, Table 4.)
[b] 1 = high-priority parameter, 2 = medium-priority parameter, 3 = low-priority parameter (see NUREG/CR-6697, Attachment B, Table 4.1)
[c] D = deterministic, S = stochastic
[d] Distributions Statistical Parameters:
Lognormal-n: 1= mean, 2 = standard deviation
Bounded lognormal-n: 1= mean, 2 = standard deviation, 3 = minimum, 4 = maximum
Truncated lognormal-n: 1= mean, 2 = standard deviation, 3 = lower quantile, 4 = upper quantile
Bounded normal: 1 = mean, 2 = standard deviation, 3 = minimum, 4 = maximum
Triangular: 1 = minimum, 2 = maximum, 3 = most likely
Uniform: 1 = minimum, 2 = maximum
* Designates principal radionuclide-of-concern; undesignated radionuclides are included as daughter products.
Additional Sensitivity Analysis Data:
Sampling technique = Latin Hypercube
Number of observations =2000
Number of repetitions = 1
Input Rank Correlation Coefficients (NUREG/CR-6697):
Total porosity and bulk density = - 0.99 (contaminated zone, unsaturated and saturated zones)
Total porosity and effective porosity = 0.96 (unsaturated and saturated zones)
Effective porosity and bulk density = -0.99 (unsaturated and saturated zones)
Well Pumping Rate and Irrigation Rate = 0.96

Appendix H
Results of Sensitivity Analysis: Soil

Radionuclide	Sensitive Parameter	PRCC Value
Am-241	Plant transfer factor for Am	0.93
	Thickness of contaminated zone	0.79
	Depth of roots	-0.59
C-14	Thickness of contaminated zone	0.98
	Depth of roots	-0.76
	Thickness of evasion layer for C-14 in soil	0.35
Cm-243	Plant transfer factor for Cm	0.91
	Thickness of contaminated zone	0.73
	External gamma shielding factor	0.60
	Depth of roots	-0.56
Cm-244	Plant transfer factor for Cm	0.92
	Thickness of contaminated zone	0.78
	Depth of roots	-0.60
Cm-245	Plant transfer factor for Cm	0.84
	Thickness of contaminated zone	0.80
	Depth of roots	-0.54
Cm-246	Plant transfer factor for Cm	0.92
	Thickness of contaminated zone	0.79
	Depth of roots	-0.60
Co-60	External gamma shielding factor	0.95
	Plant transfer factor for Co	0.65
	Thickness of contaminated zone	0.39
	Meat transfer factor for Co	0.35
Cs-137	Plant transfer factor for Cs	0.86
	External gamma shielding factor	0.76
	Thickness of contaminated zone	0.58
	Milk transfer factor for Cs	0.39
	Depth of roots	-0.35
	Meat transfer factor for Cs	0.28
Eu-152	External gamma shielding factor	1.00
	Kd of Eu-152 in contaminated zone	0.26
Eu-154	External gamma shielding factor	0.99
H-3	Thickness of contaminated zone	0.93
	Depth of roots	-0.64
	Kd of H-3 in contaminated zone	-0.27
I-129	Plant transfer factor for I	0.89
	Thickness of contaminated zone	0.75
	Milk transfer factor for I	0.60
	Depth of roots	-0.49
	Meat transfer factor for I	0.44
Nb-94	External gamma shielding factor	0.99
	Kd of Nb-94 in contaminated zone	0.32

Radionuclide	Sensitive Parameter	PRCC Value
Ni-59	Plant transfer factor for Ni	0.90
	Milk transfer factor for Ni	0.81
	Thickness of contaminated zone	0.74
	Depth of roots	-0.54
Ni-63	Plant transfer factor for Ni	0.90
	Milk transfer factor for Ni	0.81
	Thickness of contaminated zone	0.74
	Depth of roots	-0.53
Np-237	Plant transfer factor for Np	0.92
	Thickness of contaminated zone	0.79
	Depth of roots	-0.60
Pu-238	Plant transfer factor for Pu	0.92
	Thickness of contaminated zone	0.79
	Depth of roots	-0.62
Pu-239	Plant transfer factor for Pu	0.93
	Thickness of contaminated zone	0.79
	Depth of roots	-0.60
Pu-240	Plant transfer factor for Pu	0.92
	Thickness of contaminated zone	0.79
	Depth of roots	-0.60
Pu-241	Plant transfer factor for Am	0.84
	Thickness of contaminated zone	0.75
	Depth of roots	-0.51
	Kd of Am in contaminated zone	0.26
Sr-90	Plant transfer factor for Sr	0.93
	Thickness of contaminated zone	0.78
	Depth of roots	-0.58
Tc-99	Plant transfer factor for Tc	0.91
	Thickness of contaminated zone	0.80
	Depth of roots	-0.54
	Kd of Tc-99 in contaminated zone	0.26

Appendix I
RESRAD Parameter Values for Soil DCGL Determination

RESRAD Input Parameter Values for Soil DCGL Determination										
Parameter (unit)	Type	Priority	Treatment	Value/Distribution	Basis	Distribution's Statistical Parameters[d]				
						1	2	3	4	Mean/ Median
Soil Concentrations										
Basic radiation dose limit (mrem/y)		3	D	25	10 CFR 20.1402	NR	NR	NR	NR	
Initial principal radionuclide (pCi/g)	P	2	D	1	Unit Value	NR	NR	NR	NR	
Distribution coefficients (applied to contaminated, unsaturated, and saturated zones unless otherwise noted) (cm^3/g)										
Ac-227 (daughter for Cm-243 and Pu-239)	P	1	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	6.72	3.22	0.001	0.999	825
Am-241 (also daughter for Cm-245 and Pu-241)	P	1	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	7.28	3.15	0.001	0.999	1445
			D	1.20E+04	75th percentile value – applied to Am-241 as daugther for Pu-241 in contaminated zone					
Am-243 (daughter for Cm-243)	P	1	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	7.28	3.15	0.001	0.999	1445
C-14	P	1	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	2.4	3.22	0.001	0.999	11
Cm-243	P	1	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	8.82	1.82	0.001	0.999	6761
Cm-244	P	1	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	8.82	1.82	0.001	0.999	6761
Cm-245	P	1	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	8.82	1.82	0.001	0.999	6761
Cm-246	P	1	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	8.82	1.82	0.001	0.999	6761
Co-60	P	1	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	5.46	2.53	0.001	0.999	235
Cs-137	P	1	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	6.1	2.33	0.001	0.999	446
Eu-152	P	1	D	7.22E+03	75h percentile value applied to contaminated zone only.					
				Truncated lognormal-n	NUREG/CR-6697, Att. C; distribution applied to saturated and unsaturated zones.	6.72	3.22	0.001	0.999	825
Eu-154	P	1	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	6.72	3.22	0.001	0.999	825
Gd-152 (daughter for Eu-152)	P	1	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	6.72	3.22	0.001	0.999	825

RESRAD Input Parameter Values for Soil DCGL Determination

Parameter (unit)	Type	Priority	Treatment	Value/Distribution	Basis	Distribution's Statistical Parameters[d]				
						1	2	3	4	Mean/ Median
H-3	P	1	S	4.30E-02	25[th] percentile value applied to contaminated zone only.					
				Truncated lognormal-n	NUREG/CR-6697, Att. C; distribution applied to saturated and unsaturated zones.25[th] percentile value	-2.81	0.5	0.001	0.999	0.06
I-129	P	1	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	1.52	2.19	0.001	0.999	4.6
Nb-94	P	1	D	3.56E+03	75[th] percentile value applied to contaminated zone only.					
				Truncated lognormal-n	NUREG/CR-6697, Att. C; distribution applied to saturated and unsaturated zones.	5.94	3.22	0.001	0.999	380
Ni-59	P	1	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	6.05	1.46	0.001	0.999	424
Ni-63	P	1	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	6.05	1.46	0.001	0.999	424
Np-237 (also daughter for Am-241, Cm-245, and Pu-241)	P	1	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	2.84	2.25	0.001	0.999	17
Pa-231 (daughter for Cm-243 and Pu-239)	P	1	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	5.94	3.22	0.001	0.999	380
Po-210 (daughter for Cm-246)	P	1	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	5.20	1.68	0.001	0.999	181
Pb-210 (daughter for Cm-246 and Pu-238)	P	1	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	7.78	2.76	0.001	0.999	2392
Pu-238	P	1	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	6.86	1.89	0.001	0.999	953
Pu-239 (also daughter for Cm-243)	P	1	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	6.86	1.89	0.001	0.999	953
Pu-240 (also daughter for Cm-244)	P	1	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	6.86	1.89	0.001	0.999	953
Pu-241 (also daughter for Cm-245)	P	1	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	6.86	1.89	0.001	0.999	953
Pu-242 (daughter for Cm-246)	P	1	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	6.86	1.89	0.001	0.999	953
Ra-226 (daughter for Cm-246 and Pu-238)	P	1	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	8.17	1.7	0.001	0.999	3533
Ra-228 (daughter for Cm-244 and Pu-240)	P	1	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	8.17	1.7	0.001	0.999	3533
Sr-90	P	1	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	3.45	2.12	0.001	0.999	32

RESRAD Input Parameter Values for Soil DCGL Determination

Parameter (unit)	Type	Priority	Treatment	Value/Distribution	Basis	Distribution's Statistical Parameters[d]				
						1	2	3	4	Mean/ Median
Tc-99	P	1	D	4.28E+00	75[h] percentile value applied to contaminated zone only.					
				Truncated lognormal-n	NUREG/CR-6697, Att. C; distribution applied to saturated and unsaturated zones.	-0.67	3.16	0.001	0.999	0.51
Th-228 (daughter for Cm-244 and Pu-240)	P	1	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	8.68	3.62	0.001	0.999	5884
Th-229 (daughter for Am-241, Cm-245, Np-237, and Pu-241)	P	1	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	8.68	3.62	0.001	0.999	5884
Th-230 (daughter for Cm-246 and Pu-238)	P	1	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	8.68	3.62	0.001	0.999	5884
Th-232 (daughter for Cm-244 and Pu-240)	P	1	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	8.68	3.62	0.001	0.999	5884
U-233 (daughter for Am-241, Cm-245, Np-237, and Pu-241)	P	1	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	4.84	3.13	0.001	0.999	126
U-234 (daughter for Cm-246 and Pu-238)	P	1	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	4.84	3.13	0.001	0.999	126
U-235 (daughter for Cm-243 and Pu-239)	P	1	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	4.84	3.13	0.001	0.999	126
U-236 (daughter for Cm-244 and Pu-240)	P	1	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	4.84	3.13	0.001	0.999	126
U-238 (daughter for Cm-246)	P	1	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	4.84	3.13	0.001	0.999	126
Initial concentration of radionuclides present in groundwater (pCi/l)	P	3	D	0	Ground water initially uncontaminated for this scenario	NR	NR	NR	NR	
Calculation Times										
Time since placement of material (y)	P	3	D	0		NR	NR	NR	NR	
Time for calculations (y)	P	3	D	0, 1, 3, 10, 30, 100, 300, 1000	RESRAD Default	NR	NR	NR	NR	
Contaminated Zone										
Area of contaminated zone (m^2)	P	2	D	30,000	Site-specific: largest contiguous class 1/class 2 area (rounded to nearest thousands)	NR	NR	NR	NR	

RESRAD Input Parameter Values for Soil DCGL Determination										
Parameter (unit)	Type	Priority	Treatment	Value/Distribution	Basis	Distribution's Statistical Parameters[d]				
						1	2	3	4	Mean/ Median
Thickness of contaminated zone (m)	P	2	D	2.67	75th percentile value – applied to all ROCs except those listed below.					
			S	Uniform	Site-specific distribution applied to Eu-152, Eu-154, and Nb-94	0.15	3.51			1.83
Length parallel to aquifer flow (m)	P	2	D	195	Site-specific - diameter of circle with an area of 30,000 m^2	NR	NR	NR	NR	
Contaminated fraction below water table	P	2	D	0	Ground water initially uncontaminated for this scenario	NR	NR	NR	NR	
Cover and Contaminated Zone Hydrological Data										
Cover depth (m)	P	2	D	0	Site-specific - no cover assumed	NR	NR	NR	NR	
Density of contaminated zone (g/cm^3)	P	1	S	Bounded Normal	NUREG 6697 dist for site soil type - clay loam	1.5635	0.2385	0.827	2.3	1.5635
Contaminated zone erosion rate (m/y)	P	2	D	2.2E-3	Calculated value based on site-specific slope of 6%	NR	NR	NR	NR	
Contaminated zone total porosity	P	2	S	Bounded Normal	NUREG 6697 dist for site soil type - clay loam	0.41	0.09	0.1319	0.6881	0.41
Contaminated zone field capacity	P	3	D	0.095	Calculated site-specific value (ref. 3.1)	NR	NR	NR	NR	0.095
Contaminated zone hydraulic conductivity (m/y)	P	2	S	Bounded Log Normal n	NUREG 6697 dist for site soil type - clay loam	1.36	2.17	0.00478	3190	3.90
Contaminated zone b parameter	P	2	S	Bounded Log Normal n	NUREG 6697 dist for site soil type - clay loam	1.73	0.323	2.08	15.3	5.6
Humidity in air (g/m^3)	P	3	D	8.2	Regional value for northern CA as represented by San Francisco	NR	NR	NR	NR	
Evapotranspiration coefficient	P	2	S	Uniform	NUREG/CR-6697 Att. C	0.5	0.75	NR	NR	0.625
Average annual wind speed (m/s)	P	2	D	3.04	Site-specific value (from NCDC website)	NR	NR	NR	NR	

RESRAD Input Parameter Values for Soil DCGL Determination										
Parameter (unit)	Type	Priority	Treatment	Value/Distribution	Basis	Distribution's Statistical Parameters[d]				
						1	2	3	4	Mean/ Median
Precipitation (m/y)	P	2	D	0.91	Site-specific value from HB SAFSTOR Environmental Report, section 4.1.1	NR	NR	NR	NR	
Irrigation (m/y)	B	3	S	Uniform	NUREG/CR-6697, Att C methodology	0.36	0.76	NR	NR	0.56
Irrigation mode	B	3	D	Overhead	Overhead irrigation is common practice in U. S.	NR	NR	NR	NR	
Runoff coefficient	P	2	D	0.5	Site-specific value; NUREG/CR-6697, Att. C section 4.2 methodology	NR	NR	NR	NR	
Watershed area for nearby stream or pond (m^2)	P	3	D	2.52E+07	Site-specific value from (HB SAFSTOR Environmental Report)	NR	NR	NR	NR	
Accuracy for water/soil computations	-	3	D	1.00E-03	RESRAD Default	NR	NR	NR	NR	
Saturated Zone Hydrological Data										
Density of saturated zone (g/cm^3)	P	1	S	Bounded Normal	NUREG 6697 dist for site soil type - silty clay loam	1.5105	0.1855	0.937	2.084	1.5105
Saturated zone total porosity	P	1	S	Bounded Normal	NUREG 6697 dist for site soil type - silty clay loam	0.43	0.0699	0.214	0.646	0.43
Saturated zone effective porosity	P	1	S	Bounded Normal	NUREG 6697 dist for site soil type - silty clay loam	0.342	0.0705	0.124	0.56	0.342
Saturated zone field capacity	P	3	D	0.088	Calculated site-specific value (ref. 3.1)	NR	NR	NR	NR	0.088
Saturated zone hydraulic conductivity (m/y)	P	1	S	Bounded Log Normal n	NUREG 6697 dist for site soil type - silty clay loam	0.362	1.59	0.0106	195	1.44
Saturated zone hydraulic gradient	P	2	D	0.002	Site-specific value determined using method described in NUREG/CR-6697, App. C (calculated in ref. 3.1)	NR	NR	NR	NR	
Saturated zone b parameter	P	2	S	Bounded Log Normal n	NUREG 6697 dist for site soil type - silty clay loam	1.96	0.265	3.02	15.5	7.1
Water table drop rate (m/y)	P	3	D	1.00E-03	RESRAD User Manual	NR	NR	NR	NR	
Well pump intake depth (m below water table)	P	2	S	Triangular	NUREG/CR-6697, Att. C	6	10	30		10

RESRAD Input Parameter Values for Soil DCGL Determination										
Parameter (unit)	Type	Priority	Treatment	Value/Distribution	Basis	Distribution's Statistical Parameters[d]				
						1	2	3	4	Mean/ Median
Model: Nondispersion (ND) or Mass-Balance (MB)	P	3	D	ND	ND model recommended for contaminant areas > 1,000 m^2	NR	NR	NR	NR	
Well pumping rate (m^3/y)	P	2	S	Uniform	Min, Max, median value based on site irrigation and area and calculated according to NUREG/CR-6697, Att. C section 3.10 method. (calculated in ref. 3.1)	1173	1973			1573
Unsaturated Zone Hydrological Data										
Number of unsaturated zone strata	P	3	D	1	Site-specific value	NR	NR	NR	NR	
Unsat. zone thickness (m)	P	2	S	Uniform	Site-specific distribution base on thickness of CZ and groundwater elevations	0.00	8.08			4.04
Unsat. zone soil density (g/cm^3)	P	1	S	Bounded Normal	NUREG 6697 dist for site soil type - clay loam	1.5635	0.2385	0.827	2.3	1.5635
Unsat. zone total porosity	P	2	S	Bounded Normal	NUREG 6697 dist for site soil type - clay loam	0.41	0.09	0.1319	0.6881	0.41
Unsat. zone effective porosity	P	1	S	Bounded Normal	NUREG 6697 dist for site soil type - clay loam	0.315	0.0905	0.0349	0.594	0.315
Unsat. zone field capacity	P	3	D	0.095	Site-specific value (calculated in ref. 3.1)	NR	NR	NR	NR	0.095
Unsat. zone hydraulic conductivity (m/y)	P	1	S	Bounded Log Normal n	NUREG 6697 dist for site soil type - clay loam	1.36	2.17	0.00478	3190	3.90
Unsat. zone soil-specific b parameter	P	2	S	Bounded Log Normal n	NUREG 6697 dist for site soil type - clay loam	1.73	0.323	2.08	15.3	5.6
Occupancy										
Inhalation rate (m^3/y)	B	3	D	8400	NUREG/CR-6697, Att C	NR	NR	NR	NR	
Mass loading for inhalation (g/m^3)	P	2	S	Continuous linear	NUREG/CR-6697, Att. C					2.33E-05
Exposure duration	B	3	D	30	*User's Manual for RESRAD Version 6*; parameter value not used in dose calculation	NR	NR	NR	NR	
Indoor dust filtration factor	P	2	S	Uniform	NUREG/CR-6697, Att. C	0.15	0.95			0.55

RESRAD Input Parameter Values for Soil DCGL Determination										
Parameter (unit)	**Type**	**Priority**	**Treatment**	**Value/Distribution**	**Basis**	**Distribution's Statistical Parameters[d]**				
						1	**2**	**3**	**4**	**Mean/ Median**
Shielding factor, external gamma	P	2	D	3.98E-01	75^{th} percentile value – applied for Cm-243, Co-60, Cs-137, Eu-152, Eu-154, and Nb-94					
			S	Bounded lognormal-n	NUREG/CR-6697, Att. C – applied to all ROCs except those listed above	-1.3	0.59	0.044	1	0.2725
Fraction of time spent indoors	B	3	D	0.6571	NUREG/CR-5512, Vol. 3 Table 6.87	NR	NR	NR	NR	
Fraction of time spent outdoors (on site)	B	3	D	0.1181	NUREG/CR-5512, Vol. 3 Table 6.87 (outdoors + gardening)	NR	NR	NR	NR	
Shape factor flag, external gamma	P	3	D	Circular	Circular contaminated zone assumed for modeling purposes	NR	NR	NR	NR	
Ingestion, Dietary										
Fruits, vegetables, grain consumption (kg/y)	B	2	D	112	NUREG/CR-5512, Vol. 3 (other vegetables + fruits + grain)	NR	NR	NR	NR	
Leafy vegetable consumption (kg/y)	B	3	D	21.4	NUREG/CR-5512, Vol. 3	NR	NR	NR	NR	
Milk consumption (L/y)	B	2	D	233	NUREG/CR-5512, Vol. 3	NR	NR	NR	NR	
Meat and poultry consumption (kg/y)	B	3	D	65.1	NUREG/CR5512, Vol. 3 (beef + poultry)	NR	NR	NR	NR	
Fish consumption (kg/y)	B	3	D	20.6	NUREG/CR-5512, Vol. 3	NR	NR	NR	NR	
Other seafood consumption (kg/y)	B	3	D	0.9	*User's Manual for RESRAD Version 6*, Appendix D	NR	NR	NR	NR	
Soil ingestion rate (g/y)	B	2	D	18.26	NUREG/CR-5512, Vol. 3	NR	NR	NR	NR	
Drinking water intake (L/y)	B	2	D	511	NUREG/CR-5512, Vol. 3 Table 6.87	NR	NR	NR	NR	
Contamination fraction of drinking water	P	3	D	1	All water assumed contaminated	NR	NR	NR	NR	
Contamination fraction of household water (if used)	P	3		NA						
Contamination fraction of livestock water	P	3	D	1	All water assumed contaminated	NR	NR	NR	NR	

RESRAD Input Parameter Values for Soil DCGL Determination										
Parameter (unit)	Type	Priority	Treatment	Value/Distribution	Basis	Distribution's Statistical Parameters[d]				
						1	2	3	4	Mean/ Median
Contamination fraction of irrigation water	P	3	D	1	Alll water assumed contaminate	NR	NR	NR	NR	
Contamination fraction of aquatic food	P	2	D	1	NUREG/CR-5512, Vol. 3	NR	NR	NR	NR	
Contamination fraction of plant food	P	3	D	1	NUREG/CR-5512, Vol. 3	NR	NR	NR	NR	
Contamination fraction of meat	P	3	D	1	NUREG/CR-5512, Vol. 3	NR	NR	NR	NR	
Contamination fraction of milk	P	3	D	1	NUREG/CR-5512, Vol. 3	NR	NR	NR	NR	
Ingestion, Non-Dietary										
Livestock fodder intake for meat (kg/day)	M	3	D	27.1	NUREG/CR5512, Vol. 3 Table 6.87, beef cattle + poultry + layer hen	NR	NR	NR	NR	
Livestock fodder intake for milk (kg/day)	M	3	D	63.2	NUREG/CR5512, Vol. 3 Table 6.87, forage + grain + hay	NR	NR	NR	NR	
Livestock water intake for meat (L/day)	M	3	D	50.6	NUREG/CR5512, Vol. 3 Table 6.87, beef cattle + poultry + layer hen	NR	NR	NR	NR	
Livestock water intake for milk (L/day)	M	3	D	60	NUREG/CR5512, Vol. 3 Table 6.87	NR	NR	NR	NR	
Livestock soil intake (kg/day)	M	3	D	0.5	*User's Manual for RESRAD Version 6*, Appendix L	NR	NR	NR	NR	
Mass loading for foliar deposition (g/m^3)	P	3	D	4.00E-04	NUREG/CR-5512, Vol. 3 Table 6.87, gardening	NR	NR	NR	NR	
Depth of soil mixing layer (m)	P	2	S	Triangular	NUREG/CR-6697, Att. C	0	0.15	0.6		0.23
Depth of roots (m)	P	1	D	1.22E+00	25th percentile value (Ref. 3.1) – applied to all ROCs except those listed below.					
			S	Uniform	NUREG/CR-6697, Att. C – applied for Eu-152, Eu-154, and Nb-94	0.3	4.0			2.15
Drinking water fraction from ground water	P	3	D	1	All water assumed to be supplied from groundwater	NR	NR	NR	NR	
Household water fraction from ground water (if used)	P	3		NA						

RESRAD Input Parameter Values for Soil DCGL Determination										
Parameter (unit)	Type	Priority	Treatment	Value/Distribution	Basis	Distribution's Statistical Parameters[d]				
						1	2	3	4	Mean/ Median
Livestock water fraction from ground water	P	3	D	1	All water assumed to be supplied from groundwater	NR	NR	NR	NR	
Irrigation fraction from ground water	P	3	D	1	All water assumed to be supplied from groundwater	NR	NR	NR	NR	
Wet weight crop yield for Non-Leafy (kg/m^2)	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	0.56	0.48	0.001	0.999	1.75
Wet weight crop yield for Leafy (kg/m^2)	P	3	D	2.88921	NUREG/CR-5512, Vol. 3 Table 6.87	NR	NR	NR	NR	
Wet weight crop yield for Fodder (kg/m^2)	P	3	D	1.8868	NUREG/CR-5512, Vol. 3 Table 6.87	NR	NR	NR	NR	
Growing Season for Non-Leafy (y)	P	3	D	0.246	NUREG/CR-5512, Vol. 3 Table 6.87	NR	NR	NR	NR	
Growing Season for Leafy (y)	P	3	D	0.123	NUREG/CR-5512, Vol. 3 Table 6.87	NR	NR	NR	NR	
Growing Season for Fodder (y)	P	3	D	0.082	NUREG/CR-5512, Vol. 3 Table 6.87	NR	NR	NR	NR	
Translocation Factor for Non-Leafy	P	3	D	0.1	NUREG/CR-5512, Vol. 3 Table 6.87	NR	NR	NR	NR	
Translocation Factor for Leafy	P	3	D	1	NUREG/CR-5512, Vol. 3 Table 6.87	NR	NR	NR	NR	
Translocation Factor for Fodder	P	3	D	1	NUREG/CR-5512, Vol. 3 Table 6.87	NR	NR	NR	NR	
Weathering Removal Constant for Vegetation (1/y)	P	2	S	Triangular	NUREG/CR-6697, Att. C	5.1	18	84		33
Wet Foliar Interception Fraction for Non-Leafy	P	3	D	0.35	NUREG/CR-5512, Vol. 3 Table 6.87	NR	NR	NR	NR	
Wet Foliar Interception Fraction for Leafy	P	2	S	Triangular	NUREG/CR-6697, Att. C	0.06	0.67	0.95		0.58
Wet Foliar Interception Fraction for Fodder	P	3	D	0.35	NUREG/CR-5512, Vol. 3 Table 6.87	NR	NR	NR	NR	
Dry Foliar Interception Fraction for Non-Leafy	P	3	D	0.35	NUREG/CR-5512, Vol. 3 Table 6.87	NR	NR	NR	NR	
Dry Foliar Interception Fraction for Leafy	P	3	D	0.35	NUREG/CR-5512, Vol. 3	NR	NR	NR	NR	
Dry Foliar Interception Fraction for Fodder	P	3	D	0.35	NUREG/CR-5512, Vol. 3	NR	NR	NR	NR	

RESRAD Input Parameter Values for Soil DCGL Determination										
Parameter (unit)	Type	Priority	Treatment	Value/Distribution	Basis	Distribution's Statistical Parameters[d]				
						1	2	3	4	Mean/ Median
Storage times of contaminated foodstuffs (days):										
Fruits, non-leafy vegetables, and grain	B	3	D	14	NUREG/CR-5512, Vol. 3 Table 6.87	NR	NR	NR	NR	
Leafy vegetables	B	3	D	1	NUREG/CR-5512, Vol. 3 Table 6.87	NR	NR	NR	NR	
Milk	B	3	D	1	NUREG/CR-5512, Vol. 3 Table 6.87	NR	NR	NR	NR	
Meat and poultry	B	3	D	20	NUREG/CR-5512, Vol. 3 Table 6.87 (holdup period for beef)	NR	NR	NR	NR	
Fish	B	3	D	7	*User's Manual for RESRAD Version 6*, Appendix D	NR	NR	NR	NR	
Crustacea and mollusks	B	3	D	7	*User's Manual for RESRAD Version 6*, Appendix D	NR	NR	NR	NR	
Well water	B	3	D	1	*User's Manual for RESRAD Version 6*, Appendix D	NR	NR	NR	NR	
Surface water	B	3	D	1	*User's Manual for RESRAD Version 6*, Appendix D	NR	NR	NR	NR	
Livestock fodder	B	3	D	45	*User's Manual for RESRAD Version 6*, Appendix D	NR	NR	NR	NR	
Special Radionuclides (C-14)										
C-12 concentration in water (g/cm^3)	P	3	D	2.00E-05	*User's Manual for RESRAD Version 6*, Appendix L	NR	NR	NR	NR	
C-12 concentration in contaminated soil (g/g)	P	3	D	3.00E-02	*User's Manual for RESRAD Version 6*, Appendix L	NR	NR	NR	NR	
Fraction of vegetation carbon from soil	P	3	D	2.00E-02	*User's Manual for RESRAD Version 6*, Appendix L	NR	NR	NR	NR	
Fraction of vegetation carbon from air	P	3	D	9.80E-01	*User's Manual for RESRAD Version 6*, Appendix L	NR	NR	NR	NR	
C-14 evasion layer thickness in soil (m)	P	2	D	4.27E-01	75^{th} percentile value					

RESRAD Input Parameter Values for Soil DCGL Determination										
Parameter (unit)	Type	Priority	Treatment	Value/Distribution	Basis	Distribution's Statistical Parameters[d]				
						1	2	3	4	Mean/ Median
C-14 evasion flux rate from soil (1/sec)	P	3	D	7.00E-07	*User's Manual for RESRAD Version 6*, Appendix L	NR	NR	NR	NR	
C-12 evasion flux rate from soil (1/sec)	P	3	D	1.00E-10	*User's Manual for RESRAD Version 6*, Appendix L	NR	NR	NR	NR	
Fraction of grain in beef cattle feed	B	3	D	0.2500	NUREG/CR-6697, Att. B	NR	NR	NR	NR	
Fraction of grain in milk cow feed	B	3	D	0.1000	NUREG/CR-6697, Att. B	NR	NR	NR	NR	
Dose Conversion Factors (Inhalation mrem/pCi)										
Ac-227	M	3	D	6.72E+00	FGR11 (RESRAD Dose Conversion Library)	NR	NR	NR	NR	
Am-241	M	3	D	4.44E-01	FGR11	NR	NR	NR	NR	
Am-243	M	3	D	4.40E-01	FGR11	NR	NR	NR	NR	
C-14	M	3	D	2.09E-06	FGR11	NR	NR	NR	NR	
Cm-243	M	3	D	3.07E-01	FGR11	NR	NR	NR	NR	
Cm-244	M	3	D	2.48E-01	FGR11	NR	NR	NR	NR	
Cm-245	M	3	D	4.55E-01	FGR11	NR	NR	NR	NR	
Cm-246	M	3	D	4.51E-01	FGR11	NR	NR	NR	NR	
Co-60	M	3	D	2.19E-04	FGR11	NR	NR	NR	NR	
Cs-137	M	3	D	3.19E-05	FGR11	NR	NR	NR	NR	
Eu-152	M	3	D	2.21E-04	FGR11	NR	NR	NR	NR	
Eu-154	M	3	D	2.86E-04	FGR11	NR	NR	NR	NR	
Gd-152	M	3	D	2.43E-01	FGR11	NR	NR	NR	NR	
H-3	M	3	D	6.40E-08	FGR11	NR	NR	NR	NR	
I-129	M	3	D	1.74E-04	FGR11	NR	NR	NR	NR	
Nb-94	M	3	D	4.14E-04	FGR11	NR	NR	NR	NR	
Ni-59	M	3	D	2.70E-06	FGR11	NR	NR	NR	NR	
Ni-63	M	3	D	6.29E-06	FGR11	NR	NR	NR	NR	
Np-237	M	3	D	5.40E-01	FGR11	NR	NR	NR	NR	
Pa-231	M	3	D	1.28E+00	FGR11	NR	NR	NR	NR	
Pb-210	M	3	D	1.38E-02	FGR11	NR	NR	NR	NR	

RESRAD Input Parameter Values for Soil DCGL Determination										
Parameter (unit)	Type	Priority	Treatment	Value/Distribution	Basis	Distribution's Statistical Parameters[d]				
						1	2	3	4	Mean/ Median
Po-210	M	3	D	9.40E-03	FGR11	NR	NR	NR	NR	
Pu-238	M	3	D	3.92E-01	FGR11	NR	NR	NR	NR	
Pu-239	M	3	D	4.29E-01	FGR11	NR	NR	NR	NR	
Pu-240	M	3	D	4.29E-01	FGR11	NR	NR	NR	NR	
Pu-241	M	3	D	8.25E-03	FGR11	NR	NR	NR	NR	
Pu-242	M	3	D	4.11E-01	FGR11	NR	NR	NR	NR	
Ra-226	M	3	D	8.59E-03	FGR11	NR	NR	NR	NR	
Ra-228	M	3	D	5.08E-03	FGR11	NR	NR	NR	NR	
Sr-90	M	3	D	1.31E-03	FGR11	NR	NR	NR	NR	
Tc-99	M	3	D	8.32E-06	FGR11	NR	NR	NR	NR	
Th-228	M	3	D	3.43E-01	FGR11	NR	NR	NR	NR	
Th-229	M	3	D	2.17E+00	FGR11	NR	NR	NR	NR	
Th-230	M	3	D	3.26E-01	FGR11	NR	NR	NR	NR	
Th232	M	3	D	1.64e+00	FGR11	NR	NR	NR	NR	
U-233	M	3	D	1.35E-01	FGR11	NR	NR	NR	NR	
U-234	M	3	D	1.32E-01	FGR11	NR	NR	NR	NR	
U-235	M	3	D	1.23E-01	FGR11	NR	NR	NR	NR	
U-236	M	3	D	1.25E-01	FGR11	NR	NR	NR	NR	
U-238	M	3	D	1.18E-01	FGR11	NR	NR	NR	NR	
Dose Conversion Factors (Ingestion mrem/pCi)										
Ac-227	M	3	D	1.48E-02	FGR11 (RESRAD Dose Conversion Library)	NR	NR	NR	NR	
Am-241	M	3	D	3.64E-03	FGR11	NR	NR	NR	NR	
Am-243	M	3	D	3.62E-03	FGR11	NR	NR	NR	NR	
C-14	M	3	D	2.09E-06	FGR11	NR	NR	NR	NR	
Cm-243	M	3	D	2.51E-03	FGR11	NR	NR	NR	NR	
Cm-244	M	3	D	2.02E-03	FGR11	NR	NR	NR	NR	
Cm-245	M	3	D	3.74E-03	FGR11	NR	NR	NR	NR	
Cm-246	M	3	D	3.70E-03	FGR11	NR	NR	NR	NR	
Co-60	M	3	D	2.69E-05	FGR11	NR	NR	NR	NR	
Cs-137	M	3	D	5.00E-05	FGR11	NR	NR	NR	NR	

RESRAD Input Parameter Values for Soil DCGL Determination										
Parameter (unit)	Type	Priority	Treatment	Value/Distribution	Basis	Distribution's Statistical Parameters[d]				
						1	2	3	4	Mean/ Median
Eu-152	M	3	D	6.48E-06	FGR11	NR	NR	NR	NR	
Eu-154	M	3	D	9.55E-06	FGR11	NR	NR	NR	NR	
Gd-152	M	3	D	1.61E-04	FGR11	NR	NR	NR	NR	
H-3	M	3	D	6.40E-08	FGR11	NR	NR	NR	NR	
I-129	M	3	D	2.76E-04	FGR11	NR	NR	NR	NR	
Nb-94	M	3	D	7.14E-06	FGR11	NR	NR	NR	NR	
Ni-59	M	3	D	2.10E-07	FGR11	NR	NR	NR	NR	
Ni-63	M	3	D	5.77E-07	FGR11	NR	NR	NR	NR	
Np-237	M	3	D	4.44E-03	FGR11	NR	NR	NR	NR	
Pa-231	M	3	D	1.06E-02	FGR11	NR	NR	NR	NR	
Pb-210	M	3	D	5.38E-03	FGR11	NR	NR	NR	NR	
Po-210	M	3	D	1.90E-03	FGR11	NR	NR	NR	NR	
Pu-238	M	3	D	3.20E-03	FGR11	NR	NR	NR	NR	
Pu-239	M	3	D	3.54E-03	FGR11	NR	NR	NR	NR	
Pu-240	M	3	D	3.54E-03	FGR11	NR	NR	NR	NR	
Pu-241	M	3	D	6.84E-05	FGR11	NR	NR	NR	NR	
Pu-242	M	3	D	3.36E-03	FGR11	NR	NR	NR	NR	
Ra-226	M	3	D	1.32E-03	FGR11	NR	NR	NR	NR	
Ra-228	M	3	D	1.44E-03	FGR11	NR	NR	NR	NR	
Sr-90	M	3	D	1.53E-04	FGR11	NR	NR	NR	NR	
Tc-99	M	3	D	1.46E-06	FGR11	NR	NR	NR	NR	
Th-228	M	3	D	3.96E-04	FGR11	NR	NR	NR	NR	
Th-229	M	3	D	4.03E-03	FGR11	NR	NR	NR	NR	
Th-230	M	3	D	5.48E-04	FGR11	NR	NR	NR	NR	
Th-232	M	3	D	2.73E-03	FGR11	NR	NR	NR	NR	
U-233	M	3	D	2.89E-04	FGR11	NR	NR	NR	NR	
U-234	M	3	D	2.83E-04	FGR11	NR	NR	NR	NR	
U-235	M	3	D	2.67E-04	FGR11	NR	NR	NR	NR	
U-236	M	3	D	2.69E-04	FGR11	NR	NR	NR	NR	
U-238	M	3	D	2.55E-04	FGR11	NR	NR	NR	NR	

RESRAD Input Parameter Values for Soil DCGL Determination										
Parameter (unit)	Type	Priority	Treatment	Value/Distribution	Basis	Distribution's Statistical Parameters[d]				
						1	2	3	4	Mean/ Median
Plant Transfer Factors (pCi/g plant)/(pCi/g soil)										
Ac-227	P	1	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-6.91	1.1	0.001	0.999	1.0E-03
Am-241	P	1	D	1.83E-03	75th percentile value					
Am-243	P	1	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-6.91	0.9	0.001	0.999	1.0E-03
C-14	P	1	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-0.36	0.9	0.001	0.999	7.0E-01
Cm-243	P	1	S	1.83E-03	75th percentile value					
Cm-244	P	1	D	1.83E-03	75th percentile value					
Cm-245	P	1	D	1.83E-03	75th percentile value					
Cm-246	P	1	D	1.83E-03	75th percentile value					
Co-60	P	1	D	1.46E-01	75th percentile value					
Cs-137	P	1	D	7.82E-01	75th percentile value					
Eu-152	P	1	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-6.21	1.1	0.001	0.999	2.0E-03
Eu-154	P	1	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-6.21	1.1	0.001	0.999	2.0E-03
Gd-152	P	1	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-6.21	1.1	0.001	0.999	2.0E-03
H-3	P	1	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	1.57	1.1	0.001	0.999	4.8E+00
I-129	P	1	D	3.67E-02	75th percentile value					
Nb-94	P	1	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-4.61	1.1	0.001	0.999	1.0E-02
Ni-59	P	1	D	9.12E-02	75th percentile value					
Ni-63	P	1	D	9.12E-02	75th percentile value					
Np-237	P	1	D	3.67E-02	75th percentile value					
Pa-231	P	1	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-4.61	1.1	0.001	0.999	1.0E-02
Pb-210	P	1	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-5.52	0.9	0.001	0.999	4.0E-03
Po-210	P	1	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-6.90	0.9	0.001	0.999	1.0E-03
Pu-238	P	1	D	1.83E-03	75th percentile value					
Pu-239	P	1	D	1.83E-03	75th percentile value					
Pu-240	P	1	D	1.83E-03	75th percentile value					
Pu-241	P	1	D	1.83E-03	75th percentile value					
Pu-242	P	1	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-6.91	0.9	0.001	0.999	1.0E-03
Ra-226	P	1	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-3.22	0.9	0.001	0.999	4.0E-02
Ra-228	P	1	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-3.22	0.9	0.001	0.999	4.0E-02
Sr-90	P	1	D	5.90E-01	75th percentile value					

RESRAD Input Parameter Values for Soil DCGL Determination										
Parameter (unit)	Type	Priority	Treatment	Value/Distribution	Basis	Distribution's Statistical Parameters[d]				
						1	2	3	4	Mean/ Median
Tc-99	P	1	D	9.16E+00	75th percentile value					
Th-228	P	1	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-6.91	0.9	0.001	0.999	1.0E-03
Th-229	P	1	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-6.91	0.9	0.001	0.999	1.0E-03
Th-230	P	1	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-6.91	0.9	0.001	0.999	1.0E-03
Th-232	P	1	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-6.91	0.9	0.001	0.999	1.0E-03
U-233	P	1	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-6.21	0.9	0.001	0.999	2.0E-03
U-234	P	1	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-6.21	0.9	0.001	0.999	2.0E-03
U-235	P	1	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-6.21	0.9	0.001	0.999	2.0E-03
U-236	P	1	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-6.21	0.9	0.001	0.999	2.0E-03
U-238	P	1	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-6.21	0.9	0.001	0.999	2.0E-03
Meat Transfer Factors (pCi/kg)/(pCi/d)										
Ac-227	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-10.82	1.0	0.001	0.999	2.0E-05
Am-241	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-9.90	0.2	0.001	0.999	5.0E-05
Am-243	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-9.90	0.2	0.001	0.999	5.0E-05
C-14	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-3.47	1.0	0.001	0.999	3.1E-02
Cm-243	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-10.82	1.0	0.001	0.999	2.0E-05
Cm-244	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-10.82	1.0	0.001	0.999	2.0E-05
Cm-245	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-10.82	1.0	0.001	0.999	2.0E-05
Cm-246	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-10.82	1.0	0.001	0.999	2.0E-05
Co-60	P	2	D	5.86E-02	75th percentile value					
Cs-137	P	2	D	6.52E-02	75th percentile value					
Eu-152	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-6.21	1.0	0.001	0.999	2.0E-03
Eu-154	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-6.21	1.0	0.001	0.999	2.0E-03
Gd-152	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-6.21	1.0	0.001	0.999	2.0E-03
H-3	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-4.42	1.0	0.001	0.999	1.2E-02
I-129	P	2	D	5.23E-02	75th percentile value					
Nb-94	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-13.82	0.9	0.001	0.999	1.0E-06
Ni-59	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-5.30	0.9	0.001	0.999	5.0E-03
Ni-63	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-5.30	0.9	0.001	0.999	5.0E-03
Np-237	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-6.91	0.7	0.001	0.999	1.0E-03
Pa-231	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-12.21	1.0	0.001	0.999	5.0E-06

RESRAD Input Parameter Values for Soil DCGL Determination										
Parameter (unit)	Type	Priority	Treatment	Value/Distribution	Basis	Distribution's Statistical Parameters[d]				
						1	2	3	4	Mean/ Median
Po-210	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-5.30	0.7	0.001	0.999	5.0E-03
Pb-210	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-7.13	0.7	0.001	0.999	8.0E-04
Pu-238	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-9.21	0.2	0.001	0.999	1.0E-04
Pu-239	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-9.21	0.2	0.001	0.999	1.0E-04
Pu-240	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-9.21	0.2	0.001	0.999	1.0E-04
Pu-241	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-9.21	0.2	0.001	0.999	1.0E-04
Pu-242	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-9.21	0.2	0.001	0.999	1.0E-04
Ra-226	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-6.91	0.7	0.001	0.999	1.0E-03
Ra-228	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-6.91	0.7	0.001	0.999	1.0E-03
Sr-90	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-4.61	0.4	0.001	0.999	1.0E-02
Tc-99	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-9.21	0.7	0.001	0.999	1.0E-04
Th-228	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-9.21	1.0	0.001	0.999	1.0E-04
Th-229	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-9.21	1.0	0.001	0.999	1.0E-04
Th-230	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-9.21	1.0	0.001	0.999	1.0E-04
Th-232	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-9.21	1.0	0.001	0.999	1.0E-04
U-233	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-7.13	0.7	0.001	0.999	8.0E-04
U-234	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-7.13	0.7	0.001	0.999	8.0E-04
U-235	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-7.13	0.7	0.001	0.999	8.0E-04
U-236	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-7.13	0.7	0.001	0.999	8.0E-04
U-238	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-7.13	0.7	0.001	0.999	8.0E-04
Milk Transfer Factors (pCi/L)/(pCi/d)										
Ac-227	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-13.12	0.9	0.001	0.999	2.0E-06
Am-241	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-13.12	0.7	0.001	0.999	2.0E-06
Am-243	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-13.12	0.7	0.001	0.999	2.0E-06
C-14	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-4.4	0.9	0.001	0.999	1.2E-02
Cm-243	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-13.12	0.9	0.001	0.999	2.0E-06
Cm-244	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-13.12	0.9	0.001	0.999	2.0E-06
Cm-245	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-13.12	0.9	0.001	0.999	2.0E-06
Cm-246	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-13.12	0.9	0.001	0.999	2.0E-06
Co-60	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-6.21	0.7	0.001	0.999	2.0E-03
Cs-137	P	2	D	1.39E-02	75th percentile value					

RESRAD Input Parameter Values for Soil DCGL Determination										
Parameter (unit)	Type	Priority	Treatment	Value/Distribution	Basis	Distribution's Statistical Parameters[d]				
						1	2	3	4	Mean/ Median
Eu-152	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-9.72	0.9	0.001	0.999	6.0E-05
Eu-154	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-9.72	0.9	0.001	0.999	6.0E-05
Gd-152	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-9.72	0.9	0.001	0.999	6.0E-05
H-3	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-4.6	0.9	0.001	0.999	1.0E-02
I-129	P	2	D	1.39E-02	75th percentile value					
Nb-94	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-13.12	0.7	0.001	0.999	2.0E-06
Ni-59	P	2	D	3.21E-02	75th percentile value					
Ni-63	P	2	D	3.21E-02	75th percentile value					
Np-237	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-11.51	0.7	0.001	0.999	1.0E-05
Pa-231	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-12.21	0.9	0.001	0.999	5.0E-06
Po-210	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-7.82	0.7	0.001	0.999	4.0E-04
Pb-210	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-8.11	0.9	0.001	0.999	3.0E-04
Pu-238	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-13.82	0.5	0.001	0.999	1.0E-06
Pu-239	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-13.82	0.5	0.001	0.999	1.0E-06
Pu-240	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-13.82	0.5	0.001	0.999	1.0E-06
Pu-241	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-13.82	0.5	0.001	0.999	1.0E-06
Pu-242	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-13.82	0.5	0.001	0.999	1.0E-06
Ra-226	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-6.91	0.5	0.001	0.999	1.0E-03
Ra-228	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-6.91	0.5	0.001	0.999	1.0E-03
Sr-90	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-6.21	0.5	0.001	0.999	2.0E-03
Tc-99	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-6.91	0.7	0.001	0.999	1.0E-03
Th-228	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-12.21	0.9	0.001	0.999	5.0E-06
Th-229	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-12.21	0.9	0.001	0.999	5.0E-06
Th-230	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-12.21	0.9	0.001	0.999	5.0E-06
Th-232	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-12.21	0.9	0.001	0.999	5.0E-06
U-233	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-7.82	0.6	0.001	0.999	4.0E-04
U-234	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-7.82	0.6	0.001	0.999	4.0E-04
U-235	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-7.82	0.6	0.001	0.999	4.0E-04
U-236	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-7.82	0.6	0.001	0.999	4.0E-04
U-238	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C	-7.82	0.6	0.001	0.999	4.0E-04

RESRAD Input Parameter Values for Soil DCGL Determination										
Parameter (unit)	Type	Priority	Treatment	Value/Distribution	Basis	Distribution's Statistical Parameters[d]				
						1	2	3	4	Mean/ Median
Bioaccumulation Factors for Fish ((pCi/kg)/(pCi/L))										
Ac-227	P	2	S	Lognormal-n	NUREG/CR-6697, Att. C	2.7	1.1			1.5E+01
Am-241	P	2	S	Lognormal-n	NUREG/CR-6697, Att. C	3.4	1.1			3.0E+01
Am-243	P	2	S	Lognormal-n	NUREG/CR-6697, Att. C	3.4	1.1			3.0E+01
C-14	P	2	S	Lognormal-n	NUREG/CR-6697, Att. C	10.8	1.1			4.9E+04
Cm-243	P	2	S	Lognormal-n	NUREG/CR-6697, Att. C	3.4	1.1			3.0E+01
Cm-244	P	2	S	Lognormal-n	NUREG/CR-6697, Att. C	3.4	1.1			3.0E+01
Cm-245	P	2	S	Lognormal-n	NUREG/CR-6697, Att. C	3.4	1.1			3.0E+01
Cm-246	P	2	S	Lognormal-n	NUREG/CR-6697, Att. C	3.4	1.1			3.0E+01
Co-60	P	2	S	Lognormal-n	NUREG/CR-6697, Att. C	5.7	1.1			3.0E+02
Cs-137	P	2	S	Lognormal-n	NUREG/CR-6697, Att. C	7.6	0.7			2.0E+03
Eu-152	P	2	S	Lognormal-n	NUREG/CR-6697, Att. C	3.9	1.1			4.9E+01
Eu-154	P	2	S	Lognormal-n	NUREG/CR-6697, Att. C	3.9	1.1			4.9E+01
Gd-152	P	2	S	Lognormal-n	NUREG/CR-6697, Att. C	3.2	1.1			2.5E+01
H-3	P	2	S	Lognormal-n	NUREG/CR-6697, Att. C	0	0.1			1.0E+00
I-129	P	2	S	Lognormal-n	NUREG/CR-6697, Att. C	3.7	1.1			4.0E+01
Nb-94	P	2	S	Lognormal-n	NUREG/CR-6697, Att. C	5.7	1.1			3.0E+02
Ni-59	P	2	S	Lognormal-n	NUREG/CR-6697, Att. C	4.6	1.1			9.9E+01
Ni-63	P	2	S	Lognormal-n	NUREG/CR-6697, Att. C	4.6	1.1			9.9E+01
Np-237	P	2	S	Lognormal-n	NUREG/CR-6697, Att. C	3.4	1.1			3.0E+01
Pa-231	P	2	S	Lognormal-n	NUREG/CR-6697, Att. C	2.3	1.1			9.9E+00
Po-210	P	2	S	Lognormal-n	NUREG/CR-6697, Att. C	4.6	1.1			1.0E+01
Pb-210	P	2	S	Lognormal-n	NUREG/CR-6697, Att. C	5.7	1.1			3.0E+02
Pu-238	P	2	S	Lognormal-n	NUREG/CR-6697, Att. C	3.4	1.1			3.0E+01
Pu-239	P	2	S	Lognormal-n	NUREG/CR-6697, Att. C	3.4	1.1			3.0E+01
Pu-240	P	2	S	Lognormal-n	NUREG/CR-6697, Att. C	3.4	1.1			3.0E+01
Pu-241	P	2	S	Lognormal-n	NUREG/CR-6697, Att. C	3.4	1.1			3.0E+01
Pu-242	P	2	S	Lognormal-n	NUREG/CR-6697, Att. C	3.4	1.1			3.0E+01
Ra-226	P	2	S	Lognormal-n	NUREG/CR-6697, Att. C	3.9	1.1			4.9E+01
Ra-228	P	2	S	Lognormal-n	NUREG/CR-6697, Att. C	3.9	1.1			4.9E+01
Sr-90	P	2	S	Lognormal-n	NUREG/CR-6697, Att. C	4.1	1.1			6.0E+01

RESRAD Input Parameter Values for Soil DCGL Determination										
Parameter (unit)	Type	Priority	Treatment	Value/Distribution	Basis	Distribution's Statistical Parameters[d]				
						1	2	3	4	Mean/ Median
Tc-99	P	2	S	Lognormal-n	NUREG/CR-6697, Att. C	3	1.1			2.0E+01
Th-228	P	2	S	Lognormal-n	NUREG/CR-6697, Att. C	4.6	1.1			9.9E+01
Th-229	P	2	S	Lognormal-n	NUREG/CR-6697, Att. C	4.6	1.1			9.9E+01
Th-230	P	2	S	Lognormal-n	NUREG/CR-6697, Att. C	4.6	1.1			9.9E+01
Th-232	P	2	S	Lognormal-n	NUREG/CR-6697, Att. C	4.6	1.1			9.9E+01
U-233	P	2	S	Lognormal-n	NUREG/CR-6697, Att. C	2.3	1.1			1.0E+01
U-234	P	2	S	Lognormal-n	NUREG/CR-6697, Att. C	2.3	1.1			1.0E+01
U-235	P	2	S	Lognormal-n	NUREG/CR-6697, Att. C	2.3	1.1			1.0E+01
U-236	P	2	S	Lognormal-n	NUREG/CR-6697, Att. C	2.3	1.1			1.0E+01
U-238	P	2	S	Lognormal-n	NUREG/CR-6697, Att. C	2.3	1.1			1.0E+01
Bioaccumulation Factors for Crustacea/ Mollusks ((pCi/kg)/(pCi/L))										
Ac-227	P	3	D	1.00E+03	*User's Manual for RESRAD Version 6*, Appendix D	NR	NR	NR	NR	
Am-241	P	3	D	1.00E+03	*User's Manual for RESRAD Version 6*, Appendix D	NR	NR	NR	NR	
Am-243	P	3	D	1.00E+03	*User's Manual for RESRAD Version 6*, Appendix D	NR	NR	NR	NR	
C-14	P	3	D	9.10E+03	*User's Manual for RESRAD Version 6*, Appendix D	NR	NR	NR	NR	
Cm-243	P	3	D	1.00E+03	*User's Manual for RESRAD Version 6*, Appendix D	NR	NR	NR	NR	
Cm-244	P	3	D	1.00E+03	*User's Manual for RESRAD Version 6*, Appendix D	NR	NR	NR	NR	
Cm-245	P	3	D	1.00E+03	*User's Manual for RESRAD Version 6*, Appendix D	NR	NR	NR	NR	
Cm-246	P	3	D	1.00E+03	*User's Manual for RESRAD Version 6*, Appendix D	NR	NR	NR	NR	
Co-60	P	3	D	2.00E+02	*User's Manual for RESRAD Version 6*, Appendix D	NR	NR	NR	NR	

RESRAD Input Parameter Values for Soil DCGL Determination										
Parameter (unit)	Type	Priority	Treatment	Value/Distribution	Basis	Distribution's Statistical Parameters[d]				
						1	2	3	4	Mean/ Median
Cs-137	P	3	D	1.00E+02	*User's Manual for RESRAD Version 6*, Appendix D	NR	NR	NR	NR	
Eu-152	P	3	D	1.00E+03	*User's Manual for RESRAD Version 6*, Appendix D	NR	NR	NR	NR	
Eu-154	P	3	D	1.00E+03	*User's Manual for RESRAD Version 6*, Appendix D	NR	NR	NR	NR	
Gd-152	P	3	D	1.00E+03	*User's Manual for RESRAD Version 6*, Appendix D	NR	NR	NR	NR	
H-3	P	3	D	1.00E+00	*User's Manual for RESRAD Version 6*, Appendix D	NR	NR	NR	NR	
I-129	P	3	D	5.00E+00	*User's Manual for RESRAD Version 6*, Appendix D	NR	NR	NR	NR	
Nb-94	P	3	D	1.00E+02	*User's Manual for RESRAD Version 6*, Appendix D	NR	NR	NR	NR	
Ni-59	P	3	D	1.00E+02	*User's Manual for RESRAD Version 6*, Appendix D	NR	NR	NR	NR	
Ni-63	P	3	D	1.00E+02	*User's Manual for RESRAD Version 6*, Appendix D	NR	NR	NR	NR	
Np-237	P	3	D	4.00E+02	*User's Manual for RESRAD Version 6*, Appendix D	NR	NR	NR	NR	
Pa-231	P	3	D	1.10E+02	*User's Manual for RESRAD Version 6*, Appendix D	NR	NR	NR	NR	
Pb-210	P	3	D	1.00E+02	*User's Manual for RESRAD Version 6*, Appendix D	NR	NR	NR	NR	
Po-210	P	3	D	2.00E+04	*User's Manual for RESRAD Version 6*, Appendix D	NR	NR	NR	NR	

RESRAD Input Parameter Values for Soil DCGL Determination										
Parameter (unit)	**Type**	**Priority**	**Treatment**	**Value/Distribution**	**Basis**	**Distribution's Statistical Parameters[d]**				
						1	**2**	**3**	**4**	**Mean/ Median**
Pu-238	P	3	D	1.00E+02	*User's Manual for RESRAD Version 6*, Appendix D	NR	NR	NR	NR	
Pu-239	P	3	D	1.00E+02	*User's Manual for RESRAD Version 6*, Appendix D	NR	NR	NR	NR	
Pu-240	P	3	D	1.00E+02	*User's Manual for RESRAD Version 6*, Appendix D	NR	NR	NR	NR	
Pu-241	P	3	D	1.00E+02	*User's Manual for RESRAD Version 6*, Appendix D	NR	NR	NR	NR	
Pu-242	P	3	D	1.00E+02	*User's Manual for RESRAD Version 6*, Appendix D	NR	NR	NR	NR	
Ra-226	P	3	D	2.50E+02	*User's Manual for RESRAD Version 6*, Appendix D	NR	NR	NR	NR	
Ra-228	P	3	D	2.50E+02	*User's Manual for RESRAD Version 6*, Appendix D	NR	NR	NR	NR	
Sr-90	P	3	D	1.00E+02	*User's Manual for RESRAD Version 6*, Appendix D	NR	NR	NR	NR	
Tc-99	P	3	D	5.00E+00	*User's Manual for RESRAD Version 6*, Appendix D	NR	NR	NR	NR	
Th-228	P	3	D	5.00E+02	*User's Manual for RESRAD Version 6*, Appendix D	NR	NR	NR	NR	
Th-229	P	3	D	5.00E+02	*User's Manual for RESRAD Version 6*, Appendix D	NR	NR	NR	NR	
Th-230	P	3	D	5.00E+02	*User's Manual for RESRAD Version 6*, Appendix D	NR	NR	NR	NR	
Th-232	P	3	D	5.00E+02	*User's Manual for RESRAD Version 6*, Appendix D	NR	NR	NR	NR	

RESRAD Input Parameter Values for Soil DCGL Determination										
Parameter (unit)	Type	Priority	Treatment	Value/Distribution	Basis	Distribution's Statistical Parameters[d]				
						1	2	3	4	Mean/ Median
U-233	P	3	D	6.00E+01	*User's Manual for RESRAD Version 6*, Appendix D	NR	NR	NR	NR	
U-234	P	3	D	6.00E+01	*User's Manual for RESRAD Version 6*, Appendix D	NR	NR	NR	NR	
U-235	P	3	D	6.00E+01	*User's Manual for RESRAD Version 6*, Appendix D	NR	NR	NR	NR	
U-236	P	3	D	6.00E+01	*User's Manual for RESRAD Version 6*, Appendix D	NR	NR	NR	NR	
U-238	P	3	D	6.00E+01	*User's Manual for RESRAD Version 6*, Appendix D	NR	NR	NR	NR	
Graphics Parameters										
Number of points				32	RESRAD Default	NR	NR	NR	NR	
Spacing				log	RESRAD Default	NR	NR	NR	NR	
Time integration parameters										
Maximum number of points for dose				17	RESRAD Default	NR	NR	NR	NR	

[a] P = physical, B = behavioral, M = metabolic; (see NUREG/CR-6697, Attachment B, Table 4.)
[b] 1 = high-priority parameter, 2 = medium-priority parameter, 3 = low-priority parameter (see NUREG/CR-6697, Attachment B, Table 4.1)
[c] D = deterministic, S = stochastic
[d] <u>Distributions Statistical Parameters</u>:

Lognormal-n: 1= mean, 2 = standard deviation
Bounded lognormal-n: 1= mean, 2 = standard deviation, 3 = minimum, 4 = maximum
Truncated lognormal-n: 1= mean, 2 = standard deviation, 3 = lower quantile, 4 = upper quantile
Bounded normal: 1 = mean, 2 = standard deviation, 3 = minimum, 4 = maximum
Triangular: 1 = minimum, 2 = maximum, 3 = most likely
Uniform: 1 = minimum, 2 = maximum

Appendix J
Soil DCGL Results

Table J-1: Soil DCGL Results

ROC	POM Dose[a] (mrem/y)	DCGL (pCi/g)
Am-241	9.68E-01	2.58E+01
C-14	3.97E+00	6.30E+00
Cm-243	8.61E-01	2.90E+01
Cm-244	5.20E-01	4.81E+01
Cm-245	1.41E+00	1.78E+01
Cm-246	9.70E-01	2.58E+01
Co-60	6.55E+00	3.82E+00
Cs-137	3.15E+00	7.93E+00
Eu-152	2.48E+00	1.01E+01
Eu-154	2.66E+00	9.40E+00
H-3	3.65E-02	6.86E+02
I-129	5.17E+00	4.83E+00
Nb-94	3.51E+00	7.13E+00
Ni-59	1.27E-02	1.97E+03
Ni-63	3.45E-02	7.24E+02
Np-237	2.25E+01	1.11E+00
Pu-238	8.43E-01	2.97E+01
Pu-239	9.36E-01	2.67E+01
Pu-240	9.36E-01	2.67E+01
Pu-241	2.90E-02	8.61E+02
Sr-90	1.66E+01	1.51E+00
Tc-99	2.02E+00	1.24E+01

[a] POM Dose = peak of the mean dose

Appendix K
Input for Building Surface Area Factors

Table 1: RESRAD-Build Input Parameter Values for Building Surface Area Factors

Parameter	Type[a]	Nuclide	Treatment[b]	Value	Reference Source
Exposure Duration (d)	B	All	D	365.25	NUREG/CR-5512, Vol.3,section 5.2.1
Indoor Fraction	B	All	D	0.267	NUREG/CR-5512, Vol.3,section 5.2.2.9
Evaluation Time (y)	P	All	D	1, 5 (1, 5, 10, 25, 50, 100 for Pu-241)	Use of 1y provides doses at t=0y and t=1y; multiple input applied to verify time of peak dose
Number of Rooms	P	All	D	1	NUREG/CR-5512
Deposition Velocity (m/s)	P	Am-241, Cm-243, Cm-244, Cm-245, Cm-246, Np-237, Pu-238, Pu-239, Pu-240, and Pu-241	D	1.5179E-05	50th percentile value
		C-14, Co-60, Cs-137, Eu-152, Eu-154, H-3, I-129, Nb-94, Ni-59, Ni-63, Sr-90, and Tc-99	D	4.78217E-04	75th percentile value
Resuspension Rate (s^{-1})	P	Am-241, Cm-243, Cm-244, Np-237, Pu-238, Pu-239, Pu-240, and Pu-241	D	1.79444E-08	50th percentile value
		C-14, Cm-245, Cm-246, Co-60, Cs-137, Eu-152, Eu-154, H-3, I-129, Nb-94, Ni-59, Ni-63, Sr-90, and Tc-99	D	6.70403E-10	25th percentile value
Air Exchange Rate for Room (h^{-1})	P	All	D	8.35789E-01	25th percentile value
Room Area (m^2)	P	All	D	47.77	Humboldt Bay-specific data (General Office Building)
Room Height (m)	P	All	D	2.49	Humboldt Bay-specific data (General Office Building)
Time Fraction	B	All	D	1	NUREG/CR-5512
Inhalation Rate (m^3/d)	M	All	D	45.6	Conservative inhalation rate for moderate to heavy activities - NUREG/CR-6697, Attachment C, section 5.1; NUREG/CR-5512, vol. 3, section 5.3.4
Indirect Ingestion Rate (m^2/h)	B	All	D	0.0001	NUREG/CR6755

Table 1: RESRAD-Build Input Parameter Values for Building Surface Area Factors

Parameter	Type[a]	Nuclide	Treatment[b]	Value	Reference Source
Receptor Location	B	All	D	4.24, 2.82,1.0	NUREG/CR-5512; site-specific room dimensions (General Office Building)
Shielding Thickness (cm)	P	All	D	0	Site-specific model-no shielding assumed
Shielding Density (g/cm^3)	P	All	D	2.4	RESRAD-Build default value for concrete – not used in DCGL calculations
Shielding Material	P	All	D	concrete	Default input – not used in DCGL calculations
Number of Sources	P	All		1	Various size areas
External Dose Conversion Factor, (mrem/y per pCi/cm^2)	M	All	D	RESRAD-Build Library	FGR12
Air Submersion Dose Conversion Factor, (mrem/y per pCi/m^3)	M	All	D	RESRAD-Build Library	FGR12
Inhalation Dose Conversion Factor, (mrem/pCi)	M	All	D	RESRAD-Build Library	FGR11
Ingestionl Dose Conversion Factor, (mrem/pCi)	M	All	D	RESRAD-Build Library	FGR11
Source 1: Floor					
Type	P	All		area	NUREG/CR-5512
Direction	P	All		Z	NUREG/CR-5512
Location of Center of Source: x,y,z (m)	P	All	D	4.24, 2.82, 0.0	site-specific data – center of floor based on dimensions for General Office Building room
Source length X-axis (m)	P	All	D	8.47	Not used in calculations
Source length Y-axis (m)	P	All	D	5.64	Not used in calculations
Area (m^2)	P	All	D	100, 50, 10, 8, 6, 5, 4, 3, 2, 1	Recommended size for Class 1 structure used as upper limit for area source size
Air Fraction	B	H-3 All others	D	1.0 0.07	NUREG/CR-6697, Att. C Section 8.6
Direct Ingestion (h^{-1})	B	All	D	9.32E-7	NUREG/CR6755, A.3.3

Table 1: RESRAD-Build Input Parameter Values for Building Surface Area Factors					
Parameter	Type[a]	Nuclide	Treatment[b]	Value	Reference Source
Removable Fraction	P	All	D	0.1	NUREG-1727, Table C.7.1; NUREG/CR-6755, section 3.5
Time for Source Removal (d)	P	C-14, Co-60, Cs-137, Eu-152, Eu-154, I-129, and Nb-94	D	52695.2	75th percentile value
		Sr-90 and Tc-99	D	33056.9	50th percentile value
		Am-241, Cm-243, Cm-244, Cm-245, Cm-246, H-3, Ni-59, Ni-63, Np-237, Pu-238, Pu-239, Pu-240, and Pu-241	D	18249.3	25Th percentile value
Radionuclide Concentration (pCi/m^2)	P	All	D	1.0	-

[a] P = physical, B = behavioral, M = metabolic; (see NUREG/CR-6697, Attachment B, Table 4.)
[b] D = deterministic

Appendix L
Building Surface Area Factors

	Area Factor Value:										
(m^2)	Am-241	C-14	Cm-243	Cm-244	Cm-245	Cm-246	Co-60	Cs-137	Eu-152	Eu-154	H-3
1	9.7E+01	9.7E+01	8.9E+01	1.0E+02	3.9E+01	6.4E+01	1.3E+01	1.5E+01	1.3E+01	1.3E+01	1.0E+02
2	4.9E+01	4.9E+01	4.5E+01	5.0E+01	2.1E+01	3.3E+01	7.2E+00	8.2E+00	7.2E+00	7.2E+00	5.0E+01
3	3.3E+01	3.3E+01	3.0E+01	3.3E+01	1.5E+01	2.3E+01	5.3E+00	6.0E+00	5.3E+00	5.3E+00	3.3E+01
4	2.5E+01	2.4E+01	2.3E+01	2.5E+01	1.2E+01	1.8E+01	4.3E+00	4.9E+00	4.3E+00	4.3E+00	2.5E+01
5	2.0E+01	2.0E+01	1.9E+01	2.0E+01	9.9E+00	1.5E+01	3.7E+00	4.2E+00	3.7E+00	3.7E+00	2.0E+01
6	1.6E+01	1.6E+01	1.6E+01	1.7E+01	8.6E+00	1.2E+01	3.3E+00	3.8E+00	3.3E+00	3.3E+00	1.7E+01
8	1.2E+01	1.2E+01	1.2E+01	1.2E+01	6.9E+00	9.7E+00	2.8E+00	3.2E+00	2.8E+00	2.8E+00	1.2E+01
10	9.9E+00	9.9E+00	9.5E+00	1.0E+01	5.9E+00	8.0E+00	2.5E+00	2.8E+00	2.5E+00	2.5E+00	1.0E+01
50	2.0E+00	2.0E+00	2.0E+00	2.0E+00	1.8E+00	1.9E+00	1.2E+00	1.3E+00	1.2E+00	1.2E+00	2.0E+00
100	1.0E+00	1.0E+00	1.0E+00	1.0E+00	1.0E+00	1.0E+00	1.0E+00	1.0E+00	1.0E+00	1.0E+00	1.0E+00
	Area Factor Value:										
(m^2)	I-129	Nb-94	Ni-59	Ni-63	Np-237	Pu-238	Pu-239	Pu-240	Pu-241	Sr-90	Tc-99
1	6.5E+01	1.3E+01	1.0E+02	1.0E+02	8.9E+01	1.0E+02	1.0E+02	1.0E+02	9.8E+01	9.0E+01	8.7E+01
2	3.4E+01	7.2E+00	5.0E+01	5.0E+01	4.5E+01	5.0E+01	5.0E+01	5.0E+01	4.9E+01	4.5E+01	4.4E+01
3	2.3E+01	5.3E+00	3.3E+01	3.3E+01	3.0E+01	3.3E+01	3.3E+01	3.3E+01	3.3E+01	3.0E+01	3.0E+01
4	1.8E+01	4.3E+00	2.5E+01	2.5E+01	2.3E+01	2.5E+01	2.5E+01	2.5E+01	2.5E+01	2.3E+01	2.3E+01
5	1.5E+01	3.7E+00	2.0E+01	2.0E+01	1.8E+01	2.0E+01	2.0E+01	2.0E+01	2.0E+01	1.9E+01	1.8E+01
6	1.3E+01	3.3E+00	1.7E+01	1.7E+01	1.6E+01	1.7E+01	1.7E+01	1.7E+01	1.7E+01	1.6E+01	1.5E+01
8	9.7E+00	2.8E+00	1.3E+01	1.2E+01	1.2E+01	1.3E+01	1.2E+01	1.2E+01	1.2E+01	1.2E+01	1.2E+01
10	8.0E+00	2.5E+00	1.0E+01	1.0E+01	9.4E+00	1.0E+01	1.0E+01	1.0E+01	9.9E+00	9.5E+00	9.4E+00
50	1.9E+00	1.2E+00	2.0E+00	2.0E+00	2.0E+00	2.0E+00	2.0E+00	2.0E+00	2.0E+00	2.0E+00	2.0E+00
100	1.0E+00	1.0E+00	1.0E+00	1.0E+00	1.0E+00	1.0E+00	1.0E+00	1.0E+00	1.0E+00	1.0E+00	1.0E+00

Appendix M
Input for Soil Area Factors

The input parameters for the soil area factor (AF) calculations are the same as those in Appendix I with the following exceptions documented in Reference 15.

The resident farmer scenario assumes a reasonably conservative scenario for establishing DCGL values for residual radioactivity in soil. The same scenario is assumed for the AF calculations.

Areas of difference in input values are explained in the following discussion.

1. Contaminated Fractions – Food Pathways

As the size of the contaminated area (A) varies, the fraction of the total food consumed by the receptor grown in the contaminated area will also vary. The fraction of the food supply grown in the contaminated is referred to as a "contaminated fraction." Accordingly, with the decrease in the size of the contaminated area, a decrease in the values for the contaminated fraction of plant food ingested (FPLANT), the contaminated fraction of meat ingested (FMEAT), and contaminated fraction of milk ingested (FMILK) will also result.

Adjustments to FPLANT were made based on information in the RESRAD User's Manual [Reference 10]. The following shows how the RESRAD code determines the contamination fraction (FA_3) for plants:

FA_3 = A/2,000 when 0 < A < 1,000 m^2

FA_3 = 0.5 when A > 1,000 m^2

The above equations from the RESRAD User's Manual were adjusted to vary the input values for FPLANT, FMEAT, and FMILK in order to remain consistent with the approach used for the soil DCGLs (Referance 3.1). The soil DCGLs were developed using a value of 1.0 for each of the contamination fractions, which incorporated the assumption that 100 percent of plant food, meat, and milk is obtained from an area equal to 30,000 m^2 (the size of the contaminated zone at the Humboldt Bay site). As applied to plants, use of a FA value equal to 1.0 in the calculation of the soil DCGLs effectively multiplied Equation D.5 by a factor of 2 to yield a FA value of 1.0 for areas equal to or greater than 1,000 m^2

Input values for FPLANT used in this calculation are determined as follows:

FPLANT = A/1,000 when A< l,000 m^2

FPLANT = 1.0 when A > 1,000 m^2

In addition, the following information from the RESRAD User Manual (Referance 3.5) shows how the RESRAD code determines the contaminated fractions for meat (FA_4) and milk (FA_5):

$FA_{4\&5}$ = A/20,000 when 0 < A < 20,000 m^2

$FA_{4\&5}$ = 1.0 when A > 20,000 m^2

The above relationships were used to vary input values for FMEAT and FMILK in order to remain consistent with the approach used for the soil DCGLs [Reference 13]. Table M-1 shows the values for FPLANT, FMEAT, and FMILK as a function of the area of the contaminated zone.

2. Size of the Contaminated Zone

Another RESRAD input parameter that is influenced by changes in the size of the contaminated zone is the length parallel to aquifer flow (LCZPAQ). As the area of the contaminated zone decreases, the value of LCZPAQ will also decrease. Because the contaminated zone is assumed circular in shape, the value for LCZPAQ is equal to the diameter of the circle:

Area of a Circle, $A = \pi r^2$

Rearranging and substituting for $r = \frac{LCZPAQ}{2}$

$$\text{LCZPAQ (m)} = 2\sqrt{\frac{A}{\Pi}}$$

Table M-1 also shows the values for LCZPAQ as a function of the area of the contaminated zone.

Table M-1: Contaminated Fractions as a Function of the Size of the Contaminated Zone

RESRAD Parameter	Input Value				
Contaminated Zone (m^2)	30,0000[a]	2,000	1,000	500	100
LCZPAQ (m)	195[a]	50	36	25	11
FPLANT	1.0[a]	1.0	1.0	0.5	0.10
FMEAT	1.0[a]	0.1	0.05	0.025	0.005
FMILK	1.0[a]	0.1	0.05	0.025	0.005
Contaminated Zone (m^2)	50	10	5	1	
LCZPAQ (m)	8.0	3.6	2.5	1.1	
FPLANT	0.05	0.01	0.005	0.001	
FMEAT	0.0025	0.0005	0.00025	0.00005	
FMILK	0.0025	0.0005	0.00025	0.00005	

[a] Parameter value for DCGL modeling.

Appendix N
Soil Area Factors

	Area Factor for Area Contaminated Zone (m^2):							
ROC	2000	1000	500	100	50	10	5	1
Am-241	1.0E+00	1.0E+00	2.0E+00	8.7E+00	1.6E+01	4.9E+01	7.7E+01	1.9E+02
C-14	1.0E+00	1.5E+00	4.0E+00	4.2E+01	1.1E+02	1.0E+03	2.5E+03	1.8E+04
Cm-243	1.0E+00	1.0E+00	1.6E+00	3.4E+00	4.3E+00	7.3E+00	1.1E+01	3.2E+01
Cm-244	1.0E+00	1.0E+00	2.0E+00	9.7E+00	1.9E+01	7.6E+01	1.2E+02	2.8E+02
Cm-245	1.0E+00	1.0E+00	1.9E+00	6.2E+00	9.2E+00	1.9E+01	3.0E+01	8.1E+01
Cm-246	1.0E+00	1.0E+00	2.0E+00	9.7E+00	1.9E+01	7.6E+01	1.3E+02	2.8E+02
Co-60	1.0E+00	1.0E+00	1.1E+00	1.3E+00	1.4E+00	2.2E+00	3.3E+00	1.0E+01
Cs-137	1.0E+00	1.0E+00	1.3E+00	1.7E+00	1.9E+00	3.0E+00	4.5E+00	1.4E+01
Eu-152	1.0E+00	1.0E+00	1.0E+00	1.1E+00	1.3E+00	2.0E+00	3.0E+00	9.1E+00
Eu-154	1.0E+00	1.0E+00	1.0E+00	1.2E+00	1.3E+00	2.0E+00	3.0E+00	9.2E+00
H-3	1.0E+00	1.1E+00	2.1E+00	1.0E+01	2.1E+01	1.0E+02	2.0E+02	9.3E+02
I-129	1.0E+00	1.1E+00	2.2E+00	1.1E+01	2.2E+01	9.9E+01	1.9E+02	8.3E+02
Nb-94	1.0E+00	1.0E+00	1.0E+00	1.2E+00	1.3E+00	2.0E+00	3.0E+00	9.0E+00
Ni-59	1.0E+00	1.2E+00	2.3E+00	1.2E+01	2.3E+01	1.2E+02	2.3E+02	1.2E+03
Ni-63	1.0E+00	1.2E+00	2.3E+00	1.2E+01	2.3E+01	1.2E+02	2.3E+02	1.2E+03
Np-237	1.0E+00	1.0E+00	2.0E+00	9.0E+00	1.6E+01	5.6E+01	9.8E+01	3.5E+02
Pu-238	1.0E+00	1.0E+00	2.0E+00	9.7E+00	1.9E+01	7.6E+01	1.3E+02	2.8E+02
Pu-239	1.0E+00	1.0E+00	2.0E+00	9.7E+00	1.9E+01	7.6E+01	1.3E+02	2.9E+02
Pu-240	1.0E+00	1.0E+00	2.0E+00	9.7E+00	1.9E+01	7.6E+01	1.3E+02	2.9E+02
Pu-241	1.0E+00	1.0E+00	2.0E+00	8.8E+00	1.6E+01	4.9E+01	7.8E+01	1.9E+02
Sr-90	1.0E+00	1.0E+00	2.0E+00	1.0E+01	2.0E+01	9.9E+01	2.0E+02	9.6E+02
Tc-99	1.0E+00	1.0E+00	2.0E+00	1.0E+01	2.0E+01	1.0E+02	2.0E+02	1.0E+03