APPENDIX T
SUPPORTING INFORMATION FOR THE SHORT-TERM CUMULATIVE IMPACT ANALYSES

This appendix contains the detailed tables that support the short-term cumulative impacts presented in Chapter 6 of this *Tank Closure and Waste Management Environmental Impact Statement for the Hanford Site, Richland, Washington*. The cumulative impact methodologies are described in Appendix R.

This section presents detailed tables on short-term cumulative impacts for the following resource areas: land resources, ecological resources, cultural resources, socioeconomics, and transportation (see Tables T–1 through T–4). Other resource areas do not need detailed tables to support their short-term cumulative impact analyses.

The tables in this appendix describe the past, present, and reasonably foreseeable future actions in the regions of influence that were considered in the cumulative impacts assessment for these resource areas. Past and present actions that may contribute to cumulative impacts include those conducted by government agencies, businesses, or individuals within the regions of influence considered. As described in Appendix R, Table R–4, approximately 60 projects or sets of projects were evaluated for their contributions to cumulative impacts.

Cumulative Impacts

Effects on the environment that result from the proposed action when added to other past, present, and reasonably foreseeable future actions, regardless of what agency or person undertakes such other actions (40 CFR 1508.7).

The methodology used in this *Tank Closure and Waste Management Environmental Impact Statement for the Hanford Site, Richland, Washington* to estimate cumulative impacts was divided into four phases: (1) selection of resource areas and appropriate regions of influence, (2) selection of reasonably foreseeable future actions, (3) estimation of cumulative impacts, and (4) identification of monitoring and mitigation. A flowchart showing the four phases of cumulative impacts analysis is presented in Appendix R, Figure R–2. The tables presented in this appendix form a portion of Phases 2 and 3 and contain detailed information to support the short-term cumulative impacts analysis presented in Chapter 6.

Table T–1. Past, Present, and Reasonably Foreseeable Future Actions Potentially Affecting Land and Ecological Resources

Project/Action	Total Land Area/ Terrestrial Habitat Affected[a] (hectares)	Area of Shrub-Steppe Habitat Affected (hectares)	Threatened and Endangered Species	Distance from 200 Areas (kilometers)	Notes	Source
***TC & WM EIS* Activities**						
Alternative Combination 1[b]	2/2	0	See Chapter 4, Section 4.4.6.3, for a discussion of species potentially impacted under Alternative Combination 1.	Not applicable	Chapter 4, Sections 4.4.1 and 4.4.6, provide information on *TC & WM EIS* Alternative Combination 1.	Chapter 4, Table 4–157, Table 4–161
Alternative Combination 2[b]	308/207	65.6	See Chapter 4, Section 4.4.6.3, for a discussion of species potentially impacted under Alternative Combination 2.	Not applicable	Chapter 4, Sections 4.4.1 and 4.4.6, provide information on *TC & WM EIS* Alternative Combination 2.	Chapter 4, Table 4–157, Table 4–161
Alternative Combination 3[b]	797/753	348	See Chapter 4, Section 4.4.6.3, for a discussion of species potentially impacted under Alternative Combination 3.	Not applicable	Chapter 4, Sections 4.4.1 and 4.4.6, provide information on *TC & WM EIS* Alternative Combination 3.	Chapter 4, Table 4–157 Table 4–161
Other DOE Activities at the Hanford Site						
Central Plateau closure[b]	112	56.3	Not addressed	On site	The area would be required as a source of geologic material to be used for covers and to fill voids. Although specific mining plans and precise areas and schedules for material excavation have not been identified, Borrow Area C and/or gravel pit No. 30 are the designated source areas for all geologic materials. It was further assumed that 50 percent of the disturbed area would be shrub-steppe habitat.	Fluor Hanford 2004:2-13, 2-15

Table T–1. Past, Present, and Reasonably Foreseeable Future Actions Potentially Affecting Land and Ecological Resources *(continued)*

Project/Action	Total Land Area/ Terrestrial Habitat Affected[a] (hectares)	Area of Shrub-Steppe Habitat Affected (hectares)	Threatened and Endangered Species	Distance from 200 Areas (kilometers)	Notes	Source
Other DOE Activities at the Hanford Site *(continued)*						
Decommissioning of eight surplus production reactors and their support facilities in the 100 Areas[b, c]	6.1	6.1	Impacts are not expected because reactor sites are highly disturbed.	On site	The land requirement is related to the disposal of radioactive waste in the 200 Areas. It was conservatively assumed that all of this land is shrub-steppe habitat. Five of the eight reactors have been decommissioned. Habitat loss could be offset by a gain of 5 hectares that would become available for reuse within the 100 Areas once the reactors are removed.	DOE 1992:1-27
Decommissioning of the N Reactor and its support facilities[b]	0	0	Impacts are not expected because the project area is highly developed.	On site	Undergoing interim safe storage (2006–2009).	DOE 2005:10, 12
Actions to empty the K Basins in the 100-K Area and implement dry storage of the fuel rods in the Canister Storage Building in the 200-East Area[b]	3.6	0	Impacts are not expected because the new facility was built within a disturbed area.	On site	The facility was built in the vicinity of the Canister Storage Building.	DOE 1995:5.12, 5.38, 5.39

Table T–1. Past, Present, and Reasonably Foreseeable Future Actions Potentially Affecting Land and Ecological Resources *(continued)*

Project/Action	Total Land Area/ Terrestrial Habitat Affected[a] (hectares)	Area of Shrub-Steppe Habitat Affected (hectares)	Threatened and Endangered Species	Distance from 200 Areas (kilometers)	Notes	Source
Other DOE Activities at the Hanford Site *(continued)*						
Excavation and use of geologic materials from existing borrow pits[b]	31.2	8.1	Potential impacts are expected on gray cryptantha, dwarf evening primrose, Piper's daisy, and loggerhead shrike. Ecological reviews would be necessary prior to excavation.	On site	Land use would be consistent with current designations. Some shrub-steppe habitat could be impacted. Land use was assumed to be 25 percent (8.1 hectares) of total newly disturbed area.	DOE 2001a:3-1, 5-2, Appendix A
Reactivation and use of three former borrow sites in the 100-F, 100-H, and 100-N Areas[b]	38.9	0	Not present	On site	Extraction would be authorized as an existing nonconforming use within the Preservation land use category. There would be minimal visual impact because existing sites would not be visible to the public from the Hanford Reach National Monument or the Columbia River, and they would be revegetated where possible during and after site usage.	DOE 2003a:5-1–5-3, B-1, B-2

Table T–1. Past, Present, and Reasonably Foreseeable Future Actions Potentially Affecting Land and Ecological Resources *(continued)*

Project/Action	Total Land Area/ Terrestrial Habitat Affected[a] (hectares)	Area of Shrub-Steppe Habitat Affected (hectares)	Threatened and Endangered Species	Distance from 200 Areas (kilometers)	Notes	Source
Other DOE Activities at the Hanford Site *(continued)*						
Construction and operation of the Environmental Restoration Disposal Facility near the 200-West Area[b]	414	414	Stalked-pod milkvetch and loggerhead shrike were observed on site.	On site	Total land use would be 414 hectares. Phase III (which is complete) occupies 34.4 hectares. The area is low-lying, so there would be minimal visual impact. The facility would detract from the view from Rattlesnake Mountain. Because the disposal area would be capped and revegetated where possible during and after facility usage, long-term impacts would be minimal.	DOE 1994:9-24; 2001b:6; Sackschewsky 2003:8
Closure of Nonradioactive Dangerous Waste Landfill and 600 Area Central Landfill[d]	61.1	0	Not present	On site	18.2 hectares in Borrow Area C and 42.9 hectares adjacent to the landfill to be closed. Mitigation would alleviate impacts on biological resources of concern.	DOE 2011a:1-1, 4-5, 4-6
Disposal of greater-than-Class C low-level radioactive waste	44.5	44.5	No threatened or endangered species on site. Potential to impact three state candidate species.	On site	Borehole facility would be generally visually unobtrusive, but would add to the generally developed nature of the 200 Areas, especially as seen from Rattlesnake Mountain.	DOE 2011b:2-44, 2-63, 6-92

Table T–1. Past, Present, and Reasonably Foreseeable Future Actions Potentially Affecting Land and Ecological Resources *(continued)*

Project/Action	Total Land Area/ Terrestrial Habitat Affected[a] (hectares)	Area of Shrub-Steppe Habitat Affected (hectares)	Threatened and Endangered Species	Distance from 200 Areas (kilometers)	Notes	Source
Other DOE Activities at the Hanford Site *(continued)*						
Construction and operation of a Pacific Northwest National Laboratory Physical Sciences Facility[b]	40.1	25.9	Burrowing owls were observed on site. Potential impacts are expected on the sage sparrow and loggerhead shrike.	On site		DOE 2007a:26, 38
Total for Other DOE Activities at the Hanford Site	**752**	**555**	**Not applicable**	**Not applicable**	**Not applicable**	**Not applicable**

Table T–1. Past, Present, and Reasonably Foreseeable Future Actions Potentially Affecting Land and Ecological Resources *(continued)*

Project/Action	Total Land Area/ Terrestrial Habitat Affected[a] (hectares)	Area of Shrub-Steppe Habitat Affected (hectares)	Threatened and Endangered Species	Distance from 200 Areas (kilometers)	Notes	Source
Non-DOE Activities at the Hanford Site						
Management of the Hanford Reach National Monument and Saddle Mountain National Wildlife Refuge[b]	405	101	Impacts on threatened and endangered species would be generally minor; however, a number of species are present. Those potentially affected under the *TC & WM EIS* alternatives include the loggerhead shrike, sage sparrow, long-billed curlew, and black-tailed jackrabbit.	On site	Many areas that would be affected have been previously disturbed. It was assumed that 25 percent of the area to be disturbed is shrub-steppe habitat. A total of approximately 34,826 hectares of shrub-steppe habitat are found in the monument; 1,214 hectares of shrub-steppe habitat would be restored each year. Recreation facilities and visitor services could disturb 405 hectares of land. Goal 8 of the *Hanford Reach National Monument Final Comprehensive Conservation Plan and Environmental Impact Statement, Adams, Benton, Grant and Franklin Counties, Washington* is to "protect the natural visual character and promote the opportunity to experience solitude on the Monument."	USFWS 2008:2-46, 2-52, 4-72–4-82, 4-110

Table T–1. Past, Present, and Reasonably Foreseeable Future Actions Potentially Affecting Land and Ecological Resources *(continued)*

Project/Action	Total Land Area/ Terrestrial Habitat Affected[a] (hectares)	Area of Shrub-Steppe Habitat Affected (hectares)	Threatened and Endangered Species	Distance from 200 Areas (kilometers)	Notes	Source
Non-DOE Activities at the Hanford Site *(continued)*						
Operation of the US Ecology Commercial Low-Level Radioactive Waste Disposal Site near the 200-East Area[b]	40.5	40.5	Listed species were not identified on site.	On site	The cover construction would have minimal impact on ecology; revegetation would encourage shrub-steppe habitat development. An undisturbed 6.1-hectare area of shrub-steppe habitat in the northwest corner may need to be developed for spoils.	Ecology and WSDOH 2004:26–28, 128, 130
Transport of Navy reactor compartments from the Columbia River and their disposal[b]	4	0	Not present	On site	Four hectares would be used (in trench 218-E-12B). The area to be used is classified as a disturbed area.	Navy 1996:2-2, 3-14
Rattlesnake Mountain cleanup	0	0	Not present	On site	Most facilities would be removed and replaced with two antennas and one building, which would occupy about 0.4 hectares of previously disturbed land.	DOE 2009:SUM-1, SUM-2
Total for Non-DOE Activities at the Hanford Site	**449**	**142**	**Not applicable**	**Not applicable**	**Not applicable**	**Not applicable**
Total for Hanford Site	**1,200**	**697**	**Not applicable**	**Not applicable**	**Not applicable**	**Not applicable**

Table T–1. Past, Present, and Reasonably Foreseeable Future Actions Potentially Affecting Land and Ecological Resources *(continued)*

Project/Action	Total Land Area/ Terrestrial Habitat Affected[a] (hectares)	Area of Shrub-Steppe Habitat Affected (hectares)	Threatened and Endangered Species	Distance from 200 Areas (kilometers)	Notes	Source
Other Projects/Activities in the Region of Influence						
Southridge development project, Kennewick, Washington	1,020	607	Burrowing owls were observed on site.	50 southeast	Habitat at the site includes 607 hectares of shrub steppe, 256 hectares of apple orchards, and154 hectares that are developed. An additional 101 hectares are at the planning/permitting stage.	Kennewick 2005:i, 3-17, 3-28, 3-29; Romine 2007
Hansen Park development project, Kennewick, Washington	153	0	Not addressed	48 southeast	Primarily agricultural land (based on Google Earth aerial photography).	Kennewick 2006: 149
Clearwater development project, Kennewick, Washington	164	40.5	Not addressed	48 southeast	The site is 164 hectares. It is estimated that 40.5 hectares of the site is sagebrush habitat. Other land is agricultural, fallow agricultural, and industrial (based on Google Earth aerial photography).	Kennewick 1999:2
Pasco, Washington (three subdivisions)	115	0	Not addressed	48 south-southeast	The subdivisions would be located northwest and southwest of the airport. The land appears to be mostly agricultural (based on Google Earth aerial photography).	Adams 2007
Washington State University Tri-Cities Campus expansion	38.9	0	Not addressed	35 southeast	Approximately 26.7 hectares east and 12.1 hectares west of George Washington Way are undeveloped.	TVA 2008

Table T–1. Past, Present, and Reasonably Foreseeable Future Actions Potentially Affecting Land and Ecological Resources *(continued)*

Project/Action	Total Land Area/ Terrestrial Habitat Affected[a] (hectares)	Area of Shrub-Steppe Habitat Affected (hectares)	Threatened and Endangered Species	Distance from 200 Areas (kilometers)	Notes	Source
Other Projects/Activities in the Region of Influence *(continued)*						
Red Mountain Center (mixed use development),[b] West Richland, Washington	130	130	Not addressed	34 south-southeast	The land does not appear to be agricultural and was assumed to be shrub-steppe habitat (based on Google Earth aerial photography).	Gouk 2007
Red Mountain American Viticultural Area,[b] Benton County, Washington	567	510	Not addressed	32 south	The total area is 1,781 hectares. The developed area is currently 283 hectares, but the number of vineyards could increase in the next 5 years, increasing the developed area to 567 hectares. The area is primarily native habitat with some agricultural land (based on Google Earth aerial photography). It was assumed that 90 percent of past and future development (510 hectares) is shrub-steppe habitat.	Benton County 2007:B-18
Yakima City, Washington (new subdivisions)	648	0	Not addressed	80 west	Potential for 1,000 new homes to be built. The area is mixed agricultural and rural residential land. The site is to be annexed by the city.	Benson 2007

Table T–1. Past, Present, and Reasonably Foreseeable Future Actions Potentially Affecting Land and Ecological Resources *(continued)*

Project/Action	Total Land Area/ Terrestrial Habitat Affected[a] (hectares)	Area of Shrub-Steppe Habitat Affected (hectares)	Threatened and Endangered Species	Distance from 200 Areas (kilometers)	Notes	Source
Other Projects/Activities in the Region of Influence *(continued)*						
Gravel mine, Yakima County, Washington	40.5	20.2	Not addressed	68 west	The site is located east of the city. The project has been permitted; however, work has not yet begun. The current land use is unknown because the location of the site has not been specified. It was assumed that 50 percent of the area is shrub-steppe habitat.	Patterson 2007
Residential/golf community, Walla Walla County, Washington	202	202	Not addressed	90 southeast	The parcel totals 4,856 hectares, with 202 hectares remaining to be developed. The location of the site was not specified. It was conservatively assumed that all 202 hectares to be developed are shrub-steppe habitat.	Prentice 2007
Boardman Resort, Morrow County, Oregon	648	0	Not addressed	80 south-southeast	The resort area is 911 hectares in size. A total of 648 hectares is developable. The site does not appear to be shrub-steppe habitat (based on Google Earth aerial photography).	McClane 2007
Boardman Industrial Park, Morrow County, Oregon	162	0	Not addressed	76 south	The area is agricultural land (based on Google Earth aerial photography).	McClane 2007

Table T–1. Past, Present, and Reasonably Foreseeable Future Actions Potentially Affecting Land and Ecological Resources *(continued)*

Project/Action	Total Land Area/ Terrestrial Habitat Affected[a] (hectares)	Area of Shrub-Steppe Habitat Affected (hectares)	Threatened and Endangered Species	Distance from 200 Areas (kilometers)	Notes	Source
Other Projects/Activities in the Region of Influence *(continued)*						
Operation of the U.S. Army Yakima Training Center	19,700	14,600	No impact on federally listed threatened or endangered species.	26 west	Maneuver activity effects on 19,200 hectares, plus 500 hectares affected by fires. Data not provided on area of sagebrush habitat impacted; therefore, it was assumed that sagebrush habitat would be impacted in the same proportion as it occurs on site (i.e., 74 percent).	Army 2010:2-3, 5-15, 6-25, 6-29
Sunnyside Water Conservation Program, Washington	35.2	0	No impacts are expected on the bald eagle.	24 to 48 west and southwest	The area includes three reservoirs on agricultural and pasture land.	BOR 2004:17, 43, 46

Table T–1. Past, Present, and Reasonably Foreseeable Future Actions Potentially Affecting Land and Ecological Resources *(continued)*

Project/Action	Total Land Area/ Terrestrial Habitat Affected[a] (hectares)	Area of Shrub-Steppe Habitat Affected (hectares)	Threatened and Endangered Species	Distance from 200 Areas (kilometers)	Notes	Source
Other Projects/Activities in the Region of Influence *(continued)*						
Big Horn Wind Project, Bickleton, Washington	41.2	21.8	No rare plants or federally threatened or endangered species are present.	80 southwest	The project would temporarily disturb 90.2 hectares and permanently disturb 34 hectares. The switching station and the road contain scrub oak and scattered ponderosa pine. The area includes some shrub-steppe habitat, but it is unknown how much would be affected. It was assumed that 50 percent of disturbed land would be shrub-steppe habitat. The wind turbines would be readily visible from houses and roads. Turbines would be painted a neutral color to minimize visual impacts.	BPA 2005:8-14
Wild Horse Wind Project, Kittitas County, Washington	66.8	60.3	Potential impacts are expected on 10 percent of the individual hedgehog cactus plants.	90 northwest	The 3,480-hectare site is currently zoned as Forest and Range and Commercial Agriculture; 66.8 hectares would be permanently affected. Approximately 90 percent of impacts would occur in shrub-steppe habitat.	EFSEC 2005:1-6, 1-11, 1-48, 1-49

Table T–1. Past, Present, and Reasonably Foreseeable Future Actions Potentially Affecting Land and Ecological Resources *(continued)*

Project/Action	Total Land Area/ Terrestrial Habitat Affected[a] (hectares)	Area of Shrub-Steppe Habitat Affected (hectares)	Threatened and Endangered Species	Distance from 200 Areas (kilometers)	Notes	Source
Other Projects/Activities in the Region of Influence *(continued)*						
McNary–John Day transmission line	13	6.5	No federally listed threatened or endangered plant species present along route. "May affect but unlikely to adversely affect" nine federally listed threatened and endangered species. Potential impact on two state-listed plant species.	71 south-southeast (to McNary dam)	The line is 127 kilometers long; 48 kilometers of the line are within 80 kilometers of the 200 Areas. Shrub-steppe habitat includes grazed areas.	BPA and DOE 2002:2-4, 2-31, 3-18
Walla Walla–McNary transmission line	13.8	10.9	No federally listed threatened or endangered plant species present along route. Twelve state special status species are present, including loggerhead shrike, sage sparrow, and long-billed curlew.	71 south southeast (to McNary dam)	The line is 89 kilometers long; 48 kilometers of the line are within 80 kilometers of the 200 Areas.	Pacific Power 2008:4, 5, 13, 34, 35

Table T–1. Past, Present, and Reasonably Foreseeable Future Actions Potentially Affecting Land and Ecological Resources *(continued)*

Project/Action	Total Land Area/ Terrestrial Habitat Affected[a] (hectares)	Area of Shrub-Steppe Habitat Affected (hectares)	Threatened and Endangered Species	Distance from 200 Areas (kilometers)	Notes	Source
Other Projects/Activities in the Region of Influence *(continued)*						
Transportation project, roadway from Interstate 82 to Finley, Washington	32.4	25.1	Not addressed	53 southeast	The roadway is 17.7 kilometers long and 11 meters wide. Assuming 3.7 meters are needed on each side of the road, the total width is 18.3 meters. The road passes through open land, which appears to be primarily shrub-steppe habitat with some agricultural land (based on Google Earth aerial photography). It was assumed that 13.7 kilometers are shrub-steppe habitat.	WSDOT 2007
Finley Columbia Ethanol Plant, Benton County, Washington	22.3	0	No impact	72 southeast	A total of 16.2 to 22.3 hectares of agricultural land would be disturbed. Plant is adjacent to industrial facility. Area is zoned industrial. Aesthetic impacts would be negligible.	Columbia Ethanol Plant Holdings 2006:22, 23, 27, 29

Table T–1. Past, Present, and Reasonably Foreseeable Future Actions Potentially Affecting Land and Ecological Resources *(continued)*

Project/Action	Total Land Area/ Terrestrial Habitat Affected[a] (hectares)	Area of Shrub-Steppe Habitat Affected (hectares)	Threatened and Endangered Species	Distance from 200 Areas (kilometers)	Notes	Source
Other Projects/Activities in the Region of Influence *(continued)*						
Operation of the Perma-Fix Northwest (formerly Pacific EcoSolutions) Waste Treatment Facility in Richland, Washington	18.2	0	No impact	32 southeast	The project would impact 18.2 hectares of disturbed grassland. No sensitive habitats would be affected.	DOE 1998:8, 20, 21, 50
Total for Other Projects/Activities in the Region of Influence	**23,800**	**16,200**	**Not applicable**	**Not applicable**	**Not applicable**	**Not applicable**
Grand Totals						
Alternative Combination 1	**25,000/25,000**	**16,900**	**Not applicable**	**Not applicable**	**Not applicable**	**Not applicable**
Alternative Combination 2	**25,300/25,200**	**17,000**	**Not applicable**	**Not applicable**	**Not applicable**	**Not applicable**
Alternative Combination 3	**25,800/25,800**	**17,200**	**Not applicable**	**Not applicable**	**Not applicable**	**Not applicable**

[a] For all non–*TC & WM EIS* projects and activities, it was conservatively assumed that the total land area affected and the area of undeveloped land affected would be the same; thus, only one value was provided. It was also assumed that undeveloped land equates with terrestrial habitat. For those projects and activities where the land cover was not reported, the entire project area was conservatively assumed to be terrestrial habitat. Terrestrial habitat could include shrub-steppe habitat, other native and nonnative habitat, grazing land, and cropland.

[b] All listed projects and activities are within the region of influence for land use and ecological resources. Those within the region of influence for visual resources are indicated with the superscript "b."

[c] B Reactor was recently designated a National Historic Landmark (DOE and DOI 2008). Therefore, B Reactor will not be decommissioned and moved to the Hanford Central Plateau for disposal as analyzed in the *Environmental Impact Statement, Decommissioning of Eight Surplus Production Reactors at the Hanford Site, Richland, Washington* (DOE 1989, 1992) and assumed in this *TC & WM EIS*.

[d] The 600 Area Central Landfill is referred to as the "Solid Waste Landfill" (DOE 2011a).

Note: To convert hectares to acres, multiply by 2.471; kilometers to miles, by 0.6214; meters to feet, by 3.281.

Key: DOE=U.S. Department of Energy; *TC & WM EIS=Tank Closure and Waste Management Environmental Impact Statement for the Hanford Site, Richland, Washington*.

Table T–2. Past, Present, and Reasonably Foreseeable Future Actions Potentially Affecting Cultural Resources

Action	Total Area Disturbed (hectares)	Cultural Resources Impacts	Source
***TC & WM EIS* Activities**			
Alternative Combination 1	2	On site. Specific elements of *TC & WM EIS* Alternative Combination 1 are addressed in Chapter 4, Section 4.4.7.	Chapter 4, Section 4.4.7
Alternative Combination 2	207	On site. Specific elements of *TC & WM EIS* Alternative Combination 2 are addressed in Chapter 4, Section 4.4.7.	Chapter 4, Section 4.4.7
Alternative Combination 3	753	On site. Specific elements of *TC & WM EIS* Alternative Combination 3 are addressed in Chapter 4, Section 4.4.7.	Chapter 4, Section 4.4.7
Other DOE Activities at the Hanford Site			
Central Plateau closure	112	On site. Although specific mining plans and precise areas and schedules for material excavation have not been identified, Borrow Area C and/or gravel pit No. 30 are the designated source areas for all geologic materials. Changes to the viewshed would occur. Future uses of the Central Plateau would likely include structures and activities consistent with Industrial-Exclusive use.	Fluor Hanford 2004
Decommissioning of the eight surplus production reactors and their support facilities in the 100 Areas along the Columbia River[a]	6.1	On site. The location is in a highly developed area. There would be a possible impact on archaeological or cultural properties that could be found within the 100 Areas and/or the 100-B Reactor.	DOE 1989:4.39; 1992
Decommissioning of the N Reactor and its support facilities	0	On site. Buildings 105-N and 109-N. Impacts are not expected because the project is in a highly developed area.	DOE 2005

Table T–2. Past, Present, and Reasonably Foreseeable Future Actions Potentially Affecting Cultural Resources *(continued)*

Action	Total Area Disturbed (hectares)	Cultural Resources Impacts	Source
Other DOE Activities at the Hanford Site *(continued)*			
Actions to empty the K Basins in the 100-K Area and implement dry storage of the fuel rods in the Canister Storage Building in the 200-East Area	3.6	On site. No known archaeological or historic sites were located during intensive inventories of the reference site. There would be no impact on visual resources. The new facility was built within a disturbed area.	DOE 1995:5.11
Excavation and use of geologic materials from existing borrow pits[b]	31.2	On site. The area can be seen from the viewshed of American Indian areas of interest. It is expected that excavation activities would be primarily in a previously disturbed area. No cultural resources are known to exist within the currently active borrow areas. Specific cultural resource reviews would be conducted before any expansion activities.	DOE 2001a:5-2, 5-3
Reactivation and use of three former borrow sites in the 100-F, 100-H, and 100-N Areas	38.9	On site. No cultural resources, historic properties, or American Indian areas of interest are located in the project location area. There would be no visual impacts within the viewshed of American Indian areas of interest, and the sites would be revegetated where possible during and after site usage.	DOE 2003a:5.1.6, 5.1.7, 5.2
Construction and operation of the Environmental Restoration Disposal Facility near the 200-West Area	414	On site. The facility is within the viewshed of American Indian areas of interest. The rail line that traverses the area could adversely affect a portion of the historic White Bluffs Road. No archaeological or historic sites are considered eligible for the National Register of Historic Places. The area would be revegetated where possible during and after facility operation.	DOE 1994:ES-22–27, 12; 2001b

Table T–2. Past, Present, and Reasonably Foreseeable Future Actions Potentially Affecting Cultural Resources *(continued)*

Action	Total Area Disturbed (hectares)	Cultural Resources Impacts	Source
Other DOE Activities at the Hanford Site *(continued)*			
Construction and operation of a Pacific Northwest National Laboratory Physical Sciences Facility	40.1	On site. The fenced area in the eastern portion will protect a site of cultural significance to regional tribes. Two prehistoric sites are located in the eastern buffer area near the Columbia River and are monitored to confirm they remain undisturbed.	DOE 2007a:26, 37
Construction and operation of facilities for disposal of greater-than-Class C low-level radioactive waste	44.5	On site. Impacts on cultural resources could occur during the removal and hauling of soil required for the vault alternative.	DOE 2011b:6-102, 6-103
Closure of Nonradioactive Dangerous Waste Landfill and 600 Area Central Landfill	61.1	On site. The area has previously been impacted. Closing these facilities would have no adverse impact on cultural resources.	DOE 2011a:4-3, 4-4, 4-5, Appendix A
Non-DOE Activities at the Hanford Site			
Transport and disposal of Navy reactor compartments from the Columbia River	4	On site. The area to be used is classified as disturbed. There would be no impact on cultural resources or visual impact on American Indian areas of interest.	Navy 1996

Table T–2. Past, Present, and Reasonably Foreseeable Future Actions Potentially Affecting Cultural Resources *(continued)*

Action	Total Area Disturbed (hectares)	Cultural Resources Impacts	Source
Non-DOE Activities at the Hanford Site *(continued)*			
Management of the Hanford Reach National Monument and Saddle Mountain National Wildlife Refuge	405	On site. Many of the areas to be affected have been previously disturbed. Goal 5 of the *Hanford Reach National Monument Final Comprehensive Conservation Plan and Environmental Impact Statement, Adams, Benton, Grant and Franklin Counties, Washington* is to "Protect and acknowledge the Native American, settler, atomic and Cold War histories of the Monument to ensure present and future generations recognize the significance of the area's past, incorporating a balance of views."	USFWS 2008
Rattlesnake Mountain Cleanup	4.0	On site. Activities would disturb some NRHP-eligible structures, although impacts of these activities would be mitigated. Overall, removal of structures and cleanup of waste will improve visual impacts and therefore lessen impacts on American Indian resources.	DOE 2009:13
Operation of the US Ecology Commercial Low-Level Radioactive Waste Disposal Site near the 200-East Area	40.5	On site. There is a high probability that the proposed actions would not impact any historic buildings, archaeological sites, or specific American Indian areas of interest.	Ecology and WSDOH 2004:134

Table T–2. Past, Present, and Reasonably Foreseeable Future Actions Potentially Affecting Cultural Resources *(continued)*

Action	Total Area Disturbed (hectares)	Cultural Resources Impacts	Source
Other Activities in the Region of Influence			
Red Mountain American Viticultural Area, Benton County, Washington	567	The area is within the viewshed of nearby higher elevations, which are of interest to the American Indians. The number of vineyards could increase in the next 5 years.	Benton County 2007

[a] B Reactor was recently designated a National Historic Landmark (DOE and DOI 2008). Therefore, B Reactor will not be decommissioned and moved to the Hanford Central Plateau for disposal as analyzed in the *Environmental Impact Statement, Decommissioning of Eight Surplus Production Reactors at the Hanford Site, Richland, Washington* (DOE 1989, 1992) and assumed in this *TC & WM EIS*.

[b] As a result of tribal and public comments on the *Final Hanford Comprehensive Land-Use Plan Environmental Impact Statement* (DOE 1999a), DOE designated the McGee Ranch as Preservation as a "tradeoff" for keeping Borrow Area C available as the primary source of geologic materials for site remediation. There are discussions of this decision in the following sections of the *Final Hanford Comprehensive Land-Use Plan Environmental Impact Statement*: the Summary, the main text, Appendices D and E, and the Comment-Response Document.

Note: To convert hectares to acres, multiply by 2.471.

Key: DOE=U.S. Department of Energy; NRHP=National Register of Historic Places; *TC & WM EIS=Tank Closure and Waste Management Environmental Impact Statement for the Hanford Site, Richland, Washington*.

Table T–3. Past, Present, and Reasonably Foreseeable Future Actions Potentially Affecting Socioeconomics

Project/Action	Peak Annual Employment (FTEs)	Peak Daily Traffic		Notes	Source
		Commuter[a]	Offsite Truck		
Existing Site Activities					
Baseline	9,760	7,810	Not applicable	Construction FTEs were not separated from operations FTEs. No data on truck traffic.	Chapter 3, Section 3.2.9
***TC & WM EIS* Activities**					
Alternative Combination 1[b]	1,840	1,470	4	–	Chapter 4, Section 4.4.8, provides information on *TC & WM EIS* Alternative Combination 1
Alternative Combination 2[b]	8,190	6,550	79	–	Chapter 4, Section 4.4.8, provides information on *TC & WM EIS* Alternative Combination 2
Alternative Combination 3[b]	12,500	10,000	102	–	Chapter 4, Section 4.4.8, provides information on *TC & WM EIS* Alternative Combination 3
Other DOE Activities at the Hanford Site					
Changes in land use at the Hanford Site	1,100	880	Not applicable	This ongoing activity includes industrial development, research and development initiatives, limited mining, and increased recreational use at the Hanford Site during the next 50 years.	DOE 1999a:5-48
Actions to empty the K Basins in the 100-K Area and implement dry storage of the fuel rods in the Canister Storage Building in the 200-East Area	408	326	1	This is an ongoing activity. Future milestones could require additional FTEs. Employment would be reduced after spent nuclear fuel is placed in long-term storage. Most truck trips would be on site.	DOE 1995:3.24, 5.1, 5.10, 5.47; 2007b

Table T–3. Past, Present, and Reasonably Foreseeable Future Actions Potentially Affecting Socioeconomics *(continued)*

Project/Action	Peak Annual Employment (FTEs)	Peak Daily Traffic		Notes	Source
		Commuter[a]	Offsite Truck		
Other DOE Activities at the Hanford Site *(continued)*					
Final disposition of the canyons, PUREX Plant, PUREX tunnels, and other facilities in the 200 Areas and cleanup to Industrial-Exclusive land use standards	172	138	64	The activity was assumed to have four times the values of the U Plant regional closure. It could possibly use the same workers or could potentially be done consecutively.	Fluor Hanford 2004:ES-7
Deactivation of the Fast Flux Test Facility in the 400 Area	20	16	Not applicable	This ongoing activity could require additional FTEs. Most truck trips would be on site.	DOE 2006a:2-8, 4-2, 4-3, 4-4, 4-8, 4-9
Construction and operation of a Pacific Northwest National Laboratory Physical Sciences Facility	450	450	3	This activity involves construction impacts only. Annual workers were merely relocated; therefore, they were already included in the baseline. The commuter numbers are supplied in the source document.	DOE 2007a:39–41
Construction and operation of facilities for disposal of greater-than-Class C LLW	66	53	2	Of Alternatives 3 through 5, the alternative with the largest number of employees who would in-migrate was used; other employees were assumed to relocate from other Hanford Site activities.	DOE 2011b:Section 6.2.6, Appendix D.5.2
Non-DOE Activities at the Hanford Site					
Operation of the US Ecology Commercial Low-Level Radioactive Waste Disposal Site near the 200-East Area	Included in baseline	Included in baseline	4	The facility is currently operating. Workers were already included in the region of influence. Offsite truck trips represent potential future construction.	Ecology and WSDOH 2004:25, 35, 94, 141
Management of the Hanford Reach National Monument and Saddle Mountain National Wildlife Refuge	41	76	Not applicable	The commuter traffic represents the peak weekend number of national monument visitors.	USFWS 2008:4-202, 4-217

Table T–3. Past, Present, and Reasonably Foreseeable Future Actions Potentially Affecting Socioeconomics *(continued)*

Project/Action	Peak Annual Employment (FTEs)	Peak Daily Traffic		Notes	Source
		Commuter[a]	Offsite Truck		
Other Projects/Activities in the Region of Influence					
Future land use in the region	700	700	Not applicable	Potential increases in employees exist with the North Richland Research Park. No data on truck traffic. No carpooling was assumed.	Benton County 2007:2-3
Operation of the Perma-Fix Northwest (formerly Pacific EcoSolutions) Waste Treatment Facility in Richland, Washington	150	129	4	This includes DOE waste generators and other organizations' waste generators. Commuter traffic numbers were supplied in the source document.	Richland 1998:14, 24, 25, 39, 40. DOE 1999b:1 of 9, 29 of 33, 32 of 33
Yakima River basin water management	14	14	Not applicable	Total water-related jobs and incomes would likely increase, both statewide and in the two economic regions that incorporate portions of the Yakima River basin, one of which is centered on Kennewick, Pasco, and Richland. No carpooling was assumed.	Ecology 2009:Section 5.13.2
Construction and operation of biofuels facilities	162	72	70	Commuter and truck traffic numbers were supplied in the source document.	Columbia Ethanol Plant Holdings 2006:13, 21, 32
Additional Activities Subtotal	**3,280[c]**	**2,850[c]**	**148[c]**		
Grand Totals					
Alternative Combination 1	**5,130[c]**	**4,330[c]**	**152[c]**	Additional activities subtotal added to Alternative Combination 1.	
Alternative Combination 2	**11,500[c]**	**9,410[c]**	**227[c]**	Additional activities subtotal added to Alternative Combination 2.	
Alternative Combination 3	**15,800[c]**	**12,900[c]**	**250[c]**	Additional activities subtotal added to Alternative Combination 3.	

[a] Unless otherwise noted, commuter traffic figures were calculated based on employee numbers by dividing the number of employees by 1.25 to account for carpooling.
[b] For each combination, the peaks for each component could potentially occur during different timespans. To determine the potential impact of each combination of alternatives, the peak amount for each component was totaled together. The resulting conservative total estimates represent the upper limit of workforce requirements.
[c] Total may not equal the sum of the contributions due to rounding.

Key: DOE=U.S. Department of Energy; FTE=full-time equivalent; LLW=low-level radioactive waste; PUREX=Plutonium-Uranium Extraction; *TC & WM EIS=Tank Closure and Waste Management Environmental Impact Statement for the Hanford Site, Richland, Washington*.

Table T–4. Past, Present, and Reasonably Foreseeable Future Actions Potentially Affecting Transportation

Activity	Worker		General Population	
	Collective Dose (person-rem)	LCFs	Collective Dose (person-rem)	LCFs
Historical Shipments to the Hanford Site (1943–1993)				
SNF shipments[a]	52	0.03	27	0.02
Radioactive waste[a]	240	0.14	290	0.17
Subtotal	**292**	**0.18**	**317**	**0.19**
General Radioactive Material Transport (includes DOE and non-DOE actions)				
1943–1982[a, b]	220,000	132	170,000	102
1983–2073[a, c]	154,000	92	168,000	101
Subtotal	**374,000**	**224**	**338,000**	**203**
Reasonably Foreseeable Actions				
Surplus Plutonium Disposition EIS[a]	60	0.04	67	0.04
K Basin Fuel Storage EIS (DOE 1995)	0.06	0.00	N/A	N/A
Treatment of MLLW EA (DOE 1998)	18	0.01	1.34	0.0
Treatment of MLLW EA FONSI (DOE 1999b)	0.48	0.0	0.19	0.0
WM PEIS[a, d]	15,550	9.3	18,430	11.1
WIPP SEIS-II[a]	790	0.47	5,900	3.54
Idaho HLW and Facilities Disposition FEIS[a]	520	0.31	2,900	1.74
SNL Site-Wide EIS[a]	94	0.06	590	0.35
Tritium Production in Commercial Light Water Reactor EIS[a]	16	0.01	80	0.05
LANL Site-Wide EIS (DOE 2008a)	910	0.55	287	0.17
Plutonium Residue at Rocky Flats EIS[a]	2.10	0.00	1.30	0.00
Surplus Disposition of HEU EIS[a]	400	0.24	520	0.31
Molybdenum-99 Production EIS[a]	240	0.14	520	0.31
Import of Russian Plutonium-238 EA[a]	1.80	0.00	4.40	0.00
Pantex Site-Wide EIS[a]	250	0.15	490	0.29
Draft NNSS Site-Wide EIS (DOE 2011c)	5,500	3.33	1,360	0.82
Storage and disposition of fissile material[a]	0.0	0.00	2,400[e]	1.44
Stockpile stewardship[a]	0.0	0.0	38[e]	0.02
Container system for Naval SNF[a]	11	0.010	15	0.01
DUF_6 Conversion at Paducah EIS (DOE 2004a)	770	0.46	31	0.02
S3G and D1G Prototype Reactor Plant Disposal EIS[a]	2.9	0.00	2.2	0.00
S1C Prototype Reactor Plant Disposal EIS[a]	6.7	0.00	1.9	0.00
DUF_6 Conversion at Portsmouth EIS (DOE 2004b)	520	0.31	29	0.02
ETTP DUF_6 Transport to Portsmouth EIS (DOE 2004b)	99	0.06	3.20	0.00
Spent Nuclear Fuel PEIS[a]	360	0.22	810	0.49
FRR SNF EIS (DOE 1996)	90	0.05	222	0.13

Table T–4. Past, Present, and Reasonably Foreseeable Future Actions Potentially Affecting Transportation *(continued)*

Activity	Worker		General Population	
	Collective Dose (person-rem)	LCFs	Collective Dose (person-rem)	LCFs
Reasonably Foreseeable Actions *(continued)*				
Private Fuel Storage Facility Final EIS (NRC, BIA, BLM, and STB 2001)	30	0.02	190	0.11
West Valley Demonstration Project Waste Management EIS (DOE 2003b)	520	0.31	410	0.25
MOX Fuel Fabrication at SRS EIS (NRC 2005a)	530	0.32	560	0.34
Enrichment Facility in Lea County EIS (NRC 2005b)[f]	1,500	0.90	450	0.27
Y-12 Site-Wide EIS (DOE 2011d)	0	0	309	0.19
EA for the Decontamination, Demolition, and Removal of Certain Facilities at the West Valley Demonstration Project (DOE 2006b)	14	0.00	11	0.00
West Valley Decommissioning and/or Long-Term Stewardship EIS (DOE and NYSERDA 2010)	400	0.24	72	0.043
Draft GTCC EIS (DOE 2011b)	500	0.30	170	0.1
Subtotal	**29,800**	**18**	**36,900**	**22**
Total Transportation Impacts Not Related to This *TC & WM EIS*				
Total Impacts (Through 2073)	**404,000g**	**242**	**375,000g**	**225**

[a] Values are from the *Final Supplemental Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada* (DOE 2008b).

[b] These estimates are very conservative because not many shipments were made in the 1950s and 1960s. Also, the nonexclusive shipment dose estimates are based on a very conservative method.

[c] The annual dose estimates are similar to those generated for the period 1975–1983. The methodology used to estimate traffic fatalities is detailed in Chapter 6, Section 6.3.11.2.

[d] The values are for the low-level and mixed low-level radioactive waste transportation impacts based on the amended Record of Decision, 65 FR 10061, February 25, 2000.

[e] Includes worker and general population doses.

[f] Maximum values from truck transportation were used. For consistency with other data in this table, occupational traffic fatalities were not considered.

[g] The values are rounded to three significant figures.

Key: DOE=U.S. Department of Energy; DUF_6=depleted uranium hexafluoride; EA=environmental assessment; EIS=environmental impact statement; ETTP=East Tennessee Technology Park; FONSI=Finding of No Significant Impact; FRR=foreign research reactor; GTCC=greater-than-Class C; HEU=highly enriched uranium; HLW=high-level radioactive waste; LANL=Los Alamos National Laboratory; LCF=latent cancer fatality; MLLW=mixed low-level radioactive waste; MOX=mixed oxide; N/A=not applicable; NNSS=Nevada National Security Site; PEIS=programmatic EIS; SEIS=supplemental EIS; SNF=spent nuclear fuel; SNL=Sandia National Laboratories; SRS=Savannah River Site; *TC & WM EIS=Tank Closure and Waste Management Environmental Impact Statement for the Hanford Site, Richland, Washington*; WIPP=Waste Isolation Pilot Plant; WM=waste management. The following are the complete titles of documents cited in this table as sources of data drawn from the *Yucca Mountain Final SEIS* (DOE 2008b) and thus not included among the source materials provided as references for this appendix:

- *Idaho HLW and Facilities Disposition FEIS=Idaho High-Level Waste and Facilities Disposition Final Environmental Impact Statement*
- *Import of Russian Plutonium-238 EA=Environmental Assessment of the Import of Russian Plutonium-238*
- *Molybdenum-99 Production EIS=Medical Isotopes Production Project: Molydenum-99 and Related Isotopes, Environmental Impact Statement*
- *Pantex Site-Wide EIS=Final Environmental Impact Statement for the Continued Operation of the Pantex Plant and Associated Storage of Nuclear Weapon Components*

Table T–4. Past, Present, and Reasonably Foreseeable Future Actions Potentially Affecting Transportation *(continued)*

- *Plutonium Residue at Rocky Flats EIS=Final Environmental Impact Statement on Management of Certain Plutonium Residues and Scrub Alloy Stored at the Rocky Flats Environmental Technology Site*
- *SIC Prototype Reactor Plant Disposal EIS=Final Environmental Impact Statement, S1C Prototype Reactor Plant Disposal*
- *S3G and D1G Prototype Reactor Plant Disposal EIS=Final Environmental Impact Statement, Disposal of S3G and D1G Prototype Reactor Plants*
- *SNL Site-Wide EIS=Site-Wide Environmental Impact Statement for Sandia National Laboratories, New Mexico*
- *Spent Nuclear Fuel PEIS=Department of Energy Programmatic Spent Nuclear Fuel Management and Idaho National Engineering Laboratory Environmental Restoration and Waste Management Programs Final Environmental Impact Statement*
- *Surplus Disposition of HEU EIS=Disposition of Surplus Highly Enriched Uranium Final Environmental Impact Statement*
- *Surplus Plutonium Disposition EIS=Disposition of Surplus Highly Enriched Uranium Final Environmental Impact Statement*
- *Tritium Production in Commercial Light Water Reactor EIS=Final Environmental Impact Statement for the Production of Tritium in a Commercial Light Water Reactor*
- *WIPP SEIS-II=Waste Isolation Pilot Plant Disposal Phase Final Supplemental Environmental Impact Statement*
- *WM PEIS=Waste Management Programmatic Environmental Impact Statement for Managing Treatment, Storage, and Disposal of Radioactive and Hazardous Waste*

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WSDOT (Washington State Department of Transportation), 2007, *WSDOT Projects: I-82 to SR 397 Intertie*, accessed through http://www.wsdot.wa.gov/Projects/I82/SR397/Intertie on October 3.

Code of Federal Regulations

40 CFR 1508.7, Council on Environmental Quality, "Terminology and Index: Cumulative Impact."

Federal Register

65 FR 10061, U.S. Department of Energy, 2000, "Record of Decision for the Department of Energy's Waste Management Program: Treatment and Disposal of Low-Level Waste and Mixed Low-Level Waste; Amendment of the Record of Decision for the Nevada Test Site," February 25.

APPENDIX U
SUPPORTING INFORMATION FOR THE LONG-TERM CUMULATIVE IMPACT ANALYSES

This appendix presents detailed information supporting the long-term cumulative impacts on groundwater quality and human health analyses discussed in Chapters 6 and 7 of this *Tank Closure and Waste Management Environmental Impact Statement for the Hanford Site, Richland, Washington* by describing (1) the overall groundwater modeling methodology, (2) the differences between the Hanford Site and the environmental impact statement model conceptualization, (3) current site conditions, (4) projected long-term cumulative impacts model results, and (5) potential remediation actions and the magnitude and timeframe of the benefits.

This appendix contains detailed information regarding long-term cumulative impacts on groundwater quality and human health. Long-term cumulative impacts would occur following the active project phase under each alternative. For this *Tank Closure and Waste Management Environmental Impact Statement for the Hanford Site, Richland, Washington (TC & WM EIS)*, long-term cumulative impacts were assessed out to approximately 10,000 years in the future. Figure U–1 is a flowchart showing the components of the environmental impact statement (EIS) groundwater modeling system that were used to predict the long-term cumulative impacts on groundwater quality and human health. This appendix discusses the overall groundwater modeling methodology and the predictions from the concentration-dependent analyses of long-term impacts on groundwater quality and human health. Additionally, background information regarding current Hanford Site (Hanford) conditions; the U.S. Department of Energy Richland Operations Office (DOE-RL) Hanford cleanup process for Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) past-practice units; and potential remediation actions is provided to aid in the interpretation of the long-term cumulative impacts predictions.

Cumulative Impacts

Effects on the environment that result from the proposed action when added to other past, present, and reasonably foreseeable future actions, regardless of what agency or person undertakes such other actions (40 CFR 1508.7).

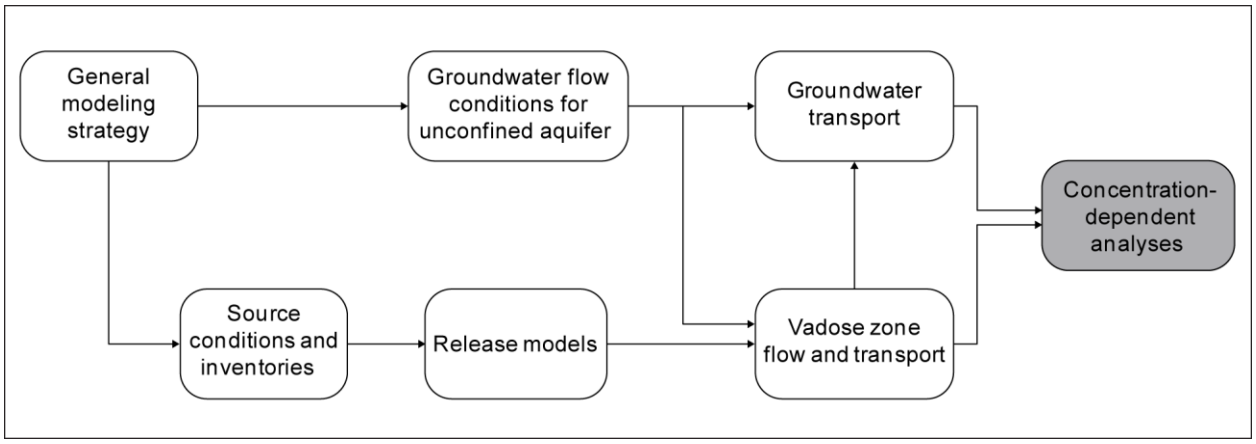


Figure U–1. Groundwater Modeling System Flowchart

U.1 GROUNDWATER QUALITY

This section discusses the methodology used for and results of the long-term groundwater impacts analysis of non–*TC & WM EIS* actions. The groundwater modeling methodology, current site conditions and future vision, and model results for future site conditions and sensitivity analyses are described in Sections U.1.1, U.1.2, and U.1.3, respectively. The presentation of the results follows the format developed for the *TC & WM EIS* alternatives (see Chapter 5 and Appendix O). This section does not present cumulative groundwater quality impacts (i.e., non–*TC & WM EIS* impacts added to the impacts of

the *TC & WM EIS* alternative combinations). Cumulative groundwater quality impacts are presented in Chapter 6.

U.1.1 Groundwater Modeling Methodology

The purpose of the long-term groundwater impacts analysis of non–*TC & WM EIS* sources is to provide a context for comparison of the *TC & WM EIS* alternatives. Therefore, the methodology was designed to be fully consistent with the long-term groundwater alternatives analysis and the *Technical Guidance Document for Tank Closure Environmental Impact Statement Vadose Zone and Groundwater Revised Analyses* (DOE 2005). This design consistency includes the models chosen to conduct the analysis, the parameter selection that affects the analysis, and the presentation and interpretation of the results.

The collective set of models used to implement the *TC & WM EIS* long-term groundwater impacts analysis is regarded as the groundwater modeling system. The design and implementation of the groundwater modeling system involved several components. Specifically, these components include the following: source term, vadose zone flow and transport, groundwater flow, groundwater transport, and linkages of all the components in the overall modeling system. Source-term representation lies at the beginning of the process for the general modeling strategy developed for the long-term groundwater impacts analysis. The general process started with a conceptual model that was developed for each of the non–*TC & WM EIS* sites (source terms) to be applied to numerical models. The inventories were gathered and applied to the release models for each source term, and the release model results were applied to the vadose zone models. The vadose zone model results were, in turn, utilized for groundwater transport. Results from the vadose zone flow and transport and the groundwater transport components were then used to complete concentration-dependent analyses. Figure U–1 shows each of the components of the groundwater modeling system.

The development of the inventory and a discussion of the end-state approach for the non–*TC & WM EIS* sources are described in Appendix S. The constituents of potential concern (COPCs) considered in this analysis include all the COPCs in the *TC & WM EIS* alternatives analysis, as well as several COPCs that originate from only non–*TC & WM EIS* sources. The inventory development relied on a search of available literature that provided estimates of the inventories for each source, estimates of uncertainties in the inventories, and a characterization of each source type and likely end state.

The approach to analyzing releases to the vadose zone for the non–*TC & WM EIS* sources was the same as that described in Appendix M for the *TC & WM EIS* alternatives. This analysis used site-specific parameters to estimate release rates from each of the sources to the vadose zone. The waste form performance parameters, release models, and infiltration profiles used in this analysis of releases to the vadose zone are fully consistent with their counterparts in the *TC & WM EIS* alternatives analysis. The results from the releases to the vadose zone analysis were used to support the vadose zone transport analysis.

The vadose zone transport analysis methodology for the non–*TC & WM EIS* sources was the same as that described in Appendix N for the *TC & WM EIS* alternatives. The vadose zone transport analysis used the STOMP [Subsurface Transport Over Multiple Phases] model to solve the nonlinear equations describing water and contaminant mass transport through the vadose zone. A fully three-dimensional model of the subsurface geology for each of the non–*TC & WM EIS* sources was developed using the same techniques that were used in the *TC & WM EIS* alternatives analysis. The material properties, infiltration profiles, and transport properties used in the vadose zone analysis are fully consistent with the *TC & WM EIS* alternatives analysis. The vadose zone transport analysis results were input into the groundwater transport analysis.

The methodology used for groundwater transport impacts analysis of non–*TC & WM EIS* sources was the same as that described in Appendices L and O for the *TC & WM EIS* alternatives. Appendix L discusses the development of the Base Case groundwater flow field, which describes the direction and rate of water movement in the aquifer. This Base Case flow field was used for both the *TC & WM EIS* alternatives analysis and the non–*TC & WM EIS* sources analysis. Appendix O discusses the use of the particle-tracking method to calculate a fully three-dimensional, regional-scale transient analysis of contaminant distribution in the aquifer. The flow field, transport properties, and concentration measurement parameters used in the groundwater transport analysis are fully consistent with the *TC & WM EIS* alternatives analysis. The outputs from the groundwater transport analysis were analyzed in terms of overall mass balance, concentration versus time at selected locations, and concentration distributions at selected times, which is the same process used for the alternatives impacts analysis. The level of protection provided for the drinking water pathway was evaluated by comparison against the maximum contaminant levels of the "National Primary Drinking Water Regulations" (40 CFR 141) and other benchmarks presented in Appendix O.

U.1.2 Current Site Conditions and Future Vision

This section describes the current site conditions that were used to establish the conceptual models developed to represent the non–*TC & WM EIS* actions analyzed in this *TC & WM EIS*. It is important to understand the existing conditions, including the hydrogeologic regime, the distribution of inventories, and the distribution of anthropogenic sources to evaluate the modeling methodology and the results of the analysis of long-term groundwater impacts on non–*TC & WM EIS* actions. It is also important to consider the analysis of ongoing actions at Hanford when evaluating the analysis results.

The groundwater modeling system used for the analyses in this *TC & WM EIS* captures the major features, events (e.g., releases, barrier placement), and processes associated with the hydrogeologic regime, source areas, and mass transfer and transport that govern groundwater contaminant distribution. Some of the features, events, and processes that occur or will occur at Hanford have a simplified representation in the groundwater modeling system due to the following:

- Site-specific data to support more-complex representations are not available.
- Uncertainties governing behaviors are large, and more-complex representations amplify these uncertainties in the outcomes.
- Complexities associated with local-scale processes tend to average out over long times at the regional scale.

The groundwater modeling system was designed to include only the complexities required to provide an unbiased evaluation of the alternatives in the context of the cumulative impacts. As processes were examined for inclusion in and parameterization for the *TC & WM EIS* groundwater model, primary emphasis was placed on representation of features events, and processes that distinguish outcomes among the alternatives. In cases where features, events, and processes did not strongly distinguish outcomes among the alternatives, and where significant uncertainties existed, the modeling system was simplified by exclusion. Such cases include:

- Pump-and-treat systems present at Hanford are not present in the groundwater modeling system; the future designs and operational lifetimes of such systems are unknown.
- Seasonal fluctuations at the Columbia River are not present in the groundwater modeling system; these complexities strongly influence contaminant transport over shorter time scales for sites near

the Columbia River; all of the sites associated with the alternatives are located in the Central Plateau.

- Contaminants have the same retardation factors with respect to the pore-water velocity at all times and locations.

- Infiltration and background recharge are uniform with respect to time and space in the groundwater modeling system; lack of long-term characterization data preclude a more complex approach for the purposes of this *TC & WM EIS*.

Subsequent subsections will discuss existing site conditions, corresponding model predictions of the current site conditions, and DOE-RL's future vision and expected remediation of Hanford outside of tank closure activities.

U.1.2.1 Regional Scale

This section provides a regional-scale description of the current site conditions for the non–*TC & WM EIS* actions that are modeled in this *TC & WM EIS*. This includes a discussion of the hydrogeologic regime, historical anthropogenic discharges, and distribution of inventories, followed by a comparison of the model to measured contaminant distributions, as well as a description of the ongoing actions at Hanford.

U.1.2.1.1 Regional-Scale Hydrogeologic Regime

The hydrogeologic regime describes the system of geology and groundwater flow that governs groundwater contaminant distribution. Hanford is located in south-central Washington in the Columbia Plateau and lies in the portion of the Columbia Basin known as the Pasco Basin. The site is also located in the Yakima Fold Belt, which is characterized by a series of east-west-oriented anticlinal ridges and synclinal valleys (Lindsey 1995; Reidel and Chamness 2007). The generalized stratigraphy for the site, starting at the ground surface, is the Hanford formation, followed by the Ringold Formation, and a basalt bedrock composed primarily of Miocene-aged tholeiitic flood basalts at the bottom. The Ringold Formation sediments (Ringold gravel, sand, silt, and mud) were deposited on top of the basalt and represent fluvial and lacustrine materials of the migrating, ancestral Columbia River and its tributaries (Reidel et al. 2006). The Hanford formation consists of glacio-fluvial sediments (Hanford gravel, sand, silt, and mud) resulting from cataclysmic flood events during the Pleistocene from glacial Lake Missoula (Bjornstad and Lanigan 2007; Lindsey 1995; Serne et al. 2010). Additionally, the Plio-Pleistocene (Cold Creek) Unit occurs locally at Hanford between the Hanford formation and the Ringold Formation, primarily in the western portion of Hanford, and was deposited after the period of the Columbia River incision that resulted in the deposition of the Ringold Formation and before the deposition of the Hanford formation (Reidel and Chamness 2007).

The water table beneath the Central Plateau and the groundwater divide located in the Central Plateau are two major hydrogeologic features that govern contaminant flow and transport throughout Hanford, especially for contaminant sources originating in the Core Zone. Much of the aquifer near the 200-East Area occurs in the highly permeable sediments of the Hanford formation, and there are few sources of natural recharge, making the water table flat near much of the eastern portion of the Central Plateau. Unlike the area in the eastern portion of the Central Plateau, the aquifer at Hanford generally occurs in the Ringold Formation; or where the Ringold Formation is not present, the base of the aquifer occurs at the top of a basalt layer. The groundwater divide, which strongly impacts the shape and direction of contaminant plumes originating from the Core Zone, occurs as groundwater flows toward the 200-East Area, sending part of the flow north through Gable Mountain – Gable Butte Gap (Gable Gap), and southeast toward the central and southeast portion of Hanford. Figure U–2 illustrates the regional water table and inferred directions of groundwater flow as depicted in the *Hanford Site Groundwater*

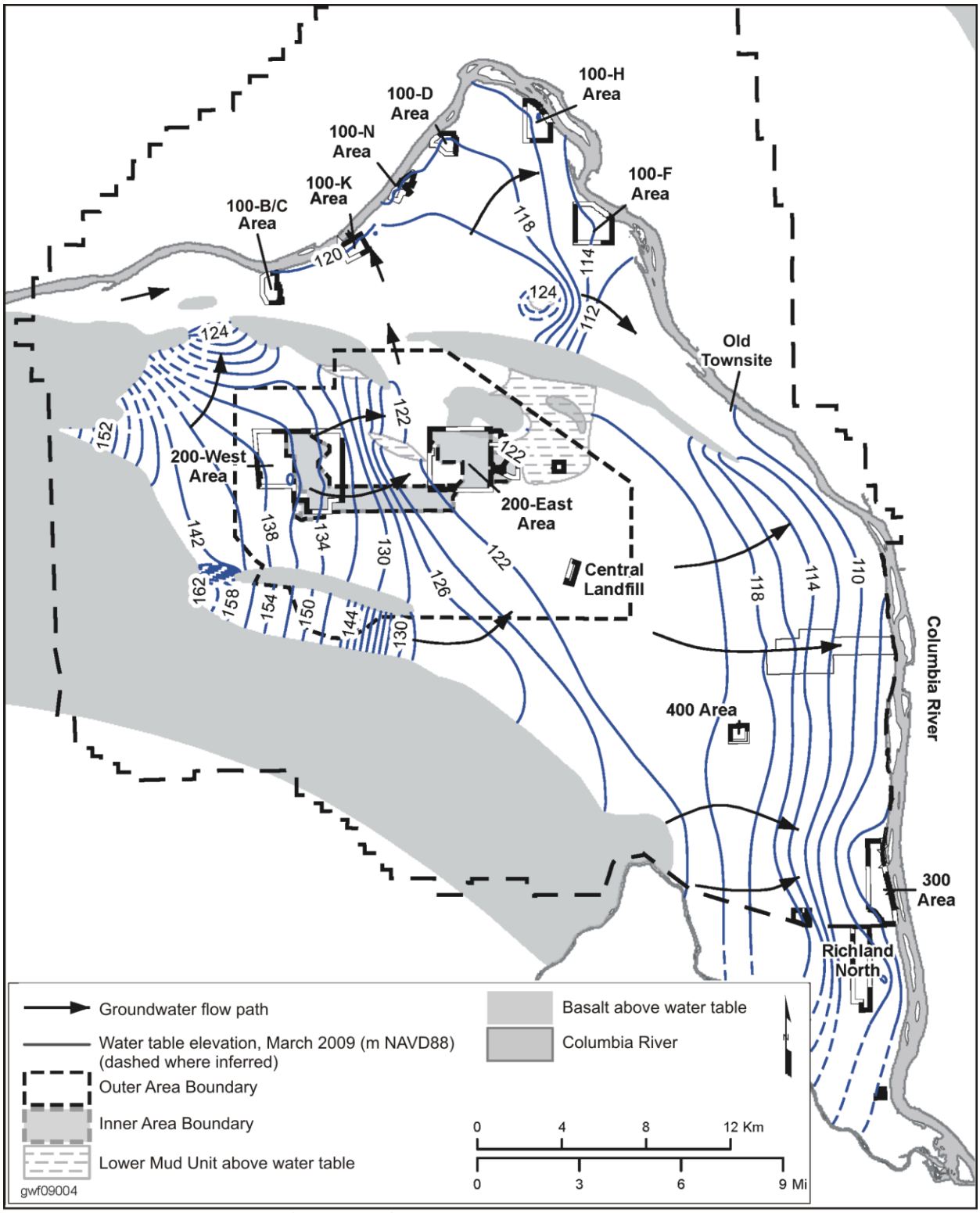
Monitoring and Performance Report for 2009 (referred to as the "2009 groundwater monitoring report") (DOE 2010a).

U.1.2.1.2 Regional-Scale Historical Anthropogenic Discharges

The effects of past anthropogenic activities have influenced contaminant distribution in the subsurface throughout the operational period of Hanford. Aqueous discharges have been released to the vadose zone as a result of different operational activities and the nature of the associated processes and structures that were needed during the operational period (DOE 2010a). For analysis purposes in this *TC & WM EIS*, aqueous sources of contamination were examined based on the amount of discharge. Sources with aqueous flux (volume per area) of less than 1 meter (3 feet) per year were categorized as moderate-discharge sources. Sources with aqueous flux (volume per area) of greater than 1 meter (3 feet) per year were categorized as heavy-discharge sources. Solid sources were categorized as low-discharge sources. The sources along the Columbia River primarily fall within the heavy- and moderate-discharge categories and include releases associated with the nuclear reactors. The sources in the central portion of the site include heavy-, moderate-, and low-discharge sites and are associated with plutonium processing and storage of waste generated from plutonium production. The sources in the 300 Area include heavy-, moderate-, and low-discharge sites and are associated with manufacturing work and experiments that were carried out during operations.

U.1.2.1.3 Regional-Scale Distribution of Inventories

Groundwater contaminant plumes underlying Hanford originate from releases during past nuclear material production activities that occurred in the 100 and 300 Areas of the Columbia River corridor and the 200 Areas of the Central Plateau. The major contaminants that make up plumes with concentrations above the drinking water standard in the upper portion of the unconfined aquifer at Hanford include hydrogen-3 (tritium), strontium-90, technetium-99, iodine-129, carbon tetrachloride, chromium, uranium, and nitrate. Of the groundwater contaminant plumes, tritium and iodine-129 have the largest areas with concentrations above drinking water standards. Table U–1 summarizes the primary locations of the major contaminant plumes in the upper portion of the unconfined aquifer. Figure U–3 shows the measured spatial distribution of the major contaminant plumes at concentrations above the drinking water standard in the upper portion of the unconfined aquifer (DOE 2010a).



Note: To convert the water table elevations from meters to feet, multiply by 3.281.
Key: Km=kilometers; m=meters; Mi=miles; NAVD88=North American Vertical Datum of 1988.
Source: DOE 2010a.

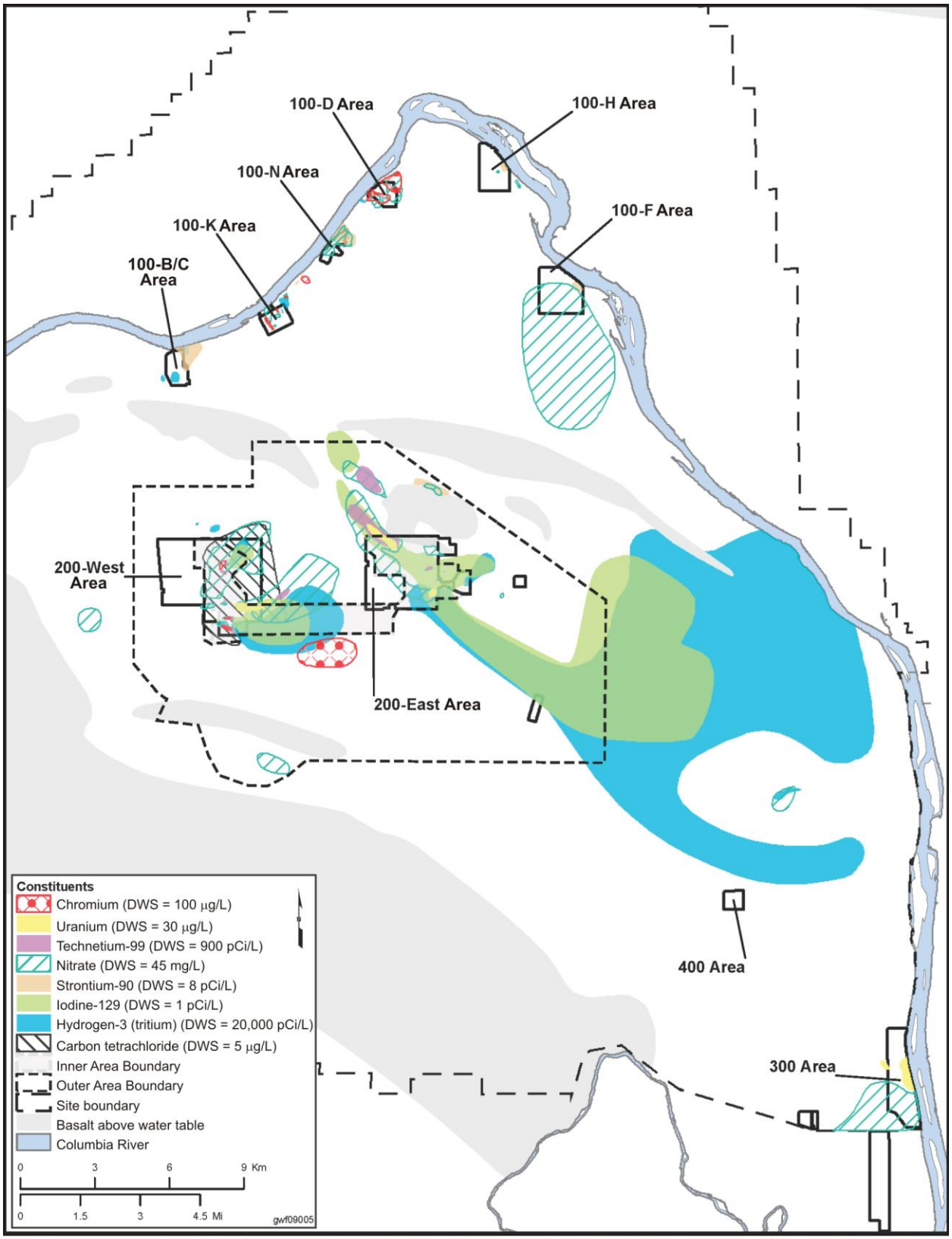
Figure U–2. Regional Water Table and Inferred Groundwater Flow Directions, March 2009

Table U–1. Primary Locations of Major Contaminant Plumes

Contaminant	Primary Locations	Primary Area (km^2)	Drinking Water Standard[a]	Mobility and Half-Life
Radionuclides				
Hydrogen-3 (tritium)	200-East Area, 200-West Area, 300 Area	126.5	20,000 pCi/L	Mobile; 12.3 years
Strontium-90	100-N Area, Gable Mountain	1.9	8 pCi/L	Moderate; 28.8 years
Technetium-99	Gable Mountain, 200-West Area	2.4	900 pCi/L	Mobile; 211,000 years
Iodine-129	200-East Area, 200-West Area	58.8	1 pCi/L	Mobile; 15.7 million years
Chemicals				
Carbon tetrachloride	200-West Area	11.5	5 µg/L	Mobile (denser than water)
Chromium	100-K Area, 100-H Area	2.0	100 µg/L	Mobile (hexavalent)
Nitrate	100-F Area, 200-East Area, 200-West Area	36.7	45,000 µg/L	Mobile
Uranium	200-East Area, 200-West Area, 300 Area	1.5	30 µg/L	Moderate; 246,000 years (U-234) 700 million years (U-235) 4.5 billion years (U-238)

[a] Drinking water standards are included because the figures from the *Hanford Site Groundwater Monitoring and Performance Report for 2009* (DOE 2010a) use them for mapping purposes. Note that the benchmark standards used for mapping purposes in this *Tank Closure and Waste Management Environmental Impact Statement for the Hanford Site, Richland, Washington* are listed in Appendix O.

Key: µg/L=micrograms per liter; km^2=square kilometers; pCi/L=picocuries per liter; U=uranium.

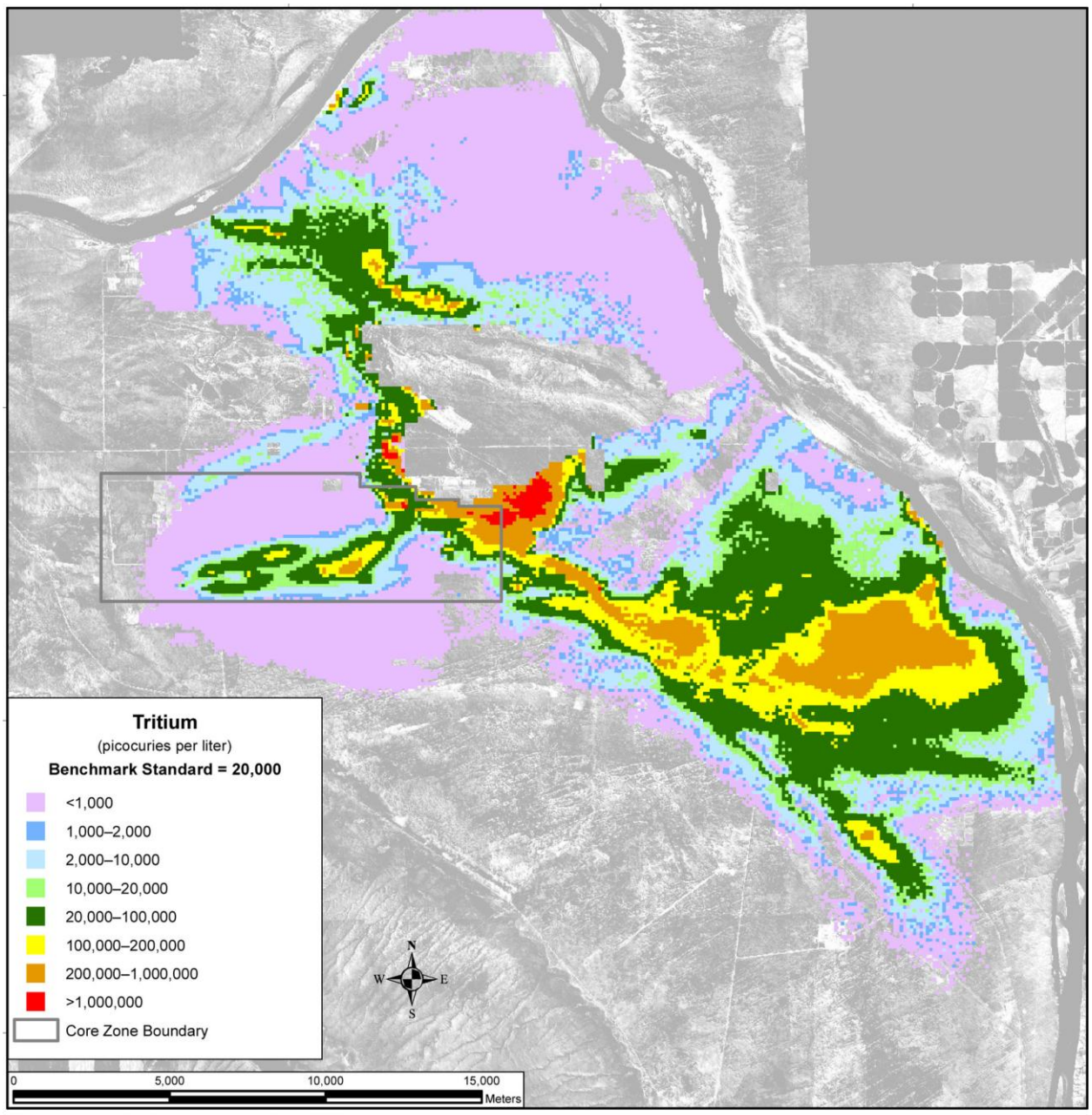


Key: µg/L=micrograms per liter; DWS=drinking water standard; Km=kilometers; mg/L=milligrams per liter; Mi=miles; pCi/L=picocuries per liter.
Source: DOE 2010a.

Figure U–3. Distribution of the Major Contaminant Plumes at Concentrations Above the Drinking Water Standard in the Upper Portion of the Unconfined Aquifer

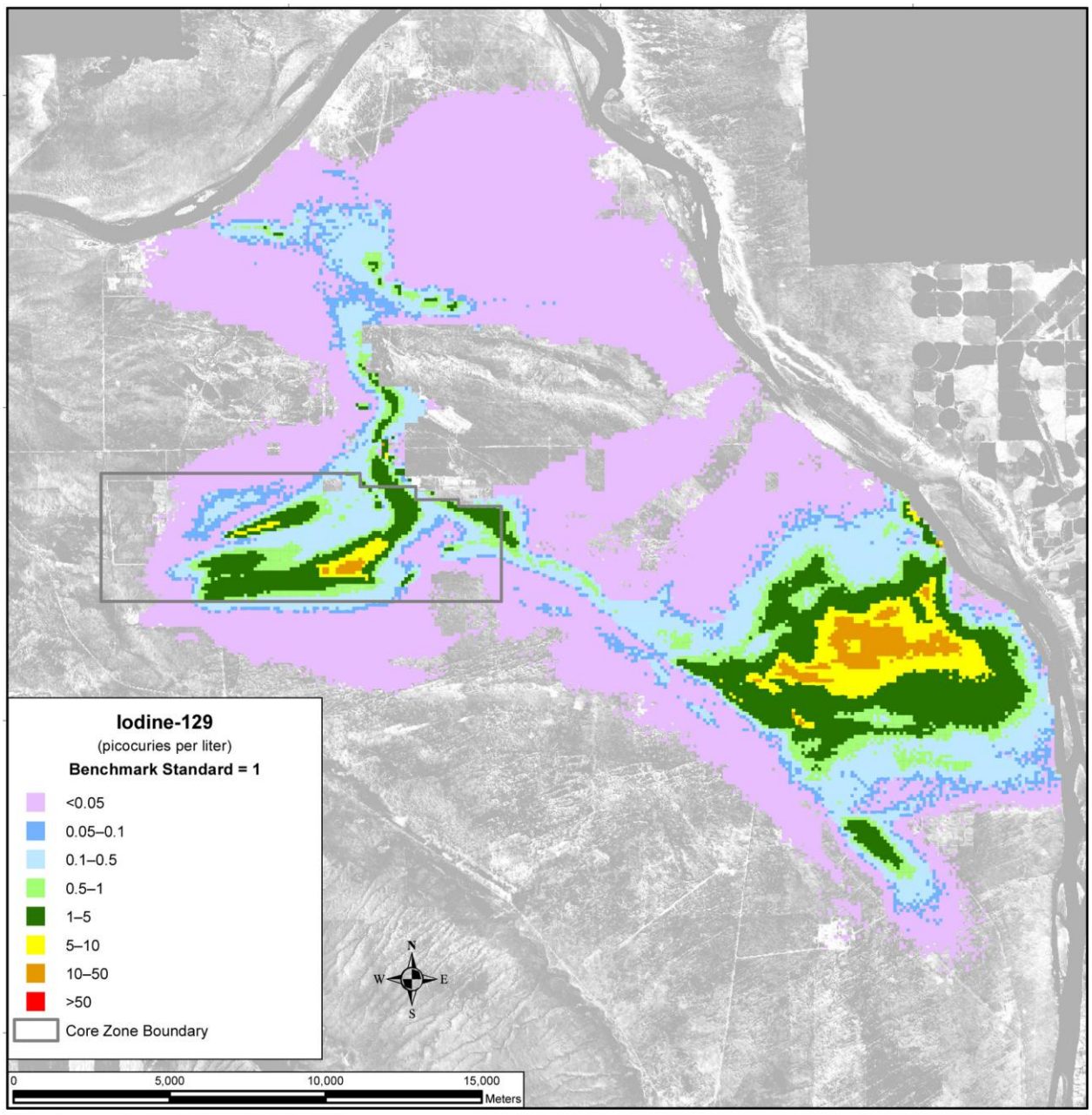
U.1.2.1.4 Regional Comparison of Modeled Versus Measured Spatial Contaminant Distributions

This section presents the results of the impacts analysis of non–*TC & WM EIS* sources in terms of the spatial distribution of COPC concentrations in calendar year (CY) 2010 and compares the results to the *Hanford Site Groundwater Monitoring and Performance Report for 2009* (referred to as the "2009 groundwater monitoring report") (DOE 2010a). Concentrations of each radionuclide and chemical are indicated by a color scale that is relative to the benchmark concentration. Concentrations greater than the benchmark concentration are indicated by the fully saturated colors green, yellow, orange, and red in order of increasing concentration. Concentrations less than the benchmark concentration are indicated by the faded colors green, blue, indigo, and violet in order of decreasing concentration. Note that the concentration ranges are on a logarithmic scale to facilitate visual comparison of concentrations that vary over three orders of magnitude. Figures U–4 through U–12 are maps of the projected concentrations of contaminants in groundwater from the *TC & WM EIS* models for tritium, iodine-129, strontium-90, technetium-99, uranium-238, carbon tetrachloride, chromium, nitrate, and total uranium, respectively.



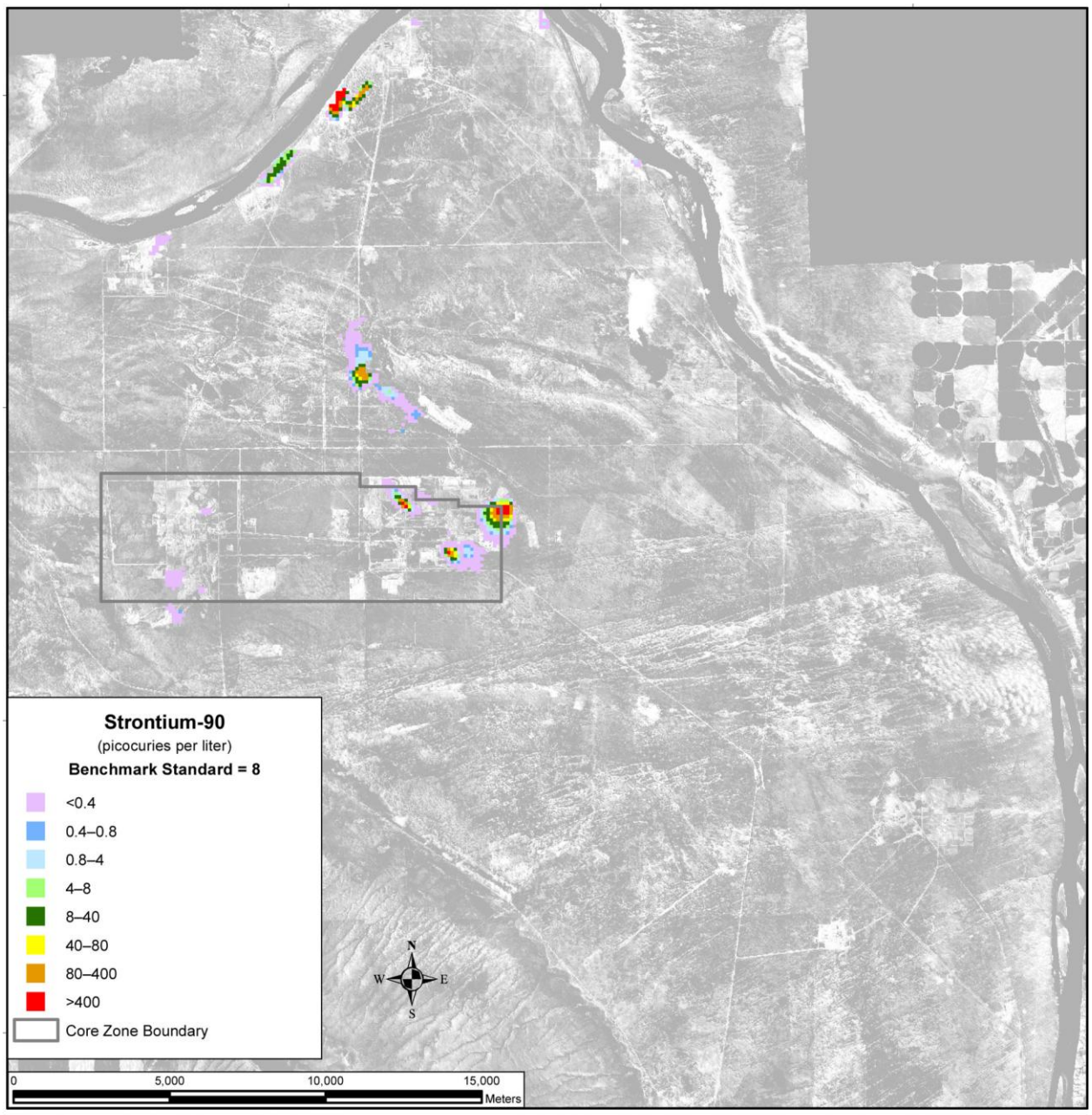
Note: To convert meters to feet, multiply by 3.281.

Figure U–4. Spatial Distribution of Groundwater Hydrogen-3 (Tritium) Concentration (Non–*TC & WM EIS* Sources), Calendar Year 2010



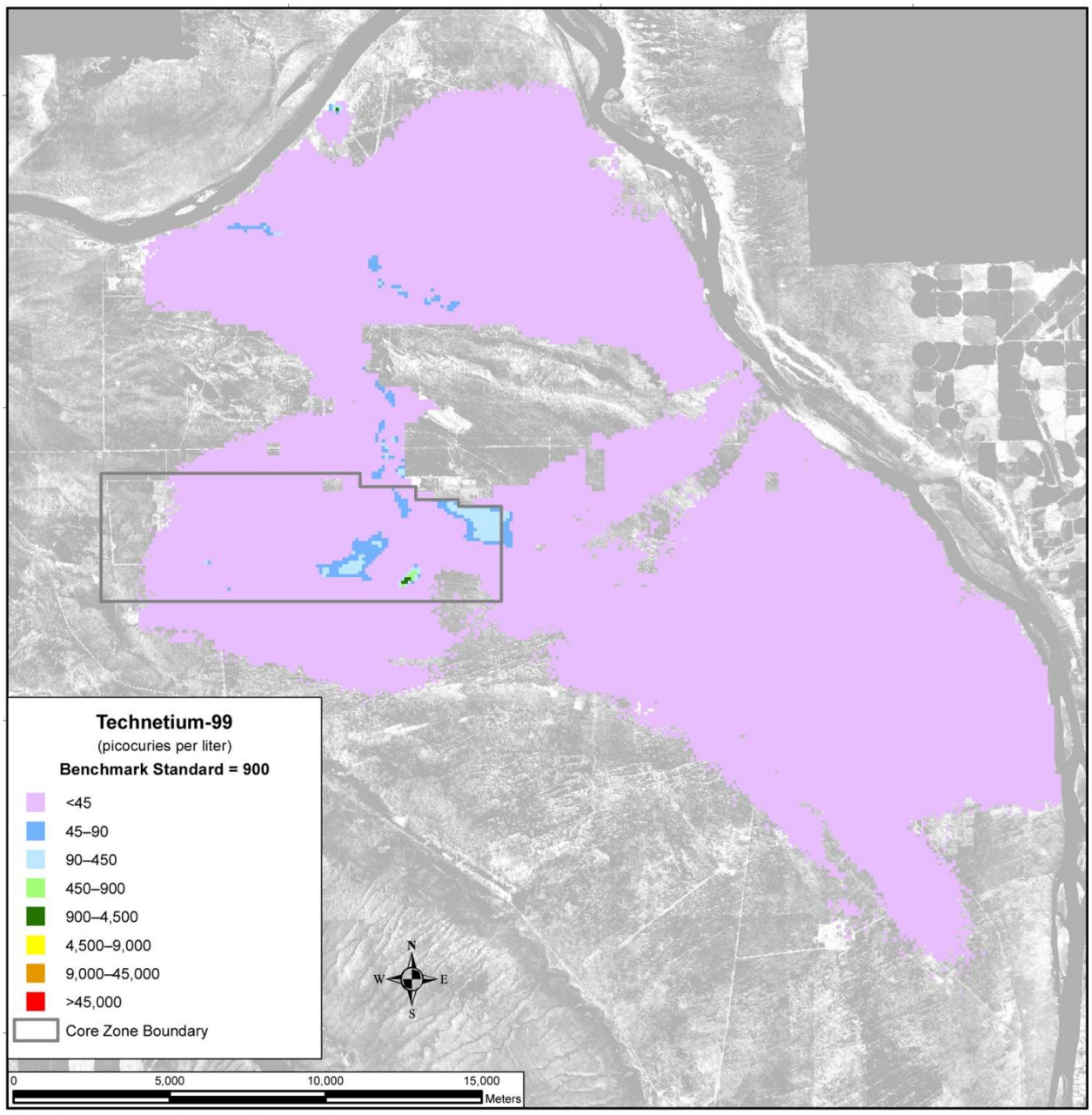
Note: To convert meters to feet, multiply by 3.281.

Figure U–5. Spatial Distribution of Groundwater Iodine-129 Concentration (Non–*TC & WM EIS* Sources), Calendar Year 2010



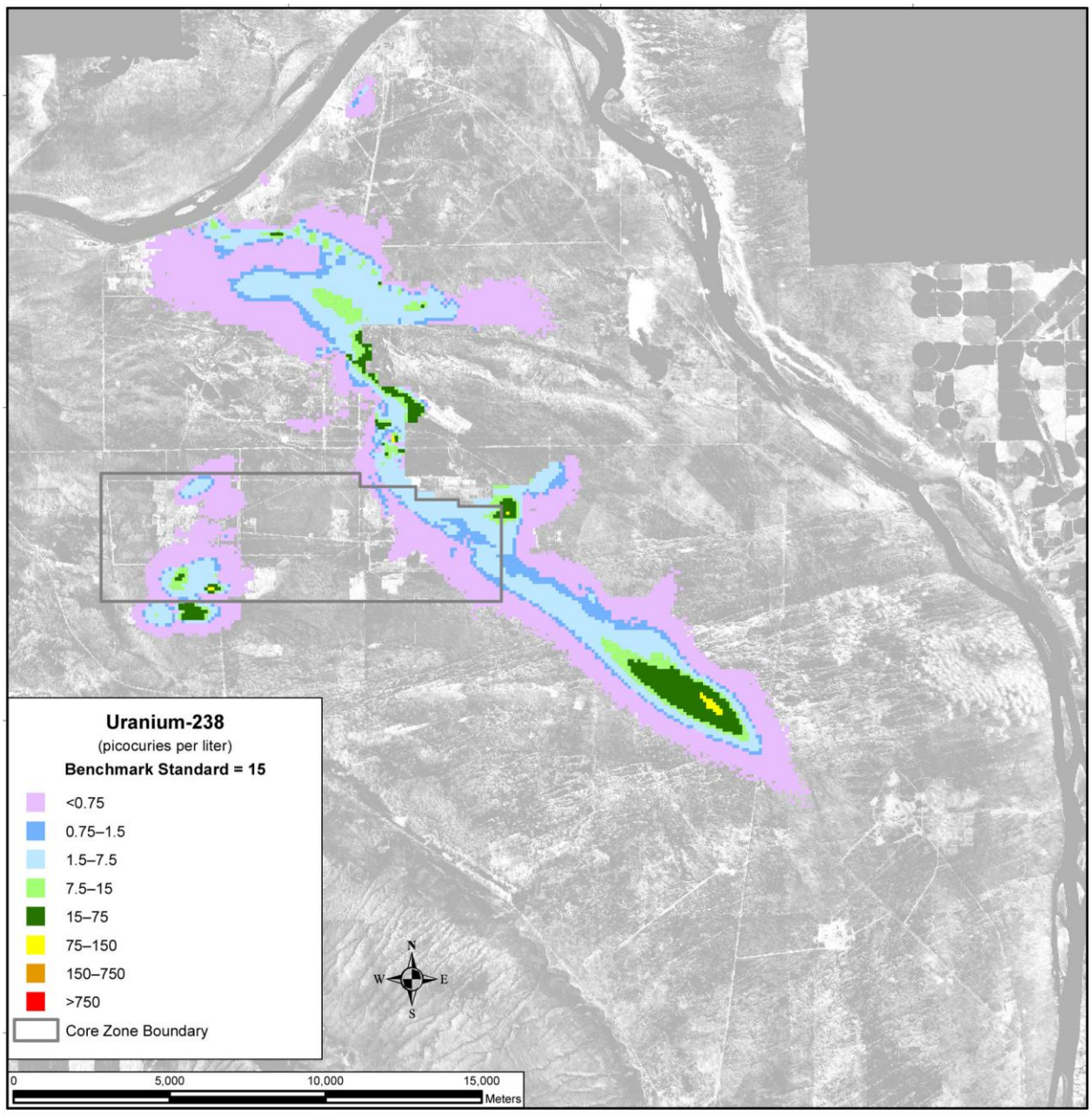
Note: To convert meters to feet, multiply by 3.281.

Figure U–6. Spatial Distribution of Groundwater Strontium-90 Concentration (Non–*TC & WM EIS* Sources), Calendar Year 2010



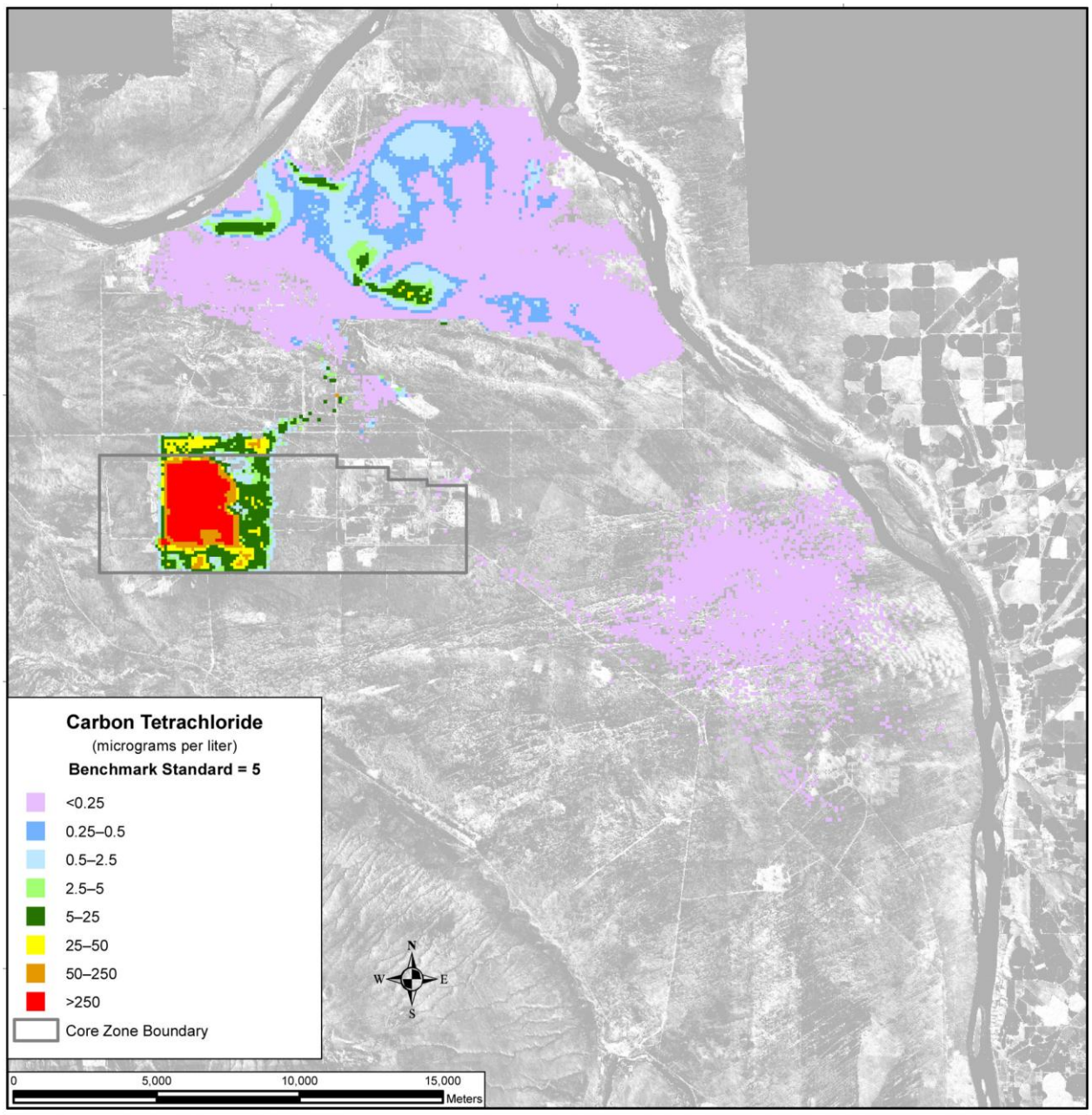
Note: To convert meters to feet, multiply by 3.281.

Figure U–7. Spatial Distribution of Groundwater Technetium-99 Concentration (Non–*TC & WM EIS* Sources), Calendar Year 2010



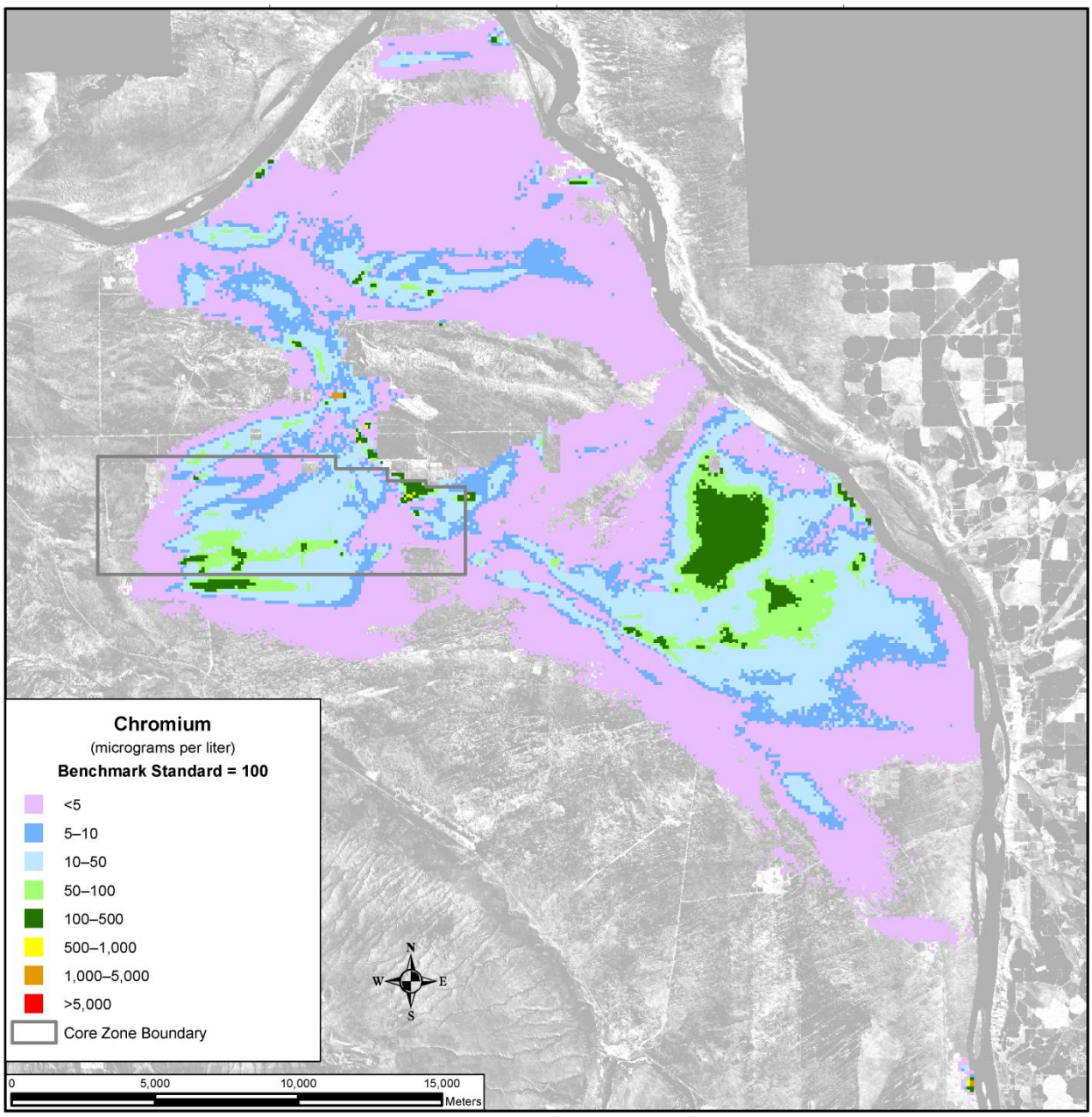
Note: To convert meters to feet, multiply by 3.281.

Figure U–8. Spatial Distribution of Groundwater Uranium-238 Concentration (Non–*TC & WM EIS* Sources), Calendar Year 2010



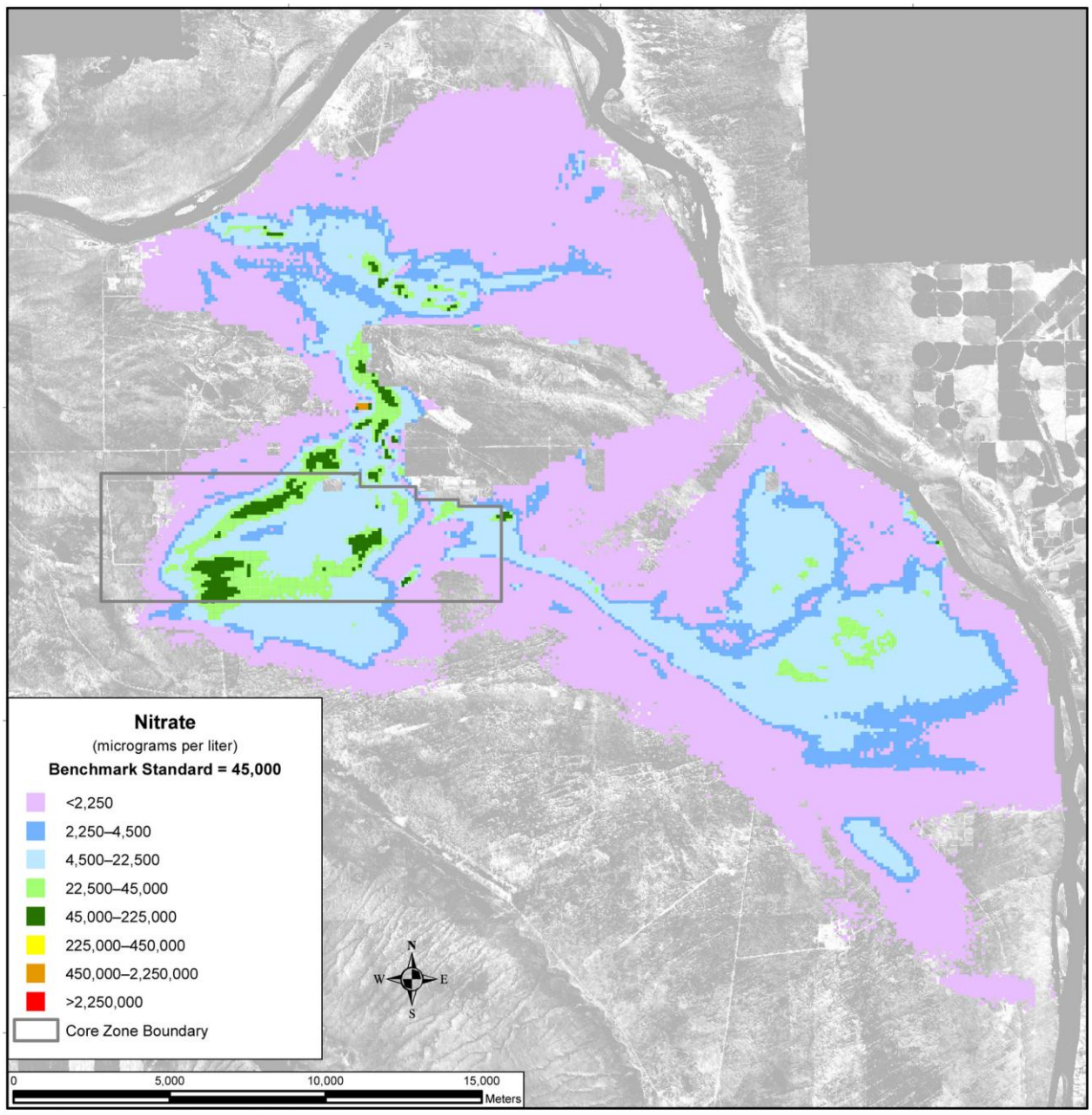
Note: To convert meters to feet, multiply by 3.281.

Figure U–9. Spatial Distribution of Groundwater Carbon Tetrachloride Concentration (Non–*TC & WM EIS* Sources), Calendar Year 2010



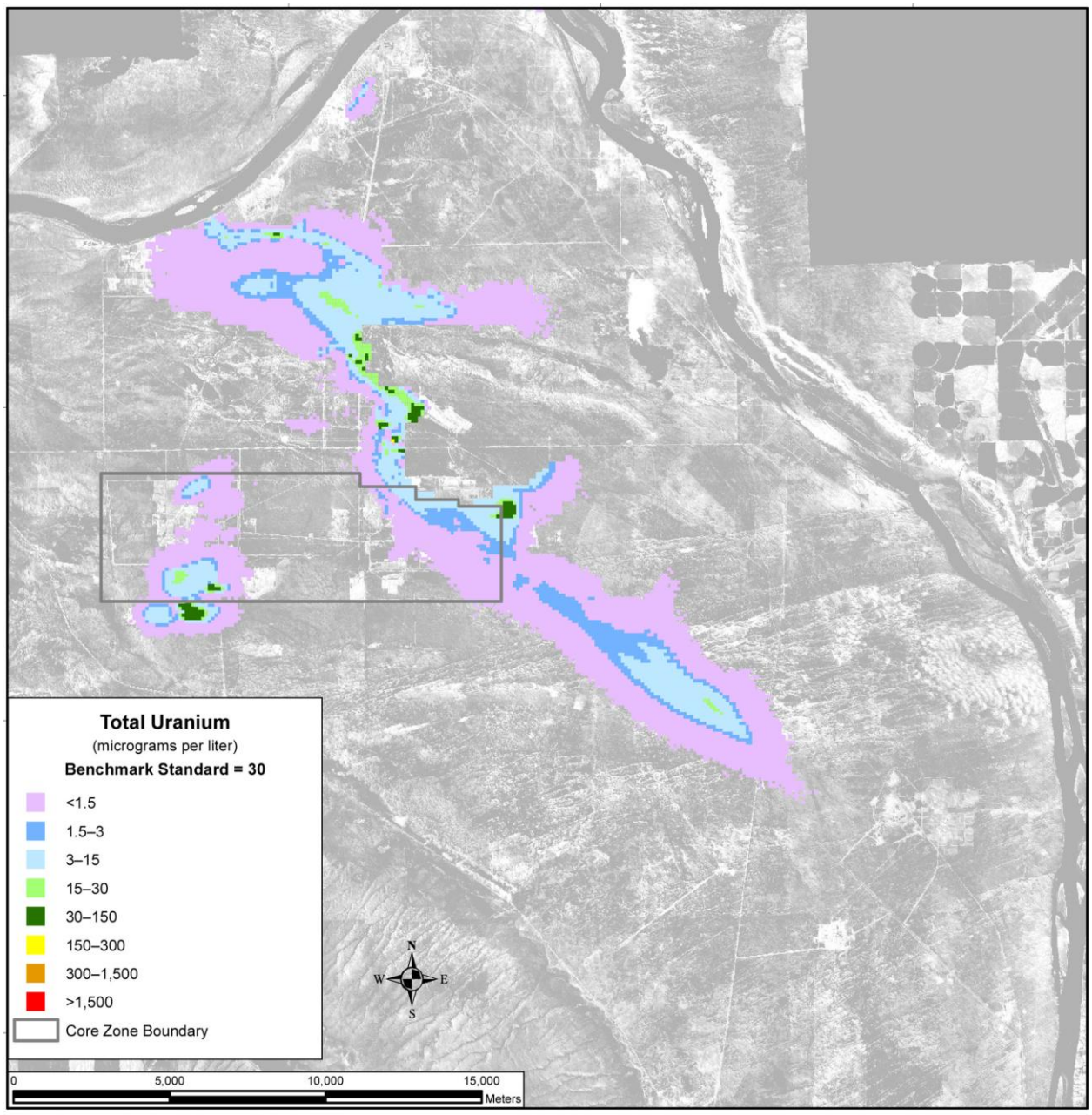
Note: To convert meters to feet, multiply by 3.281.

Figure U–10. Spatial Distribution of Groundwater Chromium Concentration (Non–*TC & WM EIS* Sources), Calendar Year 2010



Note: To convert meters to feet, multiply by 3.281.

Figure U–11. Spatial Distribution of Groundwater Nitrate Concentration (Non–*TC & WM EIS* Sources), Calendar Year 2010



Note: To convert meters to feet, multiply by 3.281.

Figure U–12. Spatial Distribution of Groundwater Total Uranium Concentration (Non–*TC & WM EIS* Sources), Calendar Year 2010

In general, at the regional scale, the simulations of groundwater transport in this *TC & WM EIS* replicate the values measured in the field to a close order of magnitude, particularly for discharges to cribs and trenches (ditches), where the historic measurements are most complete and show the strongest evidence of past-practice operations (more detail at the subregional scale is presented in Section U.1.2.2). As shown in Appendices N and O, the agreement is good for both *TC & WM EIS* alternative sources and non–*TC & WM EIS* sources. There are three contaminant plumes for which the simulated plumes are in greater disagreement with observations. All are non–*TC & WM EIS* sources, including the carbon tetrachloride plume in the 200-West Area (see Figure U–9) and the uranium-238 plume (see Figure U–8) and total uranium plume (see Figure U–12) in the 200-East Area.

Prediction of carbon tetrachloride concentrations in the unconfined aquifer is qualitatively more uncertain than for all of the other COPCs in the groundwater analysis. These uncertainties include the following:

- The mode of transport, whether as a dissolved solute or a dense nonaqueous-phase liquid (DNAPL)
- The large uncertainty in the physical form, co-contaminants, quantity, and concentration of carbon tetrachloride in the original source materials
- The strong sensitivity of model outcomes to uncertainties in transport properties

Simulation results for DNAPL flow and transport in the vadose zone at the 200-West Area exhibit sensitivities of more than several orders of magnitude to uncertainties in input parameters, which suggests that carbon tetrachloride contaminant behavior is not well understood or constrained (Oostrom et al. 2004). For purposes of the *TC & WM EIS* long-term groundwater cumulative impacts analysis, these vadose zone uncertainties were recognized to result in variations in predicted groundwater impacts that are qualitatively greater than those for other COPCs in the analysis.

Therefore, the *TC & WM EIS* analysis of the carbon tetrachloride contaminant transport was simplified (relative to all other COPCs) by eliminating vadose zone flow and transport from the analysis. The source term for the groundwater flow and transport for the major component of the 200-West Area carbon tetrachloride plume was an estimate of the mass of the dissolved carbon tetrachloride present in the aquifer. (Several minor sources of carbon tetrachloride dissolved in water at low concentrations were modeled separately.) This simplified modeling methodology for the bulk of the carbon tetrachloride plume in the 200-West Area and reduced the uncertainties from contaminant transport modeling through the vadose zone.

Hartman and Webber (2008) provided an estimate of the range of dissolved carbon tetrachloride in the unconfined aquifer in the 200-West Area of 55,900 to 64,600 kilograms (123,000 to 142,000 pounds). This *TC & WM EIS* used a value near the upper end of this range, 65,000 kilograms (143,000 pounds). This total inventory was assumed to be present in the unconfined aquifer starting in 2005, and the concentrations were modeled forward from this initial condition. In addition, because of the uncertainties in the design and implementation of the groundwater remediation system for the 200-ZP-1 Operable Unit, no credit was taken in the *TC & WM EIS* modeling for removal or containment of carbon tetrachloride (Section U.1.3.4.2 contains a sensitivity analysis examining the effect of containment and removal of carbon tetrachloride, chromium, and technetium-99 concentrations at the Core Zone Boundary and the Columbia River nearshore.) Additionally, simplifying assumptions were made that (1) there will be no continuing flux from the vadose zone to the unconfined aquifer, and (2) there is no degradation of carbon tetrachloride to other chemical forms. As documented in the *Technical Guidance Document for Tank Closure Environmental Impact Statement Vadose Zone and Groundwater Revised Analyses* (DOE 2005), the retardation factor for carbon tetrachloride was modeled as 1, which corresponds to a distribution coefficient of 0 milligrams per liter (i.e., sorption is not a factor). In light of these approximations, the predicted concentrations of carbon tetrachloride should be considered qualitatively more uncertain than other contaminants in the cumulative impacts analysis.

Figure U–9 shows the predicted spatial distribution of carbon tetrachloride in the unconfined aquifer from non–*TC & WM EIS* sources in CY 2010. Note that the bulk of the mass of carbon tetrachloride is confined to a roughly rectangular area beneath 200-West Area. This is consistent with the assumed starting configuration. Note also that, in the absence of the containment (i.e., groundwater pump and treat was not included in the model), part of the carbon tetrachloride mass from the 200-West Area has migrated north through Gable Gap. Gable Mountain Pond, which included a small inventory of dissolved carbon tetrachloride, is a relatively small contributor to the mass of carbon tetrachloride north of Gable

Mountain. The mass of carbon tetrachloride north of Gable Mountain is in excess of that observed from field measurements. The excess northern migration of mass is caused by not considering containment in the modeling and by uncertainty in the location of the highly conductive Hanford/Ringold gravel contact. This uncertainty is discussed in detail in Appendix L.

Uranium-238 and total uranium simulation results show higher impacts resulting from heavy-discharge facilities in the 200-East Area (e.g., B Pond) than actually observed. The disagreement of these plumes with field measurements may be due to two possible areas of uncertainty that may dominate the simulation of these impacts. The first is the uncertainty regarding the inventory of uranium-238 and total uranium in the heavy-discharge ponds (see Appendix S), which is estimated to be approximately 50 percent. The second, and probably more important source of uncertainty, is the interaction of uranium-238 and total uranium with subsurface materials beneath these facilities. The *TC & WM EIS* analysis is based on a distribution coefficient for uranium of about 0.6 milliliters per gram (DOE 2005). This value, although appropriate for far-field conditions in the unconfined aquifer, is likely not representative of the conditions beneath the heavy-discharge sources (e.g., B Pond). Therefore, the prediction of the uranium-238 and total uranium contaminant plumes for large non–*TC & WM EIS* sources should be considered an overestimate of the actual impacts by about an order of magnitude.

U.1.2.1.5 Regional Consideration of Ongoing Hanford Site Activities

The potentially applicable laws, regulations, and other requirements that affect the activities associated with the *TC & WM EIS* alternatives are listed in Chapter 8. The *TC & WM EIS* groundwater modeling methodology was designed and implemented to evaluate the long-term impacts of the Tank Closure, Fast Flux Test Facility (FFTF) Decommissioning, and Waste Management alternatives in a manner consistent with these requirements. In particular, development of the alternatives and the data needed to evaluate the alternatives was driven by these and associated quality assurance and data acceptance requirements. The same methodology was extended to other sources (non–*TC & WM EIS* sources) to provide a context for evaluating the alternatives.

The regulatory framework for cleanup of non–*TC & WM EIS* sources includes considerations and processes that are outside the scope of Chapter 8. The regulatory framework for the non–*TC & WM EIS* sources includes CERCLA, which provides the basis for evaluating the end-state conditions likely to result from the cleanup activities. The major Hanford cleanup actions that involve non–*TC & WM EIS* sources include river corridor sources and associated groundwater and Central Plateau non-tank-farm sources and associated groundwater. An overview of Hanford cleanup activities, including the decisionmaking process, cleanup requirements, and goals and milestones, is provided in the *Central Plateau Cleanup Completion Strategy* (DOE 2009).

For the purposes of evaluating the long-term impacts of the alternatives in the context of the non–*TC & WM EIS* sources, this appendix contains discussion of the groundwater modeling methodology and results. Comparison of the model results with field conditions is included in this discussion to provide additional information regarding processes and assumptions in the modeling and their potential influence on the comparison of the alternatives. In addition, this appendix includes a series of discussions (at the subregional level in Section U.1.2.2) of some salient features of the CERCLA cleanup process for non–*TC & WM EIS* sources. The purpose of these discussions is to provide additional context to the modeling results by providing insight into CERCLA cleanup goals that are not reflected in the modeling methodology or results.

Under CERCLA and Resource Conservation and Recovery Act (RCRA) processes, cleanup at Hanford has been under way since the mid-1990s. The first stage in this process involved cleanup actions to remove highly radioactive spent nuclear fuel and other materials. Other cleanup actions have focused on the excavation of waste sites, followed by treatment and/or disposal of contaminated materials,

installation of groundwater treatment systems, and removal of surplus facilities. Cleanup and closure decisions have been reached using both CERCLA and RCRA authorities. CERCLA and RCRA processes establish a decisionmaking framework, milestones to complete cleanup, cleanup goals and levels that the actions must meet, and a description of the anticipated end state of the cleanup.

In general, remedial investigation/feasibility study (RI/FS) work plans are prepared initially under CERCLA for source operable units containing liquid-waste sites that constitute primary sources of groundwater contamination and for the corresponding groundwater operable units. Once the basic RI/FS process is under way for these operable units, additional RI/FS work plans are prepared to investigate burial grounds and other low-risk source operable units. To accelerate cleanup of the river corridor area, expedited response and interim remedial actions were implemented. The responses/actions resulting from the interim-action Records of Decision (RODs) addressing contaminated soil consist principally of excavating contaminated soil for treatment (as required) and disposal to protect groundwater from future contamination. The responses for contaminated groundwater are disposing of it as interim actions to keep key contaminants from reaching the Columbia River. In general, CERCLA RODs require contaminated soils to be cleaned to levels that will keep future groundwater contamination at or below drinking water or aquatic standards. Specific CERCLA RODs for different parts of Hanford are listed below under each subregional discussion.

Major milestones of the Hanford Federal Facility Agreement and Consent Order, also known as the Tri-Party Agreement (TPA), have been established to complete investigation and resultant remedial actions for certain operable units. Interim milestones serve to demonstrate acceptable progress toward completion of the major milestones. Cleanup performed in accordance with the major and interim milestones will meet CERCLA requirements for the river corridor source and groundwater operable units. Major milestones specific to different subregions are listed below under each subregional discussion.

Under CERCLA, remedial action objectives (RAOs) are descriptions of what the remedial action is expected to accomplish (i.e., media- or site-specific goals for protecting human health and the environment). They are defined as specifically as possible and are developed based on anticipated future land use, exposure assumptions, and potential applicable or relevant and appropriate requirements (ARARs). RAOs provide a basis for evaluating the capability of a specific remediation action to achieve compliance with potential ARARs and the intended level of risk protection for human health and the environment. The objectives for protection of human health and the environment are achieved by eliminating, reducing, or controlling the site risks posed through each exposure pathway through treatment, engineering, or institutional controls.

The goal of RAOs is to restore groundwater to drinking water standards and ensure that the aquatic life in the Columbia River is protected by achieving ambient water quality standards where there are ecological receptors, including within the hyporheic (a region near or around the stream bed) zone. The U.S. Environmental Protection Agency (EPA) states the following in the National Contingency Plan regulations implementing CERCLA (40 CFR 300.430(a)(1)(iii)(F)):

> EPA expects to return usable ground waters to their beneficial uses wherever practicable, within a timeframe that is reasonable given the particular circumstances of the sites. When restoration of ground water to beneficial uses is not practicable, EPA expects to prevent further migration of the plume, prevent exposure to the contaminated ground water, and evaluate further risk reduction.

For more information, see the *Summary of Key Existing EPA CERCLA Policies for Groundwater Restoration* (EPA 2009).

This end-state vision provides the reasonable future conditions that will result from river corridor cleanup actions. In the aggregate, the goal of CERCLA actions is to mitigate existing sources of groundwater and surface-water contamination so that both Federal and state human health and ecological protection criteria will be achieved.

U.1.2.2 Subregional Scale

This section provides a description of the current site conditions for the past-practice actions that are modeled in this *TC & WM EIS* by subregion. A discussion of the hydrogeologic regime, historical anthropogenic discharges, and distribution inventories, followed by a comparison of the modeled versus measured contaminant distributions and a description of the ongoing actions, is included for each subregion evaluated in the cumulative impacts analysis.

U.1.2.2.1 100 Areas

The 100 Areas comprise the groundwater sources in the northern portion of Hanford along the "horn" of the Columbia River, where the nuclear reactors were built. The 100 Areas include the 100-B, -C, -K, -N, -D, -H, and -F Areas.

U.1.2.2.1.1 100 Areas Hydrogeologic Regime

The hydrogeologic regime describes the system of geology and groundwater flow that governs groundwater contaminant distribution. The general stratigraphy across the 100 Areas includes suprabasalt sediments composed of Holocene deposits, the Hanford formation, all major units of the Ringold Formation, and basalt. The 100 Areas are located on the north limb of the Wahluke syncline, except for the 100-B and -C Areas, which are centered or just to the south of the axis of the syncline (Lindsey 1992). Ringold mud is present in the eastern portion of the 100 Areas but pinches out moving toward the west. Ringold mud is an important geologic feature to note in the 100 Areas because it is relatively impermeable to the downward migration of groundwater (DOE 2010a).

In the 100 Areas, the vadose zone predominantly occurs in the Hanford gravels and sands, except the 100-N Area, where the vadose zone also comprises Ringold gravel. Figures U–13 through U–15 depict cross sections that are typical of the vadose zone lithology in the 100 Areas. The vadose zone ranges in thickness up to approximately 30 meters (98 feet) in depth. Toward the eastern portion of the 100 Areas, the vadose zone is generally shallower, to depths of around 13 meters (42.7 feet) (Lindsey 1992).

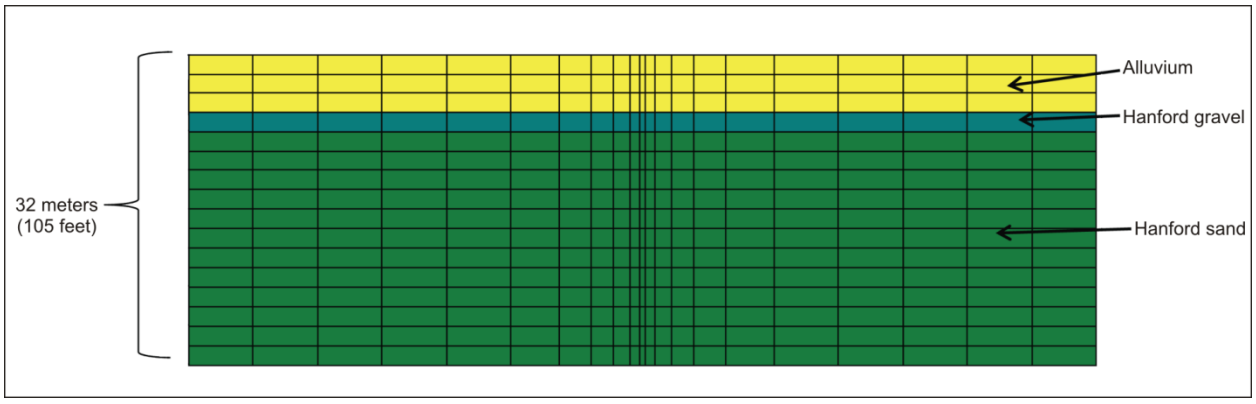


Figure U–13. West-to-East Cross Section of Vadose Zone Lithology for 183-KE Filter Waste Facility Drywell

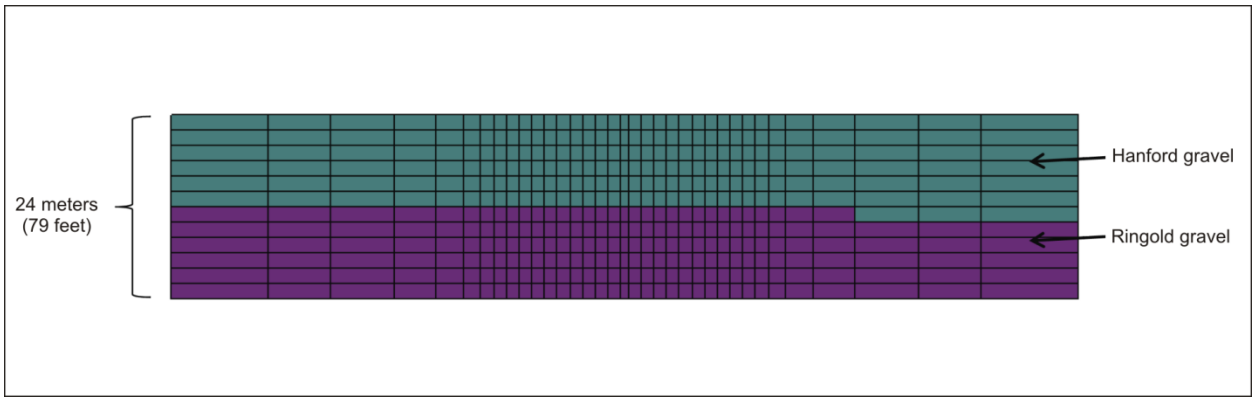


Figure U–14. Northwest-to-Southwest Cross Section of Vadose Zone Lithology for 1325-N Liquid Waste Disposal Facility

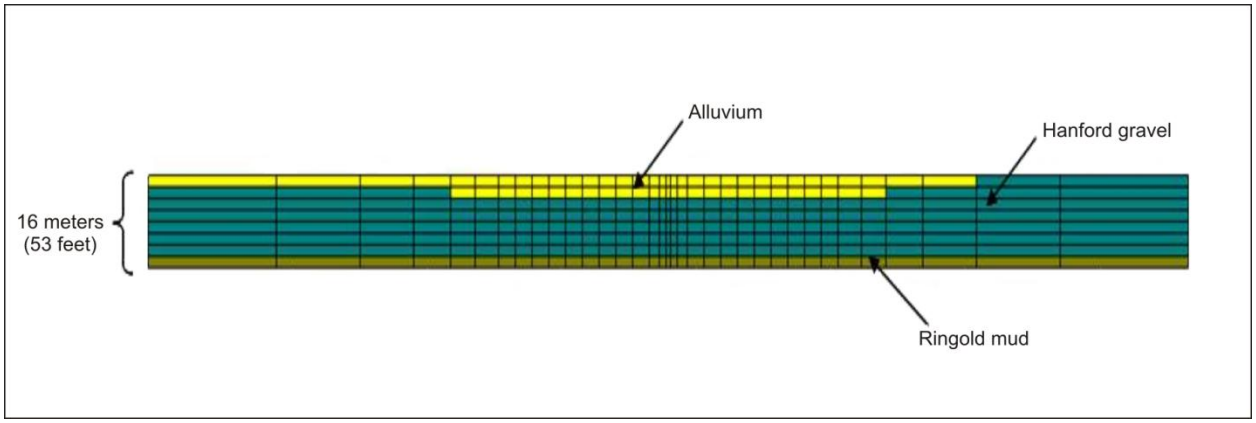
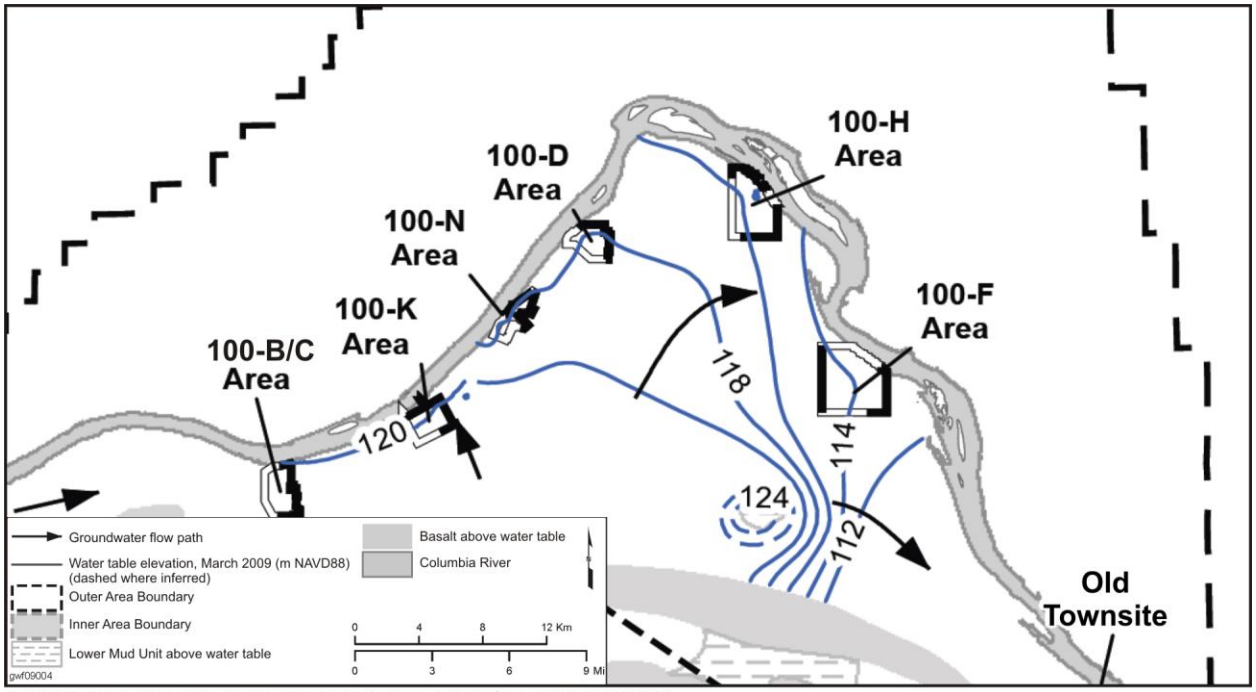


Figure U–15. West-to-East Cross Section of Vadose Zone Lithology for 105-H Pluto Crib

Groundwater enters the 100 Areas south from the gaps between Umtanum Ridge, Gable Butte, and Gable Mountain and from upgradient areas along the Columbia River. Groundwater flows primarily to the north and discharges to the Columbia River. The water table ranges from between 120 meters (394 feet) above mean sea level in the western portion of the 100 Areas to approximately 114 meters (374 feet) above mean sea level in the eastern portion of the 100 Areas. The water table gradient in the 100 Areas is a major influence on the direction of flow, especially near the "horn," where the movement of water through the 100 Areas changes from north and northwest toward the Columbia River to east toward the Columbia River. In addition, note that the Columbia River does cause seasonal variations in local flow (DOE 2010a).

Figure U–16 illustrates the 100 Areas water table and inferred directions of groundwater flow as depicted in the 2009 groundwater monitoring report (DOE 2010a).



Note: To convert the water table elevations from meters to feet, multiply by 3.281.
Key: Km=kilometers; m=meters; Mi=miles; NAVD88=North American Vertical Datum of 1988.
Source: Modified from DOE 2010a.

Figure U–16. 100 Areas Water Table and Inferred Groundwater Flow Directions, March 2009

U.1.2.2.1.2 100 Areas Historical Anthropogenic Discharges

The effects of past anthropogenic activities have influenced contaminant transport in the subsurface in the 100 Areas. The primary sources of contamination in the 100 Areas were the support systems of the nuclear reactors and the structures and processes associated with reactor operations. These operations generated large quantities of liquid and solid waste. Releases to the vadose zone included releases from temporary surface impoundments, cribs and trenches (ditches), ponds, burial grounds, and unplanned-release sites. Though anthropogenic activities have diminished over time, residual effects continue to influence contaminant transport (DOE 2010a). For analysis purposes in this *TC & WM EIS*, aqueous sources of contamination were examined based on the amount of discharge. Sources with aqueous flux (volume per area) of less than 1 meter (3 feet) per year were categorized as moderate-discharge sources. Sources with aqueous flux of greater than 1 meter (3 feet) per year were categorized as heavy-discharge sources. Solid sources were categorized as low-discharge sources. The majority of the anthropogenic contaminant sources in the 100 Areas fall into the heavy- or moderate-discharge categories.

U.1.2.2.1.3 100 Areas Comparison of Modeled Versus Measured Spatial Contaminant Distributions

This section discusses the distribution of inventories as described in the 2009 groundwater monitoring report (DOE 2010a) and compares the results of the impacts analysis of past-practice sources in the 100 Areas in terms of the spatial distribution of COPC concentrations in CY 2010. Concentrations of each radionuclide and chemical are indicated by a color scale that is relative to the benchmark concentration. Concentrations greater than the benchmark concentration are indicated by the fully saturated colors green, yellow, orange, and red in order of increasing concentration. Concentrations less than the benchmark concentration are indicated by the faded colors green, blue, indigo, and violet in order of decreasing concentration. Note that the concentration ranges are on a logarithmic scale to facilitate visual comparison of concentrations that vary over three orders of magnitude.

Chromium, nitrate, strontium-90, and tritium are the primary contaminants that make up the contaminant plumes in the majority of the 100 Areas. Contamination is generally limited to the unconfined aquifer in the 100 Areas. Concentrations in aquifer tubes along the Columbia River (screened in the Ringold upper mud) indicate that concentrations in some shallow tubes are lower than in the mid-depth and deeper tubes because groundwater is mixed with water from the Columbia River (DOE 2010a). Figure U–17 shows the spatial distribution of chromium concentrations in groundwater in the 100 Areas as predicted in the impacts analysis of past-practice sources. In general, the simulations of groundwater transport replicate the values measured in the field. Figures U–18 through U–20 show the spatial distributions of the major chromium plumes in the 100 Areas as reported in the 2009 groundwater monitoring report.

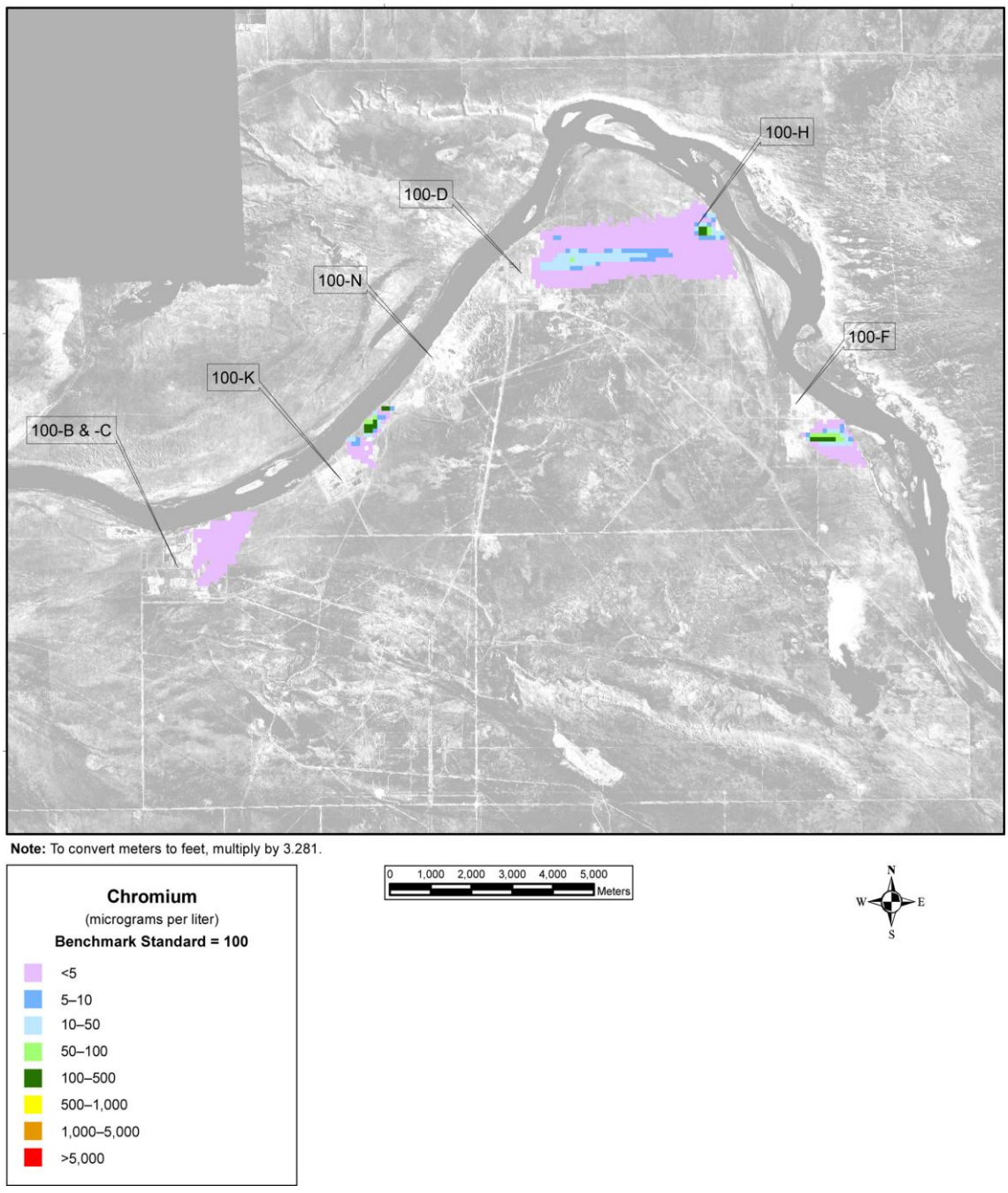
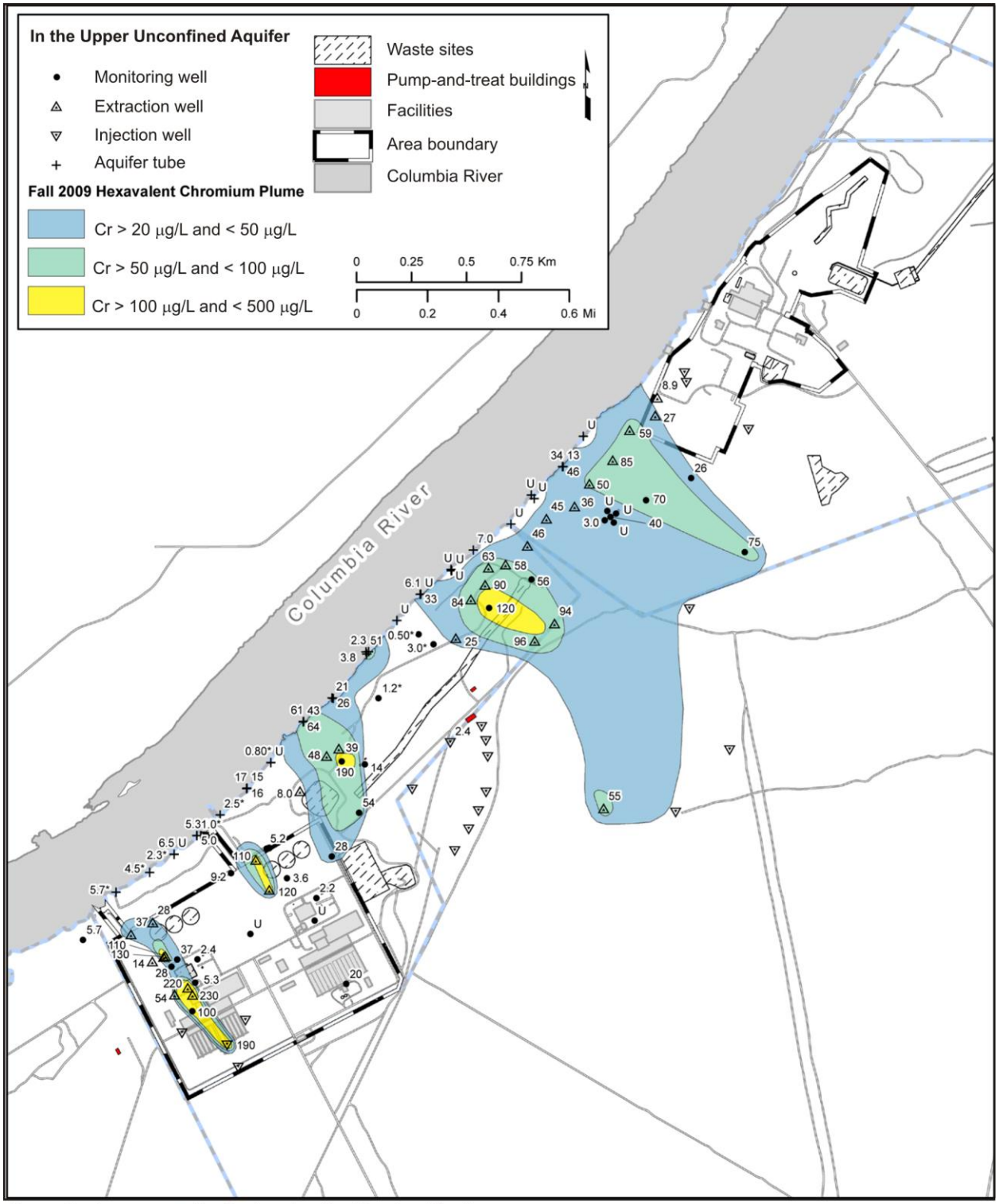


Figure U–17. Spatial Distribution of Groundwater Chromium Concentration (Past-Practice Sources), 100 Areas, Calendar Year 2010



Key: µg/L=micrograms per liter; Cr=chromium; Km=kilometers; Mi=miles.
Source: DOE 2010a.

Figure U–18. Field-Reported Spatial Distribution of Groundwater Chromium Concentration, 100-K Area, Calendar Year 2009

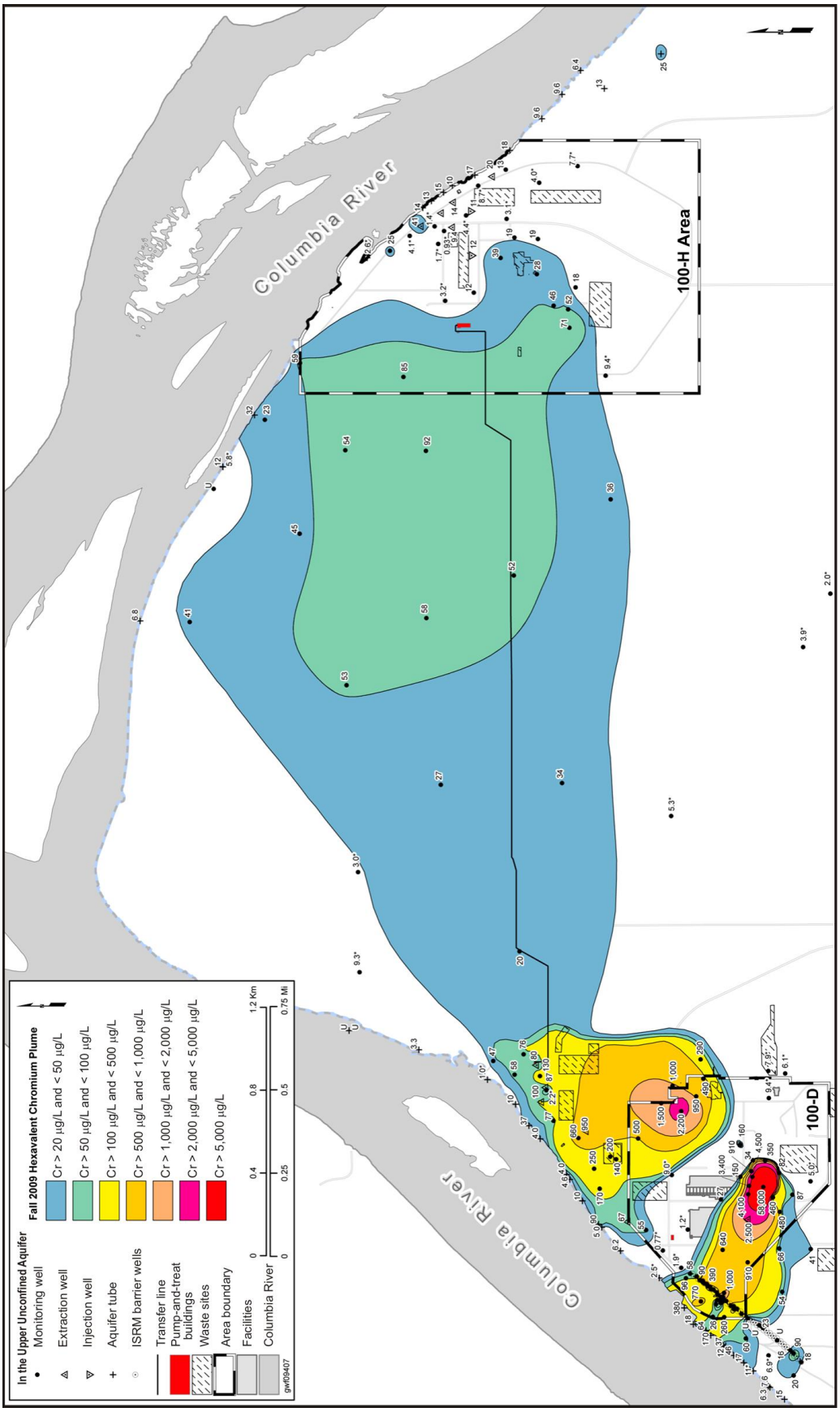
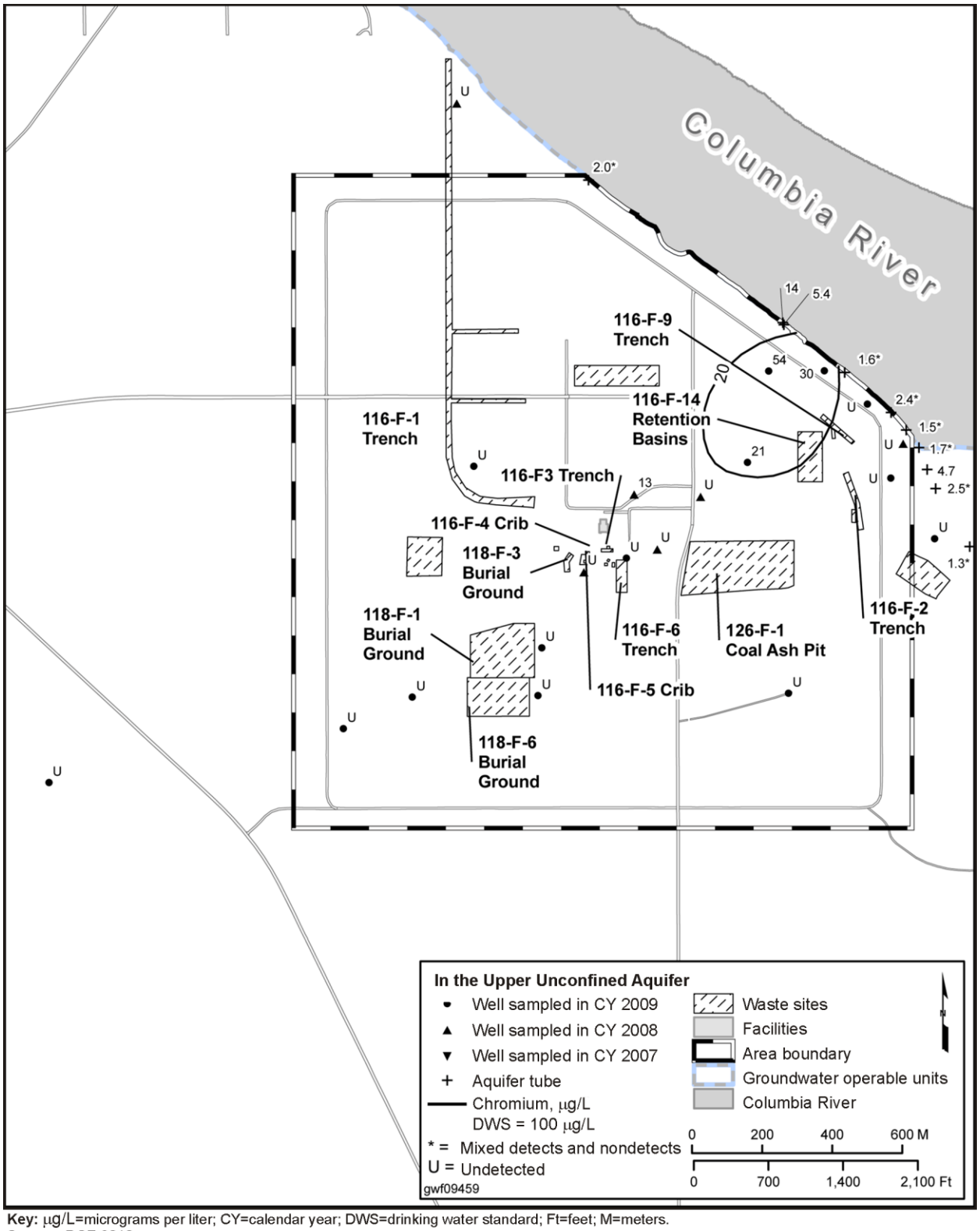


Figure U–19. Field-Reported Spatial Distribution of Groundwater Chromium Concentration, 100-H Area, Calendar Year 2009

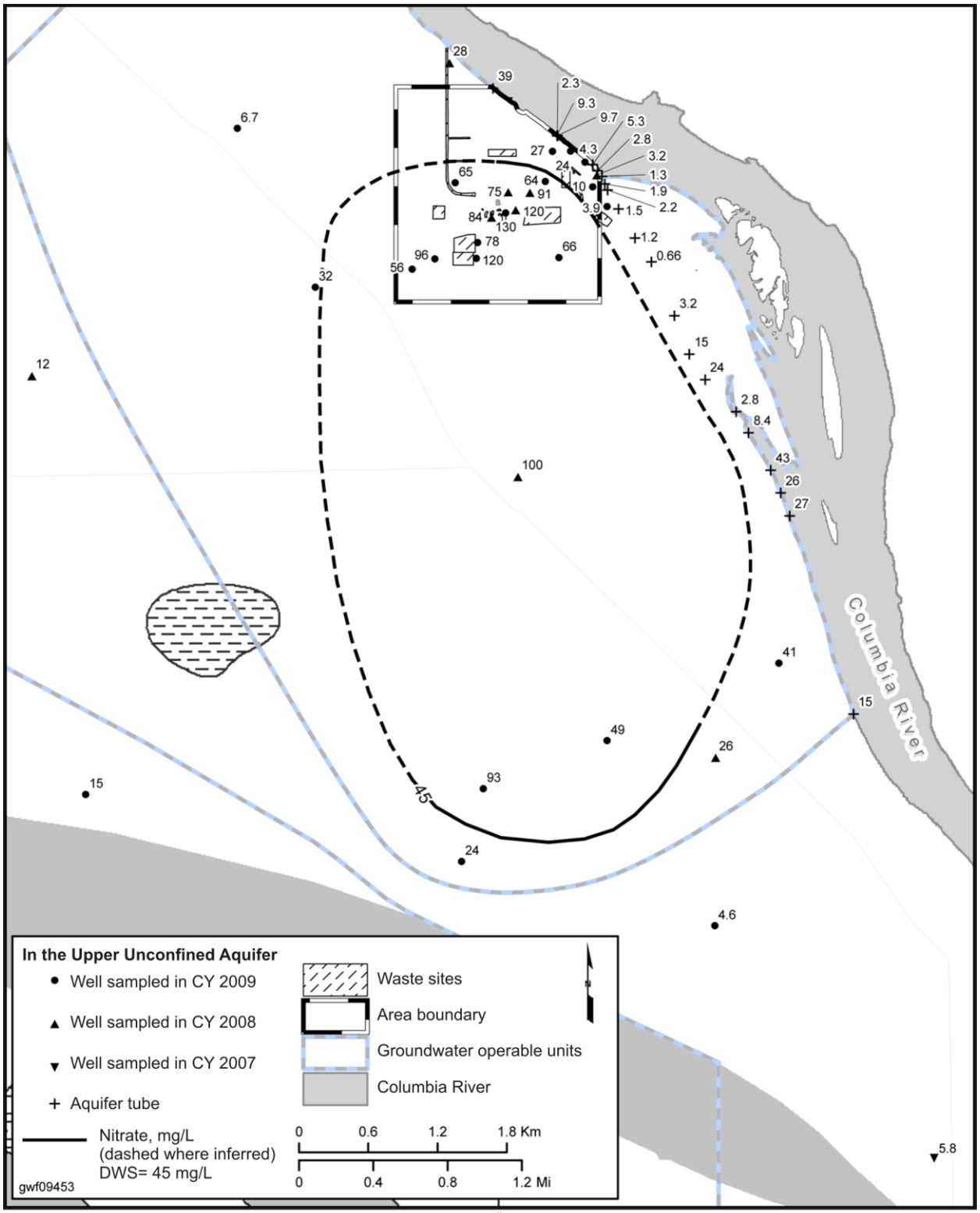
Key: µg/L-micrograms per liter; Cr=chromium; ISRM=in situ REDOX [reduction-oxidation] manipulation; Km=kilometers; Mi=miles.
Source: DOE 2010a.



Key: µg/L=micrograms per liter; CY=calendar year; DWS=drinking water standard; Ft=feet; M=meters.
Source: DOE 2010a.

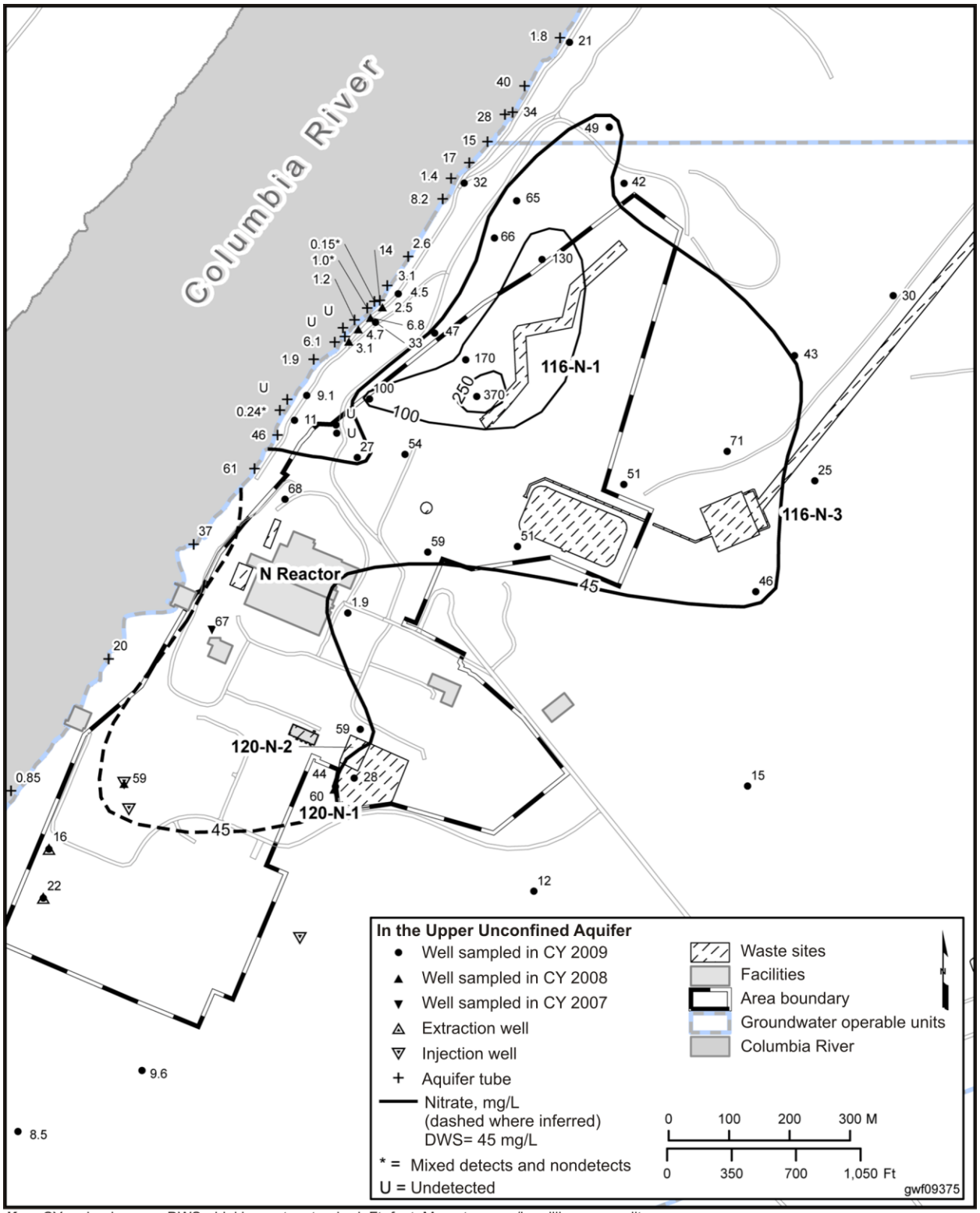
Figure U–20. Field-Reported Spatial Distribution of Groundwater Chromium Concentration, 100-F Area, Calendar Year 2009

The 2009 groundwater monitoring report specifies the presence of a large nitrate plume in the 100-F Area with concentrations exceeding the drinking water standard. Additional plumes exceeding the drinking water standard are also reported in the 100-D Area and much of the 100-N Area. Though these plumes are depicted in the 2009 groundwater monitoring report, the attributed sources are not listed. Figures U–21 through U–23 show the spatial distributions of the major nitrate plumes in the 100 Areas as reported in the 2009 groundwater monitoring report (DOE 2010a). The nitrate simulation conducted for the impacts analysis of past-practice sources in the 100 Areas does not replicate these plumes because inventories for the sources that contribute to these plumes were not available. See Appendix S for a detailed discussion of the waste inventories used for the cumulative impact analyses.



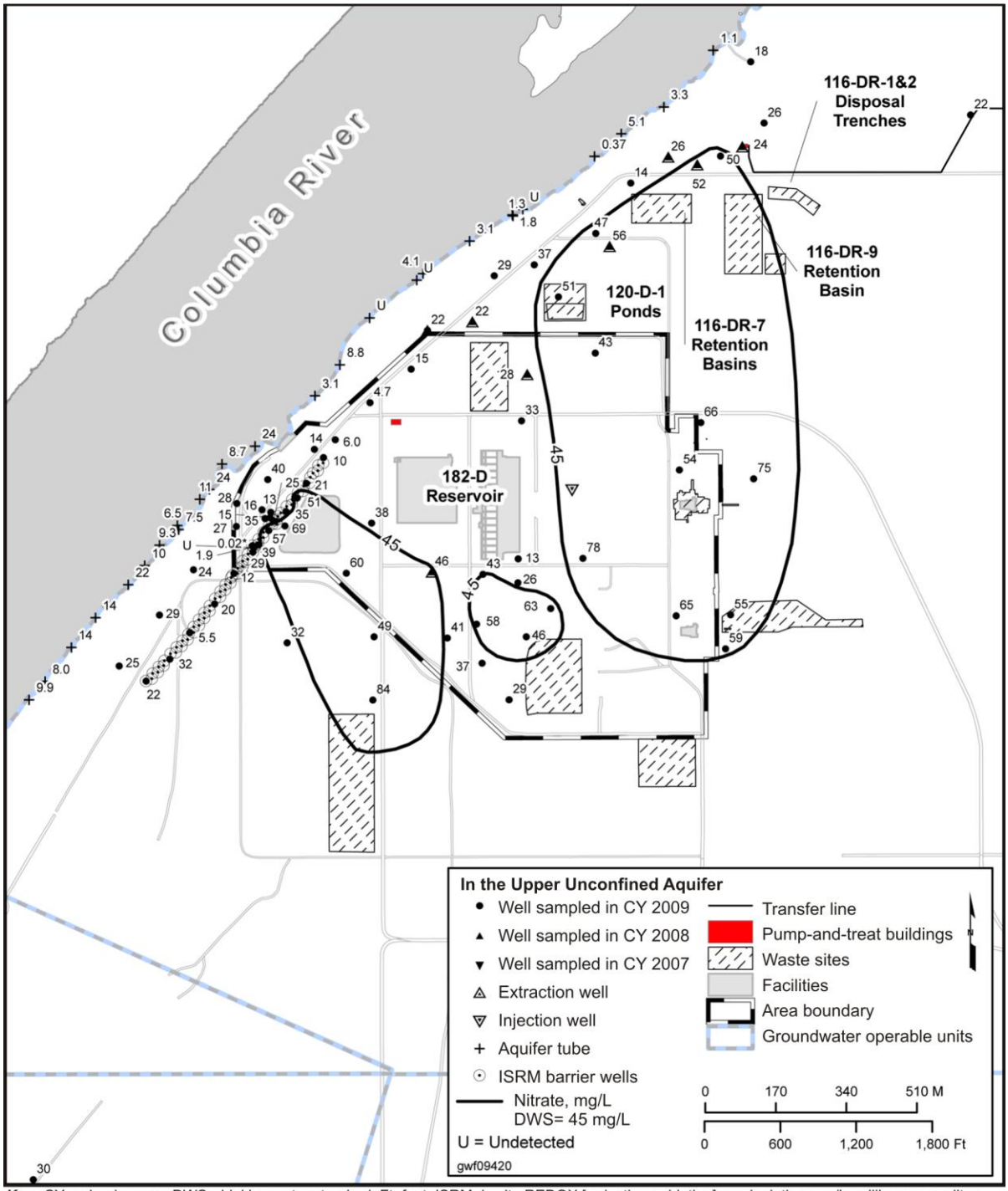
Key: CY=calendar year; DWS=drinking water standard; Km=kilometers; mg/L=milligrams per liter; Mi=miles.
Source: DOE 2010a.

Figure U–21. Field-Reported Spatial Distribution of Groundwater Nitrate Concentration, 100-F Area, Calendar Year 2009



Key: CY=calendar year; DWS=drinking water standard; Ft=feet; M=meters; mg/L=milligrams per liter.
Source: DOE 2010a.

Figure U–22. Field-Reported Spatial Distribution of Groundwater Nitrate Concentration, 100-N Area, Calendar Year 2009



Key: CY=calendar year; DWS=drinking water standard; Ft=feet; ISRM=in situ REDOX [reduction-oxidation] manipulation; mg/L=milligrams per liter; M=meters.
Source: DOE 2010a.

Figure U–23. Field-Reported Spatial Distribution of Groundwater Nitrate Concentration, 100-D Area, Calendar Year 2009

Strontium-90 is present in groundwater in most of the subareas and is generally contained in the vadose zone. Strontium-90 has a much greater affinity for sediment than for water (i.e., a high distribution coefficient), so its rate of transport in groundwater is considerably slower than the actual groundwater flow rate, and the plume characteristics change slowly over time. Figure U–24 shows the spatial distribution of groundwater strontium-90 concentration in the 100 Areas as predicted in the impacts

analysis of past-practice sources. In general, the simulations of groundwater transport replicate the values measured in the field within an order of magnitude. Figures U–25 and U–26 show the spatial distributions of the major strontium-90 plumes in the 100 Areas as reported in the 2009 groundwater monitoring report.

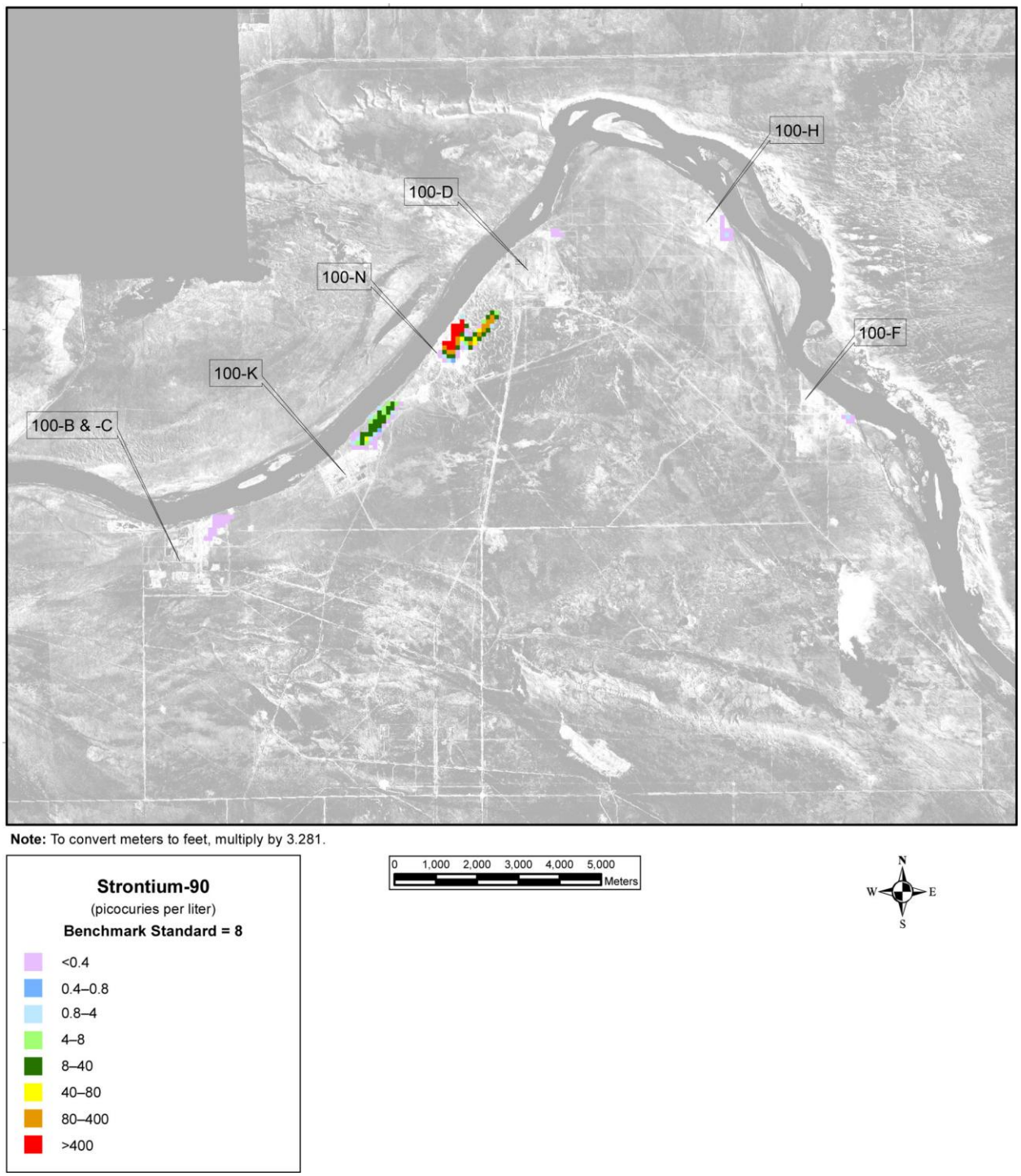
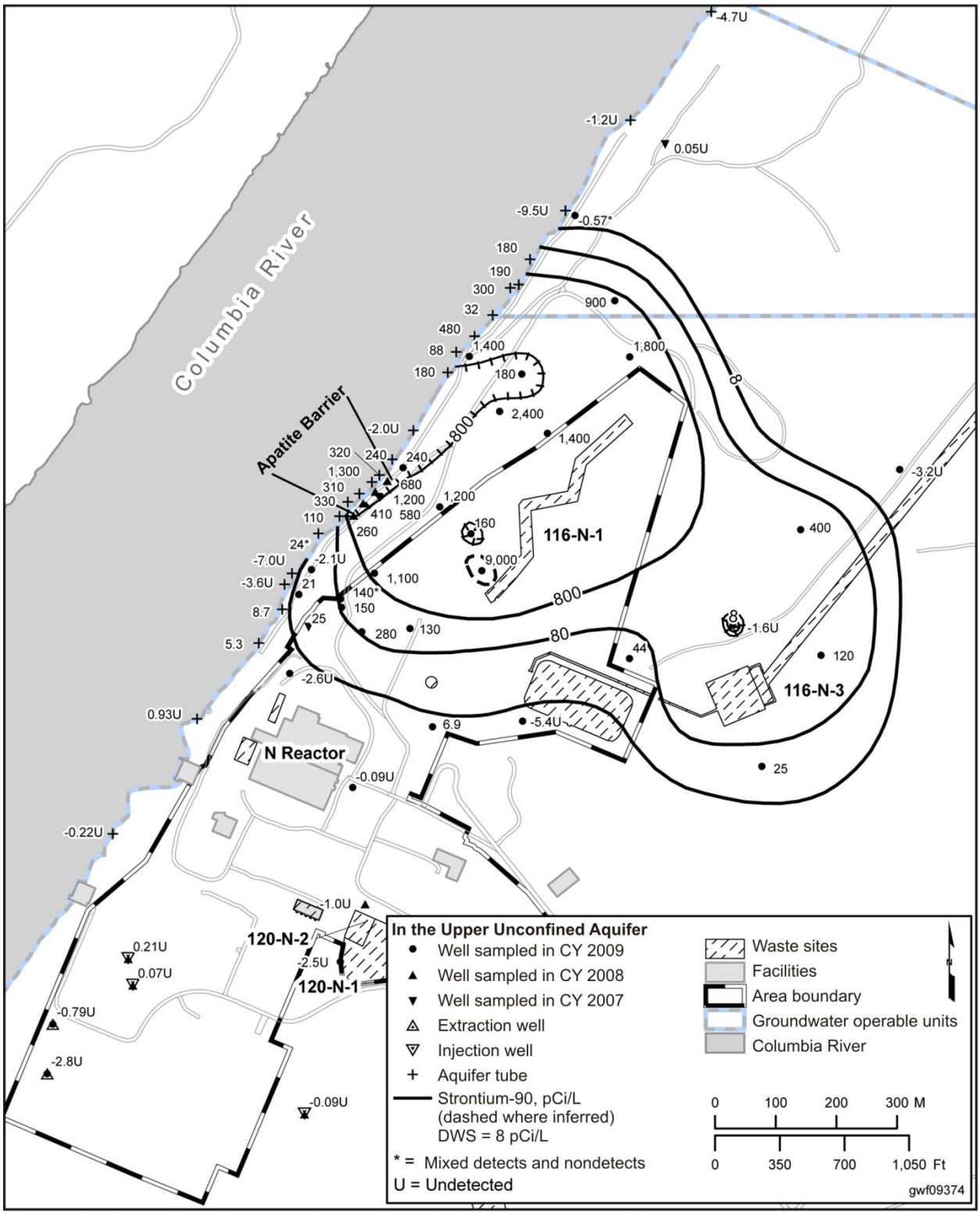
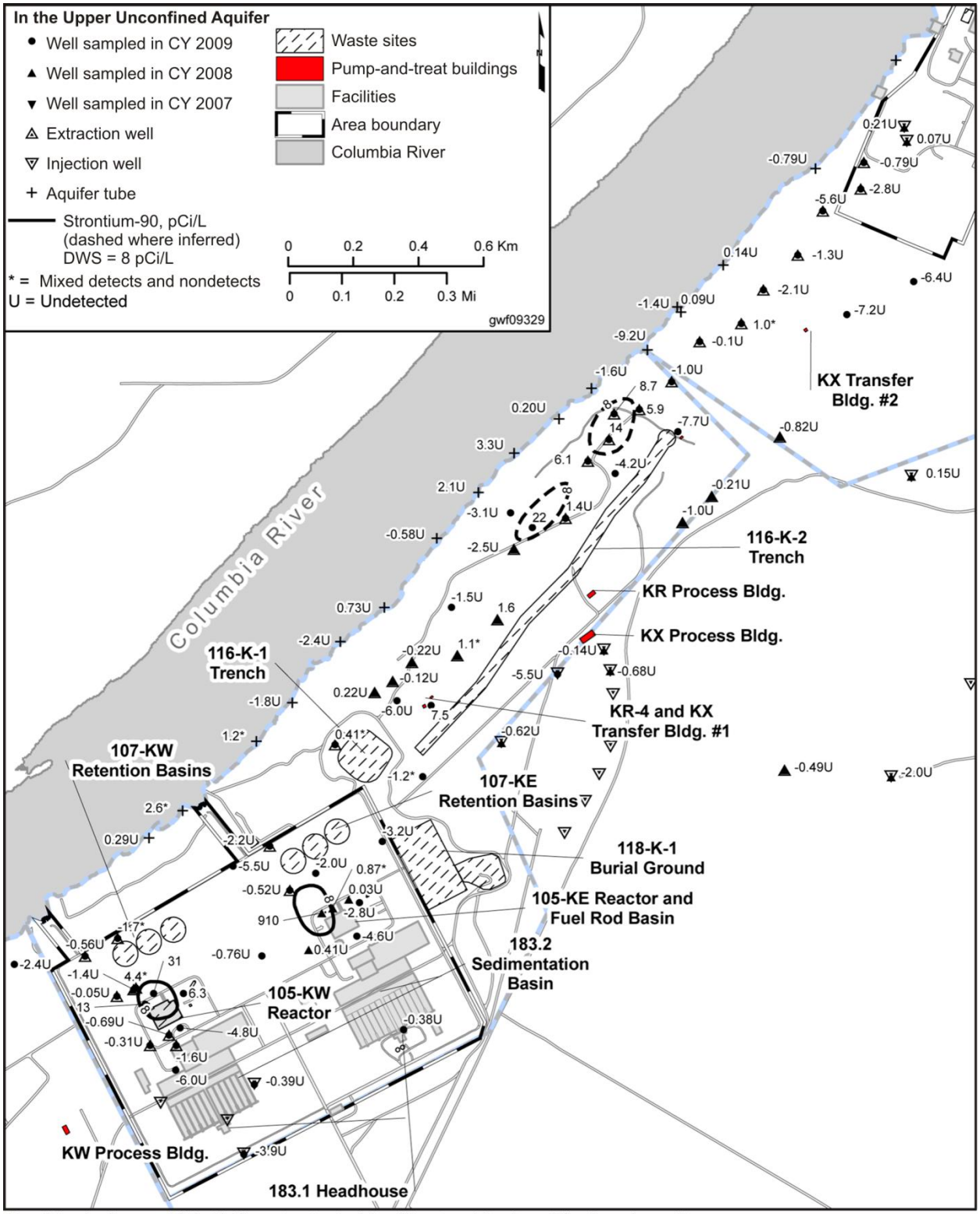


Figure U–24. Spatial Distribution of Groundwater Strontium-90 Concentration (Past-Practice Sources), 100 Areas, Calendar Year 2010



Key: CY=calendar year; DWS=drinking water standard; Ft=feet; M=meters; pCi/L=picocuries per liter.
Source: DOE 2010a.

Figure U–25. Field-Reported Spatial Distribution of Groundwater Strontium-90 Concentration, 100-N Area, Calendar Year 2009



Key: CY=calendar year; DWS=drinking water standard; Km=kilometers; Mi=miles; pCi/L=picocuries per liter.
Source: DOE 2010a.

Figure U–26. Field-Reported Spatial Distribution of Groundwater Strontium-90 Concentration, 100-K Area, Calendar Year 2009

Unlike strontium-90, tritium does not have a greater affinity for sediment than for water. Likewise, the rate of transport of tritium in groundwater is faster than that of strontium-90, and tritium is present throughout the entire thickness of the unconfined aquifer. The overall trend for tritium concentrations in the 100 Areas is elevated but slowly declining (DOE 2010a). Figure U–27 shows the spatial distribution of tritium concentrations in groundwater in the 100 Areas as predicted in the impacts analysis of past-practice sources. In general, the 100 Area simulations of groundwater transport replicate plumes with tritium concentrations above the benchmark standard in the same locations as the groundwater monitoring report. The simulations do, however, conservatively estimate the concentrations by approximately an order of magnitude in the vicinity of 1301-N Liquid Waste Disposal Facility (116-N-1) and 1325-N Liquid Waste Disposal Facility (116-N-3). Figure U–28 shows the spatial distributions of the major tritium plumes in the 100 Areas as reported in the 2009 groundwater monitoring report (DOE 2010a).

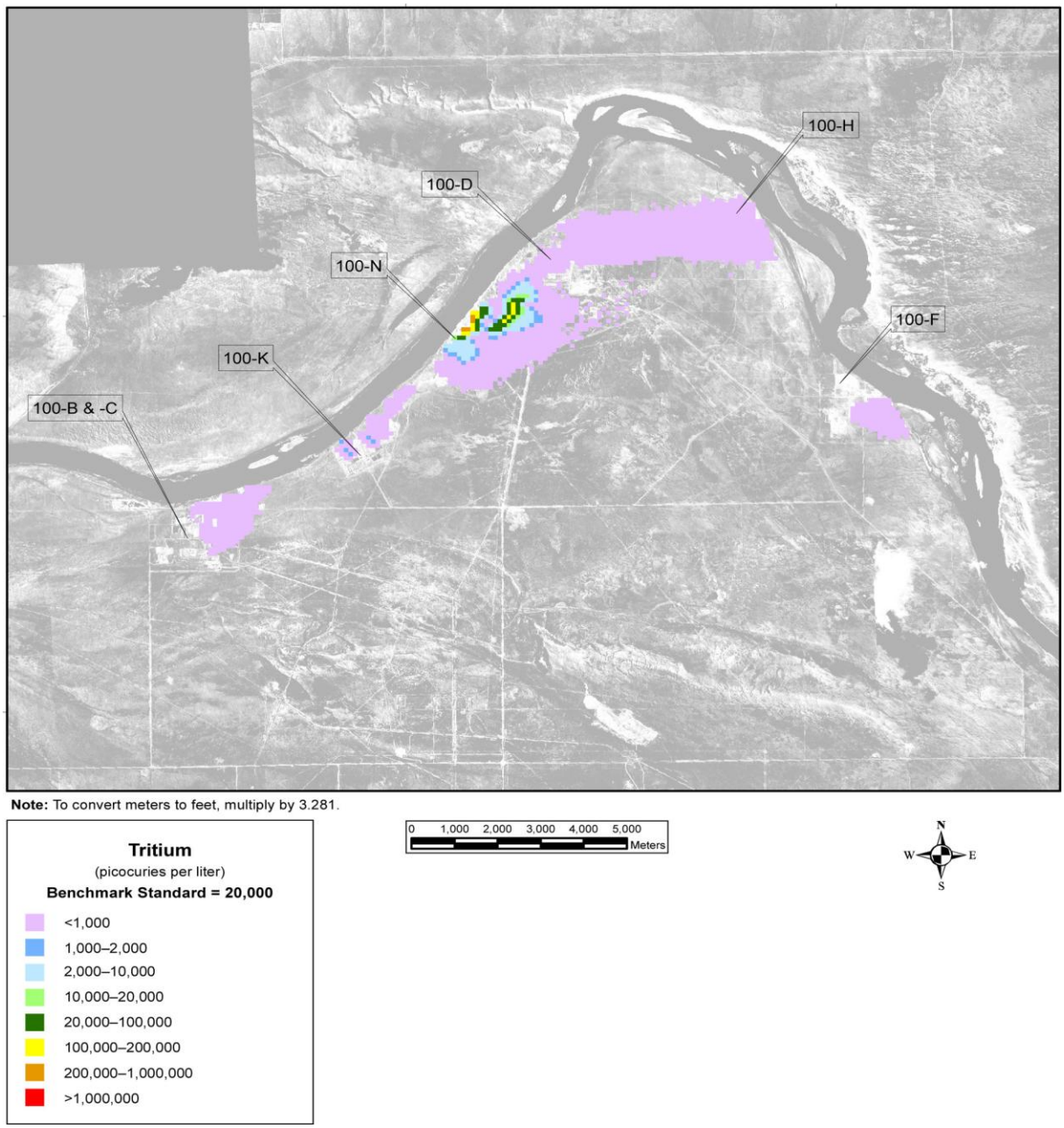
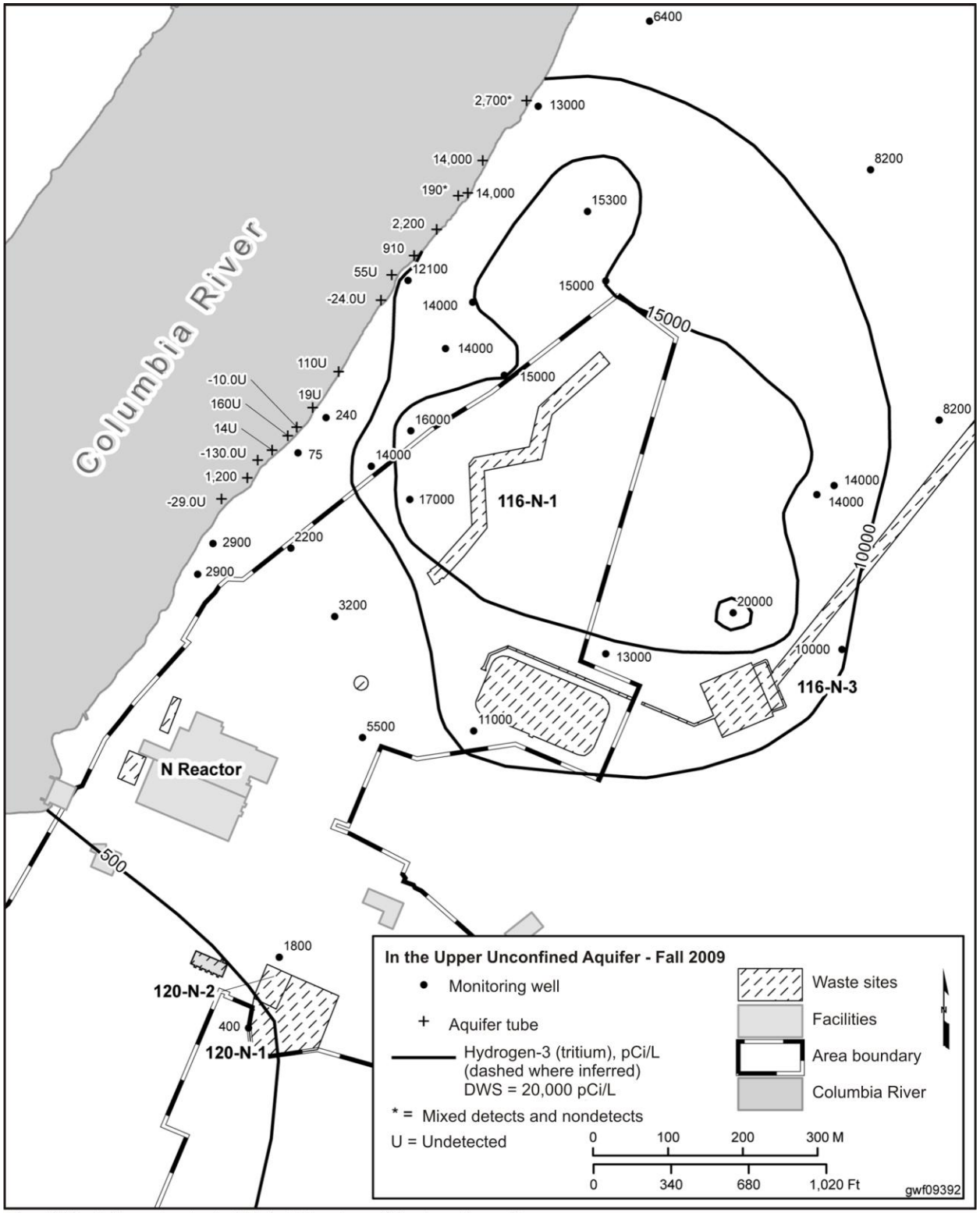


Figure U–27. Spatial Distribution of Groundwater Hydrogen-3 (Tritium) Concentration (Past-Practice Sources), 100 Areas, Calendar Year 2010



Key: DWS=drinking water standard; Ft=feet; M=meters; pCi/L=picocuries per liter.
Source: DOE 2010a.

Figure U–28. Field-Reported Spatial Distribution of Groundwater Hydrogen-3 (Tritium) Concentration, 100-N Area, Calendar Year 2009

U.1.2.2.1.4 100 Areas Consideration of Ongoing Hanford Site Activities

Cleanup of the 100 Areas has been under way since the mid-1990s. Cleanup actions have removed highly radioactive spent nuclear fuel and other materials from the 100 Areas. Other cleanup actions have focused on excavation of waste sites, followed by treatment and/or disposal of contaminated materials, installation of groundwater treatment systems, removal of surplus facilities, and placement of production reactors into a safe and stable configuration known as "interim safe storage." This section summarizes the decisions that have been reached; the milestones that have been established to complete cleanup; the goals and cleanup levels that the actions must meet; and the anticipated end-state condition of the river corridor cleanup.

Established Decisions and Milestones

The CERCLA RODs for the 100 Areas operable units are listed in Table U–2.

Table U–2. CERCLA Records of Decision for the 100 Areas

Record of Decision – Location	Date
ROD for 100-BC-1, 100-DR-1, and 100-HR-1 Operable Units – soil remediation (EPA 1995a)	September 1995
ROD for 100-IU-1, 100-IU-3, 100-IU-4, and 100-IU-5 Operable Units – remedial action (EPA 1996a)	February 1996
ROD for 100-HR-3 and 100-KR-4 Operable Units – interim remedial actions – chromium pump-and-treat system (EPA 1996b)	May 1996
Amended ROD for 100-BC-1, 100-DR-1, and 100-HR-1 Operable Units – interim remedial actions (EPA 1997a)	April 1997
Interim-action ROD for remaining sites in 100 Areas: 100-BC-1, 100-BC-2, 100-DR-1, 100-DR-2, 100-FR-1, 100-FR-2, 100-HR-1, 100-HR-2, 100-KR-1, 100-KR-2, 100-IU-2, 100-IU-6, and 200-CW-3 (EPA 1999a)	July 1999
ROD for 100-KR-2 Operable Unit K Basins – interim remedial action (EPA 1999b)	September 1999
Interim-action ROD for 100-NR-1 and 100-NR-2 Operable Units (EPA 1999c)	September 1999
Amended ROD for 100-HR-3 Operable Unit – interim remedial action – in situ REDOX manipulation (EPA 1999d)	October 1999
Replacement of Table 3 in interim ROD for 100-NR-1 and 100-NR-2 Operable Units (Bond 1999a)	October 1999
Replacement of Appendix B in interim ROD for 100-NR-1 and 100-NR-2 Operable Units (Bond 1999b)	November 1999
ROD for 100-NR-1 Operable Unit – interim remedial actions (EPA 2000a)	January 2000
Explanation of Significance Difference for interim-action ROD for remaining sites, 100-IU-6 Operable Unit – addition of 600-23 and J.A. Jones No. 1 waste sites (EPA 2000b)	June 2000
ROD for 100-BC-1, 100-BC-2, 100-DR-1, 100-DR-2, 100-FR-2, 100-HR-2, and 100-KR-2 Operable Units (100 Areas burial grounds) (EPA 2000c)	September 2000
Explanation of Significant Difference for ROD for 100-HR-3 Operable Unit (EPA 2003a)	April 2003
Explanation of Significant Difference for treatment, storage, and disposal interim-action ROD for 100-NR-1 Operable Unit and for interim-action ROD for 100-NR-1/100-NR-2 Operable Unit (EPA 2003b)	May 2003
Explanation of Significant Difference for the 100 Area remaining sites – adds waste sites, ARARs, and institutional controls (EPA 2004a)	February 2004
Amendment to interim ROD for 100-KR-2 Operable Unit (EPA 2005a)	June 2005

Key: ARAR=applicable or relevant and appropriate requirement; CERCLA=Comprehensive Environmental Response, Compensation, and Liability Act; REDOX=reduction-oxidation; ROD=Record of Decision.
Source: DOE 2006.

"Key facilities" (as identified in Section 8 of the TPA) in the 100 Areas include the 105-B, 105-C, 105-D, 105-DR, 105-F, 105-H, 105-KE, 105-KW, and 105-N Reactor Buildings (Ecology, EPA, and DOE 1989). CERCLA removal actions have been used to initiate disposition of these key facilities (except the B Reactor, which is a designated National Historic Landmark) into interim safe storage, pending final decommissioning.

The following three major TPA milestones specifically apply to cleanup of the river corridor source and groundwater operable units:

- M-015-00D – Complete the RI/FS process through the submittal of a proposed plan for all 100 and 300 Area operable units (December 31, 2012).

- M-016-00A – Complete all interim response actions for the 100 Area units, except the 100-K Area, by the specified due date as approved in a remedial design/remedial action (RD/RA) work plan. Completion of interim response actions is defined as completion of the interim ROD or action memorandum requirements in accordance with an approved RD/RA work plan or removal action work plan and approval by EPA and/or the Washington State Department of Ecology (Ecology) of the appropriate project closeout documents (December 31, 2012).

- M-016-00C – Complete all interim response actions for the 100-K Area. Completion of interim response actions is defined as completion of the interim ROD or action memorandum requirements in accordance with an approved RD/RA work plan or removal action work plan and the approval by EPA of the appropriate project closeout documents (December 31, 2020).

Significant response actions that have occurred in the river corridor as a result of these RODs and subsequent modifications have included the following:

- Waste site remediation program – Remediation to prevent future contamination of groundwater along the river cooridor occurred at more than 150 waste sites, including many high-priority liquid-waste sites, which have been excavated and backfilled with clean soil. Approximately 8.2 million metric tons (18 billion pounds) of contaminated soil has been disposed of at the Environmental Restoration Disposal Facility (ERDF). For a summary of remedial actions taken through 2006 for the 100 Areas, see the second *CERCLA Five-Year Review Report for the Hanford Site*, Sections 1.4 and 3.4 (DOE 2006).

- Pump-and-treat systems in the 100-K, 100-D, 100-H, and 100-N Areas – The 100-K, 100-D, and 100-H large pump-and-treat systems have treated over 7.6 billion liters (2 billion gallons) of groundwater and removed nearly 1 metric ton (2,200 pounds) of chromium from the aquifer. For more information, see *Hanford Site Groundwater Monitoring for Fiscal Year 2008* (Hartman, Rediker, and Richie 2009) chapters on the 100-KR-4, 100 NR-2, 100-HR-3-D, and 100-HR-3-H systems; treatment statistics for all pump-and-treat systems are reported annually in the groundwater monitoring report.

- Biostimulation test – Molasses was injected at the 100-D Area biostimulation treatability test site to nourish bacteria that can reduce hexavalent chromium to trivalent chromium, which is less toxic and less mobile than hexavalent chromium. For more information, see *Hanford Site Groundwater Monitoring for Fiscal Year 2008* (Hartman, Rediker, and Richie 2009), Section 2.5.2.9, In Situ Biostimulation Test.

- Electrocoagulation – New technology enabling cost-effective remediation of chromium-contaminated groundwater was tested. For more information, see *Hanford Site Groundwater Monitoring for Fiscal Year 2008* (Hartman, Rediker, and Richie 2009), Section 2.5.2.6, Electrocoagulation Tests.

- In situ REDOX [reduction-oxidation] manipulation – By injecting nontoxic chemicals into an aquifer, contaminants can be successfully immobilized to aquifer sediments, or reduced to a less toxic form (e.g., hexavalent chromium reduced to trivalent chromium). Maintaining the in situ REDOX manipulation barrier depends on the presence of naturally occurring iron. Studies have shown that fortifying the barrier with more iron offers a sustainable long-term repair. For more information, see *Hanford Site Groundwater Monitoring for Fiscal Year 2008* (Hartman, Rediker, and Richie 2009), Section 2.5.2.3, In Situ Redox Manipulation System, and Section 2.5.2.5, Zero-Valent Iron Injection.

- Apatite barrier installation – The barrier removes strontium-90 from groundwater and allows it to radioactively decay in the soil by binding it into the apatite mineral matrix. For more information, see the *Hanford Site Groundwater Monitoring for Fiscal Year 2008* (Hartman, Rediker, and Richie 2009), Section 2.4.2.3, Permeable Reactive Barrier.

- Polysulfide injection – New technology to reduce chromium within groundwater was tested. For more information, see *Geochemical Characterization of Chromate Contamination in the 100 Area Vadose Zone at the Hanford Site* (Dresel et al. 2008).

- Phytoremediation field demonstration – The coyote willow (a common plant that grows along the banks of the Columbia River) can be used in phytoremediation to extract strontium-90 from groundwater prior to its migration to the Columbia River. For more information, see *Hanford Site Groundwater Monitoring for Fiscal Year 2008* (Hartman, Rediker, and Richie 2009), Section 2.4.2.5, Phytoremediation.

- Spent nuclear fuel and related sludge removal actions – A total of 2,087 metric tons (4.6 million pounds) of spent nuclear fuel has been removed from the K-East and K-West Basins. The spent nuclear fuel was packaged and moved to dry, safe storage on the Central Plateau. Contaminated water has been removed from the K-East Basin and the basin has been removed. The sludge from both basins has been placed in containers that are now in the K-West Basin. The K-East Basin has been completely demolished. After completion of sludge removal, the K-West Basin will be demolished. The transuranic sludge will be treated and stored on the Central Plateau pending shipment to the Waste Isolation Pilot Plant near Carlsbad, New Mexico (DOE 2010b).

- Facility removal actions – Over 300 structures have been demolished in the river corridor. In addition, five 100 Area reactors have been placed in interim safe storage (DOE 2010b).

Cleanup Goals and Levels

The two RAOs for the 100 Area source operable units are listed in Table U–3.

Table U–3. Remedial Action Objectives for the 100 Area Source Operable Units

Objective Number	Description
1	Protect human and ecological receptors from exposure to contaminants in soil, structures, and debris by dermal exposure, inhalation, or ingestion of radionuclides, inorganics, or organics. Protection will be achieved by reducing concentration of, or limiting exposure pathways to, contaminants in the upper 4.6 meters (15 feet) of the soil in the soil exposure scenario. The levels of reduction will be such that the total dose for radionuclides does not exceed 15 millirem per year above Hanford Site background levels for 1,000 years following remediation and Washington State Model Toxics Control Act Method B levels for inorganics and organics.
2	Control the sources of groundwater contamination to minimize the impacts on groundwater resources, protect the Columbia River from further adverse impacts, and reduce the degree of groundwater cleanup that may be required under future actions. Protection will be such that contaminants remaining in the soil after remediation do not result in an adverse impact on groundwater that could exceed MCLs and non-zero MCL goals under the Safe Drinking Water Act. The Safe Drinking Water Act MCL for radionuclides will be attained at a designated point of compliance beneath or adjacent to the waste site in groundwater. The location and measurement of the point of compliance will be defined by EPA and Ecology. Monitoring for compliance will be performed at the defined point. Protect the Columbia River from adverse impacts so contaminants remaining in the soil after remediation do not result in an impact on groundwater and, therefore, the Columbia River, that could exceed the ambient water quality criteria under the Clean Water Act for protection of fish. Because there are no ambient water quality criteria for radionuclides, MCLs will be used. The protection of receptors (aquatic species, with emphasis on salmon) in surface waters will be achieved by reducing or eliminating further contaminant loadings to groundwater so receptors at the point of groundwater discharge in the Columbia River are not subject to additional adverse risks. Measurement of compliance will be at a nearshore well, in the downgradient plume. The location and measurement will be defined by EPA and Ecology.

Key: Ecology=Washington State Department of Ecology; EPA=U.S. Environmental Protection Agency; MCL=maximum contaminant level.
Source: DOE 2006.

Post-cleanup sampling is performed and cleanup verification packages are prepared to ensure that cleanup levels are actually achieved. For example, see the second *CERCLA Five-Year Review Report for the Hanford Site* (DOE 2006), Table 1.5, for a listing of approved cleanup verification packages for the 100 Areas.

The following groundwater and surface-water RAOs have been developed for the river corridor:[1]

- Prevent unacceptable risk to human health from ingestion of, and incidental exposure to, groundwater containing nonradioactive contaminant concentrations above Federal and state standards.

- Prevent unacceptable risk to human health from ingestion of, and incidental exposure to, groundwater containing radioactive contaminant concentrations above Federal standards.

[1] This list reflects the typical categories and outcomes that groundwater RAOs have taken. For RAOs specific to existing river corridor groundwater decisions, see the *EPA Superfund Record of Decision: Hanford 100-Area (USDOE), 100-KR-2 Operable Unit* (EPA 1999b:35) for 100-KR-2 Operable Unit groundwater and the *EPA Superfund Record of Decision: Hanford 100-Area (USDOE), 100-HR-3 and 100-KR-4 Operable Units* (EPA 1996b:33) for 100-HR-3 Operable Unit groundwater.

- Prevent unacceptable risk to human health and ecological exposure to surface water containing nonradioactive contaminant concentrations above Federal and state standards.

- Prevent unacceptable risk to human health and ecological exposure to surface water containing radioactive contaminant concentrations above Federal standards.

Anticipated Cleanup End State

Groundwater cleanup actions are currently being implemented to meet the following TPA milestones and cleanup levels:

- Chromium entering the Columbia River. "DOE shall take actions necessary to contain or remediate hexavalent chromium groundwater plumes in each of the 100 Area NPL [National Priorities List] operable units such that ambient water quality standards[2] for hexavalent chromium are achieved in the hyporheic zone and river water column" (M-016-110-T01, due December 31, 2012). Note that the point of compliance is specified as the point at which biota are impacted. In implementing interim-action RODs, the current practice has been to meet two times the ambient water quality standard in the nearest groundwater monitoring well. This allows for the minimum observed extent of mixing (1:1) to occur as the groundwater flows into the hyperheic zone. As the final RODs for remedial actions are written, this practice may be refined.

- Chromium in groundwater. "DOE shall take actions necessary to remediate hexavalent chromium groundwater plumes such that hexavalent chromium will meet drinking water standards (100 µg/L [micrograms per liter]) in each of the 100 Area NPL operable units" (M-016-110-T02, due December 31, 2020). The point of compliance is measured from samples in groundwater monitoring wells.

- Strontium-90 in groundwater. "DOE shall take actions necessary to contain the strontium-90 groundwater plume at the 100-NR-2 Operable Unit such that the default ambient water quality standard[3] (8 pCi/L [picocuries per liter]) for strontium-90 is achieved in the hyporheic zone and river water column" (M-016-110-T-03, due December 31, 2016). See the note in the first bullet above for chromium entering the Columbia River.

- All contaminants entering the Columbia River. "DOE shall implement remedial actions selected in all 100 Area Records of Decision for Groundwater Operable Units so that no contamination above drinking water standards or ambient water quality standards enters the Columbia River unless otherwise specified in a CERCLA decision" (M-016-110-T-04, due December 31, 2016). See note in first bullet above for chromium entering the Columbia River.

Table U–4 summarizes the current and planned actions and the expected cleanup end state for each of Hanford's groundwater operable units in the 100 Areas.

[2] For chromium, the drinking water standard is 100 micrograms per liter. The standard for protection of aquatic life is approximately 10 micrograms per liter. Currently, as part of the TPA, a remedial action goal of 22 micrograms per liter in groundwater has been developed , which is expected to be sufficient to meet the aquatic standard by the time the water reaches the hyporheic zone or river water column.

[3] There is no ambient water quality standard for strontium-90, so the drinking water standard is used as a default standard. However, the actual dose to aquatic receptors is significantly below published risk-based dose guidelines.

Table U–4. River Corridor Groundwater Plumes and Treatment Actions

Operable Unit	Primary Contaminants	Current Status and Actions	Future Actions	Anticipated Cleanup End State
100-BC-5	Strontium-90, chromium, hydrogen-3 (tritium)	No active remediation required at this time. To be addressed in an RI/FS/PP.	Subject to final ROD.	Groundwater to meet drinking water standards. Groundwater entering the Columbia River will meet ambient water quality standards for protection of ecological receptors. Subject to final ROD.
100-FR-3	Strontium-90, chromium	No active remediation required at this time. To be addressed in an RI/FS/PP.	Subject to final ROD.	Groundwater to meet drinking water standards. Groundwater entering the Columbia River will meet ambient water quality standards for protection of ecological receptors. Subject to final ROD.
100-HR-3-D	Chromium, nitrate	Pump-and-treat system at 2,461-liter-per-minute (650-gallon-per-minute) capacity. In situ REDOX manipulation barrier in place.	Expansion to 2,461 liters (650 gallons) per minute by 2011. (Meets TPA Milestone M-016-111B.) Additional actions subject to final ROD.	Chromium entering the Columbia River will meet ambient water quality standards for protection of ecological receptors by 2012. [See TPA Milestone M-016-110-T01.] Groundwater will meet drinking water standards by 2020. [See TPA Milestone M-016-110-T02.]
100-HR-3-H	Chromium	Pump-and-treat system at 1,136-liter-per-minute (300-gallon-per-minute) capacity.	Expansion to 2,650 liters (700 gallons) per minute by 2011. (Meets TPA Milestone M-016-111C.) Additional actions subject to final ROD.	Chromium entering the Columbia River will meet ambient water quality standards for protection of ecological receptors by 2012. [See TPA Milestone M-016-110-T01.] Groundwater will meet drinking water standards by 2020. [See TPA Milestone M-016-110-T02.]
100-KR-4	Chromium, nitrate, strontium-90, trichloroethylene	Pump-and-treat system at 4,164-liter-per-minute (1,100-gallon-per-minute) capacity. (Meets TPA Milestone M-016-11A.)	Additional actions subject to final ROD.	Chromium entering the Columbia River will meet ambient water quality standards for protection of ecological receptors by 2012. [See TPA Milestone M-016-110-T01.] Groundwater will meet drinking water standards by 2020. [See TPA Milestone M-016-110-T02.] Strontium-90 entering the Columbia River will meet ambient water quality standard (8 picocuries per liter) by 2016. [See TPA Milestone M-016-110-T-03.]

Table U–4. River Corridor Groundwater Plumes and Treatment Actions *(continued)*

Operable Unit	Primary Contaminants	Current Status and Actions	Future Actions	Anticipated Cleanup End State
100-N/NR-2	Strontium-90, sulfate, diesel (100-N)	Previous strontium-90 pump-and-treat system was not effective. Currently using apatite barrier and phytoremediation.	Subject to final ROD.	Groundwater to meet drinking water standards. Groundwater entering the Columbia River will meet ambient water quality standards for protection of ecological receptors. TPA Milestone M-016-110-T-03 sets target for strontium-90 of 8 picocuries per liter by December 31, 2016, for groundwater entering the hyporheic zone and river water column.

Key: FS=feasibility study; PP=proposed plan; REDOX=reduction-oxidation; RI=remedial investigation; ROD=Record of Decision; TPA=Tri-Party Agreement [Hanford Federal Facility Agreement and Consent Order].

U.1.2.2.2 300 Area

The 300 Area is located along the eastern reach of the Columbia River near the southeastern portion of Hanford and comprises the groundwater sources associated with nuclear fuels production and research activities that were conducted during Hanford's operational period.

U.1.2.2.2.1 300 Area Hydrogeologic Regime

The hydrogeologic regime describes the system of geology and groundwater flow that governs groundwater contaminant distribution. The geology in the 300 Area is relatively flat, with some small depressions in the Ringold Formation, where the Hanford formation dips down and fills them. The lithology in this area is generally Hanford gravel and sand sitting on top of Ringold gravel and sand. Ringold mud is present throughout the 300 Area above the Columbia River Basalt Group and is typically 10 to 15 meters (33 to 49 feet) thick (DOE 2010a).

The vadose zone in the vicinity of the 300 Area is made up almost entirely of Hanford gravel, with some occurrences of Hanford sand. Figures U–29 and U–30 depict cross sections that are typical of the vadose zone lithology in the 300 Area. The vadose zone ranges in thickness from approximately 3 to 15 meters (10 to 49 feet). The thickness of the vadose zone in this area varies due to seasonal fluctuations in the elevation of the water table (DOE 2010a).

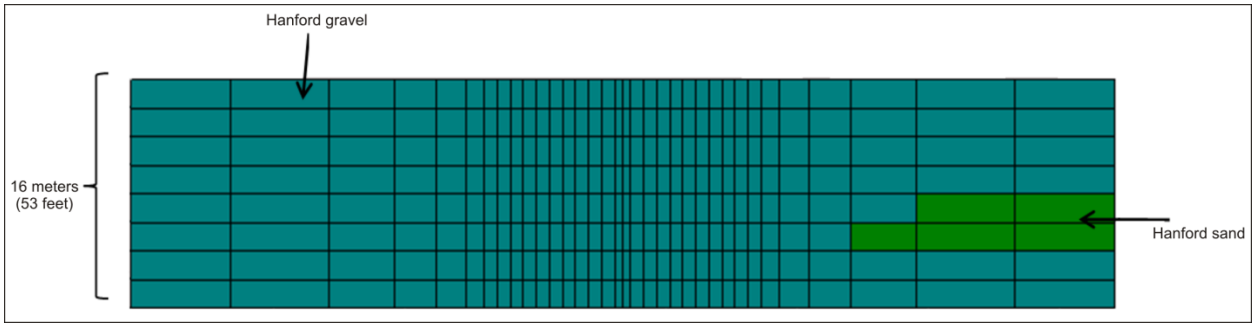


Figure U–29. West-to-East Cross Section of Vadose Zone Lithology for 300 Area Process Trenches

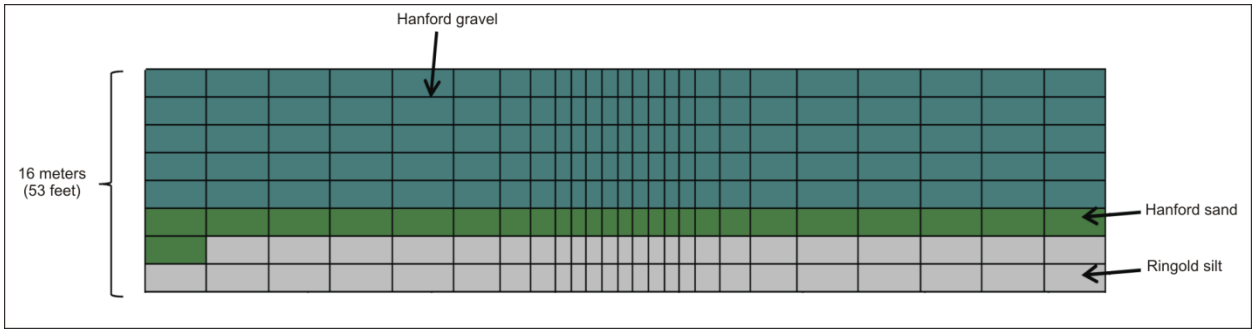
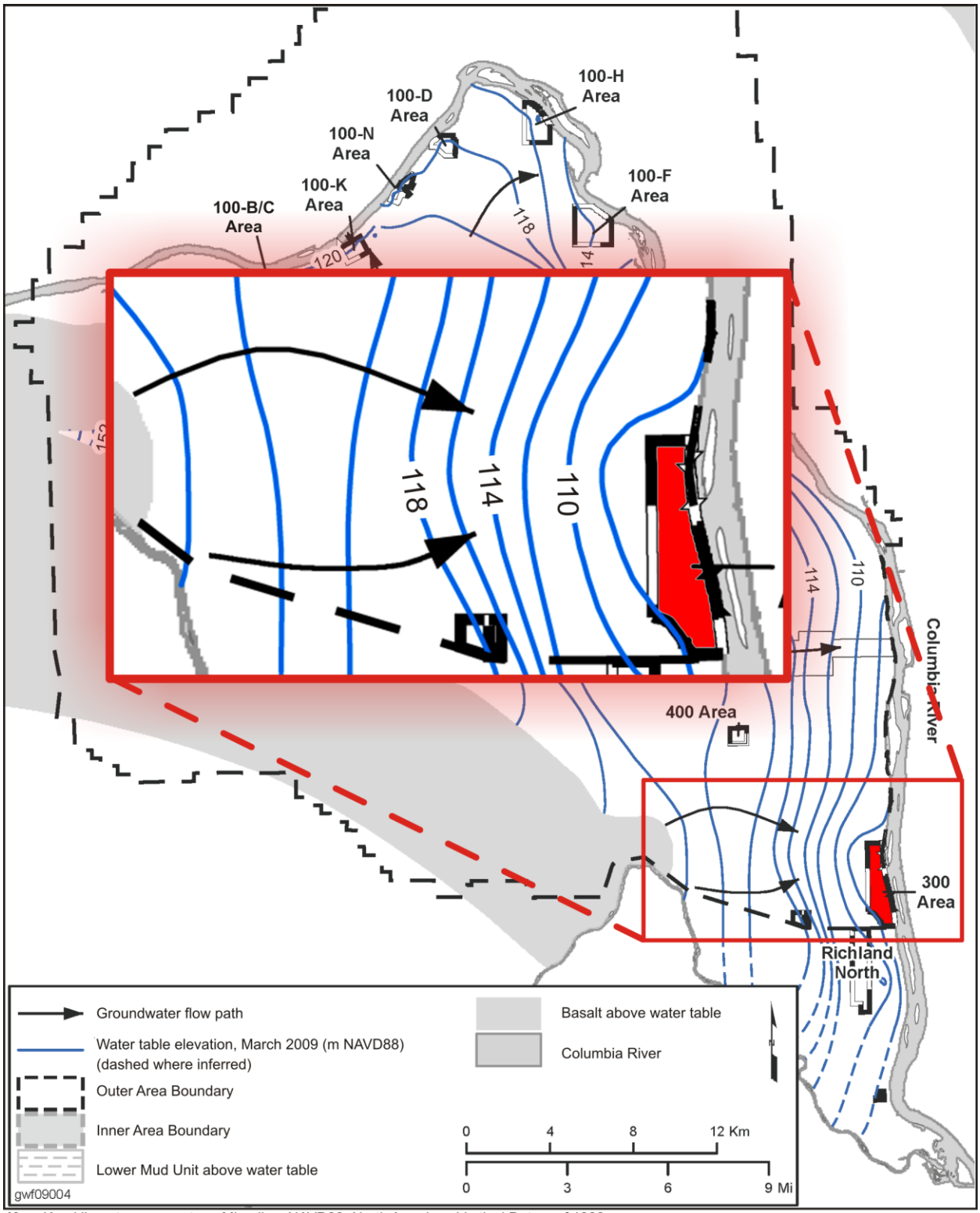


Figure U–30. West-to-East Cross Section of Vadose Zone Lithology for 300-Area Burial Ground

Groundwater in the 300 Area generally flows toward the Columbia River. Localized groundwater flow patterns in the 300 Area are impacted by variation in the permeability of the sediments and seasonal fluctuations of the Columbia River. The water table decreases from approximately 120 meters (394 feet) to the west of the 300 Area to approximately 105 meters (344 feet) as it approaches the 300 Area. Figure U–31 illustrates the 300 Area water table and inferred directions of flow as indicated by the 2009 groundwater monitoring report (DOE 2010a).



Key: Km=kilometers; m=meters; Mi=miles; NAVD88=North American Vertical Datum of 1988.
Note: To convert the water table elevations from meters to feet, multiply by 3.281.
Source: DOE 2010a.

Figure U–31. 300 Area Water Table and Inferred Groundwater Flow Directions, March 2009

U.1.2.2.2.2 300 Area Historical Anthropogenic Discharges

During Hanford's operational period, the 300 Area was used for nuclear fuel fabrication and research activities; the effects of these past anthropogenic activities continue to influence contaminant transport in the subsurface in the 300 Area. These operations generated large volumes of liquid effluents that were disposed of in facilities for infiltration to the underlying soil. For analysis purposes in this *TC & WM EIS*, aqueous sources of contamination were examined based on the amount of discharge. Sources with aqueous flux (volume per area) of less than 1 meter (3 feet) per year were categorized as moderate-discharge sources. Sources with aqueous flux of greater than 1 meter (3 feet) per year were categorized as heavy-discharge sources. Solid sources were categorized as low-discharge sources. The anthropogenic contaminant sources in the 300 Area included heavy-discharge sites, such as ponds and trenches, that were used to dispose of wastes from fuel fabrication and fuel research activities, as well as solid waste burial grounds, individual facilities, and periodic spills and accidental releases that contributed moderate and low contaminant discharges to groundwater. Though anthropogenic activities have diminished over time, residual effects continue to influence contaminant plume migration (DOE 2010a).

U.1.2.2.2.3 300 Area Comparison of Modeled Versus Measured Spatial Contaminant Distributions

This section discusses the distribution of inventories as described in the 2009 groundwater monitoring report (DOE 2010a) and compares the results of the impacts analysis for past-practice sources in the 300 Area in terms of the spatial distribution of COPC concentrations in CY 2010. Nearly all of the disposal facilities, associated with the historical routine disposal of liquid effluent to support fuel fabrication and fuel research in the 300 Area, have been out of service for decades, and most have been remediated by removal of contaminated soil and structures. Nitrate and uranium are the major contaminants of the residual contamination remaining in the underlying vadose zone and aquifer. In general, the simulations of groundwater transport replicate the values measured in the field. Concentrations of each radionuclide and chemical are indicated by a color scale that is relative to the benchmark concentration. Concentrations greater than the benchmark concentration are indicated by the fully saturated colors green, yellow, orange, and red in order of increasing concentration. Concentrations less than the benchmark concentration are indicated by the faded colors green, blue, indigo, and violet in order of decreasing concentration. Note that the concentration ranges are on a logarithmic scale to facilitate visual comparison of concentrations that vary over three orders of magnitude.

The remedial investigation for groundwater beneath the 300 Area (DOE 1995a) identified uranium, cis-1,2-dichloroethene, and trichloroethene as COPCs for interim action (EPA 1996c). The inventory for the 300 Area sources of groundwater contamination (see Appendix S) used in this *TC & WM EIS* included nitrate, uranium-238, and total uranium. There was no identified source or inventory for the volatile organics (cis-1,2-dichloroethene and trichloroethene), and they were not modeled.

The 2009 groundwater monitoring report indicates that there are relatively high concentrations of nitrate present in the southern portion of the 300 Area, but the contamination is mostly associated with agricultural and industrial activities not associated with Hanford. The nitrate simulation of the impacts analysis of past-practice sources in the 300 Area does not replicate this plume because inventories of the attributing sources were not included.

Figures U–32 and U–33 show the spatial distribution of the uranium-238 and total uranium plumes in the 300 Area, respectively, as predicted by the impacts analysis of past-practice sources. The uranium contamination is mostly attributed to the 300 Area Process Trenches, 300 Area South Process Pond, and 300 Area North Process Ponds. Figure U–34 shows the spatial distribution of the uranium plume in the 300 Area as reported in the 2009 groundwater monitoring report.

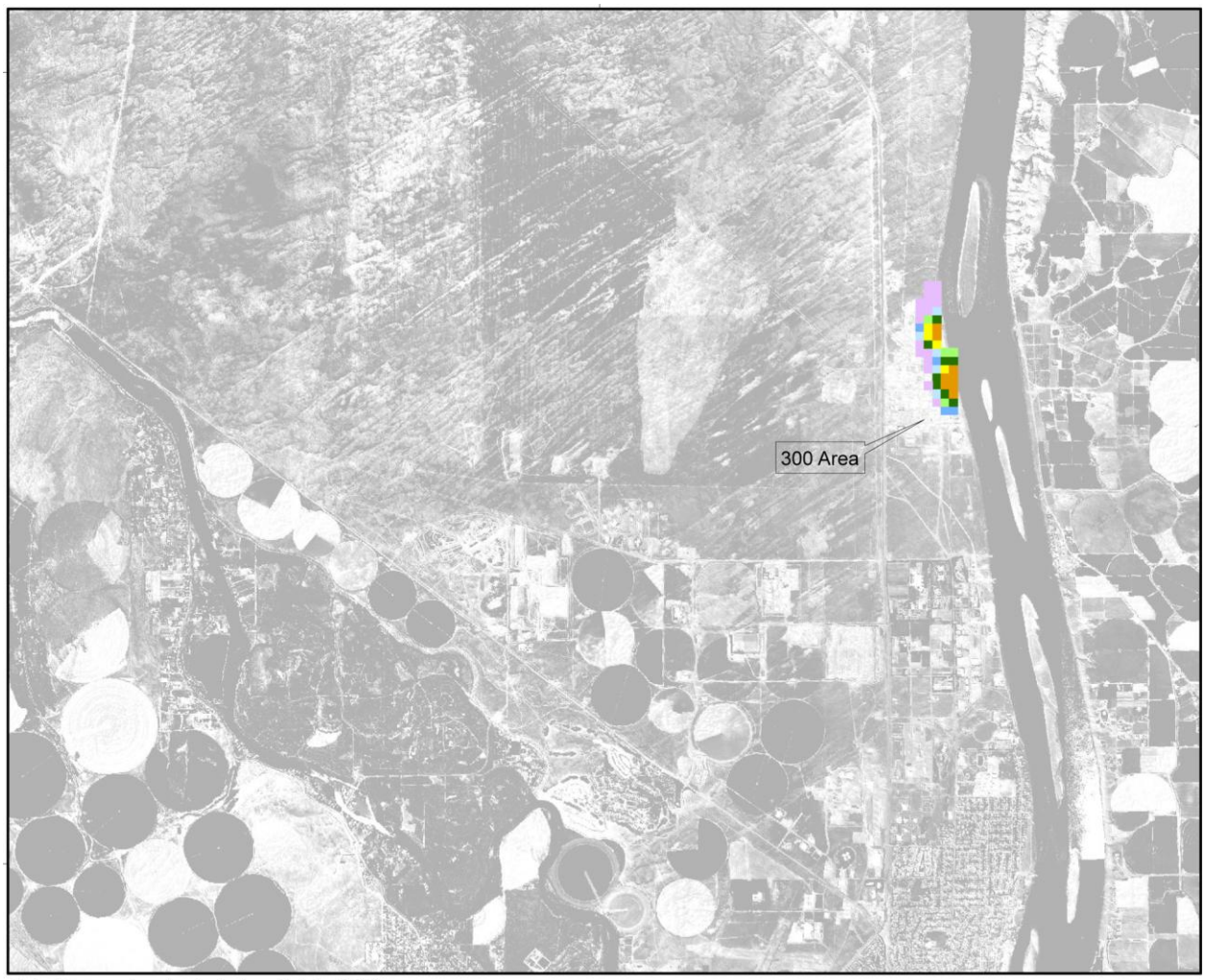


Figure U–32. Spatial Distribution of Groundwater Uranium-238 Concentration (Past-Practice Sources), 300 Area, Calendar Year 2010

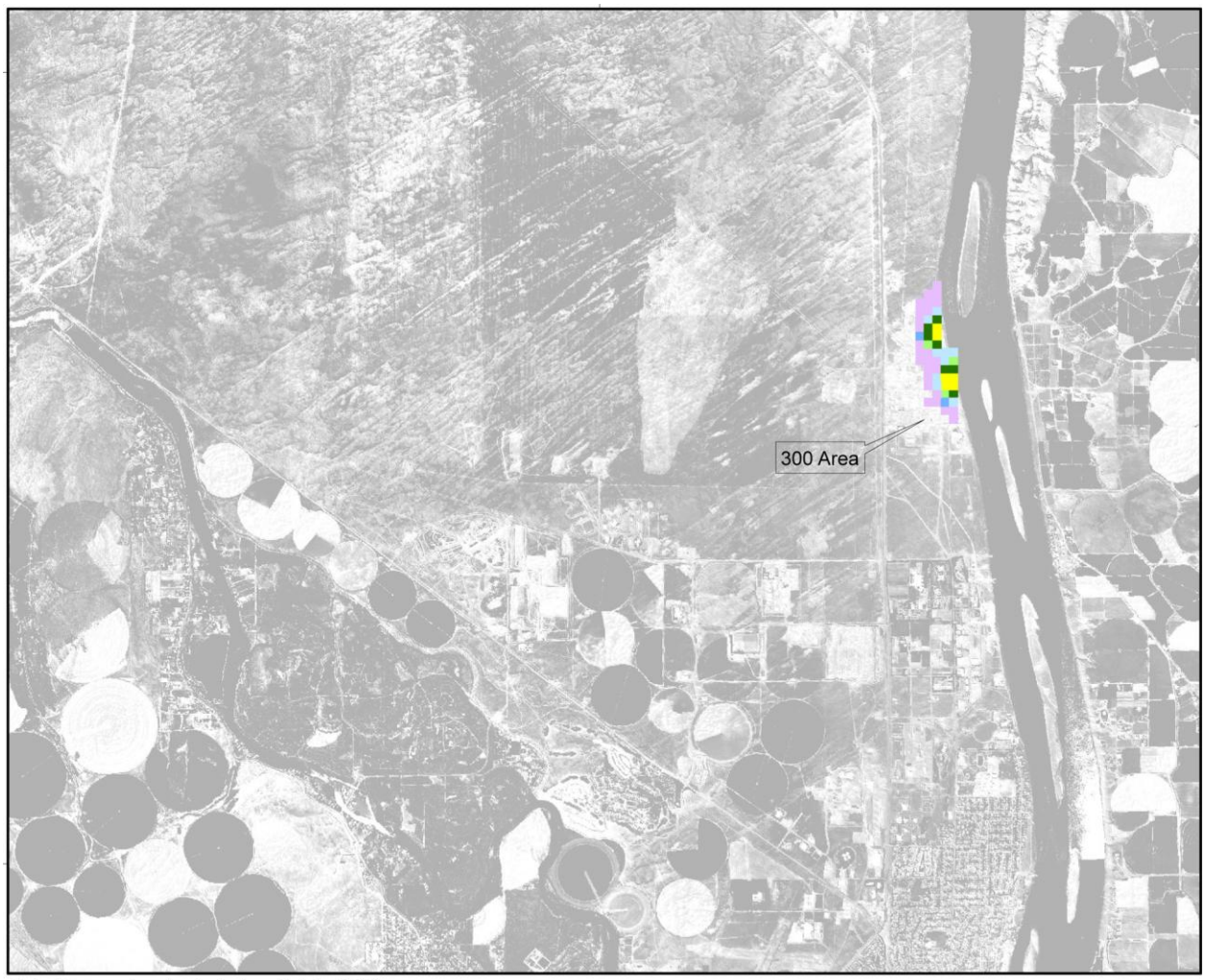
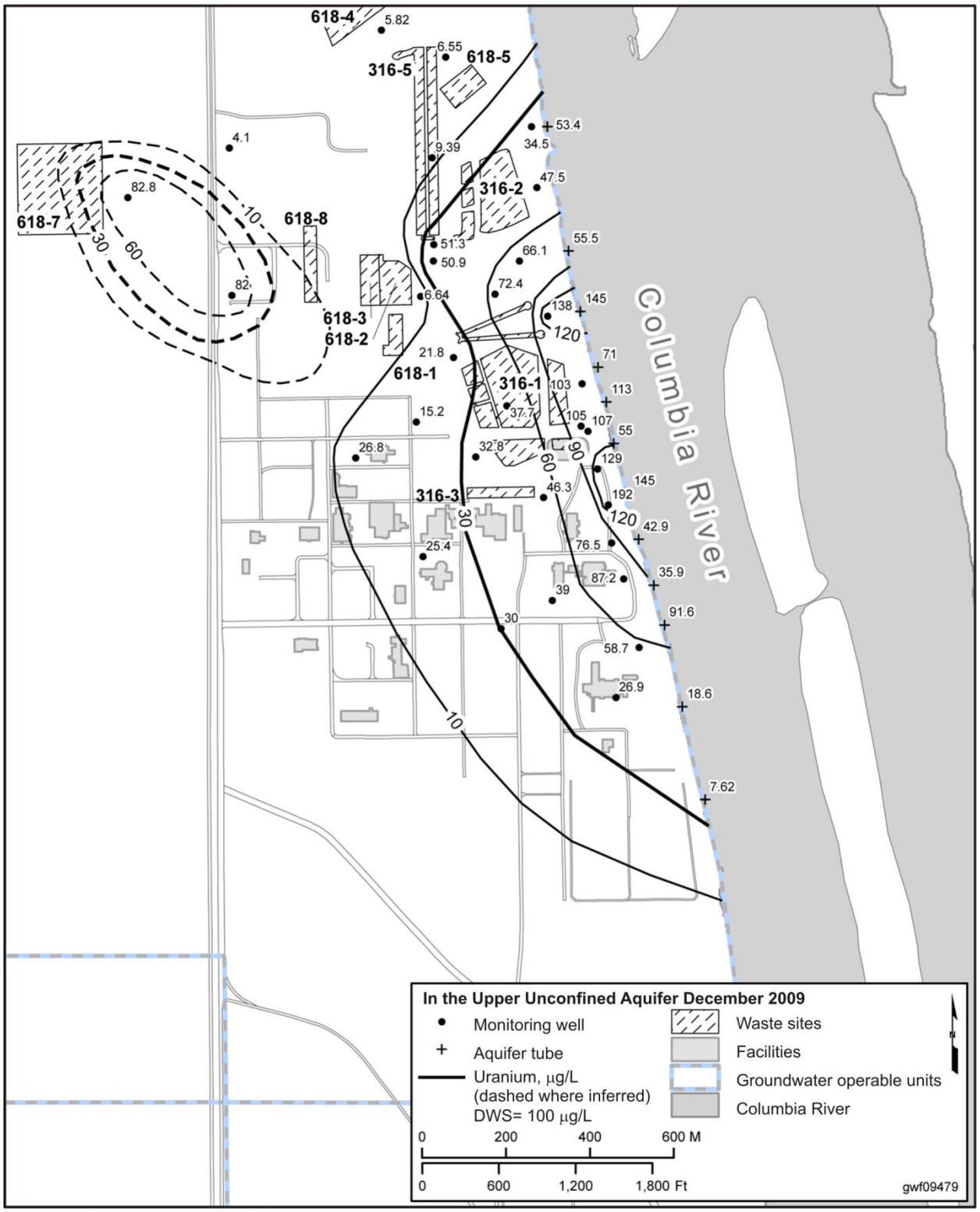


Figure U–33. Spatial Distribution of Groundwater Total Uranium Concentration (Past-Practice Sources), 300 Area, Calendar Year 2010



Key: µg/L=micrograms per liter; DWS=drinking water standard; Ft=feet; M=meters.
Source: DOE 2010a.

Figure U–34. Field-Reported Spatial Distribution of Groundwater Uranium Concentration, 300 Area, December 2009

U.1.2.2.2.4 300 Area Consideration of Ongoing Hanford Site Activities

Cleanup of the river corridor, including the 300 Area, has been under way since the mid-1990s. Cleanup and closure decisions have been reached using both CERCLA and RCRA authorities. This section summarizes the decisions that have been reached; the milestones that have been established to complete cleanup; the goals and cleanup levels that the actions must meet; and the anticipated end-state condition of the river corridor cleanup.

Established Decisions and Milestones

The CERCLA RODs for the 300 Area operable units are listed in Table U–5.

Table U–5. CERCLA Records of Decision for the 300 Area Operable Units

Record of Decision – Location	Date
Final ROD for 300-FF-1 Operable Unit and interim ROD for 300-FF-5 Operable Unit – removal, treatment, monitoring (EPA 1996c)	July 1996
Explanation of Significant Difference for ROD for 300-FF-1 Operable Unit – site-specific variance from land-disposal-restriction treatment standard for lead (EPA 2000d)	January 2000
Explanation of Significant Difference for ROD for 300-FF-5 Operable Unit – expansion of 300-FF-5 scope, increased monitoring, and new operations and maintenance plan (EPA 2000e)	June 2000
ROD for interim remedial actions for 300-FF-2 Operable Unit – removal, treatment, and monitoring (EPA 2001)	April 2001
Explanation of Significant Difference for ROD for 300-FF-2 Operable Unit – soil cleanup level (EPA 2004b)	May 2004

Key: CERCLA=Comprehensive Environmental Response, Compensation, and Liability Act; ROD=Record of Decision.
Source: DOE 2006.

Significant response actions that have occurred in the river corridor as a result of these RODs and subsequent modifications include the following:

- Waste Site Remediation Program – Remediation to prevent future contamination of groundwater along the river corridor occurred at more than 150 waste sites, including many high-priority liquid-waste sites that have been excavated and backfilled with clean soil. Approximately 8.2 million metric tons (18 billion pounds) of contaminated soil have been disposed of at the ERDF. For a summary of remedial actions taken through 2006 for the 300 Area, see the second *CERCLA Five-Year Review Report for the Hanford Site*, Sections 1.4 and 3.4 (DOE 2006).

The following two major TPA milestones specifically apply to cleanup of the river corridor source and groundwater operable units:

- M-016-00B – Complete all interim 300 Area remedial actions, including Burial Grounds 618-10 and 618-11, but not including sites associated with retained 300 Area facilities and the utility corridors. Completion of interim remedial actions for waste sites associated with the retained 300 Area facilities and their utilities is subject to approved RD/RA work plans due September 30, 2018.

- M-015-00D – Complete the RI/FS process through the submittal of a proposed plan for all 300 Area operable units (due December 31, 2012).

Cleanup Goals and Levels

The RAOs for the 300 Area source operable units are listed in Table U–6.

Table U–6. Remedial Action Objectives for the 300 Area Source Operable Units

Objective Number	Description
1	Protect human and ecological receptors from exposure to contaminants in soil, structures, and debris by dermal exposure, inhalation, or ingestion of radionuclides, inorganics, or organics. Protection will be achieved by reducing concentration of, or limiting exposure pathways to, contaminants in the upper 4.6 meters (15 feet) of the soil in the soil exposure scenario. The levels of reduction will be such that the total dose for radionuclides does not exceed 15 millirem per year above Hanford Site background levels for 1,000 years following remediation and Washington State Model Toxics Control Act Method B levels for inorganics and organics.
2	Control the sources of groundwater contamination to minimize the impacts on groundwater resources, protect the Columbia River from further adverse impacts, and reduce the degree of groundwater cleanup that may be required under future actions. Protection will be such that contaminants remaining in the soil after remediation do not result in an adverse impact on groundwater that could exceed MCLs and non-zero MCL goals under the Safe Drinking Water Act. The Safe Drinking Water Act MCL for radionuclides will be attained at a designated point of compliance beneath or adjacent to the waste site in groundwater. The location and measurement of the point of compliance will be defined by EPA and Ecology. Monitoring for compliance will be performed at the defined point. Protect the Columbia River from adverse impacts so contaminants remaining in the soil after remediation do not result in an impact on groundwater and, therefore, the Columbia River, that could exceed the ambient water quality criteria under the Clean Water Act for protection of fish. Because there are no ambient water quality criteria for radionuclides, MCLs will be used. The protection of receptors (aquatic species, with emphasis on salmon) in surface waters will be achieved by reducing or eliminating further contaminant loadings to groundwater so receptors at the point of groundwater discharge in the Columbia River are not subject to additional adverse risks. Measurement of compliance will be at a nearshore well, in the downgradient plume. The location and measurement will be defined by EPA and Ecology.

Key: Ecology=Washington State Department of Ecology; EPA=U.S. Environmental Protection Agency; MCL=maximum contaminant level.
Source: DOE 2006.

Post-cleanup sampling is performed and cleanup verification packages are prepared to ensure that cleanup levels are actually achieved. For example, the second *CERCLA Five-Year Review Report for the Hanford Site* (DOE 2006) provides a listing of approved cleanup verification packages for the 300 Area.

The following groundwater and surface-water RAOs have been developed for the river corridor:[4]

- Prevent unacceptable risk to human health from ingestion of, and incidental exposure to, groundwater containing nonradioactive contaminant concentrations above Federal and state standards.

- Prevent unacceptable risk to human health from ingestion of, and incidental exposure to, groundwater containing radioactive contaminant concentrations above Federal standards.
- Prevent unacceptable risk to human health and ecological exposure to surface water containing nonradioactive contaminant concentrations above Federal and state standards.

[4] This list reflects the typical categories and outcomes that groundwater RAOs have taken.

- Prevent unacceptable risk to human health and ecological exposure to surface water containing radioactive and nonradioactive contaminant concentrations above Federal standards.

Anticipated Cleanup End State

Groundwater cleanup actions are currently being implemented to meet the following TPA milestone and cleanup levels:

- Uranium in 300 Area groundwater. "DOE will have a remedy in place designed to meet Federal Drinking Water Standards for uranium (30 µg/L [micrograms per liter]) throughout the groundwater plume in the 300-FF-5 Operable Unit unless otherwise specified in a CERCLA decision document" (M-016-110-T05, due December 31, 2015). Note that the point of compliance is measured from samples in groundwater monitoring wells.

Table U–7 summarizes the current and planned actions and the expected cleanup end state for the 300-FF-5 Operable Unit.

Table U–7. River Corridor Groundwater Plumes and Treatment Actions

Operable Unit	Primary Contaminants	Current Status and Actions	Future Actions	Anticipated Cleanup End State
300-FF-5	Uranium	Previous cleanup levels were not met for uranium. Additional treatability testing is under way, along with a new feasibility study.	Subject to final Record of Decision.	Uranium in groundwater will have a remedy in place by December 31, 2015, that will be able to achieve drinking water standards. [See Milestone M-016-110-T05.]

U.1.2.2.3 Western Portion of the Central Plateau

The western portion of the Central Plateau is located in the western side of the Core Zone Boundary and comprises the S, T, U, and Z Areas; US Ecology Commercial Low-Level Radioactive Waste Disposal Site; and ERDF.

U.1.2.2.3.1 Western Portion of the Central Plateau Hydrogeologic Regime

The hydrogeologic regime describes the system of geology and groundwater flow that governs groundwater contaminant distribution. The stratigraphy in the western portion of the Central Plateau generally includes the Hanford formation, Plio-Pleistocene (Cold Creek) Unit, and Ringold Formation. The Hanford formation contacts the Plio-Pleistocene Unit in the western part of the area and the coarse gravel and occasional sand of the Ringold Formation in the southeast. The Hanford formation represents most of the thickness of the vadose zone in the western portion of the Central Plateau (Cole et al. 2001; Last et al. 2009; Lindsey, Connelly, and Bjornstad 1992; Lindsey 1995; Thorne et al. 2006; Williams et al. 2002). Figures U–35 through U–37 depict cross sections that are typical of the vadose zone lithology in the western portion of the Central Plateau. The vadose zone ranges between 64.0 meters (210 feet) and 106 meters (348 feet) in thickness. The vadose zone generally becomes thinner going from southwest to the northeast. The vadose zone under the ERDF is approximately 100 meters (328 feet) thick (DOE 2010a).

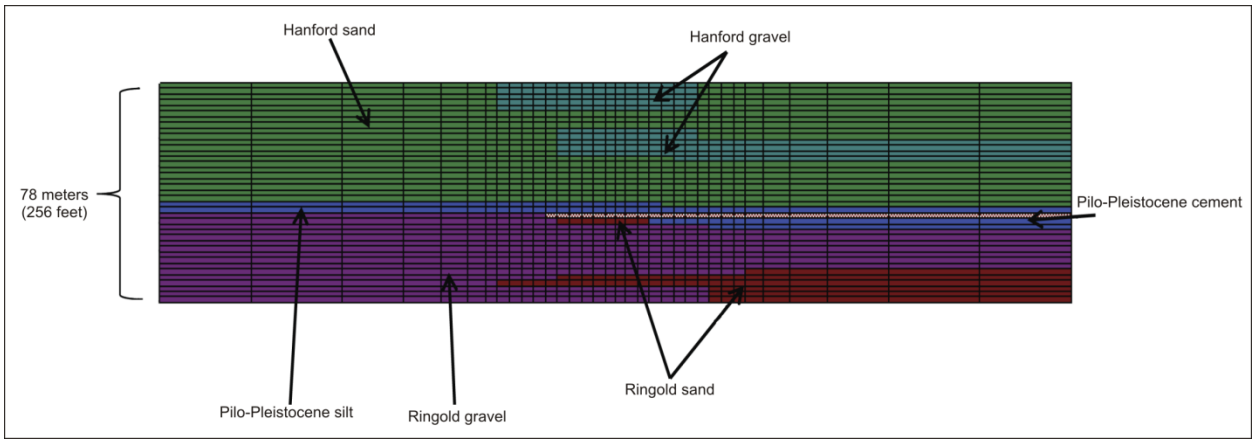


Figure U–35. West-to-East Cross Section of Vadose Zone Lithology for 216-U-1/2 Cribs

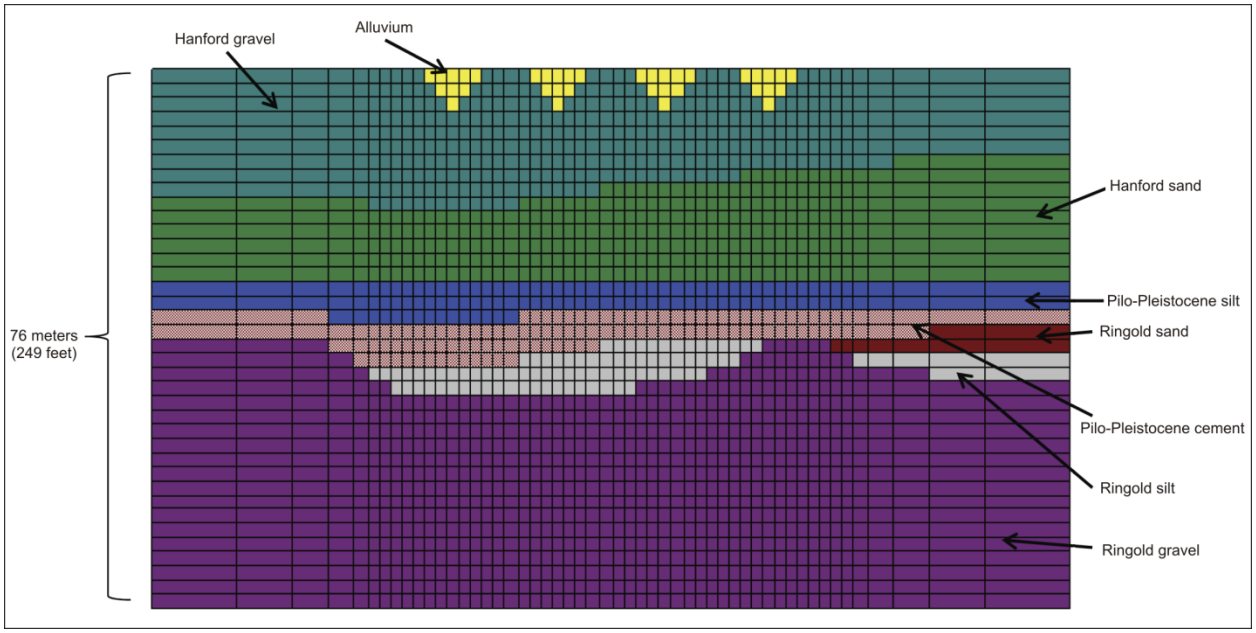


Figure U–36. West-to-East Cross Section of Vadose Zone Lithology for T Tank Farm

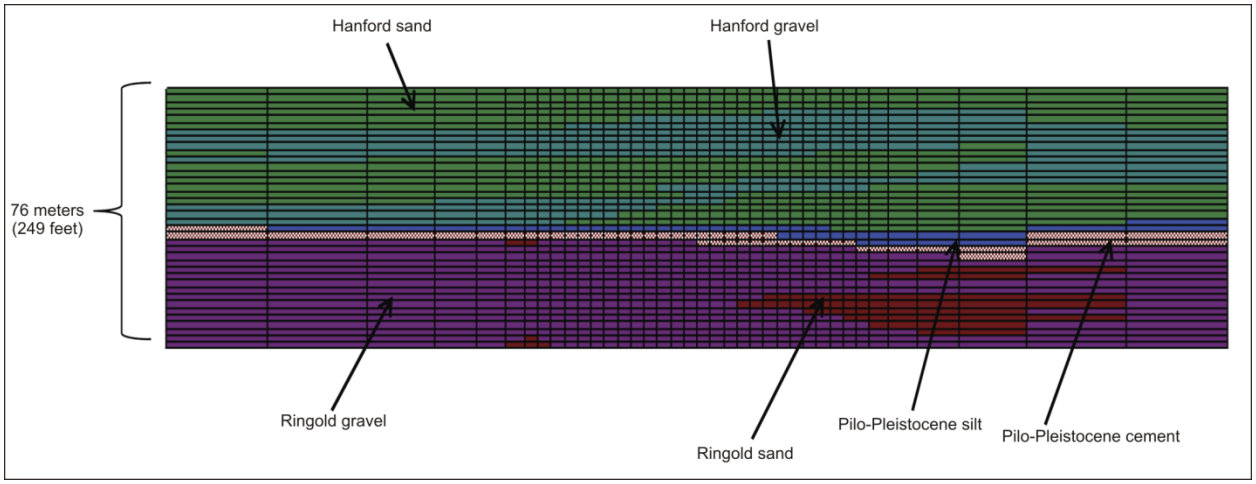
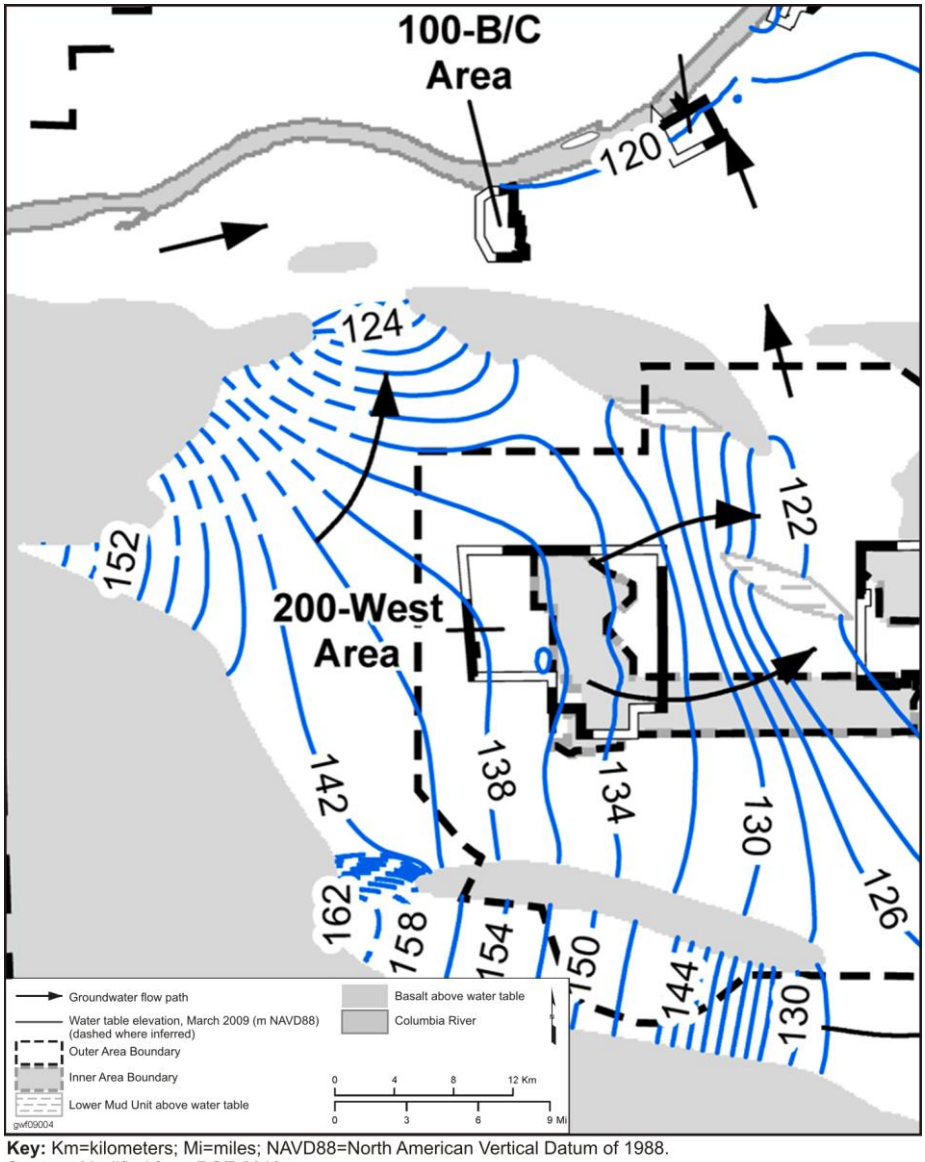


Figure U–37. West-to-East Cross Section of Vadose Zone Lithology for 216-Z-1A Trench

Groundwater in the western portion of the Central Plateau generally flows east-northeast. The water table in this area decreases in elevation from west to east, from approximately 138 meters (453 feet) in the west to approximately 130 meters (426 feet) in the east. There are a few anomalies present in the water table elevations that are attributable to pump-and-treat operations, specifically in the U and T Areas. Figure U–38 illustrates the 300 Area water table and inferred directions of flow as indicated by the 2009 groundwater monitoring report (DOE 2010a).



Key: Km=kilometers; Mi=miles; NAVD88=North American Vertical Datum of 1988.
Source: Modified from DOE 2010a.

Figure U–38. Western Portion of the Central Plateau Water Table and Inferred Groundwater Flow Directions, March 2009

U.1.2.2.3.2 Western Portion of the Central Plateau Historical Anthropogenic Discharges

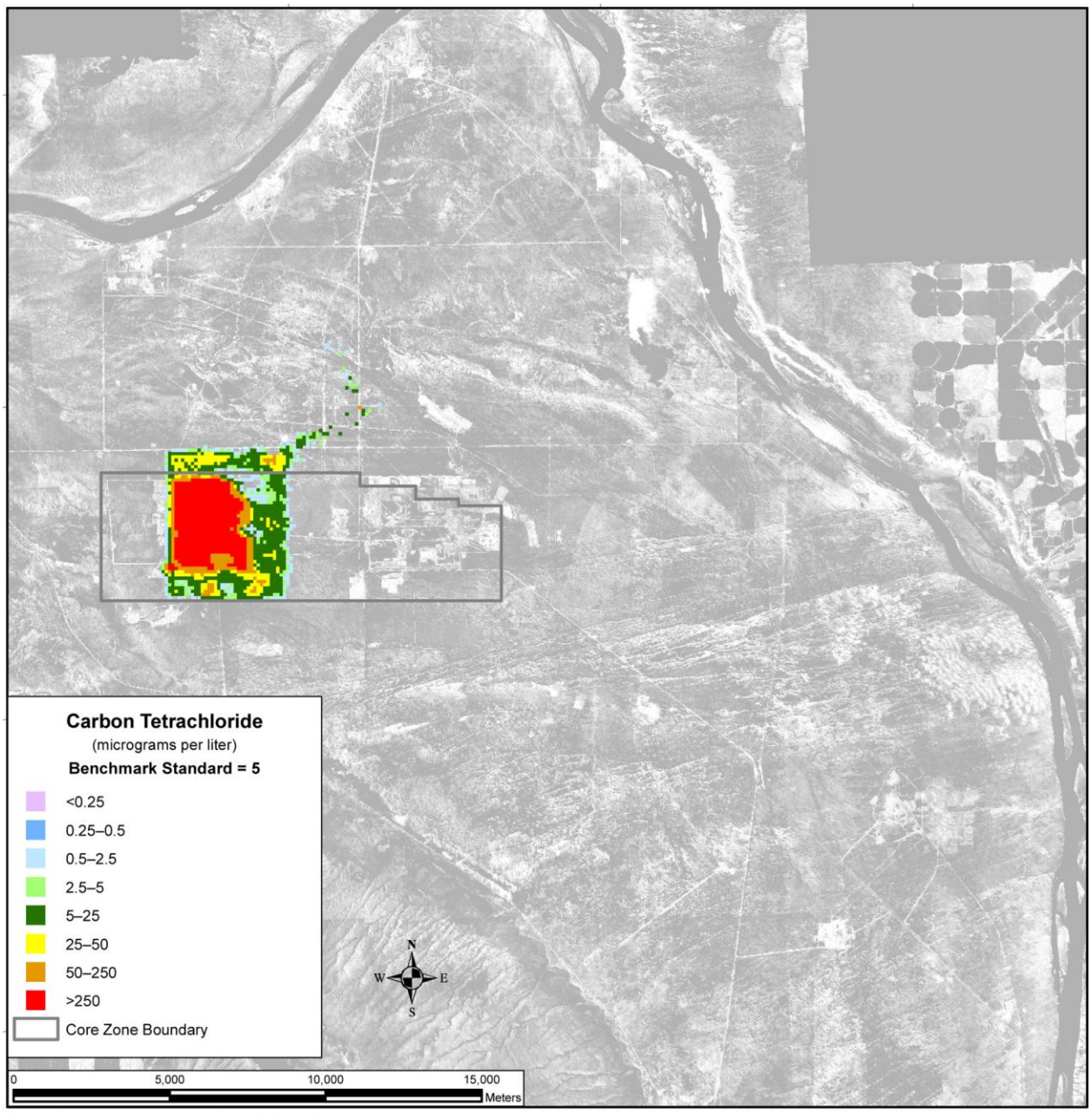
During Hanford's operational period, the main purpose of the facilities in the Central Plateau was the removal of plutonium. Likewise, the western portion of the Central Plateau was impacted by intentional and unintentional releases of liquid wastes generated from plutonium removal processes. Additionally, wastes are stored in tank farms, and there are several solid waste sites located in the western portion of the Central Plateau. The effects of these past anthropogenic activities continue to influence contaminant distribution in the subsurface in the western portion of the Central Plateau (DOE 2010a). For analysis purposes in this *TC & WM EIS*, aqueous sources of contamination were examined based on the amount of discharge. Sources with aqueous flux (volume per area) of less than 1 meter (3 feet) per year were categorized as moderate-discharge sources. Sources with aqueous flux of greater than 1 meter (3 feet) per year were categorized as heavy-discharge sources. Solid sources were categorized as low-discharge sources. Contributors to the anthropogenic contaminant sources in the western portion of the Central Plateau included heavy-discharge sites such as ponds and cribs and trenches (ditches), moderate-

discharge sites such as past leaks from tank farms, and low-discharge sites such as individual facilities. Though anthropogenic activities have diminished over time, residual effects continue to influence contaminant migration.

U.1.2.2.3.3 Western Portion of the Central Plateau Comparison of Modeled Versus Measured Spatial Contaminant Distributions

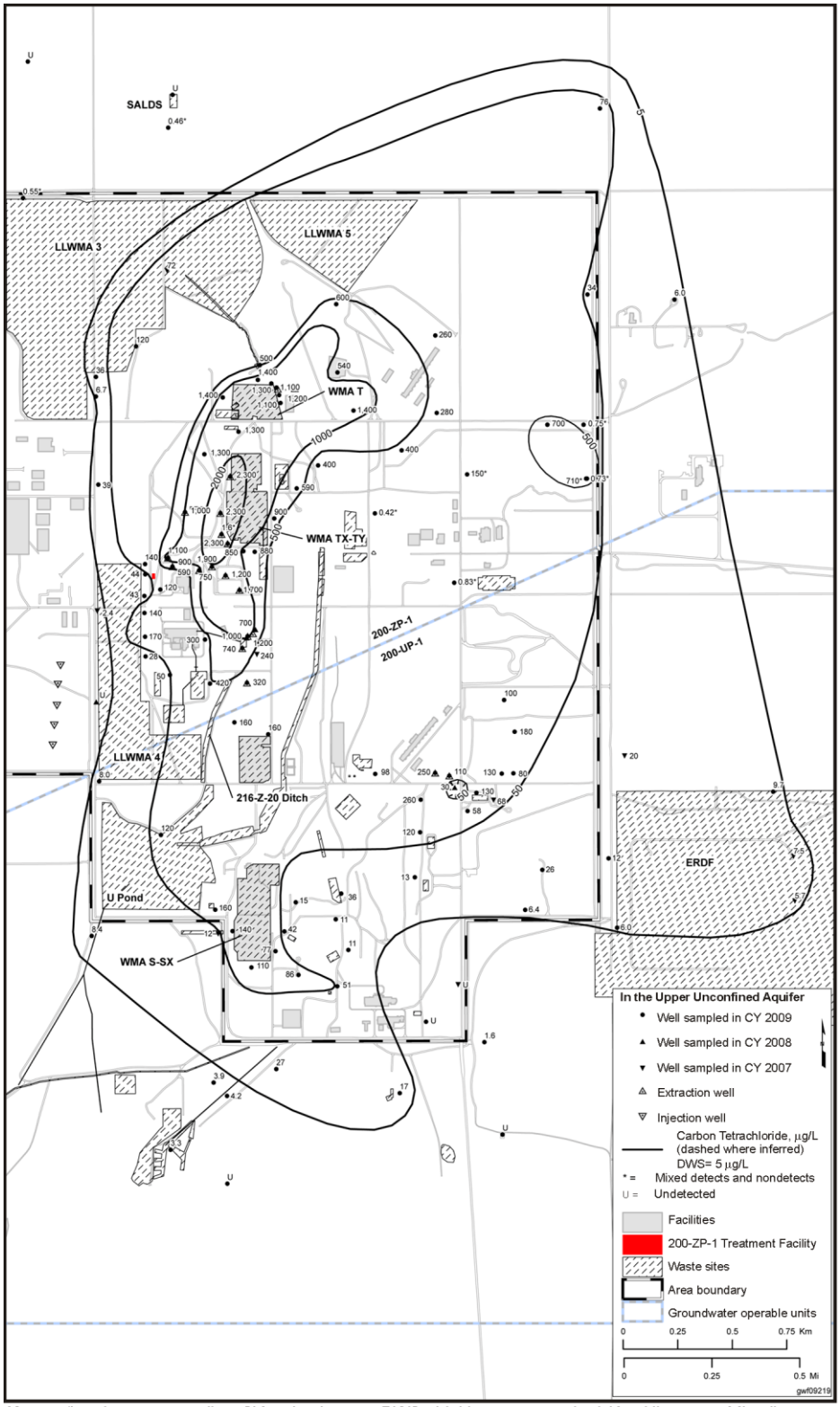
This section discusses the distribution of inventories as described in the 2009 groundwater monitoring report (DOE 2010a) and compares the results of the impacts analysis for past-practice sources in the western portion of the Central Plateau in terms of the spatial distribution of COPC concentrations in CY 2010. Concentrations of each radionuclide and chemical are indicated by a color scale that is relative to the benchmark concentration. Concentrations greater than the benchmark concentration are indicated by the fully saturated colors green, yellow, orange, and red in order of increasing concentration. Concentrations less than the benchmark concentration are indicated by the faded colors green, blue, indigo, and violet in order of decreasing concentration. Note that the concentration ranges are on a logarithmic scale to facilitate visual comparison of concentrations that vary over three orders of magnitude.

The primary contaminants that form extensive plumes within the western portion of the Central Plateau include carbon tetrachloride, chromium, nitrate, iodine-129, tritium, technetium-99, and uranium. In general, the simulations of groundwater transport replicate the values measured in the field. Carbon tetrachloride is a COPC in the western portion of the Central Plateau and is primarily associated with the discharge of the 216-Z-1A, 216-Z-9, and 216-Z-18 Trenches in the Z Area. Figure U–39 shows the spatial distribution of carbon tetrachloride as predicted in the impacts analysis of past-practice sources, and Figure U–40 is the corresponding depiction of the carbon tetrachloride plume as presented in the 2009 groundwater monitoring report (DOE 2010a). See Section U.1.2.1.4 for a discussion describing the factors leading to the qualitatively greater uncertainty in the future carbon tetrachloride spatial concentration distribution.



Note: To convert meters to feet, multiply by 3.281.

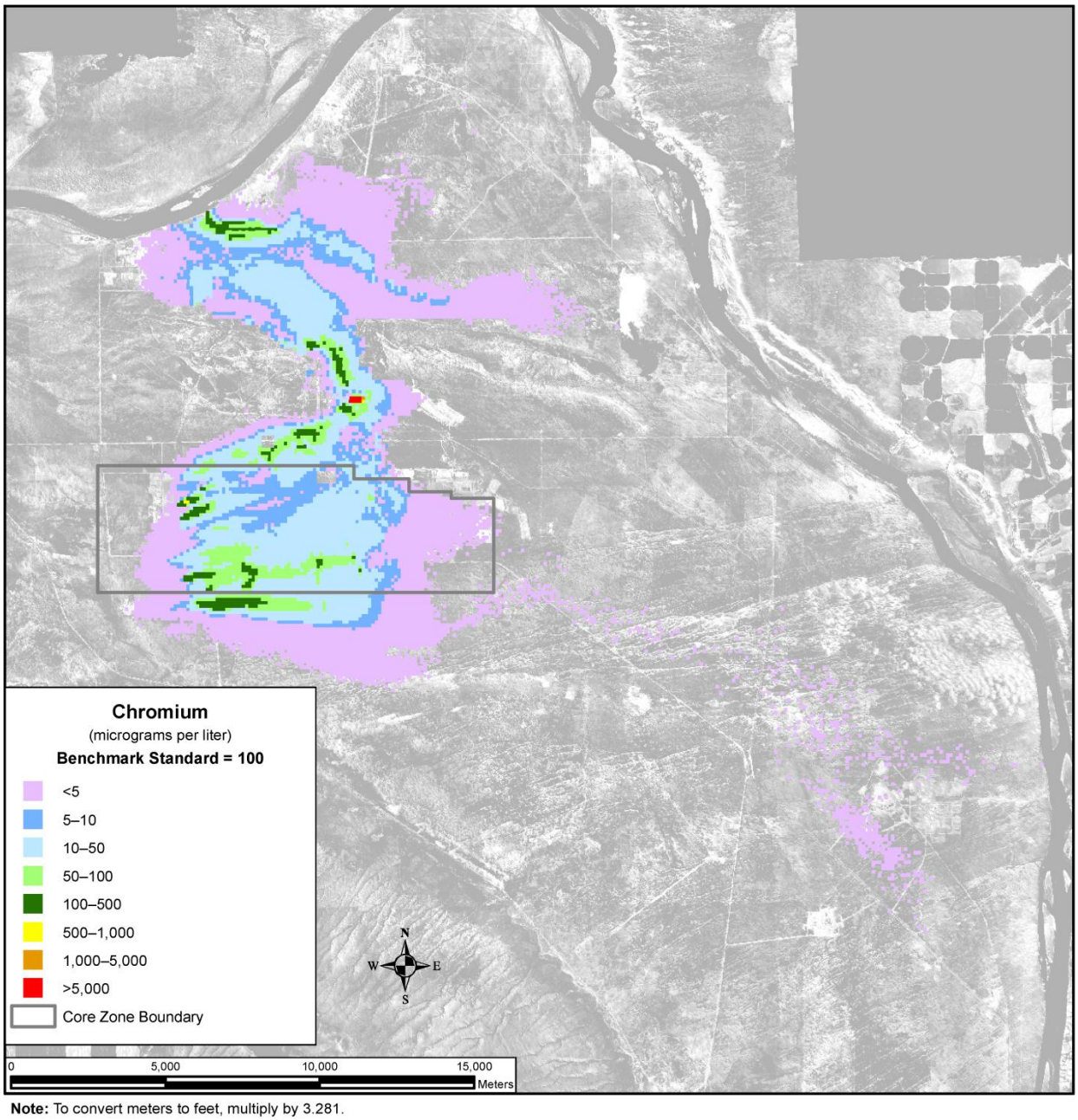
Figure U–39. Spatial Distribution of Groundwater Carbon Tetrachloride Concentration (Past-Practice Sources), Western Portion of the Central Plateau, Calendar Year 2010



Key: µg/L=micrograms per liter; CY=calendar year; DWS=drinking water standard; Km=kilometers; Mi=miles.
Source: DOE 2010a.

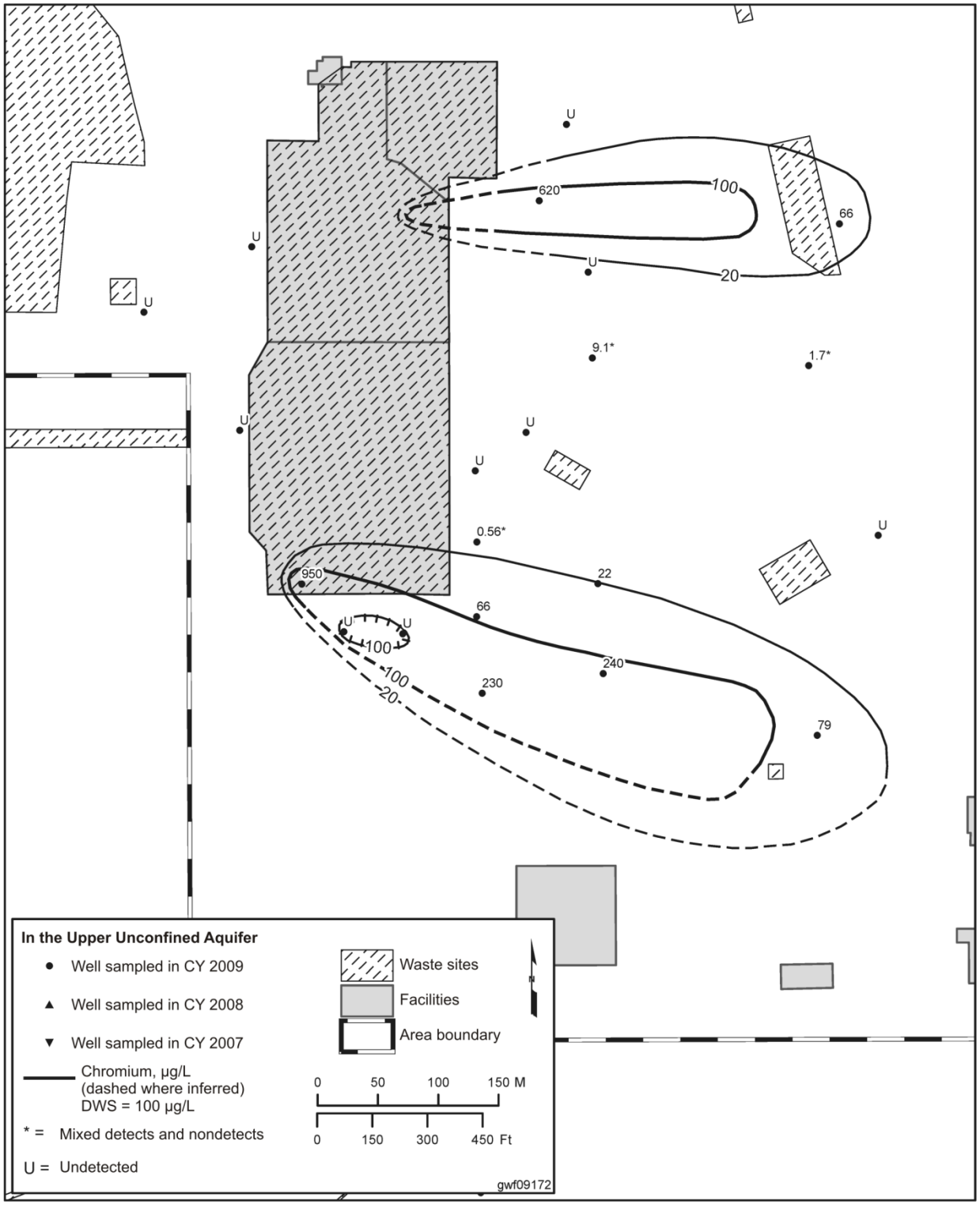
Figure U–40. Field-Reported Spatial Distribution of Groundwater Carbon Tetrachloride Concentration, 200-West Area, Calendar Year 2009

The chromium plumes in the western portion of the Central Plateau are associated with discharges to ponds (S Area), past leaks (Waste Management Area S-SX), discharges to cribs and trenches (Waste Management Area T-TX), and burial grounds. Figure U–41 shows the spatial distribution of chromium as predicted in the impacts analysis for past-practice sources. Figure U–42 is the corresponding depiction of the chromium plume near the Waste Management Area S-SX (DOE 2010a). The chromium plumes predicted by the groundwater transport simulations approximately match the plumes indicated by the 2009 groundwater monitoring report with respect to peak concentrations and locations of the plumes.



Note: To convert meters to feet, multiply by 3.281.

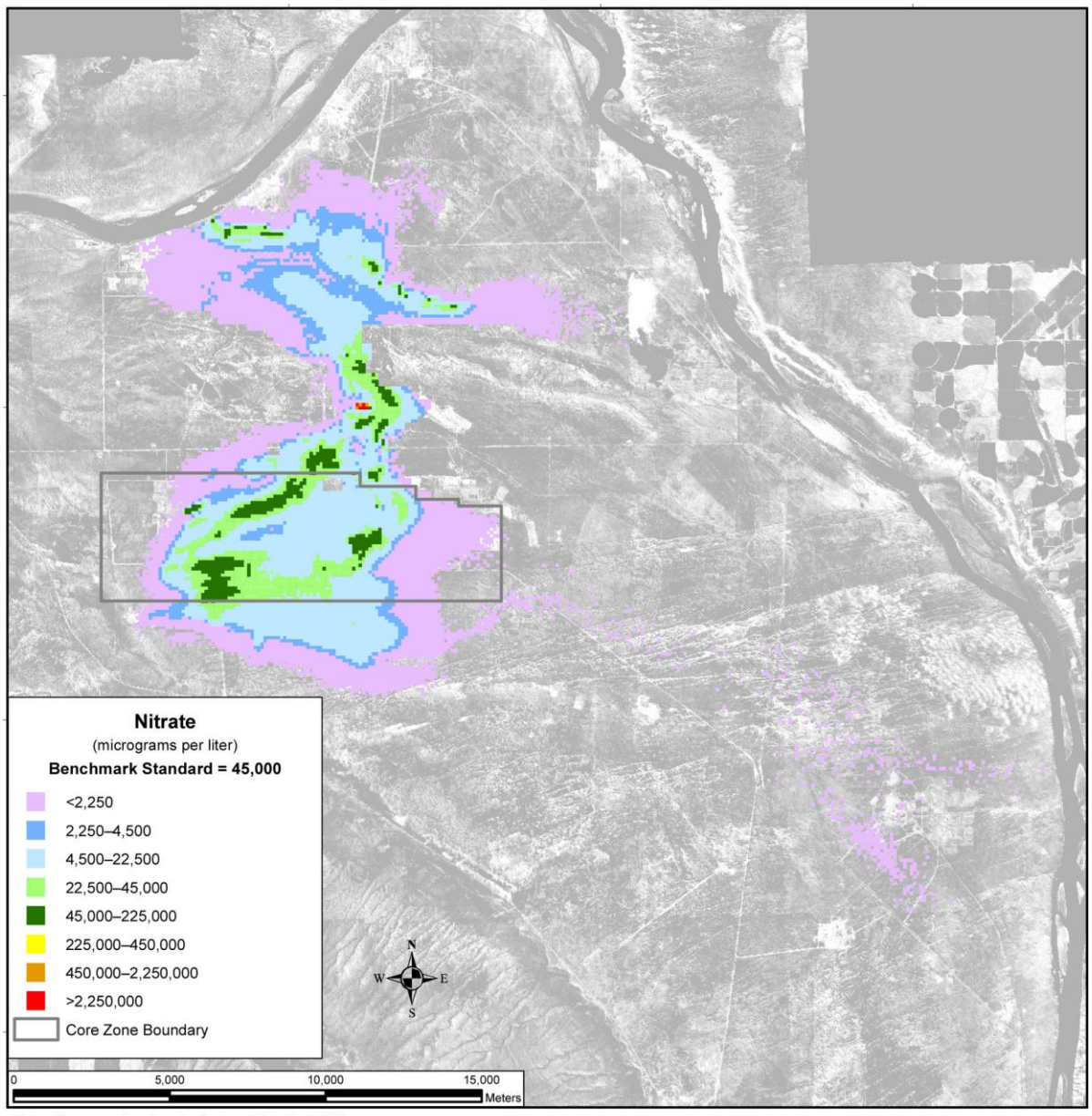
Figure U–41. Spatial Distribution of Groundwater Chromium Concentration (Past-Practice Sources), Western Portion of the Central Plateau, Calendar Year 2010



Key: µg/L=micrograms per liter; CY=calendar year; DWS=drinking water standard; Ft=feet; M=meters.
Source: DOE 2010a.

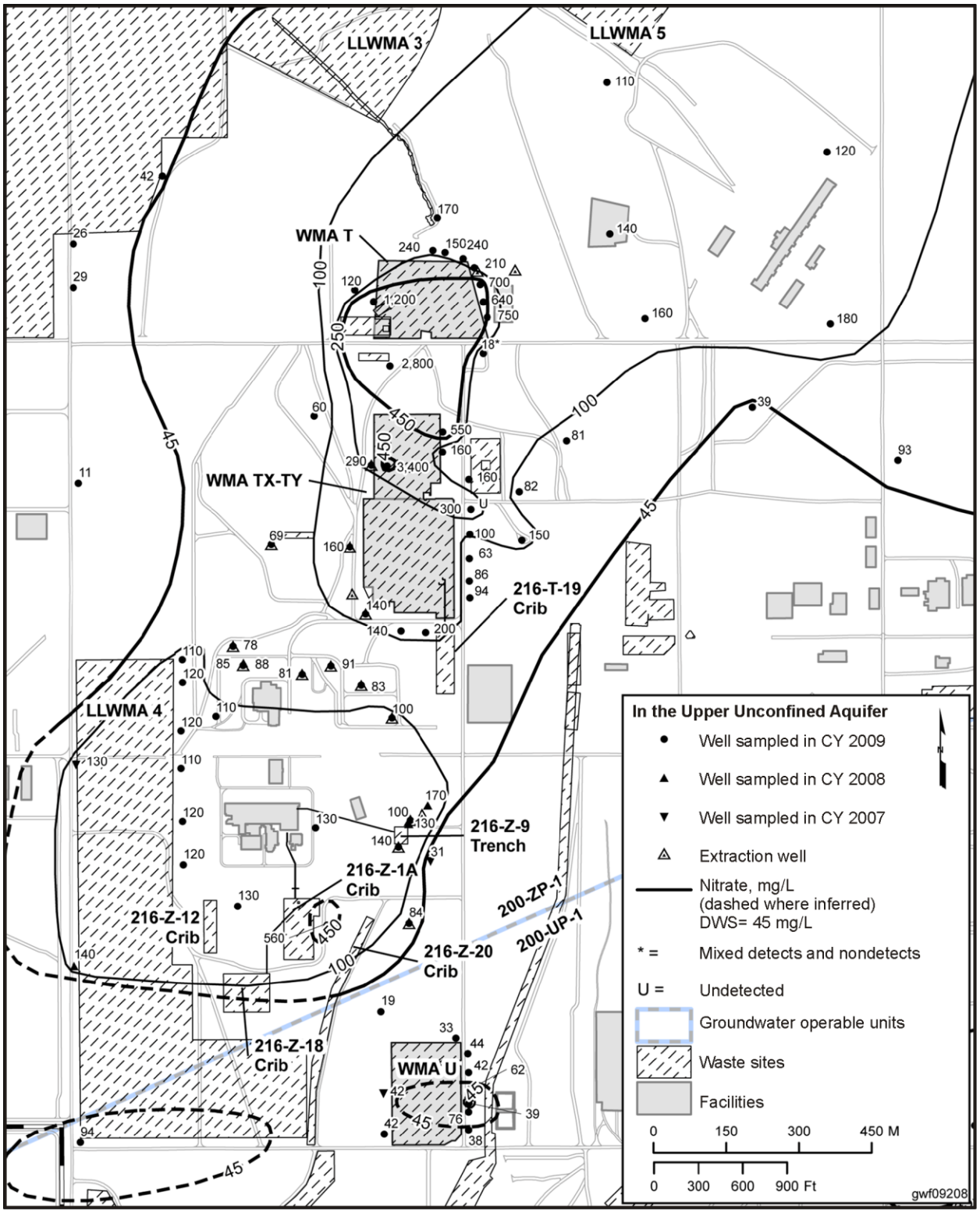
Figure U–42. Field-Reported Spatial Distribution of Groundwater Chromium Concentration (Past-Practice Sources), Waste Management Area S-SX, Calendar Year 2009

There are several nitrate plumes in the western portion of the Central Plateau that are primarily associated with the discharges from cribs and trenches (ditches). In general, the simulations of groundwater transport replicate the nitrate concentration values measured in the field within an order of magnitude, except for the large nitrate plume in the southwestern portion of the Central Plateau. The extensive plume in the southern western portion of the Central Plateau near the ERDF is not replicated in the groundwater transport and shows lower concentrations of nitrate in this area, as well as a smaller area that exceeds the benchmark standard. An inventory for nitrate was not available for the ERDF. (See Appendix S for a detailed discussion of the waste inventories used for the cumulative impacts analyses). Figure U–43 shows the spatial distribution of nitrate as predicted in the impacts analysis for past-practice sources. Figures U–44 and U–45 are the corresponding depictions of the nitrate plumes present in the western portion of the Central Plateau as presented in the 2009 groundwater monitoring report (DOE 2010a).



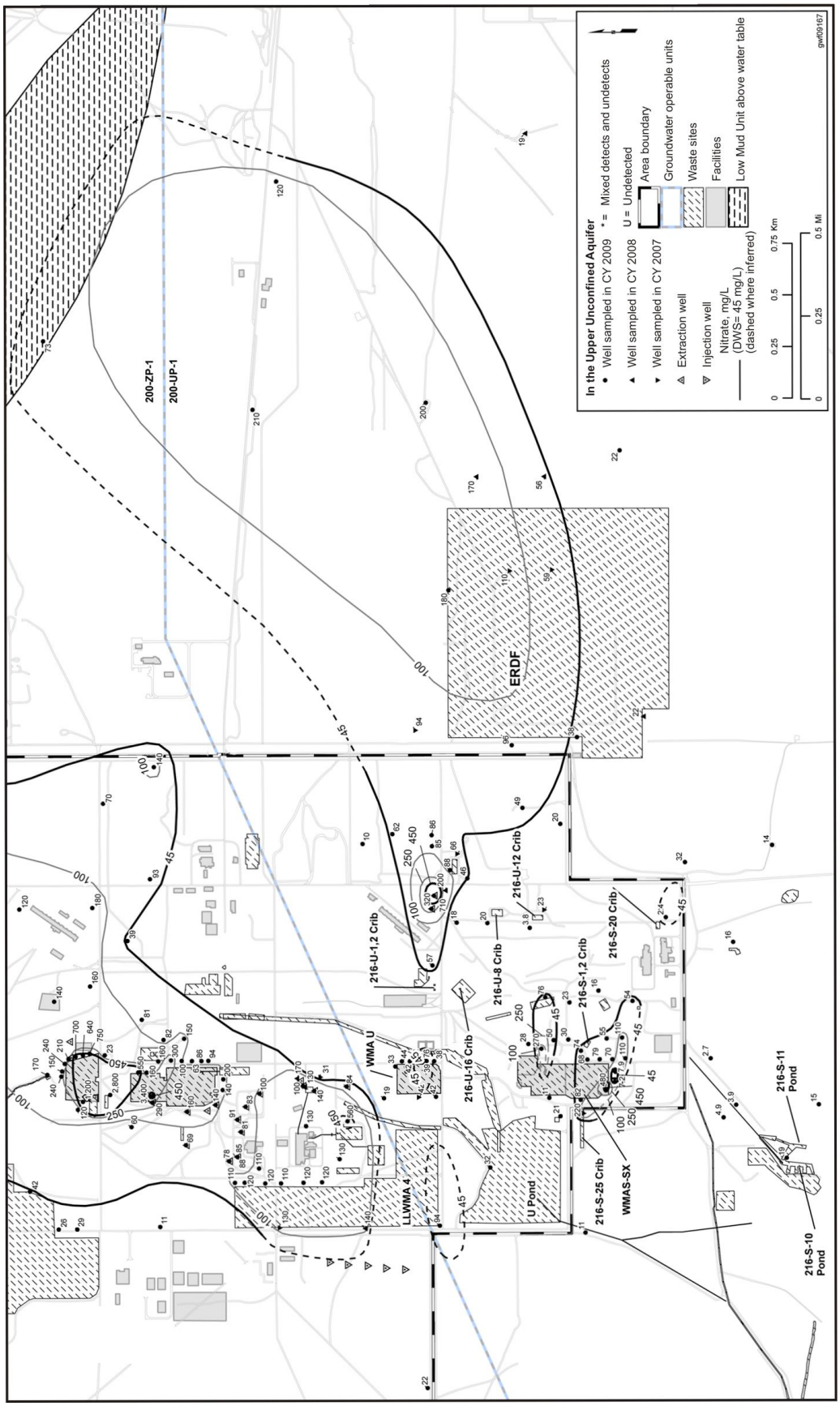
Note: To convert meters to feet, multiply by 3.281.

Figure U–43. Spatial Distribution of Groundwater Nitrate Concentration (Past-Practice Sources), Western Portion of the Central Plateau, Calendar Year 2010



Key: CY=calendar year; DWS=drinking water standard; Ft=feet; M=meters; mg/L=milligrams per liter.
Source: DOE 2010a.

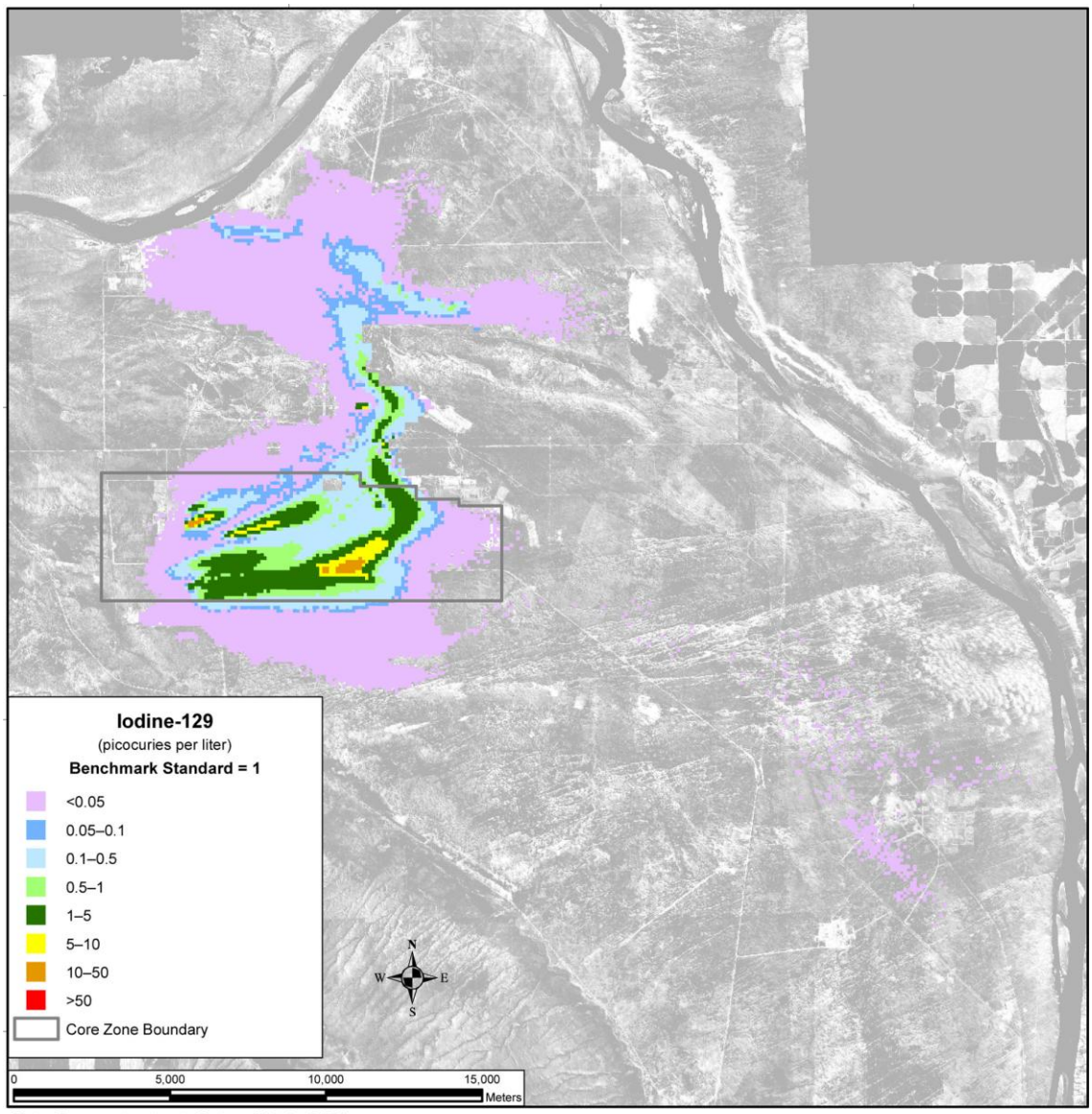
Figure U–44. Field-Reported Spatial Distribution of Groundwater Nitrate Concentration, Central and Northern Portions of the 200-West Area, Calendar Year 2009



Key: CY=calendar year; DWS=drinking water standard; Km=kilometers; mg/L=milligrams per liter; Mi=miles.
Source: DOE 2010a.

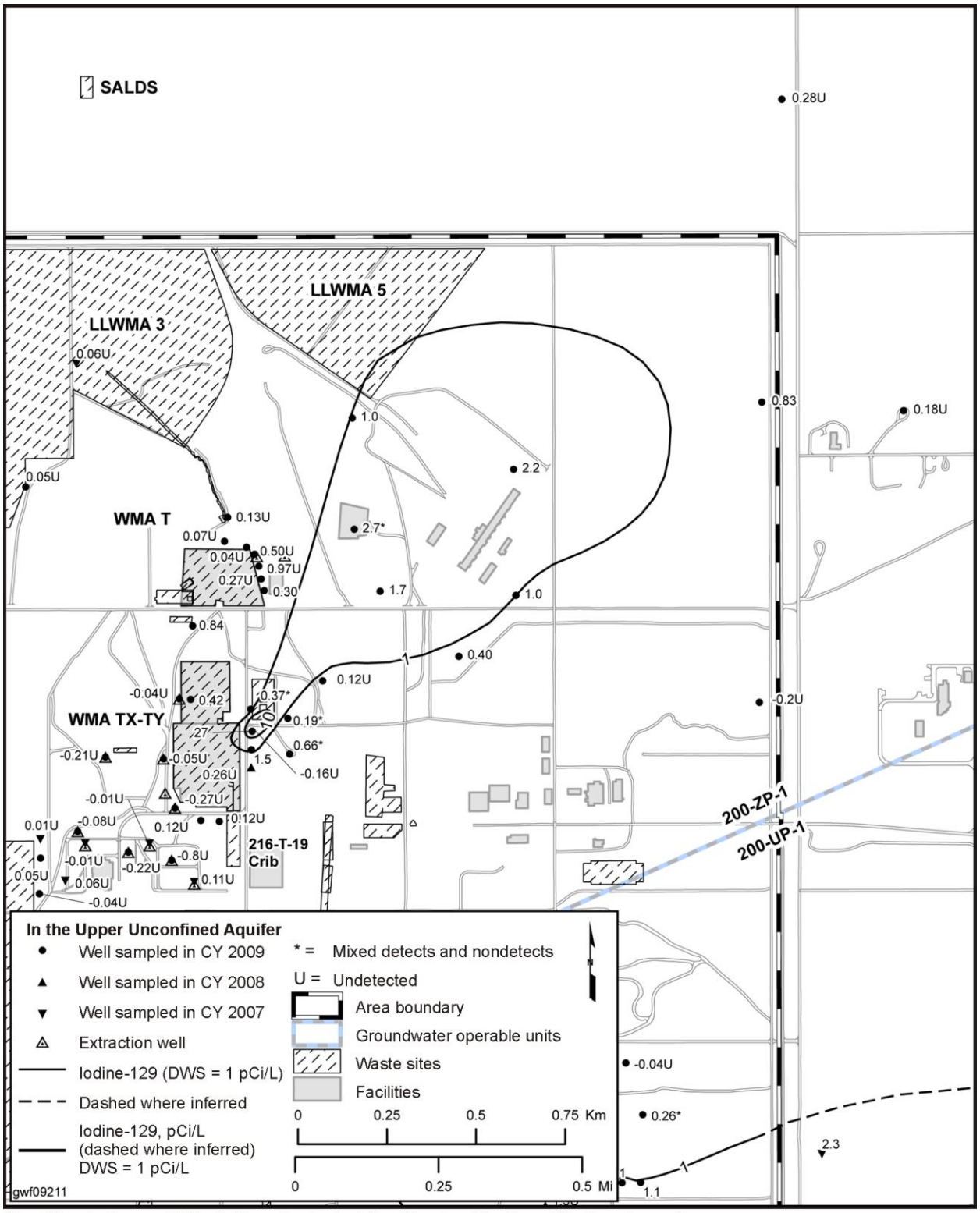
Figure U–45. Field-Reported Spatial Distribution of Groundwater Nitrate Concentration, Southern 200-West Area, Calendar Year 2009

Iodine-129 plumes in the western portion of the Central Plateau originate from the TX/TY waste management areas, U Plant, REDOX disposal facilities, and discharges from several cribs. In general, the simulations of groundwater transport replicate the values measured in the field within an order of magnitude. The largest of the iodine-129 plumes in this area originates in the southeastern 200-West Area and extends approximately 2 kilometers (1.2 miles) east into the 600 Area, with its highest concentrations measured at up to 10 times the drinking water standard. The values of iodine-129 concentrations estimated by the groundwater transport simulations approximately match the plumes for this area; however, the simulated plume extends farther east and toward the Gable Gap. Additionally, the simulated groundwater transport results indicate a plume near the 216-W-LWC Crib that is not indicated in the 2009 groundwater monitoring report (DOE 2010a). Appendix S provides a detailed discussion of the waste inventories used for the cumulative impacts analyses. Figure U–46 shows the spatial distribution of iodine-129 as predicted in the impacts analysis for past-practice sources. Figures U–47 and U–48 are depictions of the iodine-129 plumes in the western portion of the Central Plateau as presented in the 2009 groundwater monitoring report.



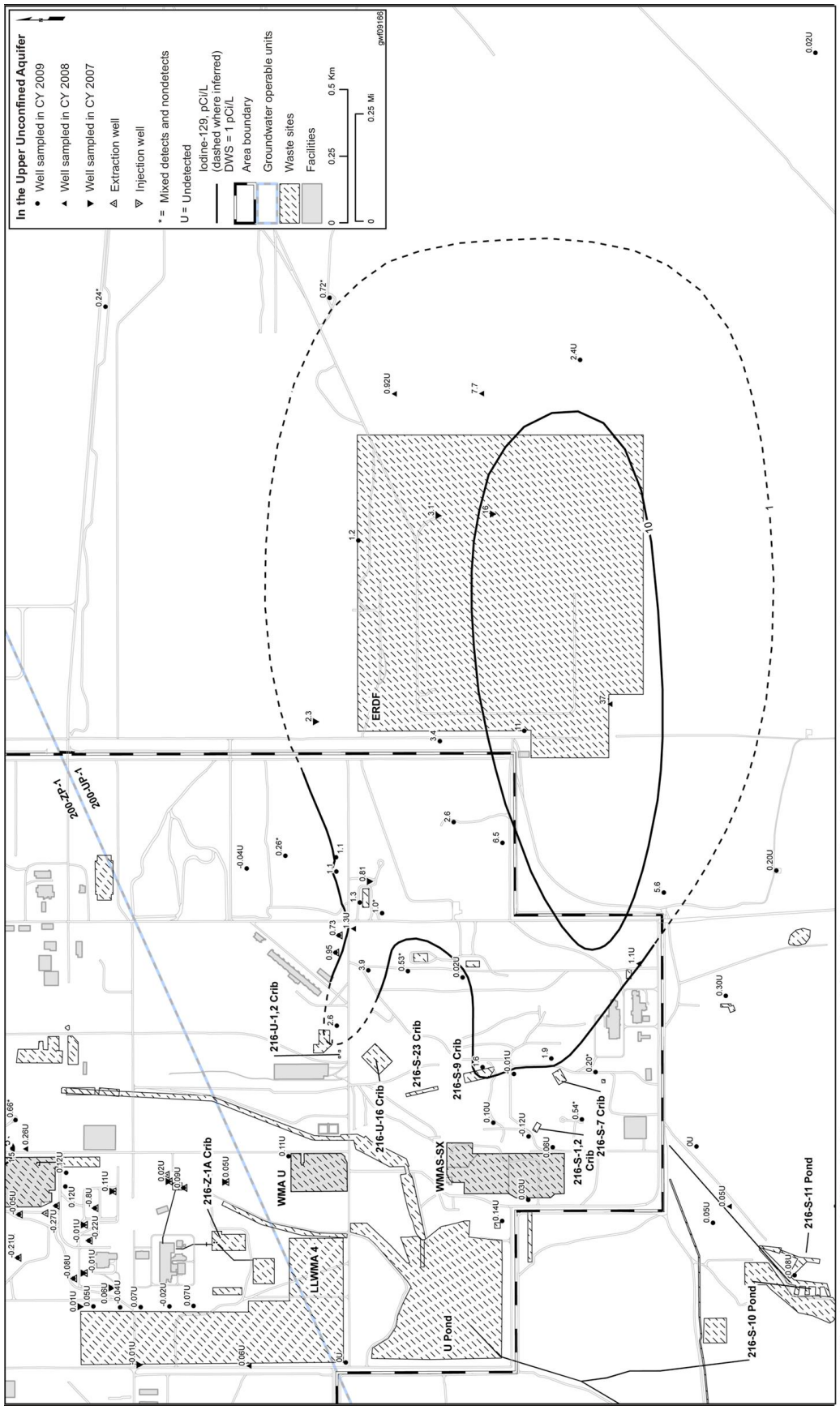
Note: To convert meters to feet, multiply by 3.281.

Figure U–46. Spatial Distribution of Groundwater Iodine-129 Concentration (Past-Practice Sources), Western Portion of the Central Plateau, Calendar Year 2010



Key: CY=calendar year; DWS=drinking water standard; Km=kilometers; Mi=miles; pCi/L=picocuries per liter.
Source: DOE 2010a.

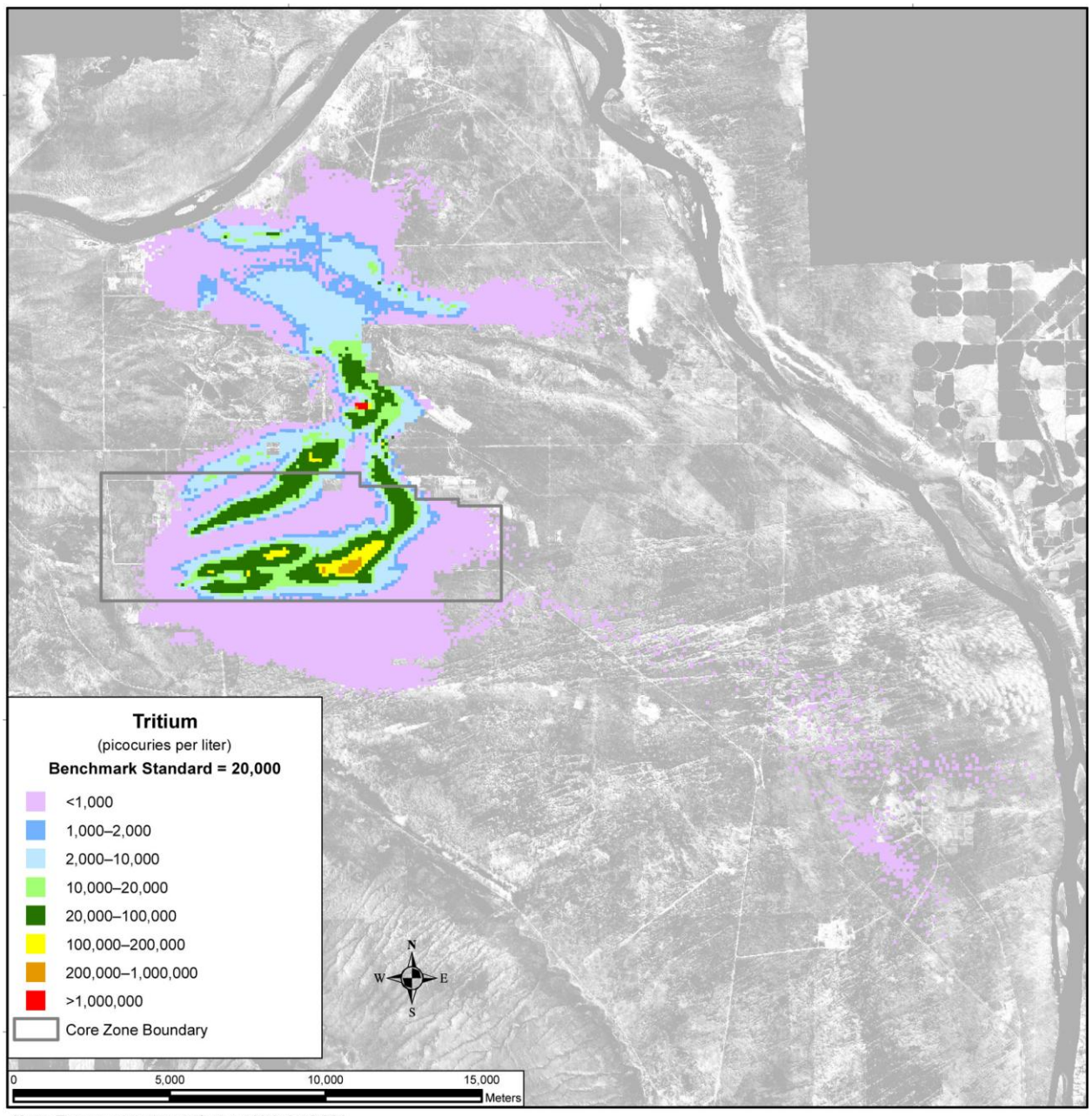
Figure U–47. Field-Reported Spatial Distribution of Groundwater Iodine-129 Concentration, Northern 200-West Area, Calendar Year 2009



Key: CY=calendar year; DWS=drinking water standard; Km=kilometers; Mi=miles; pCi/L=picocuries per liter.
Source: DOE 2010a.

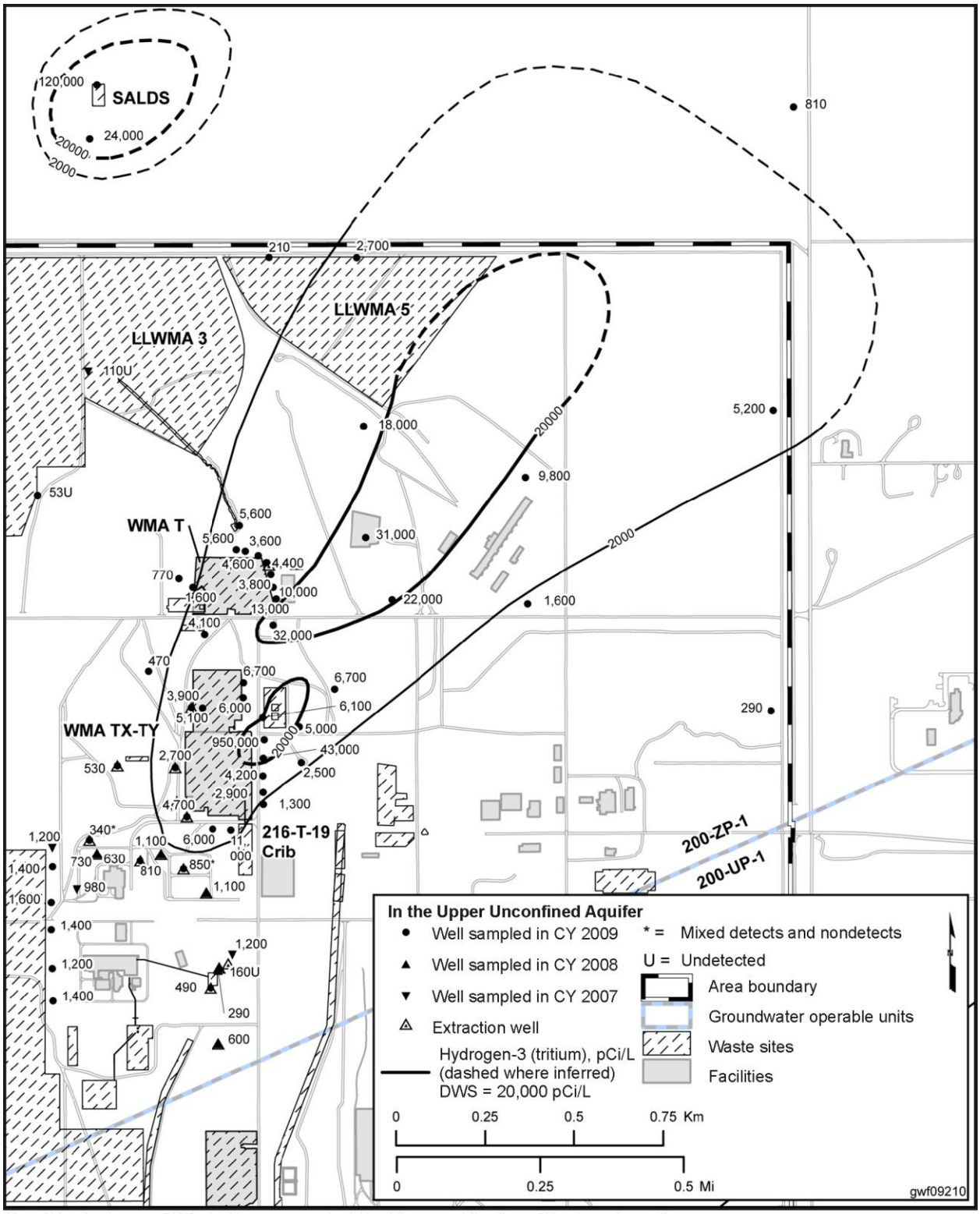
Figure U–48. Field-Reported Spatial Distribution of Groundwater Iodine-129 Concentration, Southern 200-West Area, Calendar Year 2009

In the northern portion of the western Central Plateau, tritium contamination can be attributed to waste disposal facilities adjacent to the T/TX/TY waste management areas, as well as from permitted discharges from the State-Approved Land Disposal Site. In the southern portion of the western Central Plateau, tritium contamination can be attributed to waste disposal facilities associated with the REDOX Facility, with a large plume extending from the REDOX Facility cribs and a smaller plume extending from 216-S-25 Crib. Figure U–49 shows the spatial distribution of tritium as predicted in the impacts analysis for past-practice sources. Figures U–50 and U–51 are the depictions of the tritium plumes in the western portion of the Central Plateau as presented in the 2009 groundwater monitoring report (DOE 2010a). The predicted plumes generally correspond to the field plumes, except the tritium plume originating from the State-Approved Land Disposal Site, which was not included in the simulations.



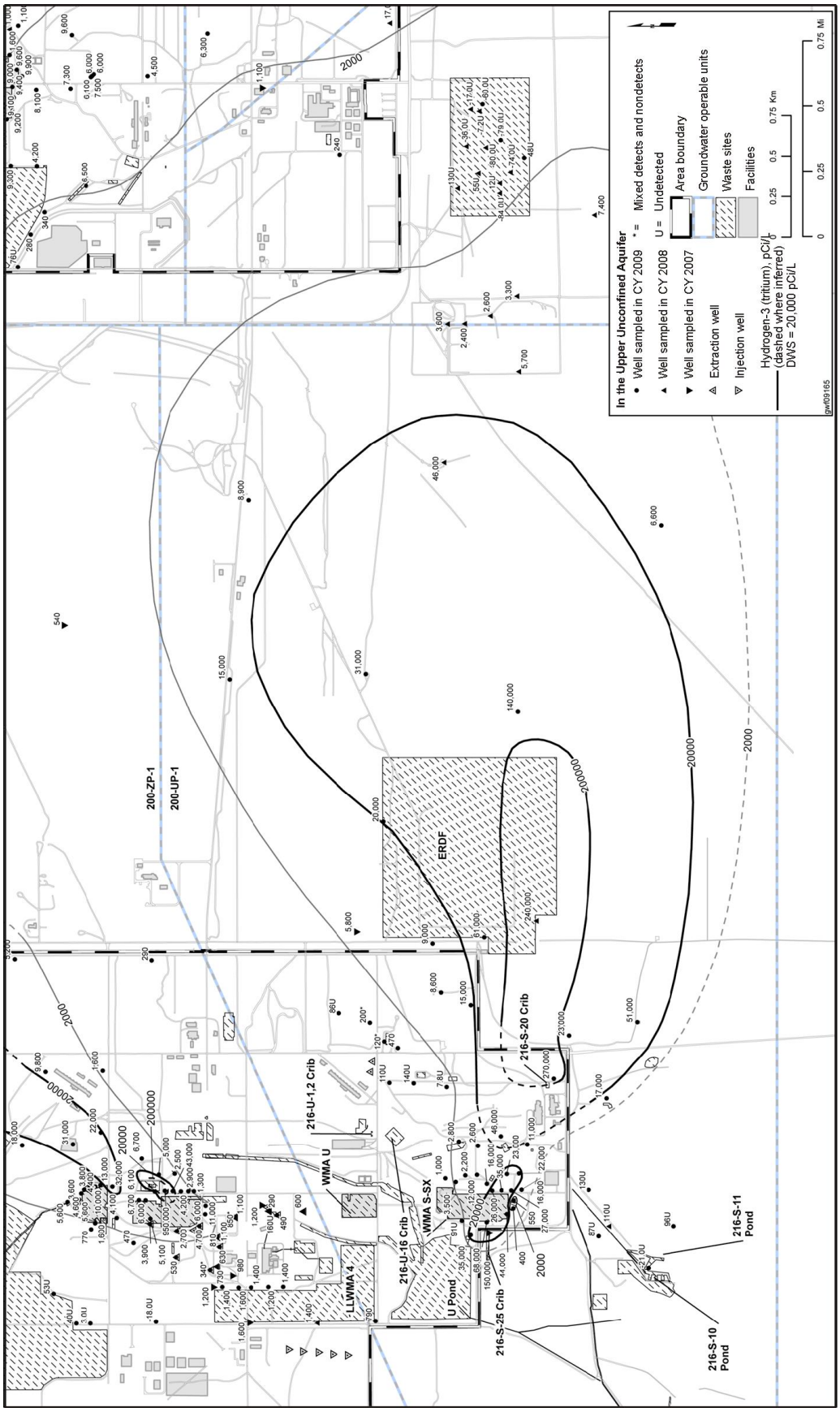
Note: To convert meters to feet, multiply by 3.281.

Figure U–49. Spatial Distribution of Groundwater Hydrogen-3 (Tritium) Concentration (Past-Practice Sources), Western Portion of the Central Plateau, Calendar Year 2010



Key: CY=calendar year; DWS=drinking water standard; Km=kilometers; Mi=miles; pCi/L=picocuries per liter.
Source: DOE 2010a.

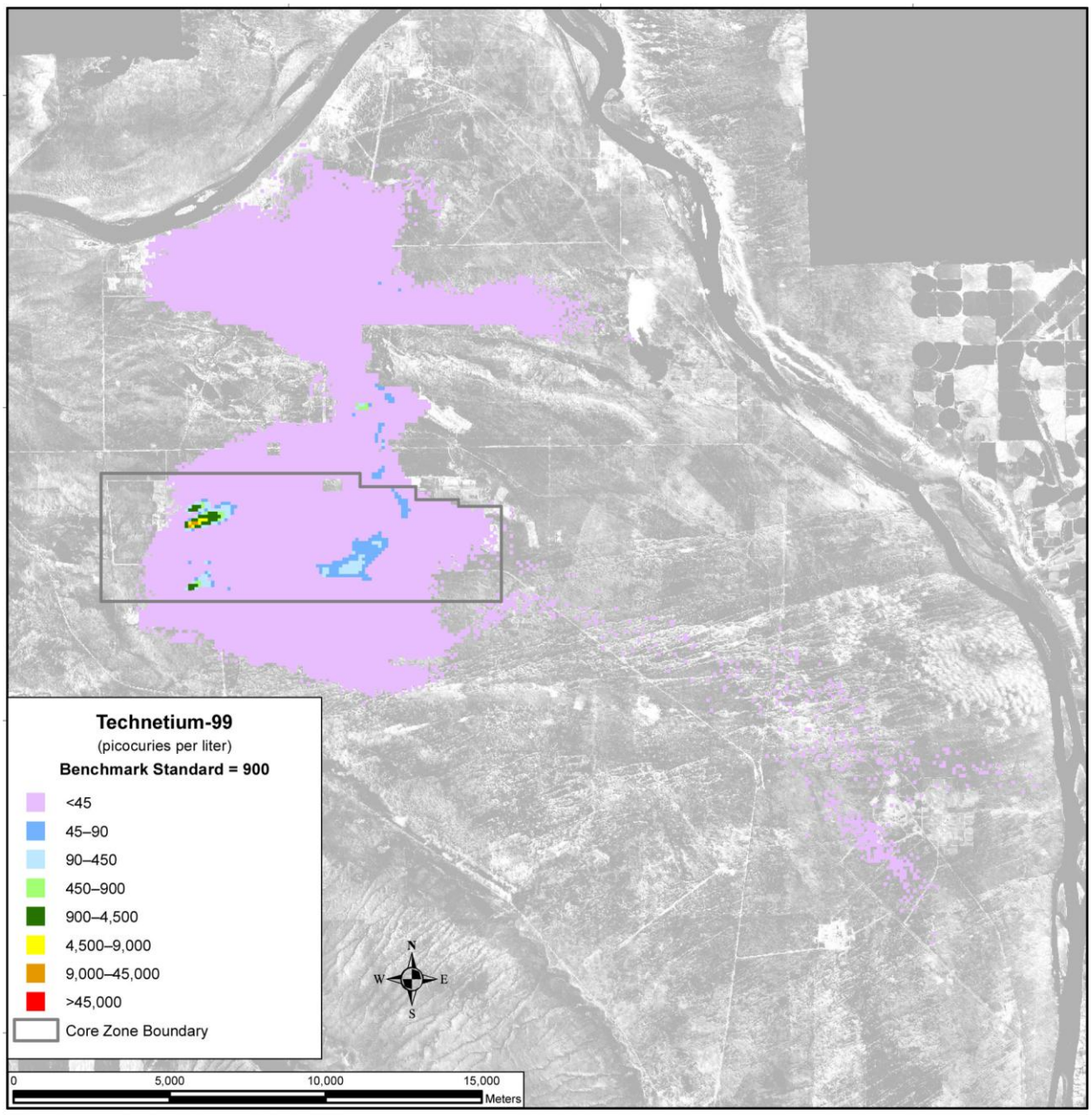
Figure U–50. Field-Reported Spatial Distribution of Groundwater Hydrogen-3 (Tritium) Concentration, Northern 200-West Area, Calendar Year 2009



Key: CY=calendar year; DWS=drinking water standard; Km=kilometers; Mi=miles; pCi/L=picocuries per liter.
Source: DOE 2010a.

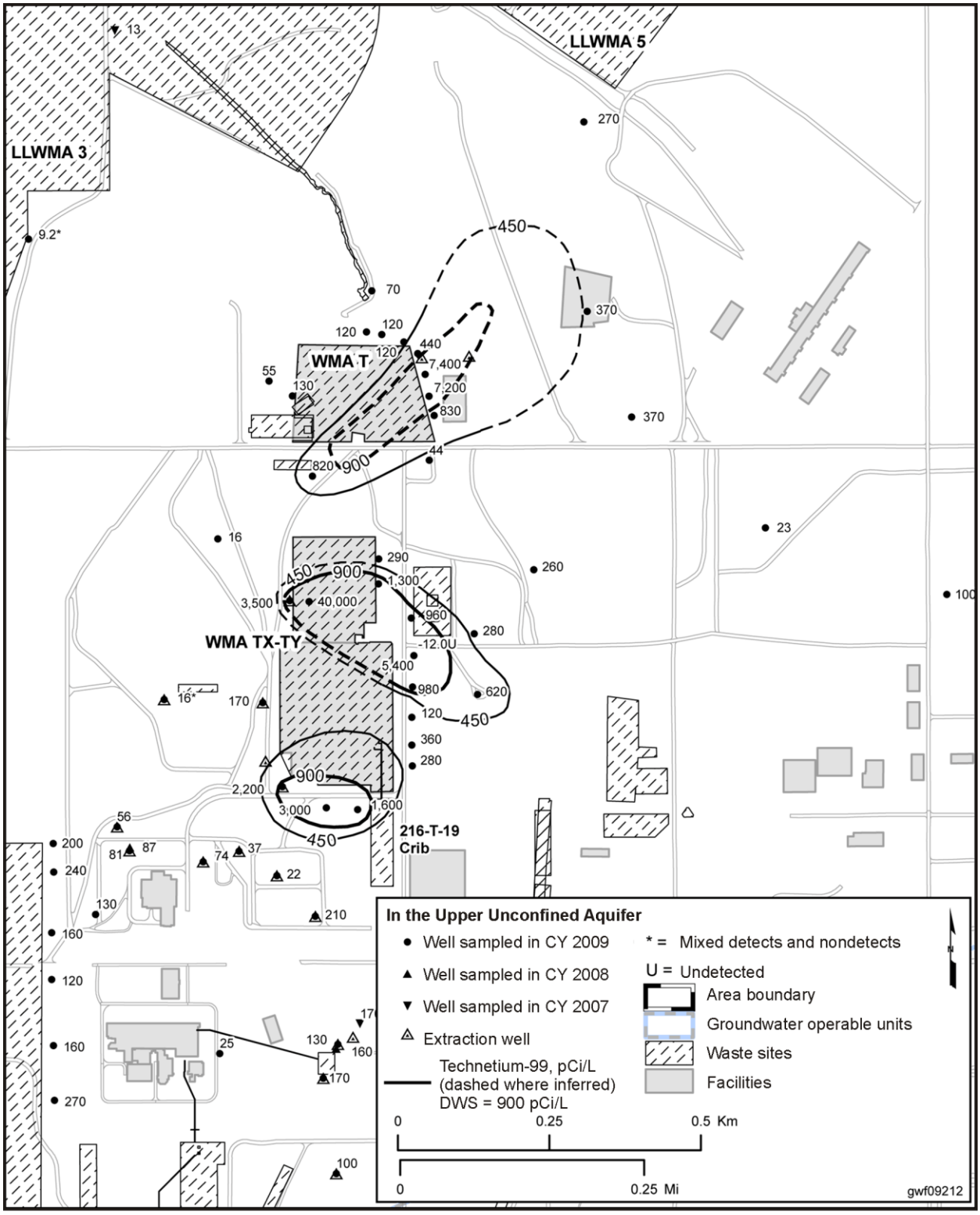
Figure U–51. Field-Reported Spatial Distribution of Groundwater Hydrogen-3 (Tritium) Concentration, Southern 200-West Area, Calendar Year 2009

Technetium-99 contamination is present in the western Central Plateau on the eastern side of Waste Management Area T, downgradient from the 216-U-1/2 Cribs near U Plant and near Waste Management Areas S-SX and U (DOE 2010a). In general, the simulations of groundwater transport replicate the technetium-99 concentration values measured in the field within an order of magnitude in the vicinity of Waste Management Areas T and TX-TY. In the vicinity of Waste Management Areas U and S-SX, and the ERDF, the groundwater transport simulations depict concentrations approximately one order of magnitude lower than the 2009 groundwater monitoring report (DOE 2010a). (Appendix S provides a detailed discussion of the waste inventories used for the cumulative impacts analysis). The angle and extent of the plume near Waste Management Area T are closely replicated in the groundwater transport simulations. The plumes in Waste Management Areas TX-TY are comingled, appearing as a single plume, and extend more toward the Gable Gap in the groundwater transport simulations, but are in approximately the same location as depicted in the 2009 groundwater monitoring report (DOE 2010a). The plumes near Waste Management Areas U and S-SX also extend slightly more toward the Gable Gap than in the 2009 groundwater monitoring report. The plume near the ERDF is present in the groundwater transport simulation results at approximately the same size and angle as in the 2009 groundwater monitoring report; however, it is further to the east. Figure U–52 shows the spatial distribution of technetium-99 as predicted in the impacts analysis for past-practice sources. Figures U–53 and U–54 are the depictions of the technetium-99 plumes in the western portion of the Central Plateau as presented in the 2009 groundwater monitoring report.



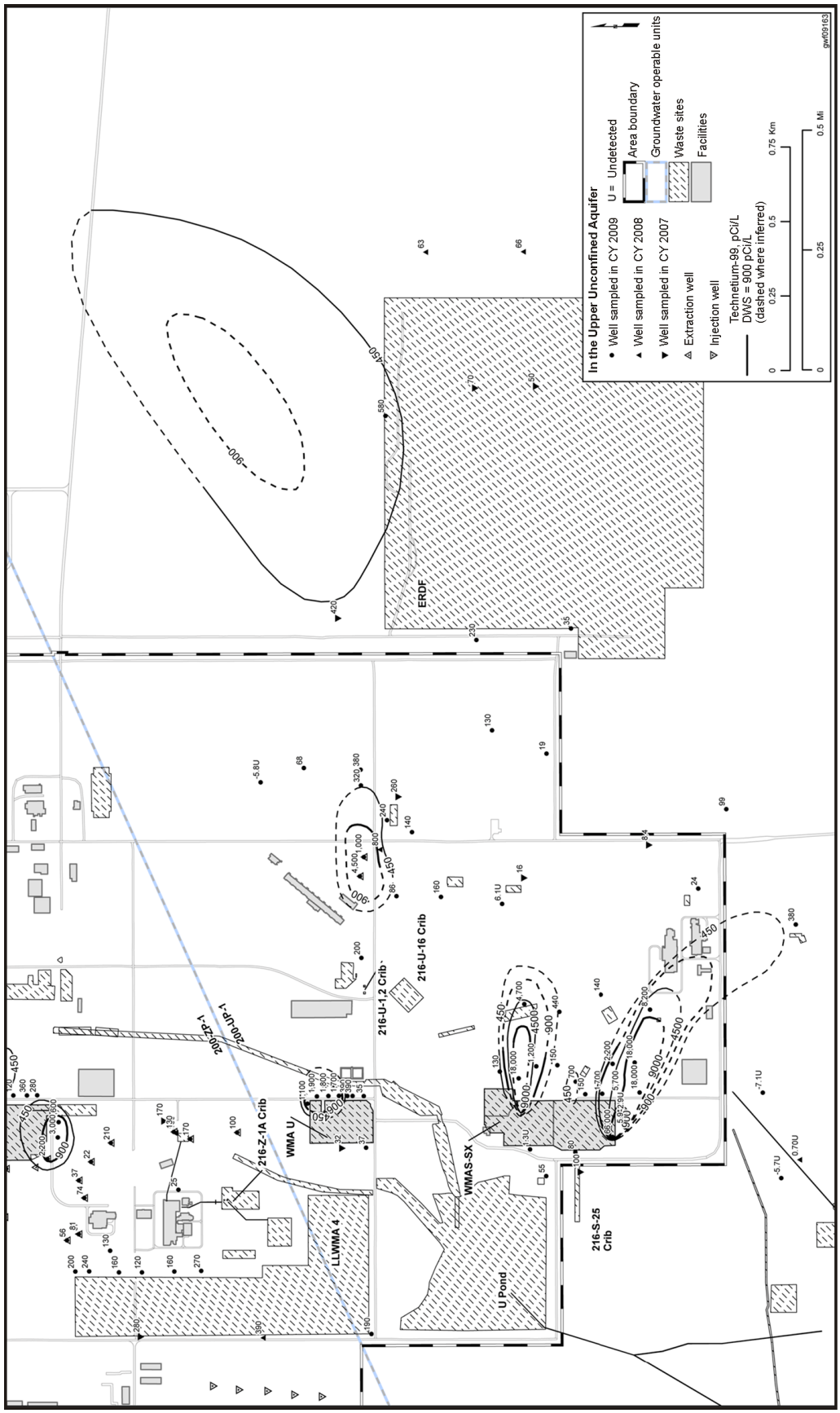
Note: To convert meters to feet, multiply by 3.281.

Figure U–52. Spatial Distribution of Groundwater Technetium-99 Concentration (Past-Practice Sources), Western Portion of the Central Plateau, Calendar Year 2010



Key: CY=calendar year; DWS=drinking water standard; Km=kilometers; Mi=miles; pCi/L=picocuries per liter.
Source: DOE 2010a.

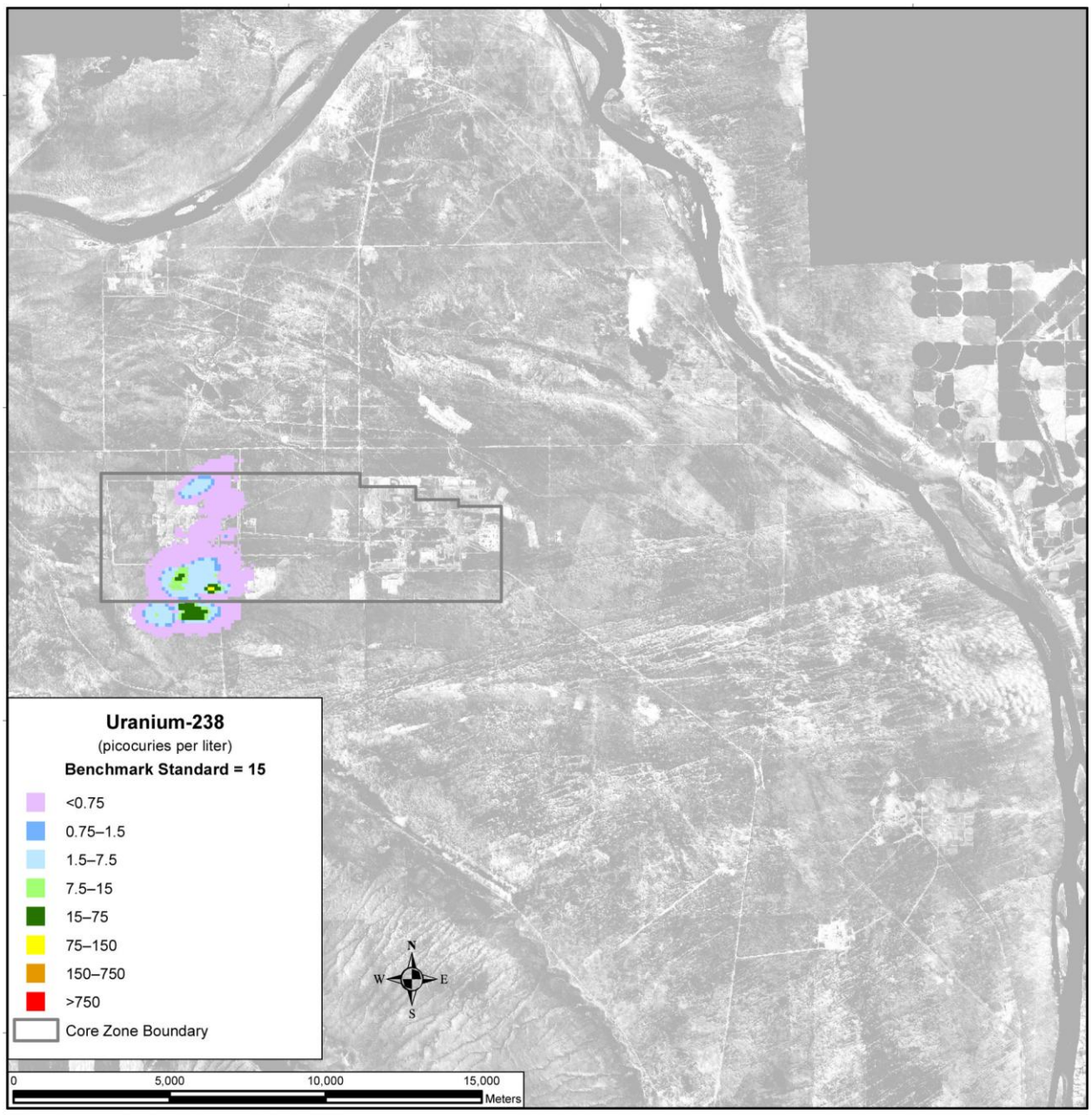
Figure U–53. Field-Reported Spatial Distribution of Groundwater Technetium-99 Concentration, Northern 200-West Area, Calendar Year 2009



Key: CY=calendar year; DWS=drinking water standard; Km=kilometers; Mi=miles; pCi/L=picocuries per liter.
Source: DOE 2010a.

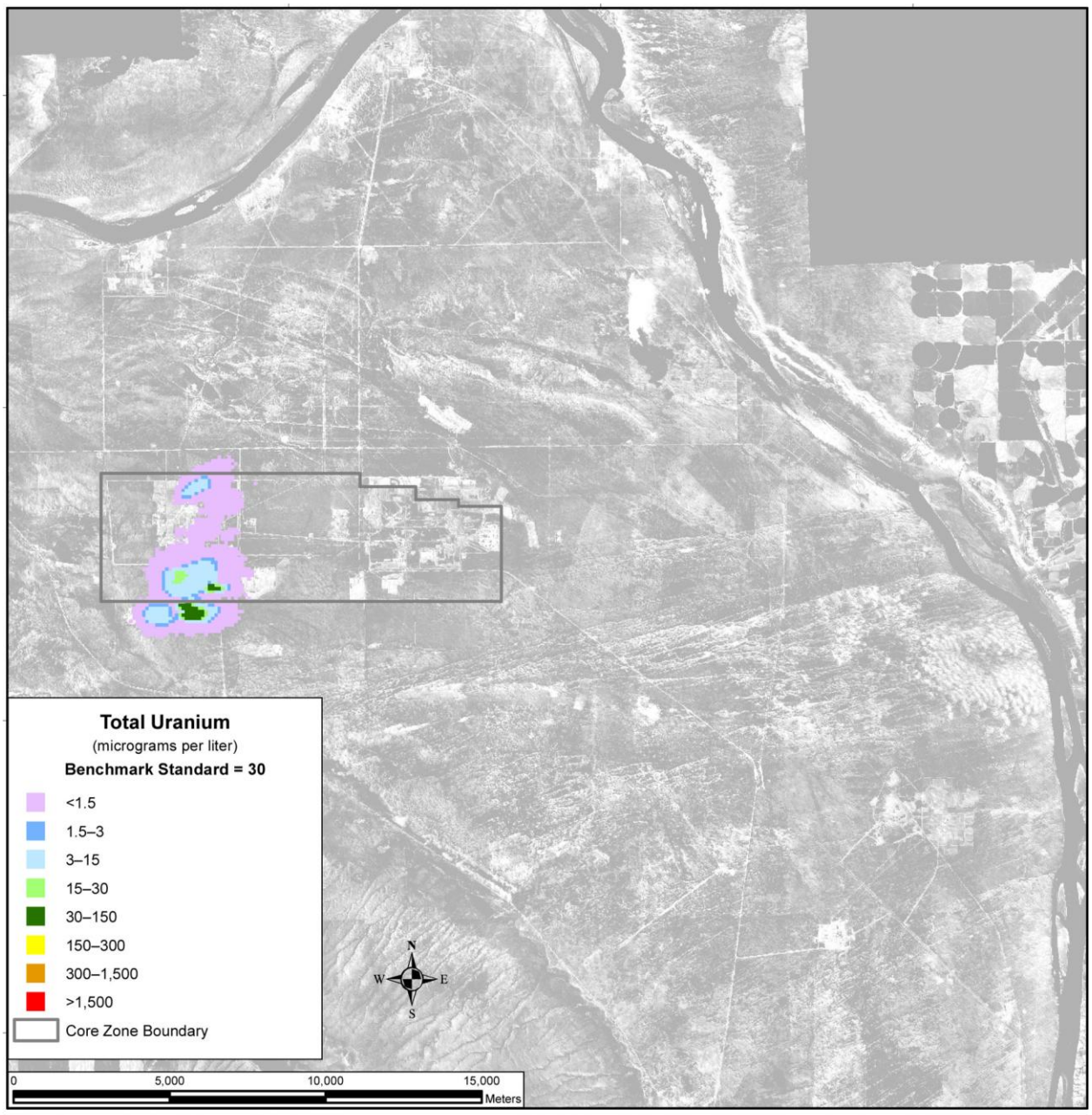
Figure U–54. Field-Reported Spatial Distribution of Groundwater Technetium-99 Concentration, Southern 200-West Area, Calendar Year 2009

Uranium contamination present in the western Central Plateau is primarily associated with the U Area cribs and Waste Management Area U. Uranium interacts with soil particles and can undergo chemical sorption, and is not as mobile in the vadose zone as technetium-99 (DOE 2010b). The 2009 groundwater monitoring report (DOE 2010a) indicates a uranium plume above the benchmark standard in the vicinity of the 216-U-1/2 Cribs, and also discusses elevated uranium concentrations present west and northwest of Waste Management Areas S and SX near U Pond (DOE 2010a). The values of uranium total concentrations estimated by the groundwater transport simulations are lower than in the 2009 groundwater monitoring report for the area near the 216-U-1/2 Cribs. Additionally, the groundwater transport simulations estimate a plume with concentrations above the benchmark standard in the vicinity of the 216-S-5 Crib and 216-S-6 Crib that is not present in the 2009 groundwater monitoring report. (Appendix S provides a detailed discussion of the waste inventories used for the cumulative impacts analysis.) Figures U–55 and U–56 show the spatial distributions of uranium-238 and total uranium as predicted in the impacts analysis for past-practice sources. Figure U–57 is a depiction of the uranium plume in the western portion of the Central Plateau as presented in the 2009 groundwater monitoring report.



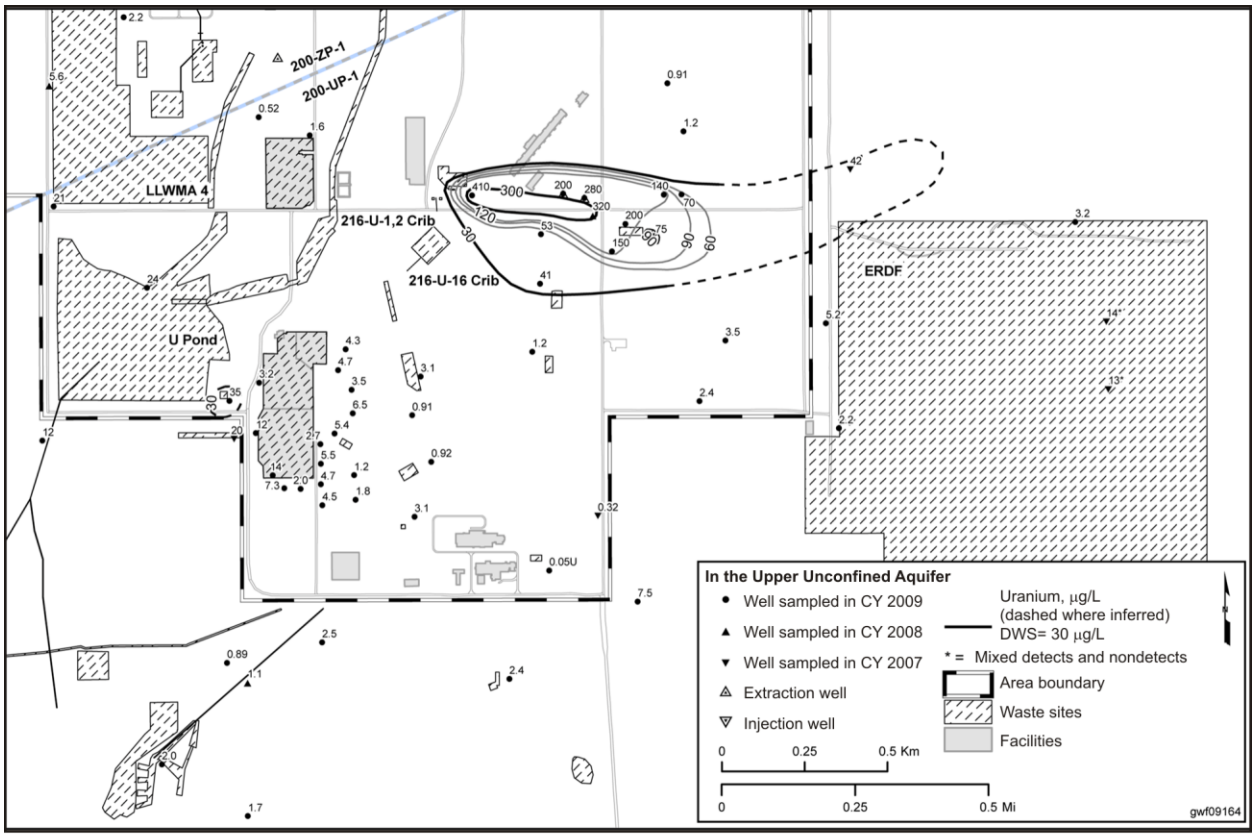
Note: To convert meters to feet, multiply by 3.281.

Figure U–55. Spatial Distribution of Groundwater Uranium-238 Concentration (Past-Practice Sources), Western Portion of the Central Plateau, Calendar Year 2010



Note: To convert meters to feet, multiply by 3.281.

Figure U–56. Spatial Distribution of Groundwater Total Uranium Concentration (Past-Practice Sources), Western Portion of the Central Plateau, Calendar Year 2010



Key: µg/L=micrograms per liter; CY=calendar year; DWS=drinking water standard; Km=kilometers; Mi=miles.
Source: DOE 2010a.

Figure U–57. Field-Reported Spatial Distribution of Groundwater Uranium Concentration, 200-West Area, 2009

U.1.2.2.3.4 Western Portion of the Central Plateau Consideration of Ongoing Hanford Site Activities

Cleanup of the Central Plateau is a highly complex activity because of the large number of waste sites, surplus facilities, active treatment and disposal facilities, and areas of deep soil contamination. Past discharges of more than 1,703 billion liters (450 billion gallons) of liquids to the soil have resulted in about 155 square kilometers (60 square miles) of contaminated groundwater. For areas of groundwater contamination in the Central Plateau, the CERCLA goal is to restore the aquifer to achieve drinking water standards.[5] In those instances where remediation goals are not achievable in a reasonable timeframe, programs will be implemented to prevent migration of the plume beyond the Central Plateau, prevent exposure to contaminated groundwater, and evaluate further risk-reduction opportunities as new technologies become available. Near-term actions are being taken to control plume migration for key contaminants until remediation goals are achieved.

[5] This goal is expressed in the *Hanford Site Groundwater Strategy: Protection, Monitoring, and Remediation* (DOE 2004:14). This strategy document was approved by DOE-RL, DOE Office of River Protection, EPA, and Ecology. This goal has more recently been embedded into RAO No. 1 for the 200-ZP-1 Operable Unit groundwater: "Return the 200-ZP-1 OU groundwater to beneficial use (restore groundwater to achieve domestic drinking water levels) by achieving the cleanup levels (provided later in Table 11). This objective is to be achieved within the entire 200-ZP-1 OU groundwater plumes. The estimated timeframe to achieve cleanup levels is within 150 years" (EPA 2008).

Groundwater beneath the western portion of the Central Plateau comprises two operable units, as described below.

- The 200-ZP-1 Operable Unit is located in the northern half of the 200-West Area and includes a large plume of carbon tetrachloride and smaller plumes of technetium-99, chromium, trichloroethylene, and iodine-129.

- The 200-UP-1 Operable Unit is located in the southern half of the 200-West Area and includes contaminant plumes of technetium-99 and uranium.

The *Central Plateau Cleanup Completion Strategy* (DOE 2009) describes DOE's vision for completion of the Central Plateau cleanup and outlines the decisions needed to achieve the vision. The Central Plateau strategy involves steps to (1) contain and remediate contaminated groundwater; (2) implement a geographic cleanup approach that guides remedy selection from a plateau-wide perspective and protects groundwater from future contamination; (3) develop treatment methods for deep-vadose-zone contamination to prevent future groundwater contamination; and (4) conduct essential waste management operations in coordination with cleanup actions.

One of DOE's foremost objectives with the Central Plateau strategy is to make cleanup decisions that will identify the final footprint for permanent waste management and containment of residual contamination within the 52-square-kilometer (20-square-mile) Industrial-Exclusive area. The final footprint identified for long-term waste management and containment of residual contamination should be as small as practical and remain under Federal ownership and control for as long as a potential hazard exists. Outside the final footprint, the remainder of the Central Plateau will be available for other potential uses, consistent with the applicable comprehensive land-use plan (CLUP) land use designation, while maintained under Federal ownership and control.

Accordingly, the Central Plateau strategy is organized into the following three principal components:

- Inner Area – Defined as the final footprint area of Hanford that will be dedicated to long-term waste management and containment of residual contamination. The boundary of the Inner Area is defined by waste disposal decisions already in place and by the anticipated future decisions that will result in the requirement for continued waste management and control of residual contamination. The Inner Area is anticipated to be approximately 26 square kilometers (10 square miles) or less in size and will remain under Federal ownership and control for as long as potential hazards exist. If future waste management facilities are required to support mission completion, e.g., tank waste treatment, those facilities will be located within the Inner Area. As activities and time progress and decisions are made about specific actions in the future, the exact locations for facility placements may vary from those locations identified in the early planning documents.

- Outer Area – Defined as all areas of the Central Plateau beyond the boundary of the Inner Area. It is DOE's intent to clean up the Outer Area to a level comparable to that achieved for the river corridor. Contaminated soil and debris removed as part of Outer Area cleanup will be placed within the Inner Area for final disposal. Completion of cleanup for the approximately 168-square-kilometer (65-square-mile) Outer Area will shrink the active footprint of cleanup for the Central Plateau to the Inner Area.

- Groundwater Remediation – As acknowledged in the *Hanford Site Groundwater Strategy: Protection, Monitoring, and Remediation* (DOE 2004) and then reaffirmed in the final ROD for the 200-ZP-1 Operable Unit (EPA 2008), DOE's goal is to restore Central Plateau groundwater to its beneficial uses. This includes groundwater underlying both the Inner and Outer Areas.

Established Decisions and Milestones

The following RODs have been published for areas of the Central Plateau:

- ROD for interim remedial measure for the 200-ZP-1 Operable Unit, June 1995 (EPA 1995b)
- ROD for interim remedial action for the 200-UP-1 Operable Unit, February 1997 (EPA 1997b)
- ROD for the 221-U Facility (Canyon Disposition Initiative), September 2005 (EPA 2005b)
- ROD for the 200-ZP-1 Operable Unit, September 2008 (EPA 2008)

These decisions provide a basis for extrapolating cleanup goals to be determined in the remaining Central Plateau decisions and for projecting the expected end state that would result from those cleanup actions.

The following TPA milestones form the principal commitments for completing Central Plateau cleanup activities:

- M-015-00 – Complete the RI/FS (or RCRA Facility Investigation/Corrective Measures Study and RI/FS) process for all non-tank-farm operable units except for canyon-associated past-practice waste-site operable units covered in Milestone M-85-00 by December 31, 2016.[6]

- M-016-00 – Complete remedial actions for all non-tank-farm and non-canyon operable units by September 30, 2024.[7]

- M-016-119-T01 – DOE will have a remedy in place to contain existing groundwater plumes (except iodine, nitrate, and tritium) in the National Priorities List 200 Areas (Central Plateau) by December 31, 2020.

Groundwater cleanup on the Central Plateau is driven by the following TPA milestones:

- M-015-17A – Submit a 200-UP-1 Operable Unit RI/FS report and proposed plan to EPA (due September 30, 2010, pending approval of Change Package M-15-09-02).

- M-015-21A – Submit a 200-BP-5 and 200-PO-1 Operable Unit feasibility study report and proposed plan(s) to Ecology (due December 31, 2012, pending approval of Change Package M-15-09-02).

- M-015-82A – Submit a treatability test plan as an amendment to the 200-BP-5 Operable Unit RI/FS work plan to determine whether a 189-liter-per-minute (50-gallon-per-minute) pump-and-treat system can be sustained in the shallow and discontinuous aquifer to contain and reduce the mass of the uranium and commingled technetium-99 plumes near the B/BX/BY tank farms. The plan will include initial aquifer tests to determine sustained yield. If sufficient sustained yield can be demonstrated, treatability testing will follow in accordance with the approved treatability test plan (due December 31, 2011).

- M-015-82B – Initiate aquifer tests within 6 months of approval of the treatability test plan. Full-scale deployment of the treatment system will be made via the 200-BP-5 Operable Unit RD/RA work plan (due date to be determined).

[6] This milestone reflects the proposed changes included in TPA Change Package M-15-09-02. This change package underwent a 45-day public review and comment period that started May 3, 2010.

[7] This milestone reflects the proposed changes included in TPA Change Package M-16-09-03. This change package underwent a 45-day public review and comment period that started May 3, 2010.

- M-016-119-T01 – DOE will have a remedy in place to contain existing groundwater plumes (except iodine, nitrate, and tritium) in the National Priorities List 200 Areas (Central Plateau) (due December 31, 2020).

- M-016-120 – DOE will have a groundwater treatment system (not to exceed a 189-liter-per-minute [50-gallon-per-minute] pump-and-treat capacity) for the technetium-99 plume at the S/SX/SY tank farms within the 200-UP-01 Operable Unit. This milestone may be met by utilizing treatment capacity at another location, such as the new 200-West Area pump-and-treat system or the Effluent Treatment Facility (due December 31, 2011).

- M-016-122 – Begin Phase I operation of the new 200-West Area pump-and-treat system per the RD/RA work plan and the 200-ZP-1 Operable Unit ROD. This action will provide the initial portion of the overall pump-and-treat capacity expected to be required by the 200-ZP-1 and 200-UP-1 Operable Unit RODs. This initial operation can provide treatment for the technetium-99 plume at the S/SX/SY tank farms within the 200-UP-1 Operable Unit (due December 31, 2011).

- M-016-124 – Submit the 200-ZP-1 Operable Unit remedial design report (due August 31, 2010).

Significant response actions that have occurred in the western portion of the Central Plateau as a result of these RODs and subsequent modifications include the following:

- The 200-UP-1 Operable Unit has a pump-and-treat system that began operations in 1994. The goals for that treatment system are to contain the existing plumes of uranium and technetium-99 within the Central Plateau and to reduce concentrations to below 10 times drinking water standards. The draft feasibility study and proposed plan was submitted by DOE to EPA in September 2010. Final treatment system goals and designs will be defined in the 200-UP-1 Operable Unit ROD, which will be issued following public comment on the proposed plan. The ROD for the 200-UP-1 Operable Unit is expected to be completed in 2012. The current 200-West Area groundwater treatment system has been designed with sufficient capacity and expansion capability (e.g., for uranium treatment) to also support the needs expected to be defined in the 200-UP-1 Operable Unit ROD. For more information, see the "Responsiveness Summary" section in the *Record of Decision, Hanford 200 Area, 200-ZP-1 Superfund Site, Benton County, Washington* (EPA 2008).

- In the mid-1980s, carbon tetrachloride was found in the unconfined aquifer beneath the 200-West Area of Hanford. During this time, groundwater monitoring results indicated that the carbon tetrachloride plume was widespread and that concentrations were increasing. The source of the carbon tetrachloride contamination was determined to be liquid waste discharged to the vadose zone through engineered disposal sites. A groundwater pump-and-treat system began operations in 1994. The goal of this system is to ameliorate the highest concentration portion of the plume of carbon tetrachloride (EPA 1995a). Soil vapor extraction was initiated in February 1992 to remove carbon tetrachloride contamination from the vadose zone in the vicinity of these disposal sites. The purpose of the remediation using soil vapor extraction is to mitigate the threat to the environment caused by the migration of carbon tetrachloride vapors through the soil column and into groundwater. Since February 1992, soil vapor extraction has been operated as an interim action pending final cleanup activities for these waste sites. Final cleanup activities will be determined as part of the CERCLA RI/FS process for the 200-PW-1 Operable Unit. The 200-PW-1 Operable Unit includes the waste sites and associated vadose zone that received the carbon tetrachloride liquid waste. Another groundwater pump-and-treat system is being designed and will be installed and operated in accordance with an approved RD/RA work plan to meet

CERCLA requirements and achieve RAOs. The system will be designed to capture and treat contaminated groundwater to reduce the mass of carbon tetrachloride, total chromium, hexavalent chromium, nitrate, trichloroethylene, iodine-129, technetium-99, and tritium throughout the 200-ZP-1 Operable Unit by a minimum of 95 percent in 25 years. The pump-and-treat component will be designed and implemented in combination with monitored natural attenuation to achieve cleanup levels for all COPCs in 125 years. Carbon tetrachloride concentrations in groundwater above 100 micrograms per liter correspond to approximately 95 percent of the mass of carbon tetrachloride currently residing in the aquifer.[8] Specific extraction and injection well locations, treatment equipment design, operation requirements, and other system details will be determined during the remedial design phase. The remedial design will also consider as necessary the need for treatment of other constituents (such as uranium) that may be captured by the 200-ZP-1 Operable Unit extraction wells. In addition to the pump-and-treat system, natural attenuation processes will be used to reduce concentrations to below the cleanup levels. Natural attenuation processes to be relied on as part of this component include abiotic degradation, dispersion, sorption, and, for tritium, natural radioactive decay because of its relatively short 12.3-year half-life. Monitoring will be employed in accordance with the approved RD/RA documents to evaluate the effectiveness of the pump-and-treat system and natural attenuation processes.[9] Fate and transport analyses conducted as part of the feasibility study indicate that the timeframe necessary to reduce the remaining COPC concentrations to acceptable levels through monitored natural attenuation would be approximately 100 years. Modeling also indicates that this portion of the plume area would remain in the Central Plateau geographic area during this timeframe. The overarching requirement is to meet the groundwater cleanup levels identified in this ROD within 125 years.

[8] The *Performance Monitoring Plan for the 200-ZP-1 Groundwater Operable Unit Remedial Action* (DOE 2010c) for the 200-West Area pump-and-treat system defines the groundwater monitoring data collection activities associated with implementation of the 200-ZP-1 Operable Unit remedial action selected remedy as described in the ROD. This plan presents the types of data collected, well networks monitored, frequency of data collection, and analysis of the data to satisfy the requirements of the ROD. The more specific aspects of data collection are described in a sampling and analysis plan and/or a quality assurance project plan. The performance monitoring plan is approved by EPA. After operations begin, an annual performance monitoring report will document this information and provide an evaluation of how the system is meeting the RAOs defined in the ROD.

[9] The natural attenuation process will apply to all of the COPCs identified in the 200-ZP-1 Operable Unit ROD. These COPCs include carbon tetrachloride, trichloroethylene, nitrate, total chromium, hexavalent chromium, iodine-129, technetium-99, and tritium. The natural attenuation process will also apply to uranium, which is a COPC for the 200-UP-1 Operable Unit. However, note that, after 25 years of pump-and-treat operations, it is likely that several of these COPCs (e.g., trichloroethylene, total chromium, hexavalent chromium) may drop below their corresponding cleanup level specified in the ROD. In this case, monitored natural attenuation in the out-years would not be required for these COPCs. The performance monitoring plan (DOE 2010c) identifies the initial network of wells that will be monitored to track performance of the remedial action. This network was strategically selected based on the three-dimensional shape of the plumes within the 61-meter-thick (200-foot-thick) aquifer. A number of new monitoring wells are proposed to be installed to address areas that are lacking well coverage. This monitoring plan will be reviewed with DOE-RL and EPA on an annual basis to determine whether any changes are needed to the sampling network, sampling frequency, or analyses to be performed. The specific parameters that will be tested to measure the effectiveness of natural attenuation have not been defined at this time but will likely be similar to those specified in *Abiotic Degradation Rates for Carbon Tetrachloride and Chloroform: Progress in FY 2009* (Amonette et al. 2010).

- In 2006, DOE proposed installing an interim barrier over the contaminated soils in the tank farms. DOE and Ecology decided to install an interim surface barrier at the T tank farm. The barrier was placed over tank T-106 and nearby tanks. The barrier is installed over the largest-recorded past release from a single-shell tank and is intended to mitigate the impact of this release. Tank T-106 leaked 435,321 liters (115,000 gallons) that contained approximately 37.4 curies of technetium-99 in 1973 (Corbin et al. 2005). Prior to installing this extraction system, groundwater concentrations were more than 100 times drinking water standards for technetium-99.[10] In 2008, 23.8 grams[11] (0.4 curies) of technetium-99 were extracted during the first full year of operation of this system (Hartman, Rediker, and Richie 2009).

- In 2010, DOE initiated a study that focused on uranium via vadose zone ammonia injection. In January 2010, Pacific Northwest National Laboratory completed a laboratory evaluation of gaseous technologies focused on immobilization of uranium (Szecsody et al. 2010) that recommended pursuing ammonia injection because it was best suited for field implementation. The uranium sequestration pilot test will inject an air/ammonia mixture into a narrow slice of the vadose zone. The ammonia is expected to react with the sediment pore water, thereby increasing its pH to a level where dissolution of aluminosilicate minerals is encouraged. Once a sufficient volume of soil has been reacted, ammonia injection will be stopped to allow pore-water pH to return to normal due to natural buffering processes. During this process, those aluminosilicate minerals that had dissolved when the pH was very high will precipitate and coat or entrain a substantial fraction of the mobile uranium.[12]

Cleanup Goals and Levels

Evaluation of the Central Plateau operable units[13] is expected to have the following common RAOs:

- Prevent unacceptable risk to human health from direct contact with COPCs present in contaminated soil. Unacceptable risks are (1) an excess lifetime cancer risk[14] greater than 10^{-4} to 10^{-6} or (2) a Hazard Index greater than 1 under reasonable maximum-exposure scenarios. The point of compliance (depth in the soil column) for protecting human health will be established through the RI/FS process and will be consistent with reasonably foreseeable land use and associated exposures.

[10] From DOE 2009 p.2.8-7, "Well 299-W11-46 (located at the northeast corner of T Tank Farm) was converted to an extraction well in fiscal year (FY) 2007 to mitigate technetium-99. The well is screened between 6.22 to 9.32 m below the water table (74.05 m bgs) and had an annual average technetium-99 concentration of 9,300 pCi/L in FY 2008. The maximum concentration in well 299-W11-46 was 18,000 pCi/L. This is down an order of magnitude from the FY 2007 annual average concentration of 97,000 pCi/L and maximum of 63,200 pCi/L [*sic*]." Note that the average and maximum values appear to be switched with one another.

[11] The total mass of technetium-99 in groundwater in this area has not been estimated.

[12] Pacific Northwest National Laboratory demonstrated a laboratory-based approach to measure six phases of uranium in Hanford soil ranging from an aqueous (highly mobile) phase to crystalline phosphates and silicates that are highly immobile and release uranium only when extracted with 8-molar nitric acid at 95 degrees Celsius (203 degrees Fahrenheit) for 2 hours (Szecsody et al. 2010). Similar measurements of field site samples showing the change in the relatively mobile and immobile phases of uranium will be analyzed to evaluate the effectiveness of the field test. The *Data Quality Objectives Summary Report for the Uranium Sequestration Pilot Test* (CHPRC 2011) provides additional details of the analytical approach.

[13] Central Plateau operable units include 200-EA-1/200-IS-1 (200-East Area Inner Area/Pipelines); 200-WA-1 (200-West Area Inner Area); 200-OA-1/200-CW-1/3 (Outer Area); 200-DV-1 (deep vadose zone); 200-SW-2 (burial grounds); 200-CB-1 (B Plant canyon and associated waste sites); 200-CP-1 (PUREX [Plutonium-Uranium Extraction] canyon and associated waste sites); 200-CR-1 (REDOX canyon and associated waste sites); and 200-PW-1/3/6 (plutonium-contaminated sites). Operable unit designations reflect the proposed changes included in TPA Change Package C-09-07. This change package is undergoing a 45-day public review and comment period that started May 3, 2010.

[14] The Model Toxics Control Act uses a level of 10^{-5}excess lifetime risk of incidence of cancer.

- Mitigate unacceptable risk to ecological receptors associated with exposure to waste or soil contaminated above risk-based criteria. (A specific biointrusion depth will be established based upon a review of scientific studies on key indicator terrestrial biota that are directly relevant and applicable to the ecological setting of the Inner Area of the Central Plateau.)

- Prevent migration of COPCs in the vadose zone from the source unit to groundwater in concentrations that would degrade the groundwater aquifer above applicable standards such as Federal maximum contaminant levels.

- Return contaminated groundwater aquifers to maximum beneficial use within a reasonable timeframe.[15]

- Prevent COPCs in groundwater from migrating to the Columbia River above applicable ambient water quality criteria.[16]

Anticipated Cleanup End State

Cleanup decisions for the Central Plateau will lead to a combination of actions for waste sites and groundwater that collectively will meet the cleanup goals described in the previous sections. For areas of groundwater contamination in the Central Plateau, the goal is remediation of the aquifer to achieve drinking water standards. For waste sites, remedies will be implemented that prevent future groundwater contamination. In those instances where remediation goals are not achievable in a reasonable timeframe, programs will be implemented to prevent further migration of the plume, prevent exposure to contaminated groundwater, and evaluate further risk-reduction opportunities as new technologies become available. Near-term actions will be taken when appropriate to control plume migration until remediation goals are achieved.

Table U–8 summarizes the current and planned actions and the expected cleanup end-state condition for the Central Plateau groundwater operable units.

[15] This terminology is directly from CERCLA policy for groundwater cleanup. For the 200-ZP-1 Operable Unit ROD, the following timeframe is established in an RAO: "RAO #1: Return the 200-ZP-1 OU groundwater to beneficial use (restore groundwater to achieve domestic drinking water levels) by achieving the cleanup levels (provided later in Table 11). This objective is to be achieved within the entire 200-ZP-1 OU groundwater plumes. The estimated timeframe to achieve cleanup levels is within 150 years." EPA has determined that a 150-year timeframe is "reasonable" for cleanup of this plume in the 200-West Area (EPA 2008).

[16] This commitment is also embedded within TPA milestone M-016-119-T01, which states: "DOE will have a remedy in place to contain existing groundwater plumes (except iodine, nitrate, and tritium) in the 200 NPL Area (Central Plateau). The due date for this milestone is 12/31/2020."

Table U–8. Western Portion of the Central Plateau Groundwater Plumes and Treatment Actions

Operable Unit	Primary Contaminants	Current Status and Actions	Future Actions	Anticipated Cleanup End State
200-ZP-1	Carbon tetrachloride, technetium-99 (other COPCs are chromium, trichloroethylene, nitrate, tritium, and iodine-129)	Pump-and-treat system at 1,893-liter-per-minute (500-gallon-per-minute) capacity for carbon tetrachloride. Additional extraction wells near the T tank farm for technetium-99 (about 189 liters [50 gallons] per minute).	Expansion to 8,328–9,464 liters (2,200–2,500 gallons) per minute by 2012 (200-ZP-1 Operable Unit ROD [EPA 2008]).	Cleanup goal is to achieve 95 percent mass removal for eight COPCs within 25 years (by about 2036). Cleanup levels to be reached through monitoring natural attenuation within an additional 100-year time period. Meet drinking water standards for all COPCs, except carbon tetrachloride, which is to meet 3.4 micrograms per liter (lower than drinking water standards) (200-ZP-1 Operable Unit ROD [EPA 2008]).
200-UP-1	Uranium, technetium-99	Pump-and-treat system for uranium and technetium-99 (up to 189 liters [50 gallons] per minute) began in 1994. Target cleanup levels (10 times the maximum contaminant level) were met in 2005. One-year rebound study conducted, then pumping resumed.	System capacity of 189 liters (50 gallons) per minute for technetium-99 near the S/SX/SY tank farms to begin in fiscal year 2012 (TPA Milestone M-016-120). Additional treatment requirements subject to final ROD for 200-UP-1 Operable Unit. Anticipated to be treated using the 200-ZP-1 Operable Unit treatment system.	Cleanup levels are anticipated to be consistent with other groundwater RODs at Hanford, i.e., drinking water standards or below.

Key: COPC=constituent of potential concern; Hanford=Hanford Site; ROD=Record of Decision; TPA=Tri-Party Agreement [Hanford Federal Facility Agreement and Consent Order].

U.1.2.2.4 Eastern Portion of the Central Plateau

The eastern portion of the Central Plateau comprises the B Area, the 600 Area Nonradioactive Dangerous Waste Landfill (NRDWL), the PUREX [Plutonium-Uranium Extraction] Plant, and the proposed greater-than-Class C (GTCC) waste disposal facility, and is located in the eastern side of the Core Zone Boundary, south of Gable Mountain and Gable Gap.

U.1.2.2.4.1 Eastern Portion of the Central Plateau Hydrogeologic Regime

The hydrogeologic regime describes the system of geology and groundwater flow that governs groundwater contaminant distribution. The layering of geology in the eastern portion of the Central Plateau is fairly complex when compared with other areas of Hanford. The Ringold Formation is present in the southwest part of the eastern portion of the Central Plateau and gradually thins out and disappears in the northern part of the 200-East Area. In the north, the Hanford formation sits directly on top of

basalt. The absence of the Ringold Formation near the northern boundary of the 200-East Area is the result of flooding events that eroded the Ringold Formation and deposited a thick sequence of Hanford gravel and sand materials. The absence of all or major parts of the Ringold Formation occurs over a wide area from Gable Gap through the northern boundary of the 200-East Area and is most likely related to the "erosional window" described by Thorne et al. (2006) in Gable Gap, where the Elephant Mountain Member basalt has been eroded. Erosional paleochannels present in this area have recently been described in more detail by Bjornstad et al. (2010). Further to the east, Ringold materials reappear and the Ringold Formation thickens. The thickness of the Ringold Formation is controlled by the proximity to the erosional surface; it is thicker at its margins and thinner to absent within the erosional channel. The Hanford formation is thickest to the west, and is also thick in the north, where the Hanford formation directly contacts basalt. To the northeast, the Hanford formation thins considerably as the basalt surface rises in an area of lower topography (Bjornstad et al. 2010; Cole et al. 2001; Lindsey 1995; Thorne et al. 2006; Williams et al. 2002).

The erosional surface plays a role in the thickness of the vadose zone in addition to the stratigraphy at the water table. In general, the vadose zone is almost entirely Hanford formation, consisting of Hanford sand and Hanford gravel. There are locations in the south of the eastern portion Central Plateau where Ringold gravel and sand are also present in the vadose zone. In the NRDWL area, the vadose zone is made up almost entirely of Hanford sand and gravel. The vadose zone is uniformly about 100 meters (328 feet) in thickness in the southern portion, and gradually changes to between 64 meters (210 feet) in thickness in the northwestern portion of the area to about 56 meters (184 feet) in thickness in the northeastern portion of the area. However, the vadose zone in the NRDWL area is much thinner, on the order of about 40 meters (131 feet) thick (Bjornstad et al. 2010; Cole et al. 2001; DOE 2010a; Lindsey 1995; Thorne et al. 2006; Williams et al. 2002;). Figures U–58 and U–59 depict cross sections that are typical of the vadose zone lithology in the eastern portion of the Central Plateau.

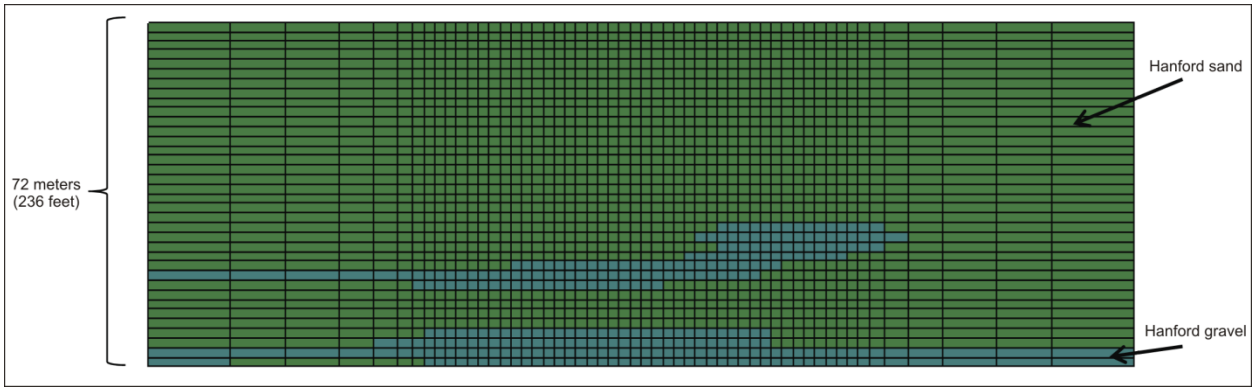


Figure U–58. West-to-East Cross Section of Vadose Zone Lithology for C Tank Farm

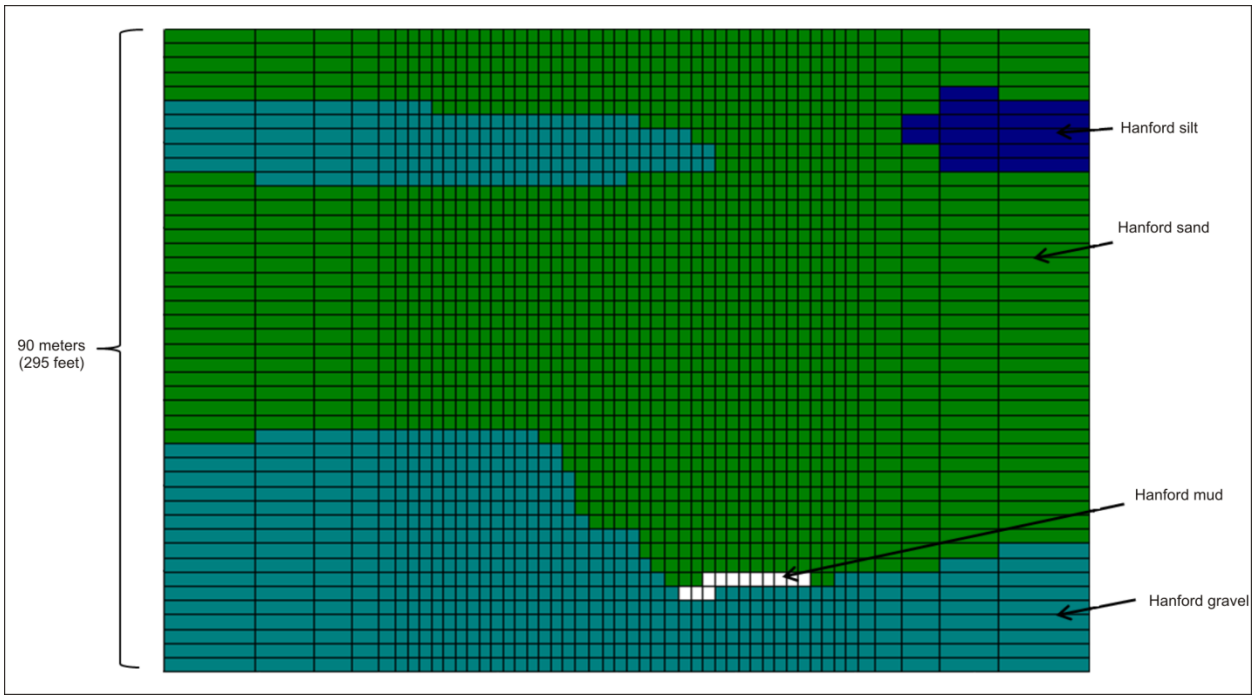
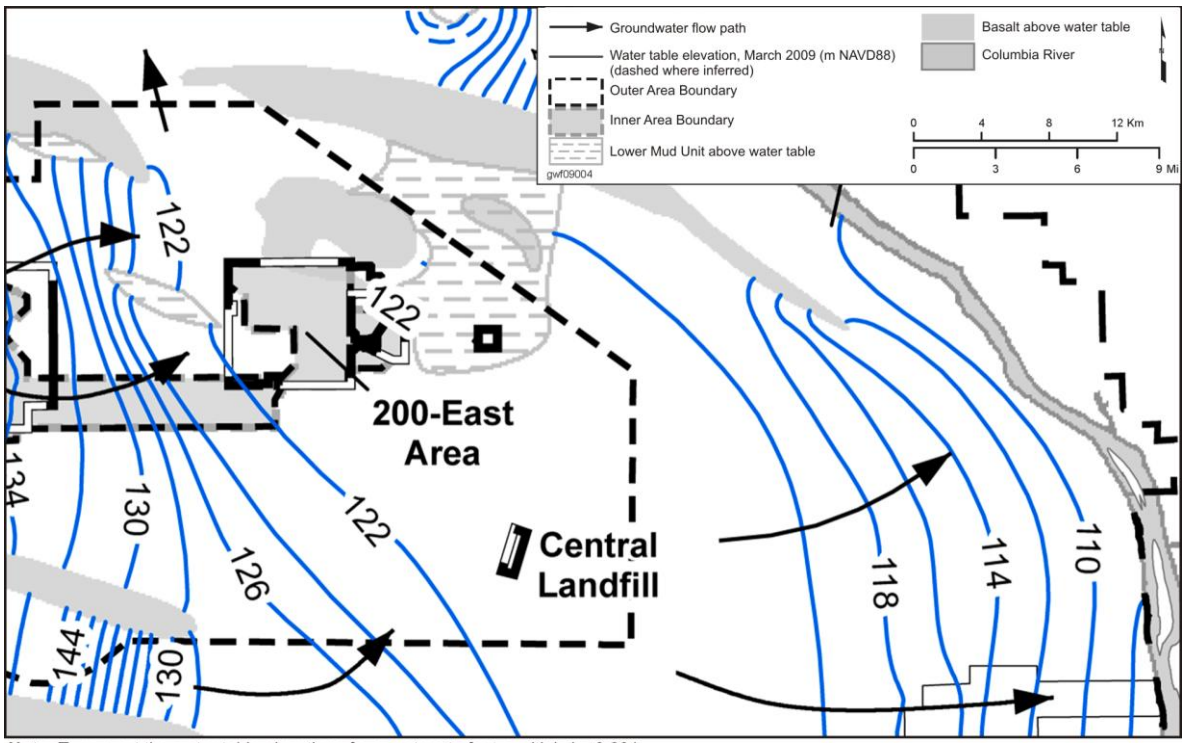


Figure U–59. West-to-East Cross Section of Vadose Zone Lithology for A Tank Farm

The flat water table is a significant hydrogeologic feature in the eastern portion of the Central Plateau. It stays at approximately 122 meters (400 feet) in elevation across the eastern portion of the Central Plateau. Figure U–60 illustrates the water table and inferred directions of groundwater flow in the eastern portion of the Central Plateau as depicted in the 2009 groundwater monitoring report. The groundwater divide, which strongly influences the shape and extents of contaminant plumes, occurs near the 200-East Area, sending flow north through the Gable Gap and southeast toward the central and southeast portion of Hanford (DOE 2010a).



Note: To convert the water table elevations from meters to feet, multiply by 3.281.
Key: Km=kilometers; Mi=miles; NAVD88=North American Vertical Datum of 1988.
Source: Modified from DOE 2010a.

Figure U–60. Eastern Portion of the Central Plateau Water Table and Inferred Groundwater Flow Directions, March 2009

U.1.2.2.4.2 Eastern Portion of the Central Plateau Historical Anthropogenic Discharges

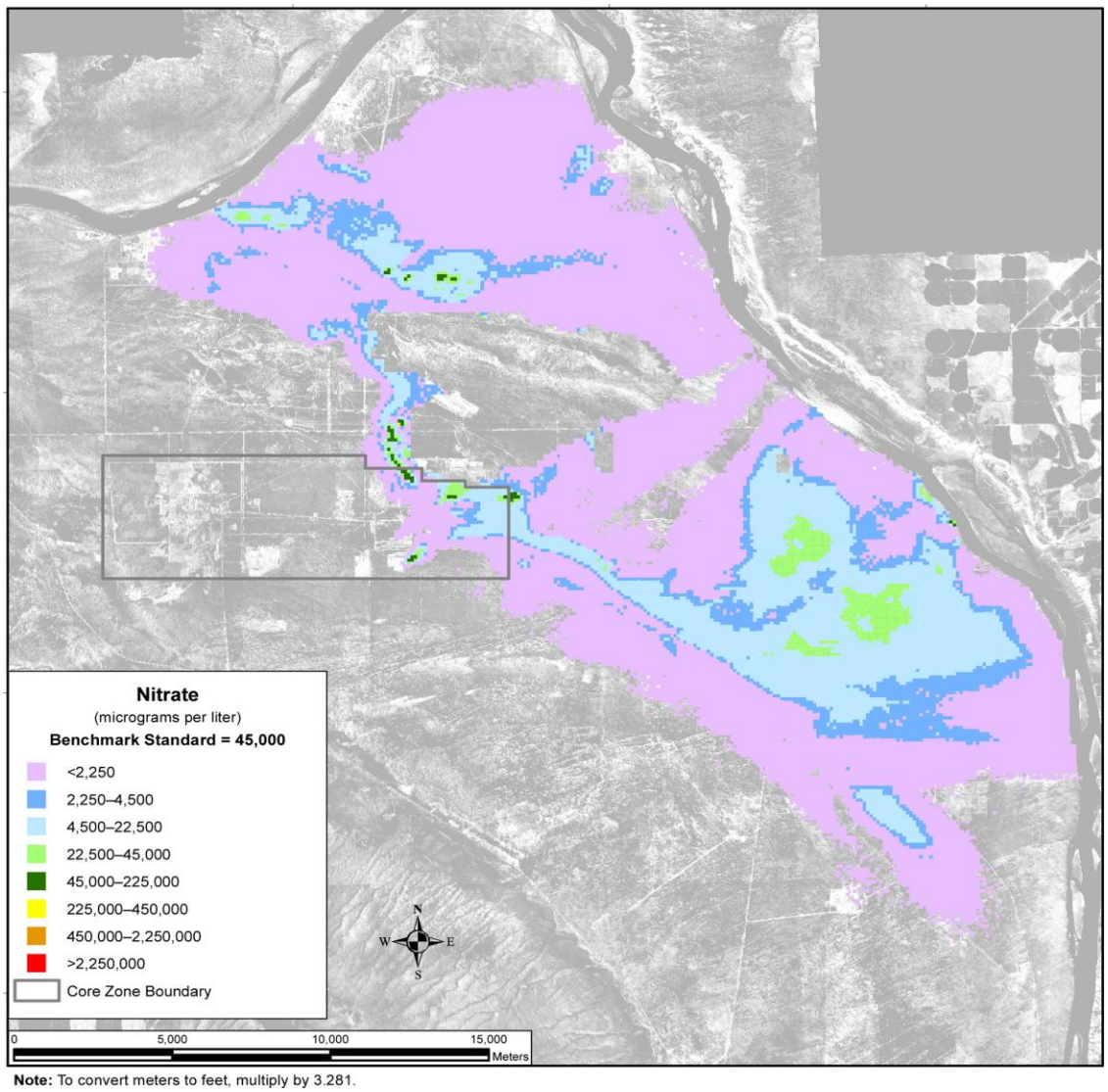
During Hanford's operational period, the main purpose of the facilities in the Central Plateau was the removal of plutonium. Likewise, the eastern portion of the Central Plateau was impacted by intentional and unintentional releases of liquid wastes generated from plutonium removal processes. Additionally, wastes are stored in tank farms, and there are several solid waste sites located in the eastern portion of the Central Plateau. The effects of these past anthropogenic activities continue to influence contaminant distribution in the subsurface in the eastern portion of the Central Plateau (DOE 2010a). For analysis purposes in this *TC & WM EIS*, aqueous sources of contamination were examined based on the amount of discharge. Sources with aqueous flux (volume per area) of less than 1 meter (3 feet) per year were categorized as moderate-discharge sources. Sources with aqueous flux of greater than 1 meter (3 feet) per year were categorized as heavy-discharge sources. Solid sources were categorized as low-discharge sources. The anthropogenic contaminant sources in the eastern portion of the Central Plateau included heavy-discharge sites such as ponds and cribs and trenches (ditches), moderate-discharge sites such as past leaks from tank farms, and low-discharge sites. Though anthropogenic activities have diminished over time, residual effects continue to influence contaminant migration.

U.1.2.2.4.3 Eastern Portion of the Central Plateau Comparison of Modeled Versus Measured Spatial Contaminant Distributions

This section discusses the distribution of inventories as described in the 2009 groundwater monitoring report (DOE 2010a) and compares the results of the impacts analysis for past-practice sources in the eastern portion of the Central Plateau in terms of the spatial distribution of COPC concentrations in CY 2010. Concentrations of each radionuclide and chemical are indicated by a color scale that is relative to the benchmark concentration. Concentrations greater than the benchmark concentration are indicated by the fully saturated colors green, yellow, orange, and red in order of increasing concentration.

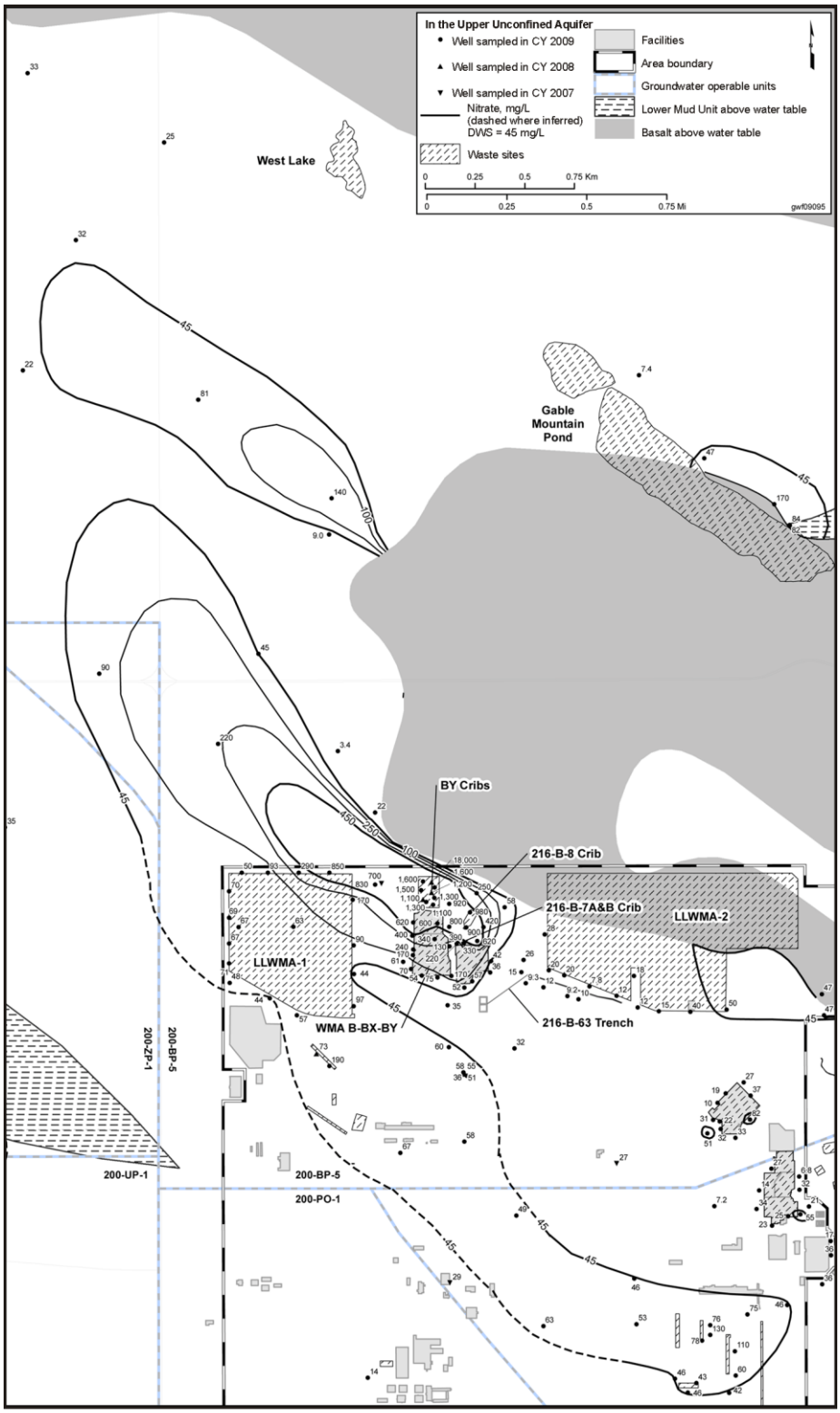
Concentrations less than the benchmark concentration are indicated by the faded colors green, blue, indigo, and violet in order of decreasing concentration. Note that the concentration ranges are on a logarithmic scale to facilitate visual comparison of concentrations that vary over three orders of magnitude.

The primary contaminants forming extensive plumes within the eastern portion of the Central Plateau include nitrate, iodine-129, tritium, technetium-99, and uranium. In general, the simulations of groundwater transport replicate the values measured in the field. Nitrate is found above the drinking water standard in the eastern portion of the Central Plateau near the BY Cribs. The nitrate plume above the drinking water standard in this area is primarily associated with the discharges from the BY Cribs, the B/BX/BY waste management areas, and the 216-B-12 and 216-B-62 Cribs. In the vicinity of the BY Cribs and the B/BX/BY waste management areas the values of nitrate concentrations above the benchmark standard that are estimated by the groundwater transport simulations approximately match the values indicated in the 2009 groundwater monitoring report. Figure U–61 shows the spatial distribution of nitrate as predicted in the impacts analysis for past-practice sources. Figure U–62 is the corresponding depiction of the nitrate plumes as presented in the 2009 groundwater monitoring report (DOE 2010a).



Note: To convert meters to feet, multiply by 3.281.

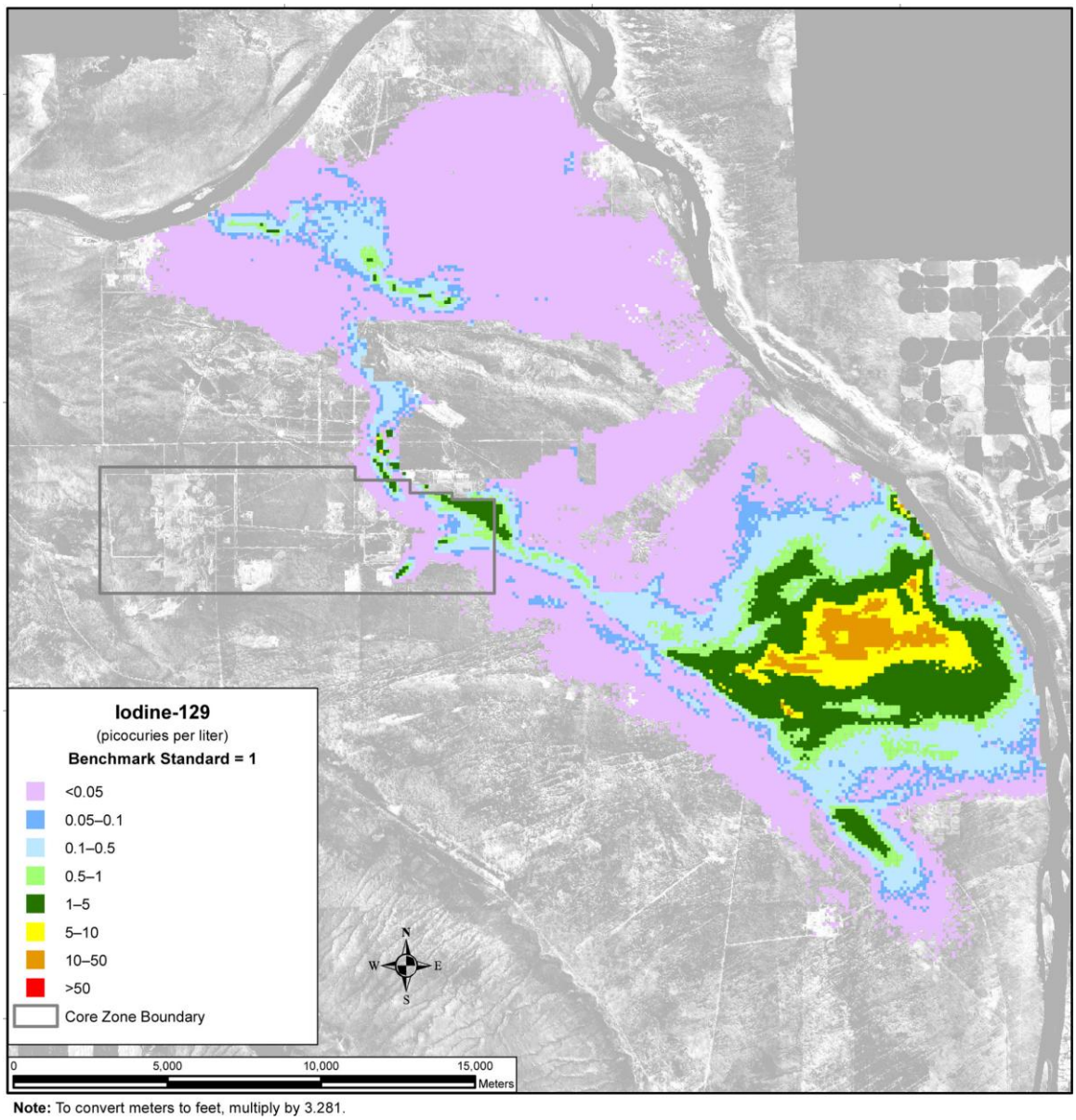
Figure U–61. Spatial Distribution of Groundwater Nitrate Concentration (Past-Practice Sources), Eastern Portion of the Central Plateau, Calendar Year 2010



Key: CY=calendar year; DWS=drinking water standard; Km=kilometers; mg/L=milligrams per liter; Mi=miles.
Source: DOE 2010a.

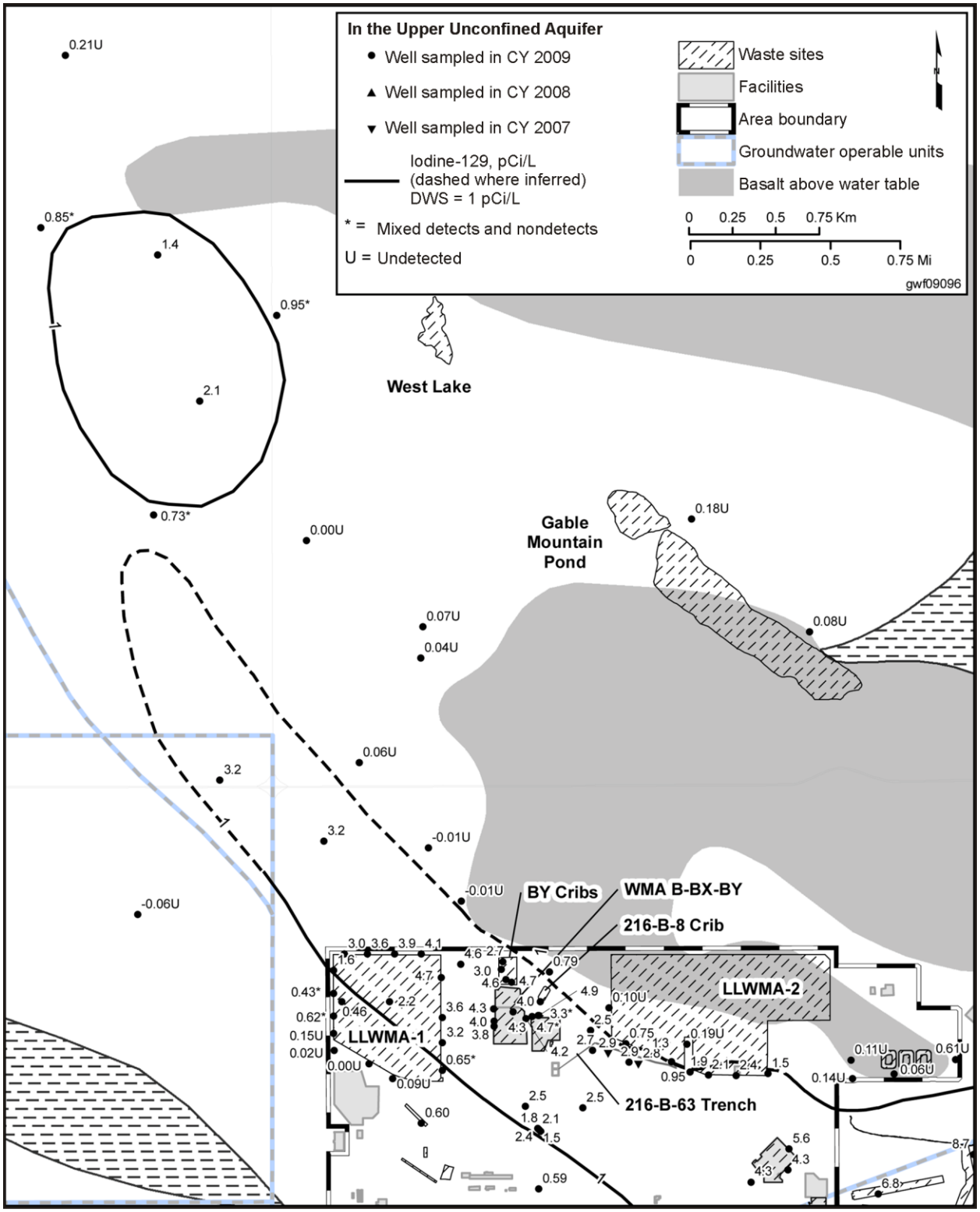
Figure U–62. Field-Reported Spatial Distribution of Groundwater Nitrate Concentration, 200-East Area and 600 Area, Calendar Year 2009

The highest concentrations of iodine-129 in the eastern portion of the Central Plateau are found near the B/BX/BY waste management areas and the associated cribs to the north, as well as near Waste Management Area C and B Pond. The iodine-129 plumes with concentrations above the benchmark standard originating from the eastern portion of the Central Plateau that are predicted by the groundwater transport simulations generally match the concentration values indicated by the 2009 groundwater monitoring report (DOE 2010a). In general, the locations of the iodine-129 plumes with concentrations above the benchmark standard are replicated by the groundwater transport simulations. The shapes and extents of the plumes near the BY Cribs and B/BX/BY waste management areas are closely replicated by the groundwater transport simulations, and the large plume that extends to the southeast shows a similar shape, but extends further east toward the Columbia River. Figure U–63 shows the spatial distribution of iodine-129 as predicted in the impacts analysis for past-practice sources. Figures U–64 and U–65 are the depictions of iodine-129 plumes in the eastern portion of the Central Plateau as presented in the 2009 groundwater monitoring report (DOE 2010a).



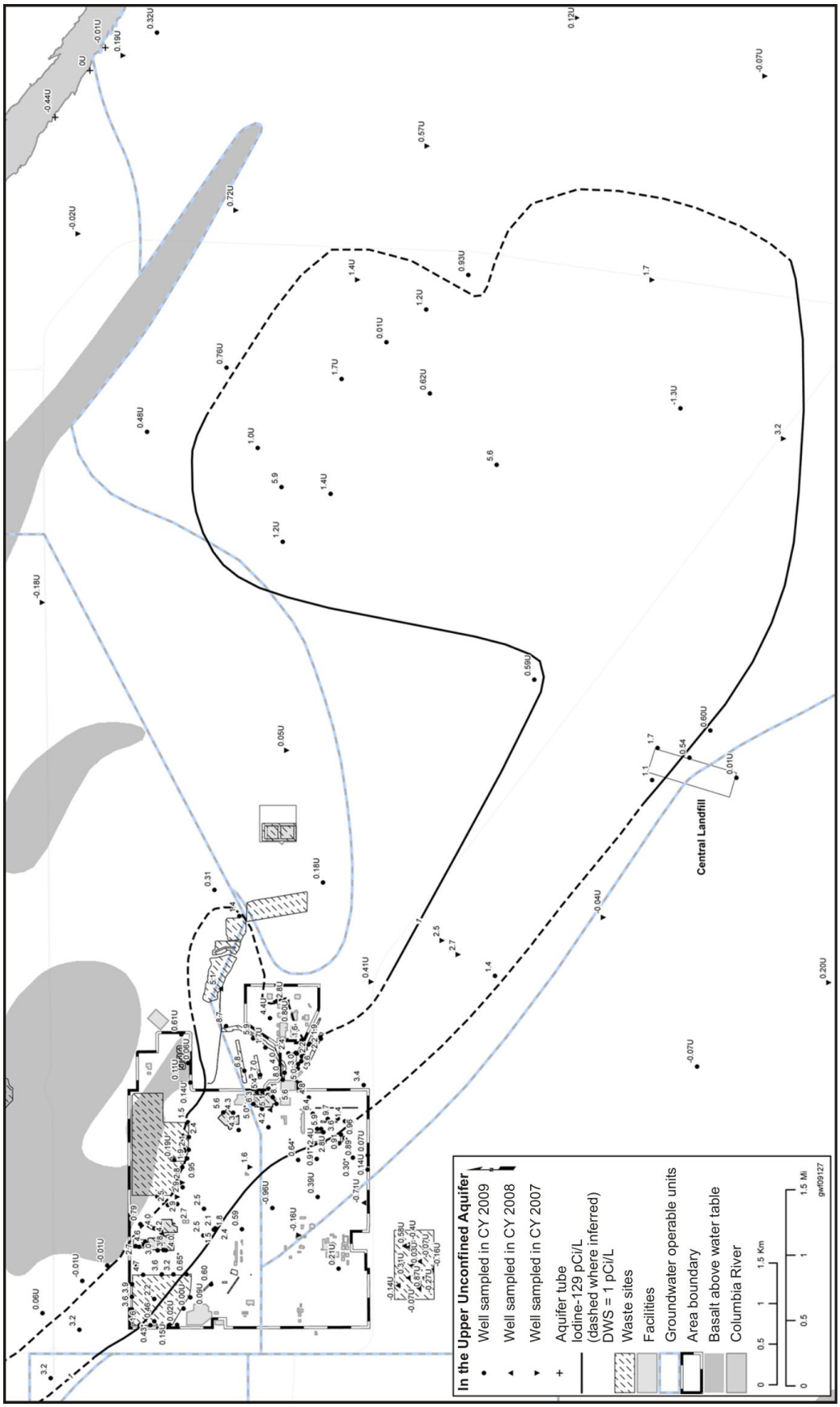
Note: To convert meters to feet, multiply by 3.281.

Figure U–63. Spatial Distribution of Groundwater Iodine-129 Concentration (Non–*TC & WM EIS* Sources), Eastern Portion of the Central Plateau, Calendar Year 2010



Key: CY=calendar year; DWS=drinking water standard; Km=kilometers; Mi=miles; pCi/L=picocuries per liter.
Source: DOE 2010a.

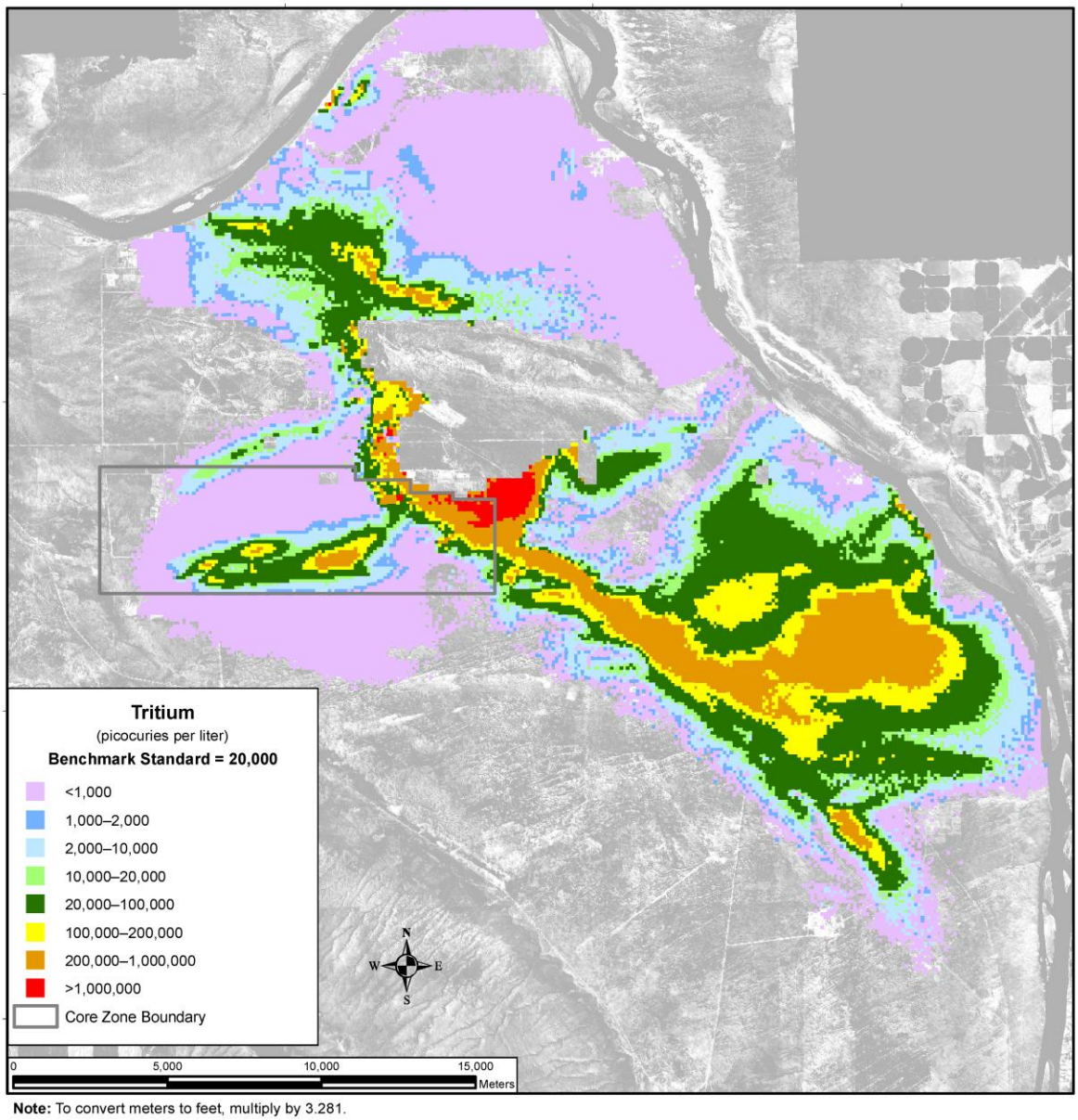
Figure U–64. Field-Reported Spatial Distribution of Groundwater Iodine-129 Concentration, Northern 200-East Area, Calendar Year 2009



Key: CY=calendar year; DWS=drinking water standard; Km=kilometers; Mi=miles; pCi/L=picocuries per liter.
Source: DOE 2010a.

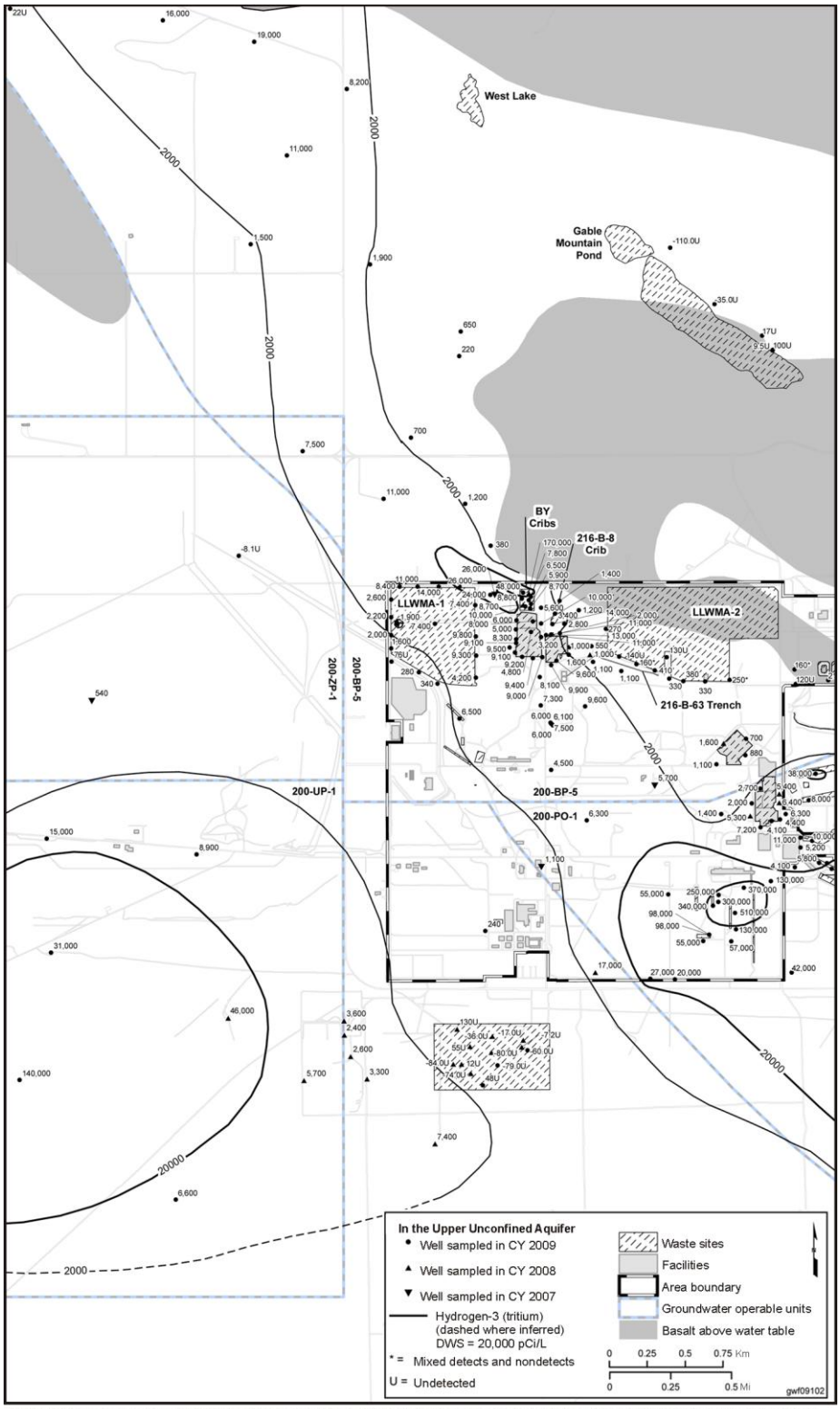
Figure U–65. Field-Reported Spatial Distribution of Groundwater Iodine-129 Concentration, Southern 200-East Area, Calendar Year 2009

In the eastern portion of the Central Plateau, tritium contamination can primarily be attributed to discharges from the 216-B-50 and 216-B-57 Cribs. In general, the groundwater transport simulations match the general locations and extents of the tritium plumes, with the concentrations above the benchmark standard that were indicated in the 2009 groundwater monitoring report, except the groundwater transport simulations show the tritium plume above the benchmark standard extending through Gable Gap toward the 100 Areas. The concentrations predicted by the groundwater transport simulations replicate the concentrations indicated in the 2009 groundwater monitoring report (DOE 2010a) within an order of magnitude, except near the northeastern boundary of the Core Zone, where the vadose zone is thin. Figure U–66 shows the spatial distribution of tritium as predicted in the impacts analysis for past-practice sources. Figures U–67 and U–68 are depictions of the tritium plumes originating from sources in the eastern portion of the Central Plateau as presented in the 2009 groundwater monitoring report.



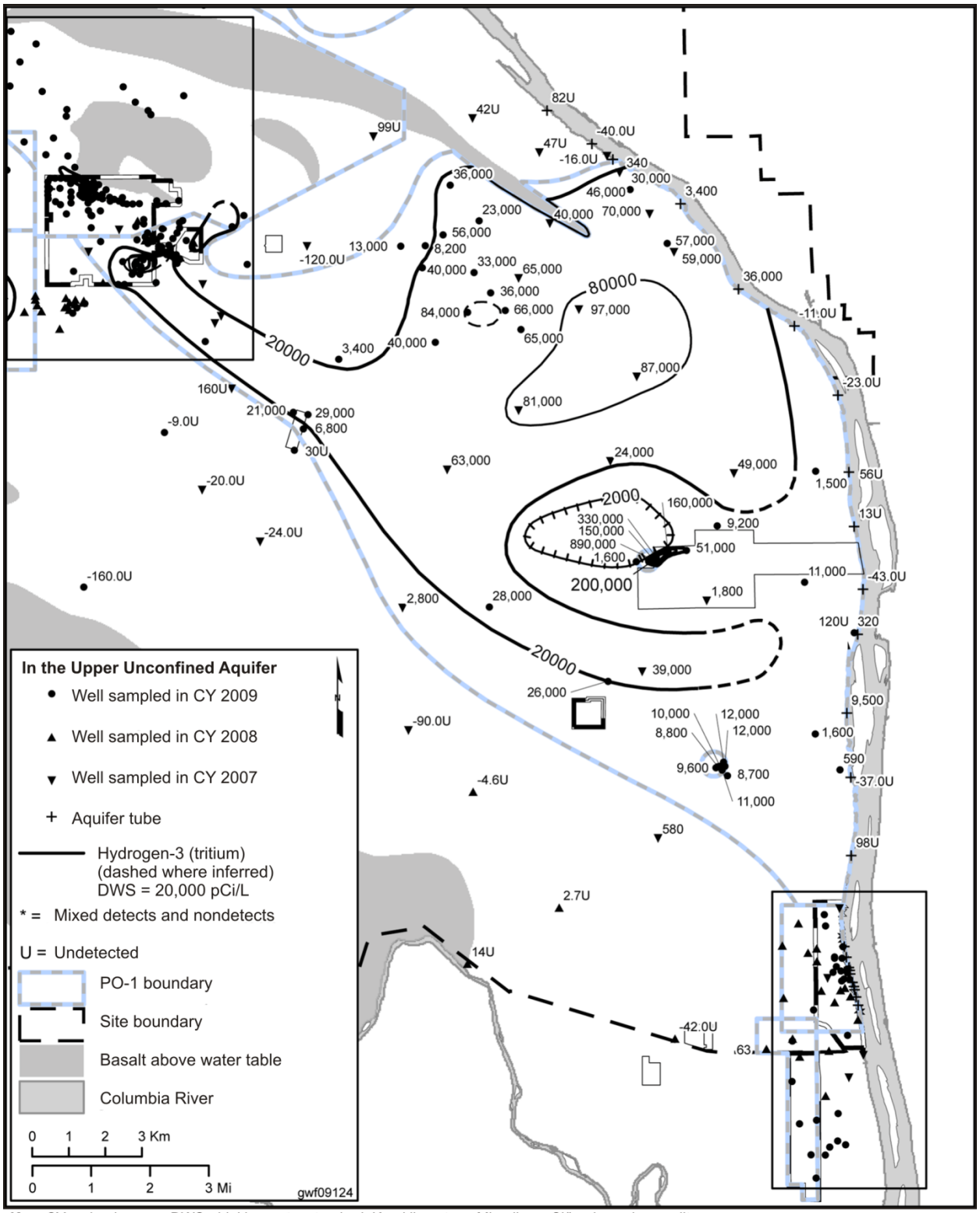
Note: To convert meters to feet, multiply by 3.281.

Figure U–66. Spatial Distribution of Groundwater Hydrogen-3 (Tritium) Concentration (Past-Practice Sources), Eastern Portion of the Central Plateau, Calendar Year 2010



Key: CY=calendar year; DWS=drinking water standard; Km=kilometers; Mi=miles; pCi/L=picocuries per liter.
Source: DOE 2010a.

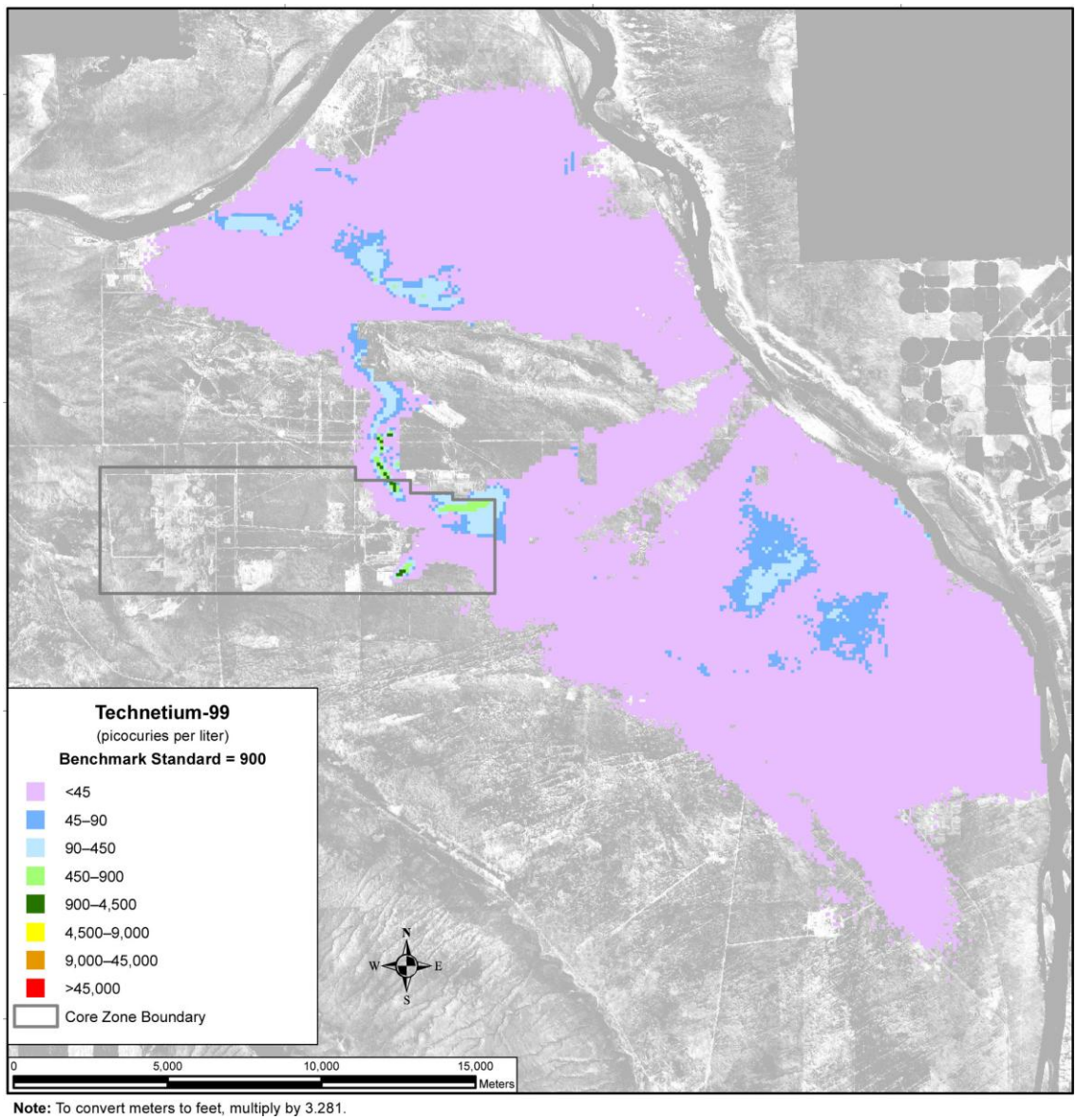
Figure U–67. Field-Reported Spatial Distribution of Groundwater Hydrogen-3 (Tritium) Concentration, Northern 200-East Area, Calendar Year 2009



Key: CY=calendar year; DWS=drinking water standard; Km=kilometers; Mi=miles; pCi/L=picocuries per liter.
Source: DOE 2010a.

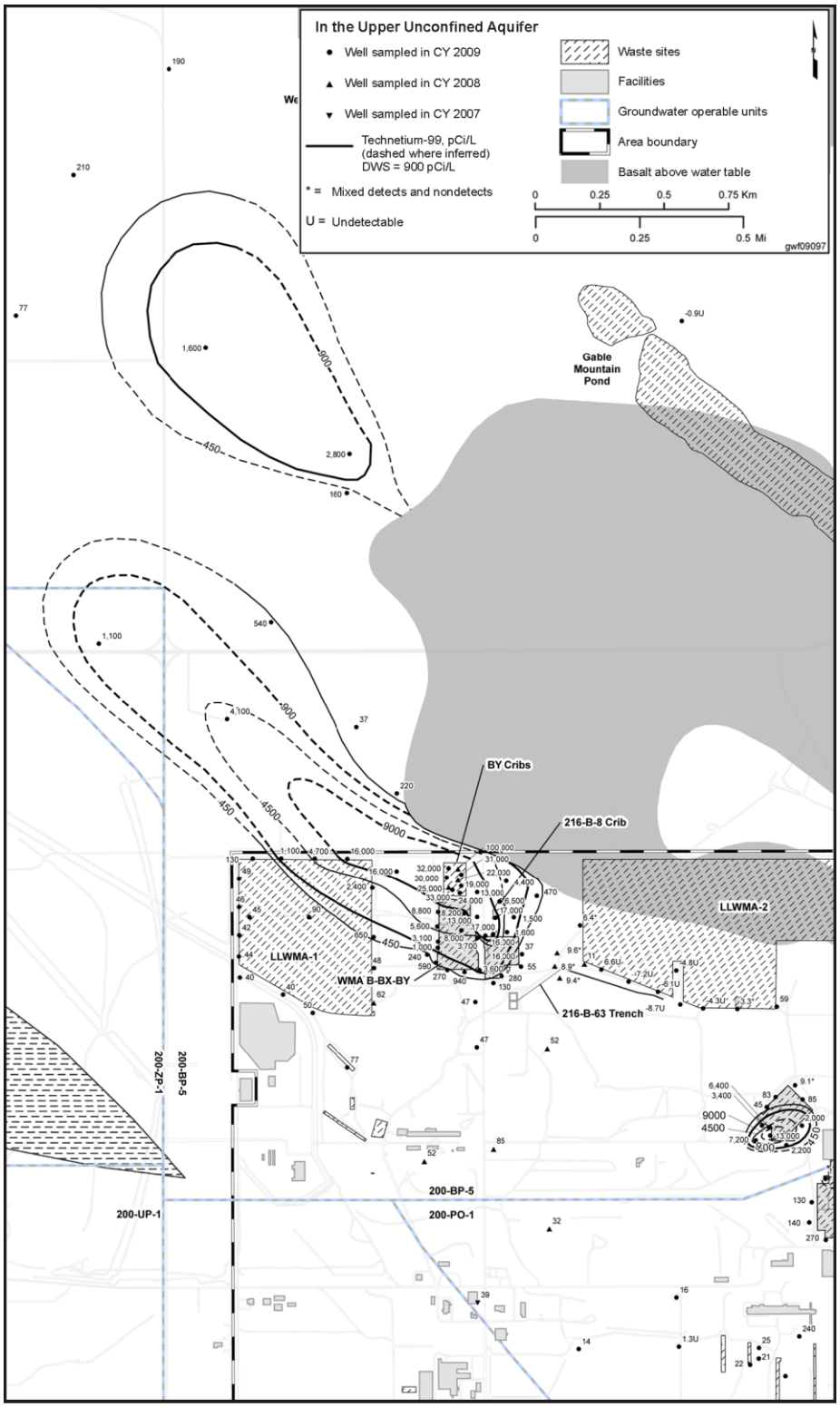
Figure U–68. Field-Reported Spatial Distribution of Groundwater Hydrogen-3 (Tritium) Concentration, Southern 200-East Area, Calendar Year 2009

Technetium-99 contamination is present in the eastern Central Plateau near the A/AX, B/BX/BY, and C waste management areas. The PUREX Plant and BY Cribs also contribute to the technetium-99 contamination in this area. The technetium-99 concentration plumes above the benchmark standard that are predicted by the groundwater transport simulations generally replicate the concentrations and plume locations indicated in the 2009 groundwater monitoring report (DOE 2010a) within an order of magnitude, except in the vicinity of the PUREX Plant and C waste management area. The technetium-99 plumes predicted by the groundwater transport simulations in the vicinity of the PUREX Plant and C waste management area predict concentrations approximately an order of magnitude lower than the 2009 groundwater monitoring report. Appendix S provides a detailed discussion of the waste inventories used for the cumulative impacts analyses. Figure U–69 shows the spatial distribution of technetium-99 as predicted in the impacts analysis for past-practice sources. Figures U–70 and U–71 are the depictions of the technetium-99 plumes in the eastern portion of the Central Plateau as presented in the 2009 groundwater monitoring report.



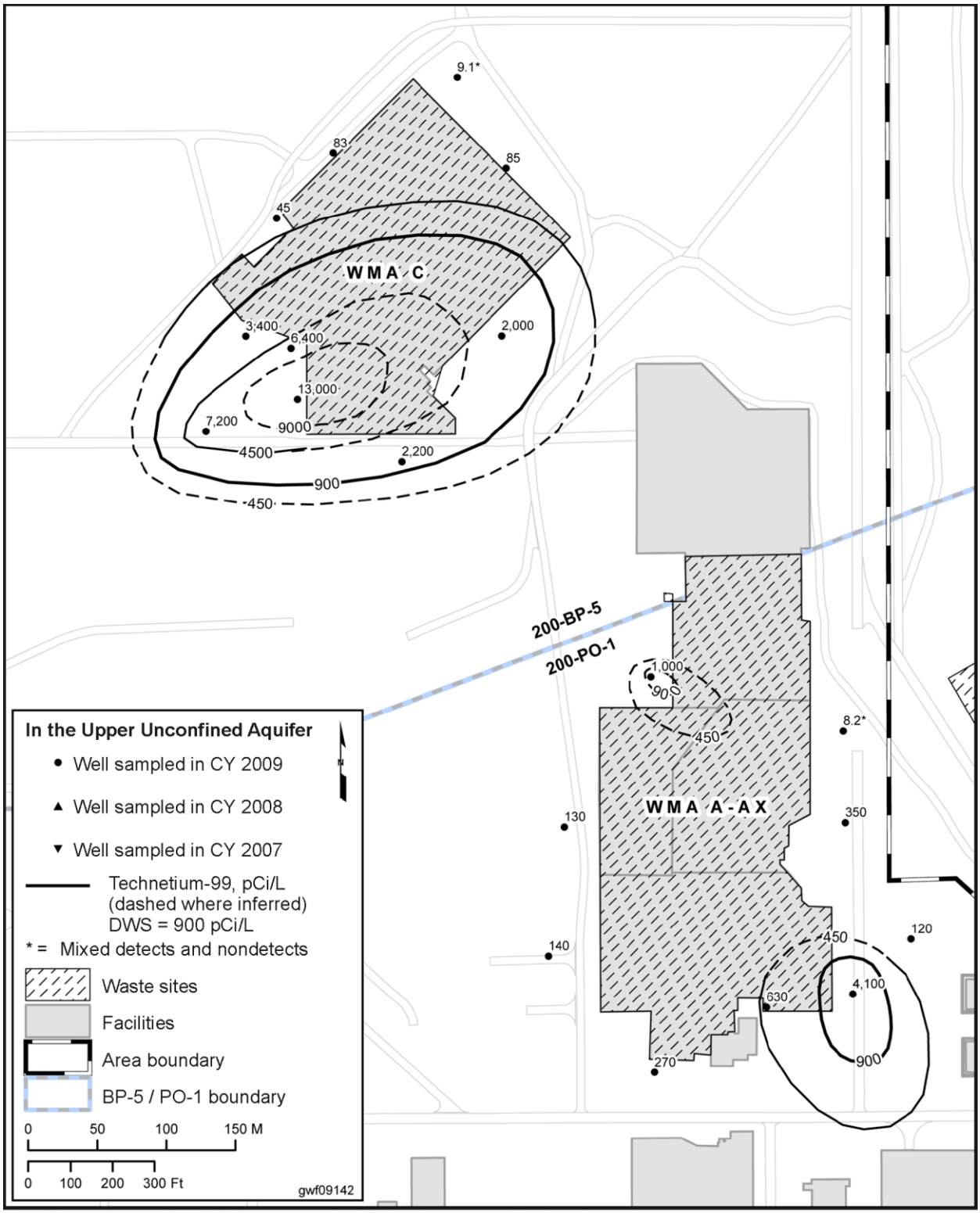
Note: To convert meters to feet, multiply by 3.281.

Figure U–69. Spatial Distribution of Groundwater Technetium-99 Concentration (Past Practice Sources), Eastern Portion of the Central Plateau, Calendar Year 2010



Key: CY=calendar year; DWS=drinking water standard; Km=kilometers; Mi=miles; pCi/L=picocuries per liter.
Source: DOE 2010a.

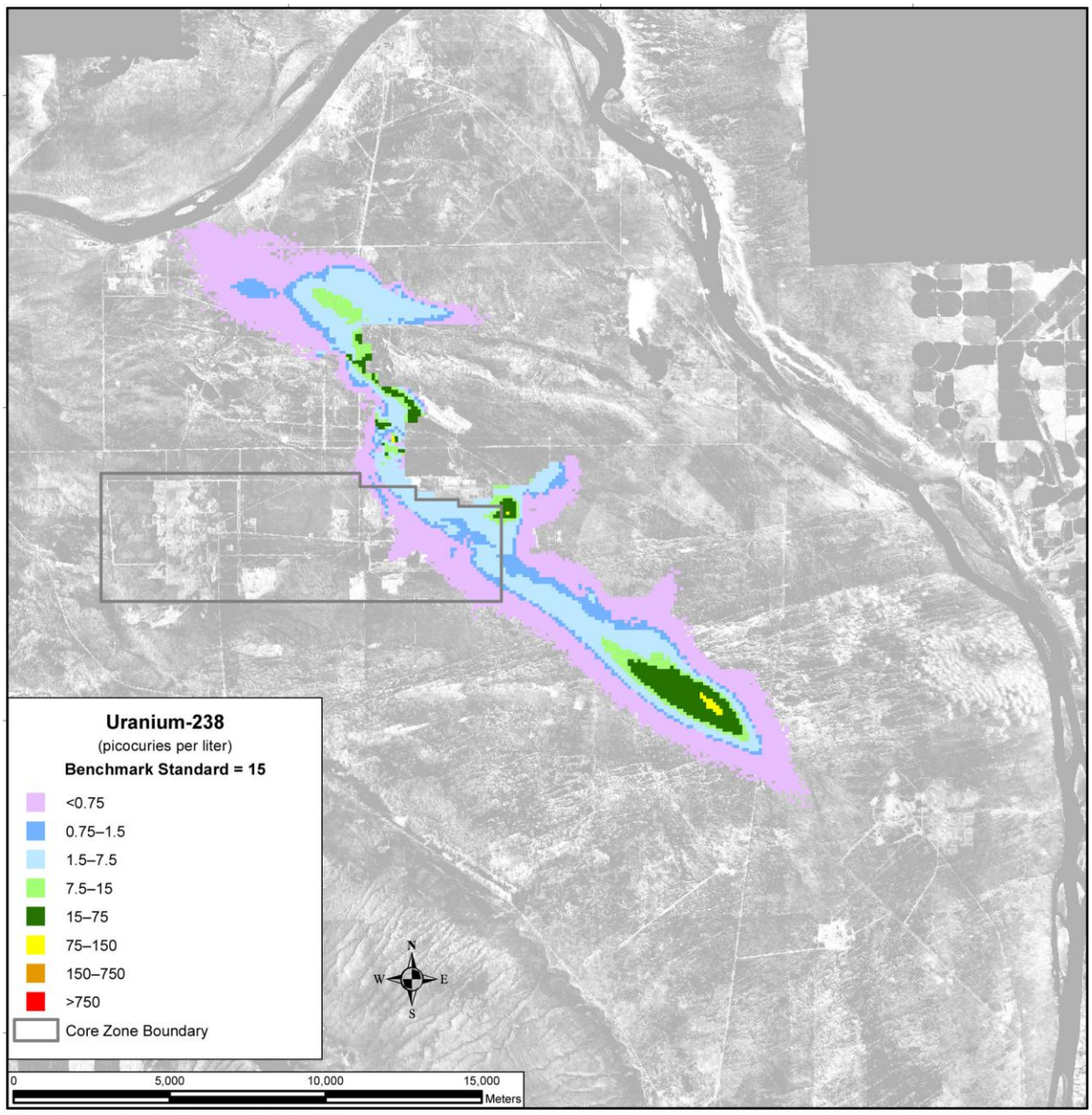
Figure U–70. Field-Reported Spatial Distribution of Groundwater Technetium-99 Concentration, BY Cribs, Calendar Year 2009



Key: CY=calendar year; DWS=drinking water standard; Ft=feet; M=meters; pCi/L=picocuries per liter.
Source: DOE 2010a.

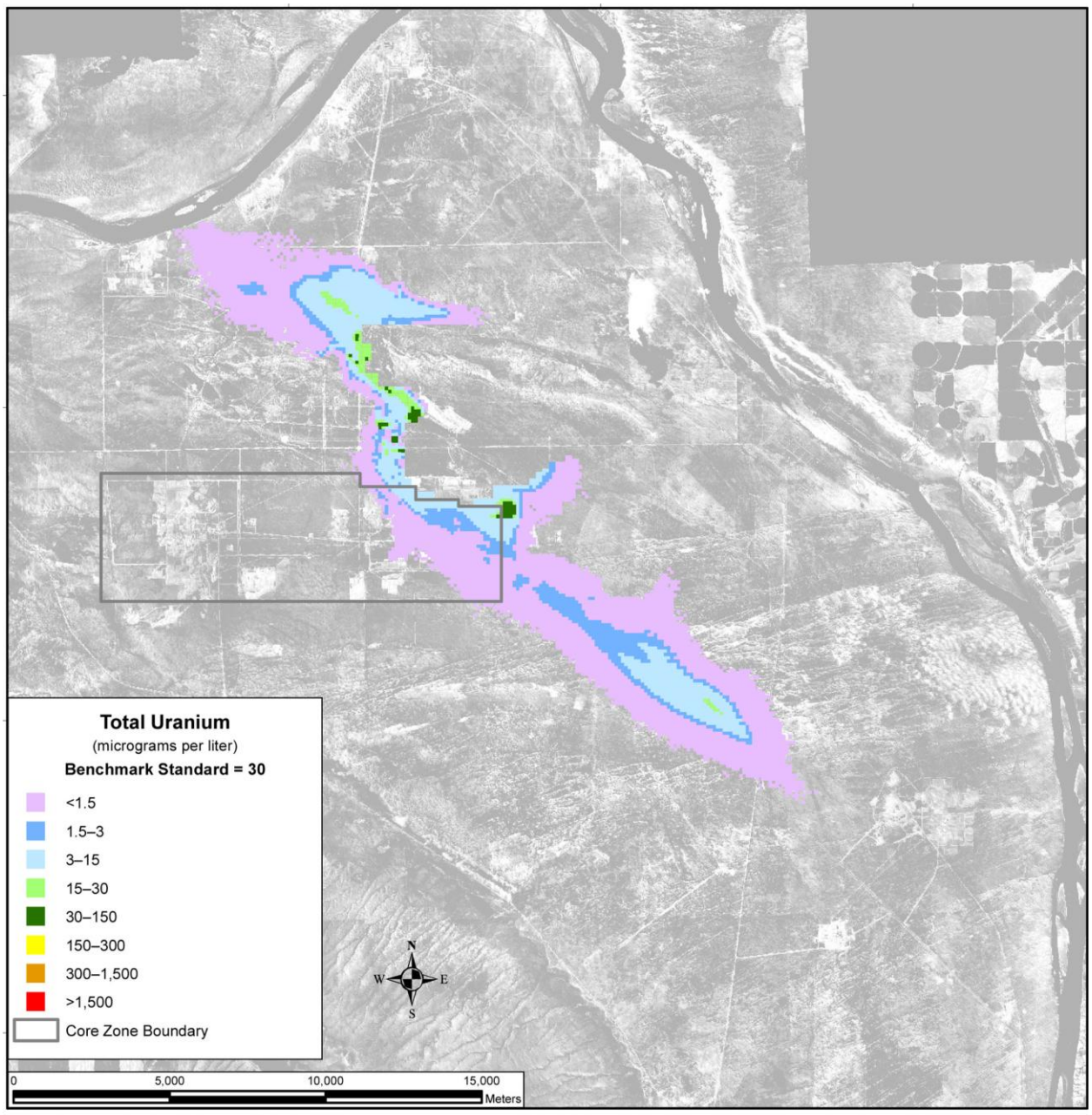
Figure U–71. Field-Reported Spatial Distribution of Groundwater Technetium-99 Concentration, A/AX and C Waste Management Areas, Calendar Year 2009

Uranium concentrations above the drinking water standard are present near the B/BX/BY waste management areas, extending northwest, and near the 216-B-12 Crib and some of the PUREX Cribs in the eastern portion of the Central Plateau. Figures U–72 and U–73 show the spatial distribution of uranium-238 and total uranium as predicted in the impacts analysis of past-practice sources. Figures U–74 and U–75 are the depictions of the uranium plumes in the eastern portion of the Central Plateau as presented in the 2009 groundwater monitoring report (DOE 2010a). Uranium-238 and total uranium simulation results show higher impacts resulting from heavy-discharge facilities in the 200-East Area (e.g., B Pond) than actually observed. The disagreement of these plumes with field measurements suggests that two possible areas of uncertainty may dominate the simulation of these impacts. The first is the uncertainty in the inventory of uranium-238 and total uranium in the heavy-discharge ponds (see Appendix S), which is approximately 50 percent. The second, and likely more important source of uncertainty, is the interaction of uranium-238 and total uranium with subsurface materials beneath these facilities. The *TC & WM EIS* analysis is based on a distribution coefficient for uranium of about 0.6 milliliters per gram (DOE 2005). This value, although appropriate for far-field conditions in the unconfined aquifer, is probably not representative of the conditions beneath the heavy-discharge sources (e.g., B Pond). Therefore, the prediction of the uranium-238 and total uranium contaminant plumes for large past-practice sources should be considered an overestimate of the actual impacts by about an order of magnitude.



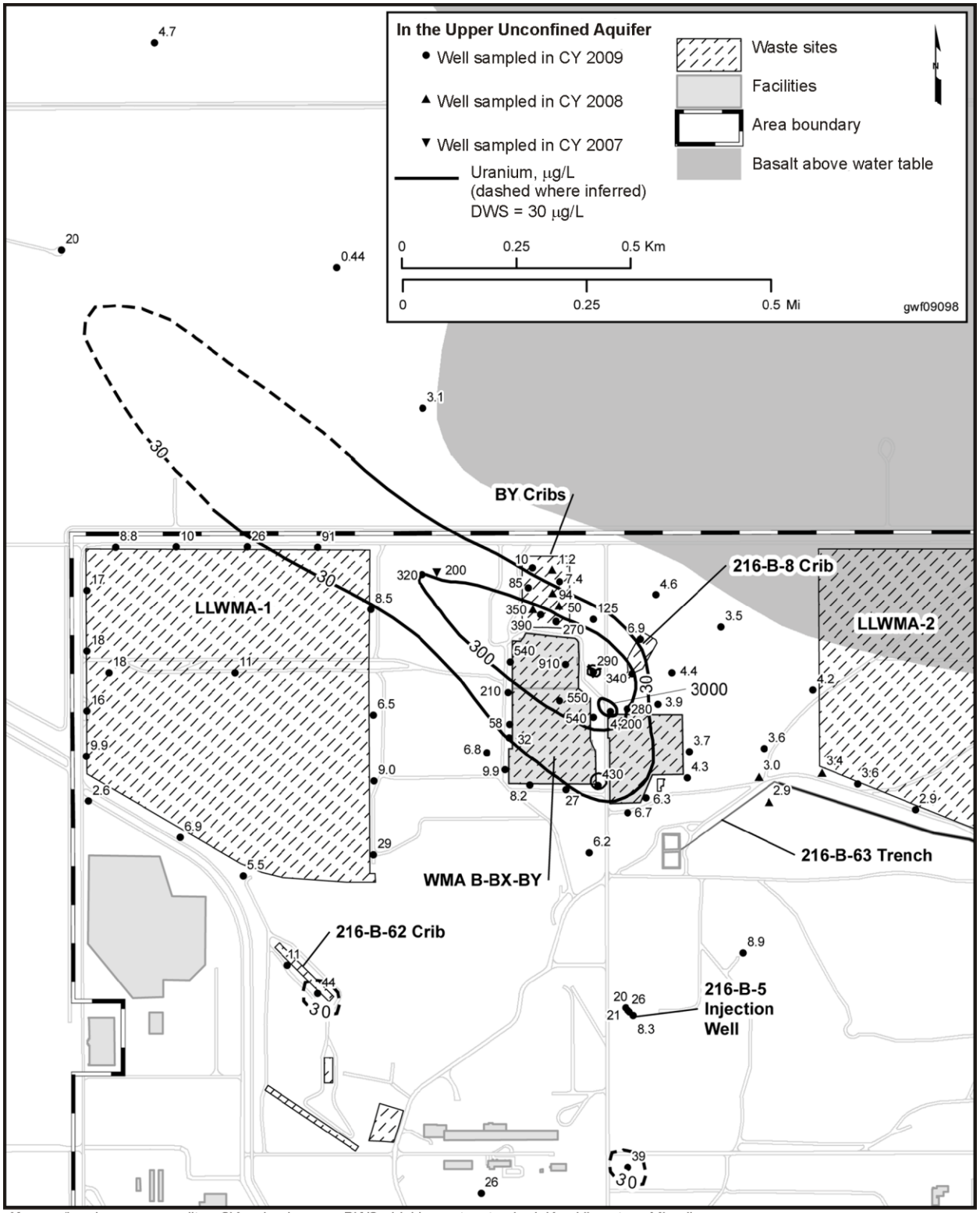
Note: To convert meters to feet, multiply by 3.281.

Figure U–72. Spatial Distribution of Groundwater Uranium-238 Concentration (Past-Practice Sources), Eastern Portion of the Central Plateau, Calendar Year 2010



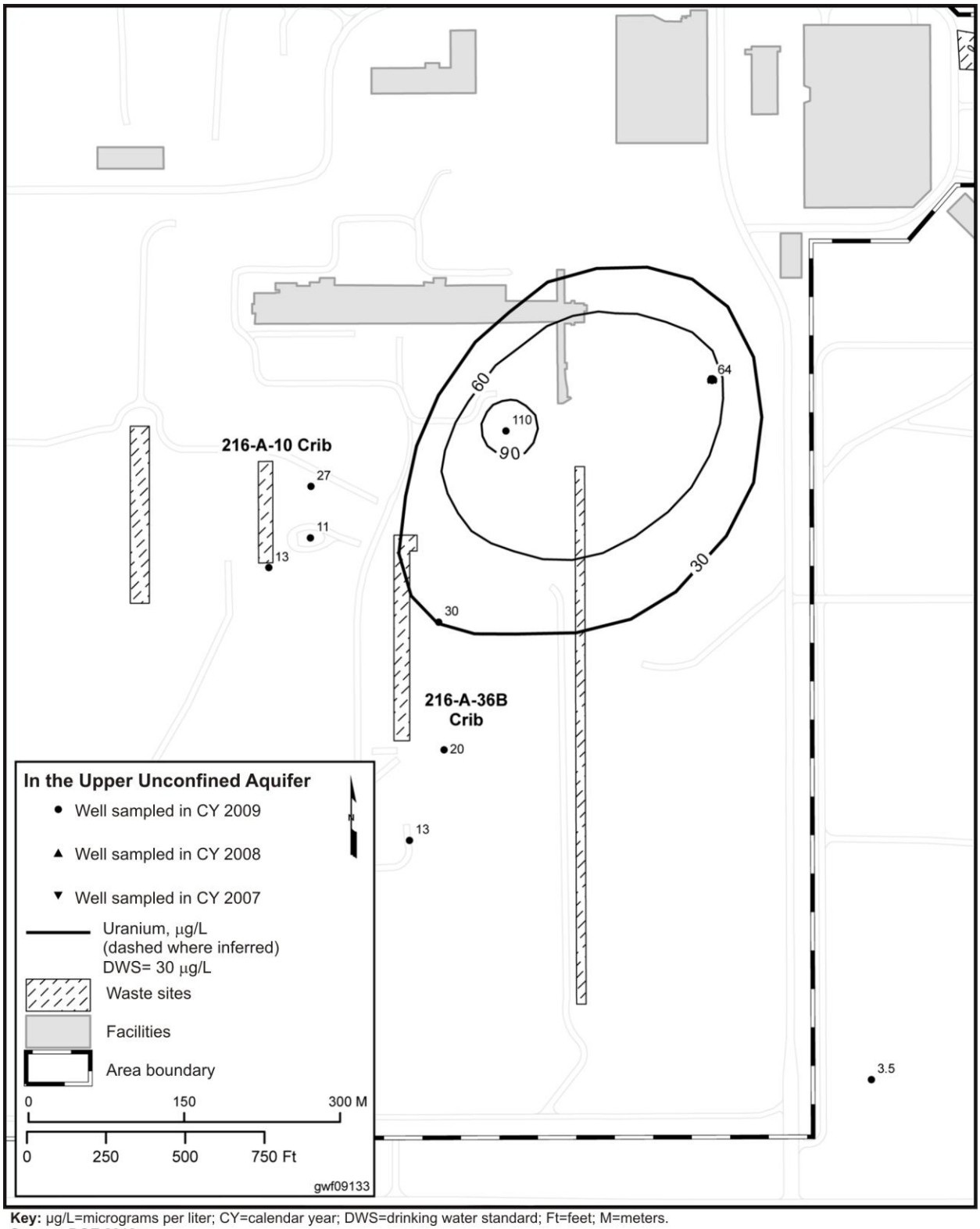
Note: To convert meters to feet, multiply by 3.281.

Figure U–73. Spatial Distribution of Groundwater Total Uranium Concentration (Past-Practice Sources), Eastern Portion of the Central Plateau, Calendar Year 2010



Key: μg/L=micrograms per liter; CY=calendar year; DWS=drinking water standard; Km=kilometers; Mi=miles.
Source: DOE 2010a.

Figure U–74. Field-Reported Spatial Distribution of Groundwater Uranium Concentration, BY Cribs, Calendar Year 2009



Key: µg/L=micrograms per liter; CY=calendar year; DWS=drinking water standard; Ft=feet; M=meters.
Source: DOE 2010a.

Figure U–75. Field-Reported Spatial Distribution of Groundwater Uranium Concentration, PUREX [Plutonium-Uranium Extraction] Cribs, Calendar Year 2009

U.1.2.2.4.4 Eastern Portion of the Central Plateau Consideration of Ongoing Hanford Site Activities

Cleanup of the Central Plateau is a highly complex activity because of the large number of waste sites, surplus facilities, active treatment and disposal facilities, and areas of deep soil contamination. Past discharges of more than 1,703 billion liters (450 billion gallons) of liquids to the soil have resulted in about 155 square kilometers (60 square miles) of contaminated groundwater. For areas of groundwater contamination in the Central Plateau, the CERCLA goal is to restore the aquifer to achieve drinking water standards.[17] In those instances where remediation goals are not achievable in a reasonable timeframe, programs will be implemented to prevent migration of the plume beyond the Central Plateau, prevent exposure to contaminated groundwater, and evaluate further risk-reduction opportunities as new technologies become available. Near-term actions are being taken to control plume migration for key contaminants until remediation goals are achieved.

Groundwater beneath the eastern portion of the Central Plateau comprises two operable units, as described below.

- The 200-BP-5 Operable Unit is located in the northern half of the 200-East Area and includes contaminant plumes of uranium and technetium-99.

- The 200-PO-1 Operable Unit is located in the southern half of the 200-East Area and includes extensive plumes of tritium, iodine-129, and nitrate.

The *Central Plateau Cleanup Completion Strategy* (DOE 2009) describes DOE's vision for completion of the Central Plateau cleanup and outlines the decisions needed to achieve the vision. The Central Plateau cleanup strategy, objectives, and vision are described in the subregional discussion for the western portion of the Central Plateau.

Established Decisions and Milestones

The following ROD has been published for areas of the Central Plateau:

- ROD for interim remedial actions for portions of the 100 Areas (100-BC-1, 100-BC-2, 100-DR-1, 100-DR-2, 100-FR-1, 100-FR-2, 100-HR-1, 100-HR-2, 100-KR-1, 100-KR-2, 100-IU-2, and 100-IU-6 Operable Units), 100 Area reactor waste, and portions of the 200 Areas (200-CW-3 Operable Units), July 1999 (EPA 1999a)

The following TPA milestones form the principal commitments for completing Central Plateau cleanup activities:

- M-015-00 – Complete the RI/FS (or RCRA Facility Investigation/Corrective Measures Study and RI/FS) process for all non-tank-farm operable units except for canyon-associated past-practice waste-site operable units covered in Milestone M-85-00 by December 31, 2016.[18]

[17] This goal is expressed in the *Hanford Site Groundwater Strategy: Protection, Monitoring, and Remediation* (DOE 2004:14). This strategy document was approved by DOE-RL, the DOE Office of River Protection, EPA, and Ecology. This goal has more recently been embedded into RAO No. 1 for the 200-ZP-1 Operable Unit groundwater: "Return the 200-ZP-1 OU groundwater to beneficial use (restore groundwater to achieve domestic drinking water levels) by achieving the cleanup levels (provided later in Table 11). This objective is to be achieved within the entire 200-ZP-1 OU groundwater plumes. The estimated timeframe to achieve cleanup levels is within 150 years" (EPA 2008).

[18] This milestone reflects the proposed changes included in TPA Change Package M-15-09-02. This change package underwent a 45-day public review and comment period that started May 3, 2010.

- M-016-00 – Complete remedial actions for all non-tank-farm and non-canyon operable units by September 30, 2024.[19]

- M-016-119-T01 – DOE will have a remedy in place to contain existing groundwater plumes (except iodine, nitrate, and tritium) in the National Priorities List 200 Areas (Central Plateau) by December 31, 2020.

Significant characterization and response actions that have occurred in the eastern portion of the Central Plateau as a result of these RODs and subsequent modifications include the following:

- Installation of soil desiccation pilot test equipment is under way to support startup in October 2010. Characterization of the test site is complete (DOE 2010d) and was performed in accordance with the requirements contained in the approved sampling and analysis plan (DOE 2008). Numerical simulation has shown that moisture removal will interrupt contaminant transport toward groundwater (Oostrom et al. 2009). The soil desiccation pilot test is designed to demonstrate feasibility of this technology and collect data to allow its evaluation in feasibility studies that address deep vadose zone contamination. The principal intent of this test is to provide information (e.g., cost and effectiveness) that can be used in the CERCLA feasibility study process for deep vadose zone sites with technetium-99 contamination to evaluate potential remedial actions. Actual deployment of a full-scale remedial action using desiccation technology would be selected in a ROD for a specific CERCLA operable unit or for a corrective action decision for an RCRA unit. The first feasibility study that will address this issue is the 200-WA-1 Operable Unit (based on proposed TPA changes), which includes the BC cribs and trenches (ditches) site. The 200-DV-1 Operable Unit feasibility study will also use information from this test in evaluating possible remedies. The 200-DV-1 Operable Unit includes the seven sets of B and T cribs and trenches (ditches) that are included with the Tank Closure alternatives in this *TC & WM EIS*.[20]

- DOE will submit a treatability test plan for determining whether a 189-liter-per-minute (50-gallon-per-minute) capacity pump-and-treat system can be sustained in the shallow and discontinuous aquifer to contain and reduce the mass of uranium and commingled technetium-99 plumes near the B/BX/BY tank farms by December 31, 2010 (TPA Milestone M-015-82). If sufficient sustained yield can be demonstrated, treatability testing will follow in accordance with the approved treatability test plan. Full-scale deployment of the treatment systems will be made via the 200 BP-5 Operable Unit RD/RA work plan.

- In 1980, DOE completed a characterization study of the 216-B-5 Reverse Well (Smith 1980). Waste, which contained approximately 4.3 kilograms (9.5 pounds) of plutonium from B Plant that was pumped into a settling tank between 1945 and 1947. Subsequently, material was pumped into 216-B-5 well which extended approximately 3 meters (10 feet) into groundwater. The characterization study suggests approximately 50 percent of the plutonium inventory remained in the settling tank and was not discharged to the well. Monitoring wells were also drilled around the reverse well. Plutonium and strontium-90 exceeding 10 nanocuries per gram of soil were limited to within 6 meters (20 feet) of the reverse well in 1979 (when the study was performed).

[19] This milestone reflects the proposed changes included in TPA Change Package M-16-09-03. This change package underwent a 45-day public review and comment period that started May 3, 2010.

[20] The seven sets of B and T Cribs included in the *TC & WM EIS* Tank Closure alternatives include 33 individual waste sites. Of these, 32 are currently assigned to the 200-TW-1 and 200-TW-2 Operable Units and will therefore be assigned to the new deep vadose zone operable unit, 200-DV-1. Of this set of 33 waste sites, only 216-T-28 will be assigned to an operable unit other than 200-DV-1. The 216-T-28 waste site is currently assigned to the 200-LW-1 Operable Unit; it will be reassigned to the 200-WA-1 Operable Unit. TPA Change Package C-09-07 lists the proposed revisions in operable unit assignments for Central Plateau waste sites.

Plutonium concentrations exceeding 100 nanocuries per gram were limited to a narrow 1-meter (3-foot) layer, located at the position of the 1948 water table. In 1995, DOE implemented a treatability test plan *Pilot-Scale Treatability Test Plan for the 200-BP-5 Operable Unit* (DOE 1995b) for portions of the 200-BP-5 groundwater operable units that had been identified as candidates for accelerated remedial action. One location included the 216-B-5 Reverse Well with key groundwater contaminants identified as cesium-137, strontium-90, and plutonium-239 and -240. The treatability test and its results are described in *200-BP-5 Operable Unit Treatability Test Report* (DOE 1996) and included groundwater extraction tests, analytical studies, and risk assessment modeling. The conclusion of the treatability test regarding the 216-B-5 Reverse Well was that the B-5 Reverse Well plumes will not produce an unacceptable risk to offsite groundwater users. Therefore, it is recommended that the plumes be removed from the accelerated IRM (interim remedial measure) pathway and that the future course of action include only groundwater monitoring to track plume movement and verify modeling results.

Cleanup Goals and Levels

Evaluation of the Central Plateau operable units[21] is expected to have the following common RAOs:

- Prevent unacceptable risk to human health from direct contact with COPCs present in contaminated soil. Unacceptable risks are (1) an excess lifetime cancer risk[22] greater than 10^{-4} to 10^{-6} or (2) a Hazard Index greater than 1 under reasonable maximum-exposure scenarios. The point of compliance (depth in the soil column) for protecting human health will be established through the RI/FS process and will be consistent with reasonably foreseeable land use and associated exposures.

- Mitigate unacceptable risk to ecological receptors associated with exposure to waste or soil contaminated above risk based criteria. (A specific biointrusion depth will be established based upon a review of scientific studies on key indicator terrestrial biota that are directly relevant and applicable to the ecological setting of the Inner Area of the Central Plateau.)

- Prevent migration of COPCs in the vadose zone from the source unit to groundwater in concentrations that would degrade the groundwater aquifer above applicable standards such as Federal maximum contaminant levels.

- Return contaminated groundwater aquifers to maximum beneficial use within a reasonable timeframe.[23]

[21] Central Plateau operable units include 200-EA-1/200-IS-1 (200-East Area Inner Area/Pipelines); 200-WA-1 (200-West Area Inner Area); 200-OA-1/200-CW-1/3 (Outer Area); 200-DV-1 (deep vadose zone); 200-SW-2 (burial grounds); 200-CB-1 (B Plant canyon and associated waste sites); 200-CP-1 (PUREX canyon and associated waste sites); 200-CR-1 (REDOX canyon and associated waste sites); and 200-PW-1/3/6 (plutonium-contaminated sites). Operable unit designations reflect the proposed changes included in TPA Change Package C-09-07. This change package is undergoing a 45-day public review and comment period that started May 3, 2010.

[22] The Model Toxics Control Act uses a risk level of 10^{-5}.

[23] This terminology is directly from CERCLA policy for groundwater cleanup. For the 200-ZP-1 Operable Unit ROD, the following timeframe is established in an RAO: "RAO #1: Return the 200-ZP-1 OU groundwater to beneficial use (restore groundwater to achieve domestic drinking water levels) by achieving the cleanup levels (provided later in Table 11). This objective is to be achieved within the entire 200-ZP-1 OU groundwater plumes. The estimated timeframe to achieve cleanup levels is within 150 years." EPA has determined that a 150-year timeframe is "reasonable" for cleanup of this plume in the 200-West Area.

- Prevent COPCs in groundwater from migrating to the Columbia River above applicable ambient water quality criteria.[24]

Anticipated Cleanup End State

Cleanup decisions for the Central Plateau will lead to a combination of actions for waste sites and groundwater that collectively will meet the cleanup goals described in the previous sections. For areas of groundwater contamination in the Central Plateau, the goal is remediation of the aquifer to achieve drinking water standards. For waste sites, remedies will be implemented that prevent future groundwater contamination. In those instances where remediation goals are not achievable in a reasonable timeframe, programs will be implemented to prevent further migration of the plume, prevent exposure to contaminated groundwater, and evaluate further risk-reduction opportunities as new technologies become available. Near-term actions will be taken when appropriate to control plume migration until remediation goals are achieved.

Table U–9 summarizes the current and planned actions and the expected cleanup end state for the Central Plateau groundwater operable units.

Table U–9. Eastern Portion of the Central Plateau Groundwater Plumes and Treatment Actions

Operable Unit	Primary Contaminants	Current Status and Actions	Future Actions	Anticipated Cleanup End State
200-PO-1	Hydrogen-3 (tritium), iodine-129, nitrate	No active treatment. Monitoring only.	Future treatment is subject to the final 200-PO-1 Operable Unit ROD.	Cleanup levels are anticipated to be consistent with other groundwater RODs at Hanford, i.e., drinking water standards or below. For tritium, natural radioactive decay is expected to cause this plume to dissipate in the near future to reach drinking water standards. The nitrate and iodine-129 plumes are expected to dissipate within a reasonable time period to reach drinking water standards. Some localized treatment systems may be needed.
200-BP-5	Uranium, technetium-99	No active treatment. Monitoring only. A treatability test was performed in the mid-1990s for this plume, but no action was warranted at that time.	Future treatment is subject to the final 200-BP-5 Operable Unit ROD. A treatability test plan to determine viability of a pump-and-treat system capacity of at least 189 liters (50 gallons) per minute for uranium and technetium-99 is being prepared (per TPA Milestones M-015-82A and B). Some active treatment is anticipated to address plumes of uranium and technetium-99 that are continuing to emerge in groundwater.	Cleanup levels are anticipated to be consistent with other groundwater RODs at Hanford, i.e., drinking water standards or below.

Key: Hanford=Hanford Site; ROD=Record of Decision; TPA=Tri-Party Agreement [Hanford Federal Facility Agreement and Consent Order].

[24] This commitment is also embedded within TPA milestone M-016-119-T01, which states: "DOE will have a remedy in place to contain existing groundwater plumes (except iodine, nitrate, and tritium) in the 200 NPL Area (Central Plateau). The due date for this milestone is 12/31/2020."

In addition to the cleanup end states in the eastern portion of the Central Plateau, a possible new disposal facility was considered in the cumulative impacts analysis. As discussed in Chapter 1, DOE has prepared the *Draft Environmental Impact Statement for the Disposal of Greater-Than-Class C (GTCC) Low-Level Radioactive Waste and GTCC-Like Waste (GTCC EIS)* (DOE 2011), which addresses the disposal of low-level radioactive waste (LLW) generated by activities licensed by the U.S. Nuclear Regulatory Commission or an agreement state that contains radionuclides in concentrations exceeding Class C limits as defined in (10 CFR 61). The *GTCC EIS* also addresses DOE LLW and transuranic waste that have characteristics similar to GTCC LLW and that may not have an identified path to disposal.

Hanford is being considered as a candidate location for a new GTCC waste disposal facility in the *Draft GTCC EIS*. Such a facility is not expected to be operational until after 2019. In addition, DOE estimates there are about 12,000 cubic meters (420,000 cubic feet) of GTCC LLW and similar DOE waste (DOE 2011) already in storage or projected to be generated from existing facilities or that may be generated in the future as a result of actions proposed by DOE or commercial entities. Detailed information on this waste is provided in the *Draft GTCC EIS* (DOE 2011).

If Hanford were selected to host a GTCC disposal facility pursuant to the *Final GTCC EIS*, DOE would conduct an appropriate project-specific National Environmental Policy Act review, including a cumulative impacts analysis. These offsite inventories have been estimated since publication of the *Draft TC & WM EIS* and are included in the groundwater impacts analysis in this *Final TC & WM EIS*. However, because the GTCC disposal facility is only being considered at Hanford and is not a currently operating facility or past waste site, and therefore is not similar to the other types of facilities included in the cumulative groundwater impacts analysis, an additional analysis was completed for the potential GTCC disposal facility to help the reader understand the contribution of this facility to the long-term environmental impacts.

Of the inventories evaluated for the potential GTCC waste disposal facility, only two constituents, technetium-99 and iodine-129, were predicted to be released to the aquifer over the 10,000-year model period. Figure U–76 shows the technetium-99 concentration versus time at the Core Zone Boundary and the Columbia River nearshore for all of the cumulative impacts analysis sites. This concentration-versus-time graph is shown as a point of comparison for the individual source locations discussed below. The peak technetium-99 concentration is estimated to be close to the benchmark for the early peak (circa CY 1960) and within an order of magnitude for the later peak (circa CY 3500). The early rise in the technetium-99 concentration-versus-time curve is due to liquid releases and the relatively rapid travel time through the vadose zone. The later peak in concentration versus time is due to partition-limited releases and the slower travel time through the vadose zone because of lower moisture content. Figure U–77 shows the iodine-129 concentration-versus-time graph at the Core Zone Boundary and the Columbia River nearshore for all of the cumulative impacts analysis sites. The iodine-129 concentration-versus-time graph shows a similar behavior to the technetium-99 concentration-versus-time; however, the peaks are elevated. The early peak is more than an order of magnitude above the benchmark and the later peak is close to the benchmark.

Figures U–78 and U–79 show concentration versus time for technetium-99 and iodine-129 at the Core Zone Boundary for the GTCC waste disposal site. These figures can be directly compared with Figures U–76 and U–77. Note that the GTCC waste sources are major contributors to the non-*TC & WM EIS* technetium-99 and iodine-129 concentrations at the Core Zone Boundary after CY 3940.

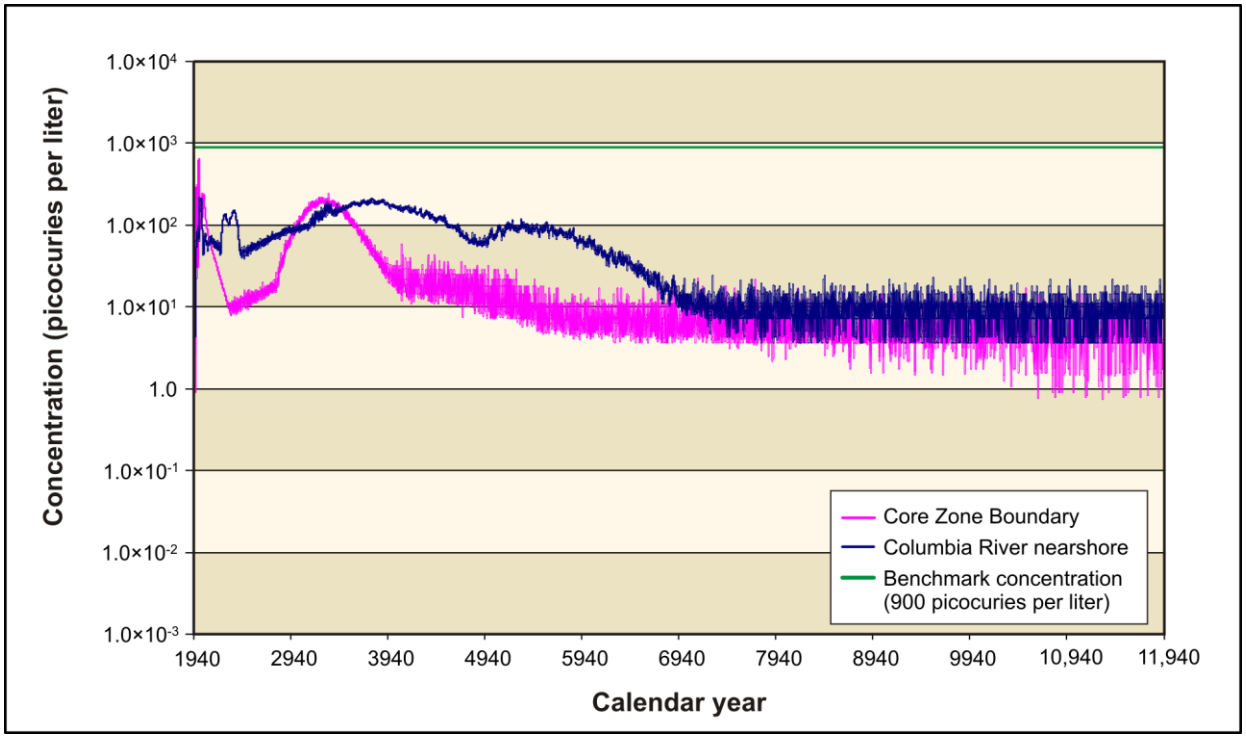


Figure U–76. Technetium-99 Concentration Versus Time (Including Greater-Than-Class C Waste Inventory)

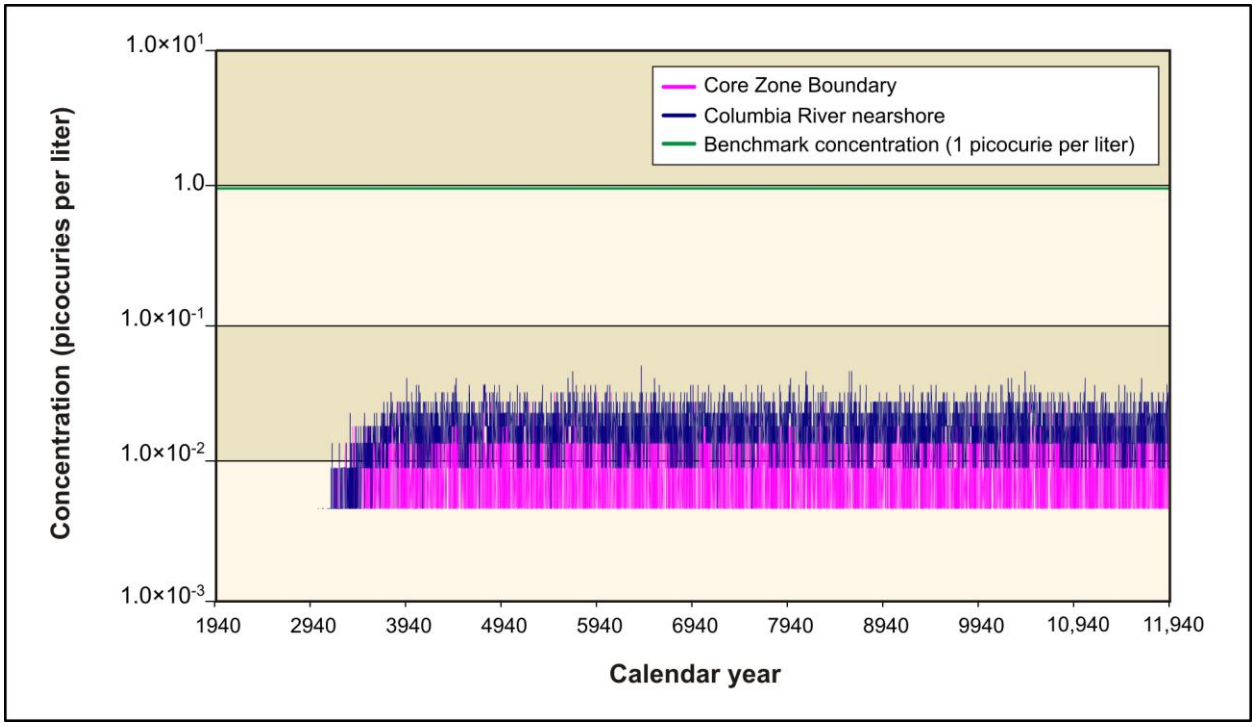


Figure U–77. Iodine-129 Concentration Versus Time (Including Greater-Than-Class C Waste Inventory)

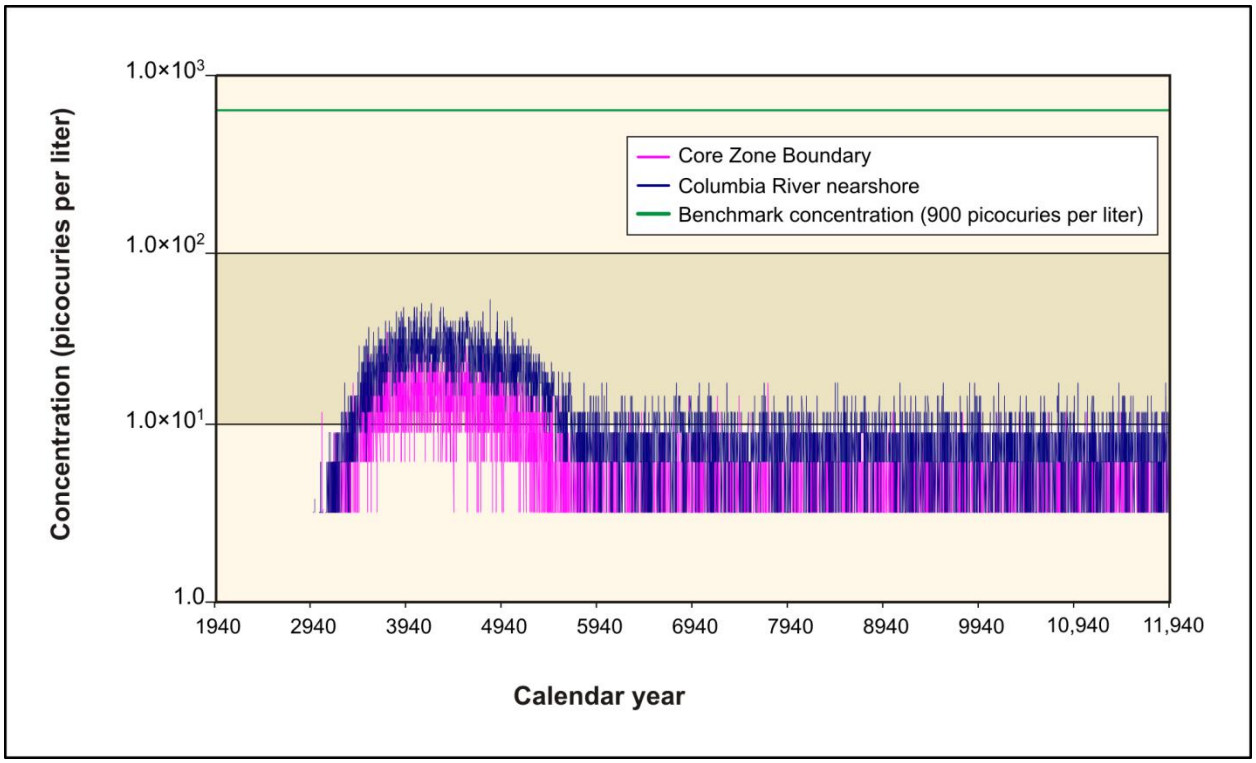


Figure U–78. Technetium-99 Concentration Versus Time (Greater-Than-Class C Waste Disposal Site Only)

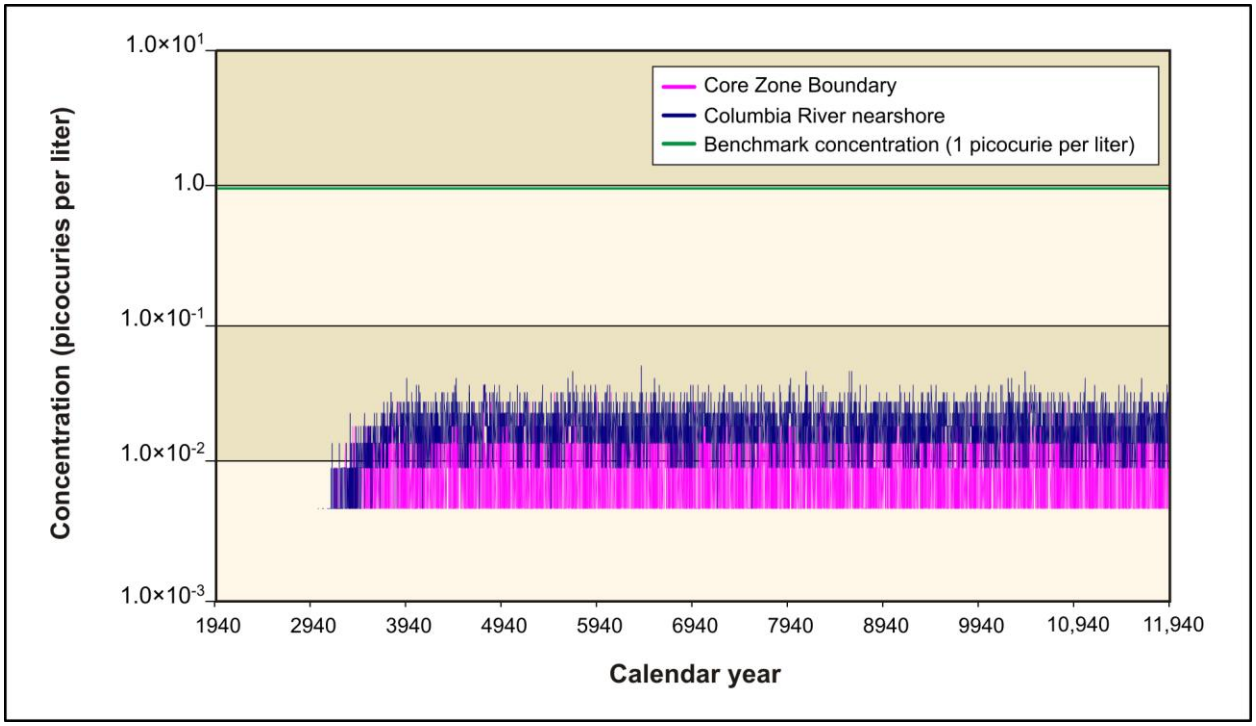


Figure U–79. Iodine-129 Concentration Versus Time (Greater-Than-Class C Waste Disposal Site Only)

U.1.2.2.5 North of the Central Plateau

The region north of the Central Plateau comprises the area north of the Core Zone Boundary and south of the 100 Areas. It includes the eastern portion of Gable Butte, Gable Gap, the western portion of Gable Mountain, West Lake, and Gable Mountain Pond.

U.1.2.2.5.1 North of the Central Plateau Hydrogeologic Regime

The hydrogeologic regime describes the system of geology and groundwater flow that governs groundwater contaminant distribution. The lithology in this region consists of Hanford gravel, Hanford sand, Plio-Pleistocene (Cold Creek) gravel, Plio-Pleistocene silt, Ringold Formation, and basalt. This region can be separated into distinct zones based on the lithology. In the northern area of Gable Gap, there is a flat layer of Hanford formation sitting on top of a layer of Ringold Formation that conforms to the basalt layer below. This continues down the western half of Gable Gap until about the northernmost portion of the Gable Mountain Pond. South of this is a zone of flat Hanford formation sitting on top of a flat Plio-Pleistocene layer. The basalt in this zone is relatively flat. There are some small partial layers of Ringold Formation in this zone occurring below the Plio-Pleistocene. On the eastern half of Gable Gap, there is a thick layer of Hanford formation conforming directly to the basalt layer. In the southern half of this zone, underneath Gable Mountain Pond in the West Lake channel, the basalt layer becomes thicker, and the Plio-Pleistocene layer is deposited on top, with a flat Hanford layer sitting at the surface. There are two major features in this region that impact groundwater flow and contaminant distribution. The first is the presence of anticlines and synclines in this area. There is an anticline that runs through the northern section of the region below Gable Butte and Gable Mountain, and there are a small syncline and another anticline that border the northeast and southwest edges of Gable Mountain Pond. There is also a syncline that runs through the middle of Gable Gap into the very northern portion of the 200-East Area. The second major feature in this area is West Lake. This is the only naturally occurring lake at Hanford. The lake tends to deposit large amounts of salt upon recharge (Bjornstad et al. 2010; DOE 2010e).

The vadose zone in this region is primarily composed of Hanford gravel and Hanford sand. Other formations are present at the bottom of the vadose zone near the water table. The units that protrude into the vadose zone include Plio-Pleistocene, Ringold, and basalt. Plio-Pleistocene protrudes above the water table in the southern half of the region and Ringold protrudes above the water table in the western half. The vadose zone is generally between 30 meters (98 feet) thick in the north and about 60 meters (197 feet) thick in the south. The vadose zone also becomes thinner from the west to the east. In the vicinity of West Lake and Gable Mountain Pond, the vadose zone is thin, with thicknesses ranging from approximately 10 to 15 meters (33 to 49 feet) (Bjornstad et al. 2010). Figure U–80 is a representative cross section of the vadose zone at Gable Mountain Pond.

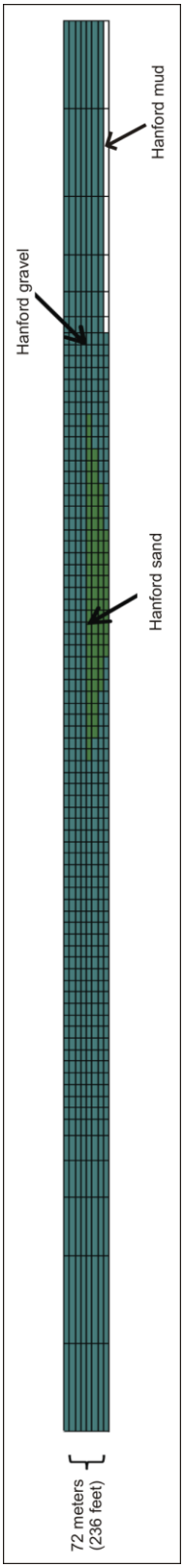
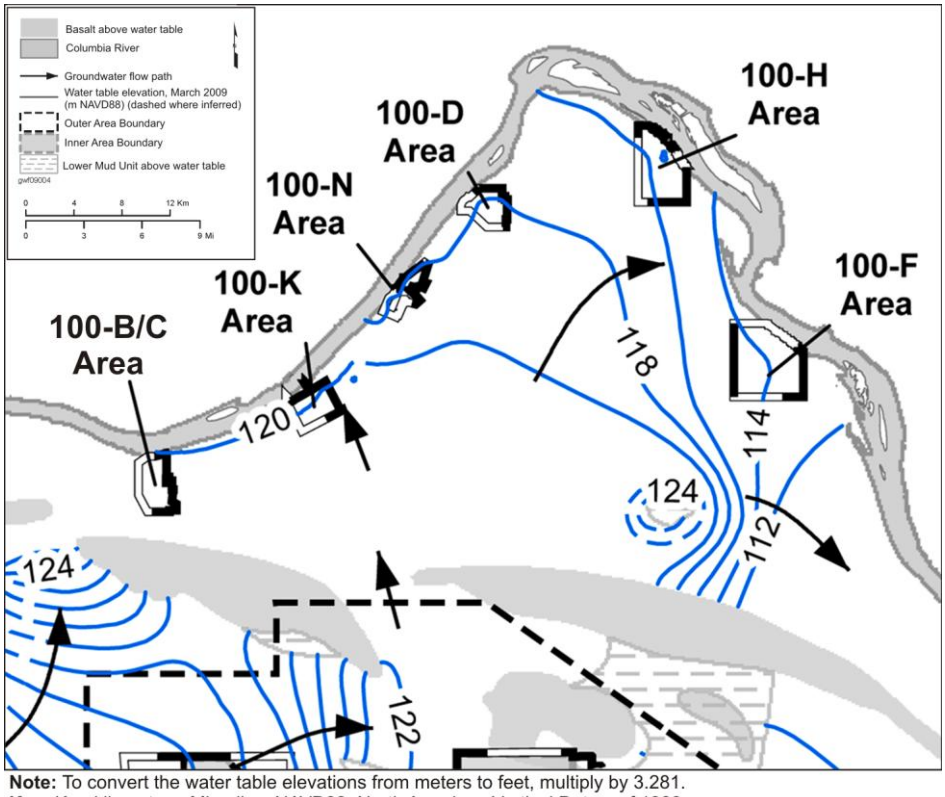


Figure U–80. West-to-East Cross Section of Vadose Zone Lithology for Gable Mountain Pond

The water table is flat in this region, at about 120 meters (394 feet) in elevation. Figure U–81 illustrates the water table and inferred directions of groundwater flow in the region north of the Central Plateau as indicated in the 2009 groundwater monitoring report (DOE 2010a).



Note: To convert the water table elevations from meters to feet, multiply by 3.281.
Key: Km=kilometers; Mi=miles; NAVD88=North American Vertical Datum of 1988.
Source: Modified from DOE 2010a.

Figure U–81. North of the Central Plateau Water Table and Inferred Groundwater Flow Directions, March 2009

U.1.2.2.5.2 North of the Central Plateau Historical Anthropogenic Discharges

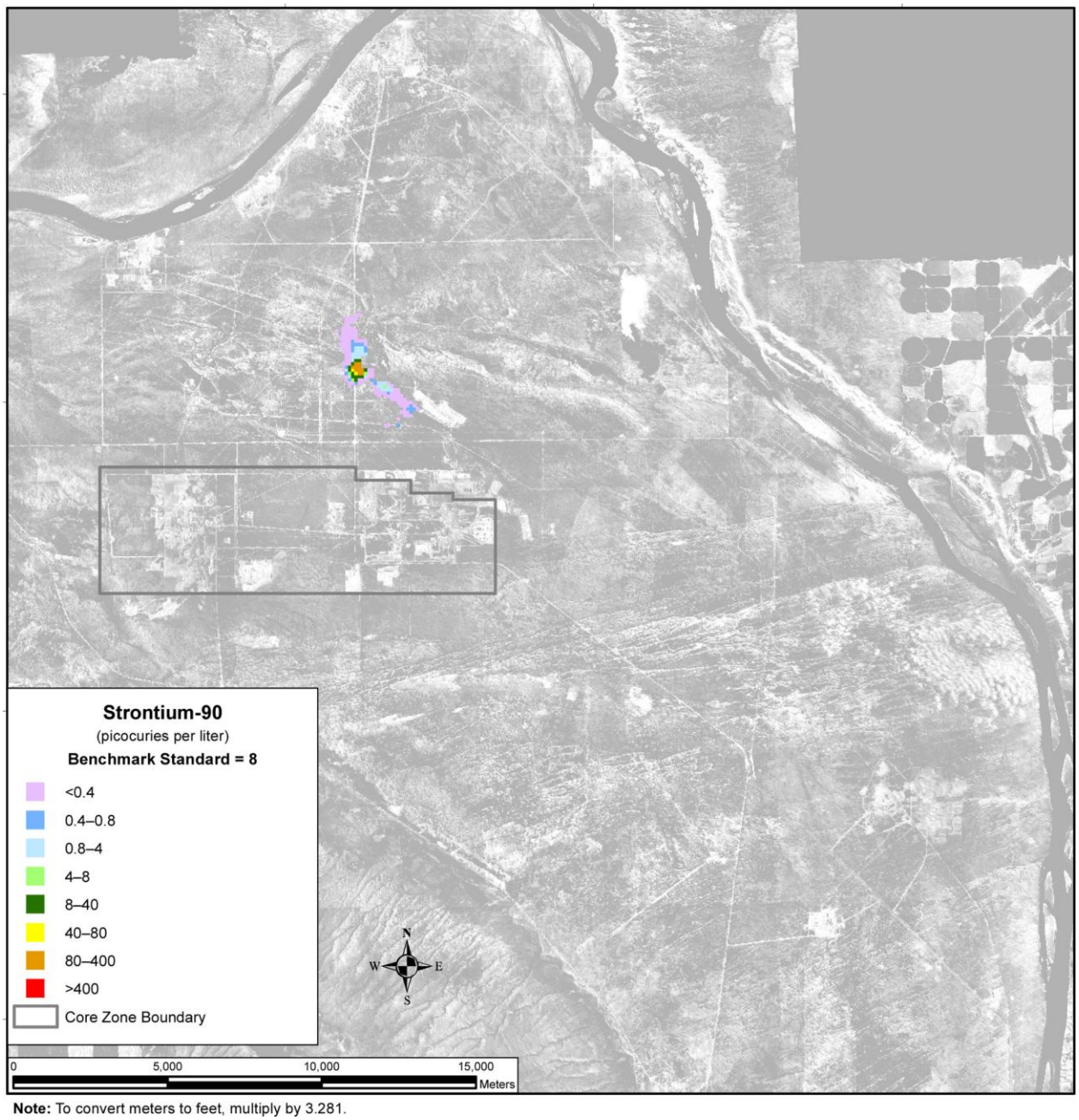
Large volumes of processing waste were discharged in the area north of the Central Plateau (DOE 2010a), both intentionally and unintentionally, during Hanford's operational period. For analysis purposes in this *TC & WM EIS*, aqueous sources of contamination were examined based on the amount of discharge. Sources with aqueous flux (volume per area) of less than 1 meter (3 feet) per year were categorized as moderate-discharge sources. Sources with aqueous flux of greater than 1 meter (3 feet) per year were categorized as heavy-discharge sources. Solid sources were categorized as low-discharge sources. The anthropogenic sources in the northern portion of the Central Plateau were primarily heavy-discharge sites and included ponds and trenches (ditches), with Gable Mountain Pond being a major source of influence on regional flow.

U.1.2.2.5.3 North of the Central Plateau Comparison of Modeled Versus Measured Spatial Contaminant Distributions

This section discusses the distribution of inventories as described in the 2009 groundwater monitoring report (DOE 2010a) and compares the results of the impacts analysis of past-practice sources in the region north of the Central Plateau in terms of the spatial distribution of COPC concentrations in CY 2010. Concentrations of each radionuclide and chemical are indicated by a color scale that is relative to the benchmark concentration. Concentrations greater than the benchmark concentration are indicated by the fully saturated colors green, yellow, orange, and red in order of increasing concentration. Concentrations

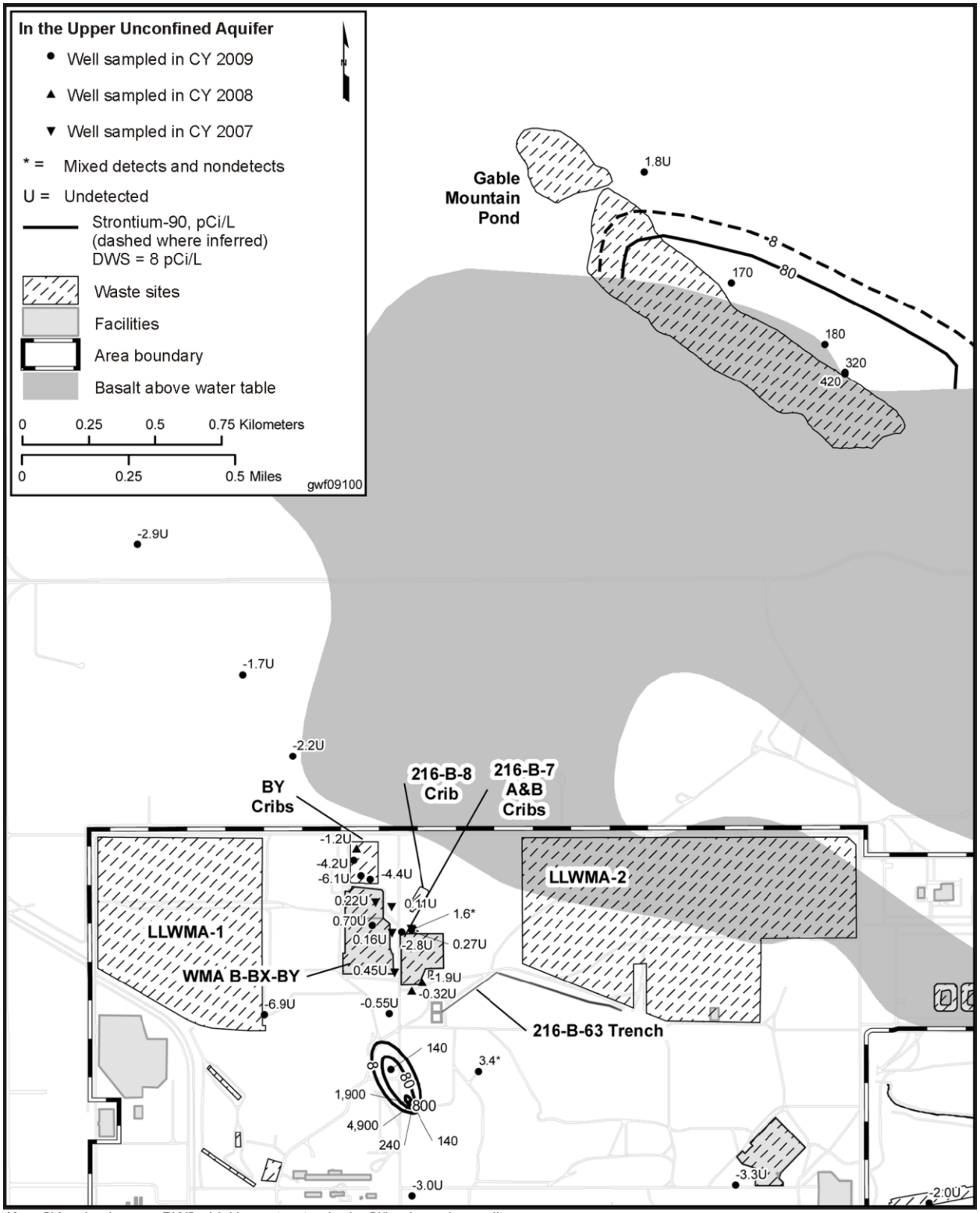
less than the benchmark concentration are indicated by the faded colors green, blue, indigo, and violet in order of decreasing concentration. Note that the concentration ranges are on a logarithmic scale to facilitate visual comparison of concentrations that vary over three orders of magnitude.

The primary contaminant forming extensive plumes within the region north of the Central Plateau is strontium-90. Figure U–82 shows the spatial distribution of strontium-90 as predicted in the impacts analysis of past-practice sources. Figure U–83 is the corresponding depiction of the strontium-90 plumes as presented in the 2009 groundwater monitoring report (DOE 2010a). Note that some of the modeled source areas, including Gable Mountain Pond, were moved from their actual locations to place them entirely over active areas of the aquifer (see Appendix O for more detail).



Note: To convert meters to feet, multiply by 3.281.

Figure U–82. Spatial Distribution of Groundwater Strontium-90 Concentration (Past-Practice Sources), North of the Central Plateau, Calendar Year 2010



Key: CY=calendar year; DWS=drinking water standard; pCi/L=picocuries per liter.
Source: DOE 2010a.

Figure U–83. Field-Reported Spatial Distribution of Groundwater Strontium-90, North of the Central Plateau, Calendar Year 2009

U.1.2.2.5.4 North of the Central Plateau Consideration of Ongoing Hanford Site Activities

Existing contaminant plumes north of the Central Plateau are largely associated with discharges or waste within the Central Plateau. Past discharges of liquids to the soil have resulted in about 155 square kilometers (60 square miles) of contaminated groundwater. Within the Central Plateau itself, programs will be implemented to prevent migration of the plume beyond the Central Plateau, prevent exposure to contaminated groundwater, and evaluate further risk-reduction opportunities as new technologies become available. North of the Central Plateau, programs will be implemented to evaluate the nature and extent of contamination and processes impacting natural attenuation.

U.1.2.2.6 Southeast of the Central Plateau

Southeast of the Central Plateau comprises the region southeast of the Core Zone that extends southeast toward the 300 Area. The region southeast of the Central Plateau includes the 600 Area NRDWL, the Fast Flux Test Facility, and several outlying portions of the 300 Area.

U.1.2.2.6.1 Southeast of the Central Plateau Hydrogeologic Regime

The hydrogeologic regime describes the system of geology and groundwater flow that governs groundwater contaminant distribution. The lithology in the region that extends southeast of the Central Plateau is composed of Hanford sand and Hanford gravel sitting on top of Ringold sand and Ringold gravel. In portions, these units also sit on top of Ringold mud. These units then conform to a layer of basalt. The vadose zone is primarily composed of Hanford formation sediments. In the southwest portion of this region, basalt is found above the water table (DOE 2010a). Additionally, an erosional paleochannel composed of highly conductive Hanford formation materials is present in the vadose zone beginning in the Central Plateau and continuing to the southeast toward the Fast Flux Test Facility (Bjornstad et al. 2010).

The vadose zone varies in thickness in the area southeast of the Central Plateau. The thickest portions of the vadose zone are in the northwest near the Core Zone, where it is approximately 90 meters (295 feet) thick; it becomes thinner as it approaches the 300 Area, where it is approximately 15 meters (49 feet) thick (DOE 2010a). Figure U–84 is a representative cross section of the vadose zone lithology at the 600 Area NRDWL.

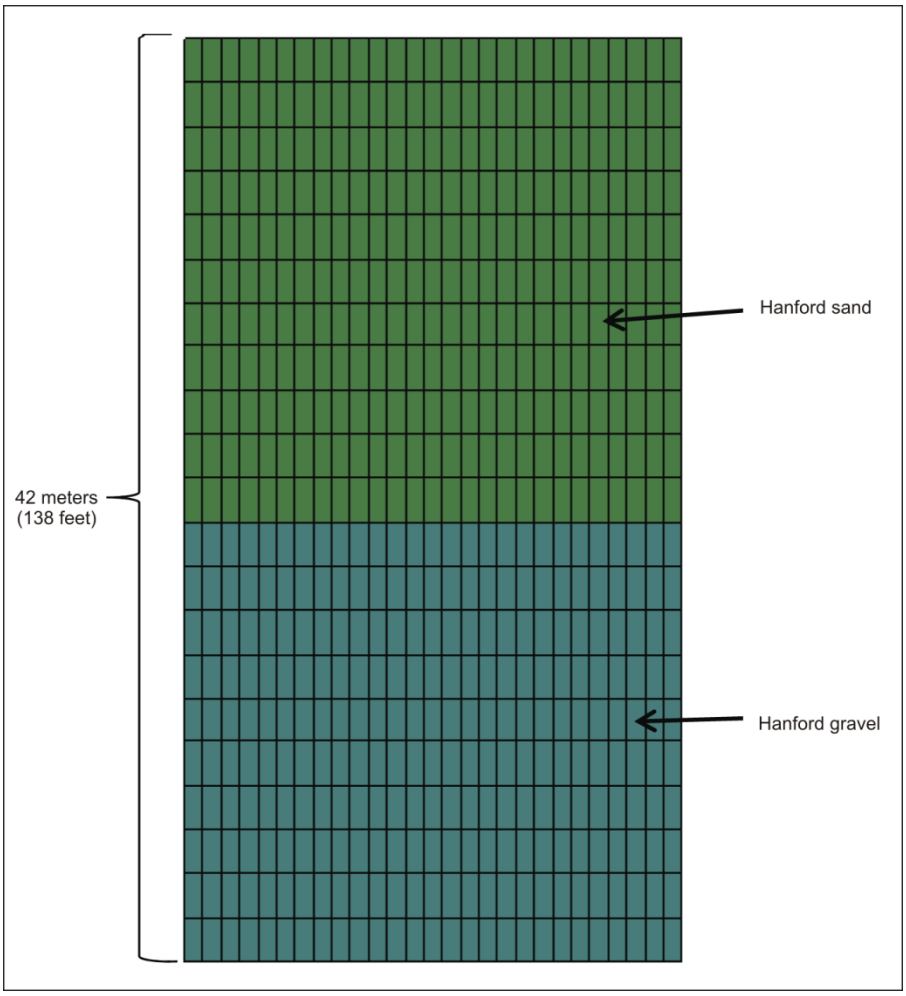
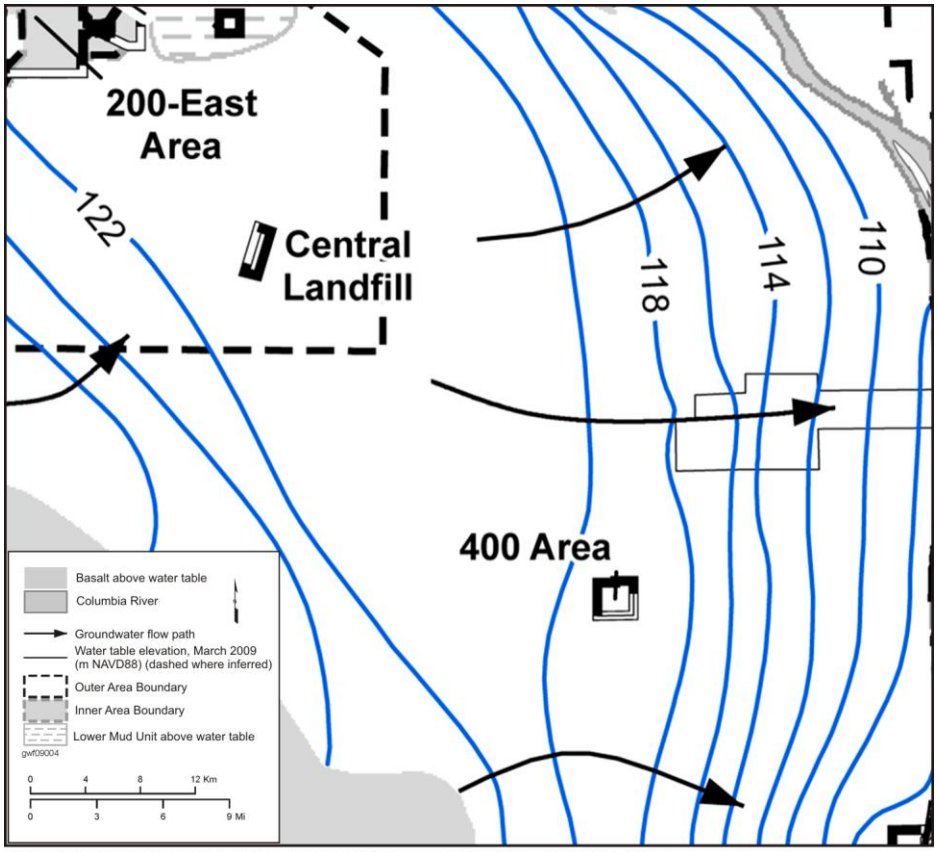


Figure U–84. West-to-East Cross Section of Vadose Zone Lithology for 600 Area Nonradioactive Dangerous Waste Landfill

The water table ranges from about 126 meters (413 feet) in elevation to about 112 meters (367 feet) in elevation from west to east. Figure U–85 illustrates the water table and inferred directions of groundwater flow in the region southeast of the Central Plateau as indicated by the 2009 groundwater monitoring report (DOE 2010a). In the western portion of this area, water movement is from southwest to northeast. Then, as water enters the high-conductivity channel, water flow is diverted toward the southeast. On the eastern half of the site, water flow is primarily from west to east (DOE 2010a).



Note: To convert the water table elevations from meters to feet, multiply by 3.281.
Key: Km=kilometers; Mi=miles; NAVD88=North American Vertical Datum of 1988.
Source: Modified from DOE 2010a.

Figure U–85. Southeast of the Central Plateau Water Table and Inferred Groundwater Flow Directions, March 2009

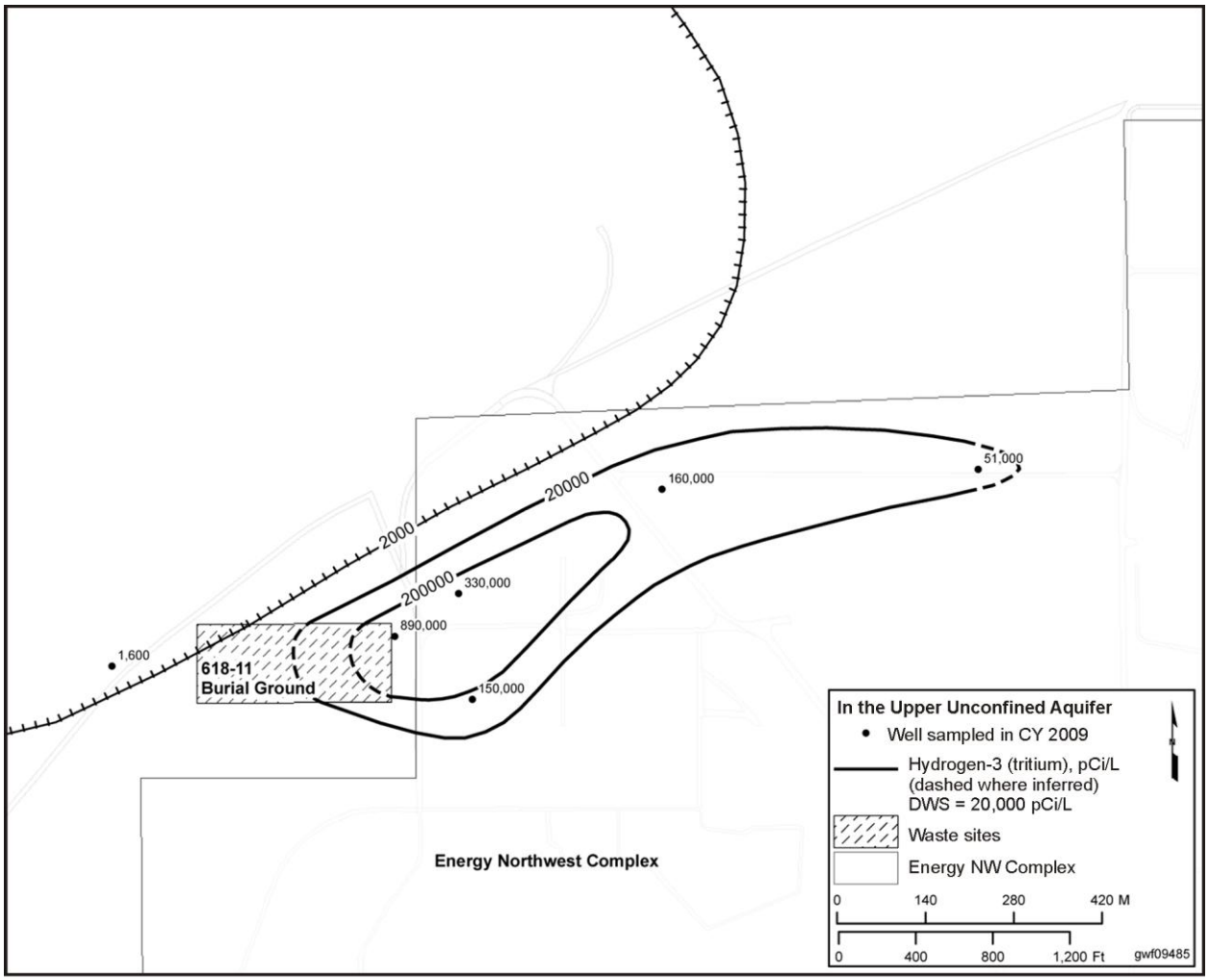
U.1.2.2.6.2 Southeast of the Central Plateau Historical Anthropogenic Discharges

The principal sources of anthropogenic discharges during Hanford's operational period in the region southeast of the Central Plateau included the 300 North Cribs, 321 Cribs, 300 Wye Burial Ground (618-11), and the 600 Area NRDWL (DOE 2010a). These sources were moderate- and low-discharge sources. For analysis purposes in this *TC & WM EIS*, sources with aqueous flux (volume per area) of less than 1 meter (3 feet) per year were categorized as moderate-discharge sources. Sources with aqueous flux of greater than 1 meter (3 feet) per year were categorized as heavy-discharge sources. Solid sources were categorized as low-discharge sources.

U.1.2.2.6.3 Southeast of the Central Plateau Comparison of Modeled Versus Measured Spatial Contaminant Distributions

The groundwater flow patterns greatly influence the observed contaminant distributions in the region southeast of the Central Plateau. Groundwater contamination is primarily impacted by sources located in the 200-East Area and, in general, is not impacted by waste sites located southeast of the Central Plateau. The 2009 groundwater monitoring report does, however, indicate a tritium plume in the 300 Area that greatly exceeds the drinking water standard. The tritium plume is attributed to the 300 Wye Burial Ground (618-11); however, this plume is not reflected in the prediction for the 300 Area impacts analysis of past-practice sources because an inventory for tritium was not available. Appendix S provides a detailed discussion of the waste inventories used for the cumulative impacts analysis. Figure U–86 shows the spatial distribution of tritium, as reported in the 2009 groundwater monitoring report (DOE 2010a).

Other sources located in this area (300 North Cribs, 321 Cribs, and 600 Area NRDWL) have minimal impact on the groundwater contamination in this region.



Key: CY=calendar year; DWS=drinking water standard; Ft=feet; M=meters; pCi/L=picocuries per liter.
Source: DOE 2010a.

Figure U–86. Field-Reported Spatial Distribution of Groundwater Hydrogen-3 (Tritium) Concentration, Burial Ground 618-11, Calendar Year 2009

U.1.2.2.6.4 Southeast of the Central Plateau Consideration of Ongoing Hanford Site Activities

Existing contaminant plumes southeast of the Central Plateau are largely associated with discharges or waste within the Central Plateau. Past discharges of more than 1,703 billion liters (450 billion gallons) of liquids to the soil have resulted in about 155 square kilometers (60 square miles) of contaminated groundwater. Within the Central Plateau itself, programs will be implemented to prevent migration of the plume beyond the Central Plateau, prevent exposure to contaminated groundwater, and evaluate further risk-reduction opportunities as new technologies become available. Southeast of the Central Plateau, programs will be implemented to evaluate the nature and extent of contamination and processes impacting natural attenuation.

U.1.3 Model Results for Future Site Conditions and Sensitivity Analyses

U.1.3.1 Release and Mass Balance

This section presents the results of the impacts analysis of non–*TC & WM EIS* sources in terms of the total amount of COPCs released to the vadose zone, groundwater, and Columbia River (see Appendix S for a description of non–*TC & WM EIS* sources). Releases of radionuclides are totaled in curies; chemicals, in kilograms. Both are totaled over the 10,000-year period of analysis. Table U–10 lists the releases to the vadose zone, groundwater, and Columbia River of the COPCs that contribute the bulk of the risk.

Table U–10. Release of the COPC Drivers to the Vadose Zone, Groundwater, and Columbia River from Non–*TC & WM EIS* Sources

Release to:	Radionuclide (curies)				Chemical (kilograms)		
	H-3	I-129	Tc-99	U-238	Cr	NO_3	Utot
Vadose zone	2.38×10^{6}	1.15×10^{1}	1.17×10^{3}	3.60×10^{3}	3.52×10^{5}	7.62×10^{7}	7.08×10^{6}
Groundwater	2.03×10^{6}	1.14×10^{1}	1.15×10^{3}	2.16×10^{2}	3.57×10^{5}	7.66×10^{7}	1.31×10^{5}
Columbia River	7.21×10^{4}	1.14×10^{1}	1.15×10^{3}	2.12×10^{2}	3.77×10^{5}	7.90×10^{7}	1.15×10^{5}

Note: Total amount released over the 10,000-year period of analysis.
Key: COPC=constituent of potential concern; Cr=chromium; H-3=hydrogen-3 (tritium); I=iodine; NO_3=nitrate; Tc=technetium; *TC & WM EIS=Tank Closure and Waste Management Environmental Impact Statement for the Hanford Site, Richland, Washington*; U=uranium; Utot=total uranium.

U.1.3.2 Concentration Versus Time

The reader is reminded that the maximum concentrations listed in Table U–11 and the concentrations versus time presented in Figures U–87 through U–95 are aggregated results from over 300 individual source areas. Further, the concentration-versus-time plots show the maximum concentrations regardless of where they occur along the Core Zone Boundary and the Columbia River nearshore. The reader should not attempt to interpret these results in terms of the classic conceptualization of a groundwater contamination plume moving beneath an observation well. The characteristics of any individual contributing source, including the inventory, release rate, transport rate through the vadose zone, and transport through the unconfined aquifer, typically do not lead to a readily identifiable signature in the concentration tables or the concentration-versus-time results.

This section presents the results of the impacts analysis for non–*TC & WM EIS* sources in terms of groundwater COPC concentrations versus time at the Core Zone Boundary and Columbia River. Table U–11 lists the maximum COPC concentrations at the Core Zone Boundary and the Columbia River nearshore in the peak year of the 10,000-year period of analysis. Figures U–87 through U–95 include concentration-versus-time plots for tritium, iodine-129, strontium-90, technetium 99, uranium-238, carbon tetrachloride, chromium, nitrate, and total uranium, respectively. In the *Draft TC & WM EIS*, a line denoting the 95th percentile upper confidence limit of the concentrations was included on several of these figures to address the discrete nature of the concentrations carried across a barrier or the river. This confidence interval was calculated to aid in interpreting data with a significant amount of random fluctuation (noise). However, in this *Final TC & WM EIS*, the particle-tracking simulations were run with 1 million particles instead of 100,000 particles. The results of the particle-tracking simulations with 1 million particles greatly reduced the amount of random fluctuation (noise) in the concentration-versus-time figures, and the confidence intervals were not needed to aid in interpreting the data. A more detailed discussion of the particle-tracking simulations is presented in Appendix O. The benchmark concentration of each radionuclide and chemical is included on each of the figures as a reference point. Note that the concentrations are plotted on a logarithmic scale to facilitate visual comparison of concentrations that vary over five orders of magnitude.

Table U–11. Calculated Maximum COPC Concentrations in the Peak Year at the Core Zone Boundary and Columbia River Nearshore from Non–*TC & WM EIS* Sources

Contaminant	Core Zone Boundary (peak year)	Columbia River Nearshore (peak year)	Benchmark Concentration[a]
Radionuclide (picocuries per liter)			
Hydrogen-3 (tritium)	112,000,000 (1997)	4,140,000 (1986)	20,000
Carbon-14	1,090 (1998)	5 (1992)	2,000
Strontium-90	1,730 (1998)	27,600 (1991)	8
Technetium-99	657 (1980)	212 (1991)	900
Iodine-129	42.2 (1962)	19.8 (2017)	1
Cesium-137	0 N/A	1,430 (1985)	200
Uranium isotopes (includes uranium-233, -234, -235, -238)	839 (1959)	6,190 (1979)	15
Neptunium-237	7 (2061)	2 (3662)	15
Plutonium isotopes[b] (includes plutonium-239, -240)	26 (7725)	2 (1991)	15
Chemical (micrograms per liter)			
1-Butanol	518 (1998)	2 (3891)	3,600
Boron and compounds	0.02 (3270)	1 (2364)	7,000
Carbon tetrachloride	577 (2035)	208 (2067)	5
Chromium[c]	13,300 (1959)	7,210 (1979)	100
Dichloromethane	0.2 (3321)	0.1 (3923)	5
Fluoride	160,000 (2008)	30,700 (2032)	4,000
Hydrazine/hydrazine sulfate	0.009 (3308)	0.043 (3281)	0.022
Lead	0 N/A	32 (2397)	15
Manganese	93 (3705)	0.4 (2223)	1,600
Mercury	1.7 (2016)	0.002 (10,973)	2
Nitrate	1,040,000 (1947)	846,000 (1976)	45,000
Total uranium	1,220 (1959)	1,910 (1979)	30
Trichloroethylene	0.02 (3220)	0.07 (3297)	5

[a] The sources of the benchmark concentrations are provided in Appendix O, Section O.3.

[b] The plutonium isotopes impact at the Core Zone Boundary is due primarily to the 216-B-5 Reverse Well where plutonium was injected directly into groundwater. Negligible contributions were predicted from all other waste sites (including burial grounds) within the Central Plateau.

[c] It was assumed for analysis purposes that all chromium is hexavalent.

Note: Peak concentrations of some non–*TC & WM EIS* source constituents occurred in the past. The relationships of past to future non–*TC & WM EIS* source constituent concentrations are presented in the concentration-versus-time plots in Figures U–87 through U–95.

Key: COPC=constituent of potential concern; N/A=not applicable; *TC & WM EIS=Tank Closure and Waste Management Environmental Impact Statement for the Hanford Site, Richland, Washington*.

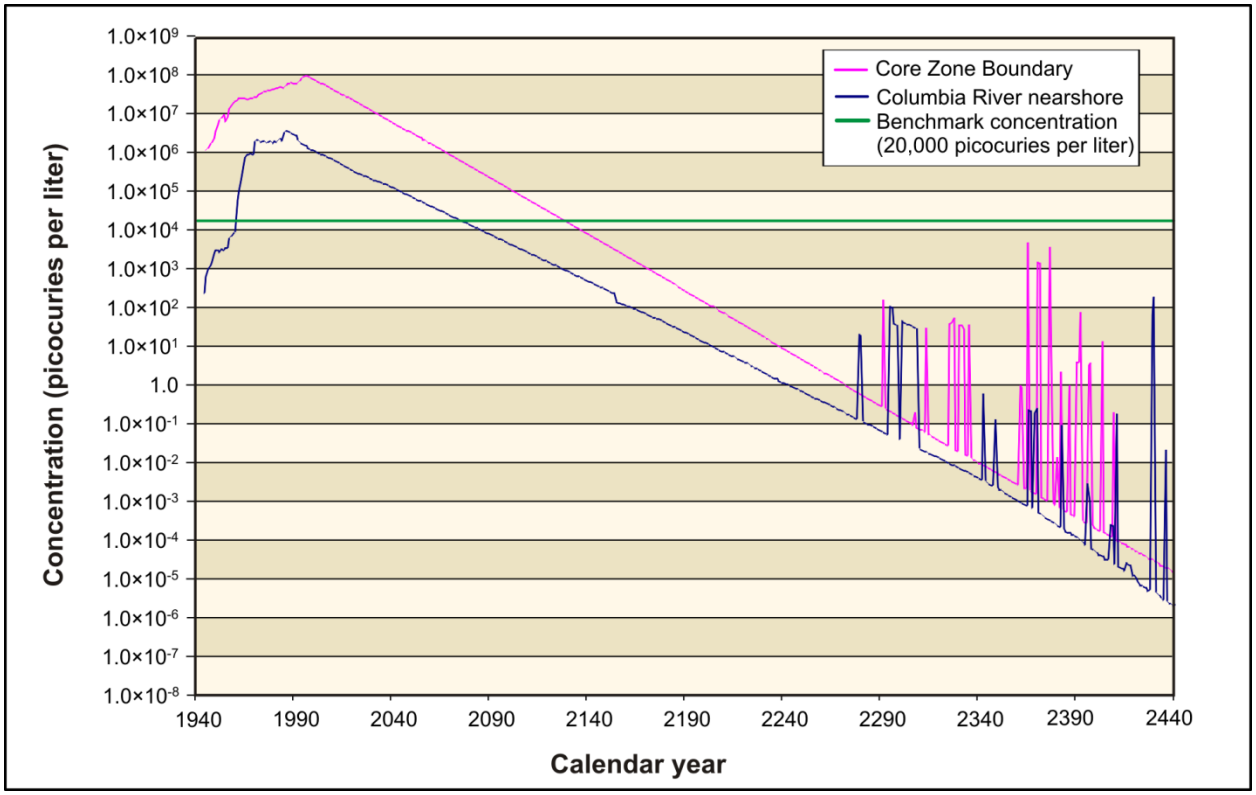


Figure U–87. Hydrogen-3 (Tritium) Concentration Versus Time (Non–*TC & WM EIS* Sources)

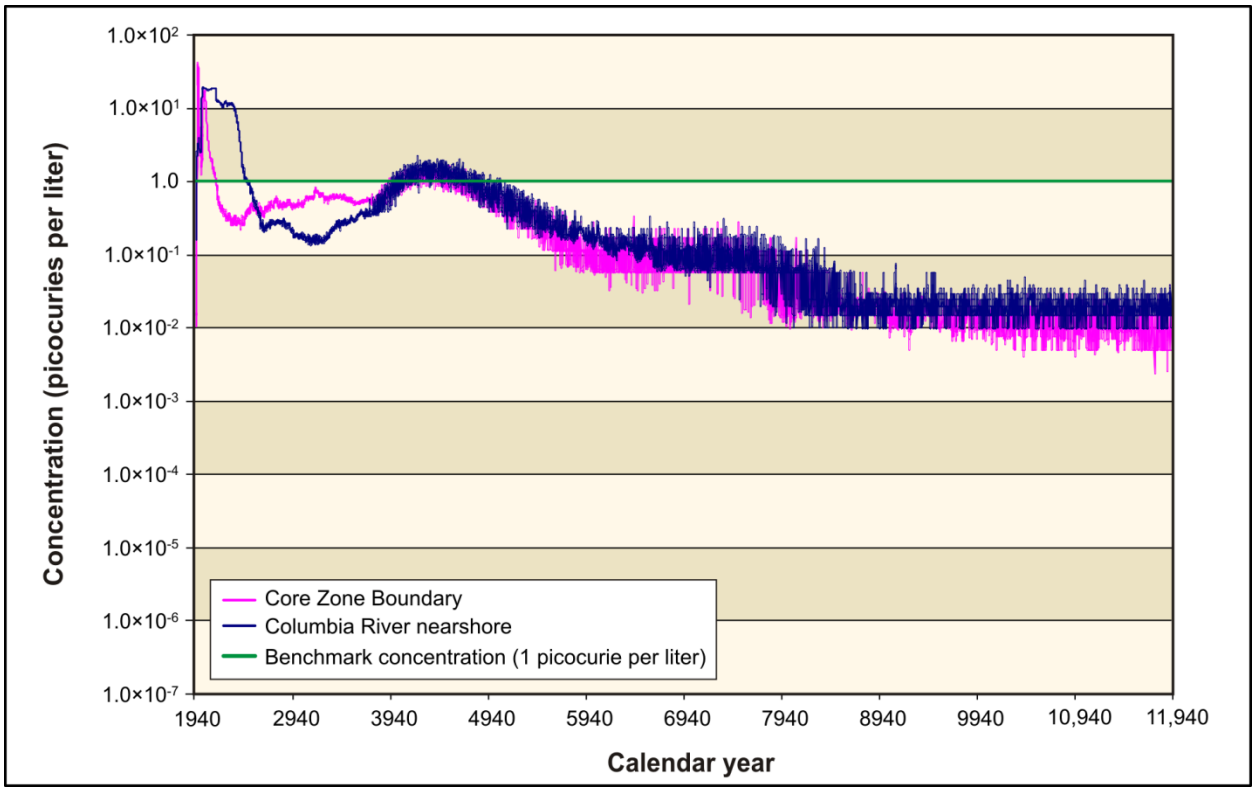


Figure U–88. Iodine-129 Concentration Versus Time (Non–*TC & WM EIS* Sources)

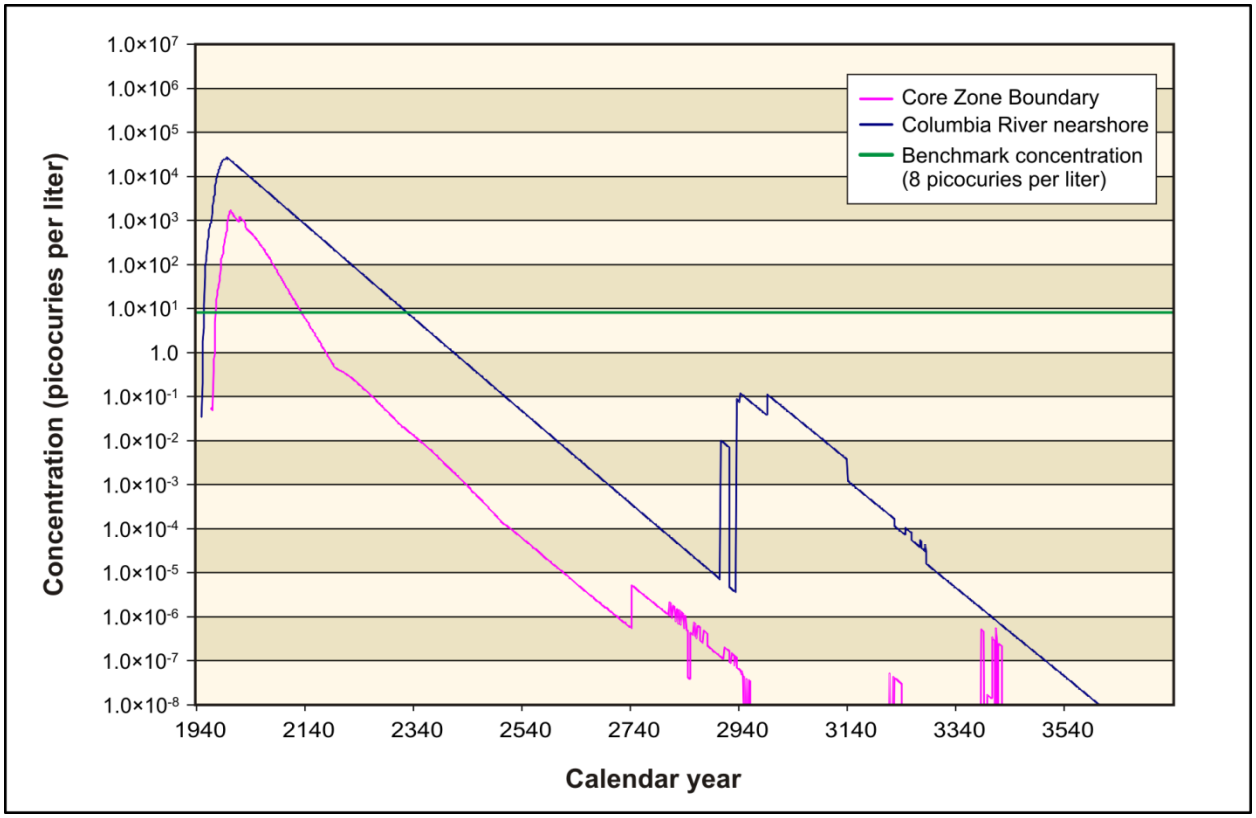


Figure U–89. Strontium-90 Concentration Versus Time (Non–*TC & WM EIS* Sources)

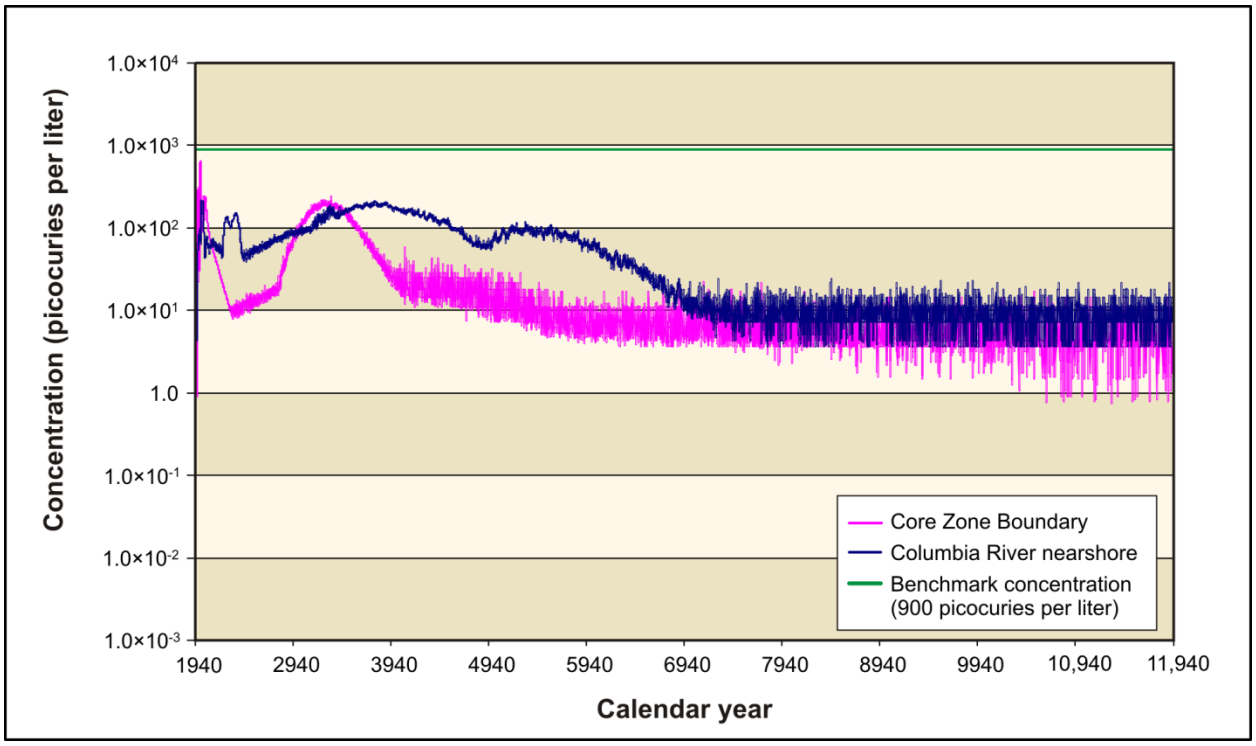


Figure U–90. Technetium-99 Concentration Versus Time (Non–*TC & WM EIS* Sources)

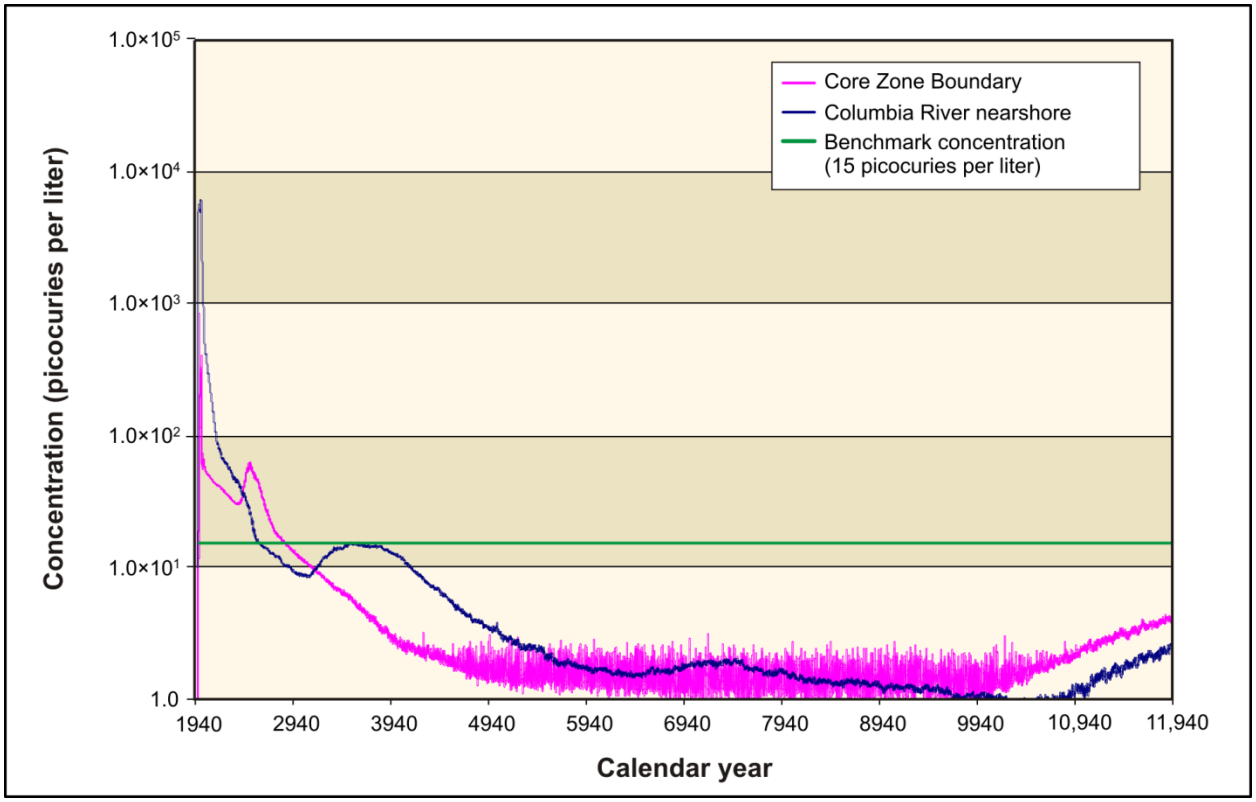


Figure U–91. Uranium-238 Concentration Versus Time (Non–*TC & WM EIS* Sources)

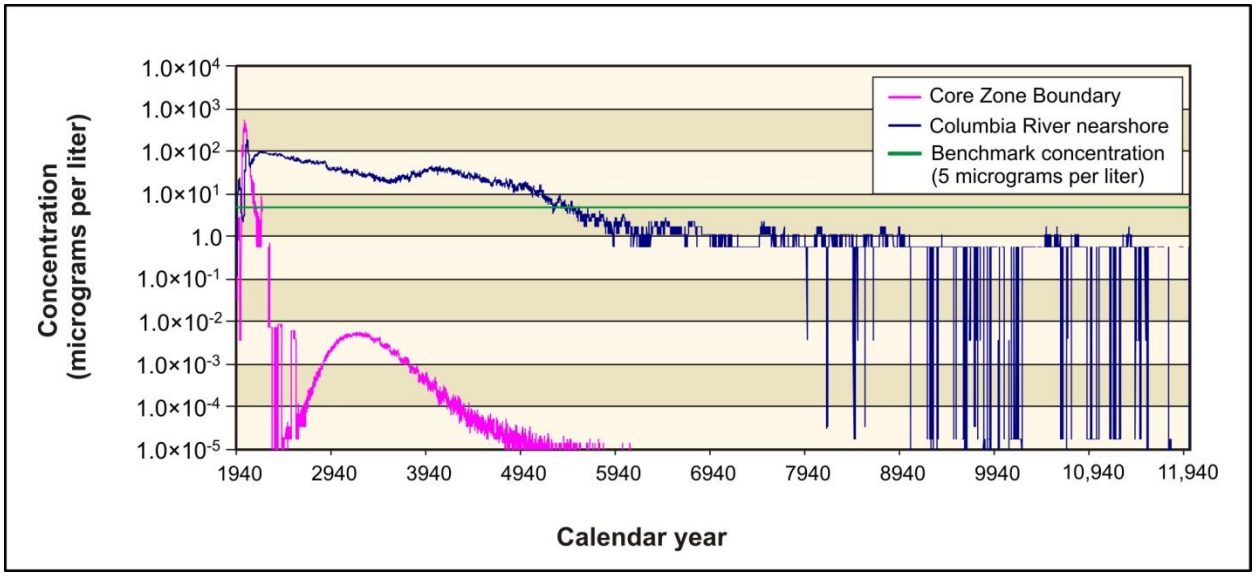


Figure U–92. Carbon Tetrachloride Concentration Versus Time (Non–*TC & WM EIS* Sources)

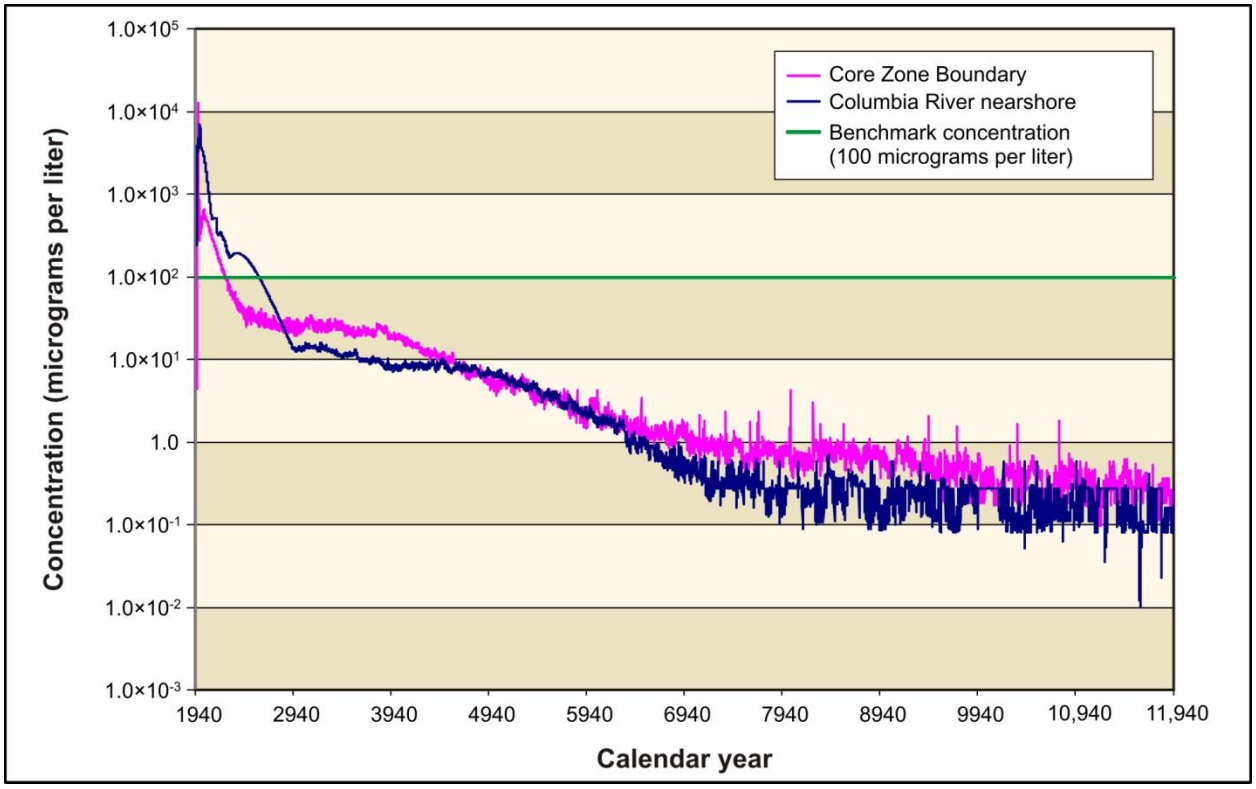


Figure U–93. Chromium Concentration Versus Time (Non–*TC & WM EIS* Sources)

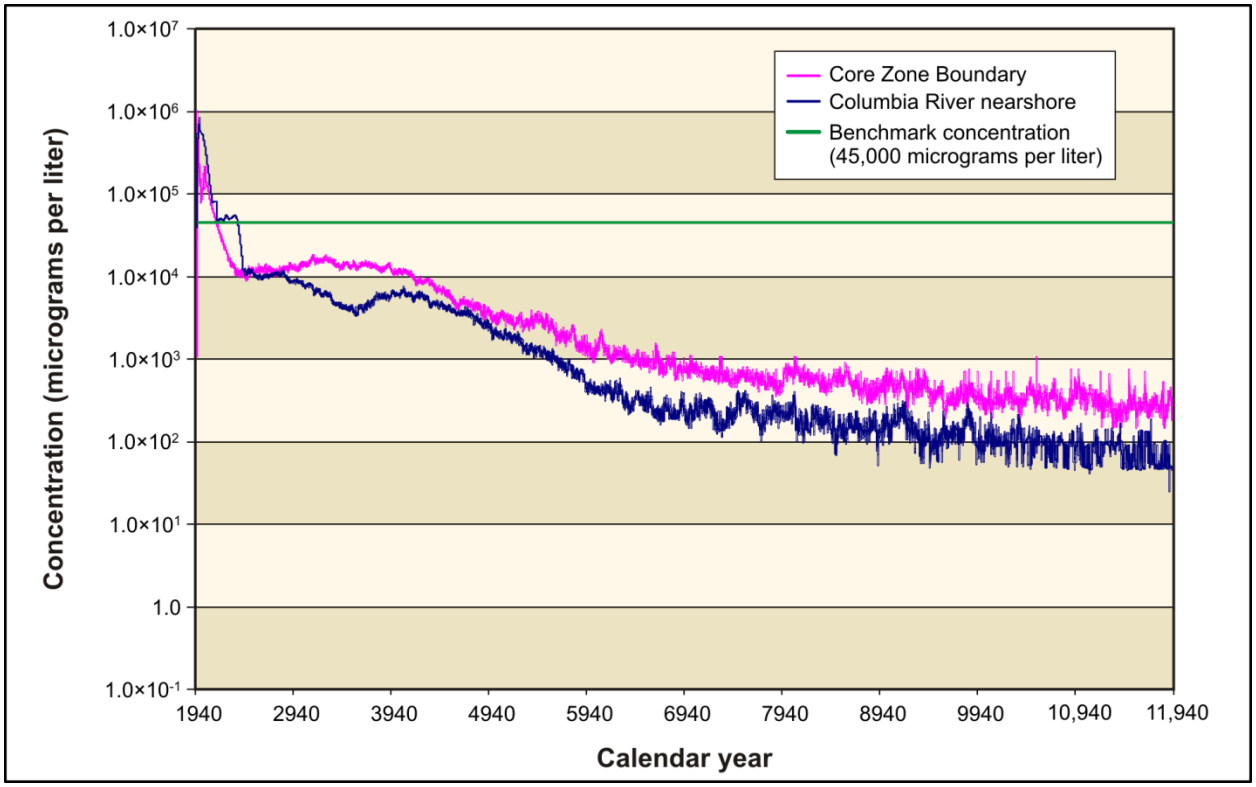


Figure U–94. Nitrate Concentration Versus Time (Non–*TC & WM EIS* Sources)

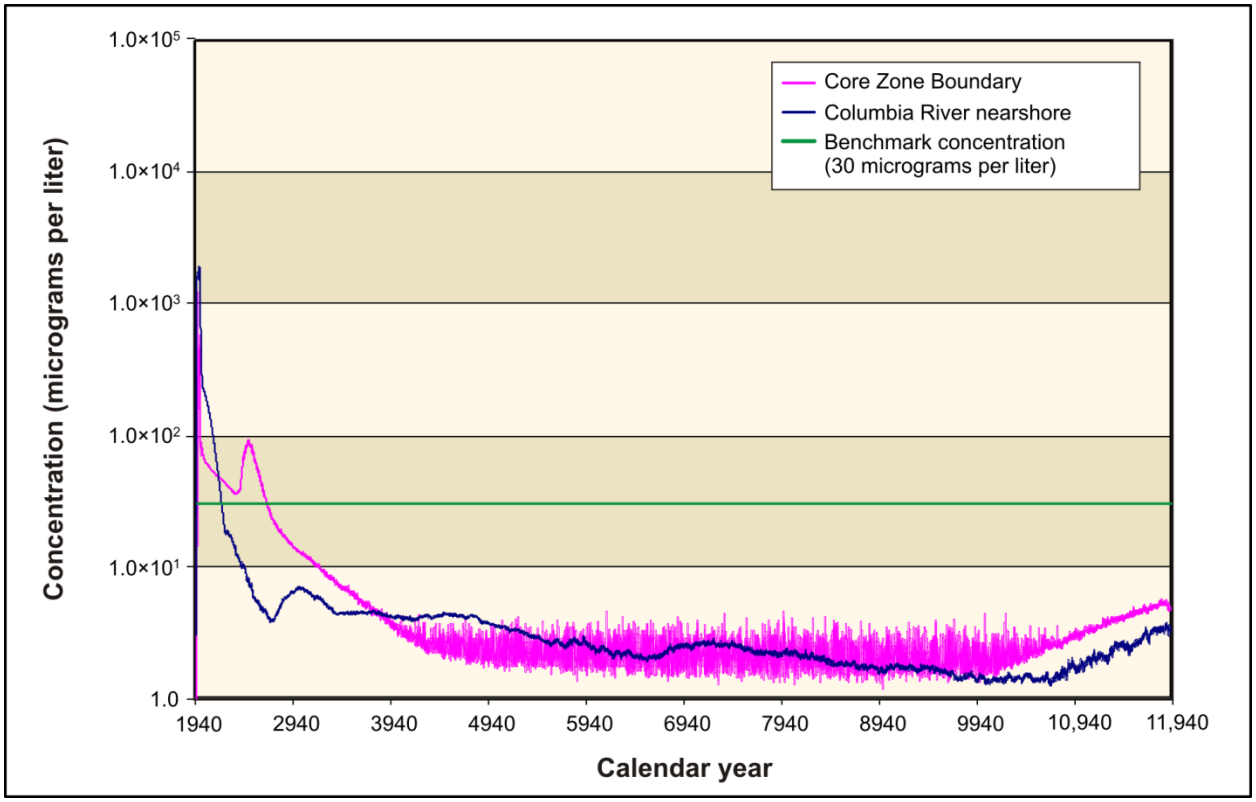


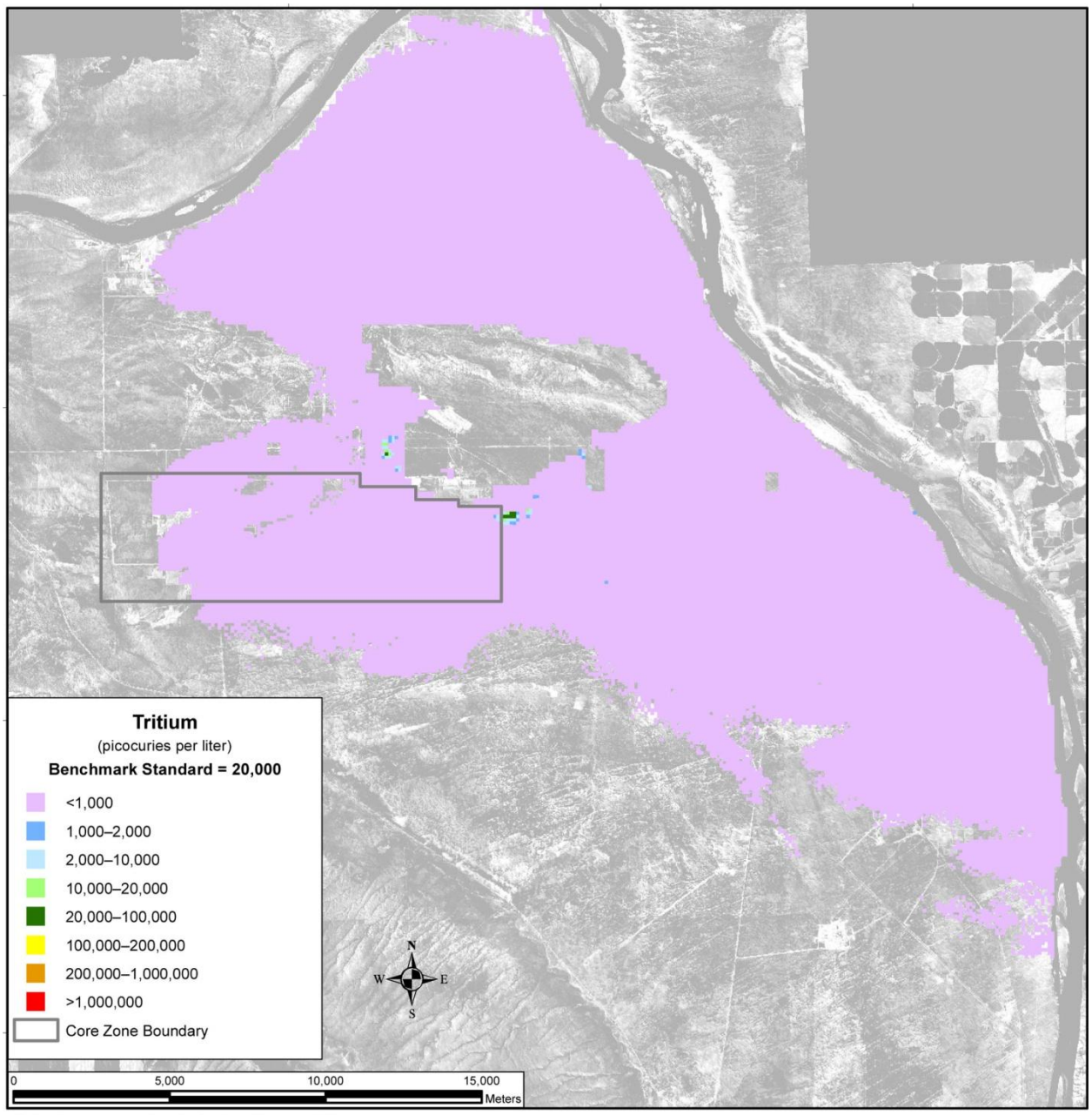
Figure U–95. Total Uranium Concentration Versus Time (Non–*TC & WM EIS* Sources)

U.1.3.3 Predicted Spatial Distribution of Concentration

This section presents the results predicted by the impacts analysis of non–*TC & WM EIS* sources in terms of the spatial distribution of COPC concentrations in groundwater at selected times in the future. Concentrations of each radionuclide and chemical are indicated by a color scale that is relative to the benchmark concentration. Concentrations greater than the benchmark concentration are indicated by the fully saturated colors green, yellow, orange, and red in order of increasing concentration. Concentrations less than the benchmark concentration are indicated by the faded colors green, blue, indigo, and violet in order of decreasing concentration. Note that the concentration ranges are on a logarithmic scale to facilitate visual comparison of concentrations that vary over three orders of magnitude.

In general, the simulations of groundwater transport for current conditions in this *TC & WM EIS* replicate the values measured in the field to a close order of magnitude, particularly for discharges to cribs and trenches (ditches), where the historic measurements are most complete and show the strongest signature of past-practice operations. The major contaminants that make up plumes with concentrations above the drinking water standard in the upper portion of the unconfined aquifer at Hanford include tritium, strontium-90, technetium-99, iodine-129, carbon tetrachloride, chromium, uranium, and nitrate. As shown in Appendices N and O, the agreement is good for both *TC & WM EIS* alternative sources and non–*TC & WM EIS* sources. As previously noted, there are two contaminants for which the simulated plumes for current conditions are in greater disagreement with observation: carbon tetrachloride (plume in the 200-West Area) and uranium (uranium-238 plume and total uranium plume in the 200-East Area).

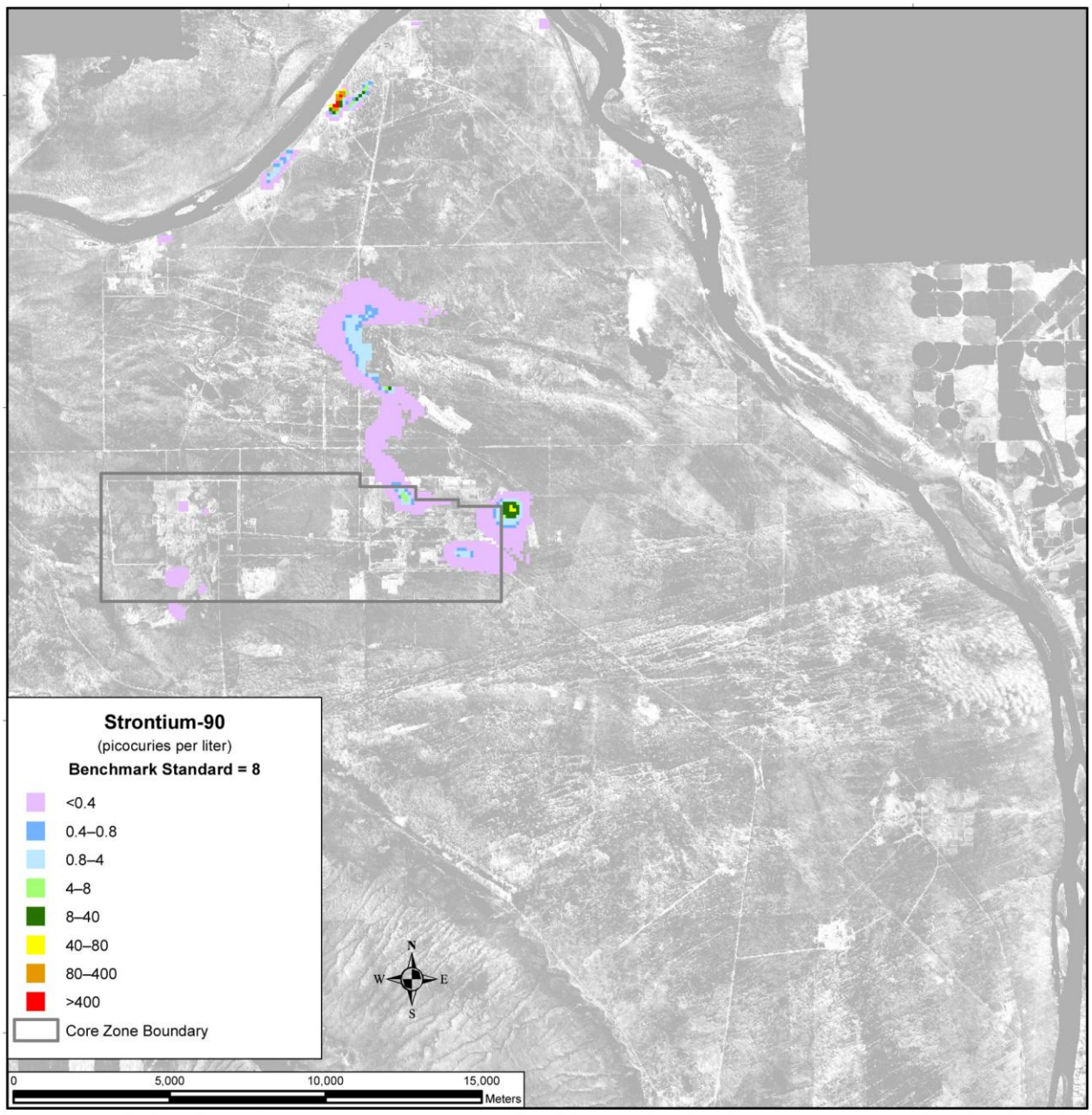
As indicated in Section U.1.2.1.3, tritium is one of the major COPCs, and is currently present in the 200-East Area, 200-West Area, and 300 Area. Tritium is a short-lived, mobile radionuclide, and though there is widespread tritium contamination present at Hanford, radioactive decay is expected to prevail; thus, tritium is not expected to be a contaminant of concern in the future. Figure U–96 presents the projected tritium concentrations in groundwater in CY 2135.



Note: To convert meters to feet, multiply by 3.281.

Figure U–96. Spatial Distribution of Groundwater Hydrogen-3 (Tritium) Concentration (Non–*TC & WM EIS* Sources), Calendar Year 2135

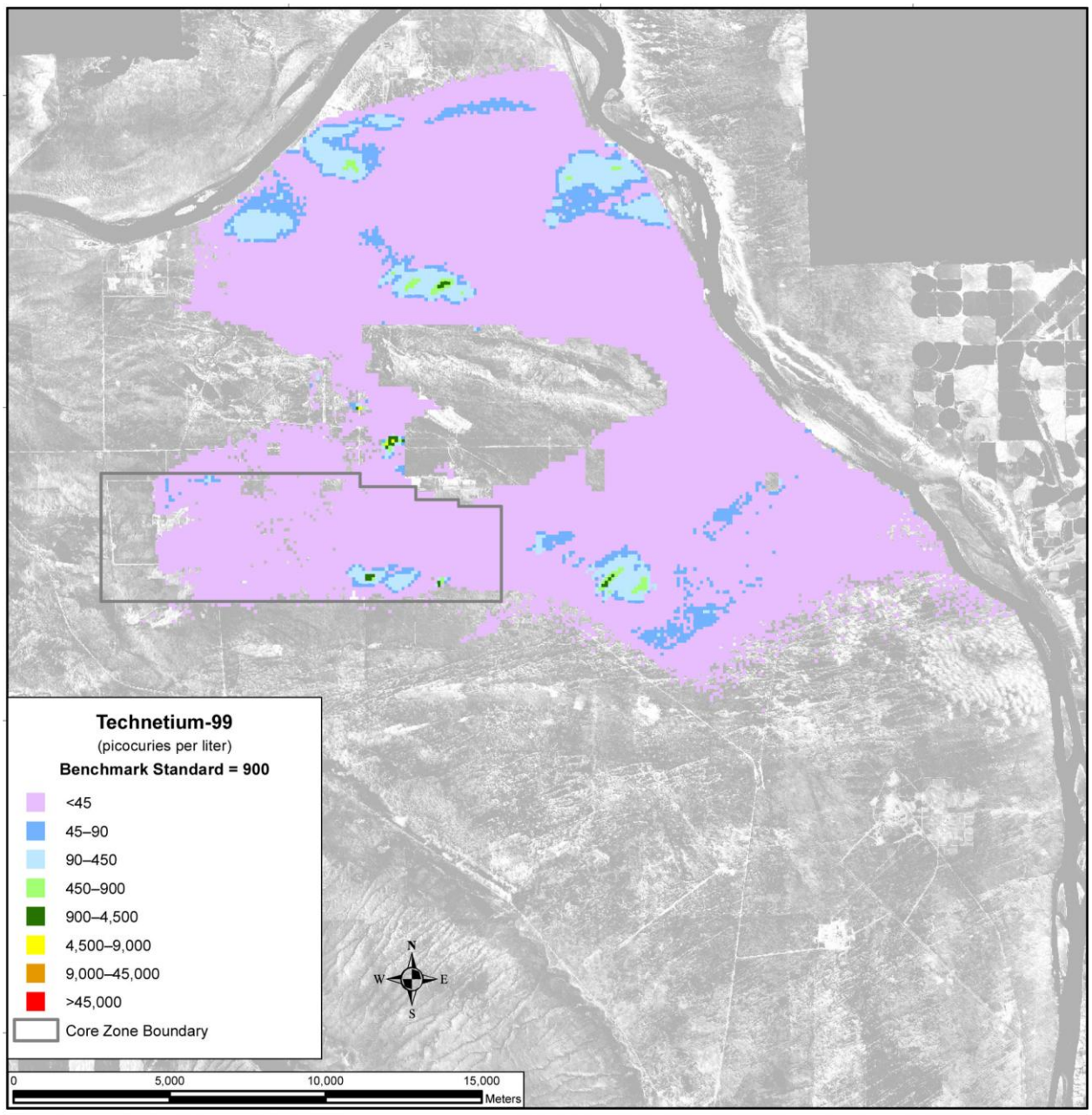
Strontium-90 is present in the 100-N Area and Gable Mountain. Strontium-90 has a relatively short half-life (29 years) and is moderately mobile. Though strontium-90 has a short half-life it also has a greater affinity for sediment than water, and its rate of transport is considerably slower than the actual groundwater flow rate. As a result, strontium-90 plume characteristics tend to change slowly over time and are expected to persist until radioactive decay reduces its concentration. Figure U–97 presents the projected strontium-90 concentrations in groundwater in CY 2135.



Note: To convert meters to feet, multiply by 3.281.

Figure U–97. Spatial Distribution of Groundwater Strontium-90 Concentration (Non–*TC & WM EIS* Sources), Calendar Year 2135

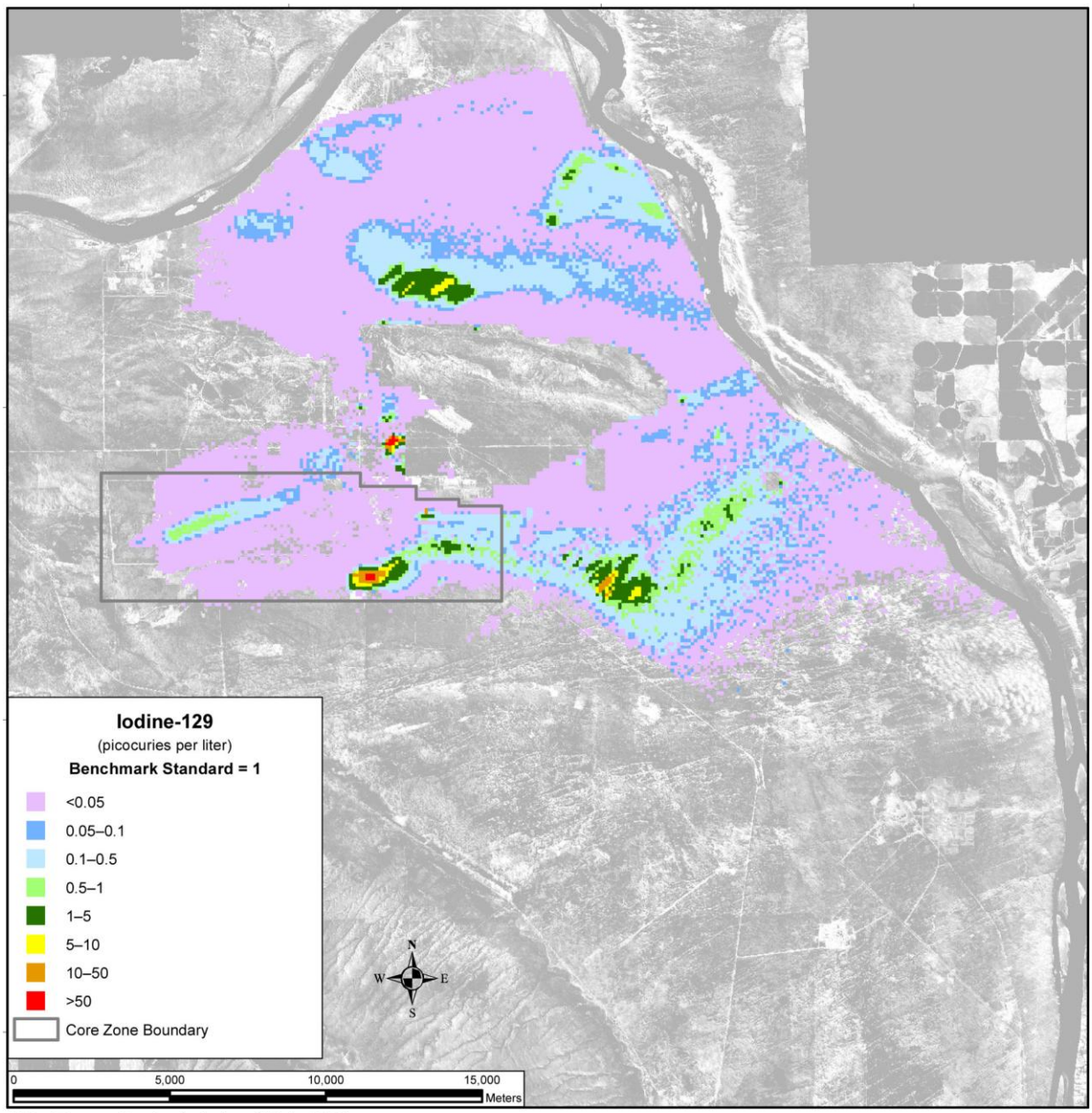
Technetium-99 is a long-lived, mobile radionuclide that is currently present in the 200-West Area and Gable Mountain. Technetium-99 is expected to persist due to its long half-life; however, some natural attenuation is expected to occur as a result of dispersion. Figure U–98 presents the projected technetium-99 concentrations in groundwater in CY 3890.



Note: To convert meters to feet, multiply by 3.281.

Figure U–98. Spatial Distribution of Groundwater Technetium-99 Concentration (Non–*TC & WM EIS* Sources), Calendar Year 3890

Iodine-129 is currently present in the 200-East and 200-West Areas. Iodine-129, like technetium-99, is a long-lived, mobile radionuclide. Iodine-129 is expected to persist due to its long half-life; however, some natural attenuation is expected to occur as a result of dispersion. Figure U–99 presents the projected iodine-129 concentrations in groundwater in CY 3890.

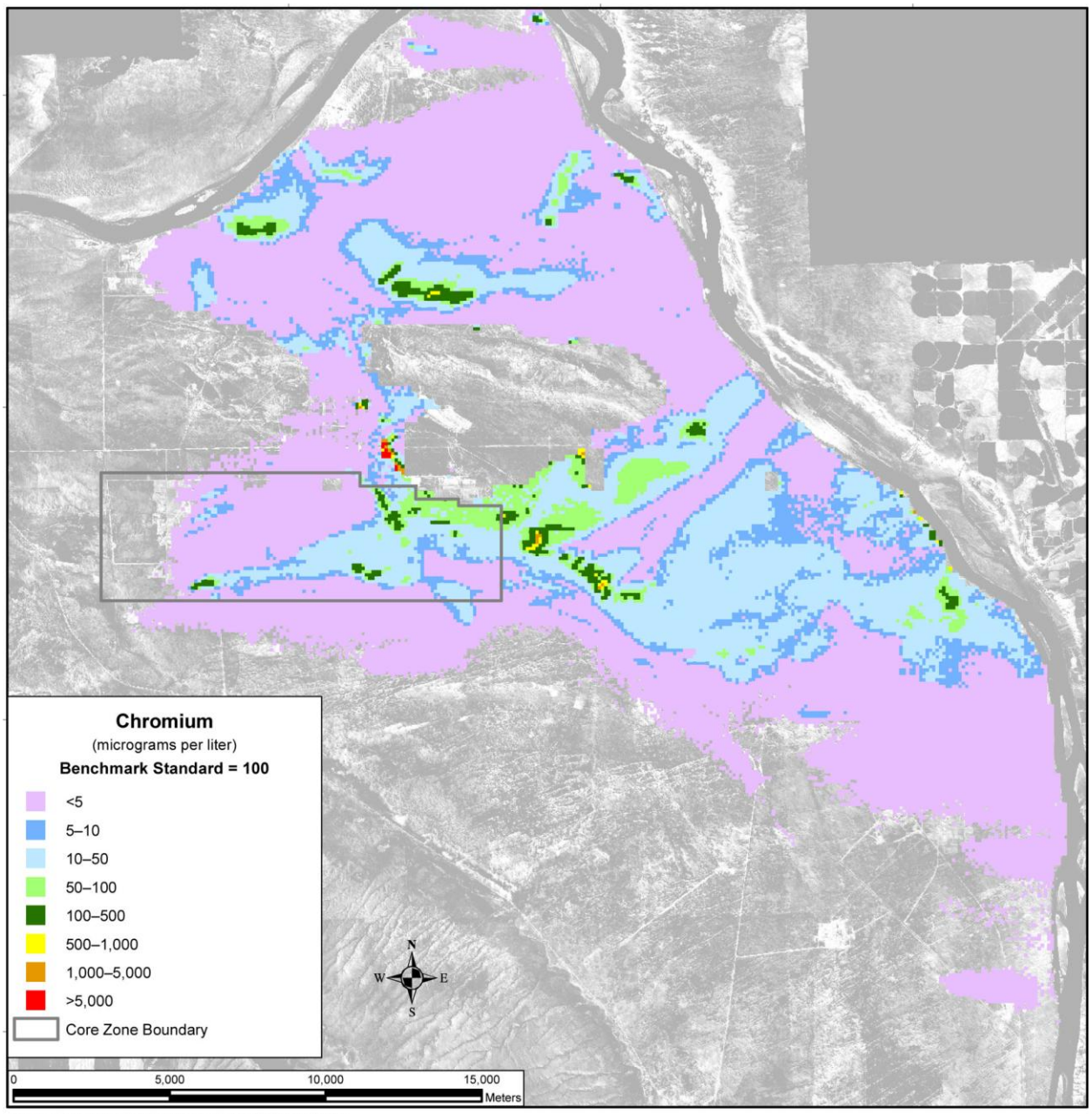


Note: To convert meters to feet, multiply by 3.281.

Figure U–99. Spatial Distribution of Groundwater Iodine-129 Concentration (Non–*TC & WM EIS* Sources), Calendar Year 3890

Future projections of carbon tetrachloride are not included in this section due to the factors discussed in Section U.1.2.1.4, which lead to the qualitatively greater uncertainty in the future carbon tetrachloride spatial concentration distribution. Instead, a sensitivity analysis discussing variations resulting from capture-and-removal scenarios that are representative of groundwater remediation goals is presented in Section U.1.3.4.2.

Figure U–100 shows the projected chromium concentrations in groundwater in CY 2135. Hexavalent chromium is a mobile contaminant that is not strongly retained in the vadose zone, and concentrations are expected to attenuate over time as a result of mobilization and dispersion. In CY 2135, the majority of the chromium contamination from the 100 and 300 Area sources will have migrated to the Columbia River. The remaining source in CY 2135 is Waste Management Area S-SX.

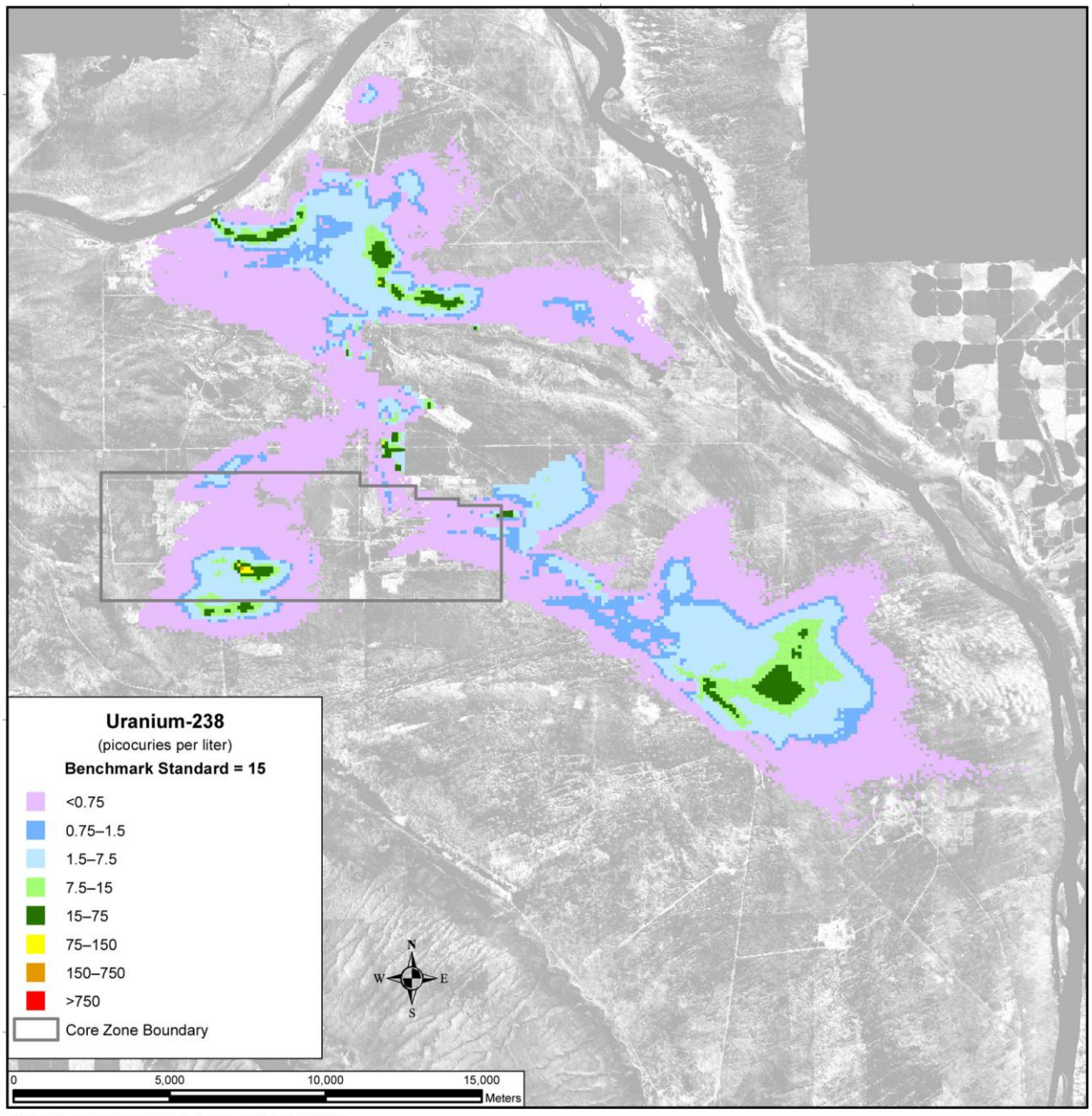


Note: To convert meters to feet, multiply by 3.281.

Figure U–100. Spatial Distribution of Groundwater Chromium Concentration (Non–*TC & WM EIS* Sources), Calendar Year 2135

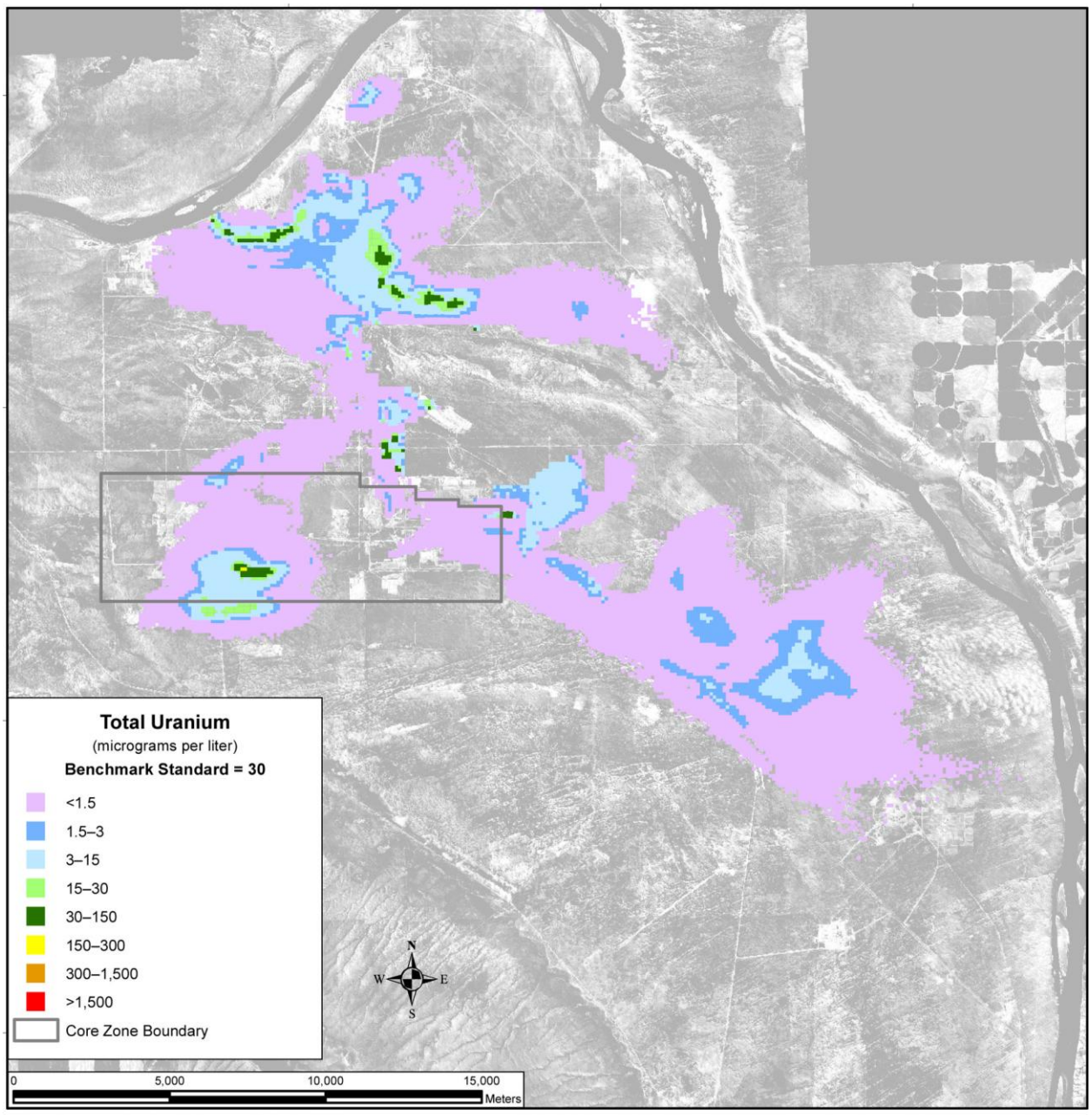
Uranium is primarily present in the 200-East Area, the 200-West Area, and the 300 Area. Uranium is moderately mobile and has a long half-life (4.5 billion years for uranium-238) (DOE 2010a). Uranium-238 and total uranium simulation results show higher impacts resulting from heavy-discharge facilities in the 200-East Area (e.g., B Pond) than actually observed. The disagreement of these plumes with field measurements suggests that two possible areas of uncertainty may dominate the simulation of these impacts. The first is the uncertainty in the inventory of uranium-238 and total uranium in the heavy-discharge ponds (see Appendix S), which is approximately 50 percent. The second, and probably more important source of uncertainty, is the interaction of uranium-238 and total uranium with subsurface materials beneath these facilities. The *TC & WM EIS* analysis is based on a distribution coefficient for uranium of about 0.6 milliliters per gram (DOE 2005). This value, although appropriate for far-field

conditions in the unconfined aquifer, is probably not representative of the conditions beneath the heavy-discharge sources (e.g., B Pond). Therefore, the prediction of the uranium-238 and total uranium contaminant plumes for large non–*TC & WM EIS* sources should be considered an overestimate of the actual impacts by about an order of magnitude. Figures U–101 and U–102 show the projected uranium-238 and total uranium concentrations in groundwater in CY 2135, respectively.



Note: To convert meters to feet, multiply by 3.281.

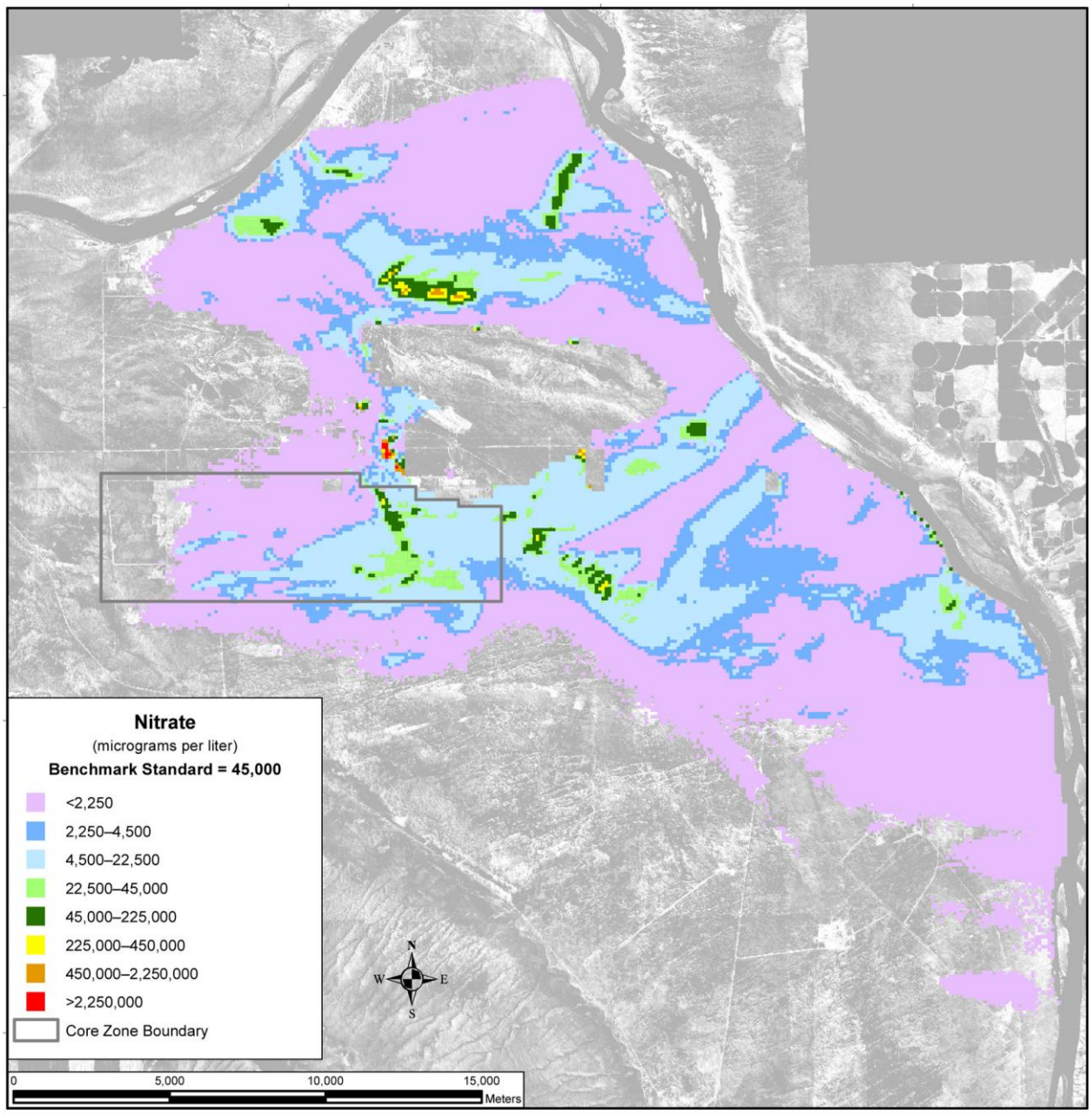
Figure U–101. Spatial Distribution of Groundwater Uranium-238 Concentration (Non–*TC & WM EIS* Sources), Calendar Year 2135



Note: To convert meters to feet, multiply by 3.281.

Figure U–102. Spatial Distribution of Groundwater Total Uranium Concentration (Non–*TC & WM EIS* Sources), Calendar Year 2135

Nitrate is primarily present in the 100-F Area, 200-East Area, and 200-West Area. Like chromium, nitrate is a mobile contaminant, and natural attenuation is expected to occur as a result of dispersion over time. Figure U–103 presents the projected nitrate concentrations in groundwater in CY 2135.



Note: To convert meters to feet, multiply by 3.281.

Figure U–103. Spatial Distribution of Groundwater Nitrate Concentration (Non–*TC & WM EIS* Sources), Calendar Year 2135

U.1.3.4 Sensitivity Analyses

Cleanup decisions regarding non-tank-farm contamination sites are outside the scope of this *TC & WM EIS*; however, it is recognized that cleanup and planning processes for the cleanup of some of these sites have occurred or are currently in progress, in accordance with RCRA, CERCLA, and/or the TPA and in consultation with applicable Federal and state agencies. Non-tank-farm sites were evaluated in the *TC & WM EIS* cumulative impacts analysis, and the end states were represented as either all waste left in place or removal of some or all of the waste, with treatment and disposal. Selection of the end states was guided by information provided by DOE that met specific quality assurance requirements. Appendix S, Section S.3.1, provides additional detail on the approach to selecting end states for the sites

evaluated in the cumulative impacts analysis. Not all of the sites with past cleanup activities had documentation that met the *TC & WM EIS* quality assurance criteria; therefore, the removal, treatment, and disposal end state was not included in the cumulative impacts modeling. As a result, the cumulative impacts analysis does not project future impacts resulting from some past and ongoing cleanups conducted under CERCLA and does not account for cleanups under existing CERCLA plans. Sensitivity analyses evaluating the magnitude and timeframe of potential impacts that may occur from cleanup and remediation activities are included in this appendix to demonstrate the potential influences of remedial actions at some of the prominent waste sites located on the Central Plateau and along the Columbia River corridor. These sensitivity analyses can be used as a tool to help Federal and state agencies better define future remediation options and prioritize cleanup efforts.

U.1.3.4.1 Flux Reduction

Releases from past anthropogenic activities at Hanford have left a signature in the underlying vadose zone and in some cases contaminants have already reached the aquifer. The results of the cumulative impacts and alternatives analyses suggest that additional measures could be implemented to support closure and better define remediation options for the cleanup process. Possible remediation techniques, including subsurface barriers, soil vapor extraction, soil desiccation, or other technologies developed in the future, could be implemented to reduce solute flux from the vadose zone and into groundwater at the time of closure.

The flux-reduction sensitivity analysis was designed to evaluate the potential response of the groundwater system to reductions in flux from the vadose zone that would occur if remediation activities were implemented. The objectives of this analysis were as follows:

- Evaluate the timeframe over which flux reduction might be effective.
- Analyze the response of the aquifer system to reductions in flux from the vadose zone.
- Evaluate the effectiveness of vadose zone flux remediation measures for sources with different amounts of discharge.

The flux-reduction sensitivity analysis evaluated cumulative impact sites in the Central Plateau and along the river corridor, as well as tank farm sources from Tank Closure Alternative 2B (landfill closure). The cumulative impacts sites included in the analysis were as follows:

- Ponds (B, S, T, U, and Gable Mountain)
- River corridor sources (1301-N, 100-K Mile Long Trench, and 300 Area Process Ponds)
- BC Cribs (and trenches [ditches])
- REDOX sources (216-U-8, 216-S-7, 216-S-8)
- PUREX sources (216-A-9, 216-A-10, 216-A-30, 216-B-12)

Tank Closure Alternative 2B (landfill closure) was the basis for the alternative sources that were analyzed in the flux-reduction sensitivity, which included the following:

- Tank farm past leaks (A, AX, B, BX, BY, C, S, SX, T, TX, TY, and U)
- Ancillary equipment (A, AN, AP, AW, AX, AY, AZ, B, BY, C, S, SY, T, TX, TY, and U)
- Retrieval leaks (A, AX, B, BX, BY, C, S, SX, T, TX, TY, and U)
- Tank residuals (A, AN, AP, AW, AX, AY, AZ, B, BX, BY, C, S, SX, SY, T, TX, TY, and U)
- Cribs and trenches (ditches) (B, BX, BY, T, TX, and TY)

Reductions in flux from the vadose zone of 50, 75, and 99 percent were calculated and applied to each of the individual sites that were analyzed. A range of heavy-, moderate-, and low-discharge sites were included in the analysis. The timeframe for which the vadose zone flux reduction would occur was

assumed to be CY 2035. After the flux reduction was applied to a site, the groundwater concentrations were calculated using the particle-tracking code. The results that were reported for the Core Zone and Columbia River tracking objects were compared with the base (EIS) cases. A more detailed description of particle tracking and the reporting objects can be found in Appendix O.

Figure U–104 is a schematic of a typical graph of solute at the water table showing flux versus time that highlights the major features that can be evaluated when interpreting a flux graph. As aqueous and contaminant discharges are released to the vadose zone, there is an increase in flux from the vadose zone into the aquifer. It is possible that not all of the features highlighted in the schematic will occur in every circumstance; however the features are significant to evaluate when they do occur. It is important to assess the shape and length of duration of the peak and the breakthrough shoulder in relationship to the start time of the flux reduction so that the effectiveness of a flux reduction can be evaluated.

Figure U–105 illustrates general timeframes in which a flux reduction could occur. A flux reduction occurring prior to the peak flux reaching the aquifer (labeled "A" on Figure U–105) would be most effective in a flux-reduction scenario because most of the mass would still be in the vadose zone and potentially available for recovery, sequestration, or immobilization. A flux reduction occurring during the peak, or just following the peak but before the flux leveled off (labeled "B" on Figure U–105) would be of marginal utility, depending on the length and duration of the peak, because less mass would be available for recovery, sequestration, or immobilization. A vadose zone flux reduction occurring after the breakthrough shoulder (labeled "C" on Figure U–105) would be the least practical because most of the contaminant flux would already have reached the aquifer. The general shape of the flux graphs is largely determined by the vadose zone geology, the geometry of the source, the background rate of recharge, the magnitude and time pattern of initial aqueous discharge, and the degree of interaction of the solute and vadose zone sediments. This analysis investigated the role of initial aqueous discharge and retardation of solute in the vadose zone on the potential effectiveness of flux reduction. Three ranges of values of aqueous discharge and two solutes differentiated by the values of the distribution coefficients for liquid-solid phase partitioning were considered. In this analysis, iodine-129 did not partition to the solid phase and was assigned a retardation factor of unity (1). Uranium-238 was assumed to partition onto the solid phase and was assigned a distribution coefficient of 0.6 milliliters per gram, producing retardation factors ranging from approximately 2 to 8 for Hanford vadose zone sediments.

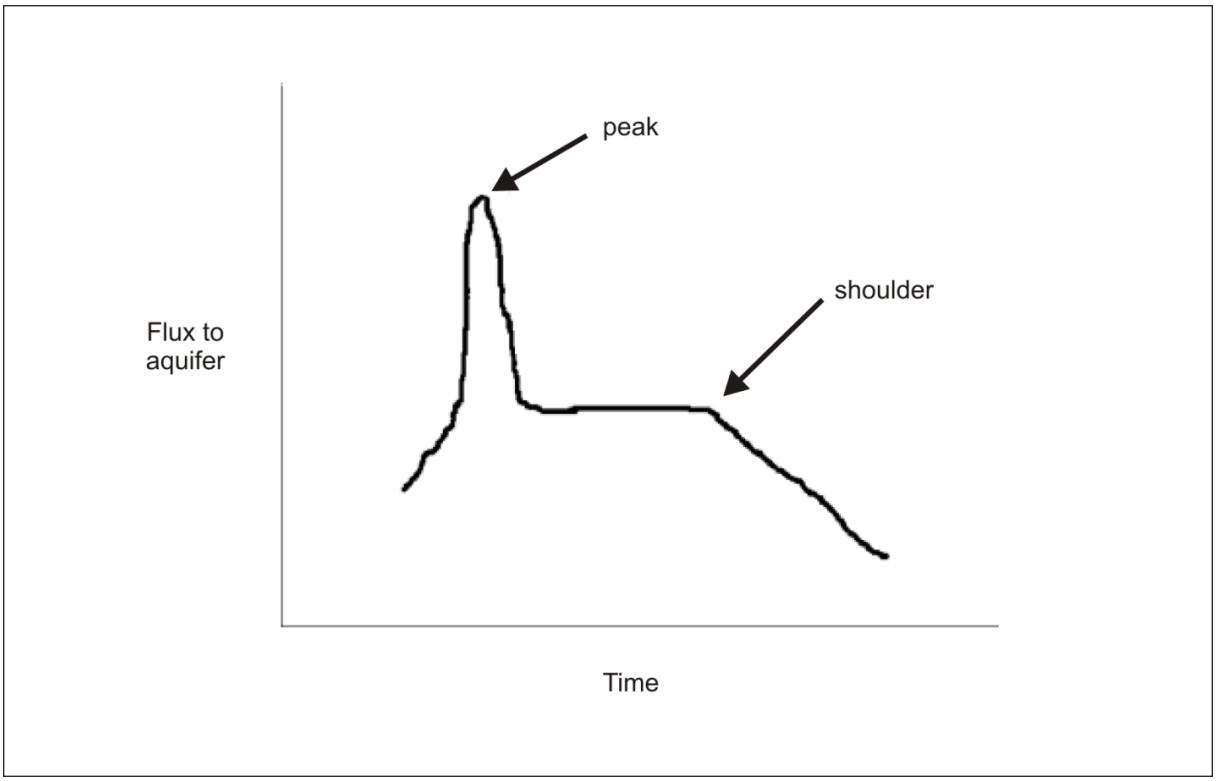


Figure U–104. Schematic of Flux to Aquifer Versus Time

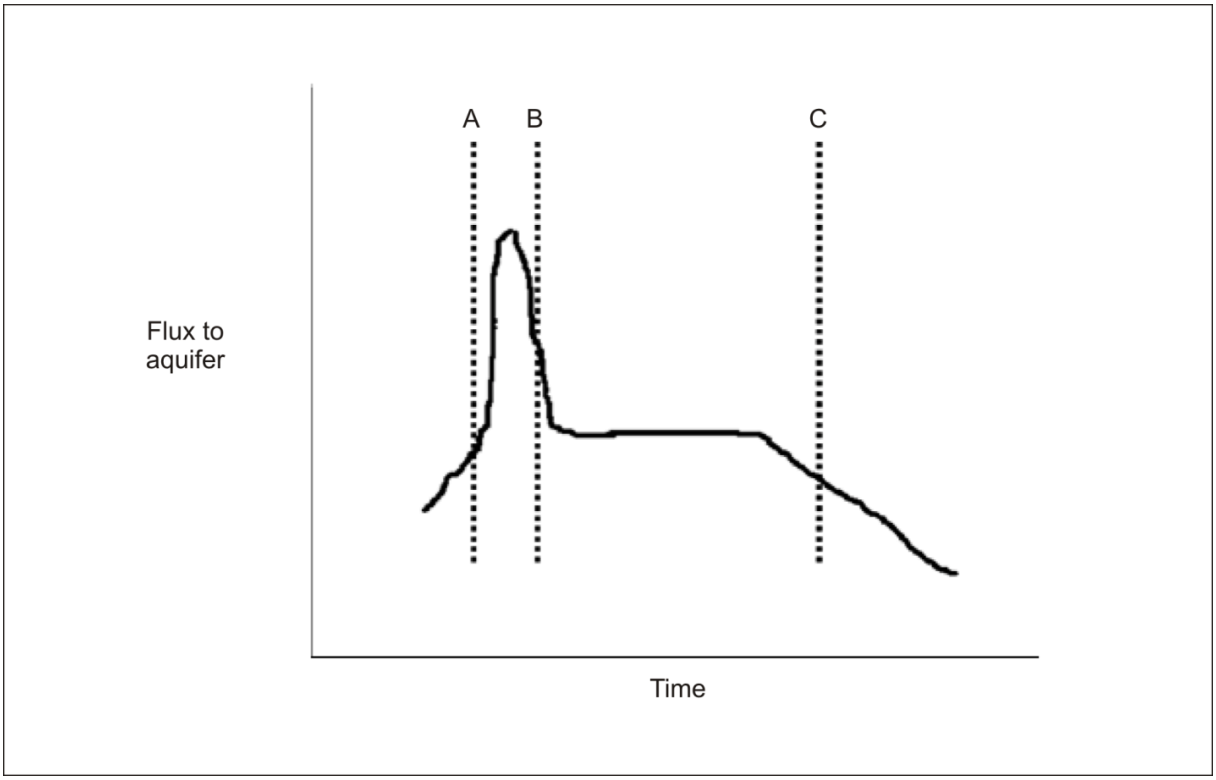


Figure U–105. Schematic of a Flux to Aquifer Versus Time Curve in Relationship to the Start of a Flux Reduction

U.1.3.4.1.1 Heavy-Discharge Conditions

Heavy-discharge sites are characterized as sites that had aqueous flux (volume per area) of greater than 1 meter (3 feet) per year. Two of the heavy-discharge sites that were evaluated in the flux-reduction analysis are the 216-A-9 Crib and the TY Cribs, which had peak, short-term discharge rates of 906 and 92 meters (2,970 and 302 feet) per year, respectively. The 216-A-9 Crib is located in the PUREX area in the eastern portion of the Central Plateau and operated between 1956 and 1958 and between 1966 and 1967. The TY Cribs are located in the T/TX/TY waste management areas in the western portion of the Central Plateau and operated between 1946 and 1952, 1955 and 1956, and 1960 and 1966. Figures U–106 through U–109 are the iodine-129 and uranium-238 flux graphs for the 216-A-9 Crib and TY Cribs. The flux graphs for both sites are typical examples of heavy-discharge sites and show a high, sharp peak during the operational period and a tapering shoulder that lasts approximately 1,000 years or more. The flux graphs for the two sites are similar but reflect differences dependent upon the aqueous discharge of the initial release and extent of inter-phase partitioning. For conservative tracers such as iodine-129, the flux curves show a high peak, reflecting rapid movement of solute to the water table with the initial aqueous discharge, followed by more-gradual drainage with background recharge. For iodine-129, the percentage of the total flux that reached the water table prior to CY 2035 was 98 and 80 percent for the 216-A-9 Crib and TY Cribs, respectively. For release of uranium-238 at the 216-A-9 Crib, the initial aqueous discharge was so large that 80 percent of the initial solute release reached the water table during the 10,000-year period of analysis, and 88 percent of that amount reached the water table within 5 years of the initial release. Only 20 percent of the initial uranium-238 release remained in the vadose zone at the end of the period of analysis. In these cases, flux reduction may be of marginal utility because it only impacts mass represented by the shoulder of the flux graph and would not reduce the uranium-238 concentration in groundwater, as shown in Figures U–110 through U–113, which depict groundwater concentrations at the Core Zone Boundary and Columbia River nearshore locations. At the TY Cribs, the initial aqueous discharge was not as large as at the 216-A-9 Crib, and only 17 percent of the initial release of uranium-238 reached the water table within the 10,000-year period of analysis. Of the initial uranium release, 83 percent remained in the vadose zone after 10,000 years. In this case, flux reduction could be useful, as indicated by the reduction in groundwater concentrations shown in Figure U–113.

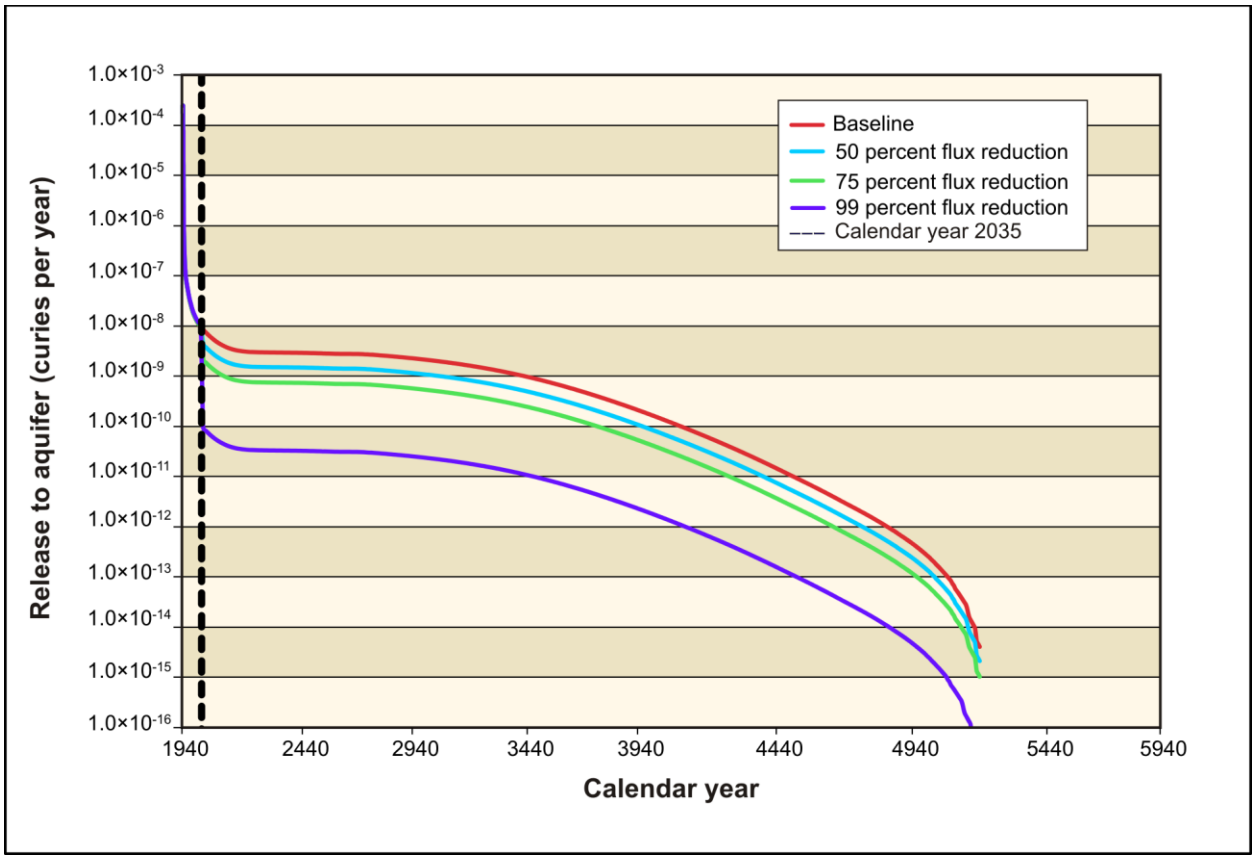


Figure U–106. Iodine-129 Flux to Aquifer Versus Time, 216-A-9 Crib

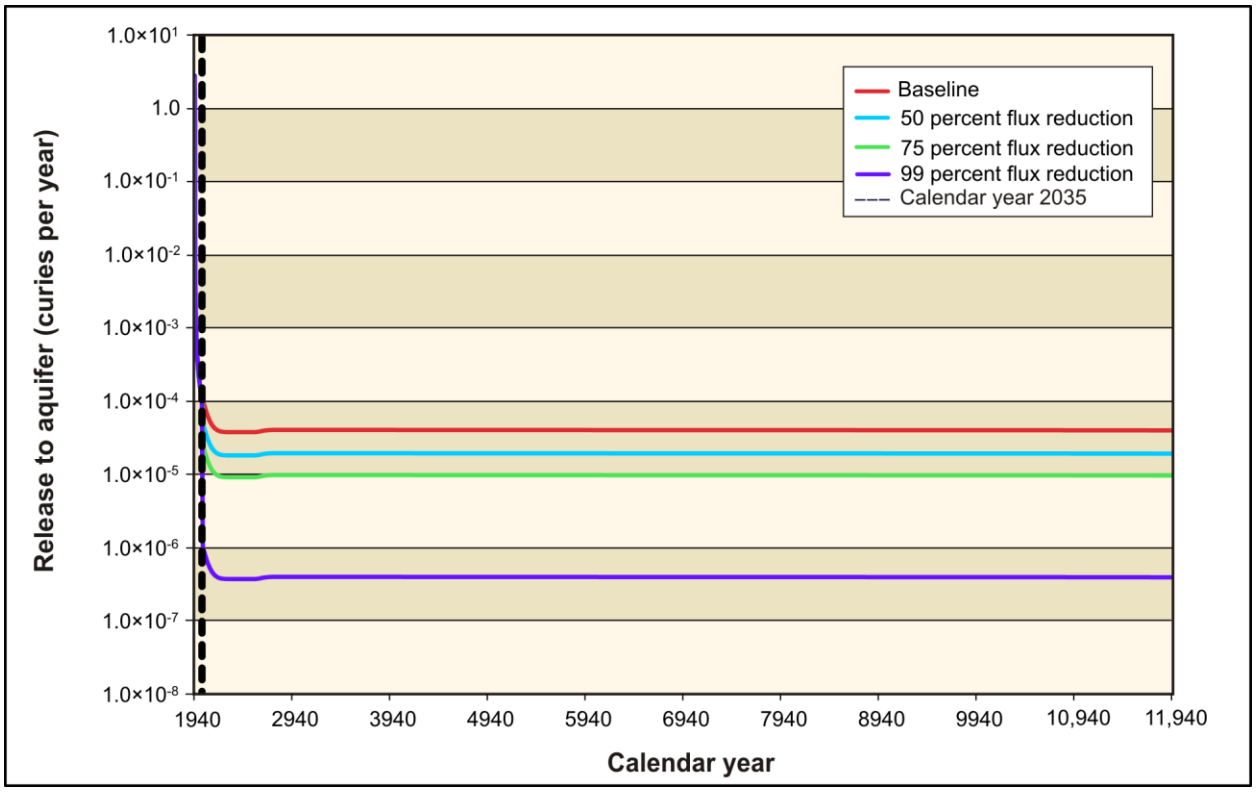


Figure U–107. Uranium-238 Flux to Aquifer Versus Time, 216-A-9 Crib

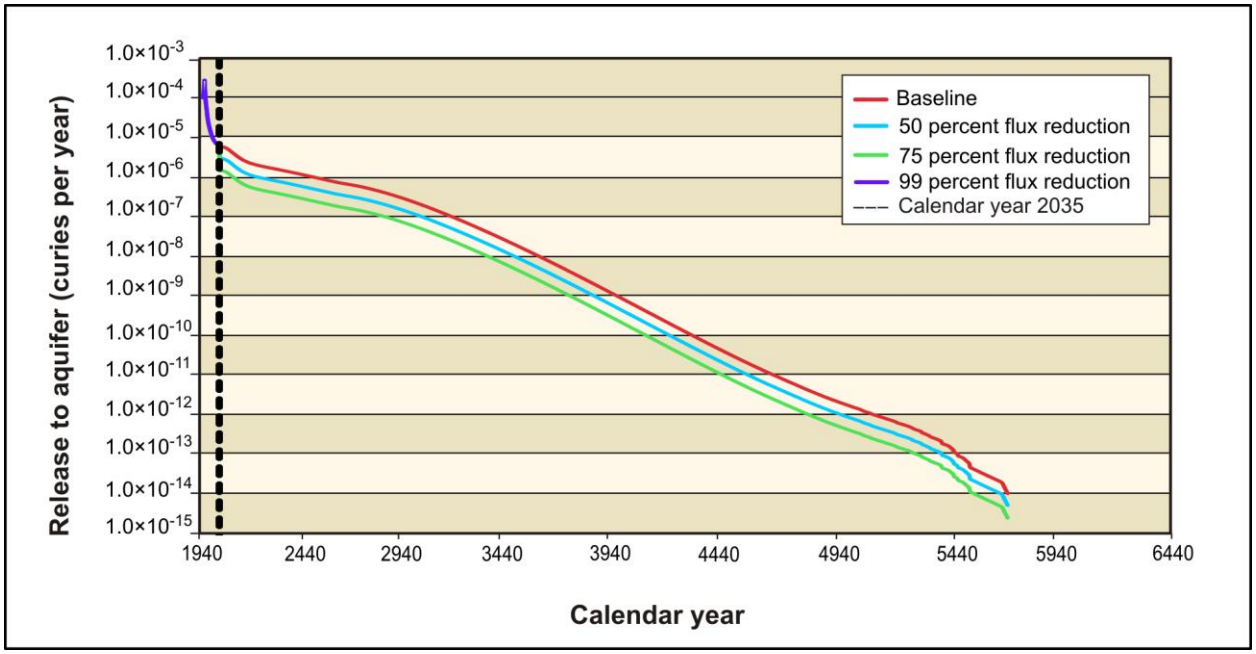


Figure U–108. Iodine-129 Flux to Aquifer Versus Time, TY Cribs

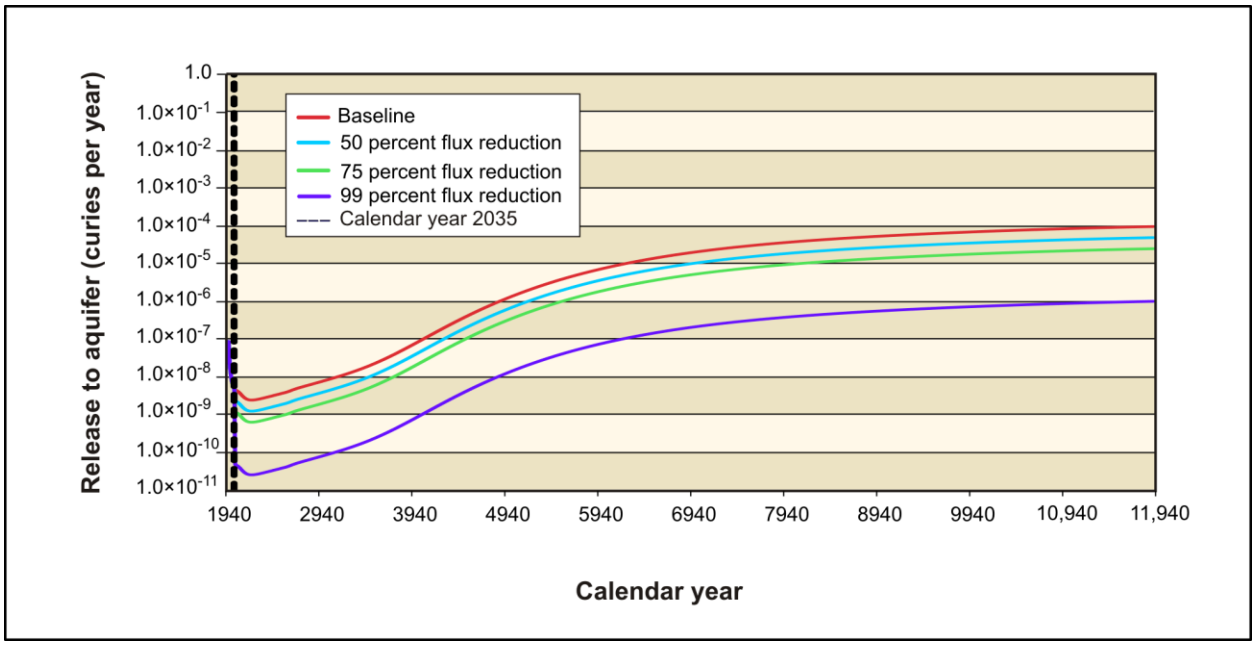


Figure U–109. Uranium-238 Flux to Aquifer Versus Time, TY Cribs

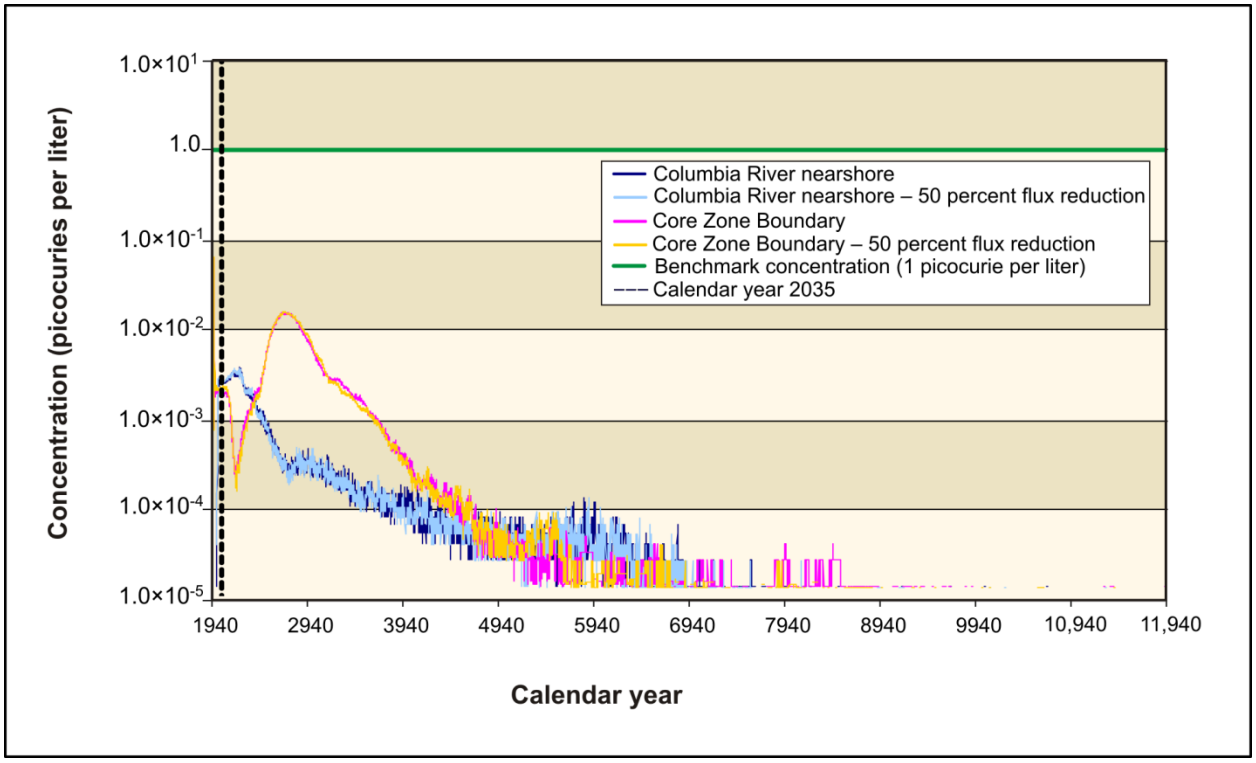


Figure U–110. Iodine-129 Concentration Versus Time, 216-A-9 Crib, Flux-Reduction Comparison

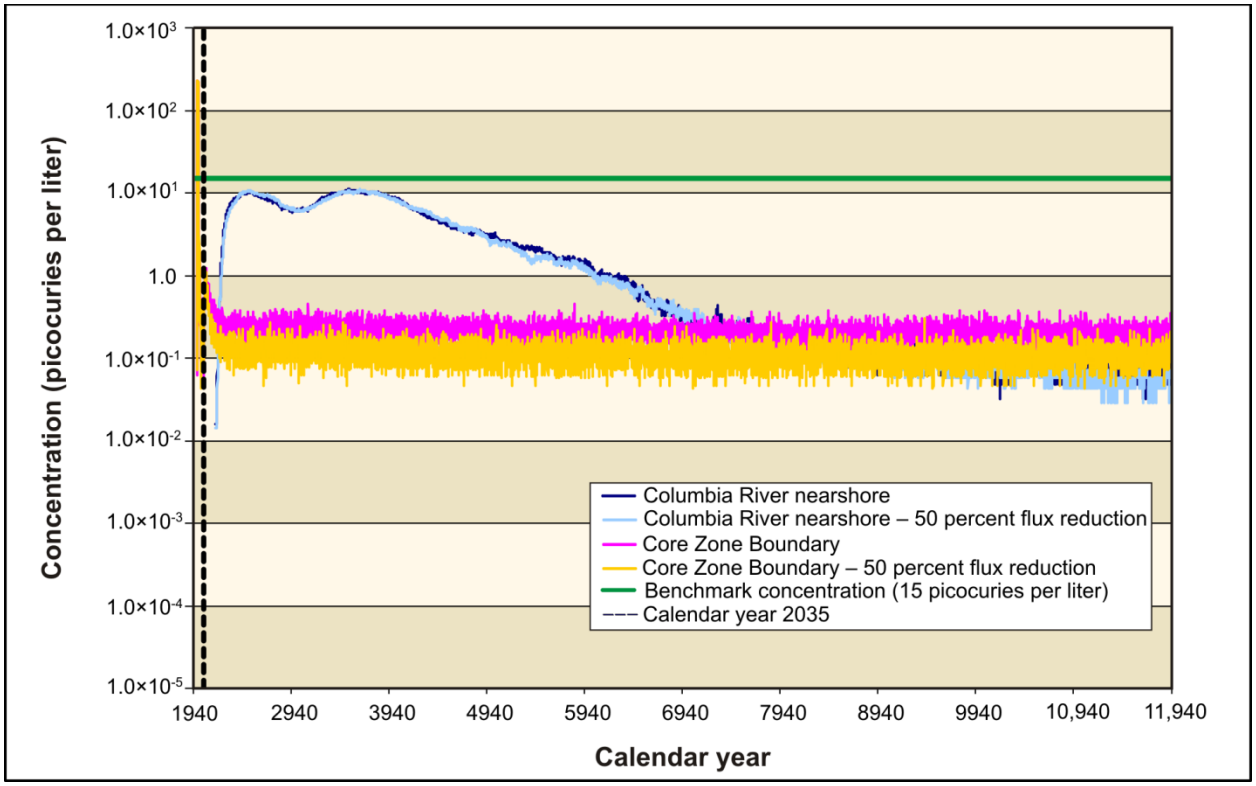


Figure U–111. Uranium-238 Concentration Versus Time, 216-A-9 Crib, Flux-Reduction Comparison

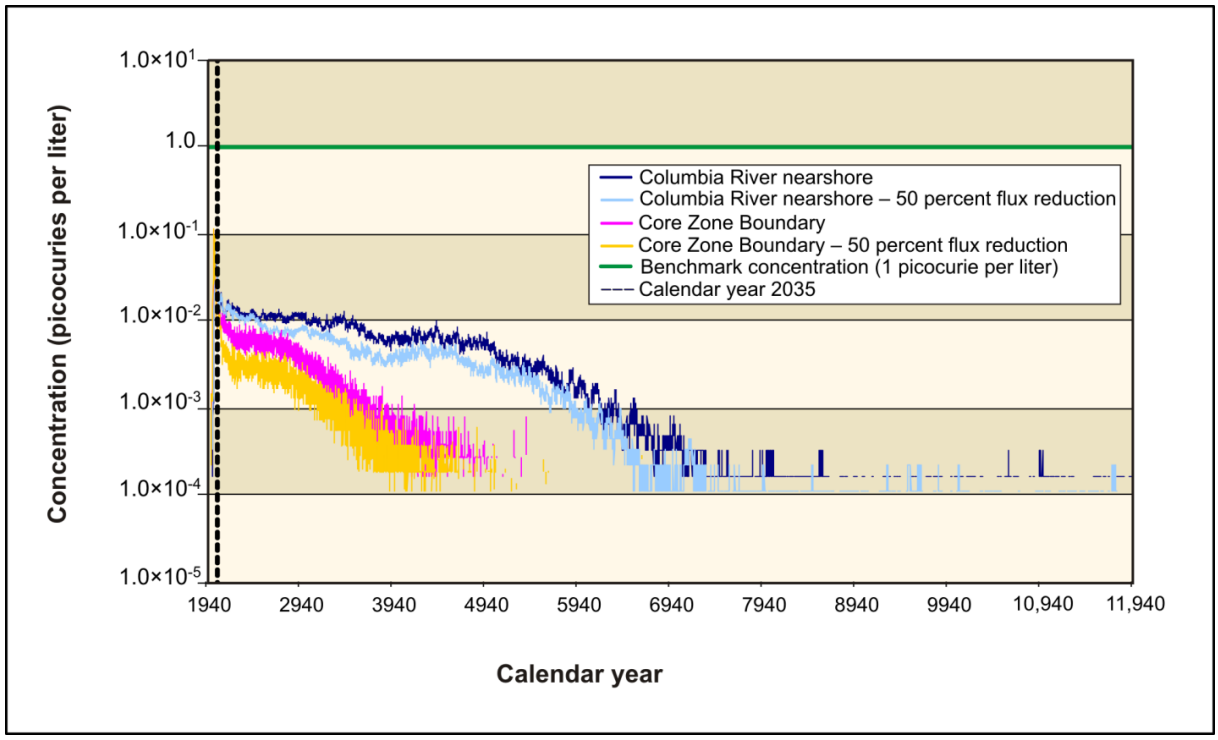


Figure U–112. Iodine-129 Concentration Versus Time, TY Crib, Flux-Reduction Comparison

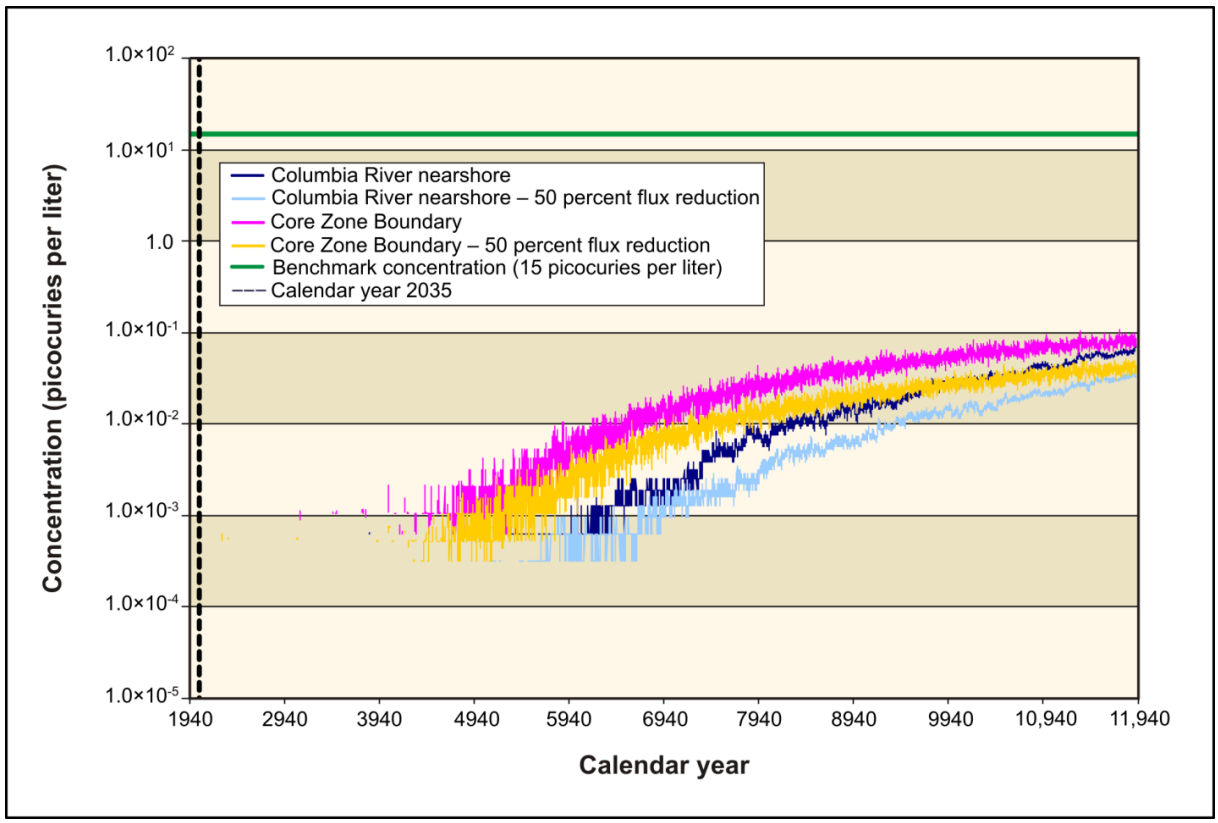


Figure U–113. Uranium-238 Concentration Versus Time, TY Crib, Flux-Reduction Comparison

U.1.3.4.1.2 Moderate-Discharge Conditions

Moderate-discharge sites are characterized as sites that had aqueous flux (volume per area) of less than 1 meter (3 feet) per year. Past leaks from the C and U tank farms are two examples of the moderate-discharge sites that were evaluated in the flux-reduction analysis. The C tank farm is located in the eastern portion of the Central Plateau and has a record of leaks occurring in 1946. The U tank farm is located in the western portion of the Central Plateau and has records of leaks occurring in 1946, 1956, and 1975. Figures U–114 through U–117 are the flux graphs for iodine-129 and uranium-238, depicting past leaks from the C and U tank farms. The graphs differ in showing the effect of inter-phase partitioning in modifying the rate of transport of solutes through the vadose zone. For conservative tracers such as iodine-129, the flux curves show a high peak reflecting rapid movement of solute to the water table with the initial aqueous discharge, followed by more-gradual drainage under background recharge conditions. The portion of total flux to the water table reaching the water table prior to CY 2035 was 87 and 22 percent for C and U tank farm releases, respectively. For uranium-238, the flux graphs have a rounded form with delay prior to initial arrival at the water table, indicating that the moderate aqueous discharge was not sufficient to rapidly transport the retarded solute (moves slower than water) through the vadose zone. Thus, for moderate-discharge sites, the effectiveness of flux reduction would depend on the magnitude of the initial release and the degree of retardation of the solute. For the cases analyzed here, the iodine-129 is rapidly transported to the water table, and the groundwater concentrations reported in Figures U–118 and U–120 do not show a response to the 50 percent flux reduction after 2035. For uranium-238, releases from the C and U tank farms would not reach the water table prior to CY 2035, and flux reduction could be effective as indicated in the groundwater concentrations depicted in Figures U–119 and U–121. For conservative tracers such as iodine-129, the flux graphs for both sites are typical examples of moderate-discharge sites and show a high, rounded peak following the operational period and a breakthrough shoulder that lasts up to approximately 1,000 years. For moderate-discharge sites, the flux graphs indicate that a reduction in flux can reduce the peak flux and the flux following the peak. A significant amount of the peak is still present after CY 2035 (dashed line) because the peak is rounded and has a longer duration that allows some of peak mass to get captured before it is released to the aquifer. Thus, flux reduction may be useful as a means of vadose zone remediation. Figures U–118 and U–119 are the concentration-versus-time graphs for the base (EIS) case and the 50 percent flux reduction case for iodine-129 and uranium-238 for the past leaks from the C tank farm. Figures U–120 and U–121 are the concentration-versus-time graphs for the base (EIS) case and the 50 percent flux-reduction case for iodine-129 and uranium-238 for the past leaks from the U tank farm. Overall, the duration of the concentration peaks is shortened by a flux reduction for moderate-discharge sites.

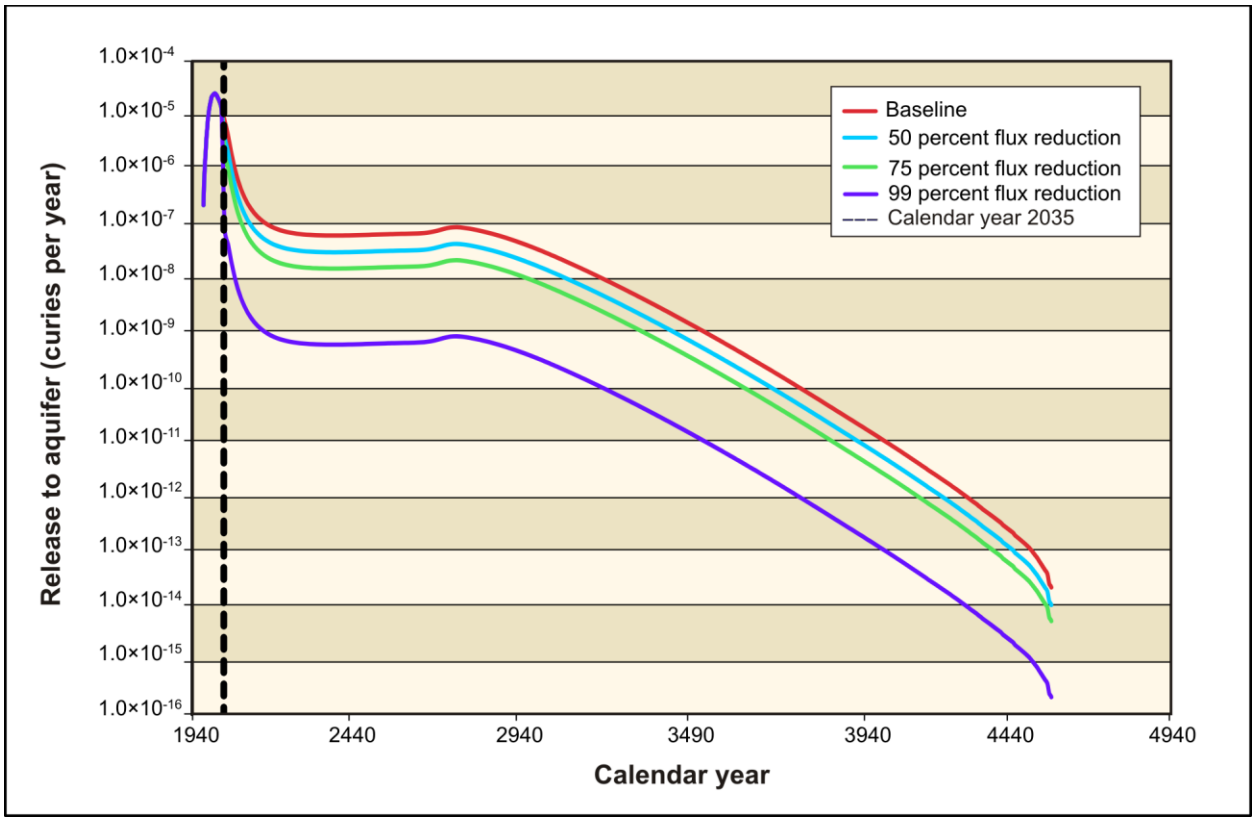


Figure U–114. Iodine-129 Flux to Aquifer Versus Time, C Tank Farm, Past Leaks

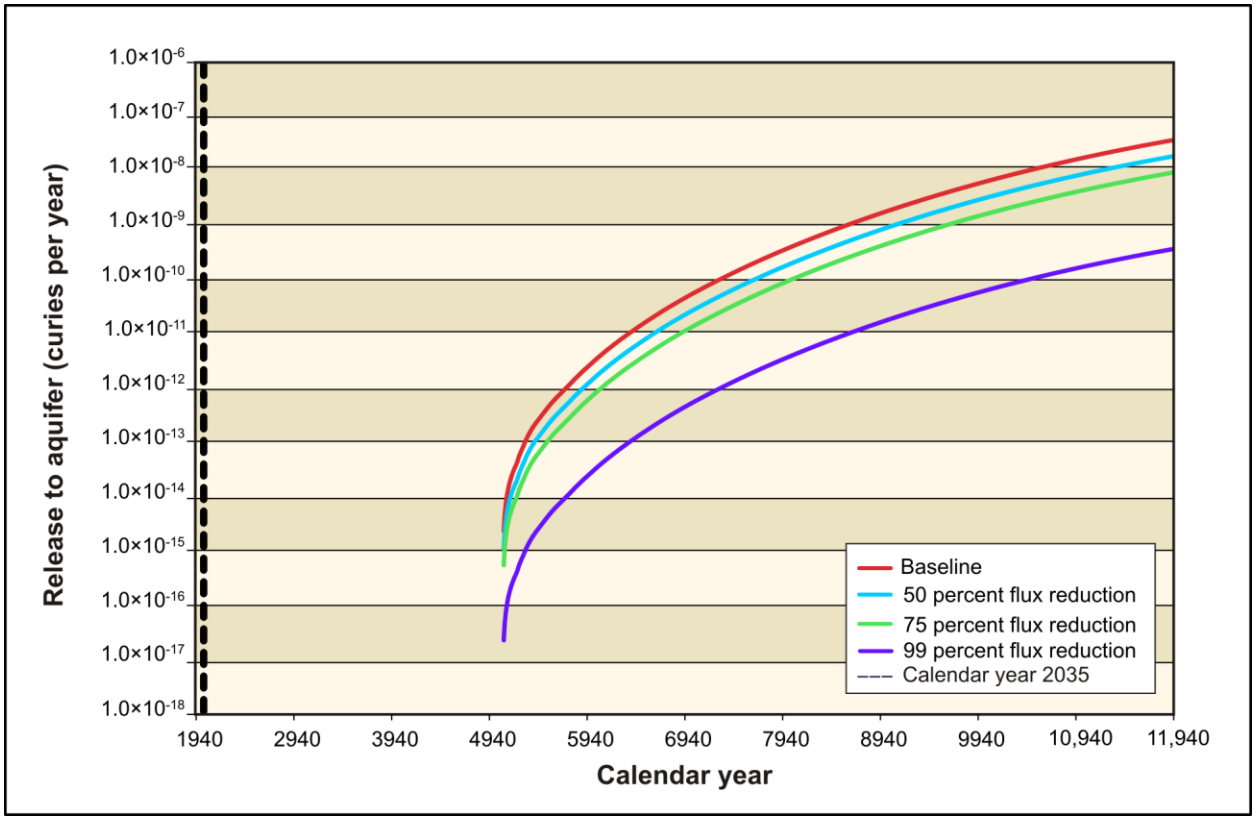


Figure U–115. Uranium-238 Flux to Aquifer Versus Time, C Tank Farm, Past Leaks

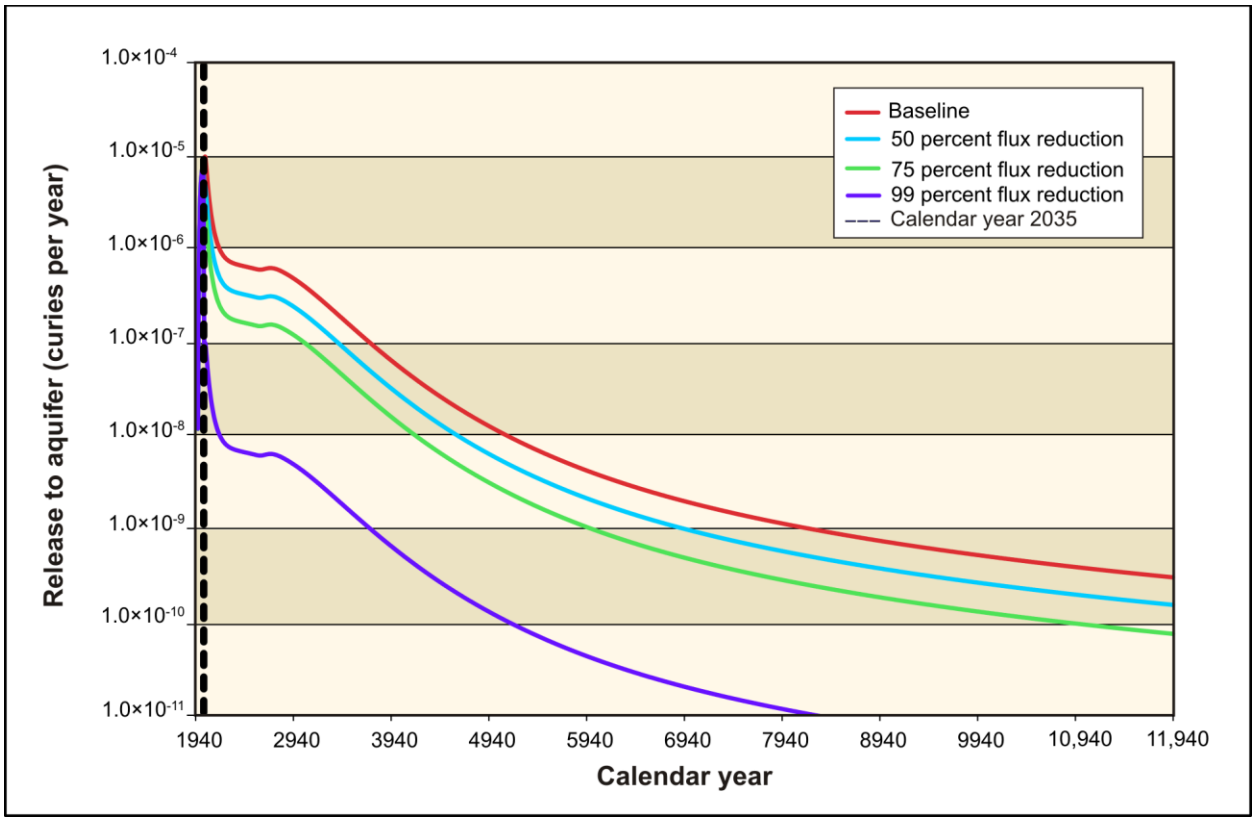


Figure U–116. Iodine-129 Flux to Aquifer Versus Time, U Tank Farm, Past Leaks

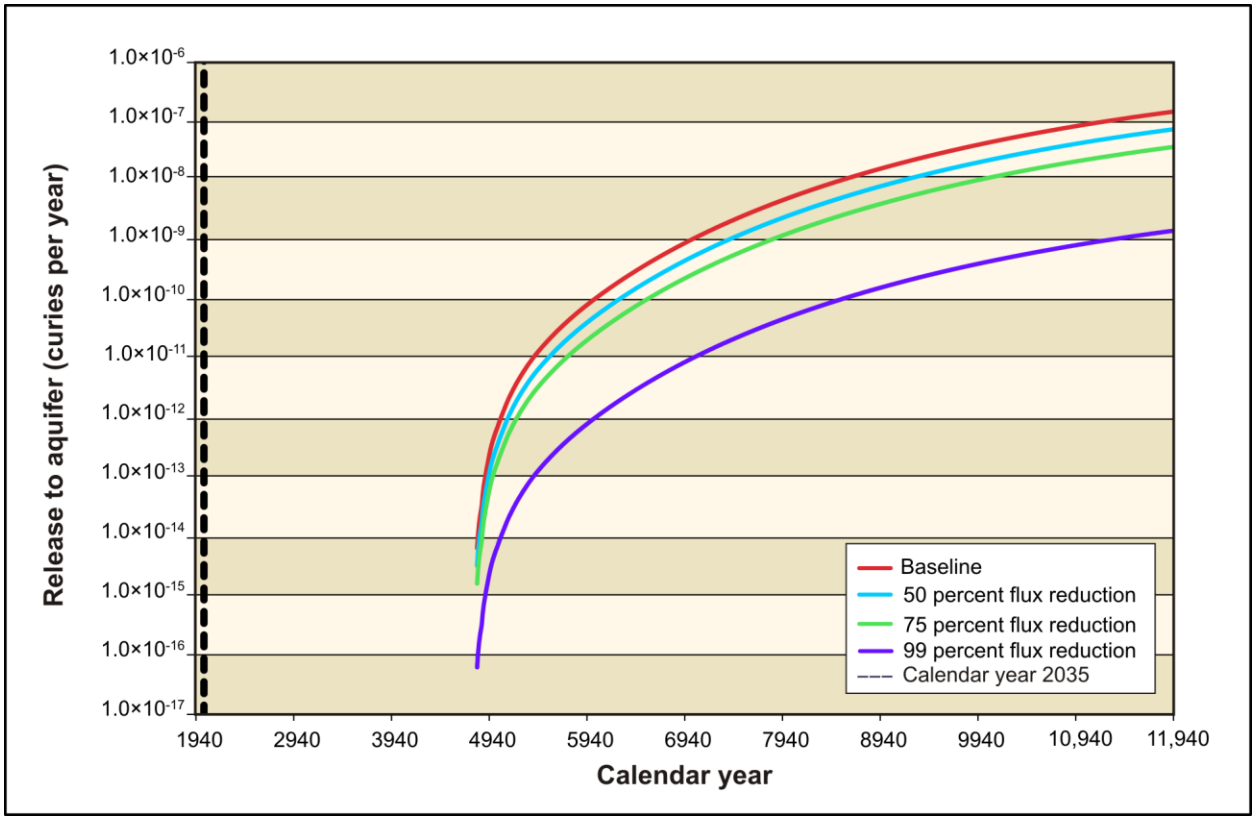


Figure U–117. Uranium-238 Flux to Aquifer Versus Time, U Tank Farm, Past Leaks

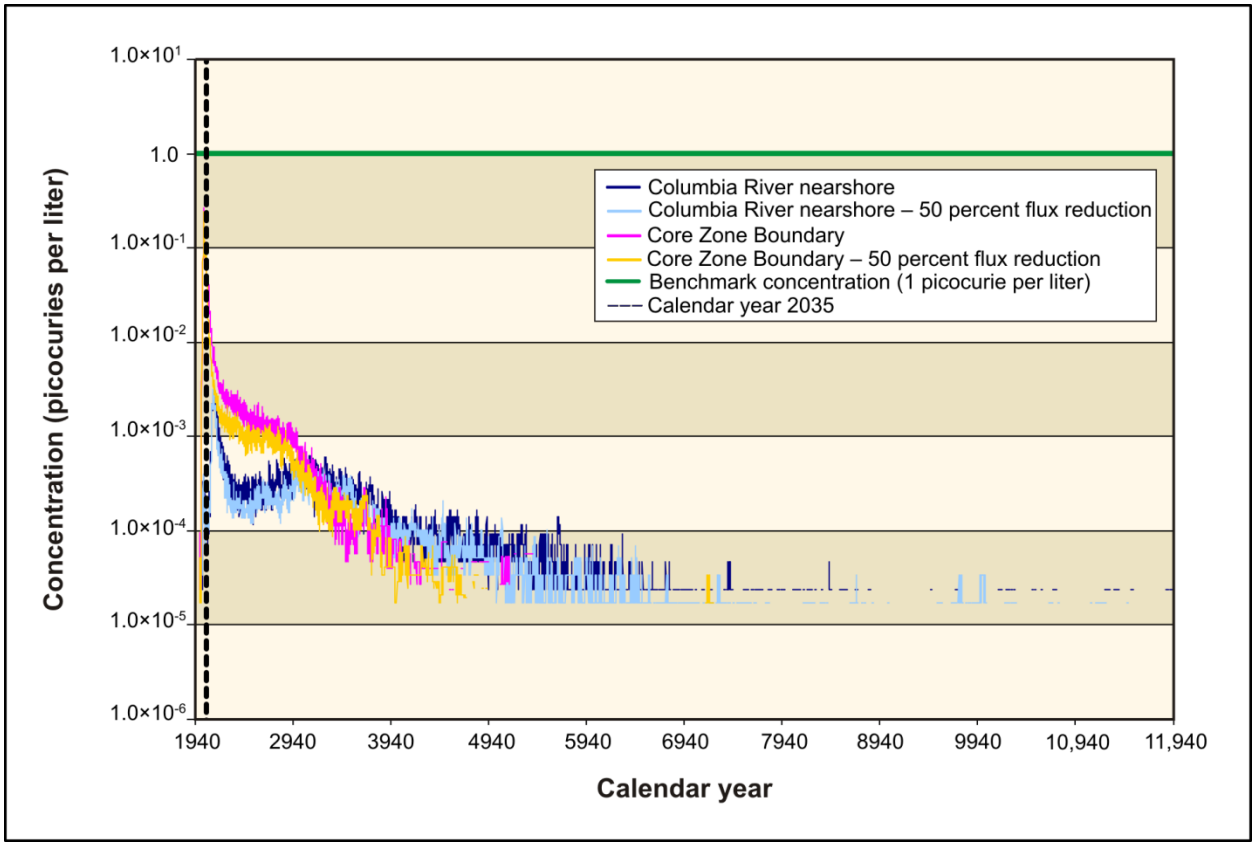


Figure U–118. Iodine-129 Concentration Versus Time, C Tank Farm, Past Leaks, Flux-Reduction Comparison

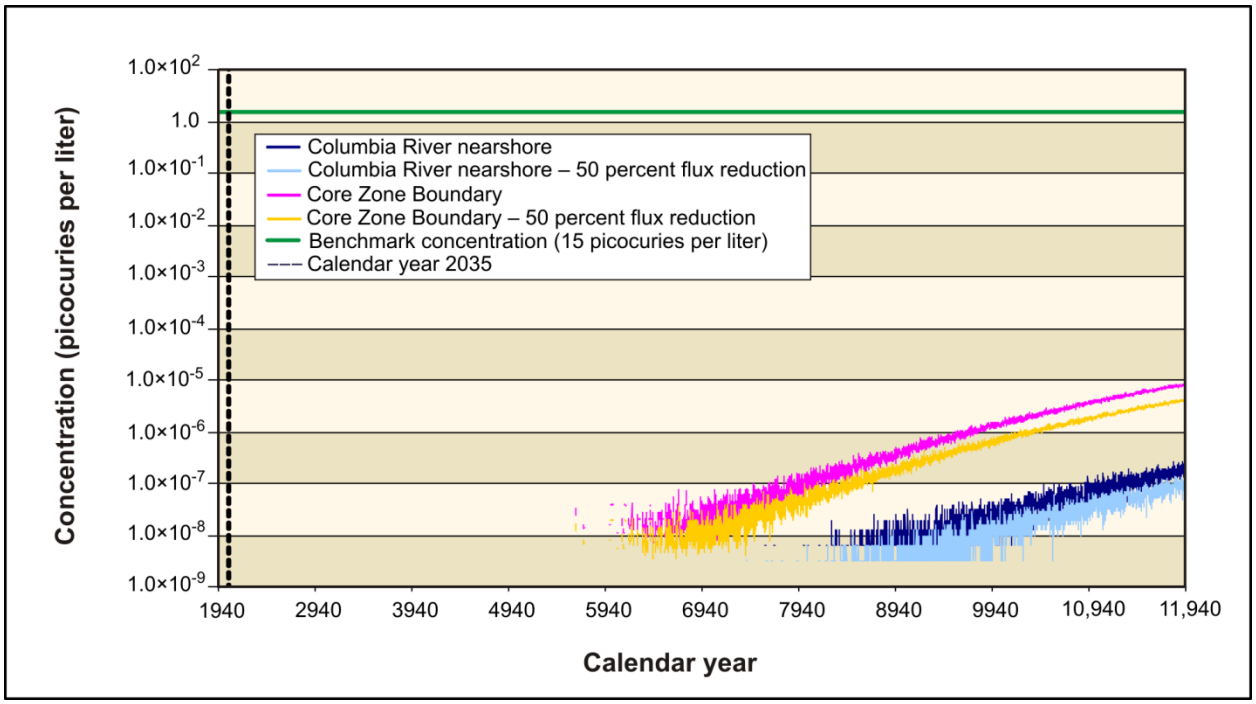


Figure U–119. Uranium-238 Concentration Versus Time, C Tank Farm, Past Leaks, Flux-Reduction Comparison

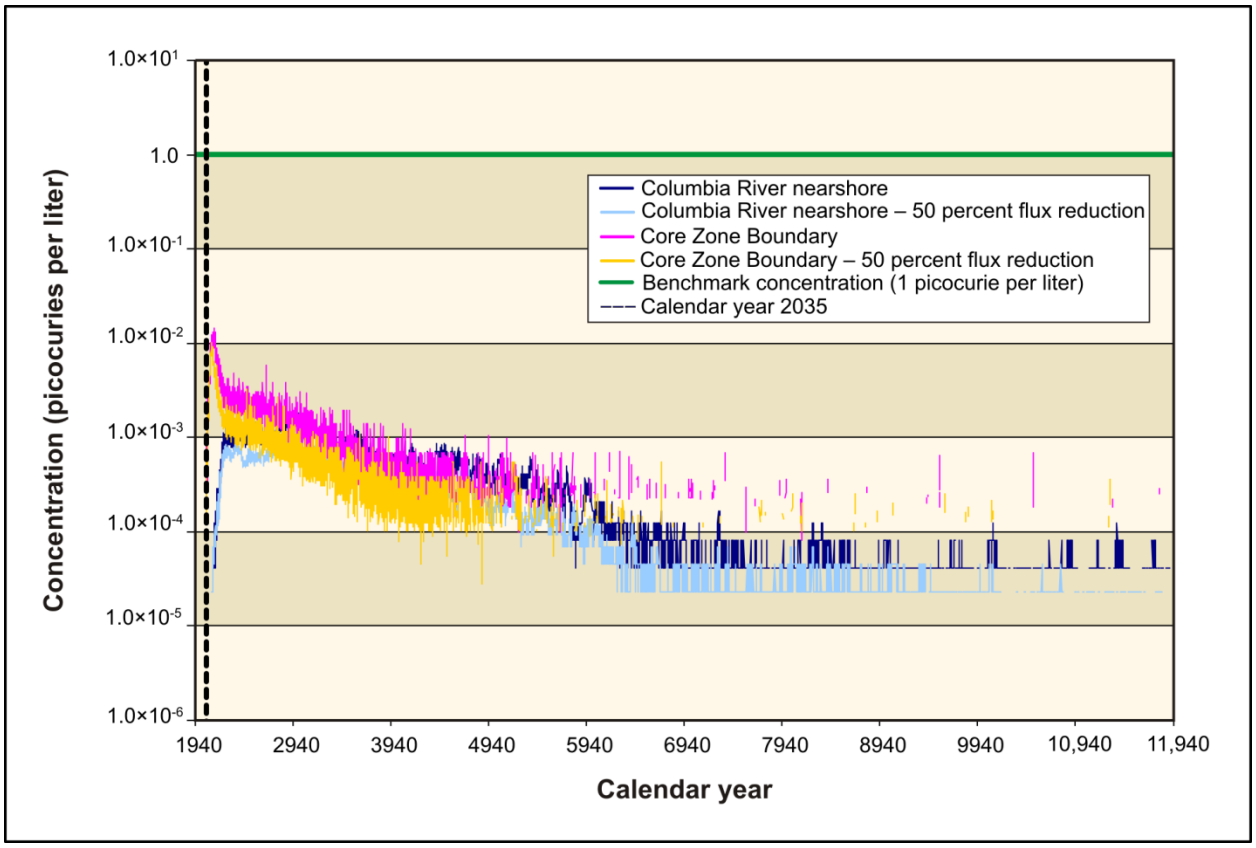


Figure U–120. Iodine-129 Concentration Versus Time, U Tank Farm, Past Leaks, Flux-Reduction Comparison

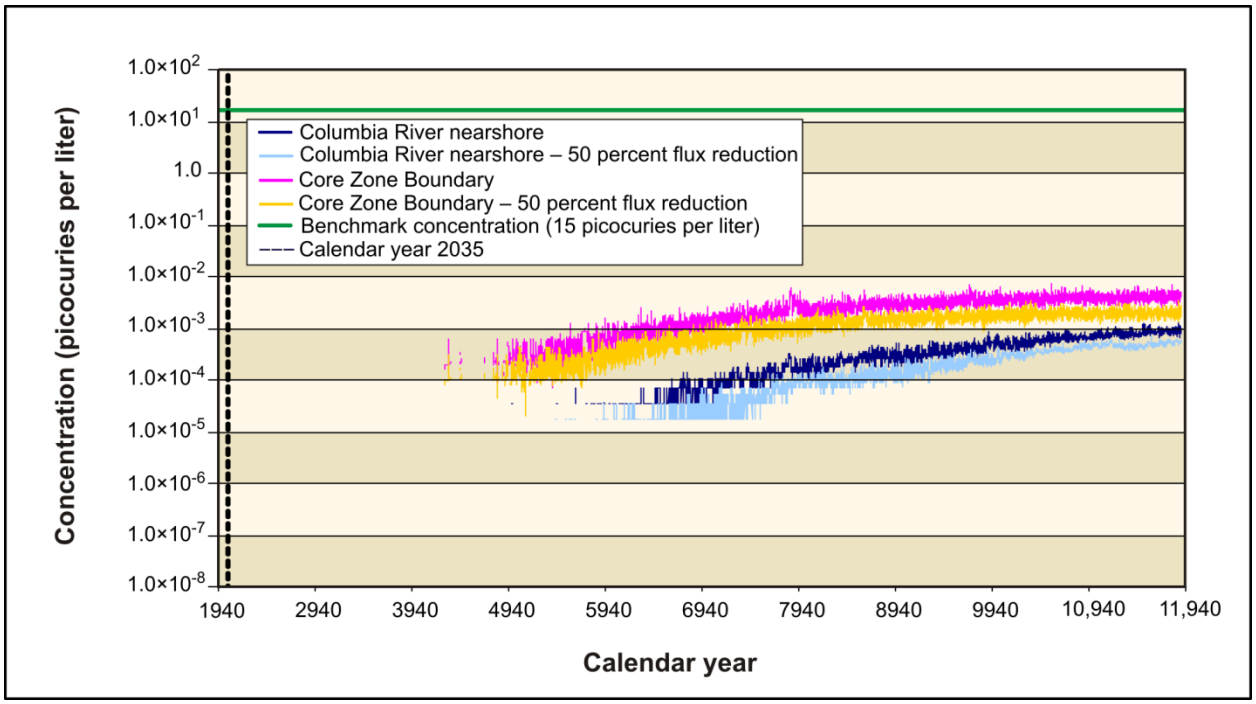


Figure U–121. Uranium-238 Concentration Versus Time, U Tank Farm, Past Leaks, Flux-Reduction Comparison

U.1.3.4.1.3 Low-Discharge Conditions

Releases of tank farm residuals from the C and U tank farms, as analyzed under Tank Closure Alternative 2B, are two examples of releases occurring under low-discharge conditions that were evaluated in the flux-reduction analysis. Figures U–122 through U–125 are the flux graphs for iodine-129 and uranium-238 for the tank residuals released from the C and U tank farms. The flux graphs for both sites are typical examples of low-discharge sites and indicate that the grouted tank farm residuals would have a slow release to the aquifer; a flux reduction would thus affect the entire duration of release. Figures U–126 through U–129 are the concentration-versus-time graphs for the base (EIS) case and the 50 percent flux-reduction case for iodine-129 and uranium-238 for the tank farm residuals from the C and U tank farms. The concentrations are reduced approximately linearly with respect to the flux reduction for low-discharge sites.

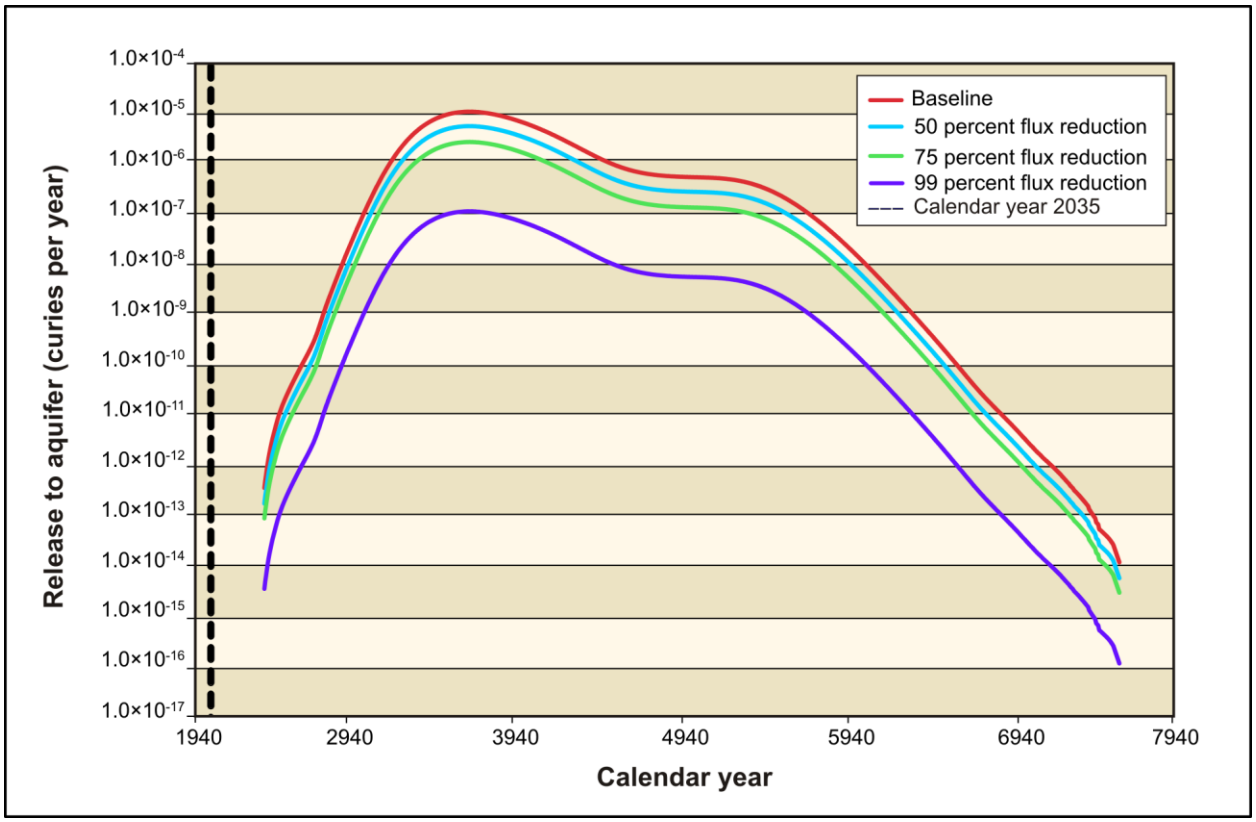


Figure U–122. Iodine-129 Flux to Aquifer Versus Time, C Tank Farm, Tank Residuals

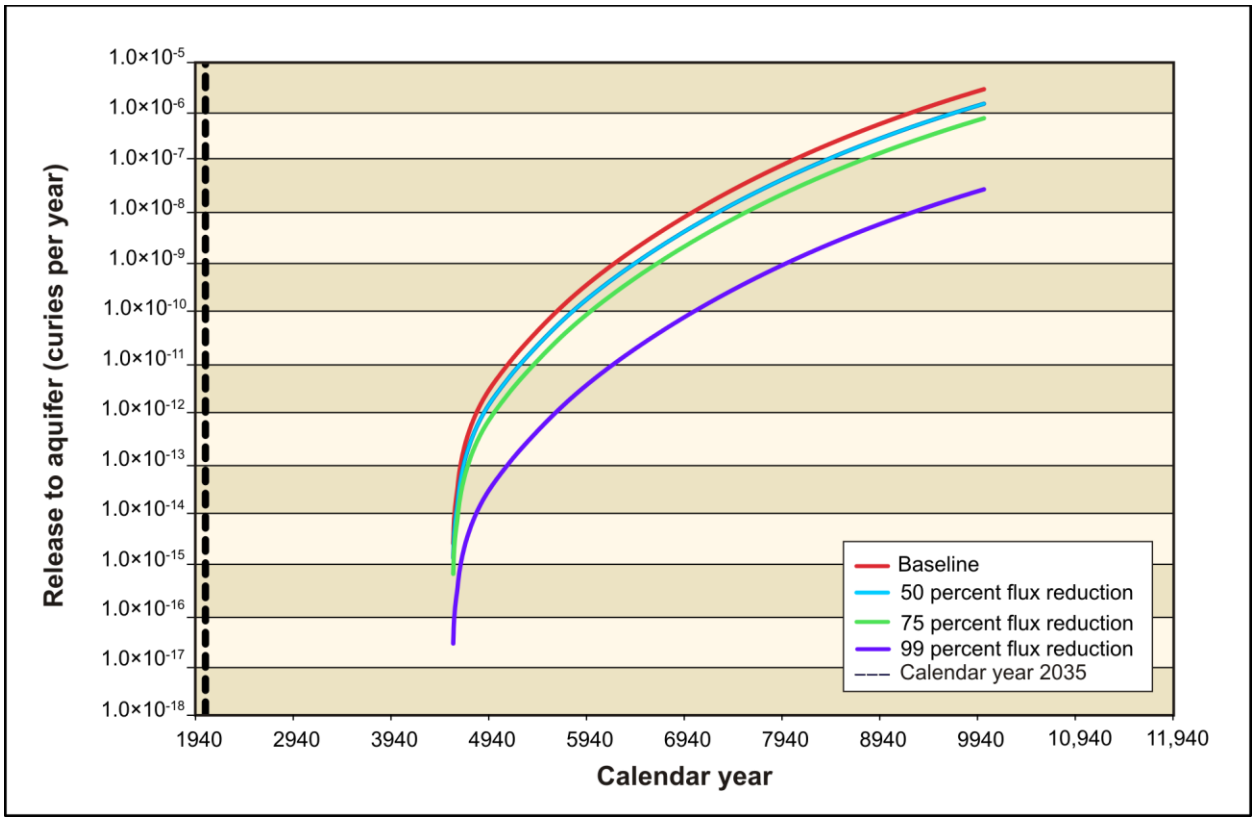


Figure U–123. Uranium-238 Flux to Aquifer Versus Time, C Tank Farm, Tank Residuals

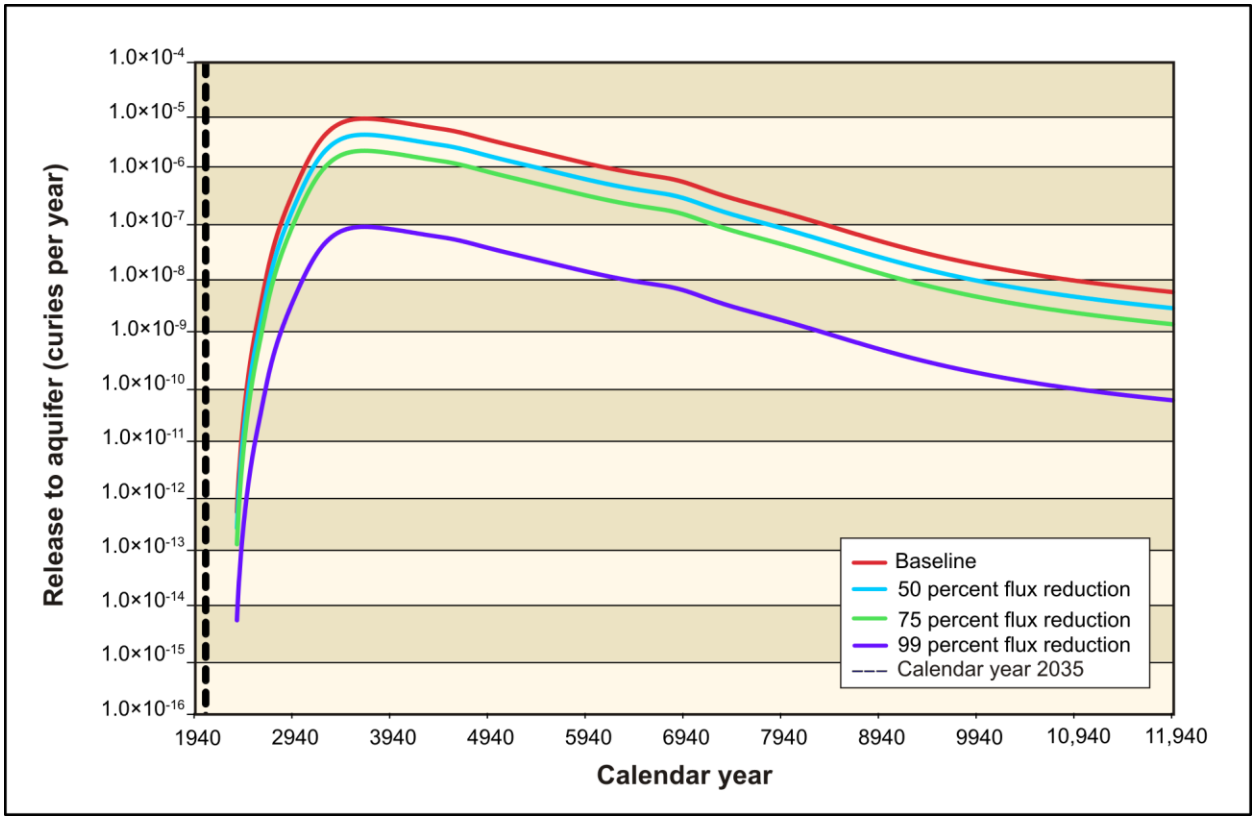


Figure U–124. Iodine-129 Flux to Aquifer Versus Time, U Tank Farm, Tank Residuals

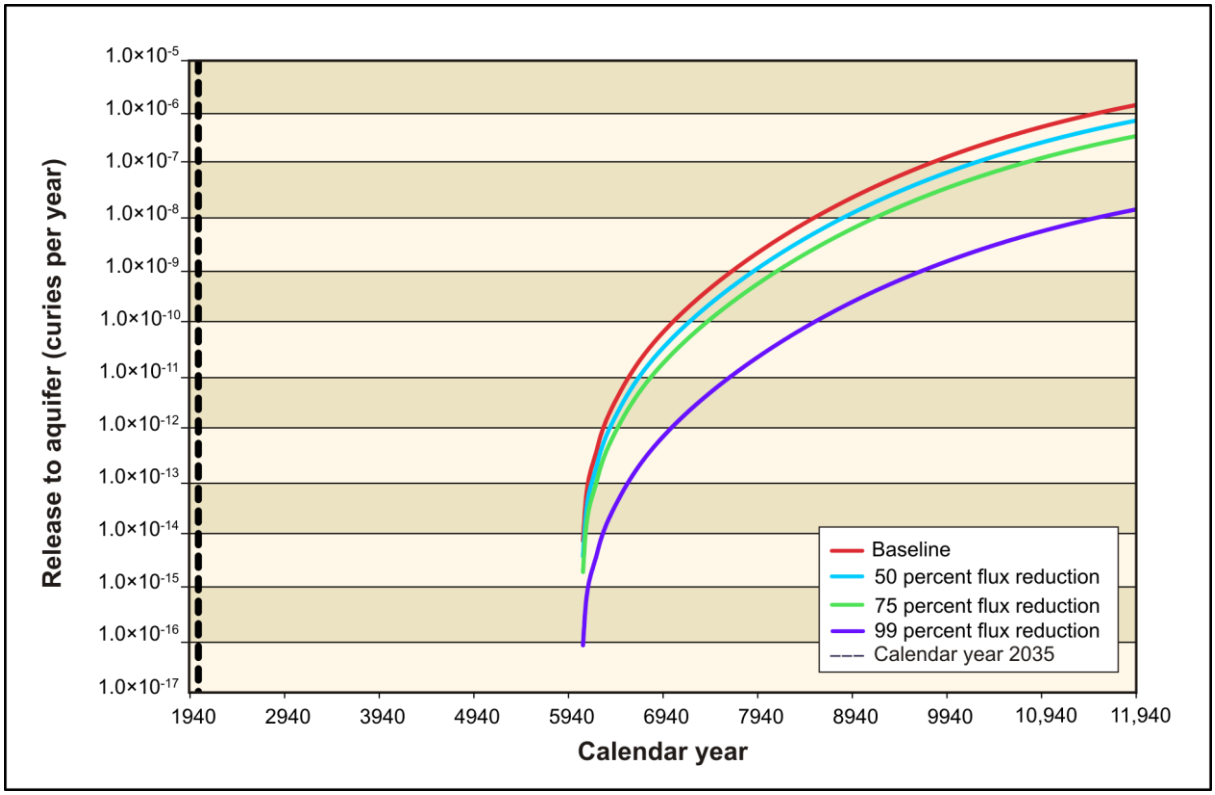


Figure U–125. Uranium-238 Flux to Aquifer Versus Time, U Tank Farm, Tank Residuals

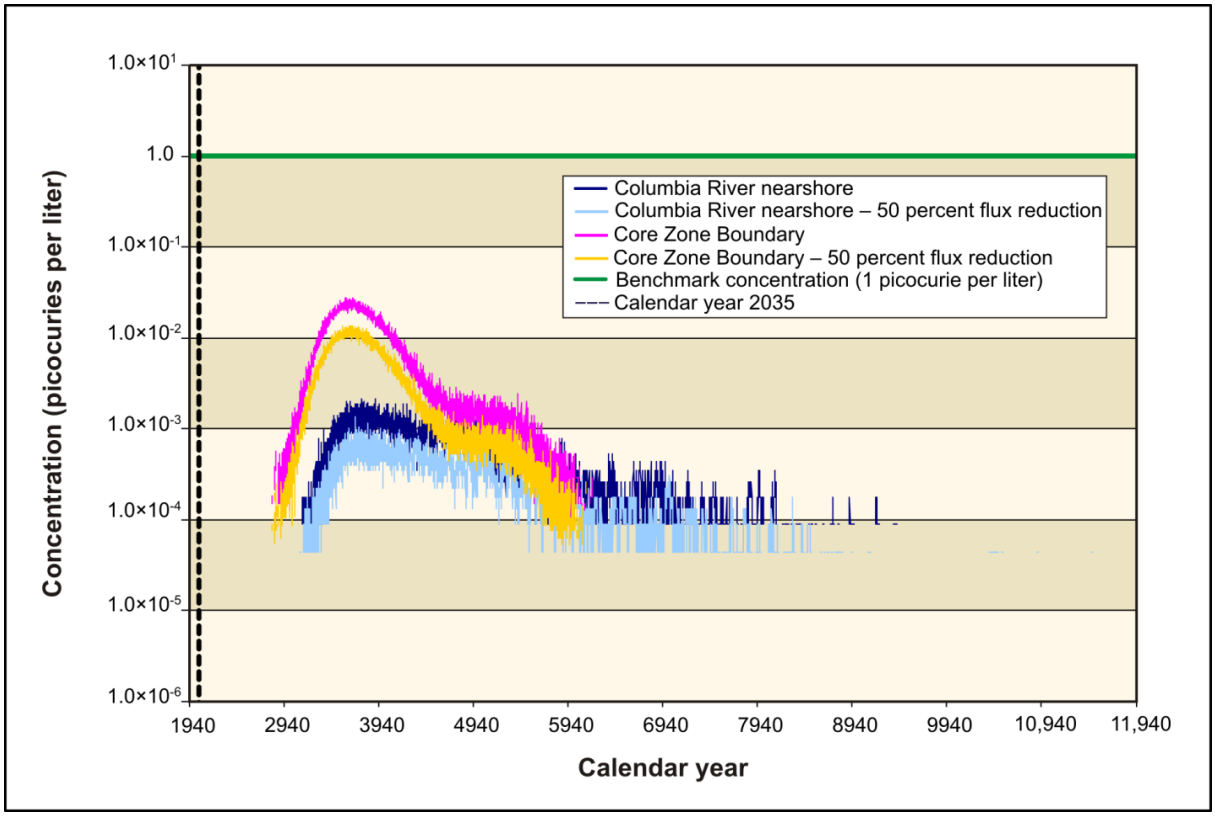


Figure U–126. Iodine-129 Concentration Versus Time, C Tank Farm, Tank Residuals, Flux-Reduction Comparison

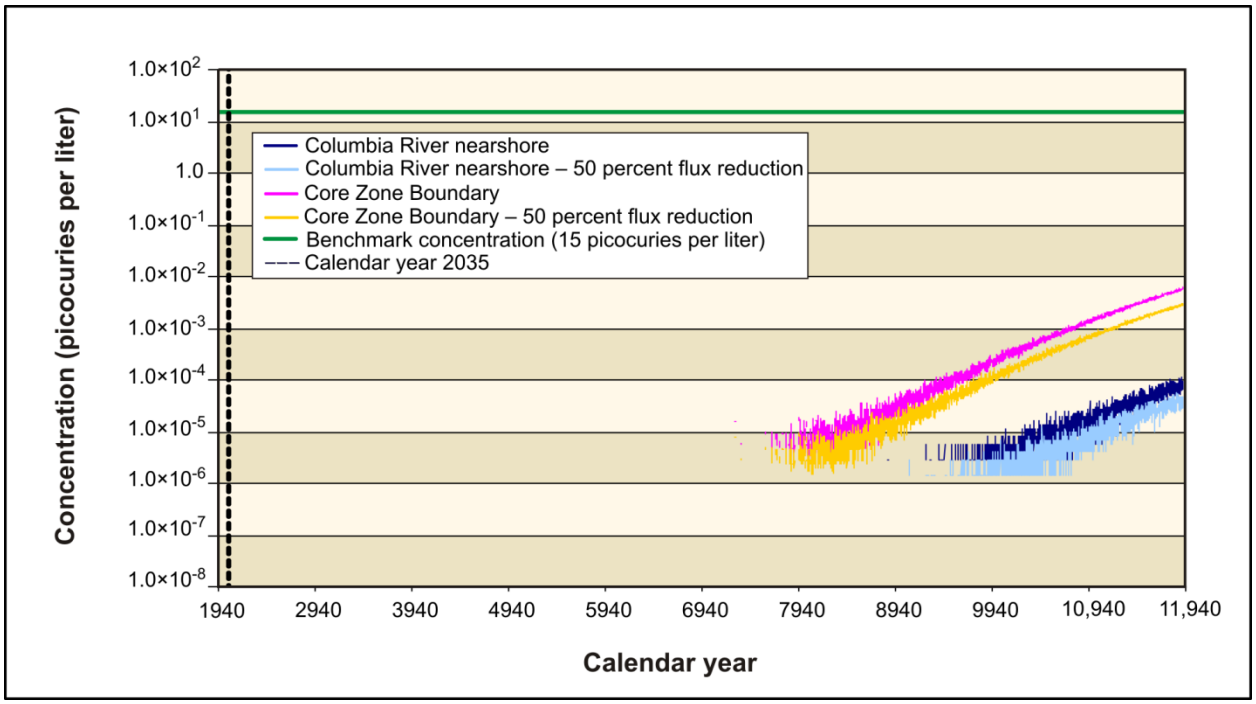


Figure U–127. Uranium-238 Concentration Versus Time, C Tank Farm, Tank Residuals, Flux-Reduction Comparison

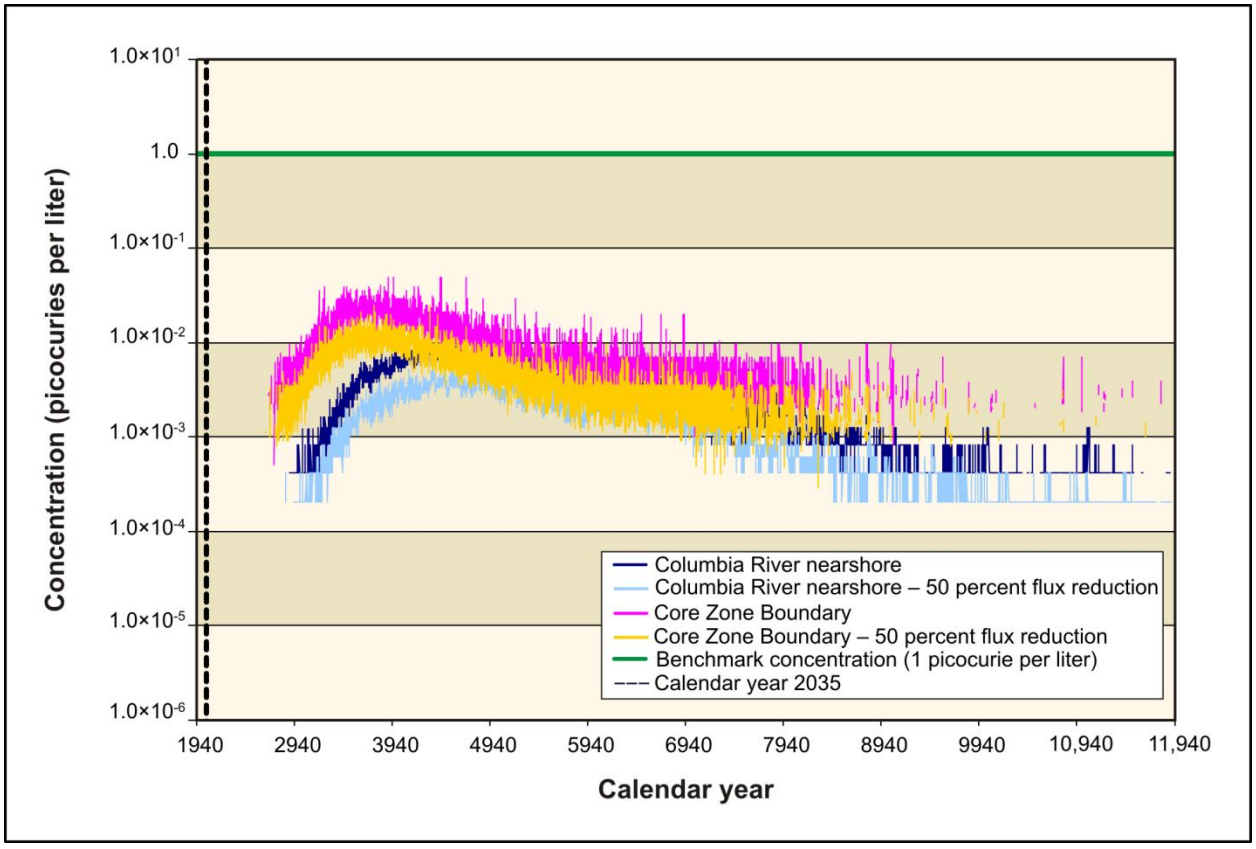


Figure U–128. Iodine-129 Concentration Versus Time, U Tank Farm, Tank Residuals, Flux-Reduction Comparison

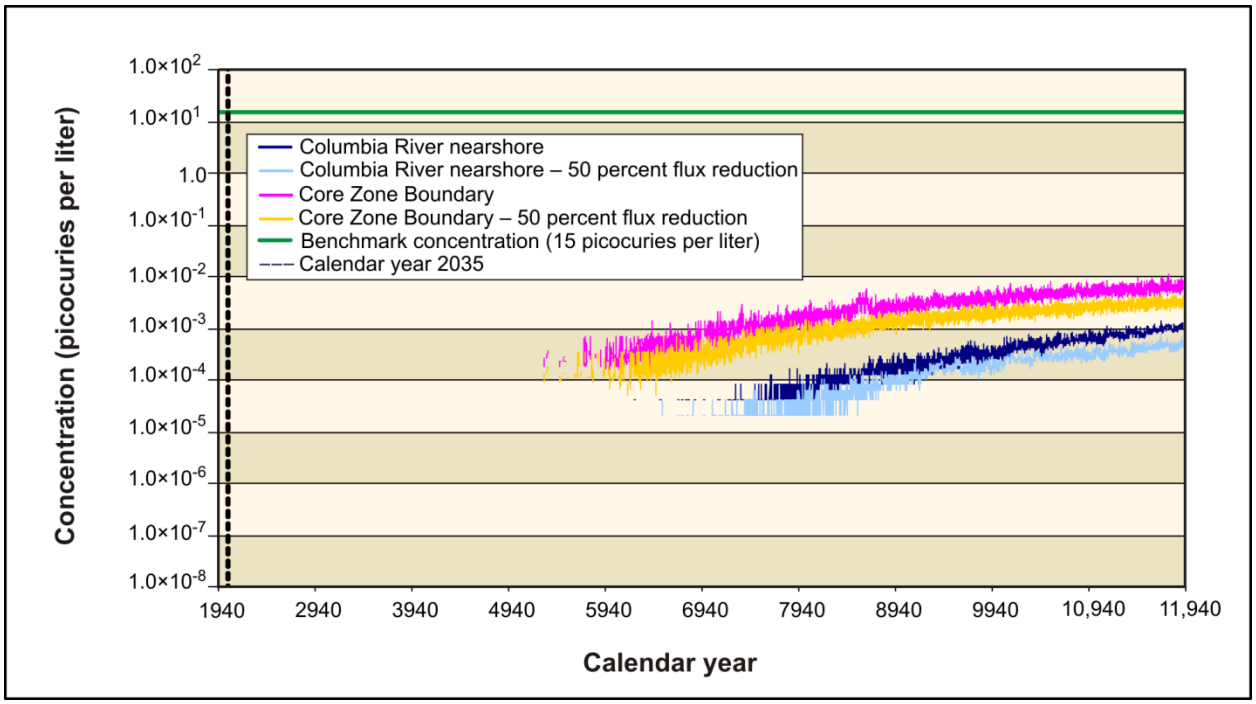


Figure U–129. Uranium-238 Concentration Versus Time, U Tank Farm, Tank Residuals, Flux-Reduction Comparison

U.1.3.4.1.4 Comparison with Partial Clean Closure (Tank Closure Alternative 4)

In the alternatives analysis (see Chapter 5, Section 5.1.1.7), Tank Closure Alternative 4 included clean closure of the SX and BX tank farms. This analysis was a specific example of the flux-reduction concept; it was limited in scope to two source areas and limited to remediation by excavation. To implement the flux-reduction concept in Tank Closure Alternative 4, fluxes from the vadose zone to the water table were assigned a value of zero curies per year starting in CY 2045. Section 5.1.1.7.4 (Analysis of Concentration Versus Time) shows the resulting response of the aquifer to this flux reduction. For comparison with the flux-reduction scenario described above, Table U–12 shows the total reduction of curies from the Tank Closure Alternative 4 analysis compared with the total number of curies in the flux-reduction sensitivity analysis.

Table U–12. Comparison of Total Curies Removed Through Flux Reductions

Radionuclide	Total Curies Removed from SX and BX Tank Farms by Partial Clean Closure, Tank Closure Alternative 4	Total Curies Removed from Sources in 50 Percent Flux-Reduction Scenario	Total Curies Removed from Sources in 75 Percent Flux-Reduction Scenario	Total Curies Removed from Sources in 99 Percent Flux-Reduction Scenario
Technetium-99	3.37×10^{1}	5.11×10^{2}	7.67×10^{2}	1.01×10^{3}
Iodine-129	5.90×10^{-2}	8.85×10^{-1}	1.33	1.75
Uranium-238	3.36×10^{-2}	7.24	1.09×10^{1}	1.43×10^{1}

U.1.3.4.1.5 Flux-Reduction Analysis Conclusions

Based on the results predicted by the flux-reduction analysis, flux reduction is likely to be effective in reducing long-term impacts on the groundwater system for moderate- and low-discharge sites and may be of marginal utility in reducing long-term impacts for heavy-discharge sites, depending on the magnitude

of the aqueous discharge occurring in the release, the degree of retardation in the vadose zone, and the inventory. Impacts may not be greatly reduced if the magnitude of the release and inventory is minimal. Note that the particular constituent(s) of concern should be identified before considering flux reduction as a remediation measure, as flux reduction may be more effective for contaminants that move through the vadose zone at a slower rate. In the flux-reduction analysis, the results indicated that certain constituents (i.e., iodine-129) migrate to the aquifer faster than other constituents (i.e., uranium-238), which comparatively travel to the groundwater system at a much slower rate. It is important to identify the constituents to be addressed by the flux reduction because, in most cases, a constituent like iodine-129 could be available at most low- and some moderate-discharge sites, whereas constituents like uranium-238 may be available at most low-, moderate-, and heavy-discharge sites.

U.1.3.4.2 Capture-and-Removal Scenario

The purpose of the capture-and-removal scenario is to provide the potential results of achieving the 200-ZP-1 ROD mass reduction goal of 95 percent mass removal within 25 years. This analysis is relevant to the depiction of CERCLA cleanup actions because there are an existing ROD, established cleanup levels, and a treatment system design that is under way. The scheduled start of the full-scale treatment system is in 2012. The *TC & WM EIS* contaminant transport results show that many of the mobile risk drivers (e.g., technetium-99) have already been released to groundwater from the vadose zone and thus cannot be effectively mitigated by soil removal actions. Therefore, the only potentially effective remediation for the impacts from these sites is containment and treatment of the groundwater itself. The 200-ZP-1 proposed plan and ROD includes the flexibility to add specific extraction wells to treat emerging contaminant plumes. The 200-ZP-1 ROD establishes specific cleanup levels to be achieved within a 100-year period following 25 years of active treatment. The actual implementation of the treatment system could be modified to ensure achievement of these levels.

Hanford Site Groundwater Monitoring for Fiscal Year 2007 indicates an upper limit of approximately 65,000 kilograms (143,000 pounds) of dissolved carbon tetrachloride located in the 200-West Area of the Core Zone Boundary (Hartman and Webber 2008). The primary sources of the carbon tetrachloride are three of the 216-Z cribs and trenches (ditches) that received waste from the Plutonium Finishing Plant (DOE 2010a). In the cumulative impacts analysis, 65,000 kilograms (143,000 pounds) of carbon tetrachloride were released directly to the aquifer in CY 2005. This did not account for current or planned containment and removal of carbon tetrachloride from the aquifer. The RAO, as defined in the interim ROD (EPA 1995b) and carried forward into the final ROD, states that the pump-and-treat remedy will capture the carbon tetrachloride plume in the unconfined aquifer (DOE 2010a) consistent with the CERCLA ROD for the 200-ZP-1 operable unit (EPA 2008). The capture-and-removal scenario was designed to evaluate the potential response of the carbon tetrachloride plume to mass removal from the aquifer that would result from pump-and-treat operations.

Three variations, in which specified masses of aqueous phase carbon tetrachloride, chromium, and technetium-99 were assumed to be released directly to the aquifer beneath the 200-West Area, are evaluated in the capture-and-removal scenario (uranium was not included in this sensitivity analysis because the cleanup targets will not be added until after completion of the CERCLA process for the 200-UP-1 Operable Unit). The base case assumed no pump-and-treat system; 65,000 kilograms (143,000 pounds) of aqueous phase carbon tetrachloride, 3,000 kilograms (6,600 pounds) of chromium, and 1.75 curies of technetium-99 were assumed to be released directly to the aquifer in CY 2005 and were allowed to migrate under the prevailing hydraulic conditions. The second case was designed to represent 95 percent carbon tetrachloride removal; this case was modeled by simulating the release of 5 percent of the mass of carbon tetrachloride (3,250 kilograms [7,150 pounds]), chromium (150 kilograms [330 pounds]), and technetium-99 (0.0875 curies) in CY 2040. The third case was designed to represent 99 percent removal by releasing 1 percent of the mass of carbon tetrachloride (650 kilograms [1,430 pounds]), chromium (30 kilograms [66 pounds]), and technetium-99 (0.0175 curies) in 2040. For

both of these pump-and-treat simulations, the effect of pumping on the flow field was not explicitly considered; all three scenarios utilized the groundwater flow field that was used in the cumulative impacts and alternatives analyses. A more detailed description of flow field development is provided in Appendix L.

Figures U–130 and U–131 demonstrate that, with no remediation (base case), the projected carbon tetrachloride concentration would remain above the 5-micrograms-per-liter benchmark standard for approximately 200 years at the Core Zone Boundary and approximately 3,000 years at the Columbia River. With 95 percent removal, the carbon tetrachloride concentration at both locations would fall below the benchmark standard within 100 years following completion of the containment and removal in CY 2040, which is consistent with the 200-ZP-1 ROD (EPA 2008). With 99 percent removal, the carbon tetrachloride concentrations at both locations would not exceed the benchmark standard and would remain 1 to 3 orders of magnitude below the benchmark standard for the next 10,000 years. Note that the time scale (*x* axis) presented in Figure U–130 is only 600 years of the model simulation for ease in interpreting the difference of the concentration-versus-time curves at the Core Zone Boundary. The time scale in Figure U–131 is the entire length of the model simulation (10,000 years).

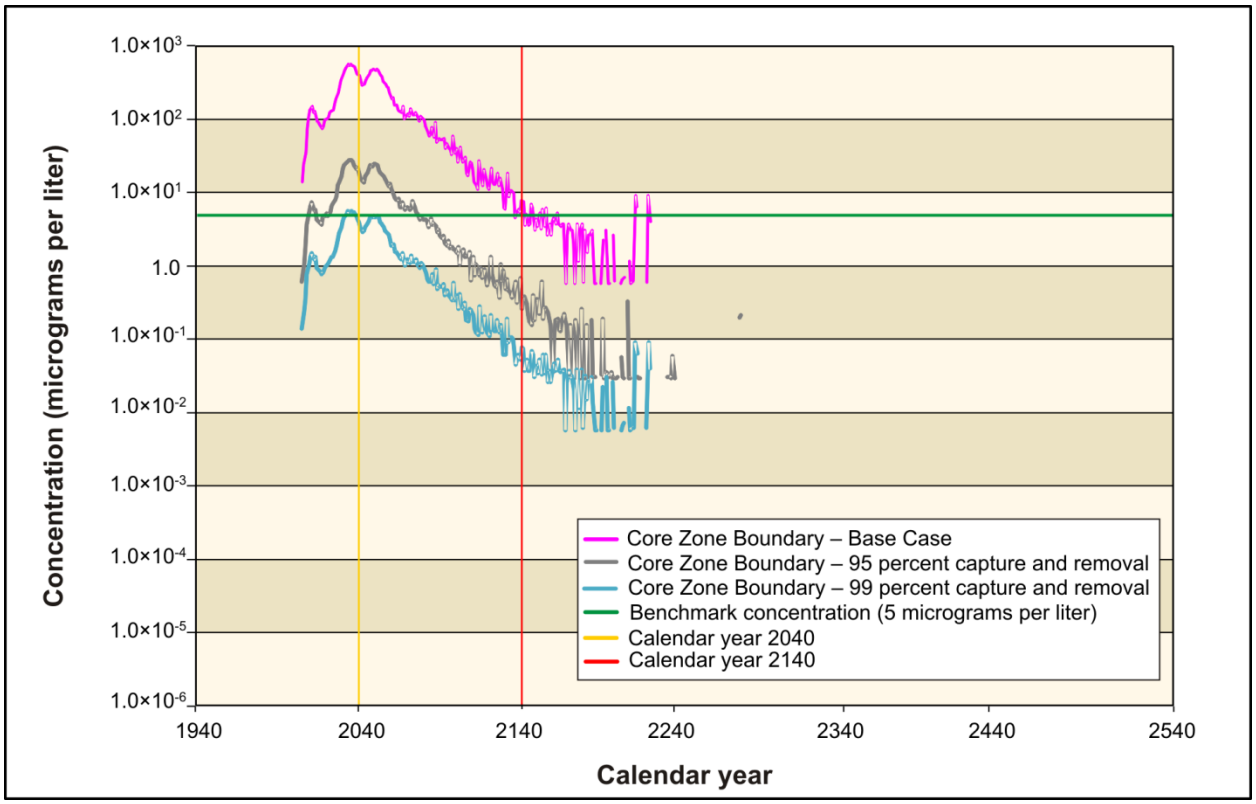


Figure U–130. Carbon Tetrachloride Concentration Versus Time at the Core Zone Boundary, Capture-and-Removal Scenario Comparison

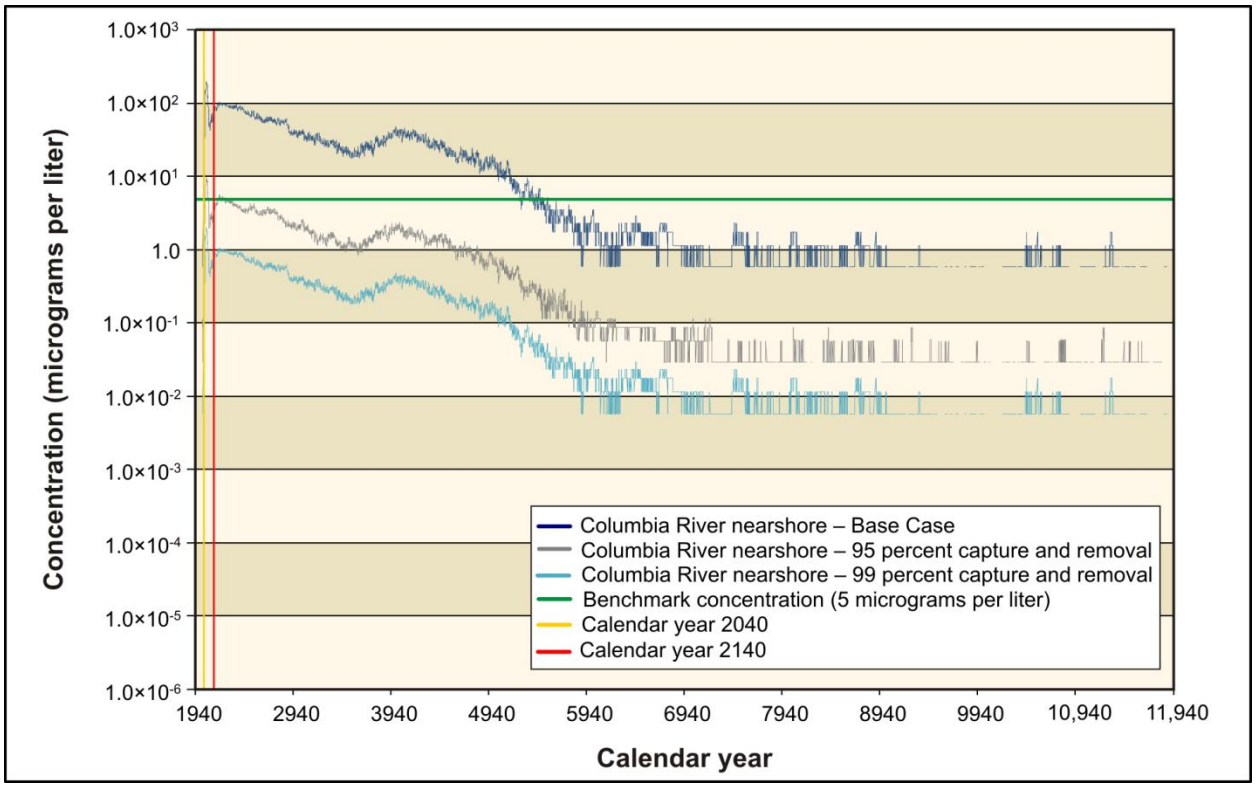


Figure U–131. Carbon Tetrachloride Concentration Versus Time at the Columbia River, Capture-and-Removal Scenario Comparison

Figures U–132 and U–133 demonstrate that, with no remediation (base case), the projected chromium concentration would remain below the 100-micrograms-per-liter benchmark standard at the Core Zone Boundary and the Columbia River. With both 95 and 99 percent removal, the chromium concentrations at both locations would peak at least two orders of magnitude below the benchmark standard. Note that the time scale (*x* axis) presented in Figure U–132 is only 600 years of the model simulation for ease in interpreting the difference of the concentration-versus-time curves at the Core Zone Boundary. The time scale in Figure U–133 is the entire length of the model simulation (10,000 years).

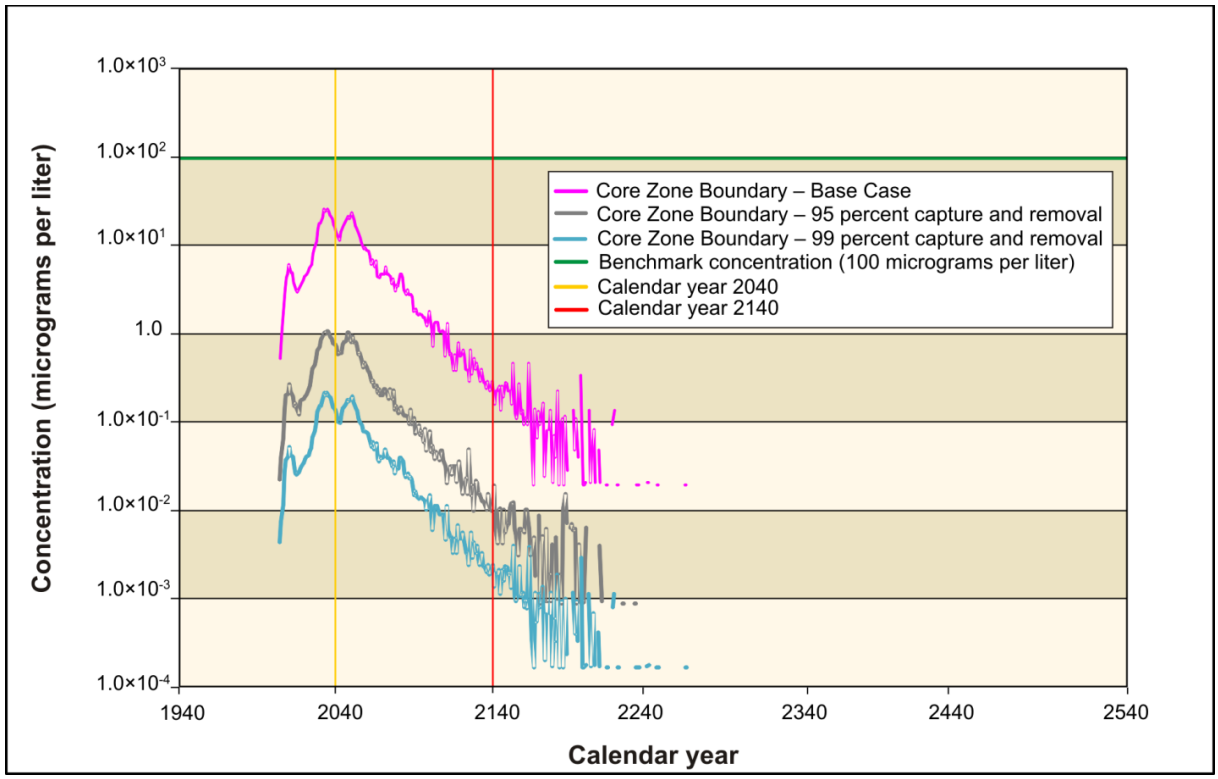


Figure U–132. Chromium Concentration Versus Time at the Core Zone Boundary, Capture-and-Removal Scenario Comparison

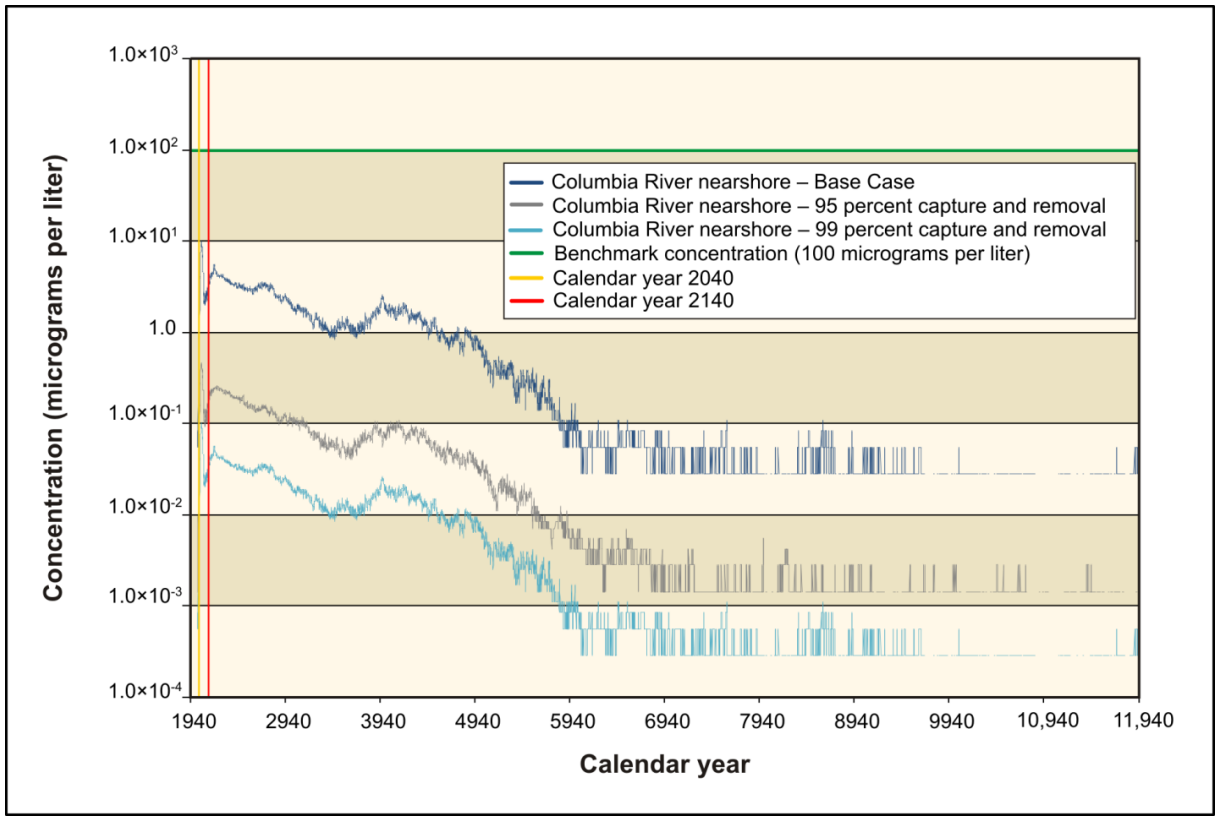


Figure U–133. Chromium Concentration Versus Time at the Columbia River, Capture-and-Removal Scenario Comparison

Figures U–134 and U–135 demonstrate that with no remediation (base case), the projected technetium-99 concentration would remain two orders below the 900-picocuries-per-liter benchmark standard at the Core Zone Boundary and at the Columbia River. With both 95 and 99 percent removal, the technetium-99 concentrations at both locations would peak at about three and a half orders of magnitude below the benchmark standard. Note that the time scale (*x* axis) presented in Figure U–134 is 600 years of the model simulation for ease in interpreting the difference of the concentration-versus-time curves at the Core Zone Boundary. The time scale in Figure U–135 is the entire length of the model simulation (10,000 years).

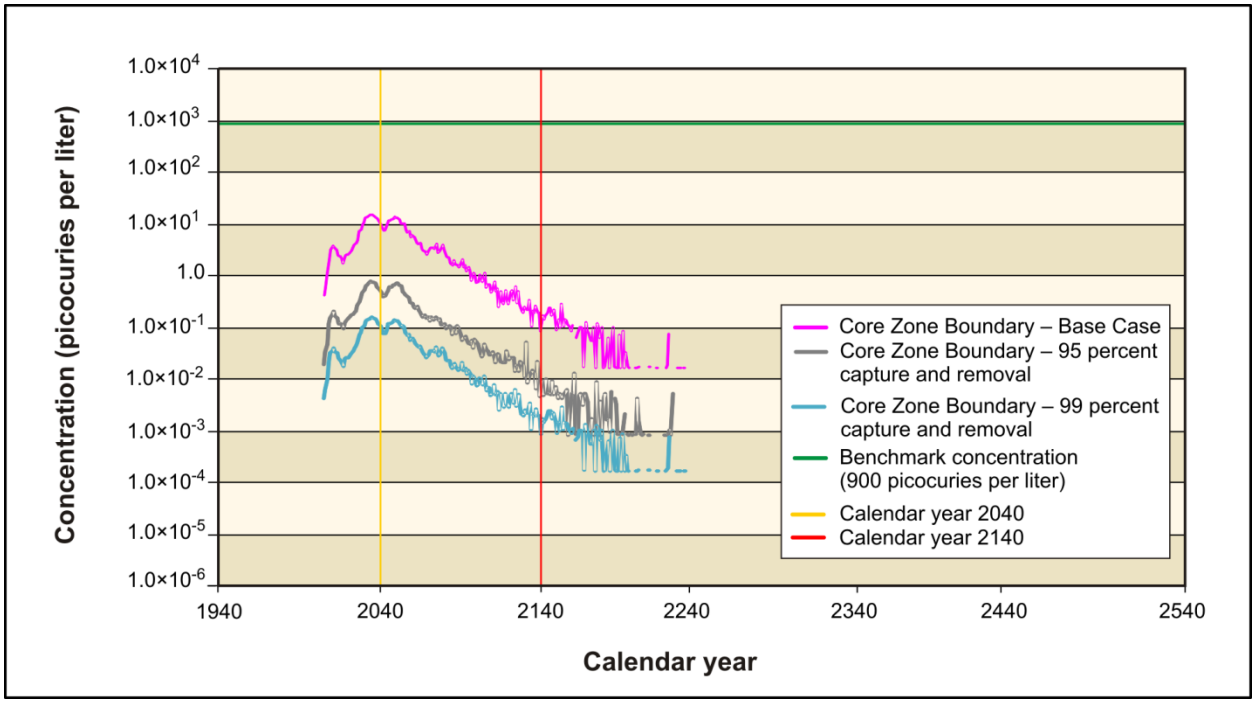


Figure U–134. Technetium-99 Concentration Versus Time at the Core Zone Boundary, Capture-and-Removal Scenario Comparison

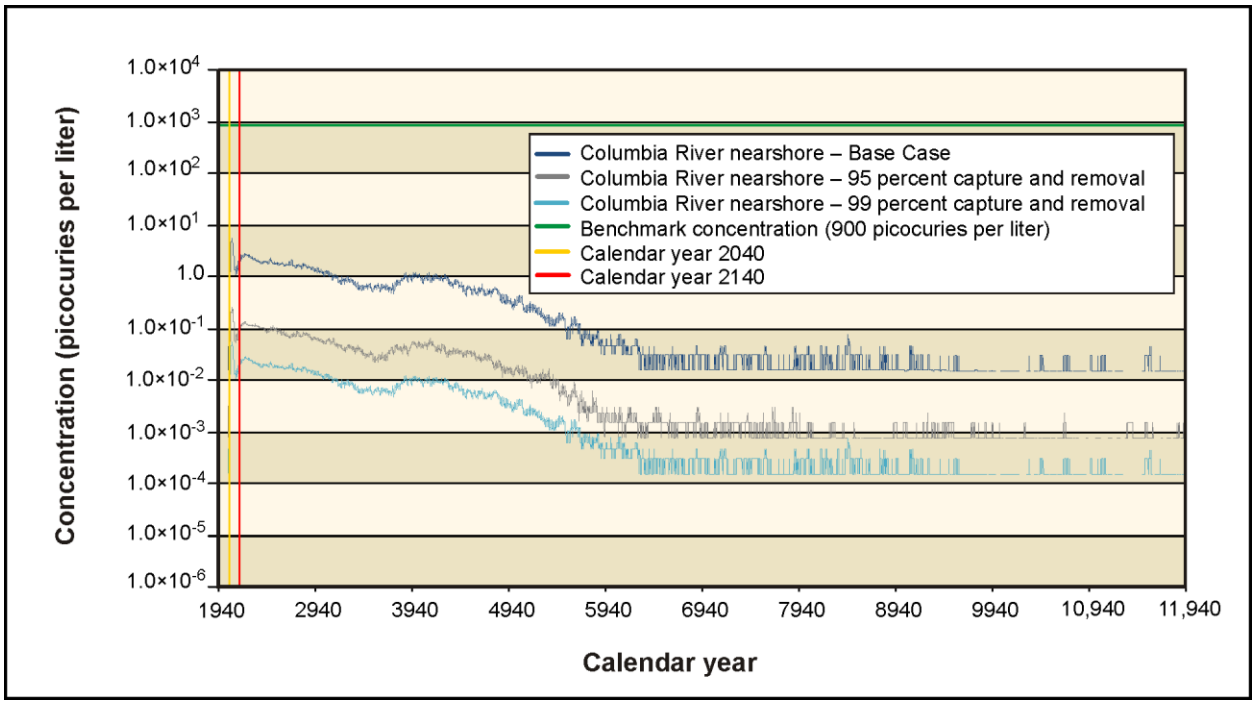


Figure U–135. Technetium-99 Concentration Versus Time at the Columbia River, Capture-and-Removal Scenario Comparison

U.2 HUMAN HEALTH

This section presents the results of the analysis of long-term cumulative impacts on human health. The same methodology used for the alternatives analysis was used to analyze cumulative impacts. A description of this methodology is presented in Appendix Q.

Alternative Combinations Analyzed in This Environmental Impact Statement

Alternative Combination 1: All No Action Alternatives for tank closure, Fast Flux Test Facility (FFTF) decommissioning, and waste management.

Alternative Combination 2: Tank Closure Alternative 2B; FFTF Decommissioning Alternative 2 with the Idaho Option for disposition of remote-handled special components (RH-SCs) and the Hanford Reuse Option for disposition of bulk sodium; and Waste Management Alternative 2 with Disposal Group 1.

Alternative Combination 3: Tank Closure Alternative 6B, Base Case; FFTF Decommissioning Alternative 3 with the Idaho Option for disposition of RH-SCs and the Hanford Reuse Option for disposition of bulk sodium; and Waste Management Alternative 2 with Disposal Group 2.

As described in Chapter 4, Section 4.4, several hundred impact scenarios could result from the potential combinations of the 11 Tank Closure, 3 FFTF Decommissioning, and 3 Waste Management alternatives when factored with their associated option cases and waste disposal groups. For purposes of cumulative impacts analysis, three combinations of alternatives were chosen to represent key points along the range of actions and associated overall impacts that could result from full implementation of the three sets of proposed actions. Alternative Combination 1 represents the potential short-term impacts resulting from minimal DOE action and the greatest long-term impacts with respect to groundwater. Alternative Combination 2 is a midrange case that represents DOE's Preferred Alternatives. Alternative Combination 3 represents a combination that would generally result in maximum potential short-term impacts, but would likely have the lowest long-term impacts on groundwater. (Note: For some resource areas, a combination that includes Tank Closure Alternative 6A, Option Case, would result in maximum impacts.) These three alternative combinations were selected for cumulative impacts analysis in this EIS only to establish overall cumulative impact reference cases for stakeholders and

decisionmakers to consider; selection of these combinations does not preclude the selection and implementation of different combinations of the various alternatives in support of final agency decisions.

The long-term human health impacts of releases of radionuclides are estimated as dose and as the lifetime risk of the incidence of cancer. Potential human health impacts of releases of chemical constituents include both carcinogenic effects and other forms of toxicity. Impacts of carcinogenic chemicals are estimated as lifetime risk of incidence of cancer; noncarcinogenic effects, as Hazard Quotient, the ratio of the long-term intake of a single chemical to intake that produces no observable effect, and as a Hazard Index, the sum of the Hazard Quotients of a group of chemicals.

These four measures of human health impacts were calculated for each year for 10,000 years for applicable receptors at three onsite analysis locations (i.e., Core Zone Boundary, Columbia River nearshore, and Columbia River surface water) and for members of the population downstream from the site. The downstream population is assumed to comprise 5 million individuals for the foreseeable future (DOE 1987), each of whom uses surface water for domestic purposes and irrigation of a garden. This is a large amount of information that must be summarized to allow interpretation of results. The method chosen is to present the dose for the year of maximum dose, risk for the year of maximum risk, and Hazard Index for the year of maximum Hazard Index. This choice is based on the regulation of radiological impacts expressed as dose and the observation that peak risk and peak noncarcinogenic impacts expressed as Hazard Index may occur at times other than that of peak dose.

The three onsite analysis locations are the Core Zone Boundary, the Columbia River nearshore, and the Columbia River. The offsite analysis location is an access point to Columbia River surface water, which could be at various points near the site and at population centers downstream of the site. The total offsite population is assumed to be 5 million people.

Consistent with DOE guidance (DOE Guide 435.1-1) Section IV.p.(2), the potential consequences of loss of administrative or institutional control are considered by estimating the impacts on onsite receptors. Because DOE does not anticipate loss of control of the site, these onsite receptors are considered hypothetical and are applied to develop estimates for past and future periods of time.

Four types of receptors are considered. The first type, a drinking-water well user, uses groundwater as a source of drinking water. The second type, a resident farmer, uses either groundwater or surface water, but not both, for drinking water consumption and irrigation of crops. Garden size and crop yield are adequate to produce approximately 25 percent of average requirements of crops and animal products. The third type, an American Indian resident farmer, also uses either groundwater or surface water, but not both, for drinking water consumption and irrigation of crops. Garden size and crop yield are adequate to produce the entirety of average requirements of crops and animal products. The fourth type, an American Indian hunter-gatherer, is impacted by both groundwater and surface water because he drinks surface water and consumes both wild plant materials, which use groundwater, and game animals, which use surface water.

The significance of dose impacts is evaluated by comparison against the 100-millirem-per-year all-exposure-modes standard specified for protection of the public and the environment in DOE Order 458.1. The level of protection provided for the drinking water pathway is evaluated by comparison against the applicable drinking water standards presented in Chapter 5, Section 5.1.1. The significance of noncarcinogenic chemical health impacts is evaluated by comparison against a guideline value of unity (1) for Hazard Index.

Potential human health impacts of past, present, and reasonably foreseeable future non–*TC & WM EIS* actions are summarized in Tables U–13 through U–15. The key radioactive and chemical drivers of human health risk are listed in the tables. As shown in the tables, the peak radiation dose and risk may have already occurred for all locations and all receptors. As for the peak Hazard Index and

nonradiological lifetime risk, the peak has either already occurred or would occur between CYs 2035 and 3300. For the period of time prior to CY 2000, lifetime radiological risks for the year of peak risk at the Core Zone Boundary and Columbia River locations were high, approaching unity (1). Because the ratio of magnitudes of dose and risk coefficients varies among radionuclides and the dose and risk at a given location may vary in time, the year of peak dose may not correspond to the year of peak radiological risk. Similarly, for chemical constituents, some constituents produce toxic effects, but not incidence of cancer, and some carcinogenic chemicals do not produce other observable health effects. For these reasons, the year of peak hazard index may not correspond to the year of peak nonradiological risk for chemical constituents. Figure U–136 depicts the cumulative radiological risk of incidence of cancer at the Core Zone Boundary and the Columbia River nearshore for the drinking-water well user over time. The DOE cleanup goal is included to aid in the interpretation of the predicted risk. For the period after CY 2000, risks remain high, with values between 1×10^{-3} and 1×10^{-2}. The estimate of radiation dose for the years of peak dose for the offsite population is 228 person-rem per year, approximately 0.01 percent of the average background dose.

Table U–13. Human Health Impacts of Past, Present, and Reasonably Foreseeable Future Non–*TC & WM EIS* Actions at the Core Zone Boundary

Radioactive Constituent	Drinking-Water Well User			Resident Farmer			American Indian Resident Farmer		
	Concentration at Year of Peak Dose (curies per cubic meter)	Dose at Year of Peak Dose (millirem per year)	Radiological Risk at Year of Peak Radiological Risk	Concentration at Year of Peak Dose (curies per cubic meter)	Dose at Year of Peak Dose (millirem per year)	Radiological Risk at Year of Peak Radiological Risk	Concentration at Year of Peak Dose (curies per cubic meter)	Dose at Year of Peak Dose (millirem per year)	Radiological Risk at Year of Peak Radiological Risk
Hydrogen-3 (tritium)	1.12×10^{-1}	1.31×10^{4}	1.25×10^{-1}	1.12×10^{-1}	1.53×10^{4}	1.50×10^{-1}	1.12×10^{-1}	1.82×10^{4}	1.91×10^{-1}
Carbon-14	8.78×10^{-7}	1.41	2.97×10^{-5}	8.78×10^{-7}	2.87	6.79×10^{-5}	8.78×10^{-7}	8.86	2.24×10^{-4}
Strontium-90	1.65×10^{-6}	1.20×10^{2}	2.01×10^{-3}	1.65×10^{-6}	1.58×10^{2}	2.94×10^{-3}	1.65×10^{-6}	2.64×10^{2}	5.63×10^{-3}
Technetium-99	1.74×10^{-7}	3.05×10^{-1}	1.05×10^{-5}	1.74×10^{-7}	7.87×10^{-1}	3.45×10^{-5}	1.74×10^{-7}	1.61	7.55×10^{-5}
Iodine-129	1.86×10^{-9}	5.31×10^{-1}	6.04×10^{-6}	1.86×10^{-9}	6.63×10^{-1}	9.33×10^{-6}	1.86×10^{-9}	8.57×10^{-1}	1.41×10^{-5}
Uranium isotopes (includes U-233, -234, -235, -238)	7.05×10^{-8}	8.74	9.86×10^{-5}	7.05×10^{-8}	9.09	1.06×10^{-4}	7.05×10^{-8}	9.79	1.21×10^{-4}
Neptunium-237	9.04×10^{-10}	2.64×10^{-1}	1.22×10^{-6}	9.04×10^{-10}	2.68×10^{-1}	1.28×10^{-6}	9.04×10^{-10}	3.19×10^{-1}	1.45×10^{-6}
Total	**N/A**	**1.33×10^{4}**	**1.27×10^{-1}**	**N/A**	**1.54×10^{4}**	**1.54×10^{-1}**	**N/A**	**1.85×10^{4}**	**1.97×10^{-1}**
Year of peak impact	1997	1997	1997	1997	1997	1997	1997	1997	1997
Chemical Constituent	**Drinking-Water Well User**			**Resident Farmer**			**American Indian Resident Farmer**		
	Concentration at Year of Peak Hazard Index (grams per cubic meter)	Hazard Index at Year of Peak Hazard Index	Nonradiological Risk at Year of Peak Nonradiological Risk	Concentration at Year of Peak Hazard Index (grams per cubic meter)	Hazard Index at Year of Peak Hazard Index	Nonradiological Risk at Year of Peak Nonradiological Risk	Concentration at Year of Peak Hazard Index (grams per cubic meter)	Hazard Index at Year of Peak Hazard Index	Nonradiological Risk at Year of Peak Nonradiological Risk
1-Butanol	1.32×10^{-2}	3.77×10^{-3}	0.00	0.00	0.00	0.00	1.79×10^{-1}	2.58×10^{-1}	0.00
Carbon tetrachloride	0.00	0.00	9.19×10^{-4}	0.00	0.00	5.80×10^{-3}	5.77×10^{-1}	6.47×10^{2}	2.52×10^{-2}
Chromium	1.33×10^{1}	1.27×10^{2}	0.00	4.13	4.08×10^{1}	2.03×10^{-9}	5.18×10^{-1}	7.70	9.33×10^{-5}
Fluoride	2.63	1.25	0.00	6.14×10^{1}	8.21×10^{1}	0.00	1.38×10^{1}	3.88×10^{1}	0.00
Mercury	0.00	0.00	0.00	0.00	0.00	0.00	1.33×10^{-3}	8.86×10^{-1}	0.00
Nitrate	7.80×10^{2}	1.39×10^{1}	0.00	1.04×10^{3}	1.45×10^{2}	0.00	2.05×10^{2}	6.41×10^{1}	0.00
Total uranium	1.22	1.17×10^{1}	0.00	4.41×10^{-5}	4.28×10^{-4}	0.00	6.35×10^{-2}	6.43×10^{-1}	0.00
Total	**N/A**	**1.53×10^{2}**	**9.19×10^{-4}**	**N/A**	**2.68×10^{2}**	**5.80×10^{-3}**	**N/A**	**7.59×10^{2}**	**2.53×10^{-2}**
Year of peak impact	1959	1959	2035	1947	1947	2035	2035	2035	2035

Note: Concentrations are those reported for groundwater at the specified location. Total concentrations, although reported, are not used in the analysis.

Key: N/A=not applicable; *TC & WM EIS=Tank Closure and Waste Management Environmental Impact Statement for the Hanford Site, Richland, Washington*; U=uranium.

Table U–14. Human Health Impacts of Past, Present, and Reasonably Foreseeable Future Non–*TC & WM EIS* Actions at the Columbia River Nearshore

Radioactive Constituent	Drinking-Water Well User			Resident Farmer			American Indian Resident Farmer		
	Concentration at Year of Peak Dose (curies per cubic meter)	Dose at Year of Peak Dose (millirem per year)	Radiological Risk at Year of Peak Radiological Risk	Concentration at Year of Peak Dose (curies per cubic meter)	Dose at Year of Peak Dose (millirem per year)	Radiological Risk at Year of Peak Radiological Risk	Concentration at Year of Peak Dose (curies per cubic meter)	Dose at Year of Peak Dose (millirem per year)	Radiological Risk at Year of Peak Radiological Risk
Hydrogen-3 (tritium)	4.14×10^{-3}	4.84×10^{2}	3.38×10^{-3}	3.51×10^{-3}	4.77×10^{2}	4.70×10^{-3}	3.51×10^{-3}	5.68×10^{2}	5.96×10^{-3}
Carbon-14	4.77×10^{-9}	7.68×10^{-3}	1.67×10^{-7}	4.70×10^{-9}	1.54×10^{-2}	3.63×10^{-7}	4.70×10^{-9}	4.74×10^{-2}	1.20×10^{-6}
Strontium-90	2.45×10^{-5}	1.79×10^{3}	3.36×10^{-2}	2.48×10^{-5}	2.37×10^{3}	4.41×10^{-2}	2.48×10^{-5}	3.97×10^{3}	8.46×10^{-2}
Technetium-99	6.25×10^{-8}	1.09×10^{-1}	1.28×10^{-5}	6.26×10^{-8}	2.82×10^{-1}	1.24×10^{-5}	6.26×10^{-8}	5.76×10^{-1}	2.71×10^{-5}
Iodine-129	2.55×10^{-9}	7.25×10^{-1}	8.19×10^{-6}	2.53×10^{-9}	9.01×10^{-1}	1.27×10^{-5}	2.53×10^{-9}	1.16	1.92×10^{-5}
Cesium-137	1.07×10^{-6}	3.92×10^{1}	8.81×10^{-4}	1.43×10^{-6}	4.50×10^{3}	1.01×10^{-1}	1.43×10^{-6}	1.36×10^{4}	3.04×10^{-1}
Uranium isotopes (includes U-233, -234, -235, -238)	3.29×10^{-6}	4.07×10^{2}	3.28×10^{-3}	3.58×10^{-6}	4.61×10^{2}	5.40×10^{-3}	3.58×10^{-6}	4.97×10^{2}	6.15×10^{-3}
Neptunium-237	8.41×10^{-10}	2.45×10^{-1}	1.07×10^{-6}	8.52×10^{-10}	2.52×10^{-1}	1.21×10^{-6}	8.52×10^{-10}	3.01×10^{-1}	1.36×10^{-6}
Plutonium isotopes (includes Pu-239, -240)	1.44×10^{-9}	9.75×10^{-1}	6.07×10^{-6}	1.83×10^{-9}	1.30	5.83×10^{-6}	1.83×10^{-9}	1.61	6.76×10^{-6}
Total	**N/A**	**2.72×10^{3}**	**4.12×10^{-2}**	**N/A**	**7.81×10^{3}**	**1.55×10^{-1}**	**N/A**	**1.86×10^{4}**	**4.01×10^{-1}**
Year of peak impact	1986	1986	1991	1985	1985	1985	1985	1985	1985
Chemical Constituent	**Drinking-Water Well User**			**Resident Farmer**			**American Indian Resident Farmer**		
	Concentration at Year of Peak Hazard Index (grams per cubic meter)	**Hazard Index at Year of Peak Hazard Index**	**Nonradiological Risk at Year of Peak Nonradiological Risk**	**Concentration at Year of Peak Hazard Index (grams per cubic meter)**	**Hazard Index at Year of Peak Hazard Index**	**Nonradiological Risk at Year of Peak Nonradiological Risk**	**Concentration at Year of Peak Hazard Index (grams per cubic meter)**	**Hazard Index at Year of Peak Hazard Index**	**Nonradiological Risk at Year of Peak Nonradiological Risk**
Carbon tetrachloride	1.42×10^{-2}	5.79×10^{-1}	3.31×10^{-4}	2.30×10^{-2}	5.93	2.09×10^{-3}	2.30×10^{-2}	2.58×10^{1}	9.10×10^{-3}
Chromium	7.21	6.87×10^{1}	0.00	6.04	5.96×10^{1}	4.34×10^{-9}	6.04	8.97×10^{1}	1.99×10^{-4}
Fluoride	1.31×10^{1}	6.21	0.00	1.29×10^{1}	1.73×10^{1}	0.00	1.29×10^{1}	3.63×10^{1}	0.00
Manganese	6.91×10^{-5}	1.41×10^{-5}	0.00	5.77×10^{-5}	1.53×10^{-5}	0.00	5.77×10^{-5}	6.91×10^{-5}	0.00
Mercury	9.53×10^{-8}	9.08×10^{-6}	0.00	9.17×10^{-8}	2.79×10^{-5}	0.00	9.17×10^{-8}	6.13×10^{-5}	0.00
Nitrate	6.30×10^{2}	1.13×10^{1}	0.00	8.46×10^{2}	1.19×10^{2}	0.00	8.46×10^{2}	2.65×10^{2}	0.00
Total uranium	1.91	1.82×10^{1}	0.00	1.61	1.56×10^{1}	0.00	1.61	1.63×10^{1}	0.00
Total	**N/A**	**1.05×10^{2}**	**3.31×10^{-4}**	**N/A**	**2.17×10^{2}**	**2.09×10^{-3}**	**N/A**	**4.33×10^{2}**	**9.30×10^{-3}**
Year of peak impact	1979	1979	2067	1976	1976	2067	1976	1976	2067

Note: Concentrations are those reported for groundwater at the specified location. Total concentrations, although reported, are not used in the analysis.

Key: N/A=not applicable; Pu=plutonium; *TC & WM EIS=Tank Closure and Waste Management Environmental Impact Statement for the Hanford Site, Richland, Washington*; U=uranium.

Table U–15. Human Health Impacts of Past, Present, and Reasonably Foreseeable Future Non–*TC & WM EIS* Actions at the Columbia River Surface Water

Radioactive Constituent	Resident Farmer			American Indian Resident Farmer			American Indian Hunter-Gatherer		
	Concentration at Year of Peak Dose (curies per cubic meter)	Dose at Year of Peak Dose (millirem per year)	Radiological Risk at Year of Peak Radiological Risk	Concentration at Year of Peak Dose (curies per cubic meter)	Dose at Year of Peak Dose (millirem per year)	Radiological Risk at Year of Peak Radiological Risk	Concentration at Year of Peak Dose (curies per cubic meter)	Dose at Year of Peak Dose (millirem per year)	Radiological Risk at Year of Peak Radiological Risk
Hydrogen-3 (tritium)	2.40×10^{-8}	3.26×10^{-3}	3.22×10^{-8}	2.40×10^{-8}	3.98×10^{-3}	4.20×10^{-8}	3.51×10^{-3}	2.23×10^{1}	4.11×10^{-4}
Carbon-14	0.00	0.00	0.00	0.00	0.00	0.00	4.70×10^{-9}	3.10×10^{-2}	8.12×10^{-7}
Strontium-90	3.37×10^{-10}	3.22×10^{-2}	6.03×10^{-7}	3.37×10^{-10}	4.85×10^{-1}	1.01×10^{-5}	2.48×10^{-5}	1.77×10^{3}	4.60×10^{-2}
Technetium-99	5.02×10^{-12}	2.27×10^{-5}	9.95×10^{-10}	5.02×10^{-12}	5.23×10^{-5}	2.48×10^{-9}	6.26×10^{-8}	1.95×10^{-3}	1.04×10^{-7}
Iodine-129	1.07×10^{-14}	3.82×10^{-6}	5.38×10^{-11}	1.07×10^{-14}	5.83×10^{-5}	1.40×10^{-9}	2.53×10^{-9}	8.00×10^{-3}	1.96×10^{-7}
Cesium-137	2.59×10^{-12}	8.15×10^{-3}	1.83×10^{-7}	2.59×10^{-12}	4.01×10^{-2}	9.00×10^{-7}	1.43×10^{-6}	1.15×10^{4}	2.59×10^{-1}
Uranium isotopes (includes U-233, -234, -235, -238)	1.52×10^{-11}	1.96×10^{-3}	2.30×10^{-8}	1.52×10^{-11}	5.44×10^{-3}	7.69×10^{-8}	3.58×10^{-6}	4.44×10^{1}	9.69×10^{-4}
Neptunium-237	6.67×10^{-15}	1.98×10^{-6}	9.47×10^{-12}	6.67×10^{-15}	1.94×10^{-5}	1.17×10^{-10}	8.52×10^{-10}	4.94×10^{-2}	1.95×10^{-7}
Plutonium isotopes (includes Pu-239, -240)	3.66×10^{-15}	2.64×10^{-6}	1.19×10^{-11}	3.66×10^{-15}	4.13×10^{-4}	2.31×10^{-9}	1.83×10^{-9}	3.63×10^{-1}	1.35×10^{-6}
Total	**N/A**	**4.56×10^{-2}**	**8.42×10^{-7}**	**N/A**	**5.35×10^{-1}**	**1.11×10^{-5}**	**N/A**	**1.33×10^{4}**	**3.06×10^{-1}**
Year of peak impact	1985	1985	1985	1985	1985	1985	1985	1985	1985
	Resident Farmer			**American Indian Resident Farmer**			**American Indian Hunter-Gatherer**		
Chemical Constituent	**Concentration at Year of Peak Hazard Index (grams per cubic meter)**	**Hazard Index at Year of Peak Hazard Index**	**Nonradiological Risk at Year of Peak Nonradiological Risk**	**Concentration at Year of Peak Hazard Index (grams per cubic meter)**	**Hazard Index at Year of Peak Hazard Index**	**Nonradiological Risk at Year of Peak Nonradiological Risk**	**Concentration at Year of Peak Hazard Index (grams per cubic meter)**	**Hazard Index at Year of Peak Hazard Index**	**Nonradiological Risk at Year of Peak Nonradiological Risk**
Carbon tetrachloride	2.10×10^{-7}	5.40×10^{-5}	2.46×10^{-8}	2.10×10^{-7}	2.43×10^{-4}	2.69×10^{-9}	2.08×10^{-1}	2.25×10^{2}	8.76×10^{-3}
Chromium	8.66×10^{-5}	8.56×10^{-4}	9.13×10^{-15}	8.66×10^{-5}	1.40×10^{-3}	7.99×10^{-11}	1.10	4.86	1.99×10^{-4}
Fluoride	3.47×10^{-5}	4.65×10^{-5}	0.00	3.47×10^{-5}	1.03×10^{-4}	0.00	7.61	1.11	0.00
Hydrazine/hydrazine sulfate	0.00	0.00	0.00	0.00	0.00	4.02×10^{-7}	0.00	0.00	0.00
Manganese	0.00	0.00	0.00	0.00	0.00	0.00	6.47×10^{-5}	6.36×10^{-5}	0.00
Mercury	0.00	0.00	0.00	0.00	0.00	0.00	2.21×10^{-7}	8.43×10^{-6}	0.00
Nitrate	4.78×10^{-3}	7.24×10^{-4}	0.00	4.78×10^{-3}	4.51×10^{-1}	0.00	1.79×10^{2}	6.98	0.00
Total uranium	1.40×10^{-5}	1.36×10^{-4}	0.00	1.40×10^{-5}	1.89×10^{-4}	0.00	1.65×10^{-1}	7.31×10^{-2}	0.00
Trichloroethylene	0.00	0.00	0.00	0.00	0.00	5.23×10^{-10}	0.00	0.00	0.00
Total	**N/A**	**1.82×10^{-3}**	**2.46×10^{-8}**	**N/A**	**4.52×10^{-1}**	**4.06×10^{-7}**	**N/A**	**2.38×10^{2}**	**8.96×10^{-3}**
Year of peak impact	1962	1962	2146	1962	1962	3272	2067	2067	2067

Note: Concentrations are those reported for groundwater at the specified location. Total concentrations, although reported, are not used in the analysis.

Key: N/A=not applicable; Pu=plutonium; *TC & WM EIS=Tank Closure and Waste Management Environmental Impact Statement for the Hanford Site, Richland, Washington*; U=uranium.

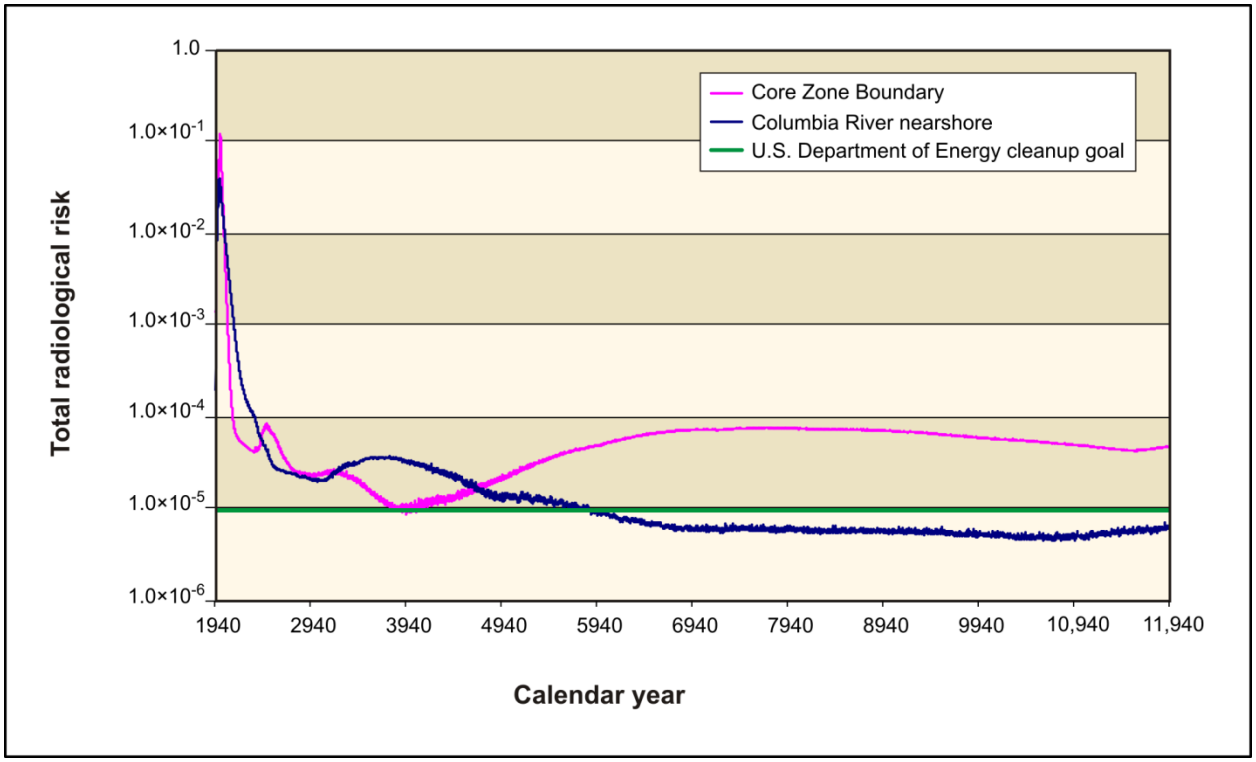


Figure U–136. Cumulative Radiological Lifetime Risk of Incidence of Cancer (Non–*TC & WM EIS* Actions) for the Drinking-Water Well User Over Time, Core Zone Boundary and Columbia River Nearshore

Potential human health impacts of Alternative Combination 1, in conjunction with the past, present, and reasonably foreseeable future (non–*TC & WM EIS*) actions discussed earlier, are summarized in Tables U–16 through U–18. The key radiological and chemical risk and hazard drivers are listed in the tables. As reflected in these tables, the impacts of Alternative Combination 1 are dominated by the impacts of non–*TC & WM EIS* sources. Figure U–137 depicts the cumulative radiological risk of incidence of cancer at the Core Zone Boundary and the Columbia River nearshore for the drinking-water well user over time. The DOE cleanup goal is included to aid in the interpretation of the predicted risk. The estimate of radiation dose for the year of peak dose for the offsite population is 229 person-rem per year, approximately 0.01 percent of the average background dose.

Table U–16. Alternative Combination 1 Cumulative Human Health Impacts at the Core Zone Boundary

Radioactive Constituent	Drinking-Water Well User			Resident Farmer			American Indian Resident Farmer		
	Concentration at Year of Peak Dose (curies per cubic meter)	Dose at Year of Peak Dose (millirem per year)	Radiological Risk at Year of Peak Radiological Risk	Concentration at Year of Peak Dose (curies per cubic meter)	Dose at Year of Peak Dose (millirem per year)	Radiological Risk at Year of Peak Radiological Risk	Concentration at Year of Peak Dose (curies per cubic meter)	Dose at Year of Peak Dose (millirem per year)	Radiological Risk at Year of Peak Radiological Risk
Hydrogen-3 (tritium)	1.12×10^{-1}	1.31×10^{4}	1.25×10^{-1}	1.12×10^{-1}	1.53×10^{4}	1.50×10^{-1}	1.12×10^{-1}	1.82×10^{4}	1.91×10^{-1}
Carbon-14	8.78×10^{-7}	1.41	2.97×10^{-5}	8.78×10^{-7}	2.87	6.79×10^{-5}	8.78×10^{-7}	8.86	2.24×10^{-4}
Strontium-90	1.65×10^{-6}	1.20×10^{2}	2.01×10^{-3}	1.65×10^{-6}	1.58×10^{2}	2.94×10^{-3}	1.65×10^{-6}	2.64×10^{2}	5.63×10^{-3}
Technetium-99	7.05×10^{-7}	1.23	4.24×10^{-5}	7.05×10^{-7}	3.18	1.40×10^{-4}	7.05×10^{-7}	6.49	3.05×10^{-4}
Iodine-129	2.02×10^{-9}	5.75×10^{-1}	6.54×10^{-6}	2.02×10^{-9}	7.18×10^{-1}	1.01×10^{-5}	2.02×10^{-9}	9.28×10^{-1}	1.53×10^{-5}
Uranium isotopes (includes U-233, -234, -235, -238)	7.05×10^{-8}	8.74	9.86×10^{-5}	7.05×10^{-8}	9.09	1.06×10^{-4}	7.05×10^{-8}	9.79	1.21×10^{-4}
Neptunium-237	9.04×10^{-10}	2.64×10^{-1}	1.22×10^{-6}	9.04×10^{-10}	2.68×10^{-1}	1.28×10^{-6}	9.04×10^{-10}	3.19×10^{-1}	1.45×10^{-6}
Total	**N/A**	**1.33×10^{4}**	**1.27×10^{-1}**	**N/A**	**1.54×10^{4}**	**1.54×10^{-1}**	**N/A**	**1.85×10^{4}**	**1.97×10^{-1}**
Year of peak impact	1997	1997	1997	1997	1997	1997	1997	1997	1997
Chemical Constituent	**Drinking-Water Well User**			**Resident Farmer**			**American Indian Resident Farmer**		
	Concentration at Year of Peak Hazard Index (grams per cubic meter)	**Hazard Index at Year of Peak Hazard Index**	**Nonradiological Risk at Year of Peak Nonradiological Risk**	**Concentration at Year of Peak Hazard Index (grams per cubic meter)**	**Hazard Index at Year of Peak Hazard Index**	**Nonradiological Risk at Year of Peak Nonradiological Risk**	**Concentration at Year of Peak Hazard Index (grams per cubic meter)**	**Hazard Index at Year of Peak Hazard Index**	**Nonradiological Risk at Year of Peak Nonradiological Risk**
1-Butanol	1.32×10^{-2}	3.77×10^{-3}	0.00	1.32×10^{-2}	6.84×10^{-3}	0.00	3.89×10^{-2}	5.62×10^{-2}	0.00
Carbon tetrachloride	0.00	0.00	9.19×10^{-4}	0.00	0.00	5.80×10^{-3}	0.00	0.00	2.52×10^{-2}
Chromium	1.33×10^{1}	1.27×10^{2}	0.00	1.33×10^{1}	1.32×10^{2}	2.05×10^{-9}	1.18×10^{1}	1.75×10^{2}	9.38×10^{-5}
Fluoride	2.63	1.25	0.00	2.63	3.52	0.00	2.97	8.33	0.00
Nitrate	1.81×10^{3}	3.23×10^{1}	0.00	1.81×10^{3}	2.54×10^{2}	0.00	1.90×10^{3}	5.96×10^{2}	0.00
Total uranium	1.22	1.17×10^{1}	0.00	1.22	1.19×10^{1}	0.00	1.21	1.22×10^{1}	0.00
Total	**N/A**	**1.72×10^{2}**	**9.19×10^{-4}**	**N/A**	**4.01×10^{2}**	**5.80×10^{-3}**	**N/A**	**7.91×10^{2}**	**2.53×10^{-2}**
Year of peak impact	1959	1959	2035	1959	1959	2035	1960	1960	2035

Note: Concentrations are those reported for groundwater at the specified location. Total concentrations, although reported, are not used in the analysis.
Key: N/A=not applicable; U=uranium.

Table U–17. Alternative Combination 1 Cumulative Human Health Impacts at the Columbia River Nearshore

Radioactive Constituent	Drinking-Water Well User			Resident Farmer			American Indian Resident Farmer		
	Concentration at Year of Peak Dose (curies per cubic meter)	Dose at Year of Peak Dose (millirem per year)	Radiological Risk at Year of Peak Radiological Risk	Concentration at Year of Peak Dose (curies per cubic meter)	Dose at Year of Peak Dose (millirem per year)	Radiological Risk at Year of Peak Radiological Risk	Concentration at Year of Peak Dose (curies per cubic meter)	Dose at Year of Peak Dose (millirem per year)	Radiological Risk at Year of Peak Radiological Risk
Hydrogen-3 (tritium)	4.14×10^{-3}	4.84×10^{2}	3.38×10^{-3}	3.51×10^{-3}	4.77×10^{2}	4.70×10^{-3}	3.51×10^{-3}	5.68×10^{2}	5.96×10^{-3}
Carbon-14	4.77×10^{-9}	7.68×10^{-3}	1.67×10^{-7}	4.70×10^{-9}	1.54×10^{-2}	3.63×10^{-7}	4.70×10^{-9}	4.74×10^{-2}	1.20×10^{-6}
Strontium-90	2.45×10^{-5}	1.79×10^{3}	3.36×10^{-2}	2.48×10^{-5}	2.37×10^{3}	4.41×10^{-2}	2.48×10^{-5}	3.97×10^{3}	8.46×10^{-2}
Technetium-99	2.92×10^{-7}	5.12×10^{-1}	1.28×10^{-5}	2.52×10^{-7}	1.14	4.99×10^{-5}	2.52×10^{-7}	2.32	1.09×10^{-4}
Iodine-129	2.55×10^{-9}	7.25×10^{-1}	8.19×10^{-6}	2.53×10^{-9}	9.01×10^{-1}	1.27×10^{-5}	2.53×10^{-9}	1.16	1.92×10^{-5}
Cesium-137	1.07×10^{-6}	3.92×10^{1}	8.81×10^{-4}	1.43×10^{-6}	4.50×10^{3}	1.01×10^{-1}	1.43×10^{-6}	1.36×10^{4}	3.04×10^{-1}
Uranium isotopes (includes U-233, -234, -235, -238)	3.29×10^{-6}	4.07×10^{2}	3.28×10^{-3}	3.58×10^{-6}	4.61×10^{2}	5.40×10^{-3}	3.58×10^{-6}	4.97×10^{2}	6.15×10^{-3}
Neptunium-237	8.41×10^{-10}	2.45×10^{-1}	1.07×10^{-6}	8.52×10^{-10}	2.52×10^{-1}	1.21×10^{-6}	8.52×10^{-10}	3.01×10^{-1}	1.36×10^{-6}
Plutonium isotopes (includes Pu-239, -240)	1.44×10^{-9}	9.75×10^{-1}	6.07×10^{-6}	1.83×10^{-9}	1.30	5.83×10^{-6}	1.83×10^{-9}	1.61	6.76×10^{-6}
Total	**N/A**	**2.72×10^{3}**	**4.12×10^{-2}**	**N/A**	**7.81×10^{3}**	**1.55×10^{-1}**	**N/A**	**1.86×10^{4}**	**4.01×10^{-1}**
Year of peak impact	1986	1986	1991	1985	1985	1985	1985	1985	1985

Chemical Constituent	Drinking-Water Well User			Resident Farmer			American Indian Resident Farmer		
	Concentration at Year of Peak Hazard Index (grams per cubic meter)	Hazard Index at Year of Peak Hazard Index	Nonradiological Risk at Year of Peak Nonradiological Risk	Concentration at Year of Peak Hazard Index (grams per cubic meter)	Hazard Index at Year of Peak Hazard Index	Nonradiological Risk at Year of Peak Nonradiological Risk	Concentration at Year of Peak Hazard Index (grams per cubic meter)	Hazard Index at Year of Peak Hazard Index	Nonradiological Risk at Year of Peak Nonradiological Risk
Carbon tetrachloride	1.42×10^{-2}	5.79×10^{-1}	3.31×10^{-4}	2.30×10^{-2}	5.93	2.09×10^{-3}	2.30×10^{-2}	2.58×10^{1}	9.10×10^{-3}
Chromium	7.21	6.87×10^{1}	0.00	6.04	5.96×10^{1}	4.34×10^{-9}	6.04	8.97×10^{1}	1.99×10^{-4}
Fluoride	1.31×10^{1}	6.21	0.00	1.29×10^{1}	1.73×10^{1}	0.00	1.29×10^{1}	3.63×10^{1}	0.00
Manganese	6.91×10^{-5}	1.41×10^{-5}	0.00	5.77×10^{-5}	1.53×10^{-5}	0.00	5.77×10^{-5}	6.91×10^{-5}	0.00
Mercury	9.53×10^{-8}	9.08×10^{-6}	0.00	9.17×10^{-8}	2.79×10^{-5}	0.00	9.17×10^{-8}	6.13×10^{-5}	0.00
Nitrate	6.30×10^{2}	1.13×10^{1}	0.00	8.46×10^{2}	1.19×10^{2}	0.00	8.46×10^{2}	2.65×10^{2}	0.00
Total uranium	1.91	1.82×10^{1}	0.00	1.61	1.56×10^{1}	0.00	1.61	1.63×10^{1}	0.00
Total	**N/A**	**1.05×10^{2}**	**3.31×10^{-4}**	**N/A**	**2.17×10^{2}**	**2.09×10^{-3}**	**N/A**	**4.33×10^{2}**	**9.30×10^{-3}**
Year of peak impact	1979	1979	2067	1976	1976	2067	1976	1976	2067

Note: Concentrations are those reported for groundwater at the specified location. Total concentrations, although reported, are not used in the analysis.
Key: N/A=not applicable; Pu=plutonium; U=uranium.

Table U–18. Alternative Combination 1 Cumulative Human Health Impacts at the Columbia River Surface Water

Radioactive Constituent	Resident Farmer			American Indian Resident Farmer			American Indian Hunter-Gatherer		
	Concentration at Year of Peak Dose (curies per cubic meter)	Dose at Year of Peak Dose (millirem per year)	Radiological Risk at Year of Peak Radiological Risk	Concentration at Year of Peak Dose (curies per cubic meter)	Dose at Year of Peak Dose (millirem per year)	Radiological Risk at Year of Peak Radiological Risk	Concentration at Year of Peak Dose (curies per cubic meter)	Dose at Year of Peak Dose (millirem per year)	Radiological Risk at Year of Peak Radiological Risk
Hydrogen-3 (tritium)	2.40×10^{-8}	3.26×10^{-3}	3.22×10^{-8}	2.40×10^{-8}	3.98×10^{-3}	4.20×10^{-8}	3.51×10^{-3}	2.23×10^{1}	4.11×10^{-4}
Carbon-14	0.00	0.00	0.00	0.00	0.00	0.00	4.70×10^{-9}	3.10×10^{-2}	8.12×10^{-7}
Strontium-90	3.37×10^{-10}	3.22×10^{-2}	6.03×10^{-7}	3.37×10^{-10}	4.85×10^{-1}	1.01×10^{-5}	2.48×10^{-5}	1.77×10^{3}	4.60×10^{-2}
Technetium-99	5.02×10^{-12}	2.27×10^{-5}	9.95×10^{-10}	5.02×10^{-12}	5.23×10^{-5}	2.48×10^{-9}	2.52×10^{-7}	7.60×10^{-3}	4.06×10^{-7}
Iodine-129	1.07×10^{-14}	3.82×10^{-6}	5.38×10^{-11}	1.07×10^{-14}	5.83×10^{-5}	1.40×10^{-9}	2.53×10^{-9}	8.00×10^{-3}	1.96×10^{-7}
Cesium-137	2.59×10^{-12}	8.15×10^{-3}	1.83×10^{-7}	2.59×10^{-12}	4.01×10^{-2}	9.00×10^{-7}	1.43×10^{-6}	1.15×10^{4}	2.59×10^{-1}
Uranium isotopes (includes U-233, -234, -235, -238)	1.52×10^{-11}	1.96×10^{-3}	2.30×10^{-8}	1.52×10^{-11}	5.44×10^{-3}	7.69×10^{-8}	3.58×10^{-6}	4.44×10^{1}	9.69×10^{-4}
Neptunium-237	6.67×10^{-15}	1.98×10^{-6}	9.47×10^{-12}	6.67×10^{-15}	1.94×10^{-5}	1.17×10^{-10}	8.52×10^{-10}	4.94×10^{-2}	1.95×10^{-7}
Plutonium isotopes (includes Pu-239, -240)	3.66×10^{-15}	2.64×10^{-6}	1.19×10^{-11}	3.66×10^{-15}	4.13×10^{-4}	2.31×10^{-9}	1.83×10^{-9}	3.63×10^{-1}	1.35×10^{-6}
Total	**N/A**	**4.56×10^{-2}**	**8.42×10^{-7}**	**N/A**	**5.35×10^{-1}**	**1.11×10^{-5}**	**N/A**	**1.33×10^{4}**	**3.06×10^{-1}**
Year of peak impact	1985	1985	1985	1985	1985	1985	1985	1985	1985
Chemical Constituent	**Resident Farmer**			**American Indian Resident Farmer**			**American Indian Hunter-Gatherer**		
	Concentration at Year of Peak Hazard Index (grams per cubic meter)	**Hazard Index at Year of Peak Hazard Index**	**Nonradiological Risk at Year of Peak Nonradiological Risk**	**Concentration at Year of Peak Hazard Index (grams per cubic meter)**	**Hazard Index at Year of Peak Hazard Index**	**Nonradiological Risk at Year of Peak Nonradiological Risk**	**Concentration at Year of Peak Hazard Index (grams per cubic meter)**	**Hazard Index at Year of Peak Hazard Index**	**Nonradiological Risk at Year of Peak Nonradiological Risk**
Carbon tetrachloride	2.10×10^{-7}	5.40×10^{-5}	2.46×10^{-8}	2.10×10^{-7}	2.43×10^{-4}	2.69×10^{-9}	2.08×10^{-1}	2.25×10^{2}	8.76×10^{-3}
Chromium	8.66×10^{-5}	8.56×10^{-4}	9.13×10^{-15}	8.66×10^{-5}	1.40×10^{-3}	7.99×10^{-11}	1.10	4.86	1.99×10^{-4}
Fluoride	3.47×10^{-5}	4.65×10^{-5}	0.00	3.47×10^{-5}	1.03×10^{-4}	0.00	7.61	1.11	0.00
Hydrazine/hydrazine sulfate	0.00	0.00	0.00	0.00	0.00	4.02×10^{-7}	0.00	0.00	0.00
Manganese	0.00	0.00	0.00	0.00	0.00	0.00	6.47×10^{-5}	6.36×10^{-5}	0.00
Mercury	0.00	0.00	0.00	0.00	0.00	0.00	2.21×10^{-7}	8.43×10^{-6}	0.00
Nitrate	4.78×10^{-3}	7.24×10^{-4}	0.00	4.78×10^{-3}	4.51×10^{-1}	0.00	1.79×10^{2}	6.98	0.00
Total uranium	1.40×10^{-5}	1.36×10^{-4}	0.00	1.40×10^{-5}	1.89×10^{-4}	0.00	1.65×10^{-1}	7.31×10^{-2}	0.00
Trichloroethylene	0.00	0.00	0.00	0.00	0.00	5.23×10^{-10}	0.00	0.00	0.00
Total	**N/A**	**1.82×10^{-3}**	**2.46×10^{-8}**	**N/A**	**4.52×10^{-1}**	**4.06×10^{-7}**	**N/A**	**2.38×10^{2}**	**8.96×10^{-3}**
Year of peak impact	1962	1962	2146	1962	1962	3272	2067	2067	2067

Note: Concentrations are those reported for groundwater at the specified location. Total concentrations, although reported, are not used in the analysis.
Key: N/A=not applicable; Pu=plutonium; U=uranium.

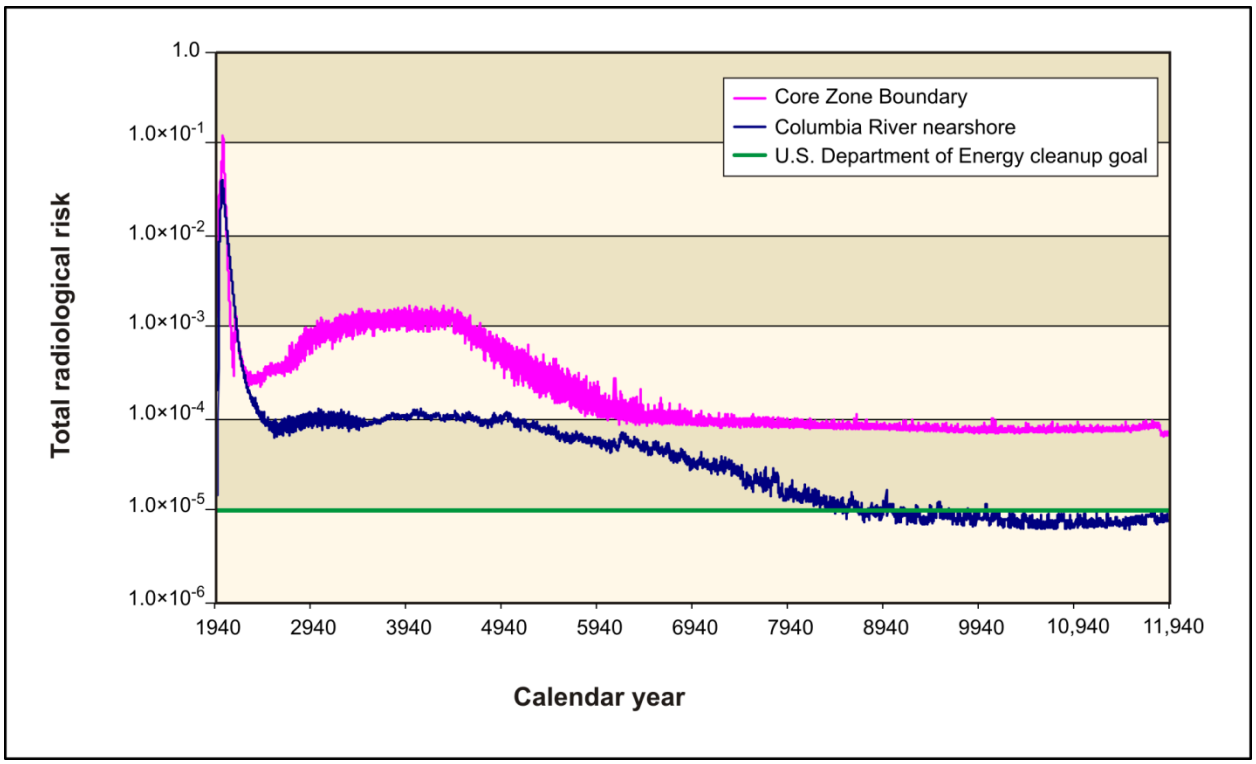


Figure U–137. Alternative Combination 1 Cumulative Radiological Lifetime Risk of Incidence of Cancer for the Drinking-Water Well User Over Time, Core Zone Boundary and Columbia River Nearshore

Potential human health impacts of Alternative Combination 2, in conjunction with the past, present, and reasonably foreseeable future (non–*TC & WM EIS*) actions discussed above, are summarized in Tables U–19 through U–21. The key radiological and chemical risk and hazard drivers are listed in the tables. As indicated in these tables, the impacts of Alternative Combination 2 are dominated by the impacts of non–*TC & WM EIS* sources. Figure U–138 depicts the cumulative radiological risk of incidence of cancer at the Core Zone Boundary and the Columbia River nearshore for the drinking-water well user over time. The DOE cleanup goal is included to aid in the interpretation of the predicted risk. The estimate of radiation dose for the year of peak dose for the offsite population is 229 person-rem per year, approximately 0.01 percent of the average background dose.

Table U–19. Alternative Combination 2 Cumulative Human Health Impacts at the Core Zone Boundary

Radioactive Constituent	Drinking-Water Well User			Resident Farmer			American Indian Resident Farmer		
	Concentration at Year of Peak Dose (curies per cubic meter)	Dose at Year of Peak Dose (millirem per year)	Radiological Risk at Year of Peak Radiological Risk	Concentration at Year of Peak Dose (curies per cubic meter)	Dose at Year of Peak Dose (millirem per year)	Radiological Risk at Year of Peak Radiological Risk	Concentration at Year of Peak Dose (curies per cubic meter)	Dose at Year of Peak Dose (millirem per year)	Radiological Risk at Year of Peak Radiological Risk
Hydrogen-3 (tritium)	1.12×10^{-1}	1.31×10^{4}	1.25×10^{-1}	1.12×10^{-1}	1.53×10^{4}	1.50×10^{-1}	1.12×10^{-1}	1.82×10^{4}	1.91×10^{-1}
Carbon-14	8.78×10^{-7}	1.41	2.97×10^{-5}	8.78×10^{-7}	2.87	6.79×10^{-5}	8.78×10^{-7}	8.86	2.24×10^{-4}
Strontium-90	1.65×10^{-6}	1.20×10^{2}	2.01×10^{-3}	1.65×10^{-6}	1.58×10^{2}	2.94×10^{-3}	1.65×10^{-6}	2.64×10^{2}	5.63×10^{-3}
Technetium-99	6.03×10^{-7}	1.05	3.63×10^{-5}	6.03×10^{-7}	2.72	1.19×10^{-4}	6.03×10^{-7}	5.55	2.61×10^{-4}
Iodine-129	2.13×10^{-9}	6.07×10^{-1}	6.90×10^{-6}	2.13×10^{-9}	7.58×10^{-1}	1.07×10^{-5}	2.13×10^{-9}	9.80×10^{-1}	1.61×10^{-5}
Uranium isotopes (includes U-233, -234, -235, -238)	7.05×10^{-8}	8.74	9.86×10^{-5}	7.05×10^{-8}	9.09	1.06×10^{-4}	7.05×10^{-8}	9.79	1.21×10^{-4}
Neptunium-237	9.04×10^{-10}	2.64×10^{-1}	1.22×10^{-6}	9.04×10^{-10}	2.68×10^{-1}	1.28×10^{-6}	9.04×10^{-10}	3.19×10^{-1}	1.45×10^{-6}
Total	**N/A**	**1.33×10^{4}**	**1.27×10^{-1}**	**N/A**	**1.54×10^{4}**	**1.54×10^{-1}**	**N/A**	**1.85×10^{4}**	**1.97×10^{-1}**
Year of peak impact	1997	1997	1997	1997	1997	1997	1997	1997	1997
Chemical Constituent	**Drinking-Water Well User**			**Resident Farmer**			**American Indian Resident Farmer**		
	Concentration at Year of Peak Hazard Index (grams per cubic meter)	Hazard Index at Year of Peak Hazard Index	Nonradiological Risk at Year of Peak Nonradiological Risk	Concentration at Year of Peak Hazard Index (grams per cubic meter)	Hazard Index at Year of Peak Hazard Index	Nonradiological Risk at Year of Peak Nonradiological Risk	Concentration at Year of Peak Hazard Index (grams per cubic meter)	Hazard Index at Year of Peak Hazard Index	Nonradiological Risk at Year of Peak Nonradiological Risk
1-Butanol	1.32×10^{-2}	3.77×10^{-3}	0.00	1.32×10^{-2}	6.84×10^{-3}	0.00	1.32×10^{-2}	1.91×10^{-2}	0.00
Carbon tetrachloride	0.00	0.00	9.19×10^{-4}	0.00	0.00	5.80×10^{-3}	0.00	0.00	2.52×10^{-2}
Chromium	1.34×10^{1}	1.27×10^{2}	0.00	1.34×10^{1}	1.32×10^{2}	2.05×10^{-9}	1.34×10^{1}	1.98×10^{2}	9.40×10^{-5}
Fluoride	2.63	1.25	0.00	2.63	3.52	0.00	2.63	7.38	0.00
Nitrate	1.81×10^{3}	3.23×10^{1}	0.00	1.81×10^{3}	2.54×10^{2}	0.00	1.81×10^{3}	5.66×10^{2}	0.00
Total uranium	1.22	1.17×10^{1}	0.00	1.22	1.19×10^{1}	0.00	1.22	1.24×10^{1}	0.00
Total	**N/A**	**1.72×10^{2}**	**9.19×10^{-4}**	**N/A**	**4.01×10^{2}**	**5.80×10^{-3}**	**N/A**	**7.84×10^{2}**	**2.53×10^{-2}**
Year of peak impact	1959	1959	2035	1959	1959	2035	1959	1959	2035

Note: Concentrations are those reported for groundwater at the specified location. Total concentrations, although reported, are not used in the analysis.
Key: N/A=not applicable; U=uranium.

Table U–20. Alternative Combination 2 Cumulative Human Health Impacts at the Columbia River Nearshore

Radioactive Constituent	Drinking-Water Well User			Resident Farmer			American Indian Resident Farmer		
	Concentration at Year of Peak Dose (curies per cubic meter)	Dose at Year of Peak Dose (millirem per year)	Radiological Risk at Year of Peak Radiological Risk	Concentration at Year of Peak Dose (curies per cubic meter)	Dose at Year of Peak Dose (millirem per year)	Radiological Risk at Year of Peak Radiological Risk	Concentration at Year of Peak Dose (curies per cubic meter)	Dose at Year of Peak Dose (millirem per year)	Radiological Risk at Year of Peak Radiological Risk
Hydrogen-3 (tritium)	4.14×10^{-3}	4.84×10^{2}	3.38×10^{-3}	3.51×10^{-3}	4.77×10^{2}	4.70×10^{-3}	3.51×10^{-3}	5.68×10^{2}	5.96×10^{-3}
Carbon-14	4.77×10^{-9}	7.68×10^{-3}	1.67×10^{-7}	4.70×10^{-9}	1.54×10^{-2}	3.63×10^{-7}	4.70×10^{-9}	4.74×10^{-2}	1.20×10^{-6}
Strontium-90	2.45×10^{-5}	1.79×10^{3}	3.36×10^{-2}	2.48×10^{-5}	2.37×10^{3}	4.41×10^{-2}	2.48×10^{-5}	3.97×10^{3}	8.46×10^{-2}
Technetium-99	2.85×10^{-7}	4.98×10^{-1}	1.28×10^{-5}	2.61×10^{-7}	1.18	5.18×10^{-5}	2.61×10^{-7}	2.41	1.13×10^{-4}
Iodine-129	2.55×10^{-9}	7.25×10^{-1}	8.19×10^{-6}	2.53×10^{-9}	9.01×10^{-1}	1.27×10^{-5}	2.53×10^{-9}	1.16	1.92×10^{-5}
Cesium-137	1.07×10^{-6}	3.92×10^{1}	8.81×10^{-4}	1.43×10^{-6}	4.50×10^{3}	1.01×10^{-1}	1.43×10^{-6}	1.36×10^{4}	3.04×10^{-1}
Uranium isotopes (includes U-233, -234, -235, -238)	3.29×10^{-6}	4.07×10^{2}	3.28×10^{-3}	3.58×10^{-6}	4.61×10^{2}	5.40×10^{-3}	3.58×10^{-6}	4.97×10^{2}	6.15×10^{-3}
Neptunium-237	8.41×10^{-10}	2.45×10^{-1}	1.07×10^{-6}	8.52×10^{-10}	2.52×10^{-1}	1.21×10^{-6}	8.52×10^{-10}	3.01×10^{-1}	1.36×10^{-6}
Plutonium isotopes (includes Pu-239, -240)	1.44×10^{-9}	9.75×10^{-1}	6.07×10^{-6}	1.83×10^{-9}	1.30	5.83×10^{-6}	1.83×10^{-9}	1.61	6.76×10^{-6}
Total	**N/A**	**2.72×10^{3}**	**4.12×10^{-2}**	**N/A**	**7.81×10^{3}**	**1.55×10^{-1}**	**N/A**	**1.86×10^{4}**	**4.01×10^{-1}**
Year of peak impact	1986	1986	1991	1985	1985	1985	1985	1985	1985
Chemical Constituent	**Drinking-Water Well User**			**Resident Farmer**			**American Indian Resident Farmer**		
	Concentration at Year of Peak Hazard Index (grams per cubic meter)	**Hazard Index at Year of Peak Hazard Index**	**Nonradiological Risk at Year of Peak Nonradiological Risk**	**Concentration at Year of Peak Hazard Index (grams per cubic meter)**	**Hazard Index at Year of Peak Hazard Index**	**Nonradiological Risk at Year of Peak Nonradiological Risk**	**Concentration at Year of Peak Hazard Index (grams per cubic meter)**	**Hazard Index at Year of Peak Hazard Index**	**Nonradiological Risk at Year of Peak Nonradiological Risk**
Carbon tetrachloride	1.42×10^{-2}	5.79×10^{-1}	3.31×10^{-4}	2.30×10^{-2}	5.93	2.09×10^{-3}	2.30×10^{-2}	2.58×10^{1}	9.10×10^{-3}
Chromium	7.21	6.87×10^{1}	0.00	6.04	5.96×10^{1}	4.34×10^{-9}	6.04	8.97×10^{1}	1.99×10^{-4}
Fluoride	1.31×10^{1}	6.21	0.00	1.29×10^{1}	1.73×10^{1}	0.00	1.29×10^{1}	3.63×10^{1}	0.00
Manganese	6.91×10^{-5}	1.41×10^{-5}	0.00	5.77×10^{-5}	1.53×10^{-5}	0.00	5.77×10^{-5}	6.91×10^{-5}	0.00
Mercury	9.53×10^{-8}	9.08×10^{-6}	0.00	9.17×10^{-8}	2.79×10^{-5}	0.00	9.17×10^{-8}	6.13×10^{-5}	0.00
Nitrate	6.30×10^{2}	1.13×10^{1}	0.00	8.46×10^{2}	1.19×10^{2}	0.00	8.46×10^{2}	2.65×10^{2}	0.00
Total uranium	1.91	1.82×10^{1}	0.00	1.61	1.56×10^{1}	0.00	1.61	1.63×10^{1}	0.00
Total	**N/A**	**1.05×10^{2}**	**3.31×10^{-4}**	**N/A**	**2.17×10^{2}**	**2.09×10^{-3}**	**N/A**	**4.33×10^{2}**	**9.30×10^{-3}**
Year of peak impact	1979	1979	2067	1976	1976	2067	1976	1976	2067

Note: Concentrations are those reported for groundwater at the specified location. Total concentrations, although reported, are not used in the analysis.
Key: N/A=not applicable; Pu=plutonium; U=uranium.

Table U–21. Alternative Combination 2 Cumulative Human Health Impacts at the Columbia River Surface Water

Radioactive Constituent	Resident Farmer			American Indian Resident Farmer			American Indian Hunter-Gatherer		
	Concentration at Year of Peak Dose (curies per cubic meter)	Dose at Year of Peak Dose (millirem per year)	Radiological Risk at Year of Peak Radiological Risk	Concentration at Year of Peak Dose (curies per cubic meter)	Dose at Year of Peak Dose (millirem per year)	Radiological Risk at Year of Peak Radiological Risk	Concentration at Year of Peak Dose (curies per cubic meter)	Dose at Year of Peak Dose (millirem per year)	Radiological Risk at Year of Peak Radiological Risk
Hydrogen-3 (tritium)	2.40×10^{-8}	3.26×10^{-3}	3.22×10^{-8}	2.40×10^{-8}	3.98×10^{-3}	4.20×10^{-8}	3.51×10^{-3}	2.23×10^{1}	4.11×10^{-4}
Carbon-14	0.00	0.00	0.00	0.00	0.00	0.00	4.70×10^{-9}	3.10×10^{-2}	8.12×10^{-7}
Strontium-90	3.37×10^{-10}	3.22×10^{-2}	6.03×10^{-7}	3.37×10^{-10}	4.85×10^{-1}	1.01×10^{-5}	2.48×10^{-5}	1.77×10^{3}	4.60×10^{-2}
Technetium-99	5.02×10^{-12}	2.27×10^{-5}	9.95×10^{-10}	5.02×10^{-12}	5.23×10^{-5}	2.48×10^{-9}	2.61×10^{-7}	7.89×10^{-3}	4.22×10^{-7}
Iodine-129	1.07×10^{-14}	3.82×10^{-6}	5.38×10^{-11}	1.07×10^{-14}	5.83×10^{-5}	1.40×10^{-9}	2.53×10^{-9}	8.00×10^{-3}	1.96×10^{-7}
Cesium-137	2.59×10^{-12}	8.15×10^{-3}	1.83×10^{-7}	2.59×10^{-12}	4.01×10^{-2}	9.00×10^{-7}	1.43×10^{-6}	1.15×10^{4}	2.59×10^{-1}
Uranium isotopes (includes U-233, -234, -235, -238)	1.52×10^{-11}	1.96×10^{-3}	2.30×10^{-8}	1.52×10^{-11}	5.44×10^{-3}	7.69×10^{-8}	3.58×10^{-6}	4.44×10^{1}	9.69×10^{-4}
Neptunium-237	6.67×10^{-15}	1.98×10^{-6}	9.47×10^{-12}	6.67×10^{-15}	1.94×10^{-5}	1.17×10^{-10}	8.52×10^{-10}	4.94×10^{-2}	1.95×10^{-7}
Plutonium isotopes (includes Pu-239, -240)	3.66×10^{-15}	2.64×10^{-6}	1.19×10^{-11}	3.66×10^{-15}	4.13×10^{-4}	2.31×10^{-9}	1.83×10^{-9}	3.63×10^{-1}	1.35×10^{-6}
Total	**N/A**	**4.56×10^{-2}**	**8.42×10^{-7}**	**N/A**	**5.35×10^{-1}**	**1.11×10^{-5}**	**N/A**	**1.33×10^{4}**	**3.06×10^{-1}**
Year of peak impact	1985	1985	1985	1985	1985	1985	1985	1985	1985
	Resident Farmer			**American Indian Resident Farmer**			**American Indian Hunter-Gatherer**		
Chemical Constituent	**Concentration at Year of Peak Hazard Index (grams per cubic meter)**	**Hazard Index at Year of Peak Hazard Index**	**Nonradiological Risk at Year of Peak Nonradiological Risk**	**Concentration at Year of Peak Hazard Index (grams per cubic meter)**	**Hazard Index at Year of Peak Hazard Index**	**Nonradiological Risk at Year of Peak Nonradiological Risk**	**Concentration at Year of Peak Hazard Index (grams per cubic meter)**	**Hazard Index at Year of Peak Hazard Index**	**Nonradiological Risk at Year of Peak Nonradiological Risk**
Carbon tetrachloride	2.10×10^{-7}	5.40×10^{-5}	2.46×10^{-8}	2.10×10^{-7}	2.43×10^{-4}	2.69×10^{-9}	2.08×10^{-1}	2.25×10^{2}	8.76×10^{-3}
Chromium	8.66×10^{-5}	8.56×10^{-4}	9.13×10^{-15}	8.66×10^{-5}	1.40×10^{-3}	7.99×10^{-11}	1.10	4.86	1.99×10^{-4}
Fluoride	3.47×10^{-5}	4.65×10^{-5}	0.00	3.47×10^{-5}	1.03×10^{-4}	0.00	7.61	1.11	0.00
Hydrazine/hydrazine sulfate	0.00	0.00	0.00	0.00	0.00	4.02×10^{-7}	0.00	0.00	0.00
Manganese	0.00	0.00	0.00	0.00	0.00	0.00	6.47×10^{-5}	6.36×10^{-5}	0.00
Mercury	0.00	0.00	0.00	0.00	0.00	0.00	2.21×10^{-7}	8.43×10^{-6}	0.00
Nitrate	4.78×10^{-3}	7.24×10^{-4}	0.00	4.78×10^{-3}	4.51×10^{-1}	0.00	1.79×10^{2}	6.98	0.00
Total uranium	1.40×10^{-5}	1.36×10^{-4}	0.00	1.40×10^{-5}	1.89×10^{-4}	0.00	1.65×10^{-1}	7.31×10^{-2}	0.00
Trichloroethylene	0.00	0.00	0.00	0.00	0.00	5.23×10^{-10}	0.00	0.00	0.00
Total	**N/A**	**1.82×10^{-3}**	**2.46×10^{-8}**	**N/A**	**4.52×10^{-1}**	**4.06×10^{-7}**	**N/A**	**2.38×10^{2}**	**8.96×10^{-3}**
Year of peak impact	1962	1962	2146	1962	1962	3272	2067	2067	2067

Note: Concentrations are those reported for groundwater at the specified location. Total concentrations, although reported, are not used in the analysis.
Key: N/A=not applicable; Pu=plutonium; U=uranium.

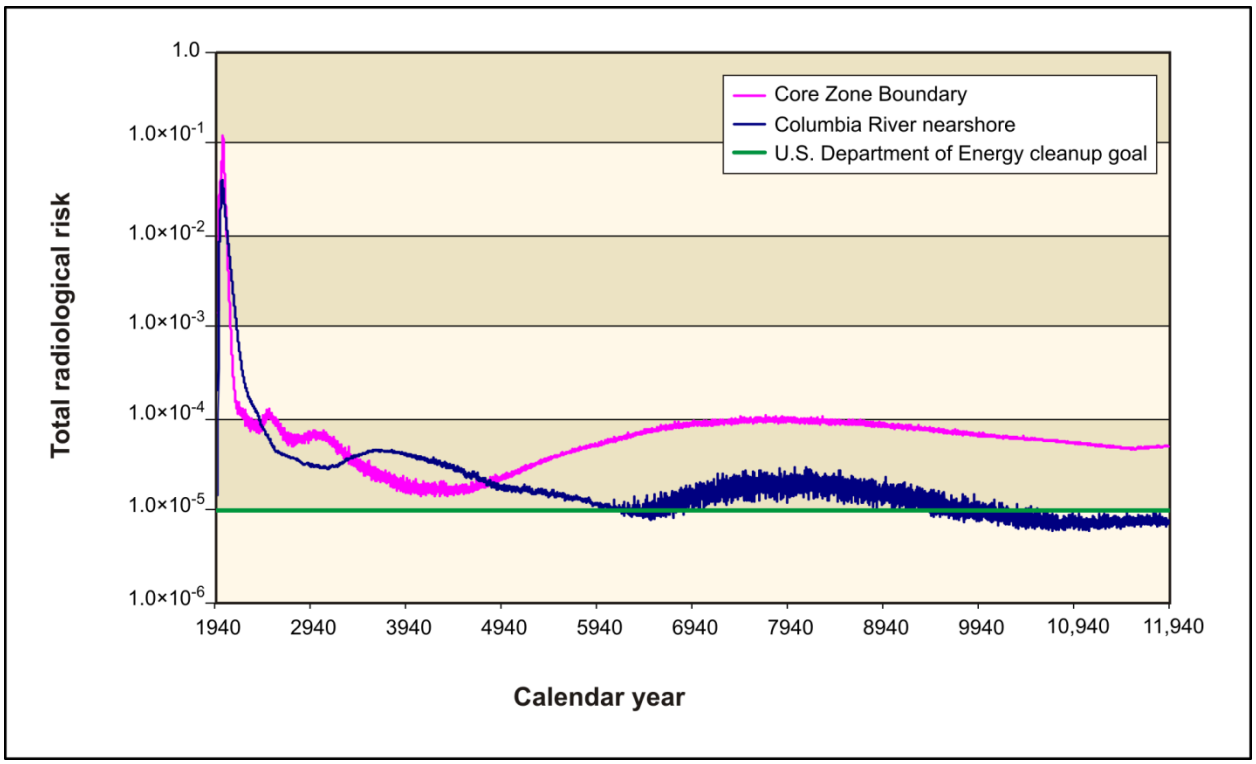


Figure U–138. Alternative Combination 2 Cumulative Radiological Lifetime Risk of Incidence of Cancer for the Drinking-Water Well User Over Time, Core Zone Boundary and Columbia River Nearshore

Potential human health impacts of Alternative Combination 3, in conjunction with the past, present, and reasonably foreseeable future (non–*TC & WM EIS*) actions discussed above, are summarized in Tables U–22 through U–24. The key radiological and chemical risk and hazard drivers are listed in the tables. As indicated in these tables, the impacts of Alternative Combination 3 are dominated by the impacts of non–*TC & WM EIS* sources. Figure U–139 depicts the cumulative radiological risk of incidence of cancer at the Core Zone Boundary and the Columbia River nearshore for the drinking-water well user over time. The DOE cleanup goal is included to aid in the interpretation of the predicted risk. The estimate of radiation dose for the year of peak dose for the offsite population is 229 person-rem per year, approximately 0.01 percent of the average background dose.

The foregoing tabulations of cumulative human health impacts, which have involved subsuming the impacts of each of the alternative combinations and those of all past, present, and reasonably foreseeable future (non–*TC & WM EIS*) actions, show that the peaks for the dose, risk, and Hazard Index occur at similar times and concentrations. A more detailed discussion of the results of the cumulative impact analyses is presented in Chapter 6.

Table U–22. Alternative Combination 3 Cumulative Human Health Impacts at the Core Zone Boundary

Radioactive Constituent	Drinking-Water Well User			Resident Farmer			American Indian Resident Farmer		
	Concentration at Year of Peak Dose (curies per cubic meter)	Dose at Year of Peak Dose (millirem per year)	Radiological Risk at Year of Peak Radiological Risk	Concentration at Year of Peak Dose (curies per cubic meter)	Dose at Year of Peak Dose (millirem per year)	Radiological Risk at Year of Peak Radiological Risk	Concentration at Year of Peak Dose (curies per cubic meter)	Dose at Year of Peak Dose (millirem per year)	Radiological Risk at Year of Peak Radiological Risk
Hydrogen-3 (tritium)	1.12×10^{-1}	1.31×10^{4}	1.25×10^{-1}	1.12×10^{-1}	1.53×10^{4}	1.50×10^{-1}	1.12×10^{-1}	1.82×10^{4}	1.91×10^{-1}
Carbon-14	8.78×10^{-7}	1.41	2.97×10^{-5}	8.78×10^{-7}	2.87	6.79×10^{-5}	8.78×10^{-7}	8.86	2.24×10^{-4}
Strontium-90	1.65×10^{-6}	1.20×10^{2}	2.01×10^{-3}	1.65×10^{-6}	1.58×10^{2}	2.94×10-3	1.65×10^{-6}	2.64×10^{2}	5.63×10^{-3}
Technetium-99	6.01×10^{-7}	1.05	3.62×10^{-5}	6.01×10^{-7}	2.71	1.19×10^{-4}	6.01×10^{-7}	5.53	2.60×10^{-4}
Iodine-129	2.13×10^{-9}	6.08×10^{-1}	6.91×10^{-6}	2.13×10^{-9}	7.59×10^{-1}	1.07×10^{-5}	2.13×10^{-9}	9.81×10^{-1}	1.62×10^{-5}
Uranium isotopes (includes U-233, -234, -235, -238)	7.05×10^{-8}	8.74	9.86×10^{-5}	7.05×10^{-8}	9.09	1.06×10^{-4}	7.05×10^{-8}	9.79	1.21×10^{-4}
Neptunium-237	9.04×10^{-10}	2.64×10^{-1}	1.22×10^{-6}	9.04×10^{-10}	2.68×10^{-1}	1.28×10^{-6}	9.04×10^{-10}	3.19×10^{-1}	1.45×10^{-6}
Total	**N/A**	**1.33×10^{4}**	**1.27×10^{-1}**	**N/A**	**1.54×10^{4}**	**1.54×10^{-1}**	**N/A**	**1.85×10^{4}**	**1.97×10^{-1}**
Year of peak impact	1997	1997	1997	1997	1997	1997	1997	1997	1997
	Drinking-Water Well User			**Resident Farmer**			**American Indian Resident Farmer**		
Chemical Constituent	**Concentration at Year of Peak Hazard Index (grams per cubic meter)**	**Hazard Index at Year of Peak Hazard Index**	**Nonradiological Risk at Year of Peak Nonradiological Risk**	**Concentration at Year of Peak Hazard Index (grams per cubic meter)**	**Hazard Index at Year of Peak Hazard Index**	**Nonradiological Risk at Year of Peak Nonradiological Risk**	**Concentration at Year of Peak Hazard Index (grams per cubic meter)**	**Hazard Index at Year of Peak Hazard Index**	**Nonradiological Risk at Year of Peak Nonradiological Risk**
1-Butanol	1.32×10^{-2}	3.77×10^{-3}	0.00	1.32×10^{-2}	6.84×10^{-3}	0.00	1.32×10^{-2}	1.91×10^{-2}	0.00
Carbon tetrachloride	0.00	0.00	9.19×10^{-4}	0.00	0.00	5.80×10^{-3}	0.00	0.00	2.52×10^{-2}
Chromium	1.34×10^{1}	1.27×10^{2}	0.00	1.34×10^{1}	1.32×10^{2}	2.05×10^{-9}	1.34×10^{1}	1.98×10^{2}	9.40×10^{-5}
Fluoride	2.63	1.25	0.00	2.63	3.52	0.00	2.63	7.38	0.00
Nitrate	1.81×10^{3}	3.23×10^{1}	0.00	1.81×10^{3}	2.54×10^{2}	0.00	1.81×10^{3}	5.66×10^{2}	0.00
Total uranium	1.22	1.17×10^{1}	0.00	1.22	1.19×10^{1}	0.00	1.22	1.24×10^{1}	0.00
Total	**N/A**	**1.72×10^{2}**	**9.19×10^{-4}**	**N/A**	**4.01×10^{2}**	**5.80×10^{-3}**	**N/A**	**7.84×10^{2}**	**2.53×10^{-2}**
Year of peak impact	1959	1959	2035	1959	1959	2035	1959	1959	2035

Note: Concentrations are those reported for groundwater at the specified location. Total concentrations, although reported, are not used in the analysis.
Key: N/A=not applicable; U=uranium.

Table U–23. Alternative Combination 3 Cumulative Human Health Impacts at the Columbia River Nearshore

Radioactive Constituent	Drinking-Water Well User			Resident Farmer			American Indian Resident Farmer		
	Concentration at Year of Peak Dose (curies per cubic meter)	Dose at Year of Peak Dose (millirem per year)	Radiological Risk at Year of Peak Radiological Risk	Concentration at Year of Peak Dose (curies per cubic meter)	Dose at Year of Peak Dose (millirem per year)	Radiological Risk at Year of Peak Radiological Risk	Concentration at Year of Peak Dose (curies per cubic meter)	Dose at Year of Peak Dose (millirem per year)	Radiological Risk at Year of Peak Radiological Risk
Hydrogen-3 (tritium)	4.14×10^{-3}	4.84×10^{2}	3.38×10^{-3}	3.51×10^{-3}	4.77×10^{2}	4.70×10^{-3}	3.51×10^{-3}	5.68×10^{2}	5.96×10^{-3}
Carbon-14	4.77×10^{-9}	7.68×10^{-3}	1.67×10^{-7}	4.70×10^{-9}	1.54×10^{-2}	3.63×10^{-7}	4.70×10^{-9}	4.74×10^{-2}	1.20×10^{-6}
Strontium-90	2.45×10^{-5}	1.79×10^{3}	3.36×10^{-2}	2.48×10^{-5}	2.37×10^{3}	4.41×10^{-2}	2.48×10^{-5}	3.97×10^{3}	8.46×10^{-2}
Technetium-99	2.85×10^{-7}	4.98×10^{-1}	1.28×10^{-5}	2.62×10^{-7}	1.18	5.18×10^{-5}	2.62×10^{-7}	2.41	1.13×10^{-4}
Iodine-129	2.55×10^{-9}	7.25×10^{-1}	8.19×10^{-6}	2.53×10^{-9}	9.01×10^{-1}	1.27×10^{-5}	2.53×10^{-9}	1.16	1.92×10^{-5}
Cesium-137	1.07×10^{-6}	3.92×10^{1}	8.81×10^{-4}	1.43×10^{-6}	4.50×10^{3}	1.01×10^{-1}	1.43×10^{-6}	1.36×10^{4}	3.04×10^{-1}
Uranium isotopes (includes U-233, -234, -235, -238)	3.29×10^{-6}	4.07×10^{2}	3.28×10^{-3}	3.58×10^{-6}	4.61×10^{2}	5.40×10^{-3}	3.58×10^{-6}	4.97×10^{2}	6.15×10^{-3}
Neptunium-237	8.41×10^{-10}	2.45×10^{-1}	1.07×10^{-6}	8.52×10^{-10}	2.52×10^{-1}	1.21×10^{-6}	8.52×10^{-10}	3.01×10^{-1}	1.36×10^{-6}
Plutonium isotopes (includes Pu-239, -240)	1.44×10^{-9}	9.75×10^{-1}	6.07×10^{-6}	1.83×10^{-9}	1.30	5.83×10^{-6}	1.83×10^{-9}	1.61	6.76×10^{-6}
Total	**N/A**	**2.72×10^{3}**	**4.12×10^{-2}**	**N/A**	**7.81×10^{3}**	**1.55×10^{-1}**	**N/A**	**1.86×10^{4}**	**4.01×10^{-1}**
Year of peak impact	1986	1986	1991	1985	1985	1985	1985	1985	1985
	Drinking-Water Well User			**Resident Farmer**			**American Indian Resident Farmer**		
Chemical Constituent	**Concentration at Year of Peak Hazard Index (grams per cubic meter)**	**Hazard Index at Year of Peak Hazard Index**	**Nonradiological Risk at Year of Peak Nonradiological Risk**	**Concentration at Year of Peak Hazard Index (grams per cubic meter)**	**Hazard Index at Year of Peak Hazard Index**	**Nonradiological Risk at Year of Peak Nonradiological Risk**	**Concentration at Year of Peak Hazard Index (grams per cubic meter)**	**Hazard Index at Year of Peak Hazard Index**	**Nonradiological Risk at Year of Peak Nonradiological Risk**
Carbon tetrachloride	1.42×10^{-2}	5.79×10^{-1}	3.31×10^{-4}	2.30×10^{-2}	5.93	2.09×10^{-3}	2.30×10^{-2}	2.58×10^{1}	9.10×10^{-3}
Chromium	7.21	6.87×10^{1}	0.00	6.04	5.96×10^{1}	4.34×10^{-9}	6.04	8.97×10^{1}	1.99×10^{-4}
Fluoride	1.31×10^{1}	6.21	0.00	1.29×10^{1}	1.73×10^{1}	0.00	1.29×10^{1}	3.63×10^{1}	0.00
Manganese	6.91×10^{-5}	1.41×10^{-5}	0.00	5.77×10^{-5}	1.53×10^{-5}	0.00	5.77×10^{-5}	6.91×10^{-5}	0.00
Mercury	9.53×10^{-8}	9.08×10^{-6}	0.00	9.17×10^{-8}	2.79×10^{-5}	0.00	9.17×10^{-8}	6.13×10^{-5}	0.00
Nitrate	6.30×10^{2}	1.13×10^{1}	0.00	8.46×10^{2}	1.19×10^{2}	0.00	8.46×10^{2}	2.65×10^{2}	0.00
Total uranium	1.91	1.82×10^{1}	0.00	1.61	1.56×10^{1}	0.00	1.61	1.63×10^{1}	0.00
Total	**N/A**	**1.05×10^{2}**	**3.31×10^{-4}**	**N/A**	**2.17×10^{2}**	**2.09×10^{-3}**	**N/A**	**4.33×10^{2}**	**9.30×10^{-3}**
Year of peak impact	1979	1979	2067	1976	1976	2067	1976	1976	2067

Note: Concentrations are those reported for groundwater at the specified location. Total concentrations, although reported, are not used in the analysis.
Key: N/A=not applicable; Pu=plutonium; U=uranium.

Table U–24. Alternative Combination 3 Cumulative Human Health Impacts at the Columbia River Surface Water

Radioactive Constituent	Resident Farmer			American Indian Resident Farmer			American Indian Hunter-Gatherer		
	Concentration at Year of Peak Dose (curies per cubic meter)	Dose at Year of Peak Dose (millirem per year)	Radiological Risk at Year of Peak Radiological Risk	Concentration at Year of Peak Dose (curies per cubic meter)	Dose at Year of Peak Dose (millirem per year)	Radiological Risk at Year of Peak Radiological Risk	Concentration at Year of Peak Dose (curies per cubic meter)	Dose at Year of Peak Dose (millirem per year)	Radiological Risk at Year of Peak Radiological Risk
Hydrogen-3 (tritium)	2.40×10^{-8}	3.26×10^{-3}	3.22×10^{-8}	2.40×10^{-8}	3.98×10^{-3}	4.20×10^{-8}	3.51×10^{-3}	2.23×10^{1}	4.11×10^{-4}
Carbon-14	0.00	0.00	0.00	0.00	0.00	0.00	4.70×10^{-9}	3.10×10^{-2}	8.12×10^{-7}
Strontium-90	3.37×10^{-10}	3.22×10^{-2}	6.03×10^{-7}	3.37×10^{-10}	4.85×10^{-1}	1.01×10^{-5}	2.48×10^{-5}	1.77×10^{3}	4.60×10^{-2}
Technetium-99	5.02×10^{-12}	2.27×10^{-5}	9.95×10^{-10}	5.02×10^{-12}	5.23×10^{-5}	2.48×10^{-9}	2.62×10^{-7}	7.89×10^{-3}	4.22×10^{-7}
Iodine-129	1.07×10^{-14}	3.82×10^{-6}	5.38×10^{-11}	1.07×10^{-14}	5.83×10^{-5}	1.40×10^{-9}	2.53×10^{-9}	8.00×10^{-3}	1.96×10^{-7}
Cesium-137	2.59×10^{-12}	8.15×10^{-3}	1.83×10^{-7}	2.59×10^{-12}	4.01×10^{-2}	9.00×10^{-7}	1.43×10^{-6}	1.15×10^{4}	2.59×10^{-1}
Uranium isotopes (includes U-233, -234, -235, -238)	1.52×10^{-11}	1.96×10^{-3}	2.30×10^{-8}	1.52×10^{-11}	5.44×10^{-3}	7.69×10^{-8}	3.58×10^{-6}	4.44×10^{1}	9.69×10^{-4}
Neptunium-237	6.67×10^{-15}	1.98×10^{-6}	9.47×10^{-12}	6.67×10^{-15}	1.94×10^{-5}	1.17×10^{-10}	8.52×10^{-10}	4.94×10^{-2}	1.95×10^{-7}
Plutonium isotopes (includes Pu-239, -240)	3.66×10^{-15}	2.64×10^{-6}	1.19×10^{-11}	3.66×10^{-15}	4.13×10^{-4}	2.31×10^{-9}	1.83×10^{-9}	3.63×10^{-1}	1.35×10^{-6}
Total	**N/A**	**4.56×10^{-2}**	**8.42×10^{-7}**	**N/A**	**5.35×10^{-1}**	**1.11×10^{-5}**	**N/A**	**1.33×10^{4}**	**3.06×10^{-1}**
Year of peak impact	1985	1985	1985	1985	1985	1985	1985	1985	1985
Chemical Constituent	**Resident Farmer**			**American Indian Resident Farmer**			**American Indian Hunter-Gatherer**		
	Concentration at Year of Peak Hazard Index (grams per cubic meter)	Hazard Index at Year of Peak Hazard Index	Nonradiological Risk at Year of Peak Nonradiological Risk	Concentration at Year of Peak Hazard Index (grams per cubic meter)	Hazard Index at Year of Peak Hazard Index	Nonradiological Risk at Year of Peak Nonradiological Risk	Concentration at Year of Peak Hazard Index (grams per cubic meter)	Hazard Index at Year of Peak Hazard Index	Nonradiological Risk at Year of Peak Nonradiological Risk
Carbon tetrachloride	2.10×10^{-7}	5.40×10^{-5}	2.53×10^{-8}	2.10×10^{-7}	2.43×10^{-4}	2.62×10^{-9}	2.08×10^{-1}	2.25×10^{2}	8.76×10^{-3}
Chromium	8.66×10^{-5}	8.56×10^{-4}	9.09×10^{-15}	8.66×10^{-5}	1.40×10^{-3}	7.99×10^{-11}	1.10	4.86	1.99×10^{-4}
Fluoride	3.47×10^{-5}	4.65×10^{-5}	0.00	3.47×10^{-5}	1.03×10^{-4}	0.00`	7.61	1.11	0.00
Hydrazine/hydrazine sulfate	0.00	0.00	0.00	0.00	0.00	4.02×10-7	0.00	0.00	0.00
Manganese	0.00	0.00	0.00	0.00	0.00	0.00	6.47×10^{-5}	6.36×10^{-5}	0.00
Mercury	0.00	0.00	0.00	0.00	0.00	0.00	2.21×10^{-7}	8.43×10^{-6}	0.00
Nitrate	4.78×10^{-3}	7.24×10^{-4}	0.00	4.78×10^{-3}	4.51×10^{-1}	0.00	1.79×10^{2}	6.98	0.00
Total uranium	1.40×10^{-5}	1.36×10^{-4}	0.00	1.40×10^{-5}	1.89×10^{-4}	0.00	1.65×10^{-1}	7.31×10^{-2}	0.00
Trichloroethylene	0.00	0.00	0.00	0.00	0.00	5.23×10^{-10}	0.00	0.00	0.00
Total	**N/A**	**1.82×10^{-3}**	**2.53×10^{-8}**	**N/A**	**4.52×10^{-1}**	**4.06×10^{-7}**	**N/A**	**2.38×10^{2}**	**8.96×10^{-3}**
Year of peak impact	1962	1962	2143	1962	1962	3272	2067	2067	2067

Note: Concentrations are those reported for groundwater at the specified location. Total concentrations, although reported, are not used in the analysis.
Key: N/A=not applicable; Pu=plutonium; U=uranium.

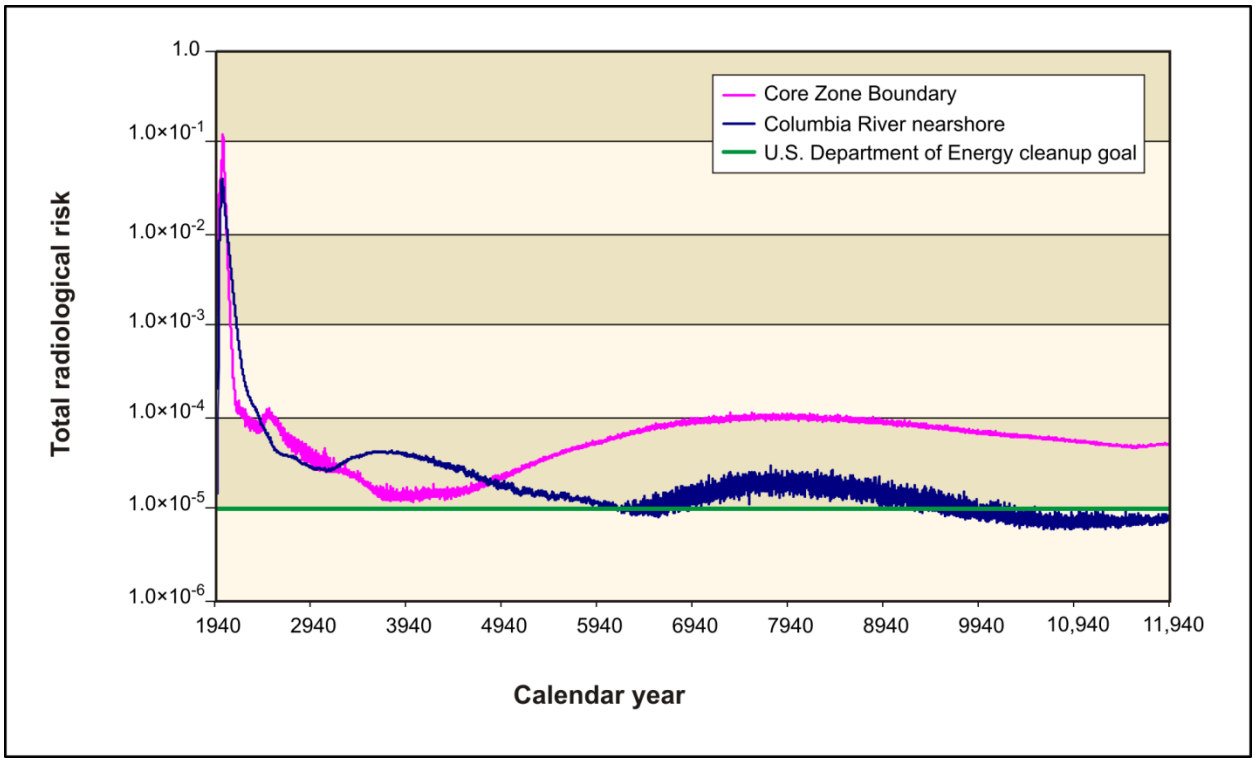


Figure U–139. Alternative Combination 3 Cumulative Radiological Lifetime Risk of Incidence of Cancer for the Drinking-Water Well User Over Time, Core Zone Boundary and Columbia River Nearshore

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APPENDIX V
RECHARGE SENSITIVITY ANALYSIS

In the *Draft Tank Closure and Waste Management Environmental Impact Statement for the Hanford Site, Richland, Washington (Draft TC & WM EIS)*, this appendix provided analysis of impacts on the Base Case flow field associated with development of the Black Rock Reservoir west of the Hanford Site. In summary, the analysis involved the development of a variant Base Case flow field with increased recharge along the western boundary of the model domain. The variant flow field was examined to evaluate the potential impacts on general Base Case flow field characteristics and associated *TC & WM EIS* alternatives. In 2008, the U.S. Department of the Interior, Bureau of Reclamation, selected the No Action Alternative within the *Final Planning Report/Environmental Impact Statement, Yakima River Basin Water Storage Feasibility Study* (BOR 2008), in effect canceling the development of the proposed Black Rock Reservoir.

In this *Final TC & WM EIS*, Appendix V includes analysis of multiple boundary recharge variants of the regional-scale groundwater Base Case flow model (this sensitivity analysis is similar to the flow field variant used to evaluate Black Rock Reservoir impacts in the *Draft TC & WM EIS*). This analysis could be used to evaluate potential climate change scenarios resulting from increased precipitation, increased creek and/or mountain-front runoff, or increased Columbia River surface-water elevations. This analysis also includes a general discussion of recharge effects on regional groundwater elevation, Central Plateau groundwater transport patterns, regional groundwater discharge distribution, and maximum technetium-99 concentrations over time within the context of Tank Closure Alternative 2B and Waste Management Alternative 2, Disposal Group 1, Subgroup 1-A.

V.1 BACKGROUND

In the *Draft Tank Closure and Waste Management Environmental Impact Statement for the Hanford Site, Richland, Washington (Draft TC & WM EIS)*, this appendix provided analysis of impacts on the Base Case flow field related to installation of the Black Rock Reservoir (BRR) west of the Hanford Site (Hanford), as proposed by the U.S. Bureau of Reclamation (BOR). The *Draft TC & WM EIS* analysis in Appendix V included the development of a variant Base Case flow field with increased recharge along the western boundary of the model domain. The variant flow field was examined and compared with the Base Case flow field to determine any impacts on the *TC & WM EIS* alternatives. In 2008, BOR's proposed BRR installation was canceled because BOR selected the "No Action Alternative" within the associated *Yakima River Basin Water Storage Feasibility Study* (BOR 2008). Accordingly, BRR analysis in this *Final TC & WM EIS* is unnecessary.

Although, at this point, the specific BRR scenario and subsequent BRR variant flow field modeling are no longer pertinent or useful, similar variant flow field analysis is useful in assessing the impacts associated with potential climate change scenarios.

Development of the *TC & WM EIS* Base Case flow model used to analyze the long-term groundwater impacts of environmental impact statement (EIS) alternatives and cumulative impacts is described in Appendix L. All flow models, including the *TC & WM EIS* Base Case, are affected by a defined set of model boundary conditions (parameters) that influence flow and transport inside the model domain. Changes in boundary condition recharge parameters (flux into the model from various sources) in the Base Case flow field have the potential to impact groundwater elevations, velocities, and flow patterns beneath Hanford. As such, changes in boundary recharge parameters could affect comparison of the long-term impacts of various alternatives examined in this *TC & WM EIS*. Examining these potential effects is the subject of this appendix.

V.2 RECHARGE SENSITIVITY ANALYSIS PURPOSE AND SCOPE

V.2.1 Purpose of Analysis

The overall goal of this analysis is to illustrate the impacts of regional and focused recharge changes (potential climate change scenarios limited to boundary recharge sensitivity) on the *TC & WM EIS* Base Case regional flow field model, as well as to evaluate the potential differences among selected *TC & WM EIS* alternatives with respect to long-term groundwater impacts.

Specifically, this sensitivity analysis involved the use of three recharge sensitivity–variant models of the *TC & WM EIS* Base Case to evaluate (1) impacts on general flow field characteristics, such as the change in water table elevation; (2) Central Plateau particle flow direction; (3) regional volumetric discharge of water along selected pathways to the Columbia River; and (4) potential changes in long-term groundwater technetium–99 concentrations resulting from the models' recharge sensitivity–variant flow fields in the context of selected Tank Closure and Waste Management alternatives evaluated in Chapter 5 of this *TC & WM EIS* (specifically, Tank Closure Alternative 2B and Waste Management Alternative 2, Disposal Group 1, Subgroup 1-A).

Unlike most other analyses in this EIS, the analyses presented in this appendix do not include evaluation of impacts on human health.

V.2.2 Scope of Modeling Effort

The scope of the recharge sensitivity modeling effort included the following:

- Development of three recharge sensitivity–variant transport models of the *TC & WM EIS* Base Case that support potential scenarios associated with long-term regional climate change
- Insertion of boundary recharge fluxes into the *TC & WM EIS* Base Case MODFLOW [modular three-dimensional finite-difference groundwater flow model] to simulate changes in the water table elevation, particle flow direction, and volumetric discharge rates of selected routes (water budget zones) to the Columba River
- Comparison of the overall characteristics of each recharge model's flow field with the *TC & WM EIS* Base Case model flow field
- Comparison of the three variant models with the Base Case flow field for specific *TC & WM EIS* alternatives with respect to long-term maximum technetium–99 concentrations at the Core Zone Boundary, Columbia River nearshore, and selected disposal facility barriers
- Evaluation of the results of each recharge sensitivity variant to determine the potential differential impacts on selected *TC & WM EIS* alternatives

V.3 RECHARGE SENSITIVITY–VARIANT MODEL DEVELOPMENT AND IMPACT ASSESSMENT METHODOLOGY

V.3.1 Relationship to the *TC & WM EIS* Modeling Framework

The *TC & WM EIS* Base Case groundwater flow model was developed for input to the *TC & WM EIS* groundwater transport model, which was used to simulate the fate and transport of contaminants for the purpose of analyzing the EIS alternatives and cumulative impacts. The Base Case groundwater flow model development and the associated flow field extraction methods are discussed in Appendix L. The *TC & WM EIS* Base Case groundwater transport model development and application are discussed in Appendix O.

The Base Case groundwater flow and transport models are calibrated to historical field observations of groundwater hydraulic heads and contaminant concentrations. Calibration to historical field observations provides a level of confidence that the Base Case model can reasonably predict future hydraulic heads and contaminant concentrations. The calibrated results produced in the Base Case groundwater modeling simulations are used as inputs to the long-term impacts analysis in this *TC & WM EIS*.

Three recharge flow and transport models are presented in this appendix. Each of the models is a variant of the Base Case groundwater flow model presented in Appendix L. Table V–1 describes each recharge model variant, the parameter changes made, and the purpose (potential climate change scenario) of the variant.

Table V–1. Description of Each *TC & WM EIS* Base Case Flow and Transport Recharge Sensitivity Model Variant

Recharge Sensitivity Variant	*TC & WM EIS* Base Case Recharge Parameter Changed and Purpose of Change
Background recharge model variant (increased yearly regional precipitation)	This variant changed the background recharge value from 3.5 millimeters per year to 35 millimeters per year, beginning at calendar year 2100, to evaluate the flow field changes that may occur if precipitation is higher in the future than assumed in the Base Case model simulations presented in this *TC & WM EIS*.
Generalized Head Boundary recharge model variant (increased western boundary creek and watershed slope runoff discharge)	This variant increased the Base Case flow model Generalized Head Boundary (GHB) head values by 10 meters (32.8 feet) for all GHB cells in the model, beginning at calendar year 2100, to evaluate the flow field changes that may occur if water influx into the model along the western highlands is higher in the future than assumed in the Base Case flow model used in this *TC & WM EIS*. This includes increasing the discharge from various points along the western boundary border–Cold Creek, Dry Creek, and Rattlesnake Mountain slope eastern runoff. Increased water influx at these various locations could come from increased precipitation runoff, increased agricultural irrigation, or other unknown sources of water affected by climate change.
Columbia River recharge model variant (increased Columbia River surface water elevation)	This variant increased the Base Case flow model Columbia River surface-water head values by 5 meters (16.4 feet) for all Columbia River cells in the model, beginning at calendar year 2100, to evaluate the flow field changes that may occur if the Columbia River surface-water elevations are higher in the future than assumed in the Base Case flow model. Increased Columbia River surface-water head values could come from changes in precipitation or runoff patterns near the Columbia River headwaters in various British Columbia watersheds or other unknown sources of water affected by climate change.

Key: *TC & WM EIS=Tank Closure and Waste Management Environmental Impact Statement for the Hanford Site, Richland, Washington.*

Sections V.3.2 and V.3.3 describe the methodology and application of the three recharge sensitivity variant flow field models listed in Table V–1.

V.3.2 Methodology for Evaluating Changes in the Flow Field and Transport Patterns

The recharge variant flow fields summarized in Table V–1 add recharge (flux) to various locations across the model domain. In general, the background recharge model variant covers the entire model (increased yearly regional precipitation flux). The Generalized Head Boundary (GHB) recharge model variant affects most of the western model boundary (increased creek and watershed slope runoff flux). The Columbia River recharge model variant affects the entire northern and eastern model boundaries (increased riverhead elevation). In all model variants, the boundary condition changes were added into the model at 100 percent starting at calendar year (CY) 2100 (no stepped-in flux over the first few years of the boundary condition change).

To evaluate and characterize the variant flow fields listed in Table V–1, the following investigative methods were used:

1. **Steady state flow field head distribution analysis generated by MODFLOW.** The three recharge variant flow field head distributions were compared with the head distributions in the *TC & WM EIS* Base Case flow field. Using Groundwater Vistas (ESI 2004), standard color ramp scales were developed to compare model hydraulic head values. For each variant, model cell head information was provided from model layer 19 at CY 2200 (long-term steady state) for all models. The results of this analysis are presented in Section V.4.1.

2. **Hanford Central Plateau directional flow field tracers (particle path line) analysis.** Central Plateau–originating directional particle flow path lines (generated by MODPATH [MODFLOW particle-tracking postprocessing package]) from the long-term steady state flow field for each of the recharge variant flow field models were compared with those from the long-term steady state flow path lines of the Base Case flow model. By means of MODDATA, a uniformly distributed set of particles was released across the Central Plateau area. The results of this analysis are presented in Section V.4.2.

3. **Zone Budget Hydrograph Analysis.** A zone budget analysis was completed for each of the recharge flow model variants. To complete the analysis, identical zones (or gates) were defined in each recharge variant to measure the water flow (volumetric discharge) from the western region of the model (where all GHB water sources originate) to (1) the northwest through Umtanum Gap, (2) the north through Gable Gap, and (3) the south and east toward the Columbia River. A comparison of the water flow through these three gates for each of the three recharge flow model variants is presented in Section V.4.3.

V.3.3 Methodology for Evaluating Changes to Peak Concentrations Over Time at the Core Zone, Columbia River, and Disposal Facility Barriers

Groundwater flow and transport analysis was performed using each of the recharge variant flow fields described in Table V–1 and the *TC & WM EIS* Base Case flow field for the purpose of evaluating maximum concentration over time at the Core Zone, Columbia River, and applicable disposal facility barriers. Particle-tracking computer code was used to simulate the migration of technetium-99 through each flow field (aquifer). A comprehensive discussion of the Base Case flow field development and extraction for use is included in Appendix L. Detailed groundwater transport information can be found in Appendix O.

Contaminant transport analysis was performed to compare the concentrations of technetium-99 and long-term impacts thereof at the Core Zone Boundary, Columbia River nearshore, and selected disposal facility barriers within the Base Case model and the three recharge model variant flow fields listed in Table V–1. This included particle-tracking transport runs from CY 2200 to CY 11,940. This comparison

was performed within the contexts of Tank Closure Alternative 2B (expanded Waste Treatment Plant vitrification, landfill closure) and Waste Management Alternative 2, Disposal Group 1, Subgroup 1-A (disposal of waste associated with Tank Closure Alternative 2B in the proposed 200-East Area Integrated Disposal Facility [IDF-East] and the River Protection Project Disposal Facility [RPPDF]). Further details regarding each EIS alternative evaluated in this recharge sensitivity analysis can be found in Chapters 2 and 5 of this *TC & WM EIS*.

The maximum concentrations of technetium-99 at the Core Zone Boundary, Columbia River nearshore, and selected waste disposal facility barriers for the *TC & WM EIS* Base Case model and three recharge variant flow fields are further discussed in Section V.4.4.

V.4 MODEL RESULTS

This section describes the results of the analyses described in Sections V.3.2 and V.3.3. In all analyses, the three recharge variant flow field models summarized in Table V–1 were compared with and differentiated from the *TC & WM EIS* Base Case flow model.

V.4.1 Changes to Steady State Groundwater Head Distribution

Hydraulic head differences in flow model long-term steady state groundwater head values are illustrated in Figure V–1 (hydraulic head difference between the Base Case flow model and the background recharge model variant); Figure V–2 (hydraulic head difference between the Base Case flow model and GHB recharge model variant); and Figure V–3 (hydraulic head difference between the Base Case flow model and Columbia River recharge model variant).

The distribution of head values in the *TC & WM EIS* Base Case is higher in the west, with elevations ranging between 125 and 160 meters (410 and 525 feet) above mean sea level (amsl). In general, the higher hydraulic head in the west progressively slopes north, east, and south to the Columbia River. The highly conductive geology in the central region of the site from Gable Gap through the eastern part of the 200-East Area, then south and east for several kilometers, results in an essentially flat water table in the center of the model. Hydraulic heads in the central regions of the model range between 120 and 122 meters (394 and 400 feet) amsl. Moderately conductive geology is typical of the northern, eastern, and southern portions of the site, and results in a gently sloping water table as groundwater moves to the Columbia River. Hydraulic heads in these regions range between 104 and 122 meters (341 and 400 feet) amsl. Hydraulic heads in areas near the Columbia River are heavily influenced by the river stage, which is simulated as a constant head boundary that ranges between 122 meters (400 feet) amsl in the northwest to 104 meters (341 feet) amsl in the southeast.

Background Recharge Model Variant Compared with *TC & WM EIS* Base Case Model

Hydraulic head distribution across the background recharge model variant is similar to that of the Base Case. Increased head elevations (up to a maximum of plus 3 meters [9.84 feet]) are noted in the background recharge variant in the western region of the Central Plateau between Cold and Dry Creeks and in the southern region of the model near the 300 Area. The majority of the head differences across the model are between plus 0.5 meters (1.64 feet) and plus 2 meters (6.56 feet), both of which are below the calibrated Base Case flow model root mean square (RMS) error value of 2.28 meters (7.48 feet) (see Appendix L for Base Case flow model calibration specifics). Similar to the Base Case flow field, the background recharge model variant flow field head values indicate a progressive slope (somewhat flat distribution in the center of the model) from west to east to the Columbia River boundary.

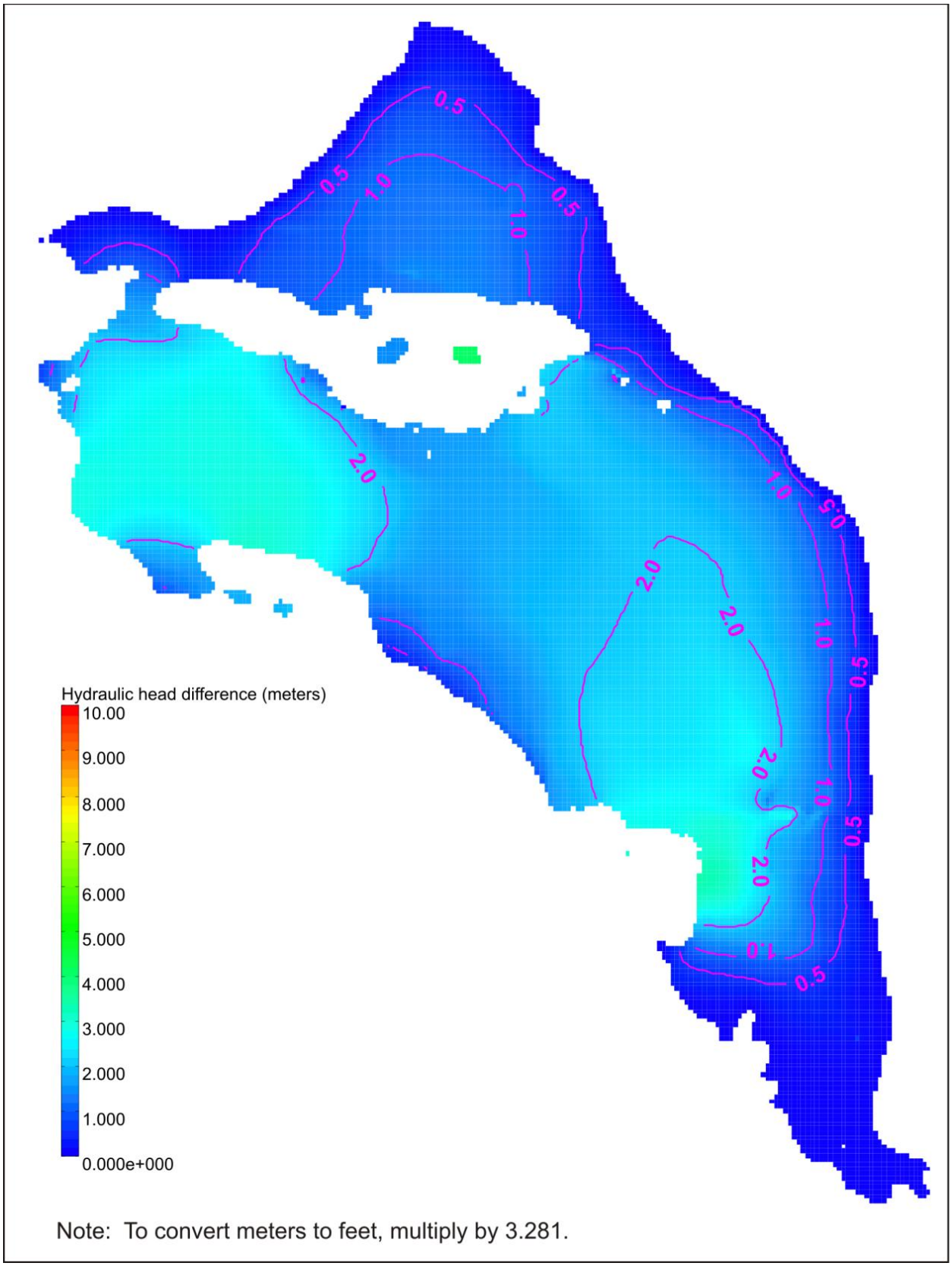


Figure V–1. Hydraulic Head Difference Between Base Case Flow Model and the Background Recharge Model Variant (from Model Layer 19, 105 to 110 meters above mean sea level)

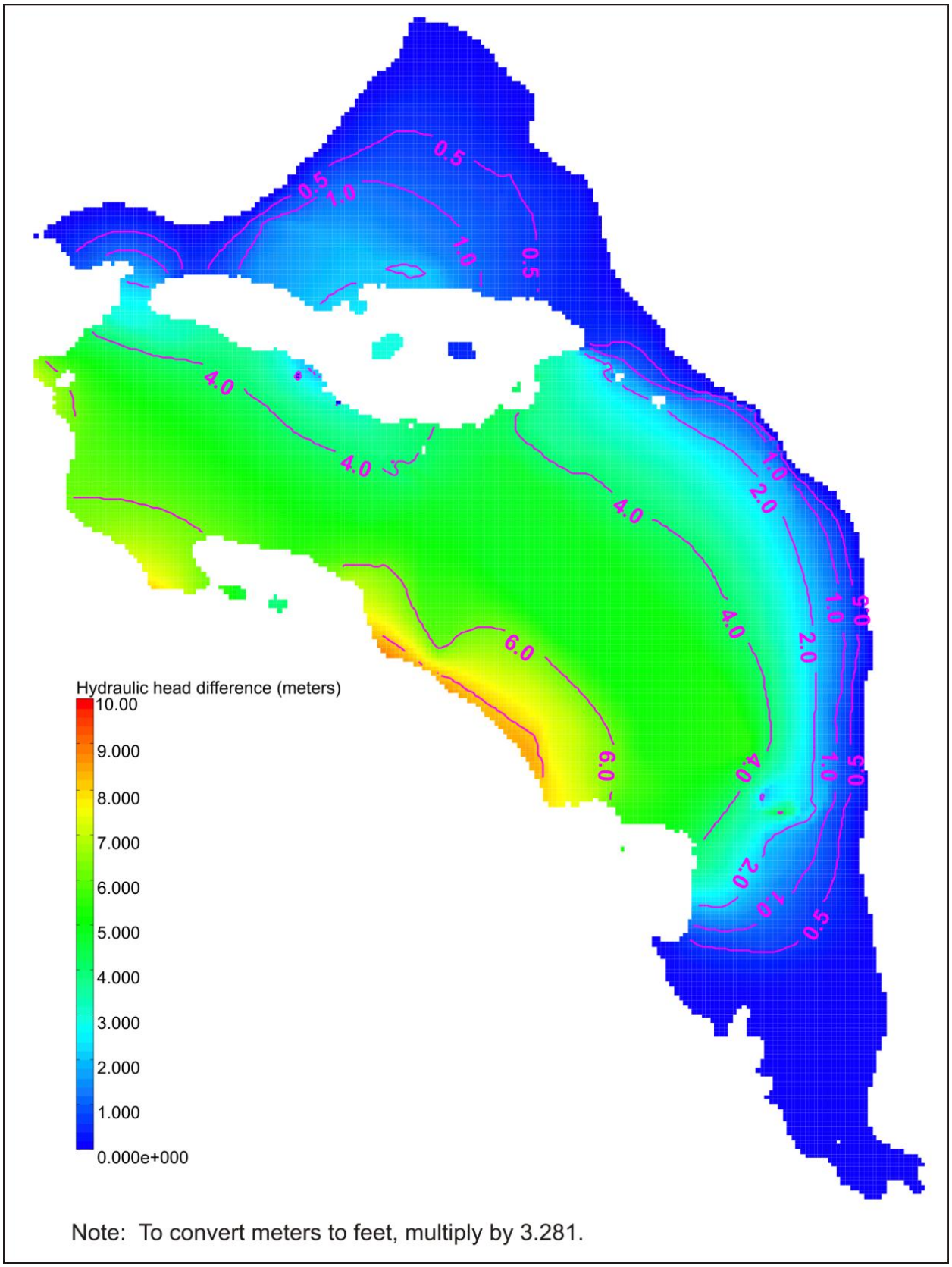


Figure V–2. Hydraulic Head Difference Between Base Case Flow Model and the Generalized Head Boundary Recharge Model Variant (from Model Layer 19, 105 to 110 meters above mean sea level)

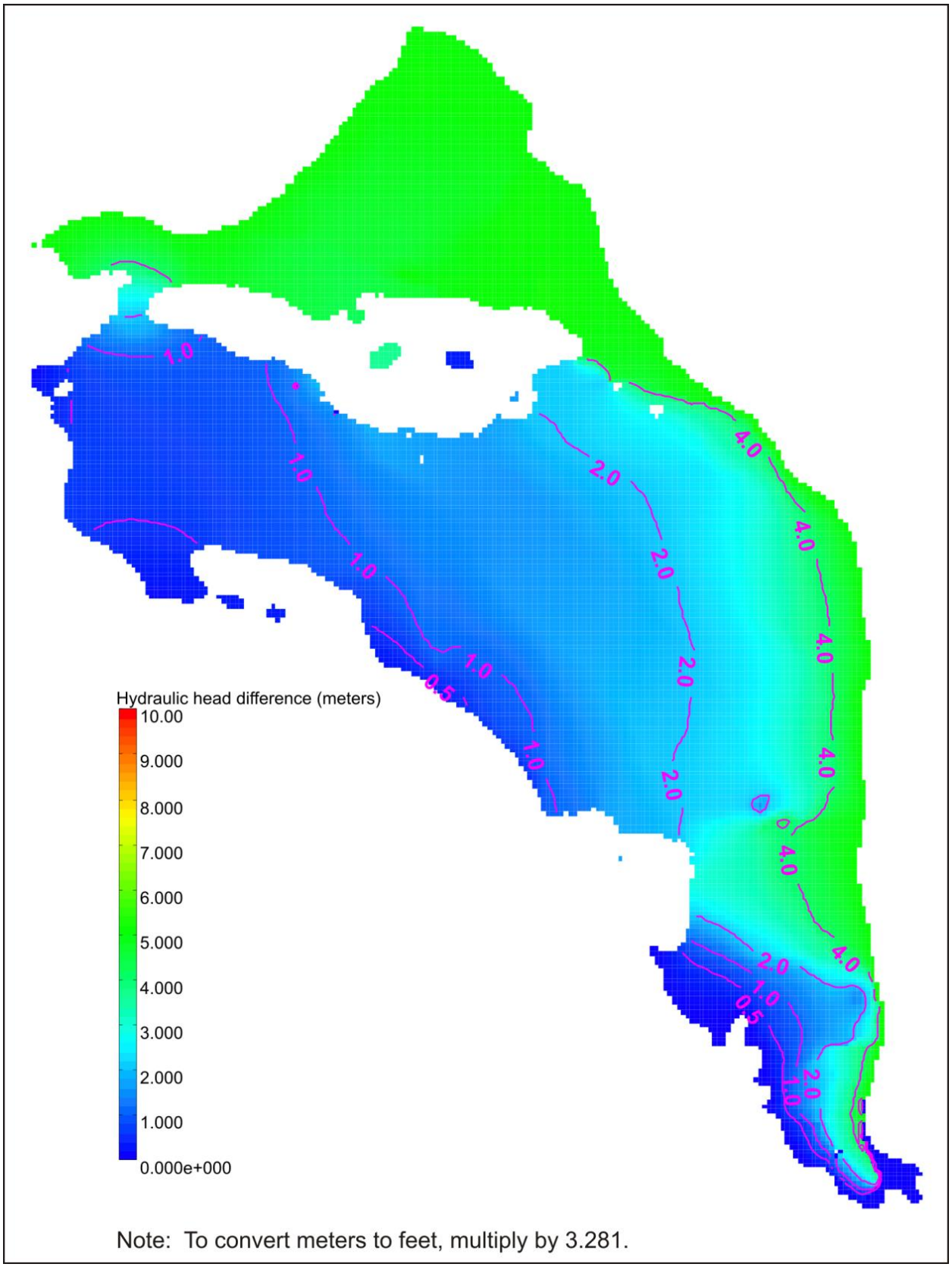


Figure V–3. Hydraulic Head Difference Between Base Case Flow Model and the Columbia River Recharge Model Variant (from Model Layer 19, 105 to 110 meters above mean sea level)

GHB Recharge Model Variant Compared with the *TC & WM EIS* Base Case Model

Most hydraulic head elevations across the GHB recharge model variant are higher than the Base Case head elevations. The head differences are especially higher along the western boundary of the GHB recharge model variant (where the GHB boundary condition cells are encoded into the model), where mounding of groundwater is observed (a difference of approximately plus 8.5 meters [27.88 feet]) in the Ringold geologic formations east of the Rattlesnake Mountain watershed slope. Both models indicate a progressive slope of head elevations, from higher in the west to lower in the east across the model, with only minor head elevation differences (between plus 0.5 meters [1.64 feet] and plus 1.0 meter [3.28 feet]) along the Columbia River boundary and southern 300 Area. The GHB recharge model variant exhibits a steeper west-to-east slope than the more moderate slope in the western region of the Base Case model. Within the Core Zone Boundary, the GHB recharge model variant shows increased head elevations of approximately plus 4.0 to 5.0 meters (13.12 to 16.4 feet). Just north of the Core Zone, across Gable Gap and extending north to the Columbia River, the head elevation differences are approximately plus 1.0 meter (3.28 feet).

Columbia River Recharge Model Variant Compared with *TC & WM EIS* Base Case Model

Hydraulic head elevations across the Columbia River recharge model variant are, in general, higher than the head elevations associated with the Base Case. The differences in heads are below the calibrated Base Case RMS error value of 2.28 meters (7.48 feet) in the eastern, southern, and central regions (including the Core Zone) of the variant model. Along the Columbia River boundary and in the northern reaches of the model, north of Gable Gap, the differences in head elevation are around plus 4 meters (13.12 feet) and exhibit less slope west to east toward the river than the Base Case flow field. The west-to-east slope in this recharge model variant's eastern regions and the Central Plateau is about the same as that observed in the Base Case flow field, with hydraulic head differences of plus 0.5 to 2 meters (1.64 to 6.56 feet).

For comparison it is important to note that, on average, the Hanford operational period increased the groundwater head elevations beneath the Core Zone more than 20 meters (66 feet) in the 200-West Area and approximately 10 meters (33 feet) in the 200-East Area due to wastewater discharges at the ground surface (Freedman 2008) as well as some direct injections to groundwater. For this recharge model variant, the increases in hydraulic head in the Core Zone (compared with head values for the *TC & WM EIS* Base Case flow field) are less than the head elevation changes observed during the Hanford operational period.

V.4.2 Changes to Central Plateau Transport Patterns (Particle Path Lines)

Results of the directional flow field tracers analysis (particle path lines) of particles released within the Hanford Central Plateau fixed regional box (64 square kilometers [24.7 square miles]) are illustrated in Figure V–4 (*TC & WM EIS* Base Case flow field), Figure V–5 (background recharge model variant flow field), Figure V–6 (GHB recharge model variant flow field), and Figure V–7 (Columbia River recharge model variant flow field). Further, a summary of analytical results associated with the bifurcating groundwater divide in the Central Plateau area, including particle paths through Gable Gap or east to the Columbia River, is presented in Table V–2.

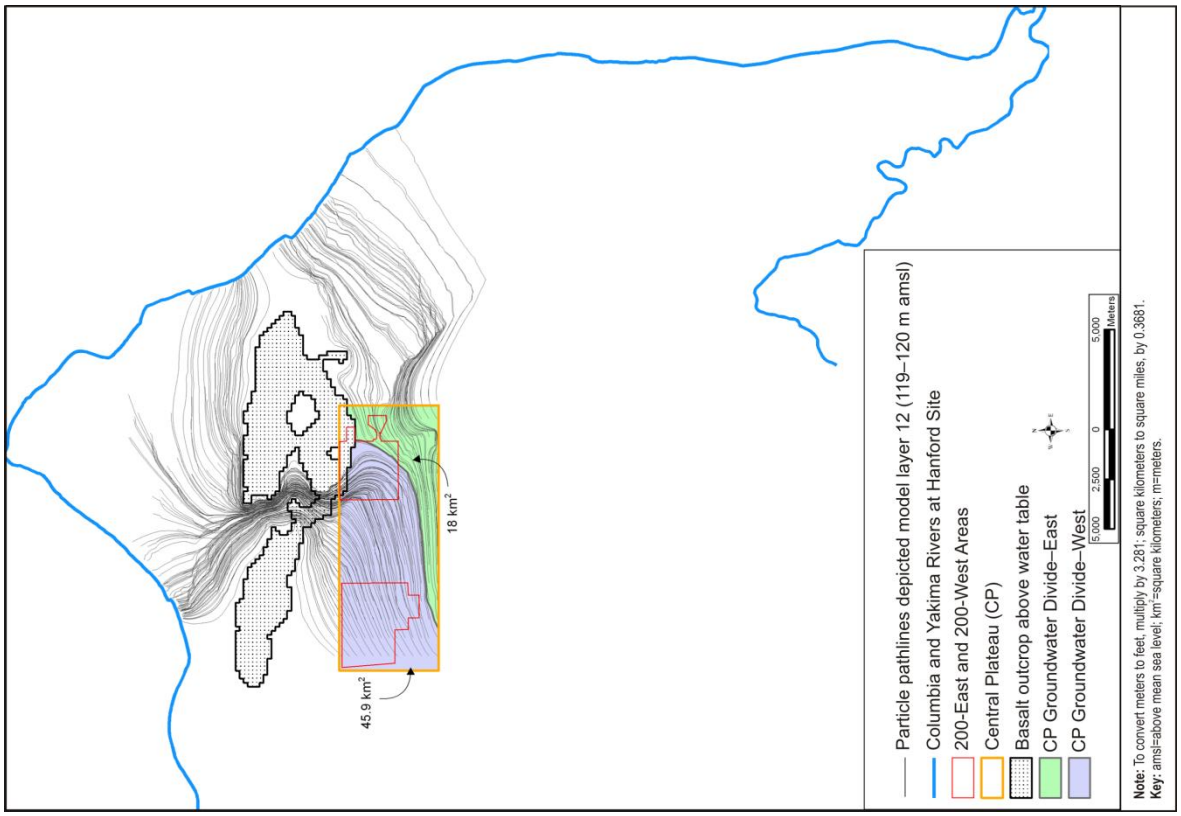


Figure V–5. Background Recharge Model Variant Flow Field, Central Plateau–Delineated Particle Path Lines

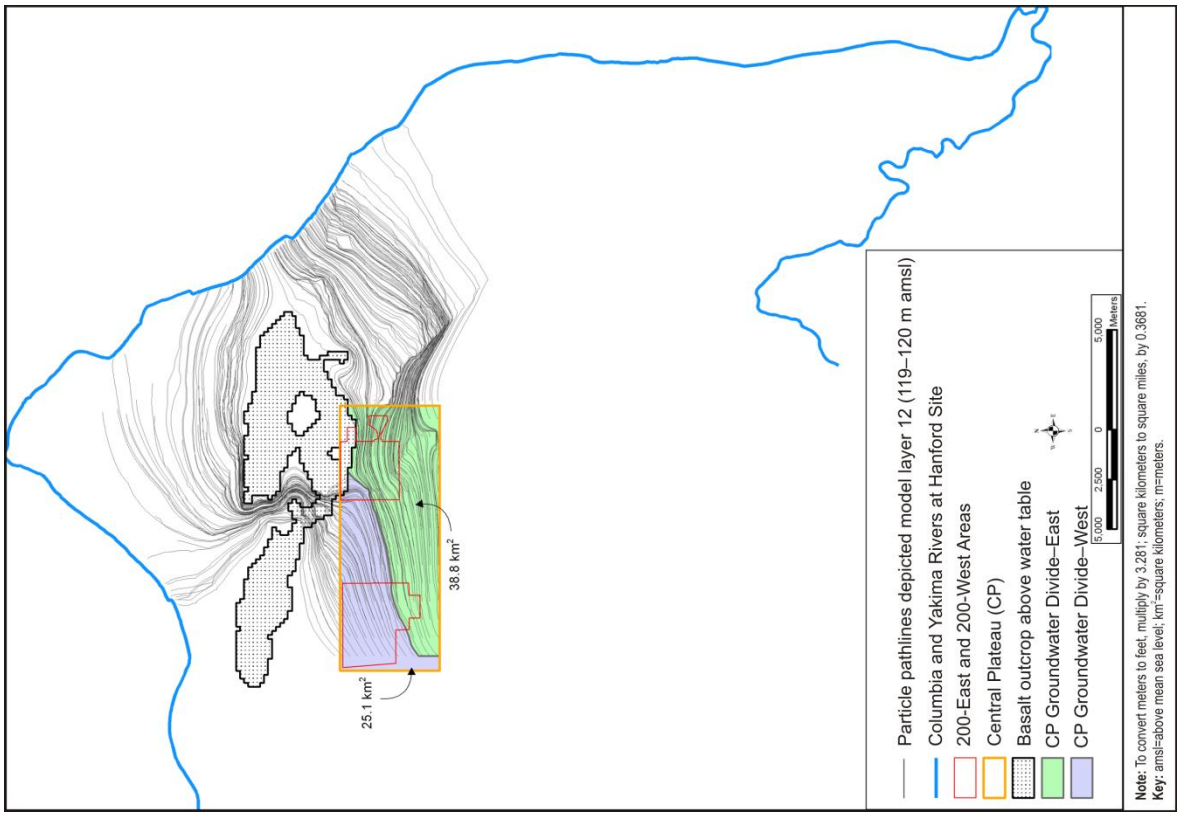


Figure V–4. *TC & WM EIS* Base Case Flow Field, Central Plateau–Delineated Particle Path Lines

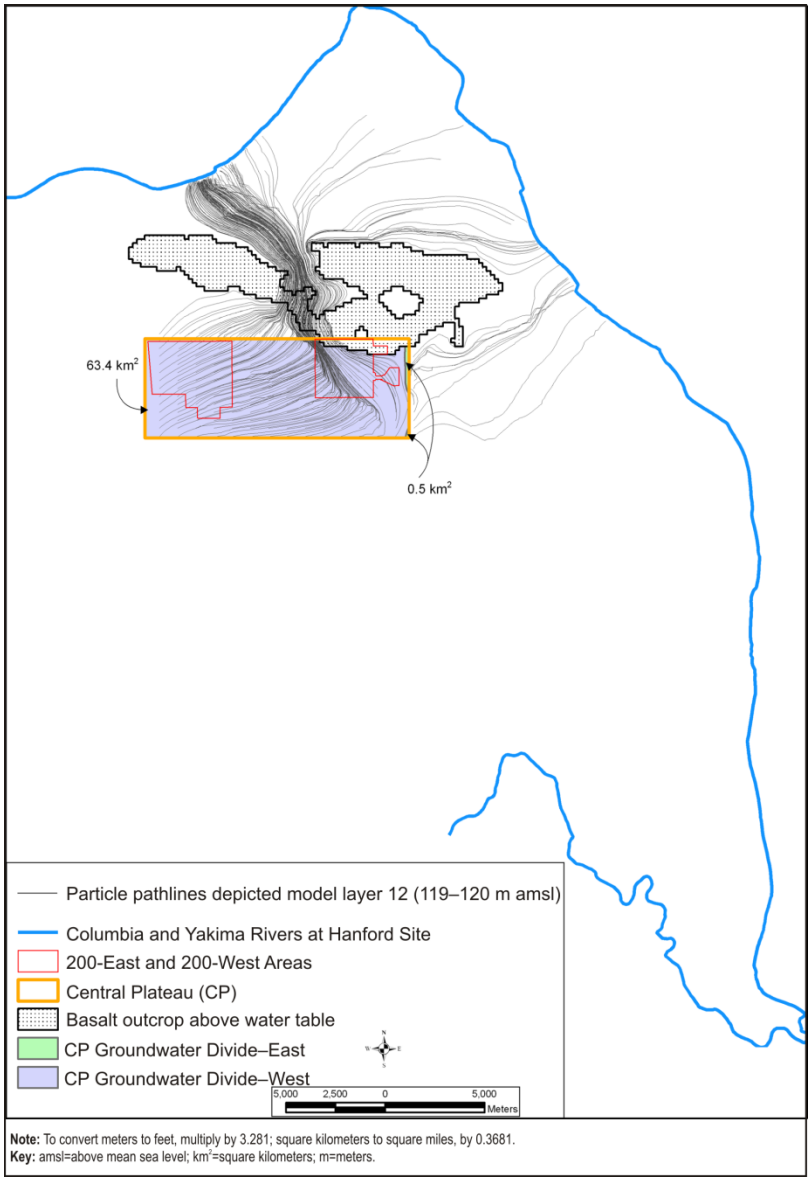


Figure V–6. Generalized Head Boundary Recharge Model Variant Flow Field, Central Plateau–Delineated Particle Path Lines

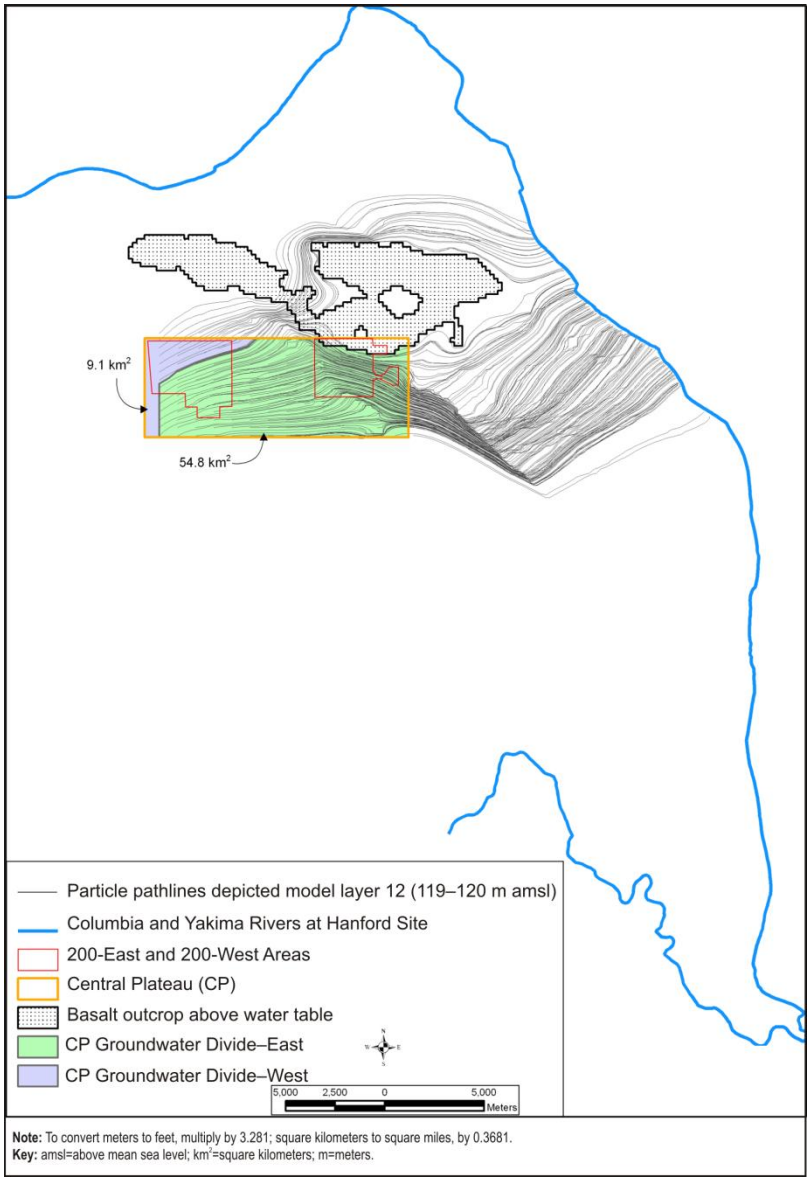


Figure V–7. Columbia River Recharge Model Variant Flow Field, Central Plateau–Delineated Particle Path Lines

Table V–2. Central Plateau Particle Path Line Direction to the Columbia River

Flow Field Model	Central Plateau Area with Particles Directed North Through Gable Mountain–Gable Butte Gap to the Columbia River		Central Plateau Area with Particles Directed East to the Columbia River	
	Area (square kilometers)	Area (percent)	Area (square kilometers)	Area (percent)
TC & WM EIS Base Case flow field	25.1	39	38.8	61
Background recharge model variant (increased yearly regional precipitation)	45.9	72	18.0	28
Generalized Head Boundary recharge model variant (increased creek and watershed slope runoff discharge)	63.4	99	0.5	1
Columbia River recharge model variant (increased surface water elevation)	9.1	14	54.8	86

Note: To convert square kilometers to square miles, multiply by 0.3861.
Key: *TC & WM EIS=Tank Closure and Waste Management Environmental Impact Statement for the Hanford Site, Richland, Washington.*

The Central Plateau is an area located just south of Gable Gap. The Hanford Core Zone, which includes the 200-East and 200-West Areas, is that part of the Central Plateau identified by the polygons in Figures V–4 through Figure V–7.

There are differences in the bifurcating groundwater divide between each of the three recharge model variant flow fields and the *TC & WM EIS* Base Case flow field. As such, there are differences in the amount of area within the Central Plateau where released particles either flow north through Gable Gap or east toward the Columbia River.

In the *TC & WM EIS* Base Case flow field, the majority of uniformly distributed particles released in the Central Plateau area travel east toward the Columbia River (see Figure V–4). In general, particles released in the 200-East Area and the southern reaches of the 200-West Area are directed east. Approximately 61 percent (39 square kilometers [15 square miles]) of the particles released from the Central Plateau area move to the east. For the remaining 39 percent (25 square kilometers [9.65 square miles]) of the Central Plateau, which includes most of the 200-West Area, particles flow north through Gable Gap. Once through Gable Gap, the majority move east toward the Columbia River, with a small quantity continuing in a northern direction toward the Columbia River.

In contrast to the *TC & WM EIS* Base Case flow field, the background recharge model variant flow field shows more of the uniformly distributed particles in the Central Plateau area directed north through Gable Gap (see Figure V–5). In the background recharge variant, the bifurcating groundwater divide shifts several miles east and south moving into the far eastern region of 200-East Area. Approximately 28 percent (18 square kilometers [5.9 square miles]) of the particles released from the Central Plateau move east toward the Columbia River, and approximately 72 percent (46 square kilometers [17.7 square miles], including all of the 200-West and most of the 200-East Areas) move north through Gable Gap. Once through Gable Gap, most of the particles in the background recharge variant flow field continue north toward the Columbia River rather than taking the longer track of turning east toward the Columbia River.

In contrast to the *TC & WM EIS* Base Case flow field, the GHB recharge model variant flow field shows just about all particles in the Central Plateau directed north through Gable Gap (see Figure V–6). The bifurcating groundwater divide seen in the Base Case flow field is hardly observable inside the Central Plateau of the GHB recharge variant. Less than 1 percent (0.5 square kilometers [0.164 square miles]) of the particles released from the Central Plateau move east toward the Columbia River, and approximately 99 percent (63 square kilometers [20.6 square miles]) of particles released in the Central Plateau move north through Gable Gap. Once through Gable Gap, virtually all of the particles in the GHB recharge variant flow field continue north toward the Columbia River (the shortest route to the river from the Central Plateau) rather than turning east toward the Columbia River.

In contrast to all other recharge model variant flow fields and the *TC & WM EIS* Base Case flow field, the Columbia River recharge model variant shows the majority of particles originating from the Central Plateau heading directly east toward the Columbia River (see Figure V–7). In comparison with the *TC & WM EIS* Base Case, the Columbia River recharge model variant's bifurcating groundwater divide moves to the northwest corner of the Central Plateau, splitting the 200-West Area. Most of the particles released in the Central Plateau in the Columbia River recharge model variant flow east toward the river; their path lines cover approximately 86 percent (55 square kilometers [18 square miles]) of the Central Plateau area. The remaining area, 14 percent (9 square kilometers [2.9 square miles]) of the Central Plateau (exclusive to the northwest corner and northern boundary of the 200-West Area), has particle path lines moving north through Gable Gap. Once through Gable Gap, the few particles that are headed north in the Columbia River variant actually turn east toward the river rather than continuing on the shorter track to the north.

In summary, depending on the type and location of recharge parameter variation, recharge can have a significant effect on the bifurcating groundwater divide position in the Central Plateau. Regarding this specific form of analysis—particle path transport patterns—it is clear that the *TC & WM EIS* Base Case model is sensitive to boundary recharge parameters. Unlike the *TC & WM EIS* Base Case, except for the Columbia River recharge model variant, all recharge model variant flow fields exhibit a shift in the groundwater divide to the east, resulting in a greater number of particles reaching the Columbia River in a shorter distance (directly north through Gable Gap). These additional redirected portions in the 200-East Area include the B, BX, and BY tank farms (and associated cribs and trenches [ditches]), as well as the proposed location of the RPPDF in the northern part of the Central Plateau between the 200-East and 200-West Areas.

V.4.3 Changes in Groundwater Discharge Rates in Selected Model Zones (Water Budget Hydrograph Analysis)

To complete the hydrographic analysis, each recharge model variant was measured for one model year (model year 261, CY 2200) at identical water budget zones (or gates) to determine volumetric groundwater flow through each gate. Water budget zones were positioned to capture groundwater flow originating with areal recharge fluxes from above, as well as GHB fluxes along the western domain boundary (where all GHB sources originate). These gate locations included (1) northwest through Umtanum Gap, (2) north through Gable Gap, and (3) south and east toward the Columbia River. An illustration of the location of each of the three groundwater flow measurement zones or gates is shown in Figure V–8.

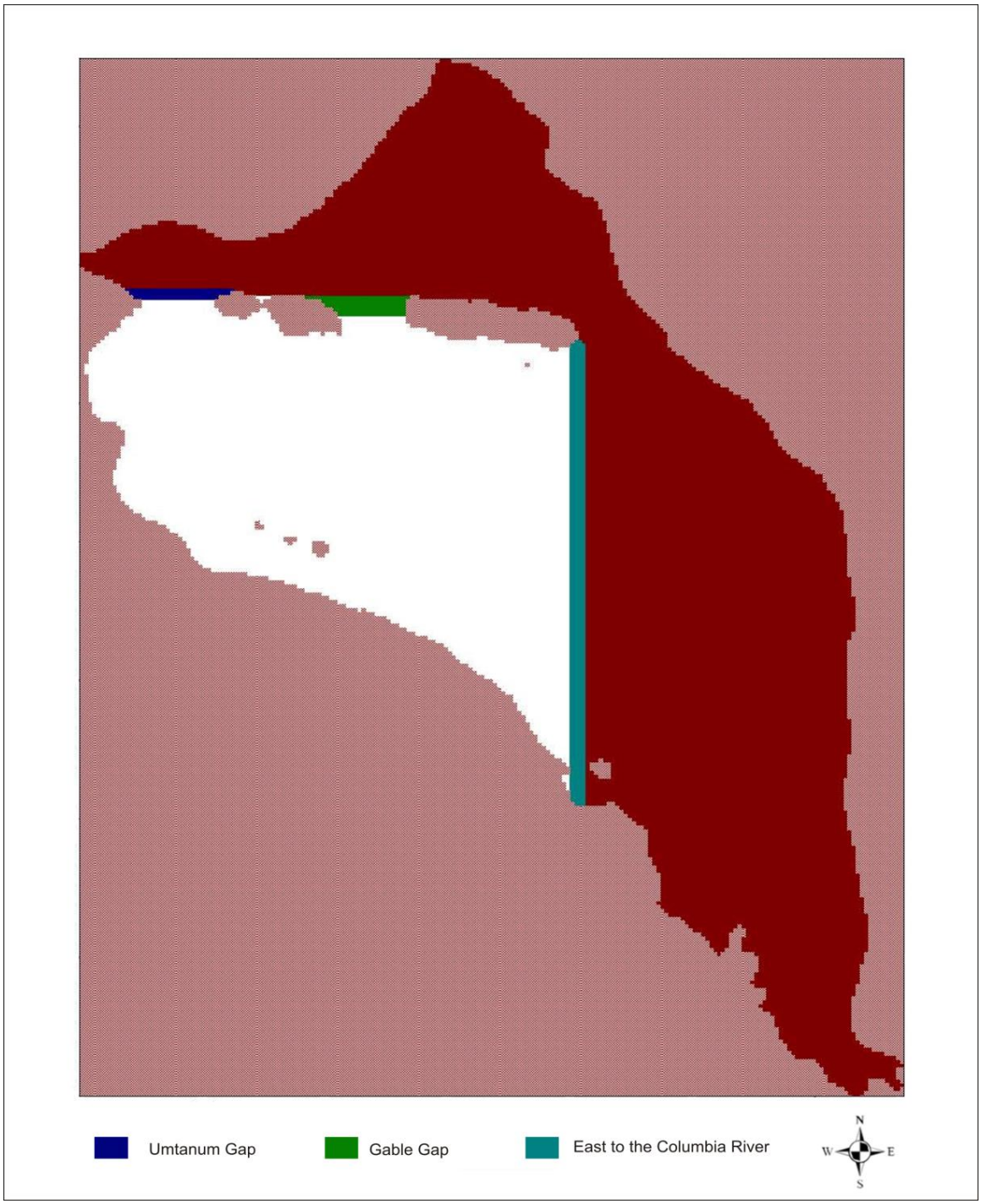
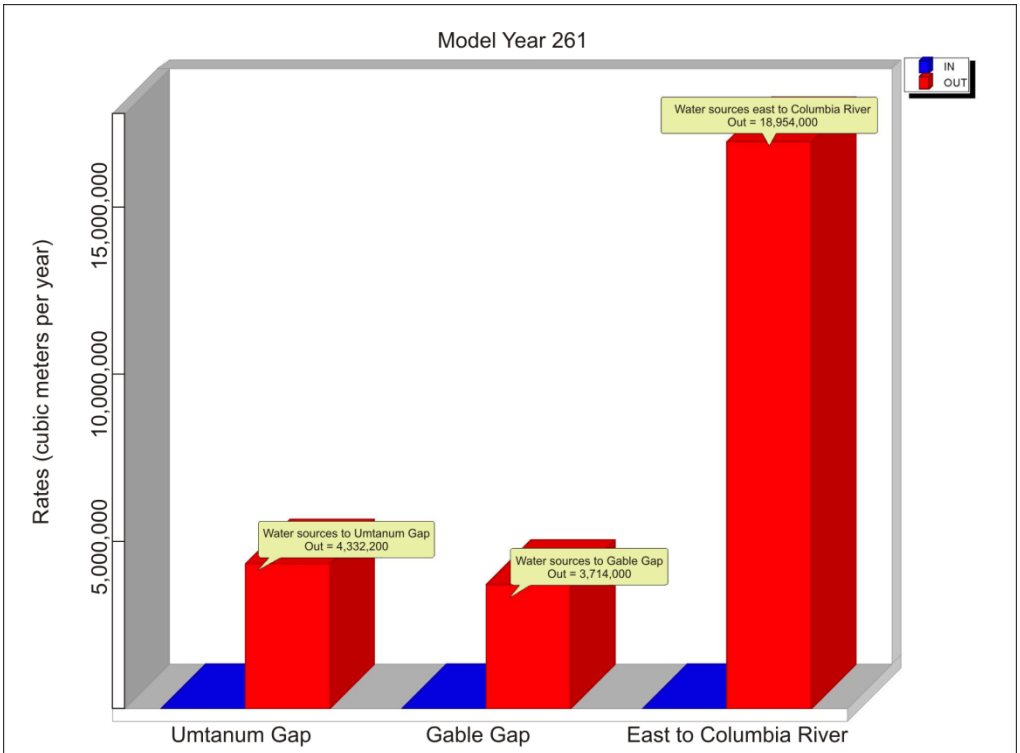


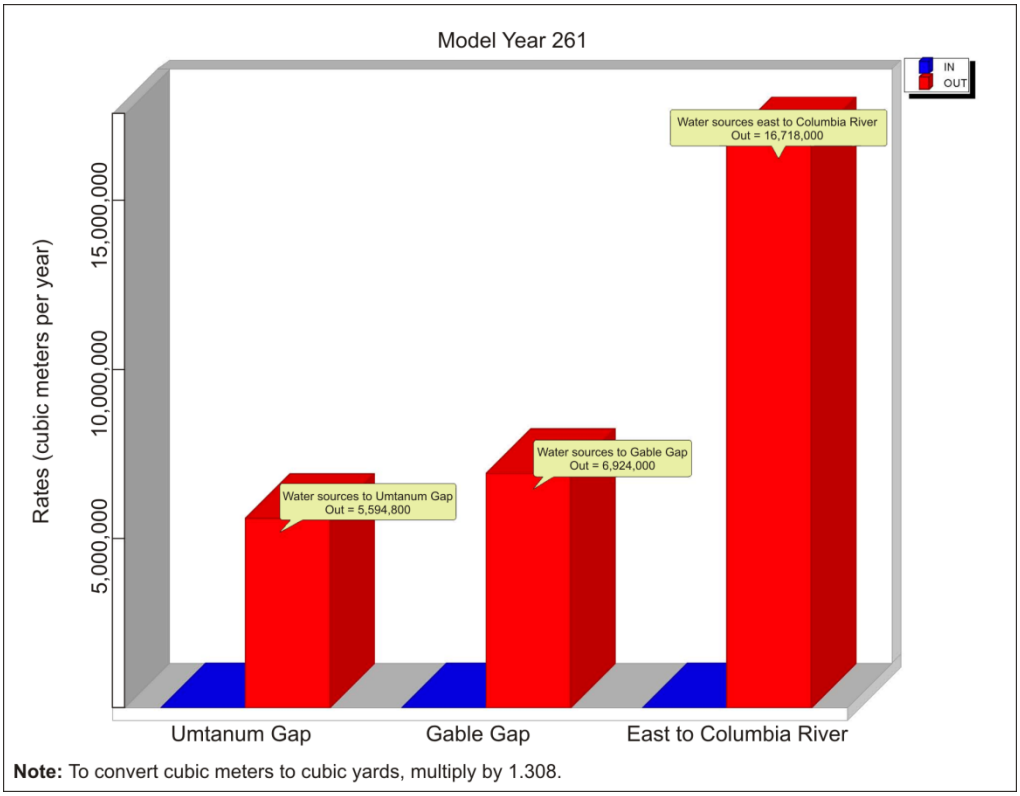
Figure V–8. Yearly Volumetric Discharge Measurement Locations (Gates) in Hanford Site Regional Groundwater Model

Results of the selected water zone budget hydrographs (yearly volumetric discharge) are included as Figure V–9 (*TC & WM EIS* Base Case), Figure V–10 (background recharge model variant), Figure V–11 (GHB recharge model variant), and Figure V–12 (Columbia River recharge model variant). Further, a summary of analytical results associated with the hydrographic analysis, including the annual volumetric discharge through selected gates, is presented in Table V–3.



Note: To convert cubic meters to cubic yards, multiply by 1.308.

Figure V–9. Yearly Volumetric Discharge Measurements for Selected Zones, *TC & WM EIS* Base Case Flow Field



Note: To convert cubic meters to cubic yards, multiply by 1.308.

Figure V–10. Yearly Volumetric Discharge Measurements for Selected Zones, Background Recharge Model Variant Flow Field

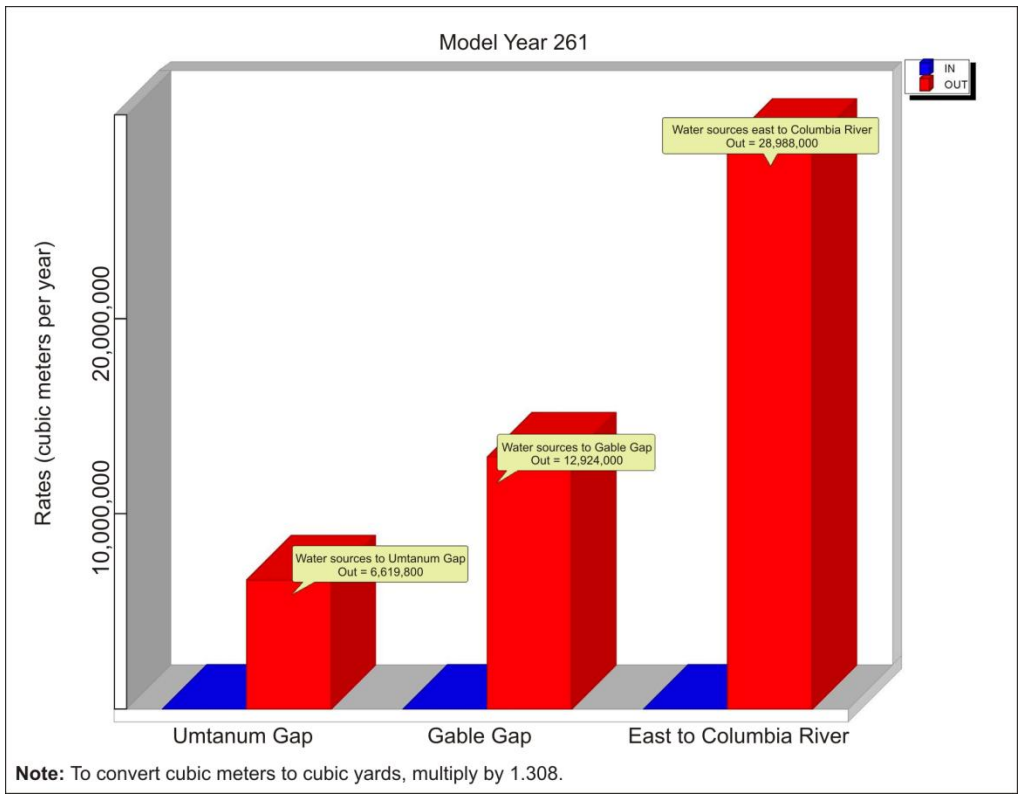


Figure V–11. Yearly Volumetric Discharge Measurements for Selected Zones, Generalized Head Boundary Recharge Model Variant Flow Field

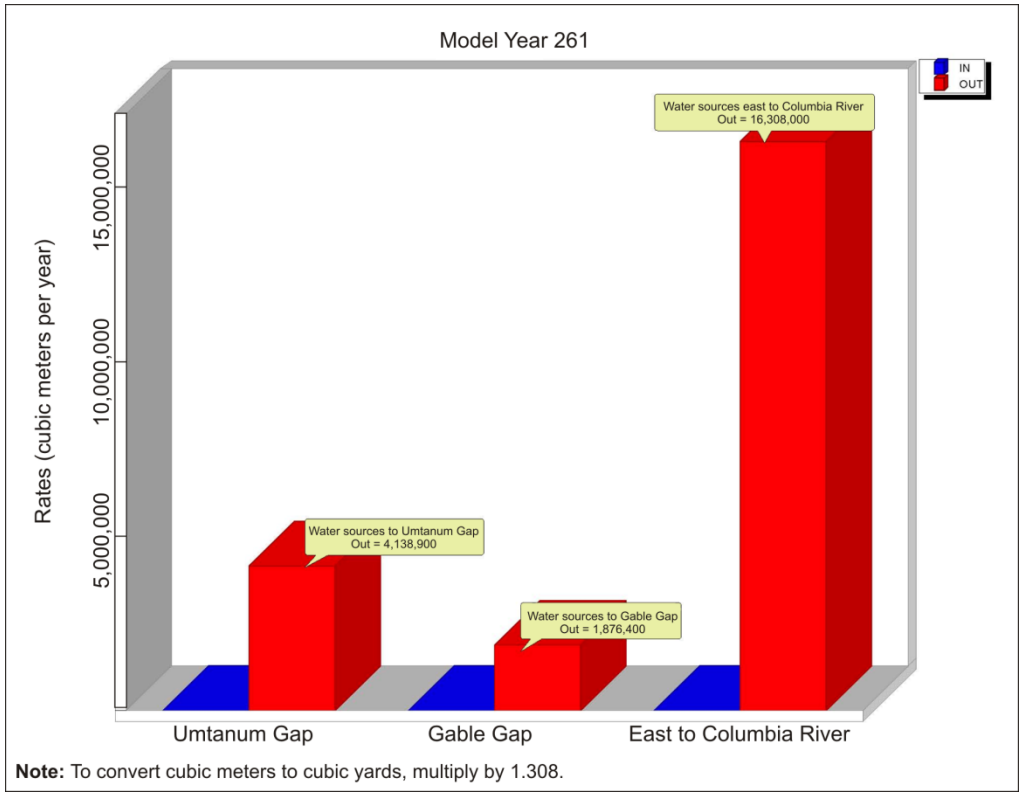


Figure V–12. Yearly Volumetric Discharge Measurements for Selected Zones, Columbia River Recharge Model Variant Flow Field

Table V–3. Summary of Water Budget Hydrographic Analysis

Recharge Variant Flow Field	Total Volumetric Discharge (cubic meters per year)	Umtanum Gap	Gable Gap	East to Columbia River
		Discharge in cubic meters per year (percent of total)		
TC & WM EIS Base Case flow field	25,000,200	4,332,200 (17%)	3,714,000 (15%)	16,954,000 (68%)
Background recharge model variant (increased yearly regional precipitation)	29,236,800	5,594,800 (19%)	6,924,000 (24%)	16,718,000 (57%)
Generalized Head Boundary recharge model variant (increased creek and watershed slope runoff discharge)	48,531,800	6,619,800 (14%)	12,924,000 (27%)	28,988,000 (60%)
Columbia River recharge model variant (increased surface water elevation)	22,323,300	4,138,900 (19%)	1,876,400 (8%)	16,308,000 (73%)

Note: To convert cubic meters to cubic yards, multiply by 1.308.
Key: *TC & WM EIS=Tank Closure and Waste Management Environmental Impact Statement for the Hanford Site, Richland, Washington.*

In the *TC & WM EIS* Base Case flow field, nearly 25 million cubic meters (32.7 million cubic yards) per year (at CY 2200) of groundwater are discharged through all three gates. For comparison, there was a 14 percent increase in total discharge (to 29.2 million cubic meters [38.2 million cubic yards] per year) in the background recharge model variant, a 48 percent increase in total discharge (to 48.5 million cubic meters [63.4 million cubic yards] per year) in the GHB recharge model variant, and an 11 percent decrease in total discharge (to 22.3 million cubic meters [29.1 million cubic yards] per year) in the Columbia River recharge model variant.

As summarized in Table V–3, of the 25 million cubic meters (32.7 million cubic yards) per year of total groundwater discharge in the *TC & WM EIS* Base Case, 68 percent passed through the "East to the Columbia River" measurement gate, 15 percent through Gable Gap, and 17 percent through Umtanum Gap. Although the total volumetric discharges associated with the background recharge and GHB recharge model variants were higher than that of the *TC & WM EIS* Base Case, the ratio and percentage of discharge through each of these measurement gates were about the same as for the Base Case (the percentage of total discharge through each of the three measurement gates was within 10 percent that of the Base Case).

In contrast to the *TC & WM EIS* Base Case flow field, the Columbia River recharge model variant exhibited both an overall decrease in total volumetric discharge and a decrease in the percentage of discharge though Gable Gap (only 8 percent of the total discharge). Further, the Columbia River recharge model variant flow field exhibited an increase in the percentage of discharge east to the Columbia River (73 percent of the total discharge) compared with that of the GHB recharge model variant (60 percent of the total discharge) and the background recharge model variant (57 percent of the total discharge).

V.4.4 Changes to Long-Term Groundwater Peak Concentrations at Selected Lines of Analysis

Groundwater flow and transport analysis was performed using each of the recharge variant flow fields outlined in Table V–1 and the *TC & WM EIS* Base Case flow field to evaluate long-term peak concentrations over time at the Core Zone Boundary, Columbia River nearshore, and applicable waste storage facility barriers, as defined in Chapters 2 and 5. Particle-tracking computer code was used to

simulate the migration of technetium-99 through each flow field (aquifer). This included particle-tracking transport runs from CY 2200 to CY 11,940.

The technetium-99 groundwater flow and transport analysis was performed within the contexts of Tank Closure Alternative 2B (peak concentration results and variances are summarized in Table V–4) and Waste Management Alternative 2, Disposal Group 1, Subgroup 1-A (peak concentration results and variances are summarized in Table V–5).

Table V–4. Tank Closure Alternative 2B, Technetium-99 Peak Concentration at Core Zone Boundary and Columbia River Nearshore

Flow Field Scenario	Core Zone Boundary			Columbia River Nearshore		
	Peak Concentration (picocuries per liter)	Peak Year	Peak Year Variance[a]	Peak Concentration (picocuries per liter)	Peak Year	Peak Year Variance[a]
TC & WM EIS Base Case flow field	1,210	2209	Not applicable	396	2254	Not applicable
Background recharge model variant (increased yearly regional precipitation)	1,710	3663	1,454	871	2487	233
Generalized Head Boundary recharge model variant (increased creek and watershed slope runoff discharge)	100	2248	39	187	2322	68
Columbia River recharge model variant (increased surface water elevation)	107	2205	–4	251	2203	–51

[a] Difference between the peak year of the selected recharge model variant and that of the *TC & WM EIS* Base Case model.

Key: *TC & WM EIS=Tank Closure and Waste Management Environmental Impact Statement for the Hanford Site, Richland, Washington.*

Table V–5. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-A, Technetium-99 Peak Concentration at Core Zone Boundary and Columbia River Nearshore

Flow Field Scenario	Core Zone Boundary			Columbia River Nearshore		
	Peak Concentration (picocuries per liter)	Peak Year	Peak Year Variance[a]	Peak Concentration (picocuries per liter)	Peak Year	Peak Year Variance[a]
TC & WM EIS Base Case flow field	497	7709	Not applicable	377	8130	Not applicable
Background recharge model variant (increased yearly regional precipitation)	7,743	7942	215	1,484	8839	709
Generalized Head Boundary recharge model variant (increased creek and watershed slope runoff discharge)	237	8350	641	335	8157	27
Columbia River recharge model variant (increased surface water elevation)	354	7796	87	246	7681	–449

[a] Difference between the peak year of the selected recharge model variant and that of the *TC & WM EIS* Base Case model.

Key: *TC & WM EIS=Tank Closure and Waste Management Environmental Impact Statement for the Hanford Site, Richland, Washington.*

Graphs illustrating peak concentrations versus time (calendar year) of technetium-99 (picocuries per liter) at the Core Zone Boundary and Columbia River nearshore within the context of Tank Closure Alternative 2B are included as Figure V–13 (*TC & WM EIS* Base Case flow field), Figure V–14 (background recharge model variant flow field), Figure V–15 (GHB recharge model variant flow field), and Figure V–16 (Columbia River recharge model variant flow field).

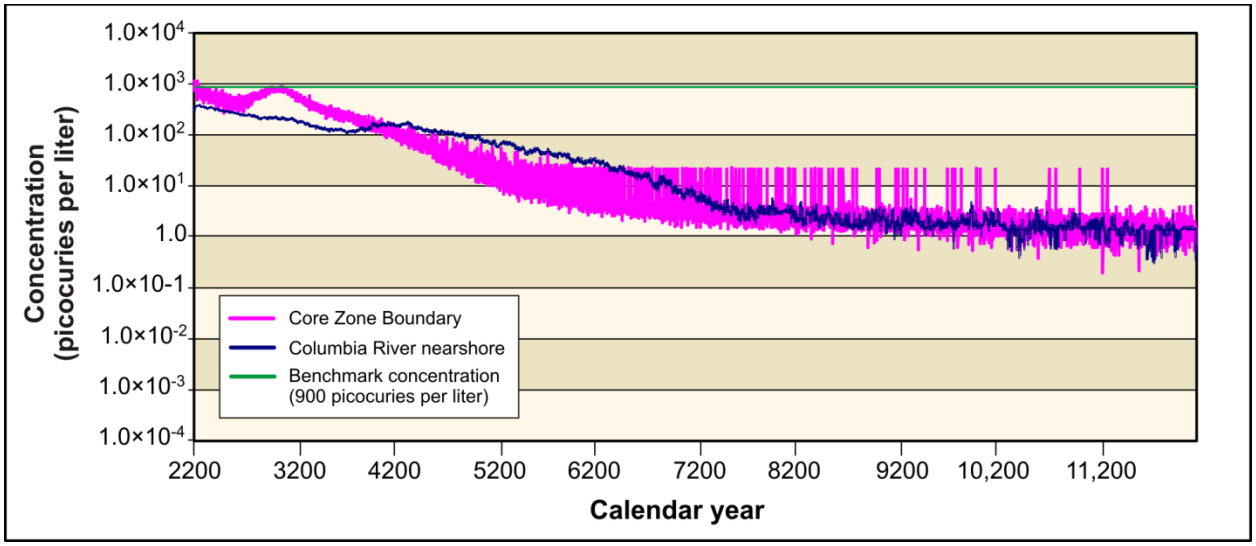


Figure V–13. Tank Closure Alternative 2B Technetium-99 Maximum Concentrations at Selected Barriers, *TC & WM EIS* Base Case Flow Field

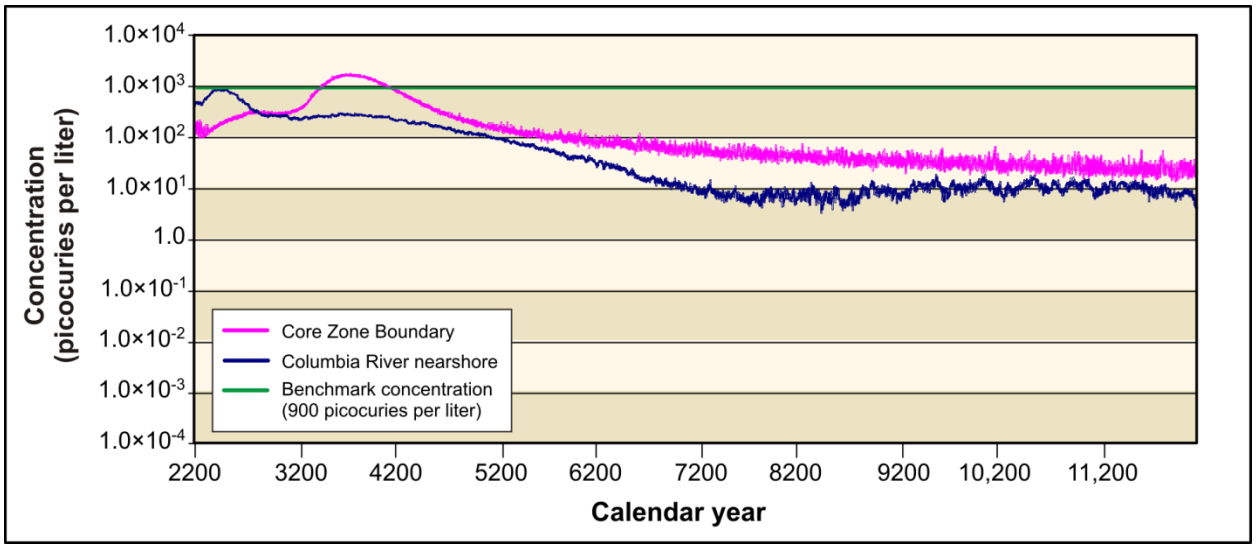


Figure V–14. Tank Closure Alternative 2B Technetium-99 Maximum Concentrations at Selected Barriers, Background Recharge Variant Flow Field

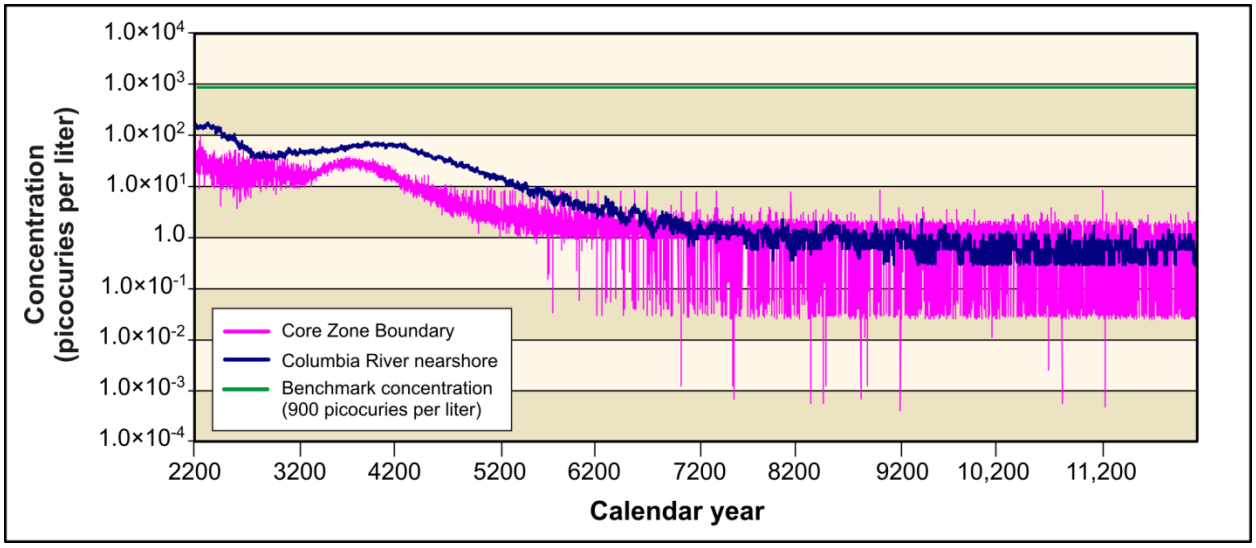


Figure V–15. Tank Closure Alternative 2B Technetium-99 Maximum Concentrations at Selected Barriers, Generalized Head Boundary Recharge Variant Flow Field

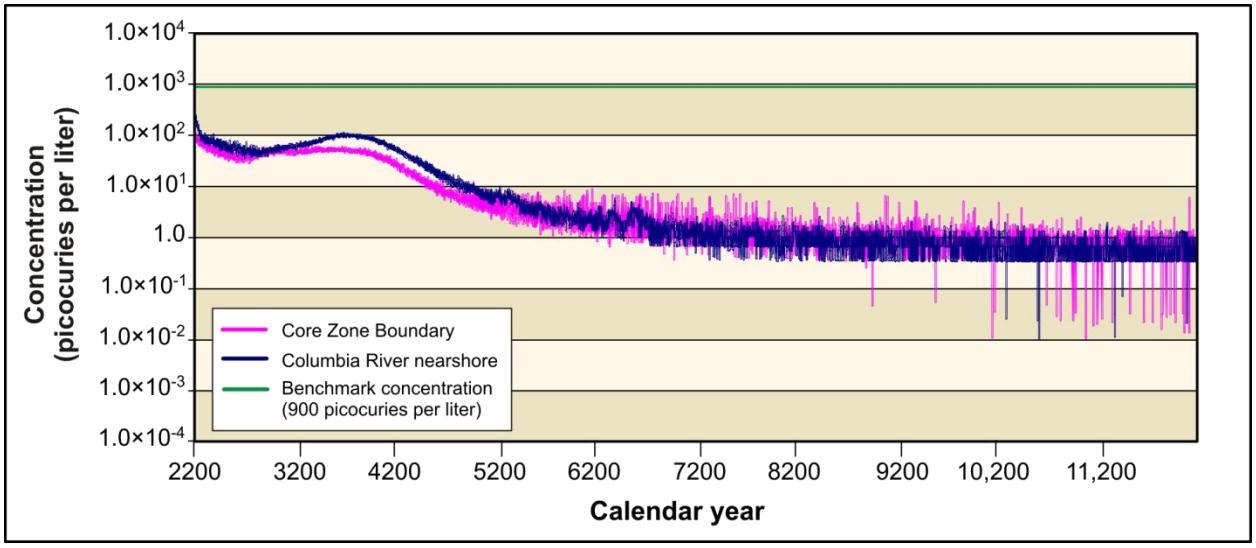


Figure V–16. Tank Closure Alternative 2B Technetium-99 Maximum Concentrations at Selected Barriers, Columbia River Recharge Variant Flow Field

Further, concentration versus time (calendar year) graphs illustrating peak technetium-99 concentrations (picocuries per liter) at the Core Zone Boundary, Columbia River nearshore, RPPDF, and IDF-East within the context of Waste Management Alternative 2, Disposal Group 1, Subgroup 1-A, are included as Figure V–17 (*TC & WM EIS* Base Case flow field), Figure V–18 (background recharge model variant flow field), Figure V–19 (GHB recharge model variant flow field), and Figure V–20 (Columbia River recharge model variant flow field).

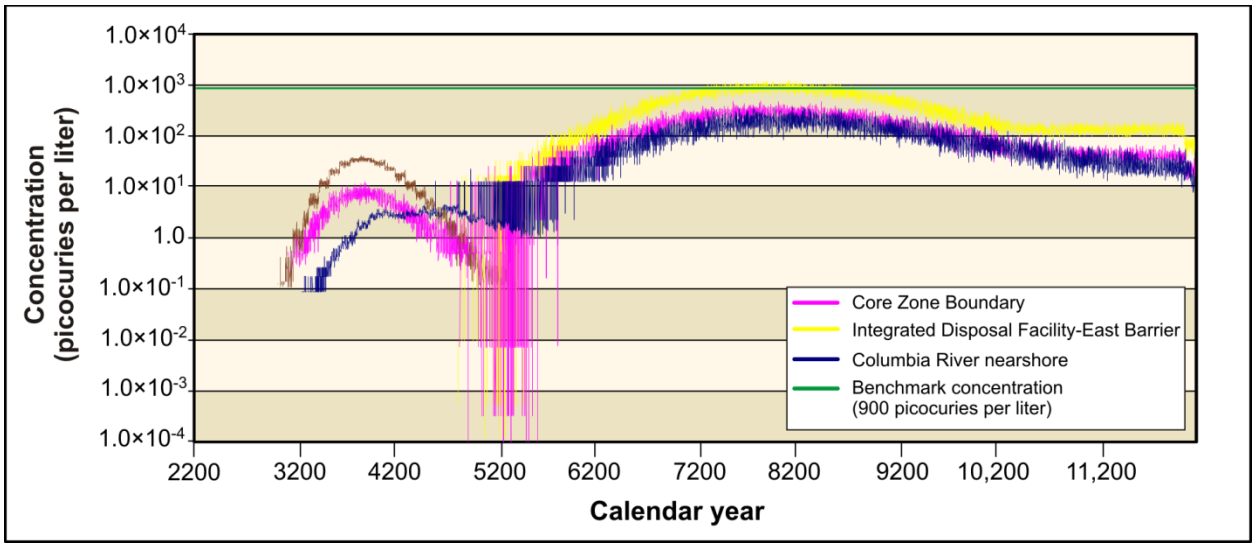


Figure V–17. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-A, Technetium-99 Maximum Concentrations at Selected Barriers, *TC & WM EIS* Base Case Flow Field

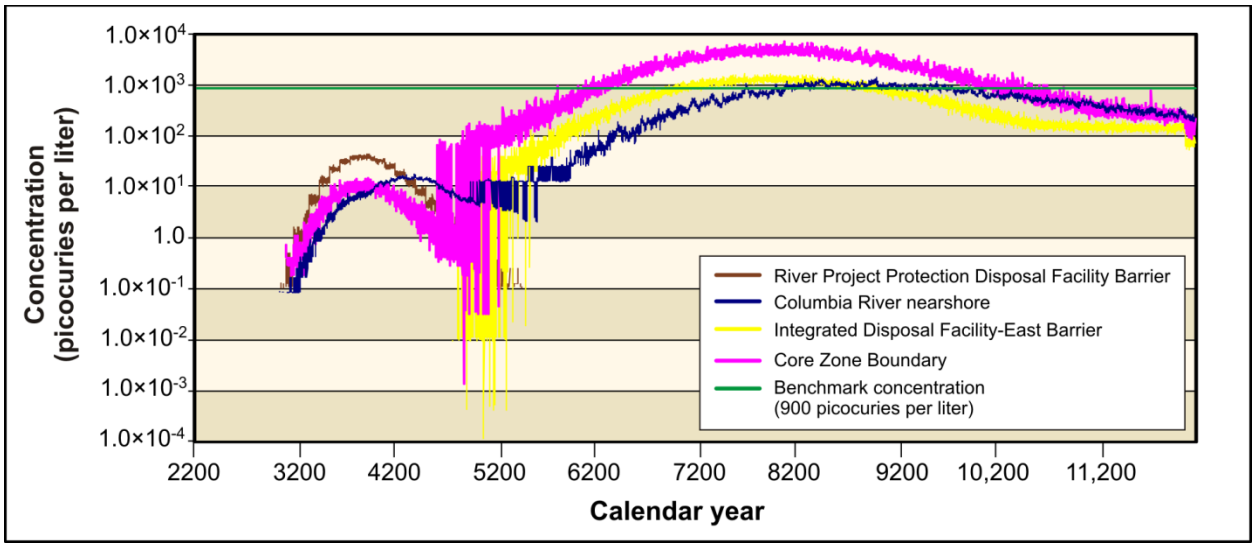


Figure V–18. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-A, Technetium-99 Maximum Concentrations at Selected Barriers, Background Recharge Variant Flow Field

Within the context of Tank Closure Alternative 2B (expanded Waste Treatment Plant vitrification, landfill closure) and regarding long-term (beyond CY 2100) flow and transport, peak technetium-99 concentrations and peak year variances associated with each of the recharge model variants are minimally impacted considering the overall period of waste release and the length of the *TC & WM EIS* Base Case transport simulation (10,000 years). None of the three recharge model variants changed the peak technetium-99 concentrations at the lines of analysis more than an order of magnitude. In general, the background recharge model variant exhibited slightly higher peak concentrations at the lines of analysis and longer travel times to the Columbia River than the Base Case flow field (see Figure V–14). Further, in general, the GHB recharge and Columbia River recharge model variants exhibited slightly lower peak concentrations than the Base Case flow field (see Figures V–15 and V–16). Long-term transport times of peak technetium-99 concentrations to the Columbia River nearshore were about the same for the GHB recharge and Columbia River recharge model variants as for the Base Case flow field.

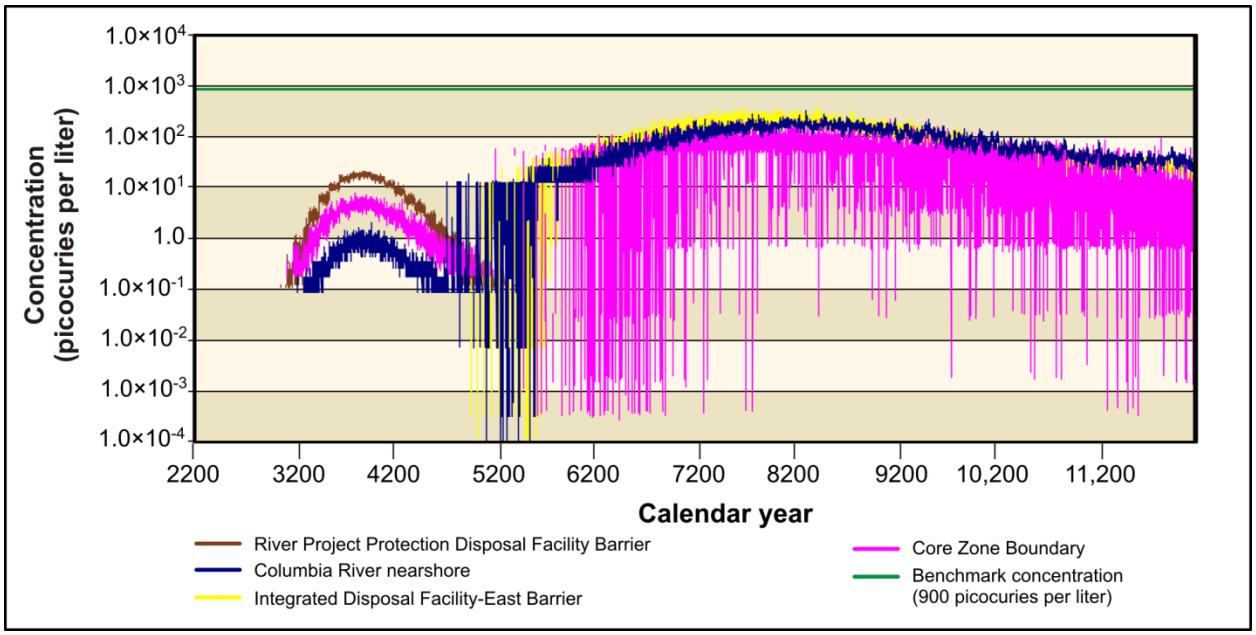


Figure V–19. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-A, Technetium-99 Maximum Concentrations at Selected Barriers, Generalized Head Boundary Recharge Variant Flow Field

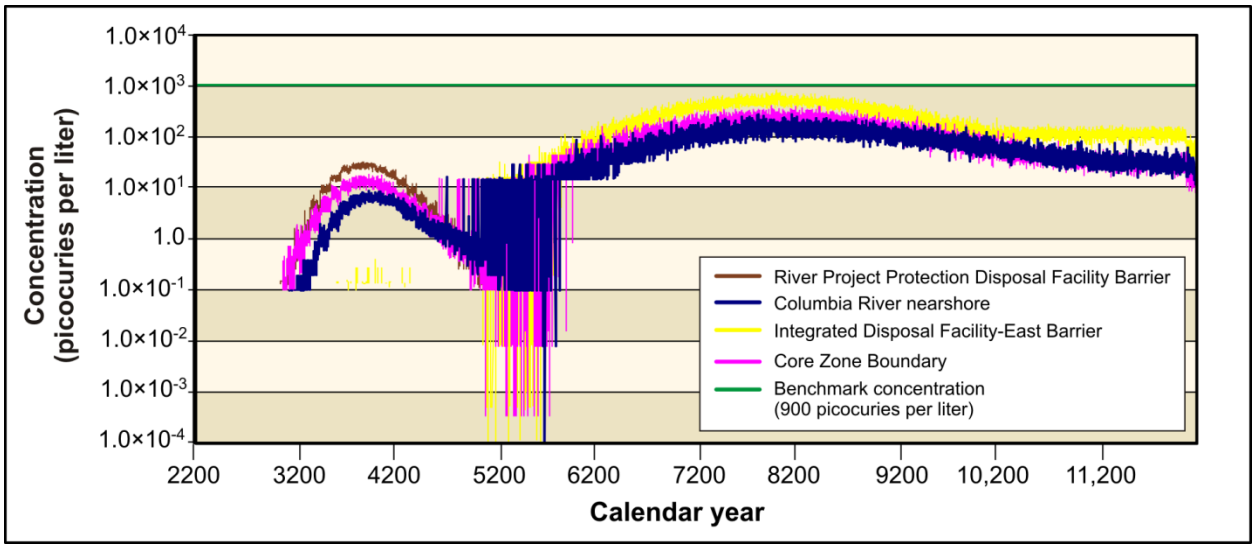


Figure V–20. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-A, Technetium-99 Maximum Concentrations at Selected Barriers, Columbia River Recharge Variant Flow Field

Within the context of Waste Management Alternative 2, Disposal Group 1, Subgroup 1-A (disposal of waste associated with Tank Closure Alternative 2B in the proposed IDF-East and RPPDF), and regarding long-term (beyond CY 2100) flow and transport, peak technetium-99 concentrations and peak year variances associated with each of the recharge model variants are minimally impacted considering the overall period of waste release and the length of the transport simulation (10,000 years). None of the three recharge model variants changed the peak technetium-99 concentrations at the lines of analysis more than an order of magnitude. However, the background recharge model variant did exhibit Core Zone Boundary, IDF-East barrier, and Columbia River nearshore peak concentrations exceeding the

benchmark technetium-99 concentration of 900 picocuries per liter. In addition, the background recharge model variant exhibited higher concentrations and longer travel times to the Columbia River nearshore than the Base Case flow field (see Figure V–18).

Overall, within the context of Waste Management Alternative 2, Disposal Group 1, Subgroup 1-A, the GHB recharge and Columbia River recharge model variants exhibited lower peak concentrations than the Base Case flow field (see Figures V–19 and V–20). Long-term travel times of peak technetium-99 concentrations to the Columbia River nearshore were about the same for the GHB recharge and Columbia River recharge model variants as for the Base Case flow field.

V.5 SUMMARY OF RESULTS AND POTENTIAL IMPLICATIONS FOR THE *TC & WM EIS* ALTERNATIVES

In summary, based on results presented in Section V.4, the following observations were made regarding each of the developed recharge model variant flow fields (described in Table V–1) relative to the *TC & WM EIS* Base Case flow field:

Background Recharge Model Variant (increased regional yearly precipitation)

- The increased yearly precipitation (to 35 millimeters per year) increases groundwater head elevations 1 to 3 meters (3.28 to 9.84 feet) across the model (most changes are below the calibrated *TC & WM EIS* Base Case RMS error value of 2.28 meters [7.48 feet]). The most significant effect is the shift of the bifurcating groundwater divide several kilometers east within the Core Zone. Thus, most of the particles released within the Central Plateau flow north through Gable Gap and continue north to the Columbia River.

- The background recharge model variant does not significantly change the maximum technetium-99 concentrations at the Core Zone Boundary and Columbia River nearshore within the context of the selected *TC & WM EIS* alternatives.

GHB Recharge Model Variant (increased western boundary, creek, and Rattlesnake Mountain watershed slope runoff discharge flux)

- The increased GHB recharge along the western boundary increases localized groundwater head elevations (6 to 9 meters [19.68 to 29.52 feet]) along the western model boundary. Included is a 4-meter (13.12-foot) increase in groundwater elevation within the Core Zone.

- The groundwater divide within the Core Zone shifts several kilometers to the east, almost out of the Central Plateau area. Thus, almost all of the particles released in the Core Zone travel north through Gable Gap and continue north to the Columbia River.

- The GHB recharge model variant does not significantly change the maximum technetium-99 concentrations at the Core Zone Boundary and Columbia River nearshore within the context of the selected *TC & WM EIS* alternatives.

Columbia River Recharge Model Variant (increased Columbia River surface water elevation)

- The increased Columbia River surface-water elevation moderately increases localized groundwater head elevations (approximately 4 meters [13.12 feet]) along the eastern and northern model boundary. Core Zone groundwater head elevations are increased roughly 1 meter (3.28 feet), which is below the calibrated *TC & WM EIS* Base Case RMS error value of 2.28 meters (7.48 feet).

- The bifurcating groundwater divide within the Core Zone shifts several kilometers to the west, crossing through the middle of the 200-West Area. As such, most of the particles released in the Core Zone travel east to the Columbia River in this model variant.

- The Columbia River recharge model variant does not significantly change the maximum technetium-99 concentrations at the Core Zone Boundary and Columbia River nearshore river barrier within the context of the selected *TC & WM EIS* alternatives.

V.6 REFERENCES

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