APPENDIX M
RELEASE TO VADOSE ZONE

This appendix supports Chapters 5, 6, and 7; describes the role of the release models with respect to the groundwater modeling process, the release models and the method used to estimate release rates to the vadose zone, and the release model parameters; discusses parameter sensitivity; and presents the results from the release models and the results of the sensitivity analyses.

M.1 INTRODUCTION

The assessment of human health impacts is an important element of analysis for this *Tank Closure and Waste Management Environmental Impact Statement for the Hanford Site, Richland, Washington (TC & WM EIS)*. Activities associated with alternatives under consideration for tank closure and waste management include the placement of waste containing radioactive and chemical constituents in the vadose zone at the Hanford Site (Hanford). The vadose zone is the unsaturated zone that extends from the top of the ground surface to the water table. In addition, past practices resulting in spills, leaks, planned discharges, and the disposal of waste also placed such materials in the vadose zone. Major steps in assessing human health impacts are estimation of (1) rate of release to the vadose zone, (2) the rate of transport through the vadose zone, (3) the rate of transport through the unconfined aquifer, and (4) the magnitude of health impacts at the points of exposure. This appendix describes methods used to estimate rates of release to the vadose zone, summarizes the values of the parameters used in the release models, summarizes the results of the application of the models, and presents a sensitivity analysis for particular cases. The relation of the release models in the groundwater monitoring system for the *TC & WM EIS* is shown in Figure M–1. Although the best-available data and models were used to develop the analysis described in this appendix, uncertainty in the results remains. This uncertainty derives from variabilities in natural and engineered materials, such as soil and grout, as well as lack of knowledge regarding elements such as the applicability of specific models to site-specific locations or the type of climate that may be experienced in the future. The release models described in this appendix are applicable for sources defined within the *TC & WM EIS* alternatives and for sources associated with the cumulative analysis. Because of the large uncertainties involved in projection of impacts beyond a period of 1,000 years, U.S. Department of Energy (DOE) guidance recommends a period of analysis of 1,000 years for assessment of performance of low-level radioactive waste (LLW) disposal facilities (DOE Manual 435.1-1). However, the low rate of movement of water and solutes through the vadose zone at Hanford and the objective of identifying peak impacts support selection of a longer period of analysis for this *TC & WM EIS*. The analysis of travel time in the vadose zone presented in Appendix N, Section N.5.1, is appropriate for constituents that move at the velocity of water. The analysis in Appendix O, Section O.6.4, for uranium, a constituent that moves slower than groundwater, supports selection of a 10,000-year period of analysis. Thus, long-term groundwater impacts in this *TC & WM EIS* are estimated for a 10,000-year period of analysis extending over calendar years 1940 to 11,939. Further details on sources associated with the cumulative analysis are presented in Appendix S.

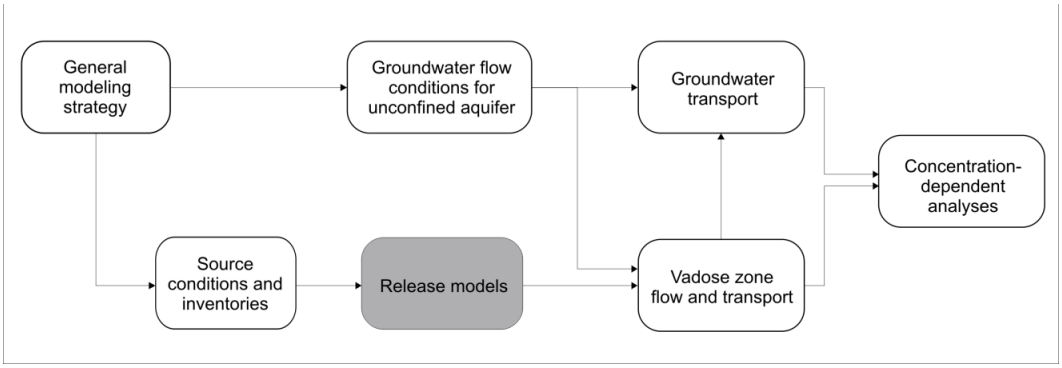


Figure M–1. Groundwater Modeling System Flowchart

M.2 DESCRIPTION OF RELEASE MODELS

A variety of sources with related release mechanisms needed to be analyzed for this *TC & WM EIS*. To provide a consistent approach and to ensure quality results, the stepwise procedure summarized in Table M–1 was applied for release model development. Releases to the vadose zone can be characterized according to the physical phase of the source and by the rate-controlling mechanism of the release. For this *TC & WM EIS*, releases to the vadose zone are characterized as occurring from the liquid- or solid-phase sources. For solid sources, release can be controlled by liquid- to solid-phase partitioning, solubility, or diffusion mechanisms. For each release model, the variation in the timing of the infiltration rate is represented as a series of pulses. The increase or decrease in the infiltration rate reflects the change in conditions, including the removal or recovery of vegetation and the placement and weathering of an engineered barrier. The form of the time dependence of the infiltration rate is presented in Figure M–2.

Table M–1. Steps in Release Model Development

Step Number	Content
1	Identify sources and characterize physical processes
2	Develop conceptual model of the release process
3	Develop mathematical description of the release
4	Develop algorithm for solution of mathematical model
5	Develop computer code implementing equations and solution algorithm
6	Verify computer code, including documentation of concepts, equations, and algorithms and execution of test cases
7	Apply release model

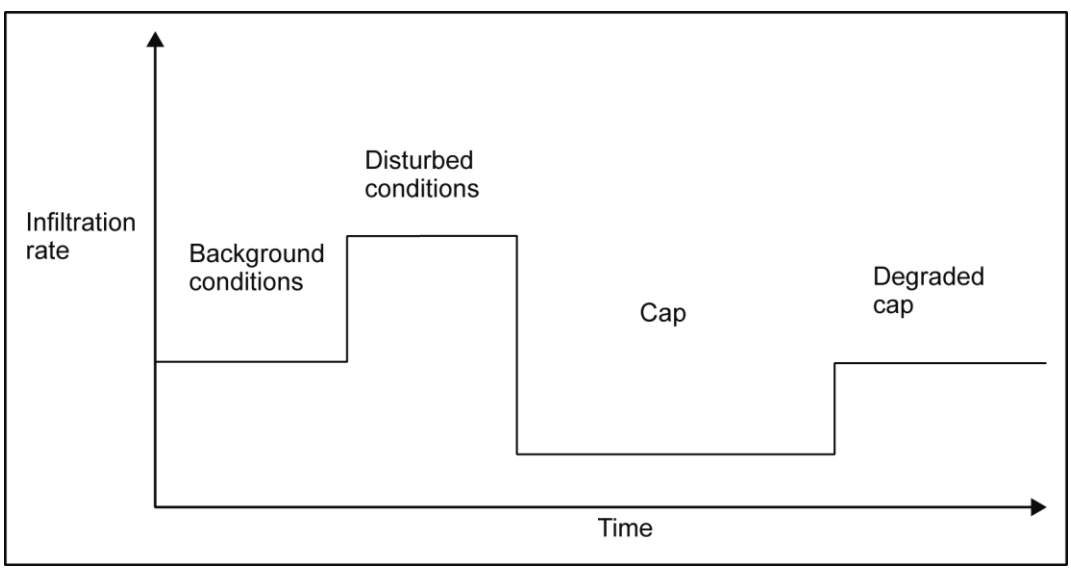


Figure M–2. Time Dependence of Infiltration Rate

The nature and level of complexity of these models is consistent with available guidance (NCRP 2005) and past site-specific analysis (Riley and Lo Presti 2004). A summary list of waste forms and associated release models is presented in Table M–2, and more-detailed descriptions of each model are presented in the following sections. Although alternative conceptual models such as constituent solubility–limited or partitioning-limited release may be applicable in given circumstances, preference is given in this analysis to the partitioning-limited mechanism due to uncertainty associated with formation of metastable, or mixed-composition, precipitation phases and the availability of site-specific measurements consistent with partitioning-limited release (Lockrem 2005; Mattigod et al. 2001).

Table M–2. Summary List of Waste Forms Evaluated in This *TC & WM EIS*

Waste Form	Material Type	Release Model
Tank Closure Alternatives		
Tank salt cake	Precipitate	Matrix solubility–limited release model
Stabilized tank residuals	Grout	Partitioning-limited, convective-flow release model
Ancillary equipment	Grout	Partitioning-limited, convective-flow release model
ILAW glass	Glass	Fractional-release-rate model
Retired ILAW melters	Glass	Fractional-release-rate model
Bulk vitrification glass	Glass	Fractional-release-rate model
Cast stone waste	Aluminosilicate	Diffusion-limited release model
Steam reforming waste	Finely divided solids	Matrix solubility–limited release model
ETF-generated secondary waste	Grout	Diffusion-limited release model
Sulfate removal grouted secondary waste	Grout	Diffusion-limited release model
FFTF Decommissioning Alternatives		
Subsurface structures	Solids, soil	Partitioning-limited, convective-flow release model
Secondary waste	Grout	Diffusion-limited release model
Waste Management Alternatives		
LLBG 218-W-5, trenches 31 and 34 waste	Solids, soil	Partitioning-limited, convective-flow release model
Onsite non-CERCLA waste	Grout	Diffusion-limited release model
Secondary waste	Grout	Diffusion-limited release model
Offsite waste	Unstabilized matrix	Diffusion-limited release model

Key: CERCLA=Comprehensive Environmental Response, Compensation, and Liability Act; ETF=Effluent Treatment Facility; FFTF=Fast Flux Test Facility; ILAW=immobilized low-activity waste; LLBG=Low-Level Radioactive Waste Burial Ground; *TC & WM EIS=Tank Closure and Waste Management Environmental Impact Statement for the Hanford Site, Richland, Washington*.

M.2.1 Liquid Sources

The set of types of sources for liquid releases include planned discharges to near-surface facilities, unplanned releases to near-surface soil, past leaks from tanks, and retrieval leaks from tanks. For a given location, the release model is defined by specification of the elevation, the area and aqueous volume of the source, the duration of the release, and inventories of constituents released during the specified time interval.

M.2.2 Solid Sources

Releases from solid sources are categorized according to the mechanism of release. Release mechanisms include partitioning from the solid to the liquid phase with convective flow through the waste form, waste form dissolution with convective flow through or around the waste form, fractional release, and partitioning from the solid to the liquid phase with diffusive transport in the waste form. The balance of this section describes details of release models for each mechanism.

M.2.2.1 Partitioning-Limited, Convective-Flow Release Model

In the partitioning-limited, convective-flow release model, the waste form of a given cross-sectional area with a constant thickness perpendicular to an infiltrating flow of water is located in the vadose zone. A schematic representation of the concept is presented in Figure M–3. This figure depicts water infiltration at a constant rate (q_{inf}) through a waste form of cross-sectional area (A_{wf}) and height (H_{wf}).

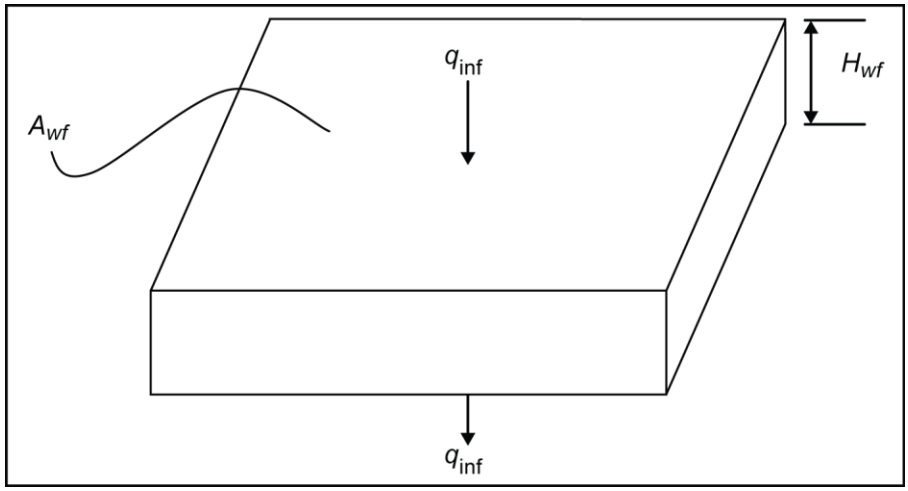


Figure M–3. Schematic of Release Concept for Partitioning-Limited, Convective-Flow Release

A constituent bound to the solid is available for transfer to water moving through the waste form, and the release rate is determined by the extent of partitioning between the solid and liquid phases within the waste form and the rate of movement of water through the waste form. Constituents are assumed free to move within the pore space of the waste form, producing a uniform concentration of the constituent throughout the waste form. A mass balance on a constituent within the waste form provides a relation between the liquid-phase concentration and the initial mass of constituent and dimensions and properties of the waste form. The mass of the constituent within the waste form is contained within the liquid and solid phases:

$$AT = V_l C_l + V_s C_{s,v} = \varepsilon V_t C_l + (1 - \varepsilon_s) V_t C_{s,v} \qquad \text{(M–1)}$$

where:

AT	=	total mass at a given time, grams
V_l	=	volume of liquid in the waste form, cubic meters
C_l	=	concentration of the constituent in the liquid phase, grams per cubic meter
V_s	=	volume of solid within the waste form, cubic meters
$C_{s,v}$	=	concentration of the constituent in the solid phase, grams per cubic meter
ε	=	volumetric moisture content of the waste form, unitless
V_t	=	total volume of the waste form, cubic meters
ε_s	=	saturated porosity of the waste form, unitless

The relationship between volumetric and mass concentration in the solid phase is as follows:

$$C_{s,v} = f_v \, \rho_s \, C_{s,m} \qquad \text{(M–2)}$$

where:

$C_{s,v}$	=	concentration of the constituent in the solid phase, grams per cubic meter
f_v	=	volumetric units conversion factor, cubic centimeters per cubic meter
ρ_s	=	particle density of the solid in the waste form, grams per cubic centimeter
$C_{s,m}$	=	concentration of constituent in the solid phase, grams per gram

The relationship between concentration of the constituent in the liquid and solid phases is represented as linear with the distribution coefficient serving as the constant of proportionality:

$$C_{s,m} = (1/f_v) \, K_d \, C_l \qquad \text{(M–3)}$$

where:

$C_{s,m}$	=	concentration of the constituent in the solid phase, grams per gram
f_v	=	volumetric units conversion factor, cubic centimeters per cubic meter
K_d	=	distribution coefficient for the constituent in the waste form, milliliters per gram
C_l	=	concentration of the constituent in the liquid phase, grams per cubic meter

Substitution of the supporting relations into the mass relation allows calculation of liquid-phase concentration for a given inventory:

$$C_l = AT / (\varepsilon_s \, V_t \, R_d) \qquad \text{(M–4)}$$

where:

C_l	=	concentration of the constituent in the liquid phase, grams per cubic meter
AT	=	total mass at a given time, grams
ε_s	=	saturated porosity of the waste form, unitless
V_t	=	total volume of the waste form, cubic meters
R_d	=	retardation factor for the constituent in the waste form, unitless

and

$$R_d = \varepsilon/\varepsilon_s + [(1 - \varepsilon_s)/\varepsilon_s] \, \rho_s \, K_d \qquad \text{(M–5)}$$

where:

R_d	=	retardation factor for the constituent in the waste form, unitless
ε	=	volumetric moisture content of the waste form, unitless
ε_s	=	saturated porosity of the waste form, unitless
ρ_s	=	particle density of the solid in the waste form, grams per cubic centimeter
K_d	=	distribution coefficient for the constituent in the waste form, milliliters per gram

In saturated flow, the retardation factor for a constituent is the ratio of the rate of movement of groundwater to the rate of movement of the constituent. A mass balance formed around the waste form during a time interval *j* reflects release by convection and decrease of mass within the waste form. The rate of flow of water through the waste form is equal to the rate of infiltration at the ground surface, which is represented as a series of pulses defined for a set of time intervals (see Figure M–1). The mass balance formed around the waste form is as follows:

$$\partial AT/\partial t = -A_{wf}\, q_{inf,j}\, C_l - \lambda_i AT$$

$$(1/AT)\, \partial AT/\partial t = -q_{inf,j} / (\varepsilon_s H_{wf} R_d) - \lambda_i$$

$$= -(f_j + \lambda_i) \qquad \text{(M–6)}$$

where:

AT	=	total mass at a given time, grams
t	=	time, years
A_{wf}	=	cross-sectional area of the waste form perpendicular to flow, square meters
$q_{inf,j}$	=	rate of infiltration during time period *j*, meters per year
C_l	=	concentration of the constituent in the liquid phase, grams per cubic meter
λ_i	=	decay constant, 1 per year
ε_s	=	saturated porosity of the waste form, unitless
H_{wf}	=	height of the waste form parallel to flow, meters
R_d	=	retardation factor for the constituent in the waste form, unitless

The total mass remaining in the waste form at any time in the time interval *j*, *AT* (grams), is as follows:

$$AT = AT_{s,j} \exp\left[-(f_j + \lambda_i)(t - t_{s,j})\right] \qquad \text{(M–7)}$$

where:

$AT_{s,j}$	=	mass in the waste form at the start of time interval *j*, grams
t	=	time, years
$t_{s,j}$	=	time at the start of time interval *j*, years

The release rate of the constituent during time interval *j*, R_{wfj} (grams per year) is as follows:

$$R_{wfj} = f_j\, AT_{s,j} \exp\left[-(f_j + \lambda_i)(t - t_{s,j})\right] \qquad \text{(M–8)}$$

where:

$AT_{s,j}$	=	mass in the waste form at the start of time interval *j*, grams
t	=	time, years
$t_{s,j}$	=	time at the start of time interval *j*, years

The partitioning-limited, convective-flow release model is applicable for contaminated soil sources and grouted waste forms that have degraded over hundreds of years. Primary parameters of the model are rate of infiltration, dimensions of the waste form, and distribution coefficient of constituents.

M.2.2.2 Matrix Solubility–Limited Release Model

In the matrix solubility–limited release model, hazardous constituents are assumed to be uniformly distributed throughout a much larger mass of soluble material, such as salt cake. The matrix is porous and water flowing through the waste form dissolves the matrix and releases encapsulated constituents. The

waste form is in the unsaturated zone with a downward flow, as depicted in Figure M–3. The time variation of infiltration is represented as a series of step functions, as shown in Figure M–1. A mass balance formed on the matrix is as follows:

$$\partial M_{sc} / \partial t = - A_{wf}\, q_{inf,j}\, C_{s,sc} \qquad \text{(M–9)}$$

where:

M_{sc}	=	mass of matrix, grams
t	=	time, years
A_{wf}	=	cross-sectional area of the waste matrix for flow, square meters
$q_{inf,j}$	=	rate of infiltration, meters per year
$C_{s,sc}$	=	solubility of waste matrix, grams per cubic meter

The mass of waste matrix present at any time during a time period is as follows:

$$M_{sc} = M_{sc,j} - [(A_{wf}\, q_{inf,j}\, C_{s,sc})\, (t - t_{s,j})] \qquad \text{(M–10)}$$

where:

M_{sc}	=	mass of waste matrix at time *t*, grams
$M_{sc,j}$	=	mass of waste matrix at start of time period *j*, grams
A_{wf}	=	cross-sectional area of the waste matrix for flow, square meters
$q_{inf,j}$	=	rate of infiltration, meters per year
$C_{s,sc}$	=	solubility of waste matrix, grams per cubic meter
t	=	time, years
$t_{s,j}$	=	time at start of time period *j*, years

During any interval, the rate of loss of waste matrix given by the second term on the right-hand side of Equation M–10 cannot exceed the amount of waste matrix present at the start of the time interval. When the waste matrix is completely removed by dissolution, the release is terminated. A mass balance on a constituent encapsulated in the waste matrix can be expressed as follows:

$$\partial AT / \partial t = - A_{wf}\, q_{inf,j}\, C_{s,sc}\, (AT / M_{sc}) - \lambda_i\, AT \qquad \text{(M–11)}$$

where:

AT	=	total amount of constituent, grams
t	=	time, years
A_{wf}	=	cross-sectional area of the waste matrix for flow, square meters
$q_{inf,j}$	=	rate of infiltration, meters per year
$C_{s,sc}$	=	solubility of waste matrix, grams per cubic meter
M_{sc}	=	mass of waste matrix at time *t*, grams
λ_i	=	decay constant for the constituent i, 1 per year

The release of hazardous constituent during time interval j (Rwfj), taking into account dissolution of the matrix and decay of the constituent, is expressed as follows:

$$Rwf_j = [(A_{wf}\, q_{inf,j}\, C_{s,sc}) / \lambda_i]\, [AT_{s,j} / M_{sc,j}]\, \{1 - \exp[-\lambda_i\, (t - t_{s,j})]\} \qquad \text{(M–12)}$$

The primary application of the matrix solubility limited-release model is for releases from salt cake in high-level radioactive waste (HLW) tanks under Tank Closure Alternatives 1 and 2A and from steam reforming waste under Tank Closure Alternative 3C. Primary parameters of the model are rate of

infiltration, mass of the waste matrix, solubility of the waste matrix, and concentration of hazardous constituents in the waste matrix.

M.2.2.3 Fractional-Release-Rate Model

In chemical reactions where reactants and products are present in excess or where complex chemical and physical processes produce a constant rate of degradation of the waste form, the release rate is linearly proportional to the amount of hazardous constituent remaining at the source. The physical configuration of the waste form is the same as that represented in Figure M–3. A mass balance on the hazardous constituent at the source is as follows:

$$\partial M / \partial t = -(f_{wf} + \lambda_i)\, M \qquad \text{(M–13)}$$

where:

M	=	mass of hazardous constituent at the source, grams
t	=	time, years
f_{wf}	=	fractional rate of degradation of the waste form, grams per gram per year
λ_i	=	decay constant, 1 per year

The amount of hazardous constituent present at the source at any time is as follows:

$$M = M_j \, exp\, [-(f_{wf} + \lambda_i)\, (t - t_s)] \qquad \text{(M–14)}$$

where:

M	=	mass of hazardous constituent at the source, grams
M_j	=	mass of hazardous constituent present at the source at the beginning of the time period *j*, grams
f_{wf}	=	fractional rate of degradation of the waste form, grams per gram per year
λ_i	=	decay constant, 1 per year
t	=	time, years
t_s	=	time at start of time period *j*, years

The release rate of the constituent from the waste form at any time is as follows:

$$R_{wf} = f_{wf}\, M_j \, exp\, [-(f_{wf} + \lambda_i)\, (t - t_s)] \qquad \text{(M–15)}$$

where:

R_{wf}	=	rate of release of the constituent from the waste form, grams per year
f_{wf}	=	fractional rate of degradation of the waste form, grams per gram per year
M_j	=	mass of hazardous constituent present at the source at the beginning of the time period *j*, grams
λ_i	=	decay constant, 1 per year
t	=	time, years
t_s	=	time at start of time period *j*, years

The fractional-release-rate model is applicable for Waste Treatment Plant (WTP) immobilized low-activity waste (ILAW) glass, bulk vitrification glass, and glass in retired melters. Primary parameters of the model are the fractional-release-rate constant and the initial inventory of hazardous constituents.

M.2.2.4 Diffusion-Limited Release Models

If a waste form were to have a value of hydraulic conductivity much lower than that of the surrounding material, convective flow would be diverted around the waste form. In this case, diffusive transport of the hazardous constituent within the waste form would constitute the primary mechanism for constituent release to the environment. The boundary condition specified for the concentration of the constituent outside the waste form plays a role in determining the release rate. In a conservative approach to specification of this boundary condition, the convective flow outside the waste form is assumed to maintain the concentration of the constituent at a low value at the outside boundary of the form. This maximizes the release rate of the constituent diffusing out of the waste form. In a less conservative approach to specification of this boundary condition, the rate of convective flow can be used to establish the concentration of the constituent at the boundary of the waste form. In addition, the waste form may degrade over time, allowing an increase in the rate of release. In the diffusion-limited release models, transport of solute occurs only in the liquid-filled pore space of the waste form, and partitioning of constituents between the solid and liquid phases is included in the release model. The geometry of the waste form is a factor in determining transport distances and the area available for release. For this *TC & WM EIS*, diffusion-controlled release models have been developed for rectangular and cylindrical geometries. For both geometries, the rate of transport by diffusion is conservatively represented by a shrinking core model to simplify the mathematical form of the model (Levenspiel 1962; Sarkar, Chakrabarti, and Dutta 2009). Key assumptions of the shrinking core model are that the interface moves slowly in comparison with the time needed for a quasi–steady state profile to develop across the depleted shell and that the amount of the diffusing constituent in the depleted shell is negligibly small. Degradation of the waste form is represented as a time-dependent increase in the tortuosity of the waste form, producing an increase in the rate of diffusion toward the outer boundary of the waste form. Tortuosity is a measure of the length of the path traversed by a diffusing species as it moves through the waste matrix, with the length of the path decreasing as the waste matrix degrades.

A source with rectangular symmetry is shown in Figure M–4.

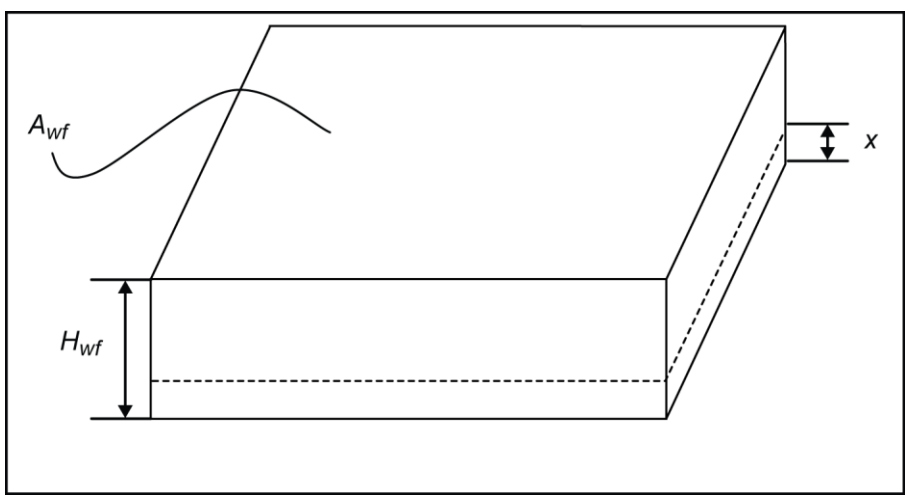


Figure M–4. Schematic of Rectangular Waste Form with Diffusion Release from Lower Surface

Resistance to mass transfer is assumed to reside in a layer, with thickness designated as x in Figure M–4, that exists between the shrinking core and the environment. The concentration of the constituent outside the waste form is assumed to be negligible. A mass balance on the diffusing constituent formed in the waste form is as follows:

$$-\varepsilon A_{wf} T D_w [(C_l - C_{vz})/x] = \varepsilon_s A_{wf} R_d C_l \partial (H_{wf} - x)/\partial t \quad \text{(M–16)}$$

$$R_d = \varepsilon/\varepsilon_s + [(1-\varepsilon_s)/\varepsilon_s] \rho_s K_d \quad \text{(M–17)}$$

where:

ε	=	volumetric moisture content of the waste form, unitless
A_{wf}	=	diffusion release area of the waste form, square meters
T	=	tortuosity of the waste form, unitless
D_w	=	diffusivity of the constituent in water, square meters per year
C_l	=	concentration of the constituent in the liquid in the core portion of the waste form, grams per cubic meter
C_{vz}	=	concentration of constituent in vadose zone between waste packages, grams per cubic meter
x	=	thickness of transport layer, meters
ε_s	=	saturated porosity of the waste form, unitless
R_d	=	retardation factor for the constituent in the waste form, unitless
H_{wf}	=	thickness of waste form, meters
t	=	time, years
ρ_s	=	particle density of the solid in the waste form, grams per cubic centimeter
K_d	=	distribution coefficient for the constituent in the waste form, milliliters per gram

Assuming that the concentration of the diffusing constituent is maintained at a low level outside of the waste form, the cumulative release of the constituent from the form, $R_{wf\text{cum}}$ (grams), calculated from the mass balance is as follows:

$$R_{wf\text{cum}} = [AT_0/(H_{wf} - x_0)] \sqrt{\{ [(2 (\varepsilon/\varepsilon_s) T D_w)/ R_d] t + x_0^2 \}} - [AT_0/(H_{wf} - x_0)] (x_0) \quad \text{(M–18)}$$

where:

AT_o	=	initial inventory of the constituent, grams
H_{wf}	=	thickness of waste form, meters
x_0	=	initial thickness of the waste form layer outside the core, meters
ε	=	volumetric moisture content of the waste form, unitless
ε_s	=	saturated porosity of the waste form, unitless
T	=	tortuosity of the waste form, unitless
D_w	=	diffusivity of the constituent in water, square meters per year
R_d	=	retardation factor for the constituent in the waste form, unitless
t	=	time, years

This rectangular geometry model assumes that the release occurs from only the lower surface of the waste form.

If the release occurs from both the upper and lower surfaces, the waste form is represented as shown in the volume of Figure M–5. Using the same approach as for a release from a single surface, the cumulative release of the constituent from both surfaces is calculated as follows:

$$R_{wf\text{cum}} = [2\, AT_0/(H_{wf}/2 - x_0)]\, \sqrt{\{\, [(2\, T\, (\varepsilon/\varepsilon_s)\, D_w\,)/\, R_d\,]\, t + x_0^{\,2}\,\}} - [2\, AT_0/(H_{wf}/2 - x_0)]\, (\, x_0\,) \qquad \text{(M–19)}$$

where:

$R_{wf\text{cum}}$	=	cumulative release of the constituent from the waste form, grams
AT_0	=	initial inventory of the constituent, grams
H_{wf}	=	thickness of waste form, meters
x_0	=	initial thickness of the waste form layer outside the core, meters
T	=	tortuosity of the waste form, unitless
ε	=	volumetric moisture content of the waste form, unitless
ε_s	=	saturated porosity of the waste form, unitless
D_w	=	diffusivity of the constituent in water, square meters per year
R_d	=	retardation factor for the constituent in the waste form, unitless
t	=	time, years

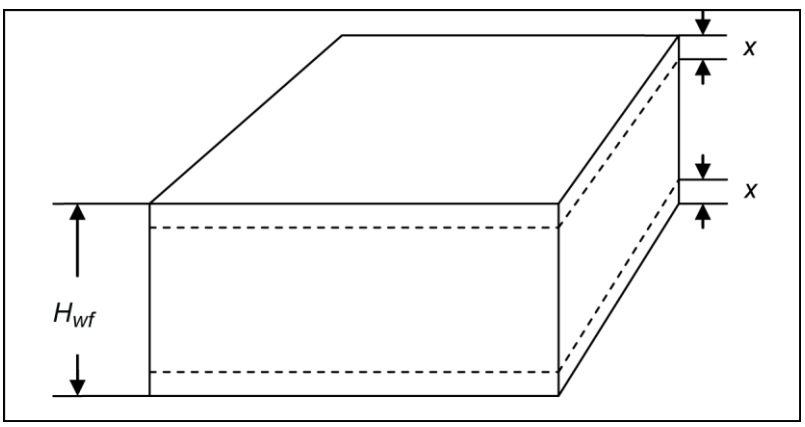


Figure M–5. Schematic of Rectangular Waste Form with Diffusion Release from Upper and Lower Surfaces

A source with cylindrical symmetry is shown in Figure M–6.

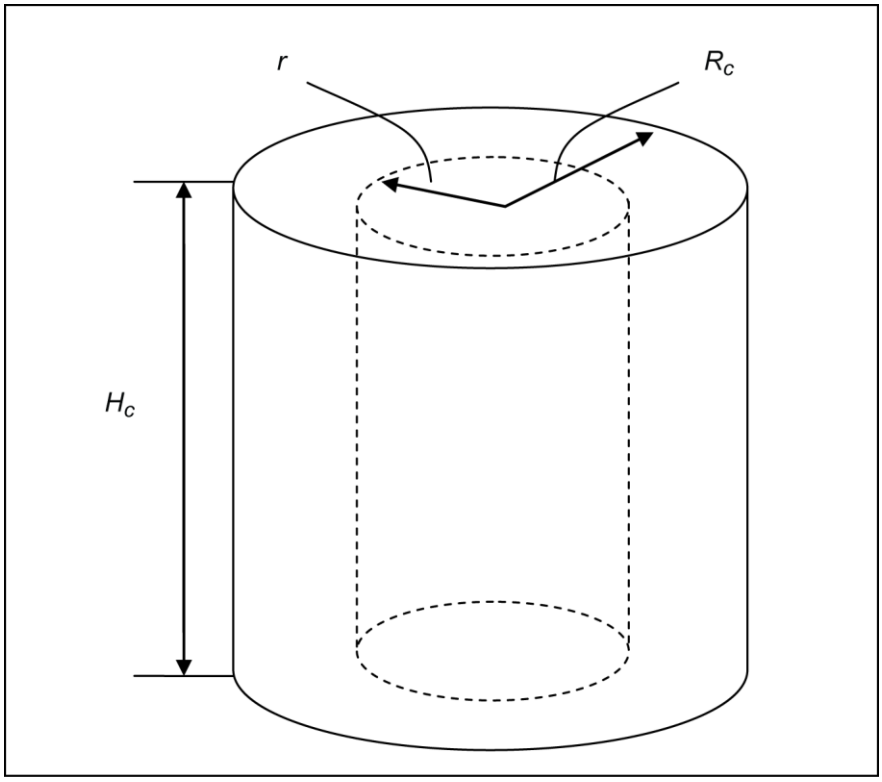


Figure M–6. Schematic of a Cylindrical Diffusion Release Model

Resistance to mass transfer is assumed to reside in an annular layer with thickness $R_c - r$ (see Figure M–6) that separates the core portion of the cylinder from the environment. Waste forms are assumed to be placed in a rectangular array, and infiltrating water flows downward through the space between waste packages. The constituent is released from the waste form by diffusion into the space between waste packages and then flows downward with the convective flow of infiltrating water. A mass balance formed on the diffusing constituent in the waste form is as follows:

$$(\varepsilon\, \pi\, H_c)\, R_d\, C_l\, \partial r^2 / \partial t = -R_{wf} \qquad \text{(M–20)}$$

$$R_{wf} = (\varepsilon\, 2\, \pi\, r\, H_c)\, T\, D_w\, [(C_l - C_{vz})/(R_c - r)] \qquad \text{(M–21)}$$

$$R_d = \varepsilon/\varepsilon_s + [(1 - \varepsilon_s)/\varepsilon_s]\, \rho_s\, K_d \qquad \text{(M–22)}$$

where:

ε	=	volumetric moisture content of the waste form, unitless
H_c	=	height of the cylindrical waste form, meters
R_d	=	retardation factor (see Equation M–5) for the constituent in the waste form, unitless
C_l	=	concentration of the constituent in the pore space of the waste form, grams per cubic meter
r	=	radius of the shrinking core, meters
t	=	time, years
R_{wf}	=	rate of release of the constituent from the waste form, grams per year
T	=	tortuosity of the waste form, unitless
D_w	=	diffusion coefficient of the constituent in water, square meters per year

C_{vz}	=	concentration of the constituent in the vadose zone between the waste packages, grams per cubic meter
R_c	=	radius of the cylinder, meters
ε_s	=	saturated porosity of the waste form, unitless
ρ_s	=	particle density of the solid in the waste form, grams per cubic centimeter
K_d	=	distribution coefficient for the constituent and waste form, milliliters per gram

If the concentration of the diffusing constituent is maintained at a low level outside of the waste form ($C_{vz} = 0$), the cumulative release of the constituent from the form calculated using the mass balance is as follows:

$$R_{wf\text{cum}} = (2\,[R_c / r_0^2]\,AT_0\,) \sqrt{\{[(2\,(\varepsilon/\varepsilon_s)\,T\,D_w\,)/\,R_d\,]\,t + (R_c - r_0)^2\,\}} - [\,R_c - r_0\,])$$

$$- ([\,AT_0 / r_0^2\,]\,[(2\,(\varepsilon/\varepsilon_s)\,T\,D_w\,)/\,R_d\,]\,t\,) \qquad \text{(M–23)}$$

where:

R_{wfcum}	=	cumulative release of the constituent from the waste form, grams
R_c	=	radius of the cylinder, meters
r_0	=	initial radius of the core of the waste form, meters
AT_0	=	initial inventory of the constituent in the waste form, grams
ε	=	volumetric moisture content of the waste form, unitless
ε_s	=	saturated porosity of the waste form, unitless
T	=	tortuosity of the waste form, unitless
D_w	=	diffusion coefficient of the constituent in water, square meters per year
R_d	=	retardation factor (see Equation M–5) for the constituent in the waste form, unitless
t	=	time, years

If the concentration of the constituent in the vadose zone between waste forms is not maintained at a low level, the solution procedure is extended to include a mass balance formed on the constituent in the volume of soil and water in the space between waste packages. This additional mass balance is expressed as follows:

$$(A_f - A_{wf}\,)\,H_{wf}\,\varepsilon_{svz}\,R_{d,vz}\,\partial\,C_{vz} / \partial t = R_{wf} - R_{vz} \qquad \text{(M–24)}$$

$$R_{vz} = A_f\,q_{\text{inf,j}}\,C_{vz} \qquad \text{(M–25)}$$

$$R_{d,vz} = (\theta_{vz} / \varepsilon_{svz}) + [(1 - \varepsilon_{svz})/\,\varepsilon_{svz}\,]\,\rho_s\,K_{d,vz} \qquad \text{(M–26)}$$

where:

A_f	=	area in horizontal plane for infiltration of water, square meters
A_{wf}	=	area in horizontal plane intersected by stacks of waste packages, square meters
H_{wf}	=	height of a stack of waste packages, meters
ε_{svz}	=	saturated porosity of the vadose zone, unitless
$R_{d,vz}$	=	retardation factor for the constituent in the vadose zone between waste packages, unitless
C_{vz}	=	concentration of the constituent in the water in the vadose zone between the waste packages, grams per cubic meter
t	=	time, years
R_{wf}	=	rate of release of the constituent from the waste form, grams per year
R_{vz}	=	rate of release of the constituent from the vadose zone between the waste packages to the vadose zone below the waste packages, grams per year

$q_{\text{inf,j}}$ = rate of infiltration during time interval *j*, meters per year
θ_{vz} = moisture content of the vadose between the waste packages, unitless
ρ_s = particle density of the solid in the waste form, grams per cubic centimeter
$K_{d,vz}$ = distribution coefficient for the constituent in the vadose zone between the waste packages, milliliters per gram

Mass balances of Equations M–20 and M–24 are solved simultaneously for the concentration of the constituent in the vadose zone between waste packages (C_{vz}) and the release rates to the vadose zone below waste packages (R_{vz}).

Diffusion-controlled release models are applicable for grout or cement waste forms, such as grouted HLW tanks or cast stone waste. Primary parameters of the model are dimensions and tortuosity of the waste form, and the diffusion coefficient, distribution coefficient, and initial inventory for the constituent.

M.3 TECHNICAL BASIS AND VALUES OF RELEASE MODEL PARAMETERS

Factors affecting release rates of constituents to the vadose zone include environmental factors, such as rate of infiltration, and factors specific to the nature of the source and the disposal system. Values of rate of infiltration adopted for use in this *TC & WM EIS* are those recommended in the *Technical Guidance Document for Tank Closure Environmental Impact Statement Vadose Zone and Groundwater Revised Analyses (Technical Guidance Document)* (DOE 2005). *Technical Guidance Document* values recommended for base case analysis are summarized in Table M–3. Post–design life conditions in Table M–3 correspond to the period of time labeled as "Degraded cap" in Figure M–2.

Table M–3. Rates of Infiltration for *TC & WM EIS* Base Case Analysis

Location	Rate of Infiltration (millimeters per year)
Pre-Hanford Background	
IDF	0.9
Balance of site	3.5
Disturbed Conditions	
Gravel (HLW tanks)	100
Sand (cribs and trenches [ditches])	50
IDF Barrier	
Design life	0.5
Post–design life	0.9
Sitewide Barrier	
Design life	0.5
Post–design life	3.5

Key: HLW=high-level radioactive waste; IDF=Integrated Disposal Facility; *TC & WM EIS=Tank Closure and Waste Management Environmental Impact Statement for the Hanford Site, Richland, Washington*.

Values of parameters related to specific actions and types of sources are summarized in the following sections for the Tank Closure, FFTF Decommissioning, and Waste Management alternatives. Tank Closure alternatives evaluate impacts occurring in the long-term period following stabilization or closure of the HLW tanks.

Under Waste Management Alternative 2, waste disposal would occur in an Integrated Disposal Facility (IDF) in the 200-East Area (IDF-East); under Waste Management Alternative 3, waste disposal would occur in IDF-East and other facilities in the 200-East Area, as well as in an IDF in the 200-West Area (IDF-West).

M.3.1 Tank Closure Alternatives

Types of sources considered for Tank Closure alternatives include past leaks, retrieval leaks, tank residuals, and ancillary equipment at 18 tank farms and planned discharges at 6 sets of cribs and trenches (ditches) associated with tank farm operations. These facilities are all in the 200-East and 200-West Areas.

M.3.1.1 Tank Farm Sources

Liquid and solid sources are considered for release analysis at the 18 HLW tank farms. Descriptions of the dimensions, configuration and closure systems for tank farms are presented in the *Tank System Closure and Facility D&D* [decontamination and decommissioning] *Data Package* (DOE 2003a).

Primary liquid sources are past leaks and retrieval leaks from 100- and 200-series tanks located at single-shell tank farms for all Tank Closure alternatives, and ancillary equipment failure leaks at all tank farms and tank failure leaks at double-shell tank farms for Tank Closure Alternatives 1 and 2A, for which tank closure does not occur.

For past leaks, 67 tanks are included in the analysis, and model parameters include volume of liquid, inventory of constituents, and time of occurrence of the leak. Volumes of liquid assumed for analysis purposes are those presented in the Hanlon waste tank summary report (Hanlon 2003). If a volume estimate is missing from the Hanlon report for a specific tank, an estimate of the leak volume of 30 cubic meters (8,000 gallons) is assumed for that tank. Inventory estimates for past leaks are developed from field investigation reports (FIRs) for tank farms B, BX, and BY (Knepp 2002); S and SX (CH2M HILL 2002); and T, TX, and TY (Myers 2005). Subsurface conditions reports are used for estimates of inventory for tank farms A, AX, and C (Wood et al. 2003) and U (Wood and Jones 2003). If an inventory estimate for a specific tank included in the Hanlon list is not presented in an FIR or subsurface conditions report, the inventory for that tank is estimated using the average concentration for leaks from that tank farm presented in the FIR or subsurface conditions report and the leak volume from the Hanlon report. Estimates of volume of leak and date of occurrence for the 67 tanks are presented in Table M–4. Estimates of date of occurrence are adopted from the FIRs, subsurface conditions reports, and preliminary field studies (Jones et al. 2000, 2001). Estimates of quantities of constituents released with past leaks are presented in Appendix D of this environmental impact statement (EIS).

Table M–4. Summary of Estimates of Volumes and Dates for Past Leaks

Tank	Leak Volume[a] (gallons)	Date of Occurrence		Tank	Leak Volume[a] (gallons)	Date of Occurrence
241-A-103	5,500	1956[b]		241-SX-104	6,000	1954[b]
241-A-104	2,500	1975[c]		241-SX-107	5,000	1964[f]
241-A-105	277,000	1963[c]		241-SX-108	35,000	1965[f]
241-AX-102	3,000	1965[b]		241-SX-109	10,000	1964[f]
241-AX-104	8,000	1965[b]		241-SX-110	5,500	1974[f]
241-B-101	8,000	1974[d]		241-SX-111	2,000	1973[f]
241-B-103	8,000	1945[b]		241-SX-112	30,000	1969[f]
241-B-105	8,000	1968[d]		241-SX-113	15,000	1962[f]
241-B-107	8,000	1966[d]		241-SX-114	8,000	1972[f]
241-B-110	10,000	1970[d]		241-SX-115	50,000	1964[f]
241-B-111	8,000	1945[b]		241-T-101	7,500	1969[g]
241-B-112	2,000	1945[b]		241-T-103	1,000	1973[g]
241-B-201	1,200	1966[c]		241-T-106	115,000	1973[g]
241-B-203	300	1966[c]		241-T-107	8,000	1944[b]
241-B-204	400	1966[c]		241-T-108	1,000	1944[b]
241-BX-101	8,000	1968[e]		241-T-109	1,000	1944[b]
241-BX-102	70,000	1951[e]		241-T-111	1,000	1944[b]
241-BX-108	2,500	1948[b]		241-TX-105	8,000	1949[b]
241-BX-110	8,000	1948[b]		241-TX-107	2,500	1977[g]
241-BX-111	8,000	1965[d]		241-TX-110	8,000	1949[b]
241-BY-103	5,000	1950[b]		241-TX-113	8,000	1949[b]
241-BY-105	8,000	1950[b]		241-TX-114	8,000	1949[b]
241-BY-106	8,000	1950[b]		241-TX-115	8,000	1949[b]
241-BY-107	15,100	1950[b]		241-TX-116	8,000	1949[b]
241-BY-108	5,000	1950[b]		241-TX-117	8,000	1949[b]
241-C-101	20,000	1946[b]		241-TY-101	1,000	1953[b]
241-C-110	2,000	1946[b]		241-TY-103	3,000	1971[g]
241-C-111	5,500	1946[b]		241-TY-104	1,400	1953[b]
241-C-201	550	1946[b]		241-TY-105	35,000	1960[g]
241-C-202	450	1946[b]		241-TY-106	20,000	1957[g]
241-C-203	400	1946[b]		241-U-101	30,000	1946[b]
241-C-204	350	1946[b]		241-U-104	55,000	1956[h]
241-S-104	24,000	1965[f]		241-U-110	8,100	1975[h]
				241-U-112	8,500	1946[b]

[a] Hanlon 2003.
[b] Anderson 1990.
[c] Wood et al. 2003.
[d] Jones et al. 2001.
[e] Knepp 2002.
[f] CH2M HILL 2002.
[g] Jones et al. 2000.
[h] Wood and Jones 2003.

The DOE estimates that a volume of 15 cubic meters (4,000 gallons) would leak from each of the 149 single-shell tanks during waste retrieval (see Section E.1.2.2.5.2). For each tank farm and alternative, the retrieval leaks are assumed to occur simultaneously in calendar year 2018. Estimates of the inventory of constituents for retrieval leaks are developed by assuming that three volumes of sluicing liquid are required to entrain one volume of tank solids and that the solids have the composition of the December 2002 estimate of the Best-Basis Inventory (BBI). The BBI is documented in the *Inventory and Source Term Data Package* (DOE 2003b). Estimates of quantities of constituents released in retrieval leaks are presented in Appendix D of this EIS.

Primary solid sources at tank farms are salt cake remaining in single-shell tanks under Tank Closure Alternatives 1 and 2A and grouted residuals in tanks and ancillary equipment under Alternatives 2B, 3A, 3B, 3C, 4, 5, and 6C.

For releases from salt cake and sludge, the release model proposed is the matrix solubility-limited release model described in Section M.2.2.2. The proposed value of solubility for the matrix is a literature estimate of the solubility of sodium nitrate at 25 degrees Celsius (°C) (77 degrees Fahrenheit [°F]): 920,000 grams per cubic meter (Weast and Selby 1967). Although the solubility of sludge would be expected to be significantly lower than that of salt cake, detailed characterization of sludge is not available for all tanks; thus, for analysis purposes, the solubility of sludge is assumed equal to that of salt cake. The mass and volume of waste in each tank farm and inventory of constituents are those documented in the *Inventory and Source Term Data Package* (DOE 2003b). For Tank Closure Alternative 1, the residual inventory in each tank at the time of failure (time of loss of administrative or institutional control) is the total inventory of the BBI. For Tank Closure Alternative 2A, the inventory remaining in each tank at the time of failure is 1 percent of the BBI. The magnitude and timing of infiltration for Tank Closure Alternatives 1 and 2A are summarized in Table M–5.

Table M–5. Tank Closure Alternatives 1 and 2A Infiltration Sequence Description

Location Conditions	Tank Closure Alternative 1	Tank Closure Alternative 2A	Infiltration Value (millimeters per year)
	Year at Start of Infiltration		
Pre-Hanford	1940	1940	3.5
Disturbed conditions	1948	1948	100
Post–barrier design life	2108	2194	3.5

For releases from grouted residuals in HLW tanks and ancillary equipment, the proposed release model is the partition-limited, convective-flow release model described in Section M.2.2.1. The inventory is assumed to reside in the bottom of the tank, occupying a volume equal to that of the residuals remaining after retrieval with a short diffusion distance in the downward vertical direction and a long diffusion distance in the upward vertical direction. Dimensions of the tank are those described in the *Tank System Closure and Facility D&D Data Package* (DOE 2003a), and the constituent inventories are fractions of the BBI appropriate for each alternative with the BBI specified in the *Inventory and Source Term Data Package* (DOE 2003b).

Primary remaining parameters of the model are the rate of recharge and the retardation factor defined in conjunction with Equation M–5. The magnitude and timing of the sequence of infiltration for Tank Closure Alternatives 2B, 3A, 3B, 3C, 4, 5, and 6C are summarized in Table M–6. Under Alternatives 2B, 3A, 3B, 3C, 4, and 6C, modified Resource Conservation and Recovery Act (RCRA) Subtitle C barriers with a design life of 500 years would be placed over the tank farms. Hanford barriers with a design life of 1,000 years would be placed over the tank farms under Tank Closure Alternative 5. Distribution coefficient values used to calculate the retardation factor are presented in Tables M–7 (radioactive constituents) and M–8 (chemical constituents) and are those either recommended for grout (DOE 2005) or reported in nationwide surveys of soil (Beyeler et al. 1999; Sheppard and Thibault 1990).

Table M–6. Tank Closure Alternatives 2B, 3A, 3B, 3C, 4, 5, and 6C Infiltration Sequence Description

Location Conditions	Tank Closure Alternatives 2B, 3A, 3B, 3C, 4, and 6C	Tank Closure Alternative 5	Infiltration Value (millimeters per year)
	Year at Start of Infiltration Value		
Pre-Hanford Site	1940	1940	3.5
Disturbed conditions	1948	1948	100
Barrier design life	2050	2050	0.5
Post–barrier design life	2550	3050	3.5

Table M–7. Values of Distribution Coefficient for Radioactive Constituents in Hanford Grout

Constituent	Distribution Coefficient (milliliters per gram)	Source
Hydrogen	0	DOE 2005
Carbon	5	DOE 2005
Potassium	15	Sheppard and Thibault 1990
Strontium	15	DOE 2005
Zirconium	600	Sheppard and Thibault 1990
Technetium	1	DOE 2005
Iodine	50	DOE 2005
Cesium	280	DOE 2005
Gadolinium	5	Sheppard and Thibault 1990
Thorium	3,200	Beyeler et al. 1999
Uranium	35	DOE 2005
Neptunium	15	DOE 2005
Plutonium	550	DOE 2005
Americium	1,900	Beyeler et al. 1999

Table M–8. Values of Distribution Coefficient for Chemical Constituents in Hanford Grout

Constituent	Distribution Coefficient (milliliters per gram)	Source
Arsenic	400	Sheppard and Thibault 1990
Boron	0	Sheppard and Thibault 1990
Cadmium	80	Sheppard and Thibault 1990
Chromium	0	DOE 2005
Fluoride	0	Sheppard and Thibault 1990
Lead	80	DOE 2005
Manganese	50	Beyeler et al. 1999
Mercury	10	DOE 2005
Molybdenum	10	Beyeler et al. 1999
Nickel	400	Beyeler et al. 1999
Nitrate	0	DOE 2005

Table M–8. Values of Distribution Coefficient for Chemical Constituents in Hanford Grout *(continued)*

Constituent	Distribution Coefficient (milliliters per gram)	Source
Silver	90	Beyeler et al. 1999
Strontium	10	Sheppard and Thibault 1990
Total uranium	0.6	Sheppard and Thibault 1990
Acetonitrile	0	DOE 2005
Benzene	1	DOE 2005
Butanol	3	DOE 2005
Polychlorinated biphenyls	170,000	DOE 2005
2,4,6-Trichlorophenol	0.38	DOE 2005
1,2-Dichloroethane	0	Sheppard and Thibault 1990
1,4-Dioxane	0	Sheppard and Thibault 1990
Carbon tetrachloride	0	Sheppard and Thibault 1990
Dichloromethane	0	Sheppard and Thibault 1990
Hydrazine	0	Sheppard and Thibault 1990
Vinyl chloride	0	Sheppard and Thibault 1990
Trichloroethylene	0	Sheppard and Thibault 1990

M.3.1.2 Tank Closure Waste Forms

The primary-waste form associated with tank farm closure is ILAW glass, while supplemental-waste forms produced to facilitate timely processing of tank waste are bulk vitrification glass, bulk vitrification castable refractory block, cast stone waste, and steam reforming waste. Secondary waste generated in the production of primary- and secondary-waste forms include Effluent Treatment Facility (ETF)–generated secondary waste, sulfate grout, retired melters, and contaminated soil. A primary constituent of ETF-generated secondary waste is iodine-129 recovered from offgasses emitted by thermal treatment processes (vitrification, bulk vitrification, and steam reforming).

Technical guidance developed for this EIS (DOE 2005) recommended use of data and analysis developed for selection of low-activity-waste supplemental technologies (Mann et al. 2003). For ILAW glass and glass in retired melters, the fractional-release-rate model is applied. The value of the fractional-release rate is 2.8×10^{-8} grams per gram per year based on analysis using the STORM [Subsurface Transport Over Reactive Multiphases] model (Mann et al. 2003). For bulk vitrification glass, the fractional-release-rate model is applied. The value of the fractional-release rate is 1.0×10^{-8} grams per gram per year based on analysis using the STORM model (Mann et al. 2003). The rate of recharge used in the STORM analysis to predict the rate of release from ILAW and bulk vitrification glass (4.2 millimeters per year) is higher than the *Technical Guidance Document* base case conditions for IDF-East (0.9 millimeters per year), a difference expected to provide conservatism in the estimate of rate of release. During the bulk vitrification process, a portion of the feed technetium is volatilized and trapped in refractory above the glass surface. For this material, the partition-limited, convective-flow release model with a value of zero for the distribution coefficient of technetium is applied. The refractory is porous ceramic material, and research has demonstrated that technetium volatilized during bulk vitrification collects in this material (Mann et al. 2003). The fraction of technetium present in the original melt that resides in the castable refractory block has been measured, and an upper limit of 6.5 percent has been established (Burandt 2006). For cast stone waste, ETF-generated secondary waste, and sulfate grouted waste forms, the cylindrical geometry, diffusion-limited release model described in Section M.2.2.4 is applied. Values of aqueous diffusivity are based on ion conductivity data (Weast and Selby 1966:5-111) with values for

key species iodate, pertechnetate, and nitrate of 1.1×10^{-5}, 1.5×10^{-5}, and 1.9×10^{-5} square centimeters per second, respectively, at 25 °C (77 °F). The porosity of grout is estimated to be 0.43, based on a crystal density of 2.65 grams per cubic centimeter for natural silicates (Freeze and Cherry 1979:337; Mason and Berry 1968) and a bulk density of 1.5 grams per cubic centimeter for grout (DOE 2003c:6-100). Because the value of effective porosity has not been established for site conditions, the value of total porosity is applied for effective porosity as a conservative limit of release rates. Site-specific tests of effective diffusivity of nitrate in grout are reported as 3×10^{-8} square centimeters per second (Lockrem 2005). Effective diffusivity is defined as the product of tortuosity and aqueous diffusivity divided by the retardation factor. Assuming that nitrate does not adsorb onto the grout, these data imply a site-specific value of tortuosity of 1.6×10^{-3}. Using the definition of effective diffusivity and *Technical Guidance Document*–recommended values of effective diffusivity (DOE 2005), the implied values of the distribution coefficient for technetium and iodine in grout are 1 and 50 milliliters per gram, respectively. Values of aqueous diffusivity and effective diffusivity for grout, consistent with the *Technical Guidance Document* (DOE 2005), are summarized in Tables M–9 and M–10 for radioactive and chemical constituents, respectively. The experimental program for characterization of steam reforming waste has established the operability of the solidification process (THORTT 2002), and characterization of release mechanisms and rates (Lorier, Pareizs, and Jantzen 2005; McGrail et al. 2003a, 2003b) is under way, but has not yielded a complete basis for long-term performance assessment. In addition, alternative forms of the final product are under investigation (Jantzen 2006). For the purpose of long-term performance assessment for this *TC & WM EIS*, steam reforming waste is assumed to have the form of a finely divided solid. In light of the above considerations, an estimate of the rate of release of constituents from steam reforming waste was developed based on the equilibrium solubility of steam reforming waste calculated using the PHREEQC [Ph, REDOX (Reduction-Oxidation), and Equilibrium – C Language] geochemical model (Parkhurst and Appelo 1999). Research has identified nepheline as the primary component of steam reforming waste (McGrail et al. 2003a). The equilibrium solubility of crystalline nepheline in the presence of potential alteration phases was estimated to be 1.75×10^{5} grams per cubic meter at 15 °C (59 °F). Additional details on this estimate and other bounding estimates of the rate of dissolution of steam reforming waste are presented in Section M.5, Sensitivity Analysis. For contaminated soil disposed of at the River Protection Project Disposal Facility (RPPDF), the partition-limited, convective-flow model is applied. Distribution factor values for soil are those recommended in the *Technical Guidance Document* (DOE 2005) for Hanford vadose zone sediments or in nationwide surveys of soil (Beyeler et al. 1999; Sheppard and Thibault 1990). These values are summarized in Tables M–11 and M–12 for radioactive and chemical constituents, respectively.

Table M–9. Values of Aqueous and Effective Diffusivity for Radioactive Constituents in Hanford Grout

Constituent	Aqueous Diffusivity (square centimeters per second)	Effective Diffusivity (square centimeters per second)
Hydrogen	9.3×10^{-5}	1.5×10^{-7}
Carbon	9.2×10^{-6}	7.9×10^{-10}
Potassium	2.0×10^{-5}	5.8×10^{-10}
Strontium	7.9×10^{-6}	2.3×10^{-10}
Zirconium	2.0×10^{-5}	1.5×10^{-11}
Technetium	1.5×10^{-5}	5.2×10^{-9}
Iodine	1.1×10^{-5}	1.0×10^{-10}
Cesium	2.1×10^{-5}	3.3×10^{-11}
Gadolinium	6.0×10^{-6}	5.1×10^{-10}
Thorium	4.3×10^{-6}	6.0×10^{-13}

Table M–9. Values of Aqueous and Effective Diffusivity for Radioactive Constituents in Hanford Grout *(continued)*

Constituent	Aqueous Diffusivity (square centimeters per second)	Effective Diffusivity (square centimeters per second)
Uranium	4.3×10^{-6}	5.5×10^{-11}
Neptunium	4.3×10^{-6}	1.3×10^{-10}
Plutonium	4.3×10^{-6}	3.5×10^{-12}
Americium	4.3×10^{-6}	1.0×10^{-12}

Table M–10. Values of Aqueous and Effective Diffusivity for Chemical Constituents in Hanford Grout

Constituent	Aqueous Diffusivity (square centimeters per second)	Effective Diffusivity (square centimeters per second)
Arsenic	9.05×10^{-6}	1.03×10^{-11}
Boron	1.25×10^{-5}	2.00×10^{-8}
Cadmium	7.19×10^{-6}	4.08×10^{-11}
Chromium	1.13×10^{-5}	1.81×10^{-8}
Fluoride	1.48×10^{-5}	2.36×10^{-8}
Lead	9.45×10^{-6}	5.36×10^{-11}
Manganese	7.12×10^{-6}	6.45×10^{-11}
Mercury	8.47×10^{-6}	3.75×10^{-10}
Molybdenum	1.98×10^{-5}	8.79×10^{-10}
Nickel	6.66×10^{-7}	7.58×10^{-13}
Nitrate	1.90×10^{-5}	3.04×10^{-8}
Silver	1.65×10^{-5}	8.32×10^{-11}
Strontium	7.91×10^{-6}	3.50×10^{-10}
Total uranium	4.26×10^{-6}	2.19×10^{-9}
Acetonitrile	8.77×10^{-7}	1.40×10^{-9}
Benzene	6.38×10^{-6}	2.26×10^{-9}
Butanol	6.26×10^{-6}	8.69×10^{-10}
Polychlorinated biphenyls	3.71×10^{-6}	9.93×10^{-15}
2,4,6-Trichlorophenol	5.00×10^{-6}	3.43×10^{-9}
1,2-Dichloroethane	6.84×10^{-6}	1.09×10^{-8}
1,4-Dioxane	6.54×10^{-6}	1.05×10^{-8}
Carbon tetrachloride	6.06×10^{-6}	9.70×10^{-9}
Dichloromethane	7.75×10^{-6}	1.24×10^{-8}
Hydrazine	1.25×10^{-5}	1.99×10^{-8}
Vinyl chloride	7.48×10^{-6}	1.20×10^{-8}
Trichloroethylene	6.33×10^{-6}	1.01×10^{-8}

Table M–11. Values of Distribution Coefficient for Radioactive Constituents for Contaminated Soil

Constituent	Distribution Coefficient (milliliters per gram)	Source
Hydrogen	0	DOE 2005
Carbon	4	DOE 2005
Potassium	15	Sheppard and Thibault 1990
Strontium	10	DOE 2005
Zirconium	600	Sheppard and Thibault 1990
Technetium	0	DOE 2005
Iodine	0	DOE 2005
Cesium	80	DOE 2005
Gadolinium	5	Sheppard and Thibault 1990
Thorium	3,200	Beyeler et al. 1999
Uranium	0.6	DOE 2005
Neptunium	2.5	DOE 2005
Plutonium	150	DOE 2005
Americium	1,900	Beyeler et al. 1999

Table M–12. Values of Distribution Coefficient for Chemical Constituents for Contaminated Soils

Constituent	Distribution Coefficient (milliliters per gram)	Source
Arsenic	400	Sheppard and Thibault 1990
Boron	0	Sheppard and Thibault 1990
Cadmium	0.8	Sheppard and Thibault 1990
Chromium	0	DOE 2005
Fluoride	0	Sheppard and Thibault 1990
Lead	80	DOE 2005
Manganese	50	Beyeler et al. 1999
Mercury	10	DOE 2005
Molybdenum	10	Beyeler et al. 1999
Nickel	400	Beyeler et al. 1999
Nitrate	0	DOE 2005
Silver	90	Beyeler et al. 1999
Strontium	10	Sheppard and Thibault 1990
Total uranium	0.6	Sheppard and Thibault 1990
Acetonitrile	0	DOE 2005
Benzene	1	DOE 2005
Butanol	3	DOE 2005
Polychlorinated biphenols	170,000	DOE 2005
2,4,6-Trichlorophenol	0.38	Sheppard and Thibault 1990
1,2-Dichloroethane	0	Sheppard and Thibault 1990
1,4-Dioxane	0	Sheppard and Thibault 1990

Table M–12. Values of Distribution Coefficient for Chemical Constituents for Contaminated Soils *(continued)*

Constituent	Distribution Coefficient (milliliters per gram)	Source
Carbon tetrachloride	0	Sheppard and Thibault 1990
Dichloromethane	0	Sheppard and Thibault 1990
Hydrazine	0	Sheppard and Thibault 1990
Vinyl chloride	0	Sheppard and Thibault 1990
Trichloroethylene	0	Sheppard and Thibault 1990

M.3.1.3 Cribs and Trenches (Ditches)

Sources at cribs and trenches (ditches) are liquid sources modeled as pulse releases characterized by liquid volume, source area, and time of occurrence. The values for these model parameters are those reported in the Hanford Soil Inventory Model (SIM) database and summarized in Appendix D of this EIS.

M.3.2 FFTF Decommissioning Alternatives

Under FFTF Decommissioning Alternative 1, the FFTF [Fast Flux Test Facility] Reactor Containment Building (RCB, Building 405), as well as the other buildings within the 400 Area Property Protected Area, would be maintained under administrative controls for 100 years through 2107. After 2107, remaining waste would be available for release to the environment.

FFTF Decommissioning Alternative 2 calls for in-place closure of FFTF. The main RCB, the two immediately adjacent support facilities (Buildings 491E and 491W), and all other above-grade structures would be dismantled. Demolition waste would be consolidated in the below-grade spaces or disposed of in an IDF. Below-grade spaces would be filled with demolition waste and stabilized with fill material (grout) to immobilize hazardous materials and minimize future subsidence. A modified RCRA Subtitle C barrier would be constructed over the filled area with a design life of 500 years.

FFTF Decommissioning Alternative 3 describes removal and clean closure of FFTF. All above-grade structures around the main RCB and the immediately adjacent support facilities would be dismantled, and the contaminated demolition debris would be disposed of at an IDF. All other radioactively contaminated equipment and hazardous materials (including asbestos and lead shielding) would be removed for disposal at an IDF. Contaminated demolition debris would be removed to an IDF, and the vacated spaces backfilled, compacted, contoured, and revegetated. All radioactive and/or hazardous material and wood and large steel components would be removed. The surface would be contoured and revegetated; no barrier would be required.

Consistent with this description of the three FFTF Decommissioning alternatives, the partition-limited, convective-flow model is applied. The magnitude and timing of infiltration sequences for FFTF Decommissioning Alternatives 1, 2, and 3 are presented in Tables M–13, M–14, and M–15, respectively. The values of infiltration rate are based on chloride mass balance and lysimeter tests[1] and are those recommended in the *Technical Guidance Document* (DOE 2005).

[1] A lysimeter is a device used to measure the rate of drainage of water through the lower boundary of a vertical column of soil subjected to a controlled rate of application of water at the upper boundary.

Table M–13. FFTF Decommissioning Alternative 1 Infiltration Sequence Description

Location Condition	Year at Start of Infiltration	Infiltration Value (millimeters per year)
Pre–Hanford Site	1940	3.5
Disturbed conditions	1980	50
End of institutional controls	2107	3.5

Note: Sites with sandy surfaces other than tank farms are assigned infiltration rates of 50 millimeters per year during disturbed conditions (DOE 2005).
Key: FFTF=Fast Flux Test Facility.

Table M–14. FFTF Decommissioning Alternative 2 Infiltration Sequence Description

Location Condition	Year at Start of Infiltration	Infiltration Value (millimeters per year)
Pre–Hanford Site	1940	3.5
Disturbed conditions	1980	50
Barrier design life	2022	0.5
Post–barrier design life	2522	3.5

Note: Sites with sandy surfaces other than tank farms are assigned infiltration rates of 50 millimeters per year during disturbed conditions (DOE 2005).
Key: FFTF=Fast Flux Test Facility.

Table M–15. FFTF Decommissioning Alternative 3 Infiltration Sequence Description

Location Condition	Year at Start of Infiltration	Infiltration Value (millimeters per year)
Pre–Hanford Site	1940	3.5
Disturbed conditions	1980	50
End of institutional controls	2107	3.5

Note: Sites with sandy surfaces other than tank farms are assigned infiltration rates of 50 millimeters per year during disturbed conditions (DOE 2005).
Key: FFTF=Fast Flux Test Facility.

M.3.3 Waste Management Alternatives

Primary facilities considered in Waste Management alternatives are one or two IDFs, the RPPDF, and trenches 31 and 34 at Low-Level Radioactive Waste Burial Ground (LLBG) 218-W-5.

M.3.3.1 Low-Level Radioactive Waste Burial Facilities

Sources at LLW disposal facilities, including LLBG 218-W-5, are modeled as contaminated soil and debris. For contaminated soil sources, the partitioning-limited, convective-flow model is applied with soil type distribution coefficients presented in Tables M–11 and M–12. For stabilized waste, the cylindrical diffusion-limited release model is applied with effective diffusivities, as summarized in Tables M–9 and M–10.

Under Waste Management Alternative 1, LLW, mixed low-level radioactive waste (MLLW), and transuranic waste would be processed at the Central Waste Complex for disposal in LLBG 218-W-5 (lined) trenches 31 and 34. These trenches would operationally close in 2035. As discussed in Appendices D and S of this EIS, a barrier would not be placed over LLBG 218-W-5, including trenches 31 and 34, in 2035. The infiltration sequence used in the modeling is described in Table M–16.

Table M–16. Waste Management Alternative 1 Infiltration Sequence Description for LLBG 218-W-5, Trenches 31 and 34

Location Condition	Year at Start of Infiltration	Infiltration Value (millimeters per year)
Pre–Hanford Site	1940	3.5
Disturbed conditions	1986	50
Post–barrier design life	2086	3.5

Key: LLBG=low-level radioactive waste burial ground.

M.3.3.2 Integrated Disposal Facility Waste Forms

Characteristics of the tank closure primary- and secondary-waste forms proposed for disposal at an IDF are those described in Section M.3.1.2. The onsite non–Comprehensive Environmental Response, Compensation, and Liability Act (non-CERCLA) and waste management secondary wastes are modeled as grouted waste forms with the characteristics described in Section M.3.1.2.

Waste Management Alternatives 2 and 3 include construction, operation, deactivation, closure, and postclosure care of IDF-East for tank, onsite non-CERCLA, FFTF decommissioning, waste management, and offsite LLW and MLLW. Under Waste Management Alternative 3, onsite non-CERCLA, FFTF decommissioning, waste management, and offsite LLW and MLLW would be disposed of in an IDF to be constructed in IDF-West, while tank LLW and MLLW would be disposed of in IDF-East. Three disposal groups were analyzed under these alternatives. Disposal Group 1 analyzes the operational completion date of 2050, with a barrier placed over the IDFs with a design life of 500 years. Disposal Group 2 analyzes the operational completion date of 2100, with a barrier placed over the IDFs with a design life of 500 years. Disposal Group 3 analyzes the operational completion date of 2165, with a barrier placed over the IDFs with a design life of 500 years. The magnitude and timing of the infiltration sequence for Waste Management Alternatives 2 and 3 are presented in Table M–17.

Table M–17. Waste Management Alternatives 2 and 3 Infiltration Sequence Description 200-East and 200-West Area Integrated Disposal Facilities

Location Condition	Disposal Group 1	Disposal Group 2	Disposal Group 3	IDF-East	IDF-West
	Year at Start of Infiltration			Infiltration Value (millimeters per year)	
Pre–Hanford Site	1940	1940	1940	0.9	3.5
Barrier design life	2050	2100	2165	0.5	0.5
Post–barrier design life	2550	2600	2665	0.9	3.5

Key: IDF-East=200-East Area Integrated Disposal Facility; IDF-West=200-West Area Integrated Disposal Facility.

M.4 RESULTS

M.4.1 Tank Closure Alternatives

M.4.1.1 Past Leaks from Cribs and Trenches (Ditches)

All Tank Closure alternatives are analyzed for the same constituent release to the vadose zone from past leaks from HLW tanks and discharges from cribs and trenches (ditches). Tables M–18 and M–19 and Figures M–7 through M–12 demonstrate the total release of radioactive and chemical constituents for the 10,000-year modeling period.

Table M–18. Radionuclide and Chemical Releases to the Vadose Zone from Tank Farm Past Leaks

Source	Radionuclide (curies)						Chemical (kilograms)					
	H-3	C-14	Tc-99	I-129	Np-237	U-238	1-Butanol	Cr	Hg	NO_3	Pb	Utot
A tank farm	4.43×10^{-1}	1.13×10^{-1}	1.24	1.46×10^{-3}	3.87×10^{-3}	5.02×10^{-3}	5.18×10^{-1}	8.44	3.53×10^{-2}	5.10×10^{3}	5.13×10^{-1}	4.52
AX tank farm	2.04×10^{-2}	4.40×10^{-3}	4.80×10^{-2}	5.64×10^{-5}	1.50×10^{-4}	1.94×10^{-4}	2.00×10^{-2}	3.26×10^{-1}	6.77×10^{-5}	2.00×10^{1}	1.98×10^{-2}	1.74×10^{-1}
B tank farm	2.86×10^{1}	3.10	2.18×10^{1}	4.20×10^{-2}	6.74×10^{-2}	2.34×10^{-1}	9.41×10^{1}	2.35×10^{2}	3.55×10^{-1}	3.35×10^{4}	5.10×10^{1}	2.44×10^{2}
BX tank farm	1.25×10^{1}	5.17×10^{-1}	4.92	9.35×10^{-3}	2.64×10^{-2}	7.16	6.56	4.97×10^{1}	3.40×10^{-2}	1.65×10^{4}	5.51	1.06×10^{4}
BY tank farm	6.49	2.20×10^{-1}	2.10	3.98×10^{-3}	1.13×10^{-2}	3.07	2.79	2.12×10^{1}	1.45×10^{-2}	7.04×10^{3}	2.35	4.52×10^{3}
C tank farm	2.68×10^{1}	1.48×10^{-1}	6.61	2.59×10^{-3}	2.30×10^{-2}	5.41×10^{-3}	1.89×10^{1}	4.15×10^{1}	2.12×10^{-2}	4.82×10^{3}	6.87	2.88
S tank farm	7.12	5.53×10^{-1}	3.87	7.44×10^{-3}	2.52×10^{-2}	8.22×10^{-2}	3.86×10^{-5}	7.81×10^{2}	6.49×10^{-2}	2.63×10^{4}	1.07×10^{1}	1.19×10^{2}
SX tank farm	9.24×10^{1}	4.79	3.75×10^{1}	7.10×10^{-2}	1.65×10^{-1}	4.21×10^{-1}	6.37×10^{-2}	3.89×10^{3}	3.57×10^{-2}	1.14×10^{5}	5.75×10^{1}	5.52×10^{2}
T tank farm	2.32×10^{2}	9.55	6.74×10^{1}	1.30×10^{-1}	2.33×10^{-1}	3.49×10^{-1}	3.78×10^{2}	1.10×10^{3}	2.35×10^{-1}	6.74×10^{4}	3.53×10^{1}	3.82×10^{2}
TX tank farm	1.30×10^{3}	1.51×10^{1}	1.07×10^{2}	2.06×10^{-1}	3.86×10^{-1}	3.16	6.13×10^{2}	3.06×10^{3}	1.34	2.44×10^{5}	1.29×10^{2}	1.29×10^{3}
TY tank farm	1.37×10^{1}	3.41×10^{-1}	2.40	4.59×10^{-3}	1.15×10^{-2}	1.33×10^{-1}	9.40	8.47×10^{1}	2.71×10^{-2}	4.19×10^{4}	2.49	1.04×10^{2}
U tank farm	8.96×10^{1}	1.61×10^{-1}	3.57	4.50×10^{-3}	2.13×10^{-2}	1.23×10^{-1}	1.77	1.61×10^{2}	7.16×10^{-2}	1.16×10^{4}	8.41×10^{-1}	1.81×10^{2}

Note: To convert kilograms to pounds, multiply by 2.2046.

Key: C-14=carbon-14; Cr=chromium; H-3=hydrogen-3 (tritium); Hg=mercury; I-129=iodine-129; NO_3=nitrate; Np-237=neptunium-237; Pb=lead; Tc-99=technetium-99; U-238=uranium-238; Utot=total uranium.

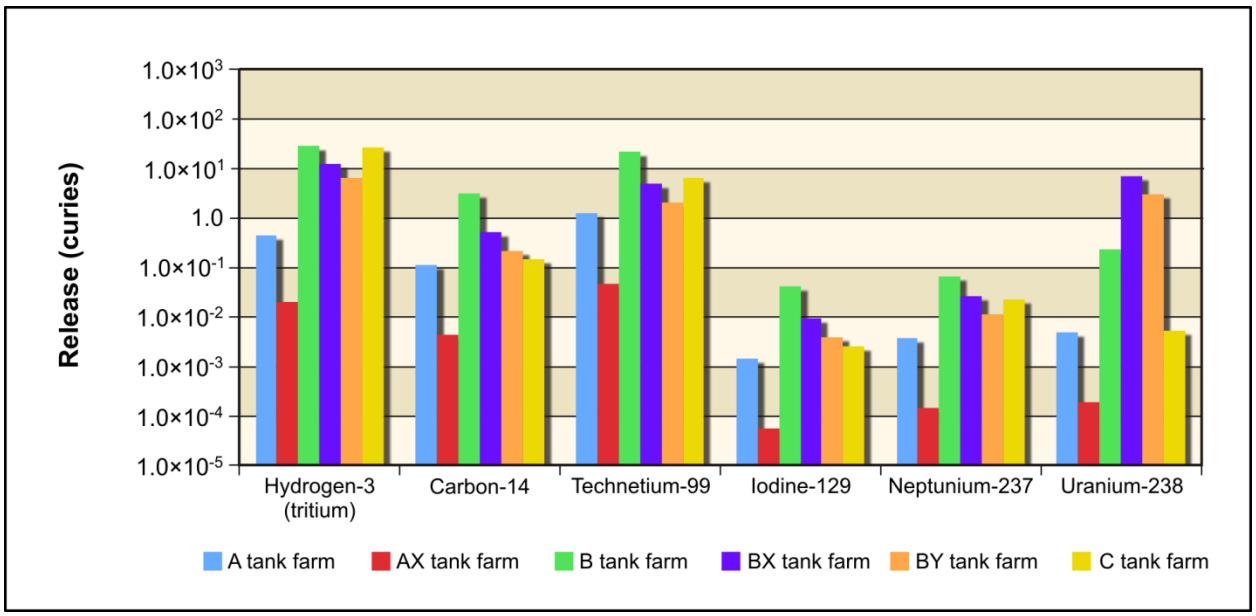


Figure M–7. Radionuclide Releases to the Vadose Zone from the 200-East Area Tank Farm Past Leaks

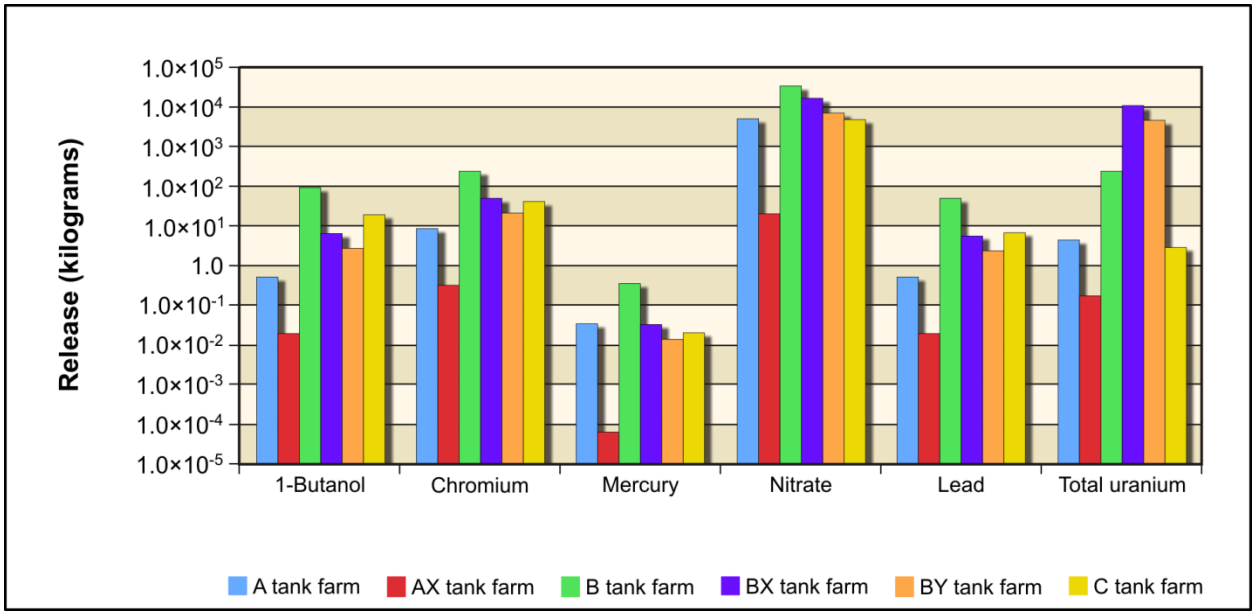


Figure M–8. Chemical Releases to the Vadose Zone from the 200-East Area Tank Farm Past Leaks

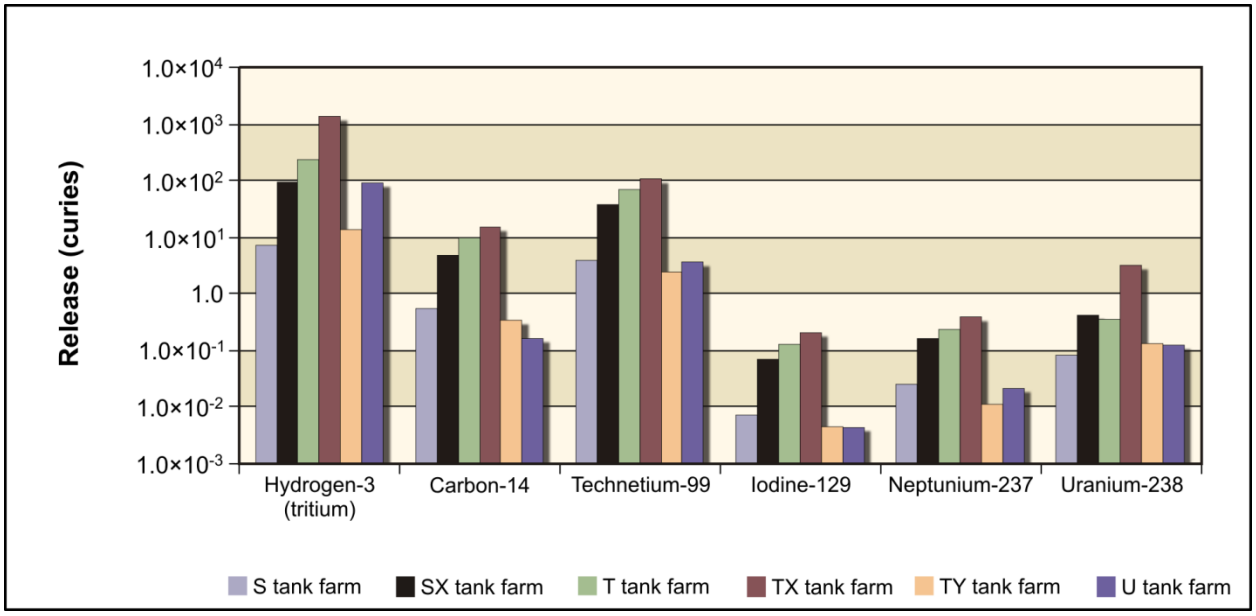


Figure M–9. Radionuclide Releases to the Vadose Zone from the 200-West Area Tank Farm Past Leaks

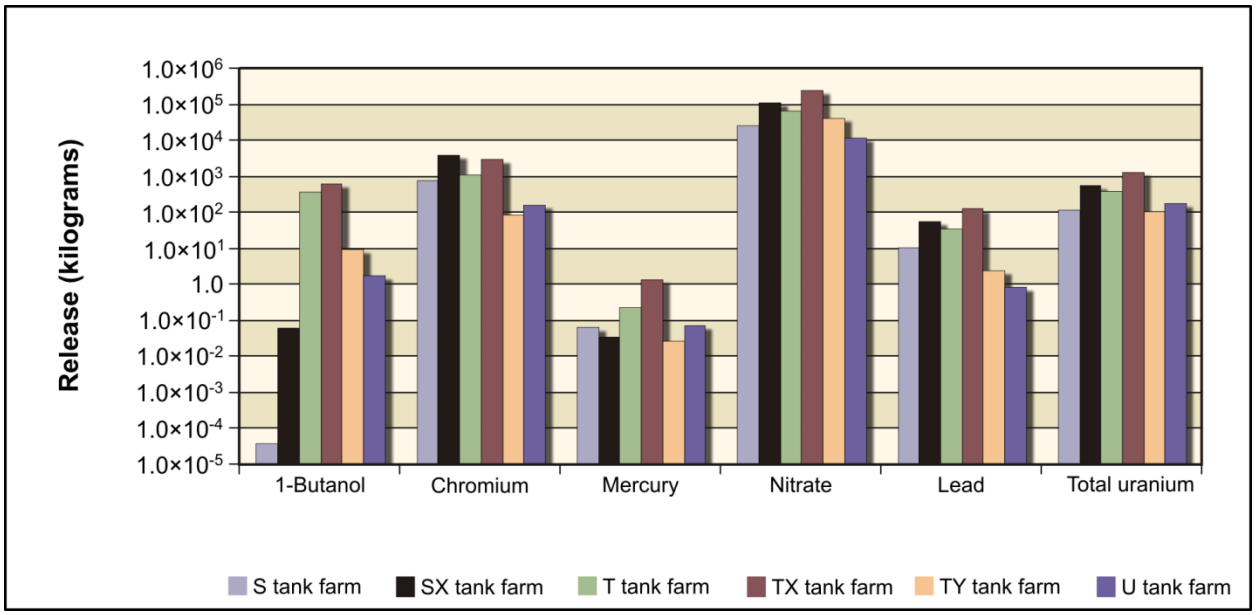


Figure M–10. Chemical Releases to the Vadose Zone from the 200-West Area Tank Farm Past Leaks

Table M–19. Radionuclide and Chemical Releases to the Vadose Zone from Alternative Cribs and Trenches (Ditches)

	Radionuclide (curies)									Chemical (kilograms)				
Source	**H-3**	**C-14**	**Sr-90**	**Tc-99**	**I-129**	**Cs-137**	**Np-237**	**U-238**	**Pu-239**	**Cr**	**Hg**	**NO_3**	**Pb**	**Utot**
B cribs and trenches	3.29×10^{-1}	1.73×10^{-1}	4.29×10^{3}	1.75×10^{-1}	6.95×10^{-4}	1.42×10^{3}	5.12×10^{-2}	1.58	1.65×10^{2}	1.78×10^{4}	1.23×10^{-2}	4.65×10^{6}	7.69	3.88×10^{2}
BX cribs and trenches	1.28×10^{3}	1.45	3.57×10^{3}	8.40	3.09×10^{-2}	1.83×10^{4}	1.07×10^{-1}	3.40×10^{-1}	6.97	5.05×10^{3}	5.25	1.77×10^{6}	–	5.04×10^{2}
BY cribs and trenches	2.82×10^{3}	8.22	1.42×10^{4}	1.29×10^{2}	1.65×10^{-1}	4.71×10^{3}	1.02	7.15×10^{-1}	2.82×10^{1}	5.81×10^{3}	1.09×10^{1}	6.71×10^{6}	–	1.06×10^{3}
T cribs and trenches	3.89×10^{4}	1.01	2.39×10^{3}	1.15	8.31×10^{-3}	6.91×10^{3}	1.51×10^{-1}	3.80×10^{-1}	3.03×10^{2}	4.21×10^{4}	6.13	1.01×10^{7}	5.50	5.64×10^{2}
TX cribs and trenches	6.82×10^{2}	6.52×10^{-1}	1.76×10^{3}	1.62	1.41×10^{-2}	1.09×10^{4}	3.73×10^{-2}	1.85×10^{-1}	3.70	2.87×10^{3}	2.87	1.04×10^{6}	–	2.74×10^{2}
TY cribs and trenches	3.77×10^{1}	3.81	1.66×10^{3}	1.80	1.70×10^{-2}	1.73×10^{3}	6.40×10^{-2}	3.01	8.87×10^{1}	7.17×10^{3}	8.18	6.75×10^{5}	1.46×10^{1}	1.11×10^{3}

Note: To convert kilograms to pounds, multiply by 2.2046.

Key: C-14=carbon-14; Cr=chromium; Cs-137=cesium-137; H-3=hydrogen-3 (tritium); Hg=mercury; I-129=iodine-129; NO_3=nitrate; Np-237=neptunium-237; Pb=lead; Pu-239=plutonium-239; Sr-90=strontium-90; Tc-99=technetium-99; U-238=uranium-238; Utot=total uranium.

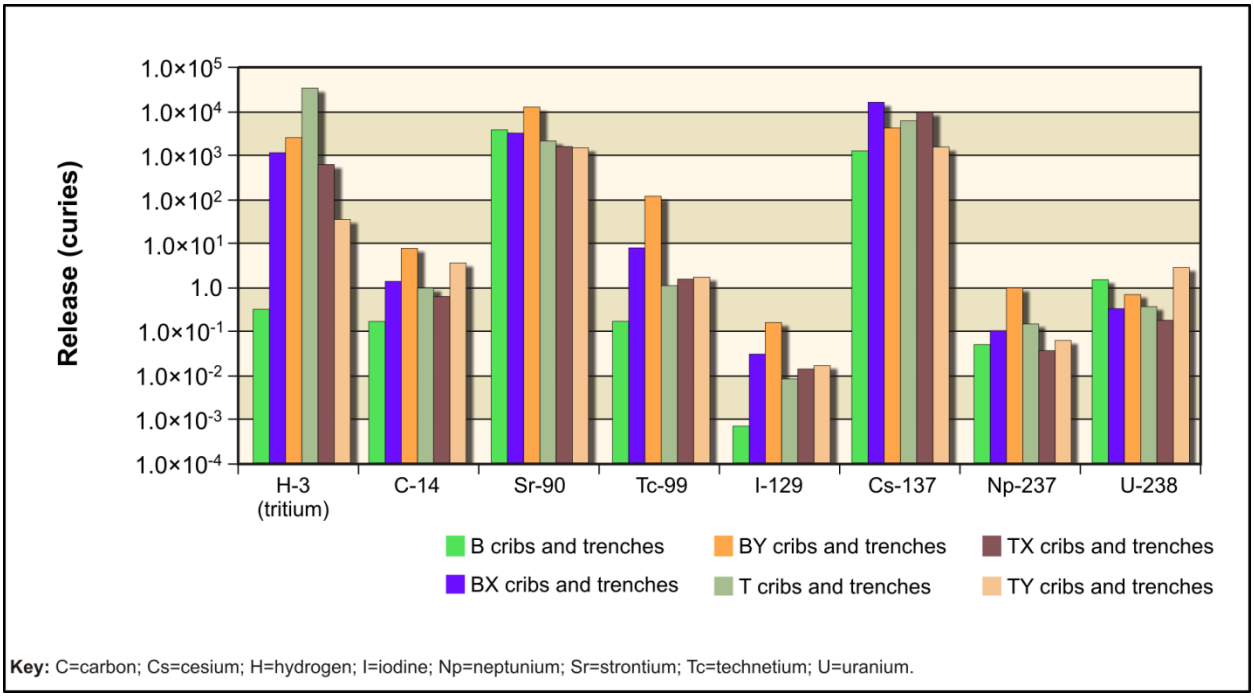


Figure M–11. Radionuclide Releases to the Vadose Zone from Alternative Cribs and Trenches (Ditches)

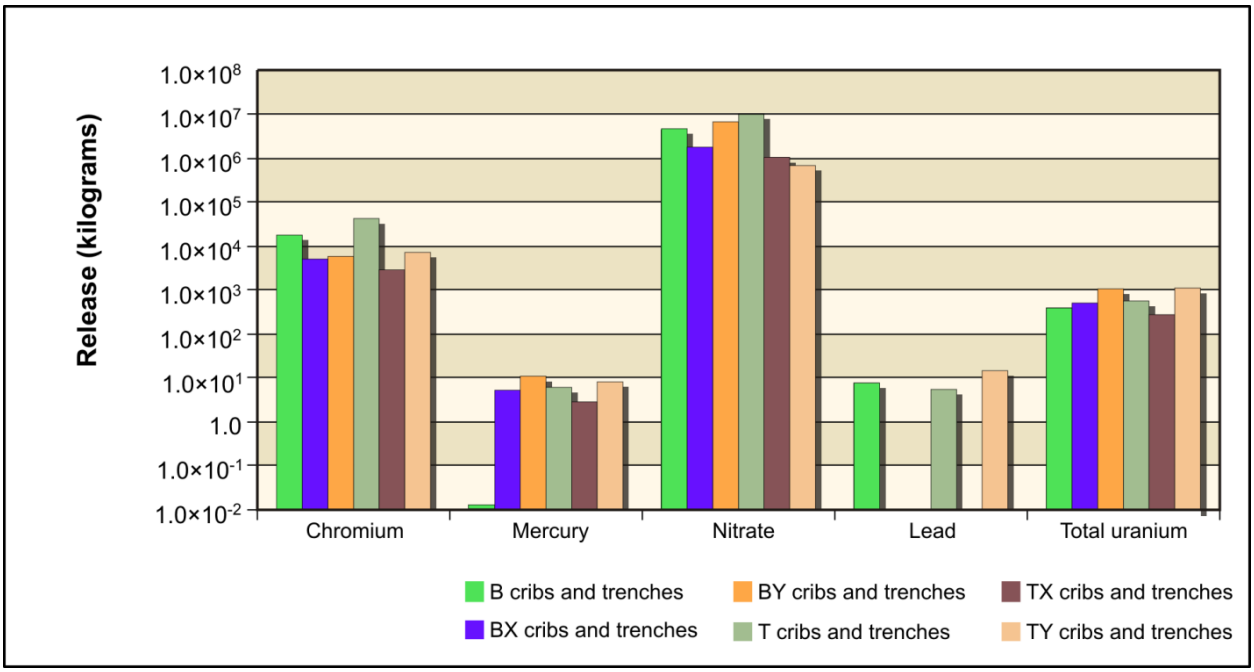


Figure M–12. Chemical Releases to the Vadose Zone from Alternative Cribs and Trenches (Ditches)

M.4.1.2 Releases from Other Sources in the Tank Farms

Releases from other sources related to the HLW tanks, including tank residuals, retrieval leaks, and ancillary equipment, were analyzed together. The amount of constituent released to the vadose zone is related to the activities under each Tank Closure alternative. Under Tank Closure Alternatives 6A and 6B, all tanks farms would be closed to a clean state by removing the tanks, ancillary equipment, and soil to a depth of 3 meters (10 feet) below the tank base. Where necessary, deep soil excavation would also be conducted to remove contamination plumes within the soil column. Therefore, releases from other sources related to the HLW tanks were not analyzed.

Under Tank Closure Alternative 1, tank farms would be maintained in the current condition indefinitely; however, for analysis purposes, they are assumed to fail after an institutional control period of 100 years. At this time, the salt cake in single-shell tanks is assumed available for leaching into the vadose zone, and the liquid contents of double-shell tanks are assumed to be discharged directly to the vadose zone. Table M–20 and Figures M–13 through M–18 indicate the constituent release estimated under Tank Closure Alternative 1.

Table M–20. Tank Closure Alternative 1 Radionuclide and Chemical Releases to the Vadose Zone from Other Sources in Tank Farms

	Radionuclide (curies)						Chemical (kilograms)								
Source	**H-3**	**C-14**	**Tc-99**	**I-129**	**Np-237**	**U-238**	**1-Butanol**	**Cr**	**Hg**	**NO_3**	**Pb**	**Utot**	**2,4,6-TCP**	**Benzene**	**PCBs**
A tank farm	2.78	1.46	1.22×10^{1}	1.71×10^{-2}	3.98×10^{-2}	5.96×10^{-1}	–	1.63×10^{4}	1.60×10^{2}	1.42×10^{6}	4.05×10^{3}	1.11×10^{4}	–	–	3.05×10^{1}
AX tank farm	4.52	1.33	8.75	1.02×10^{-2}	1.66×10^{-2}	7.72×10^{-2}	–	7.96×10^{3}	4.32×10^{1}	7.72×10^{5}	1.27×10^{3}	1.50×10^{3}	–	–	1.47×10^{1}
B tank farm	3.99	7.63	2.19×10^{2}	8.46×10^{-2}	3.52×10^{-1}	2.11×10^{1}	3.86×10^{-4}	1.13×10^{4}	1.40×10^{2}	1.93×10^{6}	6.77×10^{3}	2.89×10^{4}	–	–	5.45×10^{1}
BX tank farm	3.71	4.06×10^{1}	3.74×10^{2}	4.54×10^{-1}	7.51×10^{-1}	5.15×10^{1}	–	2.23×10^{4}	2.30×10^{2}	1.75×10^{6}	3.70×10^{3}	7.44×10^{4}	–	–	4.18×10^{1}
BY tank farm	2.83×10^{1}	5.03×10^{2}	2.54×10^{3}	5.57	8.63	5.24×10^{1}	–	7.38×10^{4}	1.75×10^{2}	6.66×10^{6}	5.14×10^{3}	6.58×10^{4}	–	–	1.11×10^{2}
C tank farm	1.43×10^{2}	1.55×10^{1}	3.58×10^{2}	1.03	5.81	5.05×10^{2}	6.47×10^{-1}	5.72×10^{3}	3.99×10^{2}	6.75×10^{5}	2.35×10^{4}	1.15×10^{5}	–	–	4.68×10^{1}
S tank farm	2.15×10^{1}	4.41×10^{2}	2.74×10^{3}	5.95	1.12×10^{1}	5.20×10^{1}	–	1.20×10^{5}	7.18×10^{1}	1.10×10^{7}	2.24×10^{3}	5.21×10^{4}	–	–	1.39×10^{2}
SX tank farm	2.74×10^{1}	2.71×10^{2}	1.77×10^{3}	3.37	6.76	2.97×10^{1}	–	1.06×10^{5}	1.47×10^{2}	6.66×10^{6}	1.76×10^{3}	3.29×10^{4}	–	–	9.24×10^{1}
T tank farm	1.19	1.43×10^{1}	1.65×10^{2}	1.16×10^{-1}	2.82×10^{-1}	2.62×10^{1}	–	1.23×10^{4}	2.02×10^{1}	7.57×10^{5}	4.40×10^{3}	3.77×10^{4}	–	–	4.94×10^{1}
TX tank farm	2.92×10^{1}	5.79×10^{2}	3.91×10^{2}	7.18	1.33×10^{1}	4.81×10^{1}	1.15×10^{-5}	6.16×10^{4}	2.84×10^{1}	1.41×10^{7}	7.15×10^{3}	4.58×10^{4}	–	–	1.73×10^{2}
TY tank farm	1.59	7.48	1.04×10^{2}	1.31×10^{-1}	2.31×10^{-1}	2.26×10^{1}	–	8.07×10^{3}	2.60×10^{2}	8.49×10^{5}	1.41×10^{3}	3.29×10^{4}	–	–	1.68×10^{1}
U tank farm	2.97×10^{1}	3.30×10^{2}	2.44×10^{3}	4.73	9.01	3.93×10^{1}	–	5.15×10^{4}	2.57×10^{1}	5.50×10^{6}	1.09×10^{4}	5.01×10^{4}	–	–	8.54×10^{1}
AN tank farm	1.18×10^{2}	1.94×10^{2}	3.69×10^{3}	3.82	8.20	7.91	8.62×10^{5}	1.86×10^{4}	4.68	6.49×10^{6}	3.64×10^{3}	2.69×10^{3}	2.76×10^{-1}	5.99×10^{-1}	2.07×10^{2}
AP tank farm	1.53×10^{3}	1.98×10^{2}	4.08×10^{3}	7.71	1.43×10^{1}	2.86	1.13×10^{6}	1.03×10^{4}	–	5.67×10^{6}	9.04×10^{2}	1.23×10^{3}	3.63×10^{-1}	7.87×10^{-1}	2.71×10^{2}
AW tank farm	1.71×10^{2}	8.98×10^{1}	1.87×10^{3}	2.12	2.40×10^{1}	3.95×10^{1}	6.66×10^{5}	2.00×10^{4}	2.10×10^{-1}	3.48×10^{6}	1.52×10^{3}	3.97×10^{4}	2.14×10^{-1}	4.64×10^{-1}	1.60×10^{2}
AY tank farm	2.49×10^{1}	1.66	8.99×10^{1}	1.43×10^{-1}	5.06	3.22	1.33×10^{5}	2.81×10^{3}	1.27×10^{2}	1.71×10^{5}	4.51×10^{3}	3.54×10^{3}	4.26×10^{-2}	9.25×10^{-2}	3.18×10^{1}
AZ tank farm	1.88×10^{2}	1.04×10^{1}	2.05×10^{3}	1.92	2.71×10^{1}	5.69	3.07×10^{5}	5.10×10^{3}	4.16	7.76×10^{5}	4.04×10^{2}	5.20×10^{3}	9.84×10^{-2}	2.14×10^{-1}	7.36×10^{1}
SY tank farm	1.09×10^{3}	3.82×10^{1}	2.47×10^{3}	2.67	3.81	4.52	3.65×10^{5}	4.75×10^{4}	8.98	2.49×10^{6}	1.58×10^{3}	2.39×10^{3}	1.17×10^{-1}	2.54×10^{-1}	8.76×10^{1}

Note: To convert kilograms to pounds, multiply by 2.2046.

Key: 2,4,6-TCP=2,4,6-trichlorophenol; C-14=carbon-14; Cr=chromium; H-3=hydrogen-3 (tritium); Hg=mercury; I-129=iodine-129; NO_3=nitrate; Np-237=neptunium-237; Pb=lead; PCBs=polychlorinated biphenyls; Tc-99=technetium-99; U-238=uranium-238; Utot=total uranium.

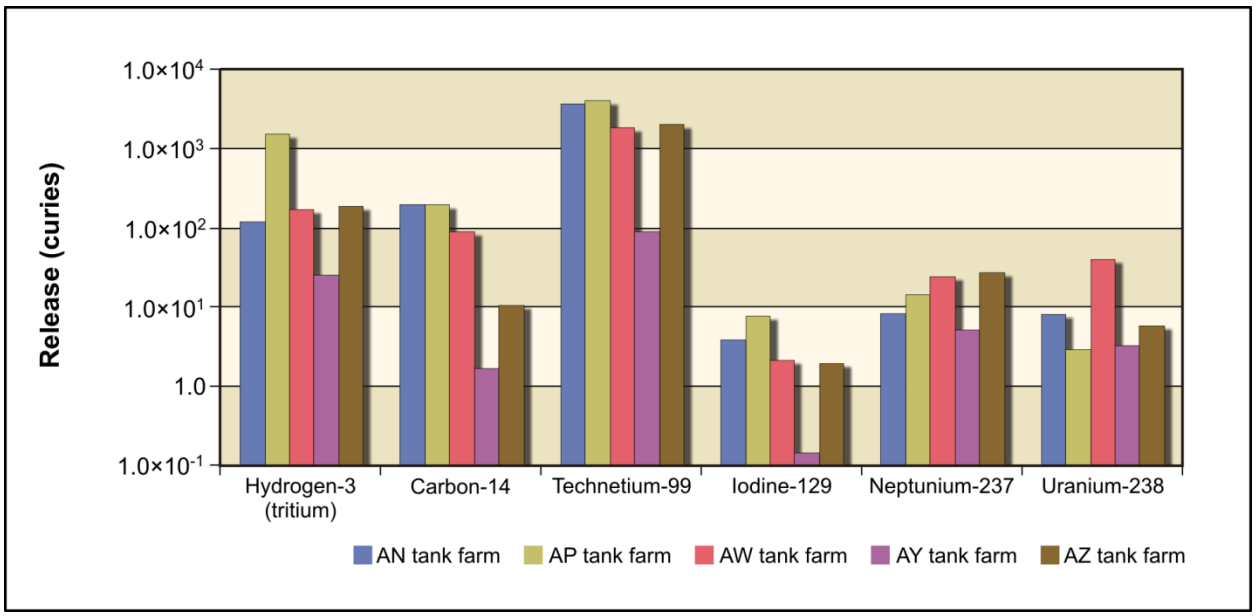


Figure M–13. Tank Closure Alternative 1 Radionuclide Releases to the Vadose Zone from Other Sources in Tank Farms AN, AP, AW, AY, and AZ

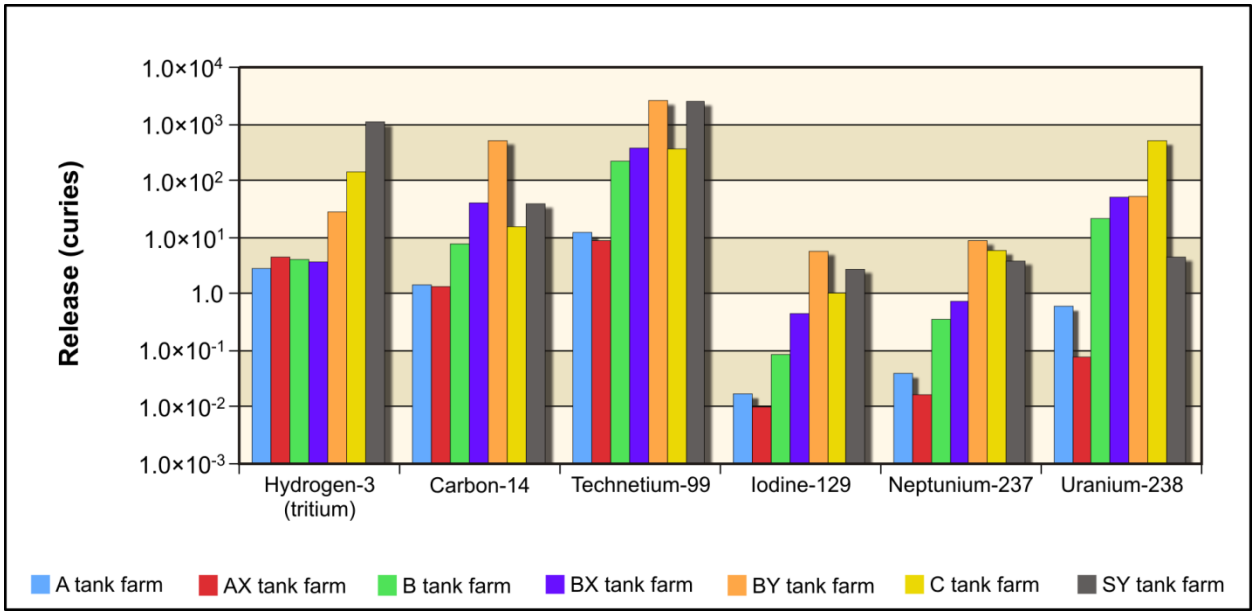


Figure M–14. Tank Closure Alternative 1 Radionuclide Releases to the Vadose Zone from Other Sources in Tank Farms A, AX, B, BX, BY, C, and SY

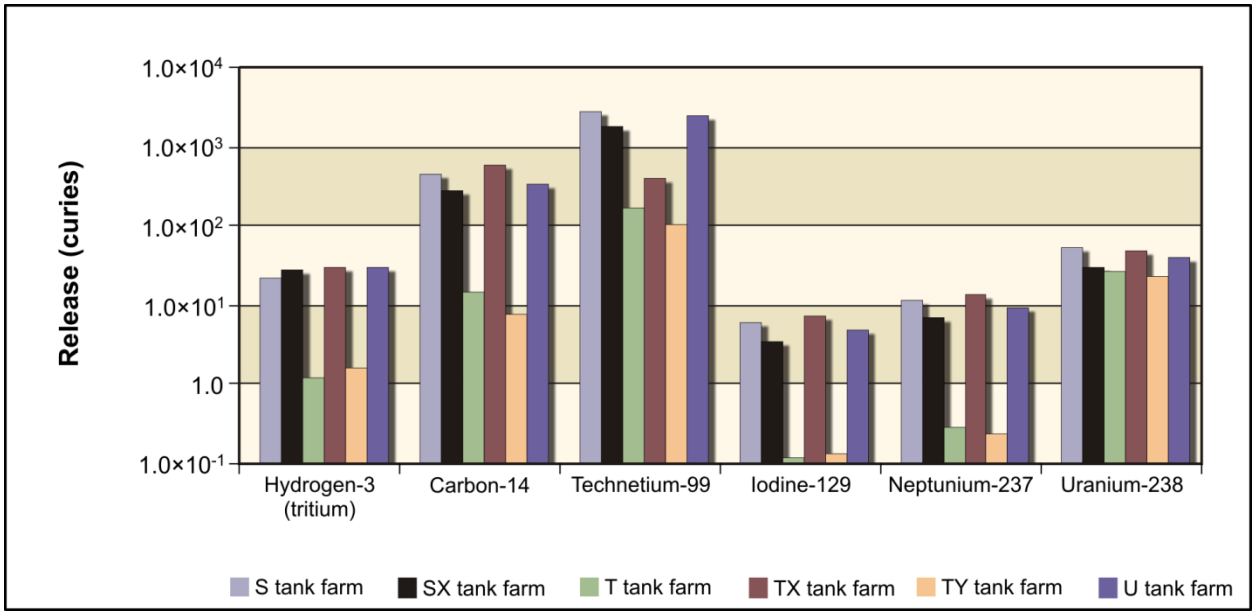


Figure M–15. Tank Closure Alternative 1 Radionuclide Releases to the Vadose Zone from Other Sources in Tank Farms S, SX, T, TX, TY, and U

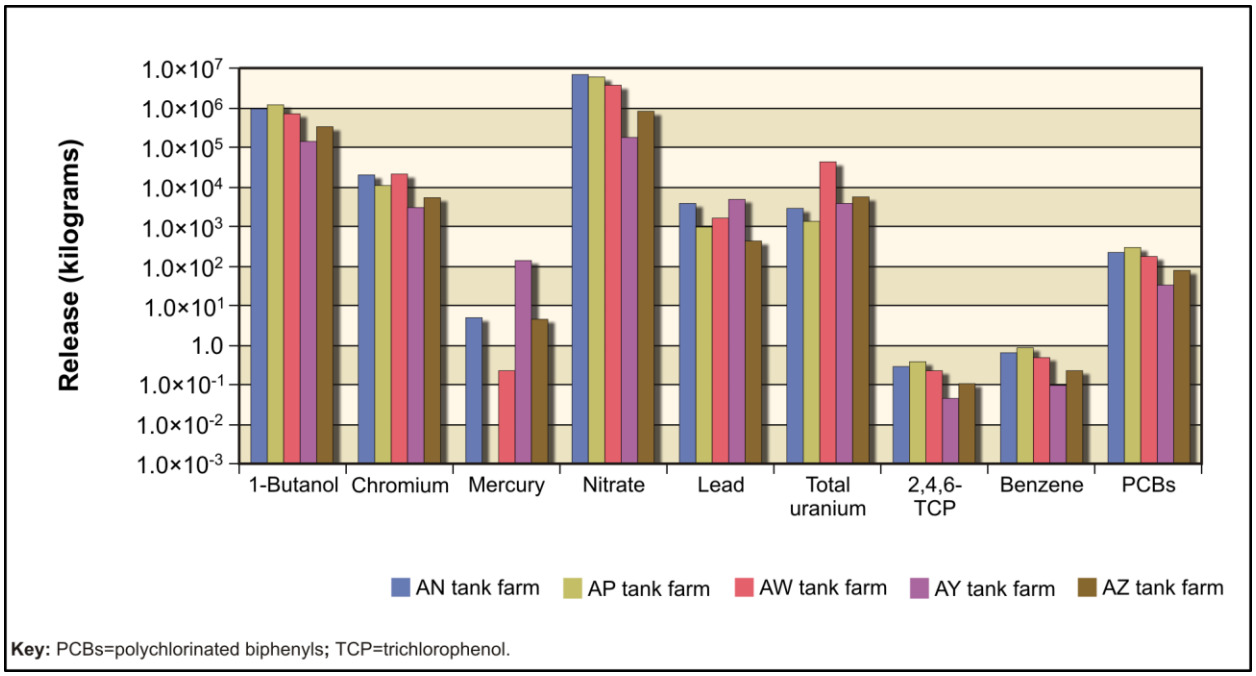


Figure M–16. Tank Closure Alternative 1 Chemical Releases to the Vadose Zone from Other Sources in Tank Farms AN, AP, AW, AY, and AZ

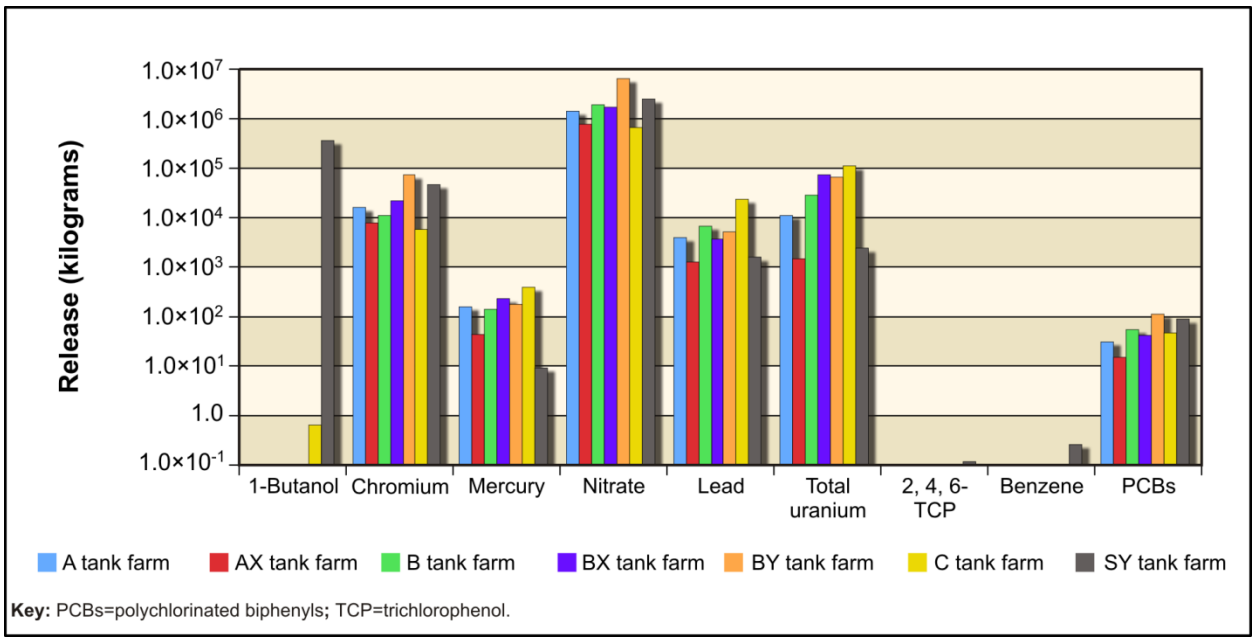


Figure M–17. Tank Closure Alternative 1 Chemical Releases to the Vadose Zone from Other Sources in Tank Farms A, AX, B, BX, BY, C, and SY

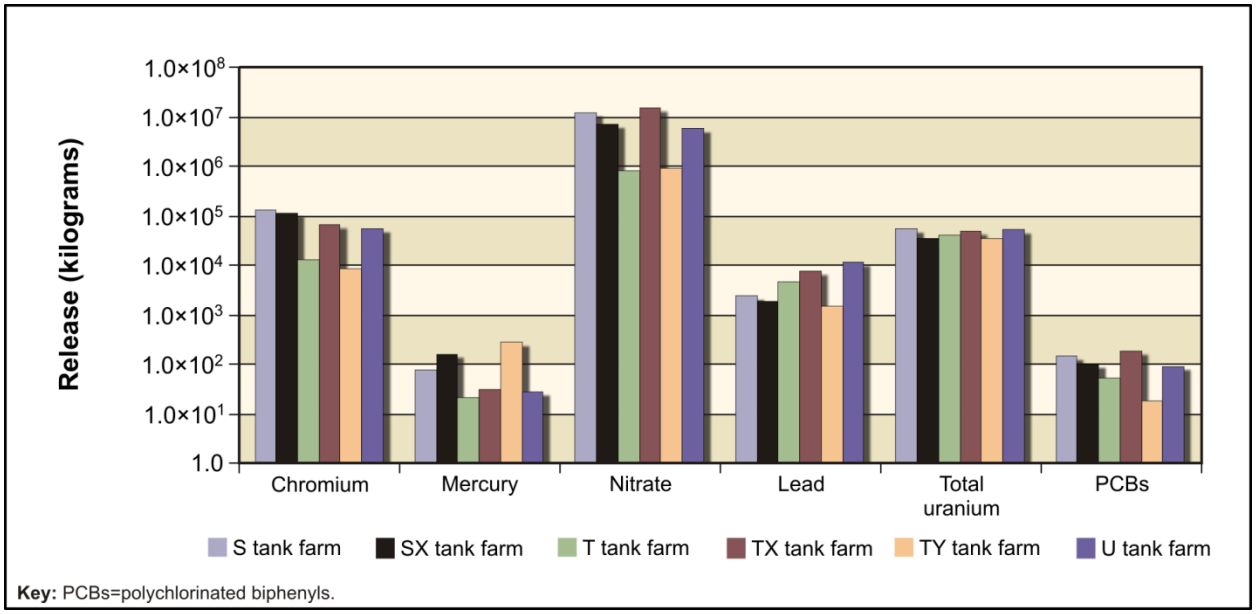


Figure M–18. Tank Closure Alternative 1 Chemical Releases to the Vadose Zone from Other Sources in Tank Farms S, SX, T, TX, TY, and U

Under Tank Closure Alternative 2A, tank waste would be retrieved to a volume corresponding to 99 percent retrieval, but residual material in tanks would not be stabilized. After an institutional control period of 100 years, the salt cake in tanks is assumed available for dissolution in infiltrating water. Potential releases to the vadose zone under Tank Closure Alternative 2A are indicated in Table M–21 and Figures M–19 through M–24.

Table M–21. Tank Closure Alternative 2A Radionuclide and Chemical Releases to the Vadose Zone from Other Sources in Tank Farms

	Radionuclide (curies)						Chemical (kilograms)								
Source	**H-3**	**C-14**	**Tc-99**	**I-129**	**Np-237**	**U-238**	**1-Butanol**	**Cr**	**Hg**	**NO_3**	**Pb**	**Utot**	**2,4,6-TCP**	**Benzene**	**PCBs**
A tank farm	6.31	1.73	1.51×10^{1}	2.15×10^{-2}	4.52×10^{-2}	1.03	–	3.61×10^{2}	6.39	2.66×10^{4}	1.42×10^{2}	3.43×10^{2}	–	–	4.75×10^{-1}
AX tank farm	3.69	1.70	2.17×10^{1}	1.46×10^{-2}	2.16×10^{-2}	9.26×10^{-2}	–	1.76×10^{2}	3.26	1.15×10^{5}	9.10×10^{1}	5.41×10^{1}	–	–	2.60×10^{-1}
B tank farm	3.98	3.05×10^{-1}	7.92	4.16×10^{-3}	1.82×10^{-2}	5.21×10^{-1}	3.86×10^{-4}	3.48×10^{2}	3.59	1.09×10^{5}	1.62×10^{2}	7.13×10^{2}	–	–	1.00
BX tank farm	2.08	9.41×10^{-1}	8.66	1.02×10^{-2}	1.67×10^{-2}	1.37	–	6.09×10^{2}	6.61	5.86×10^{4}	1.06×10^{2}	1.99×10^{3}	–	–	7.62×10^{-1}
BY tank farm	2.54×10^{1}	8.70	3.98×10^{1}	8.64×10^{-2}	1.35×10^{-1}	8.20×10^{-1}	–	1.20×10^{3}	2.74	1.11×10^{5}	7.97×10^{1}	1.03×10^{3}	–	–	1.45
C tank farm	1.41×10^{2}	5.85×10^{-1}	1.09×10^{1}	4.81×10^{-2}	1.46×10^{-1}	1.14×10^{1}	6.47×10^{-1}	1.85×10^{2}	9.73	1.17×10^{5}	3.78×10^{3}	2.93×10^{3}	–	–	9.22×10^{-1}
S tank farm	1.93×10^{1}	7.28	3.97×10^{1}	8.56×10^{-2}	1.62×10^{-1}	6.60×10^{-1}	–	1.73×10^{3}	1.04	1.58×10^{5}	3.22×10^{1}	7.66×10^{2}	–	–	1.73
SX tank farm	1.91×10^{1}	4.84	3.03×10^{1}	5.64×10^{-2}	1.14×10^{-1}	5.98×10^{-1}	–	1.90×10^{3}	3.25	1.47×10^{5}	3.25×10^{1}	7.00×10^{2}	–	–	1.35
T tank farm	1.02	5.65×10^{-1}	4.66	3.65×10^{-3}	9.95×10^{-3}	6.64×10^{-1}	–	3.57×10^{2}	4.97×10^{-1}	7.54×10^{4}	1.28×10^{2}	9.52×10^{2}	–	–	9.49×10^{-1}
TX tank farm	2.51×10^{1}	9.85	5.75×10^{1}	1.09×10^{-1}	2.02×10^{-1}	7.60×10^{-1}	1.15×10^{-5}	9.81×10^{2}	6.13×10^{-1}	2.15×10^{5}	1.09×10^{2}	7.34×10^{2}	–	–	2.25
TY tank farm	9.68×10^{-1}	2.24×10^{-1}	3.29	3.35×10^{-3}	6.64×10^{-3}	6.43×10^{-1}	–	2.22×10^{2}	6.41	2.37×10^{4}	3.91×10^{1}	9.35×10^{2}	–	–	3.38×10^{-1}
U tank farm	2.15×10^{1}	6.24	4.27×10^{1}	8.21×10^{-2}	1.57×10^{-1}	7.57×10^{-1}	–	9.42×10^{2}	7.07×10^{-1}	1.77×10^{5}	2.57×10^{2}	9.82×10^{2}	–	–	1.31
AN tank farm	1.22	1.99	3.79×10^{1}	3.93×10^{-2}	8.42×10^{-2}	8.12×10^{-2}	8.85×10^{3}	1.91×10^{2}	4.80×10^{-2}	6.66×10^{4}	3.74×10^{1}	2.76×10^{1}	2.83×10^{-3}	6.15×10^{-3}	2.08
AP tank farm	1.57×10^{1}	2.02	4.18×10^{1}	7.89×10^{-2}	1.47×10^{-1}	2.92×10^{-2}	1.16×10^{4}	1.06×10^{2}	–	5.80×10^{4}	9.25	1.26×10^{1}	3.71×10^{-3}	8.06×10^{-3}	2.71
AW tank farm	1.76	9.25×10^{-1}	1.92×10^{1}	2.18×10^{-2}	2.47×10^{-1}	4.06×10^{-1}	6.85×10^{3}	2.06×10^{2}	2.16×10^{-3}	3.59×10^{4}	1.56×10^{1}	4.08×10^{2}	2.20×10^{-3}	4.77×10^{-3}	1.60
AY tank farm	2.60×10^{-1}	1.74×10^{-2}	9.43×10^{-1}	1.50×10^{-3}	5.31×10^{-2}	3.38×10^{-2}	1.39×10^{3}	2.95×10^{1}	1.33	1.80×10^{3}	4.73×10^{1}	3.72×10^{1}	4.47×10^{-4}	9.70×10^{-4}	3.18×10^{-1}
AZ tank farm	1.91	1.06×10^{-1}	2.09×10^{1}	1.96×10^{-2}	2.77×10^{-1}	5.81×10^{-2}	3.13×10^{3}	5.21×10^{1}	4.25×10^{-2}	7.93×10^{3}	4.13	5.32×10^{1}	1.00×10^{-3}	2.18×10^{-3}	7.37×10^{-1}
SY tank farm	1.12×10^{1}	3.93×10^{-1}	2.53×10^{1}	2.74×10^{-2}	3.92×10^{-2}	4.64×10^{-2}	3.75×10^{3}	4.87×10^{2}	9.22×10^{-2}	2.56×10^{4}	1.62×10^{1}	2.45×10^{1}	1.21×10^{-3}	2.61×10^{-3}	8.78×10^{-1}

Note: To convert kilograms to pounds, multiply by 2.2046.

Key: 2,4,6-TCP=2,4,6-trichlorophenol; C-14=carbon-14; Cr=chromium; H-3=hydrogen-3 (tritium); Hg=mercury; I-129=iodine-129; NO_3=nitrate; Np-237=neptunium-237; Pb=lead; PCBs=polychlorinated biphenyls; Tc-99=technetium-99; U-238=uranium-238; Utot=total uranium.

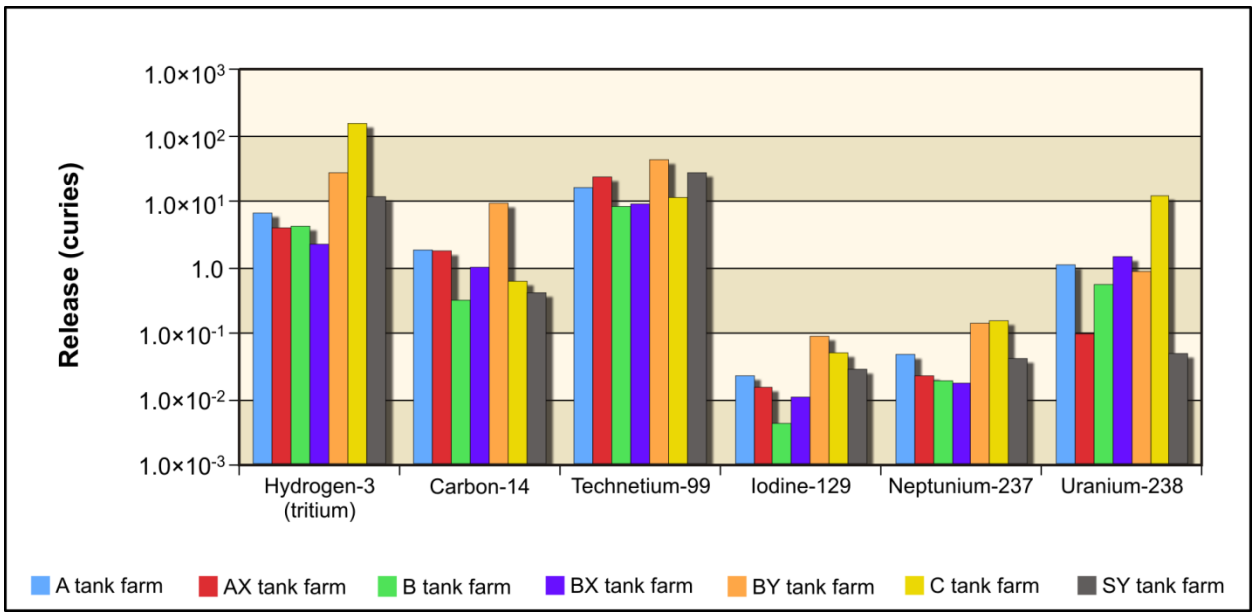


Figure M–19. Tank Closure Alternative 2A Radionuclide Releases to the Vadose Zone from Other Sources in Tank Farms A, AX, B, BX, BY, C, and SY

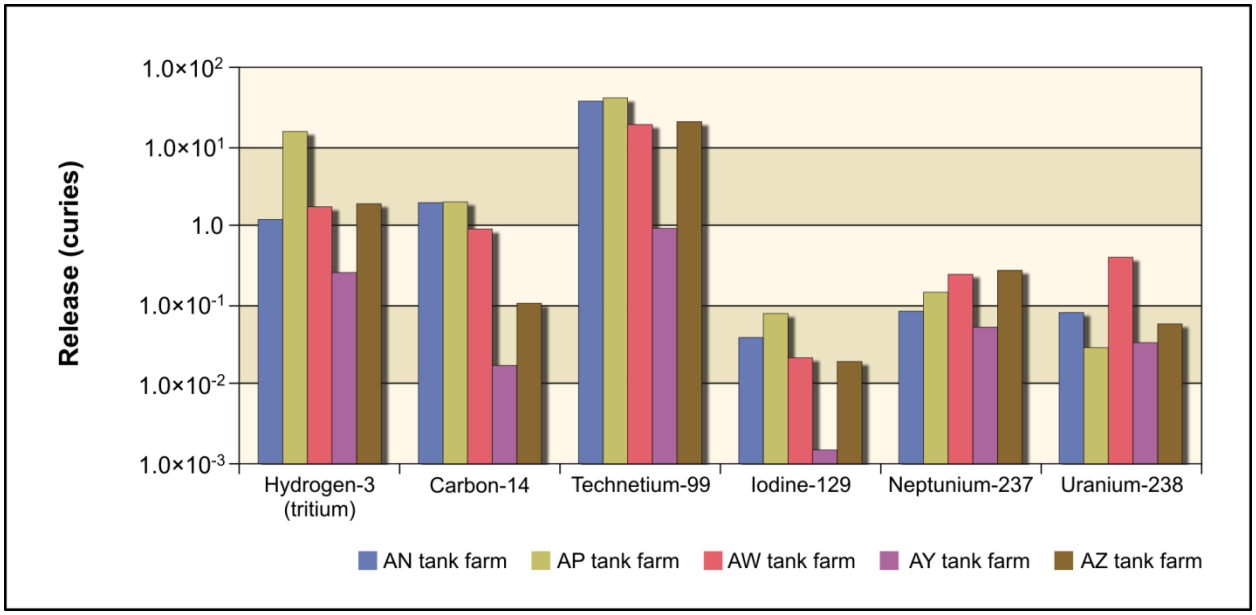


Figure M–20. Tank Closure Alternative 2A Radionuclide Releases to the Vadose Zone from Other Sources in Tank Farms AN, AP, AW, AY, and AZ

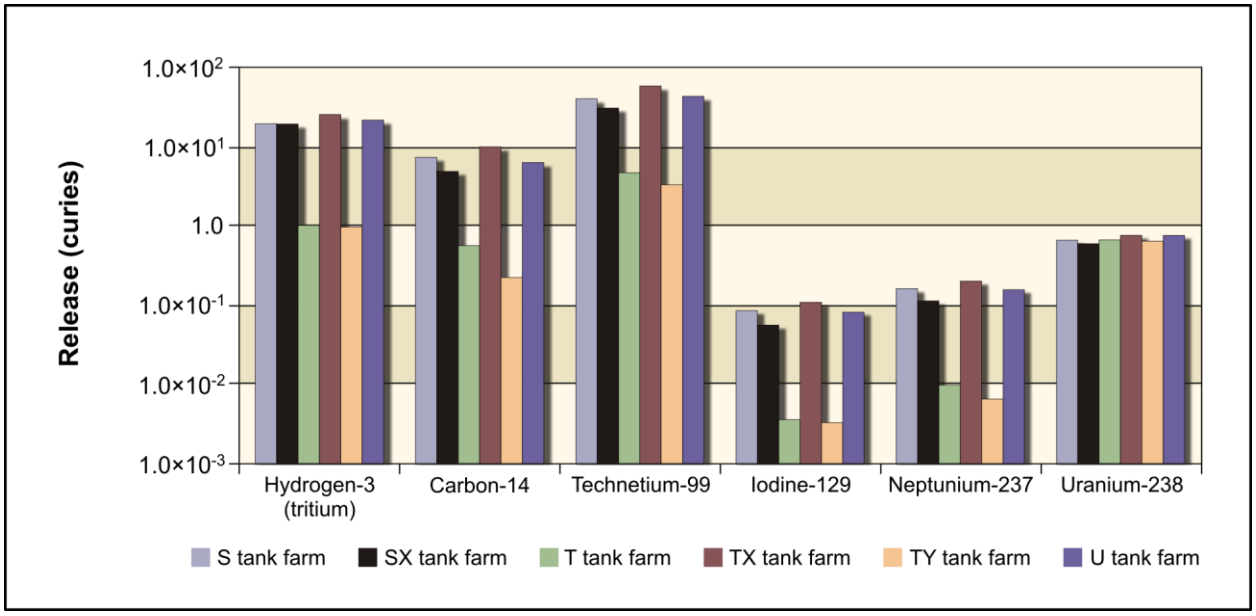


Figure M–21. Tank Closure Alternative 2A Radionuclide Releases to the Vadose Zone from Other Sources in Tank Farms S, SX, T, TX, TY, and U

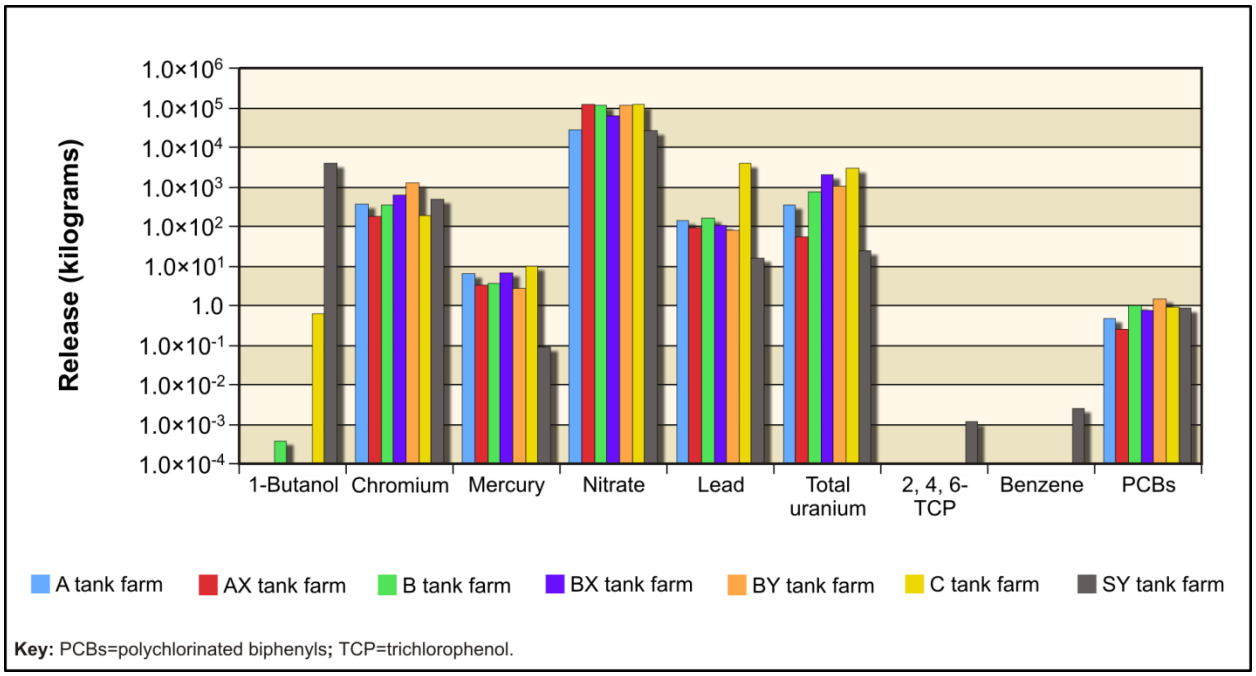


Figure M–22. Tank Closure Alternative 2A Chemical Releases to the Vadose Zone from Other Sources in Tank Farms A, AX, B, BX, BY, C, and SY

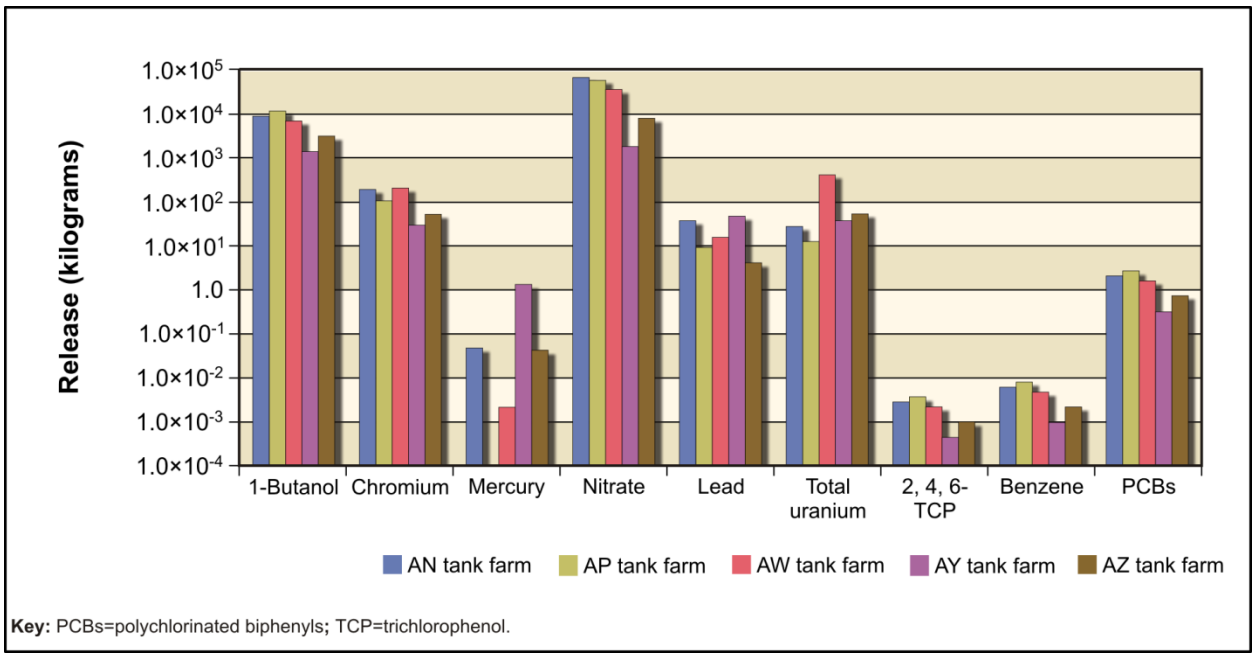


Figure M–23. Tank Closure Alternative 2A Chemical Releases to the Vadose Zone from Other Sources in Tank Farms AN, AP, AW, and AZ

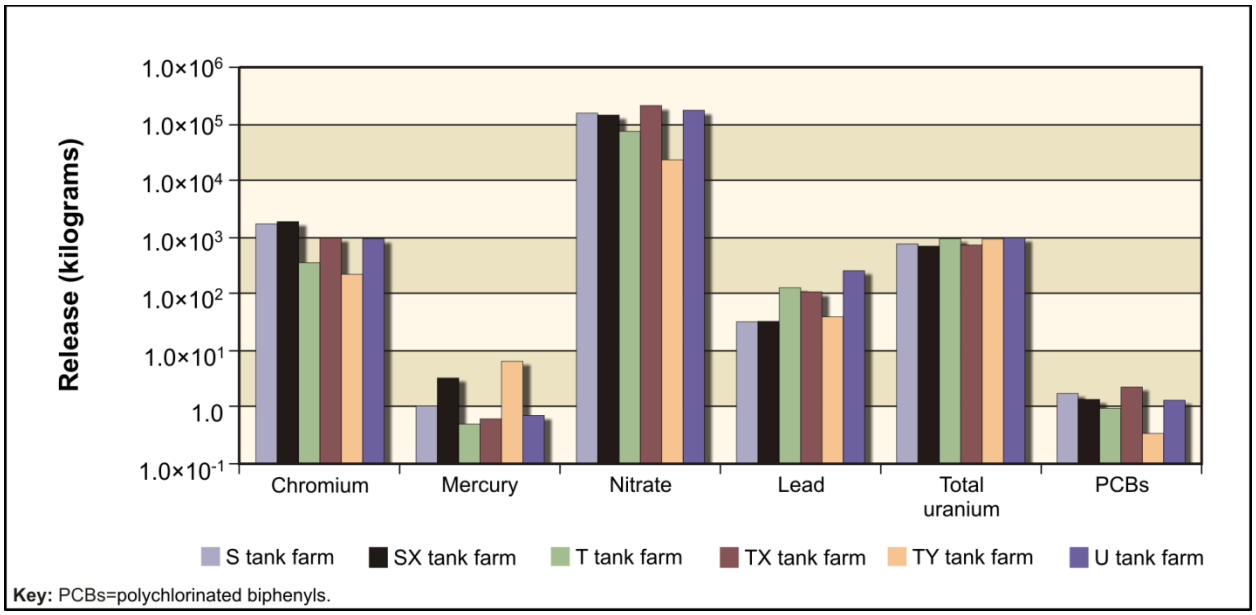


Figure M–24. Tank Closure Alternative 2A Chemical Releases to the Vadose Zone from Other Sources in Tank Farms S, SX, T, TX, TY, and U

Activities under Tank Closure Alternatives 2B, 3A, 3B, 3C, and 6C would be similar to those of Tank Closure Alternative 2A, except that residual material in tanks would be stabilized in place. Soil would be removed down to 4.6 meters (15 feet) for the BX and SX tank farms and replaced with clean soil from onsite sources. Potential releases to the vadose zone under Tank Closure Alternatives 2B, 3A, 3B, 3C, and 6C from tank residuals, ancillary equipment, retrieval losses, and unplanned releases are indicated in Tables M–22 through M–25 and Figures M–25 through M–42.

Table M–22. Tank Closure Alternatives 2B, 3A, 3B, 3C, and 6C Tank Farms Radionuclide and Chemical Releases to the Vadose Zone from Ancillary Equipment in Tank Farms

	Radionuclide (curies)						Chemical (kilograms)								
Source	**H-3**	**C-14**	**Tc-99**	**I-129**	**Np-237**	**U-238**	**1-Butanol**	**Cr**	**Hg**	**NO_3**	**Pb**	**Utot**	**2,4,6-TCP**	**Benzene**	**PCBs**
A tank farm	1.18	4.04×10^{-1}	3.31	4.64×10^{-3}	1.08×10^{-2}	1.62×10^{-1}	–	7.97×10^{1}	7.83×10^{-1}	6.94×10^{3}	1.98×10^{1}	5.39×10^{1}	–	–	2.28×10^{-3}
AX tank farm	6.03×10^{-1}	4.29×10^{-1}	2.80	3.26×10^{-3}	5.31×10^{-3}	2.47×10^{-2}	–	5.33×10^{1}	2.90×10^{-1}	5.18×10^{3}	8.56	1.00×10^{1}	–	–	1.33×10^{-3}
B tank farm	1.10×10^{-1}	5.70×10^{-2}	1.57	6.01×10^{-4}	2.48×10^{-3}	1.53×10^{-1}	–	8.13×10^{1}	1.02	1.40×10^{4}	4.92×10^{1}	2.10×10^{2}	–	–	6.39×10^{-3}
BY tank farm	2.63	1.49	6.87	1.50×10^{-2}	2.32×10^{-2}	1.41×10^{-1}	–	1.98×10^{2}	4.69×10^{-1}	1.79×10^{4}	1.38×10^{1}	1.77×10^{2}	–	–	5.05×10^{-3}
C tank farm	6.71×10^{-1}	1.33×10^{-1}	3.00	8.49×10^{-3}	4.89×10^{-2}	4.26	–	4.78×10^{1}	3.36	5.60×10^{3}	1.98×10^{2}	9.64×10^{2}	–	–	6.16×10^{-3}
S tank farm	3.06	1.07	5.91	1.28×10^{-2}	2.42×10^{-2}	1.12×10^{-2}	–	2.60×10^{2}	1.54×10^{-1}	2.38×10^{4}	4.82	1.12×10^{2}	–	–	5.00×10^{-3}
T tank farm	1.99×10^{-1}	1.18×10^{-1}	1.32	9.22×10^{-4}	2.25×10^{-3}	2.10×10^{-1}	–	9.79×10^{1}	1.61×10^{-1}	6.04×10^{3}	3.51×10^{1}	3.01×10^{2}	–	–	6.33×10^{-3}
TX tank farm	4.23	1.66	9.80	1.86×10^{-2}	3.43×10^{-2}	1.25×10^{-1}	–	1.60×10^{2}	7.38×10^{-2}	3.65×10^{4}	1.85×10^{1}	1.19×10^{2}	–	–	8.83×10^{-3}
TY tank farm	2.22×10^{-1}	6.68×10^{-2}	9.09×10^{-1}	1.14×10^{-3}	2.03×10^{-3}	1.99×10^{-1}	–	7.07×10^{1}	2.28	7.45×10^{3}	1.24×10^{1}	2.88×10^{2}	–	–	2.28×10^{-3}
U tank farm	4.87	1.63	1.14×10^{1}	2.19×10^{-2}	4.19×10^{-2}	1.82×10^{-1}	–	2.39×10^{2}	1.19×10^{-1}	2.56×10^{4}	5.07×10^{1}	2.33×10^{2}	–	–	6.33×10^{-3}
AN tank farm	2.90×10^{-2}	5.74×10^{-2}	1.11	1.15×10^{-3}	2.46×10^{-3}	2.37×10^{-3}	2.58×10^{2}	5.57	1.40×10^{-3}	1.94×10^{3}	1.09	8.06×10^{-1}	8.28×10^{-5}	1.80×10^{-4}	1.73×10^{-3}
AP tank farm	2.77×10^{-1}	5.07×10^{-2}	1.06	2.01×10^{-3}	3.75×10^{-3}	7.44×10^{-4}	2.95×10^{2}	2.71	–	1.48×10^{3}	2.36×10^{-1}	3.22×10^{-1}	9.46×10^{-5}	2.05×10^{-4}	9.85×10^{-4}
AW tank farm	5.46×10^{-3}	2.70×10^{-2}	6.19×10^{-1}	6.28×10^{-4}	7.95×10^{-3}	1.26×10^{-2}	2.21×10^{2}	6.63	6.97×10^{-5}	1.16×10^{3}	5.05×10^{-1}	1.32×10^{1}	7.10×10^{-5}	1.54×10^{-4}	3.52×10^{-4}
AY tank farm	3.44×10^{-3}	8.70×10^{-4}	4.99×10^{-2}	7.90×10^{-5}	2.81×10^{-3}	1.79×10^{-3}	7.38×10^{1}	1.56	7.03×10^{-2}	9.51×10^{1}	2.47	1.96	2.37×10^{-5}	5.13×10^{-5}	3.66×10^{-5}
AZ tank farm	2.29×10^{-2}	2.42×10^{-3}	4.92×10^{-1}	4.60×10^{-4}	6.51×10^{-3}	1.37×10^{-3}	7.37×10^{1}	1.23	1.00×10^{-3}	1.86×10^{2}	9.71×10^{-2}	1.25	2.37×10^{-5}	5.13×10^{-5}	1.14×10^{-4}
SY tank farm	2.41×10^{-1}	1.14×10^{-2}	7.47×10^{-1}	8.10×10^{-4}	1.16×10^{-3}	1.37×10^{-3}	1.11×10^{2}	1.44×10^{1}	2.72×10^{-3}	7.55×10^{2}	4.76×10^{-1}	7.25×10^{-1}	3.55×10^{-5}	7.70×10^{-5}	4.34×10^{-4}

Note: To convert kilograms to pounds, multiply by 2.2046.

Key: 2,4,6-TCP=2,4,6-trichlorophenol; C-14=carbon-14; Cr=chromium; H-3=hydrogen-3 (tritium); Hg=mercury; I-129=iodine-129; NO_3=nitrate; Np-237=neptunium-237; Pb=lead; PCBs=polychlorinated biphenyls; Tc-99=technetium-99; U-238=uranium-238; Utot=total uranium.

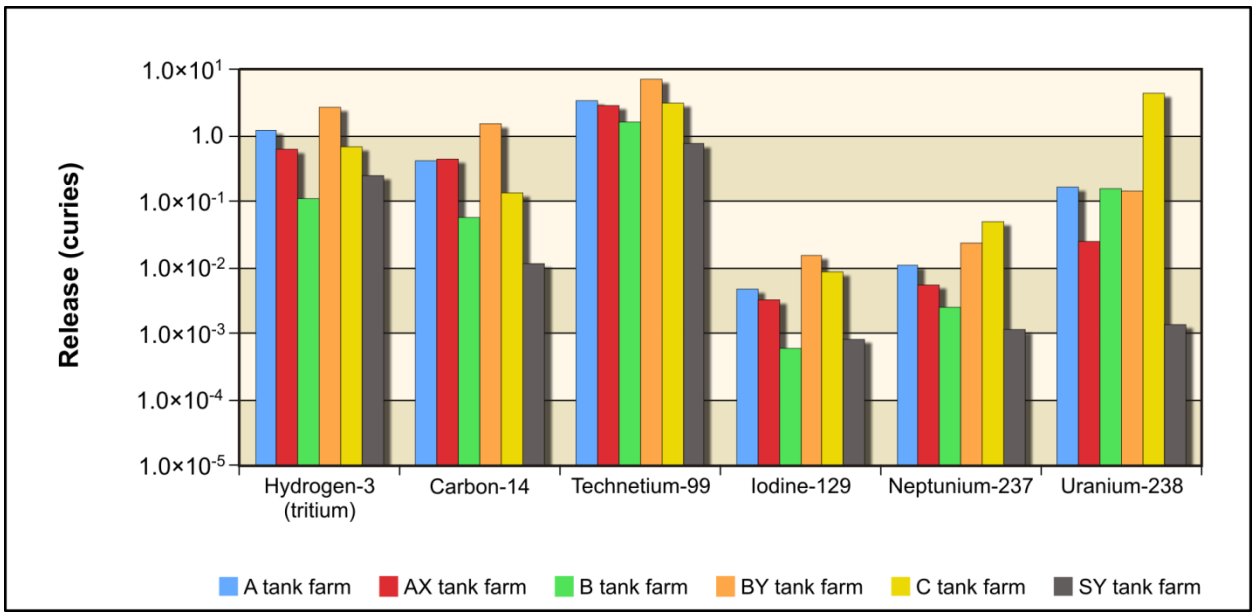


Figure M–25. Tank Closure Alternatives 2B, 3A, 3B, 3C, and 6C Radionuclide Releases to the Vadose Zone from Ancillary Equipment in Tank Farms A, AX, B, BX, BY, C, and SY

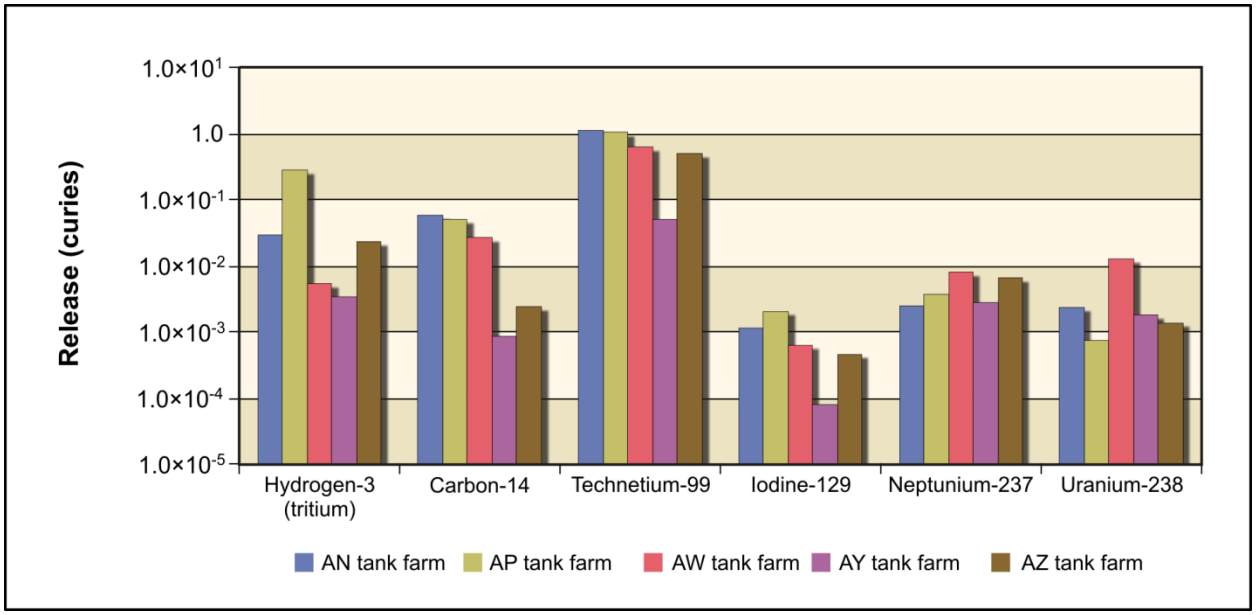


Figure M–26. Tank Closure Alternatives 2B, 3A, 3B, 3C, and 6C Radionuclide Releases to the Vadose Zone from Ancillary Equipment in Tank Farms AN, AP, AW, AY, and AZ

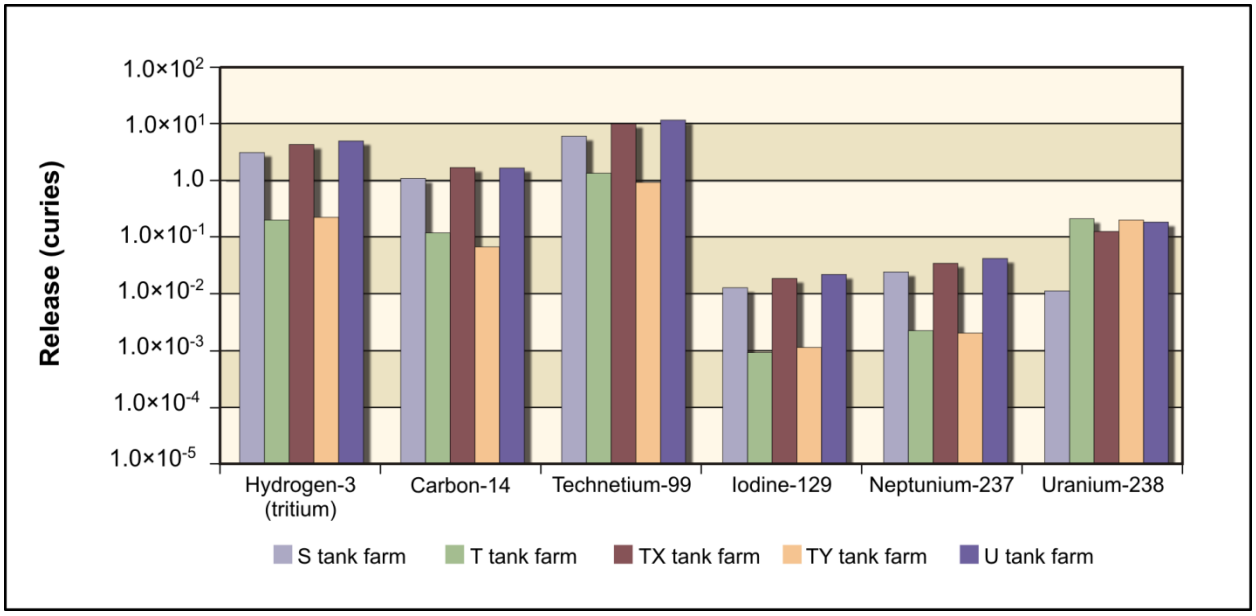


Figure M–27. Tank Closure Alternatives 2B, 3A, 3B, 3C, and 6C Radionuclide Releases to the Vadose Zone from Ancillary Equipment in Tank Farms S, SX, T, TX, TY, and U

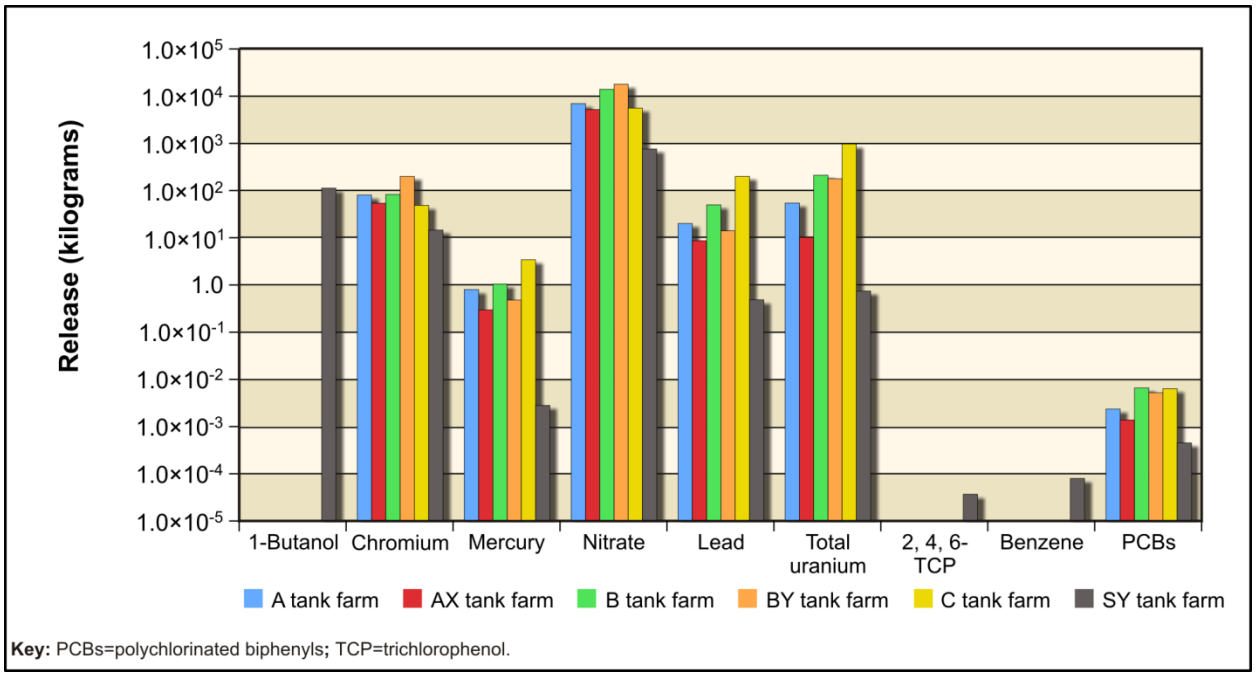
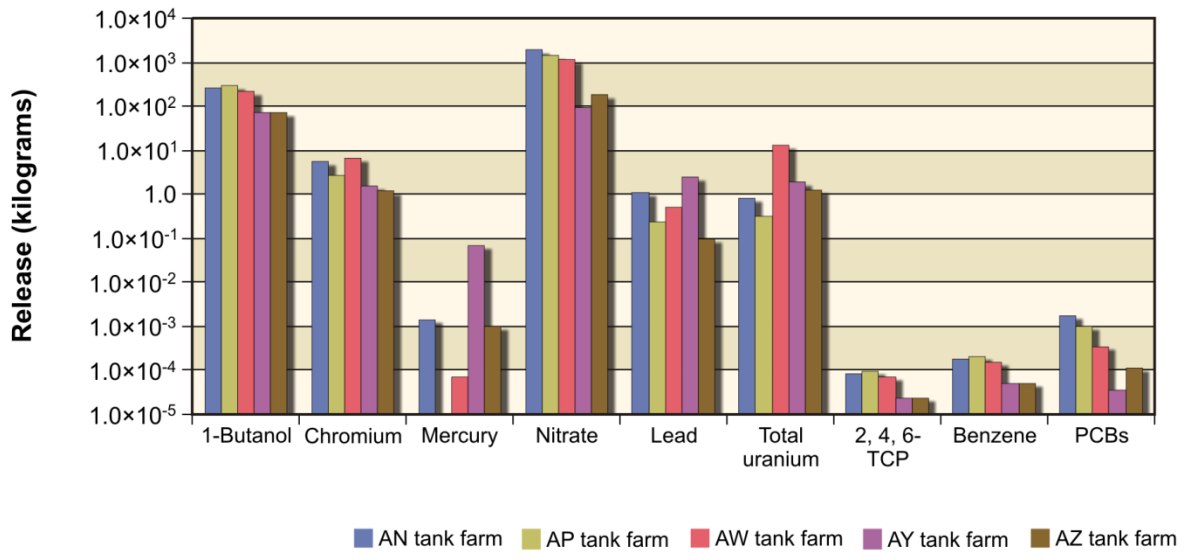
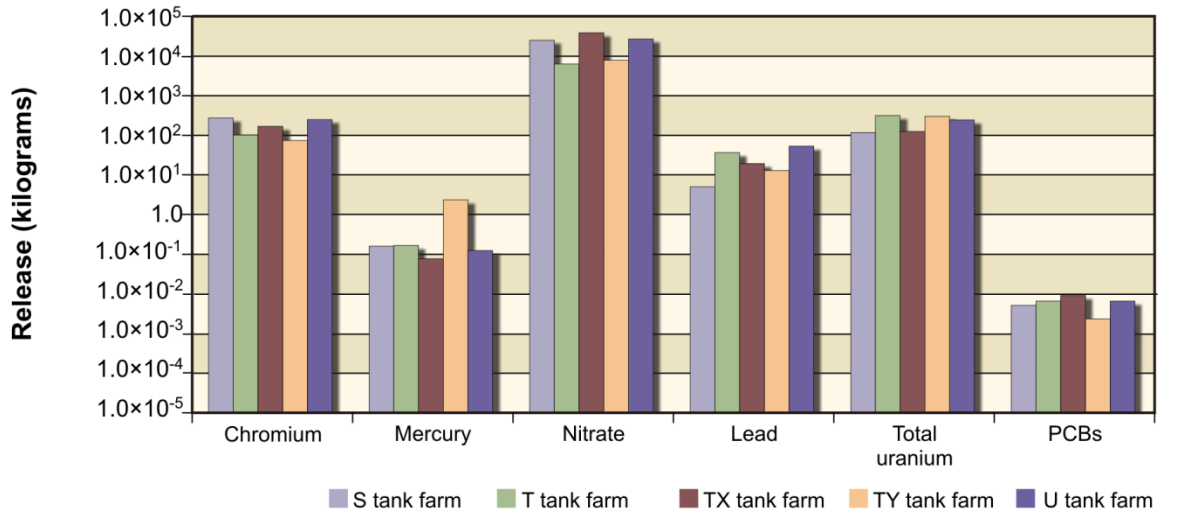


Figure M–28. Tank Closure Alternatives 2B, 3A, 3B, 3C, and 6C Chemical Releases to the Vadose Zone from Ancillary Equipment in Tank Farms A, AX, B, BX, BY, C, and SY



Key: PCBs=polychlorinated biphenyls; TCP=trichlorophenol.

Figure M–29. Tank Closure Alternatives 2B, 3A, 3B, 3C, and 6C Chemical Releases to the Vadose Zone from Ancillary Equipment in Tank Farms AN, AP, AW, AY, and AZ



Key: PCBs=polychlorinated biphenyls.

Figure M–30. Tank Closure Alternatives 2B, 3A, 3B, 3C, and 6C Chemical Releases to the Vadose Zone from Ancillary Equipment in Tank Farms S, SX, T, TX, TY, and U

Table M–23. Tank Closure Alternatives 2B, 3A, 3B, 3C, and 6C Radionuclide and Chemical Releases to the Vadose Zone from Retrieval Losses in Tank Farms

	Radionuclide (curies)						Chemical (kilograms)								
Source	**H-3**	**C-14**	**Tc-99**	**I-129**	**Np-237**	**U-238**	**1-Butanol**	**Cr**	**Hg**	**NO_3**	**Pb**	**Utot**	**2,4,6-TCP**	**Benzene**	**PCBs**
A tank farm	2.10	4.85×10^{-1}	5.06	7.38×10^{-3}	1.24×10^{-2}	5.43×10^{-1}	–	1.19×10^{2}	4.02	5.53×10^{3}	8.21×10^{1}	1.79×10^{2}	–	–	1.59×10^{-1}
AX tank farm	1.75	6.15×10^{-1}	1.48×10^{1}	6.54×10^{-3}	8.43×10^{-3}	3.15×10^{-2}	–	4.39×10^{1}	2.54	1.02×10^{5}	6.98×10^{1}	2.93×10^{1}	–	–	1.06×10^{-1}
B tank farm	3.22×10^{-1}	8.93×10^{-2}	1.26	9.81×10^{-4}	2.62×10^{-3}	1.58×10^{-1}	–	1.20×10^{2}	1.18	7.29×10^{4}	4.42×10^{1}	2.15×10^{2}	–	–	4.25×10^{-1}
BX tank farm	5.30×10^{-1}	2.23×10^{-1}	2.31	2.48×10^{-3}	3.94×10^{-3}	5.00×10^{-1}	–	2.31×10^{2}	2.71	2.89×10^{4}	4.26×10^{1}	7.25×10^{2}	–	–	3.19×10^{-1}
BY tank farm	3.78	1.59	7.46	1.57×10^{-2}	2.52×10^{-2}	1.55×10^{-1}	–	2.29×10^{2}	4.93×10^{-1}	1.55×10^{4}	1.47×10^{1}	1.95×10^{2}	–	–	3.19×10^{-1}
C tank farm	5.56×10^{-1}	1.02×10^{-1}	2.72	4.85×10^{-3}	3.42×10^{-2}	2.18	–	4.15×10^{1}	2.44	9.53×10^{4}	3.33×10^{3}	8.04×10^{2}	–	–	4.25×10^{-1}
S tank farm	4.39	1.15	6.36	1.35×10^{-2}	2.55×10^{-2}	1.31×10^{-1}	–	2.73×10^{2}	1.73×10^{-1}	2.40×10^{4}	5.05	1.35×10^{2}	–	–	3.19×10^{-1}
SX tank farm	4.33	7.71×10^{-1}	5.55	9.27×10^{-3}	1.96×10^{-2}	1.83×10^{-1}	–	4.21×10^{2}	1.20	5.35×10^{4}	7.89	2.40×10^{2}	–	–	3.99×10^{-1}
T tank farm	4.66×10^{-1}	2.97×10^{-1}	1.71	1.59×10^{-3}	4.92×10^{-3}	1.95×10^{-1}	–	1.38×10^{2}	1.37×10^{-1}	6.19×10^{4}	4.96×10^{1}	2.79×10^{2}	–	–	4.25×10^{-1}
TX tank farm	5.86	1.71	1.01×10^{1}	1.92×10^{-2}	3.56×10^{-2}	1.56×10^{-1}	–	2.05×10^{2}	2.53×10^{-1}	3.74×10^{4}	1.90×10^{1}	1.59×10^{2}	–	–	4.78×10^{-1}
TY tank farm	3.59×10^{-1}	8.03×10^{-2}	1.36	9.23×10^{-4}	2.33×10^{-3}	2.21×10^{-1}	–	7.17×10^{1}	1.57	7.84×10^{3}	1.28×10^{1}	3.23×10^{2}	–	–	1.59×10^{-1}
U tank farm	4.20	1.02	6.97	1.33×10^{-2}	2.59×10^{-2}	1.84×10^{-1}	–	1.92×10^{2}	3.32×10^{-1}	9.72×10^{4}	9.86×10^{1}	2.50×10^{2}	–	–	4.25×10^{-1}
A tank farm	1.81	8.09×10^{-1}	6.74	9.45×10^{-3}	2.20×10^{-2}	3.29×10^{-1}	–	1.62×10^{2}	1.59	1.41×10^{4}	4.02×10^{1}	1.10×10^{2}	–	–	2.17×10^{-3}

Note: To convert kilograms to pounds, multiply by 2.2046.

Key: 2,4,6-TCP=2,4,6-trichlorophenol; C-14=carbon-14; Cr=chromium; H-3=hydrogen-3 (tritium); Hg=mercury; I-129=iodine-129; NO_3=nitrate; Np-237=neptunium-237; Pb=lead; PCBs=polychlorinated biphenyls; Tc-99=technetium-99; U-238=uranium-238; Utot=total uranium.

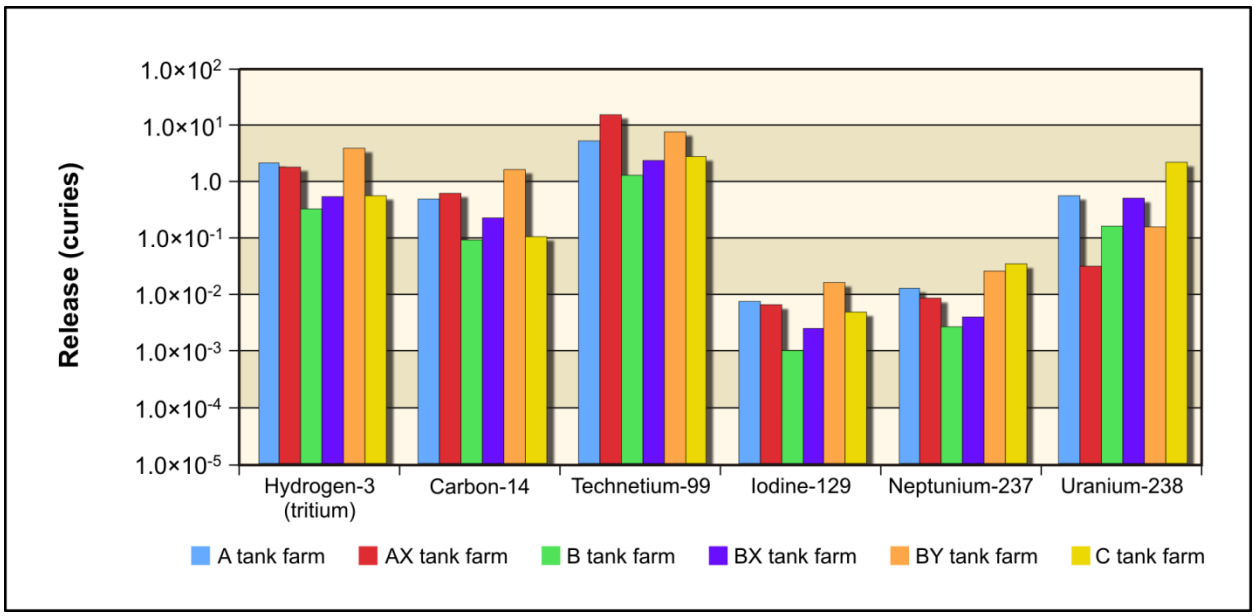


Figure M–31. Tank Closure Alternatives 2B, 3A, 3B, 3C, and 6C Radionuclide Releases to the Vadose Zone from Retrieval Losses in Tank Farms A, AX, B, BX, BY, and C

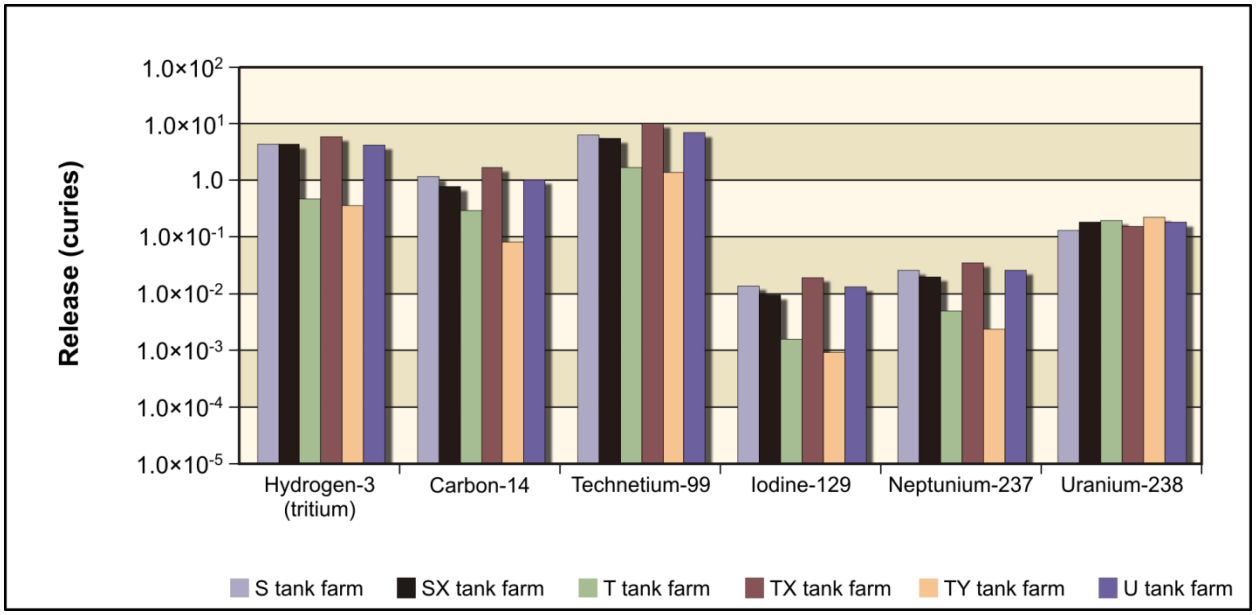


Figure M–32. Tank Closure Alternatives 2B, 3A, 3B, 3C, and 6C Radionuclide Releases to the Vadose Zone from Retrieval Losses in Tank Farms S, SX, T, TX, TY, and U

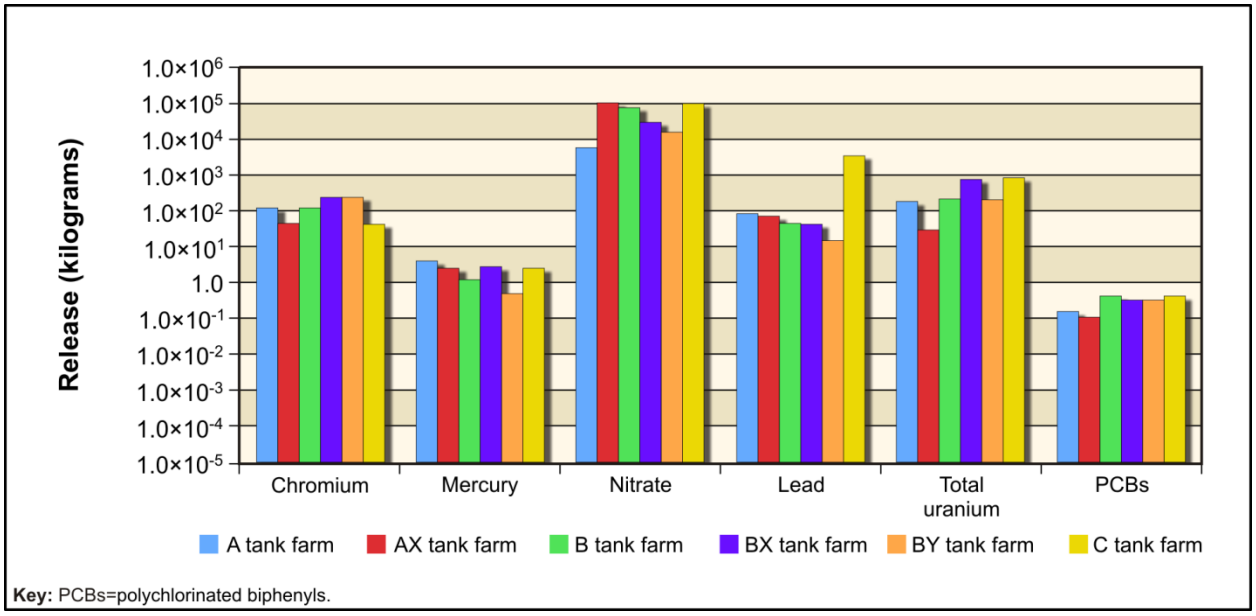


Figure M–33. Tank Closure Alternatives 2B, 3A, 3B, 3C, and 6C Chemical Releases to the Vadose Zone from Retrieval Losses in Tank Farms A, AX, B, BX, BY, and C

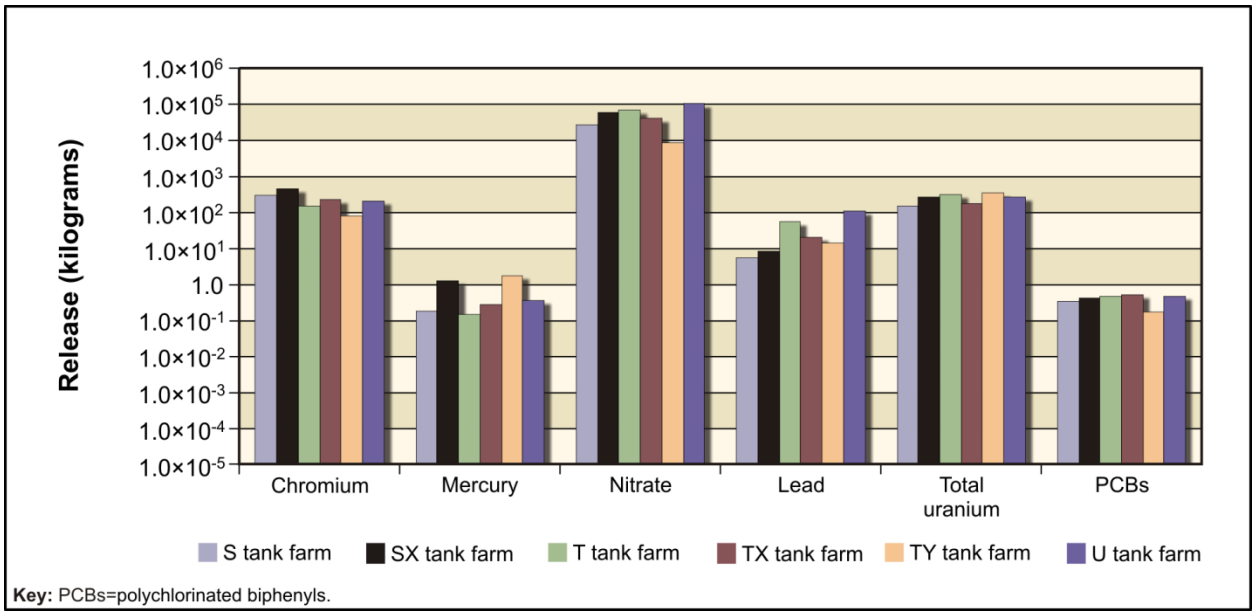


Figure M–34. Tank Closure Alternatives 2B, 3A, 3B, 3C, and 6C Chemical Releases to the Vadose Zone from Retrieval Losses in Tank Farms S, SX, T, TX, TY, and U

Table M–24. Tank Closure Alternatives 2B, 3A, 3B, 3C, and 6C Radionuclide and Chemical Releases to the Vadose Zone from Tank Residuals in Tank Farms

	Radionuclide (curies)						Chemical (kilograms)								
Source	**H-3**	**C-14**	**Tc-99**	**I-129**	**Np-237**	**U-238**	**1-Butanol**	**Cr**	**Hg**	**NO_3**	**Pb**	**Utot**	**2,4,6-TCP**	**Benzene**	**PCBs**
A tank farm	1.81	8.09×10^{-1}	6.74	9.45×10^{-3}	2.20×10^{-2}	3.29×10^{-1}	–	1.62×10^{2}	1.59	1.41×10^{4}	4.02×10^{1}	1.10×10^{2}	–	–	2.17×10^{-3}
AX tank farm	7.96×10^{-1}	6.29×10^{-1}	4.13	4.81×10^{-3}	7.83×10^{-3}	3.64×10^{-2}	–	7.87×10^{1}	4.27×10^{-1}	7.63×10^{3}	1.26×10^{1}	1.48×10^{1}	–	–	1.44×10^{-3}
B tank farm	1.17×10^{-1}	7.67×10^{-2}	2.13	8.18×10^{-4}	3.38×10^{-3}	2.08×10^{-1}	–	1.11×10^{2}	1.38	1.90×10^{4}	6.69×10^{1}	2.86×10^{2}	–	–	4.42×10^{-3}
BX tank farm	6.32×10^{-1}	4.10×10^{-1}	3.70	4.49×10^{-3}	7.42×10^{-3}	5.09×10^{-1}	–	2.20×10^{2}	2.27	1.73×10^{4}	3.66×10^{1}	7.35×10^{2}	–	–	4.33×10^{-3}
BY tank farm	5.14	5.37	2.54×10^{1}	5.55×10^{-2}	8.59×10^{-2}	5.22×10^{-1}	–	7.34×10^{2}	1.74	6.62×10^{4}	5.12×10^{1}	6.55×10^{2}	–	–	4.34×10^{-3}
C tank farm	6.64×10^{-1}	1.54×10^{-1}	3.51	9.93×10^{-3}	5.72×10^{-2}	4.98	–	5.60×10^{1}	3.93	6.56×10^{3}	2.32×10^{2}	1.13×10^{3}	–	–	4.41×10^{-3}
S tank farm	6.49	4.82	2.74×10^{1}	5.93×10^{-2}	1.12×10^{-1}	5.18×10^{-1}	–	1.20×10^{3}	7.15×10^{-1}	1.10×10^{5}	2.23×10^{1}	5.19×10^{2}	–	–	4.34×10^{-3}
SX tank farm	6.42	2.80	1.76×10^{1}	3.35×10^{-2}	6.71×10^{-2}	2.95×10^{-1}	–	1.05×10^{3}	1.46	6.62×10^{4}	1.75×10^{1}	3.27×10^{2}	–	–	5.42×10^{-3}
T tank farm	2.02×10^{-1}	1.44×10^{-1}	1.63	1.14×10^{-3}	2.78×10^{-3}	2.59×10^{-1}	–	1.21×10^{2}	1.99×10^{-1}	7.47×10^{3}	4.34×10^{1}	3.72×10^{2}	–	–	4.41×10^{-3}
TX tank farm	8.05	6.20	3.76×10^{1}	7.15×10^{-2}	1.32×10^{-1}	4.79×10^{-1}	–	6.13×10^{2}	2.83×10^{-1}	1.40×10^{5}	7.12×10^{1}	4.56×10^{2}	–	–	6.53×10^{-3}
TY tank farm	2.36×10^{-1}	7.49×10^{-2}	1.02	1.29×10^{-3}	2.28×10^{-3}	2.23×10^{-1}	–	7.95×10^{1}	2.56	8.37×10^{3}	1.39×10^{1}	3.24×10^{2}	–	–	2.15×10^{-3}
U tank farm	6.55	3.43	2.43×10^{1}	4.69×10^{-2}	8.94×10^{-2}	3.90×10^{-1}	–	5.11×10^{2}	2.55×10^{-1}	5.46×10^{4}	1.08×10^{2}	4.97×10^{2}	–	–	4.42×10^{-3}
AN tank farm	2.54×10^{-1}	1.81	3.68×10^{1}	3.80×10^{-2}	8.17×10^{-2}	7.88×10^{-2}	8.59×10^{3}	1.85×10^{2}	4.66×10^{-2}	6.47×10^{4}	3.53×10^{1}	2.68×10^{1}	2.75×10^{-3}	5.97×10^{-3}	3.53×10^{-3}
AP tank farm	2.94	1.84	4.07×10^{1}	7.91×10^{-2}	1.43×10^{-1}	2.85×10^{-2}	1.13×10^{4}	1.03×10^{2}	–	5.65×10^{4}	8.62	1.23×10^{1}	3.62×10^{-3}	7.85×10^{-3}	4.02×10^{-3}
AW tank farm	3.96×10^{-1}	8.43×10^{-1}	1.86×10^{1}	2.11×10^{-2}	2.39×10^{-1}	3.93×10^{-1}	6.63×10^{3}	1.99×10^{2}	2.09×10^{-3}	3.47×10^{4}	1.48×10^{1}	3.95×10^{2}	2.13×10^{-3}	4.62×10^{-3}	3.02×10^{-3}
AY tank farm	8.33×10^{-2}	1.57×10^{-2}	8.93×10^{-1}	1.42×10^{-3}	5.03×10^{-2}	3.20×10^{-2}	1.32×10^{3}	2.79×10^{1}	1.26	1.70×10^{3}	4.47×10^{1}	3.52×10^{1}	4.23×10^{-4}	9.19×10^{-4}	1.01×10^{-3}
AZ tank farm	3.37×10^{-1}	9.70×10^{-2}	2.04×10^{1}	1.89×10^{-2}	2.70×10^{-1}	5.66×10^{-2}	3.06×10^{3}	5.09×10^{1}	4.15×10^{-2}	7.74×10^{3}	3.81	5.18×10^{1}	9.81×10^{-4}	2.13×10^{-3}	1.01×10^{-3}
SY tank farm	2.36	3.58×10^{-1}	2.46×10^{1}	2.65×10^{-2}	3.80×10^{-2}	4.50×10^{-2}	3.64×10^{3}	4.73×10^{2}	8.95×10^{-2}	2.48×10^{4}	1.53×10^{1}	2.38×10^{1}	1.17×10^{-3}	2.53×10^{-3}	1.51×10^{-3}

Note: To convert kilograms to pounds, multiply by 2.2046.

Key: 2,4,6-TCP=2,4,6-trichlorophenol; C-14=carbon-14; Cr=chromium; H-3=hydrogen-3 (tritium); Hg=mercury; I-129=iodine-129; NO_3=nitrate; Np-237=neptunium-237; Pb=lead; PCBs=polychlorinated biphenyls; Tc-99=technetium-99; U-238=uranium-238; Utot=total uranium.

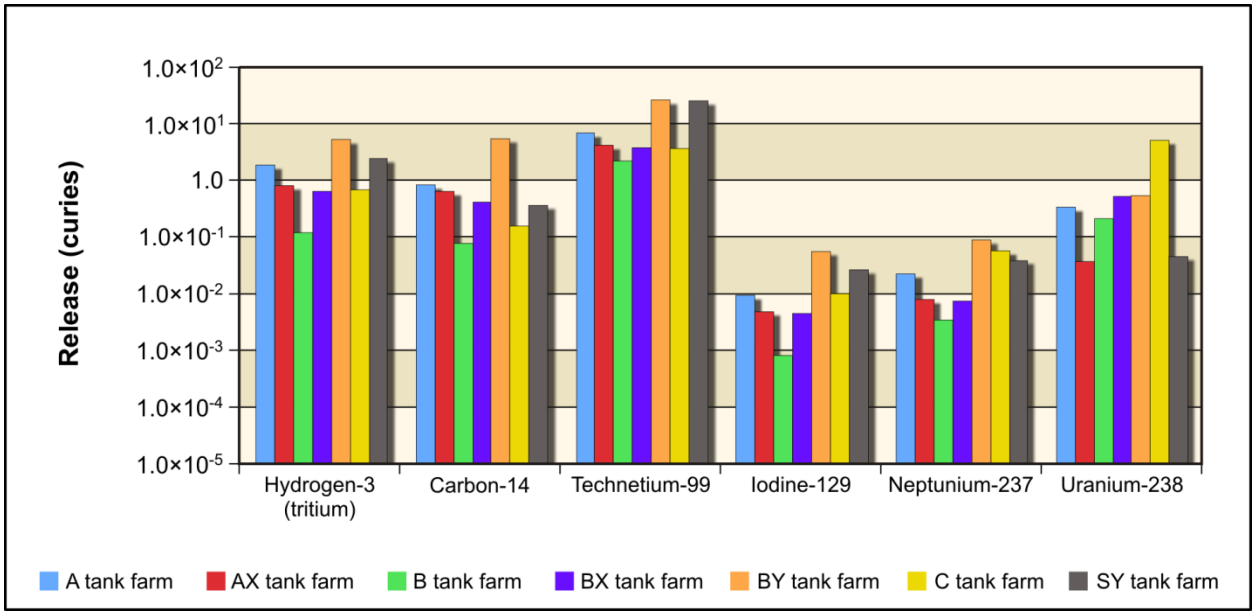


Figure M–35. Tank Closure Alternatives 2B, 3A, 3B, 3C, and 6C Radionuclide Releases to the Vadose Zone from Tank Residuals in Tank Farms A, AX, B, BX, BY, C, and SY

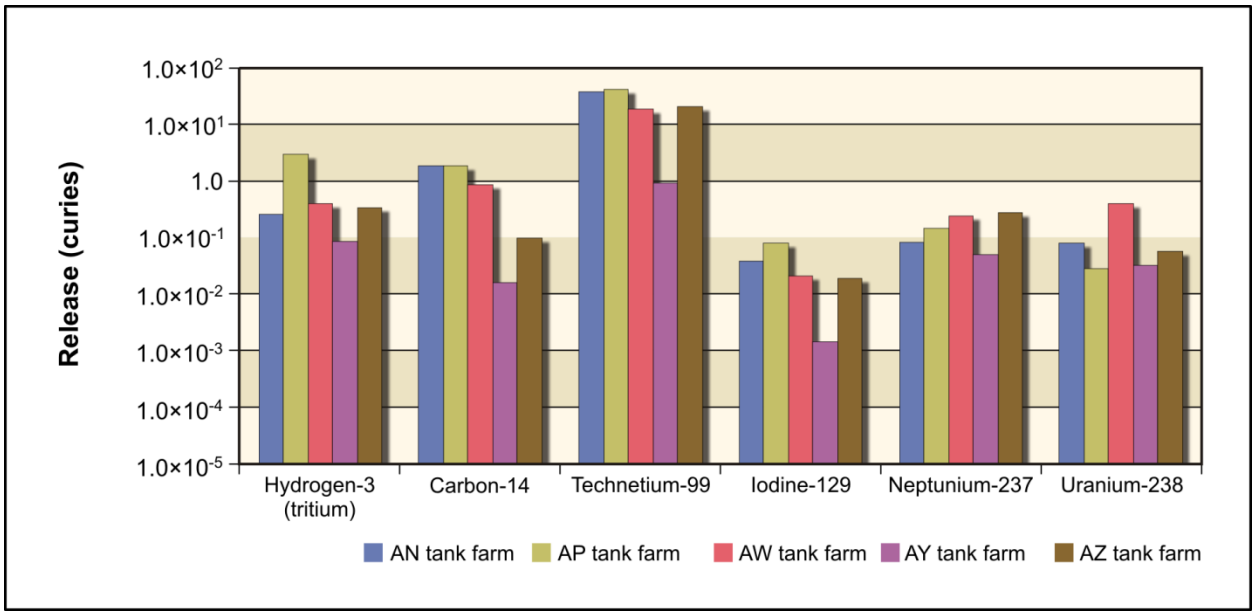


Figure M–36. Tank Closure Alternatives 2B, 3A, 3B, 3C, and 6C Radionuclide Releases to the Vadose Zone from Tank Residuals in Tank Farms AN, AP, AW, AY, and AZ

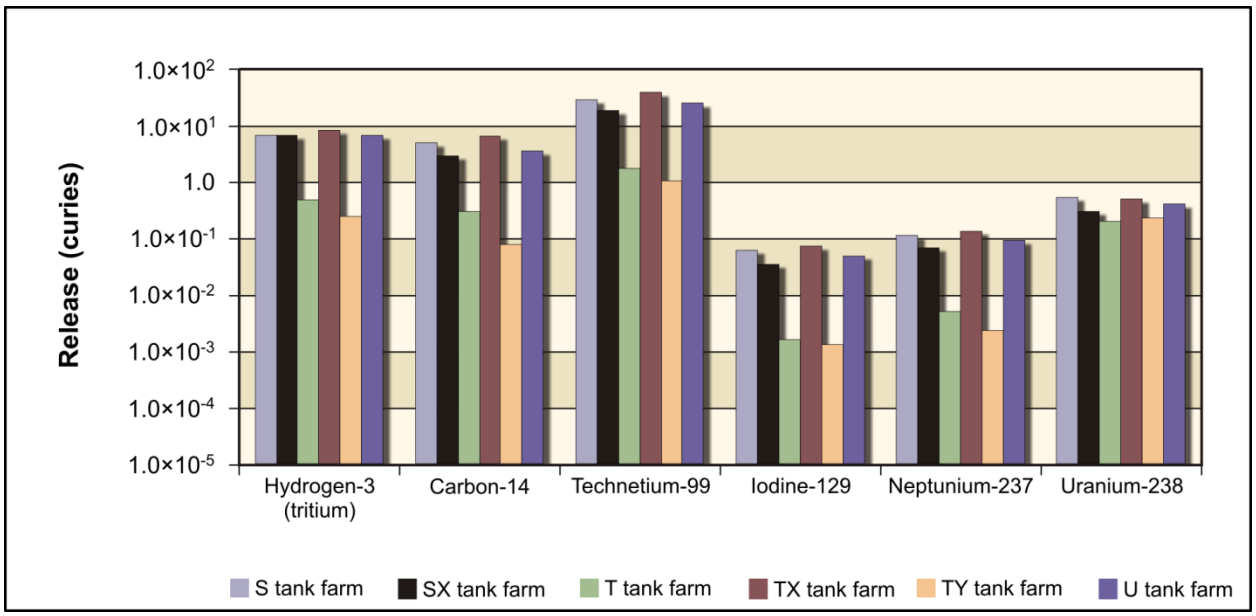


Figure M–37. Tank Closure Alternatives 2B, 3A, 3B, 3C, and 6C Radionuclide Releases to the Vadose Zone from Tank Residuals in Tank Farms S, SX, T, TX, TY, and U

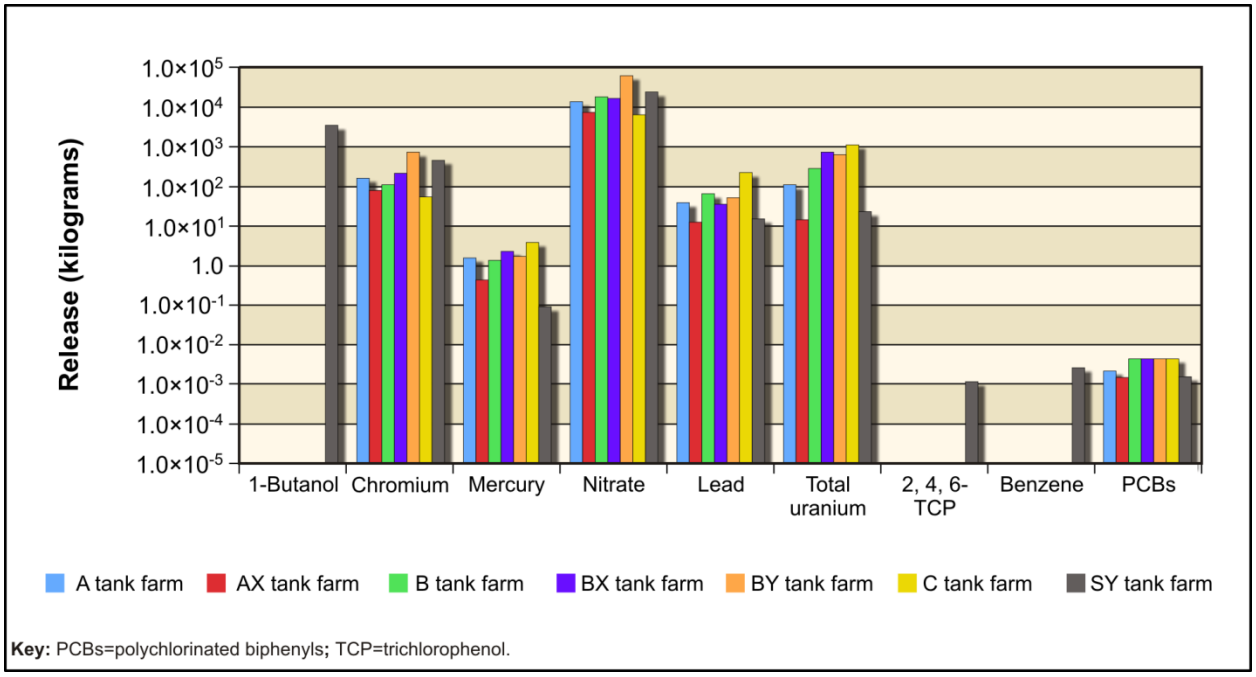
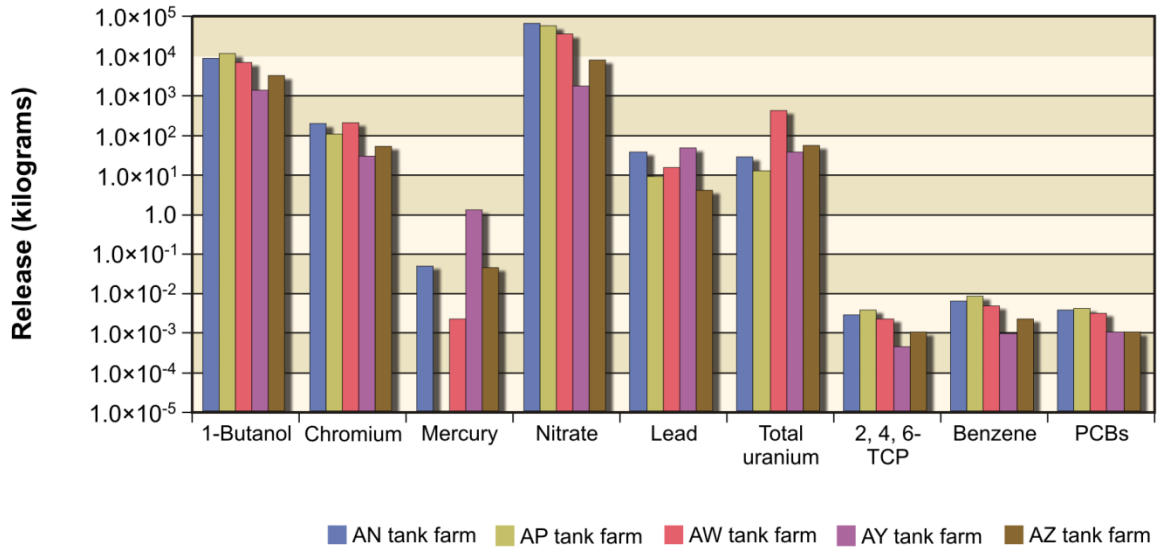
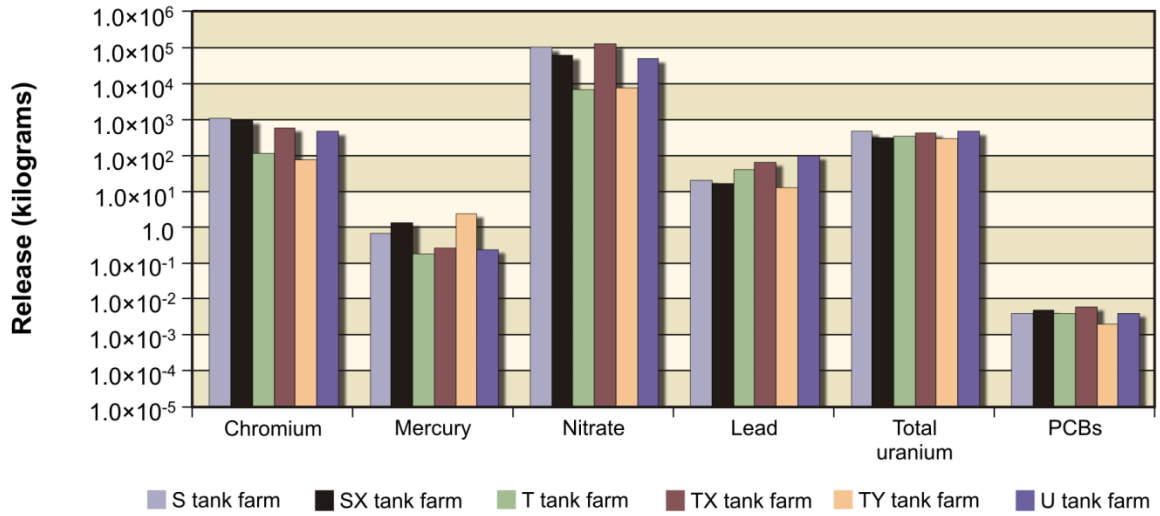


Figure M–38. Tank Closure Alternatives 2B, 3A, 3B, 3C, and 6C Chemical Releases to the Vadose Zone from Tank Residuals in Tank Farms A, AX, B, BX, BY, C, and SY



Key: PCBs=polychlorinated biphenyls; TCP=trichlorophenol.

Figure M–39. Tank Closure Alternatives 2B, 3A, 3B, 3C, and 6C Chemical Releases to the Vadose Zone from Tank Residuals in Tank Farms AN, AP, AW, AY, and AZ



Key: PCBs=polychlorinated biphenyls.

Figure M–40. Tank Closure Alternatives 2B, 3A, 3B, 3C, and 6C Chemical Releases to the Vadose Zone from Tank Residuals in Tank Farms S, SX, T, TX, TY, and U

Table M–25. Tank Closure Alternatives 2B, 3A, 3B, 3C, and 6C Radionuclide and Chemical Releases to the Vadose Zone from Unplanned Releases in Tank Farms B, BY, C, TX, and U

	Radionuclide (curies)						Chemical (kilograms)								
Source	**H-3**	**C-14**	**Tc-99**	**I-129**	**Np-237**	**U-238**	**1-Butanol**	**Cr**	**Hg**	**NO_3**	**Pb**	**Utot**	**2,4,6-TCP**	**Benzene**	**PCBs**
B tank farm	3.34	7.87×10^{-2}	2.96	1.76×10^{-3}	9.69×10^{-3}	1.57×10^{-3}	3.86×10^{-4}	3.53×10^{1}	8.41×10^{-3}	3.24×10^{3}	2.07	1.81	–	–	–
BY tank farm	9.86	8.65×10^{-3}	2.15×10^{-2}	1.88×10^{-4}	4.95×10^{-4}	2.22×10^{-3}	–	3.81×10^{1}	3.44×10^{-2}	1.17×10^{4}	–	3.30	–	–	–
C tank farm	1.39×10^{2}	1.90×10^{-1}	1.67	2.48×10^{-2}	5.58×10^{-3}	1.49×10^{-2}	6.47×10^{-1}	3.94×10^{1}	3.92×10^{-3}	9.68×10^{3}	2.16×10^{1}	3.47×10^{1}	–	–	–
TX tank farm	8.21×10^{-1}	7.88×10^{-4}	2.01×10^{-3}	1.71×10^{-5}	4.52×10^{-5}	2.02×10^{-4}	1.15×10^{-5}	3.47	3.13×10^{-3}	1.06×10^{3}	–	3.00×10^{-1}	–	–	–
U tank farm	6.36×10^{-1}	8.63×10^{-4}	2.27×10^{-2}	2.53×10^{-5}	1.30×10^{-4}	1.31×10^{-3}	–	3.76×10^{-1}	6.14×10^{-4}	2.59×10^{1}	–	1.93	–	–	–

Note: To convert kilograms to pounds, multiply by 2.2046.

Key: 2,4,6-TCP=2,4,6-trichlorophenol; C-14=carbon-14; Cr=chromium; H-3=hydrogen-3 (tritium); Hg=mercury; I-129=iodine-129; NO_3=nitrate; Np-237=neptunium-237; Pb=lead; PCBs=polychlorinated biphenyls; Tc-99=technetium-99; U-238=uranium-238; Utot=total uranium.

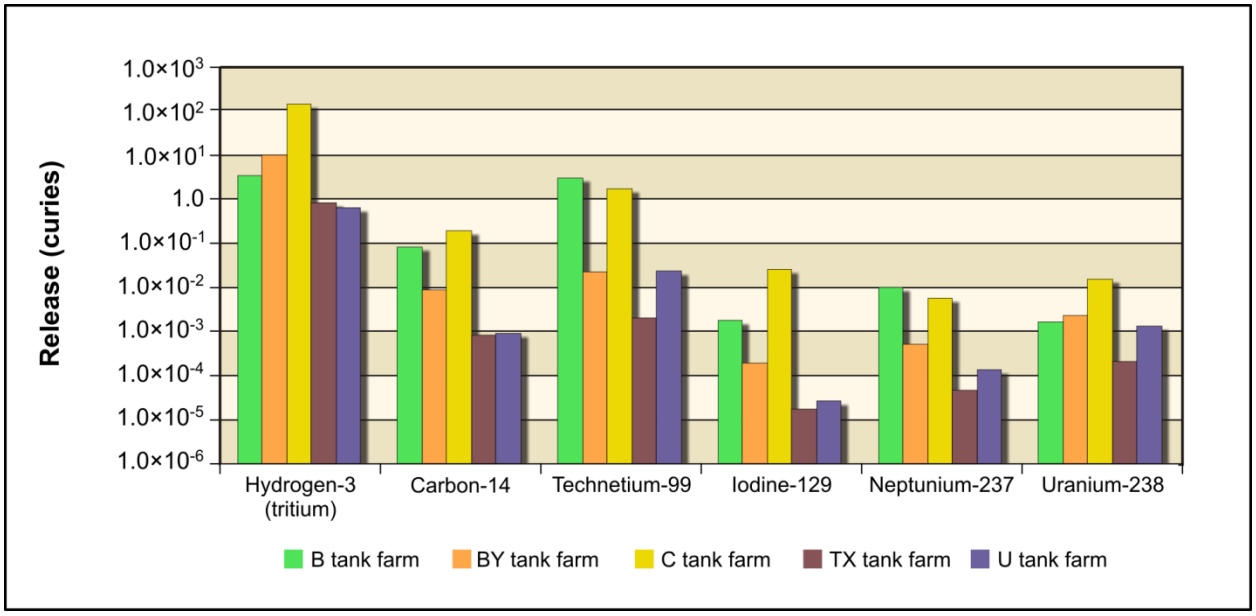


Figure M–41. Tank Closure Alternatives 2B, 3A, 3B, 3C, and 6C Radionuclide Releases to the Vadose Zone from Unplanned Releases in Tank Farms B, BY, C, TX, and U

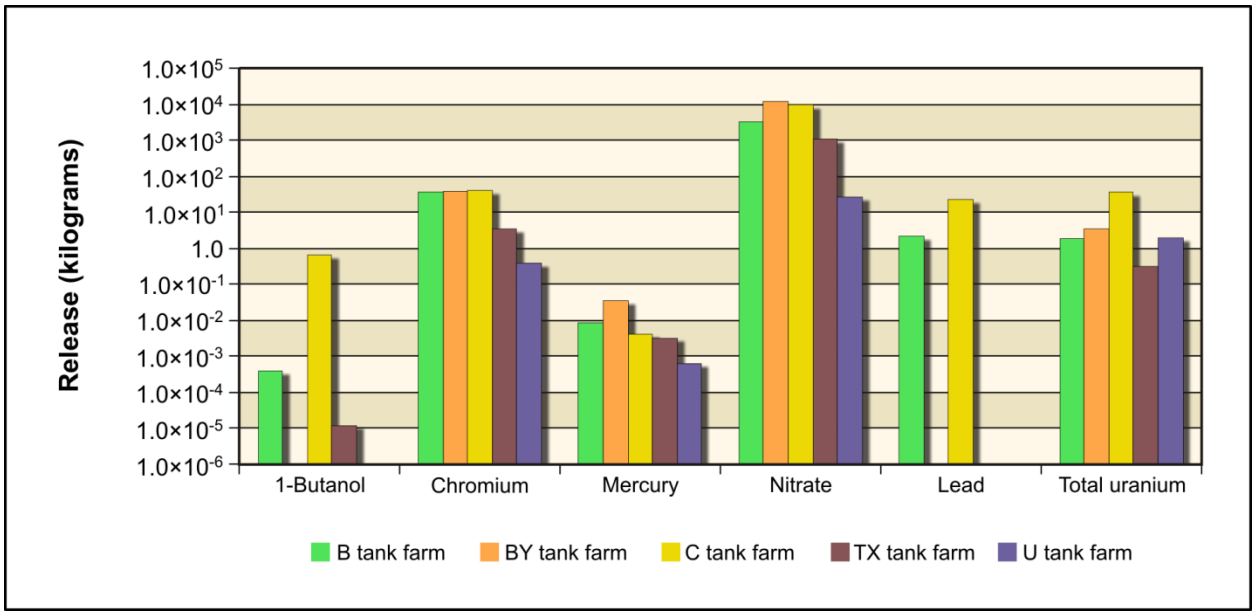


Figure M–42. Tank Closure Alternatives 2B, 3A, 3B, 3C, and 6C Chemical Releases to the Vadose Zone from Unplanned Releases in Tank Farms B, BY, C, TX, and U

Under Tank Closure Alternative 4, tank waste would be retrieved to a volume corresponding to 99.9 percent retrieval. Except for the BX and SX tank farms, residual material in tanks would be stabilized in place, and the tank farms and adjacent cribs and trenches (ditches) would be covered with an engineered modified RCRA Subtitle C barrier. The BX and SX tank farms would be closed to a clean state by removing the tanks, ancillary equipment, and soils to a depth of 3 meters (10 feet) below the tank base. Where necessary, deep soil excavation would also be conducted to remove contamination plumes within the soil column. Potential releases to the vadose zone under Tank Closure Alternative 4 are indicated in Table M–26 and Figures M–43 through M–48.

Table M–26. Tank Closure Alternative 4 Radionuclide and Chemical Releases to the Vadose Zone from Other Sources in Tank Farms

	Radionuclide (curies)						Chemical (kilograms)								
Source	**H-3**	**C-14**	**Tc-99**	**I-129**	**Np-237**	**U-238**	**1-Butanol**	**Cr**	**Hg**	**NO_3**	**Pb**	**Utot**	**2,4,6-TCP**	**Benzene**	**PCBs**
A tank farm	3.58	9.69×10^{-1}	9.02	1.29×10^{-2}	2.53×10^{-2}	7.37×10^{-1}	–	2.15×10^{2}	4.96	1.38×10^{4}	1.06×10^{2}	2.44×10^{2}	–	–	1.63×10^{-1}
AX tank farm	2.47	1.11	1.80×10^{1}	1.03×10^{-2}	1.45×10^{-2}	5.96×10^{-2}	–	1.05×10^{2}	2.87	1.08×10^{5}	7.96×10^{1}	4.08×10^{1}	–	–	1.09×10^{-1}
B tank farm	3.79	2.25×10^{-1}	5.79	3.34×10^{-3}	1.48×10^{-2}	3.12×10^{-1}	3.86×10^{-4}	2.47×10^{2}	2.34	9.19×10^{4}	1.02×10^{2}	4.54×10^{2}	–	–	4.36×10^{-1}
BY tank farm	1.74×10^{1}	3.63	1.69×10^{1}	3.63×10^{-2}	5.74×10^{-2}	3.49×10^{-1}	–	5.38×10^{2}	1.17	5.16×10^{4}	3.35×10^{1}	4.40×10^{2}	–	–	3.28×10^{-1}
C tank farm	1.40×10^{2}	4.40×10^{-1}	7.72	3.91×10^{-2}	9.41×10^{-2}	6.92	6.47×10^{-1}	1.34×10^{2}	6.18	1.11×10^{5}	3.57×10^{3}	1.91×10^{3}	–	–	4.35×10^{-1}
S tank farm	9.05	2.71	1.50×10^{1}	3.21×10^{-2}	6.07×10^{-2}	2.94×10^{-1}	–	6.51×10^{2}	3.98×10^{-1}	5.87×10^{4}	1.21×10^{1}	2.98×10^{2}	–	–	3.28×10^{-1}
T tank farm	6.97×10^{-1}	4.30×10^{-1}	3.18	2.62×10^{-3}	7.44×10^{-3}	4.30×10^{-1}	–	2.47×10^{2}	3.17×10^{-1}	6.87×10^{4}	8.88×10^{1}	6.15×10^{2}	–	–	4.36×10^{-1}
TX tank farm	1.27×10^{1}	4.00	2.36×10^{1}	4.49×10^{-2}	8.29×10^{-2}	3.28×10^{-1}	1.15×10^{-5}	4.29×10^{2}	3.58×10^{-1}	8.88×10^{4}	4.45×10^{1}	3.23×10^{2}	–	–	4.93×10^{-1}
TY tank farm	6.12×10^{-1}	1.54×10^{-1}	2.37	2.19×10^{-3}	4.58×10^{-3}	4.40×10^{-1}	–	1.50×10^{2}	4.09	1.61×10^{4}	2.65×10^{1}	6.41×10^{2}	–	–	1.63×10^{-1}
U tank farm	1.10×10^{1}	3.00	2.07×10^{1}	3.98×10^{-2}	7.66×10^{-2}	4.05×10^{-1}	–	4.81×10^{2}	4.77×10^{-1}	1.28×10^{5}	1.60×10^{2}	5.33×10^{2}	–	–	4.36×10^{-1}
AN tank farm	1.13×10^{-1}	2.42×10^{-1}	4.68	4.84×10^{-3}	1.04×10^{-2}	1.00×10^{-2}	1.09×10^{3}	2.35×10^{1}	5.92×10^{-3}	8.22×10^{3}	4.62	3.41	3.50×10^{-4}	7.59×10^{-4}	5.06×10^{-3}
AP tank farm	1.33	2.40×10^{-1}	5.03	9.50×10^{-3}	1.77×10^{-2}	3.52×10^{-3}	1.40×10^{3}	1.27×10^{1}	–	6.98×10^{3}	1.11	1.52	4.47×10^{-4}	9.70×10^{-4}	4.88×10^{-3}
AW tank farm	1.54×10^{-1}	1.14×10^{-1}	2.42	2.74×10^{-3}	3.11×10^{-2}	5.11×10^{-2}	8.63×10^{2}	2.59×10^{1}	2.72×10^{-4}	4.51×10^{3}	1.97	5.14×10^{1}	2.77×10^{-4}	6.01×10^{-4}	3.32×10^{-3}
AY tank farm	2.37×10^{-2}	2.43×10^{-3}	1.34×10^{-1}	2.13×10^{-4}	7.57×10^{-3}	4.81×10^{-3}	1.99×10^{2}	4.20	1.90×10^{-1}	2.56×10^{2}	6.71	5.29	6.36×10^{-5}	1.38×10^{-4}	1.02×10^{-3}
AZ tank farm	1.49×10^{-1}	1.24×10^{-2}	2.48	2.33×10^{-3}	3.29×10^{-2}	6.90×10^{-3}	3.73×10^{2}	6.20	5.05×10^{-3}	9.42×10^{2}	4.91×10^{-1}	6.32	1.19×10^{-4}	2.59×10^{-4}	1.10×10^{-3}
SY tank farm	1.02	4.78×10^{-2}	3.13	3.39×10^{-3}	4.84×10^{-3}	5.73×10^{-3}	4.64×10^{2}	6.03×10^{1}	1.14×10^{-2}	3.16×10^{3}	2.00	3.03	1.49×10^{-4}	3.23×10^{-4}	1.89×10^{-3}

Note: To convert kilograms to pounds, multiply by 2.2046.

Key: 2,4,6-TCP=2,4,6-trichlorophenol; C-14=carbon-14; Cr=chromium; H-3=hydrogen-3 (tritium); Hg=mercury; I-129=iodine-129; NO_3=nitrate; Np-237=neptunium-237; Pb=lead; PCBs=polychlorinated biphenyls; Tc-99=technetium-99; U-238=uranium-238; Utot=total uranium.

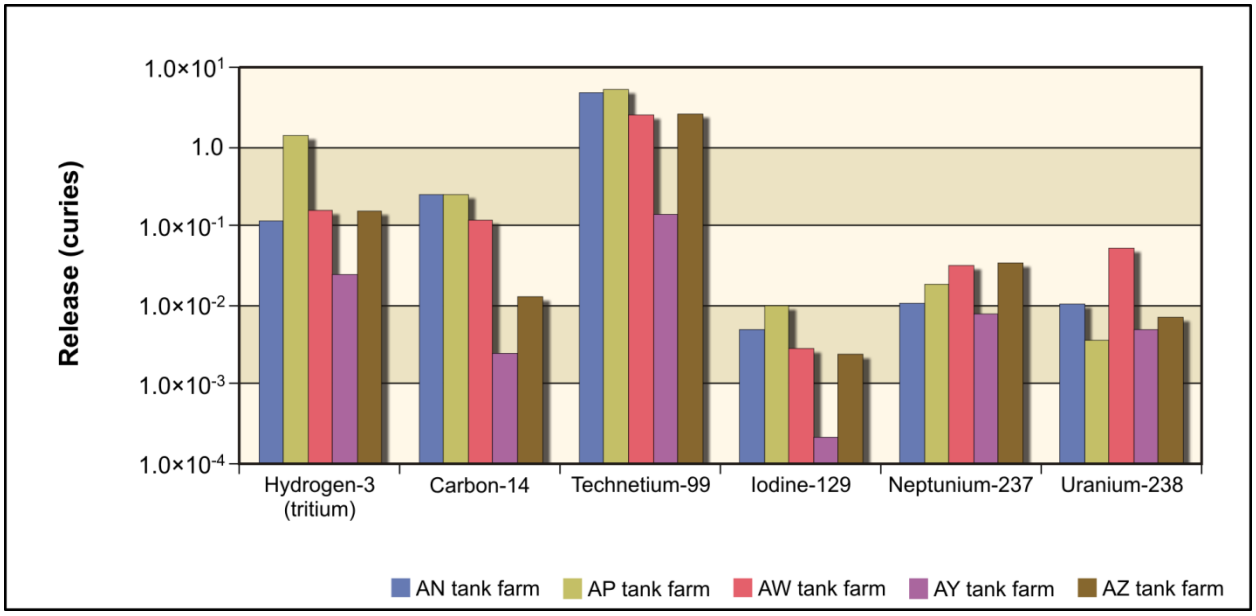


Figure M–43. Tank Closure Alternative 4 Radionuclide Releases to the Vadose Zone from Other Sources in Tank Farms AN, AP, AW, AY, and AZ

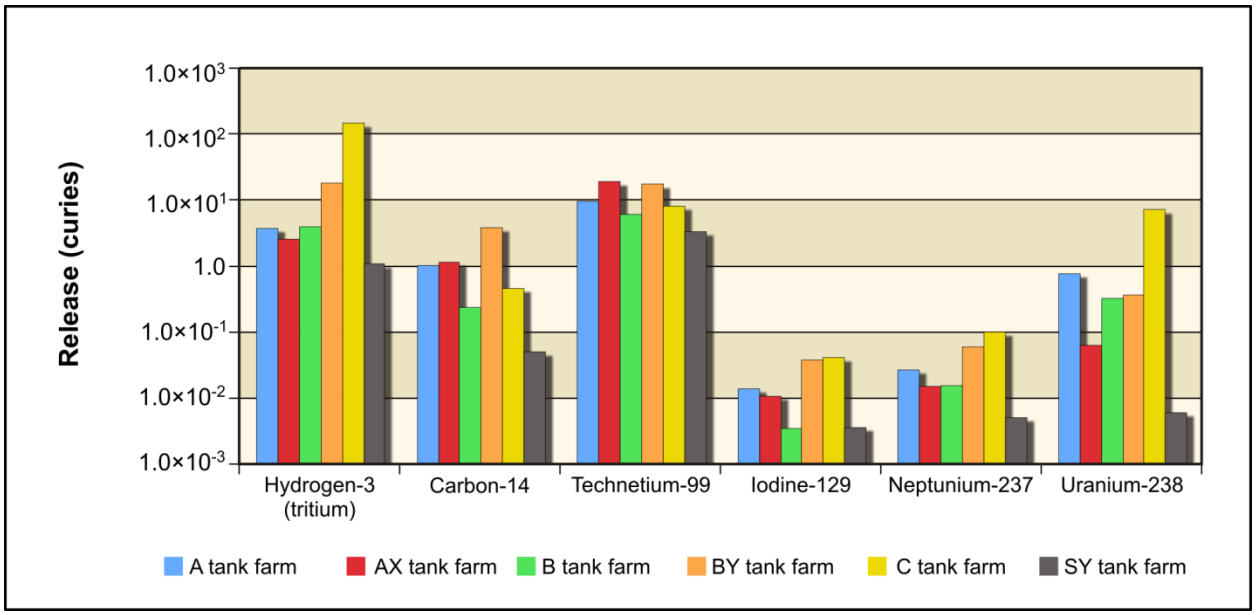


Figure M–44. Tank Closure Alternative 4 Radionuclide Releases to the Vadose Zone from Other Sources in Tank Farms A, AX, B, BY, C and SY

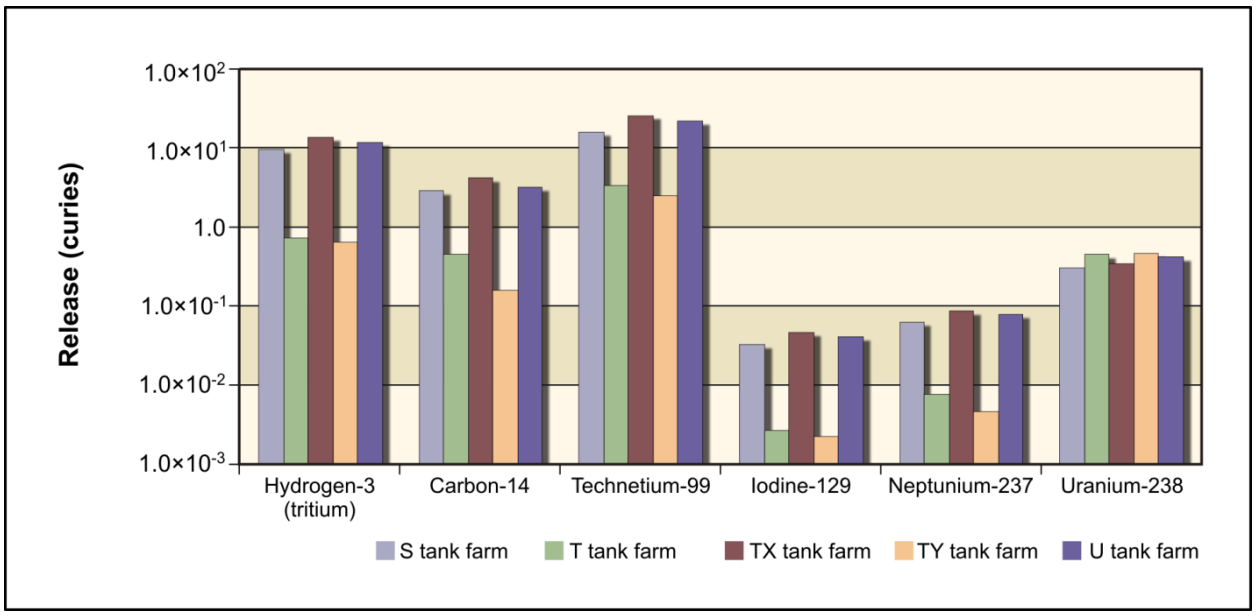


Figure M–45. Tank Closure Alternative 4 Radionuclide Releases to the Vadose Zone from Other Sources in Tank Farms S, T, TX, TY, and U

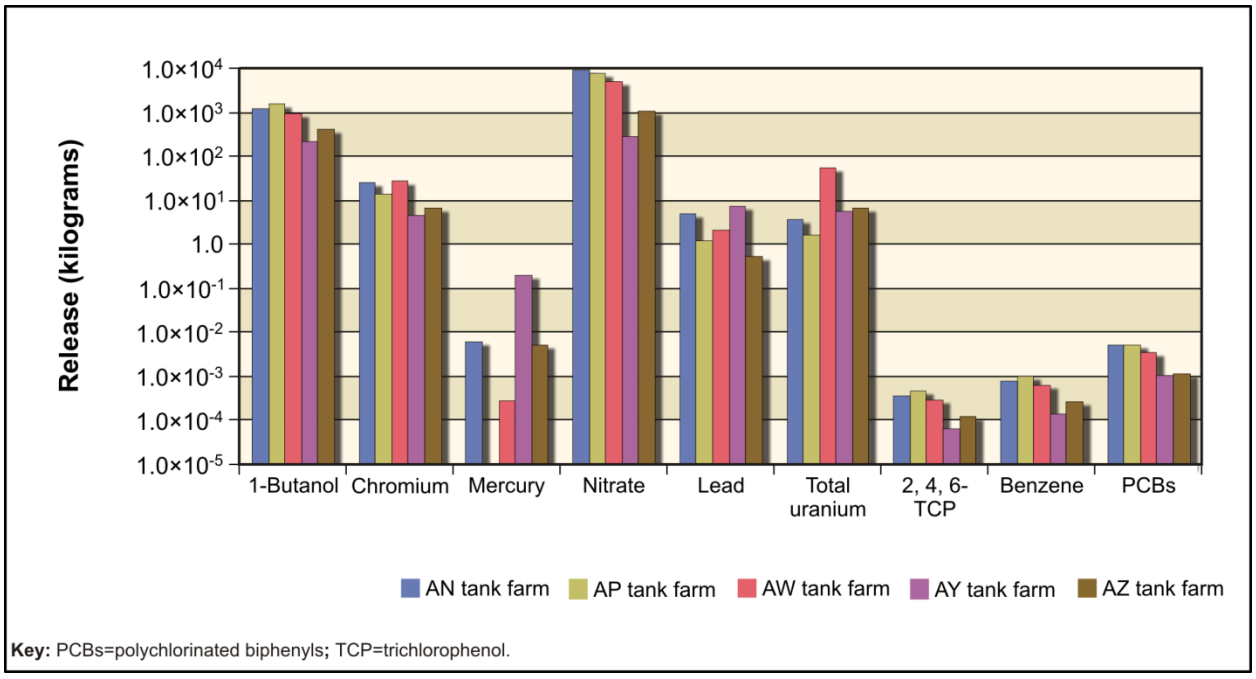


Figure M–46. Tank Closure Alternative 4 Chemical Releases to the Vadose Zone from Other Sources in Tank Farms AN, AP, AW, AY, and AZ

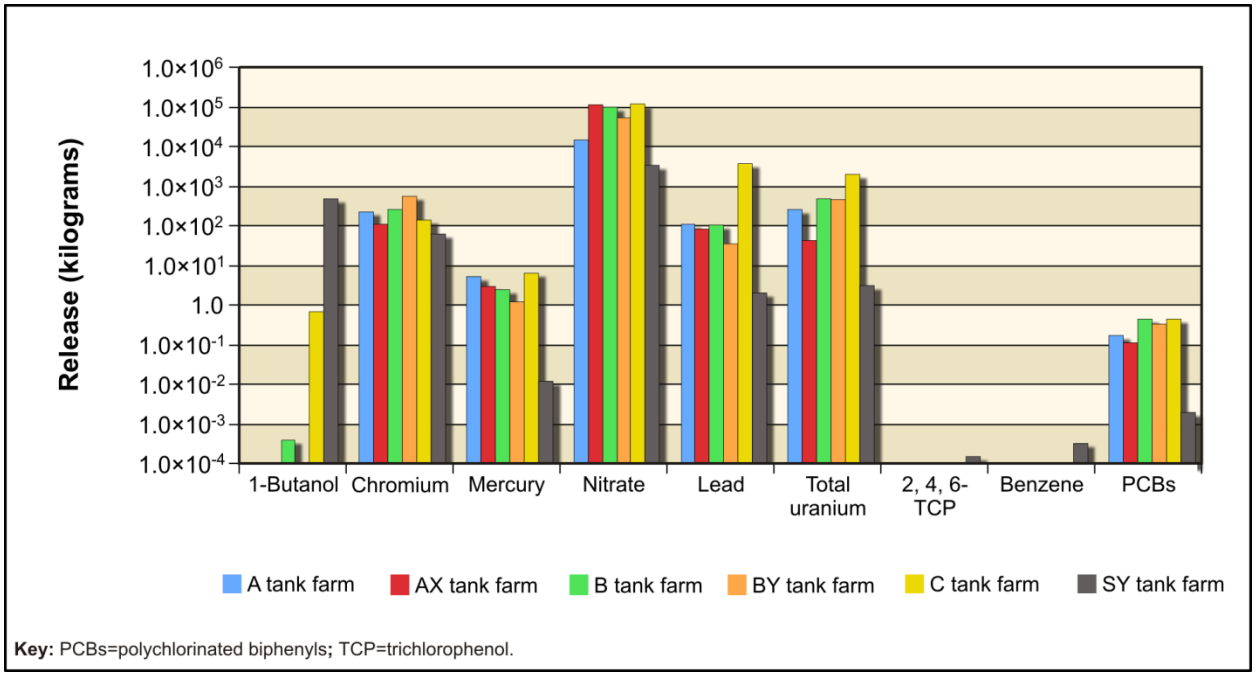


Figure M–47. Tank Closure Alternative 4 Chemical Releases to the Vadose Zone from Other Sources in Tank Farms A, AX, B, BY, C, and SY

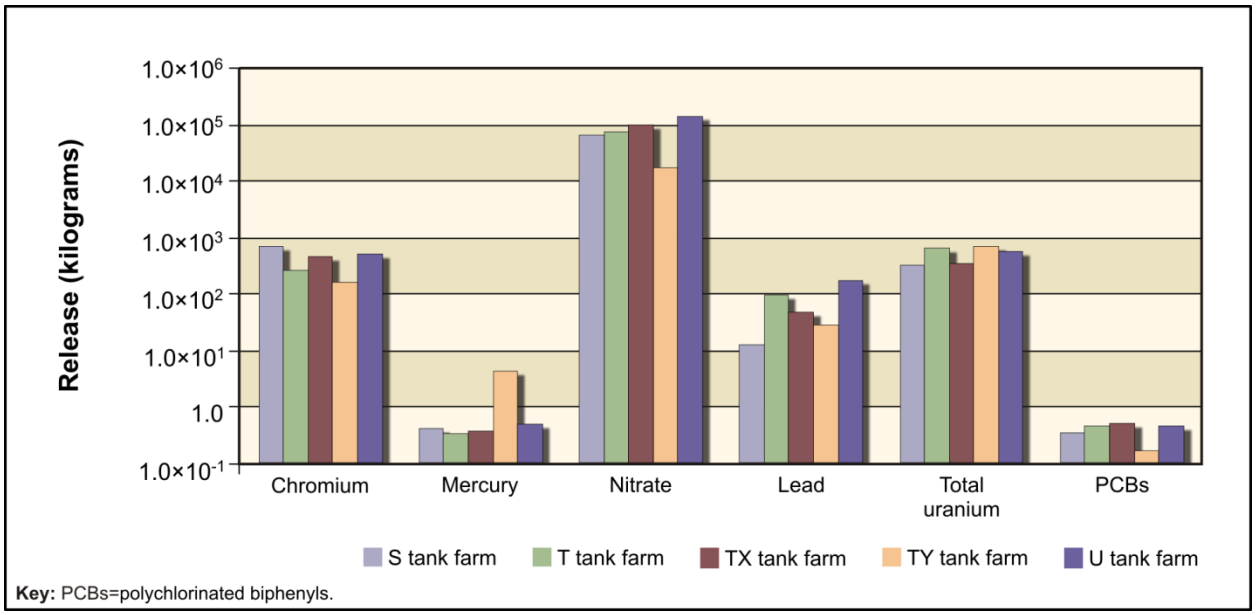


Figure M–48. Tank Closure Alternative 4 Chemical Releases to the Vadose Zone from Other Sources in Tank Farms S, T, TX, TY, and U

Under Tank Closure Alternative 5, tank waste would be retrieved to a volume corresponding to 90 percent retrieval, residual material in tanks would be stabilized in place, and the tank farms and adjacent cribs and trenches (ditches) would be covered with a Hanford barrier. Potential releases to the vadose zone under Tank Closure Alternative 5 are indicated in Table M–27 and Figures M–49 through M–54.

Table M–27. Tank Closure Alternative 5 Radionuclide and Chemical Releases to the Vadose Zone from Other Sources in Tank Farms

	Radionuclide (curies)						Chemical (kilograms)								
Source	**H-3**	**C-14**	**Tc-99**	**I-129**	**Np-237**	**U-238**	**1-Butanol**	**Cr**	**Hg**	**NO_3**	**Pb**	**Utot**	**2,4,6-TCP**	**Benzene**	**PCBs**
A tank farm	6.83	8.19	7.59×10^{1}	9.73×10^{-2}	2.44×10^{-1}	3.88	–	1.82×10^{3}	2.07×10^{1}	1.54×10^{5}	4.10×10^{2}	1.30×10^{3}	–	–	1.63×10^{-1}
AX tank farm	4.16	6.80	5.90×10^{1}	5.61×10^{-2}	9.24×10^{-2}	4.18×10^{-1}	–	8.87×10^{2}	7.12	1.84×10^{5}	1.88×10^{2}	1.86×10^{2}	–	–	1.09×10^{-1}
B tank farm	6.78×10^{-1}	8.44×10^{-1}	2.42×10^{1}	9.21×10^{-3}	3.91×10^{-2}	2.35	–	1.32×10^{3}	1.61×10^{1}	2.78×10^{5}	6.36×10^{2}	3.23×10^{3}	–	–	4.36×10^{-1}
BX tank farm	2.54	4.28	4.20×10^{1}	4.92×10^{-2}	8.38×10^{-2}	5.94	–	2.60×10^{3}	2.71×10^{1}	2.15×10^{5}	3.91×10^{2}	8.57×10^{3}	–	–	3.28×10^{-1}
BY tank farm	2.43×10^{1}	5.00×10^{1}	2.68×10^{2}	4.30×10^{-1}	8.95×10^{-1}	4.67	–	7.82×10^{3}	1.84×10^{1}	7.08×10^{5}	3.09×10^{2}	5.86×10^{3}	–	–	3.28×10^{-1}
C tank farm	1.42×10^{2}	1.83	4.26×10^{1}	1.33×10^{-1}	6.64×10^{-1}	5.59×10^{1}	6.47×10^{-1}	6.92×10^{2}	4.53×10^{1}	1.77×10^{5}	5.54×10^{3}	1.31×10^{4}	–	–	4.35×10^{-1}
S tank farm	1.69×10^{1}	4.35×10^{1}	2.86×10^{2}	4.04×10^{-1}	1.13	4.20	–	1.25×10^{4}	7.44	1.15×10^{6}	1.15×10^{2}	4.21×10^{3}	–	–	3.28×10^{-1}
SX tank farm	1.99×10^{1}	2.70×10^{1}	1.89×10^{2}	3.09×10^{-1}	7.17×10^{-1}	3.06	–	1.14×10^{4}	1.64×10^{1}	7.44×10^{5}	1.37×10^{2}	3.43×10^{3}	–	–	4.11×10^{-1}
T tank farm	1.11	1.73	1.94×10^{1}	1.34×10^{-2}	3.51×10^{-2}	2.97	–	1.45×10^{3}	2.30	1.43×10^{5}	4.51×10^{2}	4.26×10^{3}	–	–	4.36×10^{-1}
TX tank farm	2.34×10^{1}	5.73×10^{1}	3.96×10^{2}	5.43×10^{-1}	1.36	4.24	1.15×10^{-5}	6.51×10^{3}	3.15	1.48×10^{6}	4.19×10^{2}	4.05×10^{3}	–	–	4.93×10^{-1}
TY tank farm	1.20	8.39×10^{-1}	1.25×10^{1}	1.48×10^{-2}	2.73×10^{-2}	2.65	–	9.42×10^{2}	2.96×10^{1}	9.94×10^{4}	1.55×10^{2}	3.86×10^{3}	–	–	1.63×10^{-1}
U tank farm	2.11×10^{1}	3.32×10^{1}	2.61×10^{2}	4.18×10^{-1}	9.60×10^{-1}	3.92	–	5.56×10^{3}	3.01	6.70×10^{5}	8.55×10^{2}	5.02×10^{3}	–	–	4.36×10^{-1}
AN tank farm	3.72×10^{-1}	1.45×10^{1}	3.69×10^{2}	1.63×10^{-1}	6.87×10^{-1}	4.33×10^{-1}	8.64×10^{4}	1.86×10^{3}	4.37×10^{-1}	6.51×10^{5}	1.08×10^{2}	1.48×10^{2}	2.77×10^{-2}	6.01×10^{-2}	6.64×10^{-3}
AP tank farm	4.11	1.44×10^{1}	4.07×10^{2}	2.96×10^{-1}	1.14	1.42×10^{-1}	1.14×10^{5}	1.04×10^{3}	–	5.68×10^{5}	2.38×10^{1}	6.14×10^{1}	3.64×10^{-2}	7.89×10^{-2}	5.70×10^{-3}
AW tank farm	5.59×10^{-1}	6.88	1.86×10^{2}	9.78×10^{-2}	2.09	2.31	6.67×10^{4}	2.00×10^{3}	1.99×10^{-2}	3.49×10^{5}	4.90×10^{1}	2.32×10^{3}	2.14×10^{-2}	4.65×10^{-2}	3.55×10^{-3}
AY tank farm	1.27×10^{-1}	1.37×10^{-1}	9.01	9.25×10^{-3}	4.91×10^{-1}	2.49×10^{-1}	1.33×10^{4}	2.82×10^{2}	1.26×10^{1}	1.72×10^{4}	2.17×10^{2}	2.74×10^{2}	4.28×10^{-3}	9.29×10^{-3}	1.03×10^{-3}
AZ tank farm	4.47×10^{-1}	7.48×10^{-1}	2.04×10^{2}	6.90×10^{-2}	2.07	2.68×10^{-1}	3.07×10^{4}	5.11×10^{2}	3.69×10^{-1}	7.78×10^{4}	9.92	2.44×10^{2}	9.86×10^{-3}	2.14×10^{-2}	1.18×10^{-3}
SY tank farm	3.42	2.88	2.46×10^{2}	1.15×10^{-1}	3.21×10^{-1}	2.49×10^{-1}	3.66×10^{4}	4.76×10^{3}	8.41×10^{-1}	2.49×10^{5}	4.71×10^{1}	1.31×10^{2}	1.18×10^{-2}	2.55×10^{-2}	2.26×10^{-3}

Note: To convert kilograms to pounds, multiply by 2.2046.

Key: 2,4,6-TCP=2,4,6-trichlorophenol; C-14=carbon-14; Cr=chromium; H-3=hydrogen-3 (tritium); Hg=mercury; I-129=iodine-129; NO_3=nitrate; Np-237=neptunium-237; Pb=lead; PCBs=polychlorinated biphenyls; Tc-99=technetium-99; U-238=uranium-238; Utot=total uranium.

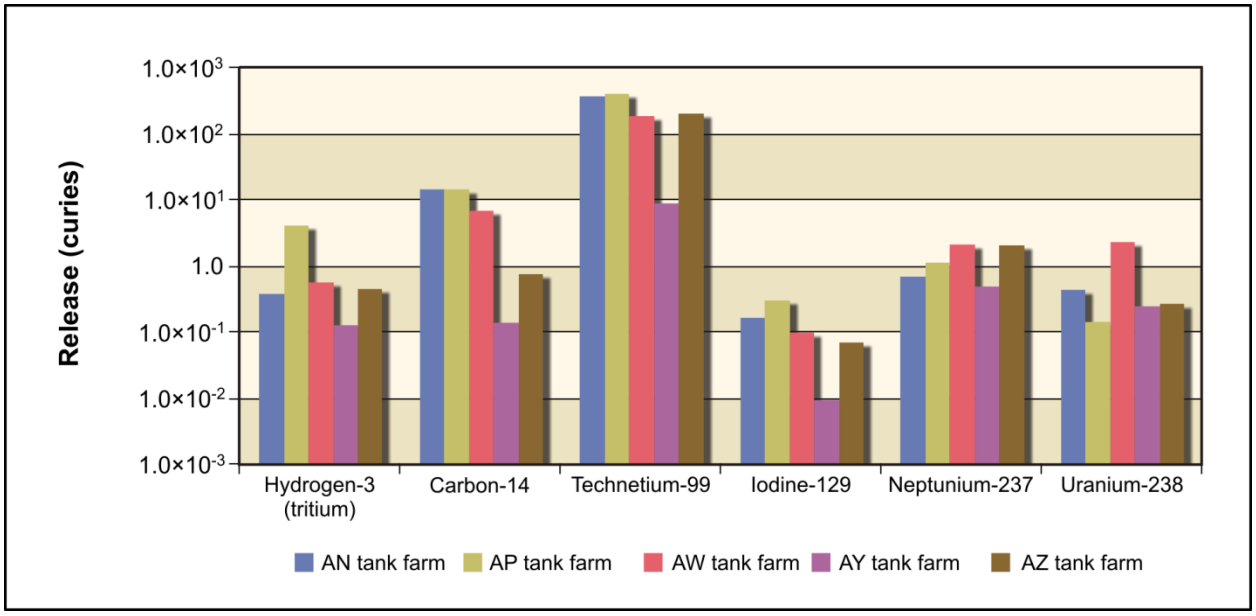


Figure M–49. Tank Closure Alternative 5 Radionuclide Releases to the Vadose Zone from Other Sources in Tank Farms AN, AP, AW, AY, and AZ

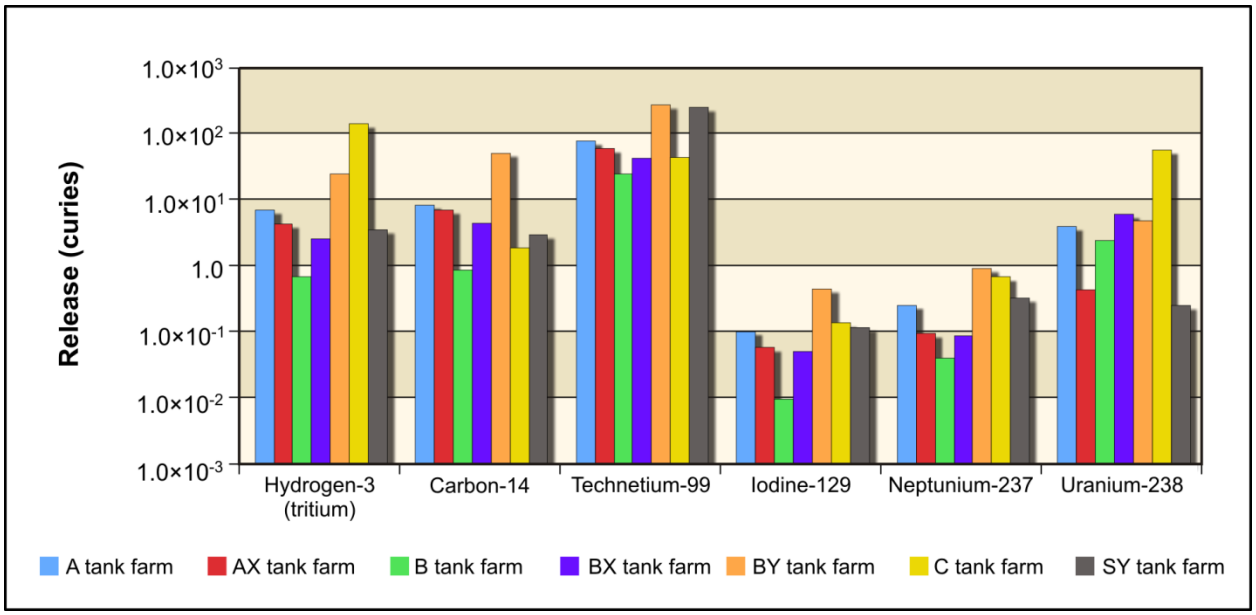


Figure M–50. Tank Closure Alternative 5 Radionuclide Releases to the Vadose Zone from Other Sources in Tank Farms A, AX, B, BX, BY, C, and SY

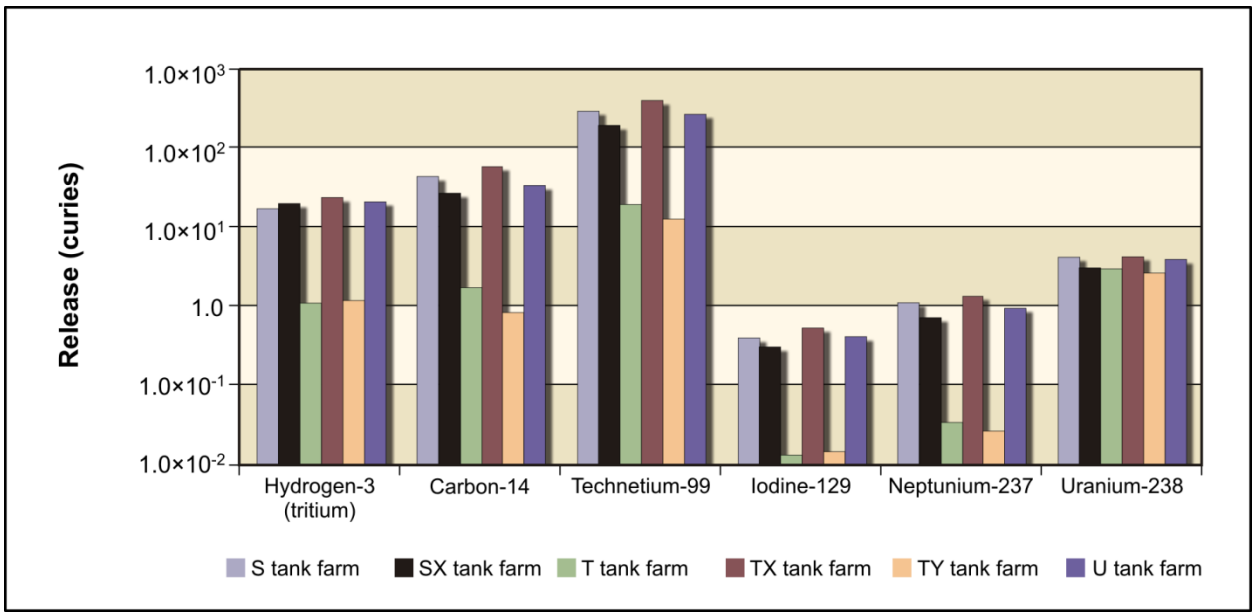


Figure M–51. Tank Closure Alternative 5 Radionuclide Releases to the Vadose Zone from Other Sources in Tank Farms S, SX, T, TX, TY, and U

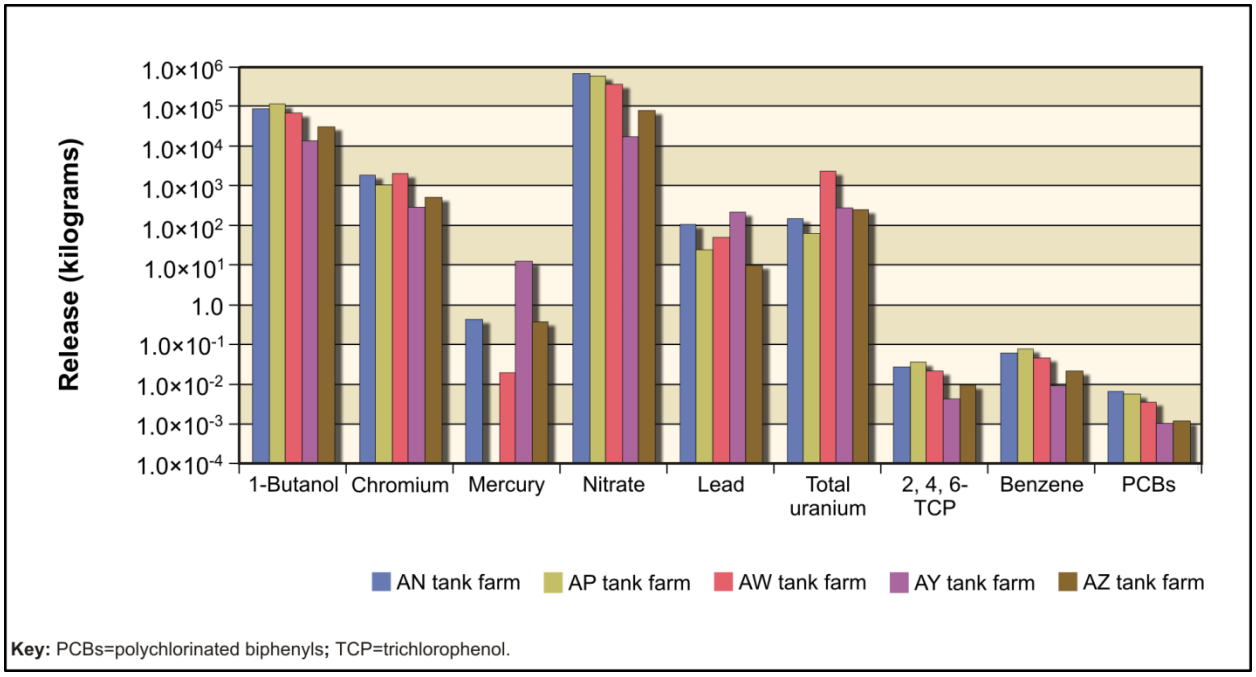


Figure M–52. Tank Closure Alternative 5 Chemical Releases to the Vadose Zone from Other Sources in Tank Farms AN, AP, AW, AY, and AZ

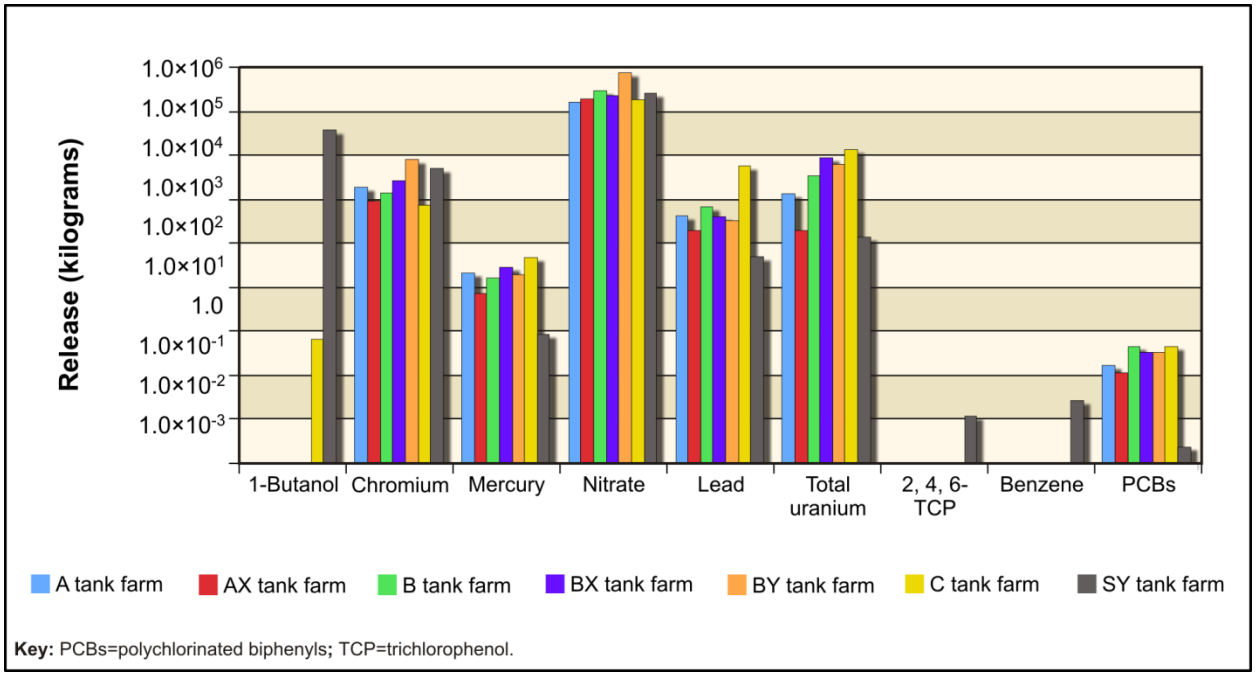


Figure M–53. Tank Closure Alternative 5 Chemical Releases to the Vadose Zone from Other Sources in Tank Farms A, AX, B, BX, BY, C, and SY

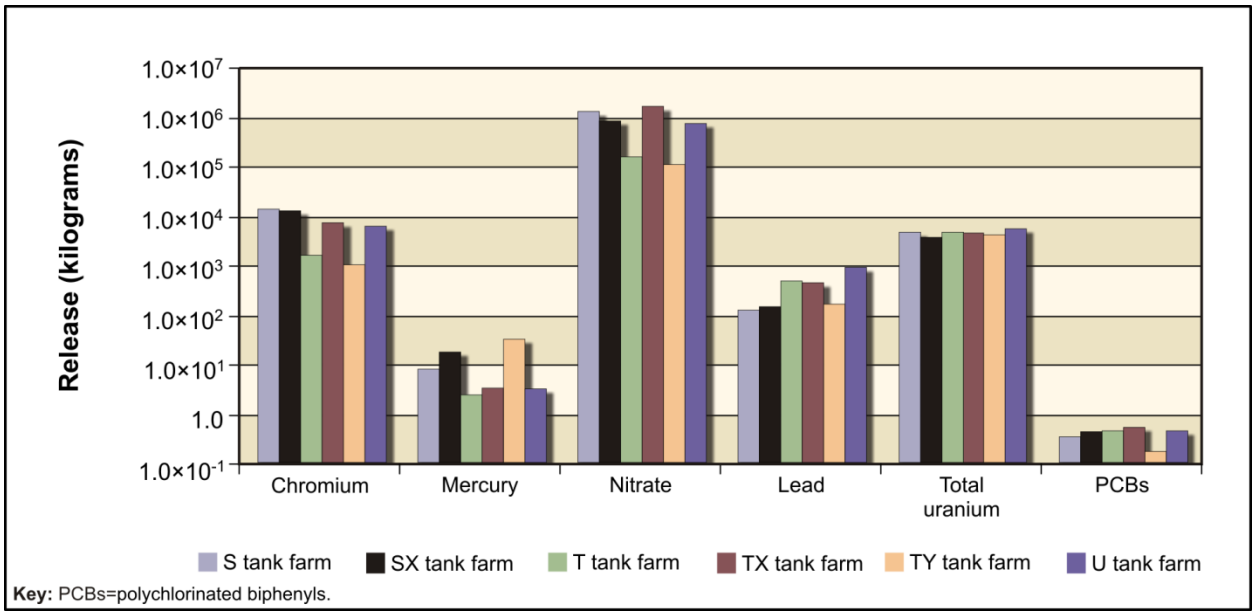


Figure M–54. Tank Closure Alternative 5 Chemical Releases to the Vadose Zone from Other Sources in Tank Farms S, SX, T, TX, TY, and U

Under Tank Closure Alternative 6A, Base Case, tank waste would be retrieved to a volume corresponding to 99.9 percent retrieval, and all tank farms would be clean-closed by removing the tanks, ancillary equipment, and soils to a depth of 3 meters (10 feet) below the tank base. Where necessary, deep soil excavation would also be conducted to remove contamination plumes within the soil column. The adjacent cribs and trenches (ditches) would be covered with an engineered modified RCRA Subtitle C barrier. The potential releases from other sources in tank farms under Alternative 6A, Base Case, originate from unplanned releases within the tank farm boundaries.

Under Tank Closure Alternative 6A, Option Case, tank waste would be retrieved to a volume corresponding to 99.9 percent retrieval, and all tank farms would be clean-closed by removing the tanks, ancillary equipment, and soils to a depth of 3 meters (10 feet) below the tank base. Where necessary, deep soil excavation would also be conducted to remove contamination plumes within the soil column. In addition, the adjacent cribs and trenches (ditches) would be clean-closed. The potential releases from other sources in tank farms under Alternative 6A, Option Case, originate from unplanned releases within the tank farm boundaries. Potential releases to the aquifer under Tank Closure Alternative 6A, Base and Option Cases, are indicated in Table M–28 and Figures M–55 and M–56.

Under Tank Closure Alternative 6B, Base Case, tank waste would be retrieved to a volume corresponding to 99.9 percent retrieval, and all tank farms would be clean-closed by removing the tanks, ancillary equipment, and soils to a depth of 3 meters (10 feet) below the tank base. Where necessary, deep soil excavation would also be conducted to remove contamination plumes within the soil column. The adjacent cribs and trenches (ditches) would be covered with an engineered modified RCRA Subtitle C barrier. The potential releases from other sources in tank farms under Alternative 6B, Base Case, originate from unplanned releases within the tank farm boundaries.

Under Tank Closure Alternative 6B, Option Case, tank waste would be retrieved to a volume corresponding to 99.9 percent retrieval, and all tank farms would be clean-closed by removing the tanks, ancillary equipment, and soils to a depth of 3 meters (10 feet) below the tank base. Where necessary, deep soil excavation would also be conducted to remove contamination plumes within the soil column. In addition, the adjacent cribs and trenches (ditches) would be clean-closed. The potential releases from other sources in tank farms under Alternative 6B, Option Case, originate from unplanned releases within the tank farm boundaries. Potential releases to the aquifer under Tank Closure Alternative 6B, Base and Option Cases, are indicated in Table M–29 and Figures M–57 and M–58.

Table M–28. Tank Closure Alternative 6A, Base and Option Cases, Radionuclide and Chemical Releases to the Vadose Zone from Other Sources in Tank Farms

	Radionuclide (curies)						Chemical (kilograms)								
Source	**H-3**	**C-14**	**Tc-99**	**I-129**	**Np-237**	**U-238**	**1-Butanol**	**Cr**	**Hg**	**NO_3**	**Pb**	**Utot**	**2,4,6-TCP**	**Benzene**	**PCBs**
B tank farm	3.34	7.87×10^{-2}	2.96	1.76×10^{-3}	9.69×10^{-3}	1.57×10^{-3}	3.86×10^{-4}	3.53×10^{1}	8.41×10^{-3}	3.24×10^{3}	2.07	1.81	–	–	–
BY tank farm	9.86	8.65×10^{-3}	2.15×10^{-2}	1.88×10^{-4}	4.95×10^{-4}	2.22×10^{-3}	–	3.81×10^{1}	3.44×10^{-2}	1.17×10^{4}	–	3.30	–	–	–
C tank farm	1.39×10^{2}	1.90×10^{-1}	1.67	2.48×10^{-2}	5.58×10^{-3}	1.49×10^{-2}	6.47×10^{-1}	3.94×10^{1}	3.92×10^{-3}	9.68×10^{3}	2.16×10^{1}	3.47×10^{1}	–	–	–
TX tank farm	8.21×10^{-1}	7.88×10^{-4}	2.01×10^{-3}	1.71×10^{-5}	4.52×10^{-5}	2.02×10^{-4}	1.15×10^{-5}	3.47	3.13×10^{-3}	1.06×10^{3}	–	3.00×10^{-1}	–	–	–
U tank farm	6.36×10^{-1}	8.63×10^{-4}	2.27×10^{-2}	2.53×10^{-5}	1.30×10^{-4}	1.31×10^{-3}	–	3.76×10^{-1}	6.14×10^{-4}	2.59×10^{1}	–	1.93	–	–	–

Note: To convert kilograms to pounds, multiply by 2.2046.

Key: 2,4,6-TCP=2,4,6-trichlorophenol; C-14=carbon-14; Cr=chromium; H-3=hydrogen-3 (tritium); Hg=mercury; I-129=iodine-129; NO_3=nitrate; Np-237=neptunium-237; Pb=lead; PCBs=polychlorinated biphenyls; Tc-99=technetium-99; U-238=uranium-238; Utot=total uranium.

Table M–29. Tank Closure Alternative 6B, Base and Option Cases, Radionuclide and Chemical Releases to the Vadose Zone from Other Sources in Tank Farms

	Radionuclide (curies)						Chemical (kilograms)								
Source	**H-3**	**C-14**	**Tc-99**	**I-129**	**Np-237**	**U-238**	**1-Butanol**	**Cr**	**Hg**	**NO_3**	**Pb**	**Utot**	**2,4,6-TCP**	**Benzene**	**PCBs**
B tank farm	3.34	7.87×10^{-2}	2.96	1.76×10^{-3}	9.69×10^{-3}	1.57×10^{-3}	3.86×10^{-4}	3.53×10^{1}	8.41×10^{-3}	3.24×10^{3}	2.07	1.81	–	–	–
BY tank farm	9.86	8.65×10^{-3}	2.15×10^{-2}	1.88×10^{-4}	4.95×10^{-4}	2.22×10^{-3}	–	3.81×10^{1}	3.44×10^{-2}	1.17×10^{4}	–	3.30	–	–	–
C tank farm	1.39×10^{2}	1.90×10^{-1}	1.67	2.48×10^{-2}	5.58×10^{-3}	1.49×10^{-2}	6.47×10^{-1}	3.94×10^{1}	3.92×10^{-3}	9.68×10^{3}	2.16×10^{1}	3.47×10^{1}	–	–	–
TX tank farm	8.21×10^{-1}	7.88×10^{-4}	2.01×10^{-3}	1.71×10^{-5}	4.52×10^{-5}	2.02×10^{-4}	1.15×10^{-5}	3.47	3.13×10^{-3}	1.06×10^{3}	–	3.00×10^{-1}	–	–	–
U tank farm	6.36×10^{-1}	8.63×10^{-4}	2.27×10^{-2}	2.53×10^{-5}	1.30×10^{-4}	1.31×10^{-3}	–	3.76×10^{-1}	6.14×10^{-4}	2.59×10^{1}	–	1.93	–	–	–

Note: To convert kilograms to pounds, multiply by 2.2046.

Key: 2,4,6-TCP=2,4,6-trichlorophenol; C-14=carbon-14; Cr=chromium; H-3=hydrogen-3 (tritium); Hg=mercury; I-129=iodine-129; NO_3=nitrate; Np-237=neptunium-237; Pb=lead; PCBs=polychlorinated biphenyls; Tc-99=technetium-99; U-238=uranium-238; Utot=total uranium.

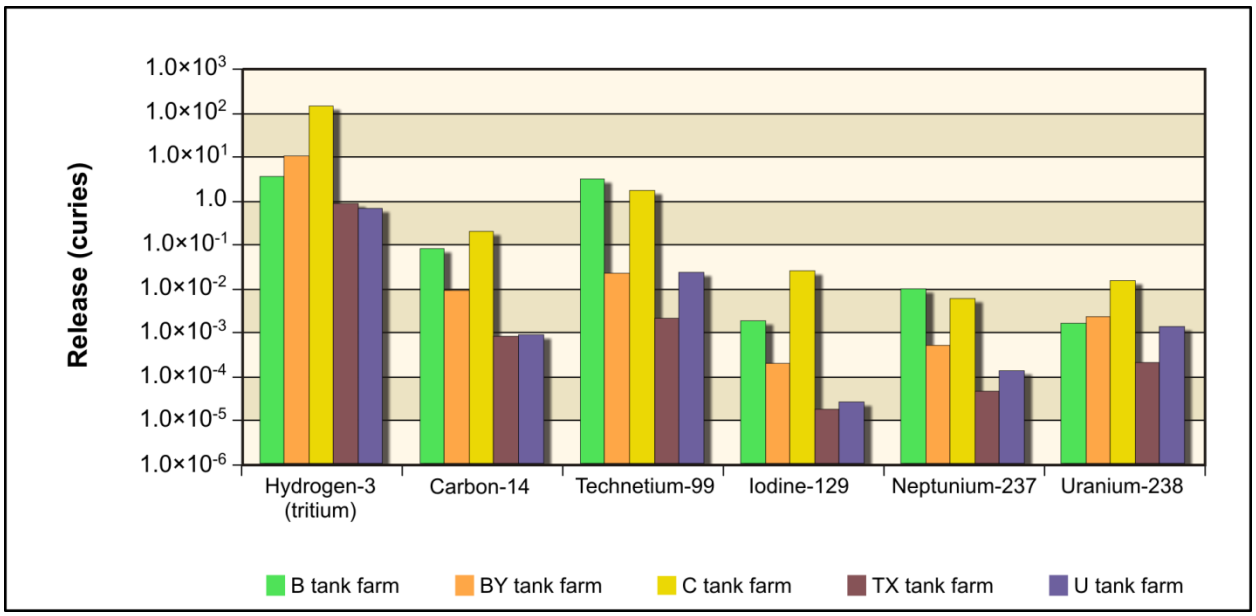


Figure M–55. Tank Closure Alternative 6A, Base and Option Cases, Radionuclide Releases to the Vadose Zone from Other Sources in Tank Farms B, BY, C, TX, and U

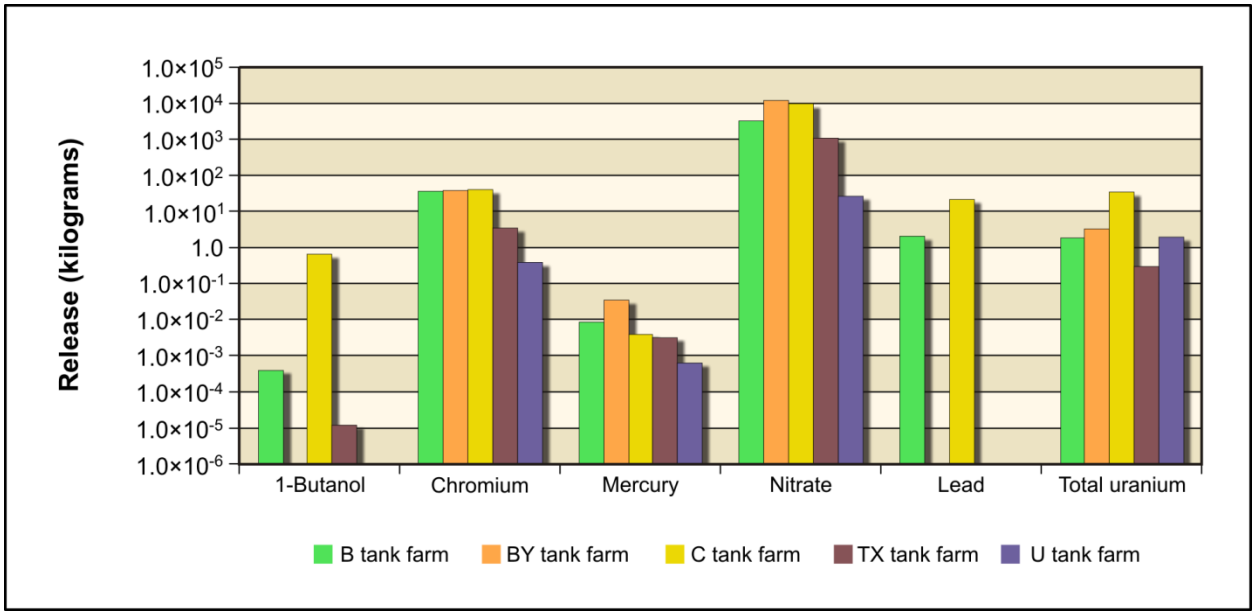


Figure M–56. Tank Closure Alternative 6A, Base and Option Cases, Chemical Releases to the Vadose Zone from Other Sources in Tank Farms B, BY, C, TX, and U

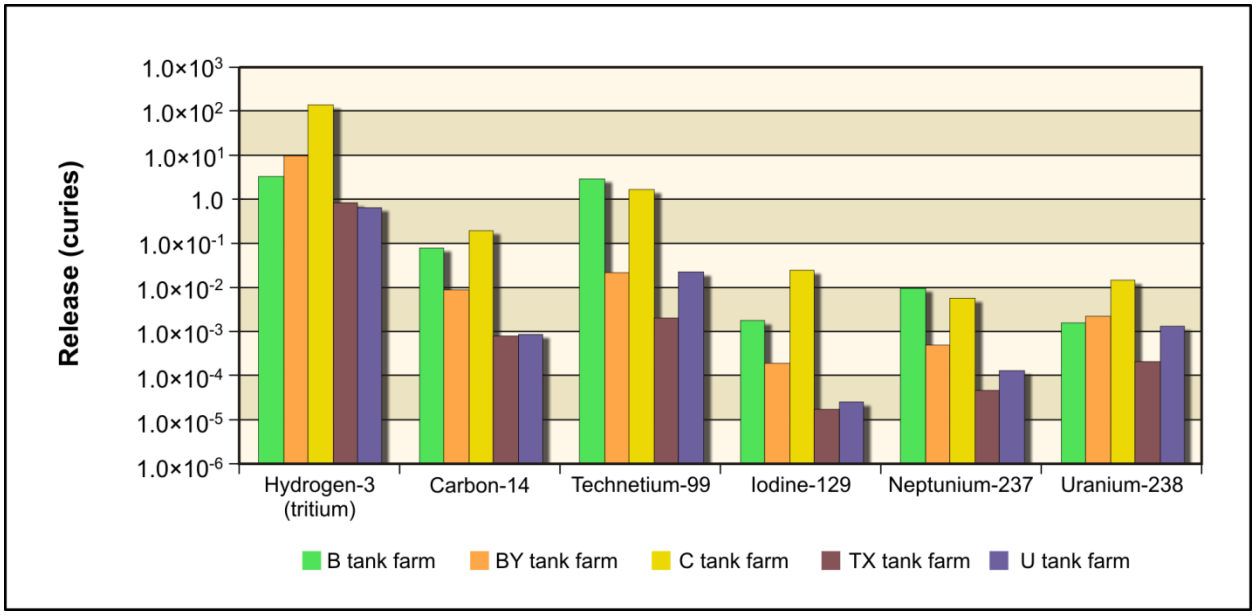


Figure M–57. Tank Closure Alternative 6B, Base and Option Cases, Radionuclide Releases to the Vadose Zone from Other Sources in Tank Farms B, BY, C, TX, and U

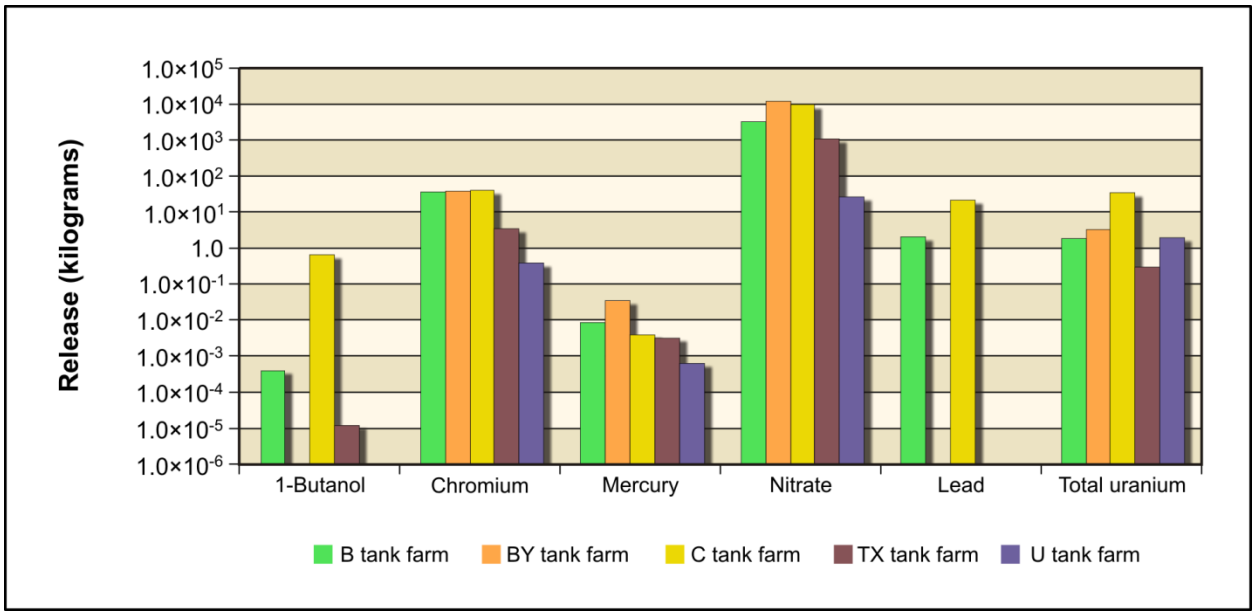


Figure M–58. Tank Closure Alternative 6B, Base and Option Cases, Chemical Releases to the Vadose Zone from Other Sources in Tank Farms B, BY, C, TX, and U

M.4.2 FFTF Decommissioning Alternatives

M.4.2.1 FFTF Decommissioning Alternative 1: No Action

Under FFTF Decommissioning Alternative 1, only those actions consistent with previous DOE National Environmental Policy Act actions would be completed. Final decommissioning of FFTF would not occur. For analysis purposes, the remaining waste would be available for release to the environment after an institutional control period of 100 years. Results for potential releases under all FFTF Decommissioning alternatives are shown in Table M–30. Potential releases to the vadose zone under FFTF Decommissioning Alternative 1 are indicated in Figure M–59.

Table M–30. FFTF Decommissioning Alternatives 1, 2, and 3 Radionuclide Releases to the Vadose Zone (curies)

Alternative	H-3	C-14	K-40	Tc-99	Cs-137
Alternative 1	3.72×10^{-1}	1.68×10^{1}	2.16×10^{-9}	2.72×10^{1}	2.27×10^{-7}
Alternative 2	4.66×10^{-7}	1.57×10^{1}	2.10×10^{-9}	2.72×10^{1}	–
Alternative 3	2.96×10^{-6}	2.57×10^{-4}	2.31×10^{-9}	4.52×10^{-6}	–

Key: C-14=carbon-14; Cs-137=cesium-137; FFTF=Fast Flux Test Facility; H-3=hydrogen-3 (tritium); K-40=potassium-40; Tc-99=technetium-99.

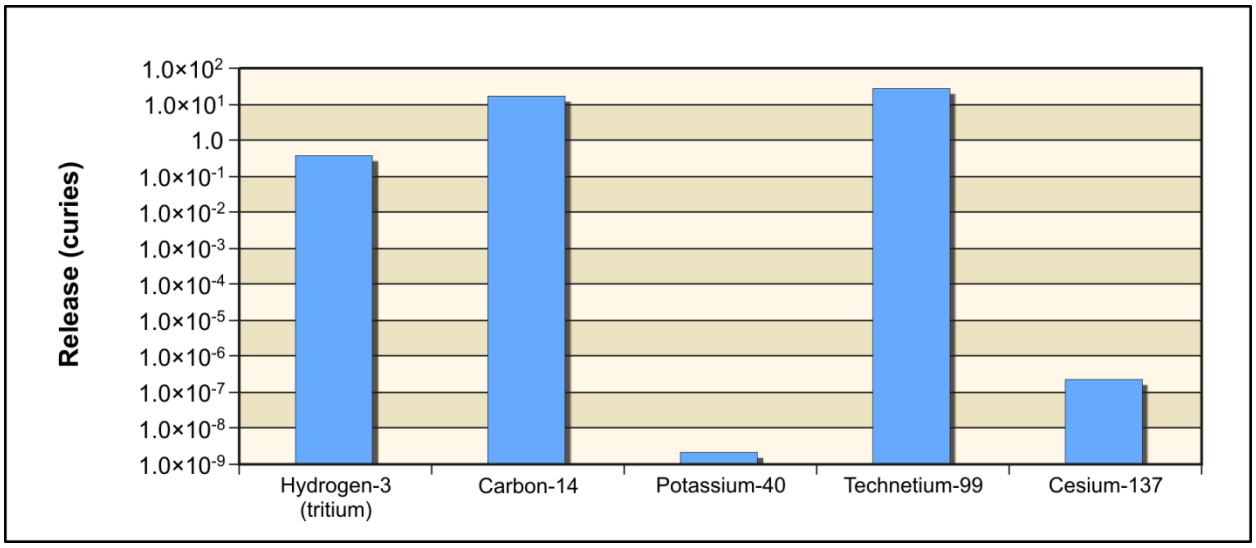


Figure M–59. FFTF Decommissioning Alternative 1 Radionuclide Releases to the Vadose Zone

M.4.2.2 FFTF Decommissioning Alternative 2: Entombment

Under FFTF Decommissioning Alternative 2, all aboveground structures and minimal below-grade structures, equipment, and materials would be removed. An RCRA-compliant barrier would be constructed over the RCB and any other remaining below-grade structures (including the reactor vessel). Potential releases to the vadose zone under FFTF Decommissioning Alternative 2 are indicated in Figure M–60.

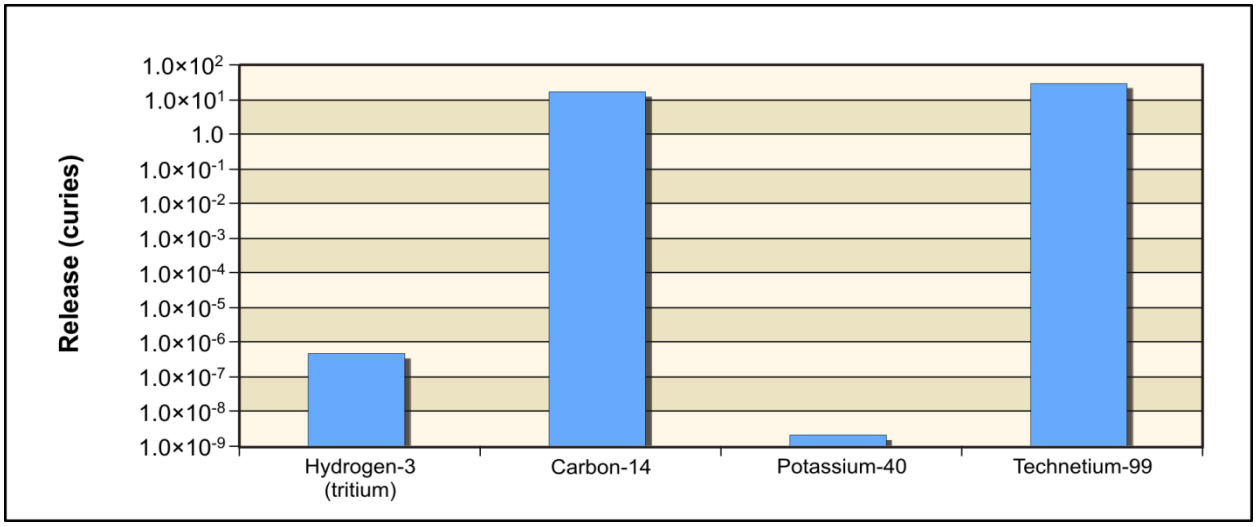


Figure M–60. FFTF Decommissioning Alternative 2 Radionuclide Releases to the Vadose Zone

M.4.2.3 FFTF Decommissioning Alternative 3: Removal

Under FFTF Decommissioning Alternative 3, all aboveground structures and contaminated below-grade structures, equipment, and materials would be removed. Potential releases to the vadose zone under FFTF Decommissioning Alternative 3 are indicated in Figure M–61.

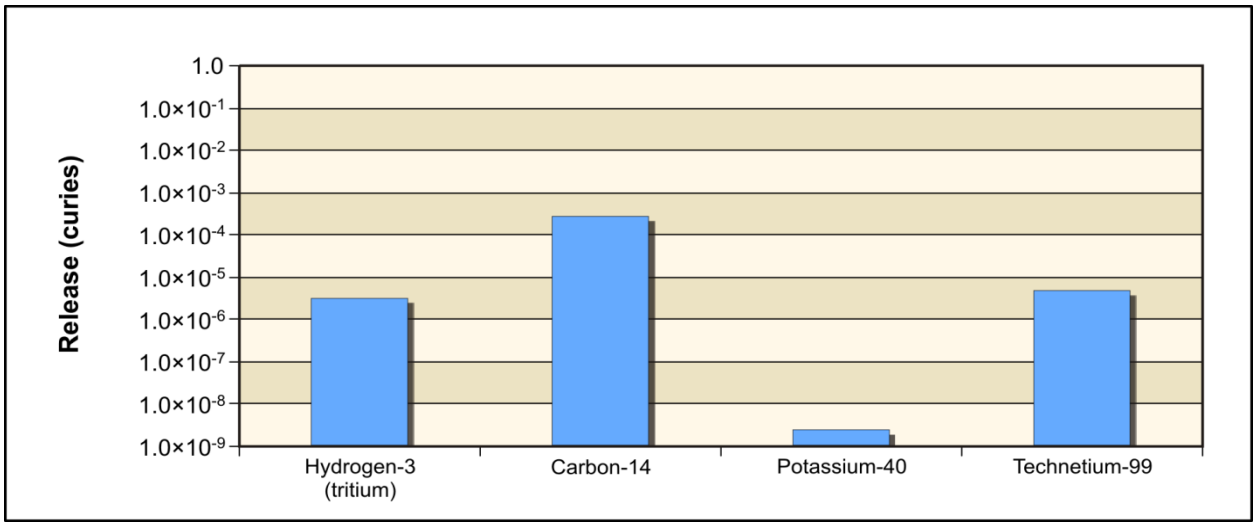


Figure M–61. FFTF Decommissioning Alternative 3 Radionuclide Releases to the Vadose Zone

M.4.3 Waste Management Alternatives

M.4.3.1 Waste Management Alternative 1

Under Waste Management Alternative 1, only the waste currently generated on site at Hanford from non-CERCLA actions would continue to be disposed of in LLBG 218-W-5, trenches 31 and 34. Although short-term impacts do not address impacts associated with closure activities for this site, for the purpose of analyzing long-term impacts, it is assumed that these trenches would be closed using an RCRA-compliant barrier consistent with the closure plans for these burial grounds. As a result, the non-CERCLA waste disposed of in these trenches from 2008 to 2035 would become available for release to the environment. Potential releases to the vadose zone under Waste Management Alternative 1 are indicated in Table M–31 and Figures M–62 and M–63.

Table M–31. Waste Management Alternative 1 Radionuclide and Chemical Releases to the Vadose Zone

Source	Radionuclide (curies)										Chemical (kilograms)					
	H-3	C-14	Sr-90	Tc-99	I-129	Cs-137	Np-237	U-238	Pu-239	Am-241	Cr	F	Hg	NO_3	Pb	Utot
Trench 31	1.75×10^{3}	5.84×10^{-2}	1.02×10^{2}	6.04×10^{-1}	6.56×10^{-4}	8.84	5.02×10^{-4}	1.06×10^{-1}	4.92×10^{-3}	1.62×10^{-4}	8.96×10^{1}	1.37×10^{2}	2.72	1.49×10^{3}	5.77×10^{1}	1.37×10^{-1}
Trench 34	1.75×10^{3}	6.07×10^{-2}	1.10×10^{2}	6.04×10^{-1}	6.56×10^{-4}	1.02×10^{1}	5.12×10^{-4}	1.07×10^{-1}	5.68×10^{-3}	1.88×10^{-4}	8.96×10^{1}	1.37×10^{2}	2.72	1.49×10^{3}	5.77×10^{1}	1.37×10^{-1}

Note: To convert kilograms to pounds, multiply by 2.2046.

Key: Am-241=americium-241; C-14=carbon-14; Cr=chromium; Cs-137=cesium-137; F=fluoride; H-3=hydrogen-3 (tritium); Hg=mercury; I-129=iodine-129; NO_3=nitrate; Np-237=neptunium-237; Pb=lead; Pu-239=plutonium-239; Sr-90=strontium-90; Tc-99=technetium-99; U-238=uranium-238; Utot=total uranium.

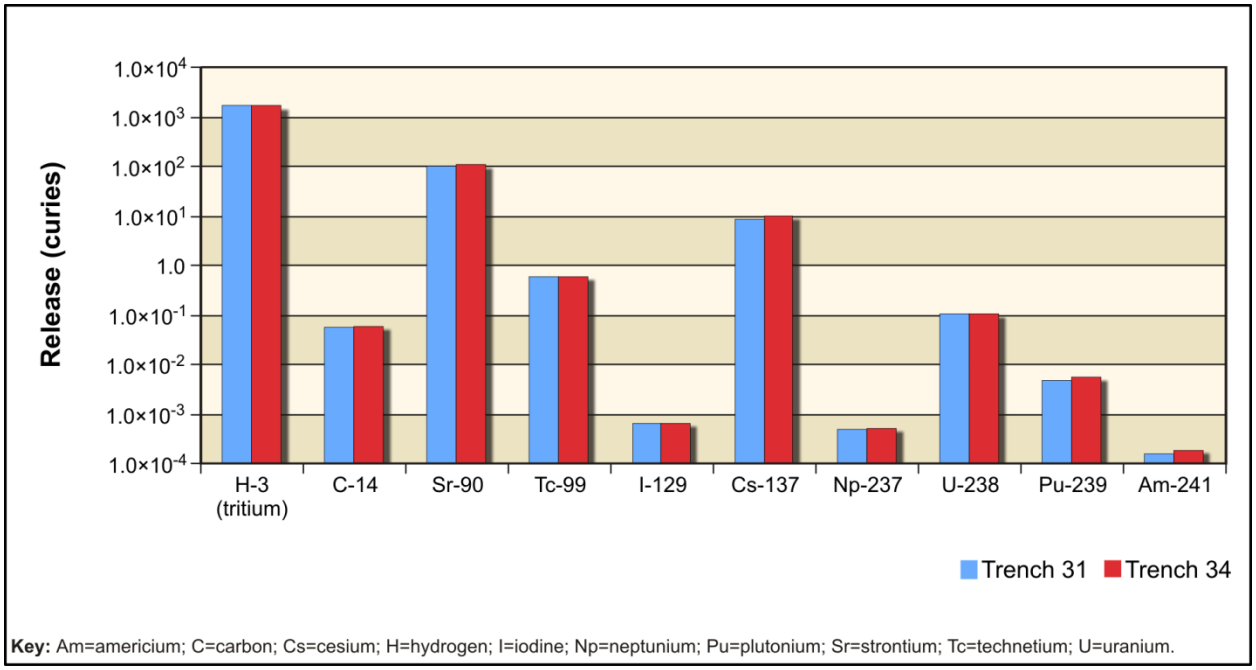


Figure M–62. Waste Management Alternative 1 Radionuclide Releases to the Vadose Zone

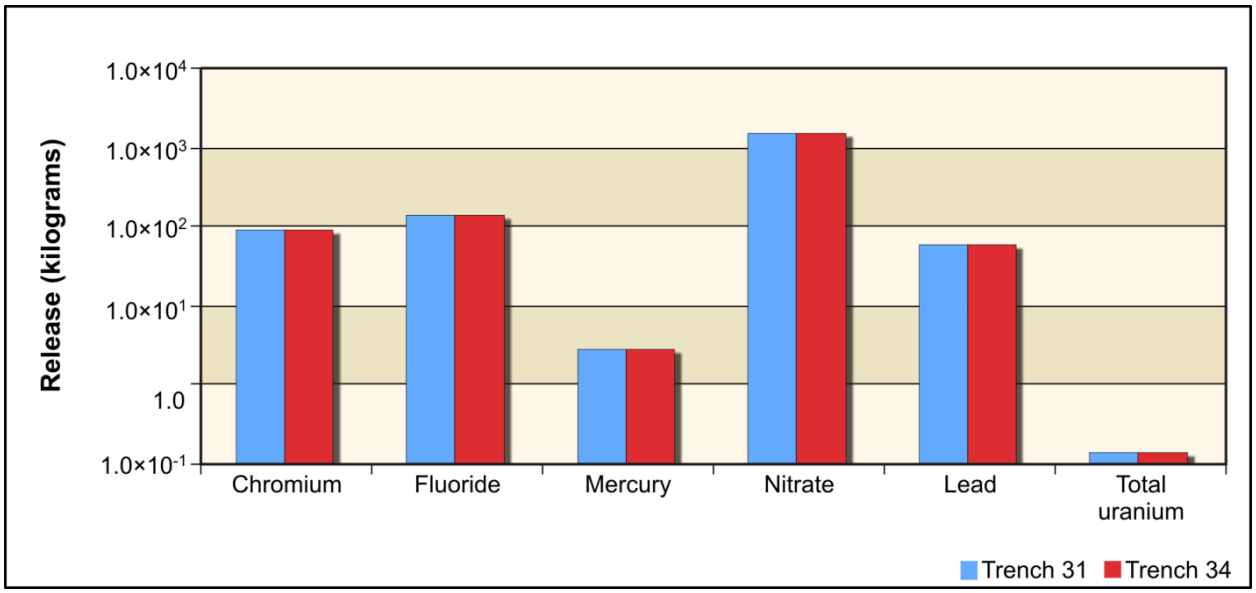


Figure M–63. Waste Management Alternative 1 Chemical Releases to the Vadose Zone

M.4.3.2 Waste Management Alternative 2

Under Waste Management Alternative 2, waste from tank treatment operations, onsite non-CERCLA sources, FFTF decommissioning, waste management, and other DOE sites would be disposed of in IDF-East. Waste from tank farm cleanup activities would be disposed of in the RPPDF. As a result, the waste disposed of in these two facilities would become available for release to the environment. Because different waste types would result from the Tank Closure action alternatives, three disposal groups were considered to account for the different IDF-East sizes and operational time periods. In addition, within these three disposal groups, subgroups were identified to allow for consideration of the different waste types resulting from the Tank Closure alternatives.

M.4.3.2.1 Waste Management Alternative 2: Disposal in IDF, 200-East Area Only, Disposal Group 1, Subgroup 1-A

Disposal Group 1, Subgroup 1-A, addresses the waste resulting from Tank Closure Alternative 2B, onsite non-CERCLA sources, FFTF decommissioning, waste management, and other DOE sites. Waste forms for IDF-East include the following:

- ILAW glass
- LAW melters
- Tank closure secondary waste
- FFTF decommissioning secondary waste
- Waste management secondary waste
- Offsite waste
- Onsite non-CERCLA waste

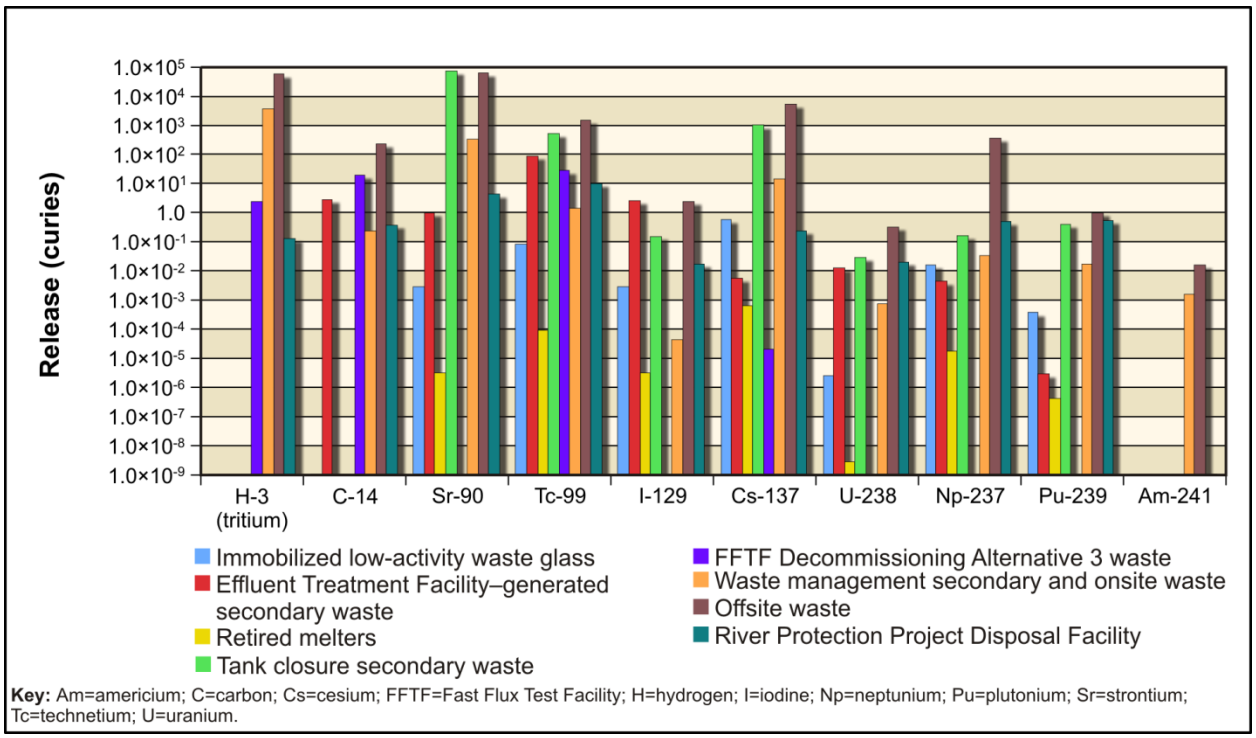
Waste forms for the RPPDF include those resulting from tank closure cleanup activities under Tank Closure Alternative 2B. Potential releases to the vadose zone under Waste Management Alternative 2, Disposal Group 1, Subgroup 1-A, are indicated in Table M–32 and Figures M–64 and M–65.

Table M–32. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-A, Radionuclide and Chemical Releases to the Vadose Zone

Source	Radionuclide (curies)										Chemical (kilograms)					
	H-3	C-14	Sr-90	Tc-99	I-129	Cs-137	Np-237	U-238	Pu-239	Am-241	Cr	F	Hg	NO_3	Pb	Utot
ILAW glass	–	-	2.71×10^{-3}	7.85×10^{-2}	2.64×10^{-3}	5.38×10^{-1}	2.31×10^{-6}	1.51×10^{-2}	3.49×10^{-4}	–	1.26×10^{2}	–	–	–	2.46	1.04×10^{1}
ETF-generated secondary waste	–	2.77	9.24×10^{-1}	8.62×10^{1}	2.50	5.44×10^{-3}	1.20×10^{-2}	4.24×10^{-3}	2.76×10^{-6}	–	4.43×10^{1}	–	8.07×10^{-1}	9.01×10^{6}	8.36×10^{-2}	4.21
Retired melters	–	–	3.02×10^{-6}	8.75×10^{-5}	2.96×10^{-6}	6.01×10^{-4}	2.58×10^{-9}	1.69×10^{-5}	3.90×10^{-7}	–	1.41×10^{-1}	–	–	–	2.74×10^{-3}	1.15×10^{-2}
TC secondary waste	–	–	7.36×10^{4}	4.92×10^{2}	1.45×10^{-1}	1.02×10^{3}	2.81×10^{-2}	1.61×10^{-1}	3.95×10^{-1}	–	1.94×10^{3}	–	2.40×10^{2}	–	3.29	1.03×10^{2}
FFTF Decommis-sioning Alternative 3 waste	2.29	1.86×10^{1}	–	2.72×10^{1}	–	1.94×10^{-5}	–	–	–	–	7.51×10^{-3}	–	–	–	9.74×10^{-5}	2.16×10^{3}
FFTF Decommis-sioning Alternative 2 waste	2.29	2.18×10^{-4}	–	1.48×10^{-2}	–	1.88×10^{-5}	–	–	–	–	7.49×10^{-3}	–	–	–	9.41×10^{-5}	1.82×10^{-3}
WM secondary and onsite waste	3.66×10^{3}	2.29×10^{-1}	3.31×10^{2}	1.35	4.19×10^{-5}	1.42×10^{1}	7.33×10^{-4}	3.26×10^{-2}	1.62×10^{-2}	1.46×10^{-3}	1.83×10^{2}	2.74×10^{2}	1.23×10^{1}	2.97×10^{3}	3.45×10^{2}	4.20×10^{-2}
Offsite waste	5.57×10^{4}	2.25×10^{2}	6.05×10^{4}	1.46×10^{3}	2.26	5.16×10^{3}	3.07×10^{-1}	3.48×10^{2}	9.20×10^{-1}	1.50×10^{-2}	8.05×10^{1}	–	2.53	–	8.70×10^{-1}	–
RPPDF	1.27×10^{-1}	3.61×10^{-1}	4.15	9.71	1.67×10^{-2}	2.30×10^{-1}	1.85×10^{-2}	4.66×10^{-1}	5.31×10^{-1}	–	5.86×10^{2}	–	1.61	3.93×10^{4}	4.97	6.60×10^{2}

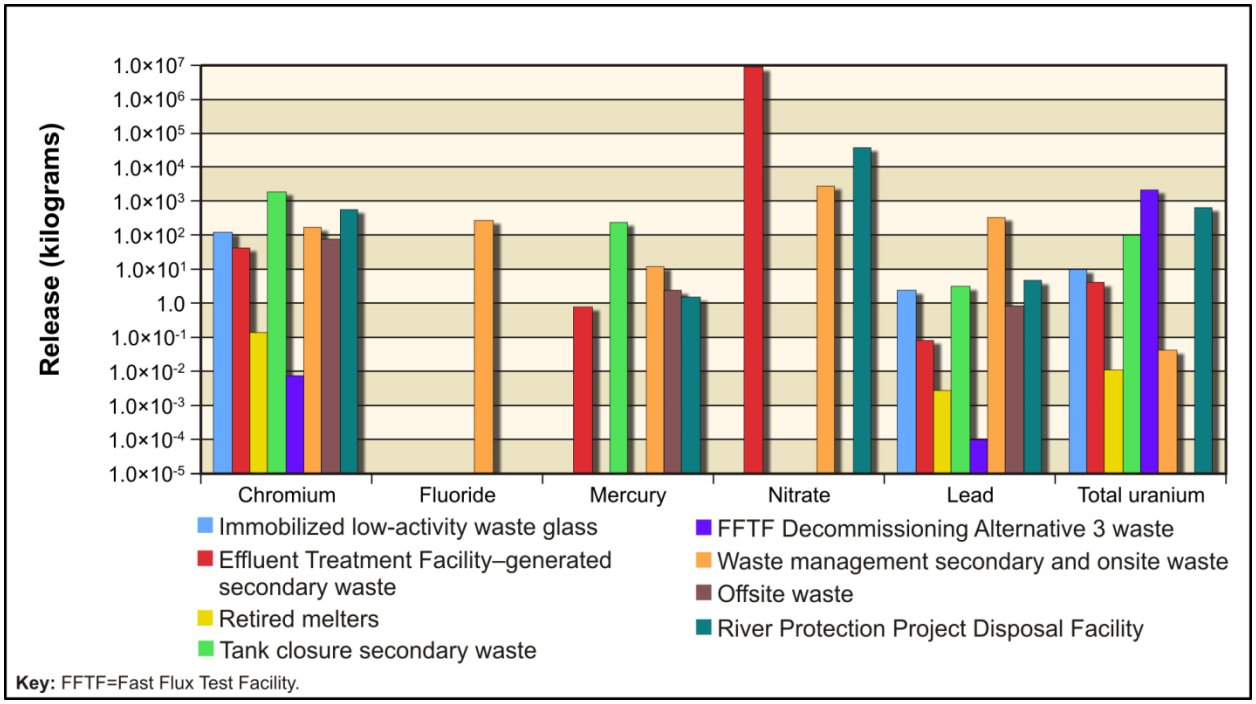
Note: To convert kilograms to pounds, multiply by 2.2046.

Key: Am-241=americium-241; C-14=carbon-14; Cr=chromium; Cs-137=cesium-137; ETF=Effluent Treatment Facility; F=fluoride; FFTF=Fast Flux Test Facility; H-3=hydrogen-3 (tritium); Hg=mercury; I-129=iodine-129; ILAW=immobilized low-activity waste; NO_3=nitrate; Np-237=neptunium-237; Pb=lead; Pu-239=plutonium-239; RPPDF=River Protection Project Disposal Facility; Sr-90=strontium-90; TC=tank closure; Tc-99=technetium-99; U-238=uranium-238; Utot=total uranium; WM=waste management.



Key: Am=americium; C=carbon; Cs=cesium; FFTF=Fast Flux Test Facility; H=hydrogen; I=iodine; Np=neptunium; Pu=plutonium; Sr=strontium; Tc=technetium; U=uranium.

Figure M–64. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-A, Radionuclide Releases to the Vadose Zone



Key: FFTF=Fast Flux Test Facility.

Figure M–65. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-A, Chemical Releases to the Vadose Zone

M.4.3.2.2 Waste Management Alternative 2: Disposal in IDF, 200-East Area Only, Disposal Group 1, Subgroup 1-B

Disposal Group 1, Subgroup 1-B, addresses the waste resulting from Tank Closure Alternative 3A, onsite non-CERCLA sources, FFTF decommissioning, waste management, and other DOE sites. Waste forms for IDF-East include the following:

- ILAW glass
- LAW melters
- bulk vitrification glass
- Tank closure secondary waste
- FFTF decommissioning secondary waste
- Waste management secondary waste
- Offsite waste
- Onsite non-CERCLA waste

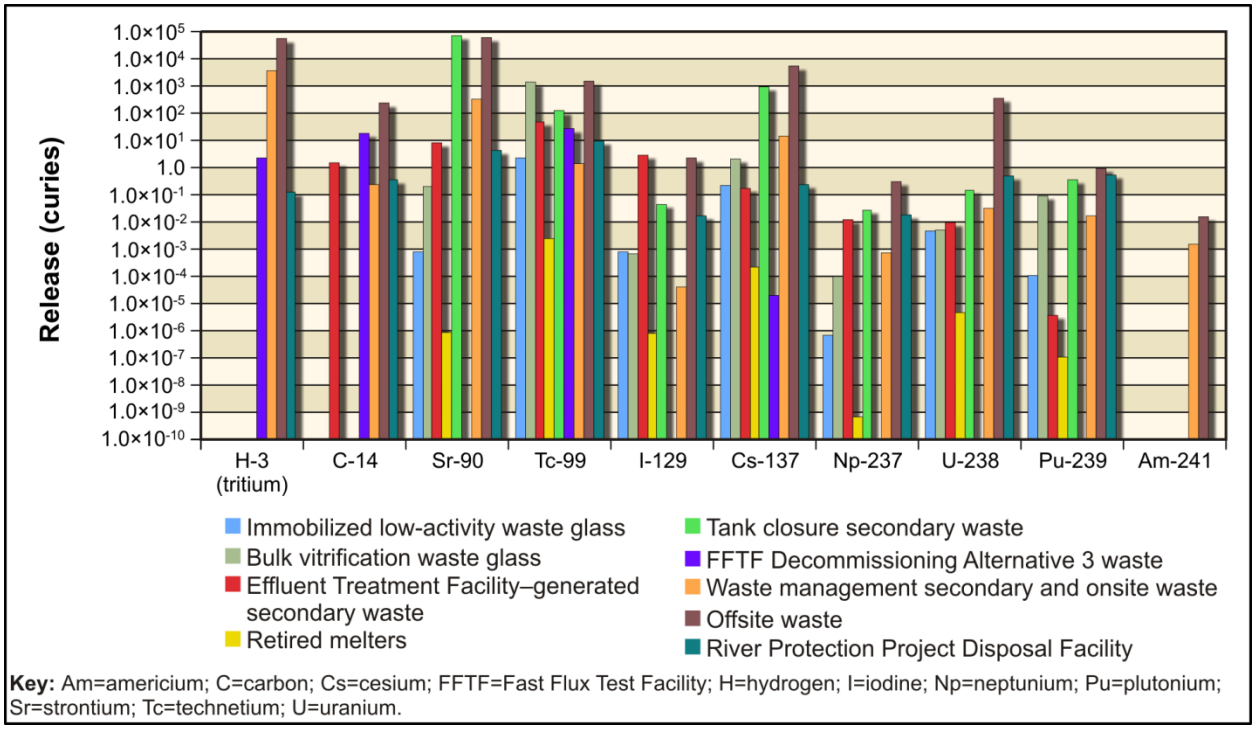
Waste forms for the RPPDF include those resulting from tank closure cleanup activities under Tank Closure Alternative 3A. Potential releases to the vadose zone under Waste Management Alternative 2, Disposal Group 1, Subgroup 1-B, are indicated in Table M–33 and Figures M–66 and M–67.

Table M–33. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-B, Radionuclide and Chemical Releases to the Vadose Zone

	Radionuclide (curies)										Chemical (kilograms)					
Source	**H-3**	**C-14**	**Sr-90**	**Tc-99**	**I-129**	**Cs-137**	**Np-237**	**U-238**	**Pu-239**	**Am-241**	**Cr**	**F**	**Hg**	**NO_3**	**Pb**	**Utot**
ILAW glass	–	–	8.12×10^{-4}	2.30	7.75×10^{-4}	2.10×10^{-1}	6.86×10^{-7}	4.49×10^{-3}	1.04×10^{-4}	–	3.71×10^{1}	–	–	–	7.39×10^{-1}	3.13
BV waste glass	–	–	1.94×10^{-1}	1.34×10^{3}	6.67×10^{-4}	2.00	9.49×10^{-5}	5.08×10^{-3}	8.95×10^{-2}	–	3.18×10^{1}	–	–	–	6.62×10^{-1}	3.41
ETF-generated secondary waste	–	1.54	7.84	4.63×10^{1}	2.74	1.69×10^{-1}	1.21×10^{-2}	9.18×10^{-3}	3.75×10^{-6}	–	2.76×10^{1}	–	8.05×10^{-1}	8.14×10^{6}	1.38×10^{1}	7.37
Retired melters	–	–	8.27×10^{-7}	2.34×10^{-3}	7.89×10^{-7}	2.13×10^{-4}	6.97×10^{-10}	4.57×10^{-6}	1.06×10^{-7}	–	3.77×10^{-2}	–	–	–	7.53×10^{-4}	3.18×10^{-3}
TC secondary waste	–	–	7.27×10^{4}	1.28×10^{2}	4.25×10^{-2}	9.16×10^{2}	2.77×10^{-2}	1.47×10^{-1}	3.59×10^{-1}	–	8.02×10^{2}	–	2.38×10^{2}	–	2.89	9.08×10^{1}
FFTF Decommis-sioning Alternative 3 waste	2.29	1.86×10^{1}	–	2.72×10^{1}	–	1.94×10^{-5}	–	–	–	–	7.51×10^{-3}	–	–	–	9.74×10^{-5}	2.16×10^{3}
FFTF Decommis-sioning Alternative 2 waste	2.29	2.18×10^{-4}	–	1.48×10^{-2}	–	1.88×10^{-5}	–	–	–	–	7.49×10^{-3}	–	–	–	9.41×10^{-5}	1.82×10^{-3}
WM secondary and onsite waste	3.66×10^{3}	2.29×10^{-1}	3.31×10^{2}	1.35	4.19×10^{-5}	1.42×10^{1}	7.33×10^{-4}	3.26×10^{-2}	1.62×10^{-2}	1.46×10^{-3}	1.83×10^{2}	2.74×10^{2}	1.23×10^{1}	2.97×10^{3}	3.45×10^{2}	4.20×10^{-2}
Offsite waste	5.57×10^{4}	2.25×10^{2}	6.05×10^{4}	1.46×10^{3}	2.26	5.16×10^{3}	3.07×10^{-1}	3.48×10^{2}	9.20×10^{-1}	1.50×10^{-2}	8.05×10^{1}	–	2.53	–	8.70×10^{-1}	–
RPPDF	1.27×10^{-1}	3.61×10^{-1}	4.15	9.71	1.67×10^{-2}	2.30×10^{-1}	1.85×10^{-2}	4.66×10^{-1}	5.31×10^{-1}	–	5.86×10^{2}	–	1.61	3.93×10^{4}	4.97	6.60×10^{2}

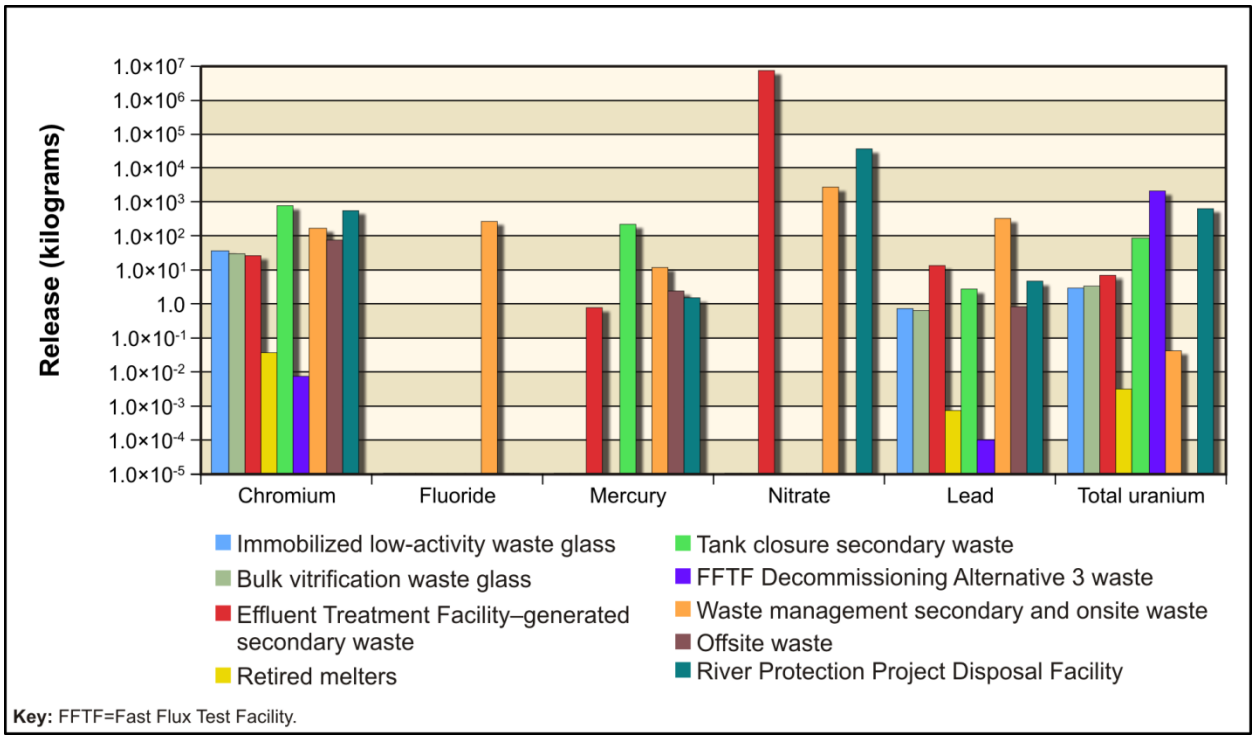
Note: To convert kilograms to pounds, multiply by 2.2046.

Key: Am-241=americium-241; BV=bulk vitrification; C-14=carbon-14; Cr=chromium; Cs-137=cesium-137; ETF=Effluent Treatment Facility; F=fluoride; FFTF=Fast Flux Test Facility; H-3=hydrogen-3 (tritium); Hg=mercury; I-129=iodine-129; ILAW=immobilized low-activity waste; NO_3=nitrate; Np-237=neptunium-237; Pb=lead; Pu-239=plutonium-239; RPPDF=River Protection Project Disposal Facility; Sr-90=strontium-90; TC=tank closure; Tc-99=technetium-99; U-238=uranium-238; Utot=total uranium; WM=waste management.



Key: Am=americium; C=carbon; Cs=cesium; FFTF=Fast Flux Test Facility; H=hydrogen; I=iodine; Np=neptunium; Pu=plutonium; Sr=strontium; Tc=technetium; U=uranium.

Figure M–66. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-B, Radionuclide Releases to the Vadose Zone



Key: FFTF=Fast Flux Test Facility.

Figure M–67. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-B, Chemical Releases to the Vadose Zone

M.4.3.2.3 Waste Management Alternative 2: Disposal in IDF, 200-East Area Only, Disposal Group 1, Subgroup 1-C

Disposal Group 1, Subgroup 1-C, addresses the waste resulting from Tank Closure Alternative 3B, onsite non-CERCLA sources, FFTF decommissioning, waste management, and other DOE sites. Waste forms for IDF-East include the following:

- ILAW glass
- LAW melters
- Cast stone waste
- Tank closure secondary waste
- FFTF decommissioning secondary waste
- Waste management secondary waste
- Offsite waste
- Onsite non-CERCLA waste

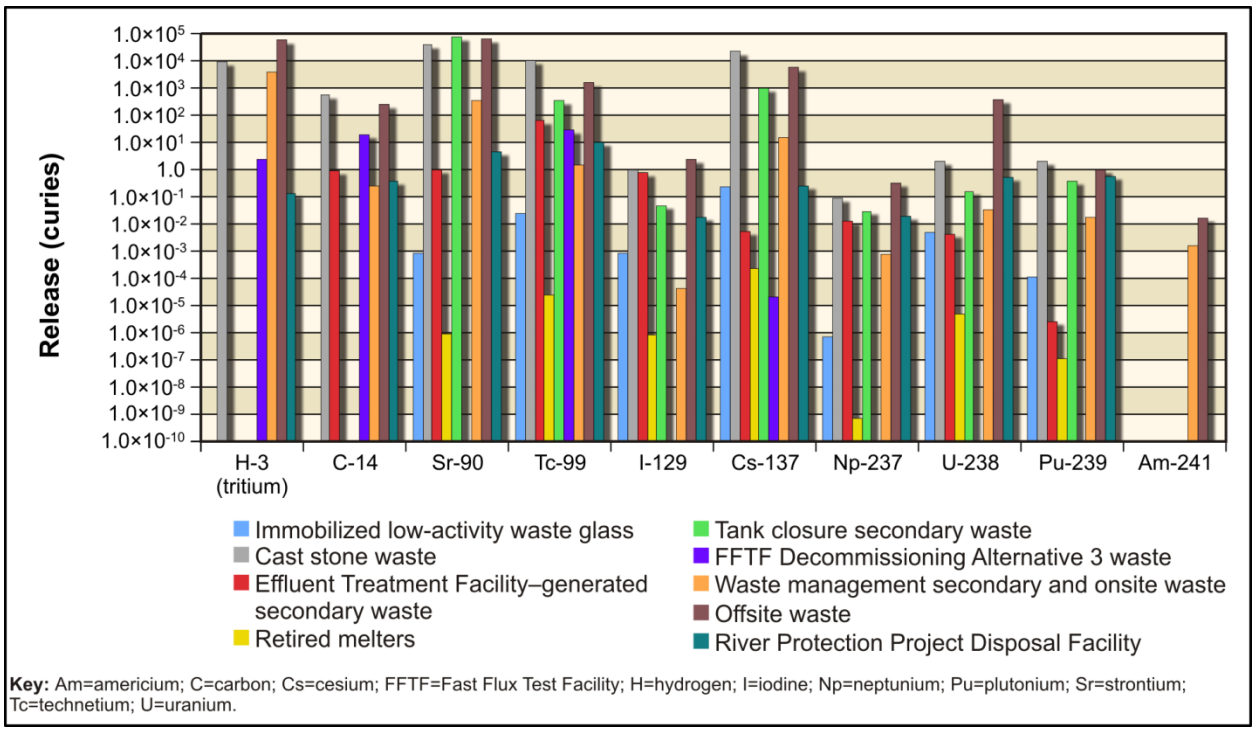
Waste forms for the RPPDF include those resulting from tank closure cleanup activities under Tank Closure Alternative 3B. Potential releases to the vadose zone under Waste Management Alternative 2, Disposal Group 1, Subgroup 1-C, are indicated in Table M–34 and Figures M–68 and M–69.

Table M–34. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-C, Radionuclide and Chemical Releases to the Vadose Zone

Source	Radionuclide (curies)										Chemical (kilograms)					
	H-3	C-14	Sr-90	Tc-99	I-129	Cs-137	Np-237	U-238	Pu-239	Am-241	Cr	F	Hg	NO_3	Pb	Utot
ILAW glass	–	–	8.12×10^{-4}	2.30×10^{-2}	7.75×10^{-4}	2.10×10^{-1}	6.86×10^{-7}	4.49×10^{-3}	1.04×10^{-4}	–	3.71×10^{1}	–	-	-	7.39×10^{-1}	3.13
Cast stone waste	8.44×10^{3}	5.03×10^{2}	3.73×10^{4}	9.14×10^{3}	8.98×10^{-1}	2.08×10^{4}	8.07×10^{-2}	1.93	1.84	–	3.25×10^{5}	–	5.39×10^{1}	4.95×10^{7}	9.08×10^{1}	1.31×10^{3}
ETF-generated secondary waste	–	8.54×10^{-1}	9.13×10^{-1}	5.81×10^{1}	7.32×10^{-1}	4.87×10^{-3}	1.19×10^{-2}	3.84×10^{-3}	2.53×10^{-6}	–	1.84×10^{1}	–	6.00×10^{-1}	2.63×10^{6}	1.06×10^{-1}	3.76
Retired melters	–	–	8.27×10^{-7}	2.34×10^{-5}	7.89×10^{-7}	2.13×10^{-4}	6.97×10^{-10}	4.57×10^{-6}	1.06×10^{-7}	–	3.77×10^{-2}	–	–	–	7.53×10^{-4}	3.18×10^{-3}
TC secondary waste	–	–	7.27×10^{4}	3.33×10^{2}	4.25×10^{-2}	9.16×10^{2}	2.77×10^{-2}	1.47×10^{-1}	3.59×10^{-1}	–	8.02×10^{2}	–	1.78×10^{2}	–	2.89	9.08×10^{1}
FFTF Decommis-sioning Alternative 3 waste	2.29	1.86×10^{1}	–	2.72×10^{1}	–	1.94×10^{-5}	–	–	–	–	7.51×10^{-3}	–	–	–	9.74×10^{-5}	2.16×10^{3}
FFTF Decommis-sioning Alternative 2 waste	2.29	2.18×10^{-4}	–	1.48×10^{-2}	–	1.88×10^{-5}	–	–	–	–	7.49×10^{-3}	–	–	–	9.41×10^{-5}	1.82×10^{-3}
WM secondary and onsite waste	3.66×10^{3}	2.29×10^{-1}	3.31×10^{2}	1.35	4.19×10^{-5}	1.42×10^{1}	7.33×10^{-4}	3.26×10^{-2}	1.62×10^{-2}	1.46×10^{-3}	1.83×10^{2}	2.74×10^{2}	1.23×10^{1}	2.97×10^{3}	3.45×10^{2}	4.20×10^{-2}
Offsite waste	5.57×10^{4}	2.25×10^{2}	6.05×10^{4}	1.46×10^{3}	2.26	5.16×10^{3}	3.07×10^{-1}	3.48×10^{2}	9.20×10^{-1}	1.50×10^{-2}	8.05×10^{1}	–	2.53	–	8.70×10^{-1}	–
RPPDF	1.27×10^{-1}	3.61×10^{-1}	4.15	9.71	1.67×10^{-2}	2.30×10^{-1}	1.85×10^{-2}	4.66×10^{-1}	5.31×10^{-1}	–	5.86×10^{2}	–	1.61	3.93×10^{4}	4.97	6.60×10^{2}

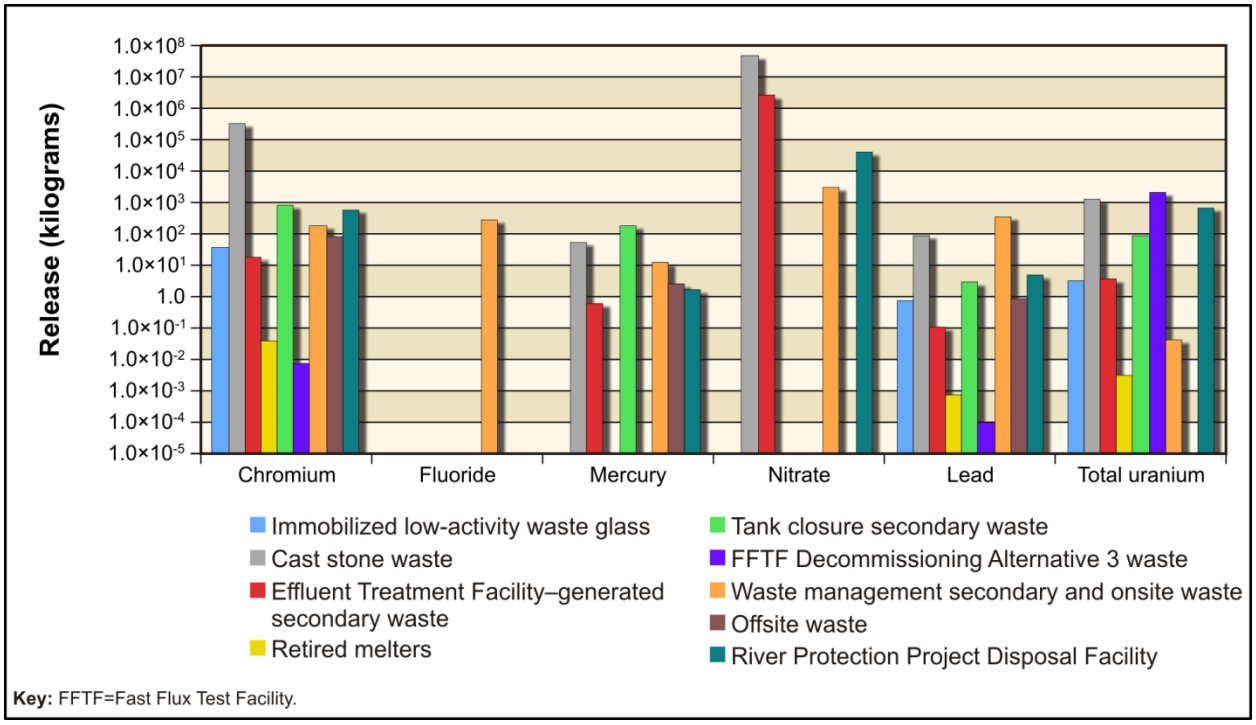
Note: To convert kilograms to pounds, multiply by 2.2046.

Key: Am-241=americium-241; C-14=carbon-14; Cr=chromium; Cs-137=cesium-137; ETF=Effluent Treatment Facility; F=fluoride; FFTF=Fast Flux Test Facility; H-3=hydrogen-3 (tritium); Hg=mercury; I-129=iodine-129; ILAW=immobilized low-activity waste; NO_3=nitrate; Np-237=neptunium-237; Pb=lead; Pu-239=plutonium-239; RPPDF=River Protection Project Disposal Facility; Sr-90=strontium-90; TC=tank closure; Tc-99=technetium-99; U-238=uranium-238; Utot=total uranium; WM=waste management.



Key: Am=americium; C=carbon; Cs=cesium; FFTF=Fast Flux Test Facility; H=hydrogen; I=iodine; Np=neptunium; Pu=plutonium; Sr=strontium; Tc=technetium; U=uranium.

Figure M–68. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-C, Radionuclide Releases to the Vadose Zone



Key: FFTF=Fast Flux Test Facility.

Figure M–69. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-C, Chemical Releases to the Vadose Zone

M.4.3.2.4 Waste Management Alternative 2: Disposal in IDF, 200-East Area Only, Disposal Group 1, Subgroup 1-D

Disposal Group 1, Subgroup 1-D, addresses the waste resulting from Tank Closure Alternative 3C, onsite non-CERCLA sources, FFTF decommissioning, waste management, and other DOE sites. Waste forms for IDF-East include the following:

- ILAW glass
- LAW melters
- Steam reforming waste
- Tank closure secondary waste
- FFTF decommissioning secondary waste
- Waste management secondary waste
- Offsite waste
- Onsite non-CERCLA waste

Waste forms for the RPPDF include those resulting from tank closure cleanup activities under Tank Closure Alternative 3C. Potential releases to the vadose zone under Waste Management Alternative 2, Disposal Group 1, Subgroup 1-D, are indicated in Table M–35 and Figures M–70 and M–71.

Table M–35. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-D, Radionuclide and Chemical Releases to the Vadose Zone

	Radionuclide (curies)										Chemical (kilograms)					
Source	**H-3**	**C-14**	**Sr-90**	**Tc-99**	**I-129**	**Cs-137**	**Np-237**	**U-238**	**Pu-239**	**Am-241**	**Cr**	**F**	**Hg**	**NO_3**	**Pb**	**Utot**
ILAW glass	–	–	8.12×10^{-4}	2.30	7.75×10^{-4}	2.10×10^{-1}	6.86×10^{-7}	4.49×10^{-3}	1.04×10^{-4}	–	3.71×10^{1}	–	–	–	7.39×10^{-1}	3.13
Steam Reforming waste	–	–	2.07×10^{2}	3.76×10^{3}	1.25	2.14×10^{3}	1.78×10^{-1}	9.54	1.69×10^{2}	–	6.01×10^{4}	–	–	–	1.25×10^{3}	6.44×10^{3}
ETF-generated secondary waste	–	1.54	7.69	4.63×10^{1}	2.74	1.71×10^{-1}	1.20×10^{-2}	8.33×10^{-3}	3.36×10^{-6}	–	2.72×10^{1}	–	8.05×10^{-1}	9.17×10^{6}	1.38×10^{1}	6.72
Retired melters	–	–	8.27×10^{-7}	2.34×10^{-3}	7.89×10^{-7}	2.13×10^{-4}	6.97×10^{-10}	4.57×10^{-6}	1.06×10^{-7}	–	3.77×10^{-2}	–	–	–	7.53×10^{-4}	3.18×10^{-3}
TC secondary waste	–	–	7.28×10^{4}	1.28×10^{2}	4.25×10^{-2}	9.17×10^{2}	2.77×10^{-2}	1.48×10^{-1}	3.59×10^{-1}	–	8.02×10^{2}	–	2.38×10^{2}	–	2.89	9.08×10^{1}
FFTF Decommis-sioning Alternative 3 waste	2.29	1.86×10^{1}	–	2.72×10^{1}	–	1.94×10^{-5}	–	–	–	–	7.51×10^{-3}	–	–	–	9.74×10^{-5}	2.16×10^{3}
FFTF Decommis-sioning Alternative 2 waste	2.29	2.18×10^{-4}	–	1.48×10^{-2}	–	1.88×10^{-5}	–	–	–	–	7.49×10^{-3}	–	–	–	9.41×10^{-5}	1.82×10^{-3}
WM secondary and onsite waste	3.66×10^{3}	2.29×10^{-1}	3.31×10^{2}	1.35	4.19×10^{-5}	1.42×10^{1}	7.33×10^{-4}	3.26×10^{-2}	1.62×10^{-2}	1.46×10^{-3}	1.83×10^{2}	2.74×10^{2}	1.23×10^{1}	2.97×10^{3}	3.45×10^{2}	4.20×10^{-2}
Offsite waste	5.57×10^{4}	2.25×10^{2}	6.05×10^{4}	1.46×10^{3}	2.26	5.16×10^{3}	3.07×10^{-1}	3.48×10^{2}	9.20×10^{-1}	1.50×10^{-2}	8.05×10^{1}	–	2.53	–	8.70×10^{-1}	–
RPPDF	1.27×10^{-1}	3.61×10^{-1}	4.15	9.71	1.67×10^{-2}	2.30×10^{-1}	1.85×10^{-2}	4.66×10^{-1}	5.31×10^{-1}	–	5.86×10^{2}	–	1.61	3.93×10^{4}	4.97	6.60×10^{2}

Note: To convert kilograms to pounds, multiply by 2.2046.

Key: Am-241=americium-241; C-14=carbon-14; Cr=chromium; Cs-137=cesium-137; ETF=Effluent Treatment Facility; F=fluoride; FFTF=Fast Flux Test Facility; H-3=hydrogen-3 (tritium); Hg=mercury; I-129=iodine-129; ILAW=immobilized low-activity waste; NO_3=nitrate; Np-237=neptunium-237; Pb=lead; Pu-239=plutonium-239; RPPDF=River Protection Project Disposal Facility; Sr-90=strontium-90; TC=tank closure; Tc-99=technetium-99; U-238=uranium-238; Utot=total uranium; WM=waste management.

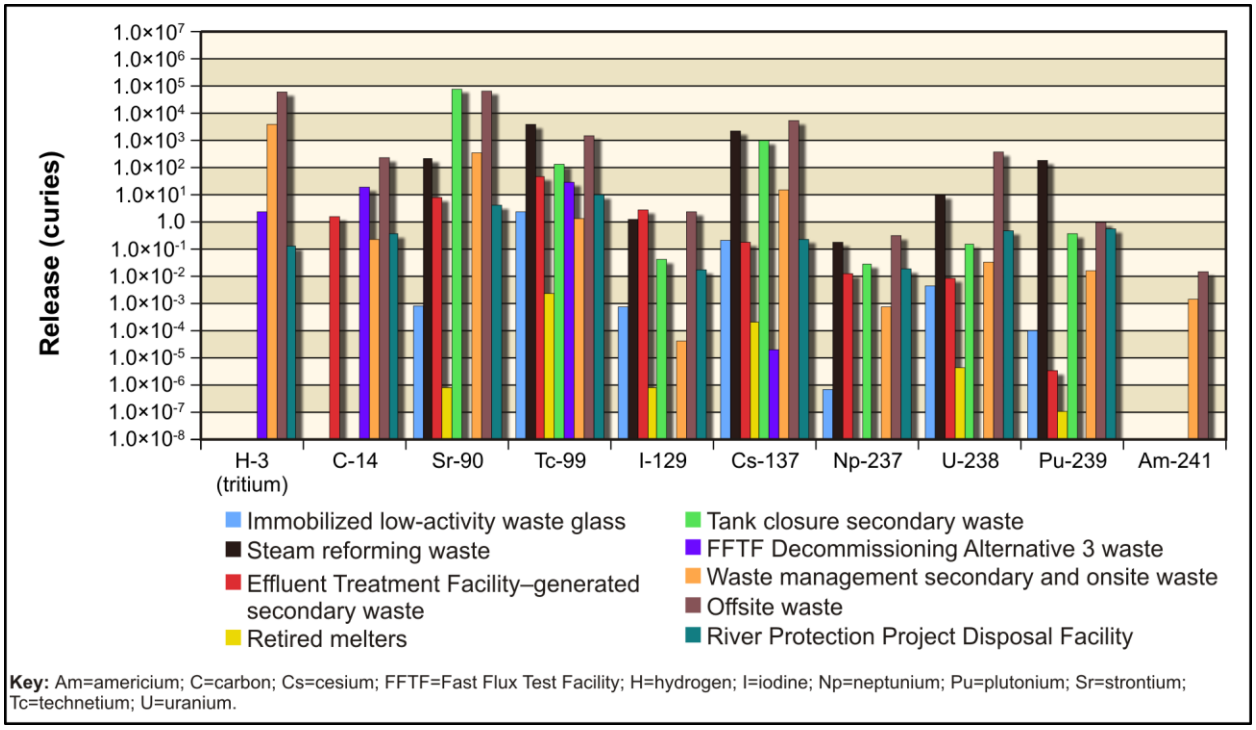


Figure M–70. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-D, Radionuclide Releases to the Vadose Zone

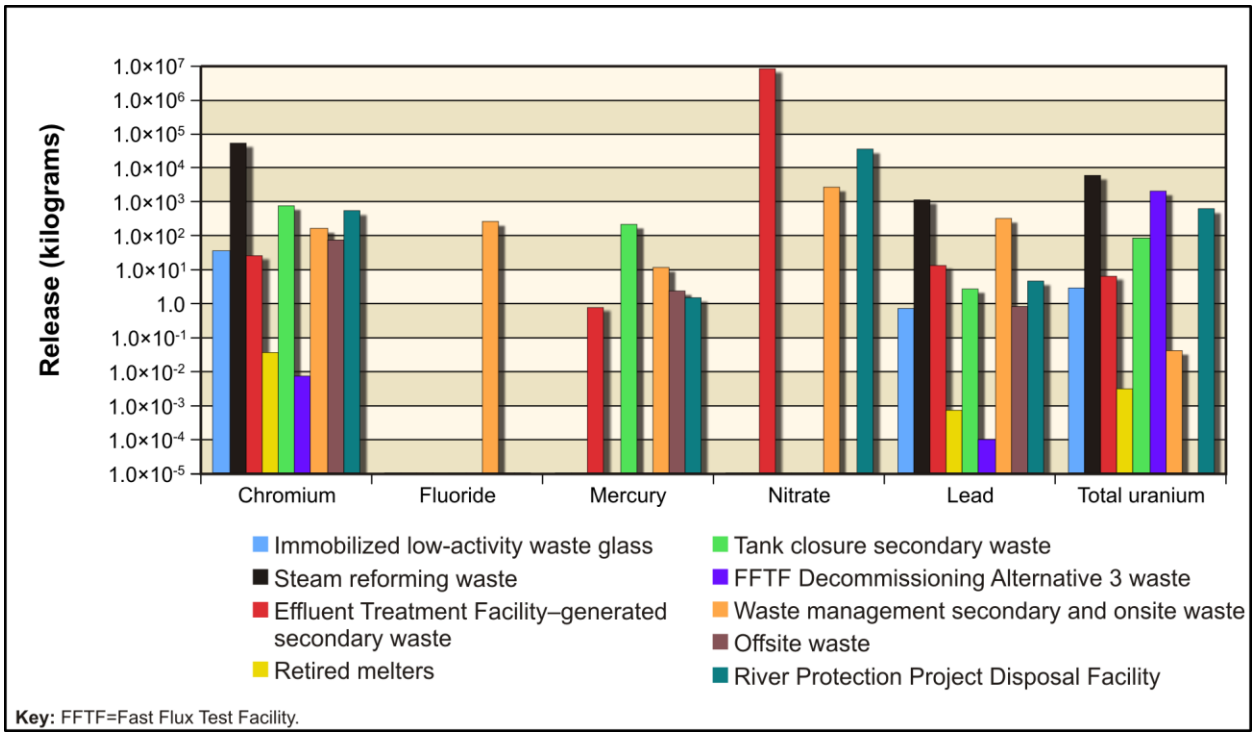


Figure M–71. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-D, Chemical Releases to the Vadose Zone

M.4.3.2.5 Waste Management Alternative 2: Disposal in IDF, 200-East Area Only, Disposal Group 1, Subgroup 1-E

Disposal Group 1, Subgroup 1-E, addresses the waste resulting from Tank Closure Alternative 4, onsite non-CERCLA sources, FFTF decommissioning, waste management, and other DOE sites. Waste forms for IDF-East include the following:

- ILAW glass
- LAW melters
- bulk vitrification glass
- Cast stone waste
- Tank closure secondary waste
- FFTF decommissioning secondary waste
- Waste management secondary waste
- Offsite waste
- Onsite non-CERCLA waste

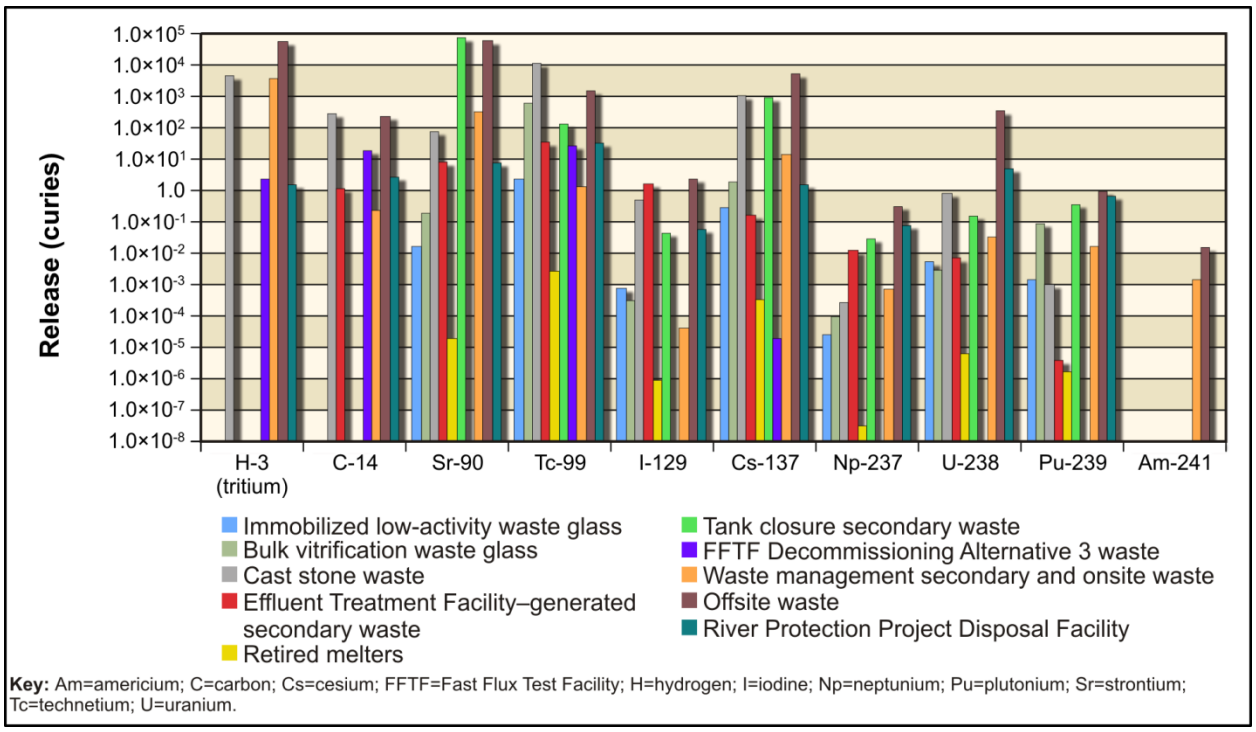
Waste forms for the RPPDF include those resulting from tank closure cleanup activities under Tank Closure Alternative 4. Potential releases to the vadose zone under Waste Management Alternative 2, Disposal Group 1, Subgroup 1-E, are indicated in Table M–36 and Figures M–72 and M–73.

Table M–36. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-E, Radionuclide and Chemical Releases to the Vadose Zone

Source	Radionuclide (curies)										Chemical (kilograms)					
	H-3	C-14	Sr-90	Tc-99	I-129	Cs-137	Np-237	U-238	Pu-239	Am-241	Cr	F	Hg	NO_3	Pb	Utot
ILAW glass	–	–	1.66×10^{-2}	2.31	7.78×10^{-4}	2.90×10^{-1}	2.51×10^{-5}	5.57×10^{-3}	1.49×10^{-3}	–	3.74×10^{1}	–	–	–	7.67×10^{-1}	3.63
BV waste glass	–	–	1.95×10^{-1}	6.18×10^{2}	3.08×10^{-4}	1.90	9.54×10^{-5}	3.00×10^{-3}	9.04×10^{-2}	–	1.47×10^{1}	–	–	–	3.55×10^{-1}	1.97
Cast stone waste	4.66×10^{3}	2.77×10^{2}	7.46×10^{1}	1.09×10^{4}	4.94×10^{-1}	1.04×10^{3}	2.77×10^{-4}	8.16×10^{-1}	1.02×10^{-3}	–	1.78×10^{5}	–	2.86×10^{1}	2.73×10^{7}	4.33×10^{1}	5.64×10^{2}
ETF-generated secondary waste	–	1.18	7.88	3.53×10^{1}	1.66	1.61×10^{-1}	1.22×10^{-2}	7.05×10^{-3}	3.79×10^{-6}	–	2.31×10^{1}	–	7.05×10^{-1}	5.20×10^{6}	7.43	5.89
Retired melters	–	–	1.92×10^{-5}	2.65×10^{-3}	8.94×10^{-7}	3.32×10^{-4}	3.12×10^{-8}	6.40×10^{-6}	1.71×10^{-6}	–	4.32×10^{-2}	–	–	–	8.80×10^{-4}	4.15×10^{-3}
TC secondary waste	–	–	7.36×10^{4}	1.28×10^{2}	4.28×10^{-2}	9.27×10^{2}	2.80×10^{-2}	1.50×10^{-1}	3.63×10^{-1}	–	8.21×10^{2}	–	2.10×10^{2}	–	2.93	9.22×10^{1}
FFTF Decommis-sioning Alternative 3 waste	2.29	1.86×10^{1}	–	2.72×10^{1}	–	1.94×10^{-5}	–	–	–	–	7.51×10^{-3}	–	–	–	9.74×10^{-5}	2.16×10^{3}
FFTF Decommis-sioning Alternative 2 waste	2.29	2.18×10^{-4}	–	1.48×10^{-2}	–	1.88×10^{-5}	–	–	–	–	7.49×10^{-3}	–	–	–	9.41×10^{-5}	1.82×10^{-3}
WM secondary and onsite waste	3.66×10^{3}	2.29×10^{-1}	3.31×10^{2}	1.35	4.19×10^{-5}	1.42×10^{1}	7.33×10^{-4}	3.26×10^{-2}	1.62×10^{-2}	1.46×10^{-3}	1.83×10^{2}	2.74×10^{2}	1.23×10^{1}	2.97×10^{3}	3.45×10^{2}	4.20×10^{-2}
Offsite waste	5.57×10^{4}	2.25×10^{2}	6.05×10^{4}	1.46×10^{3}	2.26	5.16×10^{3}	3.07×10^{-1}	3.48×10^{2}	9.20×10^{-1}	1.50×10^{-2}	8.05×10^{1}	–	2.53	–	8.70×10^{-1}	–
RPPDF	1.50	2.61	7.31	3.14×10^{1}	5.84×10^{-2}	1.57	7.75×10^{-2}	4.99	6.83×10^{-1}	–	1.86×10^{3}	–	9.23×10^{-1}	7.78×10^{4}	6.31	4.85×10^{3}

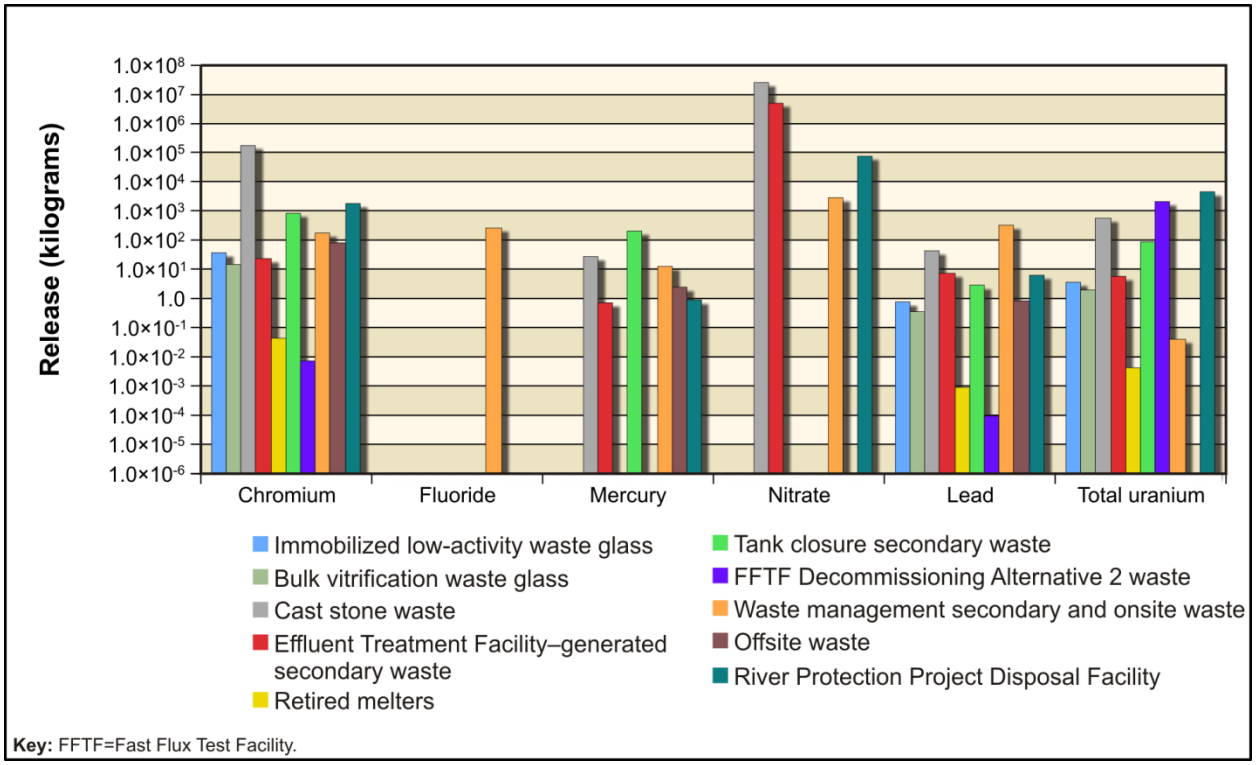
Note: To convert kilograms to pounds, multiply by 2.2046.

Key: Am-241=americium-241; BV=bulk vitrification; C-14=carbon-14; Cr=chromium; Cs-137=cesium-137; ETF=Effluent Treatment Facility; F=fluoride; FFTF=Fast Flux Test Facility; H-3=hydrogen-3 (tritium); Hg=mercury; I-129=iodine-129; ILAW=immobilized low-activity waste; NO_3=nitrate; Np-237=neptunium-237; Pb=lead; Pu-239=plutonium-239; RPPDF=River Protection Project Disposal Facility; Sr-90=strontium-90; TC=tank closure; Tc-99=technetium-99; U-238=uranium-238; Utot=total uranium; WM=waste management.



Key: Am=americium; C=carbon; Cs=cesium; FFTF=Fast Flux Test Facility; H=hydrogen; I=iodine; Np=neptunium; Pu=plutonium; Sr=strontium; Tc=technetium; U=uranium.

Figure M–72. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-E, Radionuclide Releases to the Vadose Zone



Key: FFTF=Fast Flux Test Facility.

Figure M–73. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-E, Chemical Releases to the Vadose Zone

M.4.3.2.6 Waste Management Alternative 2: Disposal in IDF, 200-East Area Only, Disposal Group 1, Subgroup 1-F

Disposal Group 1, Subgroup 1-F, addresses the waste resulting from Tank Closure Alternative 5, onsite non-CERCLA sources, FFTF decommissioning, waste management, and other DOE sites. Waste forms for IDF-East include the following:

- ILAW glass
- LAW melters
- bulk vitrification glass
- Cast stone waste
- Sulfate grout
- Tank closure secondary waste
- FFTF decommissioning secondary waste
- Waste management secondary waste
- Offsite waste
- Onsite non-CERCLA waste

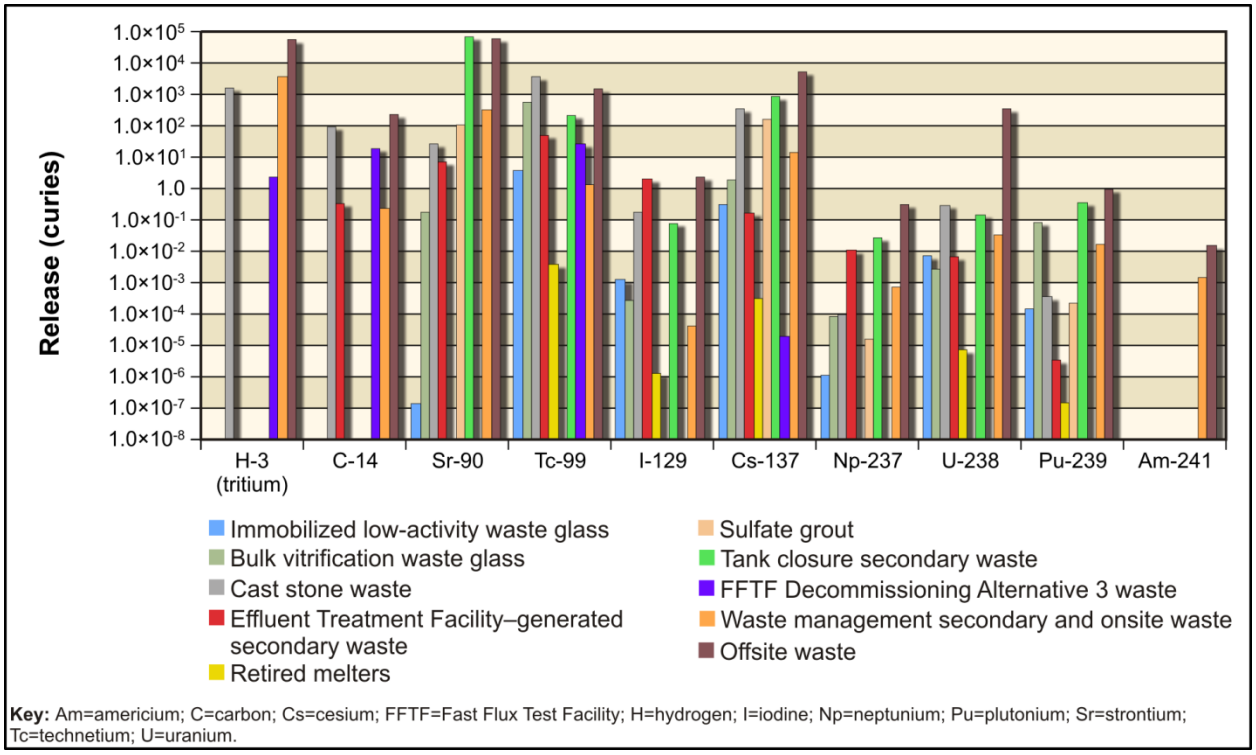
The RPPDF would not be constructed or operated under Tank Closure Alternative 5 because tank closure cleanup activities would not be conducted. Potential releases to the vadose zone under Waste Management Alternative 2, Disposal Group 1, Subgroup 1-F, are indicated in Table M–37 and Figures M–74 and M–75.

Table M–37. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-F, Radionuclide and Chemical Releases to the Vadose Zone

Source	Radionuclide (curies)										Chemical (kilograms)					
	H-3	C-14	Sr-90	Tc-99	I-129	Cs-137	Np-237	U-238	Pu-239	Am-241	Cr	F	Hg	NO_3	Pb	Utot
ILAW glass	–	–	1.34×10^{-7}	3.79	1.28×10^{-3}	3.04×10^{-1}	1.08×10^{-6}	7.39×10^{-3}	1.47×10^{-4}	–	6.09×10^{-3}	–	–	–	1.22×10^{-4}	5.15
BV waste glass	–	–	1.76×10^{-1}	5.57×10^{2}	2.77×10^{-4}	1.90	8.60×10^{-5}	2.70×10^{-3}	8.17×10^{-2}	–	1.34×10^{1}	–	–	–	3.19×10^{-1}	1.78
Cast stone waste	1.60×10^{3}	9.53×10^{1}	2.56×10^{1}	3.74×10^{3}	1.70×10^{-1}	3.51×10^{2}	9.50×10^{-5}	2.79×10^{-1}	3.49×10^{-4}	–	6.10×10^{4}	–	9.80	9.34×10^{6}	1.48×10^{1}	1.94×10^{2}
ETF-generated secondary waste	–	3.37×10^{-1}	7.09	5.03×10^{1}	2.06	1.62×10^{-1}	1.11×10^{-2}	6.47×10^{-3}	3.41×10^{-6}	–	1.15×10^{1}	–	6.90×10^{-1}	1.20×10^{7}	6.66	5.42
Retired melters	–	–	1.36×10^{-10}	3.84×10^{-3}	1.30×10^{-6}	3.10×10^{-4}	1.10×10^{-9}	7.53×10^{-6}	1.50×10^{-7}	–	6.20×10^{-6}	–	–	–	1.24×10^{-7}	5.23×10^{-3}
Sulfate grout	–	–	1.05×10^{2}	–	–	1.57×10^{2}	1.54×10^{-5}	–	2.17×10^{-4}	–	2.21×10^{5}	–	–	–	6.46×10^{1}	–
TC secondary waste	–	–	7.05×10^{4}	2.08×10^{2}	7.48×10^{-2}	8.84×10^{2}	2.69×10^{-2}	1.45×10^{-1}	3.49×10^{-1}	–	3.32×10^{2}	–	2.19×10^{2}	–	2.70	8.99×10^{1}
FFTF Decommis-sioning Alternative 3 waste	2.29	1.86×10^{1}	–	2.72×10^{1}	–	1.94×10^{-5}	–	–	–	–	7.51×10^{-3}	–	–	–	9.74×10^{-5}	2.16×10^{3}
FFTF Decommis-sioning Alternative 2 waste	2.29	2.18×10^{-4}	–	1.48×10^{-2}	–	1.88×10^{-5}	–	–	–	–	7.49×10^{-3}	–	–	–	9.41×10^{-5}	1.82×10^{-3}
WM secondary and onsite waste	3.66×10^{3}	2.29×10^{-1}	3.31×10^{2}	1.35	4.19×10^{-5}	1.42×10^{1}	7.33×10^{-4}	3.26×10^{-2}	1.62×10^{-2}	1.46×10^{-3}	1.83×10^{2}	2.74×10^{2}	1.23×10^{1}	2.97×10^{3}	3.45×10^{2}	4.20×10^{-2}
Offsite waste	5.57×10^{4}	2.25×10^{2}	6.05×10^{4}	1.46×10^{3}	2.26	5.16×10^{3}	3.07×10^{-1}	3.48×10^{2}	9.20×10^{-1}	1.50×10^{-2}	8.05×10^{1}	–	2.53	–	8.70×10^{-1}	–

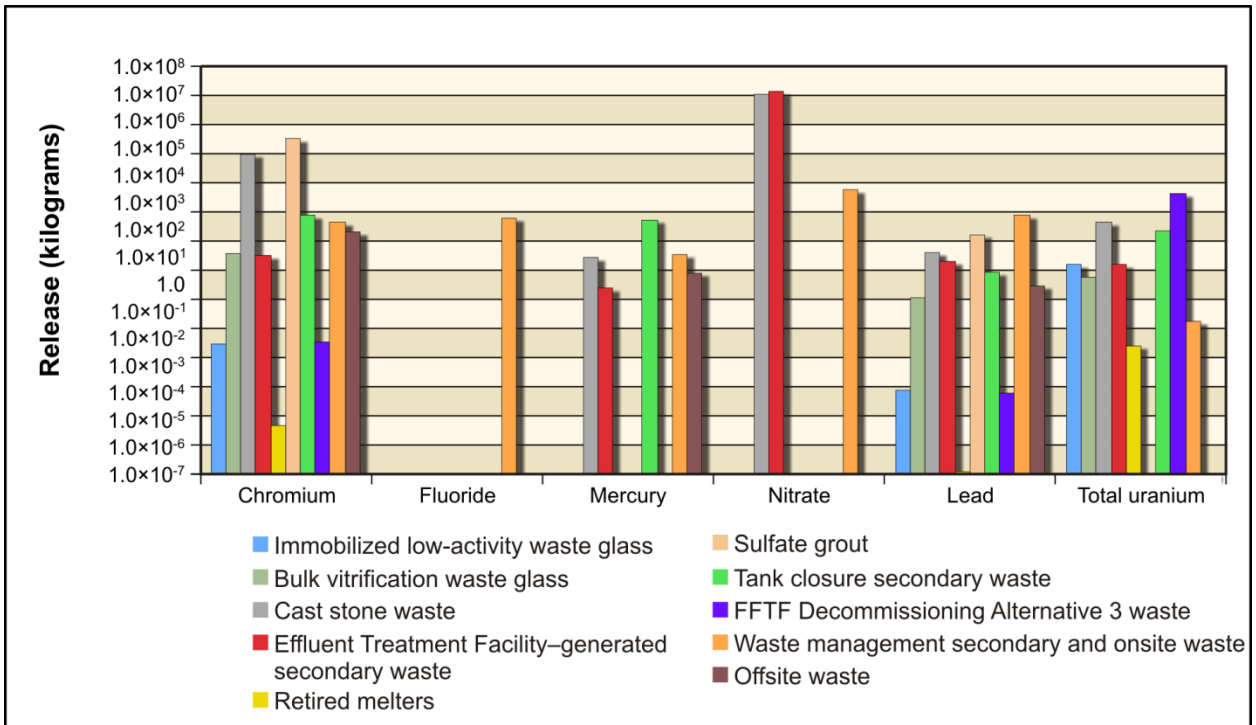
Note: To convert kilograms to pounds, multiply by 2.2046.

Key: Am-241=americium-241; BV=bulk vitrification; C-14=carbon-14; Cr=chromium; Cs-137=cesium-137; ETF=Effluent Treatment Facility; F=fluoride; FFTF=Fast Flux Test Facility; H-3=hydrogen-3 (tritium); Hg=mercury; I-129=iodine-129; ILAW=immobilized low-activity waste; NO_3=nitrate; Np-237=neptunium-237; Pb=lead; Pu-239=plutonium-239; Sr-90=strontium-90; TC=tank closure; Tc-99=technetium-99; U-238=uranium-238; Utot=total uranium; WM=waste management.



Key: Am=americium; C=carbon; Cs=cesium; FFTF=Fast Flux Test Facility; H=hydrogen; I=iodine; Np=neptunium; Pu=plutonium; Sr=strontium; Tc=technetium; U=uranium.

Figure M–74. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-F, Radionuclide Releases to the Vadose Zone



Key: FFTF=Fast Flux Test Facility.

Figure M–75. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-F, Chemical Releases to the Vadose Zone

M.4.3.2.7 Waste Management Alternative 2: Disposal in IDF, 200-East Area Only, Disposal Group 1, Subgroup 1-G

Disposal Group 1, Subgroup 1-G, addresses the waste resulting from Tank Closure Alternative 6C, onsite non-CERCLA sources, FFTF decommissioning, waste management, and other DOE sites. Waste forms for IDF-East include the following:

- Tank closure secondary waste
- FFTF decommissioning secondary waste
- Waste management secondary waste
- Offsite waste
- Onsite non-CERCLA waste

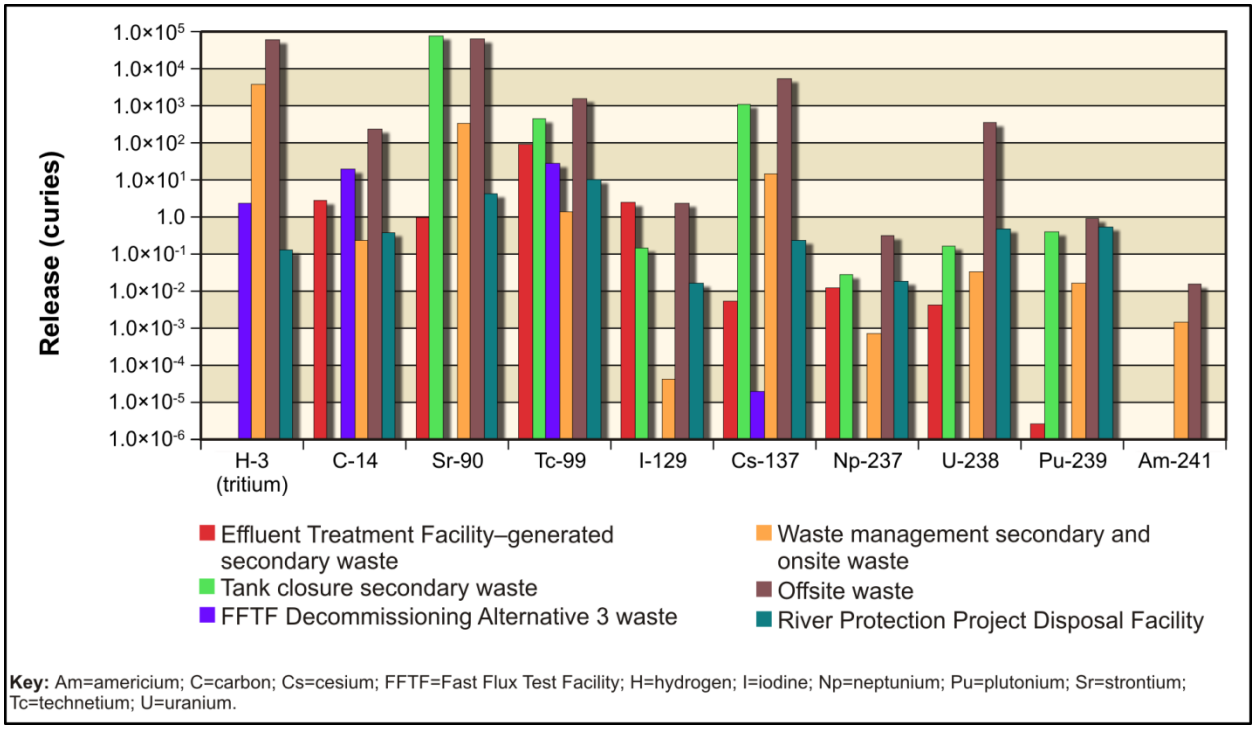
Waste forms for the RPPDF include those resulting from tank closure cleanup activities under Tank Closure Alternative 6C. Potential releases to the vadose zone under Waste Management Alternative 2, Disposal Group 1, Subgroup 1-G, are indicated in Table M–38 and Figures M–76 and M–77.

Table M–38. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-G, Radionuclide and Chemical Releases to the Vadose Zone

Source	Radionuclide (curies)										Chemical (kilograms)					
	H-3	C-14	Sr-90	Tc-99	I-129	Cs-137	Np-237	U-238	Pu-239	Am-241	Cr	F	Hg	NO_3	Pb	Utot
ETF-generated secondary waste	–	2.77	9.24×10^{-1}	8.62×10^{1}	2.50	5.44×10^{-3}	1.20×10^{-2}	4.24×10^{-3}	2.76×10^{-6}	–	4.43×10^{1}	–	8.07×10^{-1}	9.01×10^{6}	8.36×10^{-2}	4.21
TC secondary waste	–	–	7.35×10^{4}	4.31×10^{2}	1.45×10^{-1}	1.02×10^{3}	2.81×10^{-2}	1.61×10^{-1}	3.95×10^{-1}	–	1.94×10^{3}	–	2.39×10^{2}	–	3.29	1.03×10^{2}
FFTF Decommissioning Alternative 3 waste	2.29	1.86×10^{1}	–	2.72×10^{1}	–	1.94×10^{-5}	–	–	–	–	7.51×10^{-3}	–	–	–	9.74×10^{-5}	2.16×10^{3}
FFTF Decommissioning Alternative 2 waste	2.29	2.18×10^{-4}	–	1.48×10^{-2}	–	1.88×10^{-5}	–	–	–	–	7.49×10^{-3}	–	–	–	9.41×10^{-5}	1.82×10^{-3}
WM secondary and onsite waste	3.66×10^{3}	2.29×10^{-1}	3.31×10^{2}	1.35	4.19×10^{-5}	1.42×10^{1}	7.33×10^{-4}	3.26×10^{-2}	1.62×10^{-2}	1.46×10^{-3}	1.83×10^{2}	2.74×10^{2}	1.23×10^{1}	2.97×10^{3}	3.45×10^{2}	4.20×10^{-2}
Offsite waste	5.57×10^{4}	2.25×10^{2}	6.05×10^{4}	1.46×10^{3}	2.26	5.16×10^{3}	3.07×10^{-1}	3.48×10^{2}	9.20×10^{-1}	1.50×10^{-2}	8.05×10^{1}	–	2.53	–	8.70×10^{-1}	–
RPPDF	1.27×10^{-1}	3.61×10^{-1}	4.15	9.71	1.67×10^{-2}	2.30×10^{-1}	1.85×10^{-2}	4.66×10^{-1}	5.31×10^{-1}	–	5.86×10^{2}	–	1.61	3.93×10^{4}	4.97	6.60×10^{2}

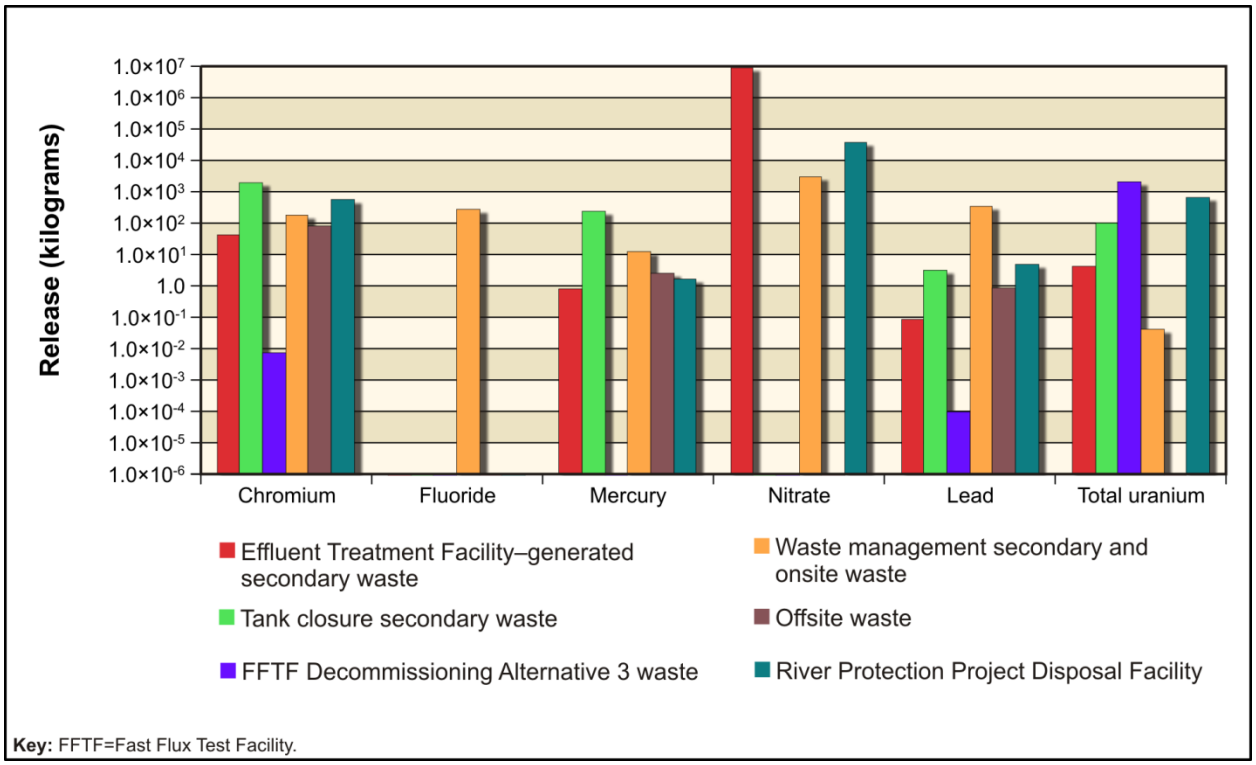
Note: To convert kilograms to pounds, multiply by 2.2046.

Key: Am-241=americium-241; C-14=carbon-14; Cr=chromium; Cs-137=cesium-137; ETF=Effluent Treatment Facility; F=fluoride; FFTF=Fast Flux Test Facility; H-3=hydrogen-3 (tritium); Hg=mercury; I-129=iodine-129; ILAW=immobilized low-activity waste; NO_3=nitrate; Np-237=neptunium-237; Pb=lead; Pu-239=plutonium-239; RPPDF=River Protection Project Disposal Facility; Sr-90=strontium-90; TC=tank closure; Tc-99=technetium-99; U-238=uranium-238; Utot=total uranium; WM=waste management.



Key: Am=americium; C=carbon; Cs=cesium; FFTF=Fast Flux Test Facility; H=hydrogen; I=iodine; Np=neptunium; Pu=plutonium; Sr=strontium; Tc=technetium; U=uranium.

Figure M–76. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-G, Radionuclide Releases to the Vadose Zone



Key: FFTF=Fast Flux Test Facility.

Figure M–77. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-G, Chemical Releases to the Vadose Zone

M.4.3.2.8 Waste Management Alternative 2: Disposal in IDF, 200-East Area Only, Disposal Group 2, Subgroup 2-A

Disposal Group 2, Subgroup 2-A, addresses the waste resulting from Tank Closure Alternative 2A, onsite non-CERCLA sources, FFTF decommissioning, waste management, and other DOE sites. Waste forms for IDF-East include the following:

- ILAW glass
- LAW melters
- Tank closure secondary waste
- FFTF decommissioning secondary waste
- Waste management secondary waste
- Offsite waste
- Onsite non-CERCLA waste

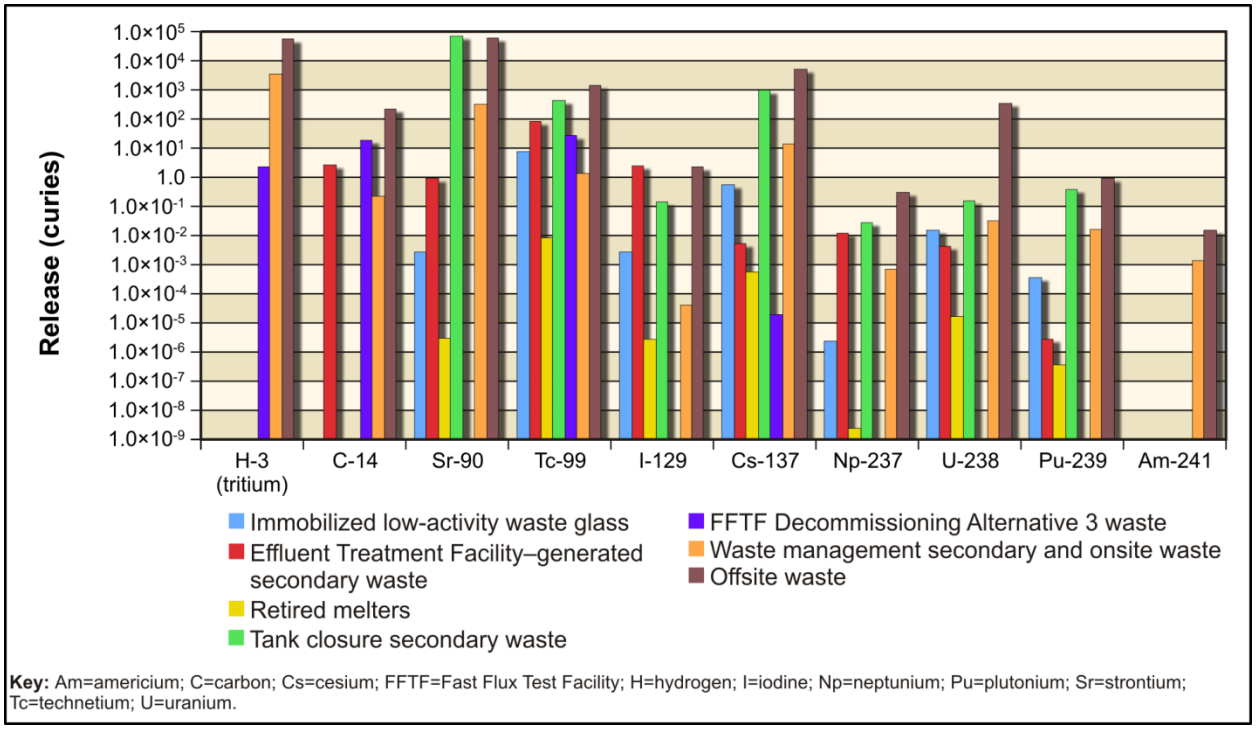
The RPPDF would not be constructed or operated under Tank Closure Alternative 2A because tank closure cleanup activities would not be conducted. Potential releases to the vadose zone under Waste Management Alternative 2, Disposal Group 2, Subgroup 2-A, are indicated in Table M–39 and Figures M–78 and M–79.

Table M–39. Waste Management Alternative 2, Disposal Group 2, Subgroup 2-A, Radionuclide and Chemical Releases to the Vadose Zone

Source	Radionuclide (curies)										Chemical (kilograms)					
	H-3	C-14	Sr-90	Tc-99	I-129	Cs-137	Np-237	U-238	Pu-239	Am-241	Cr	F	Hg	NO_3	Pb	Utot
ILAW glass	–	–	2.71×10^{-3}	7.81	2.63×10^{-3}	5.38×10^{-1}	2.30×10^{-6}	1.51×10^{-2}	3.48×10^{-4}	–	1.26×10^{2}	–	–	–	2.46	1.04×10^{1}
ETF-generated secondary waste	–	2.76	9.19×10^{-1}	8.62×10^{1}	2.48	5.41×10^{-3}	1.19×10^{-2}	4.22×10^{-3}	2.74×10^{-6}	–	4.43×10^{1}	–	8.03×10^{-1}	9.01×10^{6}	8.31×10^{-2}	4.19
Retired melters	–	–	2.91×10^{-6}	8.38×10^{-3}	2.84×10^{-6}	5.78×10^{-4}	2.46×10^{-9}	1.62×10^{-5}	3.74×10^{-7}	–	1.35×10^{-1}	–	–	–	2.62×10^{-3}	1.10×10^{-2}
TC secondary waste	–	–	7.32×10^{4}	4.31×10^{2}	1.45×10^{-1}	1.02×10^{3}	2.80×10^{-2}	1.60×10^{-1}	3.92×10^{-1}	–	1.94×10^{3}	–	2.38×10^{2}	–	3.27	1.02×10^{2}
FFTF Decommis-sioning Alternative 3 waste	2.29	1.85×10^{1}	–	2.72×10^{1}	–	1.93×10^{-5}	–	–	–	–	7.51×10^{-3}	–	–	–	9.67×10^{-5}	2.15×10^{3}
FFTF Decommis-sioning Alternative 2 waste	2.29	2.16×10^{-4}	–	1.48×10^{-2}	–	1.87×10^{-5}	–	–	–	–	7.49×10^{-3}	–	–	–	9.34×10^{-5}	1.81×10^{-3}
WM secondary and onsite waste	3.66×10^{3}	2.27×10^{-1}	3.29×10^{2}	1.35	4.17×10^{-5}	1.41×10^{1}	7.29×10^{-4}	3.24×10^{-2}	1.61×10^{-2}	1.44×10^{-3}	1.83×10^{2}	2.74×10^{2}	1.22×10^{1}	2.97×10^{3}	3.43×10^{2}	4.17×10^{-2}
Offsite waste	5.57×10^{4}	2.24×10^{2}	6.01×10^{4}	1.46×10^{3}	2.26	5.12×10^{3}	3.05×10^{-1}	3.48×10^{2}	9.13×10^{-1}	1.49×10^{-2}	8.05×10^{1}	–	2.52	–	8.63×10^{-1}	–

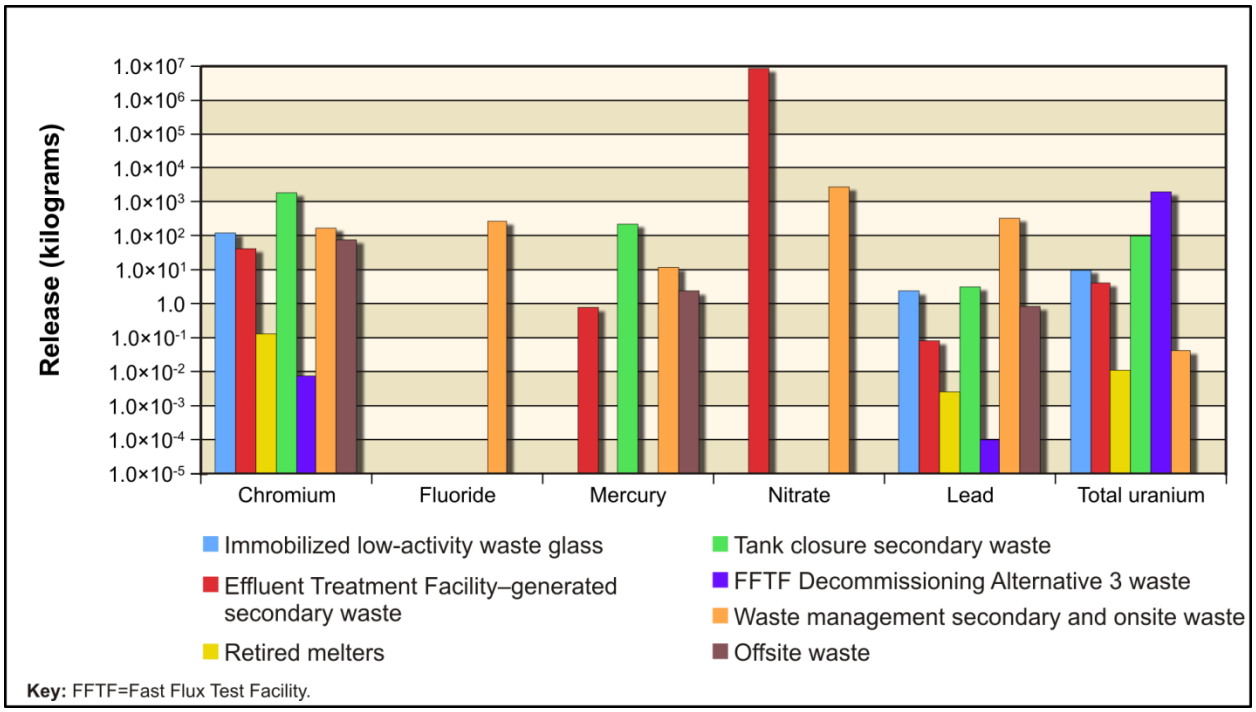
Note: To convert kilograms to pounds, multiply by 2.2046.

Key: Am-241=americium-241; C-14=carbon-14; Cr=chromium; Cs-137=cesium-137; ETF=Effluent Treatment Facility; F=fluoride; FFTF=Fast Flux Test Facility; H-3=hydrogen-3 (tritium); Hg=mercury; I-129=iodine-129; ILAW=immobilized low-activity waste; NO_3=nitrate; Np-237=neptunium-237; Pb=lead; Pu-239=plutonium-239; Sr-90=strontium-90; TC=tank closure; Tc-99=technetium-99; U-238=uranium-238; Utot=total uranium; WM=waste management.



Key: Am=americium; C=carbon; Cs=cesium; FFTF=Fast Flux Test Facility; H=hydrogen; I=iodine; Np=neptunium; Pu=plutonium; Sr=strontium; Tc=technetium; U=uranium.

Figure M–78. Waste Management Alternative 2, Disposal Group 2, Subgroup 2-A, Radionuclide Releases to the Vadose Zone



Key: FFTF=Fast Flux Test Facility.

Figure M–79. Waste Management Alternative 2, Disposal Group 2, Subgroup 2-A, Chemical Releases to the Vadose Zone

M.4.3.2.9 Waste Management Alternative 2: Disposal in IDF, 200-East Area Only, Disposal Group 2, Subgroup 2-B

Disposal Group 2, Subgroup 2-B, addresses the waste resulting from Tank Closure Alternative 6B, Base and Option Cases; onsite non-CERCLA sources; FFTF decommissioning; waste management; and other DOE sites. Waste forms for IDF-East include the following:

- Preprocessing Facility (PPF) glass
- PPF melters
- Tank closure secondary waste
- FFTF decommissioning secondary waste
- Waste management secondary waste
- Offsite waste
- Onsite non-CERCLA waste

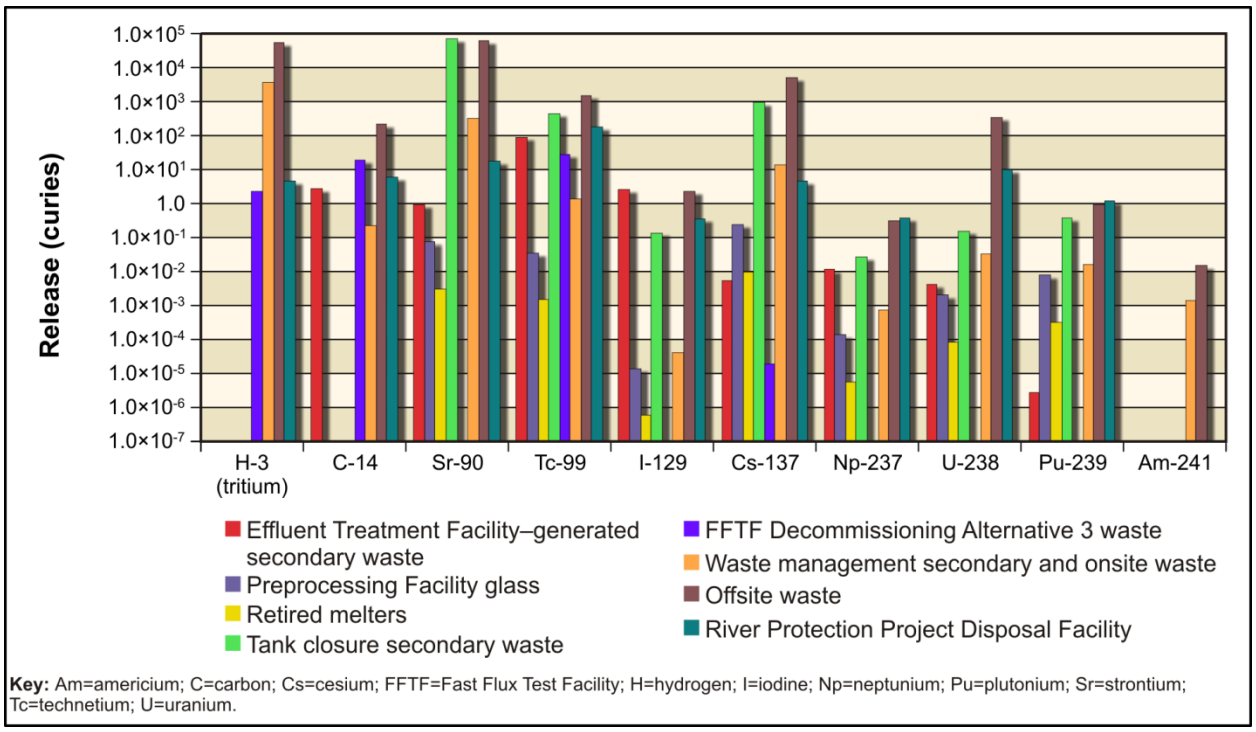
Waste forms for the RPPDF include those resulting from tank closure cleanup activities under Tank Closure Alternative 6B, Base and Option Cases. Potential releases to the vadose zone under Waste Management Alternative 2, Disposal Group 2, Subgroup 2-B, Base and Option Cases, are indicated in Tables M–40 and M–41 and Figures M–80 through M–83.

Table M–40. Waste Management Alternative 2, Disposal Group 2, Subgroup 2-B, Base Case, Radionuclide and Chemical Releases to the Vadose Zone

Source	Radionuclide (curies)										Chemical (kilograms)					
	H-3	C-14	Sr-90	Tc-99	I-129	Cs-137	Np-237	U-238	Pu-239	Am-241	Cr	F	Hg	NO_3	Pb	Utot
ETF-generated secondary waste	–	2.78	9.24×10^{-1}	8.73×10^{1}	2.51	5.44×10^{-3}	1.20×10^{-2}	4.28×10^{-3}	2.75×10^{-6}	–	4.53×10^{1}	–	8.06×10^{-1}	9.16×10^{6}	8.37×10^{-2}	4.31
PPF glass	–	–	7.42×10^{-2}	3.52×10^{-2}	1.40×10^{-5}	2.36×10^{-1}	1.36×10^{-4}	2.03×10^{-3}	7.96×10^{-3}	–	2.20	–	–	–	7.05×10^{-2}	4.21
Retired melters	–	–	3.07×10^{-3}	1.46×10^{-3}	5.81×10^{-7}	9.80×10^{-3}	5.64×10^{-6}	8.40×10^{-5}	3.29×10^{-4}	–	9.12×10^{-2}	–	–	–	2.92×10^{-3}	1.74×10^{-1}
TC secondary waste	–	–	7.01×10^{4}	4.37×10^{2}	1.38×10^{-1}	9.77×10^{2}	2.68×10^{-2}	1.55×10^{-1}	3.75×10^{-1}	–	1.98×10^{3}	–	2.29×10^{2}	–	3.13	1.00×10^{2}
FFTF Decommis-sioning Alternative 3 waste	2.29	1.85×10^{1}	–	2.72×10^{1}	–	1.93×10^{-5}	–	–	–	–	7.51×10^{-3}	–	–	–	9.67×10^{-5}	2.15×10^{3}
FFTF Decommis-sioning Alternative 2 waste	2.29	2.16×10^{-4}	–	1.48×10^{-2}	–	1.87×10^{-5}	–	–	–	–	7.49×10^{-3}	–	–	–	9.34×10^{-5}	1.81×10^{-3}
WM secondary and onsite waste	3.66×10^{3}	2.27×10^{-1}	3.29×10^{2}	1.35	4.17×10^{-5}	1.41×10^{1}	7.29×10^{-4}	3.24×10^{-2}	1.61×10^{-2}	1.44×10^{-3}	1.83×10^{2}	2.74×10^{2}	1.22×10^{1}	2.97×10^{3}	3.43×10^{2}	4.17×10^{-2}
Offsite waste	5.57×10^{4}	2.24×10^{2}	6.01×10^{4}	1.46×10^{3}	2.26	5.12×10^{3}	3.05×10^{-1}	3.48×10^{2}	9.13×10^{-1}	1.49×10^{-2}	8.05×10^{1}	–	2.52	–	8.63×10^{-1}	–
RPPDF	4.57	5.80	1.80×10^{1}	1.78×10^{2}	3.43×10^{-1}	4.61	3.81×10^{-1}	9.87	1.22	–	4.10×10^{3}	–	1.73	2.83×10^{5}	5.15×10^{1}	7.66×10^{3}

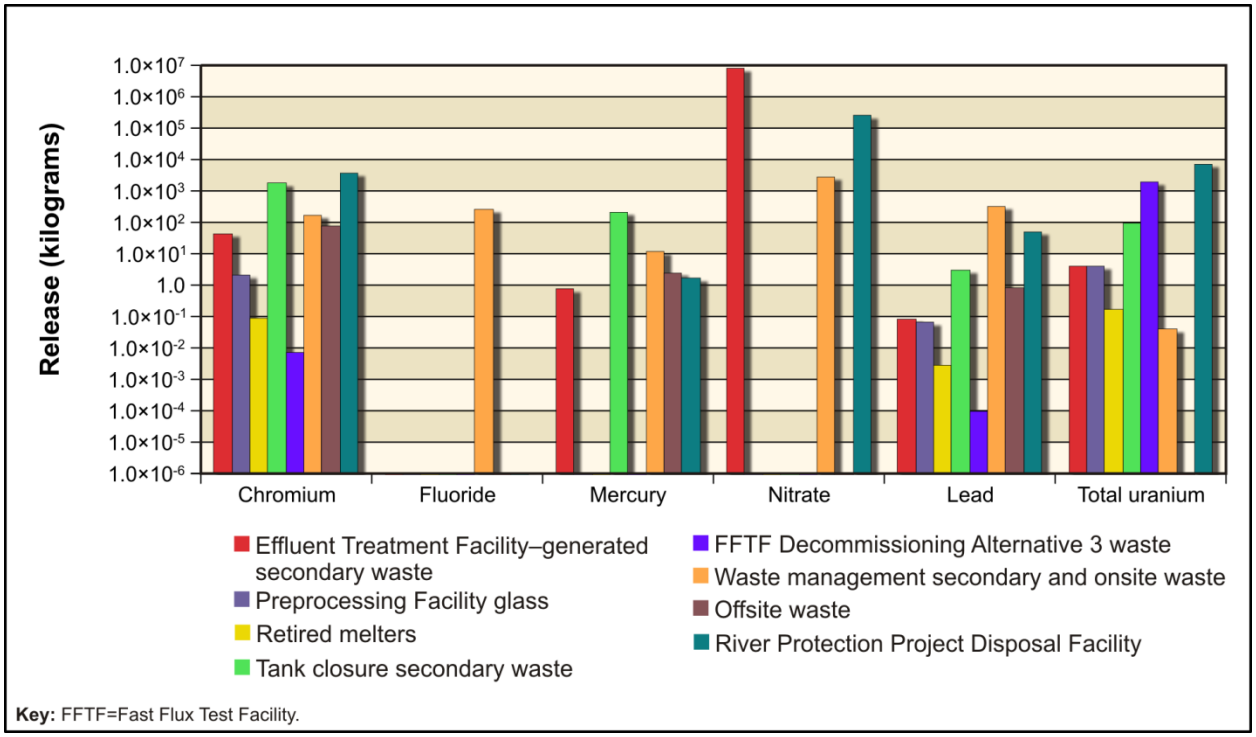
Note: To convert kilograms to pounds, multiply by 2.2046.

Key: Am-241=americium-241; C-14=carbon-14; Cr=chromium; Cs-137=cesium-137; ETF=Effluent Treatment Facility; F=fluoride; FFTF=Fast Flux Test Facility; H-3=hydrogen-3 (tritium); Hg=mercury; I-129=iodine-129; NO_3=nitrate; Np-237=neptunium-237; Pb=lead; PPF=Preprocessing Facility; Pu-239=plutonium-239; RPPDF=River Protection Project Disposal Facility; Sr-90=strontium-90; TC=tank closure; Tc-99=technetium-99; U-238=uranium-238; Utot=total uranium; WM=waste management.



Key: Am=americium; C=carbon; Cs=cesium; FFTF=Fast Flux Test Facility; H=hydrogen; I=iodine; Np=neptunium; Pu=plutonium; Sr=strontium; Tc=technetium; U=uranium.

Figure M–80. Waste Management Alternative 2, Disposal Group 2, Subgroup 2-B, Base Case, Radionuclide Releases to the Vadose Zone



Key: FFTF=Fast Flux Test Facility.

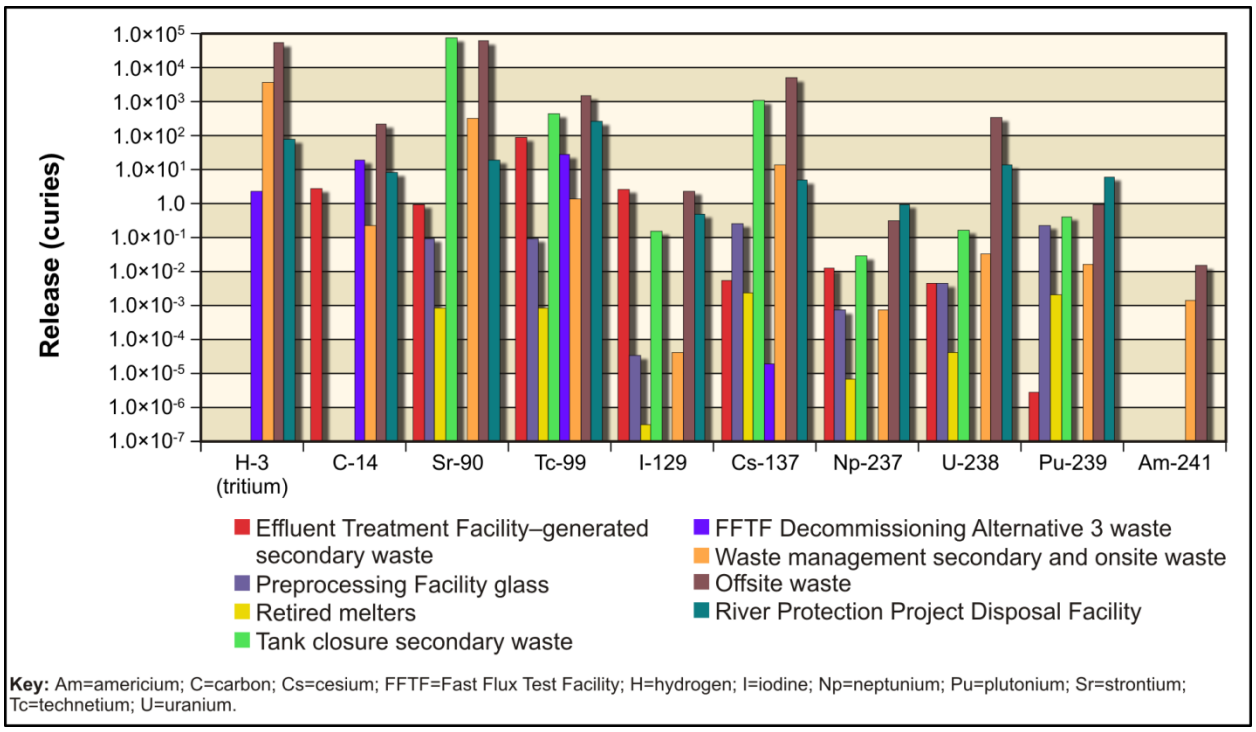
Figure M–81. Waste Management Alternative 2, Disposal Group 2, Subgroup 2-B, Base Case, Chemical Releases to the Vadose Zone

Table M–41. Waste Management Alternative 2, Disposal Group 2, Subgroup 2-B, Option Case, Radionuclide and Chemical Releases to the Vadose Zone

Source	Radionuclide (curies)										Chemical (kilograms)					
	H-3	C-14	Sr-90	Tc-99	I-129	Cs-137	Np-237	U-238	Pu-239	Am-241	Cr	F	Hg	NO_3	Pb	Utot
ETF-generated secondary waste	–	2.82	9.29×10^{-1}	8.79×10^{1}	2.53	5.48×10^{-3}	1.23×10^{-2}	4.35×10^{-3}	2.80×10^{-6}	–	5.65×10^{1}	–	8.38×10^{-1}	1.51×10^{7}	8.41×10^{-2}	4.38
PPF glass	–	–	9.09×10^{-2}	9.19×10^{-2}	3.36×10^{-5}	2.63×10^{-1}	7.26×10^{-4}	4.57×10^{-3}	2.22×10^{-1}	–	4.32×10^{1}	–	–	–	8.45×10^{-2}	6.20
Retired melters	–	–	8.33×10^{-4}	8.40×10^{-4}	3.06×10^{-7}	2.41×10^{-3}	6.63×10^{-6}	4.19×10^{-5}	2.03×10^{-3}	–	1.93×10^{-1}	–	–	–	7.02×10^{-4}	4.68×10^{-2}
TC secondary waste	–	–	7.54×10^{4}	4.40×10^{2}	1.51×10^{-1}	1.05×10^{3}	2.92×10^{-2}	1.68×10^{-1}	4.10×10^{-1}	–	2.47×10^{3}	–	2.54×10^{2}	–	3.37	1.09×10^{2}
FFTF Decommis-sioning Alternative 3 waste	2.29	1.85×10^{1}	–	2.72×10^{1}	–	1.93×10^{-5}	–	–	–	–	7.51×10^{-3}	–	–	–	9.67×10^{-5}	2.15×10^{3}
FFTF Decommis-sioning Alternative 2 waste	2.29	2.16×10^{-4}	–	1.48×10^{-2}	–	1.87×10^{-5}	–	–	–	–	7.49×10^{-3}	–	–	–	9.34×10^{-5}	1.81×10^{-3}
WM secondary and onsite waste	3.66×10^{3}	2.27×10^{-1}	3.29×10^{2}	1.35	4.17×10^{-5}	1.41×10^{1}	7.29×10^{-4}	3.24×10^{-2}	1.61×10^{-2}	1.44×10^{-3}	1.83×10^{2}	2.74×10^{2}	1.22×10^{1}	2.97×10^{3}	3.43×10^{2}	4.17×10^{-2}
Offsite waste	5.57×10^{4}	2.24×10^{2}	6.01×10^{4}	1.46×10^{3}	2.26	5.12×10^{3}	3.05×10^{-1}	3.48×10^{2}	9.13×10^{-1}	1.49×10^{-2}	8.05×10^{1}	–	2.52	–	8.63×10^{-1}	–
RPPDF	7.95×10^{1}	8.26	1.89×10^{1}	2.70×10^{2}	4.96×10^{-1}	4.77	9.11×10^{-1}	1.37×10^{1}	5.94	–	3.69×10^{4}	–	1.15×10^{1}	1.04×10^{7}	5.29×10^{1}	9.24×10^{3}

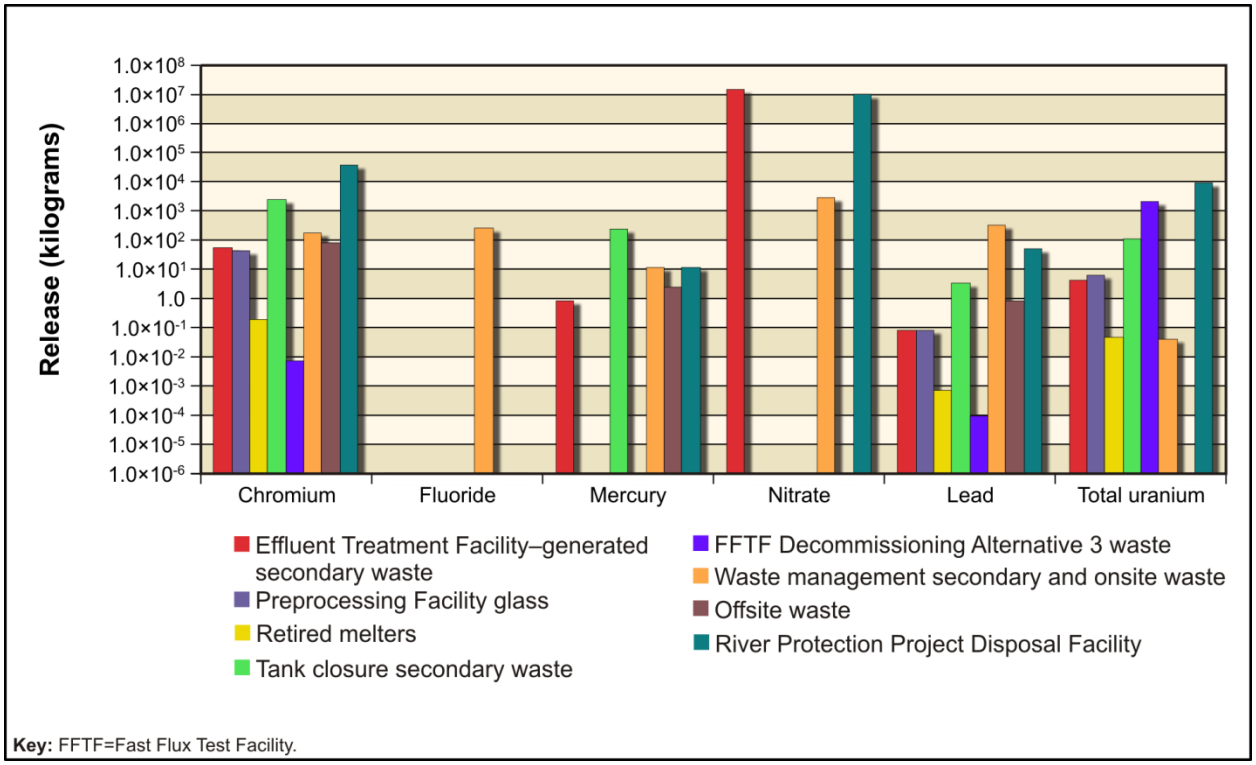
Note: To convert kilograms to pounds, multiply by 2.2046.

Key: Am-241=americium-241; C-14=carbon-14; Cr=chromium; Cs-137=cesium-137; ETF=Effluent Treatment Facility; F=fluoride; FFTF=Fast Flux Test Facility; H-3=hydrogen-3 (tritium); Hg=mercury; I-129=iodine-129; NO_3=nitrate; Np-237=neptunium-237; Pb=lead; PPF=Preprocessing Facility; Pu-239=plutonium-239; RPPDF=River Protection Project Disposal Facility; Sr-90=strontium-90; TC=tank closure; Tc-99=technetium-99; U-238=uranium-238; Utot=total uranium; WM=waste management.



Key: Am=americium; C=carbon; Cs=cesium; FFTF=Fast Flux Test Facility; H=hydrogen; I=iodine; Np=neptunium; Pu=plutonium; Sr=strontium; Tc=technetium; U=uranium.

Figure M–82. Waste Management Alternative 2, Disposal Group 2, Subgroup 2-B, Option Case, Radionuclide Releases to the Vadose Zone



Key: FFTF=Fast Flux Test Facility.

Figure M–83. Waste Management Alternative 2, Disposal Group 2, Subgroup 2-B, Option Case, Chemical Releases to the Vadose Zone

M.4.3.2.10 Waste Management Alternative 2: Disposal in IDF, 200-East Area Only, Disposal Group 3

Disposal Group 3 addresses the waste resulting from Tank Closure Alternative 6A, Base and Option Cases; onsite non-CERCLA sources; FFTF decommissioning; waste management; and other DOE sites. Waste forms for IDF-East include the following:

- PPF glass
- PPF melters
- Tank closure secondary waste
- FFTF decommissioning secondary waste
- Waste management secondary waste
- Offsite waste
- Onsite non-CERCLA waste

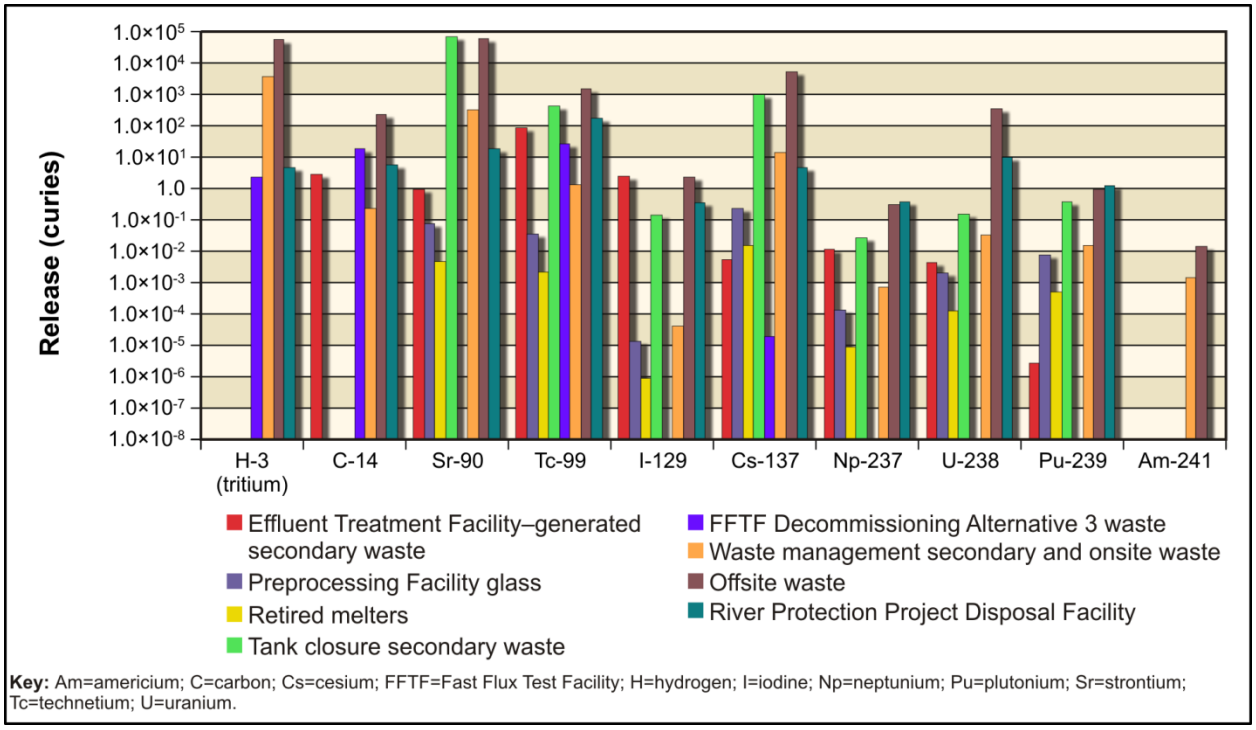
Waste forms for the RPPDF include those resulting from tank closure cleanup activities under Tank Closure Alternative 6A, Base and Option Cases. Potential releases to the vadose zone under Waste Management Alternative 2, Disposal Group 3, Base and Option Cases, are indicated in Tables M–42 and M–43 and Figures M–84 through M–87.

Table M–42. Waste Management Alternative 2, Disposal Group 3, Base Case, Radionuclide and Chemical Releases to the Vadose Zone

Source	Radionuclide (curies)										Chemical (kilograms)					
	H-3	C-14	Sr-90	Tc-99	I-129	Cs-137	Np-237	U-238	Pu-239	Am-241	Cr	F	Hg	NO_3	Pb	Utot
ETF-generated secondary waste	–	2.78	9.24×10^{-1}	8.73×10^{1}	2.51	5.44×10^{-3}	1.20×10^{-2}	4.28×10^{-3}	2.75×10^{-6}	–	4.53×10^{1}	–	8.06×10^{-1}	9.16×10^{6}	8.37×10^{-2}	4.31
PPF glass	–	–	7.42×10^{-2}	3.50×10^{-2}	1.39×10^{-5}	2.36×10^{-1}	1.35×10^{-4}	2.01×10^{-3}	7.92×10^{-3}	–	2.19	–	–	–	7.00×10^{-2}	4.19
Retired melters	–	–	4.80×10^{-3}	2.26×10^{-3}	9.03×10^{-7}	1.53×10^{-2}	8.74×10^{-6}	1.30×10^{-4}	5.13×10^{-4}	–	1.42×10^{-1}	–	–	–	4.51×10^{-3}	2.70×10^{-1}
TC secondary waste	–	–	7.01×10^{4}	4.37×10^{2}	1.38×10^{-1}	9.77×10^{2}	2.68×10^{-2}	1.55×10^{-1}	3.75×10^{-1}	–	1.98×10^{3}	–	2.29×10^{2}	–	3.13	1.00×10^{2}
FFTF Decommis-sioning Alternative 3 waste	2.29	1.84×10^{1}	–	2.72×10^{1}	–	1.92×10^{-5}	–	–	–	–	7.51×10^{-3}	–	–	–	9.59×10^{-5}	2.14×10^{3}
FFTF Decommis-sioning Alternative 2 waste	2.29	2.15×10^{-4}	–	1.48×10^{-2}	–	1.86×10^{-5}	–	–	–	–	7.49×10^{-3}	–	–	–	9.26×10^{-5}	1.79×10^{-3}
WM secondary and onsite waste	3.66×10^{3}	2.26×10^{-1}	3.27×10^{2}	1.35	4.14×10^{-5}	1.40×10^{1}	7.24×10^{-4}	3.22×10^{-2}	1.59×10^{-2}	1.43×10^{-3}	1.83×10^{2}	2.74×10^{2}	1.21×10^{1}	2.97×10^{3}	3.40×10^{2}	4.15×10^{-2}
Offsite waste	5.57×10^{4}	2.22×10^{2}	5.96×10^{4}	1.46×10^{3}	2.26	5.08×10^{3}	3.04×10^{-1}	3.47×10^{2}	9.04×10^{-1}	1.47×10^{-2}	8.05×10^{1}	–	2.50	–	8.55×10^{-1}	–
RPPDF	4.57	5.78	1.80×10^{1}	1.78×10^{2}	3.43×10^{-1}	4.61	3.80×10^{-1}	9.86	1.21	–	4.10×10^{3}	–	1.73	2.83×10^{5}	5.12×10^{1}	7.66×10^{3}

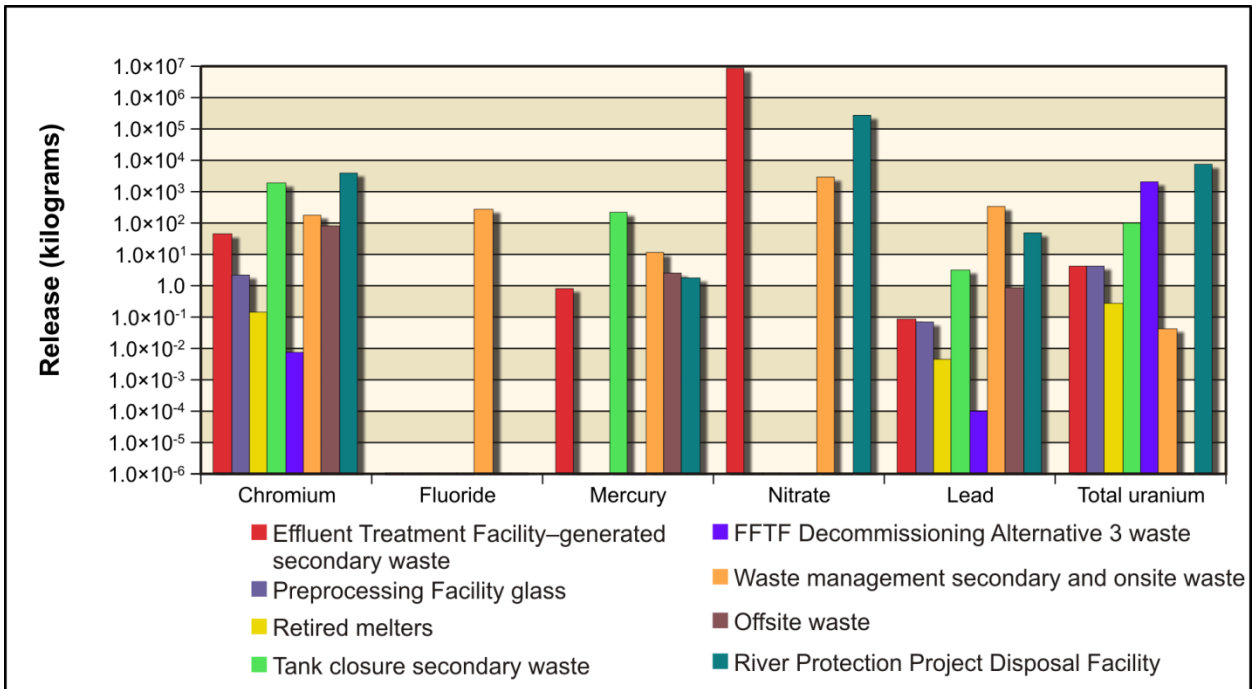
Note: To convert kilograms to pounds, multiply by 2.2046.

Key: Am-241=americium-241; C-14=carbon-14; Cr=chromium; Cs-137=cesium-137; ETF=Effluent Treatment Facility; F=fluoride; FFTF=Fast Flux Test Facility; H-3=hydrogen-3 (tritium); Hg=mercury; I-129=iodine-129; NO_3=nitrate; Np-237=neptunium-237; Pb=lead; PPF=Preprocessing Facility; Pu-239=plutonium-239; RPPDF=River Protection Project Disposal Facility; Sr-90=strontium-90; TC=tank closure; Tc-99=technetium-99; U-238=uranium-238; Utot=total uranium; WM=waste management.



Key: Am=americium; C=carbon; Cs=cesium; FFTF=Fast Flux Test Facility; H=hydrogen; I=iodine; Np=neptunium; Pu=plutonium; Sr=strontium; Tc=technetium; U=uranium.

Figure M–84. Waste Management Alternative 2, Disposal Group 3, Base Case, Radionuclide Releases to the Vadose Zone



Key: FFTF=Fast Flux Test Facility.

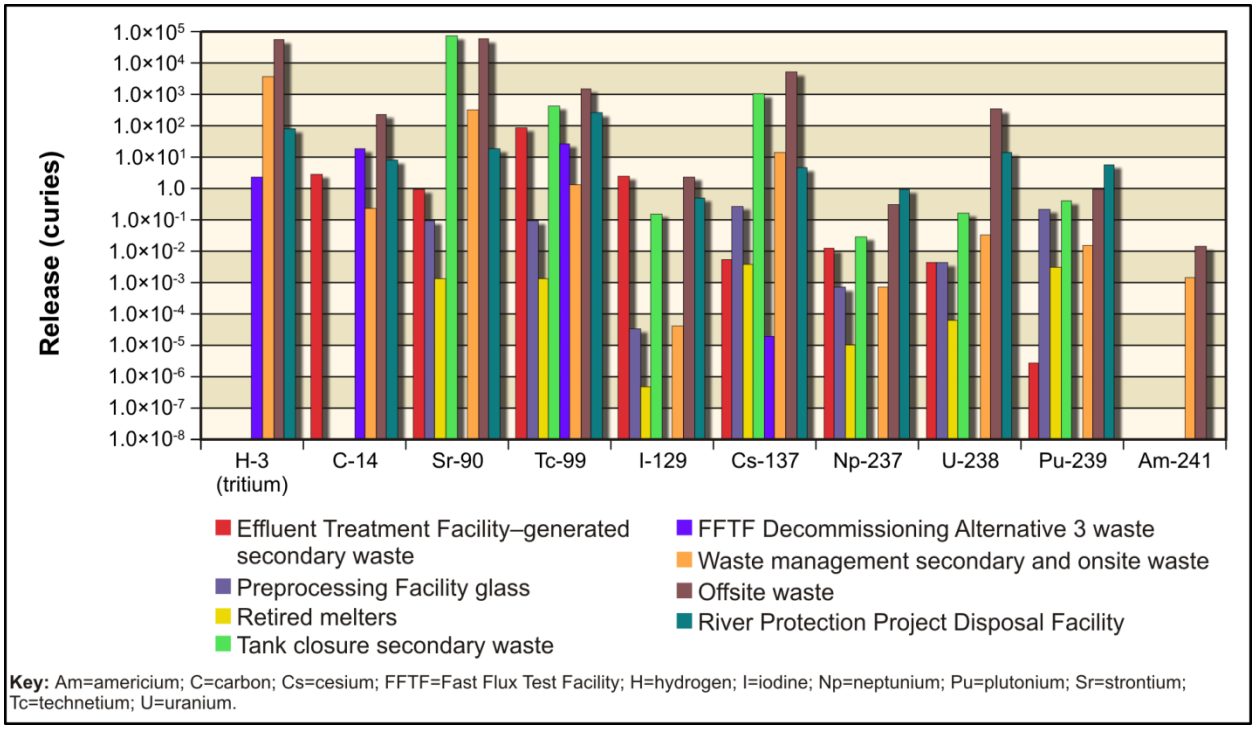
Figure M–85. Waste Management Alternative 2, Disposal Group 3, Base Case, Chemical Releases to the Vadose Zone

Table M–43. Waste Management Alternative 2, Disposal Group 3, Option Case, Radionuclide and Chemical Releases to the Vadose Zone

Source	Radionuclide (curies)										Chemical (kilograms)					
	H-3	C-14	Sr-90	Tc-99	I-129	Cs-137	Np-237	U-238	Pu-239	Am-241	Cr	F	Hg	NO_3	Pb	Utot
ETF-generated secondary waste	–	2.82	9.29×10^{-1}	8.79×10^{1}	2.53	5.48×10^{-3}	1.23×10^{-2}	4.35×10^{-3}	2.80×10^{-6}	–	5.65×10^{1}	–	8.38×10^{-1}	1.51×10^{7}	8.41×10^{-2}	4.38
PPF glass	–	–	9.09×10^{-2}	9.13×10^{-2}	3.34×10^{-5}	2.63×10^{-1}	7.21×10^{-4}	4.54×10^{-3}	2.21×10^{-1}	–	4.30×10^{1}	–	–	–	8.40×10^{-2}	6.16
Retired melters	–	–	1.31×10^{-3}	1.31×10^{-3}	4.79×10^{-7}	3.78×10^{-3}	1.04×10^{-5}	6.54×10^{-5}	3.17×10^{-3}	–	6.18×10^{-1}	–	–	–	1.21×10^{-3}	8.84×10^{-2}
TC secondary waste	–	–	7.54×10^{4}	4.40×10^{2}	1.51×10^{-1}	1.05×10^{3}	2.92×10^{-2}	1.68×10^{-1}	4.10×10^{-1}	–	2.47×10^{3}	–	2.54×10^{2}	–	3.37	1.09×10^{2}
FFTF Decommis-sioning Alternative 3 waste	2.29	1.84×10^{1}	–	2.72×10^{1}	–	1.92×10^{-5}	–	–	–	–	7.51×10^{-3}	–	–	–	9.59×10^{-5}	2.14×10^{3}
FFTF Decommis-sioning Alternative 2 waste	2.29	2.15×10^{-4}	–	1.48×10^{-2}	–	1.86×10^{-5}	–	–	–	–	7.49×10^{-3}	–	–	–	9.26×10^{-5}	1.79×10^{-3}
WM secondary and onsite waste	3.66×10^{3}	2.26×10^{-1}	3.27×10^{2}	1.35	4.14×10^{-5}	1.40×10^{1}	7.24×10^{-4}	3.22×10^{-2}	1.59×10^{-2}	1.43×10^{-3}	1.83×10^{2}	2.74×10^{2}	1.21×10^{1}	2.97×10^{3}	3.40×10^{2}	4.15×10^{-2}
Offsite waste	5.57×10^{4}	2.22×10^{2}	5.96×10^{4}	1.46×10^{3}	2.26	5.08×10^{3}	3.04×10^{-1}	3.47×10^{2}	9.04×10^{-1}	1.47×10^{-2}	8.05×10^{1}	–	2.50	–	8.55×10^{-1}	–
RPPDF	7.95×10^{1}	8.18	1.89×10^{1}	2.70×10^{2}	4.96×10^{-1}	4.77	9.07×10^{-1}	1.37×10^{1}	5.90	–	3.69×10^{4}	–	1.14×10^{1}	1.04×10^{7}	5.26×10^{1}	9.24×10^{3}

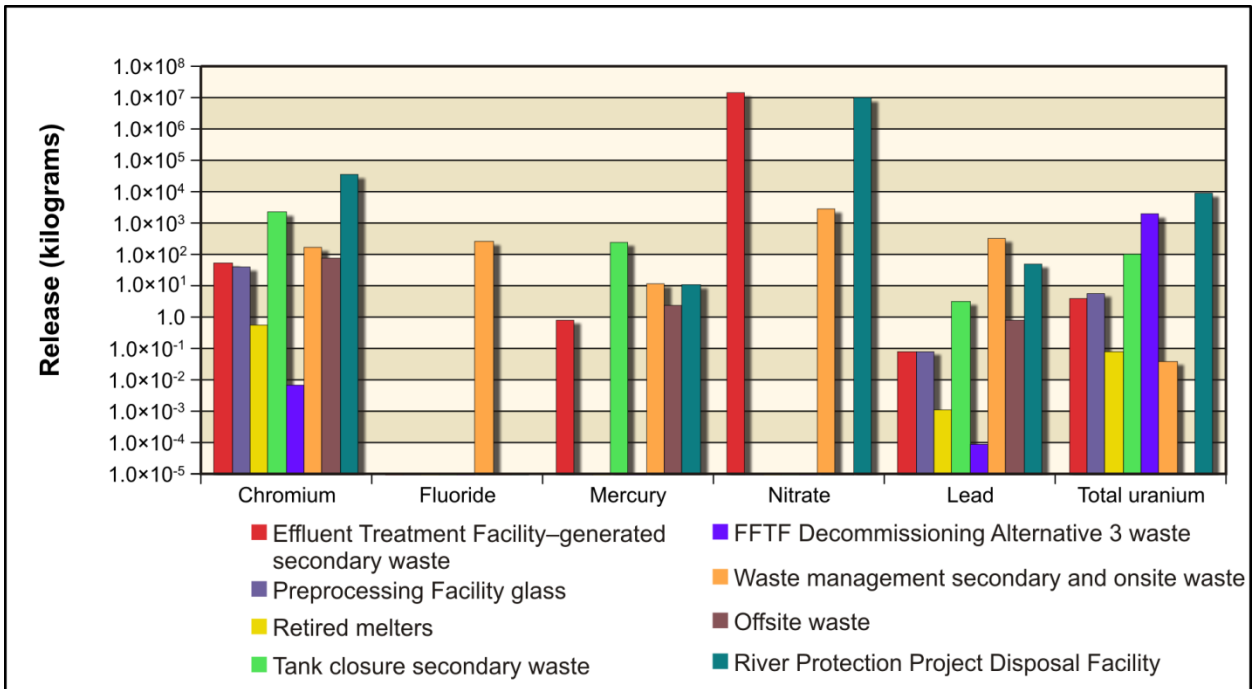
Note: To convert kilograms to pounds, multiply by 2.2046.

Key: Am-241=americium-241; C-14=carbon-14; Cr=chromium; Cs-137=cesium-137; ETF=Effluent Treatment Facility; F=fluoride; FFTF=Fast Flux Test Facility; H-3=hydrogen-3 (tritium); Hg=mercury; I-129=iodine-129; NO_3=nitrate; Np-237=neptunium-237; Pb=lead; PPF=Preprocessing Facility; Pu-239=plutonium-239; RPPDF=River Protection Project Disposal Facility; Sr-90=strontium-90; TC=tank closure; Tc-99=technetium-99; U-238=uranium-238; Utot=total uranium; WM=waste management.



Key: Am=americium; C=carbon; Cs=cesium; FFTF=Fast Flux Test Facility; H=hydrogen; I=iodine; Np=neptunium; Pu=plutonium; Sr=strontium; Tc=technetium; U=uranium.

Figure M–86. Waste Management Alternative 2, Disposal Group 3, Option Case, Radionuclide Releases to the Vadose Zone



Key: FFTF=Fast Flux Test Facility.

Figure M–87. Waste Management Alternative 2, Disposal Group 3, Option Case, Chemical Releases to the Vadose Zone

M.4.3.2.11 Waste Management Alternative 3: Disposal in IDF, 200-East and 200-West Areas

Under Waste Management Alternative 3, the waste from tank treatment operations would be disposed of in IDF-East, and that from onsite non-CERCLA sources, FFTF decommissioning, waste management, and other DOE sites would be disposed of in IDF-West. Waste from tank farm cleanup operations would be disposed of in the RPPDF. As a result, the waste disposed of in these three facilities would become available for release to the environment. Because of the different waste types that result from the Tank Closure action alternatives, three disposal groups were considered to account for the different IDF-East sizes and operational time periods. In addition, within these three disposal groups, subgroups were identified to allow consideration of the different waste types resulting from the Tank Closure alternatives.

The amount of waste disposed of at IDF-West under each subgroup is identical. Potential releases to the vadose zone from IDF-West under Waste Management Alternative 3 are indicated in Figures M–88 and M–89 (presented only once for all disposal groups under Waste Management Alternative 3).

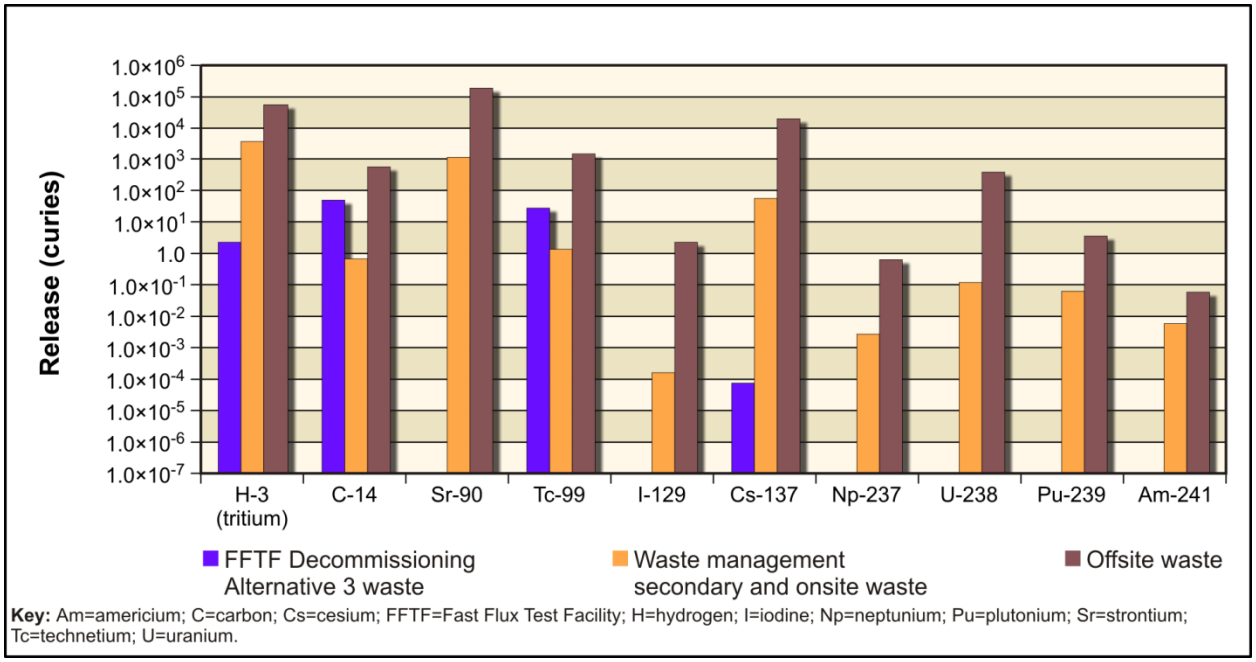


Figure M–88. Waste Management Alternative 3, All Disposal Groups, Radionuclide Releases to the Vadose Zone from the 200-West Area Integrated Disposal Facility

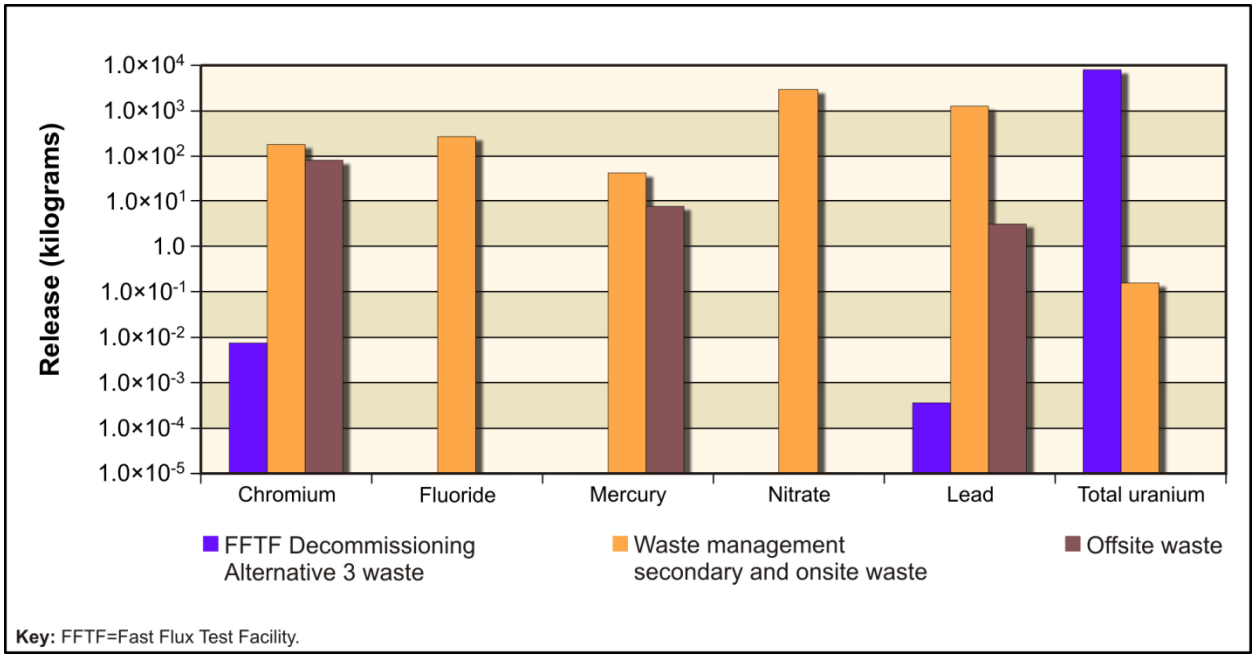


Figure M–89. Waste Management Alternative 3, All Disposal Groups, Chemical Releases to the Vadose Zone from the 200-West Area Integrated Disposal Facility

Potential releases from IDF-East and the RPPDF are discussed in the following sections.

M.4.3.2.12 Waste Management Alternative 3: Disposal in IDF, 200-East and 200-West Areas, Disposal Group 1, Subgroup 1-A

Disposal Group 1, Subgroup 1-A, addresses the waste resulting from Tank Closure Alternative 2B, onsite non-CERCLA sources, FFTF decommissioning, waste management, and other DOE sites. Waste forms for IDF-East include the following:

- ILAW glass
- LAW melters
- Tank closure secondary waste

Waste forms for IDF-West include the following:

- FFTF decommissioning secondary waste
- Waste management secondary waste
- Offsite waste
- Onsite non-CERCLA waste

Waste forms for the RPPDF include those resulting from tank closure cleanup activities under Tank Closure Alternative 2B. Potential releases to the vadose zone under Waste Management Alternative 3, Disposal Group 1, Subgroup 1-A, are indicated in Table M–44 and Figures M–90 and M–91.

Table M–44. Waste Management Alternative 3, Disposal Group 1, Subgroup 1-A, Radionuclide and Chemical Releases to the Vadose Zone

Source	Radionuclide (curies)										Chemical (kilograms)					
	H-3	C-14	Sr-90	Tc-99	I-129	Cs-137	Np-237	U-238	Pu-239	Am-241	Cr	F	Hg	NO_3	Pb	Utot
IDF-East																
ILAW glass	–	–	2.71×10^{-3}	7.85×10^{-2}	2.64×10^{-3}	5.38×10^{-1}	2.31×10^{-6}	1.51×10^{-2}	3.49×10^{-4}	–	1.26×10^{2}	–	–	–	2.46	1.04×10^{1}
ETF-generated secondary waste	–	2.77	9.24×10^{-1}	8.62×10^{1}	2.50	5.44×10^{-3}	1.20×10^{-2}	4.24×10^{-3}	2.76×10^{-6}	–	4.43×10^{1}	–	8.07×10^{-1}	9.01×10^{6}	8.36×10^{-2}	4.21
Retired melters	–	–	3.02×10^{-6}	8.75×10^{-5}	2.96×10^{-6}	6.01×10^{-4}	2.58×10^{-9}	1.69×10^{-5}	3.90×10^{-7}	–	1.41×10^{-1}	–	–	–	2.74×10^{-3}	1.15×10^{-2}
TC secondary waste	–	–	7.36×10^{4}	4.92×10^{2}	1.45×10^{-1}	1.02×10^{3}	2.81×10^{-2}	1.61×10^{-1}	3.95×10^{-1}	–	1.94×10^{3}	–	2.40×10^{2}	–	3.29	1.03×10^{2}
RPPDF	1.27×10^{-1}	3.61×10^{-1}	4.15	9.71	1.67×10^{-2}	2.30×10^{-1}	1.85×10^{-2}	4.66×10^{-1}	5.31×10^{-1}	–	5.86×10^{2}	–	1.61	3.93×10^{4}	4.97	6.60×10^{2}
IDF-West																
FFTF Decommis-sioning Alternative 3 waste	2.29	4.78×10^{1}	–	2.72×10^{1}	–	7.46×10^{-5}	–	–	–	–	7.51×10^{-3}	–	–	–	3.64×10^{-4}	7.91×10^{3}
WM secondary and onsite waste	3.66×10^{3}	6.82×10^{-1}	1.18×10^{3}	1.35	1.58×10^{-4}	5.47×10^{1}	2.62×10^{-3}	1.21×10^{-1}	6.20×10^{-2}	5.65×10^{-3}	1.83×10^{2}	2.74×10^{2}	4.16×10^{1}	2.97×10^{3}	1.30×10^{3}	1.56×10^{-1}
Offsite waste	5.57×10^{4}	5.68×10^{2}	1.87×10^{5}	1.46×10^{3}	2.26	1.93×10^{4}	6.28×10^{-1}	3.77×10^{2}	3.49	5.80×10^{-2}	8.05×10^{1}	–	7.85	–	3.24	–

Note: To convert kilograms to pounds, multiply by 2.2046.

Key: Am-241=americium-241; C-14=carbon-14; Cr=chromium; Cs-137=cesium-137; ETF=Effluent Treatment Facility; F=fluoride; FFTF=Fast Flux Test Facility; H-3=hydrogen-3 (tritium); Hg=mercury; I-129=iodine-129; IDF-East=200-East Area Integrated Disposal Facility; IDF-West=200-West Area Integrated Disposal Facility; ILAW=immobilized low-activity waste; NO_3=nitrate; Np-237=neptunium-237; Pb=lead; Pu-239=plutonium-239; RPPDF=River Protection Project Disposal Facility; Sr-90=strontium-90; TC=tank closure; Tc-99=technetium-99; U-238=uranium-238; Utot=total uranium; WM=waste management.

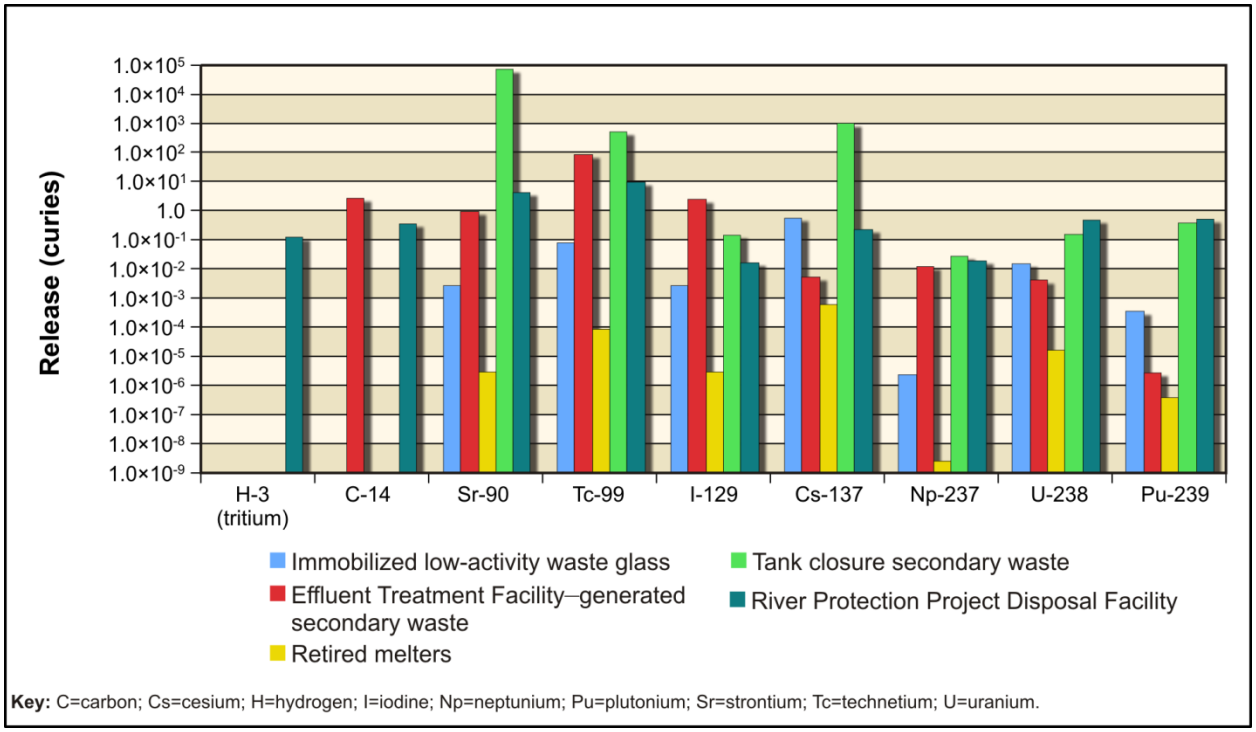


Figure M–90. Waste Management Alternative 3, Disposal Group 1, Subgroup 1-A, Radionuclide Releases to the Vadose Zone from the 200-East Area Integrated Disposal Facility

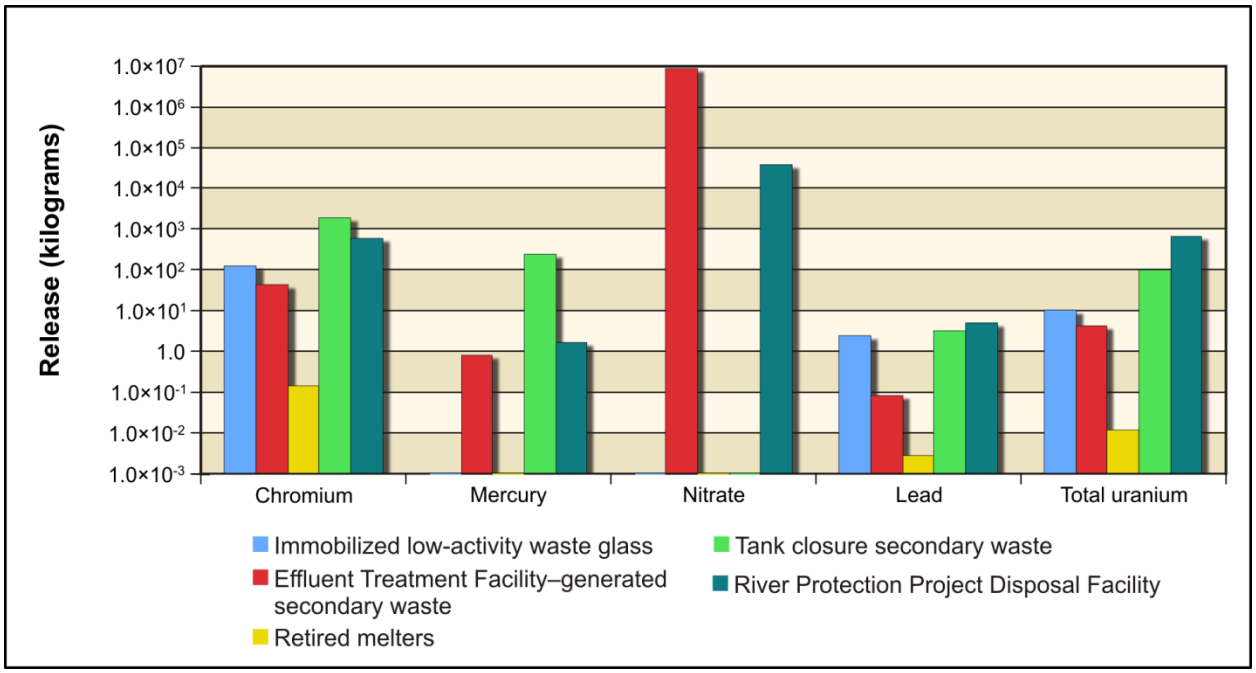


Figure M–91. Waste Management Alternative 3, Disposal Group 1, Subgroup 1-A, Chemical Releases to the Vadose Zone from the 200-East Area Integrated Disposal Facility

M.4.3.2.13 Waste Management Alternative 3: Disposal in IDF, 200-East and 200-West Areas, Disposal Group 1, Subgroup 1-B

Disposal Group 1, Subgroup 1-B, addresses the waste resulting from Tank Closure Alternative 3A, onsite non-CERCLA sources, FFTF decommissioning, waste management, and other DOE sites. Waste forms for IDF-East include the following:

- ILAW glass
- LAW melters
- bulk vitrification glass
- Tank closure secondary waste

Waste forms for IDF-West include the following:

- FFTF decommissioning secondary waste
- Waste management secondary waste
- Offsite waste
- Onsite non-CERCLA waste

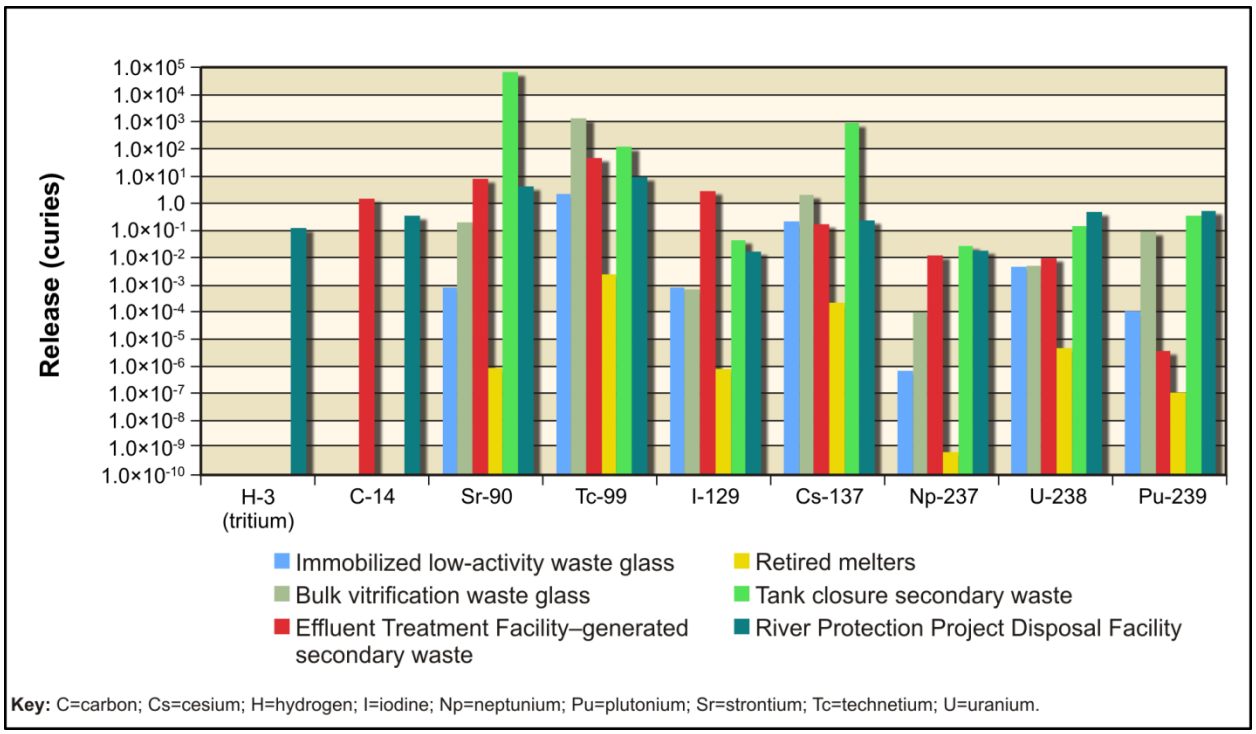
Waste forms for the RPPDF include those resulting from tank closure cleanup activities under Tank Closure Alternative 3A. Potential releases to the vadose zone under Waste Management Alternative 3, Disposal Group 1, Subgroup 1-B, are indicated in Table M–45 and Figures M–92 and M–93.

Table M–45. Waste Management Alternative 3, Disposal Group 1, Subgroup 1-B, Radionuclide and Chemical Releases to the Vadose Zone

Source	Radionuclide (curies)										Chemical (kilograms)					
	H-3	C-14	Sr-90	Tc-99	I-129	Cs-137	Np-237	U-238	Pu-239	Am-241	Cr	F	Hg	NO_3	Pb	Utot
IDF-East																
ILAW glass	–	–	8.12×10^{-4}	2.30	7.75×10^{-4}	2.10×10^{-1}	6.86×10^{-7}	4.49×10^{-3}	1.04×10^{-4}	–	3.71×10^{1}	–	–	–	7.39×10^{-1}	3.13
BV waste glass	–	–	1.94×10^{-1}	1.34×10^{3}	6.67×10^{-4}	2.00	9.49×10^{-5}	5.08×10^{-3}	8.95×10^{-2}	–	3.18×10^{1}	–	–	–	6.62×10^{-1}	3.41
ETF-generated secondary waste	–	1.54	7.84	4.63×10^{1}	2.74	1.69×10^{-1}	1.21×10^{-2}	9.18×10^{-3}	3.75×10^{-6}	–	2.76×10^{1}	–	8.05×10^{-1}	8.14×10^{6}	1.38×10^{1}	7.37
Retired melters	–	–	8.27×10^{-7}	2.34×10^{-3}	7.89×10^{-7}	2.13×10^{-4}	6.97×10^{-10}	4.57×10^{-6}	1.06×10^{-7}	–	3.77×10^{-2}	–	–	–	7.53×10^{-4}	3.18×10^{-3}
TC secondary waste	–	–	7.27×10^{4}	1.28×10^{2}	4.25×10^{-2}	9.16×10^{2}	2.77×10^{-2}	1.47×10^{-1}	3.59×10^{-1}	–	8.02×10^{2}	–	2.38×10^{2}	–	2.89	9.08×10^{1}
RPPDF	1.27×10^{-1}	3.61×10^{-1}	4.15	9.71	1.67×10^{-2}	2.30×10^{-1}	1.85×10^{-2}	4.66×10^{-1}	5.31×10^{-1}	–	5.86×10^{2}	–	1.61	3.93×10^{4}	4.97	6.60×10^{2}
IDF-West																
FFTF Decommis-sioning Alternative 3 waste	2.29	5.72×10^{-4}	–	1.48×10^{-2}	–	7.22×10^{-5}	–	–	–	–	7.49×10^{-3}	–	–	–	3.52×10^{-4}	6.66×10^{-3}
WM secondary and onsite waste	3.66×10^{3}	6.82×10^{-1}	1.18×10^{3}	1.35	1.58×10^{-4}	5.47×10^{1}	2.62×10^{-3}	1.21×10^{-1}	6.20×10^{-2}	5.65×10^{-3}	1.83×10^{2}	2.74×10^{2}	4.16×10^{1}	2.97×10^{3}	1.30×10^{3}	1.56×10^{-1}
Offsite waste	5.57×10^{4}	5.68×10^{2}	1.87×10^{5}	1.46×10^{3}	2.26	1.93×10^{4}	6.28×10^{-1}	3.77×10^{2}	3.49	5.80×10^{-2}	8.05×10^{1}	–	7.85	–	3.24	–

Note: To convert kilograms to pounds, multiply by 2.2046.

Key: Am-241=americium-241; BV=bulk vitrification; C-14=carbon-14; Cr=chromium; Cs-137=cesium-137; ETF=Effluent Treatment Facility; F=fluoride; FFTF=Fast Flux Test Facility; H-3=hydrogen-3 (tritium); Hg=mercury; I-129=iodine-129; IDF-East=200-East Area Integrated Disposal Facility; IDF-West=200-West Area Integrated Disposal Facility; ILAW=immobilized low-activity waste; NO_3=nitrate; Np-237=neptunium-237; Pb=lead; Pu-239=plutonium-239; RPPDF=River Protection Project Disposal Facility; Sr-90=strontium-90; TC=tank closure; Tc-99=technetium-99; U-238=uranium-238; Utot=total uranium; WM=waste management.



Key: C=carbon; Cs=cesium; H=hydrogen; I=iodine; Np=neptunium; Pu=plutonium; Sr=strontium; Tc=technetium; U=uranium.

Figure M–92. Waste Management Alternative 3, Disposal Group 1, Subgroup 1-B, Radionuclide Releases to the Vadose Zone from the 200-East Area Integrated Disposal Facility

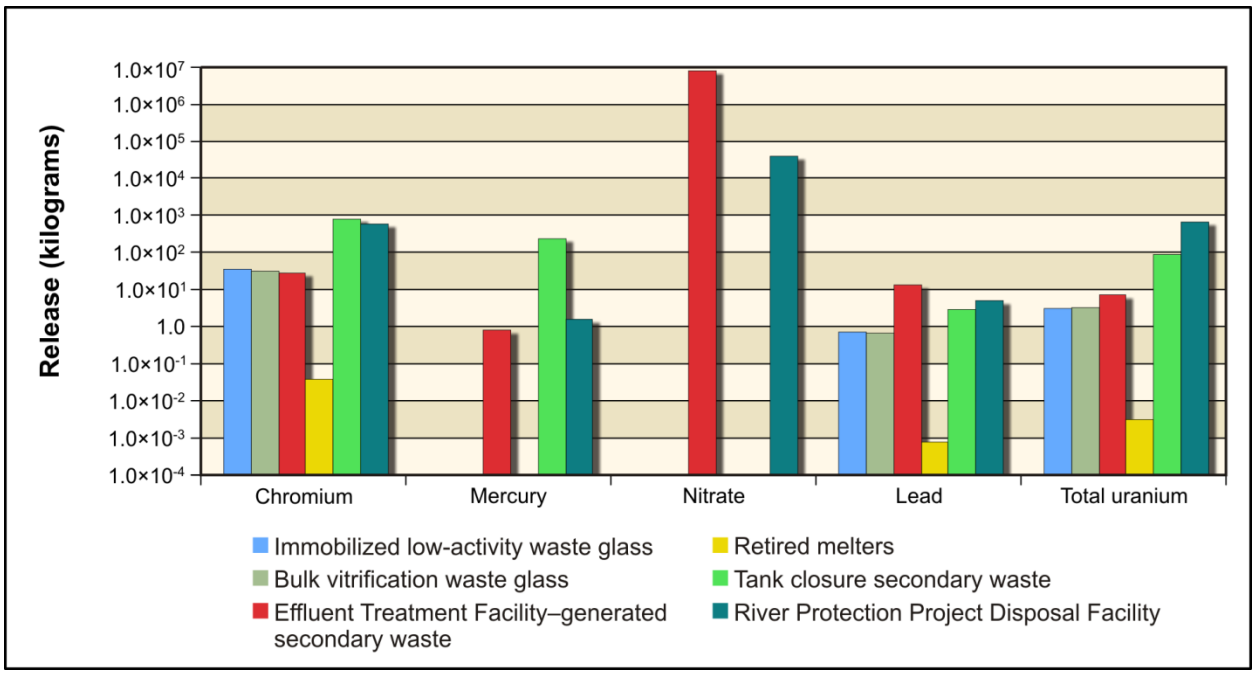


Figure M–93. Waste Management Alternative 3, Disposal Group 1, Subgroup 1-B, Chemical Releases to the Vadose Zone from the 200-East Area Integrated Disposal Facility

M.4.3.2.14 Waste Management Alternative 3: Disposal in IDF, 200-East and 200-West Areas, Disposal Group 1, Subgroup 1-C

Disposal Group 1, Subgroup 1-C, addresses the waste resulting from Tank Closure Alternative 3B, onsite non-CERCLA sources, FFTF decommissioning, waste management, and other DOE sites. Waste forms for IDF-East include the following:

- ILAW glass
- LAW melters
- Cast stone waste
- Tank closure secondary waste

Waste forms for IDF-West include the following:

- FFTF decommissioning secondary waste
- Waste management secondary waste
- Offsite waste
- Onsite non-CERCLA waste

Waste forms for the RPPDF include those resulting from tank closure cleanup activities under Tank Closure Alternative 3B. Potential releases to the vadose zone under Waste Management Alternative 3, Disposal Group 1, Subgroup 1-C, are indicated in Table M–46 and Figures M–94 and M–95.

Table M–46. Waste Management Alternative 3, Disposal Group 1, Subgroup 1-C, Radionuclide and Chemical Releases to the Vadose Zone

Source	Radionuclide (curies)										Chemical (kilograms)					
	H-3	C-14	Sr-90	Tc-99	I-129	Cs-137	Np-237	U-238	Pu-239	Am-241	Cr	F	Hg	NO_3	Pb	Utot
IDF-East																
ILAW glass	–	–	8.12×10^{-4}	2.30×10^{-2}	7.75×10^{-4}	2.10×10^{-1}	6.86×10^{-7}	4.49×10^{-3}	1.04×10^{-4}	–	3.71×10^{1}	–	–	–	7.39×10^{-1}	3.13
Cast stone waste	8.44×10^{3}	5.03×10^{2}	3.73×10^{4}	9.14×10^{3}	8.98×10^{-1}	2.08×10^{4}	8.07×10^{-2}	1.93	1.84	–	3.25×10^{5}	–	5.39×10^{1}	4.95×10^{7}	9.08×10^{1}	1.31×10^{3}
ETF-generated secondary waste	–	8.54×10^{-1}	9.13×10^{-1}	5.81×10^{1}	7.32×10^{-1}	4.87×10^{-3}	1.19×10^{-2}	3.84×10^{-3}	2.53×10^{-6}	–	1.84×10^{1}	–	6.00×10^{-1}	2.63×10^{6}	1.06×10^{-1}	3.76
Retired melters	–	–	8.27×10^{-7}	2.34×10^{-5}	7.89×10^{-7}	2.13×10^{-4}	6.97×10^{-10}	4.57×10^{-6}	1.06×10^{-7}	–	3.77×10^{-2}	–	–	–	7.53×10^{-4}	3.18×10^{-3}
TC secondary waste	–	–	7.27×10^{4}	3.33×10^{2}	4.25×10^{-2}	9.16×10^{2}	2.77×10^{-2}	1.47×10^{-1}	3.59×10^{-1}	–	8.02×10^{2}	–	1.78×10^{2}	–	2.89	9.08×10^{1}
RPPDF	1.27×10^{-1}	3.61×10^{-1}	4.15	9.71	1.67×10^{-2}	2.30×10^{-1}	1.85×10^{-2}	4.66×10^{-1}	5.31×10^{-1}	–	5.86×10^{2}	–	1.61	3.93×10^{4}	4.97	6.60×10^{2}
IDF-West																
FFTF Decommis-sioning Alternative 3 waste	2.29	4.78×10^{1}	–	2.72×10^{1}	–	7.46×10^{-5}	–	–	–	–	7.51×10^{-3}	–	–	–	3.64×10^{-4}	7.91×10^{3}
WM secondary and onsite waste	3.66×10^{3}	6.82×10^{-1}	1.18×10^{3}	1.35	1.58×10^{-4}	5.47×10^{1}	2.62×10^{-3}	1.21×10^{-1}	6.20×10^{-2}	5.65×10^{-3}	1.83×10^{2}	2.74×10^{2}	4.16×10^{1}	2.97×10^{3}	1.30×10^{3}	1.56×10^{-1}
Offsite waste	5.57×10^{4}	5.68×10^{2}	1.87×10^{5}	1.46×10^{3}	2.26	1.93×10^{4}	6.28×10^{-1}	3.77×10^{2}	3.49	5.80×10^{-2}	8.05×10^{1}	–	7.85	–	3.24	–

Note: To convert kilograms to pounds, multiply by 2.2046.

Key: Am-241=americium-241; C-14=carbon-14; Cr=chromium; Cs-137=cesium-137; ETF=Effluent Treatment Facility; F=fluoride; FFTF=Fast Flux Test Facility; H-3=hydrogen-3 (tritium); Hg=mercury; I-129=iodine-129; IDF-East=200-East Area Integrated Disposal Facility; IDF-West=200-West Area Integrated Disposal Facility; ILAW=immobilized low-activity waste; NO_3=nitrate; Np-237=neptunium-237; Pb=lead; Pu-239=plutonium-239; RPPDF=River Protection Project Disposal Facility; Sr-90=strontium-90; TC=tank closure; Tc-99=technetium-99; U-238=uranium-238; Utot=total uranium; WM=waste management.

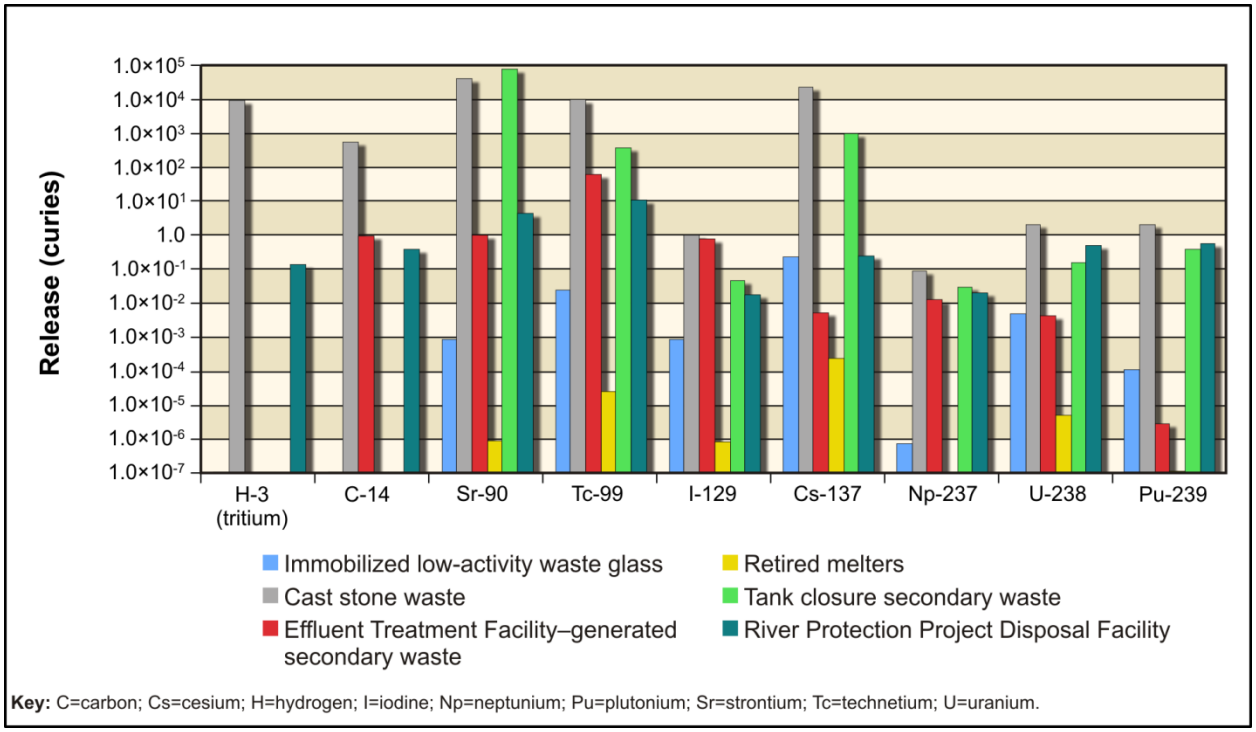


Figure M–94. Waste Management Alternative 3, Disposal Group 1, Subgroup 1-C, Radionuclide Releases to the Vadose Zone from the 200-East Area Integrated Disposal Facility

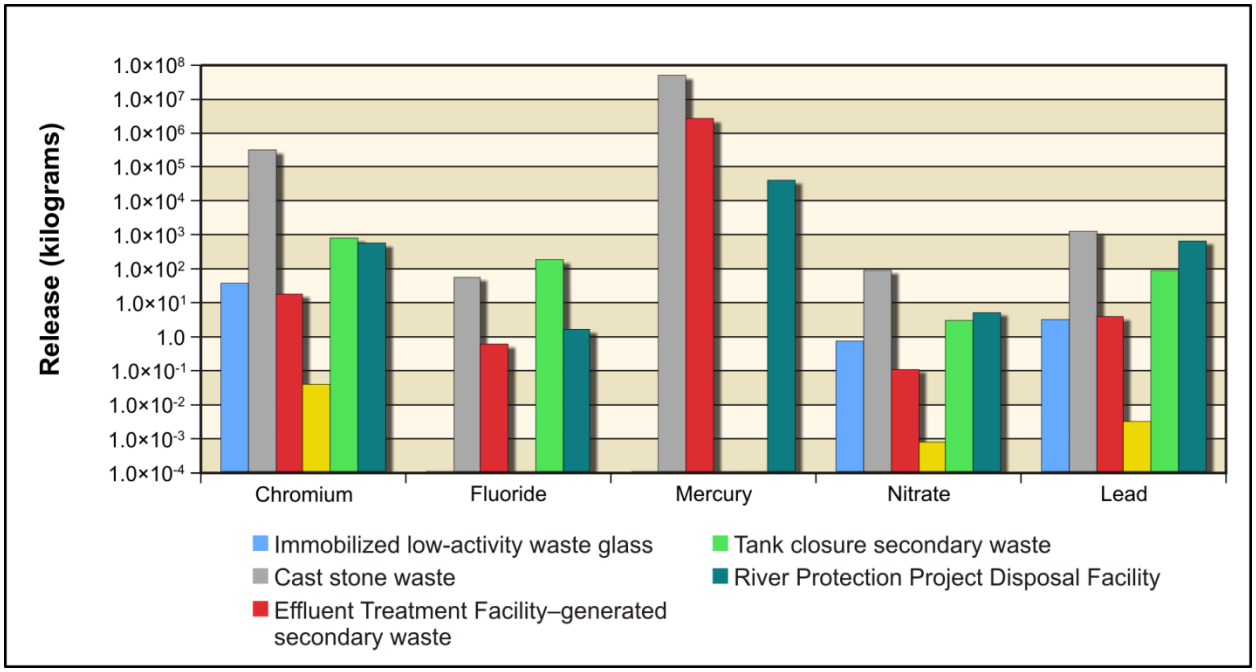


Figure M–95. Waste Management Alternative 3, Disposal Group 1, Subgroup 1-C, Chemical Releases to the Vadose Zone from the 200-East Area Integrated Disposal Facility

M.4.3.2.15 Waste Management Alternative 3: Disposal in IDF, 200-East and 200 West Areas, Disposal Group 1, Subgroup 1-D

Disposal Group 1, Subgroup 1-D, addresses the waste resulting from Tank Closure Alternative 3C, onsite non-CERCLA sources, FFTF decommissioning, waste management, and other DOE sites. Waste forms for IDF-East include the following:

- ILAW glass
- LAW melters
- Steam reforming waste
- Tank closure secondary waste

Waste forms for IDF-West include the following:

- FFTF decommissioning secondary waste
- Waste management secondary waste
- Offsite waste
- Onsite non-CERCLA waste

Waste forms for the RPPDF include those resulting from tank closure cleanup activities under Tank Closure Alternative 3C. Potential releases to the vadose zone under Waste Management Alternative 3, Disposal Group 1, Subgroup 1-D, are indicated in Table M–47 and Figures M–96 and M–97.

Table M–47. Waste Management Alternative 3, Disposal Group 1, Subgroup 1-D, Radionuclide and Chemical Releases to the Vadose Zone

Source	Radionuclide (curies)										Chemical (kilograms)					
	H-3	C-14	Sr-90	Tc-99	I-129	Cs-137	Np-237	U-238	Pu-239	Am-241	Cr	F	Hg	NO_3	Pb	Utot
IDF-East																
ILAW glass	–	–	8.12×10^{-4}	2.30	7.75×10^{-4}	2.10×10^{-1}	6.86×10^{-7}	4.49×10^{-3}	1.04×10^{-4}	–	3.71×10^{1}	–	–	–	7.39×10^{-1}	3.13
Steam reforming waste	–	–	2.07×10^{2}	3.76×10^{3}	1.25	2.14×10^{3}	1.78×10^{-1}	9.54	1.69×10^{2}	–	6.01×10^{4}	–	–	–	1.25×10^{3}	6.44×10^{3}
ETF-generated secondary waste	–	1.54	7.69	4.63×10^{1}	2.74	1.71×10^{-1}	1.20×10^{-2}	8.33×10^{-3}	3.36×10^{-6}	–	2.72×10^{1}	–	8.05×10^{-1}	9.17×10^{6}	1.38×10^{1}	6.72
Retired melters	–	–	8.27×10^{-7}	2.34×10^{-3}	7.89×10^{-7}	2.13×10^{-4}	6.97×10^{-10}	4.57×10^{-6}	1.06×10^{-7}	–	3.77×10^{-2}	–	–	–	7.53×10^{-4}	3.18×10^{-3}
TC secondary waste	–	–	7.28×10^{4}	1.28×10^{2}	4.25×10^{-2}	9.17×10^{2}	2.77×10^{-2}	1.48×10^{-1}	3.59×10^{-1}	–	8.02×10^{2}	–	2.38×10^{2}	–	2.89	9.08×10^{1}
RPPDF	1.27×10^{-1}	3.61×10^{-1}	4.15	9.71	1.67×10^{-2}	2.30×10^{-1}	1.85×10^{-2}	4.66×10^{-1}	5.31×10^{-1}	–	5.86×10^{2}	–	1.61	3.93×10^{4}	4.97	6.60×10^{2}
IDF-West																
FFTF Decommis-sioning Alternative 3 waste	2.29	4.78×10^{1}	–	2.72×10^{1}	–	7.46×10^{-5}	–	–	–	–	7.51×10^{-3}	–	–	–	3.64×10^{-4}	7.91×10^{3}
WM secondary and onsite waste	3.66×10^{3}	6.82×10^{-1}	1.18×10^{3}	1.35	1.58×10^{-4}	5.47×10^{1}	2.62×10^{-3}	1.21×10^{-1}	6.20×10^{-2}	5.65×10^{-3}	1.83×10^{2}	2.74×10^{2}	4.16×10^{1}	2.97×10^{3}	1.30×10^{3}	1.56×10^{-1}
Offsite waste	5.57×10^{4}	5.68×10^{2}	1.87×10^{5}	1.46×10^{3}	2.26	1.93×10^{4}	6.28×10^{-1}	3.77×10^{2}	3.49	5.80×10^{-2}	8.05×10^{1}	–	7.85	–	3.24	–

Note: To convert kilograms to pounds, multiply by 2.2046.

Key: Am-241=americium-241; C-14=carbon-14; Cr=chromium; Cs-137=cesium-137; ETF=Effluent Treatment Facility; F=fluoride; FFTF=Fast Flux Test Facility; H-3=hydrogen-3 (tritium); Hg=mercury; I-129=iodine-129; IDF-East=200-East Area Integrated Disposal Facility; IDF-West=200-West Area Integrated Disposal Facility; ILAW=immobilized low-activity waste; NO_3=nitrate; Np-237=neptunium-237; Pb=lead; Pu-239=plutonium-239; RPPDF=River Protection Project Disposal Facility; Sr-90=strontium-90; TC=tank closure; Tc-99=technetium-99; U-238=uranium-238; Utot=total uranium; WM=waste management.

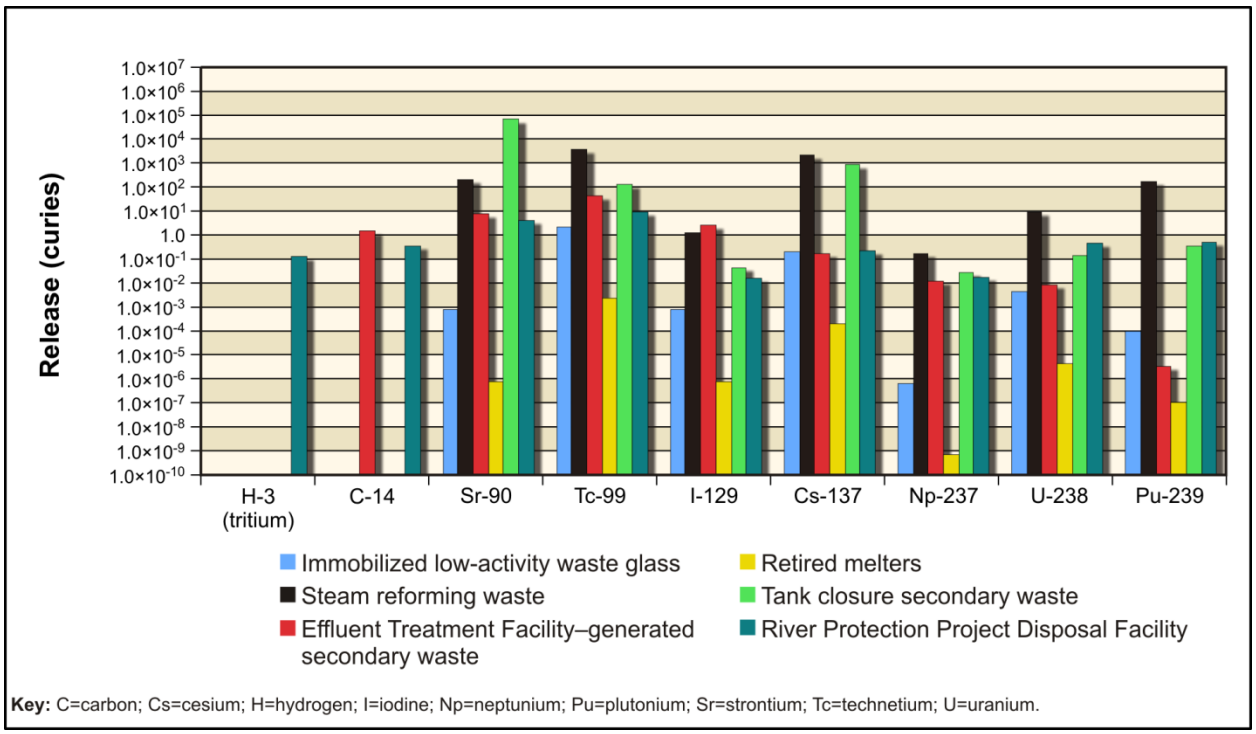


Figure M–96. Waste Management Alternative 3, Disposal Group 1, Subgroup 1-D, Radionuclide Releases to the Vadose Zone from the 200-East Area Integrated Disposal Facility

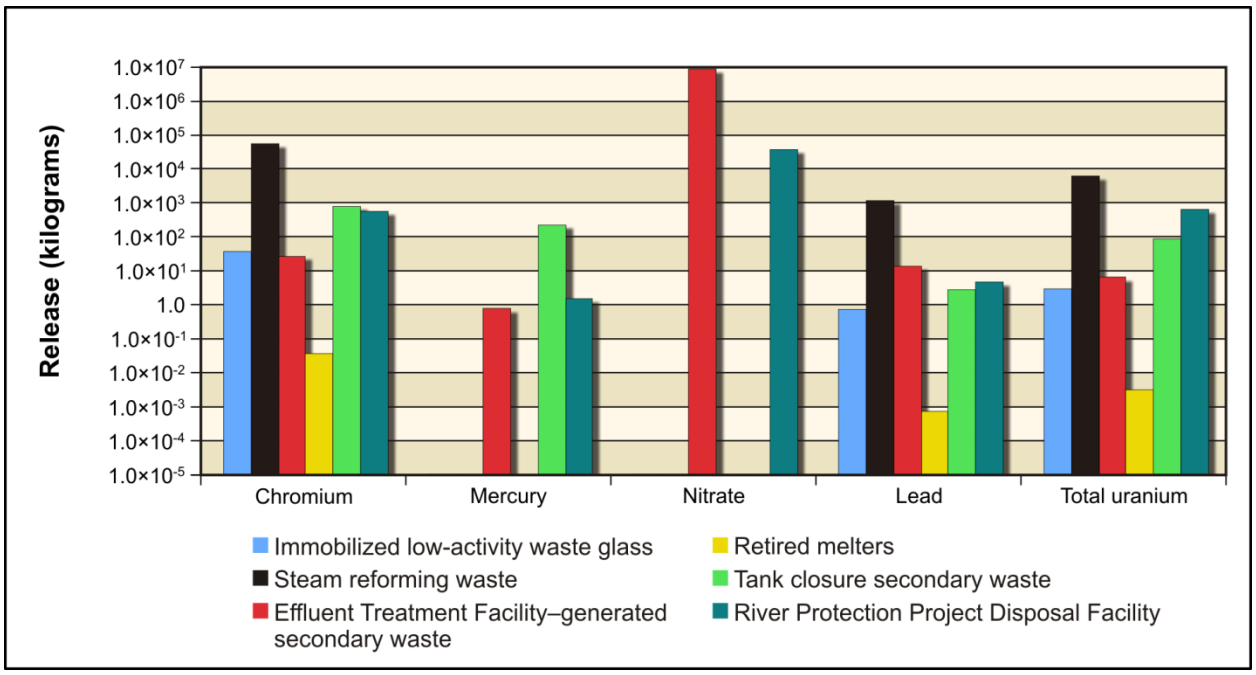


Figure M–97. Waste Management Alternative 3, Disposal Group 1, Subgroup 1-D, Chemical Releases to the Vadose Zone from the 200-East Area Integrated Disposal Facility

M.4.3.2.16 Waste Management Alternative 3: Disposal in IDF, 200-East and 200-West Areas, Disposal Group 1, Subgroup 1-E

Disposal Group 1, Subgroup 1-E, addresses the waste resulting from Tank Closure Alternative 4, onsite non-CERCLA sources, FFTF decommissioning, waste management, and other DOE sites. Waste forms for IDF-East include the following:

- ILAW glass
- LAW melters
- bulk vitrification glass
- Cast stone waste
- ETF-generated secondary solid waste
- Tank closure secondary waste

Waste forms for IDF-West include the following:

- FFTF decommissioning secondary waste
- Waste management secondary waste
- Offsite waste
- Onsite non-CERCLA waste

The RPPDF would not be constructed or operated under Tank Closure Alternative 4 because tank closure cleanup activities would not be conducted. Potential releases to the vadose zone under Waste Management Alternative 3, Disposal Group 1, Subgroup 1-E, are indicated in Table M–48 and Figures M–98 and M–99.

Table M–48. Waste Management Alternative 3, Disposal Group 1, Subgroup 1-E, Radionuclide and Chemical Releases to the Vadose Zone

Source	Radionuclide (curies)										Chemical (kilograms)					
	H-3	C-14	Sr-90	Tc-99	I-129	Cs-137	Np-237	U-238	Pu-239	Am-241	Cr	F	Hg	NO_3	Pb	Utot
IDF-East																
ILAW glass	–	–	1.66×10^{-2}	2.31	7.78×10^{-4}	2.90×10^{-1}	2.51×10^{-5}	5.57×10^{-3}	1.49×10^{-3}	–	3.74×10^{1}	–	–	–	7.67×10^{-1}	3.63
BV waste glass	–	–	1.95×10^{-1}	6.18×10^{2}	3.08×10^{-4}	1.90	9.54×10^{-5}	3.00×10^{-3}	9.04×10^{-2}	–	1.47×10^{1}	–	–	–	3.55×10^{-1}	1.97
Cast stone waste	4.66×10^{3}	2.77×10^{2}	7.46×10^{1}	1.09×10^{4}	4.94×10^{-1}	1.04×10^{3}	2.77×10^{-4}	8.16×10^{-1}	1.02×10^{-3}	–	1.78×10^{5}	–	2.86×10^{1}	2.73×10^{7}	4.33×10^{1}	5.64×10^{2}
ETF-generated secondary waste	–	1.18	7.88	3.53×10^{1}	1.66	1.61×10^{-1}	1.22×10^{-2}	7.05×10^{-3}	3.79×10^{-6}	–	2.31×10^{1}	–	7.05×10^{-1}	5.20×10^{6}	7.43	5.89
Retired melters	–	–	1.92×10^{-5}	2.65×10^{-3}	8.94×10^{-7}	3.32×10^{-4}	3.12×10^{-8}	6.40×10^{-6}	1.71×10^{-6}	–	4.32×10^{-2}	–	–	–	8.80×10^{-4}	4.15×10^{-3}
TC secondary waste	–	–	7.36×10^{4}	1.28×10^{2}	4.28×10^{-2}	9.27×10^{2}	2.80×10^{-2}	1.50×10^{-1}	3.63×10^{-1}	–	8.21×10^{2}	–	2.10×10^{2}	–	2.93	9.22×10^{1}
RPPDF	1.50	2.61	7.31	3.14×10^{1}	5.84×10^{-2}	1.57	7.75×10^{-2}	4.99	6.83×10^{-1}	–	1.86×10^{3}	–	9.23×10^{-1}	7.78×10^{4}	6.31	4.85×10^{3}
IDF-West																
FFTF Decommis-sioning Alternative 3 waste	2.29	4.78×10^{1}	–	2.72×10^{1}	–	7.46×10^{-5}	–	–	–	–	7.51×10^{-3}	–	–	–	3.64×10^{-4}	7.91×10^{3}
WM secondary and onsite waste	3.66×10^{3}	6.82×10^{-1}	1.18×10^{3}	1.35	1.58×10^{-4}	5.47×10^{1}	2.62×10^{-3}	1.21×10^{-1}	6.20×10^{-2}	5.65×10^{-3}	1.83×10^{2}	2.74×10^{2}	4.16×10^{1}	2.97×10^{3}	1.30×10^{3}	1.56×10^{-1}
Offsite waste	5.57×10^{4}	5.68×10^{2}	1.87×10^{5}	1.46×10^{3}	2.26	1.93×10^{4}	6.28×10^{-1}	3.77×10^{2}	3.49	5.80×10^{-2}	8.05×10^{1}	–	7.85	–	3.24	–

Note: To convert kilograms to pounds, multiply by 2.2046.

Key: Am-241=americium-241; BV=bulk vitrification; C-14=carbon-14; Cr=chromium; Cs-137=cesium-137; ETF=Effluent Treatment Facility; F=fluoride; FFTF=Fast Flux Test Facility; H-3=hydrogen-3 (tritium); Hg=mercury; I-129=iodine-129; IDF-East=200-East Area Integrated Disposal Facility; IDF-West=200-West Area Integrated Disposal Facility; ILAW=immobilized low-activity waste; NO_3=nitrate; Np-237=neptunium-237; Pb=lead; Pu-239=plutonium-239; RPPDF=River Protection Project Disposal Facility; Sr-90=strontium-90; TC=tank closure; Tc-99=technetium-99; U-238=uranium-238; Utot=total uranium; WM=waste management.

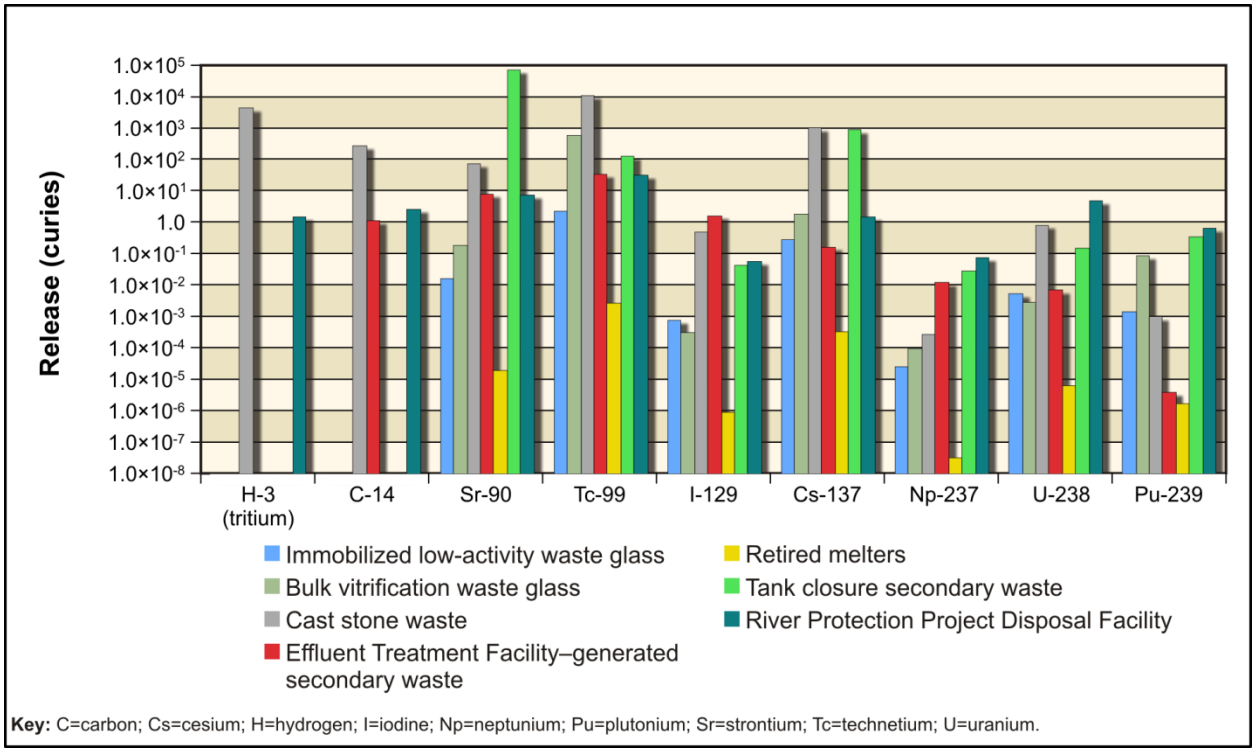


Figure M–98. Waste Management Alternative 3, Disposal Group 1, Subgroup 1-E, Radionuclide Releases to the Vadose Zone from the 200-East Area Integrated Disposal Facility

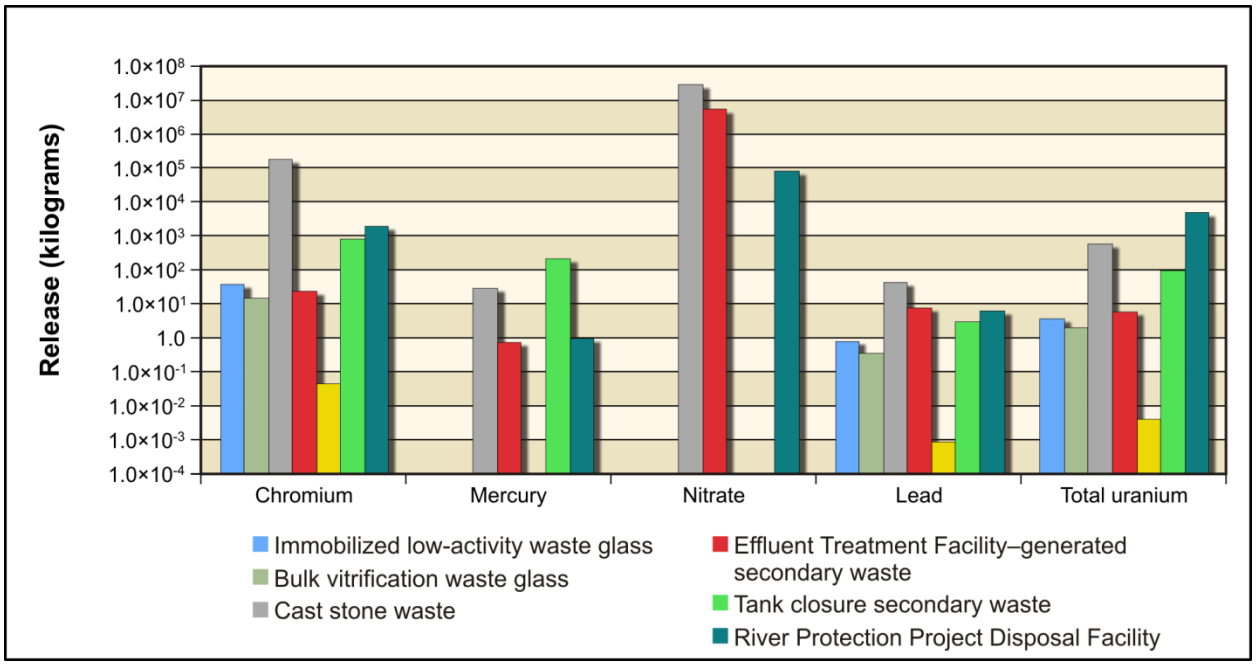


Figure M–99. Waste Management Alternative 3, Disposal Group 1, Subgroup 1-E, Chemical Releases to the Vadose Zone from the 200-East Area Integrated Disposal Facility

M.4.3.2.17 Waste Management Alternative 3: Disposal in IDF, 200-East and 200-West Areas, Disposal Group 1, Subgroup 1-F

Disposal Group 1, Subgroup 1-F, addresses the waste resulting from Tank Closure Alternative 5, onsite non-CERCLA sources, FFTF decommissioning, waste management, and other DOE sites. Waste forms for IDF-East include the following:

- ILAW glass
- LAW melters
- bulk vitrification glass
- Cast stone waste
- Sulfate grout
- Tank closure secondary waste

Waste forms for IDF-West include the following:

- FFTF decommissioning secondary waste
- Waste management secondary waste
- Offsite waste
- Onsite non-CERCLA waste

Potential releases to the vadose zone under Waste Management Alternative 3, Disposal Group 1, Subgroup 1-F, are indicated in Table M–49 and Figures M–100 and M–101.

Table M–49. Waste Management Alternative 3, Disposal Group 1, Subgroup 1-F, Radionuclide and Chemical Releases to the Vadose Zone

Source	Radionuclide (curies)										Chemical (kilograms)					
	H-3	C-14	Sr-90	Tc-99	I-129	Cs-137	Np-237	U-238	Pu-239	Am-241	Cr	F	Hg	NO_3	Pb	Utot
IDF-East																
ILAW glass	–	–	1.34×10^{-7}	3.79	1.28×10^{-3}	3.04×10^{-1}	1.08×10^{-6}	7.39×10^{-3}	1.47×10^{-4}	–	6.09×10^{-3}	–	–	–	1.22×10^{-4}	5.15
BV waste glass	–	–	1.76×10^{-1}	5.57×10^{2}	2.77×10^{-4}	1.90	8.60×10^{-5}	2.70×10^{-3}	8.17×10^{-2}	–	1.34×10^{1}	–	–	–	3.19×10^{-1}	1.78
Cast stone waste	1.60×10^{3}	9.53×10^{1}	2.56×10^{1}	3.74×10^{3}	1.70×10^{-1}	3.51×10^{2}	9.50×10^{-5}	2.79×10^{-1}	3.49×10^{-4}	–	6.10×10^{4}	–	9.80	9.34×10^{6}	1.48×10^{1}	1.94×10^{2}
ETF-generated secondary waste	–	3.37×10^{-1}	7.09	5.03×10^{1}	2.06	1.62×10^{-1}	1.11×10^{-2}	6.47×10^{-3}	3.41×10^{-6}	–	1.15×10^{1}	–	6.90×10^{-1}	1.20×10^{7}	6.66	5.42
Retired melters	–	–	1.36×10^{-10}	3.84×10^{-3}	1.30×10^{-6}	3.10×10^{-4}	1.10×10^{-9}	7.53×10^{-6}	1.50×10^{-7}	–	6.20×10^{-6}	–	–	–	1.24×10^{-7}	5.23×10^{-3}
Sulfate grout	–	–	1.05×10^{2}	–	–	1.57×10^{2}	1.54×10^{-5}	–	2.17×10^{-4}	–	2.21×10^{5}	–	–	–	6.46×10^{1}	–
TC secondary waste	–	–	7.05×10^{4}	2.08×10^{2}	7.48×10^{-2}	8.84×10^{2}	2.69×10^{-2}	1.45×10^{-1}	3.49×10^{-1}	–	3.32×10^{2}	–	2.19×10^{2}	–	2.70	8.99×10^{1}
IDF-West																
FFTF Decommis-sioning Alternative 3 waste	2.29	4.78×10^{1}	–	2.72×10^{1}	–	7.46×10^{-5}	–	–	–	–	7.51×10^{-3}	–	–	–	3.64×10^{-4}	7.91×10^{3}
WM secondary and onsite waste	3.66×10^{3}	6.82×10^{-1}	1.18×10^{3}	1.35	1.58×10^{-4}	5.47×10^{1}	2.62×10^{-3}	1.21×10^{-1}	6.20×10^{-2}	5.65×10^{-3}	1.83×10^{2}	2.74×10^{2}	4.16×10^{1}	2.97×10^{3}	1.30×10^{3}	1.56×10^{-1}
Offsite waste	5.57×10^{4}	5.68×10^{2}	1.87×10^{5}	1.46×10^{3}	2.26	1.93×10^{4}	6.28×10^{-1}	3.77×10^{2}	3.49	5.80×10^{-2}	8.05×10^{1}	–	7.85	–	3.24	–

Note: To convert kilograms to pounds, multiply by 2.2046.

Key: Am-241=americium-241; BV=bulk vitrification; C-14=carbon-14; Cr=chromium; Cs-137=cesium-137; ETF=Effluent Treatment Facility; F=fluoride; FFTF=Fast Flux Test Facility; H-3=hydrogen-3 (tritium); Hg=mercury; I-129=iodine-129; IDF-East=200-East Area Integrated Disposal Facility; IDF-West=200-West Area Integrated Disposal Facility; ILAW=immobilized low-activity waste; NO_3=nitrate; Np-237=neptunium-237; Pb=lead; Pu-239=plutonium-239; Sr-90=strontium-90; TC=tank closure; Tc-99=technetium-99; U-238=uranium-238; Utot=total uranium; WM=waste management.

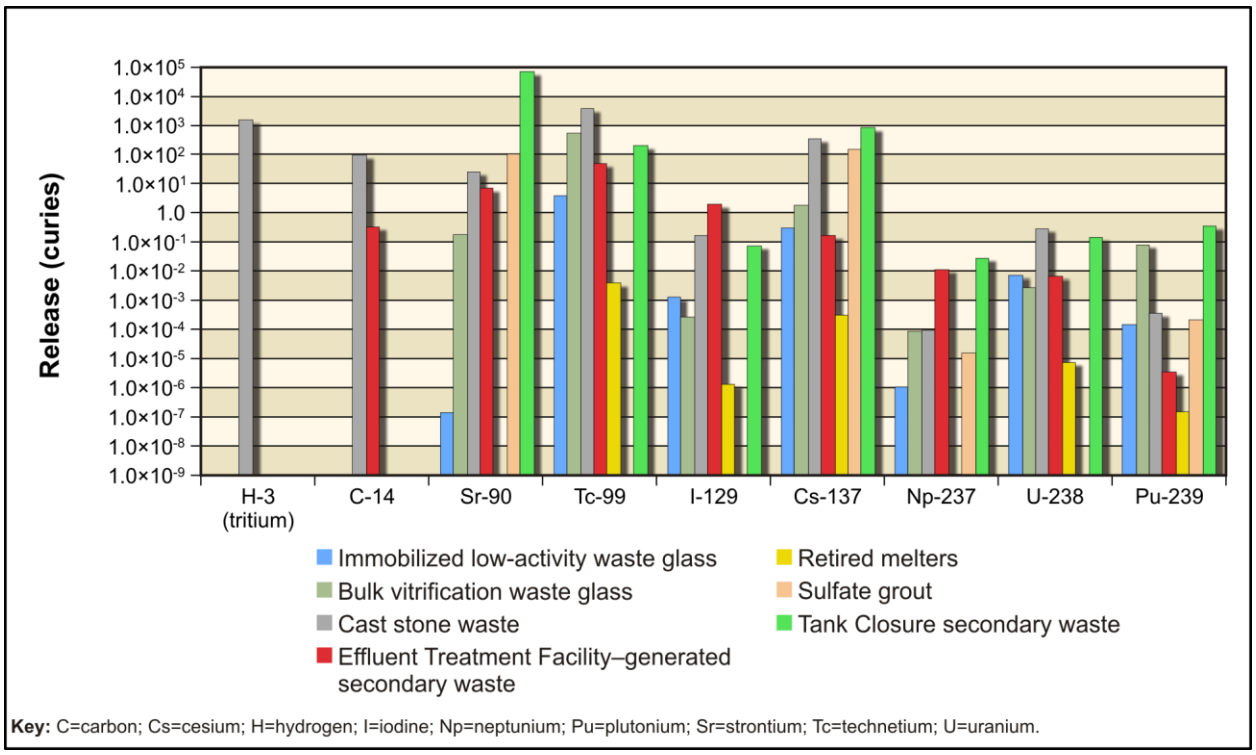


Figure M–100. Waste Management Alternative 3, Disposal Group 1, Subgroup 1-F, Radionuclide Releases to the Vadose Zone from the 200-East Area Integrated Disposal Facility

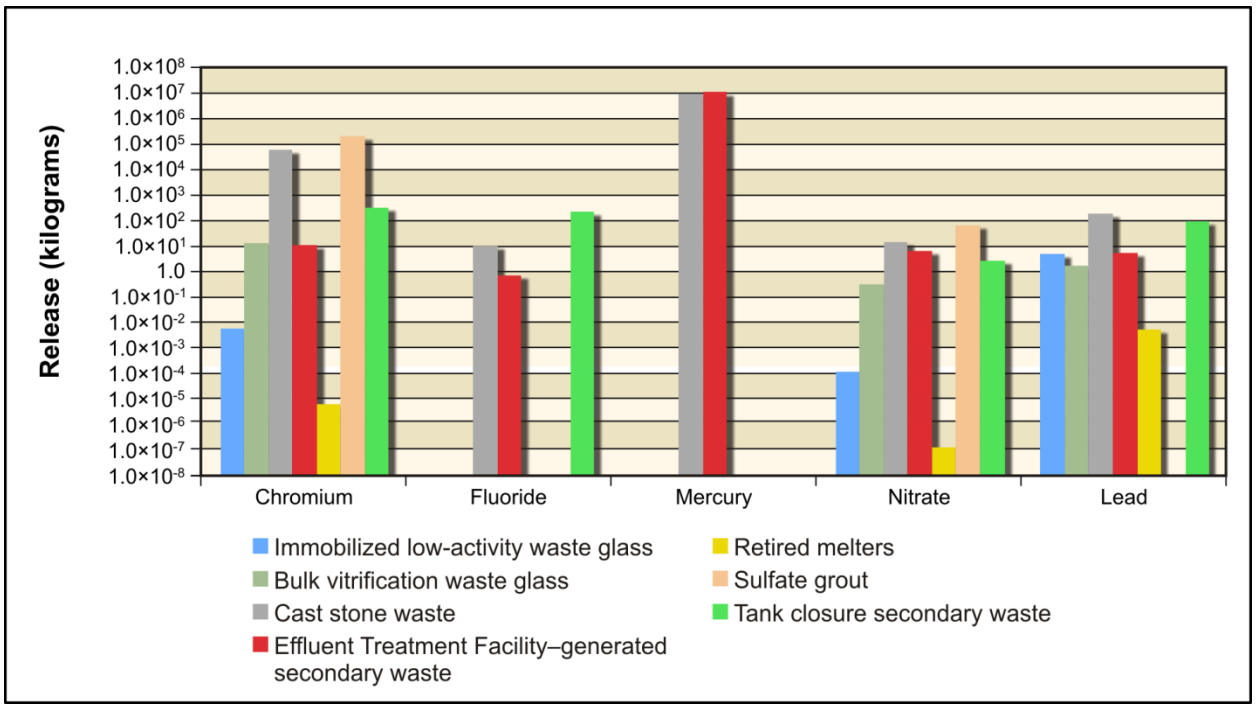


Figure M–101. Waste Management Alternative 3, Disposal Group 1, Subgroup 1-F, Chemical Releases to the Vadose Zone from the 200-East Area Integrated Disposal Facility

M.4.3.2.18 Waste Management Alternative 3: Disposal in IDF, 200-East and 200-West Areas, Disposal Group 1, Subgroup 1-G

Disposal Group 1, Subgroup 1-G, addresses the waste resulting from Tank Closure Alternative 6C, onsite non-CERCLA sources, FFTF decommissioning, waste management, and other DOE sites. Waste forms for IDF-East include the following:

- Tank closure secondary waste

The waste forms for IDF-West include the following:

- FFTF decommissioning secondary waste
- Waste management secondary waste
- Offsite waste
- Onsite non-CERCLA waste

Waste forms for the RPPDF include those resulting from tank closure cleanup activities under Tank Closure Alternative 6C. Potential releases to the vadose zone under Waste Management Alternative 3, Disposal Group 1, Subgroup 1-G, are indicated in Table M–50 and Figures M–102 and M–103.

Table M–50. Waste Management Alternative 3, Disposal Group 1, Subgroup 1-G, Radionuclide and Chemical Releases to the Vadose Zone

Source	Radionuclide (curies)										Chemical (kilograms)					
	H-3	C-14	Sr-90	Tc-99	I-129	Cs-137	Np-237	U-238	Pu-239	Am-241	Cr	F	Hg	NO_3	Pb	Utot
IDF-East																
ETF-generated secondary waste	–	2.77	9.24×10^{-1}	8.62×10^{1}	2.50	5.44×10^{-3}	1.20×10^{-2}	4.24×10^{-3}	2.76×10^{-6}	–	4.43×10^{1}	–	8.07×10^{-1}	9.01×10^{6}	8.36×10^{-2}	4.21
TC secondary waste	–	–	7.35×10^{4}	4.31×10^{2}	1.45×10^{-1}	1.02×10^{3}	2.81×10^{-2}	1.61×10^{-1}	3.95×10^{-1}	–	1.94×10^{3}	–	2.39×10^{2}	–	3.29	1.03×10^{2}
RPPDF	1.27×10^{-1}	3.61×10^{-1}	4.15	9.71	1.67×10^{-2}	2.30×10^{-1}	1.85×10^{-2}	4.66×10^{-1}	5.31×10^{-1}	–	5.86×10^{2}	–	1.61	3.93×10^{4}	4.97	6.60×10^{2}
IDF-West																
FFTF Decommis-sioning Alternative 3 waste	2.29	4.78×10^{1}	–	2.72×10^{1}	–	7.46×10^{-5}	–	–	–	–	7.51×10^{-3}	–	–	–	3.64×10^{-4}	7.91×10^{3}
WM secondary and onsite waste	3.66×10^{3}	6.82×10^{-1}	1.18×10^{3}	1.35	1.58×10^{-4}	5.47×10^{1}	2.62×10^{-3}	1.21×10^{-1}	6.20×10^{-2}	5.65×10^{-3}	1.83×10^{2}	2.74×10^{2}	4.16×10^{1}	2.97×10^{3}	1.30×10^{3}	1.56×10^{-1}
Offsite waste	5.57×10^{4}	5.68×10^{2}	1.87×10^{5}	1.46×10^{3}	2.26	1.93×10^{4}	6.28×10^{-1}	3.77×10^{2}	3.49	5.80×10^{-2}	8.05×10^{1}	–	7.85	–	3.24	–

Note: To convert kilograms to pounds, multiply by 2.2046.

Key: Am-241=americium-241; C-14=carbon-14; Cr=chromium; Cs-137=cesium-137; ETF=Effluent Treatment Facility; F=fluoride; FFTF=Fast Flux Test Facility; H-3=hydrogen-3 (tritium); Hg=mercury; I-129=iodine-129; IDF-East=200-East Area Integrated Disposal Facility; IDF-West=200-West Area Integrated Disposal Facility; NO_3=nitrate; Np-237=neptunium-237; Pb=lead; Pu-239=plutonium-239; RPPDF=River Protection Project Disposal Facility; Sr-90=strontium-90; TC=tank closure; Tc-99=technetium-99; U-238=uranium-238; Utot=total uranium; WM=waste management.

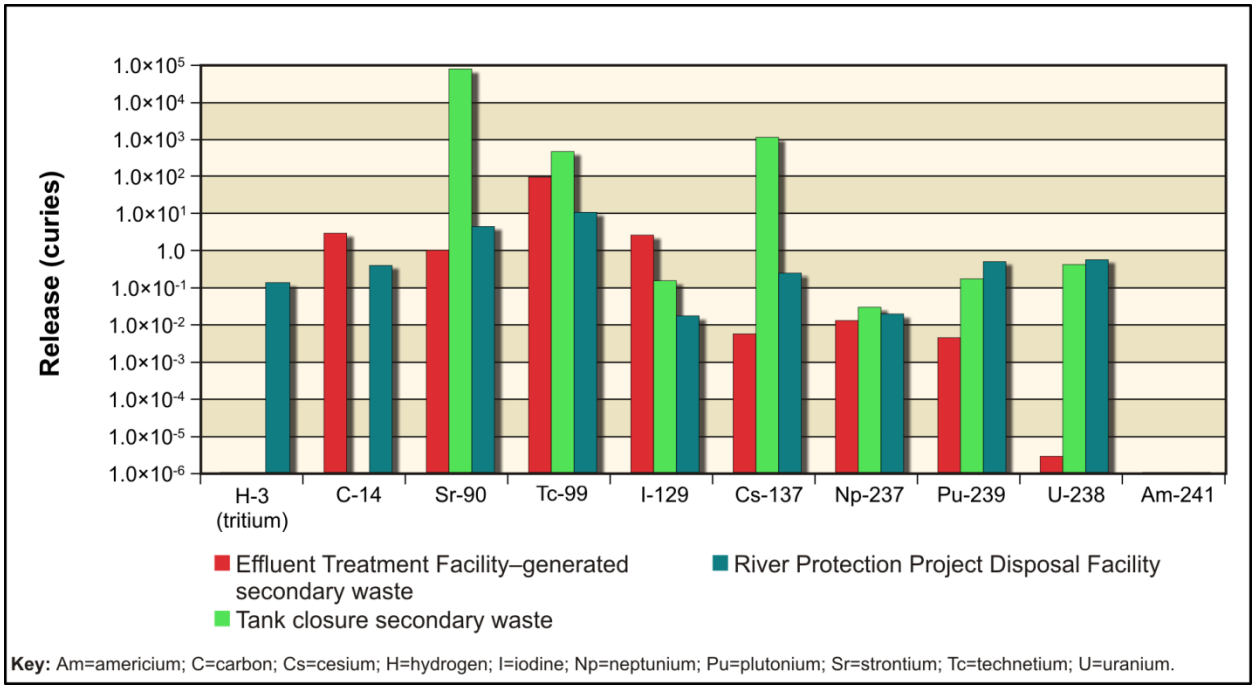


Figure M–102. Waste Management Alternative 3, Disposal Group 1, Subgroup 1-G, Radionuclide Releases to the Vadose Zone from the 200-East Area Integrated Disposal Facility

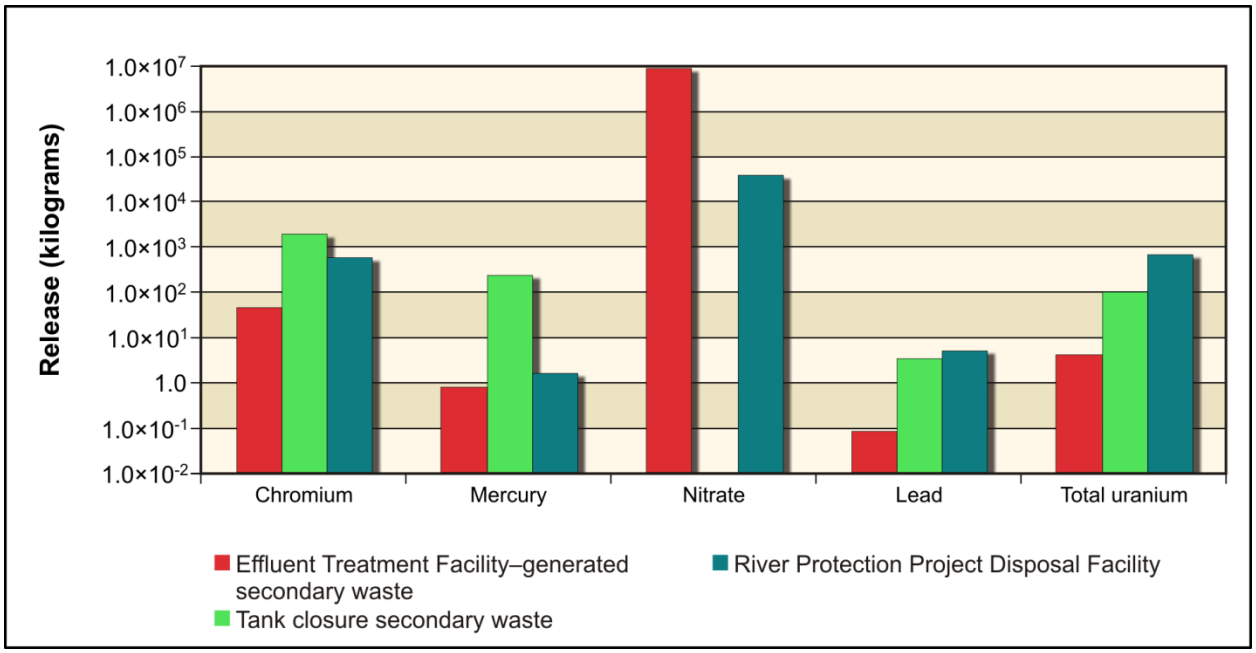


Figure M–103. Waste Management Alternative 3, Disposal Group 1, Subgroup 1-G, Chemical Releases to the Vadose Zone from the 200-East Area Integrated Disposal Facility

M.4.3.2.19 Waste Management Alternative 3: Disposal in IDF, 200-East and 200-West Areas, Disposal Group 2, Subgroup 2-A

Disposal Group 2, Subgroup 2-A, addresses the waste resulting from Tank Closure Alternative 2A, onsite non-CERCLA sources, FFTF decommissioning, waste management, and other DOE sites. Waste forms for IDF-East include the following:

- ILAW glass
- LAW melters
- Tank closure secondary waste

The waste forms for IDF-West include the following:

- FFTF decommissioning secondary waste
- Waste management secondary waste
- Offsite waste
- Onsite non-CERCLA waste

The RPPDF would not be constructed or operated under Tank Closure Alternative 2A because tank closure cleanup activities would not be conducted. Potential releases to the vadose zone under Waste Management Alternative 3, Disposal Group 2, Subgroup 2-A, are indicated in Table M–51 and Figures M–104 and M–105.

Table M–51. Waste Management Alternative 3, Disposal Group 2, Subgroup 2-A, Radionuclide and Chemical Releases to the Vadose Zone

Source	Radionuclide (curies)										Chemical (kilograms)					
	H-3	C-14	Sr-90	Tc-99	I-129	Cs-137	Np-237	U-238	Pu-239	Am-241	Cr	F	Hg	NO_3	Pb	Utot
IDF-East																
ILAW glass	–	–	2.71×10^{-3}	7.81	2.63×10^{-3}	5.38×10^{-1}	2.30×10^{-6}	1.51×10^{-2}	3.48×10^{-4}	–	1.26×10^{2}	–	–	–	2.46	1.04×10^{1}
ETF-generated secondary waste	–	2.76	9.19×10^{-1}	8.62×10^{1}	2.48	5.41×10^{-3}	1.19×10^{-2}	4.22×10^{-3}	2.74×10^{-6}	–	4.43×10^{1}	–	8.03×10^{-1}	9.01×10^{6}	8.31×10^{-2}	4.19
Retired melters	–	–	2.91×10^{-6}	8.38×10^{-3}	2.84×10^{-6}	5.78×10^{-4}	2.46×10^{-9}	1.62×10^{-5}	3.74×10^{-7}	–	1.35×10^{-1}	–	–	–	2.62×10^{-3}	1.10×10^{-2}
TC secondary waste	–	–	7.32×10^{4}	4.31×10^{2}	1.45×10^{-1}	1.02×10^{3}	2.80×10^{-2}	1.60×10^{-1}	3.92×10^{-1}	–	1.94×10^{3}	–	2.38×10^{2}	–	3.27	1.02×10^{2}
IDF-West																
FFTF Decommis-sioning Alternative 3 waste	2.29	4.78×10^{1}	–	2.72×10^{1}	–	7.46×10^{-5}	–	–	–	–	7.51×10^{-3}	–	–	–	3.64×10^{-4}	7.91×10^{3}
WM secondary and onsite waste	3.66×10^{3}	6.82×10^{-1}	1.18×10^{3}	1.35	1.58×10^{-4}	5.47×10^{1}	2.62×10^{-3}	1.21×10^{-1}	6.20×10^{-2}	5.65×10^{-3}	1.83×10^{2}	2.74×10^{2}	4.16×10^{1}	2.97×10^{3}	1.30×10^{3}	1.56×10^{-1}
Offsite waste	5.57×10^{4}	5.68×10^{2}	1.87×10^{5}	1.46×10^{3}	2.26	1.93×10^{4}	6.28×10^{-1}	3.77×10^{2}	3.49	5.80×10^{-2}	8.05×10^{1}	–	7.85	–	3.24	–

Note: To convert kilograms to pounds, multiply by 2.2046.

Key: Am-241=americium-241; C-14=carbon-14; Cr=chromium; Cs-137=cesium-137; ETF=Effluent Treatment Facility; F=fluoride; FFTF=Fast Flux Test Facility; H-3=hydrogen-3 (tritium); Hg=mercury; I-129=iodine-129; IDF-East=200-East Area Integrated Disposal Facility; IDF-West=200-West Area Integrated Disposal Facility; ILAW=immobilized low-activity waste; NO_3=nitrate; Np-237=neptunium-237; Pb=lead; Pu-239=plutonium-239; Sr-90=strontium-90; TC=tank closure; Tc-99=technetium-99; U-238=uranium-238; Utot=total uranium; WM=waste management.

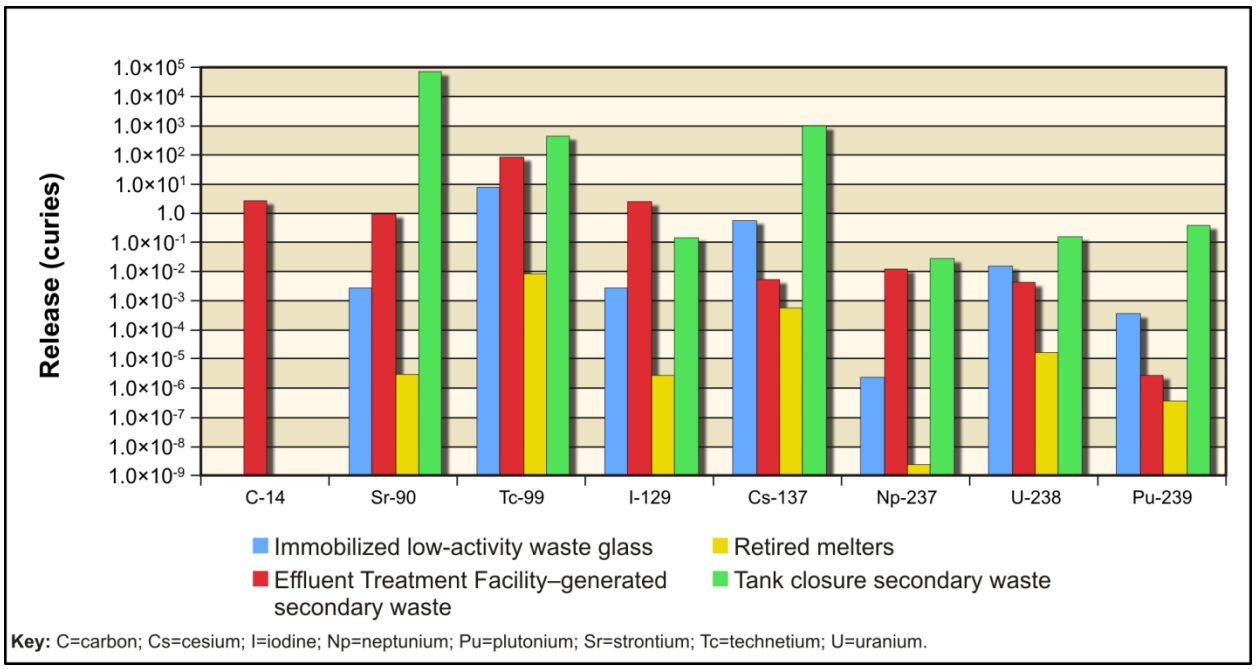


Figure M–104. Waste Management Alternative 3, Disposal Group 2, Subgroup 2-A, Radionuclide Releases to the Vadose Zone from the 200-East Area Integrated Disposal Facility

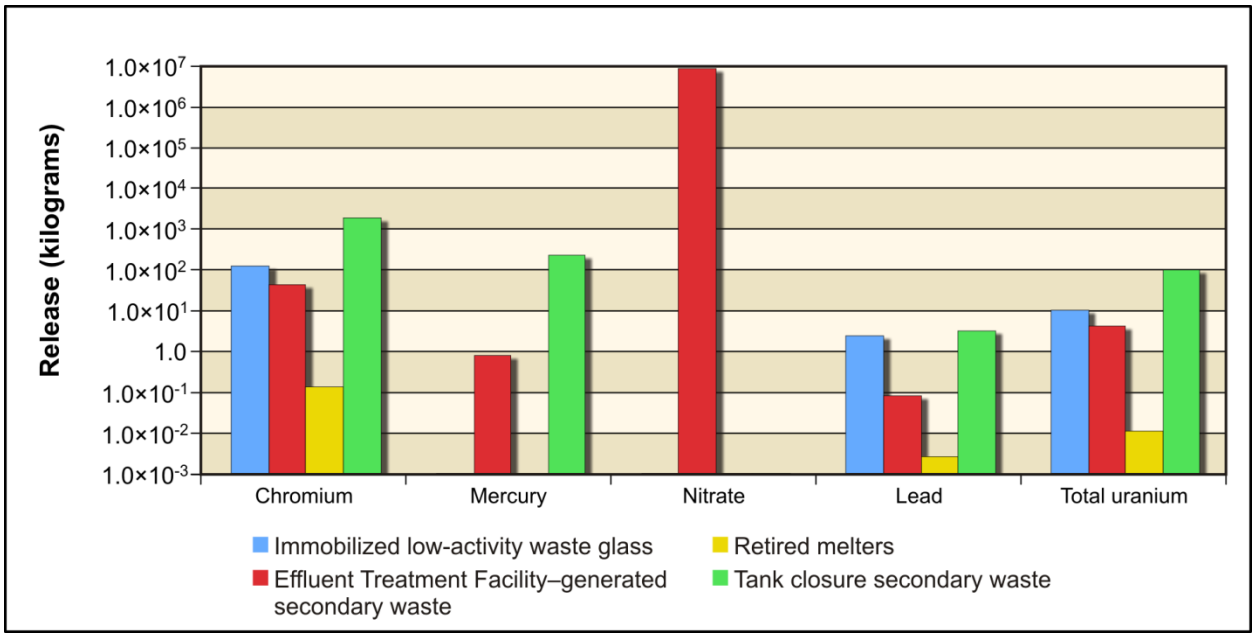


Figure M–105. Waste Management Alternative 3, Disposal Group 2, Subgroup 2-A, Chemical Releases to the Vadose Zone from the 200-East Area Integrated Disposal Facility

M.4.3.2.20 Waste Management Alternative 3: Disposal in IDF, 200-East and 200-West Areas, Disposal Group 2, Subgroup 2-B

Disposal Group 2, Subgroup 2-B, addresses the waste resulting from Tank Closure Alternative 6B, Base and Option Cases; onsite non-CERCLA sources; FFTF decommissioning; waste management; and other DOE sites. Waste forms for IDF-East include the following:

- PPF glass
- PPF melters
- Tank closure secondary waste

The waste forms for IDF-West include the following:

- FFTF decommissioning secondary waste
- Waste management secondary waste
- Offsite waste
- Onsite non-CERCLA waste

Waste forms for the RPPDF include those resulting from tank closure cleanup activities under Tank Closure Alternative 6B, Base and Option Cases. Potential releases to the vadose zone under Waste Management Alternative 3, Disposal Group 2, Subgroup 2-B, Base and Option Cases, are indicated in Tables M–52 and M–53 and Figures M–106 through M–109.

Table M–52. Waste Management Alternative 3, Disposal Group 2, Subgroup 2-B, Base Case, Radionuclide and Chemical Releases to the Vadose Zone

Source	Radionuclide (curies)										Chemical (kilograms)					
	H-3	C-14	Sr-90	Tc-99	I-129	Cs-137	Np-237	U-238	Pu-239	Am-241	Cr	F	Hg	NO_3	Pb	Utot
IDF-East																
ETF-generated secondary waste	–	2.78	9.24×10^{-1}	8.73×10^{1}	2.51	5.44×10^{-3}	1.20×10^{-2}	4.28×10^{-3}	2.75×10^{-6}	–	4.53×10^{1}	–	8.06×10^{-1}	9.16×10^{6}	8.37×10^{-2}	4.31
PPF glass	–	–	7.42×10^{-2}	3.52×10^{-2}	1.40×10^{-5}	2.36×10^{-1}	1.36×10^{-4}	2.03×10^{-3}	7.96×10^{-3}	–	2.20	–	–	–	7.05×10^{-2}	4.21
Retired melters	–	–	3.07×10^{-3}	1.46×10^{-3}	5.81×10^{-7}	9.80×10^{-3}	5.64×10^{-6}	8.40×10^{-5}	3.29×10^{-4}	–	9.12×10^{-2}	–	–	–	2.92×10^{-3}	1.74×10^{-1}
TC secondary waste	–	–	7.01×10^{4}	4.37×10^{2}	1.38×10^{-1}	9.77×10^{2}	2.68×10^{-2}	1.55×10^{-1}	3.75×10^{-1}	–	1.98×10^{3}	–	2.29×10^{2}	–	3.13	1.00×10^{2}
RPPDF	4.57	5.80	1.80×10^{1}	1.78×10^{2}	3.43×10^{-1}	4.61	3.81×10^{-1}	9.87	1.22	–	4.10×10^{3}	–	1.73	2.83×10^{5}	5.15×10^{1}	7.66×10^{3}
IDF-West																
FFTF Decommis-sioning Alternative 3 waste	2.29	4.78×10^{1}	–	2.72×10^{1}	–	7.46×10^{-5}	–	–	–	–	7.51×10^{-3}	–	–	–	3.64×10^{-4}	7.91×10^{3}
WM secondary and onsite waste	3.66×10^{3}	6.82×10^{-1}	1.18×10^{3}	1.35	1.58×10^{-4}	5.47×10^{1}	2.62×10^{-3}	1.21×10^{-1}	6.20×10^{-2}	5.65×10^{-3}	1.83×10^{2}	2.74×10^{2}	4.16×10^{1}	2.97×10^{3}	1.30×10^{3}	1.56×10^{-1}
Offsite waste	5.57×10^{4}	5.68×10^{2}	1.87×10^{5}	1.46×10^{3}	2.26	1.93×10^{4}	6.28×10^{-1}	3.77×10^{2}	3.49	5.80×10^{-2}	8.05×10^{1}	–	7.85	–	3.24	–

Note: To convert kilograms to pounds, multiply by 2.2046.

Key: Am-241=americium-241; C-14=carbon-14; Cr=chromium; Cs-137=cesium-137; ETF=Effluent Treatment Facility; F=fluoride; FFTF=Fast Flux Test Facility; H-3=hydrogen-3 (tritium); Hg=mercury; I-129=iodine-129; IDF-East=200-East Area Integrated Disposal Facility; IDF-West=200-West Area Integrated Disposal Facility; NO_3=nitrate; Np-237=neptunium-237; Pb=lead; PPF=Preprocessing Facility; Pu-239=plutonium-239; RPPDF=River Protection Project Disposal Facility; Sr-90=strontium-90; TC=tank closure; Tc-99=technetium-99; U-238=uranium-238; Utot=total uranium; WM=waste management.

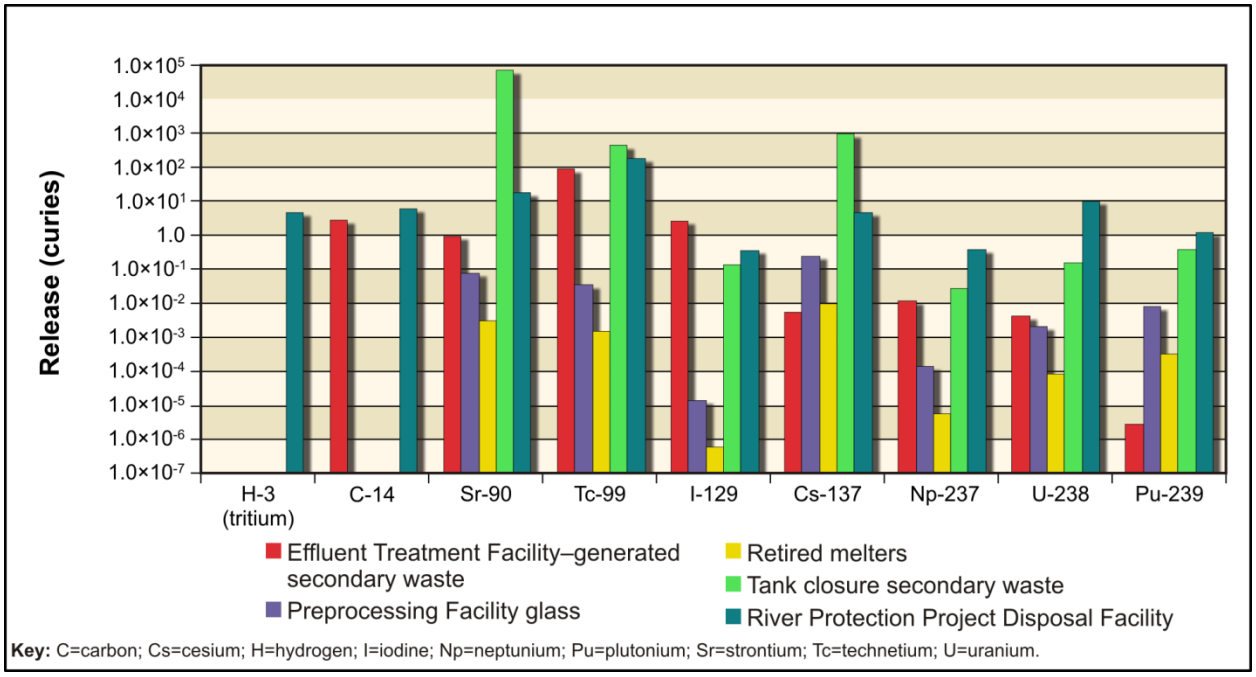


Figure M–106. Waste Management Alternative 3, Disposal Group 2, Subgroup 2-B, Base Case, Radionuclide Releases to the Vadose Zone from the 200-East Area Integrated Disposal Facility

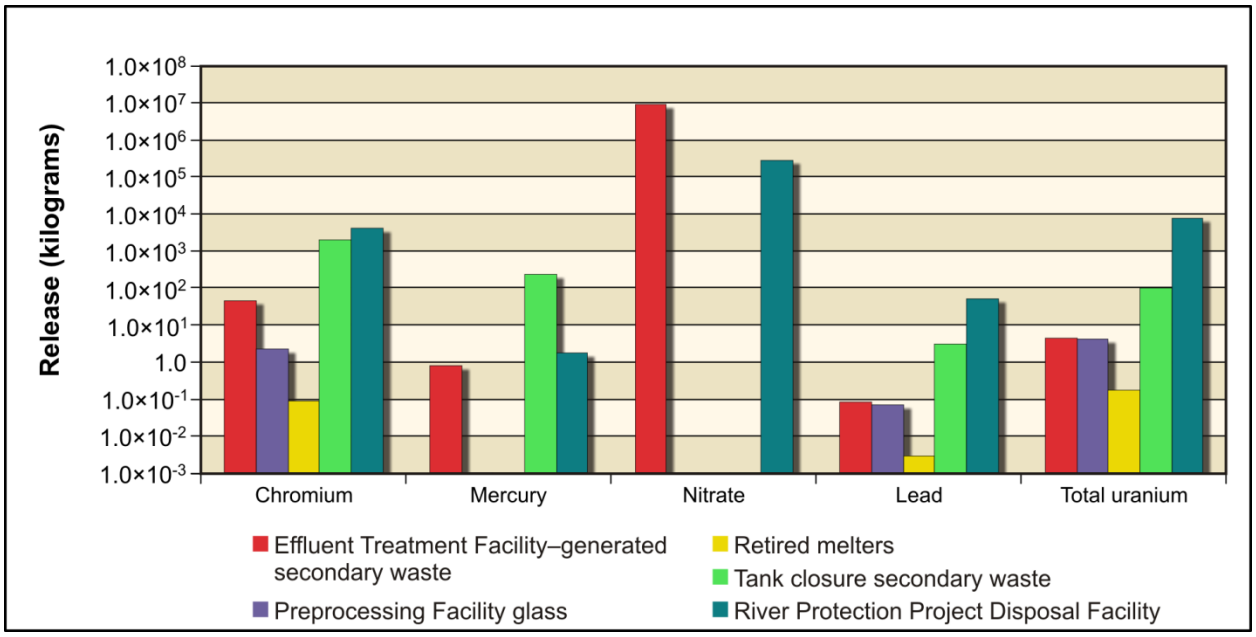


Figure M–107. Waste Management Alternative 3, Disposal Group 2, Subgroup 2-B, Base Case, Chemical Releases to the Vadose Zone from the 200-East Area Integrated Disposal Facility

Table M–53. Waste Management Alternative 3, Disposal Group 2, Subgroup 2-B, Option Case, Radionuclide and Chemical Releases to the Vadose Zone

Source	Radionuclide (curies)										Chemical (kilograms)					
	H-3	C-14	Sr-90	Tc-99	I-129	Cs-137	Np-237	U-238	Pu-239	Am-241	Cr	F	Hg	NO_3	Pb	Utot
IDF-East																
ETF-generated secondary waste	–	2.82	9.29×10^{-1}	8.79×10^{1}	2.53	5.48×10^{-3}	1.23×10^{-2}	4.35×10^{-3}	2.80×10^{-6}	–	5.65×10^{1}	–	8.38×10^{-1}	1.51×10^{7}	8.41×10^{-2}	4.38
PPF glass	–	–	9.09×10^{-2}	9.19×10^{-2}	3.36×10^{-5}	2.63×10^{-1}	7.26×10^{-4}	4.57×10^{-3}	2.22×10^{-1}	–	4.32×10^{1}	–	–	–	8.45×10^{-2}	6.20
Retired melters	–	–	8.33×10^{-4}	8.40×10^{-4}	3.06×10^{-7}	2.41×10^{-3}	6.63×10^{-6}	4.19×10^{-5}	2.03×10^{-3}	–	1.93×10^{-1}	–	–	–	7.02×10^{-4}	4.68×10^{-2}
TC secondary waste	–	–	7.54×10^{4}	4.40×10^{2}	1.51×10^{-1}	1.05×10^{3}	2.92×10^{-2}	1.68×10^{-1}	4.10×10^{-1}	–	2.47×10^{3}	–	2.54×10^{2}	–	3.37	1.09×10^{2}
RPPDF	7.95×10^{1}	8.26	1.89×10^{1}	2.70×10^{2}	4.96×10^{-1}	4.77	9.11×10^{-1}	1.37×10^{1}	5.94	–	3.69×10^{4}	–	1.15×10^{1}	1.04×10^{7}	5.29×10^{1}	9.24×10^{3}
IDF-West																
FFTF Decommis-sioning Alternative 3 waste	2.29	4.78×10^{1}	–	2.72×10^{1}	–	7.46×10^{-5}	–	–	–	–	7.51×10^{-3}	–	–	–	3.64×10^{-4}	7.91×10^{3}
WM secondary and onsite waste	3.66×10^{3}	6.82×10^{-1}	1.18×10^{3}	1.35	1.58×10^{-4}	5.47×10^{1}	2.62×10^{-3}	1.21×10^{-1}	6.20×10^{-2}	5.65×10^{-3}	1.83×10^{2}	2.74×10^{2}	4.16×10^{1}	2.97×10^{3}	1.30×10^{3}	1.56×10^{-1}
Offsite waste	5.57×10^{4}	5.68×10^{2}	1.87×10^{5}	1.46×10^{3}	2.26	1.93×10^{4}	6.28×10^{-1}	3.77×10^{2}	3.49	5.80×10^{-2}	8.05×10^{1}	–	7.85	–	3.24	–

Note: To convert kilograms to pounds, multiply by 2.2046.

Key: Am-241=americium-241; C-14=carbon-14; Cr=chromium; Cs-137=cesium-137; ETF=Effluent Treatment Facility; F=fluoride; FFTF=Fast Flux Test Facility; H-3=hydrogen-3 (tritium); Hg=mercury; I-129=iodine-129; IDF-East=200-East Area Integrated Disposal Facility; IDF-West=200-West Area Integrated Disposal Facility; NO_3=nitrate; Np-237=neptunium-237; Pb=lead; PPF=Preprocessing Facility; Pu-239=plutonium-239; RPPDF=River Protection Project Disposal Facility; Sr-90=strontium-90; TC=tank closure; Tc-99=technetium-99; U-238=uranium-238; Utot=total uranium; WM=waste management.

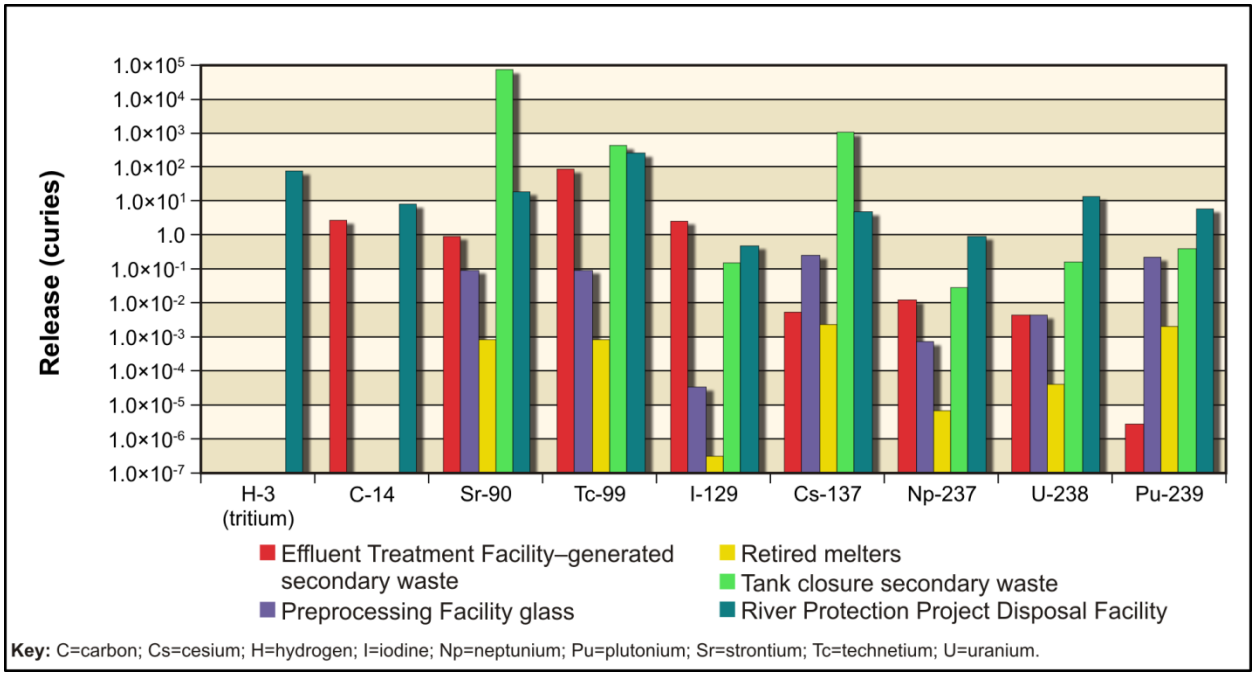


Figure M–108. Waste Management Alternative 3, Disposal Group 2, Subgroup 2-B, Option Case, Radionuclide Releases to the Vadose Zone from the 200-East Area Integrated Disposal Facility

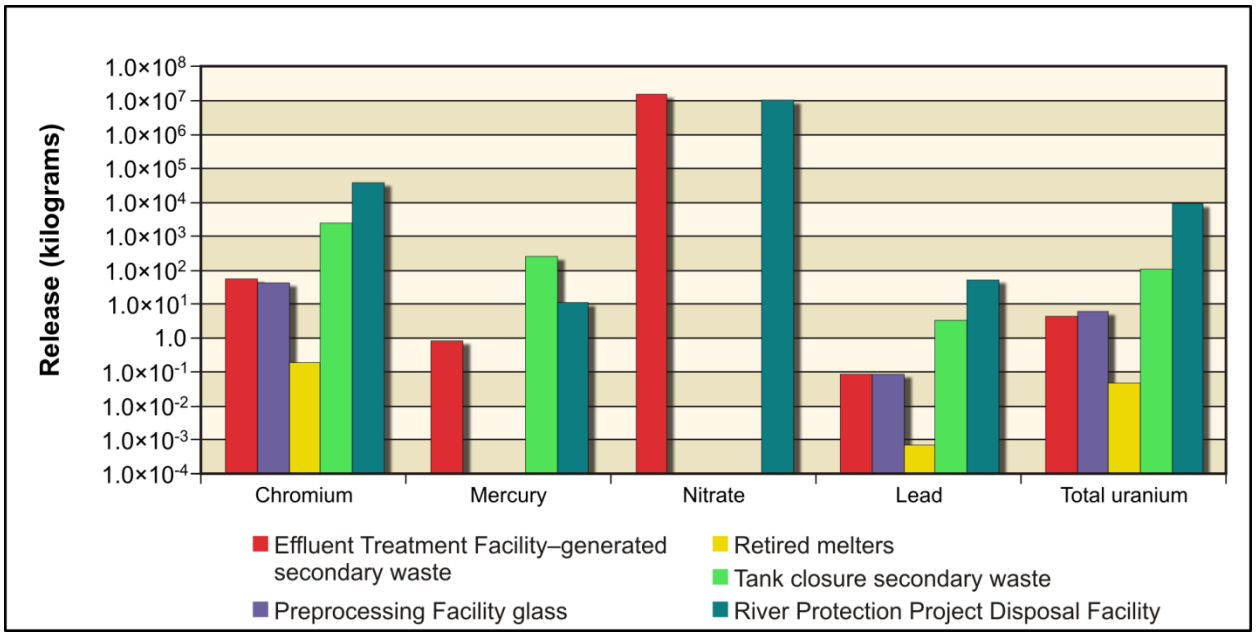


Figure M–109. Waste Management Alternative 3, Disposal Group 2, Subgroup 2-B, Option Case, Chemical Releases to the Vadose Zone from the 200-East Area Integrated Disposal Facility

M.4.3.2.21 Waste Management Alternative 3: Disposal in IDF, 200-East and 200-West Areas, Disposal Group 3

Disposal Group 3 addresses the waste resulting from Tank Closure Alternative 6A, Base and Option Cases; onsite non-CERCLA sources; FFTF decommissioning; waste management; and other DOE sites. Waste forms for IDF-East include the following:

- PPF glass
- PPF melters
- Tank closure secondary waste

The waste forms for IDF-West include the following:

- FFTF decommissioning secondary waste
- Waste management secondary waste
- Offsite waste
- Onsite non-CERCLA waste

Waste forms for the RPPDF include those resulting from tank closure cleanup activities under Tank Closure Alternative 6A, Base and Option Cases. Potential releases to the vadose zone under Waste Management Alternative 3,Disposal Group 3, Base and Option Cases, are indicated in Tables M–54 and M–55 and Figures M–110 through M–113.

Table M–54. Waste Management Alternative 3, Disposal Group 3, Base Case, Radionuclide and Chemical Releases to the Vadose Zone

Source	Radionuclide (curies)										Chemical (kilograms)					
	H-3	C-14	Sr-90	Tc-99	I-129	Cs-137	Np-237	U-238	Pu-239	Am-241	Cr	F	Hg	NO_3	Pb	Utot
IDF-East																
ETF-generated secondary waste	–	2.78	9.24×10^{-1}	8.73×10^{1}	2.51	5.44×10^{-3}	1.20×10^{-2}	4.28×10^{-3}	2.75×10^{-6}	–	4.53×10^{1}	–	8.06×10^{-1}	9.16×10^{6}	8.37×10^{-2}	4.31
PPF glass	–	–	7.42×10^{-2}	3.50×10^{-2}	1.39×10^{-5}	2.36×10^{-1}	1.35×10^{-4}	2.01×10^{-3}	7.92×10^{-3}	–	2.19	–	–	–	7.00×10^{-2}	4.19
Retired melters	–	–	4.80×10^{-3}	2.26×10^{-3}	9.03×10^{-7}	1.53×10^{-2}	8.74×10^{-6}	1.30×10^{-4}	5.13×10^{-4}	–	1.42×10^{-1}	–	–	–	4.51×10^{-3}	2.70×10^{-1}
TC secondary waste	–	–	7.01×10^{4}	4.37×10^{2}	1.38×10^{-1}	9.77×10^{2}	2.68×10^{-2}	1.55×10^{-1}	3.75×10^{-1}	–	1.98×10^{3}	–	2.29×10^{2}	–	3.13	1.00×10^{2}
RPPDF	4.57	5.78	1.80×10^{1}	1.78×10^{2}	3.43×10^{-1}	4.61	3.80×10^{-1}	9.86	1.21	–	4.10×10^{3}	–	1.73	2.83×10^{5}	5.12×10^{1}	7.66×10^{3}
IDF-West																
FFTF Decommis-sioning Alternative 3 waste	2.29	4.78×10^{1}	–	2.72×10^{1}	–	7.46×10^{-5}	–	–	–	–	7.51×10^{-3}	–	–	–	3.64×10^{-4}	7.91×10^{3}
WM secondary and onsite waste	3.66×10^{3}	6.82×10^{-1}	1.18×10^{3}	1.35	1.58×10^{-4}	5.47×10^{1}	2.62×10^{-3}	1.21×10^{-1}	6.20×10^{-2}	5.65×10^{-3}	1.83×10^{2}	2.74×10^{2}	4.16×10^{1}	2.97×10^{3}	1.30×10^{3}	1.56×10^{-1}
Offsite waste	5.57×10^{4}	5.68×10^{2}	1.87×10^{5}	1.46×10^{3}	2.26	1.93×10^{4}	6.28×10^{-1}	3.77×10^{2}	3.49	5.80×10^{-2}	8.05×10^{1}	–	7.85	–	3.24	–

Note: To convert kilograms to pounds, multiply by 2.2046.

Key: Am-241=americium-241; C-14=carbon-14; Cr=chromium; Cs-137=cesium-137; ETF=Effluent Treatment Facility; F=fluoride; FFTF=Fast Flux Test Facility; H-3=hydrogen-3 (tritium); Hg=mercury; I-129=iodine-129; IDF-East=200-East Area Integrated Disposal Facility; IDF-West=200-West Area Integrated Disposal Facility; NO_3=nitrate; Np-237=neptunium-237; Pb=lead; PPF=Preprocessing Facility; Pu-239=plutonium-239; RPPDF=River Protection Project Disposal Facility; Sr-90=strontium-90; TC=tank closure; Tc-99=technetium-99; U-238=uranium-238; Utot=total uranium; WM=waste management.

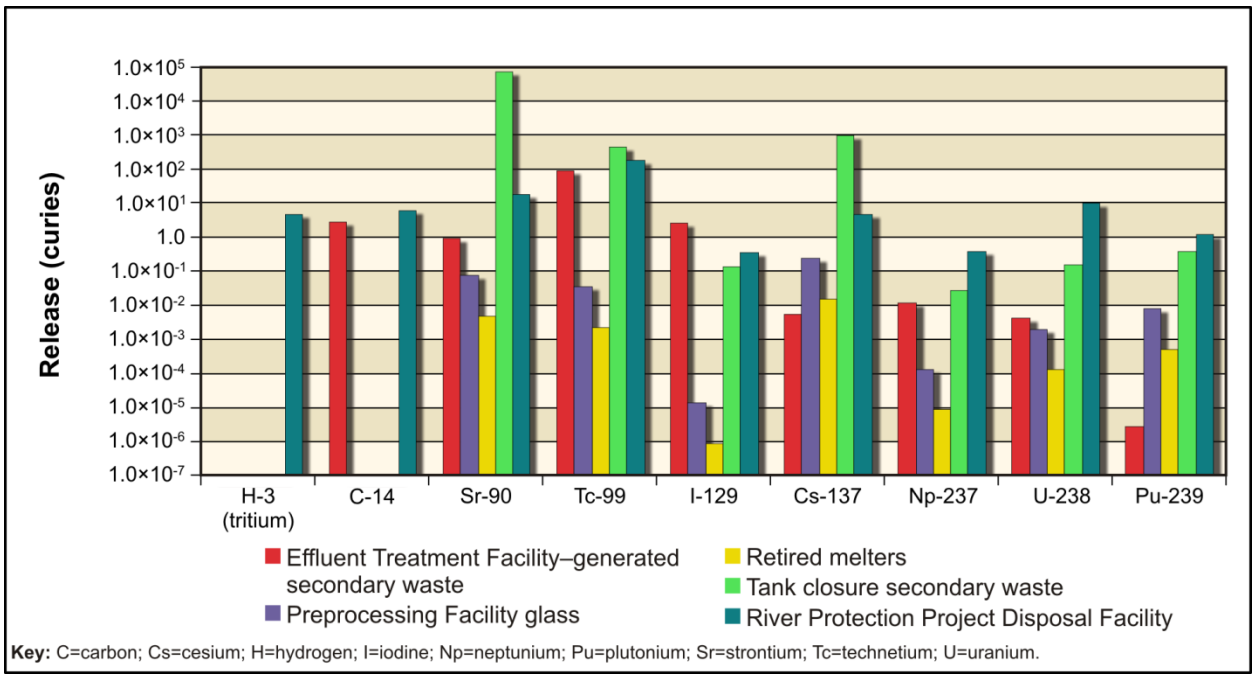


Figure M–110. Waste Management Alternative 3, Disposal Group 3, Base Case, Radionuclide Releases to the Vadose Zone from the 200-East Area Integrated Disposal Facility

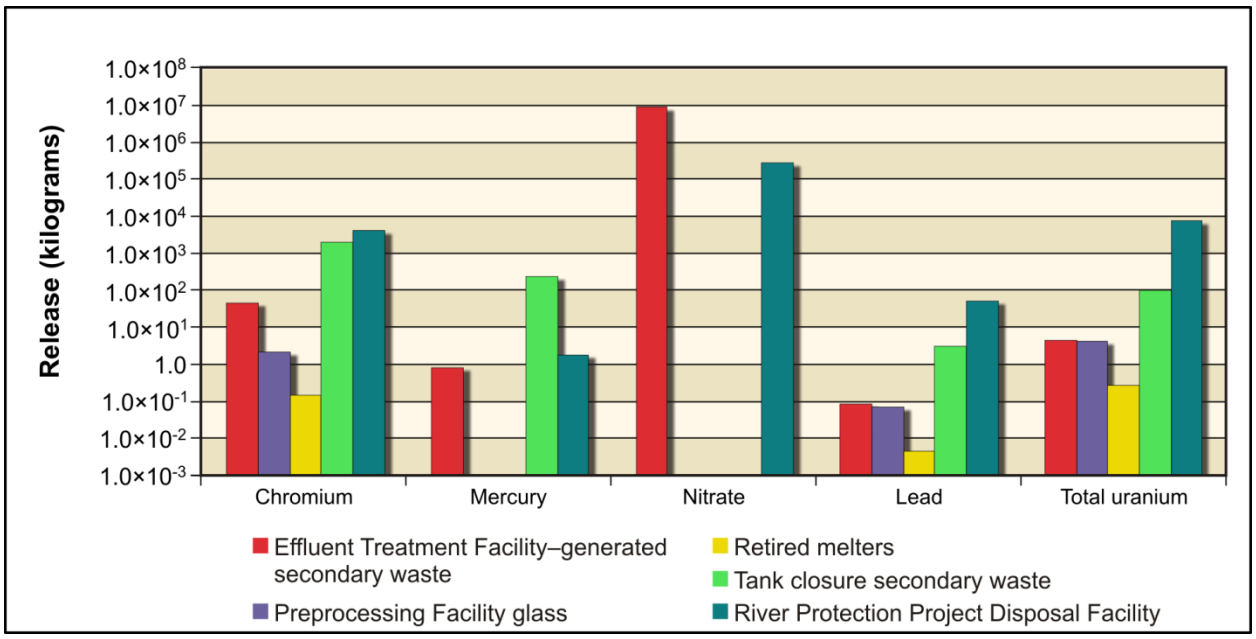


Figure M–111. Waste Management Alternative 3, Disposal Group 3, Base Case, Chemical Releases to the Vadose Zone from the 200-East Area Integrated Disposal Facility

Table M–55. Waste Management Alternative 3, Disposal Group 3, Option Case, Radionuclide and Chemical Releases to the Vadose Zone

Source	Radionuclide (curies)										Chemical (kilograms)					
	H-3	C-14	Sr-90	Tc-99	I-129	Cs-137	Np-237	U-238	Pu-239	Am-241	Cr	F	Hg	NO_3	Pb	Utot
IDF-East																
ETF-generated secondary waste	–	2.82	9.29×10^{-1}	8.79×10^{1}	2.53	5.48×10^{-3}	1.23×10^{-2}	4.35×10^{-3}	2.80×10^{-6}	–	5.65×10^{1}	–	8.38×10^{-1}	1.51×10^{7}	8.41×10^{-2}	4.38
PPF glass	–	–	9.09×10^{-2}	9.13×10^{-2}	3.34×10^{-5}	2.63×10^{-1}	7.21×10^{-4}	4.54×10^{-3}	2.21×10^{-1}	–	4.30×10^{1}	–	–	–	8.40×10^{-2}	6.16
Retired melters	–	–	1.31×10^{-3}	1.31×10^{-3}	4.79×10^{-7}	3.78×10^{-3}	1.04×10^{-5}	6.54×10^{-5}	3.17×10^{-3}	–	6.18×10^{-1}	–	–	–	1.21×10^{-3}	8.84×10^{-2}
TC secondary waste	–	–	7.54×10^{4}	4.40×10^{2}	1.51×10^{-1}	1.05×10^{3}	2.92×10^{-2}	1.68×10^{-1}	4.10×10^{-1}	–	2.47×10^{3}	–	2.54×10^{2}	–	3.37	1.09×10^{2}
RPPDF	7.95×10^{1}	8.18	1.89×10^{1}	2.70×10^{2}	4.96×10^{-1}	4.77	9.07×10^{-1}	1.37×10^{1}	5.90	–	3.69×10^{4}	–	1.14×10^{1}	1.04×10^{7}	5.26×10^{1}	9.24×10^{3}
IDF-West																
FFTF Decommis-sioning Alternative 3 waste	2.29	4.78×10^{1}	–	2.72×10^{1}	–	7.46×10^{-5}	–	–	–	–	7.51×10^{-3}	–	–	–	3.64×10^{-4}	7.91×10^{3}
WM secondary and onsite waste	3.66×10^{3}	6.82×10^{-1}	1.18×10^{3}	1.35	1.58×10^{-4}	5.47×10^{1}	2.62×10^{-3}	1.21×10^{-1}	6.20×10^{-2}	5.65×10^{-3}	1.83×10^{2}	2.74×10^{2}	4.16×10^{1}	2.97×10^{3}	1.30×10^{3}	1.56×10^{-1}
Offsite waste	5.57×10^{4}	5.68×10^{2}	1.87×10^{5}	1.46×10^{3}	2.26	1.93×10^{4}	6.28×10^{-1}	3.77×10^{2}	3.49	5.80×10^{-2}	8.05×10^{1}	–	7.85	–	3.24	–

Note: To convert kilograms to pounds, multiply by 2.2046.

Key: Am-241=americium-241; C-14=carbon-14; Cr=chromium; Cs-137=cesium-137; ETF=Effluent Treatment Facility; F=fluoride; FFTF=Fast Flux Test Facility; H-3=hydrogen-3 (tritium); Hg=mercury; I-129=iodine-129; IDF-East=200-East Area Integrated Disposal Facility; IDF-West=200-West Area Integrated Disposal Facility; NO_3=nitrate; Np-237=neptunium-237; Pb=lead; PPF=Preprocessing Facility; Pu-239=plutonium-239; RPPDF=River Protection Project Disposal Facility; Sr-90=strontium-90; TC=tank closure; Tc-99=technetium-99; U-238=uranium-238; Utot=total uranium; WM=waste management.

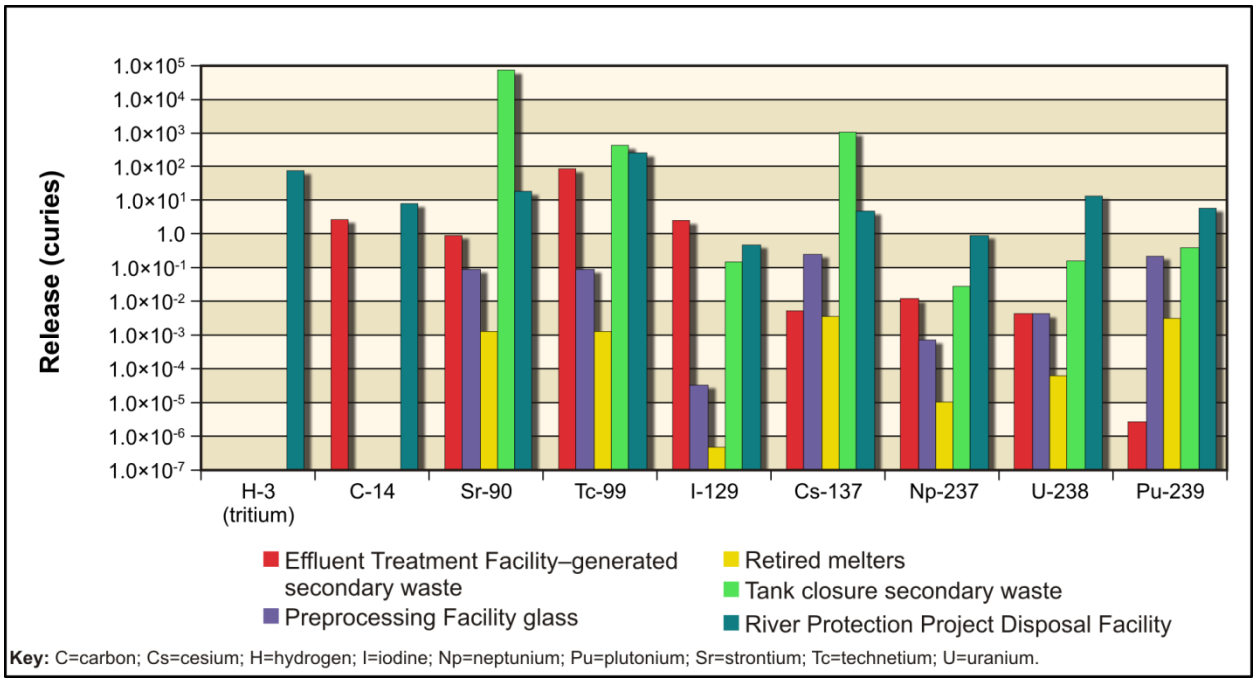


Figure M–112. Waste Management Alternative 3, Disposal Group 3, Option Case, Radionuclide Releases to the Vadose Zone from the 200-East Area Integrated Disposal Facility

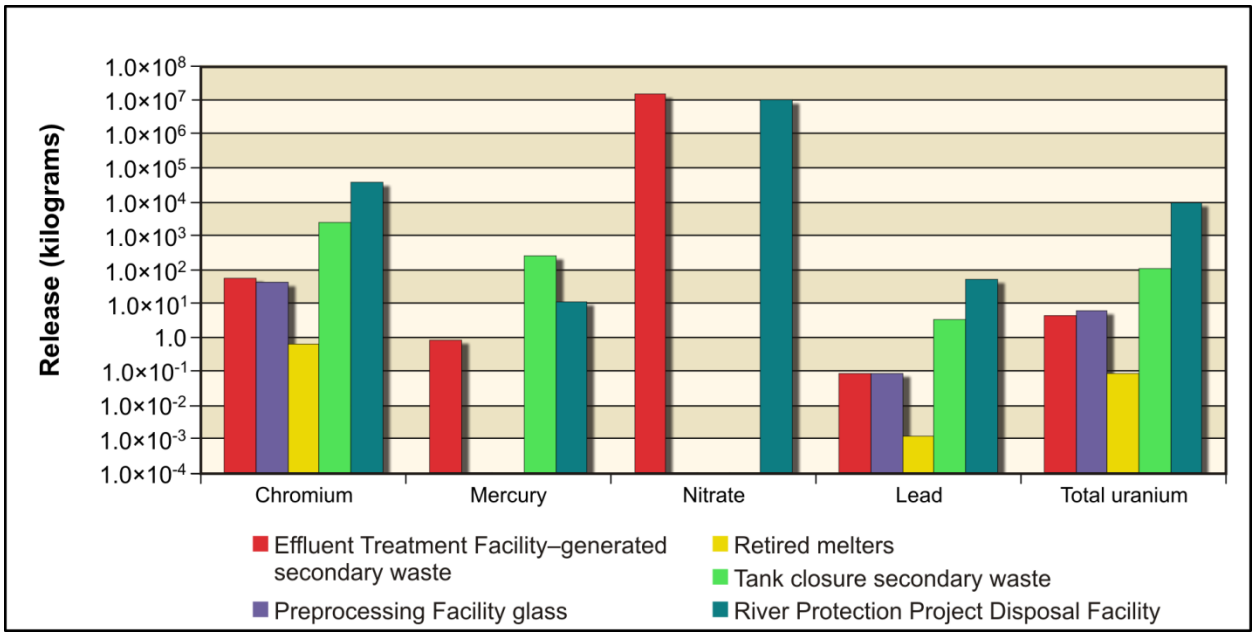


Figure M–113. Waste Management Alternative 3, Disposal Group 3, Option Case, Chemical Releases to the Vadose Zone from the 200-East Area Integrated Disposal Facility

M.5 SENSITIVITY ANALYSIS

Because of the long-term nature of processes expected to occur at Hanford, direct observation of potential impacts is not possible and mathematical models were developed to estimate the rate of release of constituents to the vadose zone. Estimates thus depend on the description of the release incorporated into the model and on values of parameters that quantify rates of physical and chemical processes constituting the model. The objective of this section is to investigate the sensitivity of the estimates of rate of release

to the vadose zone to elements of the model concepts and to values of parameters used in the models. Three cases are considered: discharge of liquid and solute representing a past leak at a tank farm, leaching from supplemental-waste forms in the 200-East Area, and diffusive release from a grouted waste form. The three cases illustrate the range of sensitivities for liquid and solid sources. The constituents technetium-99 and iodine-129 were selected for this sensitivity analysis because they move at the velocity of groundwater and have been observed in Hanford groundwater near known sources of contamination.

M.5.1 Aqueous Volumetric Release

During tank farm operations, aqueous liquids and solutes were discharged to the vadose zone in uncontrolled leakage events. The magnitude, duration, and timing of the leaks and the spatial distribution of recharge at the tank farms are not well characterized. Studies have determined that the volume of leaks may be on the order of 400 cubic meters (100,000 gallons) (Hanlon 2003) and that recharge at the tank farms may be high relative to Hanford background conditions (DOE 2005). To investigate the sensitivity of potential impacts on conditions affecting an aqueous discharge at a tank farm, two cases were evaluated. In the first case, an isolated tank in the center of a tank farm was surrounded by an area of elevated recharge, and the release duration and timing were varied. In the second case, the area of an isolated tank was subject to excess recharge while the surrounding area experienced recharge at a normal background rate, and the leak duration and timing were varied. A plan view of the configuration is presented in Figure M–114. The inner source area representing the tank is a square with sides equal to 20 meters (66 feet). In the first case, the dashed rectangle representing the tank farm area experienced recharge at 100 millimeters per year and the balance of the study area experienced recharge at 3.5 millimeters per year. In the second case, only the area of the source experienced recharge at 100 millimeters per year and the balance of the study area experienced recharge at 3.5 millimeters per year. The initial moisture profile was established as the steady state condition at a recharge rate of 3.5 millimeters per year, and elevated recharge was assumed to begin at the start time of tank farm operations. In both cases, the site geology corresponded to 200-West Area conditions with Hanford gravel, Hanford sand, Plio-Pleistocene silt, and Ringold gravel layered from the ground surface downward to the water table at a depth of 70 meters (230 feet).

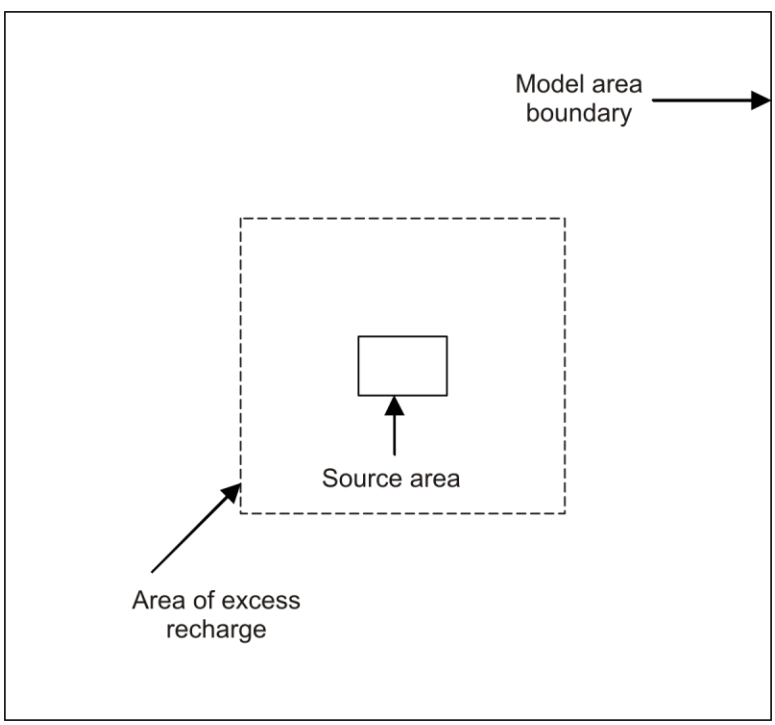


Figure M–114. Plan View of Aqueous Discharge Study Area

M.5.1.1 Extended Area of Elevated Recharge

In this first case, elevated recharge was assumed to occur over the area of a tank farm, approximately 10,000 square meters (110,000 square feet), and the leak duration and timing were varied. For a leak beginning at the start time of tank operations, rate of arrival of solute at the water table for leaks of duration of 1 year, 1 month, 1 week, and 1 day are presented in Figure M–115. The four curves plotted on this figure coincide at nearly all points in time and therefore may not be separately distinguished. Releases of relatively short duration are considered because these have the greatest potential to produce high flux of solute at the water table. Results show only a small dependence of solute flux at the water table on duration of release. For this case of extended area of elevated recharge, approximately 60 percent of the release reached the water table in the 400-square-meter (4,305-square-foot) area directly below the source, while nearly the entirety of the release reached the water table in a 1,600-square-meter (17,222-square-foot) area centered below the source. For a 1-year release duration, rate of arrival of solute at the water table for releases beginning at the start of tank farm operations and at 15 and 30 years after start are presented in Figure M–116. Results indicate that the transition from background to elevated recharge moisture conditions did not have a significant effect on the time profile of solute flux. The magnitude of peak solute flux varied by approximately 5 percent as release timing changed from start of operations to 30 years after start of operations. Results reflect the delay in arrival due to the delay in beginning of release, but the interval of time from release to peak dose decreased by approximately 1 percent as time of release changed from start of operations to 30 years after start of operations.

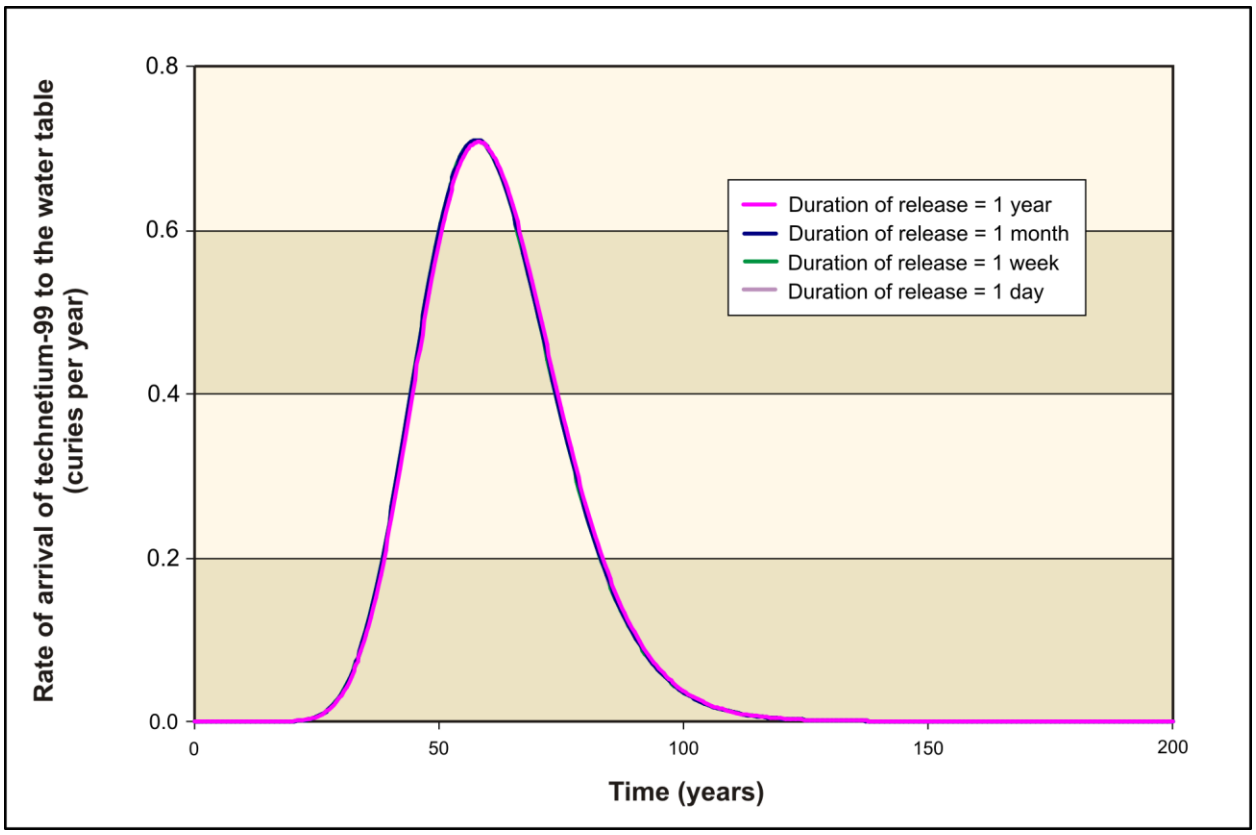


Figure M–115. Variation of Rate of Arrival of Solute at the Water Table with Release Duration for Extended Area of Elevated Recharge

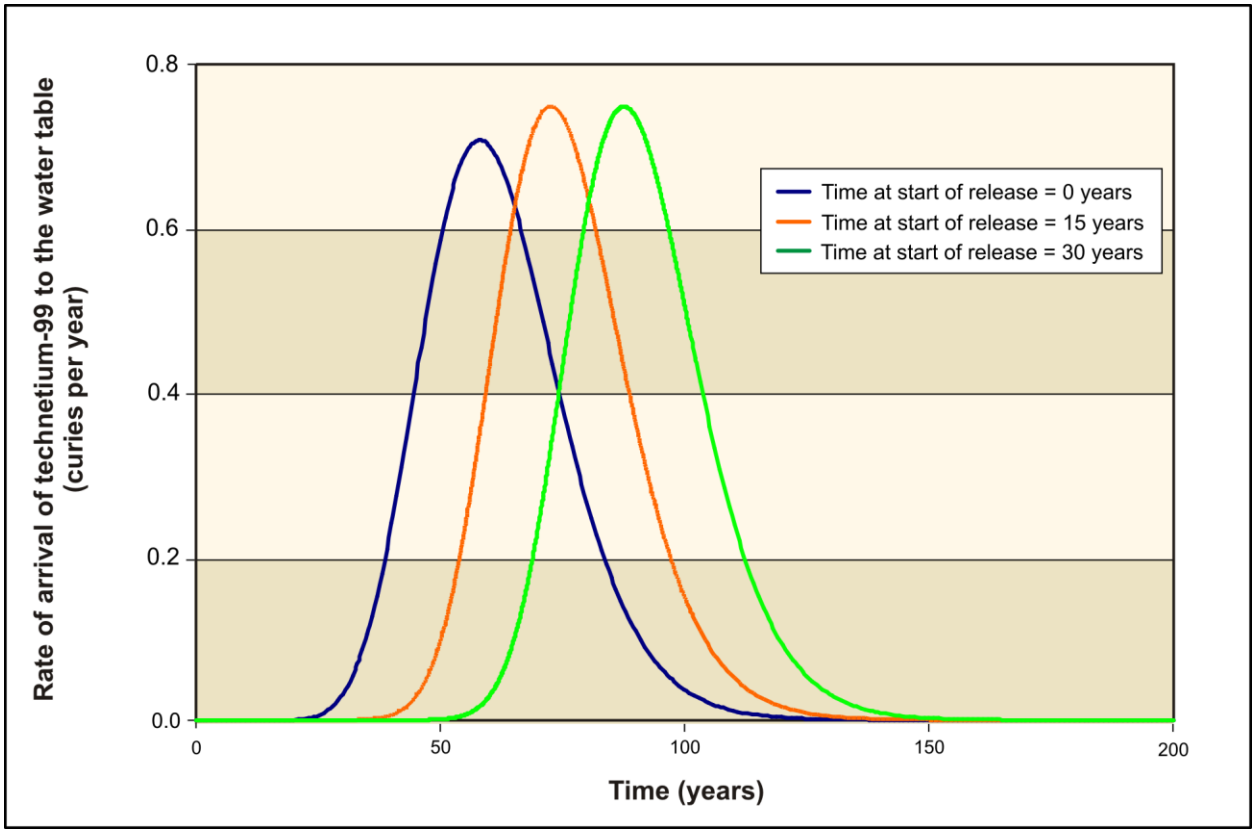


Figure M–116. Variation of Rate of Arrival of Solute at the Water Table with Release Timing for Extended Area of Elevated Recharge

M.5.1.2 Local Area of Elevated Recharge

In this second case, elevated recharge was assumed to occur only over the area of a tank, approximately 400 square meters (4,300 square feet), and the leak duration and timing were varied. For a leak beginning at the start time of tank operations, the rate of arrival of solute at the water table for leaks of duration of 1 year, 1 month, 1 week, and 1 day are presented in Figure M–117. The four curves plotted on this figure coincide at nearly all points in time and, therefore, may not be separately distinguished. Results show only a small dependence of solute flux at the water table on duration of release. For this case of local area of elevated recharge, approximately 9 percent of the release reached the water table in the 400-square-meter (4,305-square-foot) area directly below the source, approximately 30 percent of the release reached the water table in the 1,600-square-meter (17,222-square-foot) area centered below the source, and nearly the entirety of the release reached the water table in the 6,400-square-meter (68,889-square-foot) area centered below the source. Due to the restriction of elevated recharge to the area of the source and the low rate of recharge outside of the source area, horizontal spreading of water and solute reduces the flux of solute at the water table and extends the period of time during which the release reaches the water table. For a 1-year release duration, rate of arrival of solute at the water table for releases beginning at the start of tank farm operations and at 15 and 30 years after start are presented in Figure M–118. Results indicate that the transition from background to elevated recharge moisture conditions did not have a significant effect on the time profile of solute flux. The magnitude of peak solute flux varied by approximately 2 percent as release timing changed from start of operations to 30 years after start of operations. Results reflect the delay in arrival due to the delay in beginning of release, but the interval of time from release to peak dose remained approximately constant as time of release changed from start of operations to 30 years after start of operations.

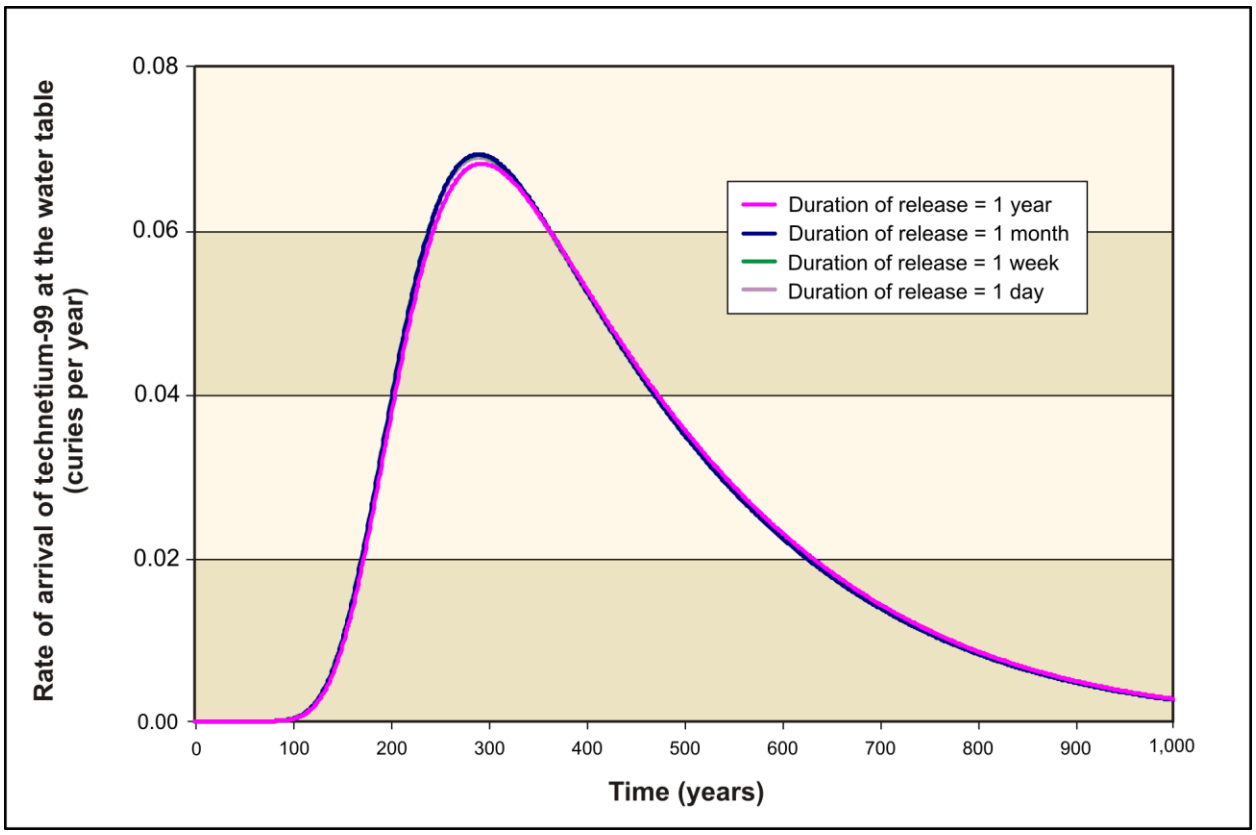


Figure M–117. Variation of Rate of Arrival of Solute at the Water Table with Release Duration for Local Area of Elevated Recharge

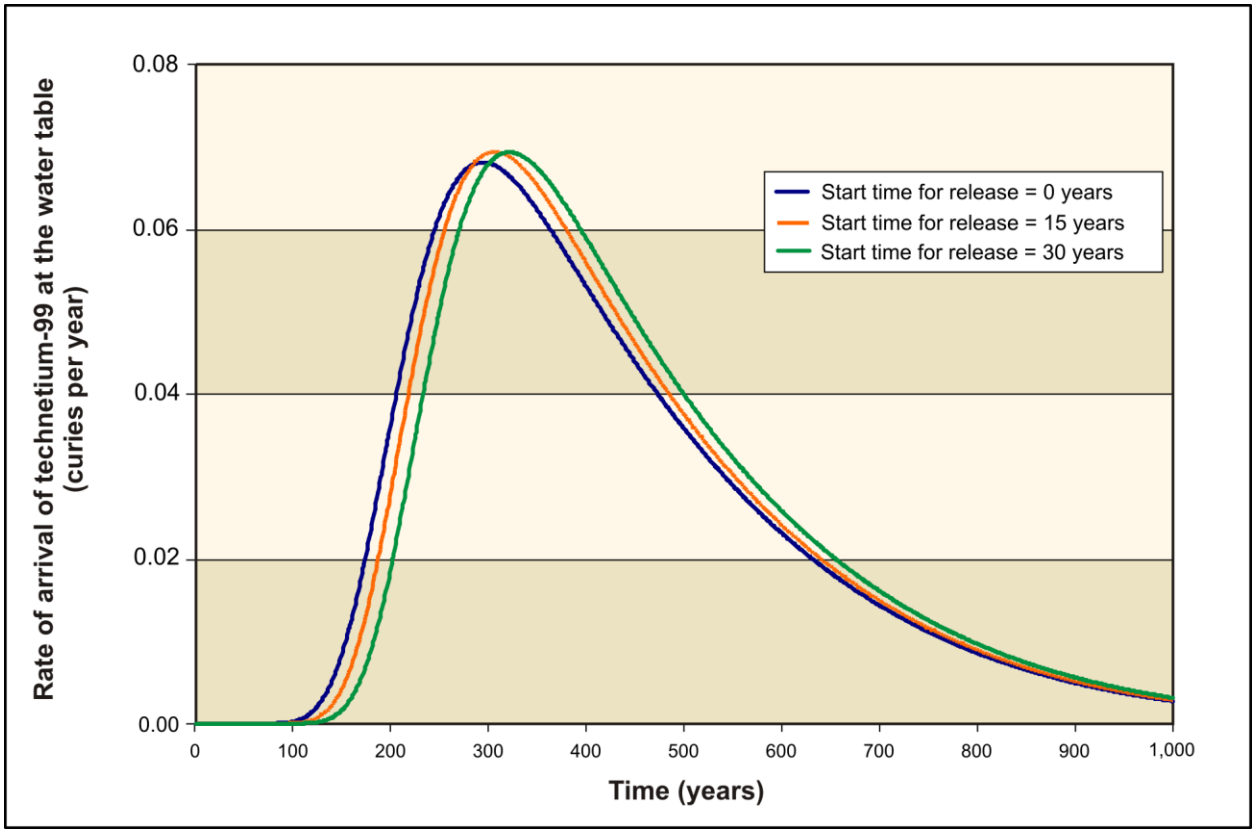


Figure M–118. Variation of Rate of Arrival of Solute at the Water Table with Release Timing for Local Area of Elevated Recharge

M.5.1.3 Conclusions

For cases of both extended and local areas of elevated recharge, solute flux at the water table showed low sensitivity to change in release duration and timing. Results show sensitivity to moisture conditions as the average travel time for the case of extended area of elevated recharge was approximately one-quarter the average travel time for the case of local area of elevated recharge.

M.5.2 Leaching from Supplemental-Waste Forms

Activities under consideration for this *TC & WM EIS* include solidification of hazardous constituents currently stored in belowground tanks in the 200-East and 200-West Areas. The primary-waste form proposed is ILAW glass. Three additional waste forms under consideration to supplement management capacity for tank constituents are bulk vitrification glass, cast stone waste, and steam reforming waste. Analysis completed for Tank Closure Alternatives 3A, 3B, and 3C provides a basis for comparative evaluation of these three waste forms. Additional details on the nature of these waste forms are provided in Appendix D of this EIS, while estimates of the inventory of technetium-99 and iodine-129 for the set of waste forms for the three variants of Tank Closure Alternative 3 are summarized in Table M–56. The balance of this section presents details on the sensitivity of estimates of the rates of release to the vadose zone of two select radionuclides to changes in the type of waste form. The background and engineered-cap-design recharge rates, selected as the basis for estimating release rates, were 0.9 and 0.5 millimeters per year, respectively, values recommended for the proposed IDF-East (DOE 2005). Depending on the type of release model applied, transition from the engineered-cap-design recharge rate to the background recharge rate at the end of the 500-year design life of the cap may produce an increase

in the rate of release from the waste form. This effect is observed in results presented in the following subsections.

Table M–56. Tank Closure Alternatives 3A, 3B, and 3C Summary of Waste Form Inventories of Technetium-99 and Iodine-129

Waste Form	Technetium-99 (curies)			Iodine-129 (curies)		
	Alt. 3A	Alt. 3B	Alt. 3C	Alt. 3A	Alt. 3B	Alt. 3C
Immobilized high-level radioactive waste	150	19,600	150	0	0	0
ILAW glass	8,440	84	8,440	2.8	2.8	2.8
Bulk vitrification glass	20,600[a]	N/A[b]	N/A[b]	6.8	N/A[b]	N/A[b]
Cast stone waste	N/A[b]	9,540	N/A[b]	N/A[b]	33.8	N/A[b]
Steam reforming waste	N/A[b]	N/A[b]	20,600	N/A[b]	N/A[b]	6.8
ETF-generated secondary waste	50	60	46	36.9	9.9	36.9

[a] The inventory of technetium-99 in the castable refractory block is 1,340 curies with the balance of the technetium-99 in intact bulk vitrification glass.

[b] Waste form not used under this alternative.

Key: Alt.=Alternative; ETF=Effluent Treatment Facility; ILAW=immobilized low-activity waste; N/A= not applicable.

M.5.3 Supplemental Waste Forms Leaching Behavior

M.5.3.1 Tank Closure Alternative 3A

For Tank Closure Alternative 3A, the inventory of technetium-99 is largely divided between ILAW glass and bulk vitrification glass, while the inventory of iodine-129 is divided between ILAW glass, bulk vitrification glass, and ETF-generated secondary waste (a grouted waste form). Release rate estimates for technetium-99 and iodine-129 under this alternative are presented in Figures M–119 and M–120, respectively. Low rates of release are predicted for the intact glass of the ILAW and bulk vitrification glass waste forms. However, the portion of technetium-99 transferred to castable refractory block in the bulk vitrification container is projected to release at a much higher rate upon placement in the vadose zone. The peak in the release rate for technetium-99 from castable refractory block reflects the increase in infiltration that is specified to occur at the end of the design life of the engineered barrier. For iodine-129, the glass waste forms release iodine at very low rates, while the ETF-generated secondary waste releases it at a higher (but still low) rate.

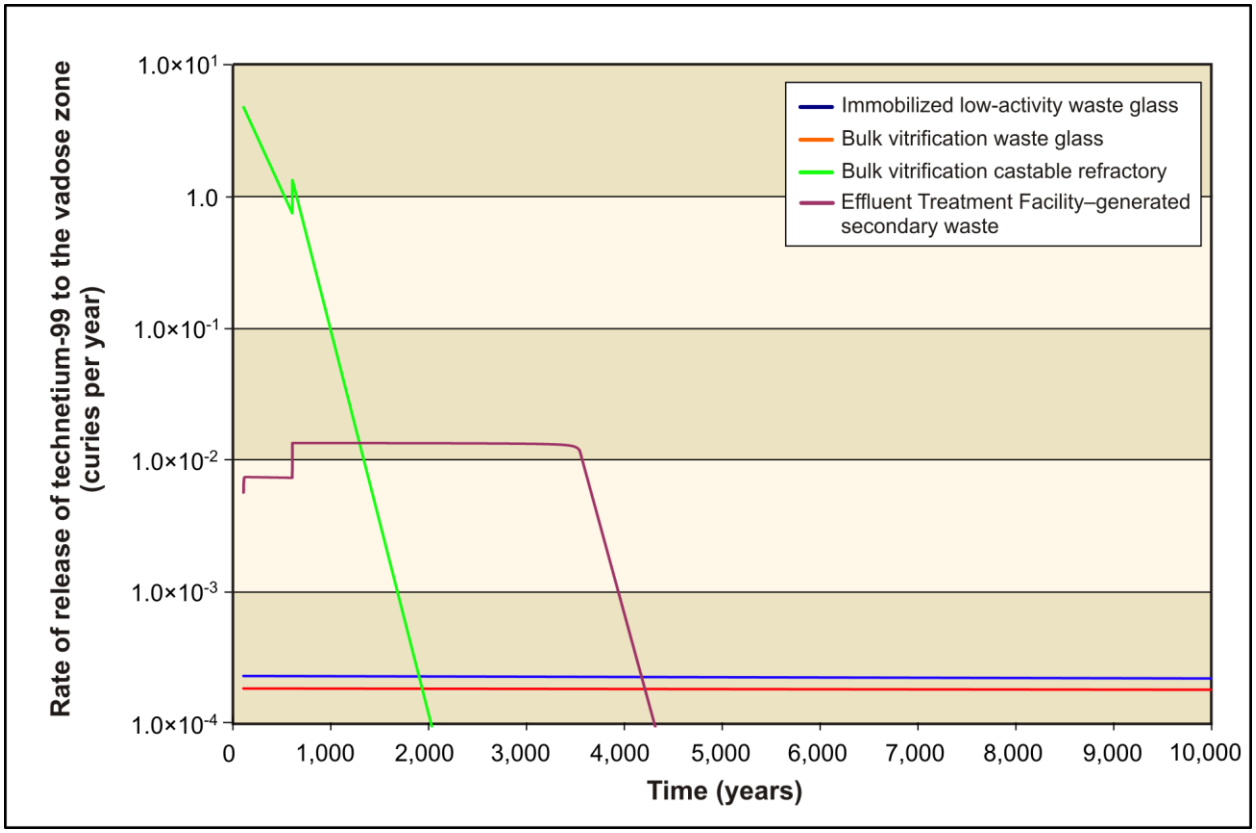


Figure M–119. Tank Closure Alternative 3A Waste Form Rates of Release of Technetium-99

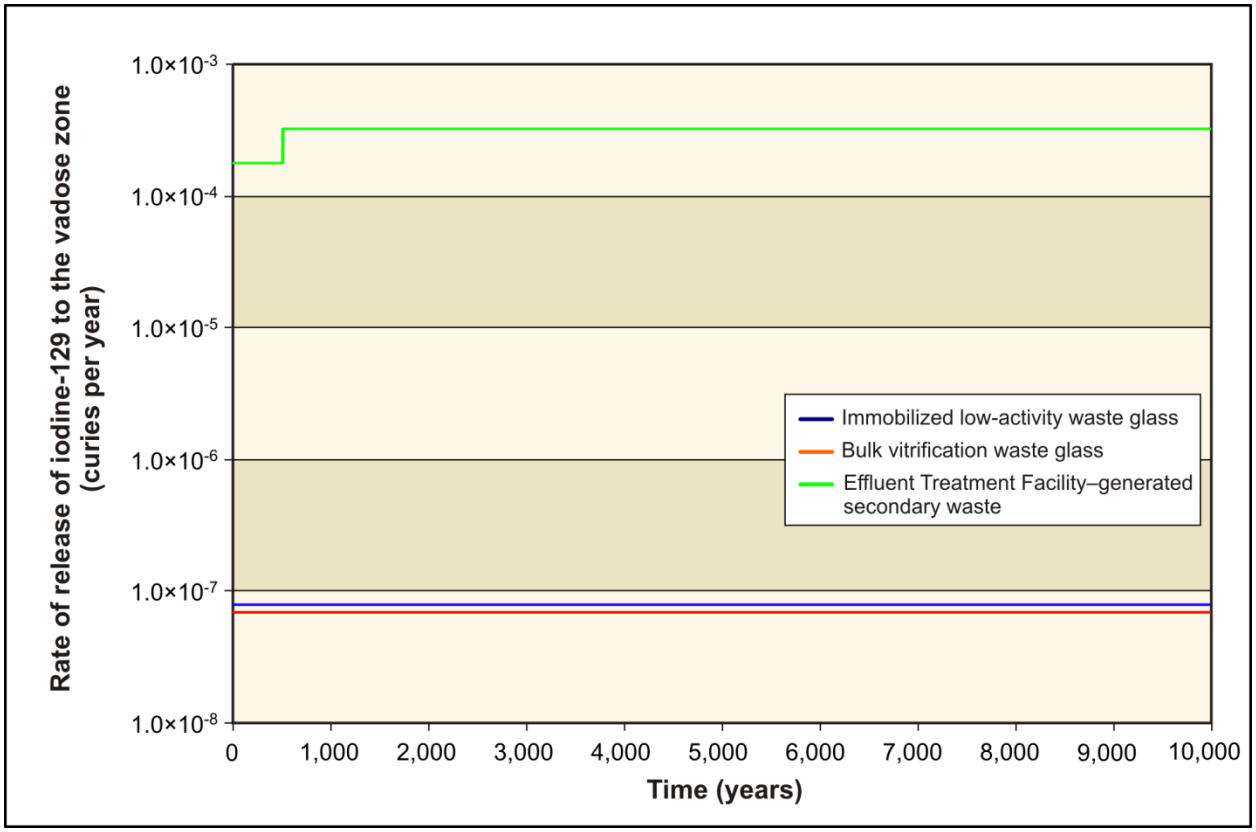


Figure M–120. Tank Closure Alternative 3A Waste Form Rates of Release of Iodine-129

M.5.3.2 Tank Closure Alternative 3B

For Tank Closure Alternative 3B, the inventory of technetium-99 is largely divided between immobilized high-level radioactive waste glass and cast stone waste, while the inventory of iodine-129 is divided between ILAW glass, cast stone waste, and ETF-generated secondary waste. Estimates of the rate of release of technetium-99 and iodine-129 under this alternative are presented in Figures M–121 and M–122, respectively. The small amount of technetium-99 present in the ILAW glass is estimated to release at a low rate, while the cast stone waste is projected to release technetium-99 at a higher rate. Nearly the entire inventory of technetium-99 in the cast stone waste form is released during the 10,000-year period of analysis. The smaller inventory of technetium-99 (60 curies) in the ETF-generated secondary waste is released over a period of approximately 3,500 years. For iodine-129, the combined rate of release from cast stone waste and ETF-generated secondary waste is comparable to that of ETF-generated secondary waste with comparable inventory under Tank Closure Alternative 3A.

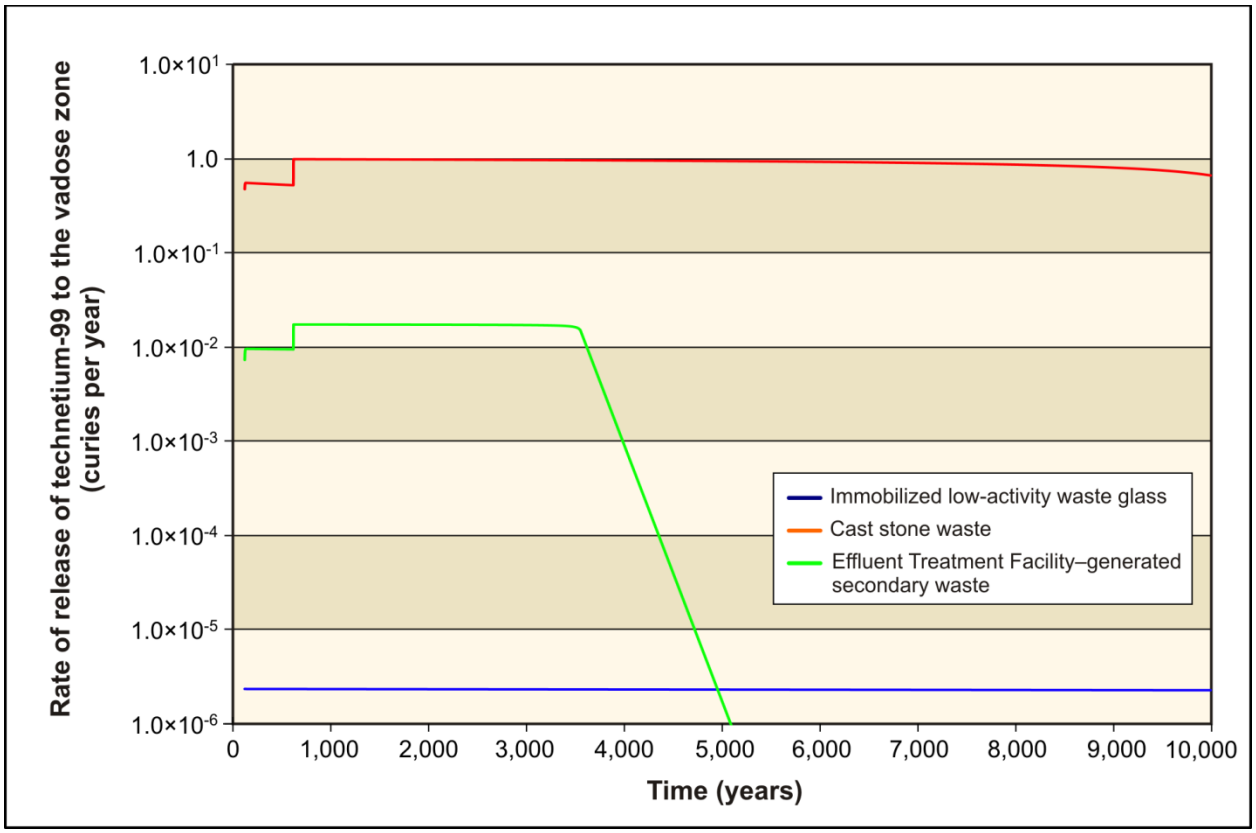


Figure M–121. Tank Closure Alternative 3B Waste Form Rates of Release of Technetium-99

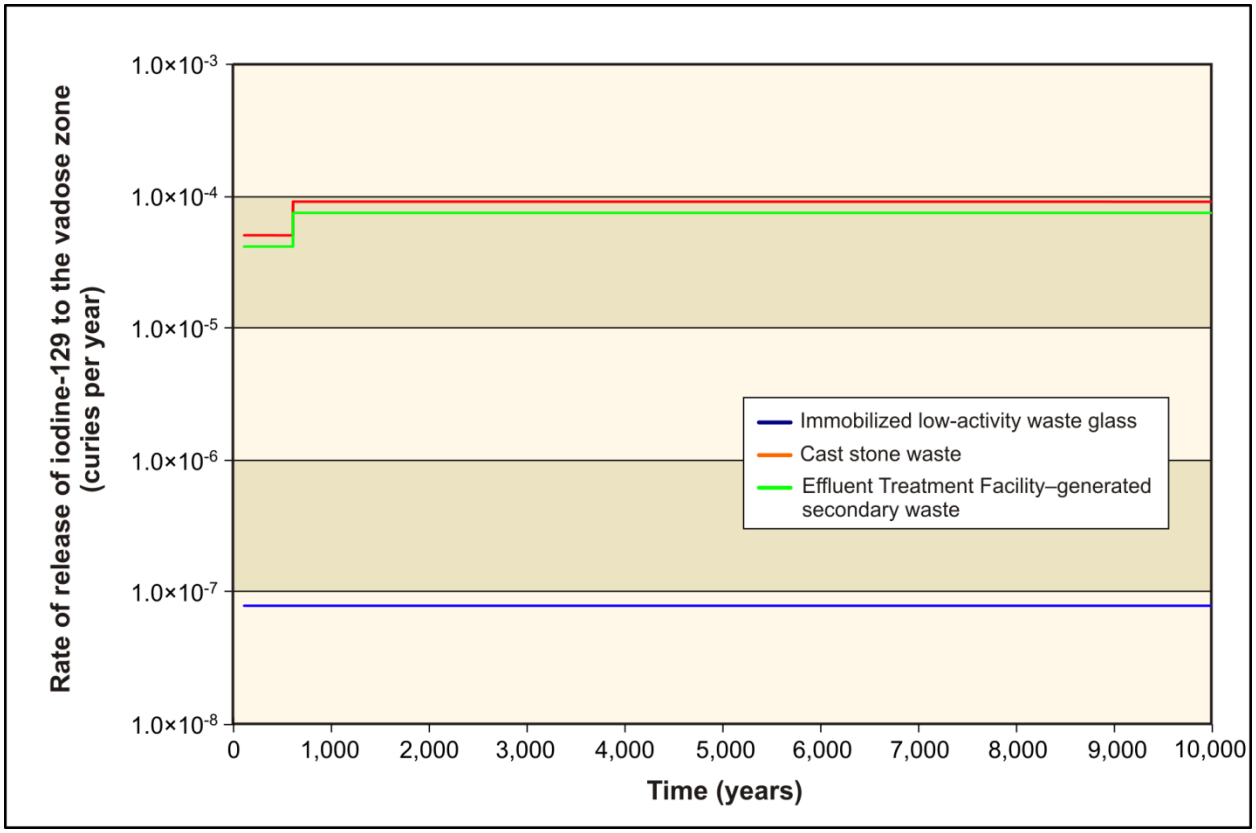


Figure M–122. Tank Closure Alternative 3B Waste Form Rates of Release of Iodine-129

M.5.3.3 Tank Closure Alternative 3C

For Tank Closure Alternative 3C, the inventory of technetium-99 is largely divided between ILAW glass and steam reforming waste, while the inventory of iodine-129 is divided between ILAW glass, steam reforming waste, and ETF-generated secondary waste. Release rate estimates of technetium-99 and iodine-129 under this alternative are presented in Figures M–123 and M–124, respectively. The estimated rate of release of both technetium-99 and iodine-129 is higher for steam reforming waste than for the ILAW glass waste form.

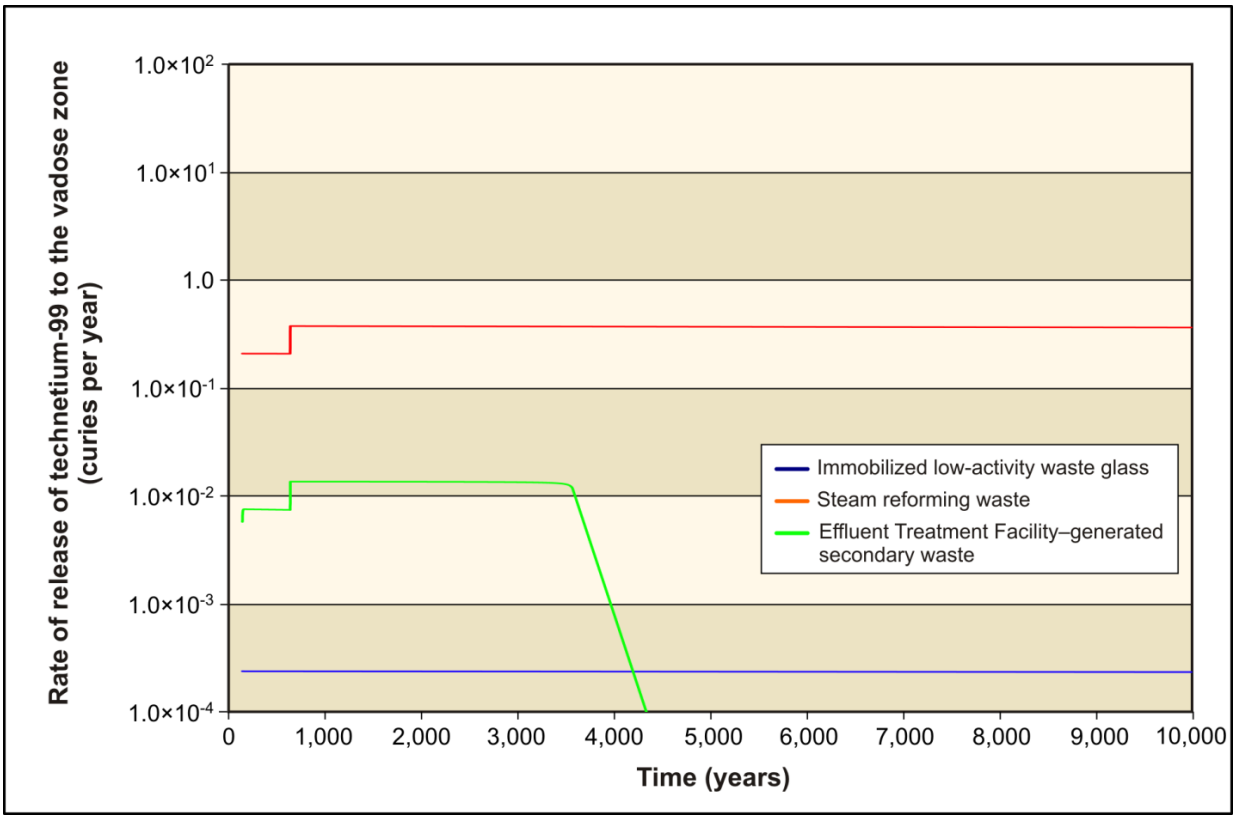


Figure M–123. Tank Closure Alternative 3C Waste Form Rates of Release of Technetium-99

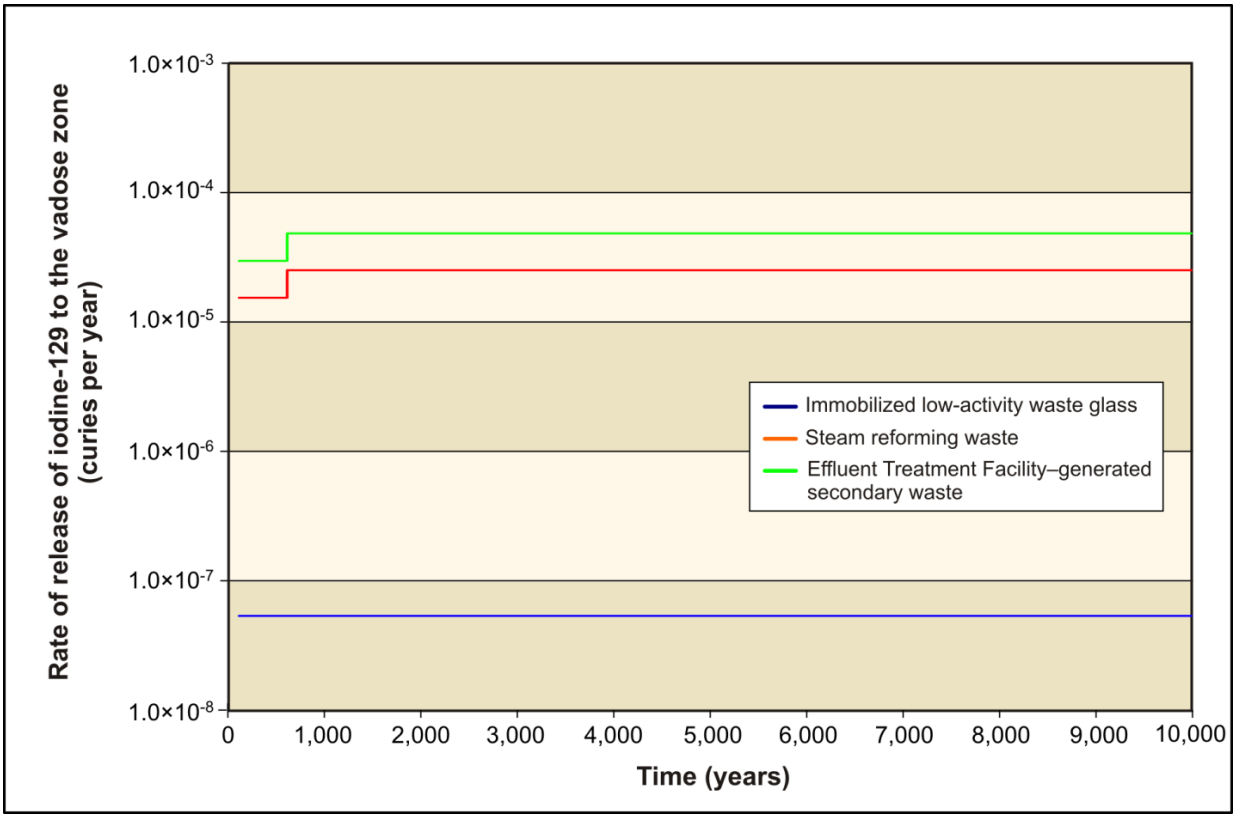


Figure M–124. Tank Closure Alternative 3C Waste Form Rates of Release of Iodine-129

M.5.3.4 Conclusions

Cumulative releases of technetium-99 and iodine-129 from the combined waste forms for Tank Closure Alternatives 3A, 3B, and 3C are presented in Figures M–125 and M–126, respectively. For technetium-99 under Alternative 3A, the majority of release is due to the castable refractory block portion of the bulk vitrification inventory, and the entirety of that inventory is released in approximately 2,000 years. For technetium-99, cumulative release from cast stone waste under Tank Closure Alternative 3B is higher than that from steam reforming waste under Tank Closure Alternative 3C or bulk vitrification glass and castable refractory block under Tank Closure Alternative 3B. For iodine-129, cumulative releases from steam reforming waste and ETF-generated secondary waste under Alternative 3C exceed the cumulative release estimated for the combined waste forms under Tank Closure Alternative 3A or 3B.

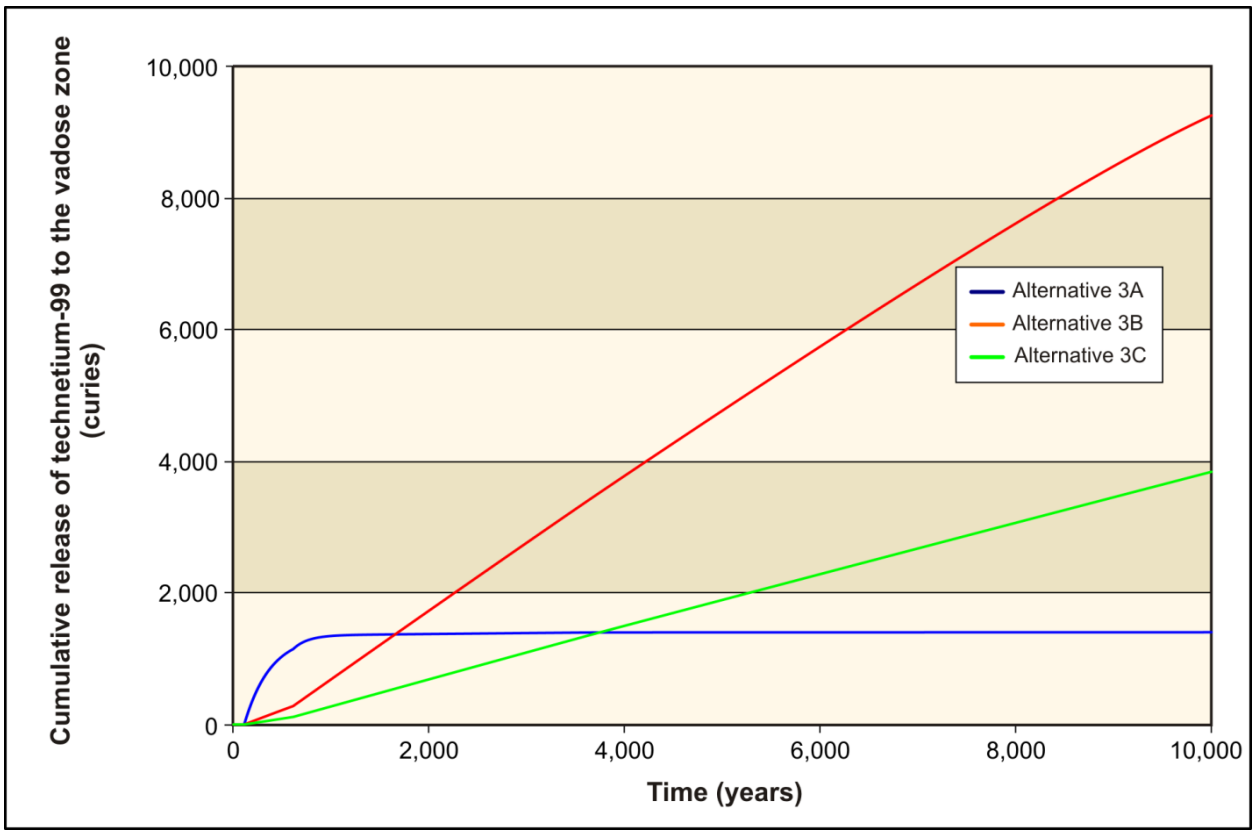


Figure M–125. Tank Closure Alternatives 3A, 3B, and 3C Waste Form Combined Cumulative Release of Technetium-99

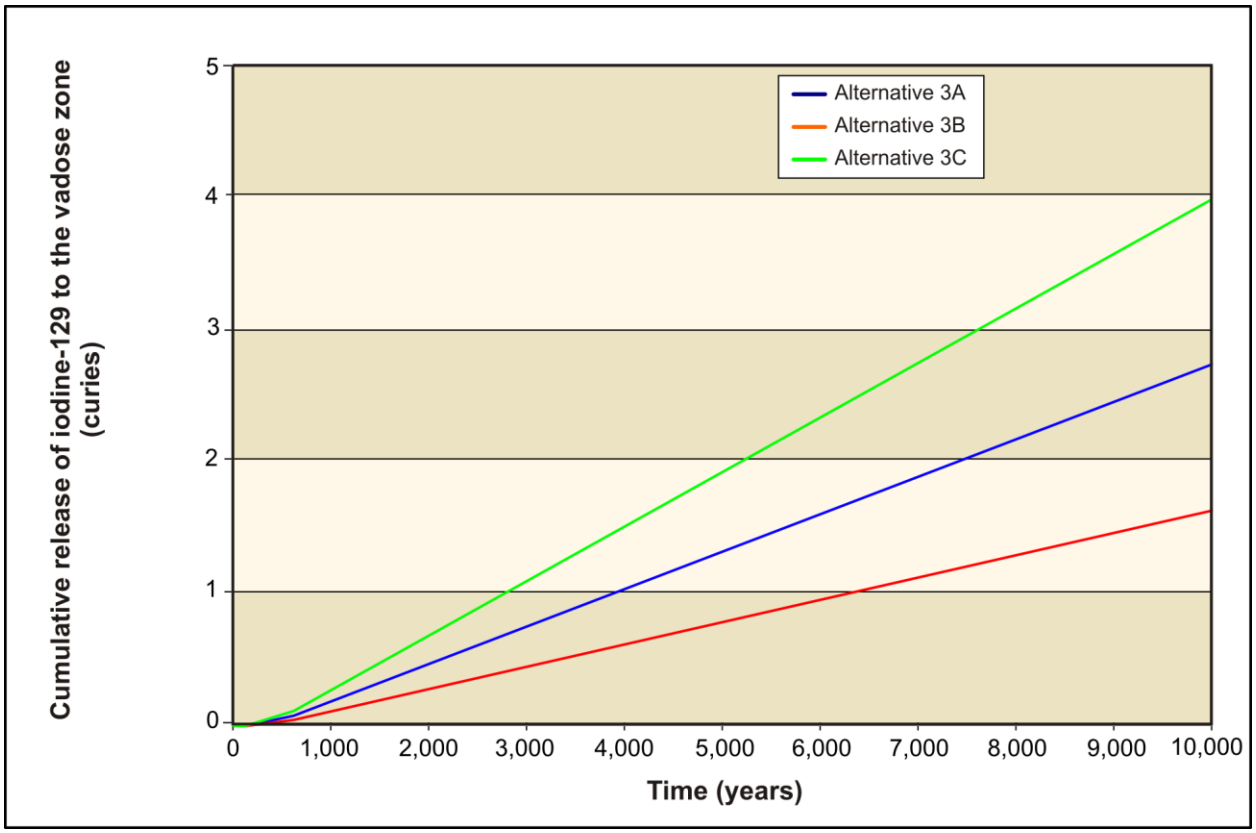


Figure M–126. Tank Closure Alternatives 3A, 3B, and 3C Waste Form Combined Cumulative Release of Iodine-129

M.5.4 Rate of Recharge and Diffusion Release

Grouted waste forms are proposed for both primary- and secondary-waste categories under the Tank Closure and Waste Management alternatives. For these waste forms and the low rates of recharge projected for the waste disposal locations, release rates under the diffusion mechanism are greater than those under the convective mechanism. In addition, for the diffusion-limited release model described in Section M.2.2.4, the release rate from the waste package would be limited by the accumulation of the released constituent in the vicinity of the waste form. This section investigates the dependence of the release rate to the vadose zone underlying the waste packages on the recharge rate in the vicinity of the waste form. In this example calculation, an inventory of 9,500 curies of technetium-99 is encapsulated in 233,000 cubic meters (8,230,000 cubic feet) of grout. Stacks of packages 5.3 meters (17.4 feet) high with a package radius of 1.55 meters (5.1 feet) are placed in a rectangular array. The constituent is released by diffusion into the vadose zone adjacent to the packages and transported downward in the convective flow due to recharge. The release rates to the underlying vadose zone for varying recharge rates are presented in Figure M–127. In the limit of very high values of recharge, the initial rate of release would be independent of the rate of recharge, indicating that the constituent rapidly transports downward and that the rate of release is controlled by diffusion within the waste form. For lower rates of recharge, the constituent concentration increases adjacent to the waste package, decreasing the rate of diffusive release from the package, and the rate of downward movement is more dependent on the rate of recharge. For the diffusion-limited release model, degradation of the waste form at the end of the 500-year design life is represented as an increase in the tortuosity of the waste form and the related effective diffusivity of the waste form–constituent pair. The results also indicate that the effect of degradation of the package is more pronounced at higher rates of recharge. The significant increase in rate of release at the time of 500 years for the 50- and 100-millimeter-per-year recharge rates is due to increase of tortuosity and

supports the premise that diffusion within the waste form is a controlled rate of release to the vadose zone below the waste form. The minor increase in rate of release for the 0.9-millimeter-per-year recharge rate indicates that diffusion release from the waste package is suppressed at a low rate of recharge.

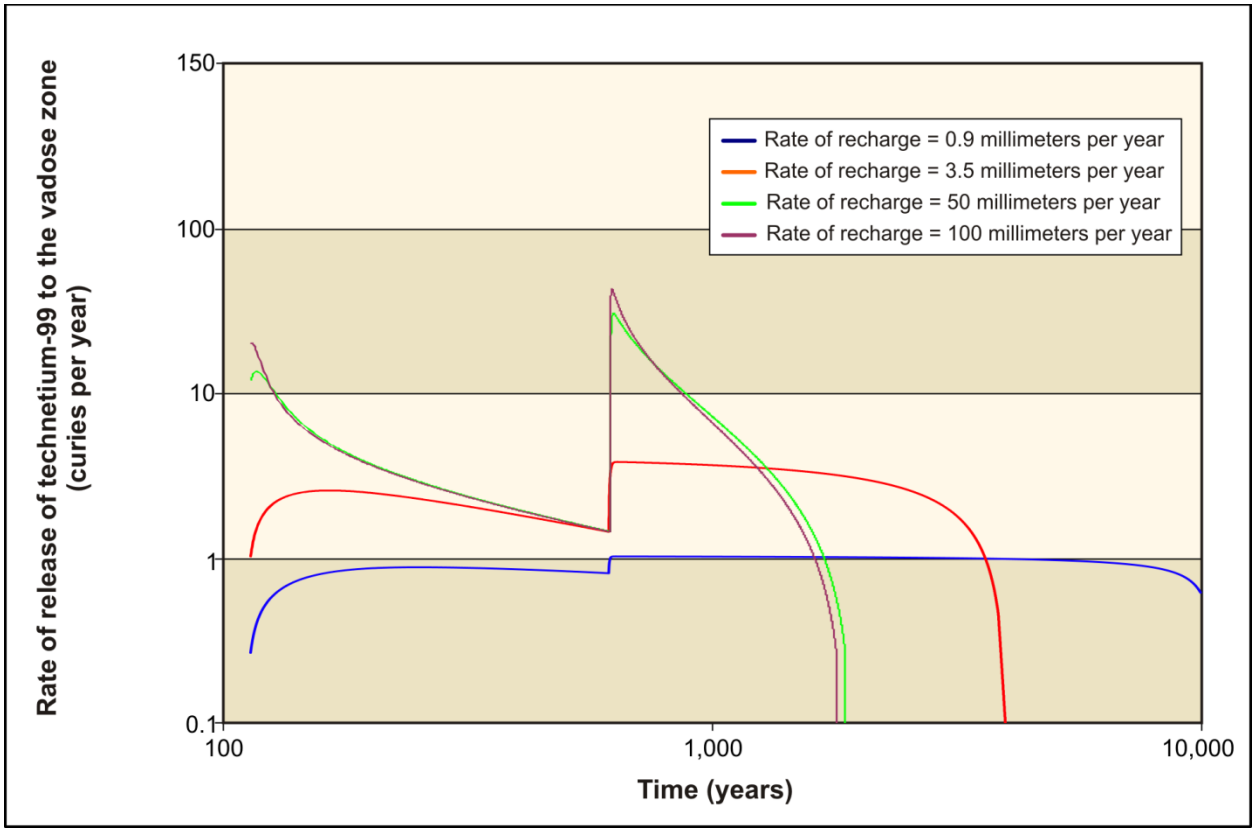


Figure M–127. Dependence of Rate of Release of Technetium-99 on Rate of Recharge for Diffusion-Limited Release Model

M.5.5 Release Mechanisms for Steam Reforming Waste

A fluidized-bed steam reformer combines a waste stream containing organics, nitrates, and dissolved solids with a carbonaceous or clay co-reactant in a reducing steam environment to produce a mineralized waste form product. Organics in the feed stream are destroyed and nitrates are converted to nitrogen gas. The solid product is produced by the drainage of small particles from the reformer bed and by capture in offgas equipment of finer particles removed from the reformer by the fluidizing gas. Depending on the fluidized-bed steam reforming (FBSR) operating conditions and the nature of the co-reactant, the solid product may adopt amorphous, glassy, or crystalline structures exhibiting a range of matrix solubility and constituent retention properties. Potential mineral phases include nepheline, carnegieite, and nosean (Olson et al. 2004a).

Approaches available for estimation of rates of release from waste forms considered in this *TC & WM EIS* include direct utilization of release rate data for disposal conditions and application of mathematical models whose parameters are derived from experimental data. Because release rate data for disposal conditions are not available, mathematical models are required to estimate rates of release from waste packages. Mass conservation and thermodynamic constraint models are applicable to the *TC & WM EIS* analysis and provide conservative upper bound estimates of performance. Mass transfer–based models consider external film resistance, diffusion through alteration layers developed on the reacting surface, and transport through the pore structure of the reacting particle. These models require knowledge of

product particle and alteration product structure and parameters such as mass transfer coefficients and effective diffusivities that have not been investigated for the current FBSR waste forms. The detailed models incorporating mass transfer, alteration and precipitation product effects, and kinetic rate forms also require data that are not currently available. While complex models are applicable with adequate data support, and use of such models provides understanding of the role of contributing physical and chemical processes, their use in the absence of complete data support is not recommended (NCRP 2005:95).

Consistent with the above discussion, release models considered in detail include a reactant (water)–limited release model supported by surface reaction rate data and a chemical reaction equilibrium–limited release model. Based on analysis of pilot plant data (Olson et al. 2004a, 2004b), the primary matrix of the FBSR product is taken to be nepheline, and constituents (e.g., silicon, sulfur, rhenium) distributed throughout the matrix are released upon dissolution of the nepheline matrix. Details of each model are presented in the following paragraphs.

M.5.5.1 Reactant-Limited Release Model

The rate of release of a constituent from a surface reaction rate–limited model does not take account of mass transfer processes involving reactants or products, the effect of alteration products on the rate of reaction, or limitations imposed by the availability of reactants. Two approaches were implemented: first, the rate of dissolution was calculated directly from experimental data; and second, the rate of reaction was calculated from the empirical expression using parameter values derived from experimental data.

In the first approach, the average fractional release rate was calculated directly from several sets of reported Single Pass Flow Through and Pressurized Unsaturated Flow test data (McGrail et al. 2003a:Appendices A and B). Fractional release rates were calculated using concentrations of silicon, sulfur, and rhenium measured in the dissolution reactor effluent in conjunction with information about sample size and chemical composition.

Based on measurements of the concentration of silicon, the daily fractional release rate ranged from 4×10^{-5} to 7×10^{-3}, with the lower values associated with the Pressurized Unsaturated Flow experiments. For sulfur, the daily fractional release rate ranged from 9×10^{-4} to 2×10^{-2}, with estimates from the Pressurized Unsaturated Flow experiments in the central region of the range. For rhenium, the daily fractional release rate ranged from 7×10^{-4} to 4×10^{-2}, with the lower values associated with the Pressurized Unsaturated Flow experiments (McGrail et al. 2003a:Appendices A and B).

These estimates are for an elevated temperature (90 °C [194 °F]) and for values of pH (acidity/alkalinity) between 7 and 9. In these calculations, the fractional release rates for sulfur and rhenium, components that were expected to be incorporated into a sodalite "cage," were not always lower than the fractional release rate for silicon, which is expected to be dissolved primarily from the nepheline mineral.

Using the results of the Single Pass Flow Through testing, parameters of a kinetic rate law were estimated by regression on the data sets for both nepheline and nosean (McGrail et al. 2003b). The kinetic law was as follows:

$$J = k_0 \, 10^{\eta \, pH} \exp(-E_a / RT) \qquad \text{(M–27)}$$

where:

J	=	normalized dissolution rate, moles per square meter per second
k_0	=	intrinsic rate constant, moles per square meter per second
η	=	pH power law coefficient, dimensionless
pH	=	negative logarithm of the molar concentration of dissolved hydrogen ions
E_a	=	activation energy, kilojoules per mole
R	=	ideal gas constant, 0.008314 kilojoules per mole per kelvin
T	=	temperature, kelvins

The values of the parameters determined from the regression of the data are presented in Table M–57. This kinetic law model can be incorporated into a more detailed flow, reaction, and transport model to develop estimates of waste form performance under disposal conditions.

Table M–57. Kinetic Rate Law Parameters for Hanford FBSR Product[a]

Parameter	Symbol	Units	Value	
			Nepheline	Nosean
Intrinsic rate constant	k_0	g-mole m^{-2} s^{-1}	2.0×10^{-9}	0.25
Activation energy	E_a	kJ mol^{-1}	16.6	48.6
pH power law coefficient	η	dimensionless	0.25	1

[a] McGrail et al. 2003b:26, 27.
Key: FBSR=fluidized-bed steam reforming; kJ=kilojoule.

The rate of dissolution in the absence of influence of mass transfer, alteration products, and precipitation effects can be estimated using the rate form of Equation M–27 and the rate parameters presented in Table M–57. At the expected disposal temperature of approximately 15 °C (59 °F) and a pH of 7, the rates of dissolution are estimated to be 0.032 and 0.0013 grams per square meter per day (6.56×10^{-6} and 2.66×10^{-7} pounds per square foot per day) for nosean and nepheline, respectively. Using a surface area per unit mass of 2.37 square meters per gram (1.16×10^4 square feet per pound) reported for granular FBSR product (McGrail et al. 2003a:3.2), the estimate of the daily fractional rate of dissolution for nepheline would be approximately 0.003, in agreement with the values calculated directly from experimental data for comparable conditions.

While the rates of release estimated in the preceding paragraphs are high, they apply primarily to the intrinsic rate of dissolution and can be reduced by consideration of both mass transfer limitations and the effects of alteration and precipitation products on the rate of reaction. At the present time, data needed to quantify the additional processes have not been collected. In addition, a major factor in estimating the high rate of dissolution of FBSR product is the high surface area per unit mass of the granular form of the product.

The dissolution of the FBSR product matrix is likely initiated by the reaction of infiltrating water with the nepheline glass or crystal. The reaction can be expressed as follows:

$$NaAlSiO_4 + 2H_2O = Na^{+1} + Al^{+3} + SiO_2(aq) + 4(OH^{-1}) \qquad \text{(M–28)}$$

The stoichiometry of the reaction dictates that 1 mole (142 grams) of nepheline is dissolved for each 2-mole (36-gram) quantity of water. On a mass-to-volume basis, this is equivalent to approximately 3.94×10^6 grams of nepheline dissolved per cubic meter of water. In the concept developed for a reactant-limited release, the amount of water available for dissolution is the amount that would flow through the cross-sectional area of waste packages perpendicular to the vertical flow of the water that would flow between the stacks of packages carrying the dissolution products downward into the vadose zone underlying the stacks of packages.

For the IDF conceptual design, the cross-sectional area of flow for a stack is approximately 2.31 square meters (24.86 square feet) and the cross-sectional area of flow for a waste package is 1.17 square meters (9.59 square feet). With an FBSR product bulk density of 1 gram per cubic centimeter (THORTT and WGI 2006:7-56) and a waste package volume of 2.25 cubic meters (594.38 gallons), a stack of four packages contains 9.0×10^6 grams of waste matrix. For IDF-East, the rate of recharge through the cap would be 0.5 millimeters per year for the first 500 years and 0.9 millimeters per year for all subsequent time. The rate of flow through the cross-sectional area of the waste packages in a stack would be 5.845×10^{-4} and 1.052×10^{-3} cubic meters per year for the first 500 and subsequent years, respectively. The rate of dissolution of the waste matrix would be calculated as follows:

$$R_{diss} = [(\rho w\ R_{inf}\ A_{inf})/\ MW_w]\ \nu_{n\text{-}w}\ MW_n \qquad \text{(M–29)}$$

where:

R_{diss}	=	rate of dissolution of the waste matrix, grams per year
ρ_w	=	density of water (1×10^6), grams per cubic meter
R_{inf}	=	rate of recharge, meters per year
A_{inf}	=	area of recharge, square meters
MW_w	=	molecular weight of water (180), grams per gram-mole
$\nu_{n\text{-}w}$	=	moles of nepheline dissolved per mole of water reacted (0.5), gram-moles per gram-mole
MW_n	=	molecular weight of nepheline (142), grams per gram-mole

The related rates of dissolution of nepheline are 2,305.5 and 4,150 grams per year for the first 500 and subsequent years, respectively. The time required for complete dissolution of the waste matrix would be 2,390 years, with average fractional release rates of 2.6×10^{-4} and 5.3×10^{-4} per year for the first 500 and subsequent years, respectively.

The *TC & WM EIS* release model that fits the constant release rate estimated above is the matrix solubility model (see Section M.2.2.2). In this model, the rate of dissolution of the waste matrix is calculated as follows:

$$R_{diss} = R_{inf}\ A_{inf}\ Cs_{WM} \qquad \text{(M–30)}$$

where:

R_{diss}	=	rate of dissolution of the waste matrix, grams per year
R_{inf}	=	rate of recharge, meters per year
A_{inf}	=	flow area of the stack of packages, square meters
Cs_{WM}	=	solubility of the waste matrix (grams per cubic meter)

With a flow area of 2.31 square meters (24.86 square feet) per stack and the matrix dissolution rates estimated above, the solubility for use in the *TC & WM EIS* matrix solubility release model is approximately 2.0×10^6 grams per cubic meter.

M.5.5.2 Solubility-Limited Release Model

The concept of chemical equilibrium can be used to place constraints on the aqueous-phase concentrations of constituents constituting a system for specified values of intensive variables. In addition, the effect of changes in intensive variables, such as temperature, can be established. The approach is limited by the need for identification and characterization of aqueous- and solid-phase constituents present in the system, including specification of stoichiometric relations and the values of thermodynamic functions (free energies of formation and enthalpy change for reactions) for all

constituents. The particular application for FBSR product release modeling is estimation of the equilibrium solubility of the material. Steps in the analysis include the following:

- Specification of constraints (e.g., temperature, pressure, pH)
- Identification of aqueous-phase constituents and complexes
- Identification of solid-phase constituents
- Calculation of the distribution of aqueous-phase constituents for the vadose zone water contacting the FBSR product
- Calculation of aqueous-phase constituents for aqueous solutions in equilibrium with the FBSR product

The conceptual model for the system is the portion of the vadose zone inside the IDF under an engineered cap in which stacks of packages containing FBSR product are in contact with vadose zone water. The chemical composition of precipitation infiltrating into the cap may be altered when in contact with material composing the cap. Within the disposal horizon, the infiltrating water is in contact with both the IDF backfill material and the FBSR product and is presumed to reach a state of chemical-thermodynamic equilibrium prior to downward movement into the vadose zone underlying the facility. The role of the package material is not included in the conceptual model. For analysis purposes, the cap and backfill are represented as sand, either quartz or amorphous silica, and the FBSR product is represented as crystalline nepheline.

The objective of the analysis is determination of the equilibrium solubility of nepheline under potential IDF disposal conditions, including consideration of conditions that cannot be known with certainty prior to operation of the facility. Conditions considered variable are temperature, gas phase composition, chemical composition of water entering the disposal horizon, and precipitation of alteration phases during dissolution of nepheline.

The geochemical model adopted for the analysis was the PHREEQC computer code (Parkhurst and Appelo 1999) developed at the U.S. Geological Survey. PHREEQC uses an ion-association aqueous model to simulate speciation and saturation, batch reaction, one-dimensional transport, or inverse modeling. Only the speciation and saturation capabilities were used in this analysis. The geochemical database, MINTEQ.DAT, supplied with the code was used in the analysis. Aqueous-phase constituents included hydrogen, hydroxide, sodium, and aluminum ions; hydroxides of aluminum; carbonate, bicarbonate, and carbonic acid; sodium carbonate and bicarbonate; and silicic acid and dissociated silicic acid. Solid-phase species included quartz, amorphous silica, gibbsite, kaolinite, analcime, and nepheline.

The conceptual model for determination of the composition of water entering the disposal horizon prior to contacting the FBSR product was movement of precipitation through the cap material at a temperature of 15 °C (59 °F). The water entering the disposal horizon was assumed in equilibrium with the ambient atmosphere at oxygen and carbon dioxide partial pressures of 0.2 and 0.03 atmospheres, respectively.

The first case determined the solubility in the absence of alteration phases or the potential for precipitation of quartz or amorphous silica. In the final solution for each of these cases, the aqueous phase was slightly oversaturated with respect to quartz and slightly undersaturated with respect to amorphous silica, and the solubility of nepheline was estimated to be 118.2 grams per cubic meter.

The second case determined the solubility of nepheline with the potential for precipitation of alteration phases (gibbsite, kaolinite, and analcime) at a temperature of 15 °C (59 °F). The final solution was undersaturated with respect to both quartz and amorphous silica, and the solubility of nepheline was

estimated to be 175,000 grams per cubic meter. The results indicated that the precipitation of alteration phases has the effect of significantly increasing the solubility of nepheline, especially for the cases involving analcime.

M.5.5.3 Conclusion

Estimates of rates of release based solely on dissolution reaction rate models not limited by reactant availability, mass transfer limitation, or alteration and precipitation product effects produce high estimates. However, data justifying incorporation of the contributing physical and chemical processes into a detailed flow and reaction model are not available at the current time. Estimates of rates of release based on the availability of water reactant are also high, but place an upper limit on potential rates of dissolution. Estimates of rates of release based on predictions of the equilibrium solubility of nepheline cover a wide range, depending on the types of alteration phases that may precipitate as nepheline dissolves. A lower-end range of estimates of the equilibrium solubility of nepheline, approximately 120 grams per cubic meter, was estimated using the PHREEQC geochemical model based on the assumption that alteration phases do not precipitate. This value is consistent with that proposed, 105 to 430 grams per cubic meter, in an evaluation of FBSR product solubility and dissolution (CEES 2010). An upper-end estimate of the equilibrium solubility of nepheline, approximately 1.75×10^5 grams per cubic meter, was estimated using the PHREEQC geochemical model based on the assumption that the alteration phases of gibbsite, kaolinite, or analcime could precipitate.

Based on observation of the formation of alteration phases in dissolution of nepheline (Tole et al. 1986), it is concluded that the upper-limit estimate of solubility, 1.75×10^5 grams per cubic meter, is reasonably conservative and is the value recommended for use in the *TC & WM EIS* impacts analysis. The lower end of the range of solubility, 120 grams per cubic meter, and the limit based on availability of water reactant, 2.01×10^6 grams per cubic meter, are recommended as a reasonable range for sensitivity analysis. Estimates of the rate of release of technetium-99 from FBSR solids to the vadose zone and of rate of arrival at the water table using these three values of release rate are presented in Figures M–128 and M–129, respectively. Consistent with the values of solubility, the peak rate of arrival at the water table is approximately a factor of 10 higher than the upper-limit solubility estimate. The flux at the water table for the lower-limit solubility case is approximately a factor of 1,000 lower than the flux at the water table for the upper-limit solubility case.

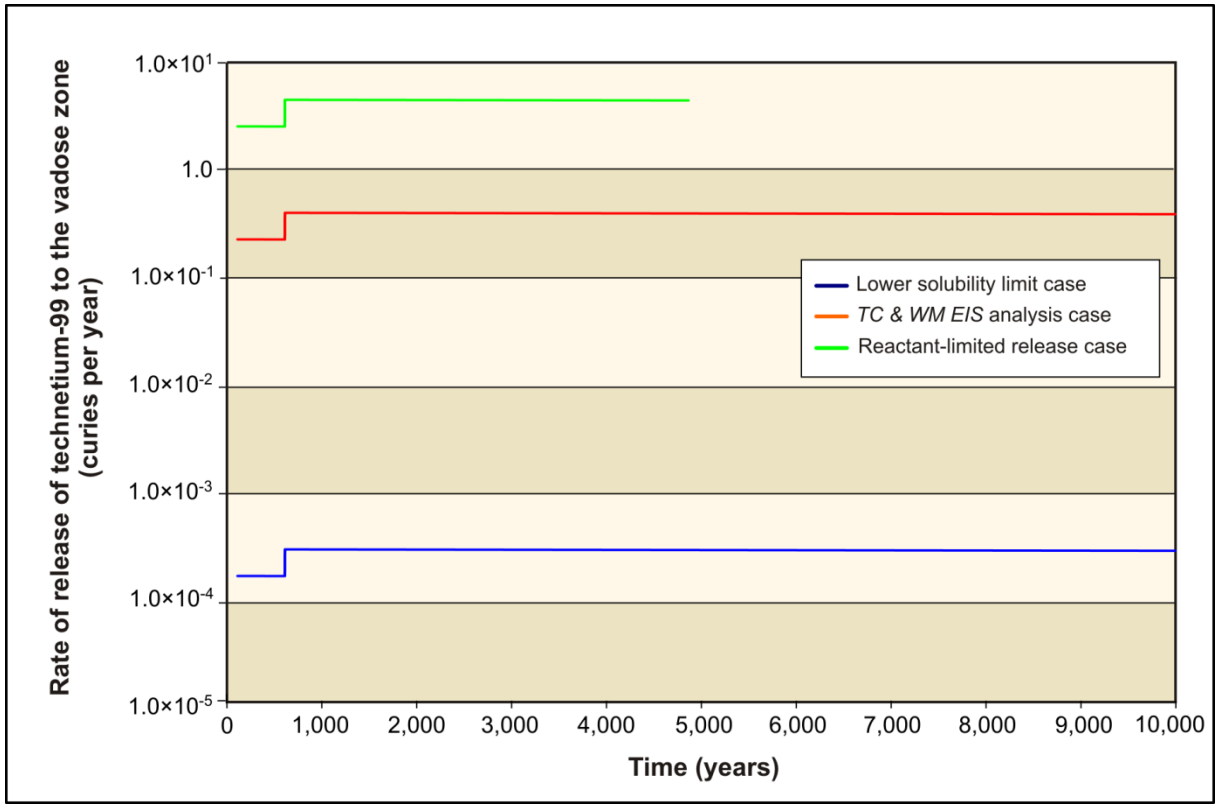


Figure M–128. Dependence of Rate of Release of Technetium-99 to the Vadose Zone on Steam Reforming Waste Release Model

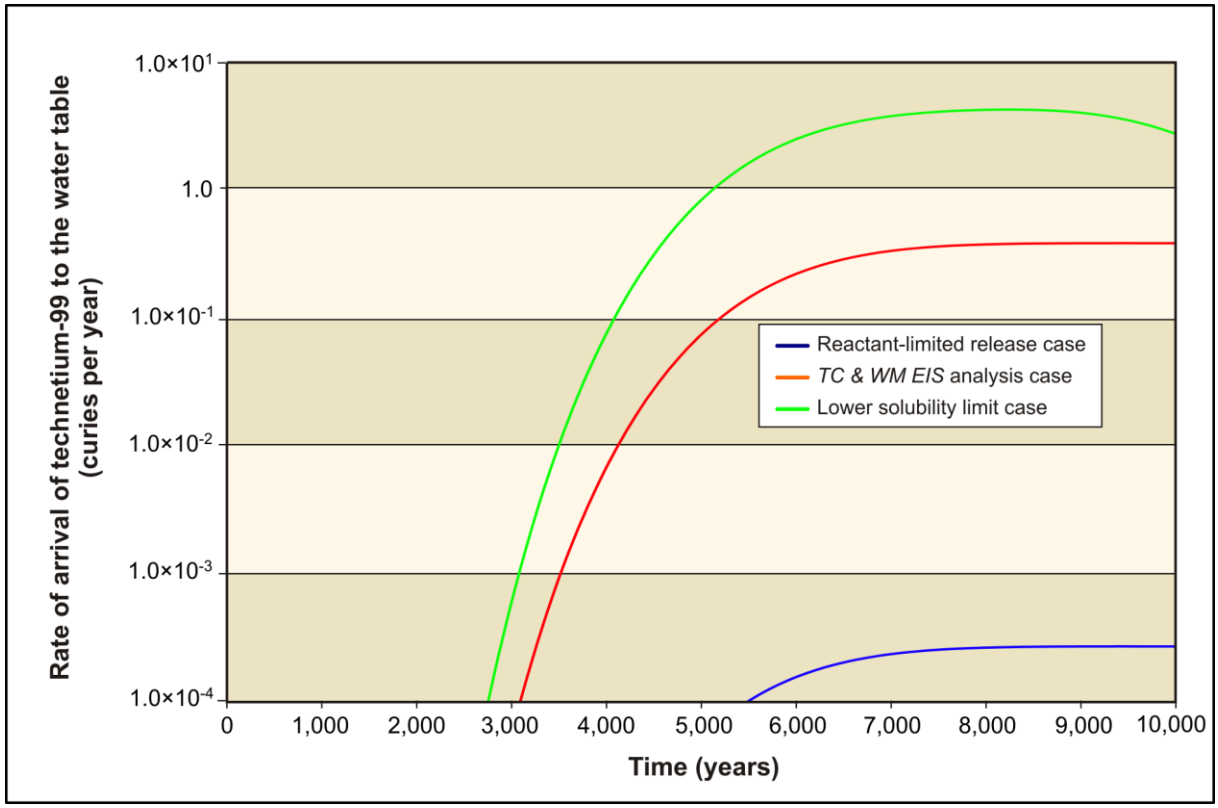


Figure M–129. Dependence of Rate of Arrival of Technetium-99 at the Water Table on Steam Reforming Waste Release Model

M.5.6 No-Retrieval-Losses Sensitivity Case

This *TC & WM EIS* evaluates the releases from other sources related to the HLW tanks, including tank residuals, retrieval leaks, ancillary equipment, and unplanned releases within the tank farm boundary that were analyzed together. The amount of constituent released to the aquifer is related to the activities under each Tank Closure alternative. The objective of this sensitivity analysis is to examine the effect on the concentrations of constituents in the groundwater of the removal of the retrieval leaks from the other sources. Figure M–130 reports the predicted flux of technetium-99 to the vadose zone for the C tank farm under Tank Closure Alternative 2B. The figure reports a release of a liquid source of technetium-99 from retrieval leaks in 2018. The timing of the release due to retrieval losses is the same for each affected tank farm, and the inventories for the HLW tanks vary between tank farms. The figure reports predicted releases of technetium-99 to the vadose zone for 1940 to 2440, so single-year releases are visible on the graph. Ancillary equipment and tank residual sources would continue to release indefinitely as the source is depleted. The sensitivity case analyzes the removal of that source from the alternative. Figure M–131 reports the predicted concentration of technetium-99 versus time for all sources under Tank Closure Alternative 2B. Figure M–132 reports the predicted concentration of technetium-99 versus time when the retrieval losses source is removed from the alternative. The benchmark value was derived from relevant regulatory standards as a means of assessing long-term human health impacts.

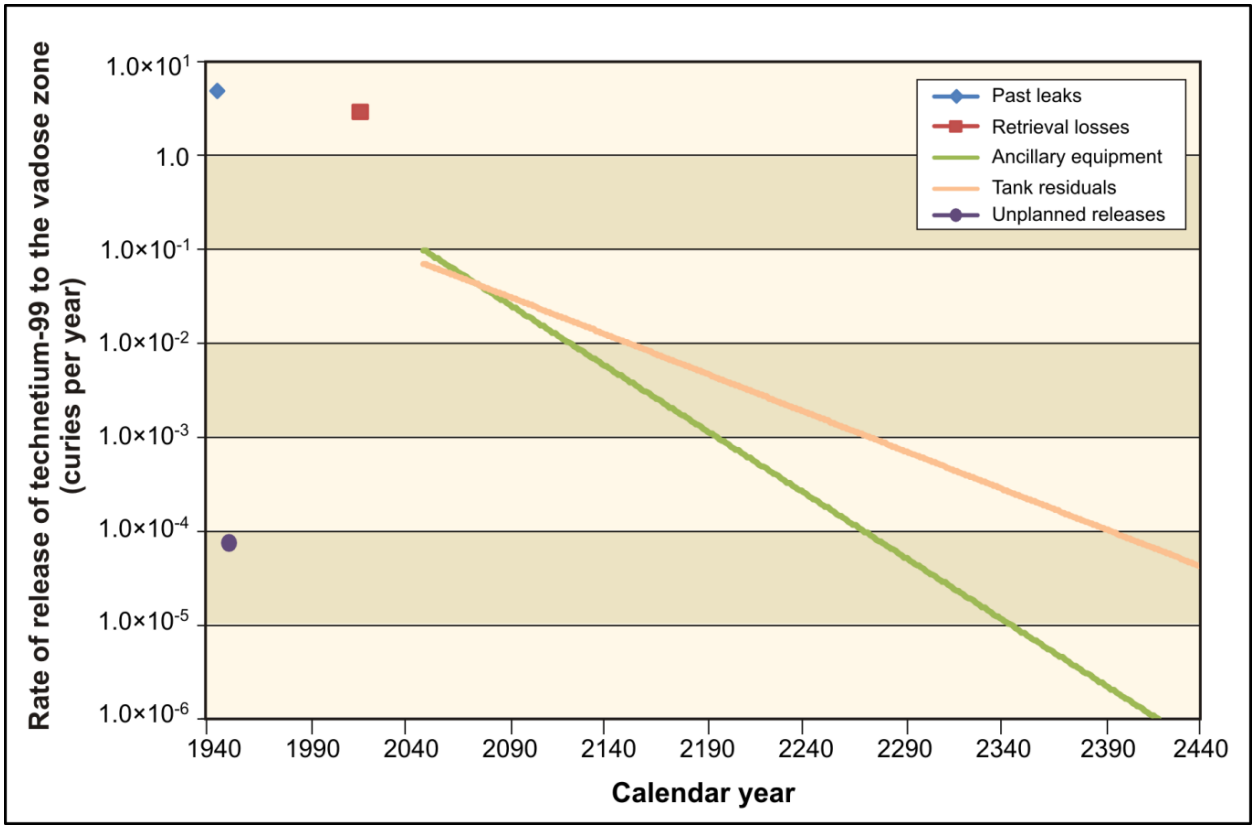


Figure M–130. Tank Closure Alternative 2B Release of Technetium-99 to the Vadose Zone from Tank Farm C

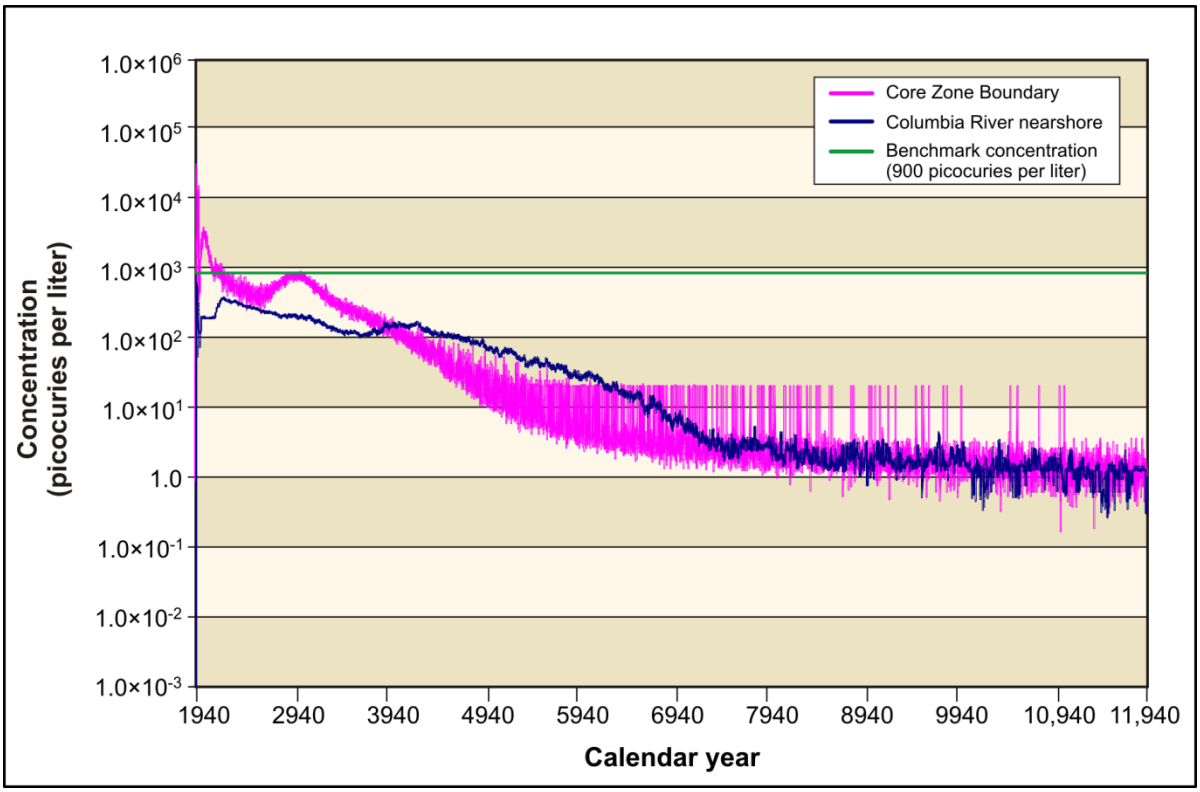


Figure M–131. Tank Closure Alternative 2B Groundwater Technetium-99 Concentration at the Core Zone Boundary and the Columbia River, Retrieval Loss Sensitivity Case

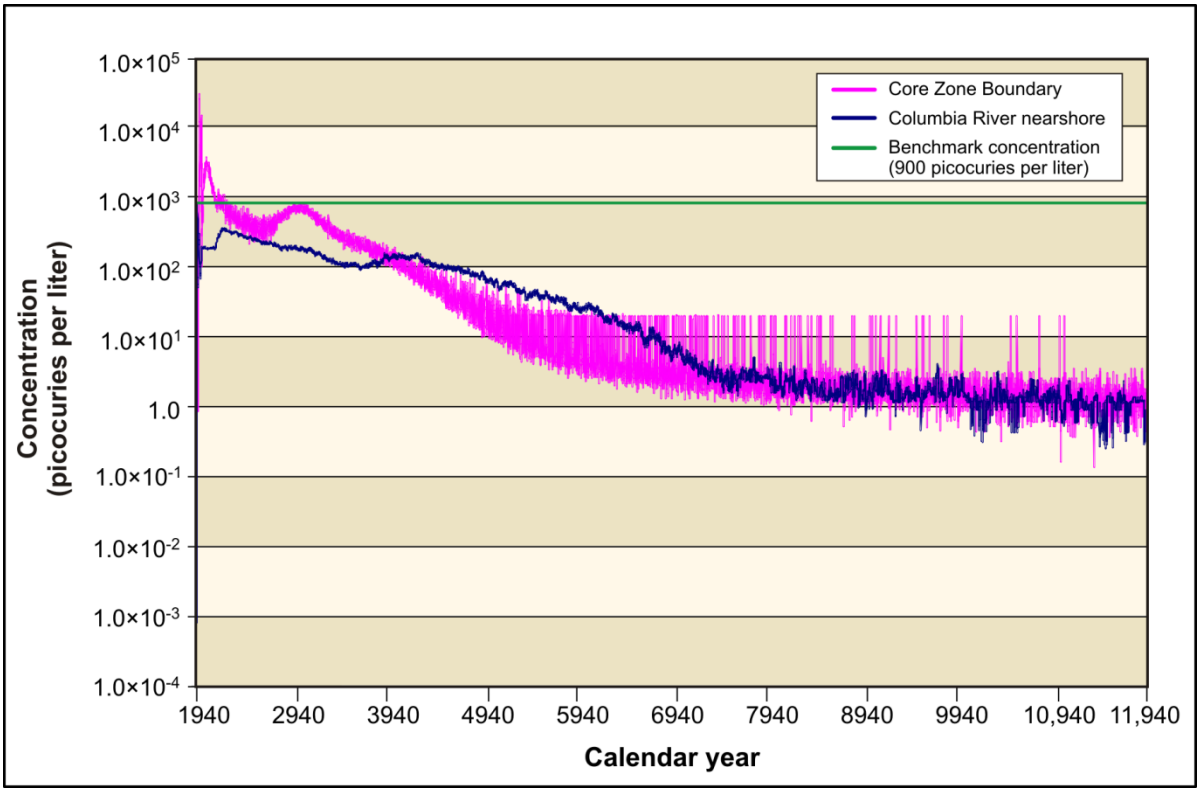


Figure M–132. Tank Closure Alternative 2B Groundwater Technetium-99 Concentration at the Core Zone Boundary and the Columbia River, No-Retrieval-Losses Sensitivity Case

M.5.7 IDF-East Sensitivity Analyses

M.5.7.1 Immobilized Low-Activity Waste Glass Sensitivity Analysis

This *TC & WM EIS* models ILAW glass using the fractional release model. In the EIS analysis, the fractional release rate is 2.80×10^{-8} grams per gram per year. The objective of this sensitivity analysis is to examine the effect of increasing and decreasing the fractional release rate on the predicted concentration in the aquifer. The sensitivity analysis examined the ILAW glass under Tank Closure Alternative 2B. Table M–58 summarizes the values of fractional release rates for the three cases analyzed. Figure M–133 reports the predicted release of technetium-99 to the vadose zone under each case.

Table M–58. Immobilized Low-Activity Waste Glass Sensitivity Analysis Cases

Sensitivity Analysis Case	Fractional Release Rate (grams per gram per year)
EIS Case	2.80×10^{-8}
Sensitivity Case 1	2.80×10^{-7}
Sensitivity Case 2	2.80×10^{-9}

Key: EIS=environmental impact statement.

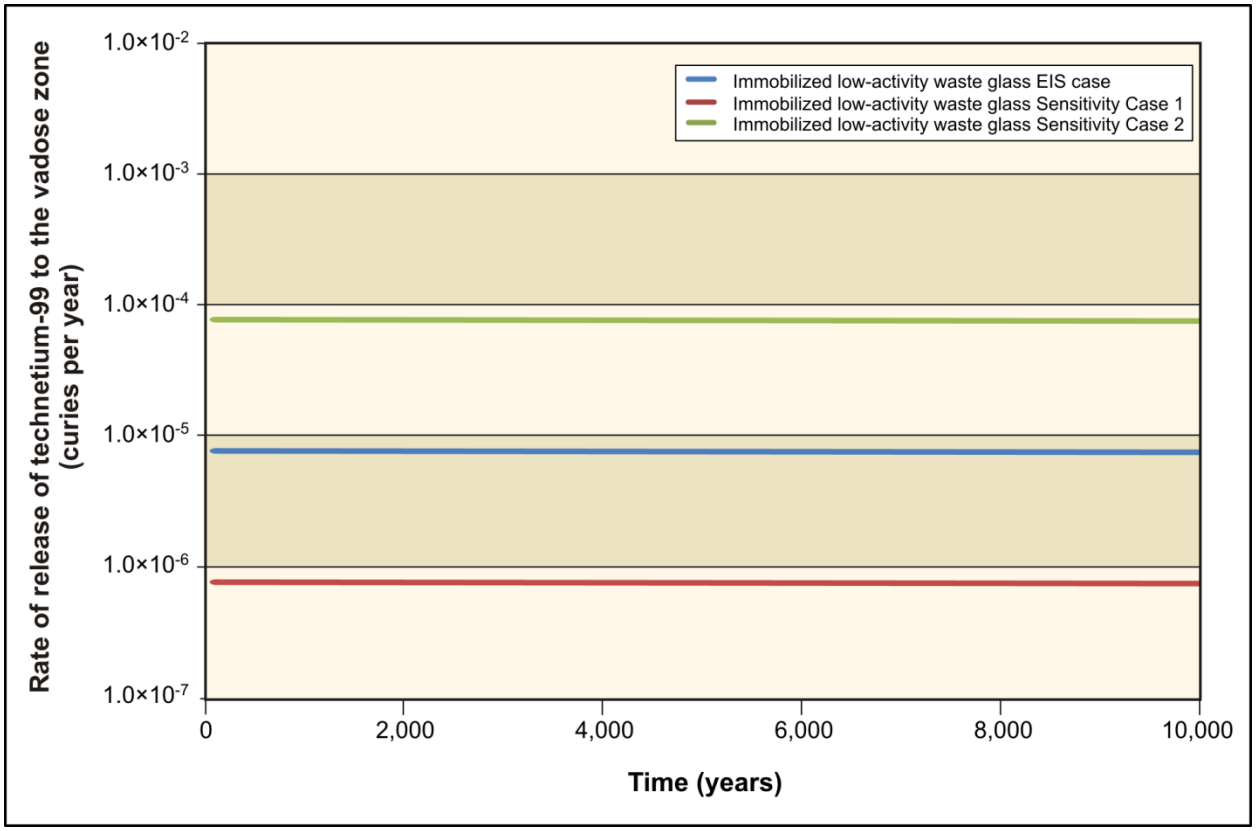
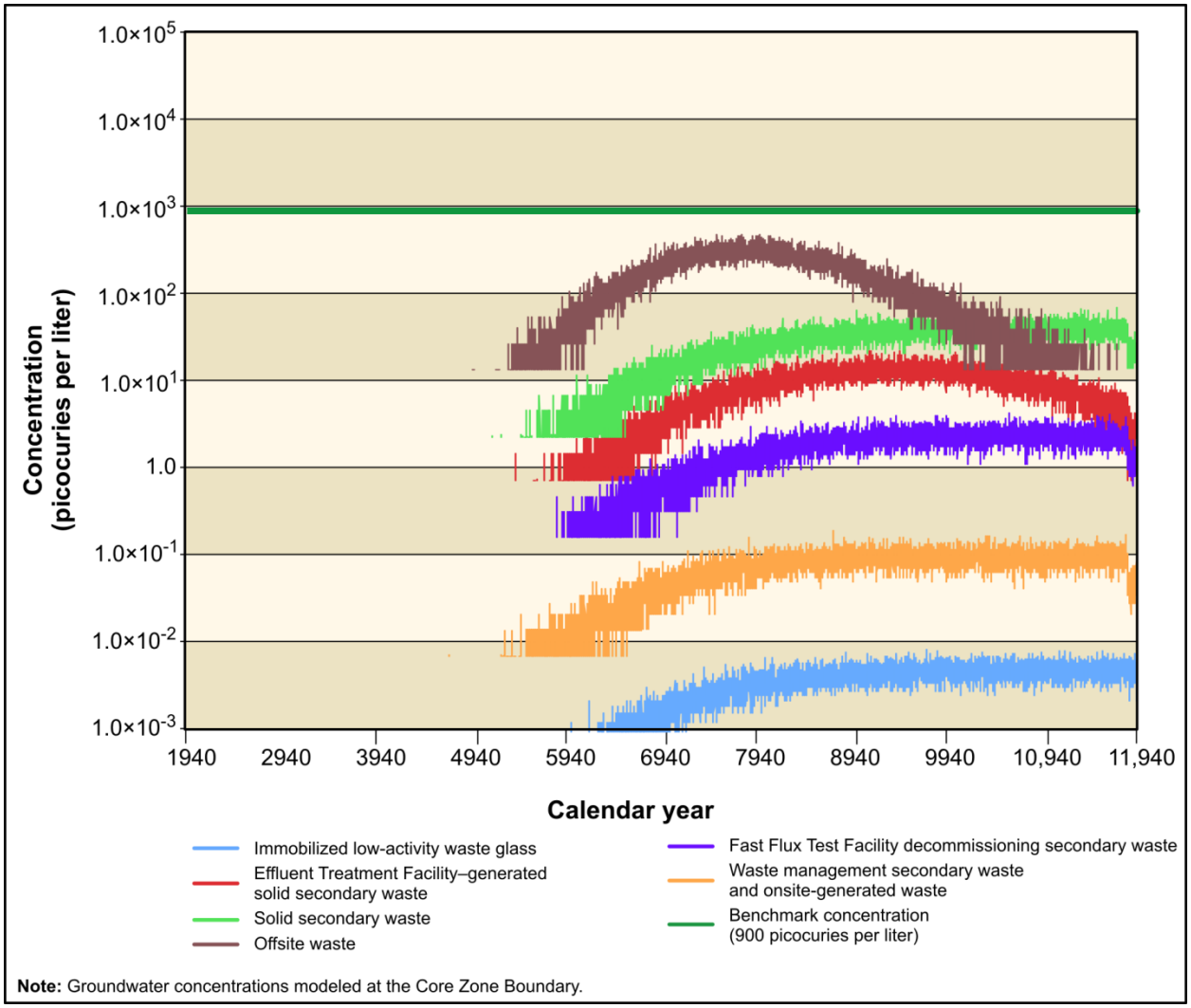


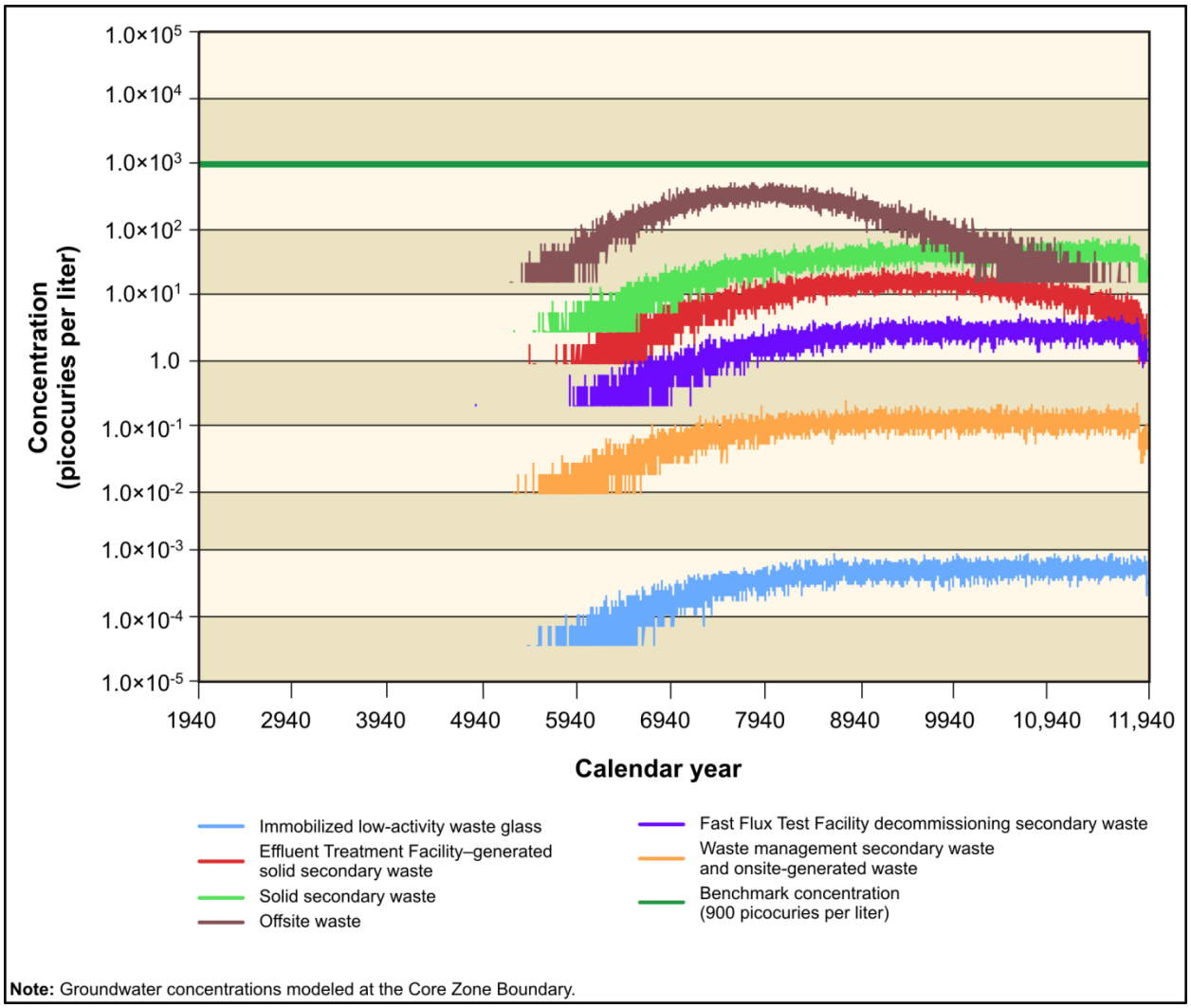
Figure M–133. Release of Technetium-99 to the Vadose Zone from Immobilized Low-Activity Waste Glass for Sensitivity Analysis

Figures M–134 through M–136 indicate the predicted concentrations of technetium-99 in groundwater versus time for the sensitivity analysis cases. Decreases in concentration after a peak reflect depletion of inventory at the source, while constant concentrations generally reflect release at the source that is a small fraction of inventory at the source.



Note: Groundwater concentrations modeled at the Core Zone Boundary.

Figure M–134. Tank Closure Alternative 2B Groundwater Technetium-99 Concentration at the Core Zone Boundary



Note: Groundwater concentrations modeled at the Core Zone Boundary.

Figure M–135. Groundwater Technetium-99 Concentration at the Core Zone Boundary, Sensitivity Case 1

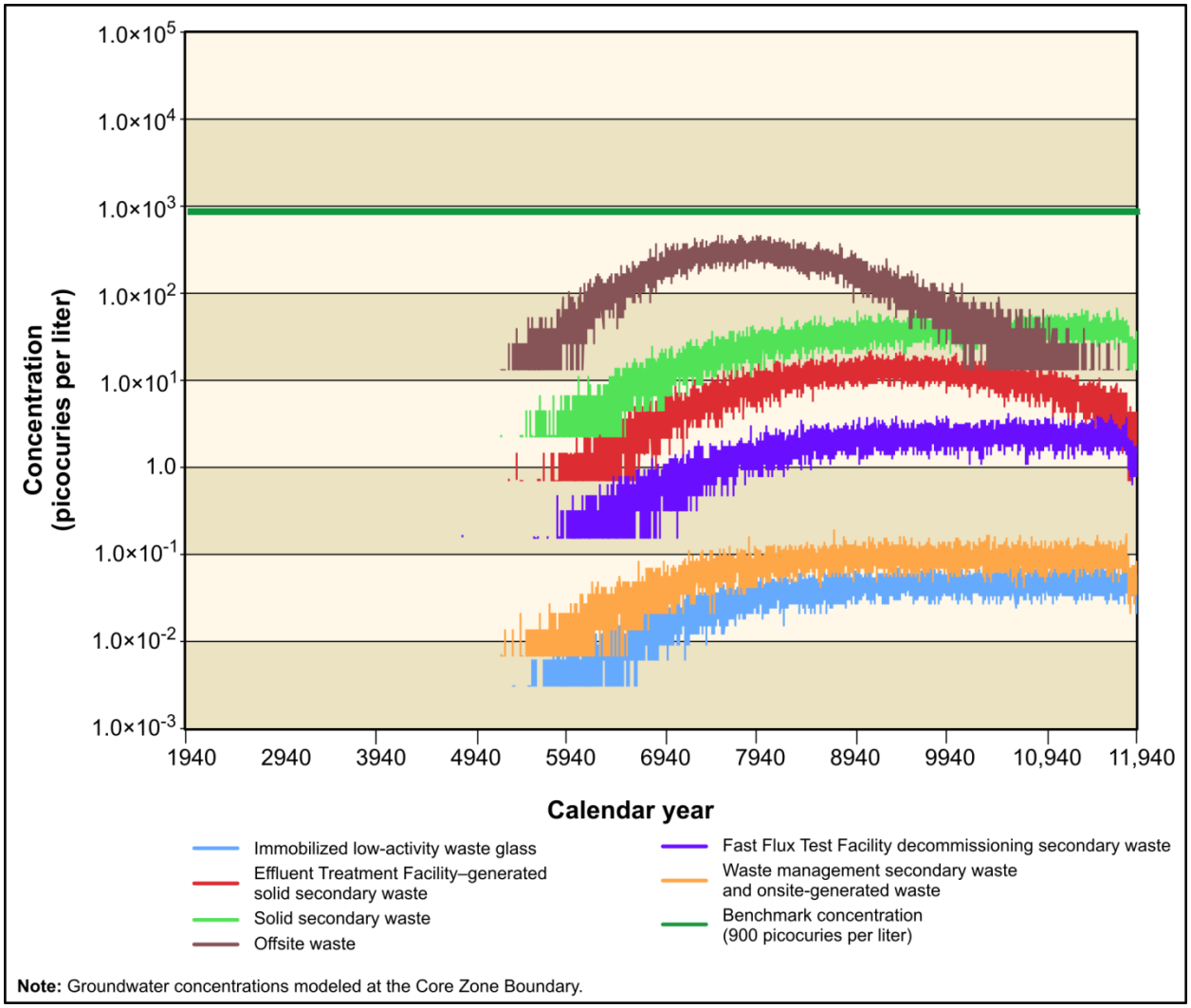


Figure M–136. Groundwater Technetium-99 Concentration at the Core Zone Boundary, Sensitivity Case 2

The results of the sensitivity analysis indicate that increasing the fractional release rate of ILAW glass by an order of magnitude increases the predicted release of technetium-99 to the vadose zone by an order of magnitude. The predicted concentration of technetium-99 in groundwater at the Core Zone Boundary follows a similar pattern. However, the contribution of ILAW glass remains a small fraction of the combined impacts for each of the analysis cases.

M.5.7.2 Iodine Recycle Sensitivity Analysis

Under Tank Closure Alternative 2B, tank closure waste would be treated in the WTP and the treated waste would be disposed of in IDF-East. Two waste forms that would result from this treatment are ILAW glass and ETF-generated secondary waste. This *Final TC & WM EIS* assumes that process flow around the melter and the melter's offgas system are such that iodine-129 would partition 20 percent into ILAW glass and 80 percent into a grouted secondary-waste form (Whyatt, Shade, and Stegen 1996). The objective of the iodine-recycle sensitivity analyses is to evaluate changes in the concentration of iodine in groundwater due to variations in the WTP process flows that increase the portion of iodine partitioned into ILAW glass. The sensitivity case evaluates the effect of partitioning 70 percent iodine-129 into ILAW glass and 30 percent into secondary grout. The distribution of inventory of iodine-129 across the waste forms for each case is presented in Table M–59. Figure M–137 reports the estimated rate of release

of iodine-129 to the vadose zone for the ILAW glass and ETF-generated secondary-waste forms. The results indicate that the rate of release from the grouted waste form is a factor of approximately 200 higher than the rate of release from the glass waste form. For the grouted waste form, the rate of release decreases in proportion to the decrease in inventory in grout by approximately a factor of three as the WTP process recycle directs iodine to the ILAW glass waste form.

Table M–59. Iodine-129 Inventory for Effluent Treatment Facility–Generated Secondary Waste and ILAW Glass for *TC & WM EIS* and Iodine-Recycle Sensitivity Analysis Cases

Waste Form	Iodine -129 (curies)	
	EIS Case	Iodine-Recycle Sensitivity Case
ETF-generated secondary waste	3.36×10^{1}	1.26×10^{1}
ILAW glass	9.55	3.35×10^{1}
ILAW melter offgas secondary waste	4.65	1.90

Key: EIS=environmental impact statement; ETF=Effluent Treatment Facility; ILAW=Immobilized Low-Activity Waste; *TC & WM EIS=Tank Closure and Waste Management Environmental Impact Statement for the Hanford Site, Richland, Washington.*

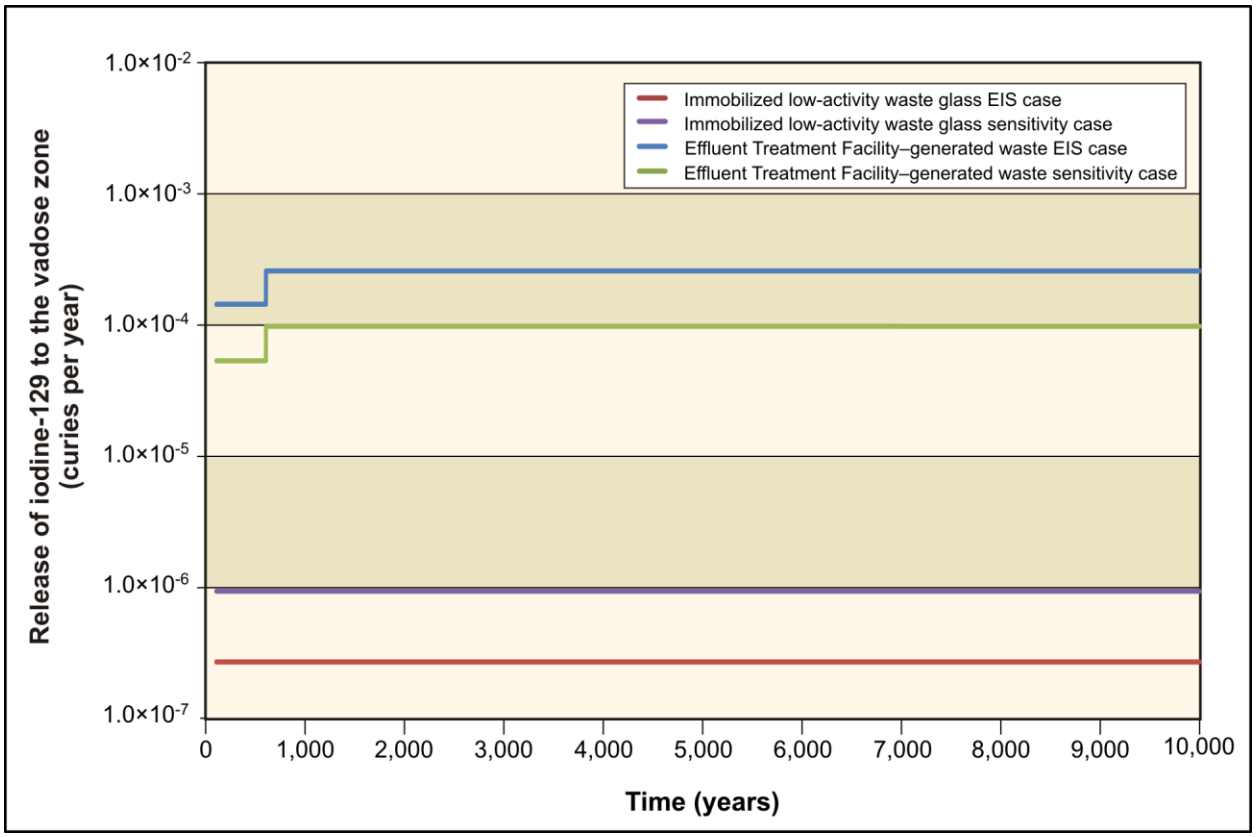


Figure M–137. Release of Iodine-129 to the Vadose Zone from Effluent Treatment Facility–Generated Secondary Waste and Immobilized Low-Activity Waste Glass for *TC & WM EIS* and Iodine-Recycle Sensitivity Cases

Figures M–138 and M–139 report the concentration of iodine-129 in the groundwater at the Core Zone Boundary for all waste forms, including those not directly affected by changes in WTP recycle flows for both the *TC & WM EIS* and iodine-recycle sensitivity cases.

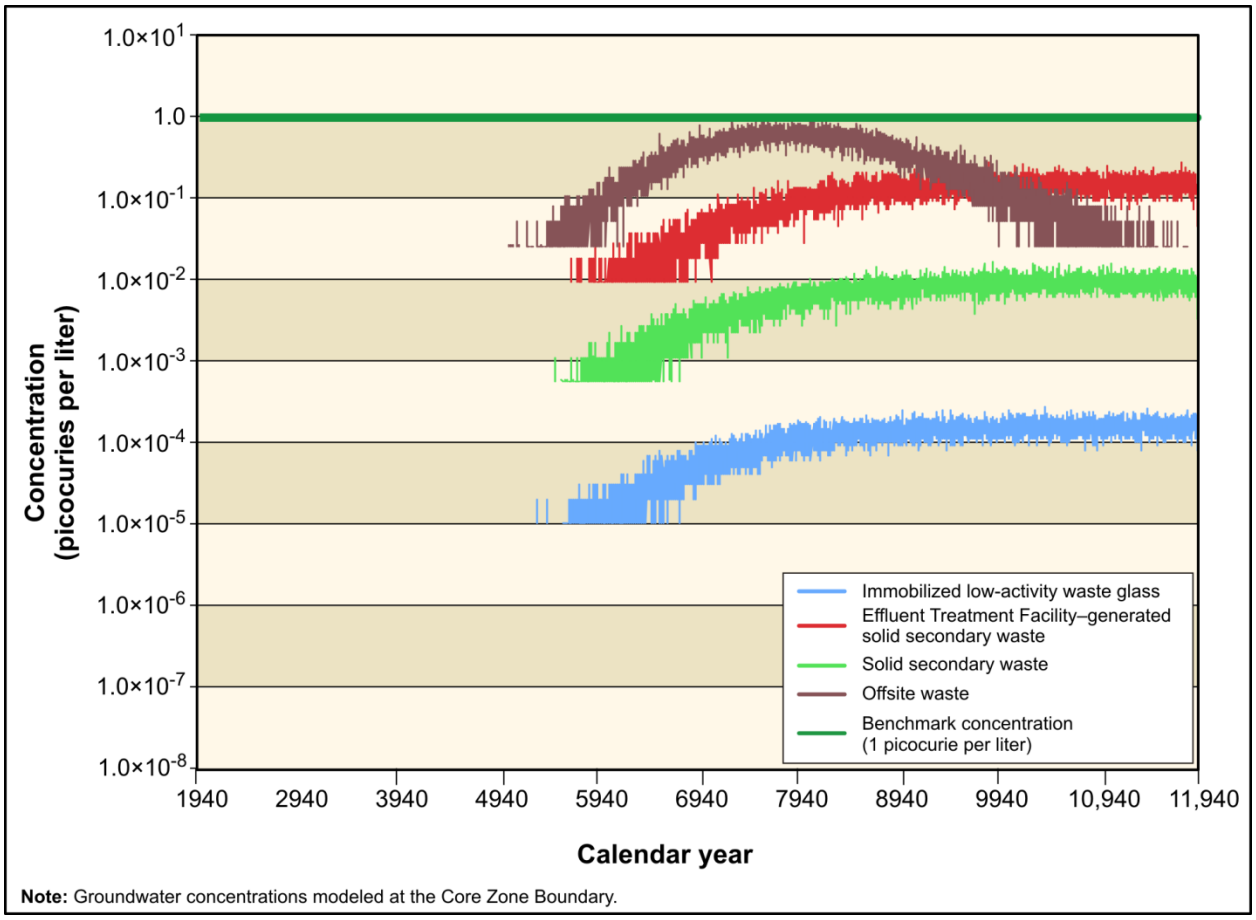


Figure M–138. Waste Management Alternative 2, Tank Closure Alternative 2B, Groundwater Iodine-129 Concentrations at the Core Zone Boundary, *TC & WM EIS* Case

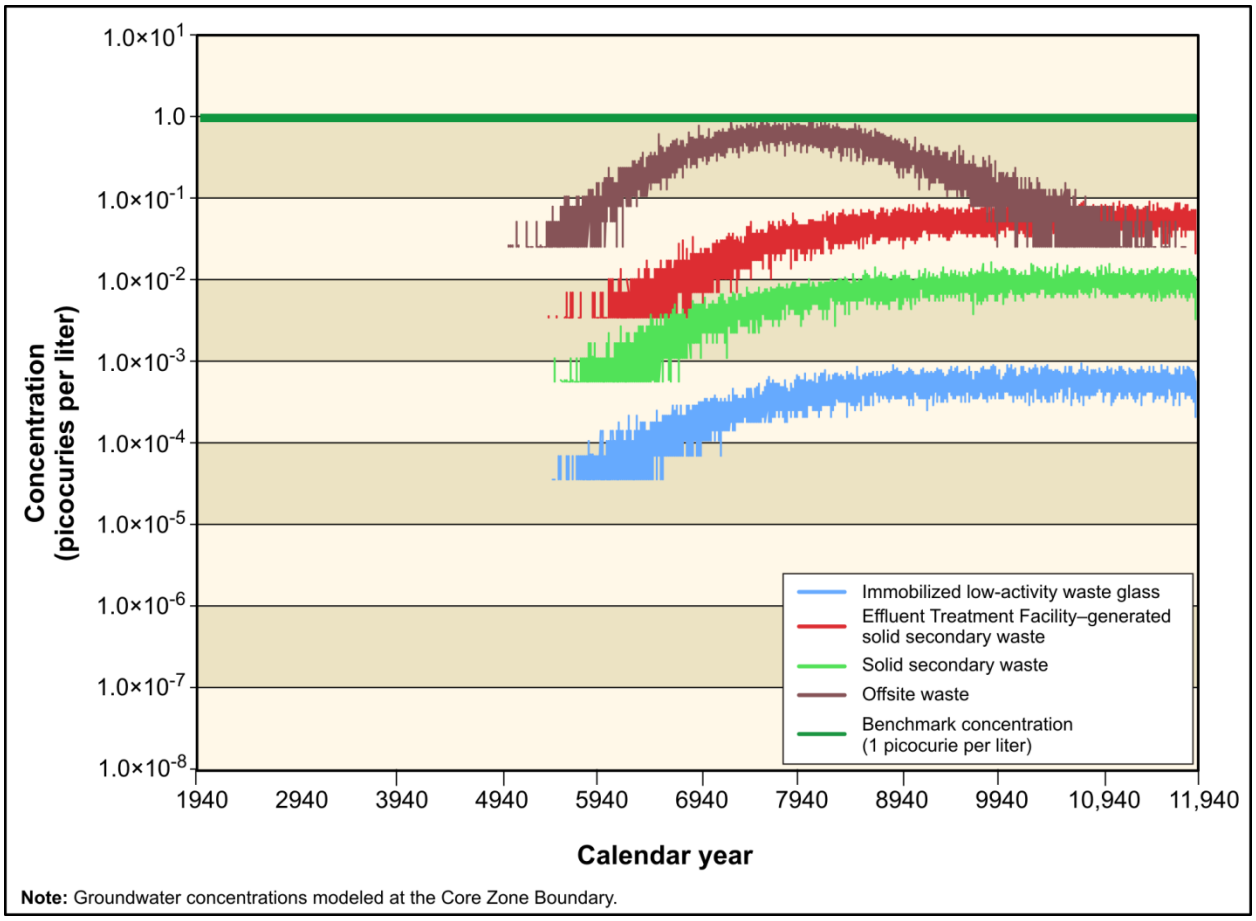


Figure M–139. Waste Management Alternative 2, Tank Closure Alternative 2B, Groundwater Iodine-129 Concentrations at the Core Zone Boundary Iodine-Recycle Sensitivity Case

The decrease of iodine-129 inventory in the ETF-generated secondary waste in the iodine-recycle sensitivity case produces a decrease in the predicted groundwater concentration at the Core Zone Boundary due to this single source by a factor of approximately 2.5. This release to the vadose zone produces a similar decrease in the flux of iodine-129 to the water table due to this single source. The increase of iodine-129 in ILAW glass under the iodine-recycle sensitivity case resulted in a 3.5 times greater predicted release to the vadose zone and concentration in the groundwater at the Core Zone Boundary, but the contribution of this source to combined impacts remains a small fraction of the impacts due to grouted secondary-waste forms.

M.5.7.3 No-Technetium-99-Removal Sensitivity Analysis

Under Tank Closure Alternative 2B, this *Final TC & WM EIS* assumes that technetium-99 would be selectively removed from the LAW waste stream as a pretreatment step within the WTP and captured in IHLW glass, which would be disposed of off site. The objective of this sensitivity analysis is to examine the predicted impacts on groundwater if the technetium-99 were not selectively removed from the LAW stream, but rather was processed through the WTP and encapsulated in ILAW glass. Table M–60 reports the technetium-99 inventory for the waste forms evaluated for this sensitivity analysis. Figure M–140 reports the predicted release of technetium-99 to the vadose zone from the affected sources. The results indicate that the rates of release from ETF-generated secondary waste and WTP secondary solid waste are similar. The *TC & WM EIS* case predicts a slightly higher rate of release from WTP secondary solid waste due to the larger technetium-99 inventory. The estimated rate of release for

the ILAW glass in the no-technetium-99-removal case is greater than three orders of magnitude higher due to the larger technetium-99 inventory that remains on site. However, the rate of release from ILAW glass remains small in absolute terms and is relative to the releases from other waste forms included under this alternative.

Table M–60. Initial Inventory for No-Technetium-99-Removal Sensitivity Analysis

Waste Form	Technetium-99 Inventory (curies)	
	***TC & WM EIS* Case**	**No-Technetium-99-Removal Sensitivity Case**
IHLW glass	2.90×10^{4}	2.47×10^{2}
ILAW glass and retired melters	2.88×10^{2}	2.88×10^{4}
ETF-generated secondary waste	8.63×10^{1}	8.63×10^{1}
WTP secondary solid waste	4.92×10^{2}	4.31×10^{2}

Key: ETF=Effluent Treatment Facility; IHLW=immobilized high-level radioactive waste; ILAW=immobilized low-activity waste; *TC & WM EIS=Tank Closure and Waste Management Environmental Impact Statement for the Hanford Site, Richland, Washington*; WTP=Waste Treatment Plant.

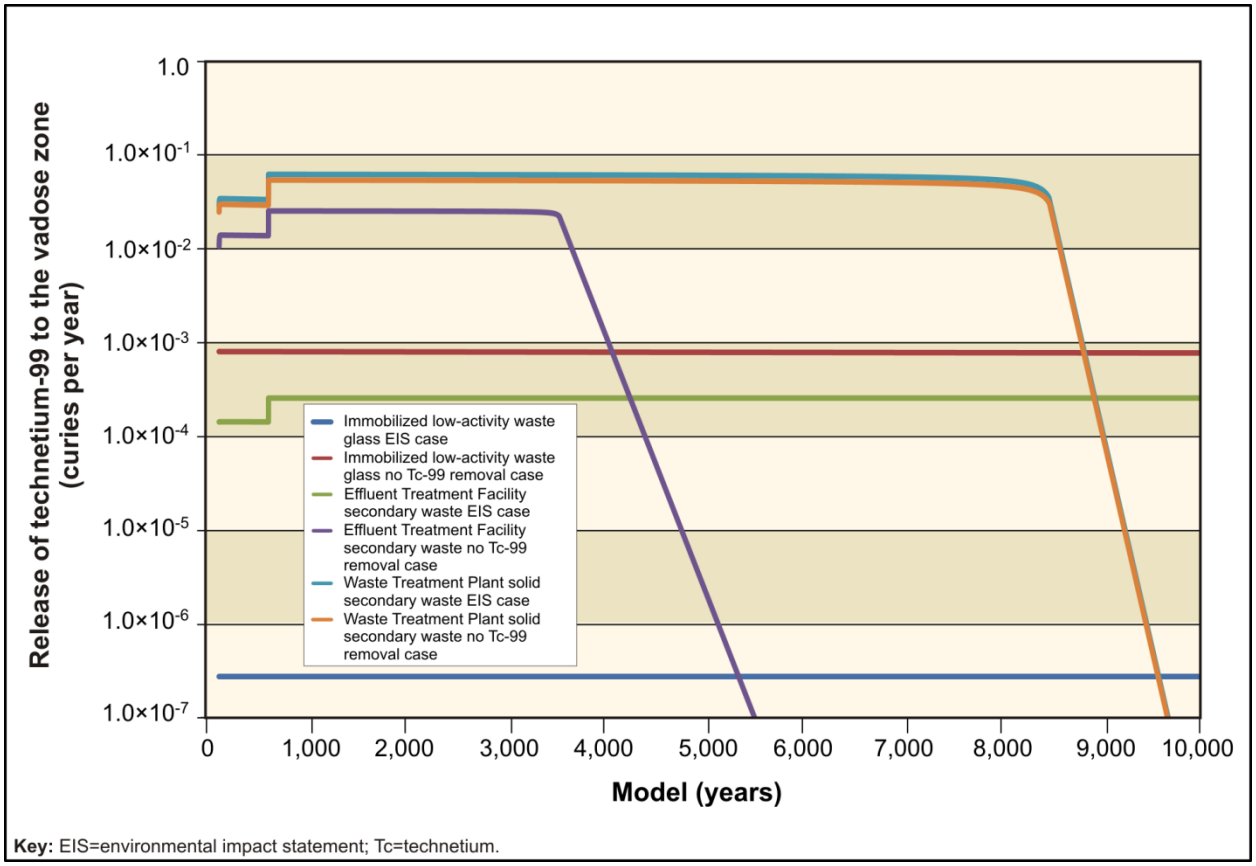


Figure M–140. Release of Technetium-99 to the Vadose Zone, *TC & WM EIS* and No-Technetium-99-Removal Sensitivity Cases

Figures M–141 and M–142 report the concentration of technetium-99 in the groundwater at the Core Zone Boundary for all waste forms, including those not directly affected by change in the technetium-99 flow.

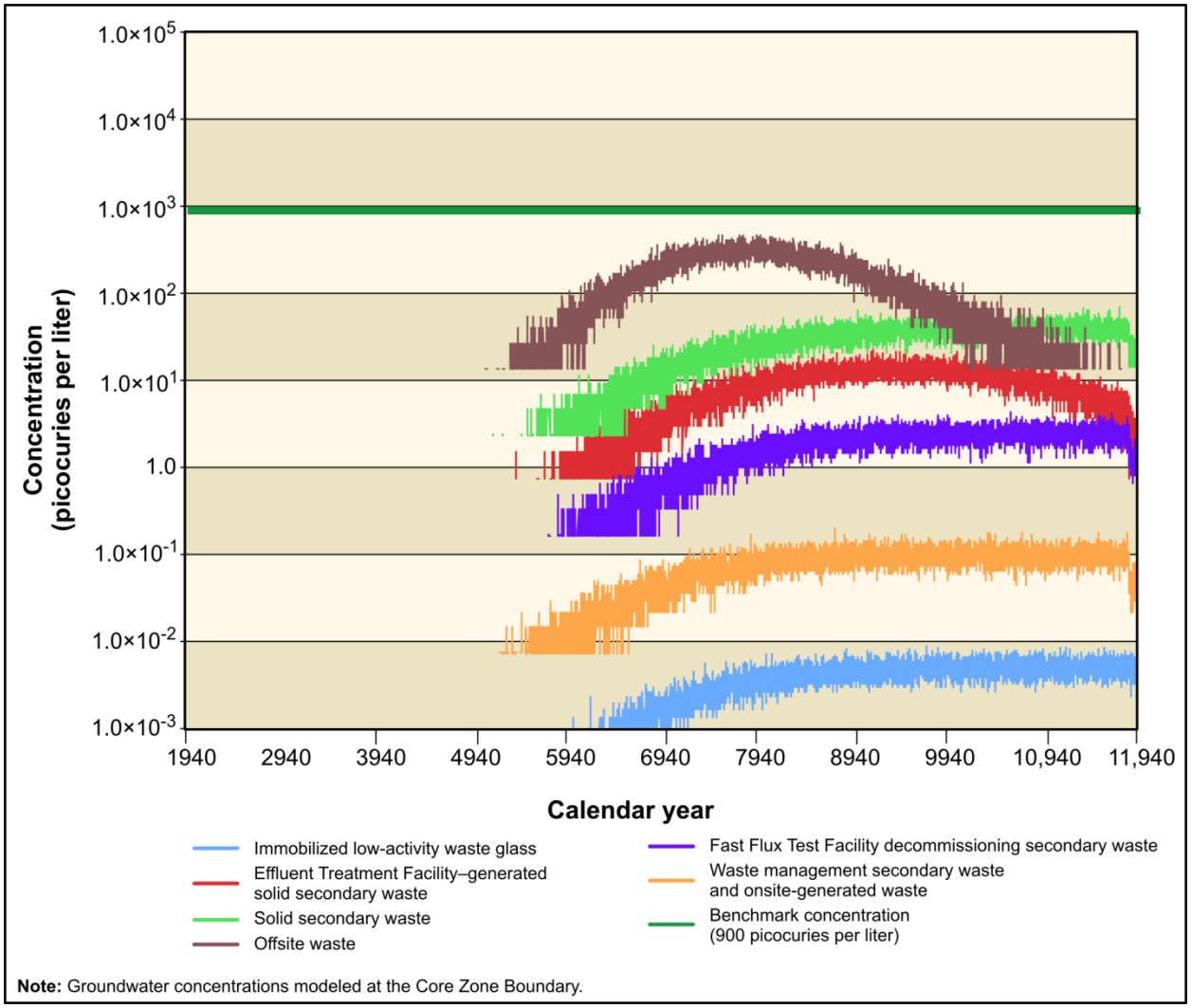


Figure M–141. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-A, Groundwater Technetium-99 Concentration at the Core Zone Boundary

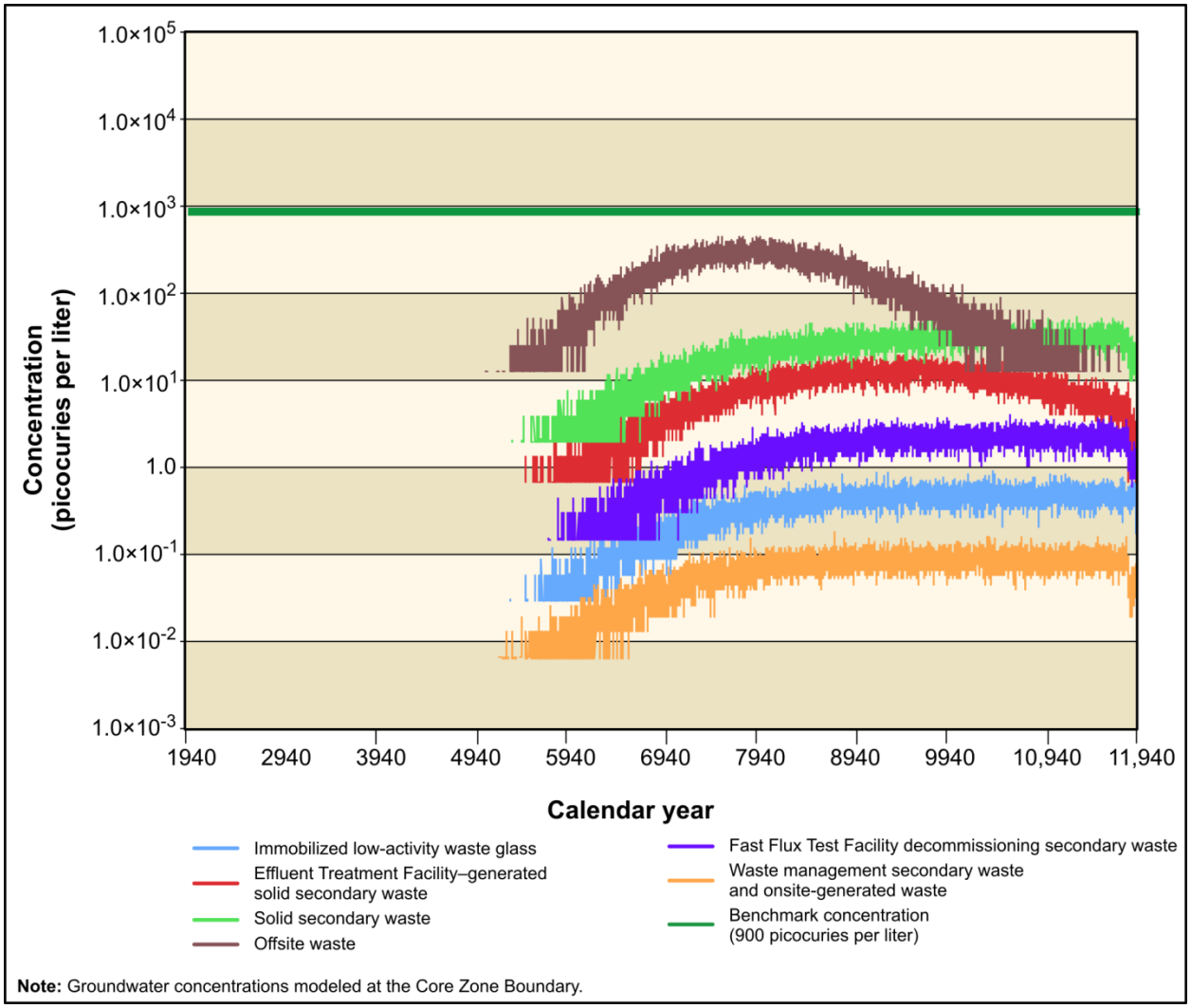


Figure M–142. Groundwater Technetium-99 Concentration at the Core Zone Boundary, No-Technetium-99-Removal Case

The increase in technetium-99 inventory in ILAW glass in the no-technetium-99-removal sensitivity case produces an increase in the predicted groundwater concentration at the Core Zone Boundary due to this single source by two orders of magnitude. The increase in technetium-99 in ILAW glass in the no-technetium-99-removal case does not make it a primary contributor to the combined impacts in this case, and the predicted groundwater concentration from this source at the Core Zone Boundary is approximately three orders of magnitude below the benchmark.

M.5.7.4 Bulk Vitrification Sensitivity Analysis

As described in Appendix E, Section E.1.2.3.6, during engineering-scale and large-scale testing, results suggested that technetium-99 might present itself in a more soluble form deposited as a vesicular glass layer on top of the bulk vitrification melt (Pierce et al. 2005). This would affect the release rates from the final waste form in an IDF. The very high temperatures associated with bulk vitrification volatilize and drive off technetium-99 from the waste feed prior to its incorporation into the vitrified glass matrix. The volatilized technetium-99 then condenses on the surface of the castable refractory block as the offgas flows out of the vitrification container (Pierce et al. 2005). The *TC & WM EIS* models the technetium-99 in the bulk vitrification supplemental-waste form with 93.5 percent of the inventory in the glass and 6.5 percent in the castable refractory block. The *TC & WM EIS* release model for bulk vitrification glass

waste form is a fractional release model, with a fractional release rate of 1.00×10^{-8} grams per gram per year. The castable refractory block is modeled using the partitioning-limited, convective-flow model.

The objective of this sensitivity analysis is to analyze the effect of optimizing the bulk vitrification system for Tank Closure Alternative 3A using the two cases described below and in Table M–61:

- Reducing the technetium-99 inventory in the castable refractory block to 0.3 percent, with 99.7 percent in the bulk vitrification performance glass
- Keeping the technetium-99 inventory in the castable refractory block at 6.5 percent, with 93.5 percent in glass with a reduced fractional release rate

Table M–61. Bulk Vitrification Sensitivity Analysis Cases

Sensitivity Cases	Technetium-99 Inventory (curies)		Fractional Release Rate
	Bulk Vitrification Glass	Castable Refractory Block	
EIS Case	1.93×10^{4}	1.34×10^{3}	1.00×10^{-8}
Sensitivity Case 1	2.06×10^{4}	6.20×10^{1}	1.00×10^{-8}
Sensitivity Case 2	1.93×10^{4}	1.34×10^{3}	1.00×10^{-9}

Key: EIS=environmental impact statement.

Figure M–143 reports the release to the vadose zone for each of the cases listed above. The short spike in release of technetium-99 from castable refractory block is due to the increased infiltration rate after the barrier lifetime.

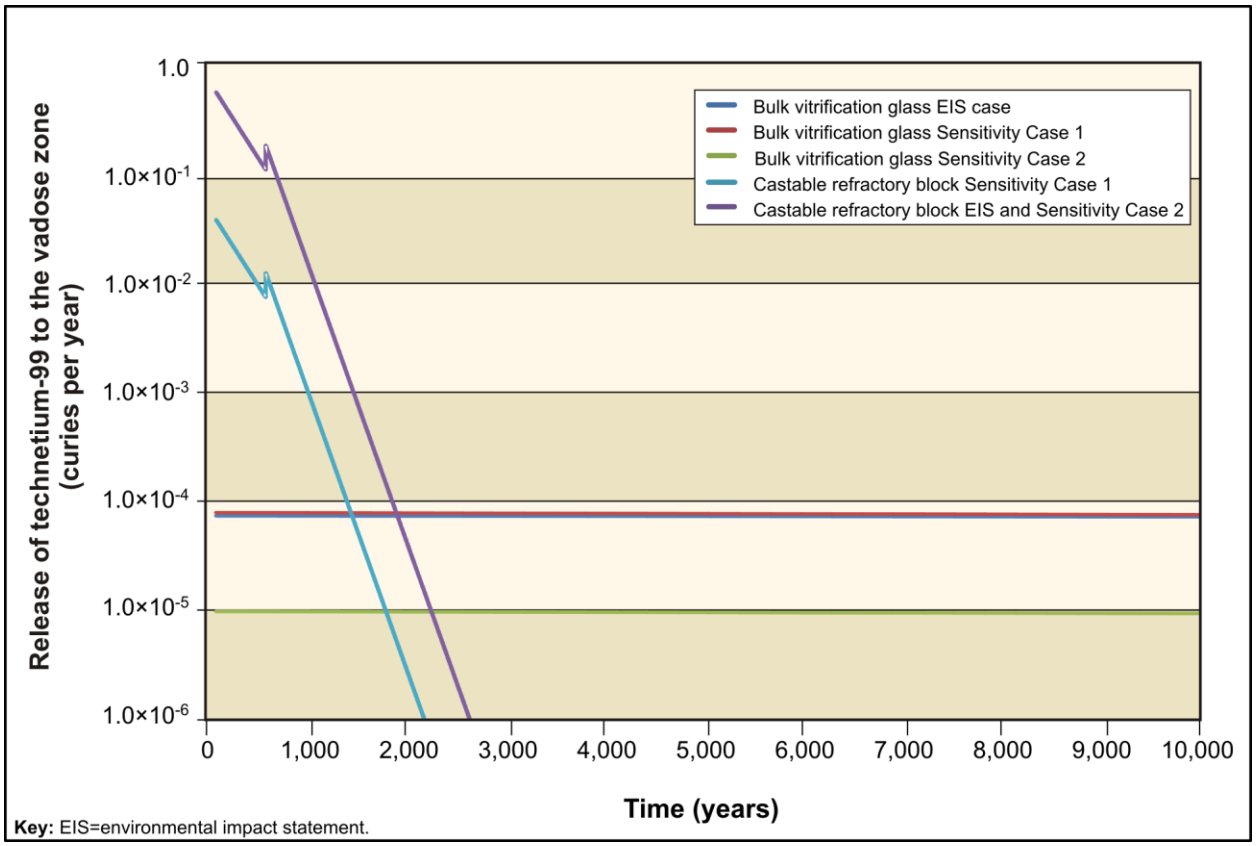


Figure M–143. Release of Technetium-99 to the Vadose Zone, Bulk Vitrification Glass Sensitivity Analysis

Predicted concentrations of technetium-99 in groundwater at the Core Zone Boundary for the *TC & WM EIS* and Sensitivity Cases 1 and 2 for all waste forms under Tank Closure Alternative 3A are presented in Figures M–144, M–145, and M–146, respectively.

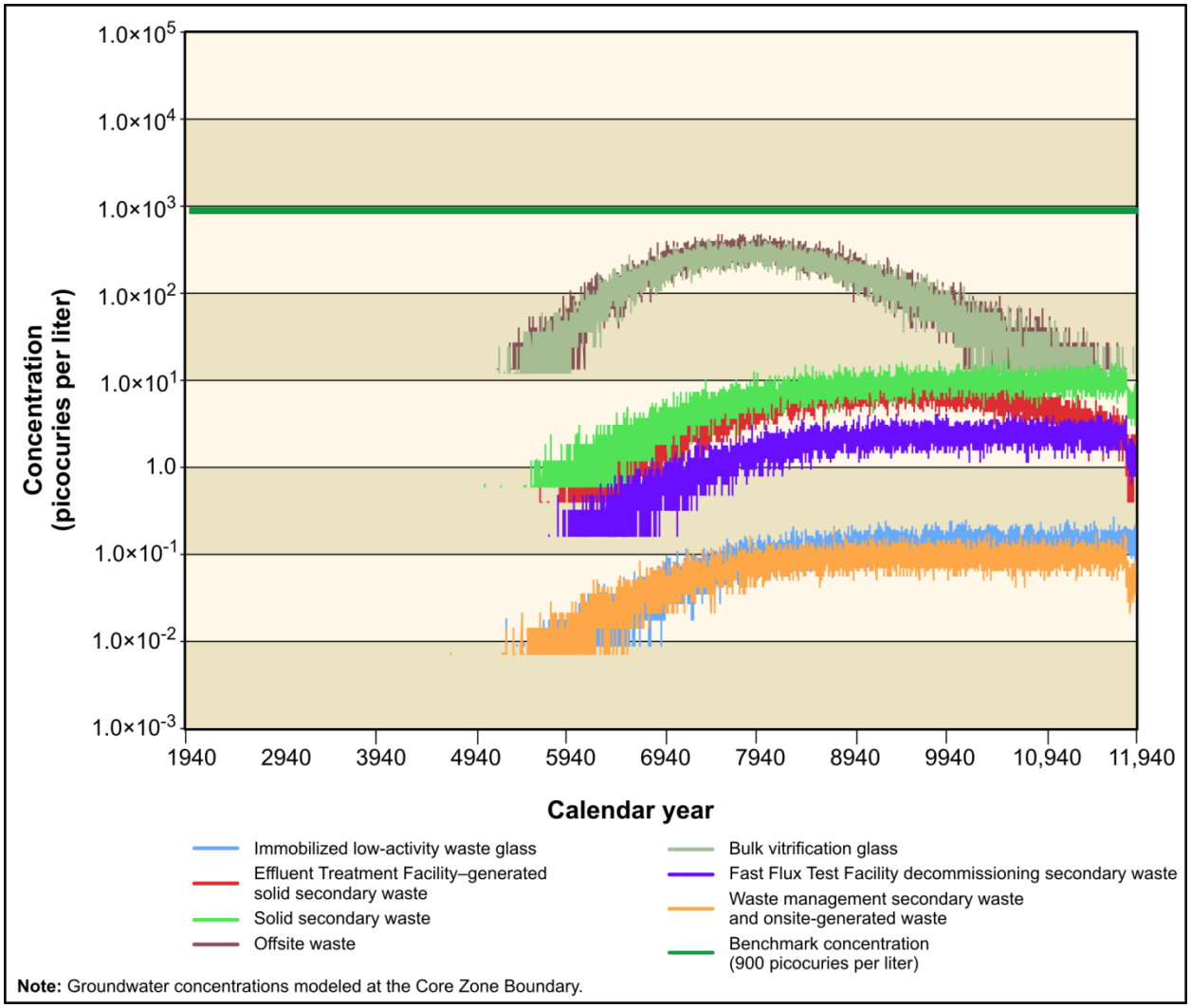
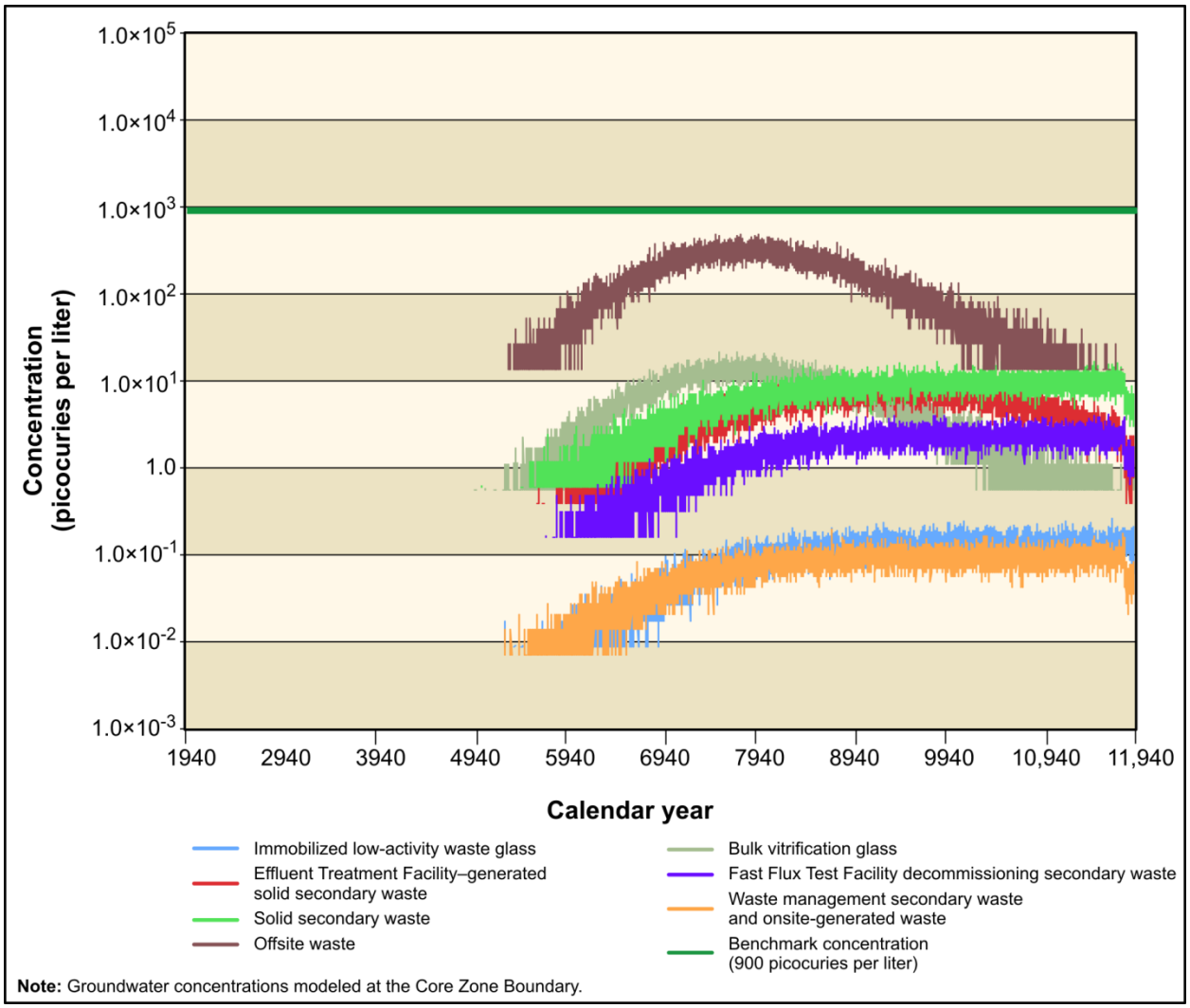


Figure M–144. Tank Closure Alternative 3A, Groundwater Technetium-99 Concentrations at the Core Zone Boundary, Bulk Vitrification EIS Case



Note: Groundwater concentrations modeled at the Core Zone Boundary.

Figure M–145. Groundwater Technetium-99 Concentrations at the Core Zone Boundary, Bulk Vitrification Sensitivity Case 1

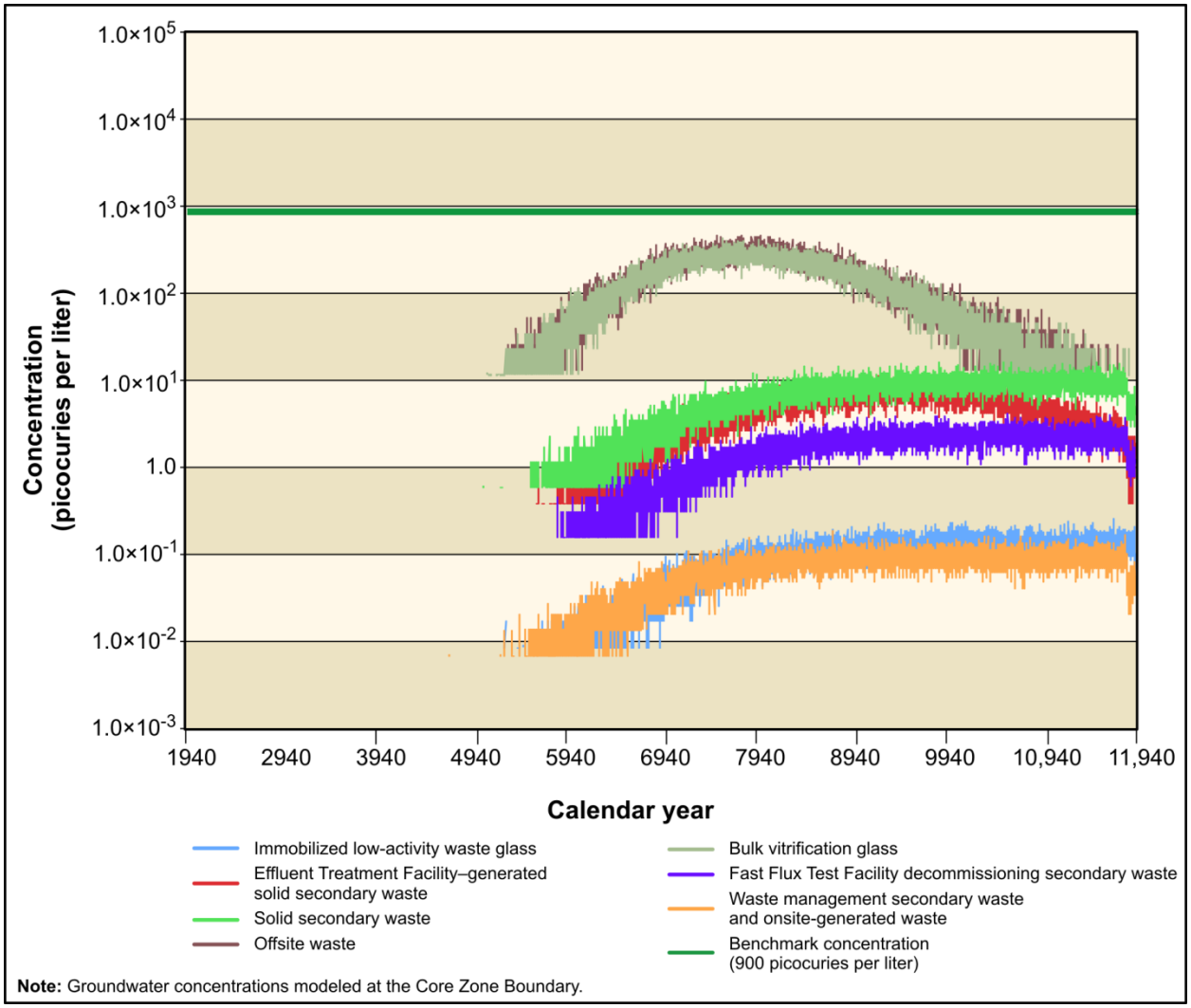


Figure M–146. Groundwater Technetium-99 Concentrations at the Core Zone Boundary, Bulk Vitrification Sensitivity Case 2

The analysis indicates that, for waste forms directly related to bulk vitrification, the release from castable refractory block is the primary source for the predicted concentrations of technetium-99 in the groundwater. Reducing the fractional release rate in the bulk vitrification glass does not result in a noticeable difference in the predicted concentrations of technetium-99 in the groundwater. The predicted concentrations of technetium-99 in bulk vitrification glass for Sensitivity Case 1 indicate that reducing the inventory in the castable refractory block provides the greatest effect in reducing the estimated concentration in the aquifer.

M.5.7.5 Grout Performance

The assessment of the long-term performance of grout to be disposed of in IDF-East assumes the waste form is saturated. The effective diffusion coefficients for iodine-129 and technetium-99 used in this EIS were 1.0×10^{-10} and 5.0×10^{-9} square centimeters per second, respectively (DOE 2005). The distribution coefficient (K_d) values that can be inferred from these effective diffusion coefficients for iodine-129 and technetium-99 are 50 milliliters per gram and 1.1 milliliters per gram, respectively.

Documentation for the Hanford site indicates that the moisture content for the waste form may be below saturated conditions, ranging from 4 percent and 7 percent moisture content (Mattigod et al. 2001). As the moisture content decreases, the aqueous diffusion coefficient decreases, leading to a smaller effective diffusion coefficient. *Diffusion and Leaching of Selected Radionuclides (Iodine-129, Technetium-99, and Uranium) Through Category 3 Waste Encasement Concrete and Soil Fill Material* (Mattigod et al. 2001) indicates that the grout effective diffusion coefficient for iodine-129 could range between 2.07×10^{-14} square centimeters per second (approximately 4 percent soil moisture content) and 1.31×10^{-12} square centimeters per second (7 percent soil moisture content) and for technetium-99, between 6.22×10^{-12} square centimeters per second (approximately 4 percent soil moisture content) and 4.24×10^{-11} square centimeters per second (7 percent soil moisture content).

The objective of this sensitivity assessment is to evaluate the effect of the suggested decrease in effective diffusion coefficient in iodine-129 and technetium-99 on the grouted waste forms disposed of at IDF-East. This sensitivity analysis for grout examined the 7 percent moisture content indicated in Mattigod et al. (2001).

The grouted waste forms considered in this analysis include ETF-generated secondary waste, solid secondary waste, FFTF Decommissioning (Alternative 3) secondary waste, waste management secondary waste, onsite non-CERCLA waste, and cast stone waste (Tank Closure Alternative 3B). These waste forms are portions of the proposed action for four Waste Management alternatives:

- Waste Management Alternative 2, Disposal Group 1, Subgroup 1-A, addresses the waste from Tank Closure Alternative 2B.
- Waste Management Alternative 2, Disposal Group 1, Subgroup 1-B, addresses the waste from Tank Closure Alternative 3A.
- Waste Management Alternative 2, Disposal Group 1, Subgroup 1-C, addresses the waste from Tank Closure Alternative 3B.
- Waste Management Alternative 2, Disposal Group 1, Subgroup 1-D, addresses the waste from Tank Closure Alternative 3C.

Waste Management Alternative 2, Disposal Group 1, Subgroup 1-A, Addresses the Waste from Tank Closure Alternative 2B

Waste Management Alternative 2, Disposal Group 1, Subgroup 1-A, addresses disposal in IDF-East of the waste from Tank Closure Alternative 2B, onsite non-CERCLA sources, FFTF decommissioning, waste management, and other DOE sites. Waste forms for IDF-East include ILAW glass, LAW melters, tank closure secondary waste, FFTF decommissioning secondary waste, waste management secondary waste, offsite waste, and onsite non-CERCLA waste. The grouted waste forms under this alternative are ETF-generated secondary waste and tank closure solid secondary waste. The waste packages are cylindrical with radii of 0.25 and 0.83 meters for ETF-generated secondary waste and tank closure solid secondary waste, respectively. Figure M–147 compares the releases of iodine-129 to the vadose zone for the grouted waste forms for both ETF-generated secondary waste and tank closure solid secondary waste. The releases to the vadose zone in curies per year decrease by approximately two orders of magnitude as the effective diffusivity decreases from the EIS case value to the sensitivity case value.

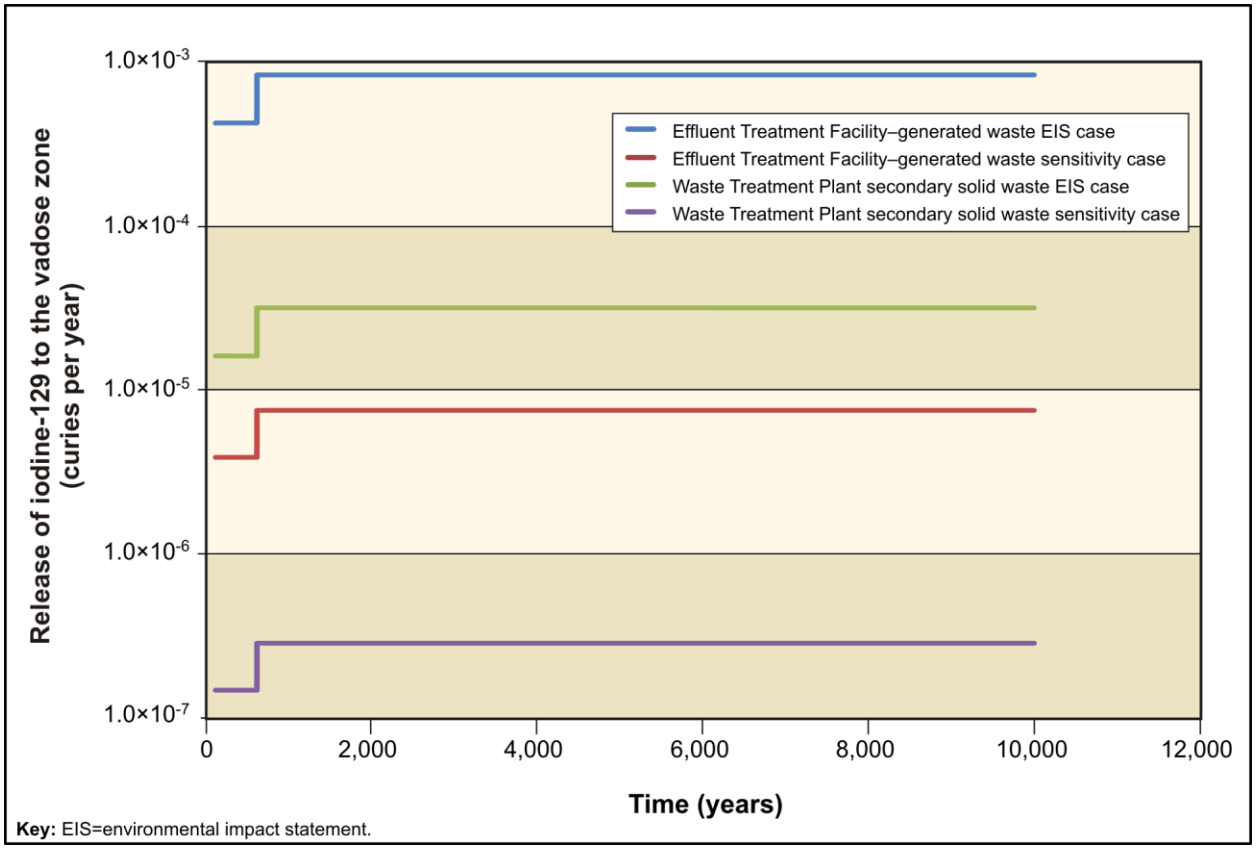
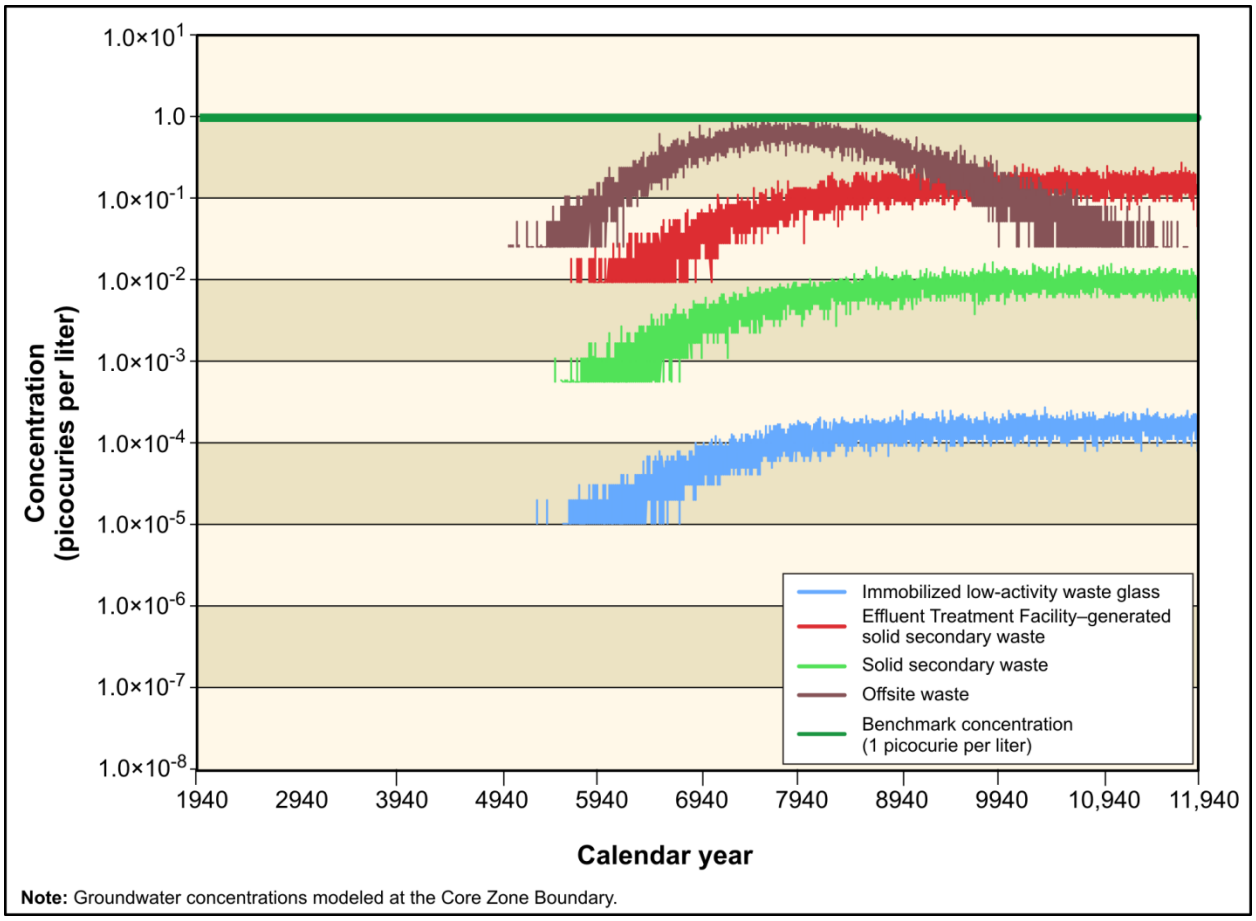


Figure M–147. Rate of Release of Iodine-129 to the Vadose Zone, Grout Performance Sensitivity Analysis

Figures M–148 and M–149 report estimated groundwater concentrations at the Core Zone Boundary resulting from each of the waste forms under this alternative. Groundwater concentrations predicted for the LAW melter, FFTF decommissioning secondary waste, waste management secondary waste, and onsite non-CERCLA waste are below 1.0×10^{-8} picocuries per liter at the Core Zone Boundary. As indicated in Figure M–149, the sensitivity case, projected concentrations of iodine-129 in the groundwater for the grouted waste forms (ETF-generated and tank closure solid secondary wastes) are decreased by approximately two orders of magnitude relative to the EIS case.



Note: Groundwater concentrations modeled at the Core Zone Boundary.

Figure M–148. Waste Management Alternative 2, Tank Closure Alternative 2B, Groundwater Iodine-129 Concentrations at the Core Zone Boundary, EIS Performance

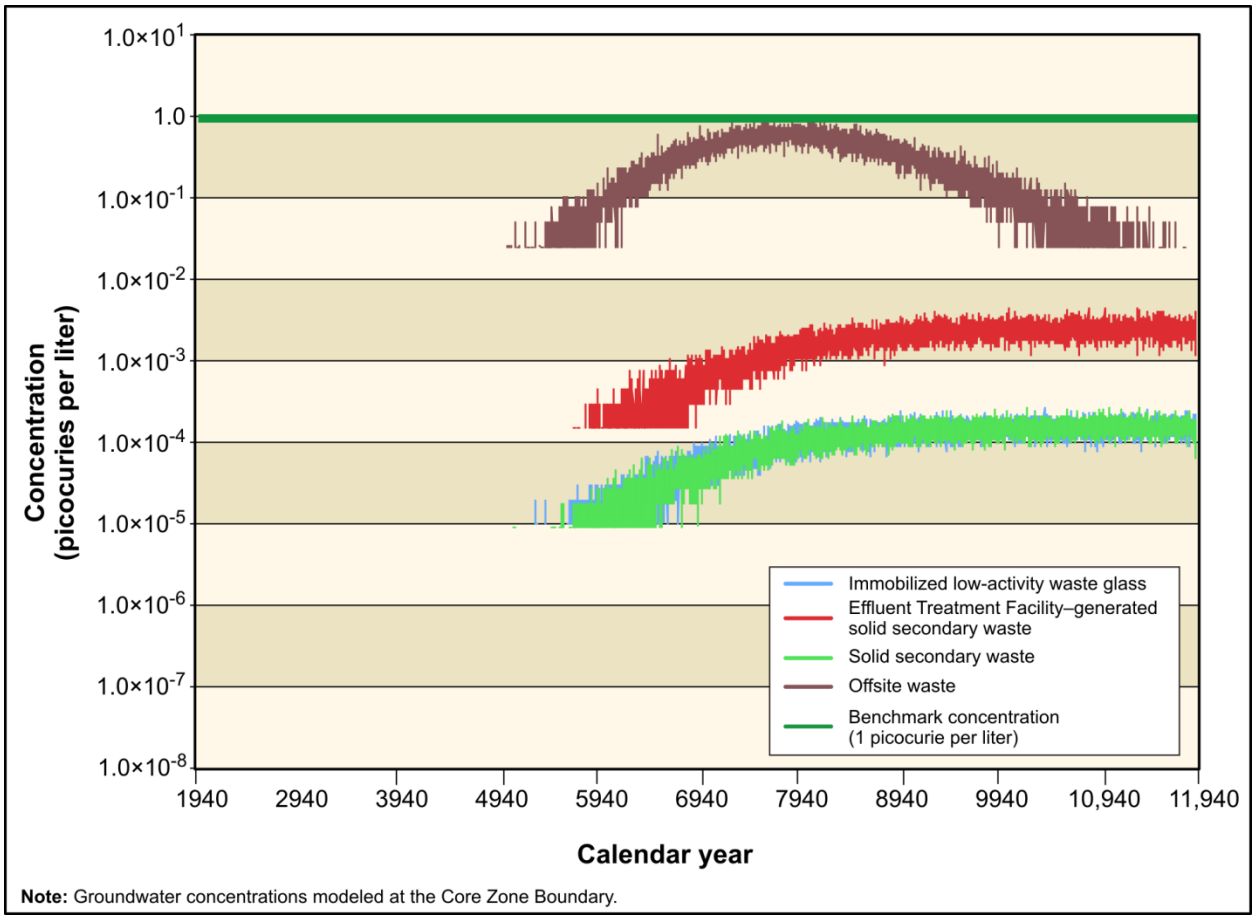
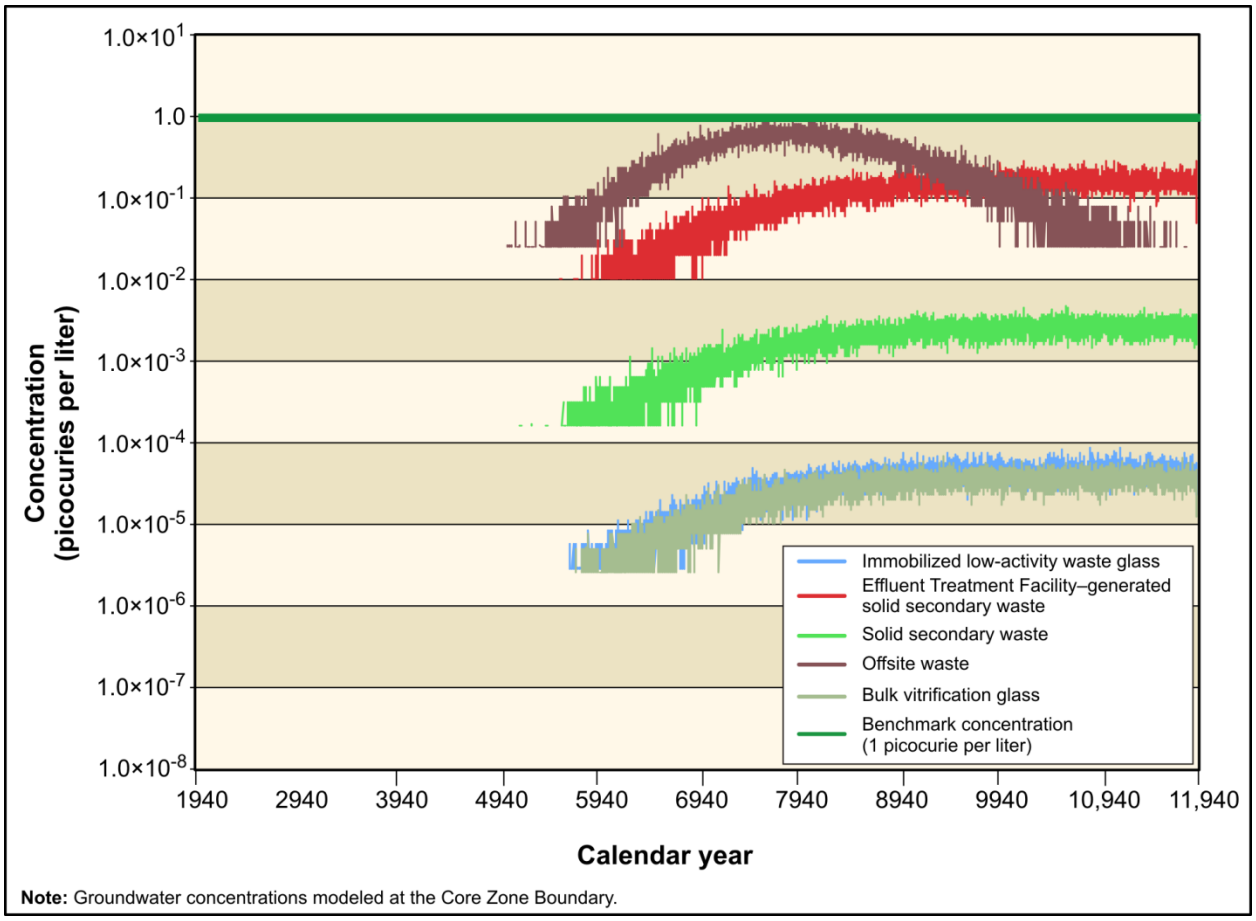


Figure M–149. Waste Management Alternative 2, Tank Closure Alternative 2B, Groundwater Iodine-129 Concentrations at the Core Zone Boundary, Grout Sensitivity Case

Waste Management Alternative 2, Disposal Group 1, Subgroup 1-B, Addresses the Waste from Tank Closure Alternative 3A

Waste Management Alternative 2, Disposal Group 1, Subgroup 1-B, addresses the waste from *TC & WM EIS* Tank Closure Alternative 3A, onsite non-CERCLA sources, FFTF decommissioning, waste management, and other DOE sites. Waste forms for IDF-East include ILAW glass, LAW melters, bulk vitrification glass, tank closure secondary waste, FFTF decommissioning secondary waste, waste management secondary waste, offsite waste, and onsite non-CERCLA waste. Figures M–150 and M–151 report projected groundwater concentrations at the Core Zone Boundary resulting from each of the waste forms under this alternative. Groundwater concentrations predicted for LAW melters, FFTF decommissioning secondary waste, waste management secondary waste, and onsite non-CERCLA waste are below 1.0×10^{-8} picocuries per liter at the Core Zone Boundary. The grouted waste forms under this alternative are ETF-generated secondary waste and tank closure solid secondary waste. As indicated in Figure M–151, the sensitivity case, the concentration of iodine-129 for the grouted waste forms in the groundwater decreased by approximately two orders of magnitude relative to the EIS case.



Note: Groundwater concentrations modeled at the Core Zone Boundary.

Figure M–150. Waste Management Alternative 2, Tank Closure Alternative 3A, Groundwater Iodine-129 Concentrations at the Core Zone Boundary, EIS Performance

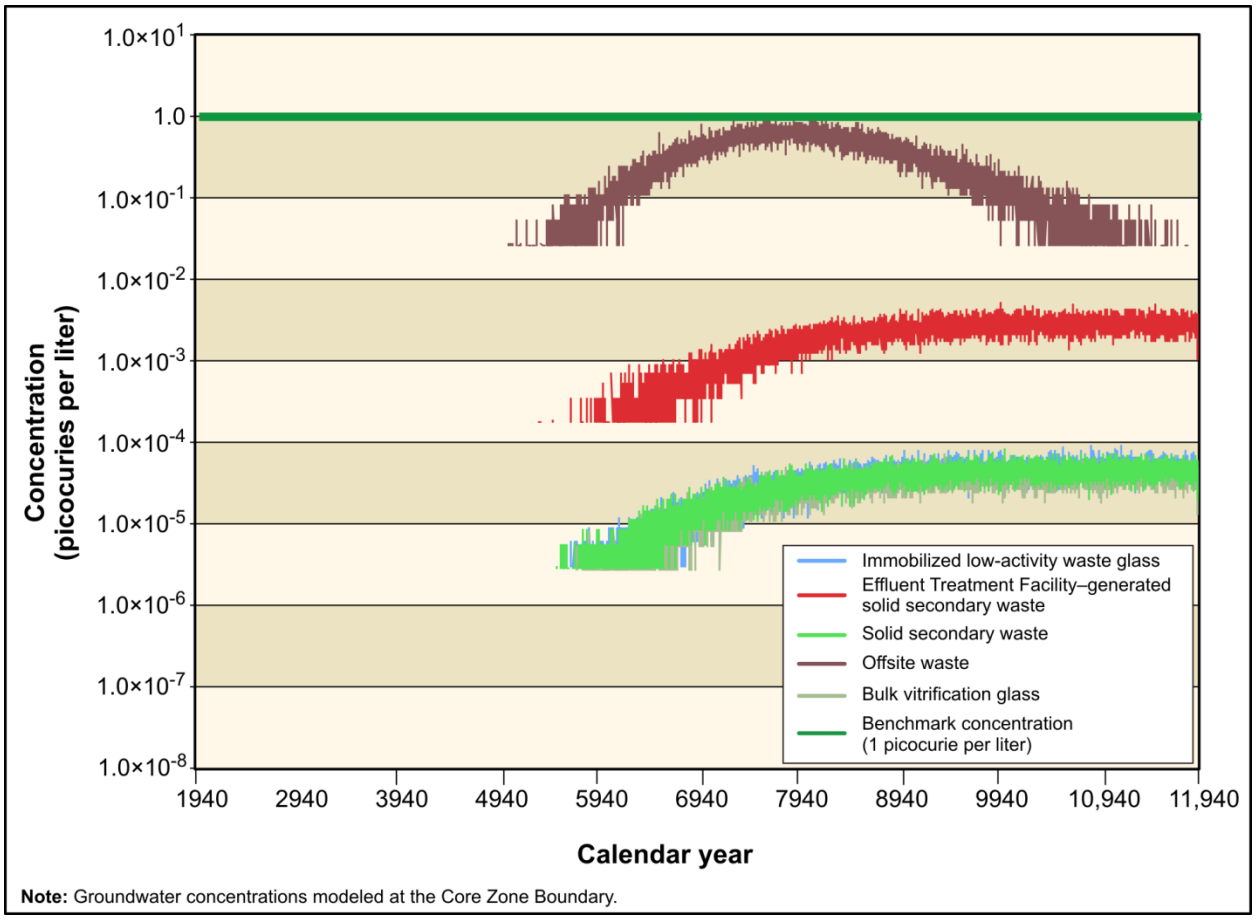
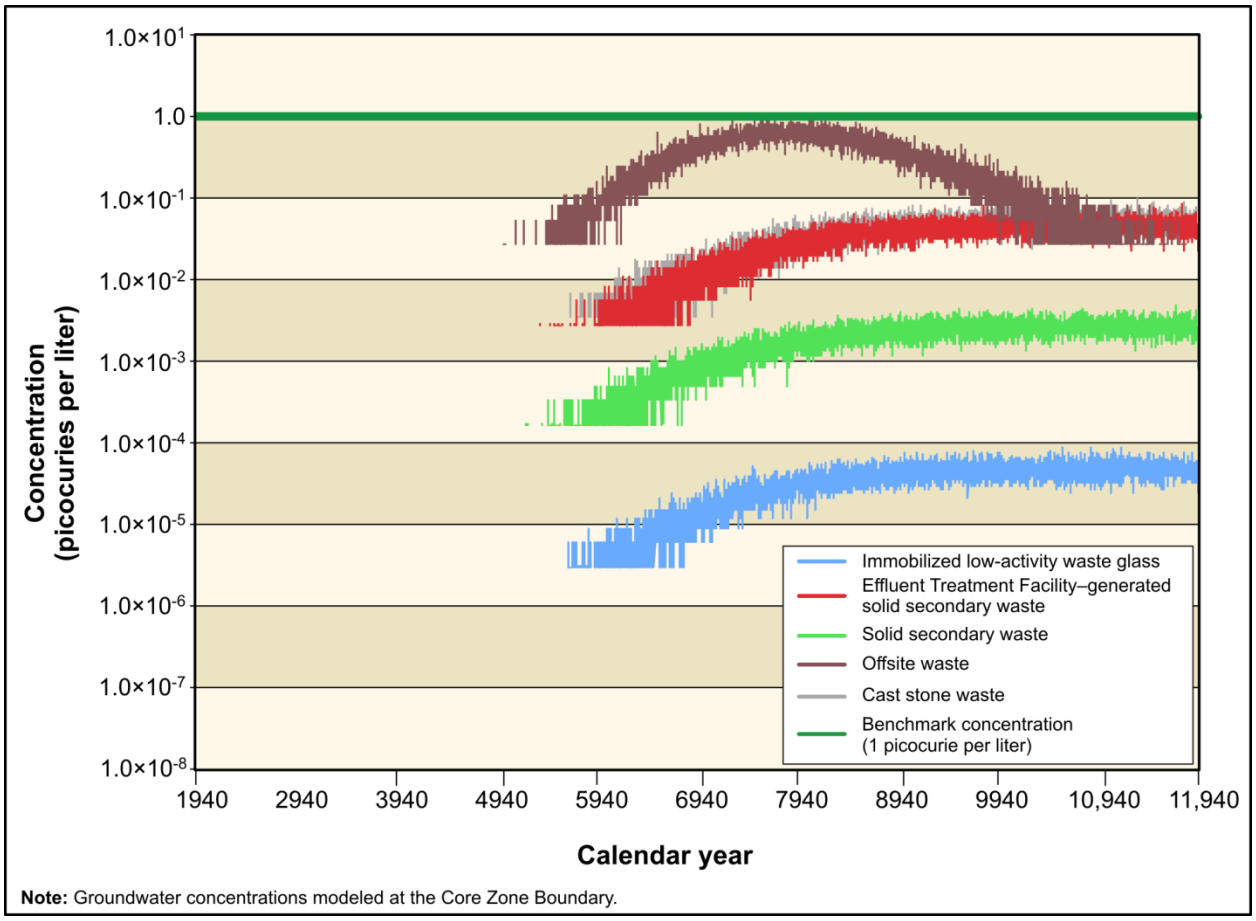


Figure M–151. Waste Management Alternative 2, Tank Closure Alternative 3A, Groundwater Iodine-129 Concentrations at the Core Zone Boundary, Grout Sensitivity Case

Waste Management Alternative 2, Disposal Group 1, Subgroup 1-C, Addresses the Waste from Tank Closure Alternative 3B

Waste Management Alternative 2, Disposal Group 1, Subgroup 1-C, addresses the waste from Tank Closure Alternative 3B, onsite non-CERCLA sources, FFTF decommissioning, waste management, and other DOE sites. Waste forms for IDF-East include ILAW glass, LAW melters, cast stone waste, tank closure secondary waste, FFTF decommissioning secondary waste, waste management secondary waste, offsite waste, and onsite non-CERCLA waste. Figures M–152 and M–153 indicate the groundwater concentration at the Core Zone Boundary resulting from each of the waste forms under this alternative. Groundwater concentrations predicted for LAW melters, FFTF decommissioning secondary waste, waste management secondary waste, and onsite non-CERCLA waste are below 1.0×10^{-8} picocuries per liter at the Core Zone Boundary. The grouted waste forms under this alternative are ETF-generated secondary waste, tank closure solid secondary waste, and cast stone waste. As indicated in Figure M–153, the sensitivity case, the concentration of iodine-129 in the grouted waste forms in the groundwater decreased by approximately two orders of magnitude relative to the EIS case.



Note: Groundwater concentrations modeled at the Core Zone Boundary.

Figure M–152. Waste Management Alternative 2, Tank Closure Alternative 3B, Groundwater Iodine-129 Concentrations at the Core Zone Boundary, EIS Performance

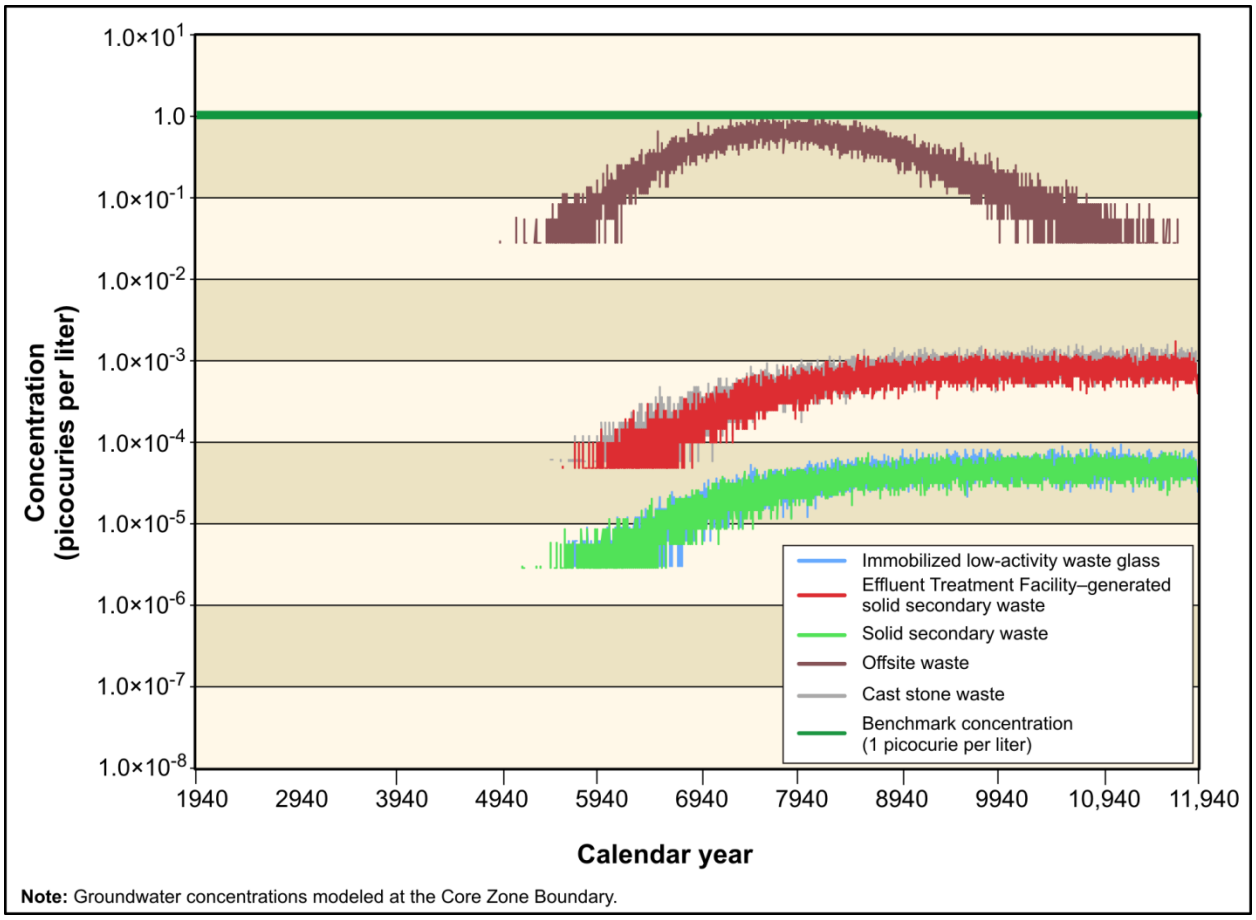
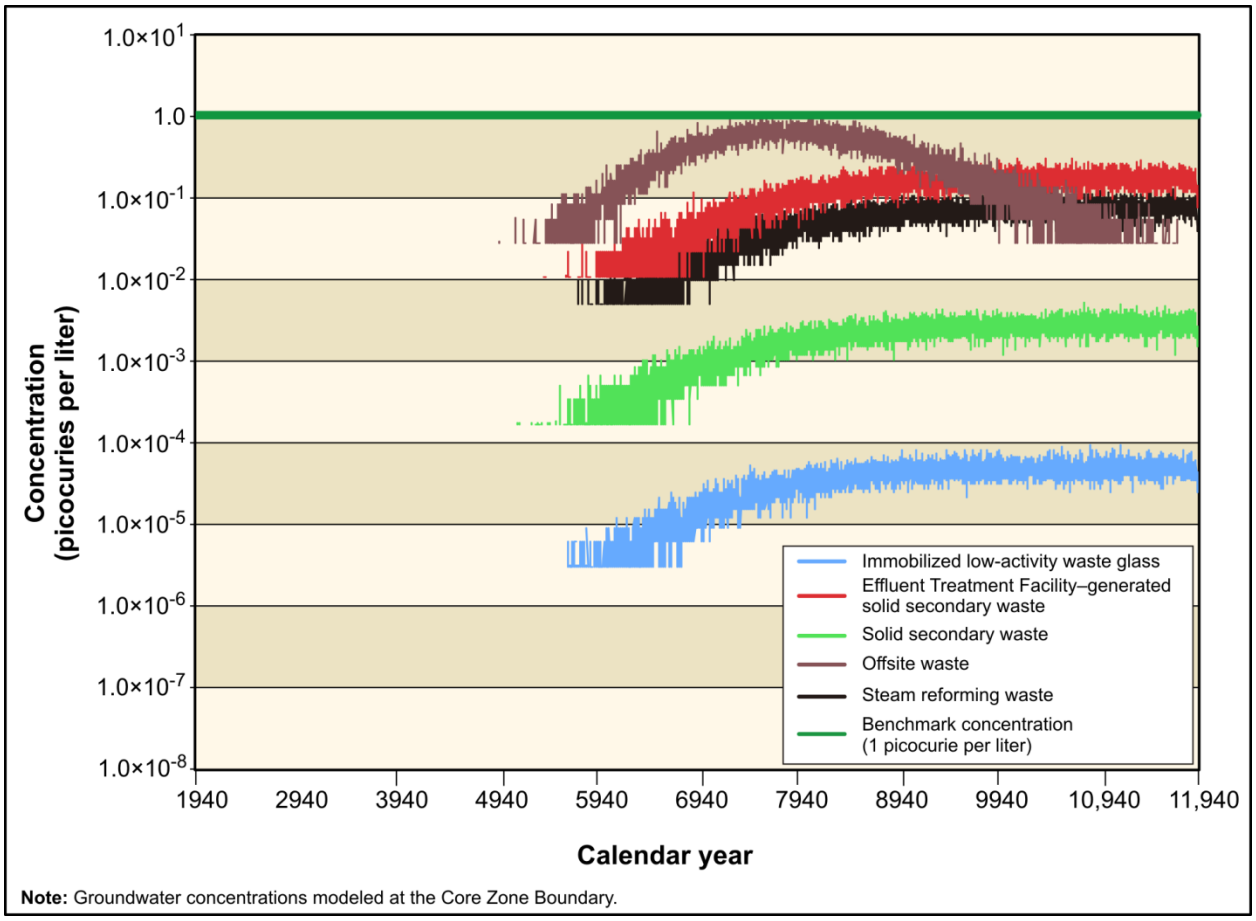


Figure M–153. Waste Management Alternative 2, Tank Closure Alternative 3B, Groundwater Iodine-129 Concentrations at the Core Zone Boundary, Grout Sensitivity Case

Waste Management Alternative 2, Disposal Group 1, Subgroup 1-D, Addresses the Waste from Tank Closure Alternative 3C

Waste Management Alternative 2, Disposal Group 1, Subgroup 1-D, addresses the waste from Tank Closure Alternative 3C, onsite non-CERCLA sources, FFTF decommissioning, waste management, and other DOE sites. Waste forms for IDF-East include ILAW glass, LAW melters, steam reforming waste, tank closure secondary waste, FFTF decommissioning secondary waste, waste management secondary waste, offsite waste, and onsite non-CERCLA waste. Figures M–154 and M–155 indicate the groundwater concentration at the Core Zone Boundary resulting from each of the waste forms under this alternative. Groundwater concentrations predicted for LAW melters, FFTF decommissioning secondary waste, waste management secondary waste, and onsite non-CERCLA waste are below 1.0×10^{-8} picocuries per liter at the Core Zone Boundary. The grouted waste forms under this alternative are ETF-generated secondary waste and tank closure solid secondary waste. As indicated in Figure M–155, the sensitivity case, the concentration of iodine-129 for the grouted waste forms in the groundwater decreased by approximately two orders of magnitude relative to the EIS case.



Note: Groundwater concentrations modeled at the Core Zone Boundary.

Figure M–154. Waste Management Alternative 2, Tank Closure Alternative 3C, Groundwater Iodine-129 Concentrations at the Core Zone Boundary, EIS Performance

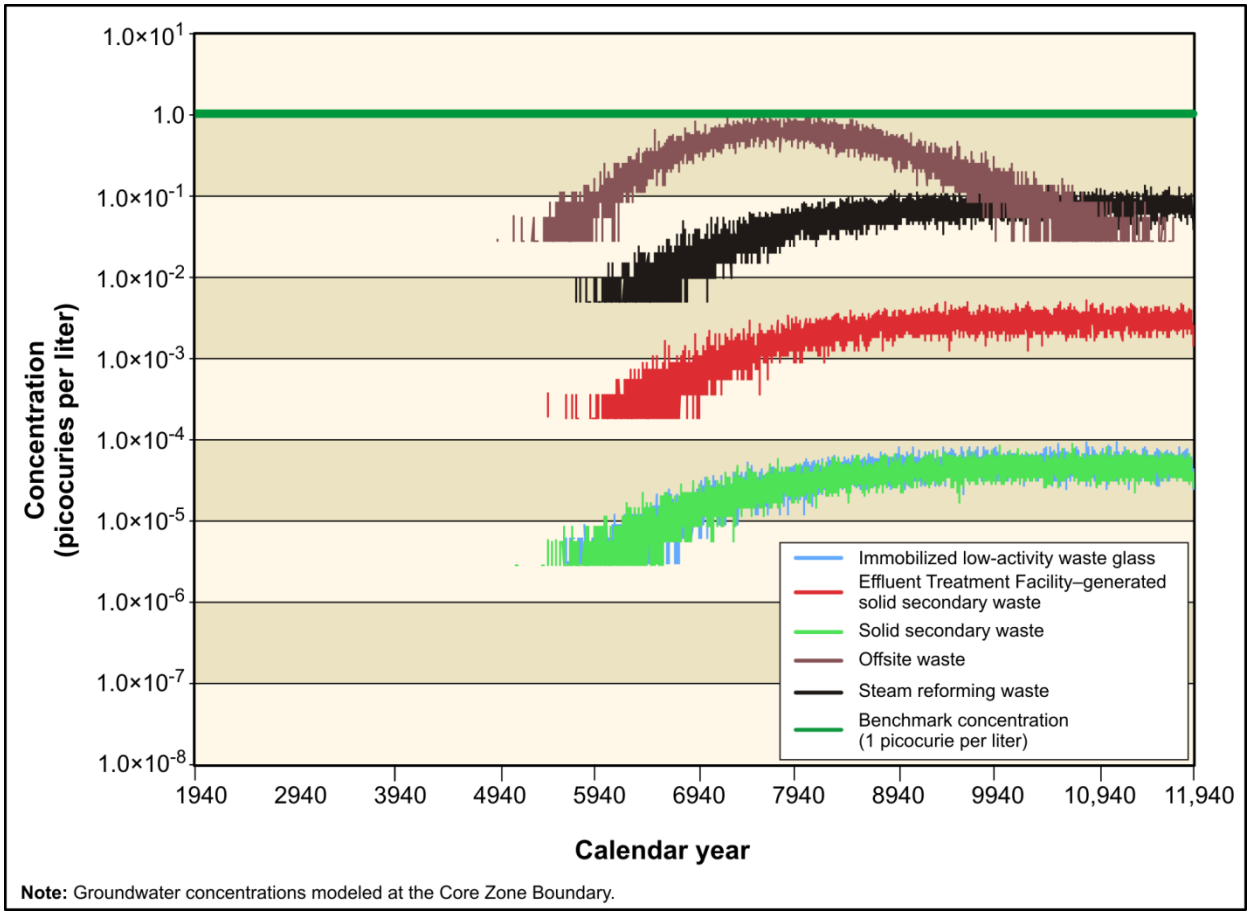


Figure M–155. Waste Management Alternative 2, Tank Closure Alternative 3C, Groundwater Iodine-129 Concentrations at the Core Zone Boundary, Grout Sensitivity Case

Conclusions:

- The decrease in effective diffusion coefficient results in a lower flux of iodine-129 from grouted waste forms to the aquifer.
- The decrease in effective diffusion coefficient results in lower estimated groundwater concentrations.
- Similar results are projected for all alternatives.

M.5.7.6 Offsite Waste

DOE has taken the mitigating action of eliminating the INL remote-handled LLW resin waste from the inventory of offsite waste considered for disposal at Hanford in this *Final TC & WM EIS*. This single waste stream removes approximately 13 curies of iodine-129 (a reduction of almost 85 percent) and 438 curies of technetium-99 (a reduction of almost 25 percent) from the offsite inventory that was considered for disposal at Hanford in the *Draft TC & WM EIS*. With the removal of the INL remote-handled LLW resins, this *Final TC & WM EIS* considers the receipt of offsite waste containing 2.3 curies of iodine-129 and 1,460 curies of technetium-99.

The objective of this sensitivity analysis is to evaluate the potential contribution to predicted long-term groundwater impacts at Hanford that are attributed to varying inventories of offsite waste. The analysis evaluates Waste Management Alternative 2, Disposal Group 1, Subgroup 1-A, which addresses the waste resulting from Tank Closure Alternative 2B. The analysis evaluated the four cases of varying inventories of iodine-129 and technetium-99 in offsite waste described in Table M–62.

Table M–62. Offsite Waste Sensitivity Cases

Offsite Sensitivity Case	Iodine-129 Inventory (curies)	Technetium-99 (curies)
Case A	0	0
Case B	1	500
Case C	2	1,000
Case D	3	1,500

Figures M–156 through M–159 report the predicted concentrations of iodine-129 in groundwater at the Core Zone Boundary and the Columbia River, with inventories ranging between 0 and 3 curies. Figures M–160 through M–163 report the predicted concentrations of technetium-99 in groundwater at the Core Zone Boundary and the Columbia River, with inventories ranging between 0 and 1,500 curies.

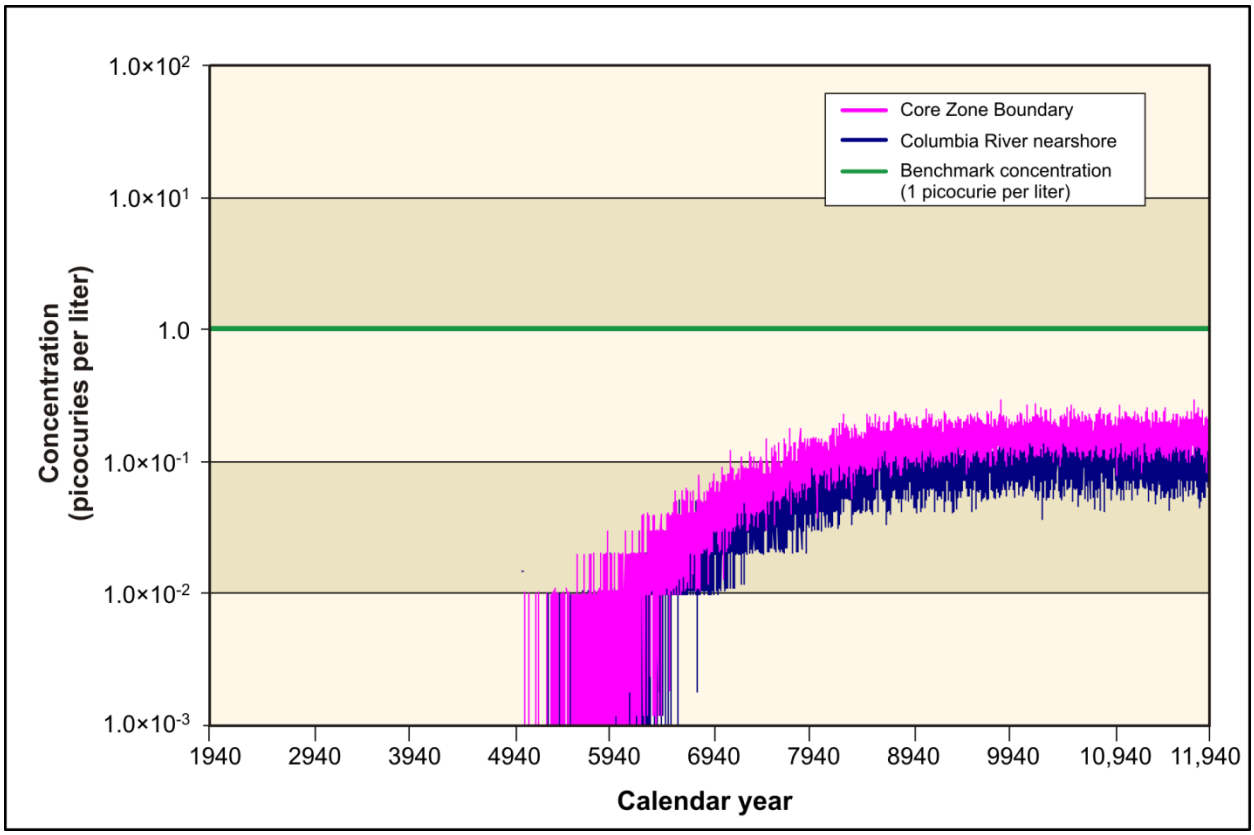


Figure M–156. Tank Closure Alternative 2B, Groundwater Iodine-129 Concentration Without Offsite Waste

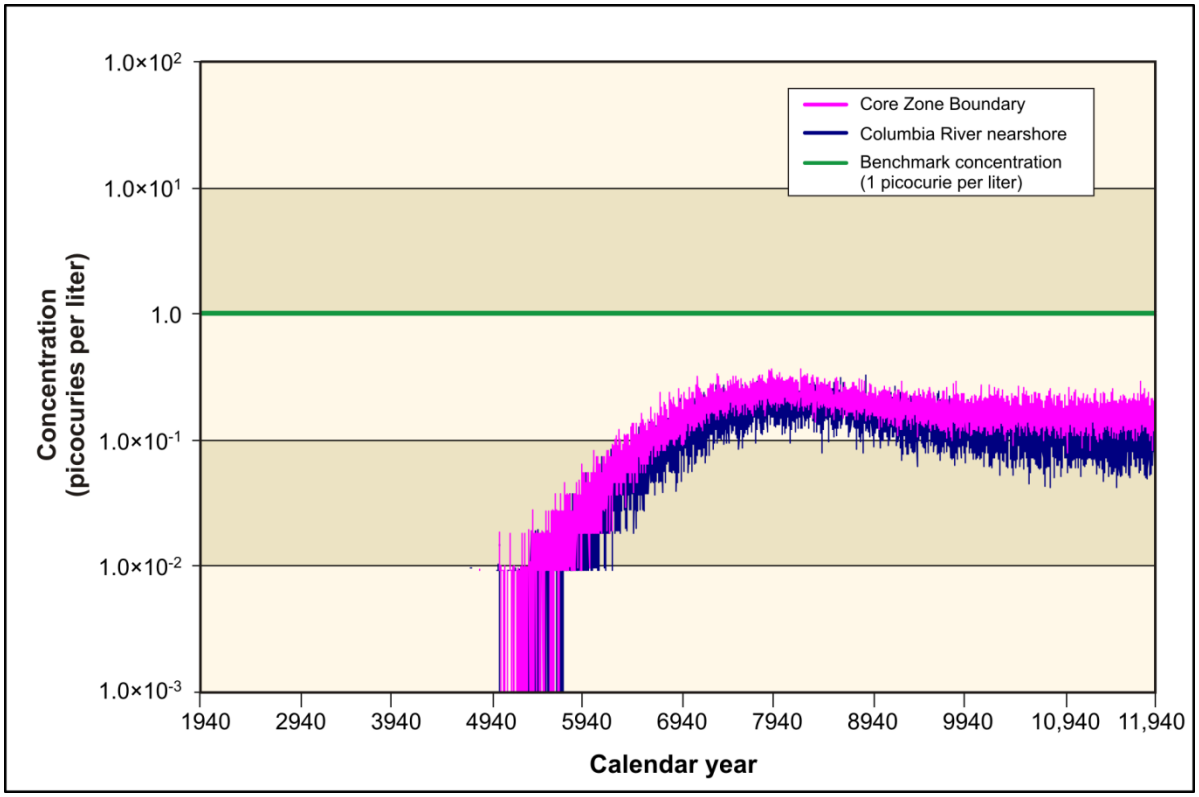


Figure M–157. Tank Closure Alternative 2B, Groundwater Iodine-129 Concentration with 1 Curie of Iodine in Offsite Waste

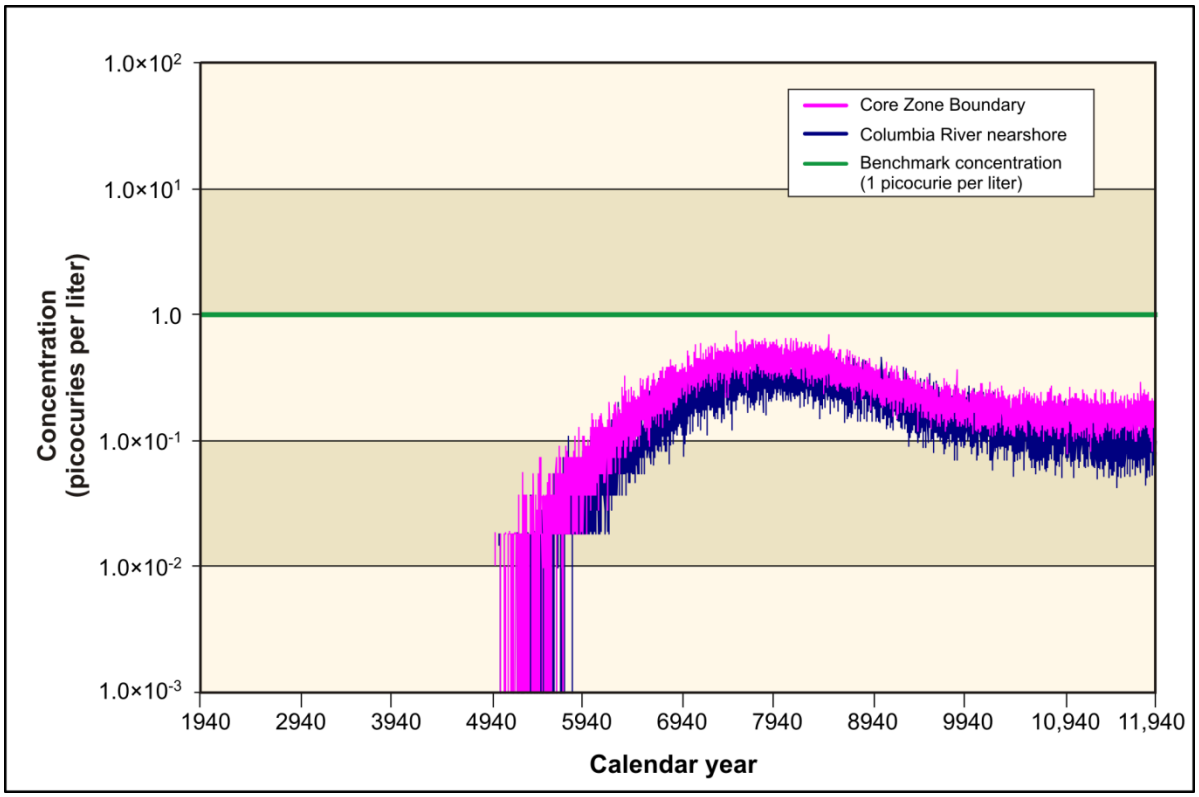


Figure M–158. Tank Closure Alternative 2B, Groundwater Iodine-129 Concentration with 2 Curies of Iodine in Offsite Waste

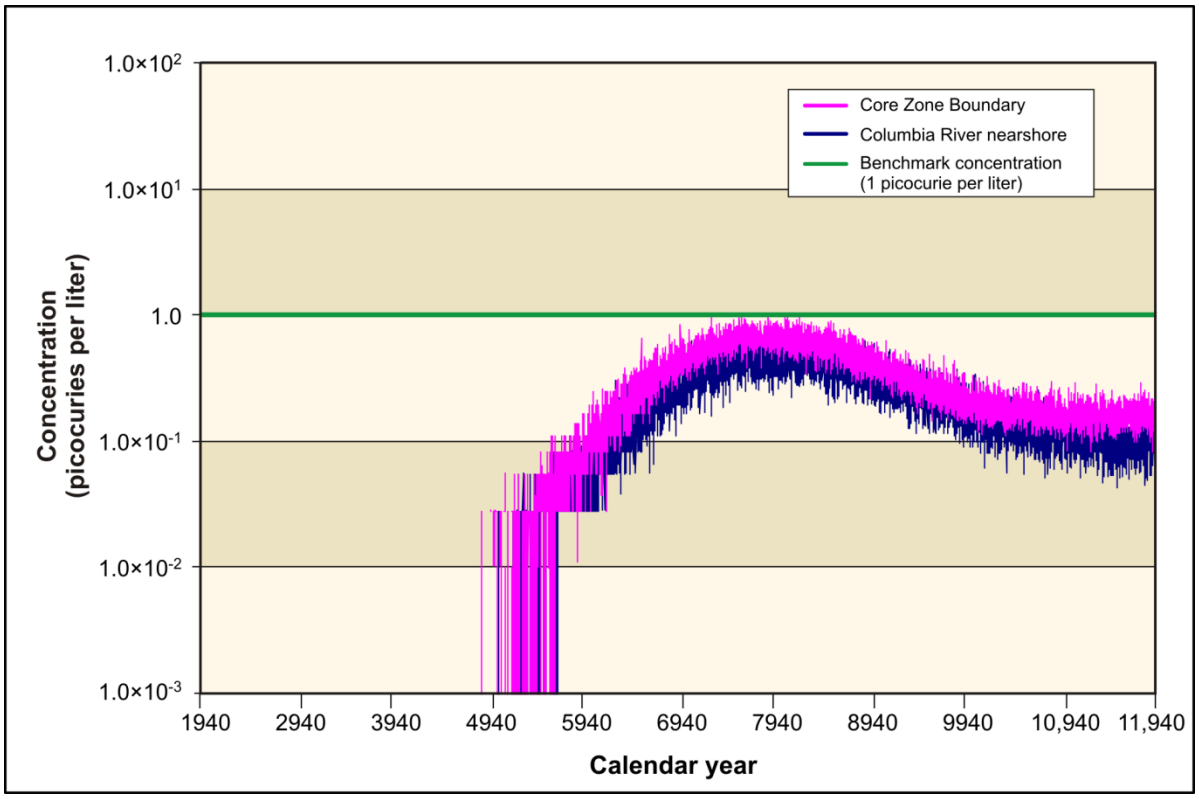


Figure M–159. Tank Closure Alternative 2B,
Groundwater Iodine-129 Concentration with 3 Curies of Iodine in Offsite Waste

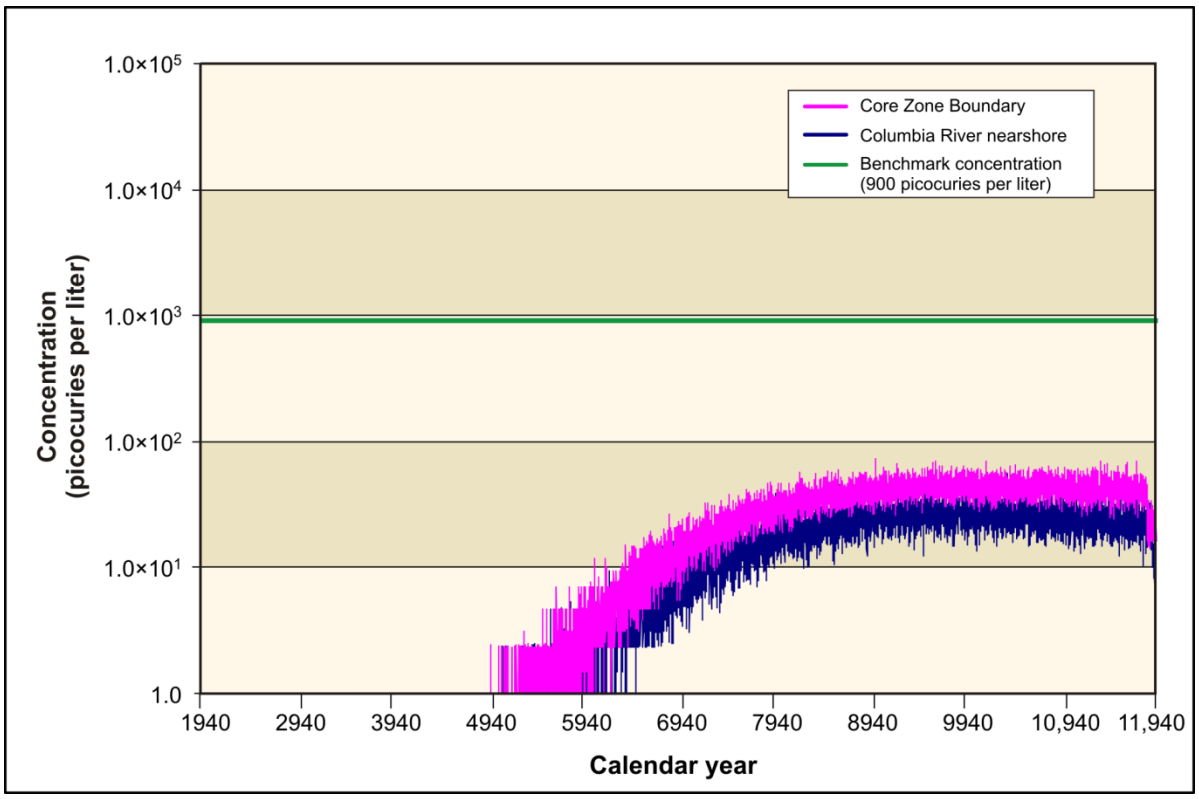


Figure M–160. Tank Closure Alternative 2B,
Groundwater Technetium-99 Concentration Without Offsite Waste

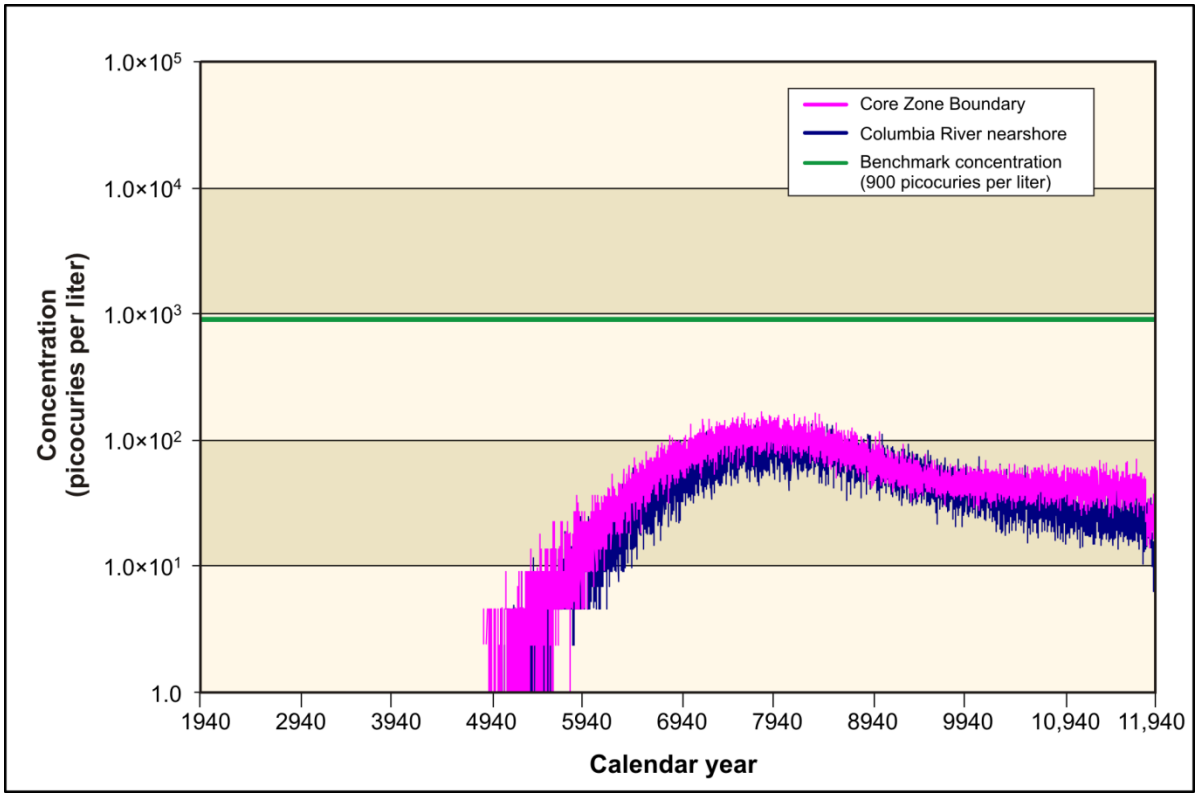


Figure M–161. Tank Closure Alternative 2B, Groundwater Technetium-99 Concentration with 500 Curies Offsite Waste

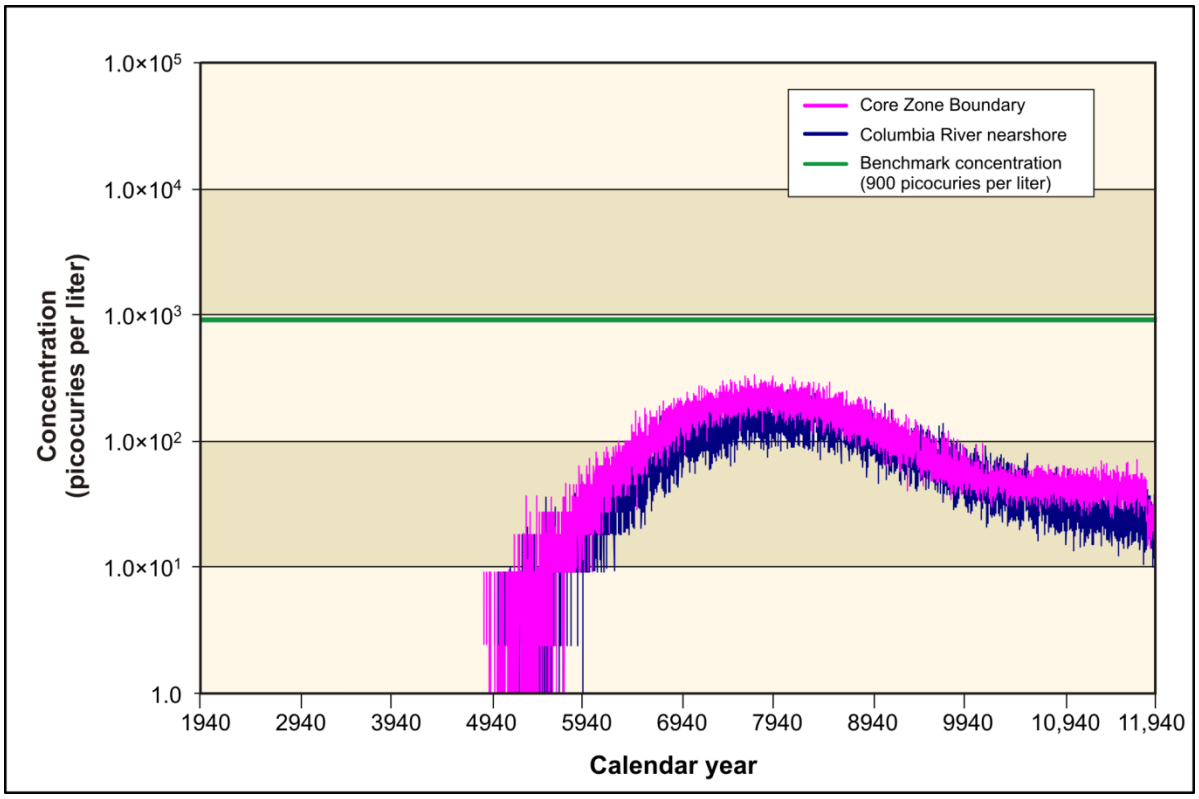


Figure M–162. Tank Closure Alternative 2B, Groundwater Technetium-99 Concentration with 1,000 Curies Offsite Waste

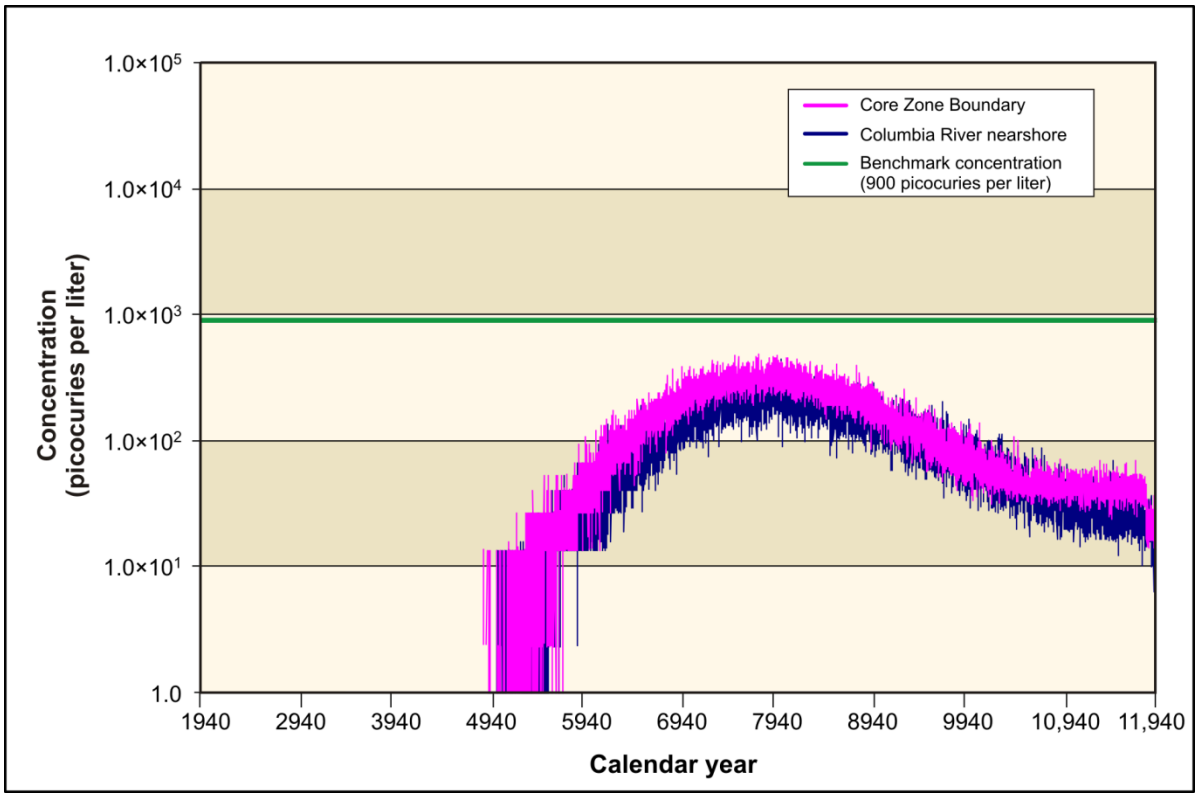


Figure M–163. Tank Closure Alternative 2B,
Groundwater Technetium-99 Concentration with 1,500 Curies Offsite Waste

The predicted groundwater concentrations for the varying inventories of iodine-129 and technetium-99 show similar dependence on time, rate of recharge, and magnitude of inventory. The increase of inventory produces a proportional increase in concentration in the aquifer. The shape of the time-series of concentrations in Figures M–156 through M–163 is due to a combination of releases from six sources. Releases of technetium-99 and iodine-129 from offsite waste occur rapidly, and the inventory of these constituents from this source is depleted within approximately 2,000 years. This release accounts for the curved early maximum portion of the graph. The latter plateau extending out for a longer period of time is due to gradual releases from other waste forms (e.g., ILAW glass). A discussion regarding the method of calculating the maximum concentration at lines of analysis (such as the Columbia River nearshore) is provided in Appendix O, Section O.2.5.

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