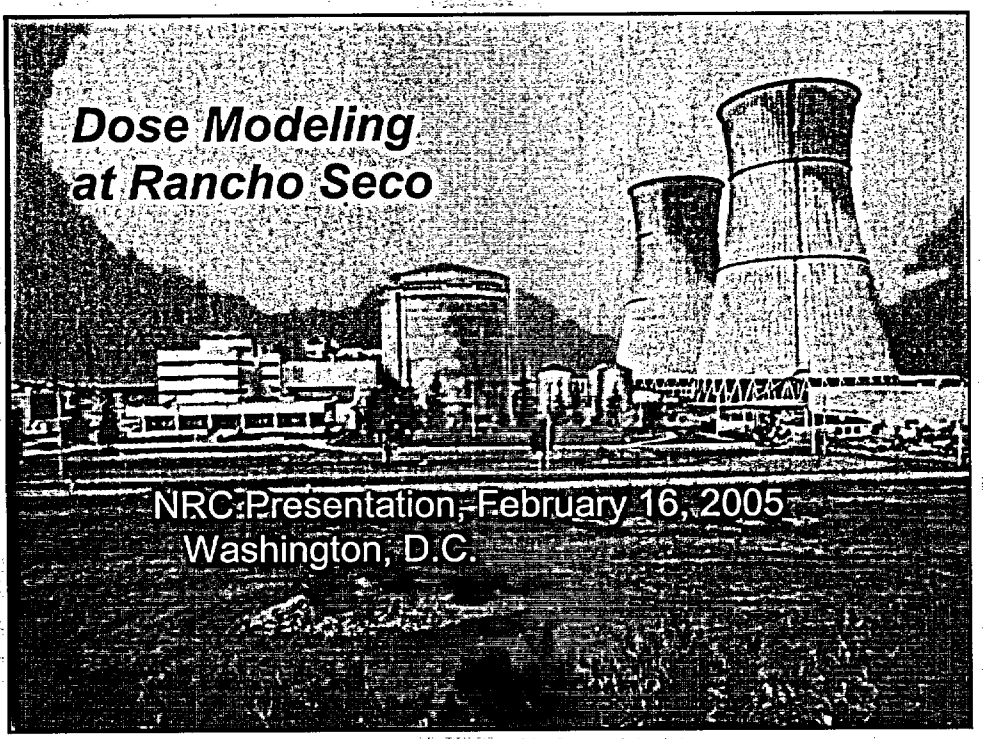
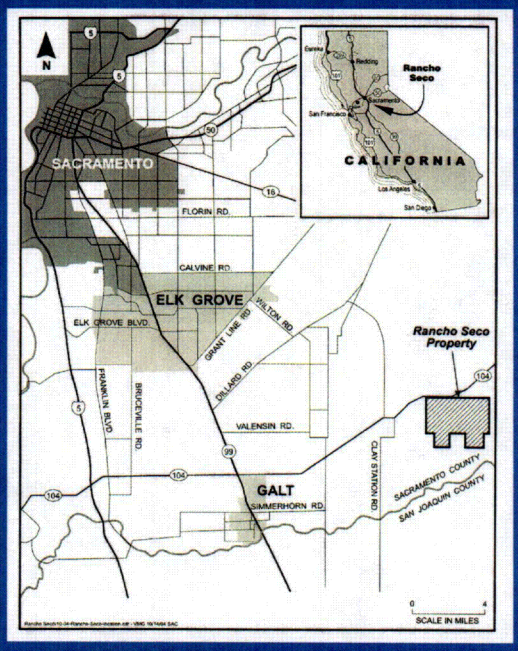
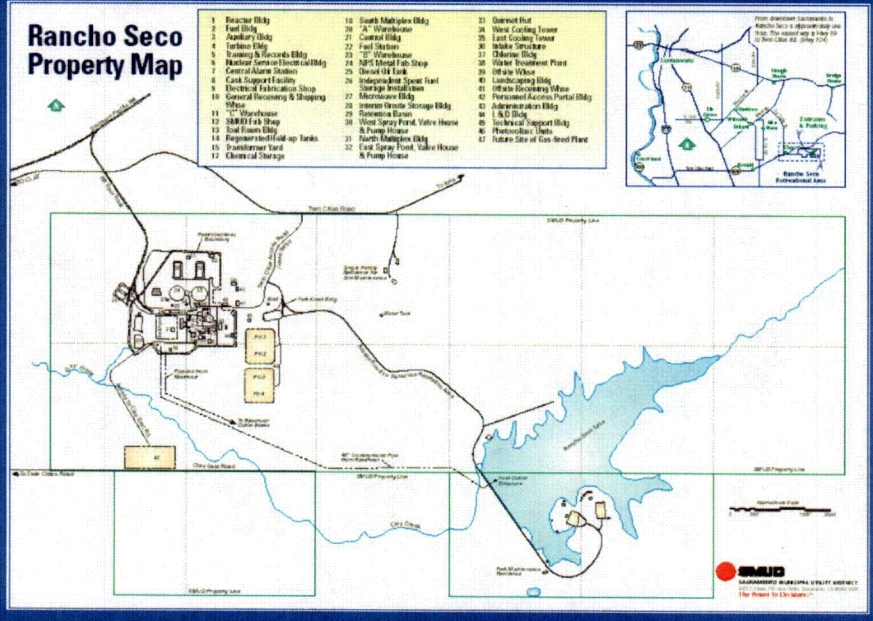


Rancho Seco Site Overview

- Located in SE Sacramento County, 25 miles from the state capital
  - Rural area used for grape production, row and silage crops, and cattle grazing
  - Current population is 5,400 persons with a 2025 estimated population of 6,520
- 2,480 acre owner-controlled area
- SMUD will retain site ownership


N
SACRAMENTO
FLORIN RD.
CALVINE RD.
ELK GROVE
ELK GROVE BLVD.
GRANT LINE RD.
HILTON RD.
DILLARD RD.
FRANKLIN BLVD.
BRUCEVILLE RD.
VALENSIN RD.
GALT
SIMMERHORN RD.
CLAY STATION RD.
SACRAMENTO COUNTY
SAN JOAQUIN COUNTY
Rancho Seco Property
Rancho Seco
CALIFORNIA
SCALE IN MILES

3


Rancho Seco Property Map
1 Reactor Bldg
2 Fuel Bldg
3 Auxiliary Bldg
4 Turbine Bldg
5 Training & Records Bldg
6 Nuclear Service Electrical Bldg
7 Central Alarm Station
8 Cask Support Facility
9 Electrical Fabrication Shop
10 General Receiving & Shipping Wkse
11 "C" Warehouse
12 SMUD Fab Shop
13 Tool Room Bldg
14 Regenerated Acid-up Tanks
15 Transformer Yard
17 Chemical Storage
18 South Multiplex Bldg
20 "A" Warehouse
21 Control Bldg
22 Fuel Station
23 "B" Warehouse
24 NPS Metal Fab Shop
25 Diesel Oil Tank
26 Independent Spent Fuel Storage Installation
27 Microwave Bldg
28 Interim Waste Storage Bldg
29 Reservoir Basin
30 West Spray Pond, Valve House & Pump House
31 North Multiplex Bldg
32 East Spray Pond, Valve House & Pump House
33 Quonset Hut
34 West Cooling Tower
35 East Cooling Tower
36 Intake Structure
37 Chlorine Bldg
38 Water Treatment Plant
39 Offsite Wkse
40 Landscaping Bldg
41 Offsite Receiving Wkse
42 Personnel Access Portal Bldg
43 Administration Bldg
44 I & D Bldg
45 Technical Support Bldg
46 Photovoltaic Units
47 Future Site of Gas-fired Plant
Rancho Seco Recreational Area
Twin Cities Road
Clay Creek
SMUD

4

C01

Steps In RSNGS Dose Modeling

- Perform a source term abstraction,
- Develop an exposure scenario,
- Derive a mathematical model based on hydrogeological knowledge,
- Derive single nuclide soil $DCGL_W$s,
- Derive single nuclide structural surface $DCGL_W$s, and
- Derive soil and surface area factors.

5

Steps to Source Term Abstraction

- Derivation of a site-specific potential radionuclide suite:
  - Theoretical PWR radionuclides were identified based on NUREG/CR–3474, NUREG–0130 and NUREG/CR–4289 guidance + ORIGEN calcs
  - Incorporated past 10 CFR 61 characterization
  - 54 theoretical radionuclides narrowed to 26 RSNGS site-specific potential radionuclides:
    - Radionuclides with half-lives <2 years were excluded,
    - Low relative abundance radionuclides discounted, and
    - Naturally occurring radionuclides indistinguishable from background were excluded.

6

Source Term Abstraction, Cont.

- Characterization samples were collected for analysis of potential radionuclides:
  - Impacted area soil samples,
  - Concrete cores to identify depth of penetration and volume activation products, and
  - Concrete scabble samples to identify surface contamination.
- Only 6 radionuclides were identified in soil
- All 26 radionuclides were identified in/on concrete

Site-Specific Suite of Radionuclides for Use at RSNGS

Radionuclide	Half Life (Years)	Decay Mode	Radionuclide	Half Life (Years)	Decay Mode
H-3	1.23E+01	β	Cs-137	3.02E+01	β
*C-14	5.73E+03	β	*Pm-147	2.62E+00	β
Na-22	2.60E+00	β^+, γ	Eu-152	1.36E+01	β, γ
*Fe-55	2.70E+00	γ	Eu-154	8.80E+00	β, γ
*Ni-59	7.50E+04	γ	Eu-155	4.96E+00	β, γ
Co-60	5.27E+00	β, γ	*Np-237	2.14E+6	α, γ
*Ni-63	1.00E+02	β	*Pu-238	8.78E+01	α, γ
*Sr-90	2.86E+01	β	*Pu-239	2.41E+04	α, γ
Nb-94	2.03E+04	β, γ	*Pu-240	6.60E+03	α, γ
*Tc-99	2.13E+05	β, γ	*Pu-241	1.44E+01	β
Ag-108m	1.27E+02	γ	Am-241	4.32E+02	α, γ
Sb-125	2.77E+00	β, γ	*Pu-242	3.76E+05	α, γ
Cs-134	2.06E+00	β, γ	*Cm-244	1.81E+01	α, γ

α – Alpha decay
β – Beta decay
β^+ – Positron decay
γ – Gamma decay

Source Term Abstraction, Cont.

- Dose modeling objective:
  - Derive single nuclide DCGLs only for detected radionuclides
  - Account for non-detected site-specific potential radionuclides when comparing to annual dose limit

Exposure Scenario Development

- Large site – 2,480 acres
  - ~147-acre Impacted Area including:
    - 87-acre fence-enclosed Industrial Area,
    - Plant liquid effluent pathway, and
    - Industrial Area storm drain outfall.
  - 560-acre reservoir and recreation area
  - 50-acre photo-voltaic electrical generating station
  - 0.9-acre, 10 CFR Part 72 licensed ISFSI
  - 30-acre natural gas-fired plant under construction
  - Six 220/230-kV transmission lines and switchyard with major interties to the Western Grid

Scenario Development, Cont.

- Long-term SMUD expectation to maintain site for electrical generation and transmission
- SMUD intends to retain site ownership through the foreseeable future

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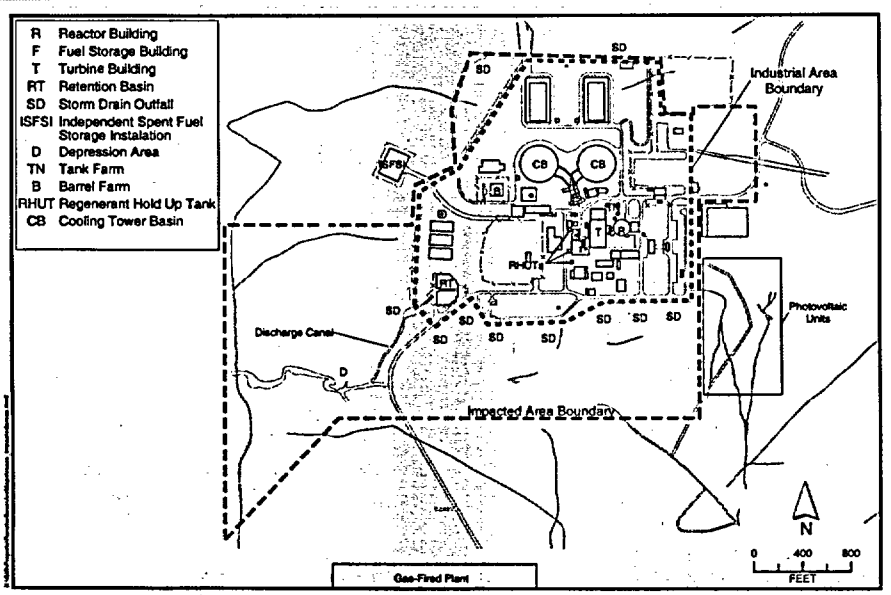

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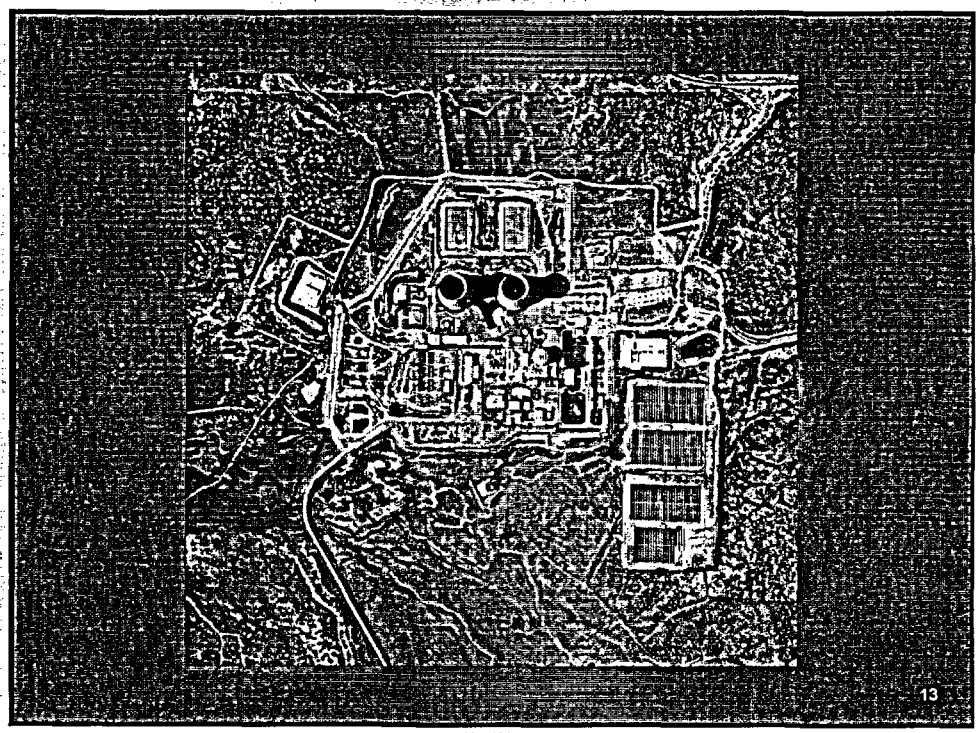
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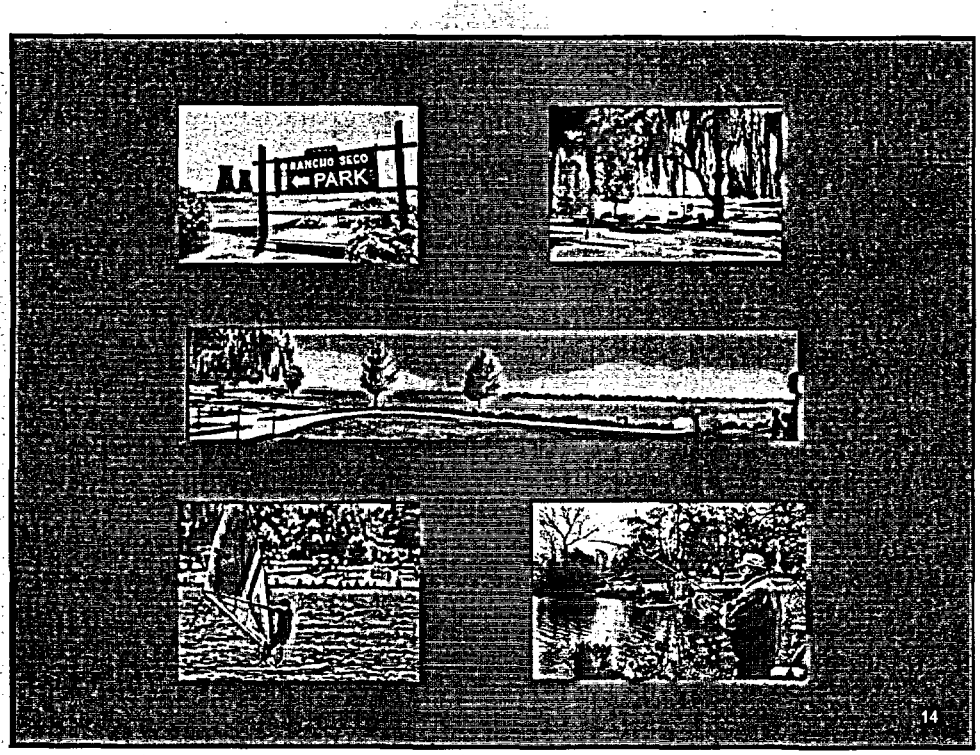
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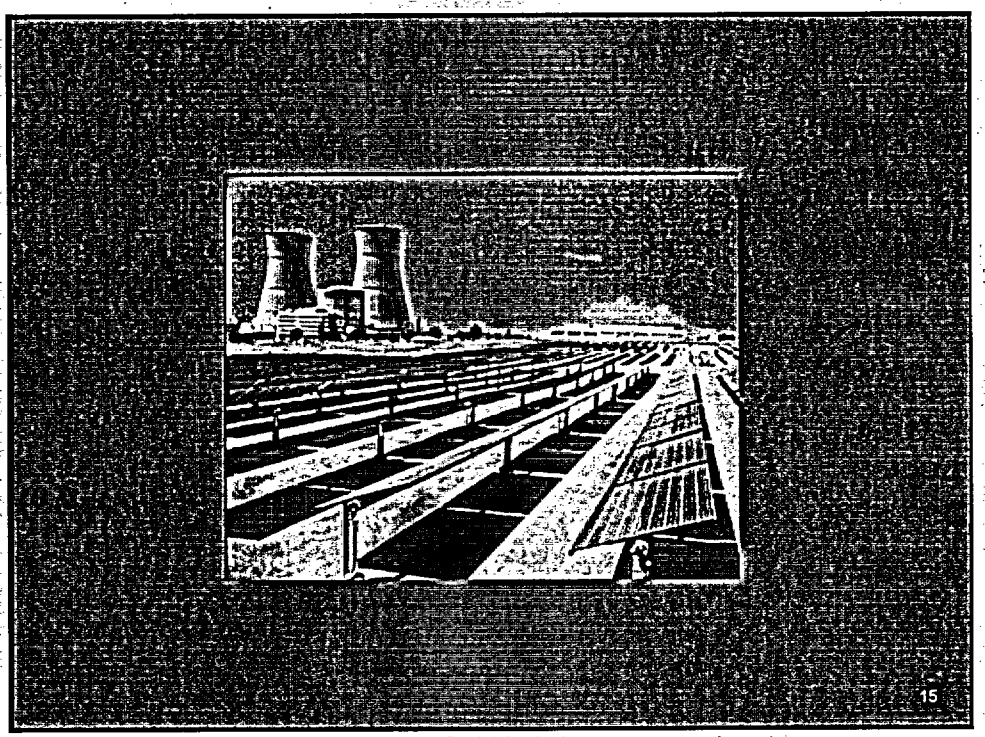
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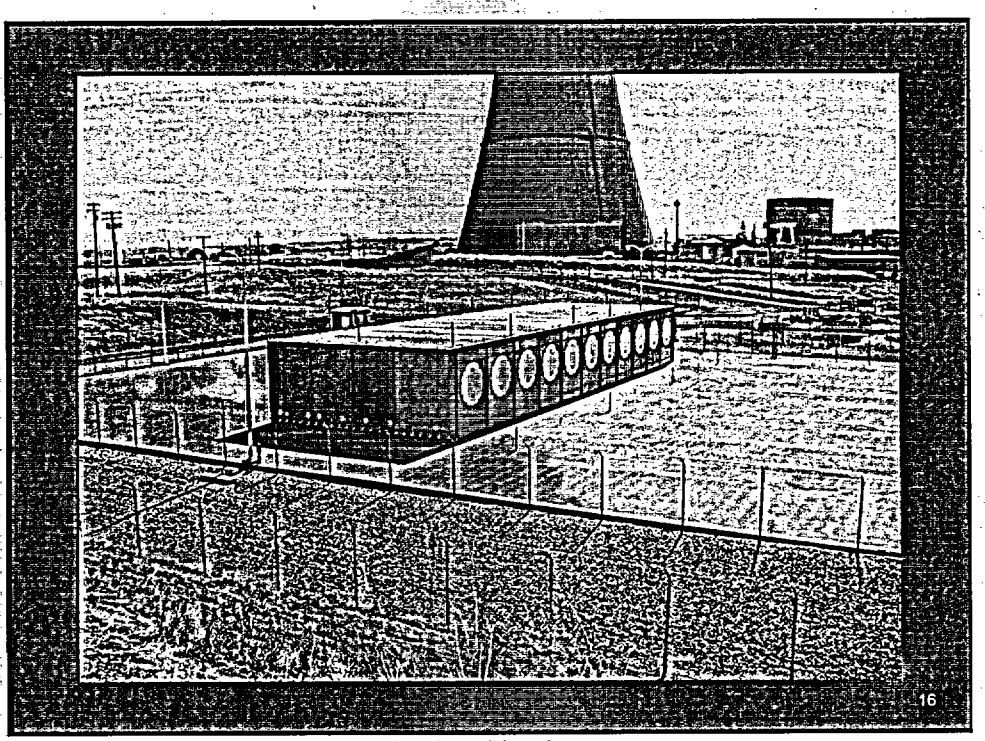
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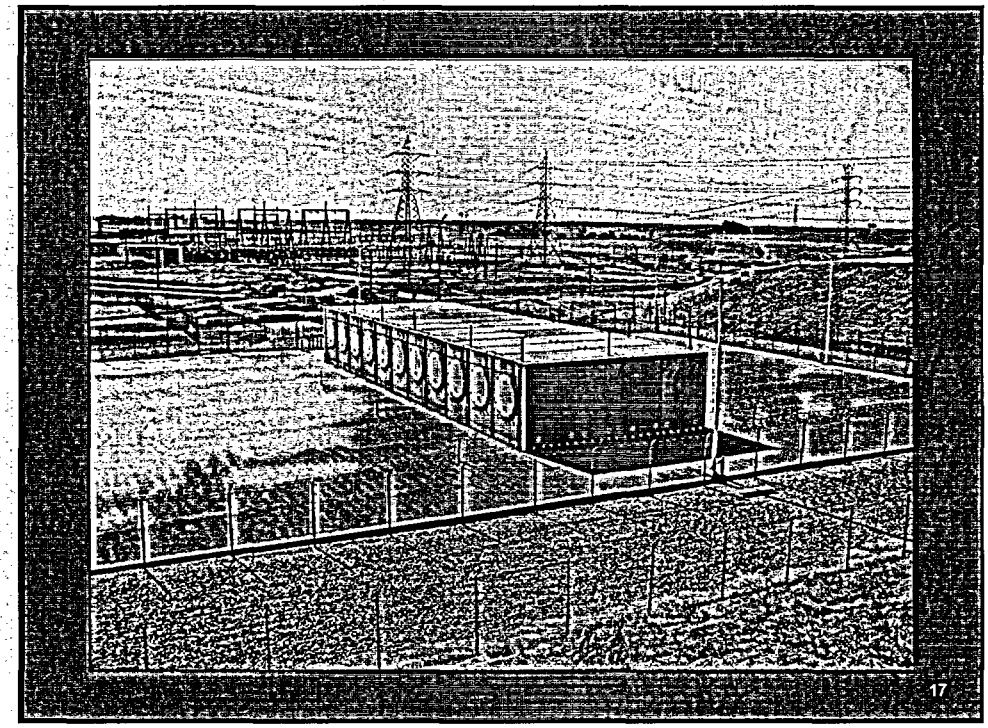

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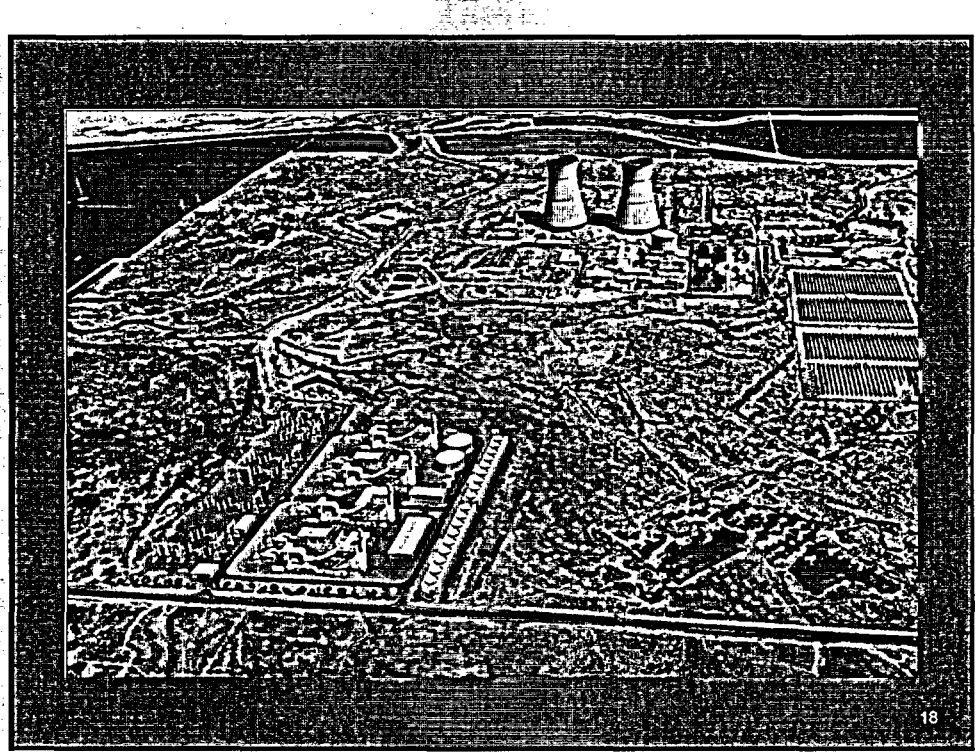


18

Scenario Development, Cont.

- Industrial worker scenario chosen for use with RESRAD for soil DCGL derivation
  - RESRAD chosen because of subsurface soil contamination
  - Industrial worker is most appropriate scenario for foreseeable future
  - No significant dose contribution from detected soil radionuclides after 100 years

19

Scenario Development, Cont.

- Industrial worker scenario assumptions for soil DCGL derivation include:
  - 2,000 hour work-year for industrial workers,
  - Time spent onsite equally divided between indoor and outdoor activities,
  - Meat, milk, plant, and aquatic food ingestion pathways are suppressed, and
  - Drinking water pathway is not suppressed.

20

Scenario Development, Cont.

- Alternative critical groups and exposure scenarios are being considered
  - A resident farmer establishes occupancy upon license termination
  - The industrial worker scenario is maintained but cattle grazing is permitted on open land areas

Scenario Development, Cont.

- Industrial worker building occupancy scenario chosen for use with RESRAD-BUILD
  - Generally follows building occupancy scenario introduced in NUREG/CR-6755
  - 2,000 hour work-year for industrial workers
  - Time onsite equally divided between indoors and outdoors

Scenario Development, Cont.

- Seven exposure pathways considered in building occupancy scenario
  - External exposure directly from the source, materials deposited on the floor, and from air submersion
  - Inhalation of airborne radioactive particulates
  - Inhalation of aerosol indoor tritiated water vapor
  - Ingestion of radioactive material directly from the source and of materials deposited on surfaces of the building

Derivation of Soil DCGLs

- RESRAD v6.22 was chosen to derive soil DCGLs due to the presence of subsurface soil contamination
  - RESRAD calculations were performed in the probabilistic mode where possible
  - Nuclide specific DCGLs were derived using the industrial worker scenario and a simplified hydrogeological mathematical site model
    - Detected radionuclides include: C-14, Co-60, Ni-63, Sr-90, Cs-134 and Cs-137

Derivation of Soil DCGLs, Cont.

- Pathways suppressed for industrial worker scenario:
  - plant ingestion pathway,
  - meat ingestion pathway,
  - milk ingestion pathway, and
  - aquatic foods ingestion pathways.

25

Derivation of Soil DCGLs, Cont.

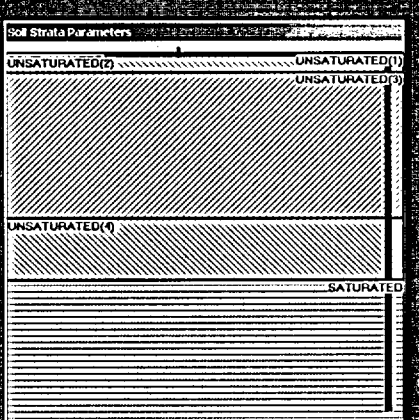
- A RESRAD simplified mathematical hydrogeological model was derived based on existing knowledge
  - Two siting studies performed prior to shutdown
    - Original plant siting study – 1967 & 1968
    - Proposed evaporation pond siting study – 1985
  - Well-documented boring results define soil profile from surface to water table
  - Approximately 140 ft from surface to water table
  - Layer of surface soil underlain by alternating layers of sand/gravel, sandstone and siltstone

26

Derivation of Soil DCGLs, Cont.

- The simplified mathematical model developed for use with RESRAD includes:
  - 15 cm layer of contaminated silt,
  - 1 ft (0.305 m) silt unsaturated zone,
  - 10 ft (3.05 m) of fine sandy soil unsaturated zone,
  - 84 ft (25.6 m) thick siltstone unsaturated zone,
  - 35½ ft (10.5 m) thick sandstone unsaturated zone,
  - Sandstone saturated zone, and
  - Well pump intake 75½ ft (23 m) below top of saturated zone.

27



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Derivation of Soil DCGLs, Cont.

- RESRAD input parameter selection process:
  - Parameters classified as:
    - behavioral,
    - metabolic, or
    - physical.
  - Physical parameter treatment
    - Measured, site-specific values or look-up values based on soil type were used if available

29

Derivation of Soil DCGLs, Cont.

- Physical parameter treatment, cont.
  - If not available, parameters were ranked by priority
    - 1 represents high priority,
    - 2 represents medium priority, and
    - 3 represents low priority.

30

Derivation of Soil DCGLs, Cont.

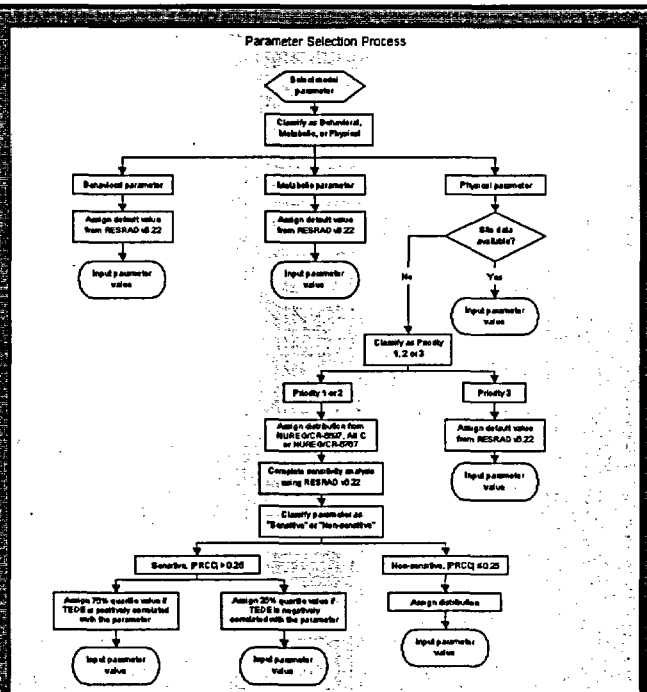
- A sensitivity analysis was performed prior to derivation of DCGLs
  - If the physical parameter was ranked as priority 3, the default value was used for the sensitivity analyses
  - Statistical parameter distributions were used for priority 1 and 2 ranked parameters (distributions obtained from NUREG/CR-6697 and NUREG/CR-6767

Derivation of Soil DCGLs, Cont.

- A probabilistic calculation was performed to identify sensitive parameters
  - The absolute value of the calculated PRCC of the peak of the mean dose was used to classify parameters as sensitive or non-sensitive
    - If the absolute value of the PRCC was >0.25, the parameter was classified as sensitive
    - If the absolute value of the PRCC was ≤0.25, the parameter was classified as non-sensitive

Derivation of Soil DCGLs, Cont.

- A probabilistic calculation was performed to identify sensitive parameters, cont.
  - Physical parameter values for use in dose modeling were selected based on sensitivity
    - If the absolute value of the PRCC was >0.25, then the parameter value at either the 75% or 25% quartile was selected based on TEDE correlation
    - If the absolute value of the PRCC was ≤0.25, then the statistical distribution of the parameter was used



Derivation of Soil DCGLs, Cont.

- A probabilistic calculation was performed to identify sensitive parameters, cont.
  - Sensitivity analyses were performed for both correlated and uncorrelated parameters
  - The uncertainty analysis input settings for this calculation were:
    - Latin Hypercube sampling,
    - random seed – 1000,
    - number of observations – 300,
    - number of repetitions – 1, and
    - grouping of observations – correlated or uncorrelated.
  - Three sensitive parameters - density of the contaminated zone, contaminated zone K_d value for Cs-137 and external gamma shielding factor

35

Derivation of Soil DCGLs, Cont.

- Potential dose from discounted (undetected) radionuclides was identified
  - 26 radionuclides were identified in the site-specific suite of potential radionuclides
  - Only six radionuclides were identified as present above MDA concentrations
  - Sensitivity analyses were performed to identify sensitive parameters for discounted radionuclides
  - Potential dose from discounted radionuclides at MDA concentrations was calculated – 0.602 mrem/year

36

Derivation of Soil DCGLs, Cont.

- Single nuclide DCGL values were calculated for detected radionuclides
  - Sensitive parameters were treated deterministically
  - Non-sensitive parameters were treated stochastically by entering statistical distributions for parameter values
  - Potential dose contribution from discounted radionuclides (0.602 mrem/year) was subtracted from the regulatory limit of 25 mrem/year
  - Single nuclide DCGL values were calculated by dividing the reduced regulatory limit by calculated peak of the mean dose in mrem/y per pCi/g

37

Single Nuclide DCGL Values for Detectable Radionuclides

Radionuclide	Peak of the Mean Dose (mrem/y per pCi/g)	DCGL (pCi/g)
C-14	2.93E-06	8.33E+06
Co-60	1.93E+00	1.26E+01
Ni-63	1.60E-06	1.52E+07
Sr-90	3.76E-03	6.49E+03
Cs-134	1.09E+00	2.24E+01
Cs-137	4.62E-01	5.28E+01

38

Derivation of Structural Surface DCGLs for Building Occupancy

- RESRAD-BUILD v3.22 used in probabilistic mode
- RESRAD-BUILD considers seven exposure pathways:
  - External exposure directly from the source,
  - External exposure to materials deposited on the floor,
  - External exposure due to air submersion,
  - Inhalation of airborne radioactive particulates,

39

Derivation of Surface DCGLs, Cont.

- RESRAD-BUILD considers seven exposure pathways, cont.:
  - Inhalation of aerosol indoor radon progeny and tritiated water-vapor (radon was not evaluated for RSNGS because the NRC does not regulate radon dose),
  - Inadvertent ingestion of radioactive material directly from the source, and
  - Ingestion of materials deposited on the surfaces of the building compartments.

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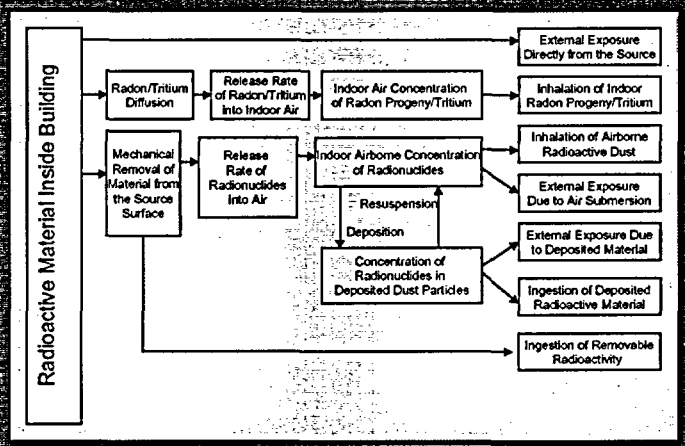

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Derivation of Surface DCGLs, Cont.

- DCGL values based on an industrial worker building occupancy scenario introduced in NUREG/CR-6755
- A sensitivity analysis was performed first to identify sensitive and non-sensitive parameters for probabilistic DCGL derivation

42

Derivation of Surface DCGLs, Cont.

- Steps to Identification Of RESRAD-BUILD Sensitive Parameters:
  - Input parameters were classified as behavioral, metabolic or physical
    - If the parameters were classified as behavioral or metabolic, site-specific parameter values or the RESRAD-BUILD default values were used for performing the sensitivity analyses
    - If the parameters were classified as physical, then they were reviewed to determine if measured, site-specific values for the parameters are available

Derivation of Surface DCGLs, Cont.

- Input parameters were classified as behavioral, metabolic or physical, cont.
  - If measured, site-specific values for physical parameters were not available, the parameters were then ranked by priority as 1, 2, or 3
    - If the physical parameters were ranked as priority 3, the assigned default values in RESRAD-BUILD were used for performing sensitivity analyses
  - Statistical parameter distributions were used for the physical parameters ranked as priority 1 or 2

Derivation of Surface DCGLs, Cont.

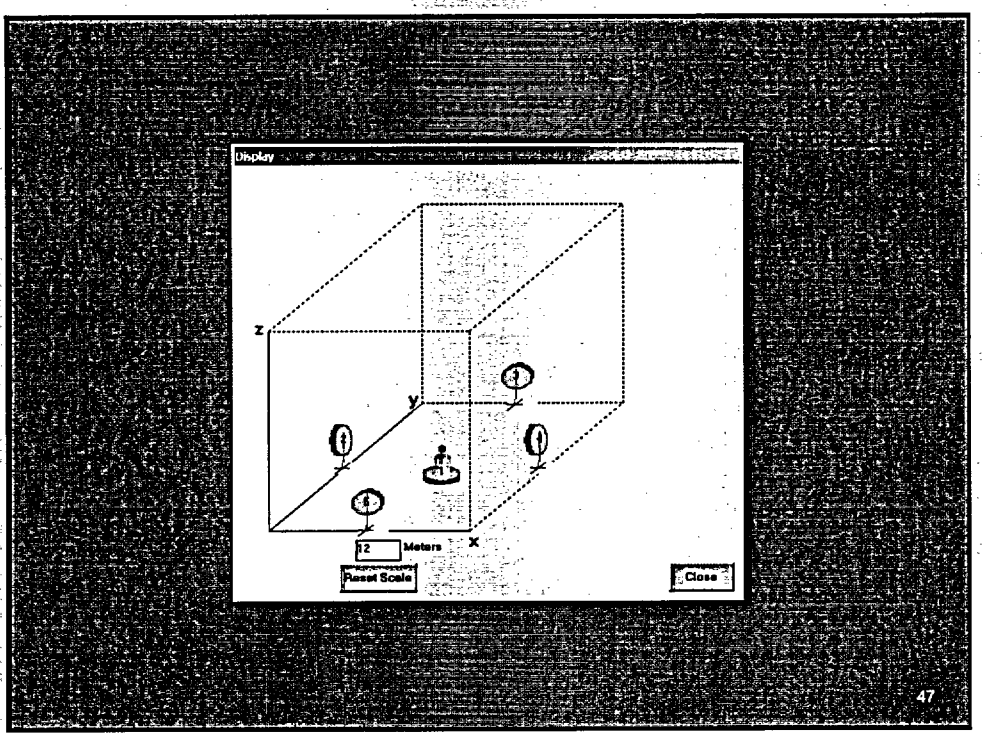
- Probabilistic calculations were then performed to identify sensitive parameters
  - The absolute value of the calculated PRCC of the peak of the mean dose was used to classify parameters as sensitive or non-sensitive
    - If the absolute value of the PRCC was >0.10, then the parameter was classified as sensitive
    - If the absolute value of the PRCC was ≤0.10, then the parameter was classified as non-sensitive

45

Derivation of Surface DCGLs, Cont.

- Physical parameters values for use in dose modeling were selected based on sensitivity
  - If the absolute value of the PRCC was > 0.10, then the parameter was treated deterministically and the value at either the 75% quartile or the 25% quartile was selected based on TEDE correlation with the parameter
  - If the absolute value of the PRCC was ≤ 0.10, then the parameter was treated stochastically and the statistical distribution of the parameter was used to calculate DCGLs
- Sensitive parameter values for room height and room floor area were selected to provide conservative calculations

46


Display
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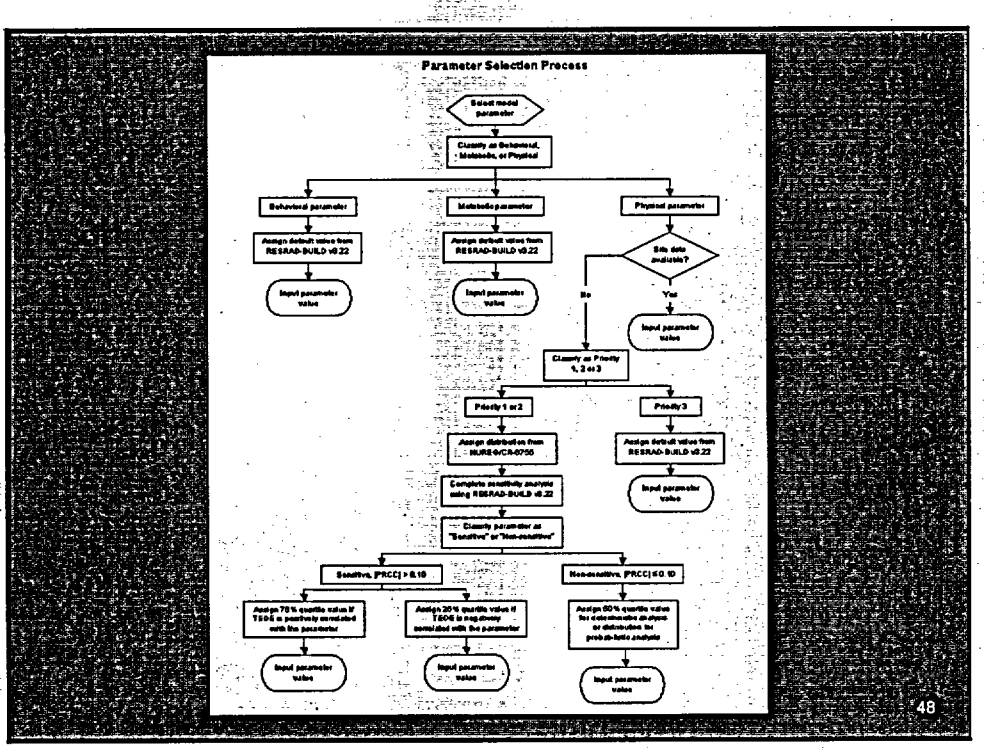
Parameter Selection Process
Select model parameter
Classify as Behavioral, Metabolic, or Physical
Behavioral parameter
Metabolic parameter
Physical parameter
Assign default value from RESRAD-BUILD v6.22
Assign default value from RESRAD-BUILD v6.22
Site data available?
Input parameter value
Input parameter value
No
Yes
Input parameter value
Classify as Priority 1, 2 or 3
Priority 1 or 2
Priority 3
Assign distribution from NUREG/CR-6755
Assign default value from RESRAD-BUILD v6.22
Complete sensitivity analysis using RESRAD-BUILD v6.22
Input parameter value
Classify parameter as "Sensitive" or "Non-sensitive"
Sensitive, |PRCC| > 0.10
Non-sensitive, |PRCC| ≤ 0.10
Assign 70 % quantile value if TEDE is positively correlated with the parameter
Assign 30 % quantile value if TEDE is negatively correlated with the parameter
Assign 50 % quantile value for deterministic analysis or distribution for probabilistic analysis
Input parameter value
Input parameter value
Input parameter value

48

Derivation of Surface DCGLs, Cont.

- RESRAD-BUILD resuspension rate was derived based on NUREG-1720
  - NUREG-1720 recommends use of a D&D resuspension factor of 9.6E-07 m^{-1}
  - The RESRAD-BUILD resuspension rate was calculated from the D&D resuspension factor and the RESRAD-BUILD sensitive parameter values for deposition velocity, air exchange rate and room height:

$$\lambda_r = R_f\left(v_{dep} + \lambda_a \times H\right)$$

Derivation of Surface DCGLs, Cont.

- Process to derive single nuclide DCGL values
  - Behavioral, metabolic and priority 3 physical parameter values were loaded into RESRAD-BUILD v3.22
  - Non-sensitive priority 1 and 2 physical parameters were treated stochastically by loading the appropriate statistical parameter distributions
  - Sensitive physical parameters were treated deterministically by loading the assigned parameter values

Derivation of Surface DCGLs, Cont.

- RESRAD-BUILD was used probabilistically to calculate dose correction factors (DCFs) in units of mrem/yr per 100 dpm/100 cm² for each of the 26 theoretical site-specific radionuclides
  - For each calculation, the Latin Hypercube sampling technique was used with a random seed of 1000, 300 observations and one repetition
- Nuclide specific DCGL values were calculated by dividing the dose limit (25 mrem/yr) by the DCF value to give DCGL values in units of dpm/100 cm²

Calculated Single Nuclide DCGL Values

Radionuclide	Dose Conversion Factor (mrem/yr per dpm/100 cm²)	DCGL (dpm/100 cm²)	Radionuclide	Dose Conversion Factor (mrem/yr per dpm/100 cm²)	DCGL (dpm/100 cm²)
*H-3	7.94E-08	3.15E+08	Cs-137	4.50E-04	5.56E+04
*C-14	2.92E-06	8.56E+06	*Pm-147	1.50E-06	1.67E+07
Na-22	1.47E-03	1.70E+04	Eu-152	7.66E-04	3.18E+04
*Fe-55	7.31E-07	3.42E+07	Eu-154	3.88E-03	6.44E+03**
*Ni-59	3.13E-07	7.99E+07	Eu-155	4.78E-05	5.23E+05
Co-60	1.64E-03	1.52E+04	*Np-237	1.05E-02	2.38E+03
*Ni-63	8.20E-07	3.05E+07	*Pu-238	7.30E-03	3.42E+03
*Sr-90	2.07E-04	1.21E+05	*Pu-239	8.19E-03	3.05E+03
Nb-94	1.09E-03	2.29E+04	*Pu-240	8.19E-03	3.05E+03
*Tc-99	2.13E-06	1.17E+07	*Pu-241	1.37E-04	1.82E+05
Ag-108m	1.13E-03	2.21E+04	Am-241	8.37E-03	2.99E+03
Sb-125	3.13E-04	7.99E+04	*Pu-242	7.81E-03	3.20E+03
Cs-134	1.14E-03	2.19E+04	*Cm-244	4.15E-03	6.02E+03

*Hard to detect radionuclides

Derivation of Area Factors for $DCGL_{EMC}$

- Area factor used for elevated measurement comparison during final status surveys

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

  - Based on methodology of NUREG-1505, Chapter 8
  - Calculated using dose pathway models and assumptions consistent with those used to calculate the $DCGL_W$

53

Derivation of Area Factors for $DCGL_{EMC}$

- Area factors for surface soils
  - RESRAD v6.22 along with parameter values and distributions used for $DCGL_W$ derivation used for calculations
    - Length parallel to aquifer varied for each calc
  - Contaminated area varied from 10,000 m^2 baseline area down to 1 m^2 area
  - Area factor calculated from:

$$AF_i = \frac{DSR_{Baseline}}{DSR_i}$$

54

Derivation of Area Factors for $DCGL_{EMC}$, Cont.

- Area factors for structural surfaces
  - Baseline $DCGL_W$s derived from contaminated floor and four walls
  - AF derivation based on same model and parameters used to derive baseline $DCGL_W$s
    - Surface AFs based on contaminated floor only (137 m^2) at $DCGL_W$
    - DCFs calculated for contaminated areas from 137 m^2 down to 1 m^2