Inputs to Calculation

Irrigation rate	0.19	m3/y
Household water use family of 4	328.7	m3/y
meat and dairy cow water ingestion (1 dairy, 1 meat)	110	L/d
Drinking Water per person	478	l/y

Well Pumping Rate

	No Irrigation, No Garden, No Livestock	**Irrigation of 22,000 m^2**	**Irrigation of 40,000 m^2**
Household Water Use (m3/yr)	328.7	328.7	328.7
Meat and Dairy Cow (m3/yr)	0.0	40.2	40.2
Irrigation (m3/yr)	0.0	4180.0	7600.0
Drinking Water (family of 4) (m3/yr)	1.9	1.9	1.9
Well Pumping Rate (m3/yr)	330.6	4550.8	7970.8

Non Radionuclide Specific	**25th**	**50th**	**75th**
Cover erosion rate	7.59E-04	1.49E-03	2.92E-03
Contaminated zone erosion rate	7.59E-04	1.49E-03	2.92E-03
Contaminated zone b parameter	2.87	3.60	4.50
Evapotranspiration	0.62	0.75	0.87
Wind speed	3.27	3.75	4.22
Runoff coefficient	0.28	0.45	0.63
Well pump intake depth	21.40	34.80	59.00
b parameter of unstaurated zone	2.87	3.60	4.50
mass loading for inhalation	1.84E-05	2.35E-05	2.87E-05
Indoor dust filtration factor	0.35	0.55	0.75
Depth of soil mixing layer	0.15	0.23	0.34
Depth of roots	1.23	2.15	3.08
Wet weight crop yield of fruit grain and non leafy vegetables	1.27	1.75	2.42
Weathering removal constant of all vegetation	21.50	33.00	47.90
Wet foliar interception fraction of leafy vegetables	0.43	0.58	0.70
Humidity in air	5.79	7.24	9.07

DCH 2015 2.13.1 Sand Soil Type

	log mea	std dev	25th	50th	75th
Am-241	6.91	1.95	2.69E+02	1.00E+03	3.73E+03
C-14	2.4	3.22	1.26E+00	1.10E+01	9.67E+01
Ce-144	5.99	1.00E-04	3.99E+02	3.99E+02	3.99E+02
Cm-243/ 244	8.13	2.64	5.72E+02	3.39E+03	2.01E+04
Co-58	5.56	2.89	3.70E+01	2.60E+02	1.82E+03
Co-60	5.56	2.89	3.70E+01	2.60E+02	1.82E+03
Cs-134	6.27	1.79	1.58E+02	5.28E+02	1.77E+03
Cs-137	6.27	1.79	1.58E+02	5.28E+02	1.77E+03
Eu-152	6.72	3.22	9.45E+01	8.29E+02	7.27E+03
Eu-154	6.72	3.22	9.45E+01	8.29E+02	7.27E+03
Eu-155	6.72	3.22	9.45E+01	8.29E+02	7.27E+03
Fe-55	5.77	1.00E-04	3.21E+02	3.21E+02	3.21E+02
H-3	-2.81	0.5	4.30E-02	6.02E-02	8.44E-02
Ni-59	4.87	2.3	2.76E+01	1.30E+02	6.15E+02
Ni-63	4.87	2.3	2.76E+01	1.30E+02	6.15E+02
Np-237	2.64	1.39	5.49E+00	1.40E+01	3.58E+01
Pu-238	5.99	1.39	1.56E+02	3.99E+02	1.02E+03
Pu-239/ 240	5.99	1.39	1.56E+02	3.99E+02	1.02E+03
Pu-241	5.99	1.39	1.56E+02	3.99E+02	1.02E+03
Sb-125	2.83	1.79	5.07E+00	1.69E+01	5.67E+01
Sr-90	3.09	1.79	6.57E+00	2.20E+01	7.35E+01
Tc-99	-3.22	1.1	1.90E-02	4.00E-02	8.39E-02

Radionuclide Specific - Kd

DCH 2015 Table 2.13.2, Loam Soil Type

	log mea	std dev	25th	50th	75th
Am-241	8.34	1.79	1.25E+03	4.19E+03	1.40E+04
C-14	2.4	3.22	1.26E+00	1.10E+01	9.67E+01
Ce-144	8.01	1.1	1.43E+03	3.01E+03	6.32E+03
Cm-243/ 244	9.85	0.69	1.19E+04	1.90E+04	3.02E+04
Co-58	6.7	2.71	1.31E+02	8.12E+02	5.05E+03
Co-60	6.7	2.71	1.31E+02	8.12E+02	5.05E+03
Cs-134	8.16	1.39	1.37E+03	3.50E+03	8.93E+03
Cs-137	8.16	1.39	1.37E+03	3.50E+03	8.93E+03
Eu-152	6.72	3.22	9.45E+01	8.29E+02	7.27E+03
Eu-154	6.72	3.22	9.45E+01	8.29E+02	7.27E+03
Eu-155	6.72	3.22	9.45E+01	8.29E+02	7.27E+03
Fe-55	6.79	0.69	5.58E+02	8.89E+02	1.42E+03
H-3	-2.81	0.5	4.30E-02	6.02E-02	8.44E-02
Ni-59	5.19	1.61	6.06E+01	1.79E+02	5.32E+02
Ni-63	5.19	1.61	6.06E+01	1.79E+02	5.32E+02
Np-237	3.14	1.39	9.05E+00	2.31E+01	5.90E+01
Pu-238	6.86	1.39	3.73E+02	9.53E+02	2.43E+03
Pu-239/ 240	6.86	1.39	3.73E+02	9.53E+02	2.43E+03
Pu-241	6.86	1.39	3.73E+02	9.53E+02	2.43E+03
Sb-125	4.11	1.1	2.90E+01	6.09E+01	1.28E+02
Sr-90	4.04	1.61	1.92E+01	5.68E+01	1.68E+02
Tc-99	-2.66	1.1	3.33E-02	6.99E-02	1.47E-01

Penetration Effective Basement Surface Area

Input to Calculation		
Conversion Factor	2.540E-02	m/in

Effective Penetration Surface Area

Basement	**Internal Surface Area[1]** (m^2)	**Internal Volume[1]**	**SA/V**	**Wall/Floor Surface Area[2]** (m^2)	**Penetration Effective Fraction of Surface Area**
Auxiliary	4.41	0.56	7.9	5352.00	0.001
Containment	43.70	6.28	7.0	2361.00	0.019
Turbine	12.64	1.28	9.9	4013.00	0.0031
Intake Structure	57.56	25.07	2.3	2235.00	0.026

1) OPPD, FC-21-0002, Description of Embedded Piping, Penetrations, and Buried Pipe to Remain in Fort Calhoun End State

2) OPPD, FC-20-006, FCSBldg End State Concrete Surface Areas & Volumes

Soil DCGL

Radionuclide	DCGL (pCi/g) 0.15 m	DCGL (pCi/g) 1.0 m
Am-241	1.402E+02	3.053E+01
C-14	5.996E+01	1.019E+01
Ce-144	2.746E+02	2.319E+02
Cm-243	6.747E+01	3.060E+01
Cm-244	2.944E+02	5.766E+01
Co-58	3.631E+01	3.128E+01
Co-60	3.970E+00	3.086E+00
Cs-134	6.424E+00	4.237E+00
Cs-137	1.374E+01	7.656E+00
Eu-152	8.857E+00	7.748E+00
Eu-154	8.220E+00	7.168E+00
Eu-155	3.081E+02	3.027E+02
Fe-55	3.660E+04	2.122E+04
H-3	1.195E+04	8.655E+02
Ni-59	1.128E+04	2.307E+03
Ni-63	4.120E+03	8.424E+02
Np-237	4.723E+00	7.619E-01
Pu-238	1.752E+02	3.536E+01
Pu-239	1.578E+02	3.184E+01
Pu-240	1.578E+02	3.185E+01
Pu-241	5.666E+03	1.040E+03
Sb-125	2.662E+01	2.348E+01
Sr-90	1.111E+01	1.731E+00
Tc-99	1.356E+02	1.542E+01

BFM *insitu* DCGL Calculation

Inputs to Calculation

unit activity over 1 m^2 of concrete	1 pCi
unit volume of fill	1 m^3
conversion factor	1.00E+06 cm^3 per m^3
bulk density of fill	1.49 g/cm^3
25 mrem/yr Dose Criterion	25 mrem/yr

Calculation

unit concentraton in fill	**LTP**	
Chapter 6 Equation 6-3		6.71E-07 pCi/g per pCi/m^2

BFM insitu DCGL Calculation

	BFM *insitu* DSR	**BFM insitu DCGL (DCGL) LTP Chapter 6 Equation 6-4**
	mrem/yr per pCi/g	**pCi/m^2**
Am-241	8.025E+00	4.642E+06
C-14	1.591E+00	2.341E+07
Ce-144	2.441E-02	1.526E+09
Cm-243	2.800E+00	1.330E+07
Cm-244	2.238E+00	1.664E+07
Co-58	5.019E-02	7.422E+08
Co-60	1.299E+00	2.868E+07
Cs-134	1.854E+00	2.009E+07
Cs-137	1.472E+00	2.531E+07
Eu-152	4.061E-02	9.173E+08
Eu-154	5.906E-02	6.307E+08
Eu-155	9.177E-03	4.059E+09
Fe-55	1.382E-03	2.695E+10
H-3	1.366E-01	2.727E+08
Ni-59	1.852E-02	2.011E+09
Ni-63	5.072E-02	7.344E+08
Np-237	4.406E+02	8.454E+04
Pu-238	1.173E+01	3.176E+06
Pu-239	1.302E+01	2.861E+06
Pu-240	1.302E+01	2.861E+06
Pu-241	2.577E-01	1.445E+08
Sb-125	3.042E-01	1.225E+08
Sr-90	2.694E+01	1.383E+06
Tc-99	4.512E+00	8.256E+06

LTP Chapter 6 Equation 6-3

$$C_{f,u} = \frac{A_{c,u}}{V_{f,u} 1x10^6 \rho_f}$$

$C_{f,u}$ = unit concentration in fill (pCi/g per pCi/m^2)
$A_{c,u}$ = unit activity of 1 pCi over a 1 m^2 area of concrete (pCi)
$V_{f,u}$ = unit fill volume of 1 m^3
Conversion Factor = 1x10^6 cm^3 per m^3
ρ_f = bulk density of fill (assumed to be sand)

LTP Chapter 6 Equation 6-4

$$DCGL_{i,j} = \frac{25}{DSR_{i,j} C_{i,u}}$$

where:
$DCGL_{i,j}$ = *insitu* scenario DCGL for radionuclide j (pCi/m^2)
$C_{i,u}$ = unit concentration in fill (pCi/g per pCi/m^2) from Equation 6-3
$DSR_{i,j}$ = BFM *insitu* dose to source ratio for radionuclide j (mrem/yr per pCi/g)
25 = 25 mrem/yr dose criterion

WI meat and milk correction factor 1.078E-01

	DSR	WI Meat	WI Milk	WI Sum	WI Corrected		Corrected DSR	DCGL Overestimate
Am-241								
C-14								
Ce-144								
Cm-243								
Cm-244								
Co-58								
Co-60								
Cs-134								
Cs-137		2.623E-01	4.573E-01	7.196E-01	7.756E-02		-6.420E-01	0.000E+00
Eu-152								
Eu-154								
Eu-155								
Fe-55								
H-3								
Ni-59								
Ni-63								
Np-237								
Pu-238								
Pu-239								
Pu-240								
Pu-241								
Sb-125								
Sr-90								
Tc-99								

995.5' Elevation: Basement Fill Model - Drilling Spoils Scenario

Assumptions and Unit Conversion Factors

Diameter Borehole	8.00 in
Drilling Depth Ground to floor	8.50 ft
Drilling depth into floor concrete	1.00 in
Fill Density	1.49 g/cm^3
Unit activity in drilling spoils	1.00 pCi/g
Depth of drilling spoils spread on ground	0.15 m
conversion factor	1.00E+06 cm^3/m^3
conversion factor	12.00 in/ft
conversion factor	0.3048 m/ft
conversion factor	0.0254 m/in

Calculations

Diameter Borehole	0.2032	m
Total drilling depth	2.62E+00	m
Drilling Spoils Volume **(LTP Chapter 6 Equation 6-5)**	8.48E-02	m^3
Concrete Concentration pCi/m^2 per 1 pCi/g in spoils **(LTP Chapter 6 Equation 6-6)**	3.90E+06	pCi/m^2 per pCi/g

Calculation of BFM Drilling Spoils DCGLs (pCi/m^2)

Radionuclide	Drilling Spoils DSR (mrem/yr per pCi/g)	BFM Drilling Spoils DCGL (pCi/m^2) LTP Chapter 6 Equation 6-7
Am-241	3.627E-03	2.687E+10
C-14	6.142E-07	1.587E+14
Ce-144	4.556E-03	2.139E+10
Cm-243	1.636E-02	5.957E+09
Cm-244	1.169E-03	8.336E+10
Co-58	3.390E-02	2.875E+09
Co-60	2.902E-01	3.358E+08
Cs-134	1.698E-01	5.739E+08
Cs-137	7.161E-02	1.361E+09
Eu-152	1.371E-01	7.108E+08
Eu-154	1.460E-01	6.675E+08
Eu-155	5.241E-03	1.859E+10
Fe-55	4.148E-08	2.349E+15
H-3	8.452E-07	1.153E+14
Ni-59	2.433E-07	4.005E+14
Ni-63	6.613E-07	1.474E+14
Np-237	3.059E-02	3.186E+09
Pu-238	1.874E-03	5.200E+10
Pu-239	2.061E-03	4.728E+10
Pu-240	2.058E-03	4.735E+10
Pu-241	8.992E-05	1.084E+12
Sb-125	4.713E-02	2.068E+09
Sr-90	1.380E-03	7.062E+10
Tc-99	9.713E-05	1.003E+12

LTP Chapter 6 Equation 6-5

$$V_{ds} = \pi (r)^2 D_{bh}$$

where:
- V_{ds} = volume of the drilling spoils on ground surface (m^3)
- π = pi constant
- r = radius of borehole (m)
- D_{bh} = depth of borehole (m)

LTP Chapter 6 Equation 6-6

$$C_{c,u} = \frac{V_{ds}\ 1x10^6 \rho_f C_{ds,u}}{\pi (r)^2}$$

where:
- $C_{c,u}$ = concrete concentration (pCi/m^2) required to produce a unit concentration of 1 pCi/g concentration in drilling spoils (pCi/m^2 per pCi/g)
- V_{ds} = volume of drilling spoils calculated by Equation 6-4(m^3)
- $1x10^6$ = conversion factor cm^3/m^3
- ρ_f = density of fill (drilling spoils) (g/cm^3)
- $C_{ds,u}$ = unit concentration in drilling spoils (1 pCi/g)
- π = pi constant
- r = radius of borehole (m)

LTP Chapter 6 Equation 6-7

$$DCGL_{ds,i} = \frac{25\ C_{c,u}}{DSR_i}$$

where:
- $DCGL_{ds,i}$ = drilling spoils DCGL for radionuclide i (pCi/m^2)
- $C_{c,u}$ = concrete concentration required to produce 1 pCi/g average concentration in drilling spoils (Equation 6-4) (pCi/m^2 per pCi/g)
- DSR_i = dose to source ratio for radionuclide i (mrem/yr per pCi/g)
- 25 = 25 mrem/yr dose criterion

BFM Concrete and Liner Excavation Scenario DCGL

Inputs to Calculation		
unit activity over a 1 m^2 area of concrete	1	pCi
minimum wall thickness in all basements	2	ft
conversion factor	30.48	cm/ft
unit area of concrete wall	1	m^2
conversion factor	1.00E+04	cm^2/m^2
concrete density	2.2	g/cm^3
Calculation		
unit concentration in excavated concrete		
LTP Chapter 6, Equation 6-8	7.46E-07	pCi/g per pCi/m^2

BFM Concrete Excavation Scenario DCGL

	Soil DCGL 1.0 m (pCi/g)	Concrete Excavation DCGL ($DCGL_{e,c}$)[1] pCi/m^2	Liner Excavation DCGL ($DCGL_{e,l}$) pCi/m^2
Am-241	3.053E+01	4.094E+07	3.155E+07
C-14	1.019E+01	1.367E+07	1.349E+07
Ce-144	2.319E+02	3.110E+08	6.179E+07
Cm-243	3.060E+01	4.104E+07	1.518E+07
Cm-244	5.766E+01	7.733E+07	6.624E+07
Co-58	3.128E+01	4.195E+07	8.170E+06
Co-60	3.086E+00	4.139E+06	8.933E+05
Cs-134	4.237E+00	5.682E+06	1.445E+06
Cs-137	7.656E+00	1.027E+07	3.092E+06
Eu-152	7.748E+00	1.039E+07	1.993E+06
Eu-154	7.168E+00	9.613E+06	1.850E+06
Eu-155	3.027E+02	4.060E+08	6.932E+07
Fe-55	2.122E+04	2.846E+10	8.235E+09
H-3	8.655E+02	1.161E+09	1.298E+09
Ni-59	2.307E+03	3.094E+09	2.538E+09
Ni-63	8.424E+02	1.130E+09	9.270E+08
Np-237	7.619E-01	1.022E+06	1.063E+06
Pu-238	3.536E+01	4.742E+07	3.942E+07
Pu-239	3.184E+01	4.270E+07	3.551E+07
Pu-240	3.185E+01	4.271E+07	3.551E+07
Pu-241	1.040E+03	1.395E+09	1.275E+09
Sb-125	2.348E+01	3.149E+07	5.990E+06
Sr-90	1.731E+00	2.321E+06	2.500E+06
Tc-99	1.542E+01	2.068E+07	2.313E+07

1) LTP Chapter 6, Equation 6-9

Sensitivity Analysis and DCGL Calculation for Liner Excavation

Inputs to calculation		
unit activity of 1 pCi over a liner area of 1 m2	1	pCi
thickness of soil mixing zone	0.15	m
	1.00	m
unit area of liner and underlying soil	1	m^2
conversion factor	1.00E+06	cm^3/m^3
soil density	1.50	g/cm^3
Calculation		
unit concentration in soil for 0.15 m soil thickness		
LTP Chapter 6 Equation 6-10	4.44E-06	pCi/g per pCi/m^2
unit concentration in soil for 1 m soil thickness		
LTP Chapter 6 Equation 6-10	6.67E-07	pCi/g per pCi/m^2

	Soil DCGL 0.15 m (pCi/g)	Soil 1.0 m DCGL (pCi/g)	Liner DCGL[2] 0.15 m (pCi/m^2)	Liner DCGL[2] 1.00 m (pCi/m^2)	0.15 m < 1.0 m?	Liner Excavation DCGL ($DCGL_{e,l}$)
Am-241	1.402E+02	3.053E+01	3.155E+07	4.580E+07	TRUE	3.155E+07
C-14	5.996E+01	1.019E+01	1.349E+07	1.529E+07	TRUE	1.349E+07
Ce-144	2.746E+02	2.319E+02	6.179E+07	3.479E+08	TRUE	6.179E+07
Cm-243	6.747E+01	3.060E+01	1.518E+07	4.590E+07	TRUE	1.518E+07
Cm-244	2.944E+02	5.766E+01	6.624E+07	8.649E+07	TRUE	6.624E+07
Co-58	3.631E+01	3.128E+01	8.170E+06	4.692E+07	TRUE	8.170E+06
Co-60	3.970E+00	3.086E+00	8.933E+05	4.629E+06	TRUE	8.933E+05
Cs-134	6.424E+00	4.237E+00	1.445E+06	6.356E+06	TRUE	1.445E+06
Cs-137	1.374E+01	7.656E+00	3.092E+06	1.148E+07	TRUE	3.092E+06
Eu-152	8.857E+00	7.748E+00	1.993E+06	1.162E+07	TRUE	1.993E+06
Eu-154	8.220E+00	7.168E+00	1.850E+06	1.075E+07	TRUE	1.850E+06
Eu-155	3.081E+02	3.027E+02	6.932E+07	4.541E+08	TRUE	6.932E+07
Fe-55	3.660E+04	2.122E+04	8.235E+09	3.183E+10	TRUE	8.235E+09
H-3	1.195E+04	8.655E+02	2.689E+09	1.298E+09	FALSE	1.298E+09
Ni-59	1.128E+04	2.307E+03	2.538E+09	3.461E+09	TRUE	2.538E+09
Ni-63	4.120E+03	8.424E+02	9.270E+08	1.264E+09	TRUE	9.270E+08
Np-237	4.723E+00	7.619E-01	1.063E+06	1.143E+06	TRUE	1.063E+06
Pu-238	1.752E+02	3.536E+01	3.942E+07	5.304E+07	TRUE	3.942E+07
Pu-239	1.578E+02	3.184E+01	3.551E+07	4.776E+07	TRUE	3.551E+07
Pu-240	1.578E+02	3.185E+01	3.551E+07	4.778E+07	TRUE	3.551E+07
Pu-241	5.666E+03	1.040E+03	1.275E+09	1.560E+09	TRUE	1.275E+09
Sb-125	2.662E+01	2.348E+01	5.990E+06	3.522E+07	TRUE	5.990E+06
Sr-90	1.111E+01	1.731E+00	2.500E+06	2.597E+06	TRUE	2.500E+06
Tc-99	1.356E+02	1.542E+01	3.051E+07	2.313E+07	FALSE	2.313E+07

2) LTP Chapter 6, Equation 6-11

LTP Chapter 6, Equation 6-8

$$C_{ec,u} = \frac{A_{c,u}}{t_w(30.48)UA_c(1x10^4)\rho_c}$$

where:

$C_{ec,u}$ = unit concentration in excavated concrete (pCi/g per pCi/m^2)
$A_{c,u}$ = unit activity of 1 pCi over a 1 m^2 area of concrete (pCi)
t_w = minimum wall thickness in all basements (ft)
30.48 = cm/ft
UA_c = unit area of concrete wall (1 m^2)
$1x10^4$ = cm^2/m^2
ρ_c = density of concrete (2.2 g/cm^2)

LTP Chapter 6, Equation 6-9

$$DCGL_{ec,i} = \frac{DCGL_{s,i}}{C_{ec,u}}$$

where:

$DCGL_{ec,i}$ = concrete excavation DCGL for radionuclide i (pCi/m^2)
$DCGL_{s,i}$ = soil DCGL (1 m thickness) for radionuclide i (pCi/g)
$C_{ec,u}$ = unit concentration in excavated concrete from Equation 6-7 (pCi/g per pCi/m^2)

LTP Chapter 6, Equation 6-10

$$C_{s,t,u} = \frac{A_u}{tUA_l 1x10^6 \rho_s}$$

where:

$C_{s,t,u}$ = unit concentration in soil for thickness t (pCi/g per pCi/m^2)
A_u = unit activity of 1 pCi over a liner area of 1 m^2 (1 pCi)
t = thickness of soil mixing zone (0.15 m or 1 m)
UA_l = unit area of liner and underlying soil (1 m^2)
$1x10^6$ = cm^3/m^3
ρ_s = density of soil (1.5 g/cm^3)

LTP Chapter 6, Equation 6-11

$$DCGL_{el,i} = \frac{DCGL_{s,t,i}}{C_{s,t,u}}$$

where:

$DCGL_{el,i}$ = liner excavation DCGL for radionuclide i (pCi/m^2)
$DCGL_{s,t,i}$ = soil DCGL for thickness t (0.15 or 1 m) for radionuclide i (pCi/g)
$C_{s,t,u}$ = unit concentration in soil for thickness t (0.15 m or 1.0 m) from Equation 6-10 (pCi/g per pCi/m^2)

BFM Wall/Floor DCGL (No IC Dose Correction)

	BFM insitu $DCGL_i$	BFM Drilling Spoils $DCGL_{ds}$	BFM Concrete Excavation $DCGL_{ec}$	BFM Liner Excavation $DCGL_{el}$	BFM Wall/Floor DCGL (Auxiliary, Turbine, Circulating Water Tunnels, Intake Structure) LTP Chapter 6 Equation 6-13	BFM Wall/Floor DCGL (Containment) LTP Chapter 6 Equation 6-13
	pCi/m^2	pCi/m^2	pCi/m^2	pCi/m^2	pCi/m^2	pCi/m^2
Am-241	4.642E+06	2.687E+10	4.094E+07	3.155E+07	4.168E+06	4.046E+06
C-14	2.341E+07	1.587E+14	1.367E+07	1.349E+07	8.629E+06	8.559E+06
Ce-144	1.526E+09	2.139E+10	3.110E+08	6.179E+07	2.553E+08	5.922E+07
Cm-243	1.330E+07	5.957E+09	4.104E+07	1.518E+07	1.003E+07	7.082E+06
Cm-244	1.664E+07	8.336E+10	7.733E+07	6.624E+07	1.369E+07	1.330E+07
Co-58	7.422E+08	2.875E+09	4.195E+07	8.170E+06	3.916E+07	8.058E+06
Co-60	2.868E+07	3.358E+08	4.139E+06	8.933E+05	3.578E+06	8.640E+05
Cs-134	2.009E+07	5.739E+08	5.682E+06	1.445E+06	4.396E+06	1.345E+06
Cs-137	2.531E+07	1.361E+09	1.027E+07	3.092E+06	7.265E+06	2.749E+06
Eu-152	9.173E+08	7.108E+08	1.039E+07	1.993E+06	1.013E+07	1.983E+06
Eu-154	6.307E+08	6.675E+08	9.613E+06	1.850E+06	9.336E+06	1.839E+06
Eu-155	4.059E+09	1.859E+10	4.060E+08	6.932E+07	3.619E+08	6.791E+07
Fe-55	2.695E+10	2.349E+15	2.846E+10	8.235E+09	1.384E+10	6.308E+09
H-3	2.727E+08	1.153E+14	1.161E+09	1.298E+09	2.208E+08	2.254E+08
Ni-59	2.011E+09	4.005E+14	3.094E+09	2.538E+09	1.219E+09	1.122E+09
Ni-63	7.344E+08	1.474E+14	1.130E+09	9.270E+08	4.451E+08	4.098E+08
Np-237	8.454E+04	3.186E+09	1.022E+06	1.063E+06	7.808E+04	7.831E+04
Pu-238	3.176E+06	5.200E+10	4.742E+07	3.942E+07	2.976E+06	2.939E+06
Pu-239	2.861E+06	4.728E+10	4.270E+07	3.551E+07	2.681E+06	2.647E+06
Pu-240	2.861E+06	4.735E+10	4.271E+07	3.551E+07	2.681E+06	2.647E+06
Pu-241	1.445E+08	1.084E+12	1.395E+09	1.275E+09	1.310E+08	1.298E+08
Sb-125	1.225E+08	2.068E+09	3.149E+07	5.990E+06	2.475E+07	5.694E+06
Sr-90	1.383E+06	7.062E+10	2.321E+06	2.500E+06	8.666E+05	8.903E+05
Tc-99	8.256E+06	1.003E+12	2.068E+07	2.313E+07	5.900E+06	6.084E+06

LTP Chapter 6 Equation 6-13

$$DCGL_{wf} = \frac{1}{\left(\frac{1}{DCGL_i} + \frac{1}{DCGL_{ds}} + \frac{1}{DCGL_e}\right)}$$

where:

$DCGL_{wf}$ = BFM wall/floor DCGL
$DCGL_i$ = BFM *insitu* scenario DCGL
$DCGL_{ds}$ = BFM drilling spoils scenario DCGL
$DCGL_e$ = BFM excavation scenario DCGL

Embedded Pipe DCGL

Inputs to Calculation

	Floor Area (ft^2)		Embedded Pipe Internal Surface Area (ft^2)
Auxiliary Floor 971' elevation	6334		260
Auxiliary Floor 989' elevation	25,109		1320
Turbine Floor 990' elevation	26,235		2009
Unit Activity in Embedded Pipe	1	pCi/m^2	
conversion factor	0.0929	m^2/ft^2	
mix distance in fill	1	m	
conversion factor	1.00E+06	cm^3/m^3	
bulk density	1.49	g/cm^3	
Dose Criterion	25	mrem/yr	

Unit Fill Concentration

LTP Chapter 6 Equation 6-15

Auxiliary Floor 971' elevation	2.75E-08	pCi/g per pCi/m^2
Auxiliary Floor 989' elevation	3.53E-08	pCi/g per pCi/m^2
Turbine Floor 990' elevation	5.14E-08	pCi/g per pCi/m^2

Embedded Pipe DCGL Calculation

	DSR	**DCGL**		
		Auxiliary Floor 971' elevation LTP Chapter 6 Equation 6-16	**Auxiliary Floor 989' elevation LTP Chapter 6 Equation 6-16**	**Turbine Floor 990' elevation LTP Chapter 6 Equation 6-16**
	mrem/yr per pCi/g	**pCi/m^2**	**pCi/m^2**	**pCi/m^2**
Am-241	1.851E+00	4.90E+08	3.83E+08	2.63E+08
C-14	5.787E-01	1.568E+09	1.224E+09	8.406E+08
Ce-144	4.811E-03	1.886E+11	1.473E+11	1.011E+11
Cm-243	5.938E-01	1.528E+09	1.193E+09	8.192E+08
Cm-244	4.747E-01	1.912E+09	1.493E+09	1.025E+09
Co-58	6.528E-03	1.390E+11	1.085E+11	7.452E+10
Co-60	1.691E-01	5.366E+09	4.190E+09	2.877E+09
Cs-134	1.365E-01	6.648E+09	5.191E+09	3.564E+09
Cs-137	1.084E-01	8.371E+09	6.537E+09	4.487E+09
Eu-152	9.568E-03	9.484E+10	7.406E+10	5.084E+10
Eu-154	1.392E-02	6.519E+10	5.090E+10	3.495E+10
Eu-155	2.164E-03	4.193E+11	3.274E+11	2.248E+11
Fe-55	3.283E-04	2.764E+12	2.158E+12	1.482E+12
H-3	3.725E-02	2.436E+10	1.902E+10	1.306E+10
Ni-59	4.373E-03	2.075E+11	1.620E+11	1.112E+11
Ni-63	8.698E-03	1.043E+11	8.146E+10	5.593E+10
Np-237	1.476E+02	6.148E+06	4.801E+06	3.296E+06
Pu-238	2.796E+00	3.246E+08	2.534E+08	1.740E+08
Pu-239	4.086E+00	2.221E+08	1.734E+08	1.190E+08
Pu-240	3.782E+00	2.399E+08	1.874E+08	1.286E+08
Pu-241	6.079E-02	1.493E+10	1.166E+10	8.002E+09
Sb-125	6.833E-02	1.328E+10	1.037E+10	7.119E+09
Sr-90	4.010E+00	2.263E+08	1.767E+08	1.213E+08
Tc-99	1.151E+00	7.884E+08	6.156E+08	4.226E+08

LTP Chapter 6 Equation 6-15

$$C_{f,e_i} = \frac{A_{ep,u} SA_{ep,e_i} 0.0929}{SA_{f,e_i} 0.0929 D_m 1x10^6 \rho_f}$$

where:

$C_{f,ei}$ = concentration in fill from release of activity from embedded pipe at floor elevation i (pCi/g per pCi/m^2)
$A_{ep,u}$ = unit activity in embedded pipe (1 pCi per m^2),
$SA_{ep,ei}$ = embedded pipe internal surface area in floor elevation i (ft^2),
0.0929 = Conversion Factor (m^2/ft^2)
$SA_{f,ei}$ = floor surface area at elevation i (ft^2),
D_m = mix distance in fill (1 m)
$1x10^6$ = Conversion factor (g/cm^3)
ρ_f = bulk density of fill (assumed to be sand) (g/cm^3)

LTP Chapter 6 Equation 6-16

$$DCGL_{ep,e_i,j} = \frac{25}{DSR_{ep,j} C_{f,e_i}}$$

Where:

$DCGL_{ep,ei,j}$ = embedded pipe DCGL at floor elevation i for radionuclide j (pCi/m^2)
25 = 25 mrem/yr dose criterion
$DSR_{ep,j}$ = embedded pipe DSR for radionuclide j (mrem/yr per pCi/g)
$C_{f,ei}$ = concentration in fill from release of activity from embedded pipe at floor elevation i (Equation 6-15) (pCi/g per pCi/m^2)

	16	sv/y per Bq/g
Steel scrap mass	14657	t
conversion factor	1000	kg/t
Nureg-1640 surface dose factoe	3.2	Sv/yr per Bq/cm2
Conversion Factor	0.0037	(mrem/yr per pCi/cm2) per (Sv/yr per Bq/cm2)
Nureg-1640 steel mass/surface ra	5.1	g/cm2
conversion factor	1.00E+04	cm2/m2

Calculation

NUREG-1640 surface dose factor	0.01184	mrem/yr per pCi/cm2
NUREG-1640 surface dose factor	1.18E-06	mrem/yr per pCi/m2
25 mrem/yr limit	2.11E+07	pCi/m2 per 25 mrem/yr

in	4.5	OD	0.035908404	
in	4.03	ID	0.032157971	
length	435	m	0.003750433	
	8053	kg/m3	0.391545238	m3
mass of aux embedd pipe			3153.113798	kg
pipe mass/surface area			#DIV/0!	g/cm2
pipe specific surface dose factor			#DIV/0!	Sv/yr per Bq/cm2
25 mrem/yr limit pipe specific			#DIV/0!	mrem/yr per pCi/g
mass corrected 25 mrem pipe spe			#DIV/0!	mrem/yr per pCi/g

Buried Pipe DCGL Calculation

Buried Pipe Excavation and *insitu* Scenario DCGL calculation

Inputs to Calculation			
unit activity in pipe over a 1 cm^2 area		1	dpm
conversion factor		2.22	dpm/pCi
unit surface area of pipe (and underlying soil)		1	cm^2
thickness of soil mixing zone	excavation scenario	100	cm
	excavation scenario	15	cm
	insitu scenario	2.54	cm
density of soil	excavation scenario	1.5	g/cm^3
	insitu scenario	1.49	g/cm^3
Multiplication factor to calulate dpm/100 cm^2DCGL		100	cm^2
Dose Criterion		25	mrem/yr

Calculation		
0.15 m mix unit soil concentration buried pipe		
LTP Chapter 6 Equation 6-17	2.00E-02	pCi/g per dpm/cm^2
1.0 m mix unit soil concentration buried pipe		
LTP Chapter 6 Equation 6-17	3.00E-03	pCi/g per dpm/cm^2

Buried Pipe Excavation Scenario DCGL

	DSR 0.15 m Mix Thickness mrem/yr per pCi/g	**DSR 1.0 m Mix Thickness mrem/yr per pCi/g**	**DCGL 0.15 m thickness LTP Chapter 6 Equation 6-19 (dpm/100 cm2)**	**DCGL 1.0 m thickness LTP Chapter 6 Equation 6-19 (dpm/100 cm2)**	**Is 0.15 m Thickness DCGL less Than 1.0 m Thickness DCGL?**	**DCGL Buried Pipe Excavation Scenario (dpm/100 cm2)**
Am-241	1.678E-01	8.030E-01	7.442E+05	1.037E+06	TRUE	7.442E+05
C-14	3.386E-02	2.315E-01	3.688E+06	3.596E+06	FALSE	3.596E+06
Ce-144	8.733E-02	1.011E-01	1.430E+06	8.234E+06	TRUE	1.430E+06
Cm-243	3.557E-01	7.916E-01	3.511E+05	1.052E+06	TRUE	3.511E+05
Cm-244	8.069E-02	4.268E-01	1.548E+06	1.951E+06	TRUE	1.548E+06
Co-58	6.581E-01	7.240E-01	1.898E+05	1.150E+06	TRUE	1.898E+05
Co-60	5.938E+00	7.137E+00	2.103E+04	1.166E+05	TRUE	2.103E+04
Cs-134	3.403E+00	4.209E+00	3.670E+04	1.978E+05	TRUE	3.670E+04
Cs-137	1.481E+00	2.028E+00	8.432E+04	4.105E+05	TRUE	8.432E+04
Eu-152	2.709E+00	3.010E+00	4.610E+04	2.766E+05	TRUE	4.610E+04
Eu-154	2.916E+00	3.252E+00	4.282E+04	2.560E+05	TRUE	4.282E+04
Eu-155	7.751E-02	7.738E-02	1.611E+06	1.076E+07	TRUE	1.611E+06
Fe-55	9.315E-05	2.301E-04	1.341E+09	3.618E+09	TRUE	1.341E+09
H-3	8.727E-04	1.539E-02	1.431E+08	5.409E+07	FALSE	5.409E+07
Ni-59	5.204E-04	3.036E-03	2.400E+08	2.742E+08	TRUE	2.400E+08
Ni-63	1.425E-03	8.314E-03	8.763E+07	1.001E+08	TRUE	8.763E+07
Np-237	3.157E+00	1.994E+01	3.955E+04	4.175E+04	TRUE	3.955E+04
Pu-238	1.304E-01	6.873E-01	9.576E+05	1.211E+06	TRUE	9.576E+05
Pu-239	1.448E-01	7.633E-01	8.624E+05	1.091E+06	TRUE	8.624E+05
Pu-240	1.447E-01	7.633E-01	8.630E+05	1.091E+06	TRUE	8.630E+05
Pu-241	4.138E-03	2.354E-02	3.018E+07	3.537E+07	TRUE	3.018E+07
Sb-125	9.037E-01	9.851E-01	1.382E+05	8.451E+05	TRUE	1.382E+05
Sr-90	1.543E+00	1.019E+01	8.093E+04	8.170E+04	TRUE	8.093E+04
Tc-99	1.550E-01	1.402E+00	8.056E+05	5.938E+05	FALSE	5.938E+05

Buried Pipe Insitu Scenario DCGL Calculation

0.15 m mix unit soil concentration buried pipe		
LTP Chapter 6 Equation 6-15	1.19E-01	pCi/g per dpm/cm2

	DSR 0.0254 m Mix Thickness mrem/yr per pCi/g	**DCGL Buried Pipe *insitu* Scenairo LTP Chapter 6 Equation 6-16**
Am-241	2.657E-02	7.905E+05
C-14	2.367E-03	8.874E+06
Ce-144	1.731E-04	1.213E+08
Cm-243	1.514E-02	1.387E+06
Cm-244	1.210E-02	1.736E+06
Co-58	4.426E-04	4.746E+07
Co-60	1.144E-02	1.836E+06
Cs-134	1.697E-02	1.238E+06
Cs-137	1.348E-02	1.558E+06
Eu-152	7.917E-05	2.653E+08
Eu-154	1.150E-04	1.826E+08
Eu-155	1.772E-05	1.185E+09
Fe-55	3.929E-06	5.346E+09
H-3	3.260E-04	6.443E+07
Ni-59	7.457E-05	2.817E+08
Ni-63	2.042E-04	1.029E+08
Np-237	1.057E+00	1.987E+04
Pu-238	2.854E-02	7.360E+05
Pu-239	3.170E-02	6.626E+05
Pu-240	3.170E-02	6.626E+05
Pu-241	7.593E-04	2.766E+07
Sb-125	1.038E-03	2.024E+07
Sr-90	2.537E-01	8.279E+04
Tc-99	1.424E-02	1.475E+06

Buried Pipe DCGL Calculation
LTP Chapter 6 Equation 6-20

Buried Pipe DCGL

Am-241	3.833E+05
C-14	2.559E+06
Ce-144	1.413E+06
Cm-243	2.802E+05
Cm-244	8.182E+05
Co-58	1.890E+05
Co-60	2.079E+04
Cs-134	3.564E+04
Cs-137	7.999E+04
Eu-152	4.609E+04
Eu-154	4.281E+04
Eu-155	1.609E+06
Fe-55	1.072E+09
H-3	2.941E+07
Ni-59	1.296E+08
Ni-63	4.732E+07
Np-237	1.323E+04
Pu-238	4.161E+05
Pu-239	3.747E+05
Pu-240	3.748E+05
Pu-241	1.443E+07
Sb-125	1.372E+05
Sr-90	4.093E+04
Tc-99	4.234E+05

LTP Chapter 6 Equation 6-20

$$DCGL_{bp,i} = \frac{1}{(1/DCGL_{bpi,i} + 1/DCGL_{bpe,i})}$$

where:

$DCGL_{bp,i}$ = Buried pipe DCGL for radionuclide i
$DCGL_{bpi,i}$ = Buried pipe *insitu* scenario DCGL for radionuclide i
$DCGL_{bpe,i}$ = Buried pipe excavation scenario DCGL for radionuclide i

LTP Chapter 6 Equation 6-17

$$C_{s,u,i} = \frac{A_{bp,u}/2.22}{(SA_{bp,u} t_{m,s} \rho_s)}$$

where:

$C_{s,u,i}$ = unitized soil concentration for buried pipe scenario i (pCi/g per dpm/cm^2)
$A_{bp,u}$ = unit activity in pipe over a 1 cm^2 area (1 dpm)
2.22 = conversion factor (dpm/pCi)
$SA_{bp,u}$ = unit surface area of buried pipe (1 cm^2)
$t_{m,i}$ = thickness of soil mixing zone for buried pipe scenario *i* (*insitu* scenario 2.54 cm or excavation scenario 15 cm and 100 cm)
ρ_s = density of soil (g/cm^3)

LTP Chapter 6 Equation 6-19

$$DCGL_{bp,s,i} = \left(\frac{25}{C_{bp,u,s} DSR_{bp,i}}\right)100$$

where:

$DCGL_{bp,s,i}$ = buried pipe DCGL for scenario *s* and radionuclide *i* (dpm/100 cm^2)
25 = 25 mrem/yr dose criterion
$C_{bp,u,s}$ = unitized soil concentration for buried pipe scenario *s* calculated using Equation 6-17 (pCi/g per dpm/cm^2)
$DSR_{bp,i}$ = buried pipe DSR for radionuclide i (mrem/yr per pCi/g)
100 = 100 cm^2 to calculate the DCGL in units of dpm/100 cm^2.

ROC DCGL Adjusted for IC Radionuclide Dose Contribution

Inputs to Calculation

IC Dose contribution fraction for BFM wall/floor, soil, buried pipe, and above ground building	0.05
IC dose adjustment fraction for BFM wall/floor, soil, buried pipe, and above ground building	0.95
IC dose contribution Fraction for embedded pipe and fill	0.1
IC dose adjustment factor for embedded pipe and fill	0.9

IC Adjusted ROC

ROC	Soil DCGL (pCi/g) IC Adjusted	
	0.15 m	**1.0 m**
C-14	5.70E+01	9.68E+00
Co-60	3.77E+00	2.93E+00
Cs-137	1.31E+01	7.27E+00
Eu-152	8.41E+00	7.36E+00

ROC	BFM Wall/Floor DCGL (pCi/m^2)		IC Adjusted
	Auxiliary, Turbine, Circulating Water Tunnels, Intake Structure	Containment	
C-14	8.20E+06	8.13E+06	
Co-60	3.40E+06	8.21E+05	
Cs-137	6.90E+06	2.61E+06	
Eu-152	9.62E+06	1.88E+06	
Sr-90	8.23E+05	8.46E+05	

ROC	Embedded Pipe DCGL (pCi/m2) IC Adjusted		
	Auxiliary Floor 971' elevation (pCi/m^2)	Auxiliary Floor 989' elevation (pCi/m2)	Turbine Floor 990' elevation (pCi/m2)
C-14	1.41E+09	1.10E+09	7.57E+08
Co-60	4.83E+09	3.77E+09	2.59E+09
Cs-137	7.53E+09	5.88E+09	4.04E+09
Eu-152	8.54E+10	6.67E+10	4.58E+10
Sr-90	2.04E+08	1.59E+08	1.09E+08

ROC	Buried Pipe DCGL ($dpm/100\ cm^2$) IC Adjusted
C-14	2.43E+06
Co-60	1.98E+04
Cs-137	7.60E+04
Eu-152	4.38E+04

ROC	Above Ground Building DCGL[1] ($dpm/100\ cm^2$)	Above Ground Building DCGL ($dpm/100\ cm^2$) IC Adjusted
C-14	3.70E+06	3.52E+06
Co-60	7.10E+03	6.75E+03
Cs-137	2.80E+04	2.66E+04
Eu-152[2]	1.27E+04	1.21E+04

1) Screening Values NUREG-1757, Vol 2, Table H-1

2) Eu-152 screening value is the P_{crit} 0.90 from Table 5.19 of NUREG/CR-5512, Volume 3

ROC	Fill DCGL (pCi/g) IC Adjusted
C-14	1.29E+01
Co-60	1.59E+01
Cs-137	1.36E+01
Eu-152	5.50E+02

Existing Groundwater Dose Conversion Factors

ROC	Water Dependent Dose[1] at t=1 yr (mrem/yr)	Well Water Concentration[1] at t = 1 yr (pCi/L)	Exisiting Groundwater Dose Conversion Factor (mrem/yr per pCi/L) LTP Chapter 6 Equation 6-21
C-14	0.45	1.663E+02	2.68E-03
Co-60	0.15	5.886E+00	2.52E-02
Cs-137	0.11	1.544E+00	6.86E-02
Eu-152	0.01	2.505E+00	3.63E-03
Sr-90	3.95	3.585E+01	1.10E-01

1) RESRAD File "FCS Embedded Pipe DSR"

LTP Chapter 6 Equation 6-21

$$DCF_{egw,i} = \frac{D_{wd,t,i}}{C_{ww,t,i}}$$

where:

$DCF_{egw,i}$ = dose conversion factor for radionuclide i (mrem/yr per pCi/L)
$D_{wd,t,i}$ = water dependent dose at time t for radionuclide i (mrem/yr)
$C_{ww,t,i}$ = well water concentration at time t for radionuclide i (pCi/L)

Basment Backfill DCGL

	BFM insitu Fill DCGL mrem/yr per pCi/g
Am-241	3.115E+00
C-14	1.433E+01
Ce-144	1.023E+03
Cm-243	8.928E+00
Cm-244	1.117E+01
Co-58	4.575E+02
Co-60	1.767E+01
Cs-134	1.197E+01
Cs-137	1.508E+01
Eu-152	6.108E+02
Eu-154	4.200E+02
Eu-155	2.703E+03
Fe-55	1.716E+04
H-3	1.733E+02
Ni-59	1.190E+03
Ni-63	4.345E+02
Np-237	5.655E-02
Pu-238	2.131E+00
Pu-239	1.919E+00
Pu-240	1.919E+00
Pu-241	9.916E+01
Sb-125	8.165E+01
Sr-90	8.859E-01
Tc-99	5.399E+00

Soil Area Factors

Input to Calculation

1 m^2 LPAF	1.00 m
2 m^2 LPAF	1.41
5 m^2 LPAF	2.24
10 m^2 LPAF	3.16
100 m^2 LPAF	10.00
143 m^2 LPAF	11.96

Soil Area Factor DCGL 0.15 m (pCi/m^2)						
	1 m^2	**2 m^2**	**5 m^2**	**10 m^2**	**100 m^2**	**142 m^2**
C-14	2.048E+07	8.550E+06	2.531E+06	9.712E+05	3.529E+04	2.085E+04
Co-60	4.876E+01	2.772E+01	1.493E+01	9.826E+00	5.117E+00	4.925E+00
Cs-137	1.976E+02	1.133E+02	6.136E+01	4.045E+01	2.144E+01	2.066E+01
Eu-152	1.032E+02	5.885E+01	3.177E+01	2.092E+01	1.104E+01	1.064E+01
Ni-63	2.177E+07	1.102E+07	4.445E+06	2.229E+06	2.236E+05	1.564E+05
Sr-90	1.027E+04	5.402E+03	2.383E+03	1.282E+03	1.588E+02	1.128E+02

Soil Area Factor 0.15 m (pCi/m^2)						
	1 m^2	**2 m^2**	**5 m^2**	**10 m^2**	**100 m^2**	**143 m2**
C-14	3.42E+05	1.43E+05	4.22E+04	1.62E+04	5.89E+02	3.48E+02
Co-60	1.23E+01	6.98E+00	3.76E+00	2.48E+00	1.29E+00	1.24E+00
Cs-137	1.44E+01	8.25E+00	4.47E+00	2.94E+00	1.56E+00	1.50E+00
Eu-152	1.17E+01	6.64E+00	3.59E+00	2.36E+00	1.25E+00	1.20E+00
Ni-63	5.28E+03	2.67E+03	1.08E+03	5.41E+02	5.43E+01	3.80E+01
Sr-90	9.24E+02	4.86E+02	2.14E+02	1.15E+02	1.43E+01	1.02E+01

Soil Area Factor DCGL 1.0 m (pCi/m^2)						
	1 m^2	**2 m^2**	**5 m^2**	**10 m^2**	**100 m^2**	**143 m^2**
C-14	1.719E+06	7.712E+05	2.536E+05	1.052E+05	4.607E+03	2.773E+03
Co-60	3.427E+01	2.020E+01	1.113E+01	7.390E+00	4.279E+00	4.147E+00
Cs-137	1.495E+02	8.897E+01	4.929E+01	3.277E+01	1.876E+01	1.798E+01
Eu-152	7.513E+01	4.444E+01	2.454E+01	1.631E+01	9.537E+00	9.273E+00
Ni-63	3.600E+06	1.806E+06	7.237E+05	3.621E+05	3.624E+04	2.534E+04
Sr-90	2.252E+03	1.146E+03	4.705E+02	2.394E+02	2.502E+01	1.754E+01

Soil Area Factor 1.0 m (pCi/m^2)						
	1 m^2	**2 m^2**	**5 m^2**	**10 m^2**	**100 m^2**	**143 m^2**
C-14	1.69E+05	7.57E+04	2.49E+04	1.03E+04	4.52E+02	2.72E+02
Co-60	1.11E+01	6.55E+00	3.61E+00	2.39E+00	1.39E+00	1.34E+00
Cs-137	1.95E+01	1.16E+01	6.44E+00	4.28E+00	2.45E+00	2.35E+00
Eu-152	9.70E+00	5.74E+00	3.17E+00	2.11E+00	1.23E+00	1.20E+00
Ni-63	4.27E+03	2.14E+03	8.59E+02	4.30E+02	4.30E+01	3.01E+01
Sr-90	1.30E+03	6.62E+02	2.72E+02	1.38E+02	1.45E+01	1.01E+01

Inputs to Calculation

Conversion factor	0.0037	(mrem/yr per pCi/cm^2) per (Sv/yr per Bq/cm^2)
Conversion factor	1.00E+04	cm2 per m2
dose criterion	25	mrem/yr
years before excavatiuon occurs	30	yr

		NUREG-1640, Table 2.1 - Effective Dose Equivalent		LLBP Offsite Recycle/Disposal Concentrations That Result in 25 mrem/yr LTP Chapter 6, Equation 6-25					
	Half-Life	Concrete	Steel	Concrete	Steel	BFM Wall/Floor DCGL (Auxiliary, Turbine, Circulating Water Tunnels, Intake Structure)	BFM Wall/Floor DCGL (Containment)	Auxiliary BFM Wall/Floor DCGL less than concrete recycle/disposal?	Containment BFM Wall/Floor DCGL less than steel recycle/disposal?
		Sv/yr per Bq/cm^2	Sv/yr per Bq/cm^2	pCi/m^2 per 25 mrem/yr	pCi/m^2 per 25 mrem/yr				
Am-241	432.2	2.20E-03	9.40E+00	3.22E+10	7.54E+06	4.168E+06	4.046E+06	TRUE	TRUE
C-14	5730	4.10E-04	6.30E-03	1.654E+11	1.076E+10	8.629E+06	8.559E+06	TRUE	TRUE
Ce-144	0.7784	1.90E-02	2.00E-01	1.414E+21	1.343E+20	2.553E+08	5.922E+07	TRUE	TRUE
Cm-243	28.5	1.10E-01	6.60E+00	1.274E+09	2.123E+07	1.003E+07	7.082E+06	TRUE	TRUE
Cm-244	18.11	6.40E-02	5.20E+00	3.328E+09	4.095E+07	1.369E+07	1.330E+07	TRUE	TRUE
Co-58	0.19	2.70E-01	3.30E+00	3.007E+55	2.460E+54	3.916E+07	8.058E+06	TRUE	TRUE
Co-60	5.271	1.00E+00	1.00E+01	3.489E+09	3.489E+08	3.578E+06	8.640E+05	TRUE	TRUE
Cs-134	2.062	5.80E-01	8.60E+00	2.787E+12	1.879E+11	4.396E+06	1.345E+06	TRUE	TRUE
Cs-137	30	2.20E-01	3.20E+00	6.142E+08	4.222E+07	7.265E+06	2.749E+06	TRUE	TRUE
Eu-152	13.33	4.40E-01	4.30E+00	7.305E+08	7.475E+07	1.013E+07	1.983E+06	TRUE	TRUE
Eu-154	8.8	4.90E-01	4.30E+00	1.464E+09	1.668E+08	9.336E+06	1.839E+06	TRUE	TRUE
Eu-155	4.96	1.10E-02	8.80E-02	4.062E+11	5.077E+10	3.619E+08	6.791E+07	TRUE	TRUE
Fe-55	2.7	7.60E-06	9.10E-05	1.963E+16	1.640E+15	1.384E+10	6.308E+09	TRUE	TRUE
H-3	12.35	2.40E-04	3.80E-03	1.516E+12	9.573E+10	2.208E+08	2.254E+08	TRUE	TRUE
Ni-59	7.50E+04	7.60E-06	9.10E-05	8.893E+12	7.427E+11	1.219E+09	1.122E+09	TRUE	TRUE
Ni-63	96	7.40E-06	9.40E-05	1.134E+13	8.926E+11	4.451E+08	4.098E+08	TRUE	TRUE
Np-237	2.14E+06	3.80E+00	6.20E+01	1.778E+07	1.090E+06	7.808E+04	7.831E+04	TRUE	TRUE
Pu-238	87.74	1.00E-01	6.10E+00	8.563E+08	1.404E+07	2.976E+06	2.939E+06	TRUE	TRUE
Pu-239	2.41E+04	1.10E-01	6.60E+00	6.148E+08	1.025E+07	2.681E+06	2.647E+06	TRUE	TRUE
Pu-240	6.54E+03	1.10E-01	6.60E+00	6.162E+08	1.027E+07	2.681E+06	2.647E+06	TRUE	TRUE
Pu-241	1.44E+01	2.20E-03	1.10E-01	1.301E+11	2.602E+09	1.310E+08	1.298E+08	TRUE	TRUE
Sb-125	2.77E+00	1.50E-01	1.40E+00	8.189E+11	8.773E+10	2.475E+07	5.694E+06	TRUE	TRUE
Sr-90	29.12	5.20E-03	1.20E-01	2.653E+10	1.150E+09	8.666E+05	8.903E+05	TRUE	TRUE
Tc-99	2.13E+05	2.20E-02	3.20E-01	3.072E+09	2.112E+08	5.900E+06	6.084E+06	TRUE	TRUE

LTP Chapter 6, Equation 6-25

$$C_{m,i} = \frac{25(1x10^4)}{(DF_{m,i}0.0037e^{(-\lambda_i 30)})}$$

where:

$C_{m,i}$ = concentration in material *m* (concrete or steel) for radionuclide *i* that results in a recycle/disposal dose of 25 mrem/yr (pCi/m^2)
25 = 25 mrem/yr dose criterion
1x10^4 = conversion factor (cm^2/m^2)
$DF_{m,i}$ = NUREG-1640, Table 2,1 dose factor for material *m* and radionuclide *i* (Sv/yr per Bq/cm^2)
0.0037 = conversion factor (mrem/yr per pCi/cm^2 per Sv/yr per Bq/cm^2)
λ_i = radioactive decay constant for radionuclide *i* (.693/$t_{1/2}$)
30 = time after license termination that large-scale excavation occurs (yr)

LLBP Embedded Pipe Drilling Spoils

Assumptions and Unit Conversion Factors

Diameter Borehole	8	in
Drilling Depth (bgs)	21.4	m
Concrete foundation depth	12	ft
Embedded Pipe Internal Diameter		
Auxiliary	4.03	in
	18.81	in
Turbine (max Turbine EP ID)	9.4	in
Fill and soil density	1.5	g/cm^3
Unit activity in drilling spoils	1	pCi/g
Depth of drilling spoils spread on ground	0.15	m
conversion factor	1.00E+06	cm^3/m^3
conversion factor	0.0254	m/in
conversion factor	6.45E-04	m^2/in^2
dose criterion	25	mrem/yr
Years after license termination	30	yr
Drilling spoils spread depth on ground surface	0.15	m

Calculations

Drilling Spoils Volume		
LTP Chapter 6, Equation 6-22	0.69	m^3
Spread Area	4.63	m^2
Length Parallel to Aquifer Flow	2.15	m
Aux EP 4.03 in concentration pCi/m2 per 1 pCi/g in spoils	1.59E+07	pCi/m^2 per pCi/g
LTP Chapter 6, Equation 6-23		
Aux EP 18.81 in concentration pCi/m2 per 1 pCi/g in spoils	1.61E+07	pCi/m^2 per pCi/g
LTP Chapter 6, Equation 6-23		
Turbine EP 9.4 in concentration pCi/m2 per 1 pCi/g in spoils	6.83E+06	pCi/m^2 per pCi/g
LTP Chapter 6, Equation 6-23		

LTP Chapter 6, Equation 6-22

$$V_{ds} = \pi\,(0.0254d/2)^2\,D_{bh}$$

where:

V_{ds} = volume of the drilling spoils on ground surface (m^3)
π = pi constant
0.0254 = conversion factor m/in
d = diameter of borehole (in) = 8 in
D_{bh} = depth of borehole (m) = 21.4 m

LTP Chapter 6, Equation 6-23

$$C_{ep,a} = \frac{V_{ds}\ 1x10^6\,\rho_{f,s}\,C_{ds,a}}{A_{ep}}$$

where:

$C_{ep,a}$ = embedded pipe concentration (pCi/m^2) required to produce a unit concentration of 1 pCi/g concentration in drilling spoils (pCi/m^2 per pCi/g)
V_{ds} = volume of drilling spoils calculated by Equation 6-22 (m^3)
$1x10^6$ = conversion factor cm^3/m^3
$\rho_{f,s}$ = density of fill/soil (g/cm^3)
$C_{ds,a}$ = unit concentration in drilling spoils (1 pCi/g)
A_{ep} = internal surface area of embedded pipe contacted by drill (m^2)

and:

$$A_{ep,4.03} = \pi 4.03d(6.45x10^{-4})$$
$$A_{ep,18.81} = 2\pi(d/2)^2 6.45x10^{-4}$$
$$A_{ep,9.4} = \pi 9.4d(6.45x10^{-4})$$

where:

$A_{ep,4.03}$ = internal surface area of 4.03 inch internal diameter pipe that is contacted by 8 in diameter drill
d = diameter of drill borehole = 8 in
$6.45x10^{-4}$ = conversion factor m^2/in^2
$A_{ep,18.81}$ = internal surface area of 18.81inch internal diameter pipe that is contacted by 8 inch diameter drill
$A_{ep,9.4}$ = internal surface area of 9.4 inch internal diameter pipe that is contacted by 8 inch diameter drill

LLBP Embedded Pipe Drilling Spoils Concentration That Results in 25 mrem/yr (pCi/m2)

Radionuclide	Half-life[1]	Drilling Spoils DSR (mrem/yr per pCi/g)	Auxiliary EP 4.03 in ID: EP LLBP Drilling Spoils Concentration (pCi/m^2) **LTP Chapter 6, Equation 6-24**	Auxiliary EP 18.81 in ID: EP LLBP Drilling Spoils Concentration (pCi/m^2) **LTP Chapter 6, Equation 6-24**	Turbine EP 9.4 in ID: EP LLBP Drilling Spoils Concentration (pCi/m^2) **LTP Chapter 6, Equation 6-24**	Auxiliary Basement: Dose From EP LLBP Drilling Spoils at BFM Embedded Pipe DCGL 4.03/971	4.03/989	18.81/971	Turbine Basement: Dose From EP LLBP Drilling Spoils at BFM Embedded Pipe DCGL Concentration 18.81/989	9.4/990
Am-241	432.2	1.028E-02	4.066E+10	4.10E+10	1.743E+10	0.01	0.01	0.01	0.01	0.02
C-14	5730	8.899E-06	4.493E+13	4.526E+13	1.926E+13	0.00	0.00	0.00	0.00	0.00
Ce-144	0.7784	2.448E-02	6.470E+21	6.518E+21	2.774E+21	0.00	0.00	0.00	0.00	0.00
Cm-243	28.5	8.099E-02	1.020E+10	1.028E+10	4.374E+09	0.15	0.12	0.15	0.12	0.19
Cm-244	18.11	1.795E-03	6.995E+11	7.047E+11	2.999E+11	0.00	0.00	0.00	0.00	0.00
Co-58	0.19	1.838E-01	2.604E+56	2.623E+56	1.116E+56	0.00	0.00	0.00	0.00	0.00
Co-60	5.271	1.595E+00	1.298E+10	1.299E+10	5.529E+09	0.42	0.32	0.41	0.32	0.52
Cs-134	2.062	9.205E-01	1.035E+13	1.043E+13	4.438E+12	0.00	0.00	0.00	0.00	0.00
Cs-137	30	3.883E-01	2.052E+09	2.067E+09	8.795E+08	4.08	3.19	4.05	3.16	5.10
Eu-152	13.33	7.499E-01	2.527E+09	2.546E+09	1.083E+09	37.53	29.31	37.25	29.09	46.93
Eu-154	8.8	7.990E-01	5.294E+09	5.333E+09	2.269E+09	12.32	9.62	12.22	9.54	15.40
Eu-155	4.96	2.599E-02	1.014E+12	1.021E+12	4.345E+11	0.41	0.32	0.41	0.32	0.52
Fe-55	2.7	2.638E-07	3.335E+18	3.360E+18	1.430E+18	0.00	0.00	0.00	0.00	0.00
H-3	12.35	5.798E-06	3.699E+14	3.727E+14	1.586E+14	0.00	0.00	0.00	0.00	0.00
Ni-59	7.50E+04	1.905E-06	2.092E+14	2.107E+14	8.968E+13	0.00	0.00	0.00	0.00	0.00
Ni-63	96	5.210E-06	9.495E+13	9.566E+13	4.071E+13	0.00	0.00	0.00	0.00	0.00
Np-237	2.14E+06	1.568E-01	2.541E+09	2.560E+09	1.089E+09	0.00	0.00	0.00	0.00	0.00
Pu-238	87.74	2.872E-03	1.758E+11	1.771E+11	7.537E+10	0.00	0.00	0.00	0.00	0.00
Pu-239	2.41E+04	3.172E-03	1.257E+11	1.266E+11	5.389E+10	0.00	0.00	0.00	0.00	0.00
Pu-240	6.54E+03	3.157E-03	1.266E+11	1.275E+11	5.427E+10	0.00	0.00	0.00	0.00	0.00
Pu-241	1.44E+01	2.688E-04	6.279E+12	6.326E+12	2.692E+12	0.00	0.00	0.00	0.00	0.00
Sb-125	2.77E+00	2.555E-01	2.834E+12	2.856E+12	1.215E+12	0.00	0.00	0.00	0.00	0.01
Sr-90	29.12	9.795E-03	8.305E+10	8.367E+10	3.561E+10	0.00	0.00	0.00	0.00	0.00
Tc-99	2.13E+05	7.804E-04	5.105E+11	5.143E+11	2.189E+11	0.00	0.00	0.00	0.00	0.00

1) RESRAD Users Manual Version 6 Table 3.1

LTP Chapter 6, Equation 6-24

$$C_{ep,i} = \frac{25\ C_{ep,a}}{DSR_i}$$

where:

$C_{ep,i}$ = concentration in embedded pipe that results in 25 mrem/yr through the LLBP drilling spoils scenario for radionuclide i (pCi/m^2)
$C_{ep,a}$ = embedded pipe concentration required to produce 1 pCi/g average concentration in drilling spoils (Equation 6-23) (pCi/m^2 per pCi/g)
DSR_i = dose to source ratio for radionuclide i (mrem/yr per pCi/g)
25 = 25 mrem/yr dose criterion

Is BFM Embedded Pipe DCGL less than Embedded Pipe LLBP Drilling Spoils Concentration?