

**Inputs to Calculation**

Irrigation rate	0.19 m <sup>3</sup> /y
Household water use family of 4	328.7 m <sup>3</sup> /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 <sup>2</sup>	Irrigation of 40,000 m <sup>2</sup>
Household Water Use (m <sup>3</sup> /yr)	328.7	328.7	328.7
Meat and Dairy Cow (m <sup>3</sup> /yr)	0.0	40.2	40.2
Irrigation (m <sup>3</sup> /yr)	0.0	4180.0	7600.0
Drinking Water (family of 4) (m <sup>3</sup> /yr)	1.9	1.9	1.9
Well Pumping Rate (m <sup>3</sup> /yr)	330.6	4550.8	7970.8



## Penetration Effective Basement Surface Area

### Input to Calculation

Conversion Factor 2.540E-02 m/in

### Effective Penetration Surface Area

Basement	Internal Surface Area <sup>1</sup> (m <sup>2</sup> )	Internal Volume <sup>1</sup>	SA/V	Wall/Floor Surface Area <sup>2</sup> (m <sup>2</sup> )	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)	DCGL (pCi/g)
	0.15 m	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 Concrete and Liner Excavation Scenario DCGL**

<b>Inputs to Calculation</b>			
unit activity over a 1 m <sup>2</sup> 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 <sup>2</sup>	
conversion factor	1.00E+04	cm <sup>2</sup> /m <sup>2</sup>	
concrete density	2.2	g/cm <sup>3</sup>	
<b>Calculation</b>			
unit concentration in excavated concrete			
<b>LTP Chapter 6, Equation 6-8</b>	7.46E-07	pCi/g per pCi/m <sup>2</sup>	

**BFM Concrete Excavation Scenario DCGL**

	Soil DCGL 1.0 m (pCi/g)	Concrete Excavation DCGL (DCGL <sub>e,c</sub> ) <sup>1</sup> pCi/m <sup>2</sup>	Liner Excavation DCGL (DCGL <sub>e,l</sub> ) pCi/m <sup>2</sup>
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



**LTP Chapter 6, Equation 6-8**

$$C_{ec,u} = \frac{A_{c,u}}{t_w(30.48)UA_c(1 \times 10^4)\rho_c}$$

where:

$C_{ec,u}$  = unit concentration in excavated concrete (pCi/g per pCi/m<sup>2</sup>)  
 $A_{c,u}$  = unit activity of 1 pCi over a 1 m<sup>2</sup> 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<sup>2</sup>)  
 $1 \times 10^4$  = cm<sup>2</sup>/m<sup>2</sup>  
 $\rho_c$  = density of concrete (2.2 g/cm<sup>3</sup>)

**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<sup>2</sup>)  
 $DCGL_{s,i}$  = 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<sup>2</sup>)

**LTP Chapter 6, Equation 6-10**

$$C_{s,t,u} = \frac{A_u}{tUA_l 1 \times 10^6 \rho_s}$$

where:

$C_{s,t,u}$  = unit concentration in soil for thickness t (pCi/g per pCi/m<sup>2</sup>)  
 $A_u$  = unit activity of 1 pCi over a liner area of 1 m<sup>2</sup> (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<sup>2</sup>)  
 $1 \times 10^6$  = cm<sup>3</sup>/m<sup>3</sup>  
 $\rho_s$  = density of soil (1.5 g/cm<sup>3</sup>)

**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<sup>2</sup>)  
 $DCGL_{s,t,i}$  = 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<sup>2</sup>)





LTP Chapter 6 Equation 6-15

$$C_{f,ei} = \frac{A_{ep,u} S A_{ep,ei} 0.0929}{S A_{f,ei} 0.0929 D_m 1 \times 10^6 \rho_f}$$

where:

$C_{f,ei}$  = concentration in fill from release of activity from embedded pipe at floor elevation i (pCi/g per pCi/m<sup>2</sup>)  
 $A_{ep,u}$  = unit activity in embedded pipe (1 pCi per m<sup>2</sup>),  
 $S A_{ep,ei}$  = embedded pipe internal surface area in floor elevation i (ft<sup>2</sup>),  
0.0929 = Conversion Factor (m<sup>2</sup>/ft<sup>2</sup>)  
 $S A_{f,ei}$  = floor surface area at elevation i (ft<sup>2</sup>),  
 $D_m$  = mix distance in fill (1 m)  
 $1 \times 10^6$  = Conversion factor (g/cm<sup>3</sup>)  
 $\rho_f$  = bulk density of fill (assumed to be sand) (g/cm<sup>3</sup>)

LTP Chapter 6 Equation 6-16

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

Where:

$DCGL_{ep,ei,j}$  = embedded pipe DCGL at floor elevation i for radionuclide j (pCi/m<sup>2</sup>)  
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<sup>2</sup>)

	16 sv/yr per Bq/g
Steel scrap mass	14657 t
conversion factor	1000 kg/t
Nureg-1640 surface dose factor	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  
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<sub>bp,i</sub> = Buried pipe DCGL for radionuclide i

DCGL<sub>bpi,i</sub> = Buried pipe *insitu* scenario DCGL for radionuclide i

DCGL<sub>bpe,i</sub> = 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<sup>2</sup>)

$A_{bp,u}$  = unit activity in pipe over a 1 cm<sup>2</sup> area (1 dpm)

2.22 = conversion factor (dpm/pCi)

$SA_{bp,u}$  = unit surface area of buried pipe (1 cm<sup>2</sup>)

$t_{m,i}$  = thickness of soil mixing zone for buried pipe scenario  $i$  (*insitu* scenario 2.54 cm or excavation scenario 15 cm and 100 cm)

$\rho_s$  = density of soil (g/cm<sup>3</sup>)

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<sup>2</sup>)

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<sup>2</sup>)

$DSR_{bp,i}$  = buried pipe DSR for radionuclide  $i$  (mrem/yr per pCi/g)

100 = 100 cm<sup>2</sup> to calculate the DCGL in units of dpm/100 cm<sup>2</sup>.

# 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 <sup>2</sup> ) 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/m <sup>2</sup> ) IC Adjusted		
	Auxiliary Floor 971' elevation (pCi/m <sup>2</sup> )	Auxiliary Floor 989' elevation (pCi/m <sup>2</sup> )	Turbine Floor 990' elevation (pCi/m <sup>2</sup> )
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 <sup>2</sup> ) 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 <sup>1</sup> (dpm/100 cm <sup>2</sup> ) IC Adjusted	Above Ground Building DCGL (dpm/100 cm <sup>2</sup> ) 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 <sup>2</sup>	1.27E+04	1.21E+04

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

2) Eu-152 screening value is the P<sub>crit</sub> 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 <sup>1</sup> at t=1 yr (mrem/yr)	Well Water Concentration <sup>1</sup> at t = 1 yr (pCi/L)	Existing 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<sub>egw,i</sub> = dose conversion factor for radionuclide i (mrem/yr per pCi/L)  
D<sub>wd,t,i</sub> = water dependent dose at time t for radionuclide i (mrem/yr)  
C<sub>ww,t,i</sub> = well water concentration at time t for radionuclide i (pCi/L)

## Basment Backfill DCGL

	<b>BFM insitu Fill DCGL</b> <b>mrem/yr per pCi/g</b>
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





