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2.4.13 Accidental Releases of Liquid Effluents to Ground and Surface Waters

The purpose of this section is to provide a conservative analysis of a postulated, accidental release of radioactive liquid effluents to the environment at the Clinch River Nuclear (CRN) Site (Figure 2.4.13-1), in accordance with the guidance provided in Branch Technical Position (BTP) 11-6, *Postulated Radioactive Releases Due to Liquid-Containing Tank Failures*; DC/COL-ISG-013, *Assessing the Radiological Consequences of Accidental Releases of Radioactive Materials from Liquid Waste Tanks for Combined License Applications* (Reference 2.4.13-1); and DC/COL-ISG-014, *Assessing the Radiological Consequences of Accidental Releases of Radioactive Materials from Liquid Waste Tanks in Ground and Surface Waters for Combined License Applications* (Reference 2.4.13-2). The accident scenario is described and the methodology used to evaluate radionuclide transport is presented, along with potential contamination migration pathways to water users. The radionuclide concentrations and associated doses to which a water user might be exposed are compared against regulatory limits.

2.4.13.1 Accident Source

It is postulated that a liquid radwaste tank outside of containment or outdoors ruptures with its contents released to the environment. The maximum tank volume with liquid radioactive waste is 10,000 gallons. The initial postulated radionuclide inventory of the spill is shown on Table 2.0-5. A simplified release scenario is assumed, in which 80 percent of the tank volume is transferred instantaneously to the groundwater at a point within the power block area, and no credit is taken for the time that radionuclides may take (and the associated radioactive decay) to travel from the Liquid Waste Management System (LWMS) tank to the saturated zone. Analyzing a release of 80 percent of the tank volume is based on the guidance in DC/COL-ISG-013 (Reference 2.4.13-1) which states “The radionuclide inventory for the tank and its components assumed to fail should be based on a conservative estimate of 80 percent capacity of that tank and its components.” It is anticipated that a postulated radionuclide release will be mixed with groundwater of the CRN Site and will travel toward the Clinch River arm of the Watts Bar Reservoir.

Each of the four reactor vendors provided source term information for the accidental release of radioactive liquids, consistent with the guidance in NEI 10-01 (Reference 2.4.13-19). The source terms of the four SMR vendors were evaluated. The source term concentration for one vendor was found to be more conservative. On this basis, the source term and tank volume (10,000 gallons) associated with this vendor was adopted as the surrogate plant values. However, based upon the large amount of conservatism included in the surrogate plant values as compared to the other SMR designs, a lower activity was used for Zr-95 and Nb-95. In addition, the surrogate plant values were compared to the PSEG ESPA source term values (Reference 2.4.13-20) to assess the reasonableness of the surrogate plant source terms. This comparison concluded that the surrogate plant source terms are conservative when compared to source terms for large light water reactors and are considered to be reasonable for use.

DC/COL-ISG-013 (Reference 2.4.13-1) also indicates that an applicant may take credit for mitigating design features provided they demonstrate that “such features are durable and passive and that the receiving system has the storage capacity to hold the expected volume of liquid wastes.” As a reactor technology has not been selected, no mitigation design features are considered in this analysis. Mitigation features included in the design of the reactor technology selected are addressed in the Combined License Application.

2.4.13.2 Receptors

NUREG-0800, *Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants: LWR Edition*, Section 2.4.13, and BTP 11-6 require the consideration of radiation exposure to members of the public at points beyond the site boundary where the Applicant has no administrative control. Radiation doses are then calculated based on various consumption pathways on an annual basis as defined in Regulatory Guide 1.109, *Calculation of Annual Doses to Man from Routine Releases of Reactor Effluents for the Purpose of Evaluating Compliance with 10 CFR Part 50, Appendix I*. The nearest site boundary beyond which the Tennessee Valley Authority (TVA) has no administrative control is the right bank (looking downstream) of the Clinch River arm of Watts Bar Reservoir (herein, referred to as the Reservoir).

The nearest surface water intake is the Oak Ridge Bear Creek Plant, located downstream of the CRN Site as shown on Table 2.4.1-1 and Figure 2.4.1-1 (Location No. 45). This plant is also known as the City of Oak Ridge's West End Water Treatment Plant (WTP) and the K-25 Water Treatment Plant. The Oak Ridge Bear Creek Plant ceased water production on September 30, 2014, and Oak Ridge Utilities which now owns the facility has no plans to resume production at the site. Further downstream of the CRN Site, the closest surface water intakes in the Watts Bar Reservoir are near Kingston, TN. The Kingston Fossil Plant uses the Emory River/Watts Bar Reservoir as a source of thermoelectric cooling water, and the Kingston Water System uses the Tennessee River/Watts Bar Reservoir for public drinking water supply.

2.4.13.3 Primary Conceptual Model

Figure 2.4.13-2 illustrates the primary conceptual model used to evaluate, for the CRN Site, an accidental liquid release of effluent to groundwater or to surface water via the groundwater pathway. The geology of the CRN Site consists of regolith composed of fill, clayey soils, and saprolite underlain by fractured bedrock, with fracture frequency decreasing with depth. As discussed in Subsection 2.5.1.2.5.1.2, solution widening of fractures has occurred, resulting in open and clay-filled cavities. Groundwater flow occurs primarily in the fractures and is approximately bounded within the upper 100 feet (ft) of subsurface material below ground surface as discussed in Subsection 2.4.12.1.3. Groundwater flow is toward the Reservoir.

Following release, it is assumed that radionuclides travel through the construction fill material and the shallow, pervasively fractured bedrock before reaching the Reservoir (Figure 2.4.13-2). The travel distance is taken to be the minimum distance between the power block area and the Reservoir, which is a distance of 1400 ft. The shortest distance provides a conservative estimate, as less travel time allows for less decay of radionuclides.

During saturated zone transport, radionuclide concentrations of the liquid effluent released to the groundwater would be reduced by the processes of sorption, dispersion, and radioactive decay. The key elements embodied in the conceptual model are described and discussed in Subsection 2.4.13.5.

2.4.13.4 Alternate Conceptual Model

An alternate groundwater pathway involves groundwater discharge to the surface, via springs and seeps to onsite surface drainages and surface water discharge into the Clinch River arm of the Watts Bar Reservoir during wet periods (Figure 2.4.13-3). This scenario would be consistent with the conceptual model of groundwater flow in the Valley and Ridge Physiographic Province as discussed in Subsection 2.4.12.1.2. However, this alternate groundwater pathway is less conservative than the primary conceptual model, as additional surface water dilution from wet period runoff along with dilution in the Reservoir would lower radionuclide concentrations below those of the primary conceptual model. Thus, no further evaluation was undertaken to determine

radionuclide concentrations in the Reservoir based on the alternative conceptual model for radioactive release. As discussed in Subsection 2.4.12.3.1, it is very unlikely that there is shallow groundwater flow underneath the Clinch River arm of the Watts Bar Reservoir and exposure to water users on the opposite side of the Reservoir.

2.4.13.5 Radionuclide Transport Analysis

A radionuclide transport analysis has been conducted to estimate the radionuclide concentrations that might result in exposure to existing and future water users based on an instantaneous release of the radioactive liquid from a hypothetical storage device. Analysis of liquid effluent release commences with a screening model, using demonstratively conservative assumptions and coefficients. Radionuclide concentrations resulting from the screening analysis are then compared to the effluent concentration limits (ECLs) identified in 10 CFR 20, Appendix B, Table 2, Column 2, to determine acceptability. Further analysis, using more realistic modeling techniques, is conducted for the radionuclides identified in the screening analysis.

2.4.13.5.1 Radionuclide Transport in Groundwater and Surface Water

The effects of transport in groundwater and dilution in the Reservoir are modeled using an analytical approach outlined in Reference 2.4.13-3 for calculating the discharge rate (flux) of a radionuclide entering a surface water body that has intercepted the aquifer containing the transported material following an instantaneous release. The flux in this case is given by Equation 4.41 of Reference 2.4.13-3. Multiplying this equation by V_T/Q gives the following expression for the dilution factor:

$$1/D_L = \frac{V_T}{Q}\frac{(X+\frac{Ut}{R_d})}{4\sqrt{\pi D_x t^3/R_d}}\exp\left(-\frac{\left(X-\frac{Ut}{R_d}\right)^2}{\frac{4D_x t}{R_d}}-\lambda t\right)$$ Equation 2.4.13-1

Where:

- D_L = dilution factor = C_0/C
- C_0 = source concentration
- C = concentration in the intercepting waterbody
- D_x = longitudinal dispersion coefficient [L^2/T]
- D_x = α_L * U
- R_d = retardation coefficient
- Q = flow rate of the Reservoir [L^3/T]
- α_L = longitudinal dispersivity of the aquifer [L]
- V_T = volume of release [L^3]
- U = pore velocity of groundwater [L/T]
- λ = decay constant [T^{-1}]
- x = distance [L]
- t = time [T]

Equation 2.4.13-1 allows calculation of D_L as a function of time and can be solved by trial to find the minimum dilution factor, which yields the maximum concentration in the Reservoir. As

discussed in Reference 2.4.13-21, this equation accounts for the processes of advection, dispersion, sorption (retardation), and radioactive decay during groundwater transport, as well as dilution due to mixing with flows (Q) of the Reservoir.

2.4.13.5.2 Estimation of Initial Concentrations (C_0)

Application of dilution factors obtained from Equation 2.4.13-1 requires an initial concentration (C_0) for each radionuclide of concern. This is obtained by dividing the peak activity of the radionuclide by the tank volume. However, some daughter products (e.g., Pu-239) will arise after the release that are not included in the source term (Table 2.0-5), and others listed in the inventory will increase in activity as daughter products of a decay chain. Peak activity was determined by simulating decay of the source term inventory at various time steps ranging from 0 to 50 years for relevant radionuclides to capture the maximum activity of daughter products (Table 2.4.13-1).The maximum activity for each radionuclide was selected and divided by the release volume to arrive at C_0 values for these radionuclides (Table 2.4.13-2).

Note that this approach overestimates the total activity released, as parent radionuclide activities are not decreased while daughter product activities are increased. With the exceptions of Nb-93m and U-235, all radionuclides showed peak activity well within the timescale of 50 years.

Nb-93m and U-235 do not reach peak activity within 50 years. Nb-93m was removed from further consideration because its parent radionuclide, Zr-93, is very long lived (half-life over 1 million years) and, therefore, significant concentrations of Nb-93m, which is relatively short-lived with a half-life of about 14 years, will not accumulate. As for U-235, which arises from the decay chain Np-239 → Pu-239 → U-235m → U-235, near complete decay of Np-239 to U-235 would not occur for thousands of years, as the decay chain includes Pu-239, which is long-lived (half-life of about 24,000 years). However, computing the activity of U-235 that would result from the complete decay of the activity of its parent radionuclide, Np-239, gives an activity about 2.5×10^{-5} Curies (Ci), 700 times the value used in this analysis (3.56×10^{-8} Ci). This assumes each atom of Np-239 becomes an atom of U-235 and no decay occurs thereafter, and uses the fact that activity (in units of Ci) is equal to the product of the number of atoms times the radioactive decay constant (in units of s^{-1}). Given that the results presented below show predicted exposure concentrations of U-235 on the order of 10^{-10} times the ECL, the initial activity value used for the analysis is not expected to have any significant effect on the subsequent dose analysis, as multiplying the concentration by 700 would still yield a value less than 10^{-6} of the ECL.

2.4.13.5.3 Input Parameters

The input parameter values to determine the dilution factor, D_L, as defined in Equation 2.4.13-1, are as follows:

2.4.13.5.3.1 Tank Volume and Volume Released (V_T)

The maximum tank volume with liquid radioactive waste is 10,000 gallons. It is assumed that 80 percent of the tank volume is transferred instantaneously to the groundwater at a point within the power block area. Thus, 8000 gallons (1069.4 cubic ft) is used as input for V_T in Equation 2.4.13-1.

2.4.13.5.3.2 Groundwater Pore Velocity (U) and Groundwater Travel Time

The magnitude of groundwater pore velocity, U, is computed using the relation (Equation 4.8 of Reference 2.4.13-3):

$$U = -\frac{K}{n_e}\frac{dH}{dx}$$ Equation 2.4.13-2

Where:

K = hydraulic conductivity [L/T]

n_e = effective porosity (unitless)

dH/dx = hydraulic gradient [L/L]

A hydraulic conductivity of 2.6 ft/day is used based on the results of the onsite aquifer pumping test analysis as discussed in Subsection 2.4.12.2.4.1. This is the computed hydraulic conductivity for the observation well oriented along the predominant groundwater flow path (parallel to strike).

The effective porosity was assigned a value of 0.0467 based on testing performed at the Oak Ridge Reservation (References 2.4.13-4 and 2.4.13-5) as discussed in Subsection 2.4.12.2.4.1. The selected value is the average of 90 tests conducted using immersion-saturation porosimetry.

Based on site water level measurements, as discussed in Subsection 2.4.12.2.2, the horizontal hydraulic gradient at the CRN Site ranges from 0.03 to 0.11. The mean, 0.07, is used as the representative horizontal hydraulic gradient.

The resulting groundwater pore velocity (U), computed using Equation 2.4.13-2, is about 3.9 ft/day. The distance from the power block area to the Reservoir is approximately 1400 ft. Thus, the groundwater travel time from the edge of the power block area to the Reservoir is estimated to be about 359 days (1400 ft/[3.9 ft/day]).

2.4.13.5.3.3 River Flow Rate (Q)

Outflow data for the Melton Hill Reservoir were used to assess the volumetric flow rate of the Reservoir near the CRN Site. Melton Hill Dam is located approximately five river miles upstream of the CRN Site. Daily average flow data were available from August 1962 to October 2013. This time range includes additional zero flow data associated with the early period of record before Melton Hill Dam was closed and filling of the reservoir was underway. The following statistics were calculated for this time period:

1. Daily average outflow rates range from 0 to nearly 35,000 cubic feet per second (cfs).

2. Zero flow was recorded for about 3.7 percent of the days in the period of record.

3. Daily average flow rate over the entire period of record is 4876 cfs.

4. Annual averages (based on calendar year) range from 2005 to 8071 cfs.

5. Lowest average flow rate over a continuous 365-day period was about 1760 cfs, which occurred from December 12, 2007 to December 10, 2008.

Additionally, TVA conducted its own analysis and determined the average weekly discharge from Melton Hill Dam over its lifetime to be approximately 4800 cfs with a maximum weekly discharge of approximately 25,450 cfs. TVA also analyzed expected flow frequency from Melton Hill Dam

based on 100 years of reservoir and system simulation conducted for the development of reservoir operating policy and determined a minimum flow requirement from Melton Hill Dam to be 400 cfs average daily flow. This minimum daily average release can be met, and has in the past been met, by operating the hydropower generating units for a period of only one hour per day. This can result in periods, potentially lasting up to 46 hr, where there are no releases from Melton Hill Dam. However, events during which there is no release from Melton Hill Dam for periods in excess of 36 hr are extremely rare. A bypass, which can produce a continuous flow rate of 400 cfs even when the hydropower generating units are not operating, will be installed at the dam.

Based on Equation 2.4.13-1, increase in flow (Q) in the Reservoir results in increase of dilution factor (D_L), which in turn results in decrease in radionuclide concentrations in the Reservoir (C). Taking a conservative approach (i.e., least dilution and maximum radionuclide concentration in the Reservoir), the minimum flow of 400 cfs average daily flow was used as input for Q in Equation 2.4.13-1. As noted in Reference 2.4.13-3, contaminated groundwater "would enter the surface water as a diffuse patch" as a result of source geometry (e.g., a pool of liquid on the ground surface) and dispersion processes which tend to spread the plume in all directions during transport, promoting mixing of contaminated groundwater seepage with the flow in the Reservoir. The dilution flow rate of 400 cfs is selected to represent the near-field dilution (i.e., dilution at the interface of groundwater and surface water interaction) which results as groundwater enters the Reservoir via seepage through the riverbed prior to being available to a receptor.

2.4.13.5.3.4 Aquifer Bulk Density (ρ_b)

The aquifer bulk density is estimated based on the estimates of the geotechnical engineering properties. Table 2.4.13-3 presents estimates of the bulk density for each geologic formation at the CRN Site using relationships between saturated density, water content, and grain density (Reference 2.4.13-6). As shown in Table 2.4.13-4, measurements from the rock strata at the CRN Site, the primary media for groundwater transport and radionuclide travel, indicated a bulk density of about 2.7 g/cm^3. However, the lowest value computed, 1.4 g/cm^3 (for the existing fill and overlying soils), was selected to produce the lowest retardation coefficient (Equation 2.4.13-4) which is conservative for transport analysis.

2.4.13.5.3.5 Aquifer Longitudinal Dispersivity (α_L)

The longitudinal dispersivity was estimated using the relation between dispersivity and transport distance scale given in Equation 14b of Reference 2.4.13-7. This equation was chosen because it provides a higher weight to measured data points that have high reliability in Reference 2.4.13-7.

$$\alpha_L = 0.83\ (\log_{10} x)^{2.414} \qquad \text{Equation 2.4.13-3}$$

The length scale, x, in the above equation is in meters and α_L is also in meters. The length scale used in the above equation is 426.7 m (1400 ft) for the transport distance from the edge of power block area to the edge of the Reservoir. The estimated α_L is 8.57 m (28.1 ft).

2.4.13.5.3.6 Radioactive Half-Life and Decay Constant

Radioactive half-lives for the radionuclides under consideration were obtained from References 2.4.13-8, 2.4.13-9, and 2.4.13-10. Radionuclide half-lives were used to calculate the decay constant for each radionuclide, which are given in Table 2.4.13-2.

2.4.13.5.3.7 Distribution Coefficients (K_d)

Distribution coefficients, K_d, were applied to selected radionuclides based on laboratory testing carried out using samples from the CRN Site as shown on Table 2.4.13-4. K_d is used in the computation of the retardation coefficient, R_d, using the relation:

$$R_d = 1 + \frac{\rho_b K_d}{n_e} \qquad \text{Equation 2.4.13-4}$$

Where ρ_b is the bulk density and n_e is the effective porosity of the aquifer. Non-zero K_d values were used for elements for which site-specific laboratory measurements were available. The geometric mean of the laboratory-derived K_d values was assigned as the representative value for each element. K_d test result summary statistics and analysis notes are presented in Table 2.4.13-4. No site-specific K_d value was measured for the Yttrium (Y) series of radioisotopes, such as Y-91. However, Y chemistry is similar to a lanthanide and is often associated in the environment with lanthanides such as cerium (Ce) (Reference 2.4.13-11). The site-specific geometric mean K_d value for Ce is 54 mL/g and thus the likely K_d value for Y is also 54 mL/g. Table 2.4.13-5 presents the resulting R_d values as well as the associated solute travel times (used as t in Equation 2.4.13-1) which are computed as the product of the groundwater travel time and R_d.

2.4.13.6 Radionuclide Concentration in the Reservoir

Minimum dilution factors and associated maximum concentrations in the Reservoir are provided in Table 2.4.13-5. For screening purposes, dilution factors were initially calculated without considering the effects of sorption (using Equation 2.4.13-1 with R_d = 1). The resulting concentrations in the Reservoir were compared against the ECLs. This resulted in several exceedances of ECLs.

Further analysis accounting for sorption of the radioisotopes listed in Subsection 2.4.13.5.3.7 (Table 2.4.13-4) was performed considering the effects of sorption/retardation. This resulted in a decrease of the estimated concentrations in the Reservoir to below the ECL for all isotopes (Table 2.4.13-5). These concentrations were carried forward for dose evaluation, as described in the Subsection 2.4.13.7.

The resultant concentrations in the Reservoir in Table 2.4.13-5 (with sorption) are used to develop the annual dose estimates and the following conservatisms have been included in their determination.

The radionuclide release was assumed to enter the groundwater instantaneously with no consideration of any containment barrier, radionuclide decay, or onsite surface water dilution as a result of wet periods, and all radionuclide concentrations (including daughter products) are assumed to be coincidentally at their peak. This is conservative because it overestimates the concentrations and the annual dose for many of the radionuclides of interest.

The flow rate in the Reservoir is assumed to be 400 cfs, which represents the minimum release requirement for the upstream Melton Hill Dam per its reservoir operating policy. The value of 400 cfs is 4.4 times lower than the minimum daily average flow rate over a continuous 365-day period (1760 cfs) and 12.2 times lower than the daily average flow rate (4876 cfs). Also, the 400 cfs flow rate assumes no tributary or groundwater inflows between the Melton Hill Dam and the CRN Site, which are reasonably expected to occur and which would increase flow downstream of the dam. This lower assumed flow rate results in higher radionuclide concentrations at the receptor and consequently higher doses.

The distribution coefficient for radionuclides, for which no site-specific distribution coefficients are available (e.g., Nb-95, Sb-124), is assumed to be zero, even though non-zero values are reported in literature. A larger retardation factor (associated with non-zero distribution coefficients) would result in longer radionuclide travel time, more radioactive decay, and lower concentrations in the Reservoir. For example, Reference 2.4.13-18 reports distribution coefficient values for Nb ranging from 80 to 100 cm^3/g, based on batch and column experiments conducted with crushed rock. If similar values were used in the analysis, the calculated Nb-95 concentration in the Reservoir would be essentially zero, and the dose to the receptor would be greatly reduced.

Finally, the travel time for the release is that associated with the shortest path between the power block area and the Reservoir, which limits radioactive decay and results in higher concentrations in the Reservoir and higher doses.

2.4.13.7 Dose Evaluation

In addition to meeting the 10 CFR 20, Appendix B, ECLs, the dose due to the radionuclide concentrations in the Reservoir (Table 2.4.13-5) must also meet the 10 CFR 20.1301 dose limit for a member of the public. The Reservoir is a potential source of drinking water, as well as of aquatic foods and is also used for recreational activities. The LADTAP II computer program (Reference 2.4.13-12) is used to calculate dose associated with liquid radioactive waste effluent and was used in the evaluation of doses due to accidental release of radioactive liquids. Whereas LADTAP II typically calculates total body and organ doses, the dose limit in 10 CFR 20.1301 is in terms of total effective dose equivalent (TEDE). As dose is directly proportional to the dose conversion factor (DCF), the dose calculated by LADTAP II for a given nuclide and exposure pathway was adjusted to TEDE by changing the DCFs applied (in the DCF library within the LADTAP II code).

The following exposure pathways were considered in evaluating dose:

- Consumption of water from the Reservoir
- Consumption of fish and invertebrate from the Reservoir
- Consumption of vegetables, milk, and meat affected by irrigation water from the Reservoir
- Boating, swimming, and shoreline activities on the Reservoir

The major inputs and assumptions are as follows:

- No dilution is credited beyond the concentrations shown in Table 2.4.13-5
- Transit time to dose receptors is assumed to be zero
- Irrigation rate is assumed to be 1 inch/week, which bounds the actual rate near the plant of 0.24 inch/week (Reference 2.4.13-13)
- Consumption and usage rates are the default values for the maximally exposed individual from Regulatory Guide 1.109, Table E-5, while assuming that the time spent on boating and swimming is each the same as that for shoreline activities
- Exposure duration is assumed to be 1 year

- TEDE dose conversion factors for ingestion are obtained from Federal Guidance Report 11 (Reference 2.4.13-14)
- TEDE dose conversion factors for ground deposition and immersion are obtained from Federal Guidance Report 12 (Reference 2.4.13-15)

LADTAP II requires the source nuclide activities to be input in the units of Ci/yr. The concentrations in Table 2.4.13-5 are converted into release rates (Ci/yr) by multiplying by an arbitrary flow rate of 1 cfs, which is then entered as the liquid effluent discharge rate. LADTAP II divides the isotopic activity by the discharge rate to obtain the initial concentrations, causing the flow rate to cancel out. With the transit time to the dose receptor input as zero, LADTAP II calculates concentrations at the receptor that are identical to those in Table 2.4.13-5. The resulting total dose from all exposure pathways is 93 mrem TEDE to an adult, the age group receiving the maximum dose. This dose is within the 10 CFR 20.1301 limit of 100 mrem TEDE.

2.4.13.8 References

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Table 2.4.13-1 (Sheet 1 of 4)
Liquid Release Source Terms vs Decay Time

Isotope	Activity (Ci) vs Decay Time							
	0 hr	1 hr	24 hr 1 day	100 hr	168 hr 1 wk	720 hr 1 mon	8760 hr 1 yr	26280 hr 3 yr
H-3	1.25×10^{2}	1.25×10^{2}	1.25×10^{2}	1.25×10^{2}	1.25×10^{2}	1.24×10^{2}	1.18×10^{2}	1.06×10^{2}
C-14	1.37×10^{-1}	1.37×10^{-1}	1.37×10^{-1}	1.37×10^{-1}	1.37×10^{-1}	1.37×10^{-1}	1.37×10^{-1}	1.37×10^{-1}
Na-24	7.68×10^{1}	7.33×10^{1}	2.54×10^{1}	7.63×10^{-1}	3.32×10^{-2}	2.92×10^{-13}	0	0
P-32	1.95×10^{1}	1.95×10^{1}	1.86×10^{1}	1.59×10^{1}	1.39×10^{1}	4.55×10^{0}	3.97×10^{-7}	1.64×10^{-22}
Cr-51	8.04×10^{3}	8.03×10^{3}	7.84×10^{3}	7.24×10^{3}	6.75×10^{3}	3.80×10^{3}	8.69×10^{-1}	1.01×10^{-8}
Mn-54	7.49×10^{2}	7.49×10^{2}	7.47×10^{2}	7.42×10^{2}	7.38×10^{2}	7.01×10^{2}	3.33×10^{2}	6.59×10^{1}
Mn-56	2.26×10^{4}	1.73×10^{4}	3.59×10^{1}	4.89×10^{-8}	5.71×10^{-16}	0	0	0
Fe-55	2.99×10^{3}	2.99×10^{3}	2.99×10^{3}	2.98×10^{3}	2.98×10^{3}	2.93×10^{3}	2.31×10^{3}	1.38×10^{3}
Fe-59	1.93×10^{2}	1.93×10^{2}	1.90×10^{2}	1.81×10^{2}	1.73×10^{2}	1.21×10^{2}	6.61×10^{-1}	7.76×10^{-6}
Co-58	1.21×10^{3}	1.21×10^{3}	1.20×10^{3}	1.16×10^{3}	1.13×10^{3}	9.02×10^{2}	3.40×10^{1}	2.68×10^{-2}
Co-60	2.59×10^{2}	2.59×10^{2}	2.59×10^{2}	2.59×10^{2}	2.58×10^{2}	2.56×10^{2}	2.27×10^{2}	1.75×10^{2}
Ni-63	9.63×10^{1}	9.63×10^{1}	9.63×10^{1}	9.63×10^{1}	9.63×10^{1}	9.63×10^{1}	9.56×10^{1}	9.43×10^{1}
Cu-64	5.25×10^{-1}	4.97×10^{-1}	1.42×10^{-1}	2.24×10^{-3}	5.47×10^{-5}	4.52×10^{-18}	0	0
Zn-65	8.50×10^{-5}	8.50×10^{-5}	8.48×10^{-5}	8.40×10^{-5}	8.33×10^{-5}	7.81×10^{-5}	3.02×10^{-5}	3.79×10^{-6}
Rb-89	1.30×10^{5}	8.36×10^{3}	3.21×10^{-24}	0	0	0	0	0
Sr-89	1.34×10^{5}	1.34×10^{5}	1.32×10^{5}	1.27×10^{5}	1.22×10^{5}	8.88×10^{4}	8.99×10^{2}	4.04×10^{-2}
Sr-90	1.87×10^{4}	1.87×10^{4}	1.87×10^{4}	1.87×10^{4}	1.87×10^{4}	1.87×10^{4}	1.83×10^{4}	1.74×10^{4}
Sr-91	1.71×10^{5}	1.59×10^{5}	2.96×10^{4}	1.14×10^{2}	7.91×10^{-1}	2.35×10^{-18}	0	0
Sr-92	1.84×10^{5}	1.43×10^{5}	3.98×10^{2}	1.44×10^{-6}	4.06×10^{-14}	0	0	0
Y-90	1.94×10^{4}	1.94×10^{4}	1.92×10^{4}	1.89×10^{4}	1.88×10^{4}	1.87×10^{4}	1.83×10^{4}	1.74×10^{4}
Y-91m	0	5.30×10^{4}	1.86×10^{4}	7.45×10^{1}	5.12×10^{-1}	3.33×10^{-18}	0	0
Y-91	1.76×10^{5}	1.76×10^{5}	1.75×10^{5}	1.69×10^{5}	1.63×10^{5}	1.24×10^{5}	2.35×10^{3}	4.12×10^{-1}
Y-92	1.86×10^{5}	1.82×10^{5}	5.88×10^{3}	2.49×10^{-3}	4.13×10^{-9}	0	0	0
Y-93	2.10×10^{5}	1.96×10^{5}	4.18×10^{4}	2.51×10^{2}	2.59×10^{0}	1.92×10^{-16}	0	0
Zr-93	0	1.05×10^{-5}	1.29×10^{-4}	1.61×10^{-4}	1.61×10^{-4}	1.61×10^{-4}	1.61×10^{-4}	1.61×10^{-4}
Zr-95	5.00×10^{3}	5.00×10^{3}	4.95×10^{3}	4.78×10^{3}	4.64×10^{3}	3.61×10^{3}	9.58×10^{1}	3.52×10^{-2}
Nb-93m	0	2.82×10^{-11}	1.05×10^{-8}	7.53×10^{-8}	1.36×10^{-7}	6.27×10^{-7}	7.60×10^{-6}	2.17×10^{-5}
Nb-95m	0	3.59×10^{-1}	7.82×10^{0}	2.42×10^{1}	3.18×10^{1}	3.43×10^{1}	9.40×10^{-1}	3.73×10^{-4}
Nb-95	5.00×10^{3}	5.00×10^{3}	5.00×10^{3}	4.99×10^{3}	4.97×10^{3}	4.64×10^{3}	2.08×10^{2}	7.89×10^{-2}
Mo-99	2.65×10^{5}	2.62×10^{5}	2.06×10^{5}	9.28×10^{4}	4.54×10^{4}	1.38×10^{2}	0	0
Tc-99m	2.35×10^{5}	2.34×10^{5}	1.96×10^{5}	8.89×10^{4}	4.35×10^{4}	1.38×10^{2}	0	0
Tc-99	0	9.95×10^{-5}	2.20×10^{-3}	6.53×10^{-3}	8.35×10^{-3}	1.01×10^{-2}	1.01×10^{-2}	1.01×10^{-2}
Ru-103	2.24×10^{5}	2.24×10^{5}	2.20×10^{5}	2.08×10^{5}	1.98×10^{5}	1.32×10^{5}	3.62×10^{2}	9.48×10^{-4}
Ru-106	8.63×10^{4}	8.63×10^{4}	8.61×10^{4}	8.56×10^{4}	8.52×10^{4}	8.15×10^{4}	4.33×10^{4}	1.09×10^{4}
Rh-103m	2.24×10^{5}	2.24×10^{5}	2.20×10^{5}	2.08×10^{5}	1.98×10^{5}	1.33×10^{5}	4.08×10^{2}	1.24×10^{-3}
Rh-106	9.16×10^{4}	8.63×10^{4}	8.61×10^{4}	8.56×10^{4}	8.52×10^{4}	8.16×10^{4}	4.38×10^{4}	1.12×10^{4}
Ag-110m	4.31×10^{2}	4.31×10^{2}	4.30×10^{2}	4.26×10^{2}	4.23×10^{2}	3.97×10^{2}	1.58×10^{2}	2.13×10^{1}
Ag-110	0	6.46×10^{0}	6.45×10^{0}	6.39×10^{0}	6.34×10^{0}	5.96×10^{0}	2.42×10^{0}	3.32×10^{-1}

Table 2.4.13-1 (Sheet 2 of 4)
Liquid Release Source Terms vs Decay Time

Isotope	Activity (Ci) vs Decay Time							
	0 hr	1 hr	24 hr 1 day	100 hr	168 hr 1 wk	720 hr 1 mon	8760 hr 1 yr	26280 hr 3 yr
Sb-124	1.18×10^{2}	1.18×10^{2}	1.17×10^{2}	1.13×10^{2}	1.09×10^{2}	8.36 x 101	1.77×10^{0}	3.97×10^{-4}
Te-129m	7.21×10^{3}	7.20×10^{3}	7.06×10^{3}	6.62×10^{3}	6.24×10^{3}	3.88×10^{3}	3.81×10^{0}	1.06×10^{-6}
Te-129	0	2.04×10^{3}	4.46×10^{3}	4.18×10^{3}	3.94×10^{3}	2.47×10^{3}	2.76×10^{0}	9.18×10^{-7}
Te-131m	2.73×10^{4}	2.67×10^{4}	1.57×10^{4}	2.71×10^{3}	5.63×10^{2}	1.63×10^{-3}	0	0
Te-131	0	4.80×10^{3}	3.51×10^{3}	6.18×10^{2}	1.28×10^{2}	4.68×10^{-4}	0	0
Te-132	2.02×10^{5}	2.00×10^{5}	1.63×10^{5}	8.33×10^{4}	4.56×10^{4}	3.42×10^{2}	3.86×10^{-29}	0
I-129	5.89×10^{-3}	5.89×10^{-3}	5.89×10^{-3}	5.89×10^{-3}	5.89×10^{-3}	5.90×10^{-3}	5.92×10^{-3}	5.92×10^{-3}
I-130	2.42×10^{3}	2.29×10^{3}	6.30×10^{2}	8.90×10^{0}	1.97×10^{-1}	7.19×10^{-15}	0	0
I-131	1.42×10^{5}	1.42×10^{5}	1.32×10^{5}	1.02×10^{5}	8.03×10^{4}	1.11×10^{4}	3.19×10^{-9}	0
I-132	2.07×10^{5}	2.05×10^{5}	1.68×10^{5}	8.59×10^{4}	4.70×10^{4}	3.78×10^{2}	2.20×10^{-28}	0
I-133	2.92×10^{5}	2.83×10^{5}	1.32×10^{5}	1.06×10^{4}	1.11×10^{3}	1.25×10^{-5}	0	0
I-134	3.28×10^{5}	1.49×10^{5}	1.82×10^{-3}	1.32×10^{-29}	0	0	0	0
I-135	2.78×10^{5}	2.50×10^{5}	2.25×10^{4}	7.79×10^{0}	6.24×10^{-3}	4.61×10^{-28}	0	0
Xe-131m	0	3.82×10^{0}	8.61×10^{1}	2.89×10^{2}	3.98×10^{2}	3.32×10^{2}	1.67×10^{-6}	3.59×10^{-25}
Xe-133m	0	1.09×10^{2}	1.55×10^{3}	1.29×10^{3}	5.89×10^{2}	4.21×10^{-1}	0	0
Xe-133	0	1.53×10^{3}	2.41×10^{4}	3.11×10^{4}	2.29×10^{4}	1.13×10^{3}	7.01×10^{-17}	0
Xe-135m	0	3.73×10^{4}	3.69×10^{3}	1.42×10^{0}	1.12×10^{-3}	2.82×10^{-28}	0	0
Xe-135	0	1.83×10^{4}	5.93×10^{4}	3.46×10^{2}	2.05×10^{0}	1.16×10^{-18}	0	0
Cs-134	3.01×10^{4}	3.01×10^{4}	3.01×10^{4}	3.00×10^{4}	2.99×10^{4}	2.93×10^{4}	2.15×10^{4}	1.10×10^{4}
Cs-135	0	2.47×10^{-7}	4.45×10^{-5}	7.10×10^{-5}	7.11×10^{-5}	7.11×10^{-5}	7.11×10^{-5}	7.11×10^{-5}
Cs-136	1.00×10^{4}	9.98×10^{3}	9.48×10^{3}	8.01×10^{3}	6.89×10^{3}	2.02×10^{3}	3.55×10^{-5}	4.46×10^{-22}
Cs-137	2.45×10^{4}	2.45×10^{4}	2.45×10^{4}	2.45×10^{4}	2.45×10^{4}	2.45×10^{4}	2.39×10^{4}	2.29×10^{4}
Cs-138	2.71×10^{5}	7.45×10^{4}	9.41×10^{-9}	0	0	0	0	0
Ba-136m	0	1.50×10^{3}	1.42×10^{3}	1.21×10^{3}	1.04×10^{3}	3.11×10^{2}	7.76×10^{-6}	1.61×10^{-22}
Ba-137m	0	2.32×10^{4}	2.32×10^{4}	2.32×10^{4}	2.32×10^{4}	2.31×10^{4}	2.27×10^{4}	2.17×10^{4}
Ba-140	2.50×10^{5}	2.49×10^{5}	2.37×10^{5}	2.00×10^{5}	1.71×10^{5}	4.92×10^{4}	6.43×10^{-4}	4.24×10^{-21}
La-140	2.58×10^{5}	2.58×10^{5}	2.53×10^{5}	2.24×10^{5}	1.95×10^{5}	5.67×10^{4}	9.48×10^{-4}	1.04×10^{-20}
Ce-141	2.36×10^{5}	2.36×10^{5}	2.31×10^{5}	2.16×10^{5}	2.03×10^{5}	1.25×10^{5}	9.96×10^{1}	1.77×10^{-5}
Ce-144	2.02×10^{5}	2.02×10^{5}	2.02×10^{5}	2.00×10^{5}	1.99×10^{5}	1.88×10^{5}	8.30×10^{4}	1.40×10^{4}
Pr-143	2.15×10^{5}	2.15×10^{5}	2.04×10^{5}	1.74×10^{5}	1.51×10^{5}	4.66×10^{4}	1.78×10^{-3}	1.21×10^{-19}
Pr-144m	0	3.02×10^{3}	3.02×10^{3}	3.00×10^{3}	2.98×10^{3}	2.82×10^{3}	1.27×10^{3}	2.18×10^{2}
Pr-144	0	1.84×10^{5}	2.02×10^{5}	2.00×10^{5}	1.99×10^{5}	1.88×10^{5}	8.44×10^{4}	1.45×10^{4}
Nd-144	0	0	0	5.44×10^{-13}	1.08×10^{-12}	5.27×10^{-12}	4.42×10^{-11}	6.98×10^{-11}
U-235m	0	3.28×10^{0}	1.78×10^{-1}	5.21×10^{-1}	6.37×10^{-1}	7.24×10^{-1}	7.25×10^{-1}	7.24×10^{-1}
U-235	0	2.34×10^{-13}	6.94×10^{-13}	4.03×10^{-12}	8.54×10^{-12}	5.26×10^{-11}	7.07×10^{-10}	2.13×10^{-9}
Np-239	2.72×10^{6}	2.69×10^{6}	2.02×10^{6}	7.94×10^{5}	3.44×10^{5}	3.85×10^{2}	0	0
Pu-239	0	8.86×10^{-3}	1.85×10^{-1}	5.13×10^{-1}	6.33×10^{-1}	7.24×10^{-1}	7.25×10^{-1}	7.24×10^{-1}
Total	8.10×10^{6}	7.77×10^{6}	5.66×10^{6}	3.55×10^{6}	2.76×10^{6}	1.45×10^{6}	3.68×10^{5}	1.43×10^{5}

Table 2.4.13-1 (Sheet 3 of 4)
Liquid Release Source Terms vs Decay Time

Isotope	Activity (Ci) vs Decay Time						Peak Activity (Ci)	Time of Peak Activity
	43800 hr 5 yr	87600 hr 10 yr	131400 hr 15 yr	219000 hr 25 yr	306600 hr 35 yr	438000 hr 50 yr		
H-3	9.44×10^{1}	7.13×10^{1}	5.39×10^{1}	3.07×10^{1}	1.75×10^{1}	7.55×10^{0}	1.25×10^{2}	0 hr
C-14	1.37×10^{-1}	1.37×10^{-1}	1.37×10^{-1}	1.37×10^{-1}	1.36×10^{-1}	1.36×10^{-1}	1.37×10^{-1}	0 hr
Na-24	0	0	0	0	0	0	7.68×10^{1}	0 hr
P-32	0	0	0	0	0	0	1.95×10^{1}	0 hr
Cr-51	1.19×10^{-16}	0	0	0	0	0	8.04×10^{3}	0 hr
Mn-54	1.30×10^{1}	2.27×10^{-1}	3.95×10^{-3}	1.20×10^{-6}	3.63×10^{-10}	1.92×10^{-15}	7.49×10^{2}	0 hr
Mn-56	0	0	0	0	0	0	2.26×10^{4}	0 hr
Fe-55	8.21×10^{2}	2.25×10^{2}	6.18×10^{1}	4.66×10^{0}	3.51×10^{-1}	7.25×10^{-3}	2.99×10^{3}	0 hr
Fe-59	9.10×10^{-11}	4.30×10^{-23}	0	0	0	0	1.93×10^{2}	0 hr
Co-58	2.11×10^{-5}	3.68×10^{-13}	6.41×10^{-21}	0	0	0	1.21×10^{3}	0 hr
Co-60	1.34×10^{2}	6.96×10^{1}	3.61×10^{1}	9.69×10^{0}	2.60×10^{0}	3.62×10^{-1}	2.59×10^{2}	0 hr
Ni-63	9.30×10^{1}	8.99×10^{1}	8.68×10^{1}	8.10×10^{1}	7.56×10^{1}	6.81×10^{1}	9.63×10^{1}	0 hr
Cu-64	0	0	0	0	0	0	5.25×10^{-1}	0 hr
Zn-65	4.77×10^{-7}	2.68×10^{-9}	1.50×10^{-11}	4.73×10^{-16}	1.49×10^{-20}	2.63×10^{-27}	8.50×10^{-5}	0 hr
Rb-89	0	0	0	0	0	0	1.30×10^{5}	0 hr
Sr-89	1.82×10^{-6}	2.47×10^{-17}	3.34×10^{-28}	0	0	0	1.34×10^{5}	0 hr
Sr-90	1.66×10^{4}	1.47×10^{4}	1.30×10^{4}	1.03×10^{4}	8.06×10^{3}	5.62×10^{3}	1.87×10^{4}	0 hr
Sr-91	0	0	0	0	0	0	1.71×10^{5}	0 hr
Sr-92	0	0	0	0	0	0	1.84×10^{5}	0 hr
Y-90	1.66×10^{4}	1.47×10^{4}	1.31×10^{4}	1.03×10^{4}	8.10×10^{3}	5.66×10^{3}	1.94×10^{4}	0 hr
Y-91m	0	0	0	0	0	0	5.30×10^{4}	1 hr
Y-91	7.24×10^{-5}	2.96×10^{-14}	1.21×10^{-23}	0	0	0	1.76×10^{5}	0 hr
Y-92	0	0	0	0	0	0	1.86×10^{5}	0 hr
Y-93	0	0	0	0	0	0	2.10×10^{5}	0 hr
Zr-93	1.61×10^{-4}	1.61×10^{-4}	1.61×10^{-4}	1.61×10^{-4}	1.61×10^{-4}	1.61×10^{-4}	1.61×10^{-4}	1 wk
Zr-95	1.29×10^{-5}	3.34×10^{-14}	8.65×10^{-23}	0	0	0	5.00×10^{3}	0 hr
Nb-93m	3.45×10^{-5}	6.12×10^{-5}	8.19×10^{-5}	1.10×10^{-4}	1.28×10^{-4}	1.41×10^{-4}	1.41×10^{-4}	50 yr
Nb-95m	1.37×10^{-7}	4.59×10^{-16}	1.19×10^{-24}	0	0	0	3.43×10^{1}	1 mon
Nb-95	2.90×10^{-5}	8.11×10^{-14}	2.10×10^{-22}	0	0	0	5.00×10^{3}	0 hr
Mo-99	0	0	0	0	0	0	2.65×10^{5}	0 hr
Tc-99m	0	0	0	0	0	0	2.35×10^{5}	0 hr
Tc-99	1.01×10^{-2}	1.01×10^{-2}	1.01×10^{-2}	1.01×10^{-2}	1.01×10^{-2}	1.01×10^{-2}	1.01×10^{-2}	1 yr
Ru-103	2.48×10^{-9}	2.74×10^{-23}	0	0	0	0	2.24×10^{5}	0 hr
Ru-106	2.74×10^{3}	8.67×10^{1}	2.75×10^{0}	2.76×10^{-3}	2.77×10^{-6}	8.83×10^{-11}	8.63×10^{4}	0 hr
Rh-103m	3.23×10^{-9}	5.57×10^{-23}	0	0	0	0	2.24×10^{5}	0 hr
Rh-106	2.81×10^{3}	9.30×10^{1}	2.95×10^{0}	3.18×10^{-3}	3.19×10^{-6}	1.09×10^{-10}	9.16×10^{4}	0 hr
Ag-110m	2.86×10^{0}	1.90×10^{-2}	1.26×10^{-4}	5.58×10^{-9}	2.46×10^{-13}	7.21×10^{-20}	4.31×10^{2}	0 hr
Ag-110	4.47×10^{-2}	3.16×10^{-4}	2.10×10^{-6}	1.03×10^{-10}	4.54×10^{-15}	1.48×10^{-21}	6.46×10^{0}	1 hr

Table 2.4.13-1 (Sheet 4 of 4)
Liquid Release Source Terms vs Decay Time

Isotope	Activity (Ci) vs Decay Time						Peak Activity (Ci)	Time of Peak Activity
	43800 hr 5 yr	87600 hr 10 yr	131400 hr 15 yr	219000 hr 25 yr	306600 hr 35 yr	438000 hr 50 yr		
Sb-124	8.92×10^{-8}	6.74×10^{-17}	5.10×10^{-26}	0	0	0	1.18×10^{2}	0 hr
Te-129m	2.96×10^{-13}	1.21×10^{-29}	0	0	0	0	7.21×10^{3}	0 hr
Te-129	2.56×10^{-13}	1.78×10^{-29}	0	0	0	0	4.46×10^{3}	1 day
Te-131m	0	0	0	0	0	0	2.73×10^{4}	0 hr
Te-131	0	0	0	0	0	0	4.80×1^{03}	1 hr
Te-132	0	0	0	0	0	0	2.02×10^{5}	0 hr
I-129	5.92×10^{-3}	5.92×10^{-3}	5.92×10^{-3}	5.92×10^{-3}	5.92×10^{-3}	5.92×10^{-3}	5.92×10^{-3}	1 yr
I-130	0	0	0	0	0	0	2.42×10^{3}	0 hr
I-131	0	0	0	0	0	0	1.42×10^{5}	0 hr
I-132	0	0	0	0	0	0	2.07×10^{5}	0 hr
I-133	0	0	0	0	0	0	2.92×10^{5}	0 hr
I-134	0	0	0	0	0	0	3.28×10^{5}	0 hr
I-135	0	0	0	0	0	0	2.78×10^{5}	0 hr
Xe-131m	0	0	0	0	0	0	3.98×10^{2}	1 wk
Xe-133m	0	0	0	0	0	0	1.55×10^{3}	1 day
Xe-133	0	0	0	0	0	0	3.11×10^{4}	100 hr
Xe-135m	0	0	0	0	0	0	3.73×10^{4}	1 hr
Xe-135	0	0	0	0	0	0	5.93×10^{4}	1 day
Cs-134	5.61×10^{3}	1.04×10^{3}	1.94×10^{2}	6.74×10^{0}	2.34×10^{-1}	1.51×10^{-3}	3.01×10^{4}	0 hr
Cs-135	7.11×10^{-5}	7.11×10^{-5}	7.11×10^{-5}	7.11×10^{-5}	7.11×10^{-5}	7.11×10^{-5}	7.11×10^{-5}	1 wk
Cs-136	0	0	0	0	0	0	1.00×10^{4}	0 hr
Cs-137	2.18×10^{4}	1.95×10^{4}	1.74×10^{4}	1.38×10^{4}	1.10×10^{4}	7.77×10^{3}	2.45×10^{4}	0 hr
Cs-138	0	0	0	0	0	0	2.71×10^{5}	0 hr
Ba-136m	0	0	0	0	0	0	1.50×10^{3}	1 hr
Ba-137m	2.07×10^{4}	1.85×10^{4}	1.65×10^{4}	1.31×10^{4}	1.04×10^{4}	7.40×10^{3}	2.32×10^{4}	1 hr
Ba-140	0	0	0	0	0	0	2.50×10^{5}	0 hr
La-140	0	0	0	0	0	0	2.58×10^{5}	0 hr
Ce-141	3.16×10^{-12}	4.23×10^{-29}	0	0	0	0	2.36×10^{5}	0 hr
Ce-144	2.37×10^{3}	2.78×10^{1}	3.27×10^{-1}	4.50×10^{-5}	6.20×10^{-9}	1.00×10^{-14}	2.02×10^{5}	0 hr
Pr-143	0	0	0	0	0	0	2.15×10^{5}	0 hr
Pr-144m	3.69×10^{1}	4.57×10^{-1}	5.36×10^{-3}	8.11×10^{-7}	1.12×10^{-10}	1.99×10^{-16}	3.02×10^{3}	1 day
Pr-144	2.46×10^{3}	3.05×10^{1}	3.58×10^{-1}	5.40×10^{-5}	7.44×10^{-9}	1.32×10^{-14}	2.02×10^{5}	1 day
Nd-144	7.41×10^{-11}	7.50×10^{-11}	7.50×10^{-11}	7.50×10^{-11}	7.50×10^{-11}	7.50×10^{-11}	7.50×10^{-11}	15 yr
U-235m	7.24×10^{-1}	7.24×10^{-1}	7.24×10^{-1}	7.24×10^{-1}	7.24×10^{-1}	7.24×10^{-1}	3.28×10^{0}	1 hr
U-235	3.56×10^{-9}	7.13×10^{-9}	1.07×10^{-8}	1.78×10^{-8}	2.50×10^{-8}	3.56×10^{-8}	3.56×10^{-8}	50 yr
Np-239	0	0	0	0	0	0	2.72×10^{6}	0 hr
Pu-239	7.24×10^{-1}	7.24×10^{-1}	7.24×10^{-1}	7.24 x 10-1	7.24×10^{-1}	7.24×10^{-1}	7.25×10^{-1}	1 yr
Total	9.29×10^{4}	6.91×10^{4}	6.04×10^{4}	4.76×10^{4}	3.76×10^{4}	2.65×10^{4}	8.53×10^{6}	

Notes:

Ci = Curies

Table 2.4.13-2 (Sheet 1 of 2)
Radionuclide Release Concentrations (C_0)

Radionuclide	Radioactive Half-Life (days)	Initial Activity (Ci)	Initial Concentration (µCi/cm^3)
H-3	4.51×10^{3}	1.25×10^{2}	3.30×10^{0}
C-14	2.09×10^{6}	1.37×10^{-1}	3.62×10^{-3}
Na-24	6.25×10^{-1}	7.68×10^{1}	2.03×10^{0}
P-32	1.43×10^{1}	1.95×10^{1}	5.15×10^{-1}
Cr-51	2.77×10^{1}	8.04×10^{3}	2.12×10^{2}
Mn-54	3.13×10^{2}	7.49×10^{2}	1.98×10^{1}
Mn-56	1.07×10^{-1}	2.26×10^{4}	5.97×10^{2}
Fe-55	9.86×10^{2}	2.99×10^{3}	7.90×10^{1}
Fe-59	4.45×10^{1}	1.93×10^{2}	5.10×10^{0}
Co-58	7.08×10^{1}	1.21×10^{3}	3.20×10^{1}
Co-60	1.93×10^{3}	2.59×10^{2}	6.84×10^{0}
Ni-63	3.51×10^{4}	9.63×10^{1}	2.54×10^{0}
Cu-64	5.29×10^{-1}	5.25×10^{-1}	1.39×10^{-2}
Zn-65	2.44×10^{2}	8.50×10^{-5}	2.25×10^{-6}
Rb-89	1.06×10^{-2}	1.30×10^{5}	3.43×10^{3}
Sr-89	5.05×10^{1}	1.34×10^{5}	3.54×10^{3}
Sr-90	1.06×10^{4}	1.87×10^{4}	4.94×10^{2}
Sr-91	3.96×10^{-1}	1.71×10^{5}	4.52×10^{3}
Sr-92	1.11×10^{-1}	1.84×10^{5}	4.86×10^{3}
Y-90	2.67×10^{0}	1.94×10^{4}	5.13×10^{2}
Y-91m	3.45×10^{-2}	5.30×10^{4}	1.40×10^{3}
Y-91	5.85×10^{1}	1.76×10^{5}	4.65×10^{3}
Y-92	1.48×10^{-1}	1.86×10^{5}	4.91×10^{3}
Y-93	4.21×10^{-1}	2.10×10^{5}	5.55×10^{3}
Zr-93	5.59×10^{8}	1.61×10^{-4}	4.26×10^{-6}
Zr-95	6.40×10^{1}	5.00×10^{3}	1.32×10^{2}
Nb-93m	4.97×10^{3}	1.41×10^{-4}	3.73×10^{-6}
Nb-95m	3.61×10^{0}	3.43×10^{1}	9.06×10^{-1}
Nb-95	3.52×10^{1}	5.00×10^{3}	1.32×10^{2}
Mo-99	2.75×10^{0}	2.65×10^{5}	7.00×10^{3}
Tc-99m	2.51×10^{-1}	2.35×10^{5}	6.21×10^{3}
Tc-99	7.78×10^{7}	1.01×10^{-2}	2.67×10^{-4}
Ru-103	3.93×10^{1}	2.24×10^{5}	5.92×10^{3}
Ru-106	3.68×10^{2}	8.63×10^{4}	2.28×10^{3}
Rh-103m	3.90×10^{-2}	2.24×10^{5}	5.92×10^{3}
Rh-106	3.45×10^{-4}	9.16×10^{4}	2.42×10^{3}
Ag-110m	2.50×10^{2}	4.31×10^{2}	1.14×10^{1}
Ag-110	2.85×10^{-4}	6.46×10^{0}	1.71×10^{-1}

Table 2.4.13-2 (Sheet 2 of 2)
Radionuclide Release Concentrations (C_0)

Radionuclide	Radioactive Half-Life (days)	Initial Activity (Ci)	Initial Concentration (µCi/cm^3)
Sb-124	6.02×10^{1}	1.18×10^{2}	3.12×10^{0}
Te-129m	3.36×10^{1}	7.21×10^{3}	1.90×10^{2}
Te-129	4.83×10^{-2}	4.46×10^{3}	1.18×10^{2}
Te-131m	1.25×10^{0}	2.73×10^{4}	7.21×10^{2}
Te-131	1.74×10^{-2}	4.80×10^{3}	1.27×10^{2}
Te-132	3.26×10^{0}	2.02×10^{5}	5.34×10^{3}
I-129	5.73×10^{9}	5.92×10^{-3}	1.56×10^{-4}
I-130	5.15×10^{-1}	2.42×10^{3}	6.39×10^{1}
I-131	8.04×10^{0}	1.42×10^{5}	3.75×10^{3}
I-132	9.58×10^{-2}	2.07×10^{5}	5.47×10^{3}
I-133	8.67×10^{-1}	2.92×10^{5}	7.71×10^{3}
I-134	3.65×10^{-2}	3.28×10^{5}	8.67×10^{3}
I-135	2.75×10^{-1}	2.78×10^{5}	7.34×10^{3}
Xe-131m	1.18×10^{1}	3.98×10^{2}	1.05×10^{1}
Xe-133m	2.19×10^{0}	1.55×10^{3}	4.10×10^{1}
Xe-133	5.24×10^{0}	3.11×10^{4}	8.22×10^{2}
Xe-135m	1.06×10^{-2}	3.73×10^{4}	9.84×10^{2}
Xe-135	3.81×10^{-1}	5.93×10^{4}	1.57×10^{3}
Cs-134	7.53×10^{2}	3.01×10^{4}	7.95×10^{2}
Cs-135	8.40×10^{8}	7.11×10^{-5}	1.88×10^{-6}
Cs-136	1.31×10^{1}	1.00×10^{4}	2.64×10^{2}
Cs-137	1.10×10^{4}	2.45×10^{4}	6.47×10^{2}
Cs-138	2.24×10^{-2}	2.71×10^{5}	7.16×10^{3}
Ba-136m	3.56×10^{-6}	1.50×10^{3}	3.96×10^{1}
Ba-137m	1.77×10^{-3}	2.32×10^{4}	6.12×10^{2}
Ba-140	1.27×10^{1}	2.50×10^{5}	6.61×10^{3}
La-140	1.68×10^{0}	2.58×10^{5}	6.82×10^{3}
Ce-141	3.25×10^{1}	2.36×10^{5}	6.24×10^{3}
Ce-144	2.84×10^{2}	2.02×10^{5}	5.34×10^{3}
Pr-143	1.36×10^{1}	2.15×10^{5}	5.68×10^{3}
Pr-144m	5.00×10^{-3}	3.02×10^{3}	7.99×10^{1}
Pr-144	1.20×10^{-2}	2.02×10^{5}	5.32×10^{3}
Nd-144	8.36×10^{17}	7.50×10^{-11}	1.98×10^{-12}
U-235m	1.81×10^{-2}	3.28×10^{0}	8.67×10^{-2}
U-235	2.57×10^{11}	3.56×10^{-8}	9.41×10^{-10}
Np-239	2.36×10^{0}	2.72×10^{6}	7.19×10^{4}
Pu-239	8.79×10^{6}	7.25×10^{-1}	1.91×10^{-2}

Notes:
Ci = Curies

Table 2.4.13-3
Computation of Aquifer Bulk Density

Parameter	**Basis**	**Geologic Formation**								
		Existing Fill/Residual Soil	**Granular Backfill**	**Weathered Rock**	**Benbolt**	**Rockdell**	**Fleanor**	**Eidson**	**Blackford**	**Newala**
Material/USCS Symbol		**ML, MH, CH**	**SW**	**Limestone/ Siltstone**	**Limestone/ Siltstone**	**Limestone**	**Siltstone**	**Limestone**	**Limestone/ Siltstone**	**Dolomite**
Total Unit Weight, γ (lb/ft^3) (wet density)	Lab testing	120	135	140	168	168	168	168	168	175
Natural Water Content, *w* (% weight)	Lab testing	30	–	–	1	1	1	1	1	1
Specific gravity	Lab testing	2.75	2.7	–	2.7	2.69	2.7	2.69	2.68	2.8
Saturated Bulk Density, γ_{sat} (g/cm^3)	Derived	1.92	2.16	2.24	2.69	2.69	2.69	2.69	2.69	2.80
Grain density, ρ_g (g/cm^3)	Assumed	2.75	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.8
Total Porosity	Derived	0.47	0.32	0.27	0.01	0.01	0.01	0.01	0.01	0.00
Dry Bulk Density, γ_{dry} (g/cm^3)	Derived	1.4	1.8	2.0	2.7	2.7	2.7	2.7	2.7	2.8

Notes:

Shaded cell highlights the value used in the analysis.

Relationships between porosity and density (Reference 2.4.13-5):

$\gamma_{dry} = (1 - n)\ \rho_g$
$n = 1 - \gamma_{dry} / \rho_g$
$n = (\rho_g - \gamma_{sat}) / (\rho_g - \rho_w)$
where n = total porosity, ρ_g = grain density, ρ_w = water density, γ_{dry} = dry bulk density, and γ_{sat} = saturated bulk density.

Total unit weight, γ, is assumed to be fully saturated.

USCS = Unified Soil Classification System

ML = Silt, low plasticity

MH = Silt, high plasticity

CH = Clay, high plasticity

SW = Sand, well-graded (diversified particle sizes)

Table 2.4.13-4 (Sheet 1 of 2)
Distribution Coefficient (K_d) Test Results and Summary Statistics

Bechtel Sample ID	Cr	Mn	Fe	Co	Ni	Zn	Sr	Zr	Ru	Ag	Te	Cs	Ce	Pu
(OW/MP)	mL/g	mL/g	mL/g	mL/g	mL/g	mL/g	mL/g	mL/g	mL/g	mL/g	mL/g	mL/g	mL/g	mL/g
101-L/101 (145'–150') cm	< 1	1009	< 1	420	115.1	564	2.8	< 1	8.4	>4	>85	421	>267	>54
101-L/101 (145'–150') mm	< 1	324	< 1	135	23.4	579	2.2	< 1	0.01	< 1	>22	353	>65	20.6
202-L/202 (156'–161') cm	< 1	4557		857	1207	79.4	323	< 1	14.6	< 1	76.5	1322	>19	33.7
202-L/202 (156'–156') mm	< 1	3720		835	322	86.1	341	< 1	19	3.2	>119	2427	>17	39.1
202-L/202 (231'–236') cm	< 1	11161		538	247	1186	85.8	< 1	7.2	< 1	6	653	>15	30.9
202-L/202 (231'–236') mm	< 1	13795		1141	433	8671	134	< 1	34.2	< 1	57.5	1674	>13	32.8
409-U/409 (46'–51') mm	< 1	0.01	< 1	132	22.7	70	7.9	< 1	8.5	>806	>20	>4546	>71	19.5
409-L/409 (191'–196') cm	< 1	6043	< 1	1187	230	564	29.5	< 1	23.3	>872	9.1	560	42.2	>15
409-L/409 (191'–196') cm	< 1	11980	4.6	1878	326	615	29.4	< 1	26.3	>865	5.3	594	>42	>15
409-L/409 (191'–196') mm	< 1	18820	8	2562	450	201	124	< 1	30	>870	>32	1941	>39	4.7
415-U/415 (27'–35') cm	< 1	435	< 1	341	59.3	207	30.1	4114	>10	>826	>21	>4318	>56	12.1
415-U/415 (27'–35') cm	1.2	296	< 1	262	64.2	171	26	4788	5.7	>829	>21	>4252	>61	12.1
415-U/415 (27'–35') cm	1.4	353	< 1	126	50.7	92.4	26.6	4533	>11	>823	>20	>4286	>68	14.7
415-U/415 (27'–35') mm	1.1	224	< 1	249	67.2	809	26.7	3444	11.6	>774	>20	>4983	>69	14.3
415-U/415 (27'–35') mm	2.2	220	< 1	298	75.6	423	26.7	3836	7.9	>967	>23	>5577	>87	>14
416-L/416 (66'–71') cm	< 1	3621	< 1	444	49.4	66.9	3	75.3	2.7	>254	9.5	218	>45	>16
416-L/416 (66'–71') mm	< 1	1940	< 1	902	69.3	316	4.8	111	4	>252	>19	2200	>45	>14
416-L/416 (111'–116') cm	< 1	690	< 1	167	28.2	389	4.8	< 1	237	>354	100.7	226	>75	>28
416-L/416 (111'–116') mm	< 1	360	< 1	112	22.1	863	3.9	< 1	2.1	>252	>20	939	>35	>14
418-U/418A (78'–85') cm	< 1	1141	< 1	256	62.7	2725	5.1	< 1	14	>857	4.4	89.1	>41	>12
418-U/418A (78'–85') cm	< 1	1225	< 1	359	87	479	6.1	< 1	10.6	>797	8	150	>41	>12
418-U/418A (78'–85') cm	< 1	969	< 1	380	93.6	697	5.8	< 1	13.7	>1051	10.8	146	>58	>15
418-U/418A (78'–85') mm	< 1	1351	< 1	456	82	330	5.1	< 1	10.9	>749	>23	688	>40	>11
418-U/418A (78'–85') mm	< 1	1321	< 1	448	91.4	268	5.2	< 1	8.5	>787	>25	678	>44	>13
419-U/419 (55'–62') cm	< 1	261	< 1	355	19	153	1.7	< 1	8.2	>813	6.7	99	>347	>21
419-U/419 (55'–62') mm	< 1	323	< 1	800	49.9	907	1.7	< 1	10.1	>825	27.9	1019	>294	>18
420-L/420 (132'–140') cm	< 1	1056	< 1	40.6	20.7	333	< 1	< 1	5.8	782	>26	91.7	>267	>14
420-L/420 (132'–140') mm	< 1	566	< 1	98.9	39.5	1505	1.3	< 1	10.8	940	>27	585	>39	>14
423-U/423 (68'–76') cm	< 1	87	< 1	152	79.2	726	15.5	< 1	1.7	28	>23	1237	>35	>14
423-U/423 (68'–76') mm	< 1	40.9	< 1	98	173	476	< 1	< 1	< 1	29	>22	3099	>36	>13

Table 2.4.13-4 (Sheet 2 of 2)
Distribution Coefficient (K_d) Test Results and Summary Statistics

Bechtel Sample ID	**Cr**	**Mn**	**Fe**	**Co**	**Ni**	**Zn**	**Sr**	**Zr**	**Ru**	**Ag**	**Te**	**Cs**	**Ce**	**Pu**
No. of test results	30	30	26	30	30	30	30	30	30	30	30	30	30	30
Minimum (mL/g)	0.5	0.5	0.5	40.6	19	66.9	0.5	0.5	0.5	0.5	4.4	89.1	13	4.7
Maximum (mL/g)	2.2	18820	8	2562	1207	8671	341	4788	237	1051	119	5577	347	54
Geometric mean (mL/g)	0.6	793.9	0.6	345.5	84.9	405.4	10.2	3.2	8.6	149.5	20.9	845.2	54.0	16.7
Median (mL/g)	0.5	989.0	0.5	357.0	72.5	449.5	6.0	0.5	10.1	784.5	21.5	813.5	44.5	14.5
Average (mL/g)	0.6	2929.6	0.9	534.3	155.3	818.4	42.7	697.1	18.6	547.0	29.7	1645.7	79.1	18.7

Notes:

Test results reported as “<1” were assigned a value of 0.5 mL/g as a censored data. This is based on convention for censored data to be half of the detection limit (Reference 2.4.13-16).

Empty cells represent no data.

Test results reported as greater than a value (e.g., “>20”) were assigned the bounding value (e.g., 20) for statistical analysis.

Highlights indicate non-zero values used in the transport/dilution analysis.

Table 2.4.13-5 (Sheet 1 of 3)
Transport/Dilution Analysis Parameters and Results

Source Term Characteristics						Dilution – No Sorption				Sorption Parameters		Dilution – With Sorption			
Radionuclide	Half-life[a] (days)	Decay Constant[b] (days^{-1})	Initial Activity[c] (Ci)	Initial Concentration[d] (µCi/cm^3)	ECL[e] (µCi/cm^3)	Minimum Dilution Factor[f]	Minimum Dilution Time (years)	River Concentration[g] (µCi/cm^3)	C/ECL[h]	K_d[i] (cm^3/g)	R[j]	Minimum Dilution Factor[f]	Minimum Dilution Time (years)	River Concentration[g] (µCi/cm^3)	C/ECL[h]
H-3	4.51×10^{3}	1.54×10^{-4}	1.25×10^{2}	3.30×10^{0}	1.00×10^{-3}	6.02×10^{6}	0.94	5.49×10^{-7}	5.49×10^{-4}	0	1.0	6.02×10^{6}	0.94	5.49×10^{-7}	5.49×10^{-4}
C-14	2.09×10^{6}	3.32×10^{-7}	1.37×10^{-1}	3.62×10^{-3}	3.00×10^{-5}	5.71×10^{6}	0.94	6.34×10^{-10}	2.11×10^{-5}	0	1.0	5.71×10^{6}	0.94	6.34×10^{-10}	2.11×10^{-5}
Na-24	6.25×10^{-1}	1.11×10^{0}	7.68×10^{1}	2.03×10^{0}	5.00×10^{-5}	1.41×10^{57}	0.17	1.43×10^{-57}	0	0	1.0	1.41×10^{57}	0.17	1.43×10^{-57}	0
P-32	1.43×10^{1}	4.85×10^{-2}	1.95×10^{1}	5.15×10^{-1}	9.00×10^{-6}	3.09×10^{12}	0.62	1.67×10^{-13}	0	0	1.0	3.09×10^{12}	0.62	1.67×10^{-13}	0
Cr-51	2.77×10^{1}	2.50×10^{-2}	8.04×10^{3}	2.12×10^{2}	5.00×10^{-4}	1.03×10^{10}	0.72	2.07×10^{-8}	4.14×10^{-5}	0.6	19.0	1.04×10^{38}	4.8	2.05×10^{-36}	0
Mn-54	3.13×10^{2}	2.21×10^{-3}	7.49×10^{2}	1.98×10^{1}	3.00×10^{-5}	1.21×10^{7}	0.92	1.63×10^{-6}	5.45×10^{-2}	793.9	23801.0	*	*	*	0
Mn-56	1.07×10^{-1}	6.48×10^{0}	2.26×10^{4}	5.97×10^{2}	7.00×10^{-5}	5.77×10^{142}	0.07	1.03×10^{-140}	0	793.9	23801.0	*	*	*	0
Fe-55	9.86×10^{2}	7.03×10^{-4}	2.99×10^{3}	7.90×10^{1}	1.00×10^{-4}	7.27×10^{6}	0.93	1.09×10^{-5}	1.09×10^{-1}	0.6	19.0	7.51×10^{9}	15.3	1.05×10^{-8}	1.05×10^{-4}
Fe-59	4.45×10^{1}	1.56×10^{-2}	1.93×10^{2}	5.10×10^{0}	1.00×10^{-5}	7.57×10^{8}	0.79	6.74×10^{-9}	6.74×10^{-4}	0.6	19.0	1.13×10^{30}	5.95	4.52×10^{-30}	0
Co-58	7.08×10^{1}	9.79×10^{-3}	1.21×10^{3}	3.20×10^{1}	2.00×10^{-5}	1.36×10^{8}	0.84	2.35×10^{-7}	1.17×10^{-2}	345.5	10358.6	*	*	*	*
Co-60	1.93×10^{3}	3.59×10^{-4}	2.59×10^{2}	6.84×10^{0}	3.00×10^{-6}	6.46×10^{6}	0.94	1.06×10^{-6}	3.53×10^{-1}	345.5	10358.6	1.74×10^{111}	973.32	3.93×10^{-111}	0
Ni-63	3.51×10^{4}	1.97×10^{-5}	9.63×10^{1}	2.54×10^{0}	1.00×10^{-4}	5.75×10^{6}	0.94	4.43×10^{-7}	4.43×10^{-3}	84.9	2546.2	1.18×10^{16}	1553.87	2.16×10^{-16}	0
Cu-64	5.29×10^{-1}	1.31×10^{0}	5.25×10^{-1}	1.39×10^{-2}	2.00×10^{-4}	2.31×10^{62}	0.16	6.01×10^{-65}	0	0	1.0	2.31×10^{62}	0.16	6.01×10^{-65}	0
Zn-65	2.44×10^{2}	2.84×10^{-3}	8.50×10^{-5}	2.25×10^{-6}	5.00×10^{-6}	1.49×10^{7}	0.91	1.51×10^{-13}	0	405.4	12154.3	*	*	*	*
Rb-89	1.06×10^{-2}	6.54×10^{1}	1.30×10^{5}	3.43×10^{3}	9.00×10^{-4}	*	*	*	0	0	1.0	*	*	*	*
Sr-89	5.05×10^{1}	1.37×10^{-2}	1.34×10^{5}	3.54×10^{3}	8.00×10^{-6}	4.42×10^{8}	0.8	8.01×10^{-6}	1.00×10^{0}	10.2	306.8	6.32×10^{116}	27.12	5.60×10^{-114}	0
Sr-90	1.06×10^{4}	6.54×10^{-5}	1.87×10^{4}	4.94×10^{2}	5.00×10^{-7}	5.84×10^{6}	0.94	8.46×10^{-5}	1.69×10^{2}	10.2	306.8	8.22×10^{11}	231.98	6.01×10^{-10}	1.20×10^{-3}
Sr-91	3.96×10^{-1}	1.75×10^{0}	1.71×10^{5}	4.52×10^{3}	2.00×10^{-5}	3.44×10^{72}	0.14	1.31×10^{-69}	0	10.2	306.8	*	*	*	0
Sr-92	1.11×10^{-1}	6.25×10^{0}	1.84×10^{5}	4.86×10^{3}	4.00×10^{-5}	1.88×10^{140}	0.07	2.59×10^{-137}	0	10.2	306.8	*	*	*	0
Y-90	2.67×10^{0}	2.60×10^{-1}	1.94×10^{4}	5.13×10^{2}	7.00×10^{-6}	8.45×10^{26}	0.33	6.06×10^{-25}	0	54	1619.8	*	*	*	0
Y-91m	3.45×10^{-2}	2.01×10^{1}	5.30×10^{4}	1.40×10^{3}	2.00×10^{-3}	5.69×10^{254}	0.04	2.46×10^{-252}	0	54	1619.8	*	*	*	0
Y-91	5.85×10^{1}	1.18×10^{-2}	1.76×10^{5}	4.65×10^{3}	8.00×10^{-6}	2.54×10^{8}	0.82	1.83×10^{-5}	2.29×10^{0}	54	1619.8	1.14×10^{252}	67.46	4.07×10^{-249}	0
Y-92	1.48×10^{-1}	4.68×10^{0}	1.86×10^{5}	4.91×10^{3}	4.00×10^{-5}	8.09×10^{120}	0.08	6.07×10^{-118}	0	54	1619.8	*	*	*	0
Y-93	4.21×10^{-1}	1.65×10^{0}	2.10×10^{5}	5.55×10^{3}	2.00×10^{-5}	1.69×10^{70}	0.14	3.28×10^{-67}	0	54	1619.8	*	*	*	0
Zr-93	5.59×10^{8}	1.24×10^{-9}	1.61×10^{-4}	4.25×10^{-6}	4.00×10^{-5}	5.71×10^{6}	0.94	7.45×10^{-13}	0	3.2	96.9	5.53×10^{8}	91.48	7.69×10^{-15}	0
Zr-95	6.40×10^{1}	1.08×10^{-2}	5.00×10^{3}	1.32×10^{2}	2.00×10^{-5}	1.87×10^{8}	0.83	7.08×10^{-7}	3.54×10^{-2}	3.2	96.9	3.33×10^{57}	16.88	3.96×10^{-56}	0
Nb-95m	3.61×10^{0}	1.92×10^{-1}	3.43×10^{1}	9.06×10^{-1}	3.00×10^{-5}	1.39×10^{23}	0.38	6.53×10^{-24}	0	0	1.0	1.39×10^{23}	0.38	6.53×10^{-24}	0
Nb-95	3.52×10^{1}	1.97×10^{-2}	5.00×10^{3}	1.32×10^{2}	3.00×10^{-5}	2.42×10^{9}	0.76	5.46×10^{-8}	1.82×10^{-3}	0	1.0	2.42×10^{9}	0.76	5.46×10^{-8}	1.82×10^{-3}
Mo-99	2.75×10^{0}	2.52×10^{-1}	2.65×10^{5}	7.00×10^{3}	2.00×10^{-5}	3.38×10^{26}	0.34	2.07×10^{-23}	0	0	1.0	3.38×10^{26}	0.34	2.07×10^{-23}	0
Tc-99m	2.51×10^{-1}	2.76×10^{0}	2.35×10^{5}	6.21×10^{3}	1.00×10^{-3}	7.89×10^{91}	0.11	7.87×10^{-89}	0	0	1.0	7.89×10^{91}	0.11	7.87×10^{-89}	0
Tc-99	7.78×10^{7}	8.91×10^{-9}	1.01×10^{-2}	2.67×10^{-4}	6.00×10^{-5}	5.71×10^{6}	0.94	4.67×10^{-11}	0	0	1.0	5.71×10^{6}	0.94	4.67×10^{-11}	0
Ru-103	3.93×10^{1}	1.76×10^{-2}	2.24×10^{5}	5.92×10^{3}	3.00×10^{-5}	1.36×10^{9}	0.77	4.35×10^{-6}	1.45×10^{-1}	8.6	258.8	3.91×10^{121}	21.98	1.51×10^{-118}	0

Table 2.4.13-5 (Sheet 2 of 3)
Transport/Dilution Analysis Parameters and Results

Source Term Characteristics						Dilution – No Sorption				Sorption Parameters		Dilution – With Sorption			
Radionuclide	Half-life[a] (days)	Decay Constant[b] (days^{-1})	Initial Activity[c] (Ci)	Initial Concentration[d] (µCi/cm^3)	ECL[e] (µCi/cm^3)	Minimum Dilution Factor[f]	Minimum Dilution Time (years)	River Concentration[g] (µCi/cm^3)	C/ECL[h]	K_d[i] (cm^3/g)	R[j]	Minimum Dilution Factor[f]	Minimum Dilution Time (years)	River Concentration[g] (µCi/cm^3)	C/ECL[h]
Ru-106	3.68×10^{2}	1.88×10^{-3}	8.63×10^{4}	2.28×10^{3}	3.00×10^{-6}	1.08×10^{7}	0.92	2.10×10^{-4}	7.01×10^{1}	8.6	258.8	4.41×10^{39}	64.69	5.17×10^{-37}	0
Rh-103m	3.90×10^{-2}	1.78×10^{1}	2.24×10^{5}	5.92×10^{3}	6.00×10^{-3}	1.11×10^{240}	0.04	5.33×10^{-237}	0	0	1.0	1.11×10^{240}	0.04	5.33×10^{-237}	0
Rh-106	3.45×10^{-4}	2.01×10^{3}	9.16×10^{4}	2.42×10^{3}	N/A	*	*	*	0	0	1.0	*	*	*	N/A
Ag-110m	2.50×10^{2}	2.77×10^{-3}	4.31×10^{2}	1.14×10^{1}	6.00×10^{-6}	1.46×10^{7}	0.91	7.81×10^{-7}	1.30×10^{-1}	149.5	4482.8	1.01×10^{203}	231.75	1.13×10^{-202}	0
Ag-110	2.85×10^{-4}	2.43×10^{3}	6.46×10^{0}	1.71×10^{-1}	N/A	*	*	*	0	149.5	4482.8	*	*	*	N/A
Sb-124	6.02×10^{1}	1.15×10^{-2}	1.18×10^{2}	3.12×10^{0}	7.00×10^{-6}	2.29×10^{8}	0.82	1.36×10^{-8}	1.94×10^{-3}	0	1.0	2.29×10^{8}	0.82	1.36×10^{-8}	1.94×10^{-3}
Te-129m	3.36×10^{1}	2.06×10^{-2}	7.21×10^{3}	1.90×10^{2}	7.00×10^{-6}	3.13×10^{9}	0.75	6.08×10^{-8}	8.69×10^{-3}	20.9	627.6	2.23×10^{206}	31.79	8.55×10^{-205}	0
Te-129	4.83×10^{-2}	1.44×10^{1}	4.46×10^{3}	1.18×10^{2}	4.00×10^{-4}	5.13×10^{214}	0.05	2.29×10^{-213}	0	20.9	627.6	*	*	*	0
Te-131m	1.25×10^{0}	5.55×10^{-1}	2.73×10^{4}	7.21×10^{2}	8.00×10^{-6}	6.57×10^{39}	0.24	1.10×10^{-37}	0	20.9	627.6	*	*	*	0
Te-131	1.74×10^{-2}	3.98×10^{1}	4.80×10^{3}	1.27×10^{2}	8.00×10^{-5}	*	*	*	0	20.9	627.6	*	*	*	0
Te-132	3.26×10^{0}	2.13×10^{-1}	2.02×10^{5}	5.34×10^{3}	9.00×10^{-6}	2.23×10^{24}	0.36	2.39×10^{-21}	0	20.9	627.6	*	*	*	0
I-129	5.73×10^{9}	1.21×10^{-10}	5.92×10^{-3}	1.56×10^{-4}	2.00×10^{-7}	5.71×10^{6}	0.94	2.74×10^{-11}	1.37×10^{-4}	0	1.0	5.71×10^{6}	0.94	2.74×10^{-11}	1.37×10^{-4}
I-130	5.15×10^{-1}	1.35×10^{0}	2.42×10^{3}	6.39×10^{1}	2.00×10^{-5}	1.80×10^{63}	0.15	3.56×10^{-62}	0	0	1.0	1.80×10^{63}	0.15	3.56×10^{-62}	0
I-131	8.04×10^{0}	8.62×10^{-2}	1.42×10^{5}	3.75×10^{3}	1.00×10^{-6}	6.99×10^{15}	0.51	5.37×10^{-13}	0	0	1.0	6.99×10^{15}	0.51	5.37×10^{-13}	0
I-132	9.58×10^{-2}	7.24×10^{0}	2.07×10^{5}	5.47×10^{3}	1.00×10^{-4}	1.48×10^{151}	0.07	3.69×10^{-148}	0	0	1.0	1.48×10^{151}	0.07	3.69×10^{-148}	0
I-133	8.67×10^{-1}	7.99×10^{-1}	2.92×10^{5}	7.71×10^{3}	7.00×10^{-6}	1.50×10^{48}	0.2	5.14×10^{-45}	0	0	1.0	1.50×10^{48}	0.20	5.14×10^{-45}	0
I-134	3.65×10^{-2}	1.90×10^{1}	3.28×10^{5}	8.67×10^{3}	4.00×10^{-4}	5.89×10^{247}	0.04	1.47×10^{-244}	0	0	1.0	5.89×10^{247}	0.04	1.47×10^{-244}	0
I-135	2.75×10^{-1}	2.52×10^{0}	2.78×10^{5}	7.34×10^{3}	3.00×10^{-5}	4.92×10^{87}	0.11	1.49×10^{-84}	0	0	1.0	4.92×10^{87}	0.11	1.49×10^{-84}	0
Xe-131m	1.18×10^{1}	5.85×10^{-2}	3.98×10^{2}	1.05×10^{1}	1.00×10^{-8}	2.80×10^{13}	0.58	3.75×10^{-13}	3.75×10^{-5}	0	1.0	2.80×10^{13}	0.58	3.75×10^{-13}	3.75×10^{-5}
Xe-133m	2.19×10^{0}	3.17×10^{-1}	1.55×10^{3}	4.10×10^{1}	1.00×10^{-8}	6.21×10^{29}	0.3	6.59×10^{-29}	0	0	1.0	6.21×10^{29}	0.30	6.59×10^{-29}	0
Xe-133	5.24×10^{0}	1.32×10^{-1}	3.11×10^{4}	8.22×10^{2}	1.00×10^{-8}	1.97×10^{19}	0.44	4.16×10^{-17}	0	0	1.0	1.97×10^{19}	0.44	4.16×10^{-17}	0
Xe-135m	1.06×10^{-2}	6.53×10^{1}	3.73×10^{4}	9.85×10^{2}	N/A	*	*	*	N/A	0	1.0	*	*	*	N/A
Xe-135	3.81×10^{-1}	1.82×10^{0}	5.93×10^{4}	1.57×10^{3}	1.00×10^{-8}	1.05×10^{74}	0.13	1.50×10^{-71}	0	0	1.0	1.05×10^{74}	0.13	1.50×10^{-71}	0
Cs-134	7.53×10^{2}	9.21×10^{-4}	3.01×10^{4}	7.95×10^{2}	9.00×10^{-7}	7.82×10^{6}	0.93	1.02×10^{-4}	1.13×10^{2}	845.2	25338.9	1.67×10^{279}	957.62	4.75×10^{-277}	0
Cs-135	8.40×10^{8}	8.25×10^{-10}	7.11×10^{-5}	1.88×10^{-6}	1.00×10^{-5}	5.71×10^{6}	0.94	3.29×10^{-13}	0	845.2	25338.9	1.46×10^{11}	23907.19	1.29×10^{-17}	0
Cs-136	1.31×10^{1}	5.29×10^{-2}	1.00×10^{4}	2.64×10^{2}	6.00×10^{-6}	8.28×10^{12}	0.6	3.19×10^{-11}	5.32×10^{-6}	845.2	25338.9	*	*	*	0
Cs-137	1.10×10^{4}	6.30×10^{-5}	2.45×10^{4}	6.47×10^{2}	1.00×10^{-6}	5.83×10^{6}	0.94	1.11×10^{-4}	1.11×10^{2}	845.2	25338.9	3.30×10^{73}	3602.79	1.96×10^{-71}	0
Cs-138	2.24×10^{-2}	3.09×10^{1}	2.71×10^{5}	7.16×10^{3}	4.00×10^{-4}	*	*	*	*	845.2	25338.9	*	*	*	0
Ba-136m	3.56×10^{-6}	1.94×10^{5}	1.50×10^{3}	3.96×10^{1}	N/A	*	*	*	N/A	0	1.0	*	*	*	N/A
Ba-137m	1.77×10^{-3}	3.91×10^{2}	2.32×10^{4}	6.13×10^{2}	N/A	*	*	*	N/A	0	1.0	*	*	*	N/A
Ba-140	1.27×10^{1}	5.46×10^{-2}	2.50×10^{5}	6.61×10^{3}	8.00×10^{-6}	1.19×10^{13}	0.6	5.53×10^{-10}	6.92×10^{-5}	0	1.0	1.19×10^{13}	0.60	5.53×10^{-10}	6.92×10^{-5}
La-140	1.68×10^{0}	4.13×10^{-1}	2.58×10^{5}	6.82×10^{3}	9.00×10^{-6}	1.41×10^{34}	0.27	4.85×10^{-31}	0	0	1.0	1.41×10^{34}	0.27	4.85×10^{-31}	0
Ce-141	3.25×10^{1}	2.13×10^{-2}	2.36×10^{5}	6.24×10^{3}	3.00×10^{-5}	3.79×10^{9}	0.75	1.64×10^{-6}	5.48×10^{-2}	54	1619.8	*	*	*	*

Table 2.4.13-5 (Sheet 3 of 3)
Transport/Dilution Analysis Parameters and Results

Source Term Characteristics						Dilution – No Sorption				Sorption Parameters		Dilution – With Sorption			
Radionuclide	Half-life[a] (days)	Decay Constant[b] ($days^{-1}$)	Initial Activity[c] (Ci)	Initial Concentration[d] ($\mu Ci/cm^3$)	ECL[e] ($\mu Ci/cm^3$)	Minimum Dilution Factor[f]	Minimum Dilution Time (years)	River Concentration[g] ($\mu Ci/cm^3$)	C/ECL[h]	K_d[i] (cm^3/g)	R[j]	Minimum Dilution Factor[f]	Minimum Dilution Time (years)	River Concentration[g] ($\mu Ci/cm^3$)	C/ECL[h]
Ce-144	2.84×10^{2}	2.44×10^{-3}	2.02×10^{5}	5.34×10^{3}	3.00×10^{-6}	1.31×10^{7}	0.91	4.09×10^{-4}	1.36×10^{2}	54	1619.8	7.24×10^{113}	147.71	7.37×10^{-111}	0
Pr-143	1.36×10^{1}	5.097×10^{-2}	2.15×10^{5}	5.68×10^{3}	2.00×10^{-5}	5.39×10^{12}	0.61	1.05×10^{-9}	5.27×10^{-5}	0	1.0	5.39×10^{12}	0.61	1.05×10^{-9}	5.27×10^{-5}
Pr-144m	5.00×10^{-3}	1.39×10^{2}	3.02×10^{3}	7.98×10^{1}	N/A	*	*	*	N/A	0	1.0	*	*	*	N/A
Pr-144	1.20×10^{-2}	5.78×10^{1}	2.02×10^{5}	5.34×10^{3}	6.00×10^{-4}	*	*	*	*	0	1.0	*	*	*	0
Nd-144	8.36×10^{17}	8.29×10^{-19}	7.50×10^{-11}	1.98×10^{-12}	2.00×10^{-9}	5.71×10^{6}	0.94	3.47×10^{-19}	0	0	1.0	5.71×10^{6}	0.94	3.47×10^{-19}	0
U-235m	1.81×10^{-2}	3.84×10^{1}	3.28×10^{0}	8.67×10^{-2}	N/A	*	*	*	N/A	0	1.0	*	*	*	N/A
U-235	2.57×10^{11}	2.70×10^{-12}	3.56×10^{-8}	9.41×10^{-10}	3.00×10^{-7}	5.71×10^{6}	0.94	1.65×10^{-16}	0	0	1.0	5.71×10^{6}	0.94	1.65×10^{-16}	0
Np-239	2.36×10^{0}	2.94×10^{-1}	2.72×10^{6}	7.19×10^{4}	2.00×10^{-5}	4.74×10^{28}	0.31	1.52×10^{-24}	0	0	1.0	4.74×10^{28}	0.31	1.52×10^{-24}	0
Pu-239	8.79×10^{6}	7.89×10^{-8}	7.25×10^{-1}	1.92×10^{-2}	2.00×10^{-8}	5.71×10^{6}	0.94	3.35×10^{-9}	1.68×10^{-1}	16.7	501.6	2.90×10^{9}	473.18	6.60×10^{-12}	3.30×10^{-4}

(a) Values from References 2.4.13-8, 2.4.13-9, and 2.4.13-10 highlighted in yellow, green, and blue, respectively.
(b) Calculated as ln(2)/half-life.
(c) Initial activity is the peak activity value from Table 2.4.13-1.
(d) Calculated as initial activity divided by source term volume.
(e) Values from 10 CFR 20, Appendix B, Table 2, Column 2.
(f) Calculated using Equation 2.4.13-1 (Equation 4.41 of Reference 2.4.13-3).
(g) Calculated as Initial Concentration/Dilution Factor.
(h) Ratio of River Concentration to the effluent concentration limit (ECL). Values less than 10^{-6} are reported as zero.
(i) K_d = distribution coefficient; Based upon laboratory testing.
(j) R = retardation coefficient; Calculated using Equation 2.4.13-4.

Notes:

Ci = Curies

N/A: Not applicable; no ECL available.

* Indicates negligible concentrations in the Reservoir.

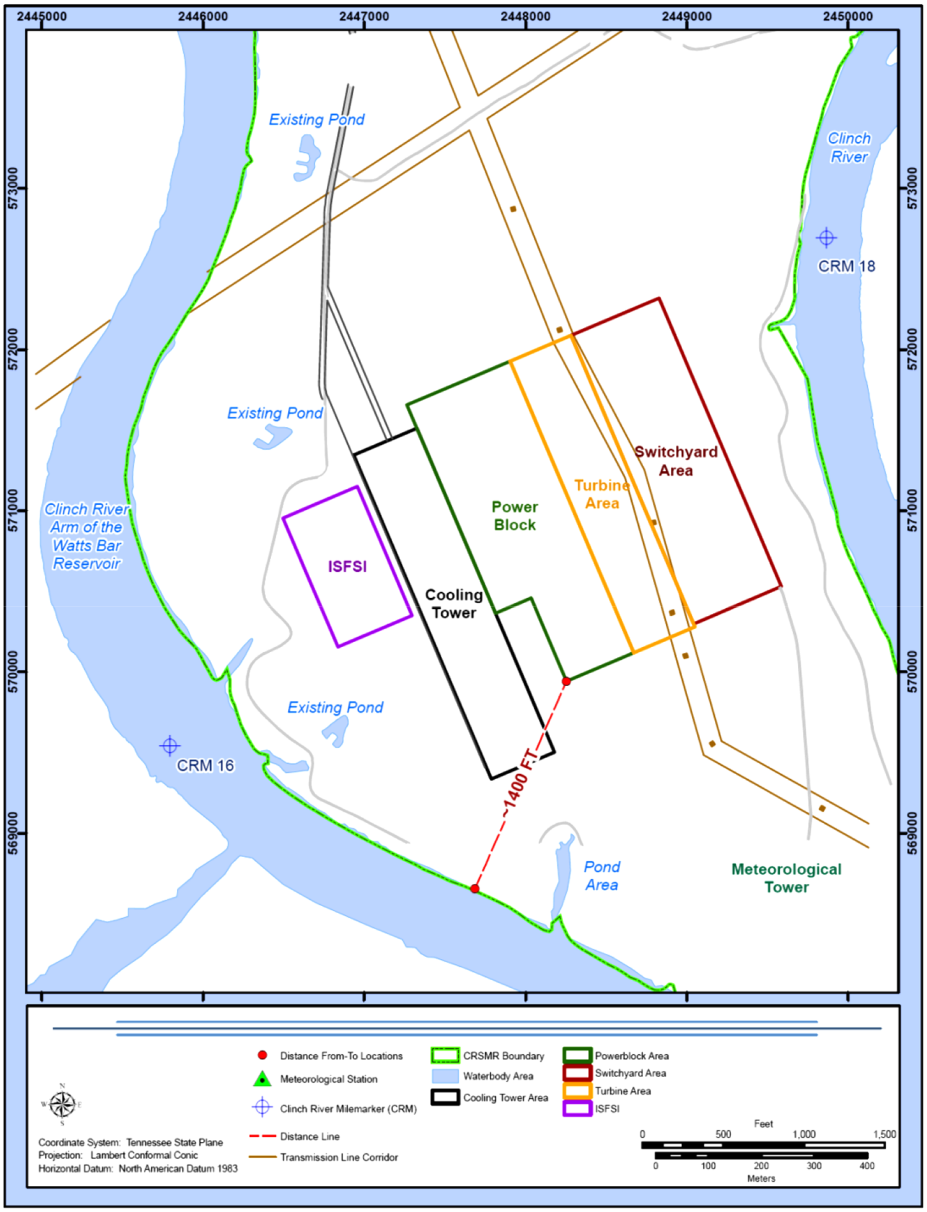


Figure 2.4.13-1. Minimum Distance from the Power Block Area to the Clinch River Arm of the Watts Bar Reservoir

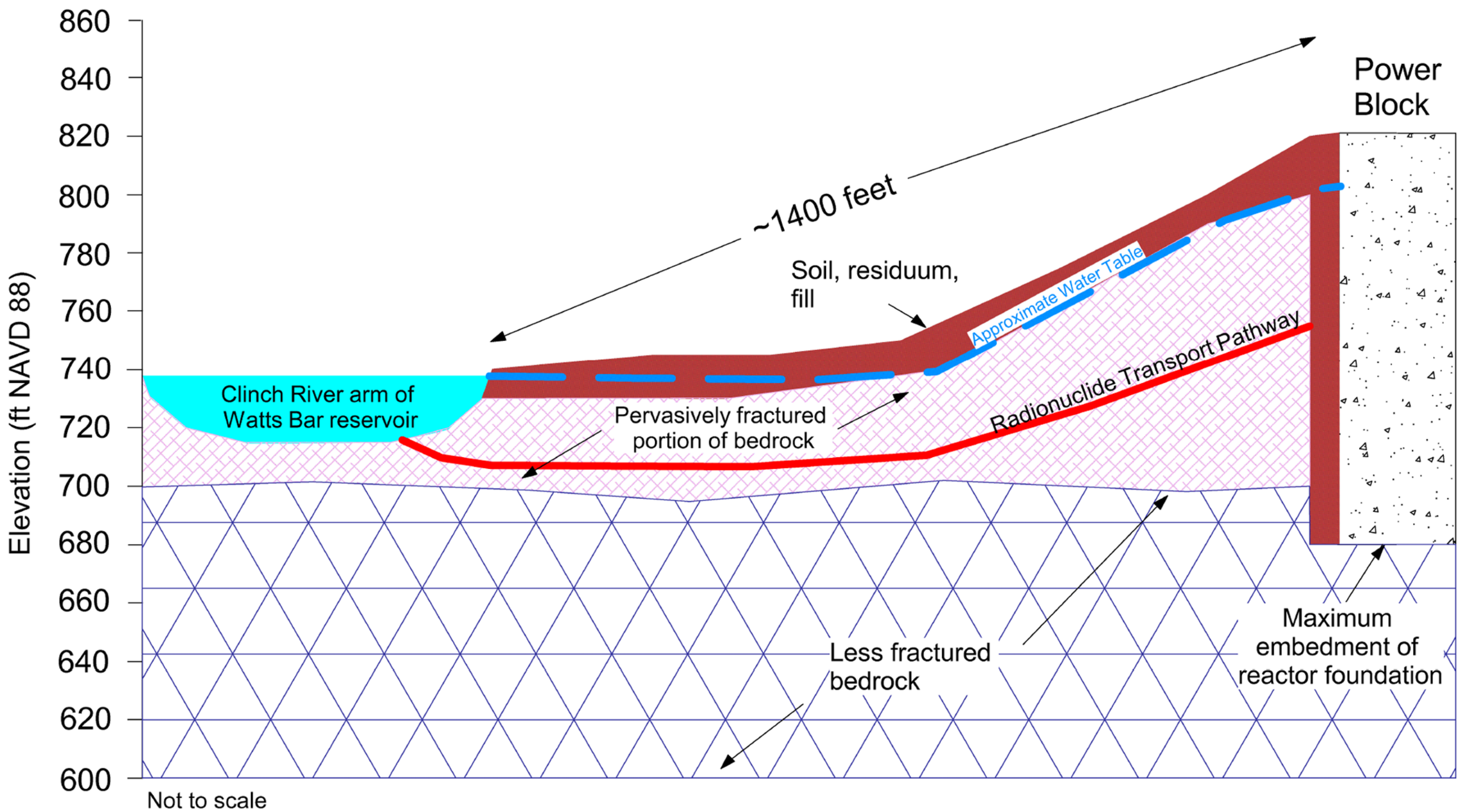
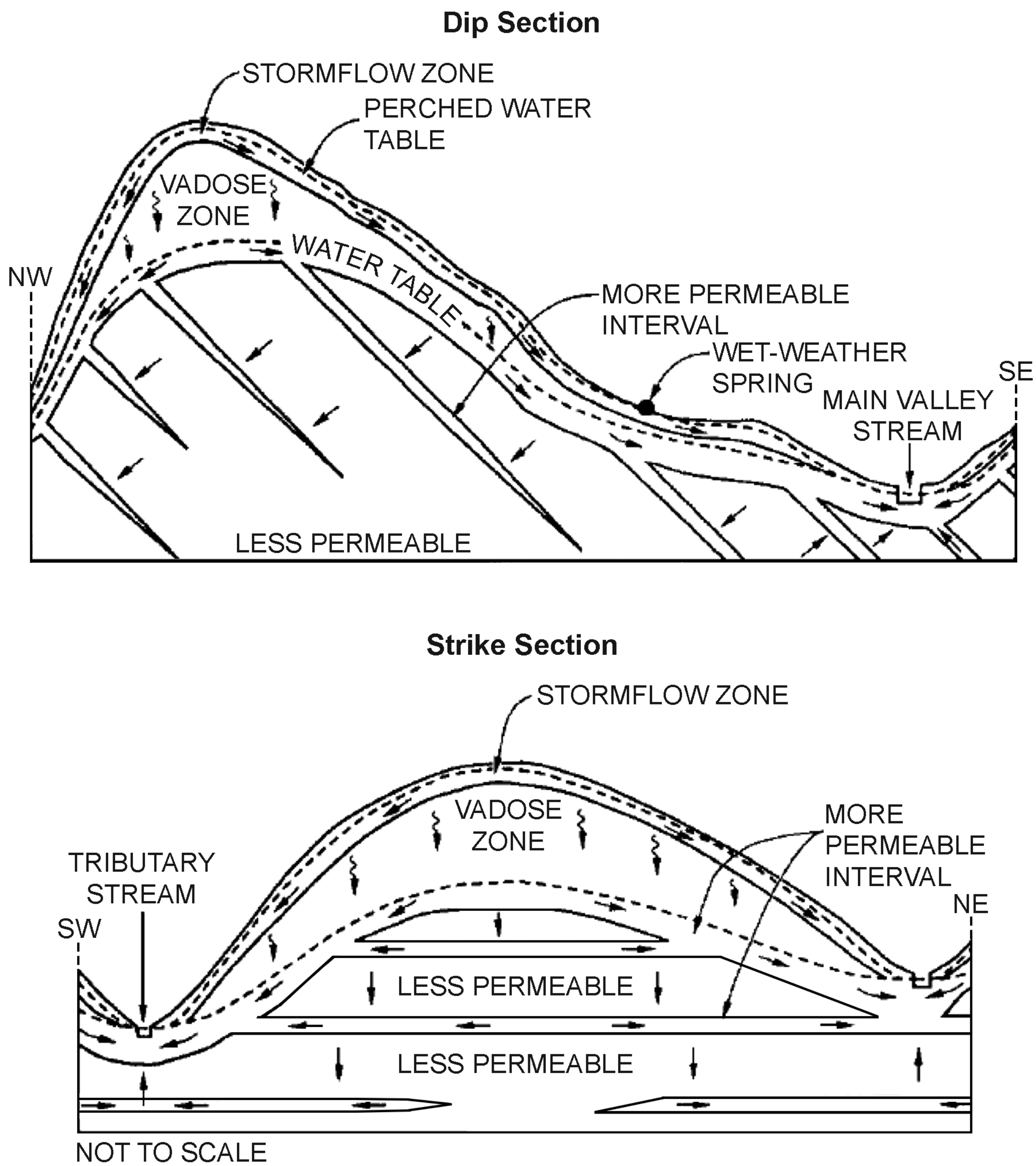


Figure 2.4.13-2. Conceptual Model for Radionuclide Transport



Source: Adapted from Reference 2.4.13-17

Figure 2.4.13-3. Alternate Conceptual Model for Radionuclide Transport