

CHAPTER 6

CUMULATIVE IMPACTS

This chapter presents the cumulative impacts analyses for the *Tank Closure and Waste Management Environmental Impact Statement for the Hanford Site, Richland, Washington*. The cumulative impacts analyses build on the impacts of the three alternative combinations presented in Chapters 4 and 5. Generally, short-term cumulative impacts are the highest when Alternative Combination 3 is included and are the lowest when Alternative Combination 1 is included. This is because Alternative Combination 3 generally uses the most resources and produces the most effluents and wastes, and Alternative 1 the least. By contrast, long-term cumulative groundwater-related impacts are generally highest with Alternative Combination 1 and lowest with Alternative Combination 3. This is largely because Alternative Combination 1 would leave the most waste and contaminants in the ground and Alternative Combination 3 the least. Although the long-term cumulative groundwater related impacts are highest with Alternative Combination 1 and lowest with Alternative Combination 3, cumulative groundwater-related impacts are dominated by the impacts of past releases.

6.1 METHODOLOGY

The methodology used in this *Tank Closure and Waste Management Environmental Impact Statement for the Hanford Site, Richland, Washington (TC & WM EIS)* to estimate cumulative impacts was divided into four phases: (1) identification of resource areas and appropriate regions of influence (ROIs); (2) identification of reasonably foreseeable future actions; (3) estimation of cumulative impacts; and (4) identification of monitoring and mitigation requirements. The detailed cumulative impacts methodology and a flow chart showing the four phases are presented in Appendix R of this environmental impact statement (EIS).

Cumulative Impact
Impact on the environment that results from the incremental impact of the 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).

Phase 1 - Identification of Resource Areas and Appropriate ROIs. This phase involved selecting the resource areas for the cumulative impacts analyses. The resource areas selected were those considered most likely to have a potential for meaningful cumulative impacts. Steps in this process included the following:

Region of Influence
A site-specific geographic area in which the principal direct and indirect effects of the proposed actions are likely to occur.

- 1(a) Examining the resource areas evaluated in recent Hanford Site (Hanford) National Environmental Policy Act (NEPA) documents, resource areas evaluated in this *TC & WM EIS* (see Chapters 4 and 5), and resource areas where historically significant impacts have occurred to develop a list of those resource areas that are likely to exhibit cumulative effects.
- 1(b) Identifying the ROI for each resource area to be evaluated. The ROIs determined the spatial limits of the cumulative impacts analyses conducted for each resource area. These ROIs are described in the introduction to Appendix R, Table R-3, of this *TC & WM EIS*.

Phase 2 - Identification of Reasonably Foreseeable Future Actions. In this phase, reasonably foreseeable future actions were examined and screened to determine those that needed to be included in the cumulative impacts analyses. Steps in this process included the following:

- 2(a) Identifying future Federal, non-Federal, or private actions planned in the ROIs. Information sources used for identification included Records of Decision (RODs); documents related to the Resource Conservation and Recovery Act (RCRA), the Comprehensive Environmental

Reasonably foreseeable actions
are ongoing and will continue into the future, are funded for future implementation, or are included in firm near-term plans.

Response, Compensation, and Liability Act (CERCLA), NEPA, and the Washington State Environmental Policy Act; the Hanford Federal Facility Agreement and Consent Order, also known as the Tri-Party Agreement (TPA); permits and permit applications; land use and development plans; and other data sources.

- 2(b) Examining each future action to determine whether the action is reasonably foreseeable, would occur within the ROI, would occur within the same timeframe as the *TC & WM EIS* proposed actions, and was not already accounted for in the analyses of the baseline environmental conditions.
- 2(c) Retaining those future actions that met the criteria listed in item 2(b) for analysis purposes. Future actions that did not meet all of the criteria were eliminated from further consideration.

Phase 3 - Estimation of Cumulative Impacts. During this phase, impact indicators for the alternative combinations (see Chapter 4, Section 4.4) were added to the baseline values and the values for the reasonably foreseeable future actions for the purpose of estimating the cumulative impacts. Steps in this process included the following:

- 3(a) Identifying and to the extent possible, quantifying the baseline conditions. Baseline conditions reflect the effects of past and present actions (i.e., level of direct/indirect, beneficial/adverse, short-term/long-term effects that a resource is currently experiencing). These conditions are described in Chapter 3, “Affected Environment,” of this *TC & WM EIS*. Current actions include both cleanup activities that could reduce the impacts of past actions and activities that could further degrade a resource. The importance of past actions to cumulative impacts is resource-specific. For example, past air pollutant releases would not affect baseline (current) site air quality, whereas liquid releases to the ground could have a lasting effect and need to be considered as part of the baseline conditions. Therefore, only past actions that will continue to have impacts on a resource were considered in the cumulative analyses.
- 3(b) Identifying the impacts of the *TC & WM EIS* Preferred Alternative(s) and the *TC & WM EIS* alternative combinations (described in Chapters 4 and 5).
- 3(c) Identifying the impacts of reasonably foreseeable future actions from Phase 2 of the cumulative impacts analysis methodology. If quantitative data were available, these values were incorporated into quantitative or semiquantitative cumulative impacts analyses. If quantitative data were not available, qualitative data were used.
- 3(d) Aggregating the effects on each resource from past, present, and reasonably foreseeable future actions, including the proposed actions. The aggregate effects were used to estimate cumulative impacts for each resource area. The degree of the impacts was largely determined using the same impact measures described in Chapters 4 and 5 of this *TC & WM EIS*.

Phase 4 - Identification of Monitoring and Mitigation Requirements. In the fourth phase, the cumulative impacts estimates developed in Phase 3 were examined to determine whether monitoring and/or mitigation activities would be needed. Steps in this process included the following:

- 4(a) Determining those resource areas where appreciable cumulative impacts are estimated.
- 4(b) Describing the measures that could be used to monitor and/or mitigate these potentially appreciable cumulative impacts.

In the *NEPA Recommendations for the Preparation of Environmental Assessments and Environmental Impact Statements*, Second Edition (known as The Green Book) (DOE 2004a:1, 2, 19, 20), the U.S.

Department of Energy (DOE) expands on Council on Environmental Quality instructions (40 CFR 1502.2) by stating that impacts should be discussed in proportion to their significance, and that this sliding-scale approach applies to all of the recommendations in The Green Book. The Green Book specifically recommends the use of the sliding scale for impact identification and quantification (Chapter 6, Section 6.1, of The Green Book).

As described in Chapter 4, Section 4.4, several hundred impacts scenarios could result from the potential combinations of the 11 Tank Closure, 3 Fast Flux Test Facility (FFTF) Decommissioning, and 3 Waste Management alternatives when factored with their associated option cases and waste disposal groups. For purposes of cumulative impact 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 Alternative(s). Alternative Combination 3 represents a combination that generally results 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 Alternative 6A, Option Case, would result in maximum impacts). Selection of these three alternative combinations for cumulative impacts analysis in this EIS was done only to establish overall cumulative impact reference cases for stakeholders and decisionmakers to consider, and does not preclude the selection and implementation of different combinations of the various alternatives in support of final agency decisions.

Analyses of cumulative impacts in this *TC & WM EIS* relied on a range of analytical methods based on the significance of the short-term and long-term cumulative impacts on a given resource area, the available data, and the need to adequately address the impacts to provide information to decisionmakers and the public. Short-term cumulative impacts are discussed in Section 6.3. Long-term cumulative impacts are discussed in Section 6.4.

The short-term cumulative impacts were assumed to occur during the active project phase for each of the three *TC & WM EIS* alternative combinations and were assessed for a period up to 188 years (2006 to 2193 under Tank Closure Alternative 2A). The following resource areas were selected for short-term cumulative impacts analysis: land resources (land use and visual resources); infrastructure; noise and vibration; air quality; geology and soils; water resources; ecological resources; cultural and paleontological resources; socioeconomics; public and occupational health and safety-normal operations; public and occupational health and safety-transportation; waste management; and industrial safety. The short-term cumulative impacts on these resource areas were analyzed based on semiquantitative data (i.e., simple addition of impact indicators) or qualitative information (i.e., non-numerical data). However, where data were not uniformly available or comparable across an ROI, some resource areas were addressed using a combination of semiquantitative and qualitative data.

The long-term cumulative impacts were assumed to occur following the active project phase for each *TC & WM EIS* alternative and were assessed out to approximately 10,000 years in the future. Resource areas selected for long-term cumulative impacts analysis included groundwater quality, public health, ecological risk, and environmental justice. In general, the long-term cumulative impacts on these resource areas were evaluated quantitatively (i.e., they were modeled).

As described in Appendix R, there would be few short-term or long-term impacts that could substantially contribute to cumulative impacts at Idaho National Laboratory (INL) because: (1) there would be no marked increase in the daily effluent emissions from, or waste generation by, the facilities; (2) sodium hydroxide, produced at INL's Sodium Processing Facility, would be returned to Hanford for use in processing tank waste; (3) hazardous and radioactive wastes would not be disposed of at INL; and (4) impacts of the activities would be small. Therefore, cumulative impacts at INL were considered and

found to be insignificant. Transportation of materials and waste to and from INL, however, is included in the cumulative impact analyses.

6.2 POTENTIAL CUMULATIVE ACTIONS

As stated under “Principles of Cumulative Effects Analysis” in the Council on Environmental Quality’s 1997 publication, *Considering Cumulative Effects Under the National Environmental Policy Act* (CEQ 1997), “cumulative effects are caused by the aggregate of past, present, and reasonably foreseeable future actions,” and “cumulative effects are the total effect...of all actions taken, no matter who (Federal, non-Federal, or private) has taken the action.” Therefore, it is important to identify past, present, and future actions that may appreciably degrade resources or add to the impacts on them.

For most resource areas, baseline conditions were culled from the information on the affected environment provided in Chapter 3 of this EIS. For example, as described in Chapter 3, current air quality in the ROI reflects both past and present activities. In contrast, current resource use alone may not adequately account for past resource loss, and therefore is not a good indicator of baseline conditions.

Past, present, and reasonably foreseeable future actions that may contribute to cumulative impacts include those located within the ROIs considered. Examples of past Hanford activities include operation of the fuel fabrication plants, production reactors, Plutonium-Uranium Extraction (PUREX) Plant and other fuel reprocessing facilities, Plutonium Finishing Plant, and research facilities, as well as waste treatment and disposal activities. Current Hanford activities include site cleanup, waste disposal, and tank waste stabilization.

Non-DOE activities at Hanford include the following:

- Continued transport of U.S. Navy reactor compartments from the Columbia River and their disposal in trench 218-E-12B in the 200-East Area
- Continued operation of the Columbia Generating Station
- Continued operation of the US Ecology Commercial Low-Level Radioactive Waste Disposal Facility
- Management of the Hanford Reach of the Columbia River as a national monument and a national wildlife refuge

Examples of past, present, and reasonably foreseeable future offsite activities that may contribute to cumulative impacts include clearing land for agriculture and urban development, water diversion and irrigation projects, waste management, industrial and commercial development, mining, power generation, and development of transportation and utility networks. Activities in the region surrounding Hanford include the following:

- Future regional land use as described in local city and county comprehensive land use plans (see Chapter 3 for descriptions and locations of the cities and counties surrounding Hanford)
- U.S. Department of Defense Base Realignment and Closure
- Cleanup of toxic, hazardous, and dangerous waste disposal sites
- Columbia River and Yakima River water management, including the proposed Black Rock Reservoir

- Power generation and transmission line projects
- Wind energy projects
- Pipeline projects
- Transportation projects

Appendix R, Table R-4, shows the activities considered in the cumulative impacts analyses.

In addition, under the American Recovery and Reinvestment Act (P.L. 111-5), DOE will conduct projects to accelerate its existing cleanup program at Hanford, including projects to demolish nuclear facilities and support facilities, remediate contaminated groundwater, and retrieve solid waste from burial grounds. These projects are focused waste sites and other locations along the Columbia River to support shrinking the active area of cleanup at the site from 1,518 to 194 square kilometers (586 to 75 square miles) or less by 2015. The projects will be conducted predominantly under CERCLA, with incorporation of NEPA values. However, additional NEPA reviews may be conducted as appropriate.

6.3 SHORT-TERM CUMULATIVE IMPACTS

Short-term cumulative impacts are associated with the active project phase during which the decommissioning and closure activities described under the *TC & WM EIS* alternatives would take place. For this EIS, short-term cumulative impacts were assumed to occur for up to 188 years (2006 to 2193 under Tank Closure Alternative 2A).

This section presents short-term cumulative impacts for the following resource areas: land resources (land use and visual resources); infrastructure; noise and vibration; air quality; geology and soils; water resources; ecological resources; cultural and paleontological resources; socioeconomics; public and occupational health and safety—normal operations; public and occupational health and safety—transportation; waste management; and industrial safety. Detailed tables supporting the short-term cumulative impacts analyses are presented in Appendix T.

6.3.1 Land Resources

Cumulative impacts related to land use were evaluated in an ROI that includes the proposed *TC & WM EIS* action areas, the site, and areas up to 80 kilometers (50 miles) from the site. The land use analysis focuses on the area of land impacted by recent and future growth within the ROI. A general description of land resources at Hanford and within the region is presented in Chapter 3, Section 3.2.1.1. Additional detailed information is presented in Appendix T, Table T-1.

Because project descriptions did not always identify existing land use, it was not always possible to determine specific future changes; however, in most cases, land use would change from agricultural or vacant land to a new use. In some cases, aerial photography obtained from Google Earth was used to determine current land use. It was assumed that, prior to the actual implementation of any offsite project within the ROI, issues such as conformance with existing land use plans and zoning would be resolved at the county or local level; thus, this issue was not addressed further.

For visual resources, the ROI includes the proposed *TC & WM EIS* action areas, the site, and nearby offsite areas. A qualitative analysis was performed to examine whether recently completed and reasonably foreseeable future actions would change the character of the viewshed. Factors considered included the overall area of land disturbed by the activities, the location of the activities relative to each other and public points of observation, and the proximity of the activities to the proposed *TC & WM EIS* action areas.

6.3.1.1 Land Use

To estimate the cumulative land area that would be disturbed within the ROI, the total area disturbed by the *TC & WM EIS* alternative combinations (see Chapter 4, Section 4.4.1) was added to the area disturbed by other DOE activities at Hanford and non-DOE activities within the ROI. Thirty-one projects within the ROI were analyzed with regard to the area of land they would disturb. These projects either were recently completed or are reasonably certain of being completed in the near future (see Appendix T, Table T-1). It should be noted that the projects evaluated do not represent the only activities affecting land use within the ROI. For example, the addition of many smaller subdivisions and commercial developments within the region and the conversion of vacant land to agricultural use would have a direct, but unknown, additive effect on land use. Uncertainties also exist regarding implementation of a number of large projects within the ROI; information sufficient to project their impacts on land use was not available when this EIS was prepared. A number of these projects are addressed separately in the following text because they have the potential for cumulative impacts on future regional land use.

Certain activities occurring at Hanford and within the ROI may positively affect future land use. For example, remediation efforts at Hanford could support potential reuse or restoration of land consistent with the land use designations described in the *Final Hanford Comprehensive Land-Use Plan Environmental Impact Statement (Hanford Comprehensive Land-Use Plan EIS)* (DOE 1999a). Reuse of land would negate the need to develop other possibly undisturbed areas. Restoration of remediated sites would return some land to more natural conditions (e.g., shrub-steppe habitat).

Table 6-1 presents the results of the cumulative land use analysis within the ROI. Cumulative actions may disturb from 9,260 to 10,051 hectares (22,881 to 24,836 acres) of land in the approximately 2.0 million hectare (5.0 million acre) area up to 80 kilometers (50 miles) from Hanford. *TC & WM EIS* alternatives would use from 2 to 793 hectares (4.9 to 1,960 acres). To determine the contribution of the three alternative combinations to the cumulative land requirement, the area disturbed by each combination was divided by the total land requirement. Thus, Combination 1 represents 0.02 percent of the cumulative land requirement brought about by recent past, present, or reasonably foreseeable future actions within the ROI; Combination 2 represents 3.2 percent; and Combination 3 represents 7.9 percent. Although not one of the three alternative combinations, the greatest land area requirement under the *TC & WM EIS* alternatives would occur under a combination of alternatives that includes the Tank Closure Alternative 6A, Option Case; FFTF Decommissioning Alternative 3 (with all facilities to be built at Hanford); and Waste Management Alternative 3 (with Disposal Group 2 or 3). Such a combination would represent 11 percent of the cumulative land requirement within the ROI. As noted above, these are conservative estimates because actual land use changes in the region would be greater than those reported for the 31 analyzed projects and some activities within the ROI could have a net positive impact on land use.

Table 6–1. Cumulative Land Area Disturbed

Actions/Activities	Land Area Disturbed (hectares)
TC & WM EIS Combined Impacts (see Chapter 4, Table 4–151)	
Alternative Combination 1	2
Alternative Combination 2	307
Alternative Combination 3	793
Other DOE Actions at the Hanford Site (see Appendix T, Table T–1)	650
Non-DOE Actions at the Hanford Site (see Appendix T, Table T–1)	445
Other Projects/Activities in the Region of Influence (see Appendix T, Table T–1)	8,162
Cumulative Totals^a	
Alternative Combination 1	9,260
Alternative Combination 2	9,565
Alternative Combination 3	10,051

^a The “cumulative totals” are the sums of the impacts under the alternative combinations and the “Other DOE” and “Non-DOE” activities.

Note: To convert hectares to acres, multiply by 2.471. Totals may not equal the sum of the contributions due to rounding.

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

Because the total area of developed land within the ROI is unknown, the change in the proportion of developed land within the region resulting from the 31 analyzed projects cannot be determined. However, considering the size of the ROI and the amount of past development, the additional disturbance of the land by the evaluated projects would be small. Because the extent of past development at Hanford (6 percent of the total land area [Neitzel 2005:4.144]) is known, it is possible to determine the effect that recent past, present, and reasonably foreseeable future development may have on the site. Thus, considering the land requirement of each of the three alternative combinations, as well as the other projects and activities occurring at the site, the total area of land disturbed at Hanford would increase to between 6.7 and 7.2 percent of the site for the three alternative combinations evaluated. Under the maximum foreseeable impact alternative combination (Tank Closure Alternative 6A, Option Case; FTF Decommissioning Alternative 3 [with all facilities to be built at Hanford]; and Waste Management Alternative 3 [with Disposal Group 2 or 3]—not included in the alternative combinations tables), the total area of disturbed land would increase to 7.5 percent. As noted above, these are conservative estimates because credit was not taken for future remediation and restoration efforts.

Additional actions that may impact land use within the ROI include decisions made in the ROD (64 FR 61615) and amended ROD (73 FR 55824) for the *Hanford Comprehensive Land-Use Plan EIS* (DOE 1999a), urban expansion, closure of the Umatilla Army Depot, the Columbia River Water Management Program, and a number of power-related projects.

The generalized land use plan implemented by the RODs for the *Hanford Comprehensive Land-Use Plan EIS* is shown in Appendix R, Figure R–1, of this *TC & WM EIS*. While there is minimal potential for development in certain areas of Hanford (e.g., the Hanford Reach National Monument, Gable Mountain, and Gable Butte) due to the applicable land-use designations described in the *Hanford Comprehensive Land-Use Plan EIS* (DOE 1999a), other areas of the site could undergo future land use changes. For example, areas designated as Industrial-Exclusive and Industrial are suitable for the treatment, storage, and disposal of various wastes, as well as activities such as reactor operations, rail and barge transport facilities, mining, manufacturing, and distribution operations, respectively. In addition, areas designated

Conservation (Mining), while principally set aside for management and protection of cultural, ecological, and natural resources, may be utilized for mining operations. Other land use designations, including Research and Development and Recreation, would permit various levels of future development. Thus, the land use plan allows for as yet unspecified future changes at the site.

The 1990 Washington State Growth Management Act (RCW 36.70A) requires counties in the region around Hanford to have comprehensive land use plans. Cities and other government jurisdictions adopt such comprehensive plans to guide future activities within their jurisdictions. These plans project land development, housing, infrastructure, and community services needs 20 years into the future. Generally, the plans encourage growth in urban growth areas (lands set aside or designated as necessary for future population growth beyond those undeveloped lands already within city boundaries) and discourage growth outside these areas. As an example, the *City of Richland Comprehensive Land Use Plan, Final* (Richland 2002:3-4) has designated urban growth areas that cover an area of 8,954 hectares (22,125 acres). Of that area, 4,563 hectares (11,275 acres) are developed and 4,391 hectares (10,850 acres) are vacant and available for future development. While the designation of such areas helps planners with long-range planning efforts, specific details regarding future development are uncertain; thus, these county comprehensive land use plans cannot be used to project reasonably foreseeable future actions.

In May 2005, the Department of Defense announced its latest round of Base Realignment and Closure actions (AFIS 2005; BRAC 2005). The 7,972-hectare (19,700-acre) Umatilla Army Depot, located about 48 kilometers (30 miles) to the south of Hanford, is the only major military facility in the ROI that would be affected. While closure of the depot is expected to result in a loss of jobs (BRAC 2005:Ind-14, C-20) and an eventual reduction in activities that cause environmental impacts, the specific impacts of its closure and reuse have not been evaluated. Thus, although this action is likely to impact future land use in the ROI, it cannot be evaluated at this time.

The Columbia River Water Management Act (RCW 90.90) requires the Washington State Department of Ecology (Ecology) to “aggressively pursue the development of water supplies to benefit both in-stream and out-of-stream uses.” Ecology is currently in the process of developing a Columbia River Water Management Program to facilitate implementation of the legislation. No specific storage or conservation projects have been identified for implementation under the Management Program; however, such projects would have clear implications for changes in future land use (Ecology 2007:1).

A number of power-related projects have been proposed for the ROI, but have been put on hold. These include the Plymouth Generation Facility (a 306-megawatt, natural gas-fired turbine electric generating facility [Benton and BPA 2003; BPA 2008]); the Wanapa Energy Center (a 1,200-megawatt gas/steam turbine electric generating facility) (BIA 2004; BPA 2008); and the 127-kilometer (79-mile) McNary to John Day 500-kilovolt line transmission line project (BPA 2008). If completed, these projects would result in additional changes in land use within the ROI.

6.3.1.2 Visual Resources

One measure of cumulative impacts is whether the visual character of the ROI would change as a result of implementation of recent past, present, and reasonably foreseeable future actions. Because of the limited size of many of the projects, their distance from Hanford, and their occurrence near areas that are presently developed, the overall change to the viewshed within the ROI is likely to be minimal. Further, many activities at Hanford would not be visible from public viewpoints (e.g., nearby higher elevations, highways, or the Columbia River) and; thus, would contribute little to overall cumulative impacts on visual resources.

As noted above, the location of new facilities relative to public points of observation is an important consideration in determining cumulative visual impacts. One of the few locations that would permit a

relatively unobstructed view of much of the ROI is the top of Rattlesnake Mountain. From this location, many activities at Hanford would be visible (see Chapter 4, Section 4.4.1.2), as would a number of offsite projects. For example, an observer atop Rattlesnake Mountain would be able to observe Borrow Area C, some of the larger projects within the 200 Areas, Black Rock Reservoir, and the Red Mountain American Viticulture Area near Benton City, Washington. These activities would replace existing views with ones that would be different than those currently experienced. Implications of cumulative visual impacts on American Indians who consider Rattlesnake Mountain an important cultural property are addressed in Section 6.3.8.3.

The relative cumulative visual impacts of the three *TC & WM EIS* alternative combinations would be similar to the combined impacts addressed in Chapter 4, Section 4.4.1.2, because all other recent past, present, and reasonably foreseeable future non-DOE actions within the ROI would remain the same for all of the alternative combinations evaluated. Thus, development associated with Combination 1 would contribute the most to cumulative visual impacts, and Combination 3 would contribute the least. As noted in the discussion of combined visual impacts, a combination of alternatives involving Tank Closure Alternative 6A, Option Case; FFTF Decommissioning Alternative 3 (with all facilities to be built at Hanford); and Waste Management Alternative 3 (with Disposal Group 2 or 3) would disturb the greatest area and alter the existing viewshed to the greatest extent.

Completion of remediation and restoration activities at Hanford would positively impact the visual environment. These activities would include, for example, decommissioning of the reactors in the 100 Areas, closure of the canyon facilities in the 200 Areas, and restoration of the borrow areas following completion of mining activities. While remediated and restored areas would not precisely replicate past conditions, they would improve the viewshed overall and lessen the cumulative visual impacts. However, not all remediation actions would lead to the restoration of more natural conditions because some facilities or sites are located within areas designated in the *Hanford Comprehensive Land-Use Plan EIS* (DOE 1999a) as Industrial-Exclusive or Industrial. These areas would continue to be available for further development, as noted in Section 6.3.1.1.

In most cases, activities within the ROI would not change the U.S. Bureau of Land Management Visual Contrast Ratings because projects would be located in or adjacent to areas that are already developed. However, the rating for Borrow Area C would change from Class II to Class III under Alternative Combination 1 and Class IV under Combinations 2 and 3. In the later case, mining activities would dominate an area that had previously undergone minimal development.

6.3.2 Infrastructure

For the purpose of providing the most meaningful analysis, electricity and water were selected as key resource indicators for assessing potential cumulative effects on utility infrastructure systems. For electric power, the ROI includes the electric power distribution and transmission system and associated power capacity that supplies the Hanford 100, 200, 300, and 400 Areas. For water, the affected ROI includes the Hanford Export Water System that supplies the Hanford 100, 200, and part of the 600 Areas. Projected requirements for these utility resources under each of the *TC & WM EIS* alternative combinations (see Chapter 4, Section 4.4.2) were added to the demands of other DOE and non-DOE activities at Hanford, all of which have the potential to impact the associated utility system and utility resource consumption within the defined ROI. The ROIs for electric power and water supply were determined to provide the most meaningful analyses of potential cumulative effects on utility infrastructure because the affected utility systems are relatively confined to Hanford and otherwise well defined, and projected demands can be quantified with the least amount of uncertainty.

Table 6–2 presents the results of the cumulative impacts analysis for utility infrastructure. The utility requirements presented in Table 6–2 represent the peak annualized utility resource demands for the three

TC & WM EIS alternative combinations, baseline demands from Chapter 3 as appropriate, and projected utility demands for various DOE activities and non-DOE activities that have the potential to occur within the same timeframe. Appendix R, Table R-4, details the actions and activities that were evaluated to determine their possible contributions to cumulative impacts at Hanford. As specifically noted in that table, many of the listed actions are already either wholly or partially accounted for in the Hanford baseline in terms of their contribution to cumulative impacts.

Table 6-2. Potential Cumulative Utility Infrastructure Requirements

Actions/Activities ^a	Peak Annualized Requirement	
	Electricity (million megawatt-hours)	Water (million liters)
<i>TC & WM EIS</i> Combined Impacts^b (see Chapter 4, Table 4-152)		
Alternative Combination 1	0.04	1,200
Alternative Combination 2	1.18	3,670
Alternative Combination 3	1.26	3,800
Other DOE Actions at the Hanford Site		
Hanford Site baseline ^c	0.17	817
Cleanup and restoration activities (2006–2035)	No data	No data
Actions to empty the K Basins in the 100-K Area (2006–2036)	–0.013	0.90
Deactivation of FFTF in the 400 Area (2006–2036) ^d	–0.020	–116
Retrieval of retrievably stored TRU waste (2017–2018) (SAIC 2007a)	0.000024	0.99
Excavation and use of geologic materials (2006–2013) (DOE 2001; 2003a)	No data	No data
Construction and Operation of the ERDF (2006–2024) (DOE 1994)	No data	No data
PNNL Physical Sciences Facility (2006–2011) (DOE 2007a)	No data	No data
Other DOE Subtotals	0.14	702
Non-DOE actions in the Region of Influence		
US Ecology Low-Level Radioactive Waste Facility (2006–2056) (Ecology and WSDOH 2004:140)	0.00045	0.076
Hanford Reach National Monument (2006–2022) (USFWS 2008)	No data	No data
Non-DOE Subtotals	0.00045	0.076
Cumulative Totals^e		
Alternative Combination 1	0.18	1,900
Alternative Combination 2	1.32	4,370
Alternative Combination 3	1.40	4,500
Utility system capacity^f	1.74	18,500

^a Activities/actions as identified in Appendix R, Table R-5. Years in parentheses reflect the timeframe in which the resource demand may potentially occur.

^b From Chapter 4, Section 4.4.2, Table 4-144.

^c From Chapter 3, Section 3.2.2, Table 3-2.

^d Assumes future decommissioning of the FFTF and 400 Area with the resulting cessation of pre-deactivation levels of utility consumption (based on fiscal year 2006 reporting).

^e The “cumulative totals” are the sums of the impacts under the alternative combinations and the “Other DOE” and “Non-DOE” activities.

^f Capacity of the electric power and water supply systems serving Hanford from Chapter 3, Section 3.2.2, Table 3-2.

Note: To convert liters to gallons, multiply by 0.26417. Subtotals or totals may not equal the sum of the contributions due to rounding.

Key: DOE=U.S. Department of Energy; ERDF=Environmental Restoration Disposal Facility; FFTF=Fast Flux Test Facility; PNNL=Pacific Northwest National Laboratory; *TC & WM EIS*=*Tank Closure and Waste Management Environmental Impact Statement for the Hanford Site, Richland, Washington*; TRU=transuranic.

Projected changes in cumulative utility resource demands over the period of analysis reflect operational activities as well as finite actions (such as final closure actions) that may result in a spike and/or subsequent reduction in demands as activities are performed or final actions are completed. The potential for the cumulative demand to exceed the capacity of the utility system that supplies the resource within the Hanford utility infrastructure ROI was assessed. In short, the focus of this analysis was to forecast the potential maximum annual utility resource demand that could occur as a basis for assessing cumulative impacts on utility infrastructure. The totals presented represent upper limits of utility demands at Hanford.

As indicated in Table 6–2, neither the capacity of the Hanford electric transmission system (1.74 million megawatt-hours per year) nor the capacity of the Hanford Export Water System (18,500 million liters per year [4,887 million gallons per year]) would be exceeded on a cumulative basis. For electric power, peak cumulative demands would range from about 10 percent of capacity under Alternative Combination 1 to 80 percent under Combination 3. For water supply, peak cumulative demands would range from about 10 percent under Combination 1 to 24 percent under Combination 3.

Based on the analysis performed, only the electric power system would be substantially impacted by the cumulative effects of the *TC & WM EIS* alternative combinations and present and future actions; up to 93 percent of the cumulative effect on electric power capacity would be attributable to *TC & WM EIS* activities alone. As referenced in this chapter and in Appendix R, proposed wind energy projects by Bonneville Power Administration and others could help alleviate any electric power shortages that could otherwise indirectly affect the Hanford electric power system in the future.

Cumulative peak annual utility demands approaching the capacity of the utility system that supplies the resource would be indicative of the need for DOE and utility providers, to consider project changes, resource conservation, augmentation of utility capacity, or some combination of measures to ensure that utility demands can be met at Hanford to support ongoing and future tank closure, waste treatment, and other related actions.

Historically, electric power consumption across Hanford and the capacity of the transmission and distribution systems was much greater, especially when the 100 Area reactors were in operation (see Chapter 3, Section 3.2.2.2). This is also true for the Hanford Export Water System, which withdraws water from the Columbia River and once supplied water to the 100 Areas, but has been reconfigured over time (see Chapter 3, Section 3.2.2.4). As indicated in Appendix R, decommissioning of the 100 Area reactor facilities is ongoing. Prior to 1990, the 200 Areas alone had annual water demands of more than 22,700 million liters (6,000 million gallons), which was supplied via the Hanford Export Water System.

As indicated in Chapter 4, Section 4.4.2, the projected resource demands from the three *TC & WM EIS* alternative combinations would be very conservative because contributing peak utility demands are likely to occur in different timeframes and not overlap. In addition, the Hanford baseline already includes utility impacts associated with existing and ongoing tank closure activities that cannot be separated out; therefore, their addition to the impacts of the *TC & WM EIS* alternative combinations unavoidably reflects some level of double counting. Future actions associated with sitewide waste cleanup and restoration activities, including proposed closure of the Central Plateau, are expected to cause a temporary increase in utility demands followed by a decline and even cessation of resource consumption after specified cleanup actions are completed. The timing and duration of associated peaks in utility consumption and subsequent reduction in utility demands upon completion of activities, are very speculative and no data are available for calculating such estimates.

Similarly, utility resource requirements for cleanup of the balance of Hanford and decontamination and decommissioning (D&D) of individual facilities have not been well quantified in available documentation such as the *Draft Hanford Remedial Action Environmental Impact Statement and Comprehensive Land*

Use Plan (DOE 1996a) or subsequent plans or studies. While there would likely be an incremental increase in utility demands in the short term to complete individual cleanup and facility D&D actions, the net effect over the longer term would be a sitewide reduction in utility demands once activities have ceased. While individual future cleanup and facility disposition and D&D actions were considered in this *TC & WM EIS* (see Appendix R, Table R-4), they are not specifically listed in Table 6-2 and their cumulative effect on utility infrastructure presents another point of uncertainty and possible conservatism in the analysis.

Some actions will undoubtedly also result in reduced resource consumption where existing facilities and infrastructure are upgraded and/or replaced with modern, more resource-efficient facilities. Such is the case with the relocation of Pacific Northwest National Laboratory (PNNL) personnel and activities from the 300 Area to the new PNNL Physical Sciences Facility to be constructed adjacent to the existing PNNL campus. Except for relatively minor construction-related impacts and utility demands, net operational impacts on Hanford utility infrastructure would be lower once the transition is complete (DOE 2007a:S-3, 15). Nevertheless, this reduction in utility resource demands has not been quantified. In any event, as the city of Richland, Washington, provides utility services to the site (DOE 2007a: 5-13, 15), any operational impacts would not directly affect the utility systems serving Hanford facilities. Such circumstances further add to the conservative nature of this analysis.

Excavation of geologic and soil resources for use across Hanford in support of ongoing activities necessarily entail some consumption of utility resources, including water for dust control and to aid crushing and sorting operations and liquid fuels for operation of heavy equipment. While not separately quantified from available data, these demands were assumed to be at least partially captured in the Hanford baseline value presented in Table 6-2. Utility resource consumption would likely increase in proportion to the excavation and conveyance of greater volumes of material to support future actions (see Section 6.3.5), and these utility requirements were already quantified to some extent within the requirements of the three *TC & WM EIS* alternative combinations.

As stated previously, the analysis also considered utility infrastructure impacts from non-DOE activities. Ongoing operations and utility resource consumption associated with the US Ecology Commercial Low-Level Radioactive Waste Disposal Facility are included in the Hanford baseline. Future closure actions would result in additional, short-term demands, but are difficult both to quantify and to separate from operational demands already included in the Hanford baseline. Estimates for these incremental demands are included in Table 6-2, where available, and likely further enhance the conservative nature and uncertainty of the analysis presented.

In addition, U.S. Fish and Wildlife Service personnel working at the Hanford Reach National Monument are using existing Hanford facilities that have been declared surplus to DOE needs, including maintenance shops, a pump house, and a reservoir, as well as sharing space with other entities such as the Bonneville Power Administration (USFWS 2008:3-145, 3-146). Utility demands associated with operation of these facilities are assumed to be part of the Hanford baseline. Nonetheless, the U.S. Fish and Wildlife Service's preferred alternative for management of the Hanford Reach National Monument would entail construction and maintenance of new facilities and other improvements, including interpretive sites, parking and boat access areas, trails, and a possible visitor center to enhance visitor use and access to areas within the Hanford Reach National Monument (USFWS 2008:4-225-4-227). While these activities would add to the cumulative demand for utility resources, the demand cannot be quantified at this time.

6.3.3 Noise and Vibration

Noise impacts from activities under the *TC & WM EIS* alternatives would primarily result from changes in vehicle traffic on access roads to Hanford, as discussed in Chapter 4, Sections 4.1.3, 4.2.3, and 4.3.3.

Based on information provided in the NEPA documents that are available (see Appendix R, Table R-4), noise impacts on the public from other DOE activities are primarily related to vehicle traffic. Impacts on wildlife could occur from various construction activities, including remediation, closure, and operation of the various borrow areas.

Noise impacts from non-DOE construction and operation activities were also considered, including impacts on the public and wildlife from construction-related activities and future industrial operations at the 300 Area. Noise impacts from existing non-DOE activities at Hanford, such as traffic noise from the Columbia Nuclear Generating Station and operation of the AREVA Nuclear Fuel Fabrication Facility, the Perma-Fix Northwest Waste Treatment Facility, and the US Ecology Low-Level Radioactive Waste Disposal Facility, are part of the existing background sound environment near Hanford.

Future activities at Hanford and in the areas near the site, such as new industries, oil and gas development, agriculture, offices, schools, residential development, new roads, and other infrastructure improvements, could result in variations in the levels of traffic noise along access roads to the site and increased noise levels near these developments. Some of the proposed developments in the area that are expected to result in increased noise levels include various wind energy projects; the Columbia Ethanol Plant in Finley, Washington; the Southridge, Hansen Park, and Clearwater Park developments in Kennewick, Washington; and the new PNNL Physical Sciences Facility at Hanford.

As such, the cumulative impact on noise levels in the region from the activities described above is expected to result in some increase in traffic noise and localized changes in noise levels from new facilities and developments. Because of the distance to the site boundary, little or no change in overall offsite noise levels is expected due to construction, operations, and decommissioning activities at Hanford.

DOE activities, other activities at Hanford, traffic through Hanford, and road work at Hanford could result in ground vibration that could affect the operation of the Laser Interferometer Gravitational-Wave Observatory (LIGO) facility. Most of the activities that were identified to have impacts on this facility result from heavy vehicles and large construction equipment. It is expected that blasting during building and road construction and during mining could also have an impact on this facility. Although DOE will coordinate vibration-producing activities with the operators of the LIGO facility, cumulative impacts from these activities are expected to result in some interference with its operations.

6.3.4 Air Quality

Cumulative impacts of criteria air pollutants are shown in Table 6-3 for DOE actions at Hanford and non-DOE actions in the region for those pollutant concentrations that have been quantified. Cumulative impacts of radiological air emissions on public and occupational health and safety are discussed in Section 6.3.10. The concentrations presented in Table 6-3 represent the maximum concentrations under the three *TC & WM EIS* alternative combinations, the baseline concentration from Chapter 3, the estimated maximum concentrations for various DOE activities and non-DOE activities that have been presented in NEPA documents, and the estimated concentrations for retrieval of retrievably stored transuranic (TRU) waste. Concentrations also are presented for operations activities.

Table 6-3 indicates that cumulative concentrations of carbon monoxide, nitrogen oxides, and sulfur oxides could be up to 495, 112, and 74 percent of applicable standards, respectively. Cumulative concentrations of particulate matter (PM) with an aerodynamic diameter less than or equal to 10 micrometers (PM₁₀) could be up to 155 times the applicable standard.

Table 6–3. Cumulative Impacts of Criteria Air Pollutants

Actions/Activities	Maximum Average Concentration (micrograms per cubic meter)			
	Carbon Monoxide (8 hours)	Nitrogen Oxides (Annual)	Particulate Matter (PM ₁₀) (24 hours)	Sulfur Oxides (1 hour)
TC & WM EIS Combined Impacts^a (see Chapter 4, Table 4–153)				
Alternative Combination 1	3,480	9.8	1,050	24.7
Alternative Combination 2	16,700	45.9	8,650	222
Alternative Combination 3	49,500	112	23,200	486
Other DOE Actions at the Hanford Site				
Hanford Site baseline ^b	40	0.26	0.88	4.6
Existing borrow areas (DOE 2001) ^c	NR	NR	4.03	NR
Retrieval of retrievably stored TRU waste (based on SAIC 2007a) (2017–2018)	1.54	0.0195	22.8	0.0023
Other DOE Subtotals	42	0.28	28	4.6
Non-DOE Actions in the Region of Influence				
Pacific EcoSolutions offsite thermal treatment of Hanford Site LLW (DOE 1999b)	0.24	0.0283	0.000442	0.0398
Pacific EcoSolutions nonthermal treatment of Hanford Site LLW (DOE 1998a)	NR	NR	0.0026	NR
Non-DOE Subtotals^d	0.24	0.028	0.003	0.040
Cumulative Totals^e				
Alternative Combination 1	3,520	10.1	1,080	29.3
Alternative Combination 2	16,700	46.2	8,680	227
Alternative Combination 3	49,500	112	23,200	491
<i>Most Stringent Standard</i>	<i>10,000</i>	<i>100</i>	<i>150</i>	<i>660</i>

^a See Chapter 4, Table 4–153.

^b See Chapter 3, Section 3.2.4.

^c Particulate matter concentration at the pit. Value is not representative of the concentration to which the public would be exposed.

^d The maximum from these non-DOE facilities is presented because the location of these estimated concentrations is not presented in the source documents.

^e The “cumulative totals” are the sums of the impacts under the alternative combinations and the “Other DOE” and “Non-DOE” activities.

Note: To convert cubic meters to cubic yards, multiply by 1.308. Values that exceed the standard value are shown in **bold** text. Subtotals or totals may not equal the sum of the contributions due to rounding.

Key: DOE=U.S. Department of Energy; LLW=low-level radioactive waste; NR=not reported; PM₁₀=particulate matter with an aerodynamic diameter less than or equal to 10 micrometers; *TC & WM EIS*=*Tank Closure and Waste Management Environmental Impact Statement for the Hanford Site, Richland, Washington*; TRU=transuranic.

The 16,700 micrograms per cubic meter carbon monoxide concentration under *TC & WM EIS* Alternative Combination 2 and the 49,500 micrograms per cubic meter carbon monoxide concentration under Alternative Combination 3 could exceed the 10,000-micrograms-per-cubic-meter 8-hour standard for carbon monoxide. The nitrogen oxide concentration under Alternative Combination 3 could exceed the 100-micrograms-per-cubic-meter standard for nitrogen oxides. The peak concentration for carbon monoxide and nitrogen oxide under the *TC & WM EIS* alternatives would result primarily from fuel-burning activities. Carbon monoxide and nitrogen oxide concentrations could be reduced by applying appropriate administrative control measures (see Chapter 7, Section 7.1.4).

PM concentrations under the *TC & WM EIS* alternative combinations could exceed the 150-micrograms-per-cubic-meter 24-hour standard for PM₁₀, ranging from 1,080 micrograms per cubic meter under Alternative Combination 1 to 23,200 micrograms per cubic meter under Alternative Combination 3. The

peak concentration for PM from the *TC & WM EIS* alternatives would result primarily from construction and earthmoving activities. PM concentrations could be reduced by applying appropriate dust control measures (see Chapter 7, Section 7.1.4).

The cumulative impacts analysis is very conservative because many of the air pollutant releases would occur at different times, and the peak concentrations would occur at different locations and may not be additive. The estimates of air pollutant concentrations for the *TC & WM EIS* alternative combinations were based on conservative analyses that would be refined in future design documents. If the more refined future analyses still predict exceedance of air quality standards, then additional measures (e.g., location changes, use of additional pollution control equipment, or administrative controls) would be instituted to reduce emissions to an acceptable level. Activities that would cause air quality standards to be exceeded would not be allowed.

Hanford facilities that are permitted in the Hanford Air Operating Permit were included in the estimate of the Hanford baseline concentrations (see Chapter 3, Section 3.2.4, of this *TC & WM EIS*) based on the annual emissions inventory.

Impacts from other onsite activities are discussed below based on the information provided in the environmental impact documents that are available.

In the 100 Area, there would be continuing fugitive dust emissions and emissions from reactor decommissioning over the next 50 years or more (DOE 1999a:3-61, 5-45) and dust from waste site excavation (DOE 2006a). In the 200 Areas, there would be ongoing fugitive dust emissions and equipment emissions from various borrow area and construction sites (DOE 1999a:3-61, 5-45), dust and equipment emissions from ongoing construction and operation of the Environmental Restoration Disposal Facility (ERDF) (DOE 1994), emissions from canyon disposition (221-U closure) (DOE 2004b); emissions from facility demolition and remediation, including excavation, backfill, and capping; (Fluor Hanford 2004), and emissions from Plutonium Finishing Plant above-grade structure removal (DOE 2003a). In the 300 Area, there would be fugitive dust emissions and other emissions from surplus facilities closure and future uses (DOE 1999a).

Other DOE activities at Hanford include activities at existing active borrow pits and quarries (DOE 2001), as well as reactivation of former borrow areas in the 100-F, 100-H, and 100-N Areas (DOE 2003b), which would produce emissions of fugitive dust and other pollutants from excavation equipment and trucks. Construction and operation of the relocated PNNL Physical Sciences Facility from the 300 Area to the PNNL campus would result in some fugitive dust emissions and other construction emissions during the period 2007 to 2008, as well as emissions of other criteria pollutants from boiler use and emergency generator operation. Maximum concentrations resulting from operation of this facility were estimated to be about 4 percent of the 8-hour carbon monoxide standard and 4 percent of the PM₁₀ 24-hour standard and are not included in Table 6-3 (DOE 2007a).

Non-DOE activities that would emit fugitive dust and other pollutants include AREVA operation, from which there are nitrogen oxides emissions; Perma-Fix nonthermal and thermal treatment of mixed low-level radioactive waste (MLLW), which may produce some combustion emissions (DOE 1998a, 1999b; Pacific EcoSolutions 2007); Volpentest Training and Education Center activities, from which emissions would be negligible except for vehicular emissions (DOE 2002a); and operation of the US Ecology Commercial Low-Level Radioactive Waste Disposal Facility, from which there are fugitive dust emissions (Ecology and WSDOH 2004). The proposed Wanapa Energy Center, if built, would be a major source of air pollutant emissions, but would not significantly deteriorate the quality of the air surrounding the proposed site or lead to deterioration of air quality in nearby pristine areas (BIA 2004:3.5-1, 3.5-2). The proposed Plymouth Generating Facility, if built, would not significantly deteriorate the quality of the

air surrounding the proposed site (Benton and BPA 2003:II-4). The Wanapa Energy Center and Plymouth Generating Facility projects are currently on hold.

Oil and gas development, including exploration and production activities, could result in fugitive dust emissions and other air pollutant emissions from drilling equipment, compressor stations, and other equipment. Maximum impacts of these activities generally occur close to the source; therefore, they are not expected to contribute substantially to impacts near Hanford. Facility conversion of waste to energy and biofuels could result in fugitive dust emissions from construction and other air pollutant emissions from operations. The Columbia Ethanol Plant in Finley, when completed, would emit annual emissions of approximately 29 metric tons of nitrogen oxides, 19 of sulfur oxides, 64 of carbon monoxide, 89 of volatile organic compounds, and 63 of particulates from vents, the stack, and roads (total particulate and PM₁₀). Emission of ethanol and other organic compounds would be below the levels of concern for human health risk (Columbia Ethanol Plant Holdings, LLC 2006). Other proposed or recently permitted biofuels facilities in the region would emit similar air pollutants.

Mobile source emissions in Benton County account for about 95 percent of annual emissions of carbon monoxide, 72 percent of nitrogen oxides, 76 percent of sulfur oxides, and 59 percent of volatile organic compounds (EPA 2007a). In addition to the industrial sources of air pollutants discussed above, there are industries that produce asphalt paving material and block, nitrogen fertilizer, crushed stone, canned fruits and vegetables, frozen foods, and nonferrous metal sheet, as well as grain storage facilities and natural gas transmission facilities (EPA 2007b).

Other development in the region could result in increases in air pollutant emissions from construction activities, vehicle traffic, and other sources related to new housing, businesses, and industries. For example, in Kennewick, the subarea plans for Southridge, Hansen Park, and Clearwater Park include the development of over 648 hectares (1,600 acres) for housing, 142 hectares (350 acres) for commercial and business use, and 81 hectares (200 acres) for industrial use (Kennewick 1999, 2002). In addition, increased mining activity and reclamation of mined areas could lead to increases in air pollutant emissions.

6.3.5 Geology and Soils

Existing conditions with regard to geology and soils are presented in Chapter 3, Section 3.2.5. These existing conditions define the Hanford baseline that was considered for this cumulative impacts analysis. The Hanford baseline already reflects past actions that have directly impacted geology and soils. Therefore, past activities were not further considered; rather, this discussion focuses on the potential for cumulative impacts on geology and soils resulting from ongoing and future actions. As such, the ROI for geologic and soil resources encompasses all of Hanford, including the proposed *TC & WM EIS* action areas and any ongoing or future actions across Hanford that may require excavation of geologic and soil resources from Borrow Area C and additional materials from Gravel Pit No. 30.

Table 6-4 presents the results of the cumulative impacts analysis for geologic and soil resources. The resource requirements presented in Table 6-4 represent the total projected material demands from the three *TC & WM EIS* alternative combinations and the projected demands to support various DOE activities and non-DOE activities that could potentially occur within the same timeframe. The potential for the cumulative demand to exceed the available reserves of geologic and soil resources at Hanford was also assessed. Appendix R, Table R-4, details the actions and activities that were considered for their possible contribution to cumulative impacts at Hanford.

Table 6–4. Potential Cumulative Geologic and Soil Resource Requirements

Actions/Activities ^a	Total Geologic and Soil Resource Requirements (cubic meters)
TC & WM EIS Combined Impacts (see Chapter 4, Table 4–154)	
Alternative Combination 1	99,000
Alternative Combination 2	6,450,000
Alternative Combination 3	18,700,000
Other DOE Actions at the Hanford Site	
Hanford Site baseline ^b	Not applicable
Excavation and use of geologic materials (2006–2013) (DOE 2001:2-2; DOE 2003a:2-2)	1,175,000
Cleanup and restoration activities (2006–2035) (DOE 1996a:5-40, 5-93)	17,820,000
Final disposition of the canyons, PUREX Plant, PUREX tunnels, and other facilities (2006–2035) (Fluor Hanford 2004:2-13, 2-15)	30,940,000
Retrieval of retrievably stored TRU waste (2017–2018) (based on SAIC 2007a)	No data
Construction and operation of the ERDF (2006–2024) (DOE 1994:9T-6)	6,420,000
PNNL Physical Sciences Facility (2006–2011) (DOE 2007a)	No data
Other DOE Subtotals	56,355,000
Non-DOE Actions in the Region of Influence	
US Ecology Low-Level Radioactive Waste Facility (2006–2056) (Ecology and WSDOH 2004:140)	552,000
Hanford Reach National Monument (2006–2022) (USFWS 2008)	No data
Non-DOE Subtotals^c	552,000
Cumulative Totals^c	
Alternative Combination 1	57,006,000
Alternative Combination 2	63,360,000
Alternative Combination 3	75,600,000
Site Resource Availability ^d	57,900,000

^a Actions/activities as identified in Appendix R, Table R–4. Years in parentheses reflect the timeframe in which the resource demand may occur.

^b Past and present geologic and soil resource consumption is not applicable to the analysis of cumulative impacts. The ROI for this analysis consists of Borrow Area C, which has not been impacted to date, and gravel pit No. 30, from which Waste Treatment Plant construction materials have been extracted to date.

^c The “cumulative totals” are the sums of the impacts under the alternative combinations and the “Other DOE” and “Non-DOE” activities.

^d Combined resource reserves from Borrow Area C and gravel pit No. 30 (see Chapter 3, Section 3.2.5).

Note: Values that exceed the established resource capacity are shown in **bold** text. Subtotals or totals may not equal the sum of the contributions due to rounding. To convert cubic meters to cubic yards, multiply by 1.308.

Key: DOE=U.S. Department of Energy; ERDF=Environmental Restoration Disposal Facility; PNNL=Pacific Northwest National Laboratory; PUREX=Plutonium-Uranium Extraction; ROI=region of influence; *TC & WM EIS*=*Tank Closure and Waste Management Environmental Impact Statement for the Hanford Site, Richland, Washington*; TRU=transuranic.

Projected cumulative impacts on geologic and soils resources over the period of analysis mainly reflect demands for sitewide cleanup and closure actions and facility D&D. Added to these demands are those associated with construction, operation, and future deactivation and closure of facilities under the three *TC & WM EIS* alternative combinations. Future closure actions, including final capping of closed disposal facilities or facilities that have undergone D&D, but contain residual waste, represent the largest activity demands for geologic and soil resources (see Table 6–4).

As for the other DOE actions considered, construction of the new PNNL Physical Sciences Facility south of the 300 Area would require geologic and soil resources as part of site preparation, including crushed stone and structural fill, dense-graded aggregate, and other materials needed to meet geotechnical specifications (DOE 2007a:15). These requirements have not been quantified as shown in Table 6–4, but the related demand would add to Hanford’s overall geologic and soil resource requirements.

Closure actions associated with non-DOE activities were also considered, including final closure of the US Ecology Commercial Low-Level Radioactive Waste Disposal Facility (see Table 6–4). As noted in Section 6.3.2, implementation of the *Hanford Reach National Monument Final Comprehensive Conservation Plan and Environmental Impact Statement, Adams, Benton, Grant and Franklin Counties, Washington* (USFWS 2008) would entail construction and maintenance of new facilities and other improvements such as interpretive sites, parking and boat access areas, trails, and a possible visitor center. These proposed activities would consume geologic and soil resources. However, these needs, as well as the ongoing demand for maintenance of existing assets, cannot be quantified at this time.

As indicated in Table 6–4, projected demands for other DOE and non-DOE activities would approach the 57.9 million cubic meters (75.7 million cubic yards) of established geologic and soil reserves from Borrow Area C and Gravel Pit No. 30 without the additional contribution from the *TC & WM EIS* alternative combinations. Projected cumulative demands for geologic and soil resources would range from about 98 percent of established reserves under Combination 1 to 31 percent in excess of established reserves under Combination 3. Although the projected volumes for geologic and soil resources for the activities listed in Table 6–4 are believed to be conservative, the analysis does indicate that completion of all contemplated future actions could require use and development of additional borrow areas beyond Borrow Area C and Gravel Pit No. 30. Geologic and soil resources, including relatively large volumes of gravel, sand, and silt, are available from the suprabasalt sediments and associated soils across Hanford and elsewhere in the region. Rock in the form of basalt is also plentiful. Alternatively, any shortfall, if realized, could be fully or partially provided from offsite commercial quarries, but would result in additional transportation impacts due to increased truck transportation to and from Hanford, as well as additional costs for obtaining these materials from commercial sources.

6.3.6 Water Resources

This section addresses the potential cumulative impacts of past, present, and reasonably foreseeable future actions on water resources, including surface water (with a special focus on the Columbia River) and the Hanford groundwater system (including the vadose zone). Existing conditions with regard to water use and surface and groundwater quality are presented in Chapter 3, Sections 3.2.2.4, 3.2.6.1, and 3.2.6.3, respectively. These existing conditions define the Hanford baseline that was considered for this cumulative impacts analysis. The Hanford baseline already reflects past DOE and non-DOE actions that have directly impacted existing surface waters, such as alteration of Columbia River hydrology, as well as historical contaminant releases from DOE or other facilities that have impacted surface and groundwater quality. Therefore, past activities are not further considered here, and this discussion is focused on the potential for ongoing and future actions to have short-term cumulative impacts on water resources.

Cumulative water resources impacts from ongoing and future DOE and non-DOE activities were considered, including individual future cleanup and facility disposition activities and D&D actions identified in Appendix R, Table R–4. Ongoing and future actions to cleanup the Central Plateau, as well as individual facility D&D actions, combined with actions associated with the *TC & WM EIS* alternative combinations (see Chapter 4, Section 4.4.5), are not expected to contribute to direct cumulative impacts on water resources. This is because, other than the Columbia River, water courses are essentially nonexistent at Hanford; surface-water drainage patterns are poorly developed to convey potentially contaminated stormwater or other effluents; the depth to groundwater across much of the site is such that any effluents would be unlikely to affect groundwater; and the most intensive cleanup and D&D activities

(on the Central Plateau) are located at some distance from the Columbia River. In addition, the application of best management practices and other mitigation measures, as well as compliance with applicable permit provisions, would be employed to ensure that stormwater runoff and infiltration does not convey soil, sediments, and other pollutants to any nearby surface water or groundwater. Furthermore, compliance with applicable permit provisions would help ensure that any generated effluents from ongoing and future actions are treated and disposed of so as to have no additional impact on surface water, the vadose zone, and groundwater. Additionally, while not easily quantified, future non-DOE activities near the site (new industries, oil and gas development, agriculture, residential development, new road construction, and other infrastructure improvements) are likely to be the larger contributors to cumulative impacts on surface water and groundwater over the timeframe considered in this analysis.

As quantified in Section 6.3.2, projected water use from the Columbia River associated with the *TC & WM EIS* alternative combinations, coupled with other future actions at Hanford, is not expected to have a substantial cumulative impact on the availability of water for downstream users. This is because the projected, cumulative demands by all DOE and non-DOE actions would only be about 20 percent of the pre-1990 water demands of the Hanford 200 Area facilities. While water use by communities that utilize the Columbia River as a water source is expected to rise commensurate with land use development and general population increases in the region, as discussed in Section 6.3.2, contemplated actions at Hanford would actually reduce the overall impact on surface-water and groundwater availability and quality.

Ongoing and future DOE actions, including many associated with the *TC & WM EIS* alternative combinations, would have a positive, short-term and long-term effect on water resources. Site-wide cleanup and closure actions and facility D&D would remove and immobilize contaminants in the Hanford vadose zone and prevent or delay their entry into the groundwater and ultimately to the Columbia River. In addition, such remedial actions, coupled with DOE efforts across Hanford to significantly curtail wastewater discharge to surface-water impoundments and the subsurface water (see Chapter 3, Section 3.2.6.3.1), have slowed and will continue to slow the migration of existing groundwater contaminant plumes to the Columbia River. Long-term impacts on water resources, including projected changes in groundwater hydrology and transport of contaminants through the Hanford groundwater system and ultimately to the Columbia River, are addressed in Section 6.4.1.

6.3.7 Ecological Resources

Although ecological resources include terrestrial resources, wetlands, aquatic resources, and threatened and endangered species, cumulative impacts were addressed only for terrestrial resources and threatened and endangered species. Because there would be no direct or indirect short-term impacts to wetlands and aquatic resources under any of the *TC & WM EIS* alternatives, actions associated with them would not contribute to cumulative impacts within the ROI. For terrestrial resources, the cumulative impacts to terrestrial habitat as a whole, and more specifically to shrub-steppe habitat, were examined. For threatened and endangered species, the analysis included federally and state-listed threatened and endangered species and other special status species. The ROI for both terrestrial resources and threatened and endangered species included the proposed *TC & WM EIS* action areas, the site, and areas up to 80 kilometers (50 miles) from the site. The analysis was limited to an 80-kilometers (50-miles) radius because that distance included a large portion of southeastern Washington, an area within which shrub-steppe habitat historically has occurred.

6.3.7.1 Terrestrial Resources

Thirty-one projects within the ROI were analyzed with regard to the area of terrestrial and shrub-steppe habitat that they would disturb. These projects either were recently completed or are reasonably certain of being completed in the near future (see Appendix T, Table T-1). It should be noted that the projects evaluated do not represent the only activities affecting terrestrial habitat within the ROI. For example, construction of many smaller subdivisions and commercial developments and conversion of land to agricultural use would also impact terrestrial habitat; however, the number and extent of these smaller activities cannot be readily determined. In addition, uncertainties exist relative to implementation of a number of large projects within the ROI; specific information regarding their impacts on ecological resources is not available at this time.

Studies have estimated that 6.07 million hectares (15 million acres) of shrub-steppe habitat (60 percent of the landscape) existed in eastern Washington before land conversion began with the arrival of white settlers. Recent studies have estimated that only about 30 percent of the landscape now consists of this habitat type. Thus, there has been a 50 percent decrease in the historical occurrence of shrub-steppe habitat since the 1840s (Jacobson and Snyder 2000:1, 20). Beyond the loss of shrub-steppe habitat, much of that which remains has been fragmented. Shrub steppe is a fragile habitat, and many of the animal species that have evolved with it require large contiguous areas to survive. Thus, fragmentation, which results in small blocks of habitat, can seriously impact wildlife populations (Dobler et al. 1996:21).

Table 6-5 presents estimates of the area of terrestrial and shrub-steppe habitat impacted by the 31 projects analyzed within the ROI. Projects are grouped by the three *TC & WM EIS* alternative combinations, other DOE activities at Hanford, non-DOE activities at Hanford, and other projects and activities within the ROI. The term, terrestrial habitat, is used in a broader sense to include shrub-steppe habitat, other native and non-native habitat, grazing land, and cropland. Because of the importance of shrub-steppe habitat, it is identified separately in the table. While it was possible to calculate the specific area of terrestrial and shrub-steppe habitat lost for the three alternative combinations, such information was not always available for other projects identified within the ROI. As these projects were not generally located in highly developed portions of the region, the entire project area was classified as terrestrial habitat. This approach is conservative because it likely overestimates the acreage of terrestrial habitat lost.

The cumulative total terrestrial habitat that could be disturbed ranges from 9,260 hectares (22,881 acres) including Alternative Combination 1 to 10,006 hectares (24,725 acres) including Combination 3. The cumulative total shrub-steppe habitat that could be disturbed ranges from 3,839 hectares (9,486 acres) under Combination 1 to 4,185 hectares (10,341 acres) under Combination 3. To determine the contribution of the three *TC & WM EIS* alternative combinations to the cumulative disturbance of terrestrial habitat within the ROI, the area impacted by each of the three combinations was divided by the total area of terrestrial habitat disturbed. Similarly, the contribution of the three alternative combinations to the cumulative disturbance of shrub-steppe habitat was determined. Thus, Combination 1 respectively represents 0.02 and 0 percent of the cumulative terrestrial and shrub-steppe habitat impacted in the ROI. Combination 2 represents 2.2 and 1.7 percent of the cumulative terrestrial and shrub-steppe habitat impacted, and Combination 3 represents 7.5 and 8.3 percent of each type, respectively. Although not one of the three alternative combinations, the greatest area of habitat affected would be under a combination of alternatives that includes Tank Closure Alternative 6A, Option Case; FFTF Decommissioning Alternative 3 (with all facilities to be built at Hanford), and Waste Management Alternative 3 (with Disposal Group 2 or 3). Such a combination would represent 10.5 and 10.2 percent of cumulative terrestrial and shrub-steppe habitat affected, respectively.

Table 6–5. Cumulative Area of Terrestrial Habitat Disturbed

Actions/Activities	Total Terrestrial Habitat Disturbed ^a	Shrub-Steppe Habitat Disturbed ^b
	hectares	
TC & WM EIS Combined Impacts (see Chapter 4, Table 4–155)		
Alternative Combination 1 ^c	2	0
Alternative Combination 2	207	66
Alternative Combination 3	749	346
Other DOE Actions at the Hanford Site (see Appendix T, Table T–1)	650	511
Non-DOE Actions at the Hanford Site (see Appendix T, Table T–1)	445	142
Other Projects/Activities in the Region of Influence (see Appendix T, Table T–1)	8,162	3,187
Cumulative Totals^d		
Alternative Combination 1	9,260	3,839
Alternative Combination 2	9,465	3,905
Alternative Combination 3	10,006	4,185

^a For those cases where the area of undeveloped land impacted by project implementation was not reported, it was conservatively assumed that the entire project area could be classified as terrestrial habitat. Terrestrial habitat could include shrub-steppe habitat, other native and nonnative habitat, grazing land, and cropland.

^b Shrub-steppe habitat includes areas specifically described as such in project documents, as well as areas conservatively estimated to be shrub steppe.

^c The specific elements of the *TC & WM EIS* alternative combinations are addressed in Chapter 4, Section 4.4.

^d The cumulative totals are the sums of the impacts under the alternative combinations and the “Other DOE” and “Non-DOE” activities. Totals may not equal the sum of the contributions due to rounding.

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

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

The total area of terrestrial and shrub-steppe habitat within the ROI is unknown, so the change in the proportion of habitat disturbed within the region resulting from the 31 analyzed projects cannot be determined. However, because the approximate area of terrestrial habitat at Hanford is known (144,000 hectares [356,000 acres] [Neitzel 2005:4.144]), as is the aerial extent of shrub-steppe habitat (approximately 27,924 hectares [69,000 acres] [DOE and Ecology 1996:5-70; Neitzel 2005:4.75]), it is possible to determine the effect that recent past, present, and reasonably foreseeable future development may have on the site. Thus, considering the land requirement of each of the three alternative combinations, as well as other projects and activities occurring at the site, the total area of terrestrial habitat would be reduced by 0.8, 0.9, and 1.3 percent under Combinations 1 through 3, respectively. With respect to shrub-steppe habitat, onsite activities would decrease existing habitat by 2.3, 2.6, and 3.6 percent, respectively. Considering the alternative combination that would disturb the greatest land area (see above), terrestrial habitat and shrub-steppe habitat would be reduced by 1.5 and 3.9 percent, respectively. These estimates are conservative because they do not account for the restoration or compensation of lost shrub-steppe habitat that is required for most projects carried out at Hanford (DOE 2003c).

6.3.7.2 Threatened and Endangered Species

As noted above, the ROI for threatened and endangered species includes the proposed *TC & WM EIS* action areas, the site, as well as areas up to 80 kilometers (50 miles) from the site. Due to differences in the levels of reporting for the 31 analyzed projects, the ability to assess cumulative impacts on threatened and endangered species is limited. For example, of the projects reviewed, 13 did not report on the status of listed species and, of those that did, 10 indicated there would be no impacts and 8 indicated that impacts were possible.

As no federally listed or state-listed threatened or endangered species would be impacted by any of the *TC & WM EIS* alternatives, actions associated with these alternatives would not contribute to cumulative impacts within the ROI (see Chapter 4, Sections 4.1.7, 4.2.7, 4.3.7, and 4.4.6.3). However, cumulative impacts on a number of other special status species observed within areas affected by activities associated with the *TC & WM EIS* alternatives are possible. These species include: Piper's daisy (state sensitive), crouching milkvetch (state watch), stalked-pod milkvetch (state watch), loggerhead shrike (Federal species-of-concern and state candidate), sage sparrow (state candidate), long-billed curlew (state monitor), and black-tailed jackrabbit (state candidate). Of these species, crouching milkvetch was not mentioned in any of the 31 projects reviewed, and Piper's daisy, stalked milkvetch, the long-billed curlew, and the black-tailed jackrabbit were mentioned in only one study each. The sage sparrow and loggerhead shrike were noted as potentially impacted in three and six of the studies reviewed, respectively. Thus, while the available data are limited, they suggest it is unlikely that cumulative impacts to populations of five of the special status species (i.e., piper's daisy, crouching milkvetch, stalked-pod milkvetch, long-billed curlew, and black-tailed jackrabbit) would occur. Cumulative impacts to the two remaining special status species (i.e., sage sparrow and loggerhead shrike) would be limited.

Although none of the federally listed and state-listed species noted above receives legal protection such as that afforded threatened or endangered species, they should be considered in project planning. Such planning is undertaken at Hanford when a comprehensive mitigation action plan is developed and projects may impact listed species (or shrub-steppe habitat). Mitigation planning related to potentially affected plants and animals was also noted for a number of the regional projects reviewed. Mitigation plans would act to limit potential impacts to species within a project area and, therefore, also act to limit cumulative impacts within the ROI.

6.3.8 Cultural and Paleontological Resources

The assessment of short-term cumulative impacts on cultural and paleontological resources includes prehistoric, historic, and paleontological resources, as well as American Indian interests, each of which will be discussed individually below. A general description of cultural and paleontological resources and American Indian interests on and in the vicinity of Hanford is presented in Chapter 3, Section 3.2.8. Cumulative impacts related to cultural and paleontological resources and American Indian interests were evaluated in an ROI that includes Hanford and nearby offsite areas. The potential for cumulative impacts on cultural resources is discussed qualitatively. These cumulative impacts are additive to the impacts of the *TC & WM EIS* alternative combinations described in Chapter 4, Section 4.4.7.

Construction of new facilities and disturbance of previously undeveloped land would have the greatest potential for cumulative impacts on cultural and paleontological resources and American Indian interests. Approximately 50 actions, including the *TC & WM EIS* alternative combinations, other DOE and non-DOE activities at Hanford, and other activities in the ROI were considered with regard to their cumulative impacts on cultural resources (see Appendix R, Table R-4). Those activities that have a potential cumulative impact are discussed further below (also see Appendix T, Table T-2).

6.3.8.1 Prehistoric Resources

The cumulative impacts of the three *TC & WM EIS* alternative combinations would be similar to the combined impacts addressed in Chapter 4, Section 4.4.7.1. Cumulative impacts that include Alternative Combination 1 would involve the least land disturbance and so would have the least potential to add to cumulative impacts. Cumulative impacts that include Alternative Combinations 2 and 3 would disturb a larger area of land.

As past surveys have indicated, prehistoric resources have a low potential of being present for the majority of DOE and non-DOE activities at Hanford. Isolated finds within the ROI have not been deemed eligible for the National Register of Historic Places.

Two activities listed in Appendix T, Table T-2, could possibly add to the impacts on prehistoric resources. Both the Hanford Reach National Monument at Hanford and Black Rock Reservoir, which is planned for construction in Yakima County, are or would be located on land that potentially could contain prehistoric resources.

6.3.8.2 Historic Resources

The cumulative impacts of the three *TC & WM EIS* alternative combinations would be similar to the combined impacts addressed in Chapter 4, Section 4.4.7.2. Other DOE activities at Hanford could have an impact on historical properties as well. Decommissioning of the eight surplus production reactors and their support facilities in the 100 Areas may have a possible impact on the 100-B Reactor Building, which is listed on the National Register of Historic Places and, on August 19, 2008, was designated as a National Historic Landmark (DOE and DOI 2008). The rail line associated with construction and operation of the ERDF near the 200-West Area could adversely affect a portion of historic White Bluffs Road. The Atmospheric Dispersion Grid would have been affected by project activities; however, the impacts were mitigated and no further mitigation is required (Poston et al. 2007). A select representative number of artifacts were removed and curated into the Hanford collection (Prendergast-Kennedy 2003:2).

The management plan for the Hanford Reach National Monument, a non-DOE project, specifies the requirement to: “Protect and acknowledge the Native American, settler, atomic and Cold War histories of the Monument...” (USFWS 2008:2-6). Cultural resources became more visible following wildfire events of August 2007 and are more vulnerable to vandalism.

The proposed Yakima County Black Rock Reservoir would be situated in a location that has a high potential for historic resources. Many of the other non-DOE activities within the ROI would have little or no impact on historic resources because they would not take place in or near areas that contain historic resources.

6.3.8.3 American Indian Interests

Effects on American Indian areas of interest can occur from cumulative impacts on the visual character of the land. Construction of new facilities and disturbance of previously undeveloped land are likely to have the greatest impacts. Many of the projects and activities assessed for cumulative impacts are of limited size, occur in presently developed areas, or are located at a distance from Hanford. These activities would produce no-to-minimal change in the viewshed.

The cumulative impacts of the three *TC & WM EIS* alternative combinations would be similar to the combined impacts addressed in Chapter 4, Section 4.4.7.3. Accordingly, Alternative Combination 1 would have the least cumulative impact, and Combination 3 the greatest due to disturbance of the largest area and the most extensive alteration of the existing viewshed among the alternative combinations.

The location of facilities is important in determining the cumulative visual impacts on American Indian areas of interest. Some activities at Hanford, as well as some offsite projects and activities, would be visible from Rattlesnake Mountain, Gable Mountain, or Gable Butte, all of which are areas of noted cultural and religious significance to American Indians. Onsite DOE projects and activities that may be visible include excavation and use of geologic materials from borrow pits, transport of materials on the borrow site haul road from Route 240 through Borrow Area C, and construction and operation of the ERDF. Reasonably foreseeable future actions affecting the viewshed also include remediation efforts at

Hanford that may produce short-term adverse impacts, but would generally result in removal of buildings and other structures and return of the environment to more natural conditions.

Construction and operation of facilities for the Hanford Reach National Monument, a non-DOE activity at Hanford, could affect American Indian interests because the Columbia River has special significance to American Indians in the region. Increased access to the Columbia River corridor by visitors could impact the area.

Other reasonably foreseeable future activities located off site, but nearby, are likely to be visible from Rattlesnake Mountain. These would include Black Rock Reservoir and the Red Mountain American Viticulture Area near Benton (see Appendix T, Table T-2).

6.3.8.4 Paleontological Resources

No paleontological resources of significance have been discovered within any of the areas potentially disturbed by the *TC & WM EIS* alternatives. Other activities listed in Appendix T, Table T-2, would not likely add to the cumulative impacts on paleontological resources.

6.3.9 Socioeconomics

The existing site activities and current socioeconomic status of the ROI are described in Chapter 3, Section 3.2.9, and the impacts of the three alternative combinations are described in detail in Chapter 4, Section 4.4.8. The ROI for the cumulative socioeconomic analysis was Benton and Franklin counties, where the majority of Hanford workers currently reside.

Those actions that could potentially have impacts on the socioeconomics of the ROI are listed in Appendix T, Table T-3. These impacts might affect local employment figures, subsequent commuter traffic, and/or offsite truck activity. For example, completion of some activities may reduce employment (e.g., after deactivation of the Plutonium Finishing Plant is completed). Uncertainties in this analysis result in additional conservatism in the cumulative impacts estimates. For example, some or all of the construction workers for the K Basins' fuel storage activity may already be employed in other construction activities described in this cumulative impacts section. There is no indication whether future milestones related to this activity will require additional full-time employees or equivalents (FTEs). As a result, those workers performing K Basins' fuel storage activities may be doubly counted in the analysis.

Some activities analyzed have already occurred or have been suspended; therefore, their impacts were not included in this cumulative impacts analysis. For example, Hanford's cleanup, restoration, and facility decommissioning activities are ongoing activities that are already included in the existing site activity statistics. In addition, projects that did not identify quantitative employment figures and/or traffic or truck load estimates were not included in the analysis. For example, plans to create 10 more wineries in the near future in the Red Mountain American Viticulture Area in Benton County could increase the number of employees and tourists in the ROI, but quantitative estimates were not available for this activity (Benton County 2006:B-14). Another example, the Clover Island project in the city of Kennewick, would increase public amenities and add a mix of water-oriented land uses and recreational uses that would support the existing waterfront and boating and increase visitors to that area, but again quantitative estimates were not available (Kennewick 2006:126). Therefore, these types of activities were not included in the quantitative cumulative impacts analysis.

Table 6-6 summarizes indicator parameters for socioeconomic cumulative impacts. The estimated direct peak employment from activities analyzed under the *TC & WM EIS* alternative combinations, plus selected site and regional activities in the ROI, would range from 4,080 FTEs for Combination 1 to 14,700 FTEs for Combination 3. This represents as high as 9.8 percent of the projected labor force in the region (150,000 in 2021, the peak year for Tank Closure Alternative 6B, Base Case). *TC & WM EIS*

alternatives would employ from 1,840 to 12,500 FTEs. The total projected number of employees from reasonably foreseeable future activities (2,235) is small when compared to the number of employees from *TC & WM EIS* Alternative Combination 3 (12,500), the highest alternative combination. Because the timing of peak employment would vary for each activity, these projections are likely to be conservative. In addition, some of the projected employees could be drawn from the existing workforce and so would not represent additional employees moving into the ROI. For comparison, in 2006, employment of approximately 10,000 people at Hanford represented about 10 percent of employment in the Hanford ROI.

Table 6–6. Cumulative Socioeconomic Impacts

Actions/Activities	Peak Annual Employment (FTEs)	Peak Daily Traffic	
		Employee Trips ^a	Offsite Truck Trips
<i>TC & WM EIS</i> Combined Impacts (see Chapter 4, Table 4–156)			
Alternative Combination 1	1,840	1,470	4
Alternative Combination 2	8,190	6,550	79
Alternative Combination 3	12,500	10,000	102
Other DOE Actions at the Hanford Site (from Appendix T, Table T–3)	1,882	1,810	68
Non-DOE Actions at the Hanford Site (from Appendix T, Table T–3)	41	76	4
Other Projects/Activities in the Region of Influence (from Appendix T, Table T–3)	312	225	39
Cumulative Totals^b			
Alternative Combination 1	4,080	3,580	115
Alternative Combination 2	10,400	8,660	189
Alternative Combination 3	14,700	12,100	212

^a Employee trips were calculated based on FTE numbers.

^b The cumulative totals are the rounded sums of the impacts under the alternative combinations and the “Other DOE” and “Non-DOE” activities. Totals may not equal the sum of the contributions due to rounding.

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

Foreseeable future activities analyzed included construction activities that have short-term impacts, including construction of a PNNL Physical Sciences Facility, biofuels facilities, and ongoing activities (e.g., K Basins’ fuel storage). Other activities resulting from implementing the ROD (64 FR 61615) and amended ROD (73 FR 55824) for the *Hanford Comprehensive Land-Use Plan EIS* (DOE 1999a), as well as other non-DOE activities in the ROI, could have longer-term impacts. The non-DOE activities analyzed included management of the Hanford Reach National Monument and Saddle Mountain National Wildlife Refuge and increased operations at the Pacific EcoSolutions Waste Treatment Facility. The total projected number of employees from these future activities would be small compared to the impacts from Alternative Combination 3 (approximately 2,240 compared to 12,500 FTEs), the alternative combination with the highest employment requirement.

The level of service on offsite roads in the Hanford ROI is expected to be impacted from the peak daily traffic resulting from all activities analyzed in this cumulative impacts section. The bulk of daily traffic (as high as 12,100 vehicles per day) would come from commuters. Additional truck trip activity off site could be as high as 212 daily truck trips. These trip totals would be variable; both employee and truck trips would increase to the peak figures during large construction projects.

6.3.10 Public and Occupational Health and Safety – Normal Operations

This section evaluates short-term public and occupational health and safety cumulative impacts to the Hanford worker population, a maximally exposed individual (MEI) in the public, and the population occurring within an 80-kilometers (50-miles) radius of influence. Radiological and nonradiological impacts were analyzed.

6.3.10.1 Cumulative Radiological Impacts

Table 6–7 presents the estimated cumulative impacts from radiological emissions and direct radiation exposure. The worker population dose of 320 person-rem for Alternative Combination 1 would represent a negligible contribution to the total cumulative dose received by workers of 99,000 person-rem since the beginning of Hanford operations in 1944. Alternative Combinations 2 and 3 would represent 12 percent and 47 percent of the cumulative doses of 113,000 and 188,000 person-rem, respectively. The cumulative worker population dose would occur to several generations of workers and would not impact the same worker population.

Table 6–7. Cumulative Radiological Human Health Impacts to Hanford Site Workers and the Public

Actions/Activities	Hanford Involved Workers		Public		
	Collective Dose (person-rem)	LCF Risk ^a	MEI Dose (millirem per year)	Collective Dose (person-rem)	LCF Risk ^a
TC & WM EIS Combined Impacts^b (see Chapter 4, Tables 4–157 and 4–158)					
Alternative Combination 1	320	0 (2×10^{-1})	0.13	600	0 (4×10^{-1})
Alternative Combination 2	14,000	9	1.7	460	0 (3×10^{-1})
Alternative Combination 3	89,000	50	1.7	600	0 (4×10^{-1})
Other DOE Actions at the Hanford Site					
Historical cumulative dose 1944–1972 (DOE 1995)	90,000	50	N/A	106,000	60
Historical cumulative dose 1972–2007 (using annual 2006 data over 36 years) (Poston et al. 2007:10.144) ^b	6,876	4	N/A	23	0 (1.4×10^{-2})
Canyon disposition (DOE 2004b:4-31 to 4-32; 5-28 to 5-29)	210	1×10^{-1}	NR ^c	NR	NR
Surplus production reactor decommissioning for nine reactors (DOE 2005a: 21)	14.1	8×10^{-3}	NR	NR	NR
Naval reactor disposal (Navy 1996:2-2; 4–34)	1,505	9×10^{-1}	NR	5.1 ^d	0 (3×10^{-3})
300-Area facilities: 313 and 314 facilities and the Fuel Supply Shutdown Facilities only (DOE 2005b:B-3)	NR	NR	0.12	NR	NR
Retrieval of TRU waste (SAIC 2007a; DOE 2002b:5-2 to 5-3)	106	6×10^{-2}	NR	NR	NR
Other DOE Subtotals^e	99,000	60	0.12 ^f	106,000	60

Table 6–7. Cumulative Radiological Human Health Impacts to Hanford Site Workers and the Public (continued)

Actions/Activities	Hanford Involved Workers		Public		
	Collective Dose (person-rem)	LCF Risk ^a	MEI Dose (millirem per year)	Collective Dose (person-rem)	LCF Risk ^a
Non-DOE Actions in the Region of Influence					
US Ecology Low-Level Radioactive Waste Facility (US Ecology 2007:2-6)	N/A	N/A	<0.01	NR	NR
Energy Northwest Columbia Generating Station (Energy Northwest 2007:51, 53; Poston et al. 2007:10.149; Rhoads 2007)	N/A	N/A	0.02 ^g	2.11 ^h	0 (1×10 ⁻³)
AREVA NP, Inc., Fuel Fabrication Facility (Poston et al. 2007:10.149; Rhoads 2007)	N/A	N/A	0.02 ^h	NR	NR
Perma-Fix Northwest Waste Processing Facility (Poston et al. 2007:10.149, Rhoads 2007)	N/A	N/A	0.02 ^h	NR	NR
IsoRay Medical, Inc. (Boyce 2007)	N/A	N/A	0.005 ⁱ	NR	NR
Moravek Biochemicals (Moravek 2005)	N/A	N/A	1.5	NR	NR
Non-DOE Subtotals	N/A	N/A	1.53 ^f	2.11	0 (1×10 ⁻³)
Cumulative Totals^j					
Alternative Combination 1	99,000	60	2	107,000	60
Alternative Combination 2	113,000	70	3	106,000	60
Alternative Combination 3	188,000	100	3	107,000	60
Most Stringent Standard or Guideline	N/A	N/A	10 ^k	N/A	N/A

^a The reported value is the projected number of LCFs in the population and is therefore presented as a whole number. When the reported value is zero, the result calculated by multiplying the collective dose to the population by the risk factor of 0.0006 LCFs per person-rem is shown in parentheses (see Appendix K, Section K.1.1.3).

^b Worker dose obtained from Chapter 3, Section 3.2.10.1. The Hanford baseline represents all exposure pathways and includes doses attributed to portions of the “Other DOE Actions” that occurred in 2006.

^c For cells stating “NR,” no values are provided in the documentation, but it is generally assumed that, because no air releases would occur, there would be little to no public exposure.

^d Includes dose to the public during transportation of the reactor packages to the Hanford Site.

^e Figures do not include the Hanford 1-year baseline. Values were rounded.

^f For conservatism, it was assumed that the MEI for all activities would be in the same location. In reality, each individual activity would have a different location.

^g Reflects the combined dose to the Hanford MEI from operations at the Columbia Generating Station, AREVA fuel fabrication facility, and Perma-Fix Northwest (Poston et al. 2007:10.149; Rhoads 2007).

^h The annual population dose from 2006 was multiplied by 17 years, the time left on the Columbia Generating Station operating license, which expires in 2024 (Energy Northwest 2006a:9).

ⁱ This dose was calculated at the emission point and assumes emissions are at detection limits. In reality, few measurable detections are recorded, and the dose would be less at the MEI location.

^j The cumulative totals are the sums of the impacts under the alternative combinations and the “Other DOE” and “Non-DOE” activities. Subtotals or totals may not equal the sum of the contributions due to rounding.

^k The regulatory limit for exposure of an individual to radiological air emissions from DOE facilities is 10 millirem per year (40 CFR 61.90–61.97, Subpart H).

Key: DOE=U.S. Department of Energy; Hanford=Hanford Site; LCF=latent cancer fatality; MEI=maximally exposed individual; N/A=not applicable; NR=not reported; *TC & WM EIS*=Tank Closure and Waste Management Environmental Impact Statement for the Hanford Site, Richland, Washington; TRU=transuranic.

The cumulative dose to the offsite MEI of 2 to 3 millirem per year would be below the 10 millirem per year limit established in the National Emission Standards for Hazardous Air Pollutants (40 CFR 61.90–61.97, Subpart H). This conclusion conservatively assumes that the dose to the MEI for each DOE and non-DOE action are additive, despite the fact that the MEI location for most actions listed in Table 6–7

would be different. For comparison, the background radiation dose a person may receive near Hanford is estimated to be 365 millirem per year (see Chapter 3, Table 3–12 and Section 3.2.10.1.1).

The cumulative population dose to the public would be dominated by the historical cumulative dose received by the public (approximately 106,000 person-rem) since the beginning of Hanford operations in 1944. The 460 to 600 person-rem contributed by the three *TC & WM EIS* alternative combinations would increase the cumulative population dose received by less than 1 percent. Implementation of Combinations 2 or 3, while slightly increasing the cumulative dose to the public in the short term, would decrease the long-term impacts, as discussed in Chapter 5.

6.3.10.1.1 Historical Exposures

Estimates of the potential cumulative dose to the population within 80 kilometers (50 miles) of Hanford for the period running from 1944 through 1972 were calculated to be approximately 106,000 person-rem (DOE 1995), which could result in up to approximately 60 latent cancer fatalities (LCFs). The majority of this dose was received through air pathways in 1945. The cumulative population dose through the water pathway during this period was estimated to be about 6,000 person-rem (which could result in approximately 4 LCFs), most of which was received between 1954 and 1964 as a result of higher production reactor power levels for Cold War plutonium production. Since 1972, this cumulative population dose increased by less than 0.1 percent based on data from Hanford annual environmental reports. The primary contributors to the population and MEI doses in 2006 were activities in the 300 Areas, a release of iodine-129 from the 200 Areas, consumption of food grown downwind, and consumption of water from the Columbia River (Poston et al. 2007:10.144).

Cancer incidence and mortality rates in the Hanford region can be used as possible indicators of cumulative impacts caused by past operational practices at Hanford. As discussed in Chapter 3, Section 3.2.10.3, the question of whether the population surrounding Hanford is subject to elevated cancer incidence or mortality rates is unresolved. Some studies indicate that there are no statistically significant increases in cancer rates; in fact, one study concluded that workers that have routine potential exposure to plutonium have lower mortality rates than other Hanford workers (NIOSH 2005).

Other epidemiological studies have shown a statistically significant elevated risk of death from multiple myeloma associated with radiation exposure among male Hanford workers. The elevated risk was observed only among workers exposed to approximately 10 rem or more. Other studies also identified an elevated risk of death from pancreatic cancer, but a recent reanalysis did not conclude there was an elevated risk. Studies of female Hanford workers have shown an elevated risk of death from musculoskeletal system and connective tissue conditions (DOE 1996b:M-224 through M-230).

In addition to those studies summarized in Chapter 3, Section 3.2.10.3, a Hanford Birth Cohort study was conducted by the Agency for Toxic Substances and Disease Registry to address public concerns related to public exposure to iodine-131 primarily in the years 1944 through 1957. Preliminary results from this study showed a small increased risk for certain men to develop a thyroid disease, although a final determination has yet to be published (ATSDR 2006).

Because studies have been inconclusive regarding whether cancer incidence or mortality rates have risen due to Hanford operations, no definitive conclusions can be made in this EIS concerning the cumulative effects of radiation exposure to Hanford workers or the public from historical environmental releases and occupational exposures.

6.3.10.1.2 Other DOE Activities at Hanford

Other DOE activities at Hanford that are not within the scope of this EIS (i.e., activities that are not part of DOE's proposed actions) include environmental restoration activities being performed under RCRA and CERCLA in accordance with the TPA requirements. Major environmental restoration activities currently planned or underway that could cause exposures to radiation include environmental restoration activities in the 100 and 200 Areas, disposition of the five canyon facilities, decommissioning of eight surplus production reactors, remediation and closure of 300 Area facilities and operable units, retrieval of TRU waste, and operation of the ERDF. Table 6-7 summarizes the contributions to cumulative impacts from these activities. Some activities described in Appendix R are not included in Table 6-7 because applicable information was not available. Note that it is difficult to differentiate between the human health impacts of DOE Hanford operations and non-DOE activities using actual monitoring data due to the proximity of effluents from the various operations.

Five canyon buildings (U, B, T, the PUREX Plant, and the Reduction-Oxidation [REDOX] Facility) are located at Hanford. All five of these buildings will eventually undergo CERCLA closure. Closure of only one of these buildings, 221-U, has been studied in detail. The selected remedy for 221-U includes demolishing the canyon to the canyon deck, filling portions of the canyon with rubble, grouting empty spaces, constructing an engineered barrier over the remnants of the canyon, and performing postclosure activities. Worker exposure from performing these activities at Building 221-U is estimated to be 42 person-rem (DOE 2004b:4-31, 4-32, 5-28, 5-29). Information regarding exposures to the public due to remediating implementation is not available, but is expected to be minimal due to the inaccessibility of Building 221-U to the public and limited radiological air emissions. The results from the analysis of remediating Building 221-U may be applied to the other four canyon buildings for a total worker population exposure of 168 person-rem, but due to the varying types and locations of radiological materials and contamination at these buildings, actual exposures could vary significantly (DOE 2004b:1-1). Canyon demolition activities have yet to commence, but demolition of 10 of the 17 U Plant ancillary facilities has been completed (DOE 2006a:2.50).

Nine surplus production reactors (B, C, D, DR, F, H, N, KE, and KW) are located at Hanford. These reactors are in various stages of decommissioning and are being placed in a safe storage condition for a period of approximately 75 years. After 75 years, it is assumed that the reactor core for each reactor will be removed in one piece for disposal in the 200 Areas. An EIS for decommissioning eight of these reactors (excluding the N Reactor) was completed in 1992. The information in that EIS was re-evaluated to update estimates and include the N Reactor. Assuming one-piece removal, the dose to workers from decommissioning the nine reactors would be 14.1 person-rem. There would be little or no radiation exposure to the public. Currently, five of the nine reactors have been placed into safe storage; one of the reactors (the B reactor) is currently being considered as a museum and may not be dismantled (DOE 2005a:10, 21, 22).

Reactor compartments removed from decommissioned nuclear ships and submarines will continue to be transported to Hanford for disposal. Future Naval Reactor program shipments will consist of naval reactor compartments from which the spent nuclear fuel has been removed. There have been approximately 117 naval reactor compartments disposed of at Hanford as of 2007 (Poston, Duncan, and Dirkes 2008). Occupational exposures to onsite and transportation workers have been estimated to be 1,505 rem for the 100 naval reactor compartment packages to be disposed of over several decades (Navy 1996:2-2; 4-34). This radiation exposure equates to approximately one (0.9) LCF (DOE 2003d). Radiation exposure to the public due to transportation and disposal of the reactors has been calculated to be 5.1 rem, and no (0.003) LCFs (Navy 1996:2-2).

The 300 Area facilities currently undergoing decontamination, decommissioning, and removal include 82 buildings and structures in the northern portion of the 300 Area, the 324 and 327 buildings, and

145 buildings and structures located primarily in the southern portion of the 300 Area (DOE 2004c, 2006b, 2006c). These 300 Area cleanup activities have the potential for creating radiation and chemical exposures to workers and the public. These exposures have not been quantified, with the exception of deactivation, decontamination, and decommissioning of the 313 and 314 facilities and the Fuel Supply Shutdown Facilities. The radiation dose to the MEI for removing each of these facilities was calculated to be 0.04 millirem per year over three years (DOE 2005b:B-3).

Per the TPA Milestone, retrieval of the 200 Area remote-handled, retrievably stored TRU waste in burial ground 218-W-4B is required to be completed by December 31, 2018. Some of this waste is located in four caissons. A Caisson Retrieval Facility will be constructed, operated, and decommissioned to retrieve the TRU waste containers from the four caissons. A total of 100 person-rem of worker exposure is expected (SAIC 2007a). A public dose was not calculated, but is expected to be negligible due to the location of this activity at burial ground 218-W-4B. Drummed TRU waste in burial grounds 218-W-4B and 218-W-4C is also being retrieved. Retrieval of this waste could incur a projected total worker dose of approximately 6 person-rem over the 5-year period (DOE 2002b:5-2, 5-3).

Operation of the ERDF involves the potential for exposure during waste transport to and placement in the ERDF. The *Remedial Investigation and Feasibility Study Report for the Environmental Restoration Disposal Facility* (DOE 1994) predicted that health risks to ERDF workers, other Hanford workers, and the public due to exposure to contaminants would be significantly less than generally accepted standards. Annual environmental monitoring (Poston, Hanf, and Dirkes 2005; Poston et al. 2006, 2007) has confirmed these predictions.

6.3.10.1.3 Non-DOE Activities

In addition to the radiological dose from DOE activities at Hanford, a dose to DOE workers and the public could also occur due to radiological releases from non-DOE operations occurring within and near Hanford. These releases are associated with the US Ecology Low-Level Radioactive Waste Disposal Facility; Energy Northwest Columbia Generating Station; AREVA NP, Inc., fuel fabrication facility; Perma-Fix Northwest waste processing facility; IsoRay Medical facility; and Moravek Biochemicals facility. Table 6-7 summarizes the actual exposures from these facilities.

US Ecology operates the Low-Level Radioactive Waste Disposal Facility at Hanford near the 200 Areas. Doses to the general public from air emissions have been calculated to be indistinguishable (less than 0.01 millirem) from background levels. For direct radiation, the maximum net (background subtracted) radiation exposure as measured at the site boundary west of trench 18 was 55 millirem per year for exposure 24 hours a day, 365 days a year. As this location is within the boundaries of Hanford, a Hanford employee would be exposed to 13 millirem, assuming the employee were present at this location 40 hours per week. This radiation exposure level is consistent with levels measured in past years. There was no facility impact on groundwater in 2006 (US Ecology 2007:1-2, 2-3, 2-6, 2-11). Potential long-term impacts of the waste disposed of at this location are included in the evaluation of long-term cumulative impacts in Section B4.

The Columbia Generating Station is located at Hanford northeast of the FFTF. This nuclear plant is licensed for operations through 2024 (Energy Northwest 2006a:9). The maximum annual dose at the Columbia Generating Station site boundary from air releases was estimated to be 0.0194 millirem. The 80-kilometer (50-mile) population collective dose in 2006 was estimated to be 0.124 person-rem, with the average individual in that population receiving 3.49×10^{-4} millirem during that year (Energy Northwest 2007:51, 53). There has been no measurable impact to other potential human exposure pathways such as food, surface water, groundwater, and soils (Energy Northwest 2006b:5-5-5-7).

AREVA NP, Inc. (formerly Framatome ANP, Inc.), operates a fuel fabrication facility just south of Hanford on Horn Rapids Road. This facility produces nuclear fuel for sale to commercial nuclear power

plants. Calculated doses to the theoretical MEI from this facility's radioactive stack emissions (ignoring radon) from 2000 to 2005 ranged from 0.000164 to 0.012 millirem per year, indicating negligible impacts from radioactive point source emissions. Environmental monitoring activities have provided no indication of air pollutant deposition in the surrounding environs, and liquid waste discharges have been within the allowed limits for radioactivity, indicating negligible impacts to human health (AREVA 2006:3-5).

The Perma-Fix Northwest (formerly known as Pacific EcoSolutions) facility is located south of Hanford in Horn Rapids Industrial Park. The site houses processing facilities for the treatment of low-level radioactive waste (LLW) and MLLW. In 2006, the calculated dose to the MEI from radiological air emissions was 0.1 millirem where the MEI was assumed to reside in a theoretical resident located 100 meters (110 yards) from the stacks. The MEI dose from direct radiation was calculated to be 1.63 millirem per year; this MEI was assumed to be a local business employee who takes daily walks during lunch along the northern perimeter of the Perma-Fix site (Pacific EcoSolutions 2007:6).

The radiological emissions reported by the Columbia Generating Station, AREVA, and Perma-Fix were used to compute a non-DOE source dose to the Hanford MEI. In 2006, this value was 0.02 millirem (Poston et al. 2007:10.149, Rhoads 2007).

IsoRay Medical, Inc., produces medical isotopes for commercial use. The facility is located at Energy Northwest's Applied Process Engineering Laboratory in Richland, Washington, just east of the Hanford boundary. Based on the two primary isotopes cesium-131 and barium-131, the dose at the emission point would be less than 0.005 millirem per year, assuming these isotopes were emitted within the detection limits. In reality, few, if any, detections have been recorded for these isotopes, and the dose to the MEI would be much less due to dilution prior to reaching the MEI (Boyce 2007).

Moravek Biochemicals, located in the Richland Industrial Center in Richland, Washington, manufactures radiochemicals and inorganic compounds for industrial use (Moravek 2009). The calculated radiological dose to an MEI 40 meters (130 feet) to the north of the facility is 1.5 millirem per year based on actual emissions of hydrogen (tritium) and carbon-14 in 2004 (Moravek 2005).

6.3.11 Public and Occupational Health and Safety – Transportation

The assessment of cumulative impacts from radioactive material transportation concentrated on impacts from offsite transportation, which would result in the greatest potential radiation exposure from non-incident transportation and fatalities from traffic accidents. The collective dose to the general population and workers was the primary measure used to quantify cumulative transportation impacts. This measure of impact was chosen because it can be directly related to LCFs using a cancer risk coefficient.

Table 6–8 summarizes the cumulative impacts from transportation activities. The cumulative impacts of the transportation of radioactive material consists of impacts from historical shipments of radioactive waste and spent nuclear fuel, general radioactive material transportation unrelated to a particular action, and reasonably foreseeable actions. The duration of impacts was assumed to begin in 1943, when Hanford began operation, and continue to an end date of about 2073. It should be noted that the estimated end dates for Tank Closure Alternatives 2A, 6A, and 6B are beyond 2073 (up to 2193). It should be further noted that Table 6-8 does not consider transportation activities that occur on Hanford roads closed to the public. An example of such actions would be intrasite transportation of waste to the ERDF. As presented in Chapter 4, Table 4–159, transportation of materials and waste to and from INL is included in Alternative Combinations 2 and 3.

Table 6–8. Cumulative Transportation Impacts

Actions/Activities	Worker		General Population		Traffic Fatalities
	Collective Dose (person-rem)	Risk (LCFs)	Collective Dose (person-rem)	Risk (LCFs)	
TC & WM EIS Combined Impacts (see Chapter 4, Table 4–159)					
Alternative Combination 1	2.62	0.00	0.08	0.00	0.00
Alternative Combination 2	2,884	1.7	425	2.6×10^{-1}	1.8
Alternative Combination 3	3,183	1.9	441	2.6×10^{-1}	2.7
Other Transportation Impacts Not Related to This TC & WM EIS (see Appendix T, Table T–4)^a					
Historical shipments to the Hanford Site	292	1.7×10^{-1}	317	1.9×10^{-1}	NL
General radioactive material transport	374,000	224	338,000	203	116
Reasonably foreseeable actions	29,214	18	39,936	24	88
Subtotals, Other Transportation Impacts	403,500 ^b	242	378,300 ^b	227	204
Cumulative Totals^c					
Alternative Combination 1	403,500 ^b	242	378,300 ^b	227	204
Alternative Combination 2	406,400 ^b	243	378,700 ^b	227	206
Alternative Combination 3	406,700 ^b	244	378,700 ^b	227	207

^a Appendix T, Table T–4, provides a detailed compilation of the transportation impacts from other activities that are not related to this TC & WM EIS.

^b The dose values are rounded to the nearest hundred.

^c The “cumulative totals” are the sums of the impacts under the alternative combinations and the other, unrelated transportation activities. The dose values were rounded to the nearest 10. Subtotals or totals may not equal the sum of the contributions due to rounding.

Key: LCF=latent cancer fatality; NL=not listed; TC & WM EIS=Tank Closure and Waste Management Environmental Impact Statement for the Hanford Site, Richland, Washington.

6.3.11.1 Historical Shipments to Hanford

The impact values provided for historical shipments to Hanford include shipments of spent nuclear fuel and radioactive waste from 1943 through 1993 (DOE 1995:Appendix I). Over the years, Hanford has received various types of wastes from Government, research institutes, and commercial nuclear facilities for disposal as well as testing purposes. A survey of Hanford’s Solid Waste Information and Tracking System (SWITS) indicates about 60,000 cubic meters (78,500 cubic yards) of solid waste from offsite generators has been disposed of at Hanford (CEES 2007). The list of offsite generators indicates locations all across the United States. The transportation risk analysis in the *Final Waste Management Programmatic Environmental Impact Statement for Managing Treatment, Storage, and Disposal of Radioactive and Hazardous Waste (WM PEIS)* (DOE 1997), which included analyses of waste transportation from multiple locations in the United States to Hanford, was used to estimate collective worker and population doses for the historical shipments. As SWITS does not identify the number of shipments, the waste volume per truck shipment assumption in the WM PEIS was used to estimate the number of historical shipments, resulting in an estimate of 3,750 shipments from 1944 through 1993. Using the estimated doses to workers and the general population in the WM PEIS, conservative collective doses to workers and the general population from historical shipments were estimated to be 292 and 317 person-rem, respectively.

It should be noted that there are considerable uncertainties in these historical estimates of collective dose. For example, the population densities and transportation routes used in the dose assessment were based on 1990 census data and the U.S. highway system as it existed in 1995. Using the 1990 census data results in an overestimate of historical collective doses because the U.S. population has increased since 1990. In contrast, using the interstate highway system as it existed in 1995 may slightly underestimate doses for shipments that occurred in the 1940s, 1950s, and 1960s because a larger portion of the transport

routes would have used non-interstate highways where the population may have been closer to the road. By the 1970s, the structure of the interstate highway system was largely fixed and most shipments would have been made on interstate highways.

6.3.11.2 General Radioactive Materials Transport

General radioactive material transports are shipments that are not related to a particular action and include shipments of radiopharmaceuticals to nuclear medicine laboratories, industrial and radiography sources, fresh and spent nuclear fuel, and LLW. Collective dose estimates from transportation of these types of materials during 1943 through 1982 were based on a U.S. Nuclear Regulatory Commission (NRC) analysis of shipments made in 1975 as documented in NUREG-0170 (NRC 1977). Collective dose estimate projections for shipments of these types of materials from 1983 through 2043 were based on analyses of unclassified shipments made in 1983, as documented in the *Department of Energy Programmatic Spent Nuclear Fuel Management and Idaho National Engineering Laboratory Environmental Restoration and Waste Management Programs Final Environmental Impact Statement* (DOE 1995). The NRC report estimated collective doses to the workers and general population of 5,600 and 4,200 person-rem, respectively, for truck, train, and airplane transports in 1975. Collective doses to workers and the general population for transports from 1943 through 1982 (39 years) were estimated to be 220,000 and 170,000 person-rem, respectively.

Collective doses to workers and the general population from truck and airplane shipments in 1983 were estimated to be 1,690 and 1,850 person-rem, respectively (DOE 1995). These doses were calculated using more refined models than those used in the NRC report. Even though the number of shipments was higher than those analyzed for the NRC report, the estimated doses were smaller by a factor of two to three. The collective doses over 91 years from 1983 through 2073 were estimated to be 154,000 and 168,000 person-rem for workers and the general population, respectively. Neither of these reports provided specific estimates for nonradiological traffic fatalities. Most of the radioactive materials are shipped incidental to other freight shipments (i.e., the shipment is non-exclusive-use and would take place whether or not the radioactive materials were on board). For exclusive-use shipments (i.e., those materials requiring exclusive use of the transport vehicle, such as spent nuclear fuel, uranium fuel cycle materials, and radioactive waste), there is a potential for non-radiological risks (traffic fatalities). Historically, there have been few accidents involving radioactive material transportation and few non-occupational fatalities (DOT 2009). Therefore, only potential future traffic fatalities were estimated for this category of transport. Using the estimated transport distances for the exclusive-use shipments (fuel cycle and wastes) from the NRC report (NRC 1977), an average traffic fatality per kilometer (1.5 fatalities per 100 million kilometers [62.1 million miles]; see Appendix H), and 91 years experience transporting materials, anticipated nonradiological traffic fatalities were estimated to be 116.

6.3.11.3 Reasonably Foreseeable Actions

Appendix T, Table T-4, lists the reasonably foreseeable actions that were considered in the cumulative transportation impacts analysis. The values provided for reasonably foreseeable actions could lead to some double-counting of impacts. For example, LLW transportation impacts addressed in the *WM PEIS* (DOE 1997) may also be included in the individual DOE facilities' sitewide EISs.

6.3.11.4 Conclusions

Table 6-8 shows that the *TC & WM EIS* alternative combination impacts, including the impacts of shipments of materials to and from INL, would be quite small compared to the overall cumulative transportation impacts. For these alternative combinations, the cumulative worker dose from all types of shipments was estimated to range between 406,400 and 406,700 person-rem (about 244 LCFs). The cumulative dose to the general population was estimated to be about 378,700 person-rem (about 227 LCFs). The cumulative nonradiological impacts (traffic fatalities), were estimated to be about 210.

To place these numbers in perspective, the National Center for Health Statistics states that the annual cancer death rate in the United States between 1999 and 2004 was about 554,000, with less than 1 percent fluctuations in the number of cancer deaths in any given year (CDC 2007). A total of about 470 LCFs among the workers and general population were estimated to result from radioactive material transportation from 1943 to 2073, an average of about 4 LCFs per year. Transportation-related LCFs represented about 0.0007 percent of the annual number of cancer deaths and were indistinguishable from the natural fluctuation in the total annual cancer death rate. The estimated number of traffic fatalities of about 210 over a period of more than 100 years was also small compared to the average annual traffic fatalities of 40,000 in the United States. Note that the majority of the cumulative risks to workers and the general population were due to the general transportation of radioactive material that is unrelated to the activities evaluated in this *TC & WM EIS*.

To provide a full range of cumulative impacts, other alternative combinations were also examined. The cumulative worker dose from all types of shipments was estimated to range up to a maximum of 407,400 person rem (about 244 LCFs). The cumulative dose to the general population was estimated to range up to 379,100 person rem (about 227 LCFs). Again, the total estimated number of LCFs among the workers and the general population (about 470, or an average of about 4 LCFs per year) was very small and is indistinguishable from the natural fluctuation in the total annual death rate from cancer. The estimated number of traffic fatalities of about 210 over a period of more than 100 years (an average of less than 4 per year) was also small compared to the total average annual traffic fatalities of 40,000 in the United States. This information shows that the impacts of the activities evaluated in this *TC & WM EIS* would be quite small compared to the overall cumulative impacts of radioactive materials transportation, and the cumulative impacts of radioactive materials transportation are only a small component of the overall transportation impacts.

6.3.12 Waste Management

Expected cumulative waste generation is presented in Table 6–9. It is unlikely that there would be major impacts on the waste management infrastructure at Hanford because sufficient capacity exists or would be constructed under the proposed Waste Management alternatives.

To estimate the cumulative waste management impacts, the waste generated by the *TC & WM EIS* alternative combinations (see Chapter 4, Section 4.4.12) and other past, present, and reasonably foreseeable future actions were summed. The cumulative waste volumes included all known or possible future actions that would generate and/or dispose of waste. These cumulative waste volumes also included past waste already disposed of in the 600 Area and the low-level radioactive waste burial grounds (LLBGs); CERCLA waste resulting from closure of the Columbia River Corridor for the 100 and 300 Areas (the volumes of CERCLA waste from the 200 Areas are unknown at this time); possible disposal of greater-than-Class C (GTCC) waste; and Naval Reactor program waste that is being disposed of at Hanford.

Table 6–9. Cumulative Waste Volumes

Actions/Activities	Waste Type (cubic meters)				
	HLW ^a	TRU Mixed	LLW/MLLW	Hazardous ^b	Nonradioactive/ Nonhazardous ^c
TC & WM EIS Alternative Combinations (see Chapter 4, Table 4–160)					
Alternative Combination 1	0	22,500	7,100	1,320	307
Alternative Combination 2	16,000	22,700	854,000	80,200	2,740
Alternative Combination 3	790,000	22,900	2,710,000	81,900	2,490,000
Other DOE Actions at the Hanford Site					
200 Area LLBGs ^d	N/A	NR	405,240	N/A	N/A
600 Area Nonradioactive Dangerous Waste Landfill	N/A	N/A	N/A	141 ^e	N/A
600 Area Central Landfill	N/A	N/A	N/A	N/A	596,000
CERCLA waste ^f	N/A	NR	21,400,000	NR	NR
Decommissioned, defueled naval reactor compartments	N/A	N/A	121,625	N/A	N/A
Other Possible Future DOE Actions at Hanford					
Disposal of GTCC waste ^g	N/A	N/A	11,000	N/A	N/A
Subtotals, Other DOE Actions and Possible Future Actions	N/A	N/A	21,937,865	141	596,000
Cumulative Totals^h					
Alternative Combination 1	0	22,500	21,970,000	1,460	596,000
Alternative Combination 2	16,000	22,700	22,791,000	80,300	599,000
Alternative Combination 3	790,000	22,900	24,648,000	82,000	3,090,000

^a Includes HLW canisters, cesium and strontium canisters, HLW melters, and other HLW. Also includes ILAW and tank debris for Alternative Combination 3.

^b Dangerous waste generated at the site is shipped off site for disposal or for recycling.

^c Nonradioactive, nonhazardous, and nondangerous waste is disposed of off site at municipal or commercial solid waste disposal facilities and is generally not held in long-term storage.

^d Total estimated waste buried in the 200-East and 200-West Area burial grounds: (200-East Area) 218-E-2, 218-E-4, 218-E-5, 218-E-5A, 218-E-10 trench, 218-E-1, 218-E-8, 218-E-12A, and 218-E-12B; (200-West Area) 218-W-1, 218-W-1A, 218-W-2, 218-W-2A, 218-W-3, 218-W-3A, 218-W-4A, 218-W-3AE, 218-W-4B, 218-W-4C, 218-W-5, 218-W-7, and 218-C-9. Some of the burial grounds may contain TRU waste.

^e The volume of buried waste in the Nonradioactive Dangerous Waste Landfill originally was 141,000 kilograms. A conversion using the density of water was used to get 141 cubic meters.

^f Total estimated CERCLA waste (LLW and MLLW) to be generated for the 100 and 300 Areas only; the amount of waste from the 200 Areas is unknown (Wood et al. 1995). Total waste disposed of from the 100 and 300 Areas as of 2007 was 6.5 million tons.

^g This is an estimate of GTCC and similar DOE waste that could be disposed of at Hanford (Joyce 2009).

^h The “cumulative totals” are the sums of the impacts under the alternative combinations and the “Other DOE” and “Other Possible Future DOE” activities. Subtotals or totals may not equal the sum of the contributions due to rounding.

Note: All values are in cubic meters except as noted. To convert cubic meters to cubic yards, multiply by 1.308.

Key: CERCLA=Comprehensive Environmental Response, Compensation, and Liability Act; DOE=U.S. Department of Energy; GTCC=greater-than-Class C; Hanford=Hanford Site; HLW=high-level radioactive waste; ILAW=immobilized low-activity waste; LLBG=low-level radioactive waste burial ground; LLW=low-level radioactive waste; MLLW=mixed low-level radioactive waste; N/A=not applicable; NR=not reported; TC & WM EIS=Tank Closure and Waste Management Environmental Impact Statement for the Hanford Site, Richland, Washington; TRU=transuranic.

Source: DOE 2007b; SAIC 2007b, 2007c, 2007d, 2008.

A general description of the existing waste management infrastructure is presented in Chapter 3, Section 3.2.12. Additional detailed information on the cumulative impacts methodology and past, present, and reasonably foreseeable future actions is provided in Appendix R.

6.3.12.1 TC & WM EIS Alternative Combinations

Chapter 4, Section 4.4.12, describes the three alternative combinations and the impacts they might have on the waste management system. Although generation of both primary and secondary waste would contribute to the overall combined impact on existing Hanford facilities devoted to treatment, storage, and disposal, as described in Chapter 4, Section 4.3.14, the Waste Management alternatives were developed to accommodate this additional generation of waste. Therefore, none of the three alternative combinations would exceed the capacity of the current or planned Hanford waste management infrastructure.

6.3.12.2 Other DOE Actions at Hanford

6.3.12.2.1 200 Area Burial Grounds

The LLBGs consist of eight burial grounds located in the 200-East and 200-West Areas that are used for disposal of LLW and MLLW. The LLBGs have been permitted under an RCRA Part A permit since 1985.

Three trenches receive mixed waste regulated by WAC 173-303, "Dangerous Waste Regulations." Trenches 31 and 34 in burial ground 218-W-5 are lined trenches with leachate collection and removal systems. Trench 94 in burial ground 218-E-12B is used for disposal of defueled U.S. Naval reactor compartments (see below). LLW and TRU waste have been placed in the other burial grounds. The TRU waste was placed in a manner that allows future retrieval and/or removal. Soil was placed over some of the waste containers to provide radiological protection (Poston et al. 2007). TRU waste has not been placed in the LLBGs without specific DOE approval since August 19, 1987.

DOE Order 435.1, *Radioactive Waste Management*, requires a disposal authorization statement authorizing operation (or continued operation) for LLW disposal facilities. In fulfillment of these requirements, a disposal authorization statement was issued on October 25, 1999, authorizing Hanford to transfer, receive, possess, and dispose of LLW at the 200-East Area and 200-West Area LLBGs. By agreement between DOE and Ecology, use of the LLBGs as disposal facilities for LLW and MLLW has been restricted to lined trenches and the Naval reactor-compartment trench only. Hence, as of July 2004, only the two lined trenches in burial ground 218-W-5 (trenches 31 and 34) and the Naval reactor-compartment trench in burial ground 218-E-12B (trench 94) are allowed to receive waste. When the two lined trenches are filled, the LLBGs will cease to operate except for reactor compartment disposal at trench 94. The remaining operational lifetimes of the LLBGs depend on the waste volume disposal rates (DOE 2006d).

The LLBGs are included in a draft remedial investigation/feasibility study work plan completed in September 2007 (DOE 2007b). The remedial investigation/feasibility study process will be used to reach a decision that will meet requirements for both National Priorities List cleanup and RCRA corrective action. Retrieval of suspect-TRU retrievably stored waste in burial ground 218-W-4C was initiated in October 2003 in accordance with TPA Milestone M-91-03-01.

6.3.12.2.2 600 Area Nonradioactive Dangerous Waste Landfill and 600 Area Central Landfill

The Nonradioactive Dangerous Waste Landfill (NRDWL) is an inactive landfill. Although an NRDWL site closure plan was written in 1990 (DOE 1990), the closure plan has not been approved. The landfill provided a site for disposal of dangerous waste generated from process operations, research and development laboratory maintenance activities, and transportation functions throughout Hanford. The NRDWL is located about 5.6 kilometers (2.5 miles) southeast of the 200-East Area on Army Loop Road, southwest of the Route 4 intersection and southeast of the 200-East Area. It began operation in 1975 and occupies an area of 4.5 hectares (11 acres). It consists of 19 parallel trenches, each 122 meters (400 feet) long, 4.9 meters (18 feet) wide at the base, and 4.6 meters (15 feet) deep. A triangular column of

undisturbed soil with approximately 1:1 side slopes separated the trenches as they were constructed. The final profile of the trench varied depending on the type of waste received. The trenches typically were backfilled and covered with 2 to 3 meters (6 to 10 feet) of soil at the end of each operating day. Beginning in 1975, chemical waste was disposed of in six trenches, asbestos in nine trenches, and nonhazardous solid waste in one trench; three were unused. The last receipt of dangerous waste was in May 1985; the last receipt of asbestos occurred in May 1988 (DOE 2007b).

The 600 Central Landfill is a non-RCRA solid waste landfill adjacent to NRDWL on the south side. It is a larger facility (27 hectares [67 acres]) that received principally solid waste, including paper, construction debris, asbestos, and lunchroom waste. It also received up to 5,000,000 liters (1,320,000 gallons) of sewage and 380,000 liters (100,000 gallons) of garage wash water. The liquid waste was discharged to east-west oriented trenches at the perimeter of the main solid-waste area, along the northeast and northwest boundaries of the 600 Central Landfill. The 600 Central Landfill is regulated under WAC 173-304, “Minimum Functional Standards for Solid Waste Handling” (DOE 2007b).

The two landfills (NRDWL and the 600 Central Landfill) were operated as a single landfill that was originally known as the Central Landfill. Because of the presence of dangerous waste in the chemical trenches, the 19 northernmost trenches were designated as the NRDWL under the Hanford Facility RCRA Permit. The southern two-thirds of the area were later designated as the 600 Central Landfill, which is a treatment, storage, and disposal unit (DOE 1990).

The TPA outlines the approach that DOE will take for permitting and closure of the Hanford RCRA regulated treatment, storage, and disposal units. These two landfills are included in a draft remedial investigation/feasibility study work plan completed in September 2007 (DOE 2007b). The remedial investigation/feasibility study process will be used to reach a decision that will meet requirements for both National Priorities List cleanup and RCRA corrective action (DOE 2007b).

6.3.12.2.3 CERCLA Waste: Closure of the Columbia River Corridor

Other DOE actions at Hanford include cleanup and closure of the Columbia River corridor, an area of roughly 210 square miles along the outer edge of Hanford that includes major portions of the Hanford Reach National Monument. These actions include:

- Deactivating, decommissioning, decontaminating, and demolishing 510 facilities, many of which are contaminated with radioactive and/or hazardous materials.
- Remediating and closing 486 waste sites, including trenches where plutonium production reactor liquid wastes were discharged.
- Placing the K-East and K-West reactors in interim safe storage. (The K-East and K-West were large plutonium production reactors that operated from 1955 until the early 1970s. A “cocooning” method will be used that will involve in situ encapsulation of the reactor piles. Five of eight reactors have already been cocooned.)
- Remediating burial grounds 618-10 and 618-11. (The 618-10 and 618-11 burial grounds contain some highly radioactive irradiated nuclear fuel, hazardous chemicals and plutonium, cesium and other radioactive material.)
- Operating the ERDF.

In 1988, Hanford was scored using the U.S. Environmental Protection Agency (EPA) hazard ranking system. Based on the scoring, Hanford was added to the National Priorities List in July 1989 as four sites: the Richland North Area, formerly the 1100 Area; 100 Areas; 200 Areas; and 300 Area. Each of

these areas was further divided into operable units (groupings of individual waste units based primarily on geographic area and common waste sources). These operable units contain contamination in the form of hazardous waste, radioactive/hazardous mixed waste, and other CERCLA hazardous substances. In anticipation of Hanford's addition to the National Priorities List, DOE, EPA, and Ecology entered into the TPA in May 1989. This agreement established a procedural framework and schedule for developing, implementing, and monitoring remedial response actions at Hanford. The TPA also addresses RCRA compliance and permitting.

Wastes from cleanup and closure of the Columbia River corridor are being disposed of in the ERDF, a CERCLA disposal facility in the Hanford 200 Areas. The ERDF is also designed and operated to meet the substantive RCRA requirements. Construction of the first two cells began in May 1995, and the first shipment of waste was received on July 1, 1996. Each cell is 152 meters (500 feet) wide at the bottom, 21 meters (70 feet) deep, and over 304 meters (1,000 feet) wide at the surface. The ERDF's liner is a system composed of multiple barriers that form a primary and secondary protection system. Each system is designed to contain and collect moisture to prevent migration of contaminants to the soil and groundwater. Once the ERDF is filled with waste, an RCRA-compliant engineered barrier will be placed on top to prevent rain infiltration. The ERDF is expected to receive about 10 million tons of waste from Hanford cleanup activities. DOE has disposed of approximately 6.5 million tons of Hanford cleanup waste in the ERDF since the facility started operations in 1996 (an average of 625,000 tons per year). The inventory included in Table 6–9 is the cumulative total for only the 100 and 300 areas. Inventories for the 200 Areas are unknown at this time. However it is anticipated that the 200 Areas will generate a large quantity of waste (Poston et al. 2007).

6.3.12.2.4 Disposal of Decommissioned, Defueled Naval Reactor Compartments

The retirement of aging weapon systems and cutbacks in the number of U.S. Navy ships in the post-Cold War era have resulted in reductions in the Naval nuclear fleet. On August 9, 1996, a ROD was issued for disposal of defueled reactor plants from U.S. Navy nuclear-powered cruisers and Ohio Class and Los Angeles class submarines (61 FR 41596). The Navy, with DOE's concurrence, decided to dispose of these reactor compartments at LLBG 218-W-5, trench 34, at Hanford. This method has very small environment impacts and provides permanent disposal of the defueled reactor compartments. In 1999, under this ROD, DOE began accepting an additional 100 reactor compartments for disposal at LLBG 218-E-12B, a 70-hectare (173-acre) waste disposal facility in the 200-East Area of Hanford. This would add to the 55 pre-Los Angeles Class submarine reactor compartments already disposed of in this facility. Through September 2007, 117 reactor compartments have been transported safely and disposed of. On average, between six and eight shipments had been made each year; however, in recent years, that number has dropped to only one or two each year, with no shipments in 2005, one in 2006, and two in 2007 (Poston, Duncan, and Dirkes 2008). The reactor compartments are classified as LLW. The iron and metal alloys within the reactor vessel have become radioactive after years of reactor operations; their exteriors are not contaminated. The reactor compartments are estimated to include a total of approximately 120,000 cubic meters (4,240,000 cubic feet) of LLW.

DOE oversees placement of reactor compartments into this area of the disposal facility and manages the disposal operations in accordance with all applicable requirements. Ecology regulates the reactor compartment disposal packages as a dangerous waste under WAC 173-303, "Dangerous Waste Regulations," due to the over 100 tons of permanent lead shielding in each reactor compartment. Treatment before disposal is not required because the solid elemental lead shielding is encapsulated by thick metal sheathing plates that meet RCRA treatment standards for disposal of radioactive lead solids.

The Final Environmental Impact Statement on the Disposal of Decommissioned, Defueled Cruiser, OHIO Class, and LOS ANGELES Class Naval Reactor Plants (Navy 1996) indicated that the EPA review did not identify any potential environmental impacts requiring substantive changes for the preferred

alternative. The EIS states that, based on the Navy's past method of disposing of pre-Los Angeles class submarine reactor compartments with very conservative engineering practices, the environmental impacts will be very small for the additional 100 reactor compartments. These conservative engineering practices have been incorporated in the Navy's preferred alternative. No additional mitigative measures were identified to further reduce the small impacts which were described in the EIS (Navy 1996).

6.3.12.3 Other Possible Future DOE Actions at Hanford

6.3.12.3.1 Greater-Than-Class-C Low-Level Radioactive Waste

The Low-Level Radioactive Waste Policy Act of 1980, as amended (42 U.S.C. 2021 et seq.), assigned the U.S. Government the responsibility for disposing of GTCC LLW generated by activities licensed by NRC or Agreement States. The act requires the Federal Government to provide for the disposal of GTCC LLW in a facility that adequately protects the safety and health of the public and is licensed by NRC. As part of its assigned responsibilities under act, DOE has begun the EIS process for development of a disposal capability for GTCC LLW and similar DOE waste (DOE-owned or -generated LLW or TRU waste with characteristics similar to GTCC LLW that may not have an identified path to disposal). Sites under consideration for disposal of GTCC LLW include the Waste Isolation Pilot Plant near Carlsbad, New Mexico; other DOE sites; and generic commercial sites (72 FR 40135).

Hanford is being considered as a candidate location for a new GTCC waste disposal facility in the *Environmental Impact Statement for the Disposal of Greater-Than-Class C Low-Level Radioactive Waste (GTCC EIS)*, DOE/EIS-0375 (72 FR 40135). Such a facility is not expected to be operational until after 2013. As described in Table 6-9, it could receive about 11,000 cubic meters (388,000 cubic feet) of GTCC LLW and similar DOE waste (Joyce 2009) already in storage or projected to be generated from facilities already in operation or that could result from proposals being analyzed in other NEPA reviews, including the *Environmental Impact Statement for Decommissioning and/or Long-Term Stewardship at the West Valley Demonstration Project and Western New York Nuclear Service Center*, DOE/EIS-0226-D (Revised) (DOE and NYSERDA 2008), and the *Environmental Impact Statement for the Proposed Consolidation of Nuclear Operations Related to Production of Radioisotope Power Systems*, DOE/EIS-0373 (69 FR 67139).

6.3.12.3.2 Long-Term Management and Storage of Elemental Mercury

DOE is preparing an *Environmental Impact Statement for the Long-Term Management and Storage of Elemental Mercury* (DOE/EIS-0423) (74 FR 31723). This EIS will evaluate alternatives for a facility (or facilities) for the long-term management and storage of elemental mercury generated within the United States as required by the Mercury Export Ban Act of 2008 (P.L. 110-414). Hanford is being considered in this EIS as a candidate host site for the long-term management and storage of elemental mercury. Any facility selected must comply with applicable requirements of the Mercury Export Ban Act of 2008; the Solid Waste Disposal Act, as amended by RCRA (42 U.S.C. 6901 et seq.); and other permitting requirements. It is estimated that the total amount of elemental mercury that would be eligible for DOE storage is between 7,500 and 10,000 metric tons over a 40-year period. DOE intends to identify the facility (or facilities) through the NEPA process.

6.3.12.4 Summary

Because the Waste Management alternatives were developed to accommodate this additional waste generation, the cumulative waste management impacts would not exceed the capacity of the planned Hanford waste management infrastructure and would therefore be unlikely to have any major impacts. As stated in Chapter 4, Section 4.4.12, Alternative Combination 3 reflects the upper end of the three combinations, but does not maximize waste management infrastructure demands. A combination that would include Tank Closure Alternative 6A, Base or Option Cases; FFTF Decommissioning

Alternative 2 (with all facilities to be built at Hanford); and Waste Management Alternatives 2 or 3 (with Disposal Group 3) would have the greatest combined impact on the waste management infrastructure for high-level radioactive waste, MLLW, and hazardous and liquid LLW. It is unlikely that there would be major cumulative impacts on the waste management infrastructure at Hanford because sufficient capacity exists or would be constructed under the Waste Management alternatives.

6.3.13 Industrial Safety

This section identifies the cumulative industrial safety impacts to Hanford workers. Appendix K contains the methodology used in estimating industrial safety impacts. Chapter 4, Sections 4.1.15, 4.2.15, and 4.3.15, provide the impacts and projected Total Recordable Cases (TRCs) for each alternative. Chapter 4, Section 4.4.13, presents the impacts for the three alternative combinations.

Hanford has experienced a decrease in the number of TRCs over the period from 1993 through 2006, as reported in the DOE *Computerized Accident Incident Reporting and Recordkeeping System* (DOE 2008). This decline reflects the type and scope of work that has been conducted in the past and is currently being conducted at Hanford. Other factors contributing to the decrease include safe work procedures, policies, and practices observed by the work force. Figure 6–1 shows the number of TRCs, and the incidence rate per 200,000 labor hours. Baseline TRCs and fatalities are 22,996 and 0.025, respectively.

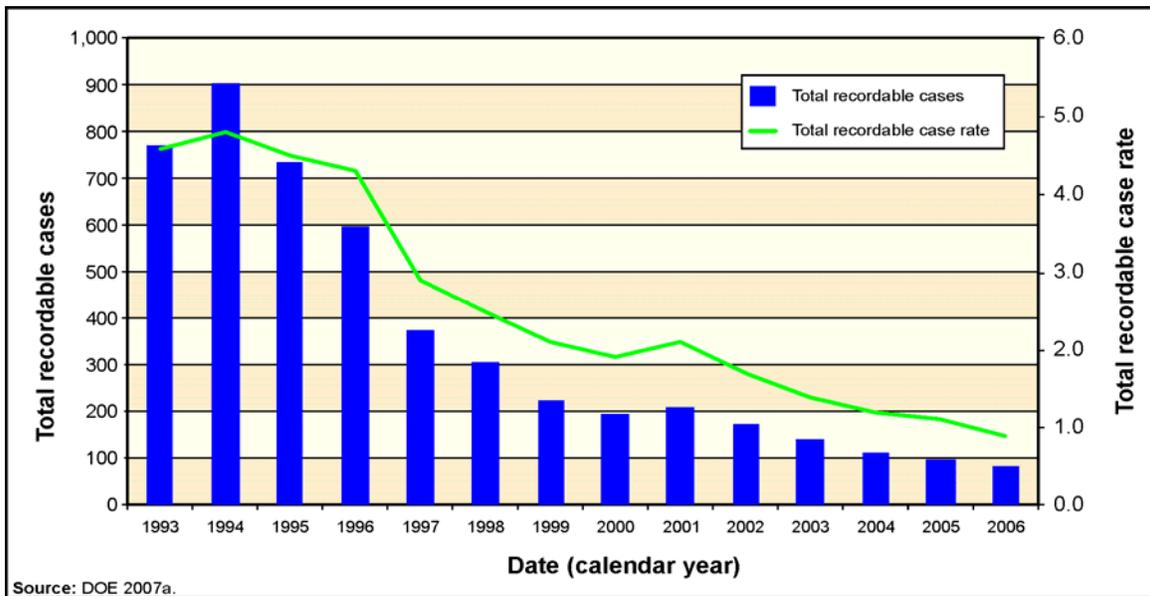


Figure 6–1. Richland Operations Industrial Safety Total Recordable Cases and Incident Rate Between 1993 and 2006

Table 6–10 shows the potential cumulative impacts to Hanford worker industrial safety for each of the alternative combinations. As shown in Table 6–10, the baseline projection of TRCs and number of fatalities for site activities is the total TRCs and number of fatalities projected to occur over the same time period as the alternative combinations. The baseline TRCs and number of fatalities were then added to the combinations. This is likely to be conservative because the baseline values include workers performing Waste Treatment Plant construction activities.

Table 6–10. Estimated Industrial Safety Cumulative Impacts

Actions/Activities	Number of Total Recordable Cases	Number of Fatalities
TC & WM EIS Alternative Combinations (see Chapter 4, Table 4–161)		
Alternative Combination 1	173	0.02
Alternative Combination 2	4,540	0.60
Alternative Combination 3	6,870	0.88
Other DOE Actions at the Hanford Site		
Hanford Site baseline	22,996	0.025
Cumulative Totals^a		
Alternative Combination 1	23,170	0.05
Alternative Combination 2	27,540	0.63
Alternative Combination 3	29,870	0.91

^a The “cumulative totals” are the sums of the impacts under the alternative combinations and the “Other DOE” activities. Totals may not equal the sum of the contributions due to rounding.

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

Alternative Combination 1 (No Action) would not have an impact on the number or rate of TRCs. It can reasonably be expected that future TRCs would remain equal to or decline from present levels. Factors influencing this include the anticipated work effort in terms of the type and amount required in the foreseeable future. Although projected to generate approximately 173 TRCs over the duration of the selected alternatives, Combination 1 includes a 100-year administrative control period that restricts access to and use of the site. Averaging the number of TRCs over the duration of the alternative combinations would increase the recordable cases by one to two per year. Other activities taking place at the same time were included as part of the baseline accounted for in the current TRCs rate and number.

The impact of Alternative Combination 2 would result in an increase in the cumulative number of illnesses, injuries, and fatalities. The magnitude of the increase would be influenced by the number of workers, hours worked, and type of work. Typically, the greatest increase would be realized during the construction phase. Averaging the number of additional recordable cases over all phases of the alternative combinations would increase the TRCs by 25 to 27 annually. However, that number would be greater during the peak construction periods and less during the operation and decommissioning phases. The lowest number of recordable cases is expected during the closure phase. Assuming current safe work policies and practices are continued, cumulative fatalities are not expected from the additional recordable cases associated with this alternative combination.

Alternative Combination 3 would generate the greatest increase in the cumulative number of recordable cases. An overall increase of approximately 6,900 TRCs over all phases of work activity was projected for Combination 3. The increased TRCs would be influenced by the annual changes in the size of the work force and the type of work performed. The construction phase of the project would generate the most cases, while postclosure care of the site would result in the fewest cases. The magnitude of the increase, when averaged over the entire duration, would be approximately 40 to 42 additional cases annually. Similar to Alternative Combination 2, the greatest increase in TRCs would occur during the construction phase, while the fewest TRCs would occur during the postclosure phase. Although the possibility of fatalities is always present during the construction of any large facility, this cumulative impacts analysis indicates a fatality would be unlikely over the entire period of analysis, assuming that safe work policies, procedures, and techniques remain in force throughout the duration of work.

6.4 LONG-TERM CUMULATIVE IMPACTS

Long-term cumulative impacts occur following the active project phase for each alternative. For this *TC & WM EIS*, long-term cumulative impacts were assessed out to approximately 10,000 years in the future.

This section presents long-term cumulative impacts for the following resource areas: groundwater quality, public health, ecological risk, and environmental justice. The detailed tables that support the long-term cumulative impacts analyses are presented in Appendix U.

6.4.1 Groundwater Quality

In this section, the cumulative long-term groundwater quality impacts are presented in conjunction with the long-term impacts of three alternative combinations. The results for the three alternative combinations are presented in Section 5.4. The results for the long-term groundwater impacts associated with the past, present, and reasonably foreseeable future action (non-*TC & WM EIS*) sources are presented in Appendix U. As discussed in Appendix U, the methodology for calculating the cumulative long-term groundwater impacts of non-*TC & WM EIS* sources is fully consistent with the methodology for calculating the impacts of the *TC & WM EIS* alternatives.

6.4.1.1 Alternative Combination 1

This section presents the results of the cumulative long-term groundwater impacts analysis including Alternative Combination 1. All of the non-*TC & WM EIS* sources discussed in Appendix S are included.

This discussion of long-term impacts is focused on the following constituent of potential concern (COPC) drivers:

- radiological risk drivers: hydrogen-3 (tritium), iodine-129, technetium-99, and uranium-238
- chemical hazard drivers: carbon tetrachloride, chromium, nitrate, and total uranium

The COPC drivers were obtained from the combination of the COPC drivers for the three individual alternatives that compose Alternative Combination 1 and the COPC drivers for the non-*TC & WM EIS* sources. They fall into three categories. Iodine-129, technetium-99, carbon tetrachloride, chromium, and nitrate are all mobile (i.e., move with groundwater) and long-lived (relative to the 10,000-year period of analysis) or stable. They are essentially conservative tracers. Tritium is also mobile, but short lived. The half-life of tritium is about 12.3 years, and tritium concentrations are strongly attenuated by radioactive decay during travel through the vadose zone and groundwater systems. Finally, uranium-238 and total uranium are long-lived or stable, but are not as mobile as the other COPC drivers. These constituents move about seven times more slowly than groundwater. The other COPCs that were analyzed do not significantly contribute to risk or hazard during the period of analysis because of limited inventory, high retardation factors (i.e., retention in the vadose zone), short half-lives (i.e., rapid radioactive decay), or a combination of these factors. The level of protection provided for the drinking water pathway was evaluated by comparison against the maximum contaminant levels provided in 40 CFR 141 and other benchmarks presented in Appendix O.

6.4.1.1.1 Analysis of Release and Mass Balance

This section presents the total amount of the COPC drivers released to the vadose zone, to groundwater, and to the Columbia River. Releases of radionuclides are totaled in curies, and releases of chemicals are totaled in kilograms. Both are totaled over the 10,000-year period of analysis.

Table 6–11 lists the release to the vadose zone for the COPC drivers. For Alternative Combination 1 and non-TC & WM EIS sources, the release to the vadose zone is controlled by inventory; the entire inventory for all sources was released to the vadose zone during the period of analysis. The release to the vadose zone for Alternative Combination 1 and non-TC & WM EIS sources is dominated by non-TC & WM EIS sources for tritium, by sources associated with Tank Closure Alternative 1 for technetium-99, and by a combination of non-TC & WM EIS sources and Tank Closure Alternative 1 for the other COPCs. For all of the COPC drivers, releases from FFTF Decommissioning alternative and Waste Management alternative sources account for less than 1 percent of the total.

Table 6–11. Alternative Combination 1 Release to Vadose Zone for COPC Drivers

	Radiological COPCs (curies)				Chemical COPCs (kilograms)		
	Hydrogen-3 (Tritium)	Iodine-129	Technetium-99	Uranium-238	Chromium ^a	Nitrate	Total Uranium
Other Activities	3.43×10^6	2.49×10^1	7.33×10^2	3.13×10^3	3.35×10^5	7.38×10^7	2.53×10^5
Tank Closure Alternative 1	5.75×10^4	4.78×10^1	2.58×10^4	9.38×10^2	6.94×10^5	9.74×10^7	6.32×10^5
FFTF Decommissioning Alternative 1	2.29	0	2.72×10^1	0	5.72×10^{-3}	0	2.79×10^{-2}
Waste Management Alternative 1	3.52×10^3	1.32×10^{-3}	1.21	7.35×10^{-1}	1.80×10^2	2.98×10^3	9.47×10^{-1}
Total	3.49×10^6	7.27×10^1	2.66×10^4	4.07×10^3	1.03×10^6	1.71×10^8	8.85×10^5

^a It was assumed, for the purposes of analysis, that all chromium was hexavalent.

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

Key: COPC=constituent of potential concern; FFTF=Fast Flux Test Facility.

Table 6–12 lists the release to groundwater for the COPC drivers. In addition to the inventory consideration discussed in the previous paragraph, release to groundwater is controlled by the transport properties of the COPC drivers and by the rate of moisture movement through the vadose zone. For iodine-129, technetium-99, chromium, and nitrate, the amount released to groundwater is essentially equal to the amount released to the vadose zone. For tritium, the amount released to groundwater is attenuated by radioactive decay during transit through the vadose zone. About 60 percent of the tritium released to the vadose zone reaches the unconfined aquifer. Because of retardation, less than 15 percent of the uranium-238 and total uranium released to the vadose zone reaches the unconfined aquifer during the period of analysis.

Table 6–12. Alternative Combination 1 Release to Groundwater for COPC Drivers

	Radiological COPCs (curies)				Chemical COPCs (kilograms)		
	Hydrogen-3 (Tritium)	Iodine-129	Technetium-99	Uranium-238	Chromium ^a	Nitrate	Total Uranium
Other Activities	2.06×10^6	2.48×10^1	7.12×10^2	1.48×10^2	3.40×10^5	7.42×10^7	1.05×10^5
Tank Closure Alternative 1	3.23×10^4	4.65×10^1	2.51×10^4	2.57×10^1	6.34×10^5	9.40×10^7	2.86×10^4
FFTF Decommissioning Alternative 1	5.30×10^{-3}	0	2.67×10^1	0	5.61×10^{-3}	0	2.35×10^{-2}
Waste Management Alternative 1	1.76×10^3	1.31×10^{-3}	1.21	3.09×10^{-5}	1.77×10^2	2.94×10^3	4.39×10^{-5}
Total	2.10×10^6	7.13×10^1	2.58×10^4	1.74×10^2	9.74×10^5	1.68×10^8	1.34×10^5

^a It was assumed, for the purposes of analysis, that all chromium was hexavalent.

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

Key: COPC=constituent of potential concern; FFTF=Fast Flux Test Facility.

Table 6–13 lists the release to the Columbia River for the radiological risk drivers. Release to the Columbia River is controlled by the transport properties of the COPC drivers in the unconfined aquifer. For iodine-129, technetium-99, chromium, and nitrate, the amount released to Columbia River is essentially equal to the amount released to groundwater. For tritium, the amount released to the Columbia River is attenuated by radioactive decay. Overall, only about 5 percent of the tritium released to groundwater reaches the Columbia River. Because of retardation, about 80 percent of the uranium-238 and total uranium released to groundwater during the period of analysis reaches the Columbia River.

Table 6–13. Alternative Combination 1 Release to Columbia River for Radiological Risk Drivers

	Radiological COPCs (curies)				Chemical COPCs (kilograms)		
	Hydrogen-3 (Tritium)	Iodine-129	Technetium-99	Uranium-238	Chromium ^a	Nitrate	Total Uranium
Other activities	1.11×10 ⁵	2.46×10 ¹	7.26×10 ²	1.40×10 ²	3.51×10 ⁵	7.47×10 ⁷	9.28×10 ⁴
Tank Closure Alternative 1	8.68×10 ²	4.54×10 ¹	2.46×10 ⁴	6.26	6.52×10 ⁵	9.42×10 ⁷	6.87×10 ³
FFTF Decommissioning Alternative 1	3.15×10 ⁻⁴	0	2.72×10 ¹	0	5.73×10 ⁻³	0	2.20×10 ⁻²
Waste Management Alternative 1	0	1.28×10 ⁻³	1.18	2.67×10 ⁻⁶	1.75×10 ²	2.90×10 ³	3.50×10 ⁻⁶
Total	1.12×10 ⁵	7.00×10 ¹	2.53×10 ⁴	1.46×10 ²	1.00×10 ⁶	1.69×10 ⁸	9.97×10 ⁴

^a It was assumed, for the purposes of analysis, that all chromium was hexavalent.

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

Key: COPC=constituent of potential concern; FFTF=Fast Flux Test Facility.

6.4.1.1.2 Analysis of Concentration Versus Time

This section presents groundwater concentration versus time at the Core Zone Boundary and the Columbia River. Because of the discrete nature of the concentration carried across a barrier or the river, a line denoting the 95th percentile upper confidence limit of the concentration is included on several of these graphs. This confidence interval was calculated to aid in interpreting data with a considerable amount of random fluctuation (noise). The confidence interval was calculated when: the concentration had a considerable amount of noise, the concentration trend was level, and the concentrations were near the benchmark. The benchmark concentration for each radionuclide and chemical is also shown. Note that the concentrations are plotted on a logarithmic scale to facilitate visual comparison of concentrations that vary over five orders of magnitude. Table 6–14 lists the maximum concentrations for the COPCs at the peak year for the Core Zone Boundary and the Columbia River nearshore.

Table 6–14. Alternative Combination 1 Maximum Concentrations for COPCs^a

Contaminant	Core Zone Boundary	Columbia River Nearshore	Benchmark Concentration ^b
Radionuclide (picocuries per liter)			
Hydrogen-3 (Tritium)	104,000,000	4,190,000	20,000
	(1996)	(1986)	
Carbon-14	46,700	196	2,000
	(1998)	(2013)	
Strontium-90	181,000	4,160,000	8
	(1998)	(1991)	

Table 6–14. Alternative Combination 1 Maximum Concentrations for COPCs^a (continued)

Contaminant	Core Zone Boundary	Columbia River Nearshore	Benchmark Concentration ^b
Radionuclide (picocuries per liter)			
Technetium-99	350,000	5,360	900
	(3837)	(4032)	
Iodine-129	697	18.3	1
	(3801)	(4411)	
Cesium-137	0 ^c	1,310,000	200
	(1997)	(1985)	
Uranium isotopes (includes U-233, -234, -235, -238)	2,200	22,400	15
	(1991)	(1973)	
Neptunium-237	114	16	15
	(2066)	(2004)	
Plutonium isotopes (includes Pu-239, -240)	2,660	4,250	15
	(11,848)	(2983)	
Chemical (microgram per liter)			
1-Butanol	17,200	49	3,600
	(1998)	(11,243)	
Acetonitrile	121	9	100
	(3338)	(3285)	
Carbon tetrachloride	3,350	60.7	5
	(2270)	(2527)	
Chromium ^d	29,400	16,100	100
	(1956)	(1978)	
Dichloromethane	0.7	0.1	5
	(3286)	(4711)	
Fluoride	90,200	14,500	4,000
	(2003)	(1982)	
Hydrazine/Hydrazine Sulfate	0.030	0.088	0.022
	(3343)	(3627)	
Lead	0 ^c	9,080	15
	(2021)	(2374)	
Manganese	392	242	1,600
	(8610)	(2286)	
Mercury	183	25.5	2
	(2015)	(1997)	
Nickel (soluble salts)	0 ^c	8,310	700
	(11,871)	(3877)	
Nitrate	13,600,000	505,000	45,000
	(1956)	(1973)	
Total Uranium	3,290	15,400	30
	(1991)	(1964)	
Trichloroethylene (TCE)	0.1	0.2	5
	(3404)	(3764)	

^a The peak cumulative concentration for some constituents occurs in the past. The relationship of past to future cumulative concentrations is presented in the time versus concentration plots in Figures 6–2 through 6–9.

^b The sources of the benchmark concentrations are provided in Appendix O, Section O.3.

^c Values that are less than 0.001 are reported as zero.

^d It was assumed, for the purposes of analysis, that all chromium was hexavalent.

Note: To convert liters to gallons, multiply by 0.26417.

Key: COPC=constituent of potential concern.

Figure 6–2 shows concentration versus time for tritium. Note that for visual clarity, the time period shown on this figure is from 1940 through 5940 rather than the full 10,000-year period of analysis.

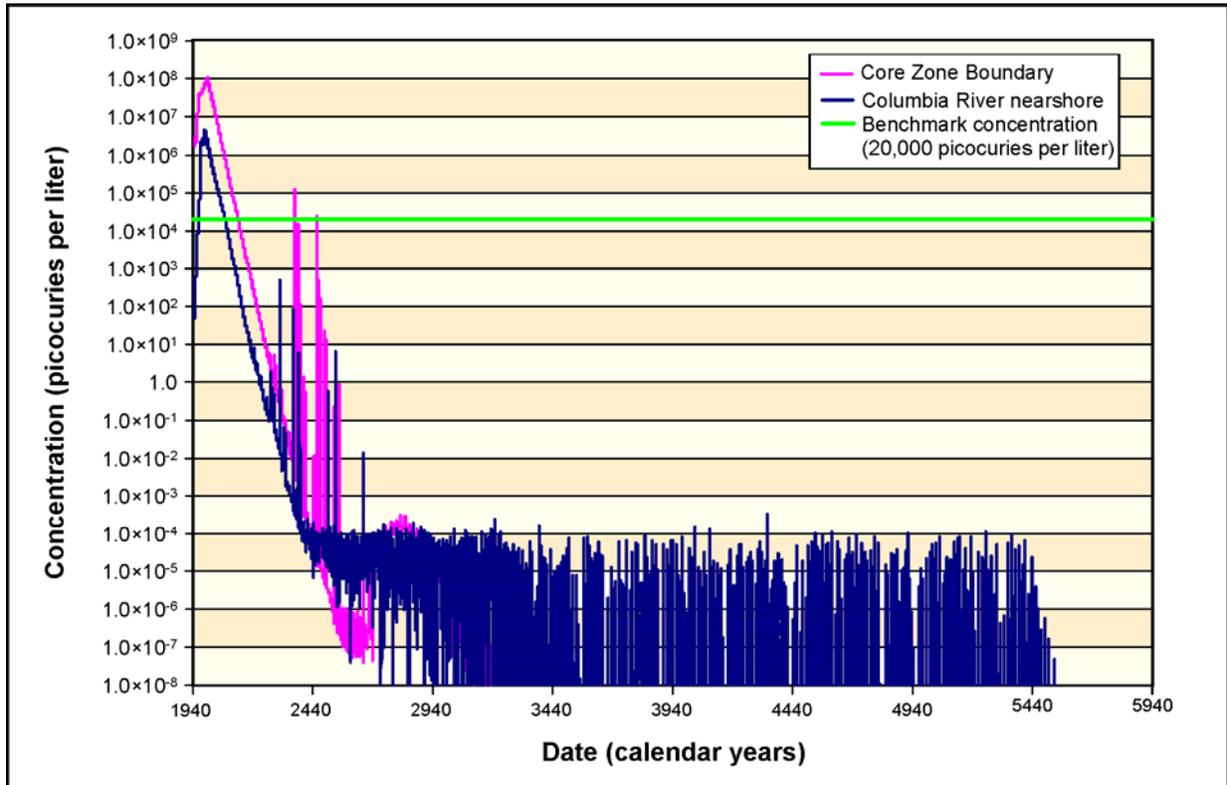


Figure 6–2. Alternative Combination 1 Cumulative Concentration Versus Time for Tritium

Concentrations at the Core Zone Boundary exceed the benchmark concentration by about three orders of magnitude for a short period of time during the early part of the period of analysis. During this time groundwater concentrations at the Columbia River nearshore peak at about two orders of magnitude above the benchmark concentration. Because the half-life of tritium is less than thirteen years, radioactive decay rapidly attenuates groundwater concentration, and tritium is essentially not a factor at times later than calendar year (CY) 2100.

Figures 6–3 through 6–7 show concentration versus time for iodine-129, technetium-99, carbon tetrachloride, chromium, and nitrate. Groundwater concentrations of iodine-129 exceed benchmark concentrations by more than two orders of magnitude during the first several thousand years of the analysis. During this time groundwater concentrations at the Columbia River nearshore exceed the benchmark concentration by about an order of magnitude. During later times in the analysis the concentrations at the Core Zone Boundary exceed the benchmark by about an order of magnitude, and are on the same order of magnitude as the benchmark at the Columbia River nearshore. Technetium-99, carbon tetrachloride, chromium, and nitrate concentrations show a similar curve, with chromium and nitrate concentrations at the Columbia River nearshore dropping below the benchmark concentrations.

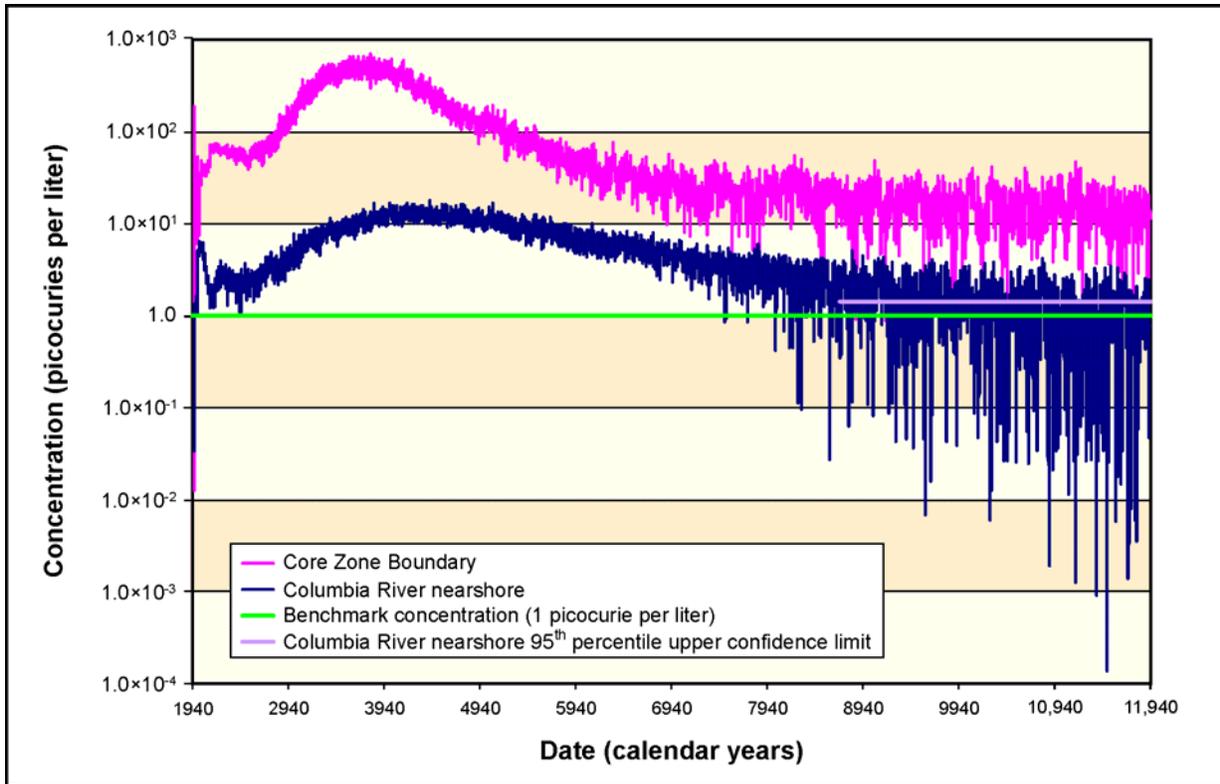


Figure 6–3. Alternative Combination 1 Cumulative Concentration Versus Time for Iodine-129

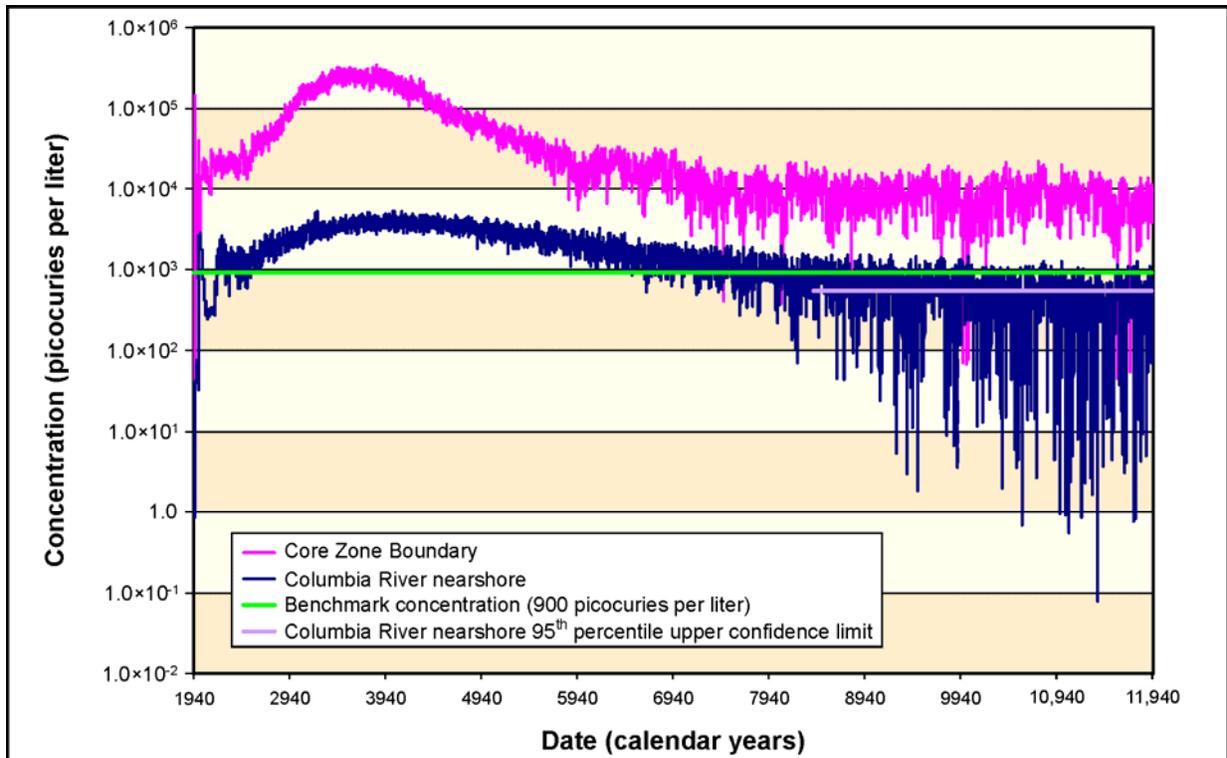


Figure 6–4. Alternative Combination 1 Cumulative Concentration Versus Time for Technetium-99

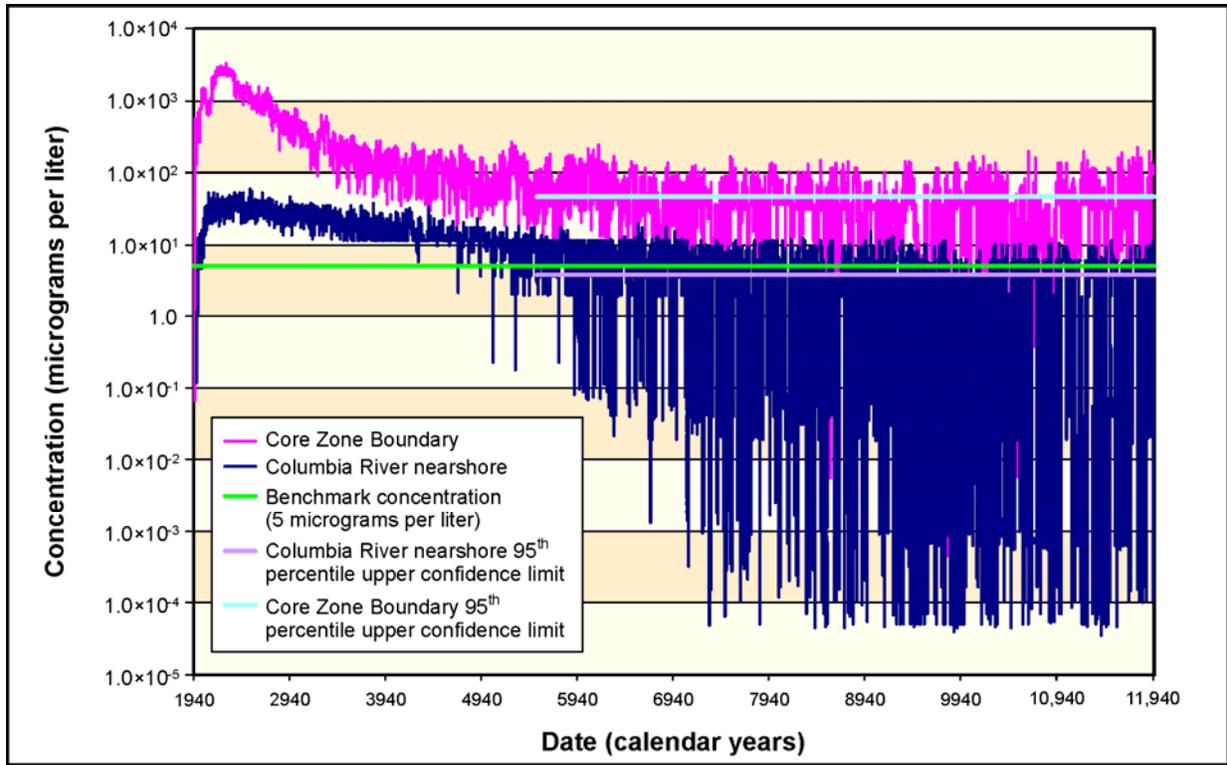


Figure 6-5. Alternative Combination 1 Cumulative Concentration Versus Time for Carbon Tetrachloride

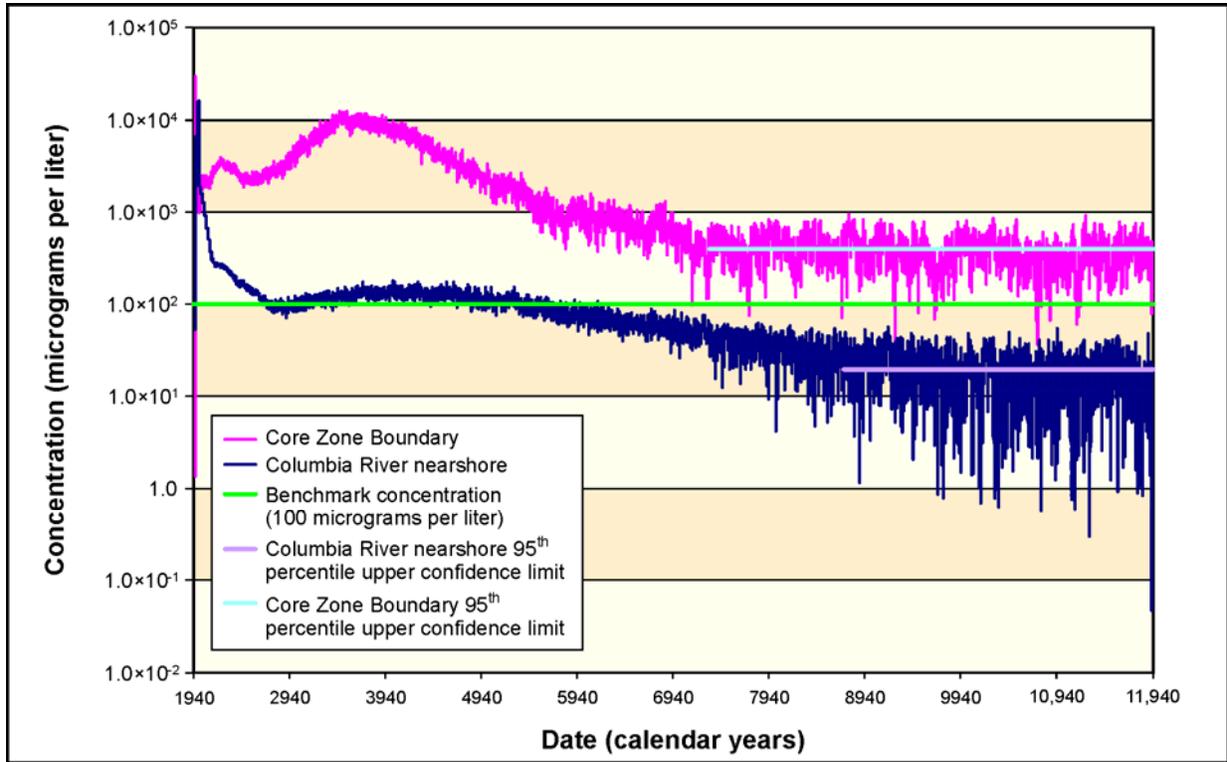


Figure 6-6. Alternative Combination 1 Cumulative Concentration Versus Time for Chromium

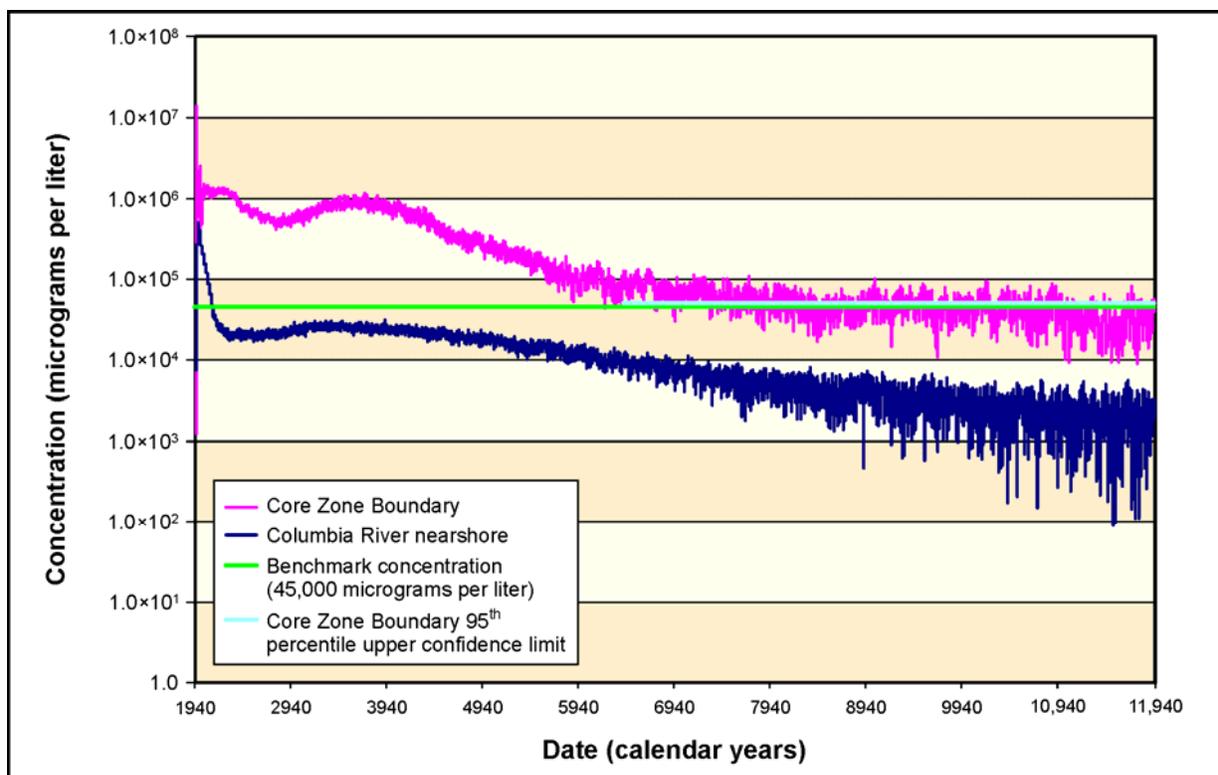


Figure 6–7. Alternative Combination 1 Cumulative Concentration Versus Time for Nitrate

Figures 6–8 and 6–9 show concentration versus time for uranium-238 and total uranium. Concentrations of uranium-238 and total uranium peak early in the period of analysis, and then maintain relatively constant for the remainder of the period of analysis. The travel times of these COPCs from the source locations to the Core Zone Boundary and Columbia River is slowed relative to the groundwater flow by a factor of about seven. After about 1,000 years, concentrations of both uranium-238 and total uranium exceed the benchmark concentration at the Core Zone Boundary by one to two orders of magnitude. Groundwater concentrations at the Columbia River nearshore remain within an order of magnitude of the benchmark during this time.

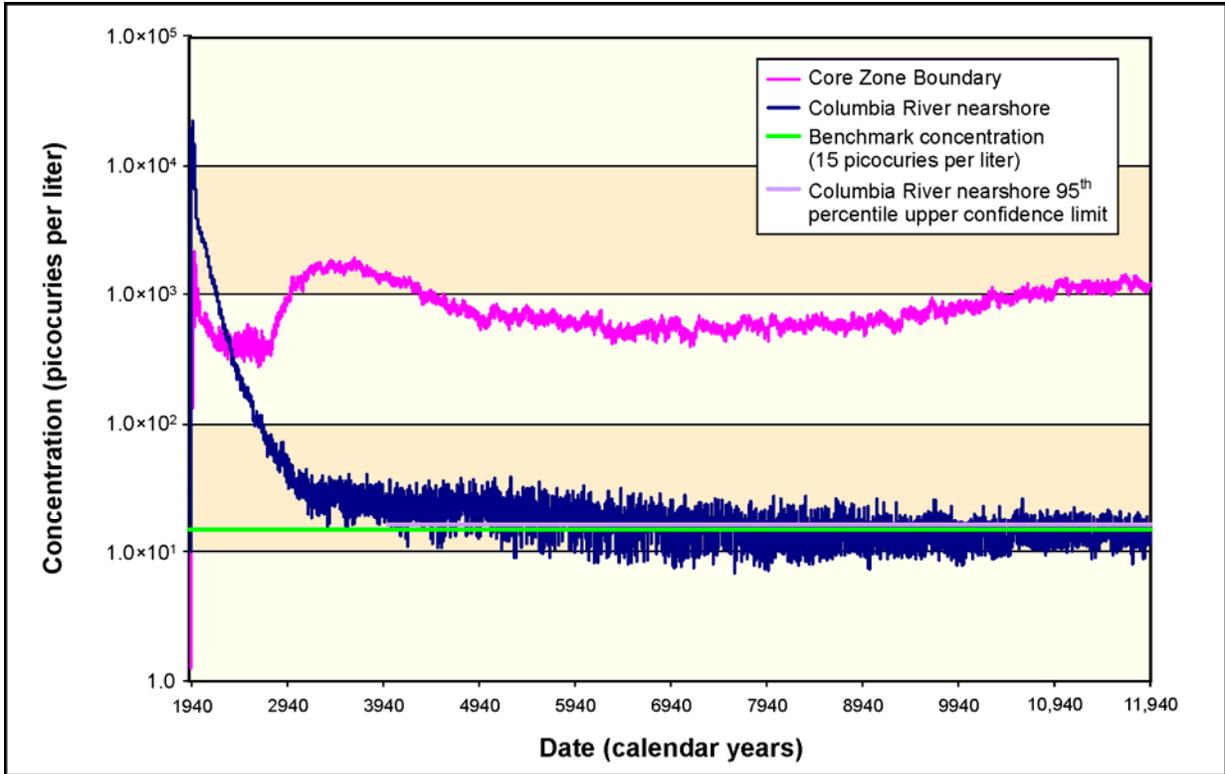


Figure 6–8. Alternative Combination 1 Cumulative Concentration Versus Time for Uranium-238

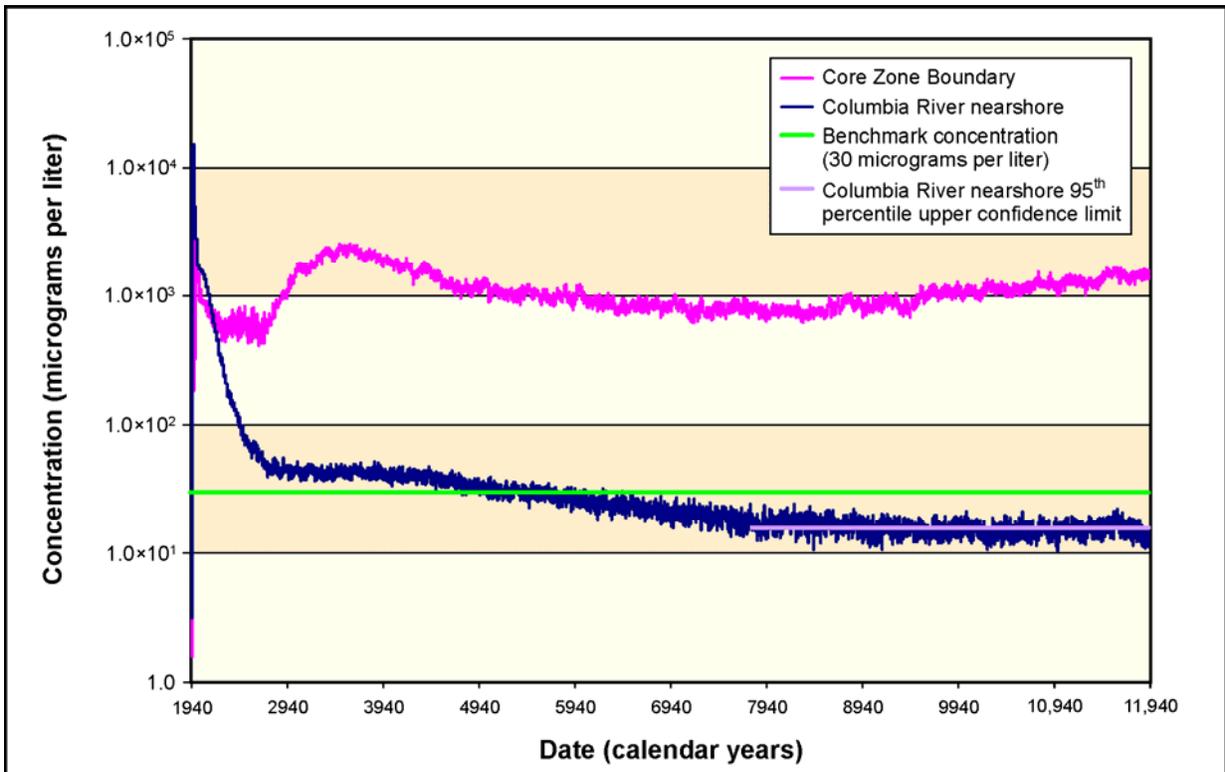


Figure 6–9. Alternative Combination 1 Cumulative Concentration Versus Time for Total Uranium

6.4.1.1.3 Analysis of Spatial Distribution of Concentration

This section presents the spatial distribution of contaminant concentrations in groundwater at selected times. Concentrations for each radionuclide and chemical are indicated by a color scale which is relative to the benchmark concentration. Concentrations greater than the benchmark concentration are indicated the fully saturated colors green, yellow, orange, and red in order of increasing concentration. Concentrations less than the benchmark concentration are indicated the faded colors green, blue, indigo, and violet in order of decreasing concentration. Note that the concentrations ranges are on a logarithmic scale to facilitate visual comparison of concentrations that vary over three orders of magnitude.

Figure 6–10 shows the spatial distribution of groundwater concentration for tritium during CY 2005. Releases from cribs and trenches (ditches), primarily associated with non-*TC & WM EIS* sources within the PUREX Plant and the REDOX Facility areas, result in groundwater concentration plumes (exceeding the benchmark concentration) that extend from the southern part of the 200-West Area across the Core Zone, and extending from the eastern part of the Core Zone southeast to the Columbia River. Peak concentrations in this plume are about ten to fifty times greater than the benchmark. Tritium concentrations are attenuated by radioactive decay to levels less than one twentieth of the benchmark concentration by CY 2135.

Figure 6–11 shows the spatial distribution of groundwater concentration for iodine-129 during CY 2005. Releases from cribs and trenches (ditches) and past leaks result in groundwater concentration plumes that exceeding the benchmark concentration associated with the T Barrier, the B Barrier, and the A Barrier. Peak concentrations in this plume are about ten to fifty times greater than the benchmark, and mostly contained within the Core Zone. Releases from the PUREX Plant area (non-*TC & WM EIS* sources) produce a plume extending south and east of the Core Zone with peak concentrations about one to five times the benchmark concentration. Around CY 3890 releases from other tank farm sources create a large iodine-129 plume extending from the Tank Farm Barriers to the Columbia River (see Figure 6–12). By CY 7140 most of the mass in the plume has reached the Columbia River, with only isolated pockets of high concentration areas where the groundwater flow velocities are extremely small (see Figure 6–13). Figure 6–14 shows the total area for which groundwater concentrations of iodine-129 exceed the benchmark concentration as a function of time. After an early peak related to releases from the PUREX Plant area, the area of exceedance peaks between CY 3240 and CY 4540 driven primarily by releases from other tank farm sources. Figures 6-15 through 6–18 show the spatial distribution at the same three times and the total area of exceedance versus time for technetium-99. The spatial distribution of technetium-99 does not include contributions from the PUREX Plant sources (compare to iodine-129 distributions) and is dominated by releases from other tank farm sources. Chromium (see Figures 6–19 through 6–21) and nitrate (see Figures 6–22 through 6–24) show similar spatial distributions to technetium-99.

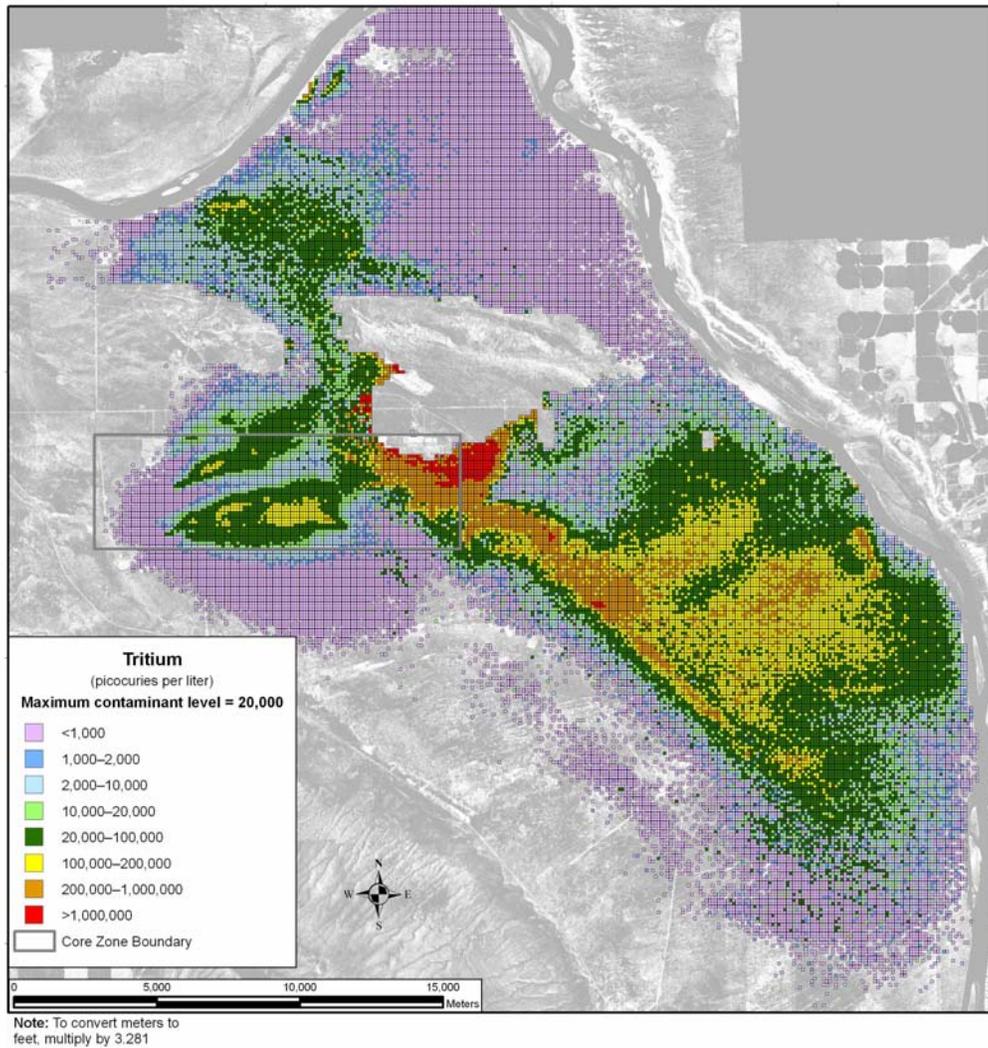


Figure 6–10. Alternative Combination 1 Spatial Distribution of Cumulative Groundwater Concentration for Tritium During Calendar Year 2005

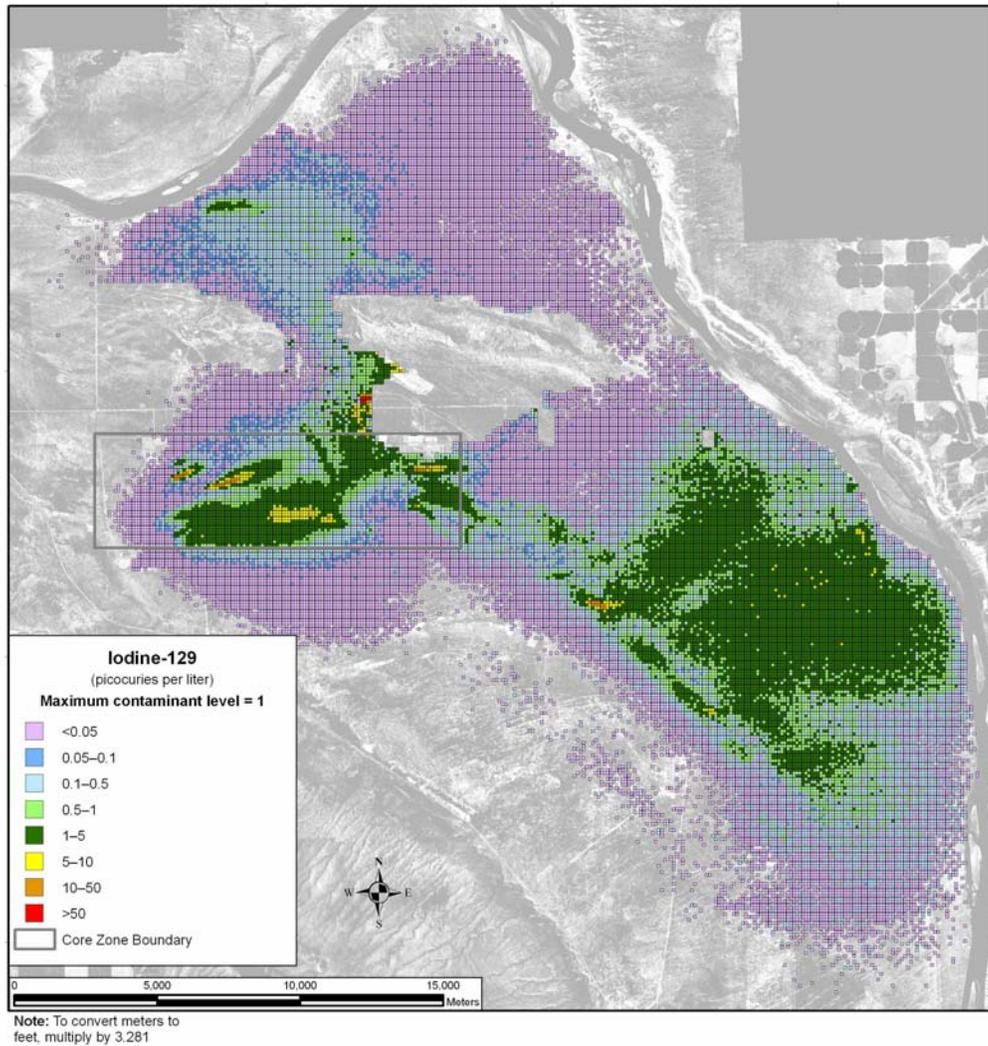


Figure 6–11. Alternative Combination 1 Spatial Distribution of Cumulative Groundwater Concentration for Iodine-129 During Calendar Year 2005

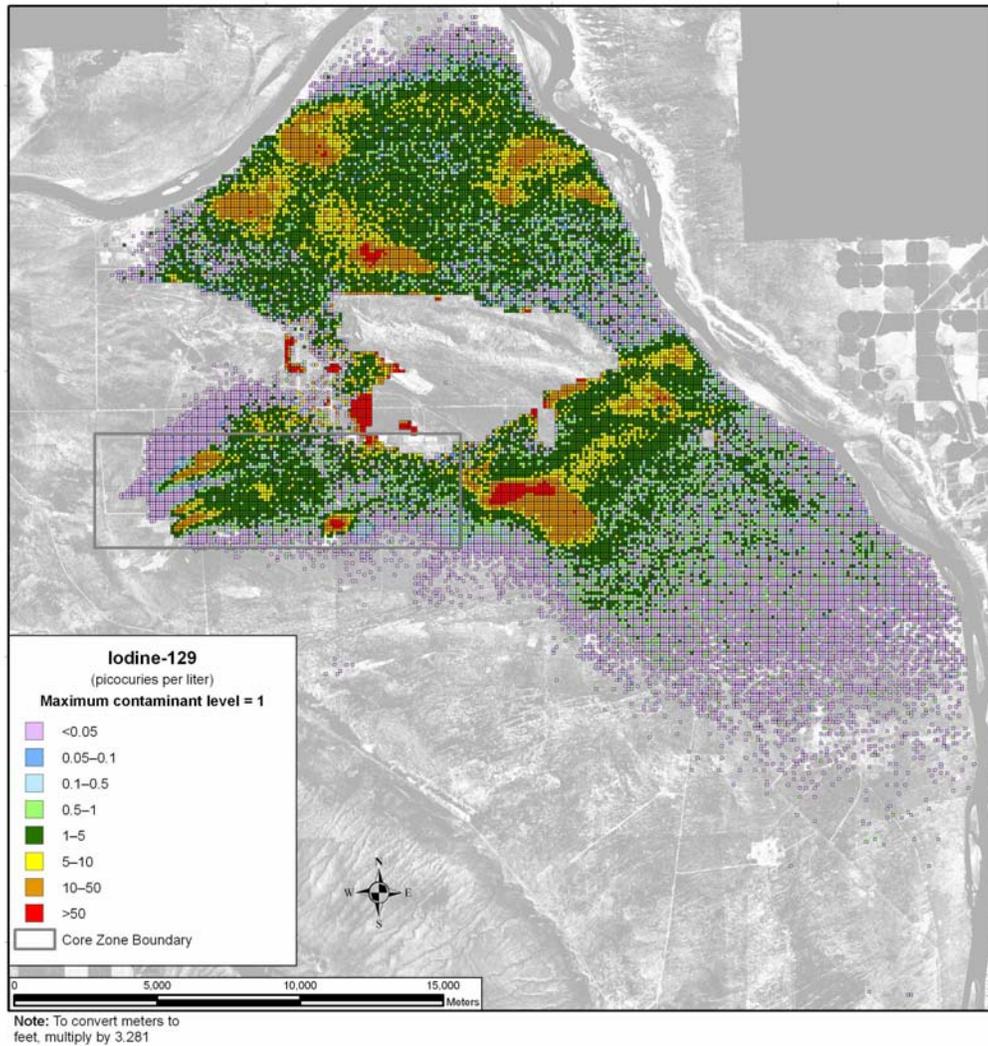


Figure 6–12. Alternative Combination 1 Spatial Distribution of Cumulative Groundwater Concentration for Iodine-129 During Calendar Year 3890

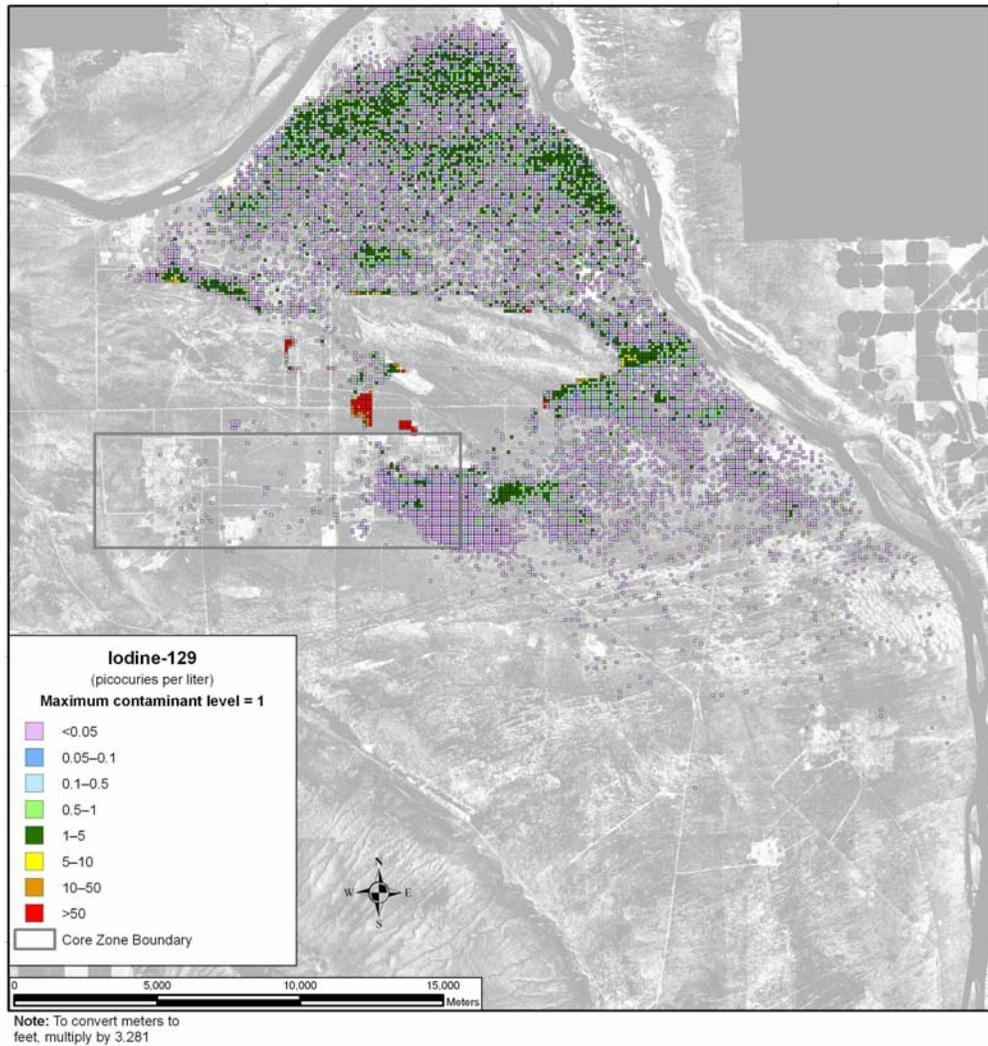


Figure 6–13. Alternative Combination 1 Spatial Distribution of Cumulative Groundwater Concentration for Iodine-129 During Calendar Year 7140

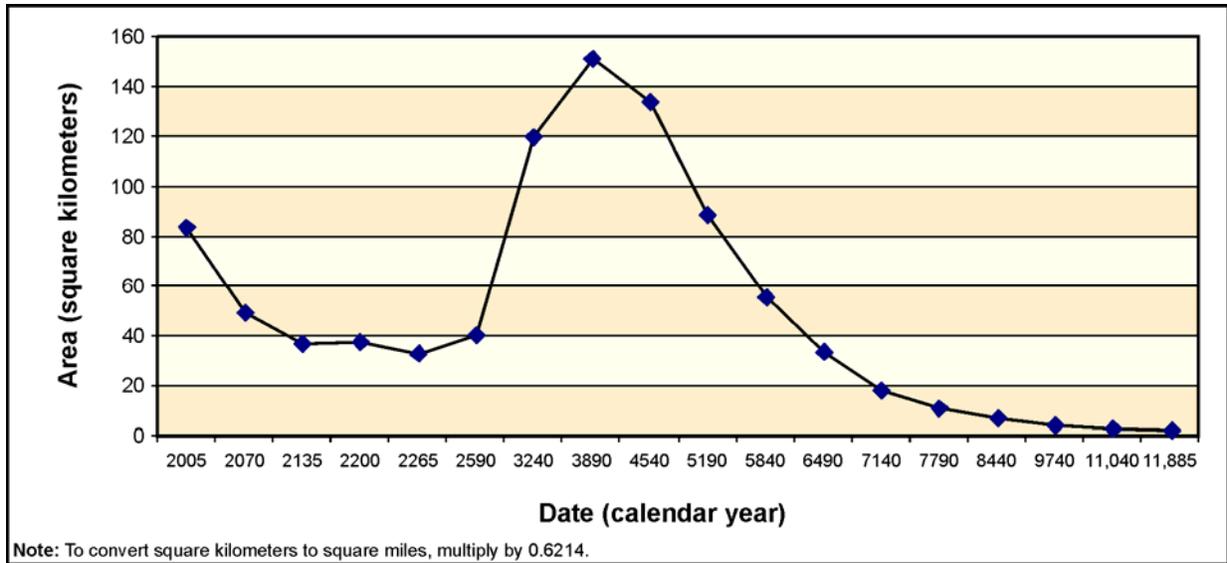


Figure 6-14. Alternative Combination 1 Total Area for Which Cumulative Groundwater Concentrations of Iodine-129 Exceed the Benchmark Concentration as a Function of Time

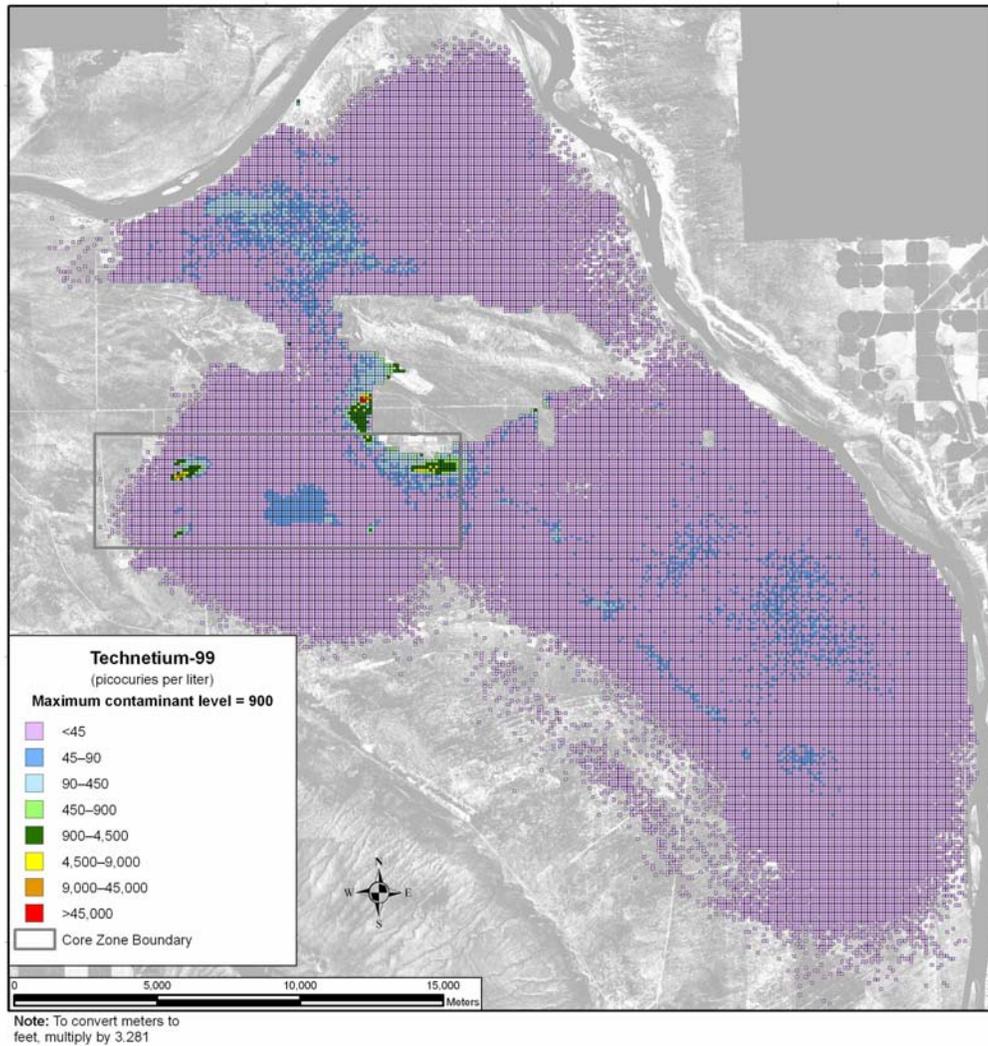


Figure 6–15. Alternative Combination 1 Spatial Distribution of Cumulative Groundwater Concentration for Technetium-99 During Calendar Year 2005

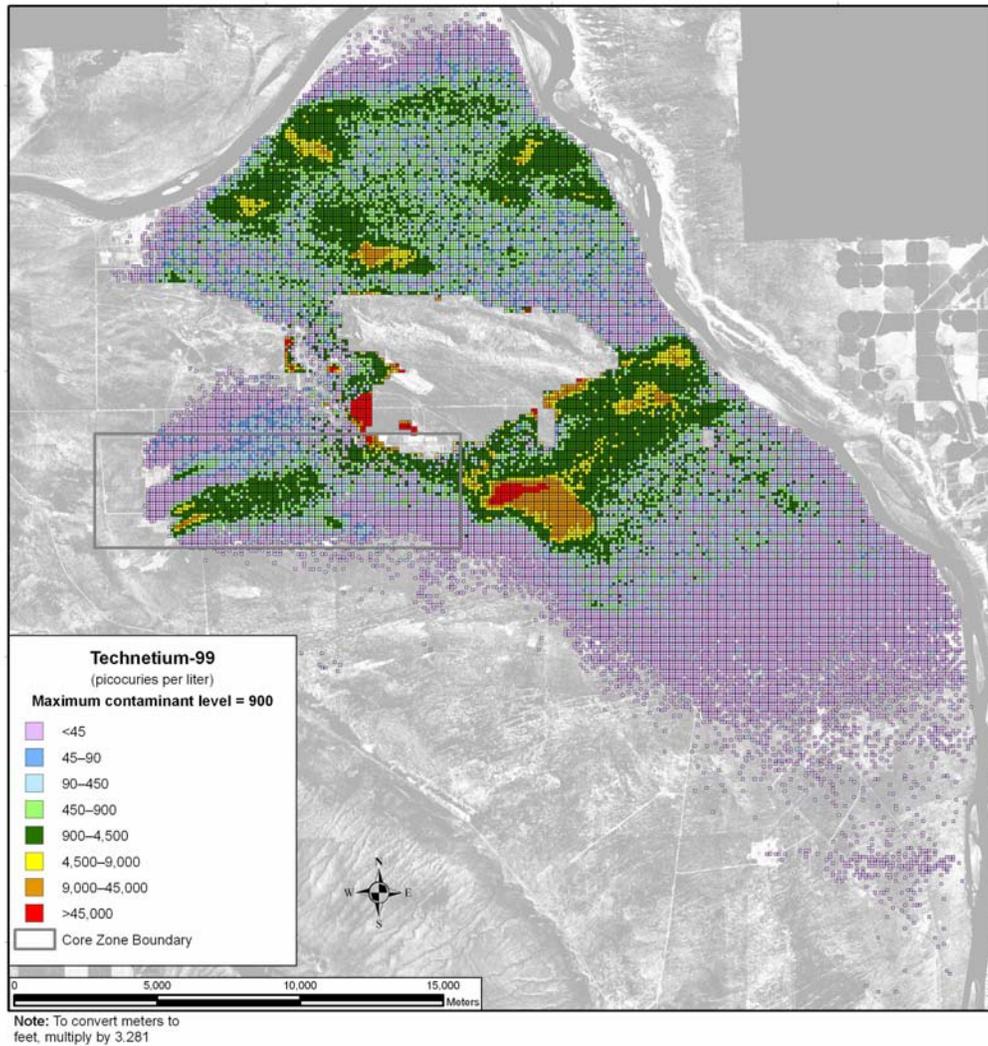


Figure 6-16. Alternative Combination 1 Spatial Distribution of Cumulative Groundwater Concentration for Technetium-99 During Calendar Year 3890

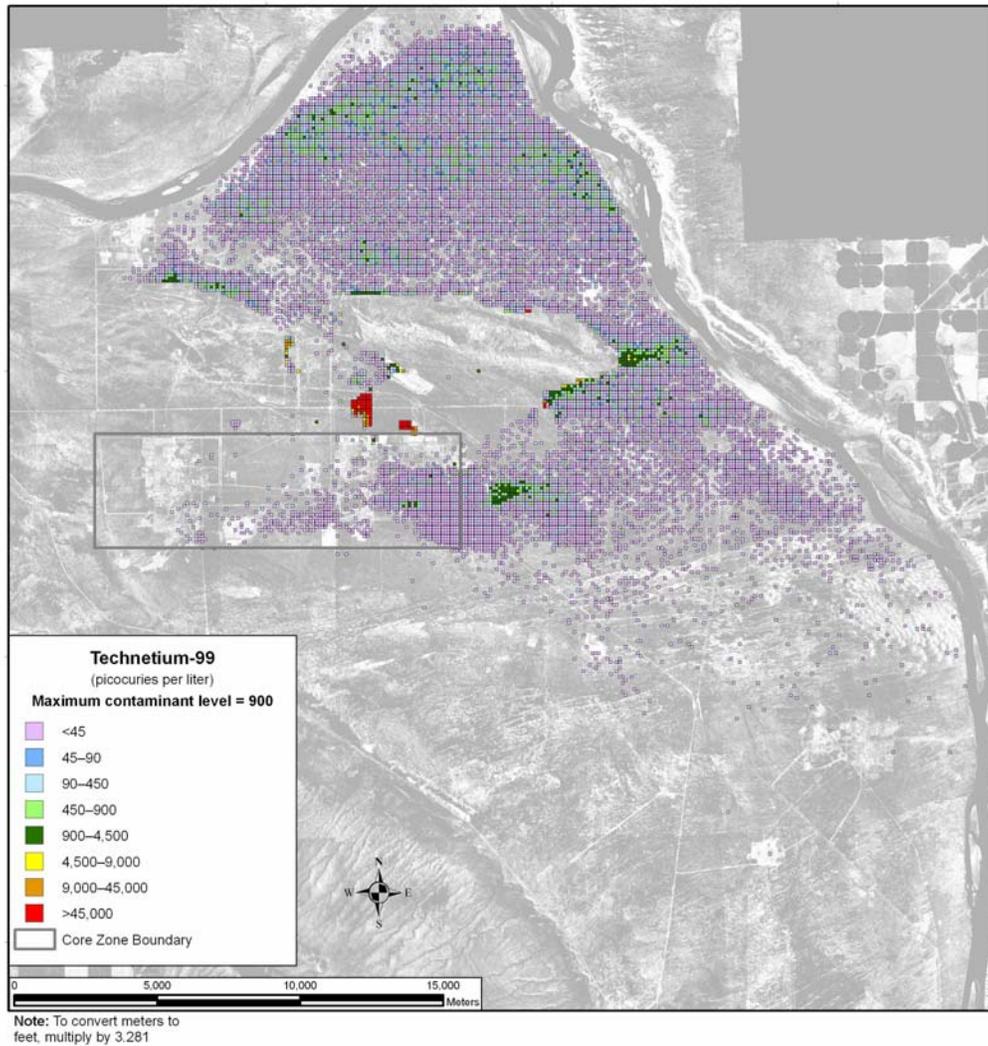


Figure 6–17. Alternative Combination 1 Spatial Distribution of Cumulative Groundwater Concentration for Technetium-99 During Calendar Year 7140

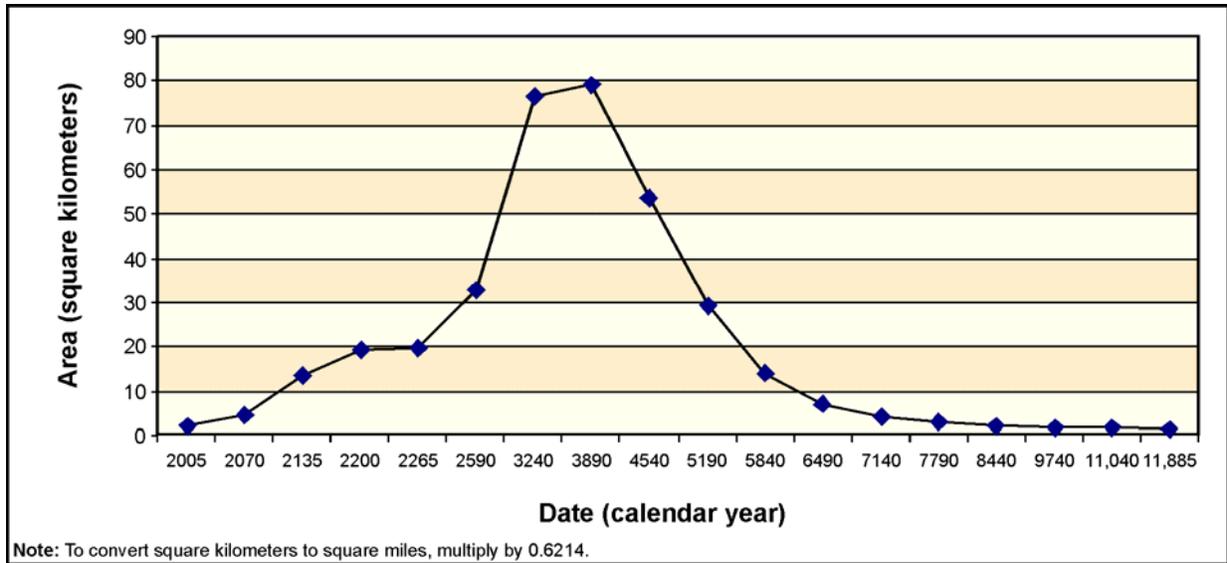


Figure 6-18. Alternative Combination 1 Total Area for Which Cumulative Groundwater Concentrations of Technetium-99 Exceed the Benchmark Concentration as a Function of Time

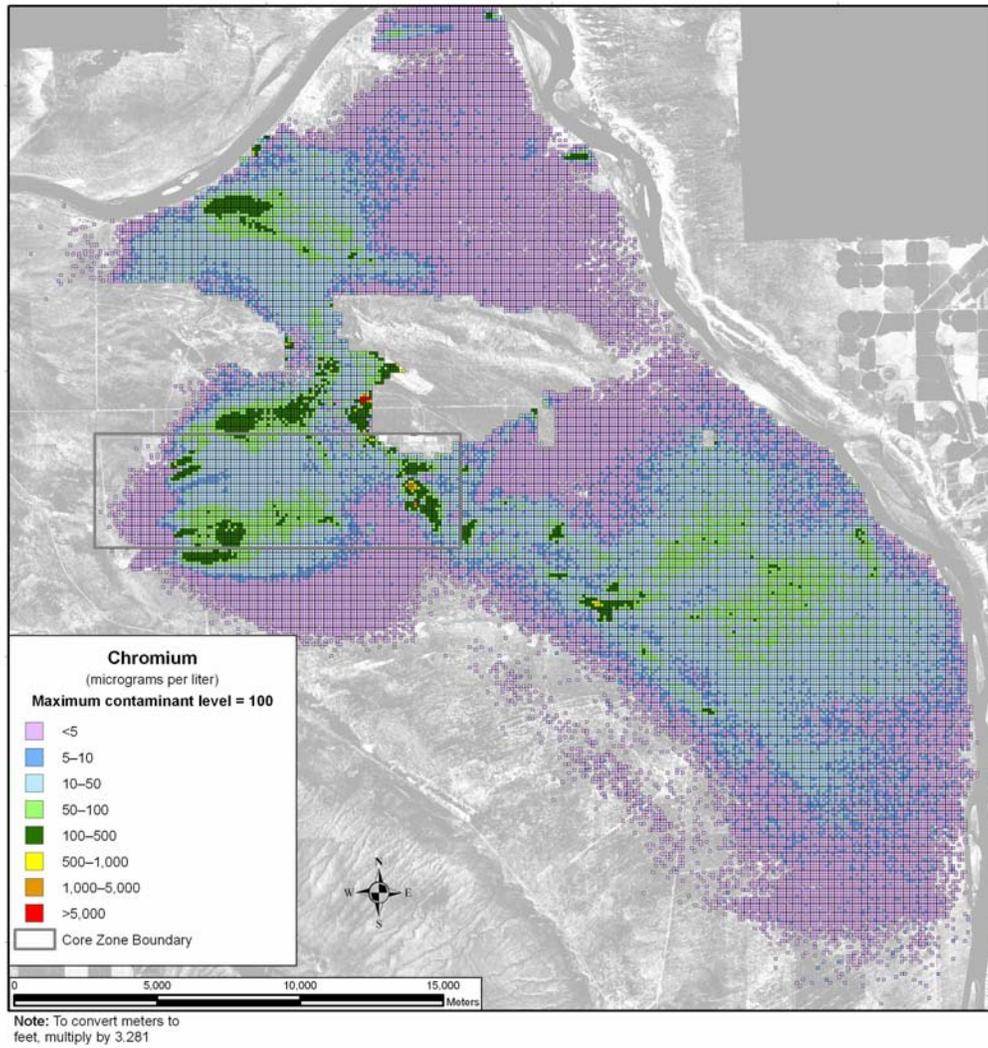


Figure 6-19. Alternative Combination 1 Spatial Distribution of Cumulative Groundwater Concentration for Chromium During Calendar Year 2005

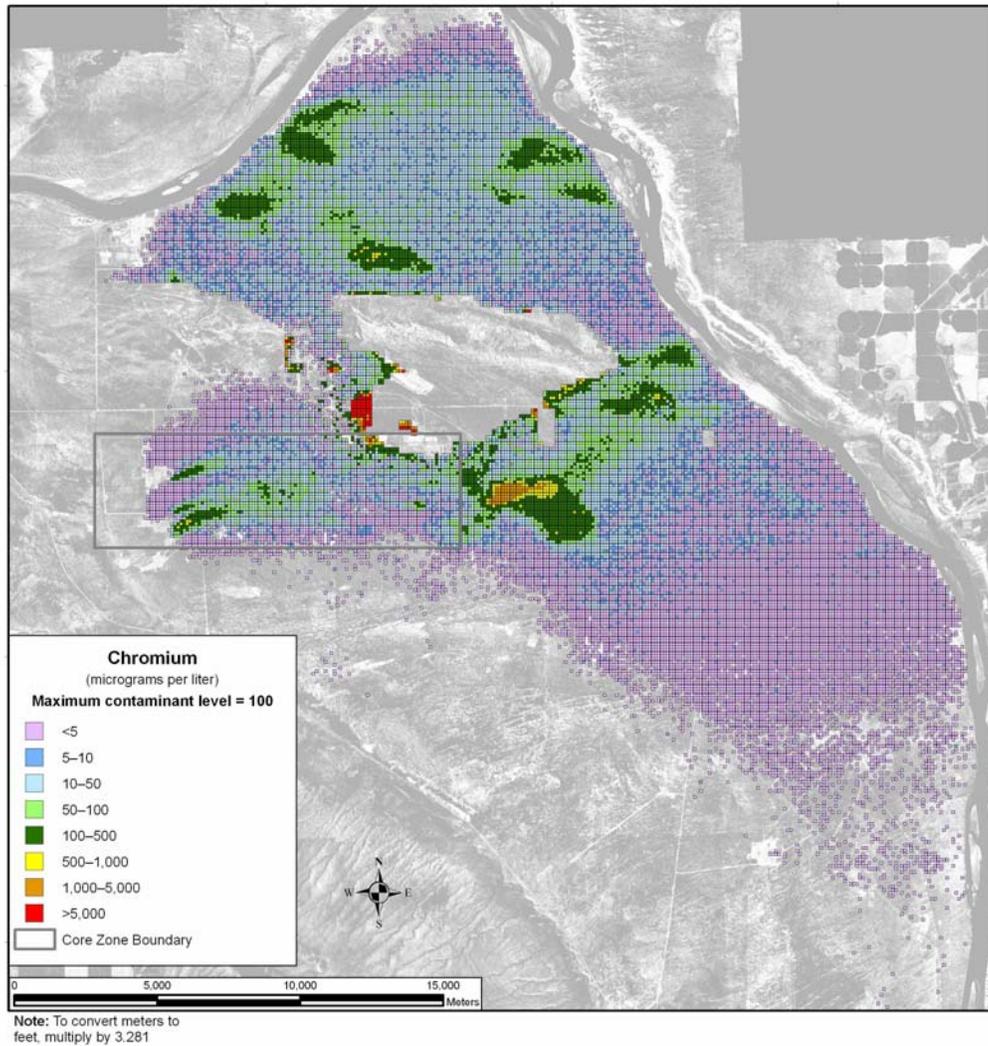


Figure 6-20. Alternative Combination 1 Spatial Distribution of Cumulative Groundwater Concentration for Chromium During Calendar Year 3890

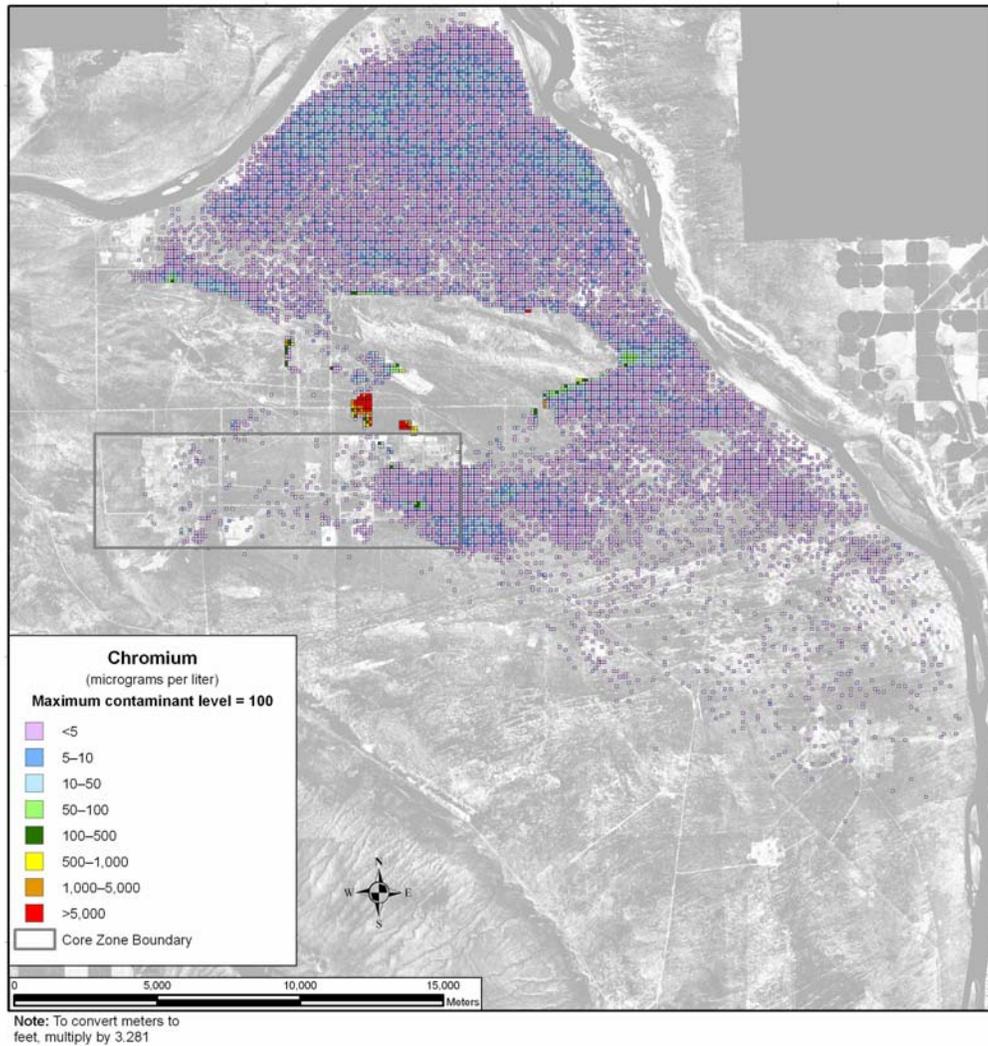


Figure 6-21. Alternative Combination 1 Spatial Distribution of Cumulative Groundwater Concentration for Chromium During Calendar Year 7140

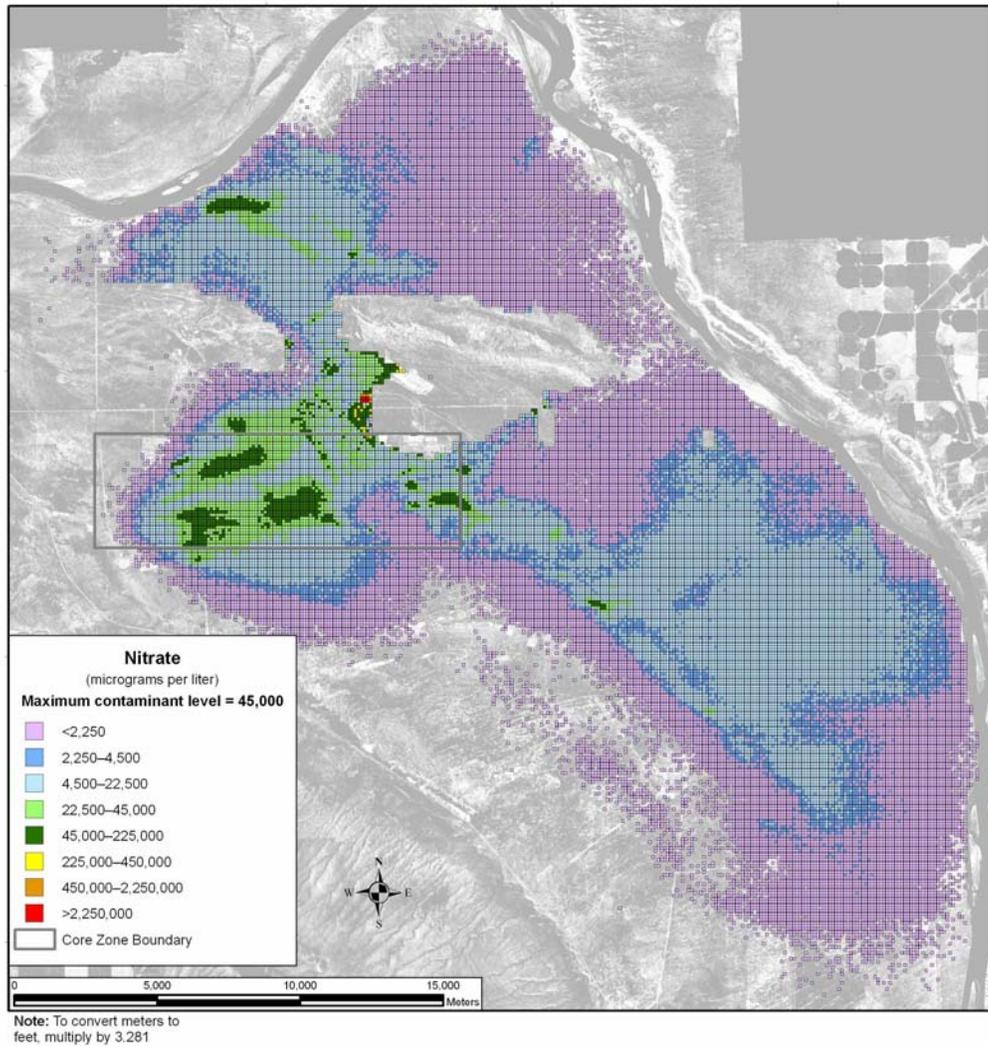


Figure 6-22. Alternative Combination 1 Spatial Distribution of Cumulative Groundwater Concentration for Nitrate During Calendar Year 2005

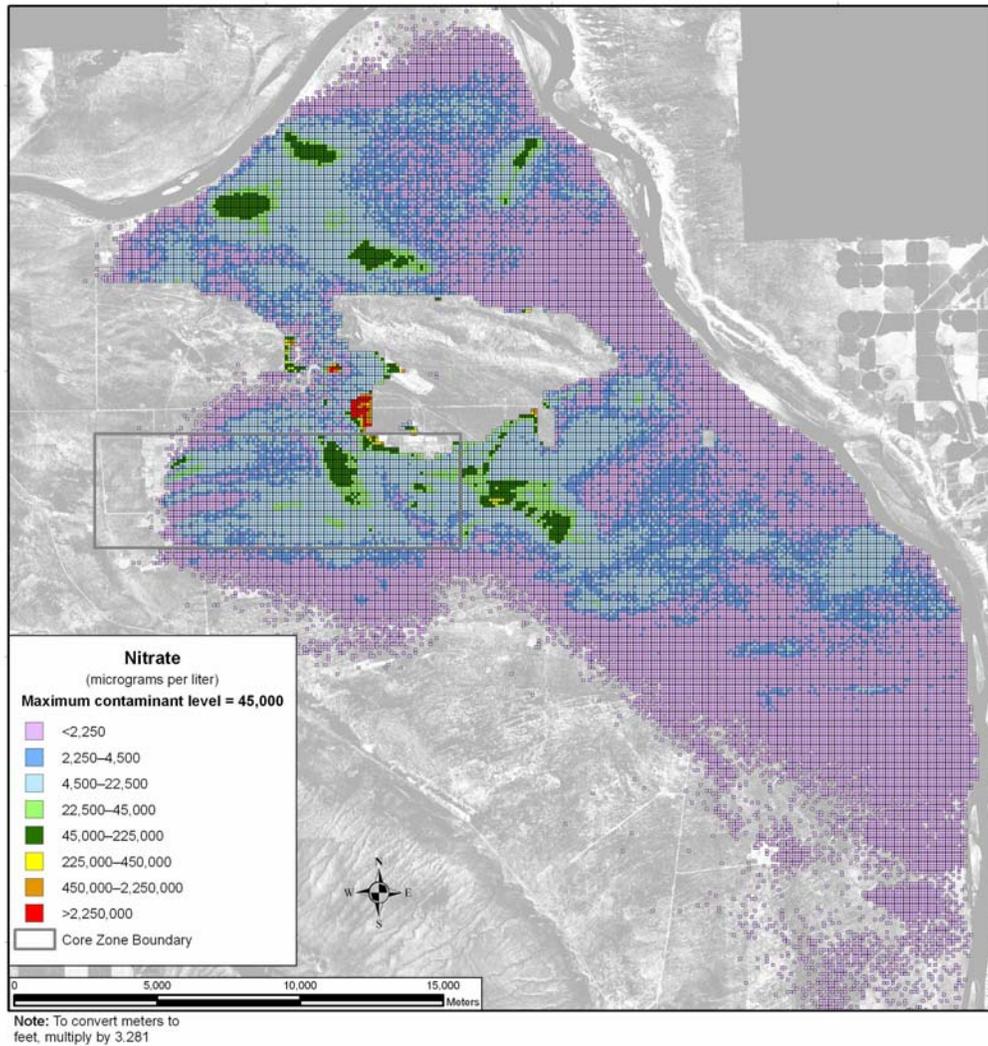


Figure 6–23. Alternative Combination 1 Spatial Distribution of Cumulative Groundwater Concentration for Nitrate During Calendar Year 2135

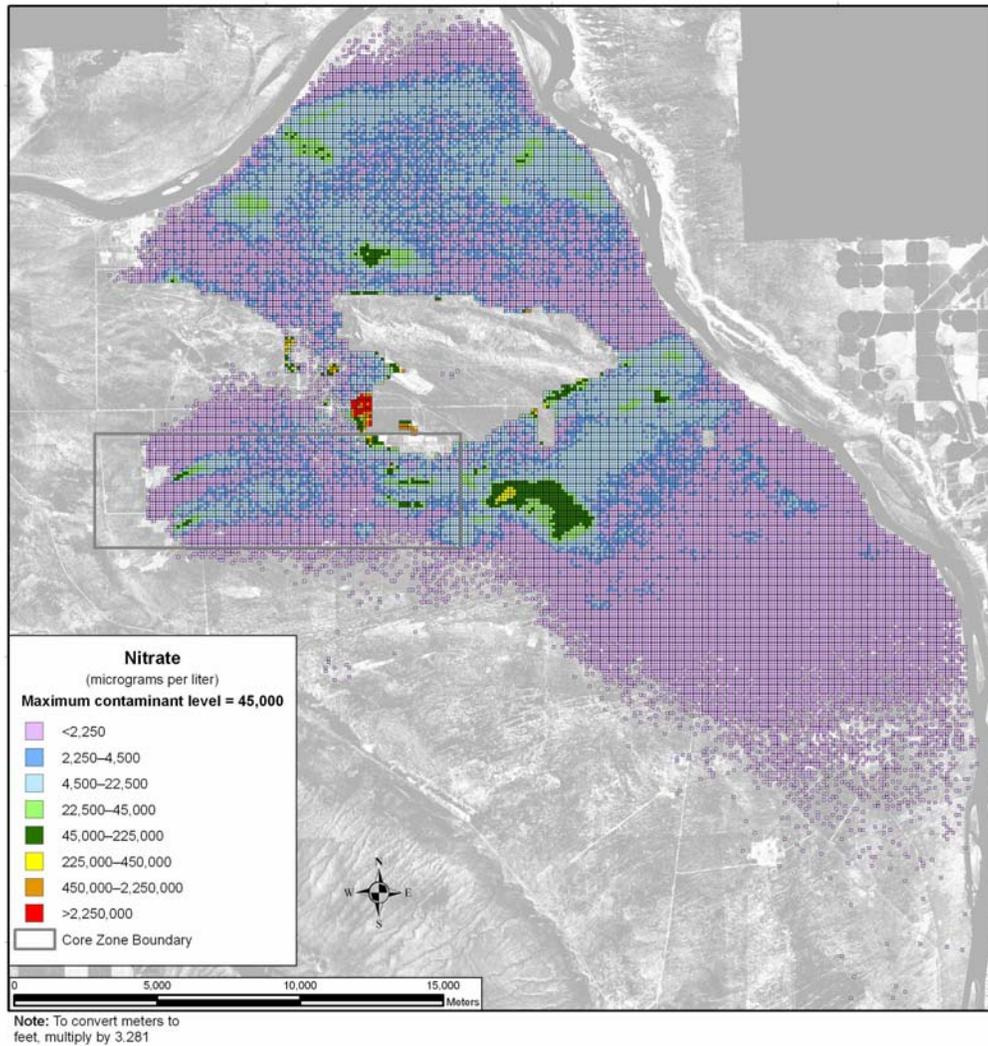


Figure 6–24. Alternative Combination 1 Spatial Distribution of Cumulative Groundwater Concentration for Nitrate During Calendar Year 3890

The carbon tetrachloride distribution is dominated by non-TC & WM EIS sources associated with the Z Area within the 200-West Area. The spatial distribution during CY 2005, shown in Figure 6–25, is a large plume covering most of the 200-West Area, with peak concentrations over an order of magnitude greater than the benchmark concentration. Note that this model result does not include the effects of carbon tetrachloride removal and containment in the 200-West Area. Figures 6–26 and 6–27 show the dissipation of the plume over time at CY 2135 and CY 3890, respectively.

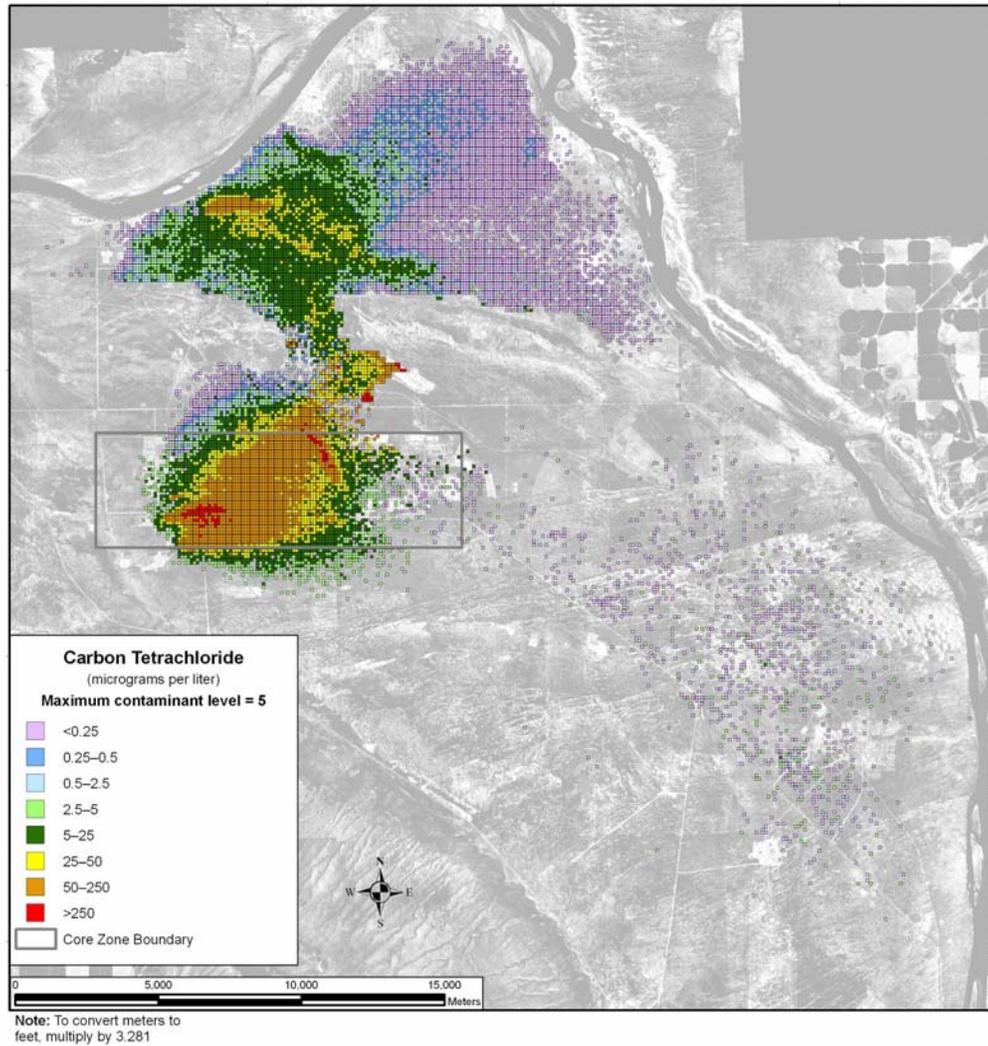


Figure 6–25. Alternative Combination 1 Spatial Distribution of Cumulative Groundwater Concentration for Carbon Tetrachloride During Calendar Year 2005

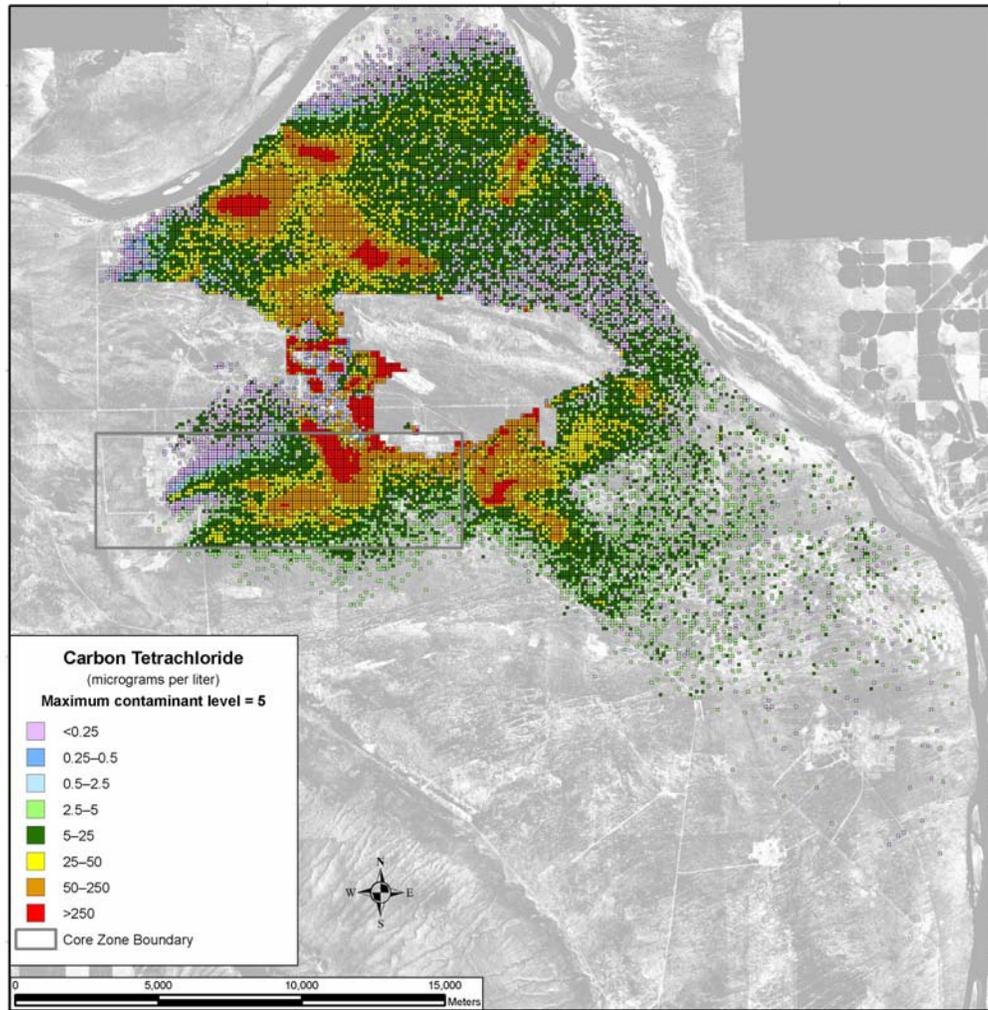


Figure 6–26. Alternative Combination 1 Spatial Distribution of Cumulative Groundwater Concentration for Carbon Tetrachloride During Calendar Year 2135

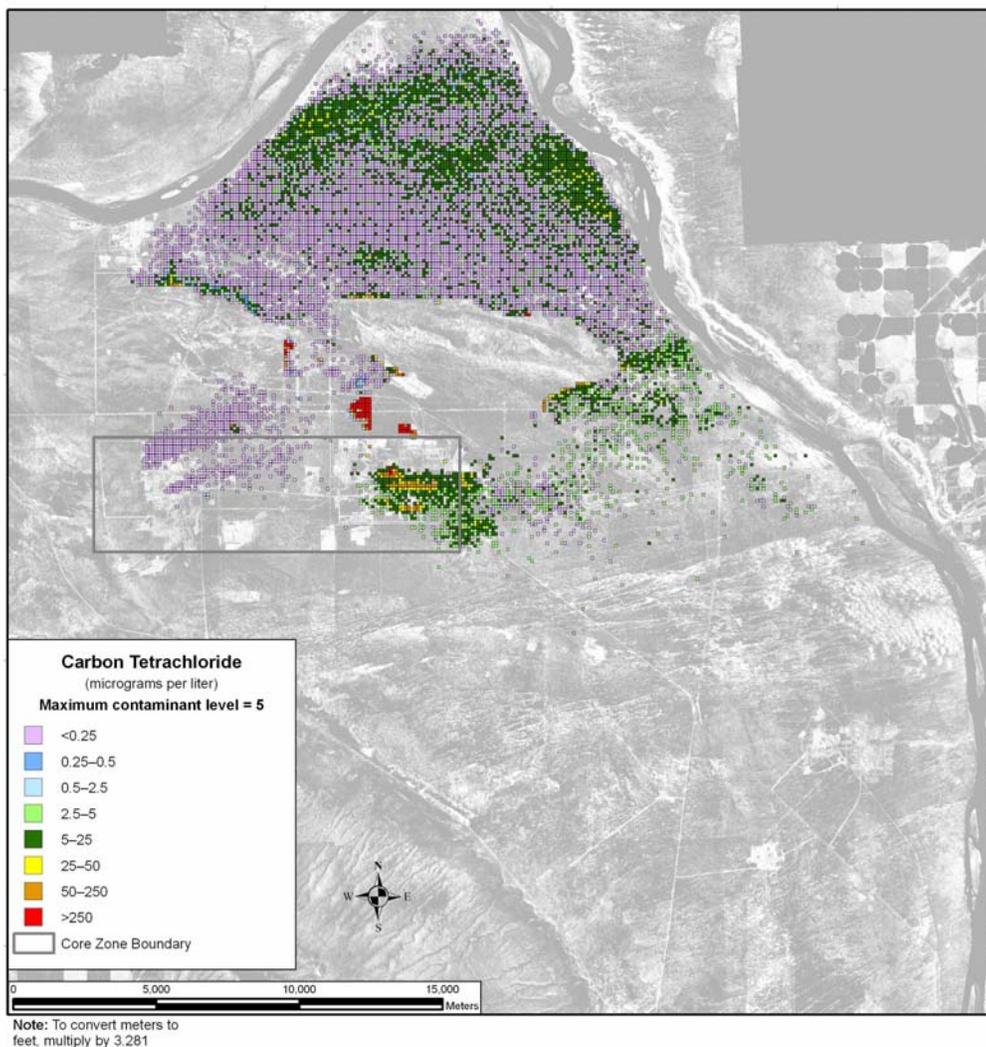


Figure 6-27. Alternative Combination 1 Spatial Distribution of Cumulative Groundwater Concentration for Carbon Tetrachloride During Calendar Year 3890

Uranium-238 and total uranium show a different spatial distribution over time. These COPCs are not as mobile as those discussed above, moving about seven times slower than the porewater velocity. As a result, travel times through the vadose zone are longer, release to the aquifer is delayed, and travel times through the aquifer to the Columbia River are longer. Figure 6–28 shows the distribution of uranium-238 during CY 2135. There are two plumes associated with releases from the ponds (non-TC & WM EIS sources) in the 200-East and 200-West Areas with peak concentrations that exceed the benchmark by an order of magnitude. By CY 3890 (see Figure 6–29) these plumes have dissipated, but releases from other tank farm sources (primarily within the A Barrier) have produced a second plume east of the Core Zone, with peak concentrations about an order of magnitude greater than the benchmark. At CY 11,885 (see Figure 6–30) the plumes from other tank farm sources have extended this plume and produced additional plumes in the 200-West Area. Figure 6–31 shows the total area for which groundwater concentrations of uranium-238 exceed the benchmark concentration as a function of time. The area of exceedance is largest early in the analysis (non-TC & WM EIS sources, primarily ponds) with an upward trend toward the end of the period of analysis (other tank farm sources). Figures 6–32 through 6–34 show the corresponding spatial distributions for total uranium.

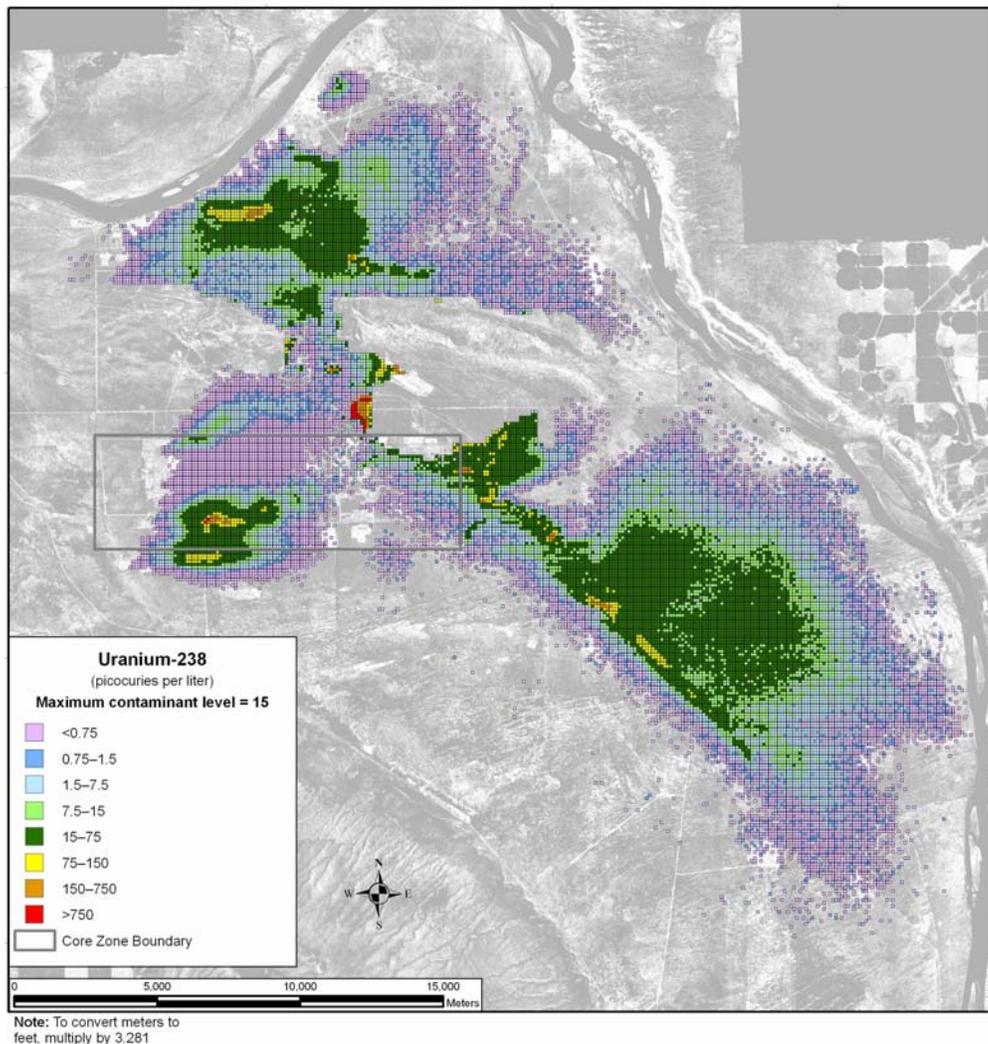


Figure 6–28. Alternative Combination/Spatial Distribution of Cumulative Groundwater Concentration for Uranium-238 During Calendar Year 2135

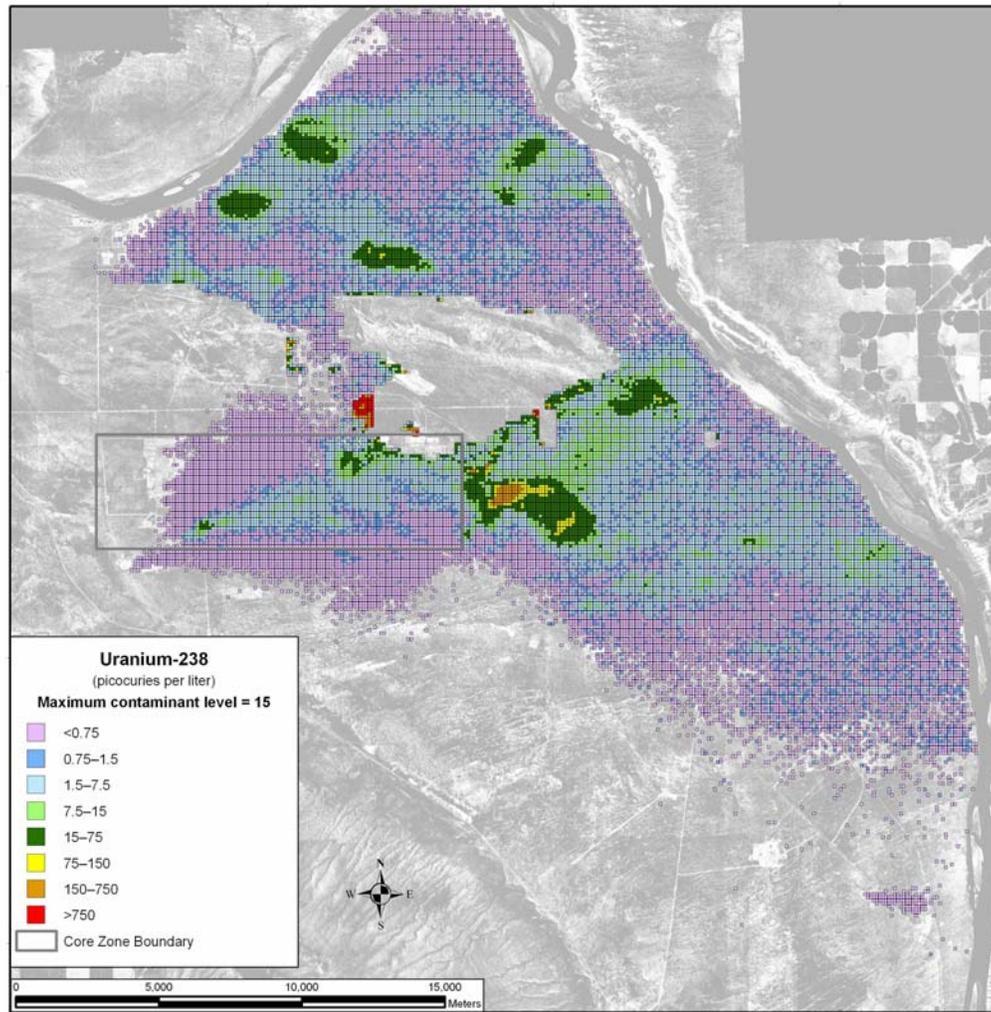


Figure 6-29. Alternative Combination 1 Spatial Distribution of Cumulative Groundwater Concentration for Uranium-238 During Calendar Year 3890

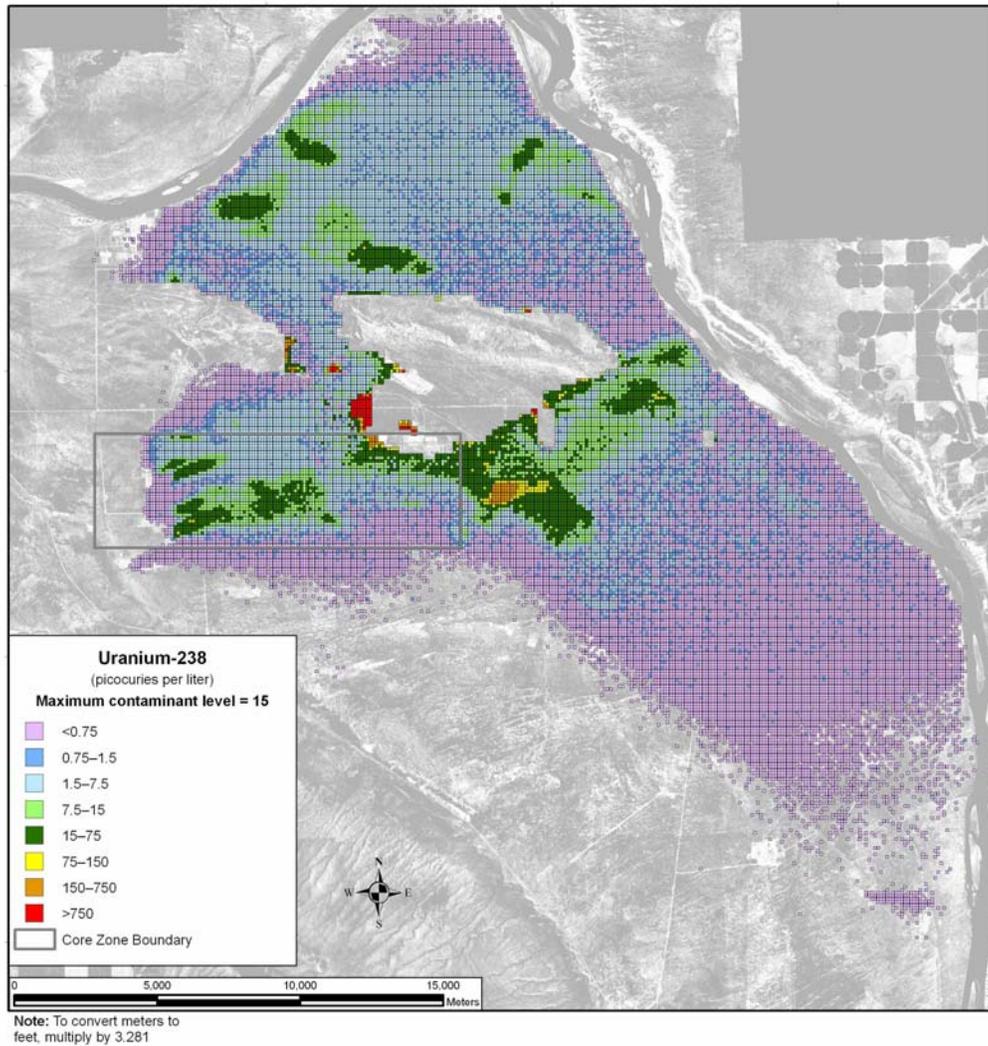


Figure 6-30. Alternative Combination 1 Spatial Distribution of Cumulative Groundwater Concentration for Uranium-238 During Calendar Year 11,885

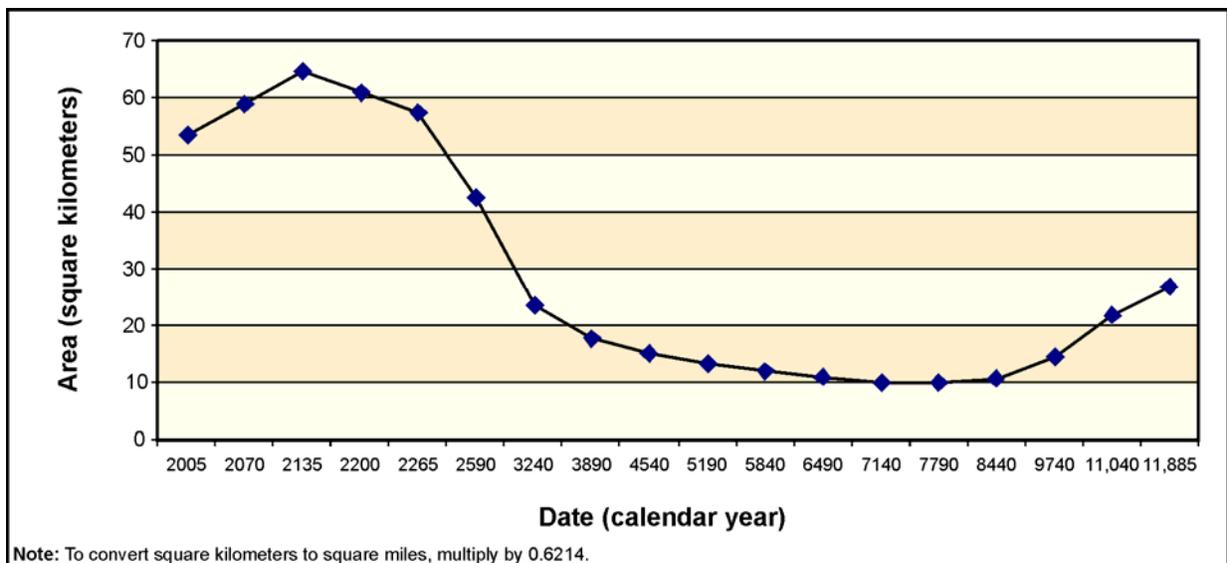


Figure 6–31. Alternative Combination 1 Total Area for Which Cumulative Groundwater Concentrations of Uranium-238 Exceed the Benchmark Concentration as a Function of Time

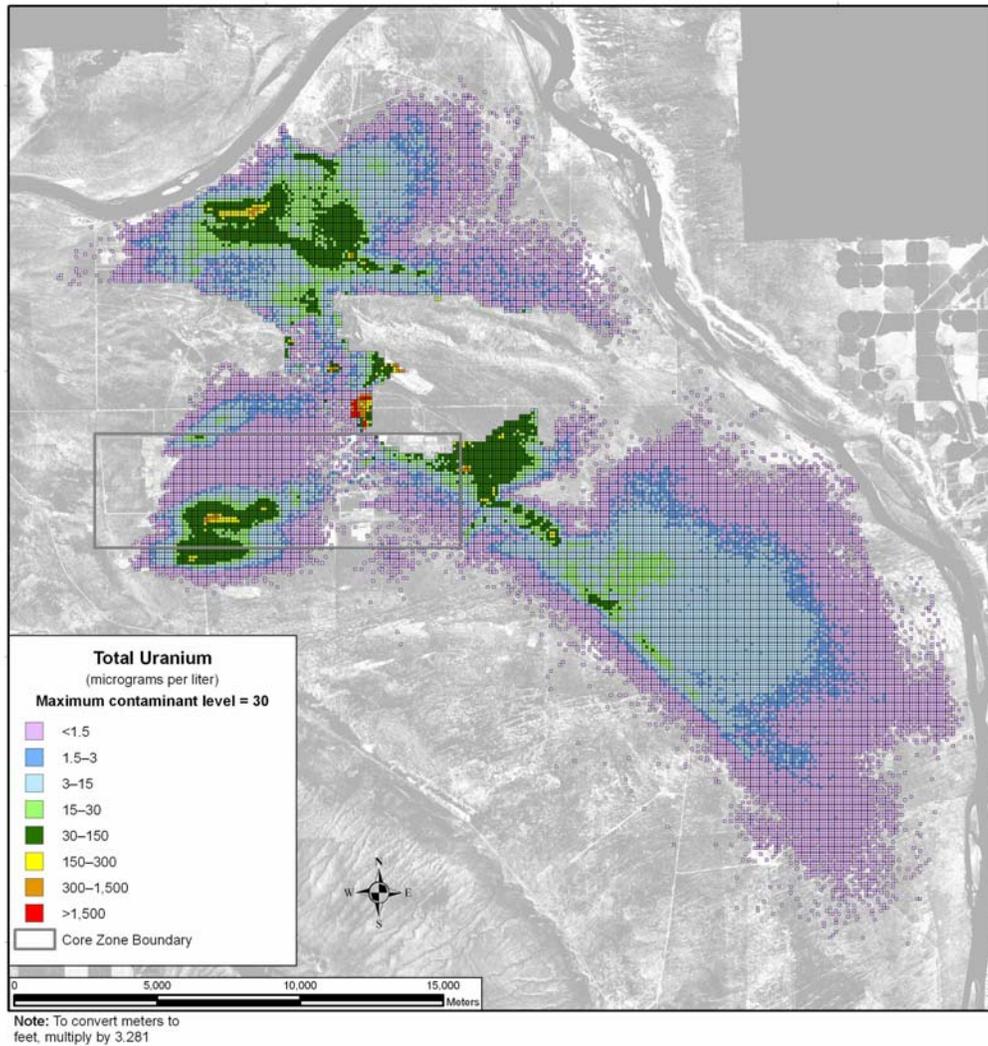


Figure 6-32. Alternative Combination 1 Spatial Distribution of Cumulative Groundwater Concentration for Total Uranium During Calendar Year 2135

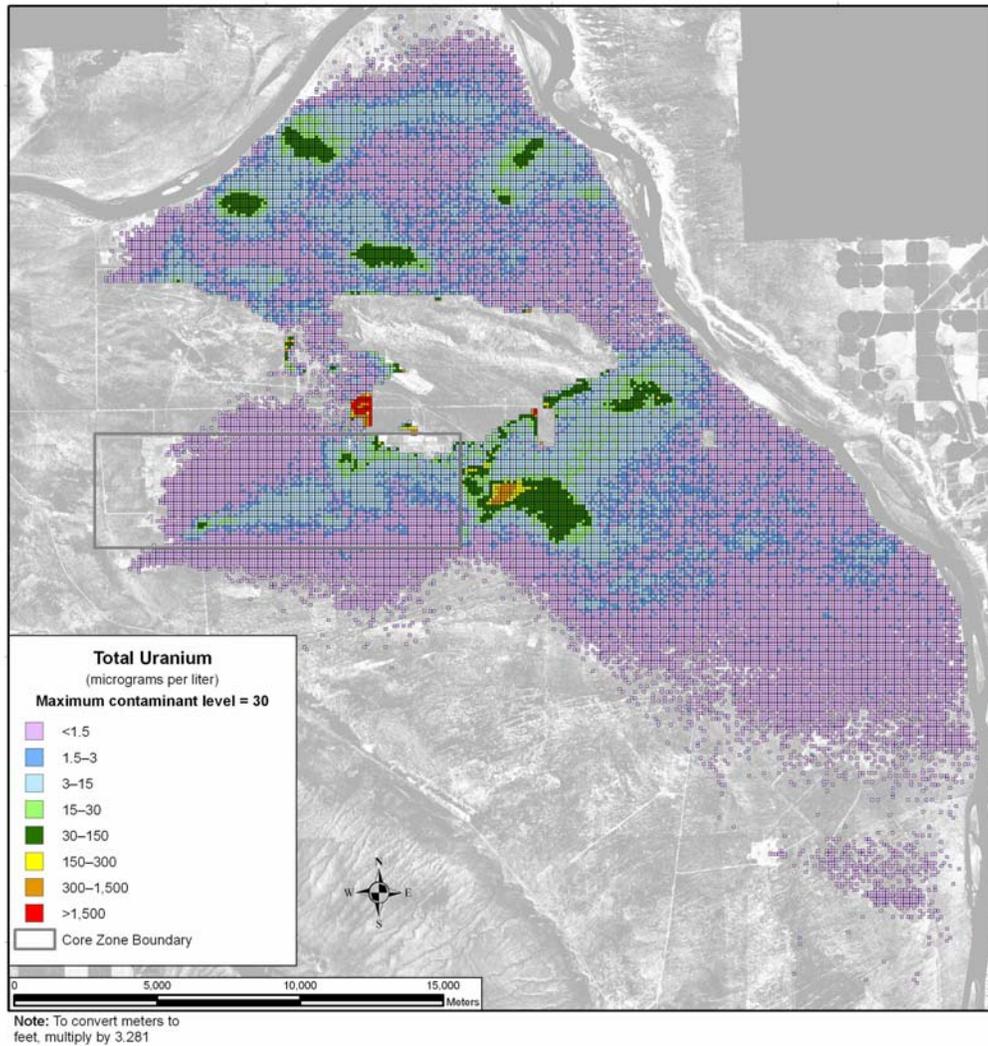


Figure 6-33. Alternative Combination 1 Spatial Distribution of Cumulative Groundwater Concentration for Total Uranium During Calendar Year 3890

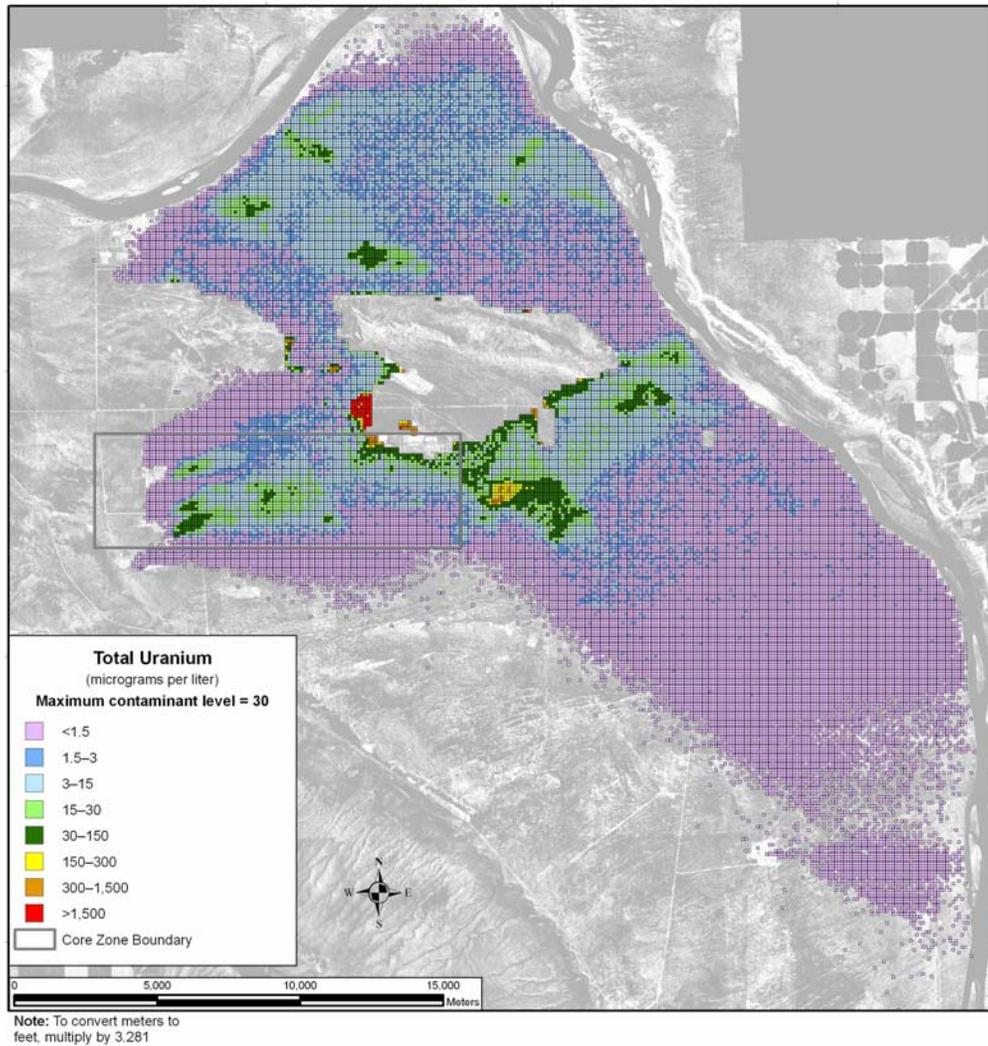


Figure 6-34. Alternative Combination 1 Spatial Distribution of Cumulative Groundwater Concentration for Total Uranium During Calendar Year 11,885

6.4.1.1.4 Summary of Impacts

The long-term cumulative impacts including Alternative Combination 1 are dominated by sources in Tank Farm Alternative 1 (technetium-99), non-*TC & WM EIS* sources (tritium and carbon tetrachloride), or a combination of both (iodine-129, uranium-238, chromium, nitrate, and total uranium). Contributions from Waste Management Alternative 1 sources and FFTF Decommissioning Alternative 1 sources account for well under 1 percent of the total amount released to the environment.

For iodine-129, technetium-99, carbon tetrachloride, chromium, and nitrate, concentrations at the Core Zone Boundary exceed benchmark standards by two to three orders of magnitude during most of the period of analysis. Concentrations at the Columbia River are about two orders of magnitude smaller. The intensities and areas of these groundwater plumes peak between CY 3200 and CY 4000.

For tritium, concentrations at the Core Zone Boundary exceed the benchmark by about three orders of magnitude during the first 100 years of the period of analysis. Concentrations at the Columbia River exceed the benchmark by about two orders of magnitude during this time. Attenuation by radioactive decay is a predominant mechanism that limits the intensity and duration of groundwater impacts by tritium. After CY 2100 tritium impacts are essentially negligible.

For uranium-238 and total uranium, discharges from ponds (non-*TC & WM EIS* sources) are the dominant contributors during the early period of the analysis. Other tank farm sources are a secondary contributor, for which limited mobility is an important factor governing the timeframes and scale of groundwater impacts.

6.4.1.2 Alternative Combination 2

This section presents the results of the cumulative long-term groundwater impacts analysis including Alternative Combination 2. This section focuses on the cumulative long-term groundwater impacts of these Alternative Combination 2 and non-*TC & WM EIS* sources, which are discussed in Chapter 5, Section 5.4. All of the non-*TC & WM EIS* sources discussed in Appendix S are included.

This discussion of long-term impacts is focused on the following COPC drivers:

- radiological risk drivers: tritium, iodine-129, technetium-99, and uranium-238
- chemical hazard drivers: carbon tetrachloride, chromium, nitrate, and total uranium

The COPC drivers were obtained from the combination of the COPC drivers for the three individual alternatives that compose Alternative Combination 2 and the COPC drivers for the non-*TC & WM EIS* sources. They fall into three categories. Iodine-129, technetium-99, carbon tetrachloride, chromium, and nitrate are all mobile (i.e., move with groundwater) and long-lived (relative to the 10,000-year period of analysis) or stable. Tritium is also mobile, but short lived. The half-life of tritium is about 12.3 years, and tritium concentrations are strongly attenuated by radioactive decay during travel through the vadose zone and groundwater systems. Finally, uranium-238 and total uranium are long-lived or stable, but are not as mobile as the other COPC drivers. These constituents move about seven times more slowly than groundwater. The other COPCs that were analyzed do not significantly contribute to risk or hazard during the period of analysis because of limited inventory, high retardation factors (i.e., retention in the vadose zone), short half-lives (i.e., rapid radioactive decay), or a combination of these factors. The level of protection provided for the drinking water pathway was evaluated by comparison against the maximum contaminant levels provided in 40 CFR 141 and other benchmarks presented in Appendix O.

6.4.1.2.1 Analysis of Release and Mass Balance

This section presents the total amount of the COPC drivers released to the vadose zone, to groundwater, and to the Columbia River. Releases of radionuclides are totaled in curies, and releases of chemicals are totaled in kilograms. Both are totaled over the 10,000-year period of analysis.

Table 6–15 lists the release to the vadose zone for the COPC drivers. For Alternative Combination 2, the release to the vadose zone is controlled by a combination of inventory and waste form. For tank closure and FFTF decommissioning sources, the entire inventory was released to the vadose zone during the period of analysis. For some waste management sources (e.g., ILAW glass), some of the inventory was not released to the vadose zone during the 10,000-year period of analysis because of retention in the waste form. The release to the vadose zone for Alternative Combination 2 and non-TC & WMEIS sources is dominated by non-TC & WMEIS sources for tritium, uranium-238, chromium, and total uranium; by non-TC & WMEIS and waste management sources for iodine-129; by non-TC & WMEIS sources and tank closure sources for nitrate; and a combination of all three types of sources for technetium-99.

Table 6–15. Alternative Combination 2 Release to Vadose Zone for COPC Drivers

	Radiological COPCs (curies)				Chemical COPCs (kilograms)		
	Hydrogen-3 (Tritium)	Iodine-129	Technetium-99	Uranium-238	Chromium ^a	Nitrate	Total Uranium
Other activities	3.43×10 ⁶	2.49×10 ¹	7.33×10 ²	3.13×10 ³	3.35×10 ⁵	7.38×10 ⁷	2.53×10 ⁵
Tank Closure Alternative 2B Base	4.60×10 ⁴	1.51	8.67×10 ²	4.54×10 ¹	1.00×10 ⁵	2.70×10 ⁷	4.13×10 ⁴
FFTF Decommissioning Alternative 2	1.73×10 ⁻⁵	0	2.72×10 ¹	0	0	0	0
Waste Management Alternative 2 Disposal Group 1-A	6.27×10 ⁴	1.80×10 ¹	2.39×10 ³	3.17×10 ²	2.97×10 ³	9.05×10 ⁶	2.65×10 ³
Total	3.54×10 ⁶	4.43×10 ¹	4.02×10 ³	3.49×10 ³	4.38×10 ⁵	1.10×10 ⁸	2.97×10 ⁵

^a It was assumed, for the purposes of analysis, that all chromium was hexavalent.

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

Key: COPC=constituent of potential concern; FFTF=Fast Flux Test Facility.

Table 6–16 lists the release to groundwater for the COPC drivers. In addition to the inventory consideration discussed in the previous paragraph, release to groundwater is controlled by the transport properties of the COPC drivers and by the rate of moisture movement through the vadose zone. For iodine-129, technetium-99, chromium, and nitrate, the amount released to groundwater is essentially equal to the amount released to the vadose zone. For tritium, the amount released to groundwater is attenuated by radioactive decay during transit through the vadose zone. About 60 percent of the tritium released to the vadose zone reaches the unconfined aquifer. Because of retardation, less than 40 percent of the uranium-238 and total uranium released to the vadose zone reaches the unconfined aquifer during the period of analysis.

Table 6–17 lists the release to the Columbia River for the COPC drivers. Release to the Columbia River is controlled by the transport properties of the COPC drivers in the unconfined aquifer. For iodine-129, technetium-99, chromium, and nitrate, the amount released to Columbia River is essentially equal to the amount released to groundwater. For tritium, the amount released to the Columbia River is attenuated by radioactive decay. Overall, only about 5 percent of the tritium released to groundwater reaches the Columbia River. Because of retardation, about 90 percent of the uranium-238 and total uranium released to groundwater during the period of analysis reaches the Columbia River.

Table 6–16. Alternative Combination 2 Release to Groundwater for COPC Drivers

	Radiological COPCs (curies)				Chemical COPCs (kilograms)		
	Hydrogen-3 (Tritium)	Iodine-129	Technetium-99	Uranium-238	Chromium ^a	Nitrate	Total Uranium
Other activities	2.06×10 ⁶	2.48×10 ¹	7.12×10 ²	1.48×10 ²	3.40×10 ⁵	7.42×10 ⁷	1.05×10 ⁵
Tank Closure Alternative 2B Base	3.23×10 ⁴	1.51	8.61×10 ²	2.91	1.04×10 ⁵	2.80×10 ⁷	2.96×10 ³
FFTF Decommissioning Alternative 2	2.58×10 ⁻⁸	0	2.62×10 ¹	0	0	0	0
Waste Management Alternative 2 Disposal Group 1-A	0	1.64×10 ¹	2.10×10 ³	3.02×10 ⁻¹⁰	2.89×10 ³	9.03×10 ⁶	5.14×10 ⁻⁵
Total	2.09×10 ⁶	4.26×10 ¹	3.70×10 ³	1.51×10 ²	4.46×10 ⁵	1.11×10 ⁸	1.08×10 ⁵

^a It was assumed, for the purposes of analysis, that all chromium was hexavalent.

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

Key: COPC=constituent of potential concern; FFTF=Fast Flux Test Facility.

Table 6–17. Alternative Combination 2 Release to Columbia River for COPC Drivers

	Radiological COPCs (curies)				Chemical COPCs (kilograms)		
	Hydrogen-3 (Tritium)	Iodine-129	Technetium-99	Uranium-238	Chromium ^a	Nitrate	Total Uranium
Other activities	1.11×10 ⁵	2.46×10 ¹	7.26×10 ²	1.40×10 ²	3.51×10 ⁵	7.47×10 ⁷	9.28×10 ⁴
Tank Closure Alternative 2B Base	8.70×10 ²	1.45	8.37×10 ²	8.46×10 ⁻¹	1.03×10 ⁵	2.78×10 ⁷	8.54×10 ²
FFTF Decommissioning Alternative 2	0	0	2.72×10 ¹	0	0	0	0
Waste Management Alternative 2 Disposal Group 1-A	0	1.59×10 ¹	2.04×10 ³	0	2.80×10 ³	8.89×10 ⁶	3.77×10 ⁻⁶
Total	1.12×10 ⁵	4.20×10 ¹	3.62×10 ³	1.41×10 ²	4.57×10 ⁵	1.11×10 ⁸	9.37×10 ⁴

^a It was assumed, for the purposes of analysis, that all chromium was hexavalent.

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

Key: COPC=constituent of potential concern; FFTF=Fast Flux Test Facility.

6.4.1.2.2 Analysis of Concentration Versus Time

This section presents groundwater concentrations versus time at the Core Zone Boundary and the Columbia River. Because of the discrete nature of the concentration carried across a barrier or the river, a line denoting the 95th percentile upper confidence limit of the concentration is included on several of these graphs. This confidence interval was calculated to aid in interpreting data with a significant amount of random fluctuation (noise). The confidence interval was calculated when: the concentration had a reasonable degree of noise, the concentration trend was level, and the concentrations were near the benchmark. The benchmark concentration for each radionuclide and chemical is also shown. Note that the concentrations are plotted on a logarithmic scale to facilitate visual comparison of concentrations that vary over five orders of magnitude. Table 6–18 lists the maximum concentrations for the COPCs at the peak year for the Core Zone Boundary and the Columbia River nearshore.

Table 6–18. Alternative Combination 2 Maximum Concentrations for COPCs^a

Contaminant	Core Zone Boundary	Columbia River Nearshore	Benchmark Concentration ^b
Radionuclide (picocuries per liter)			
Hydrogen-3 (Tritium)	104,000,000 (1996)	4,190,000 (1986)	20,000
Carbon-14	46,700 (1998)	196 (2013)	2,000
Strontium-90	181,000 (1998)	4,160,000 (1991)	8
Technetium-99	144,000 (1956)	2,870 (1999)	900
Iodine-129	190 (1956)	9.4 (4540)	1
Cesium-137	0 ^c (1997)	1,310,000 (1985)	200
Uranium isotopes (includes U-233, -234, -235, -238)	2,200 (1991)	22,400 (1973)	15
Neptunium-237	114 (2066)	16 (2004)	15
Plutonium isotopes (includes Pu-239, -240)	2,660 (11,848)	4,250 (2983)	15
Chemical (microgram per liter)			
1-Butanol	17,200 (1998)	49 (11,243)	3,600
Acetonitrile	1 (3829)	0 (4021)	100
Carbon tetrachloride	3,350 (2270)	60.7 (2527)	5
Chromium ^d	28,800 (1956)	16,100 (1978)	100
Dichloromethane	0.7 (3286)	0.1 (4711)	5
Fluoride	90,200 (2003)	14,500 (1982)	4,000
Hydrazine/Hydrazine Sulfate	0.030 (3343)	0.088 (3627)	0.022
Lead	0 ^c (2021)	9,080 (2374)	15
Manganese	392 (8610)	242 (2286)	1,600
Mercury	183 (2015)	25.5 (1997)	2
Nickel (soluble salts)	0 ^c (11,871)	8,310 (3877)	700
Nitrate	13,100,000 (1956)	505,000 (1973)	45,000
Total Uranium	3,290 (1991)	15,400 (1964)	30
Trichloroethylene (TCE)	0.1 (3404)	0.2 (3764)	5

^a The peak cumulative concentration for some constituents occurs in the past. The relationship of past to future cumulative constituent concentrations is presented in the time versus concentration plots in Figures 6–35 through 6–42.

^b The sources of the benchmark concentrations are provided in Appendix O, Section O.3.

^c Values that are less than 0.001 are reported as zero.

^d It was assumed, for the purposes of analysis, that all chromium was hexavalent.

Note: To convert liters to gallons, multiply by 0.26417.

Key: COPC=constituent of potential concern.

Figure 6–35 shows concentration versus time for tritium. Note that for visual clarity, the time period shown on this figure is from 1940 through 2540 rather than the full 10,000-year period of analysis. Concentrations at the Core Zone Boundary exceed the benchmark concentration by about three orders of magnitude for a short period of time during the early part of the period of analysis. During this time groundwater concentrations at the Columbia River nearshore peak at about two orders of magnitude above the benchmark concentration. Because the half-life of tritium is less than 13 years, radioactive decay rapidly attenuates groundwater concentration, and tritium is essentially not a factor at times later than CY 2100.

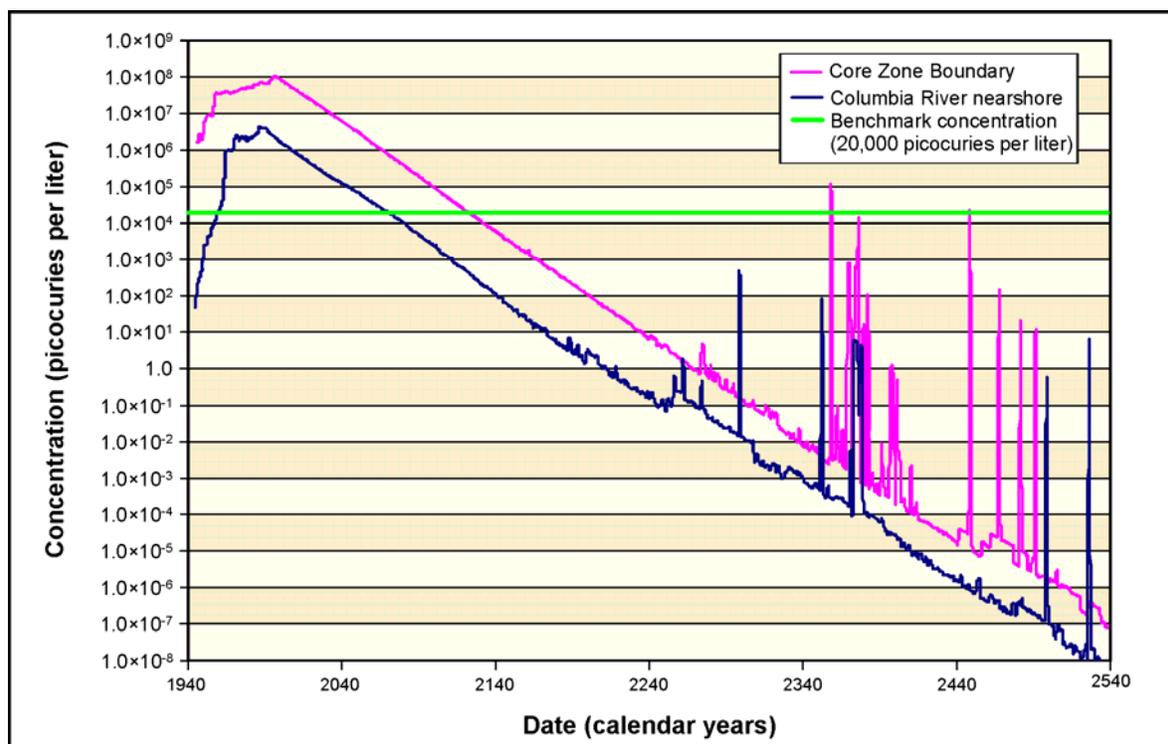


Figure 6–35. Alternative Combination 2 Cumulative Concentration Versus Time for Tritium

Figures 6–36 through 6–40 show concentration versus time for iodine-129, technetium-99, carbon tetrachloride, chromium, and nitrate (the conservative tracers). Groundwater concentrations of iodine-129 to exceed benchmark concentrations by more than an order of magnitude during the first several thousand years of the analysis. During this time groundwater concentrations at the Columbia River nearshore exceed the benchmark concentration by about an order of magnitude. During later times in the analysis the concentrations are on the same order of magnitude as the benchmark at the Core Zone Boundary and the Columbia River nearshore. Technetium-99, carbon tetrachloride, chromium, and nitrate concentrations show a similar curve, with technetium-99, chromium and nitrate concentrations at the Columbia River nearshore dropping below the benchmark concentrations.

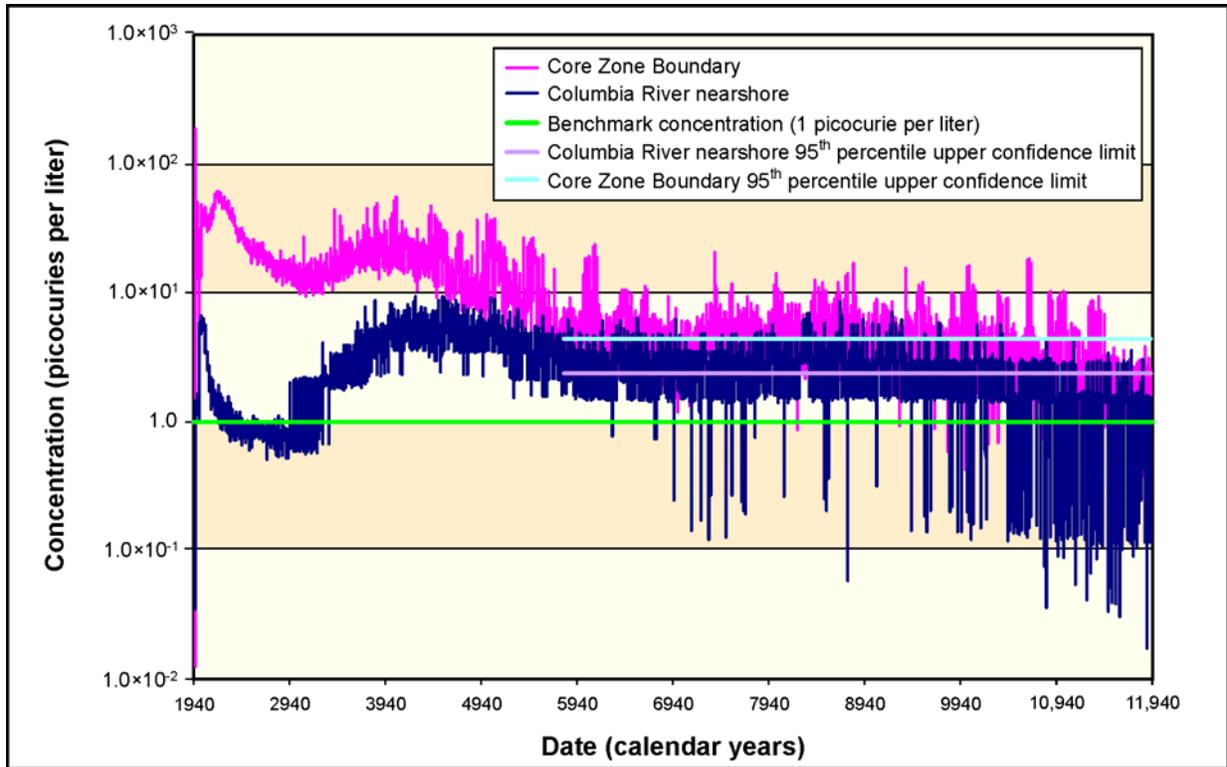


Figure 6-36. Alternative Combination 2 Cumulative Concentration Versus Time for Iodine-129

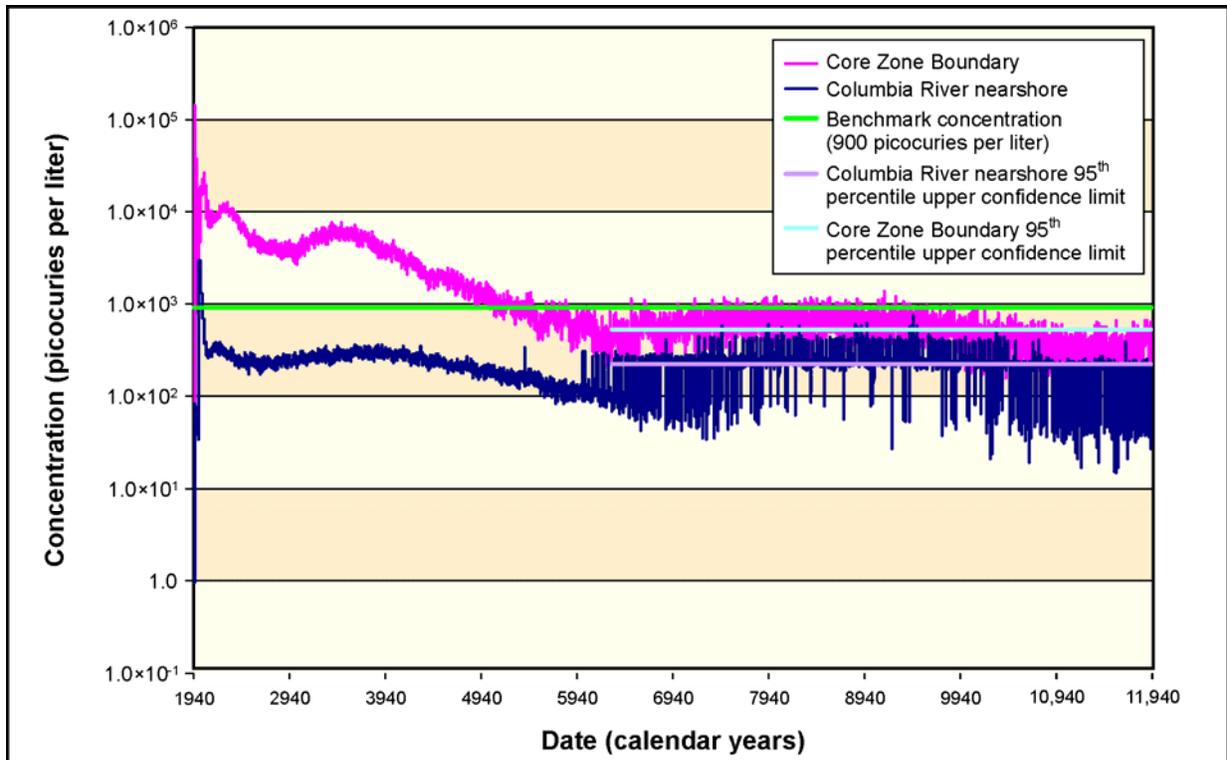


Figure 6-37. Alternative Combination 2 Cumulative Concentration Versus Time for Technetium-99

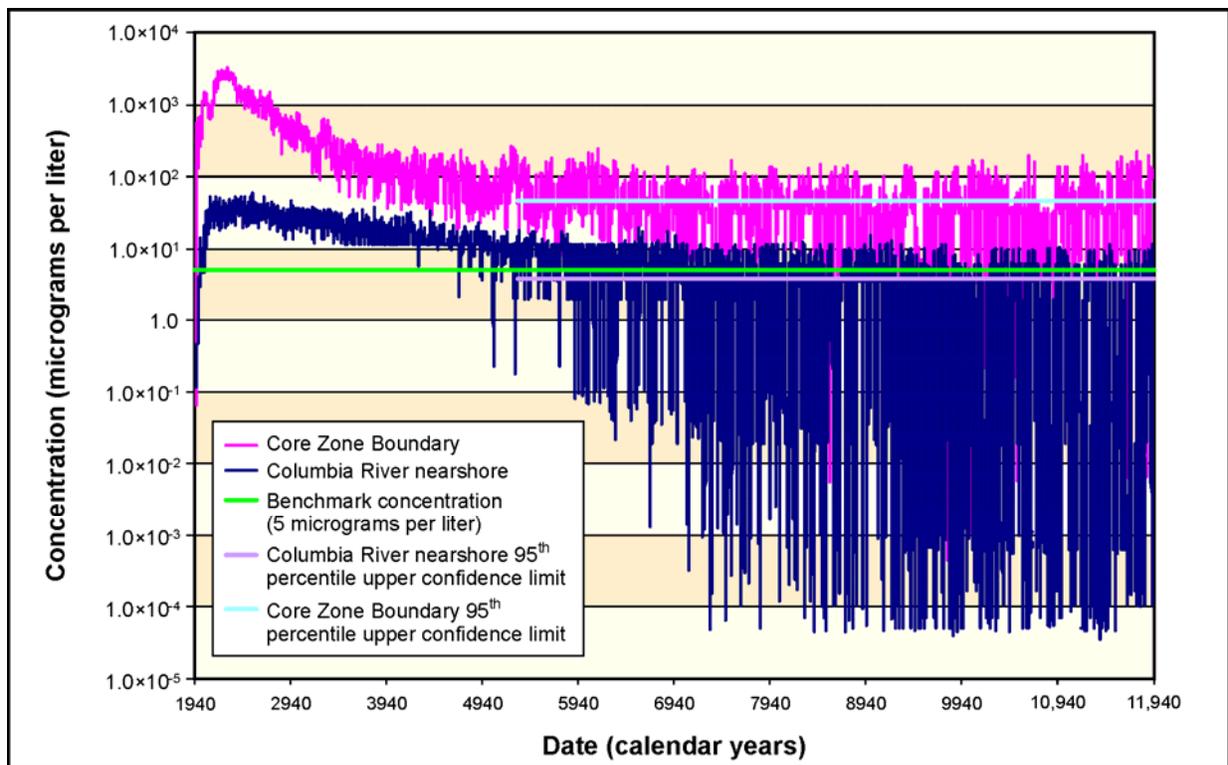


Figure 6–38. Alternative Combination 2 Cumulative Concentration Versus Time for Carbon Tetrachloride

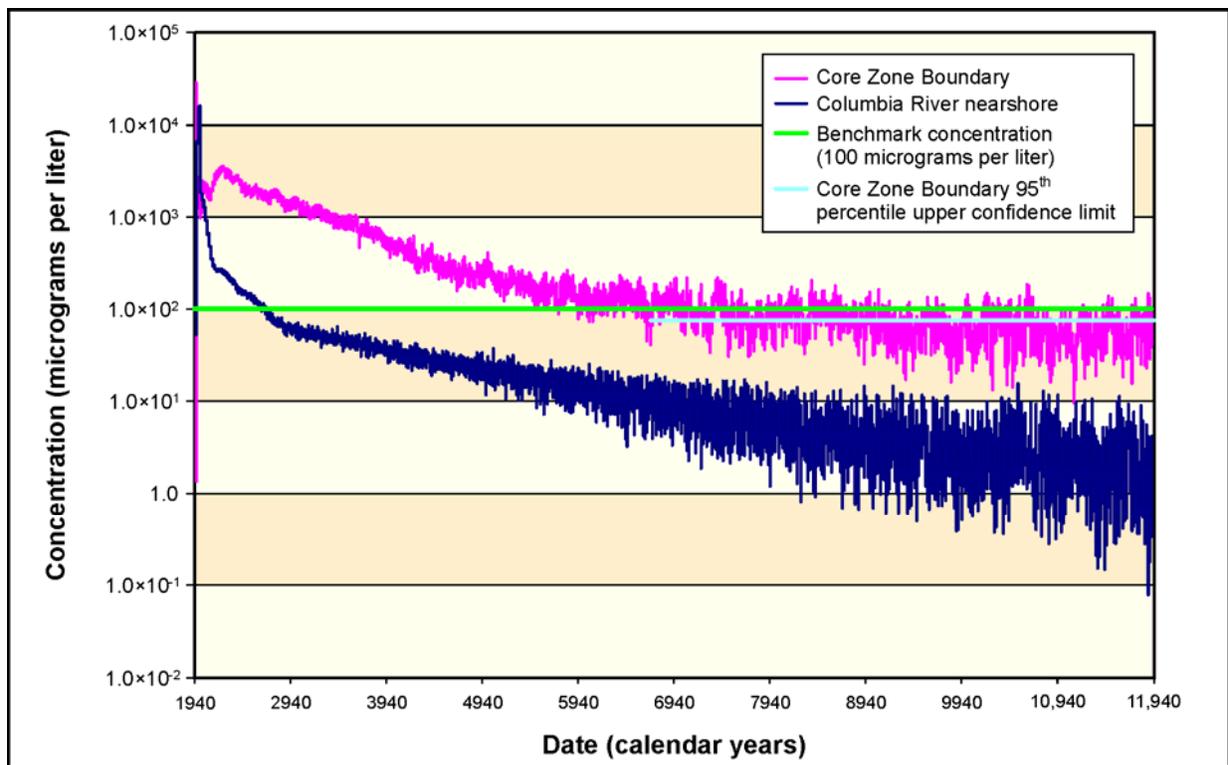


Figure 6–39. Alternative Combination 2 Cumulative Concentration Versus Time for Chromium

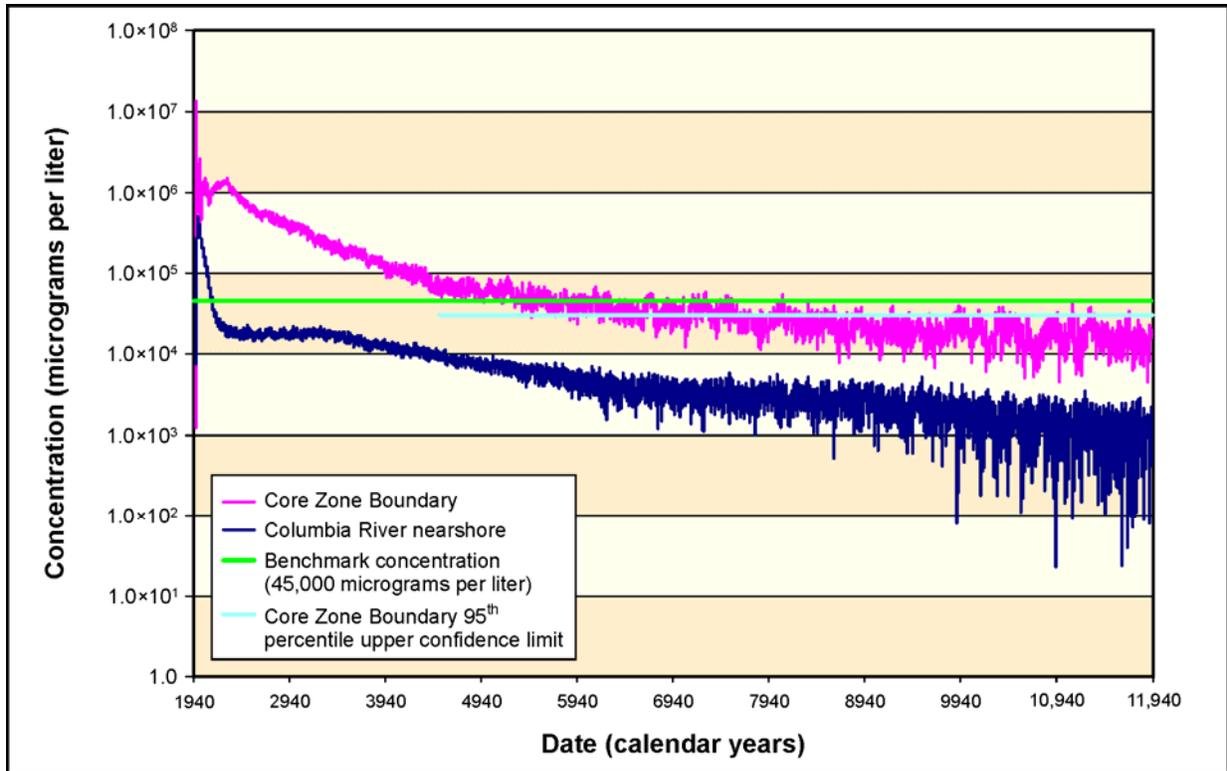


Figure 6-40. Alternative Combination 2 Cumulative Concentration Versus Time for Nitrate

Figures 6-41 and 6-42 show concentration versus time for uranium-238 and total uranium. Concentrations of uranium-238 and total uranium peak early in the period of analysis, and then maintain relatively constant for the remainder of the period of analysis. The travel times of these COPCs from the source locations to the Core Zone Boundary and Columbia River is slowed relative to the groundwater flow by a factor of about seven. After about 1,000 years, concentrations of both uranium-238 and total uranium exceed the benchmark concentration at the Core Zone Boundary by about an order of magnitude. Groundwater concentrations at the Columbia River nearshore remain within an order of magnitude of the benchmark during this time.

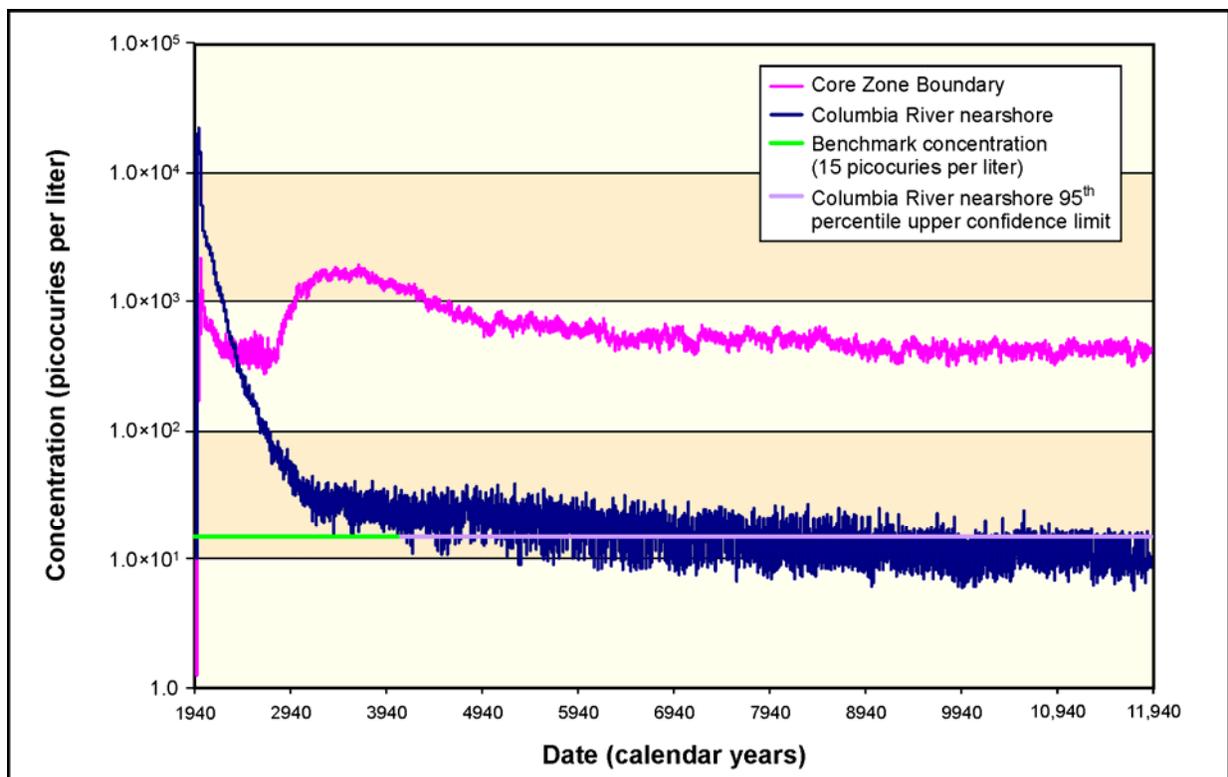


Figure 6-41. Alternative Combination 2 Cumulative Concentration Versus Time for Uranium-238

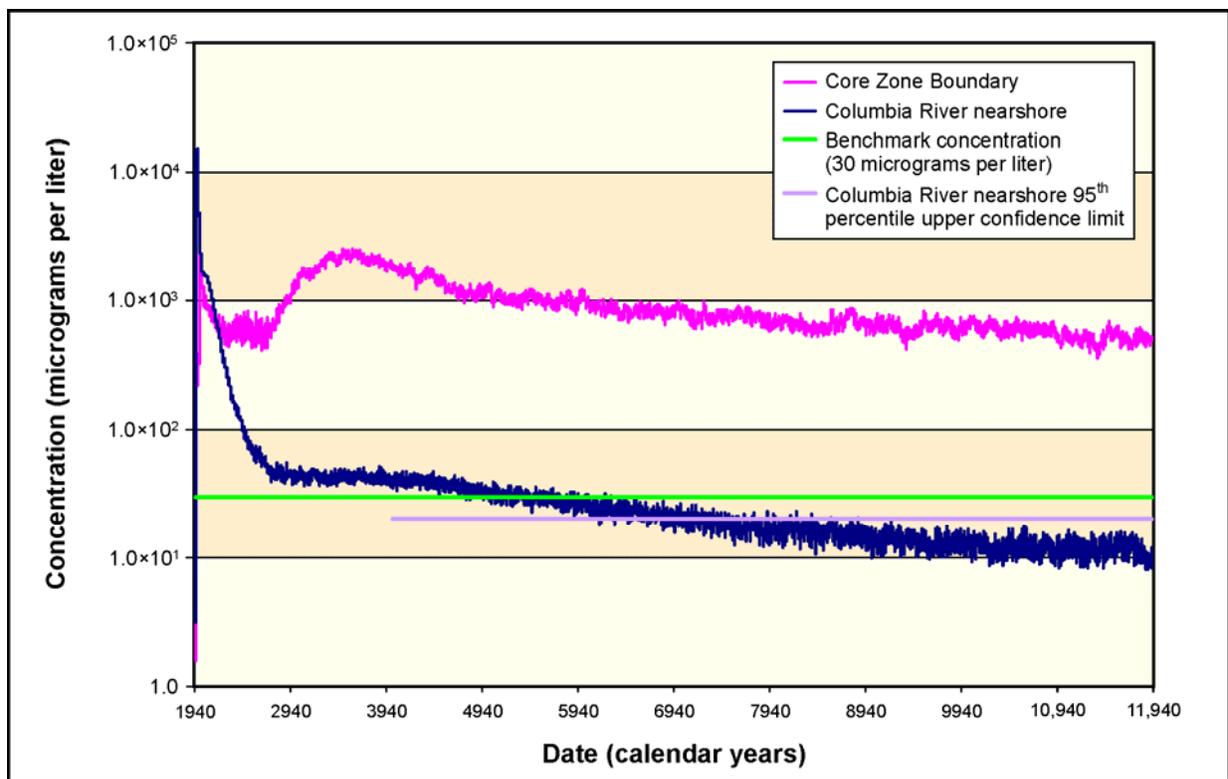


Figure 6-42. Alternative Combination 2 Cumulative Concentration Versus Time for Total Uranium

6.4.1.2.3 Analysis of Spatial Distribution of Concentration

This section the spatial distribution of contaminant concentrations in groundwater at selected times. Concentrations for each radionuclide and chemical are indicated by a color scale which is relative to the benchmark concentration. Concentrations greater than the benchmark concentration are indicated the fully saturated colors green, yellow, orange, and red in order of increasing concentration. Concentrations less than the benchmark concentration are indicated the faded colors green, blue, indigo, and violet in order of decreasing concentration. Note that the concentrations ranges are on a logarithmic scale to facilitate visual comparison of concentrations that vary over three orders of magnitude.

Figure 6-43 shows the spatial distribution of groundwater concentration for tritium during CY 2005. Releases from cribs and trenches (ditches), primarily associated with non-TC & WM EIS sources within the PUREX Plant and the REDOX Facility areas, result in groundwater concentration plumes (exceeding the benchmark concentration) that extend from the southern part of the 200-West Area across the Core Zone, and extending from the eastern part of the Core Zone southeast to the Columbia River. Peak concentrations in this plume are about ten to fifty times greater than the benchmark. Tritium concentrations are attenuated by radioactive decay to levels less than one twentieth of the benchmark concentration by CY 2135.

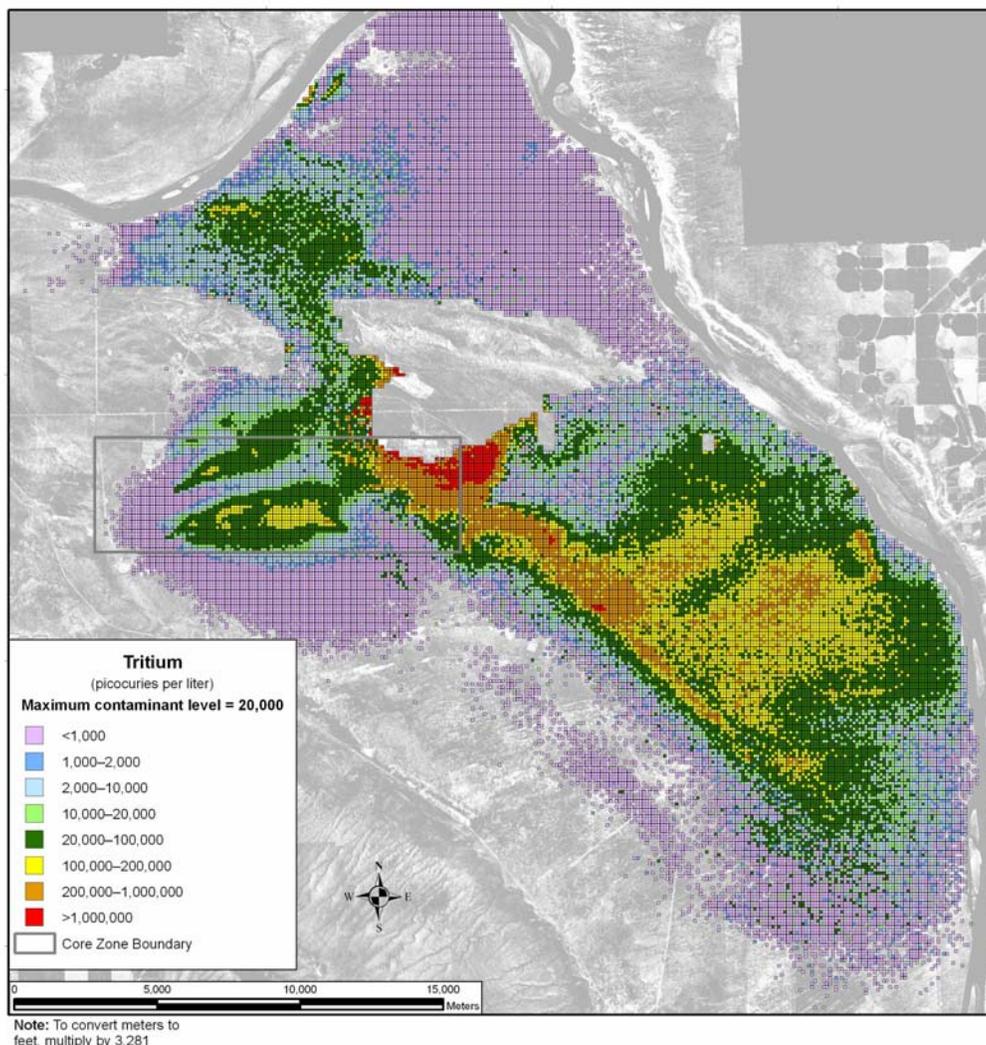


Figure 6-43. Alternative Combination 2 Spatial Distribution of Cumulative Groundwater Concentration for Tritium During Calendar Year 2005

Figure 6-44 shows the spatial distribution of groundwater concentration for iodine-129 during CY 2005. Releases from cribs and trenches (ditches) and past leaks result in groundwater concentration plumes that exceeding the benchmark concentration associated with the T Barrier, the B Barrier, and the A Barrier. Peak concentrations in this plume are about ten to fifty times greater than the benchmark, and mostly contained within the Core Zone. Releases from the PUREX Plant area (non-TC & WM EIS sources) produce a plume extending south and east of the Core Zone with peak concentrations about one to five times the benchmark concentration. Around CY 3890 releases from other tank farm sources create an iodine-129 plume extending east of the Core Zone Boundary (see Figure 6-45). By CY 7140 the groundwater concentration distribution is driven primarily by waste management sources located at the Integrated Disposal Facility (IDF) in the 200-East Area (see Figure 6-46). The impact is characterized by a plume exceeding the benchmark concentration by more than an order of magnitude that is located east of the Core Zone. Because of retention in the waste forms, this impact lasts to the end of the 10,000-year period of analysis (see Figure 6-47). Figure 6-48 shows the total area for which groundwater concentrations of iodine-129 exceed the benchmark concentration as a function of time. After an early peak related to releases from the PUREX Plant area, the area of exceedance peaks between CY 3240 and CY 4540 driven primarily by releases from other tank farm sources. A secondary peak at later times

results from releases at IDF. Figures 6-49 through 6-53 show the spatial distribution at the same four times and the total area of exceedance versus time for technetium-99. The spatial distribution of technetium-99 does not include contributions from the PUREX Plant sources (compare to iodine-129 distributions) and is dominated by releases from other tank farm sources and IDF. Chromium (see Figures 6-54 through 6-57) and nitrate (see Figures 6-58 through 6-61) show similar spatial distributions to technetium-99.

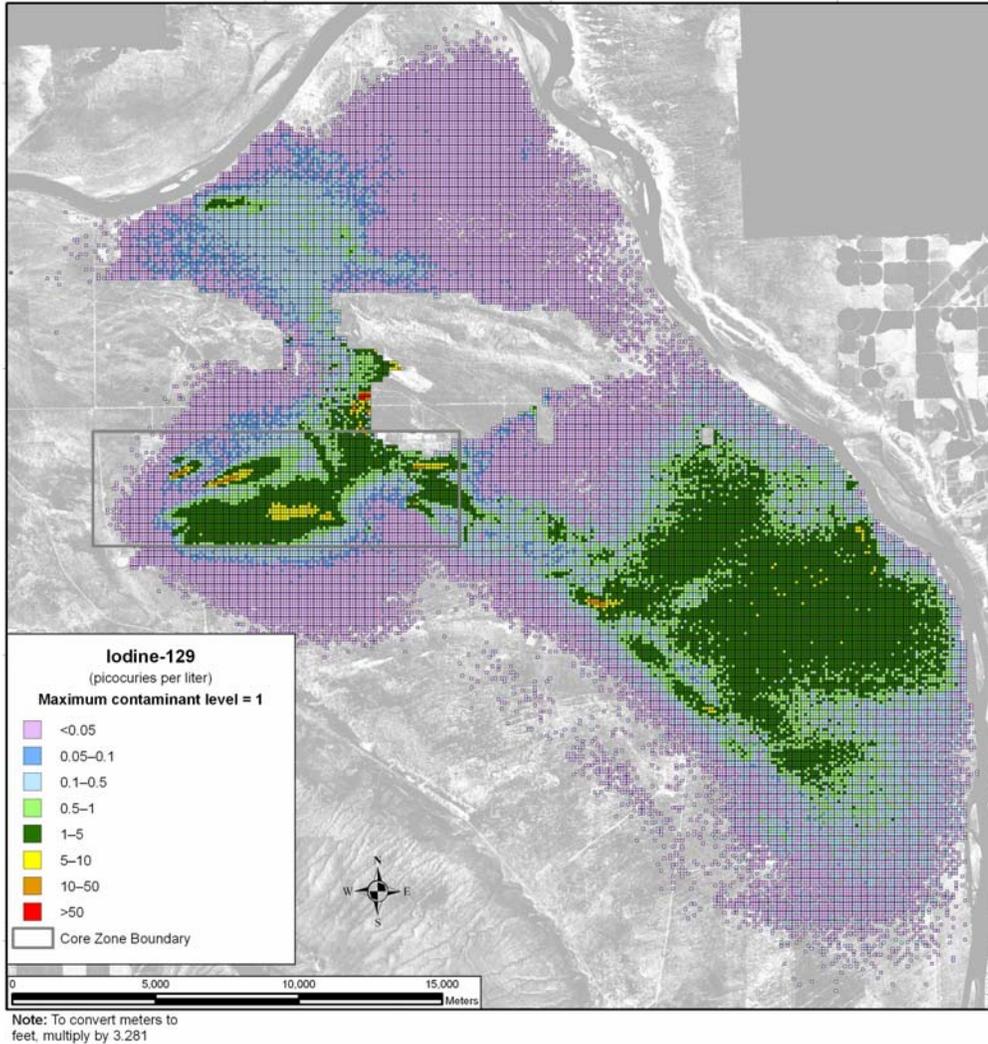


Figure 6-44. Alternative Combination 2 Spatial Distribution of Cumulative Groundwater Concentration for Iodine-129 During Calendar Year 2005

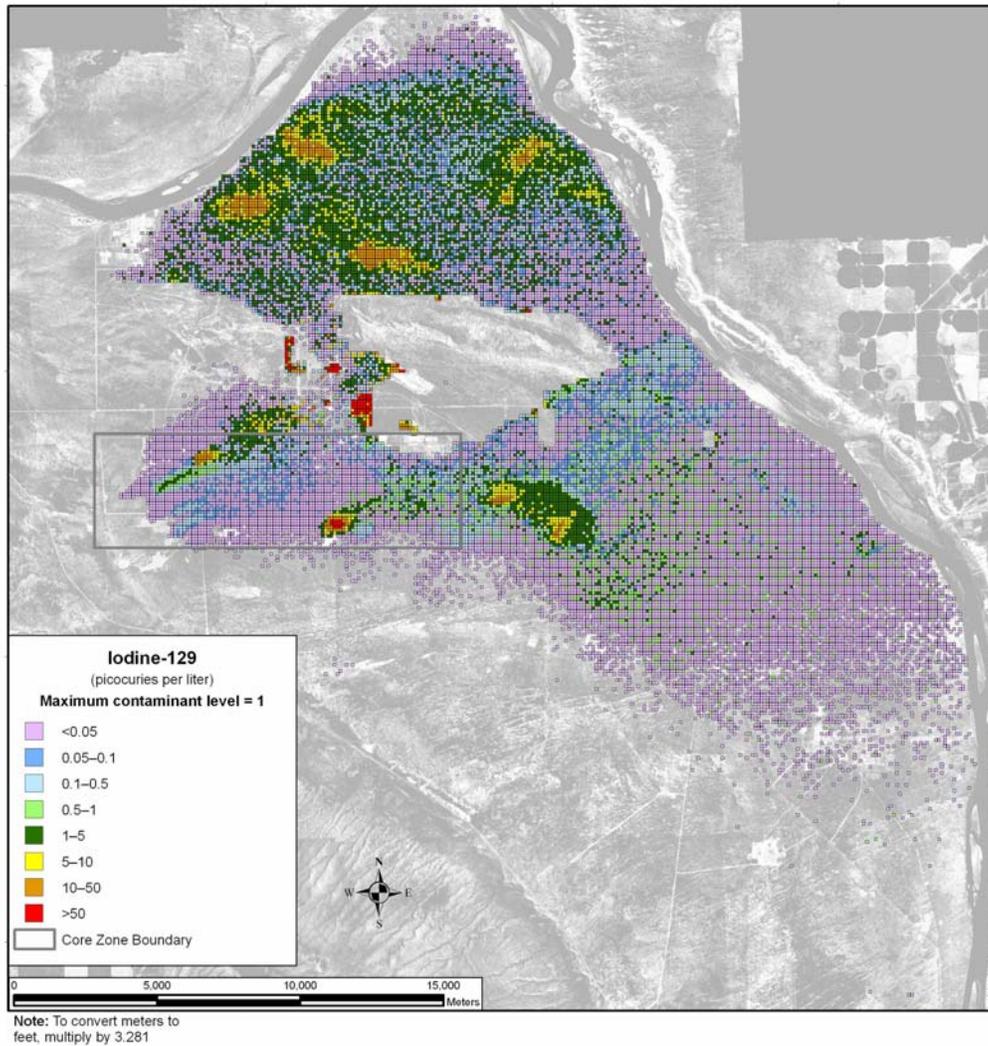


Figure 6-45. Alternative Combination 2 Spatial Distribution of Cumulative Groundwater Concentration for Iodine-129 During Calendar Year 3890

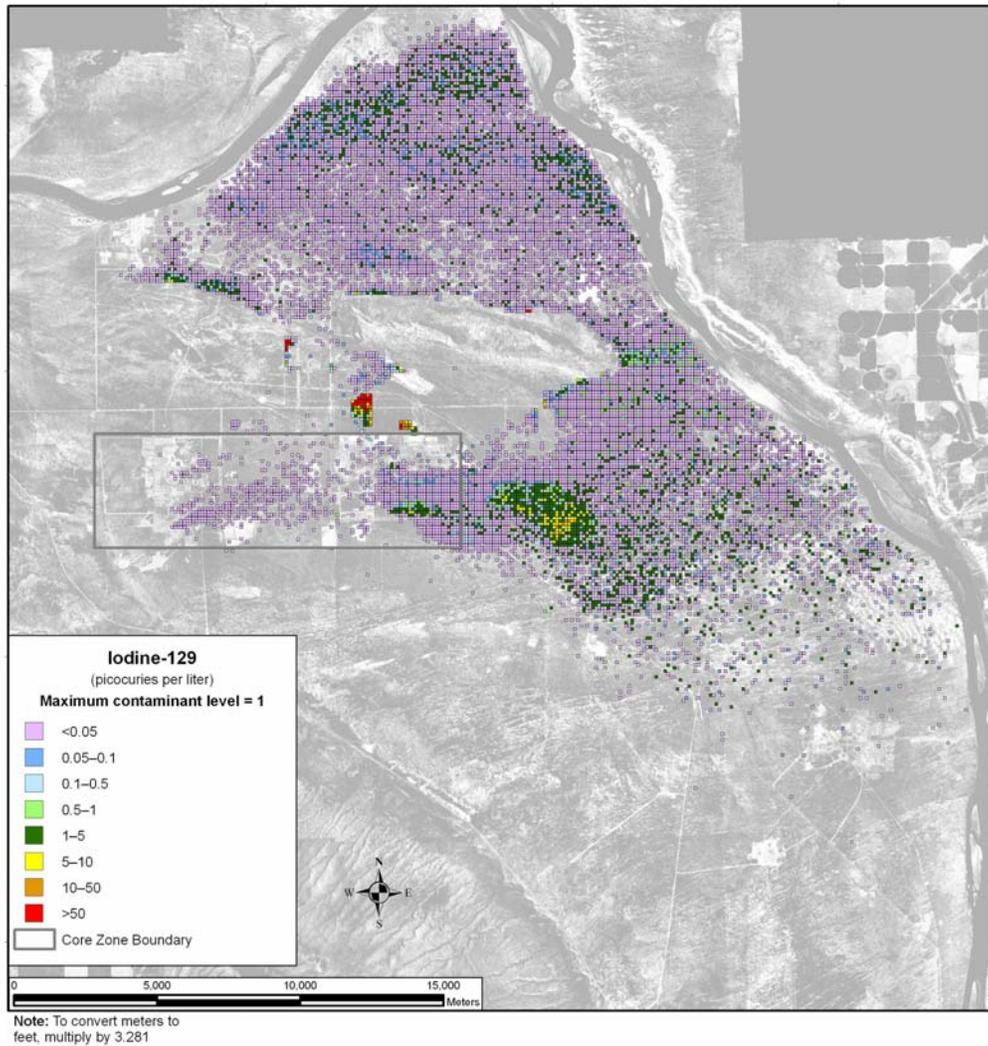


Figure 6-46. Alternative Combination 2 Spatial Distribution of Cumulative Groundwater Concentration for Iodine-129 During Calendar Year 7140

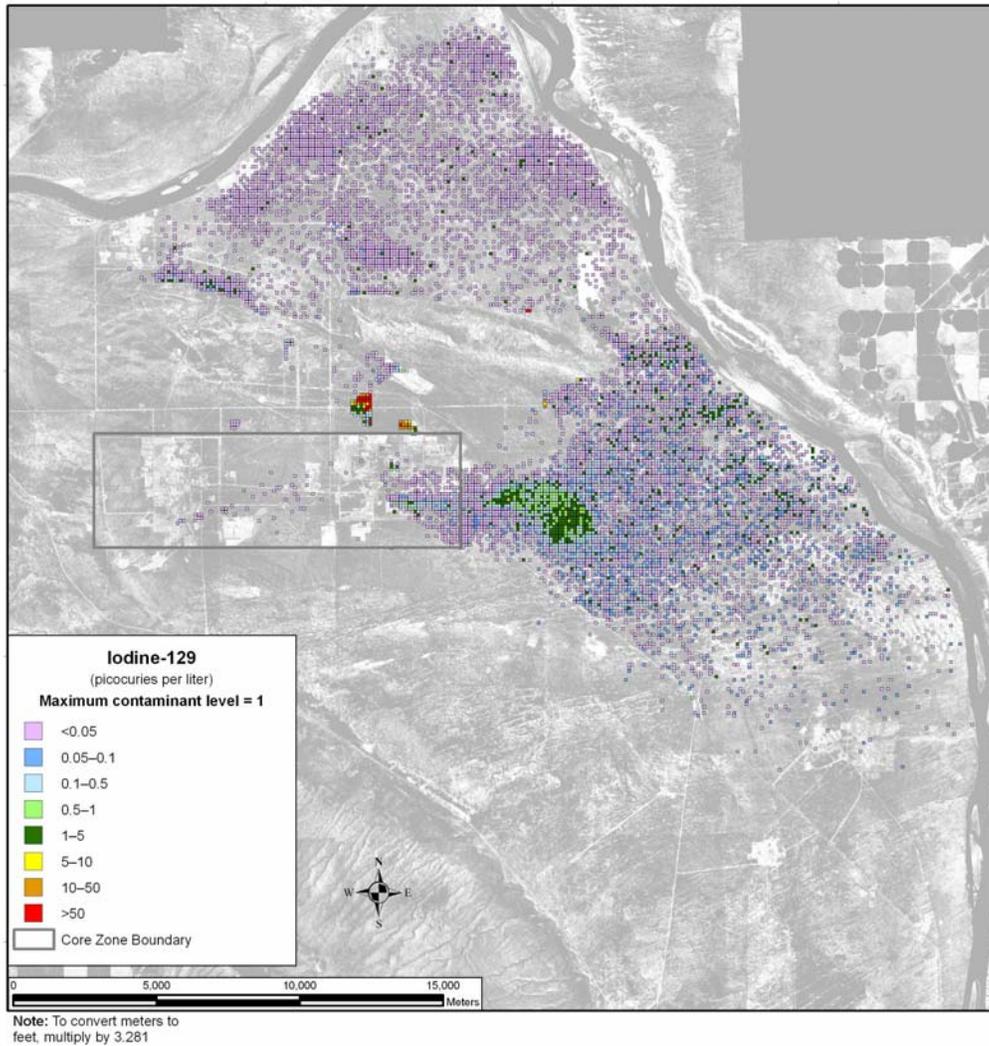


Figure 6-47. Alternative Combination 2 Spatial Distribution of Cumulative Groundwater Concentration for Iodine-129 During Calendar Year 11,885

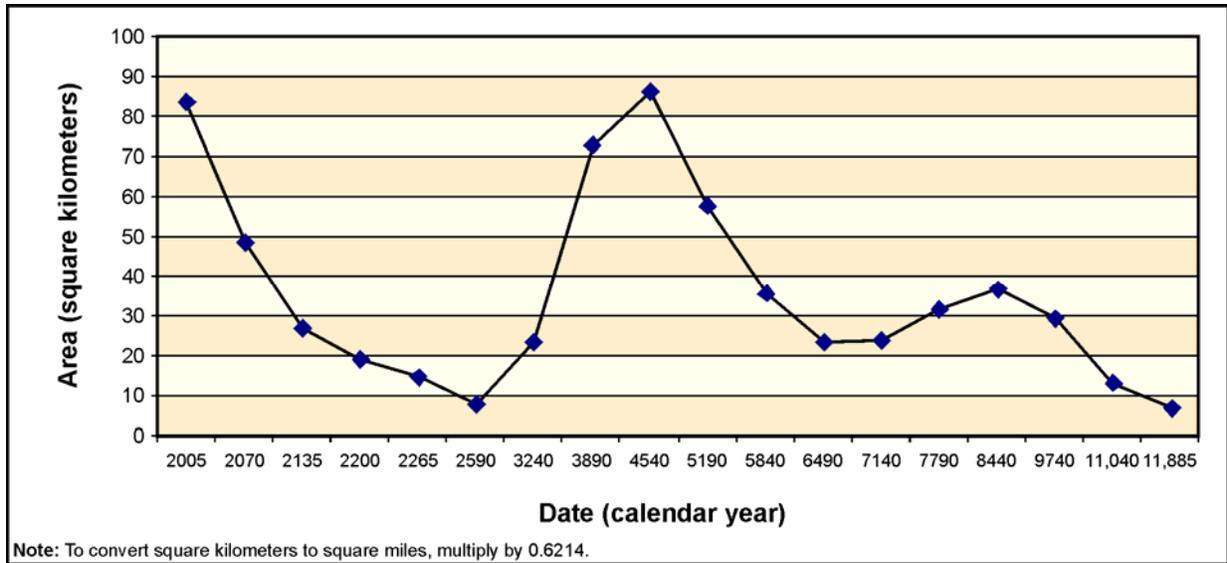


Figure 6-48. Alternative Combination 2 Total Area for Which Cumulative Groundwater Concentrations of Iodine-129 Exceed the Benchmark Concentration as a Function of Time

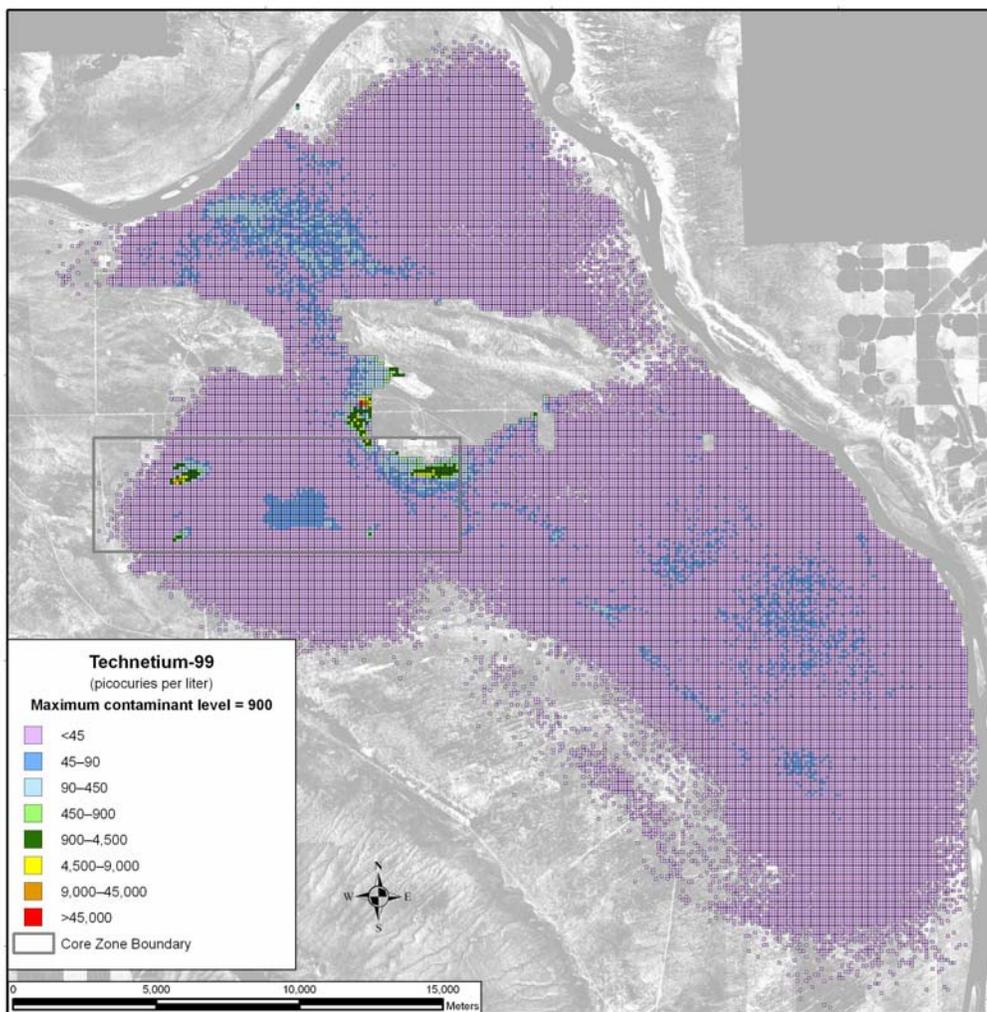


Figure 6-49. Alternative Combination 2 Spatial Distribution of Cumulative Groundwater Concentration for Technetium-99 During Calendar Year 2005

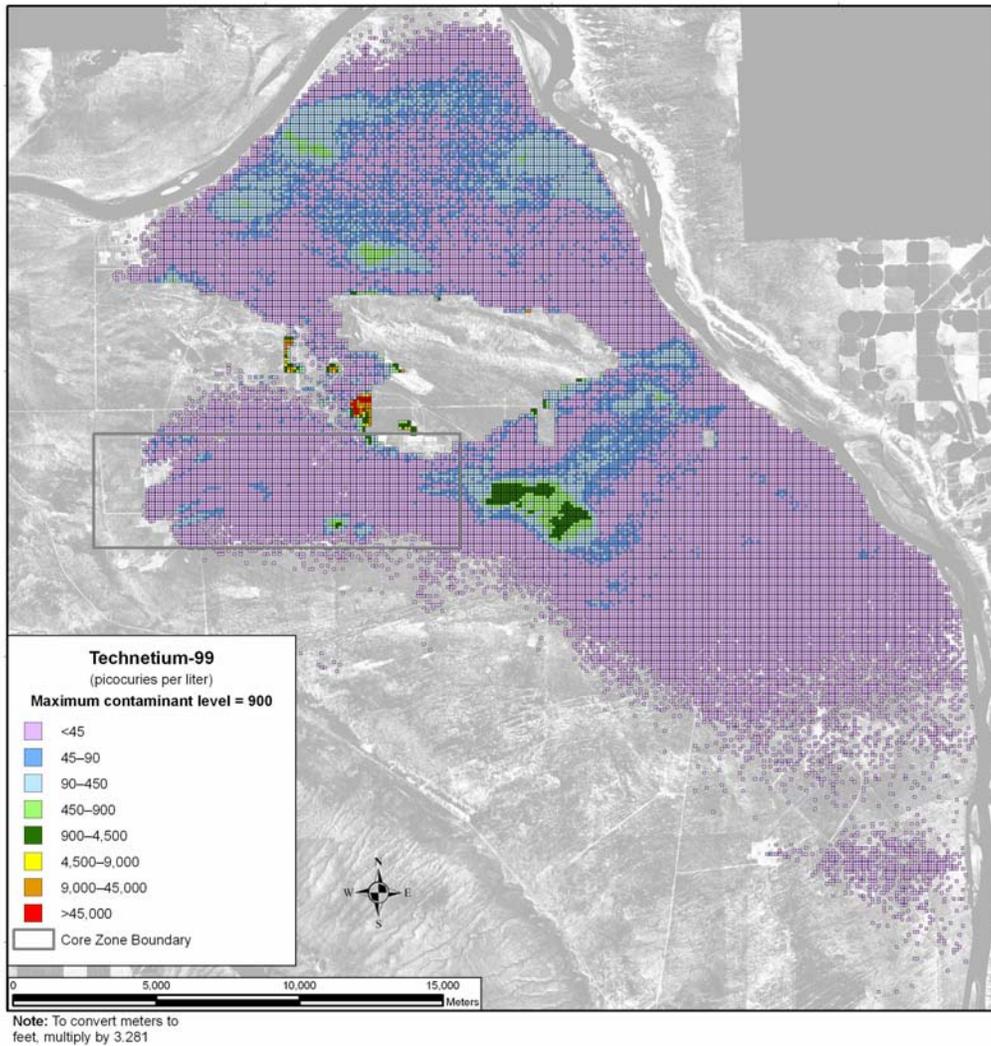


Figure 6-50. Alternative Combination 2 Spatial Distribution of Cumulative Groundwater Concentration for Technetium-99 During Calendar Year 3890

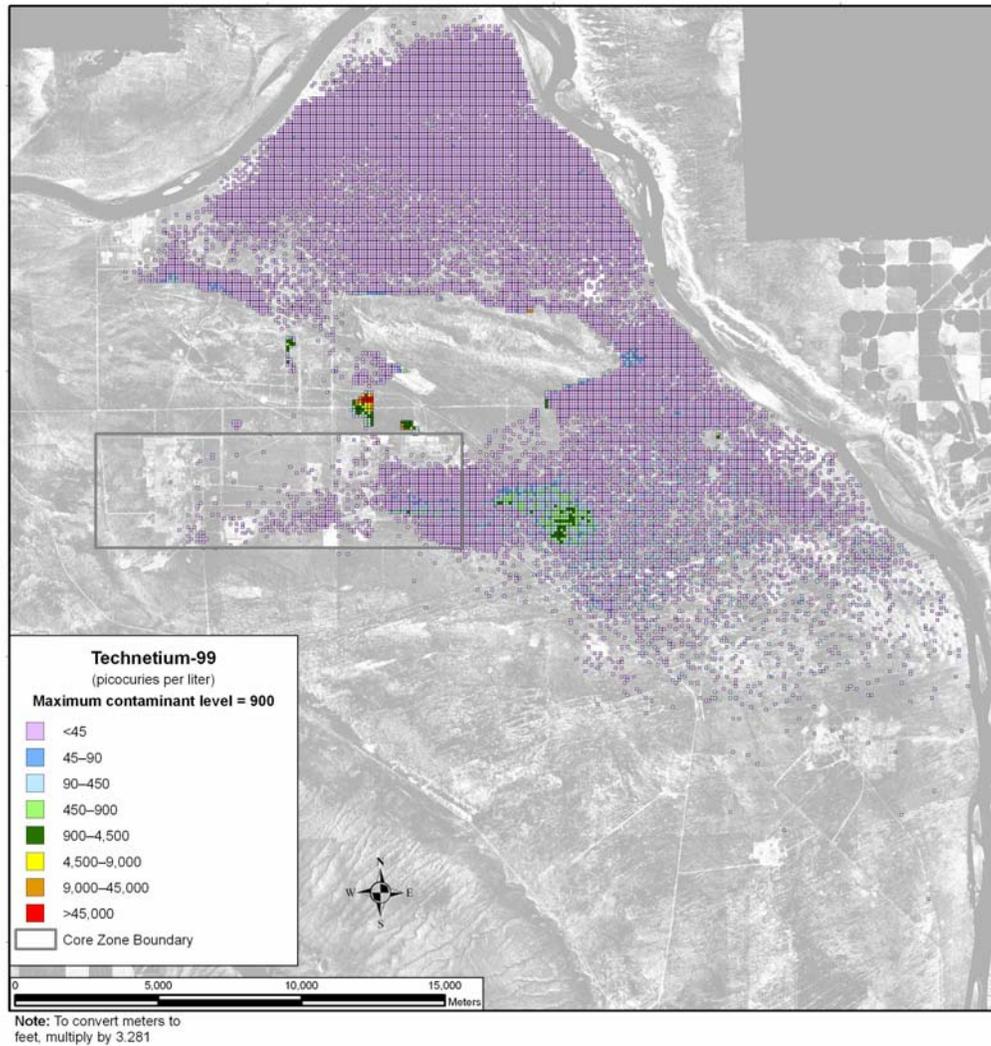


Figure 6-51. Alternative Combination 2 Spatial Distribution of Cumulative Groundwater Concentration for Technetium-99 During Calendar Year 7140

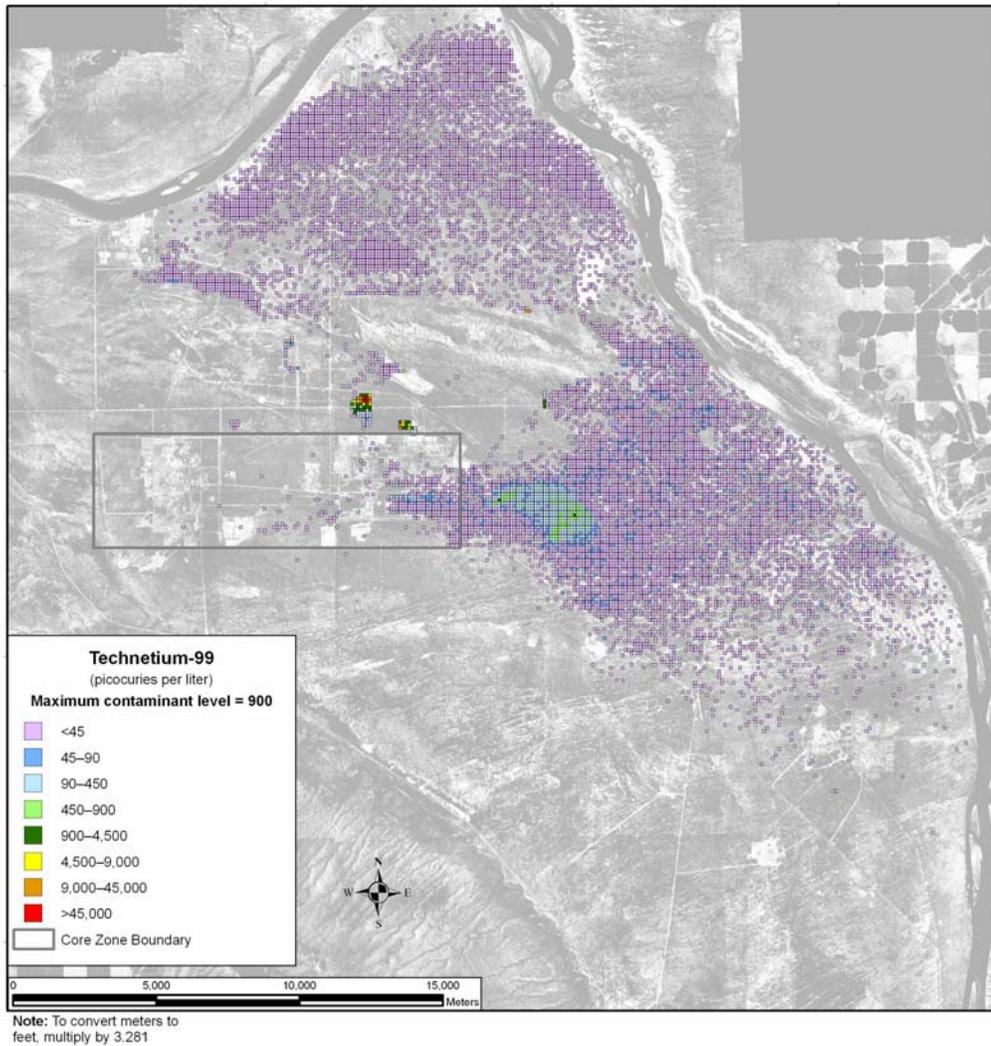


Figure 6-52. Alternative Combination 2 Spatial Distribution of Cumulative Groundwater Concentration for Technetium-99 During Calendar Year 11,885

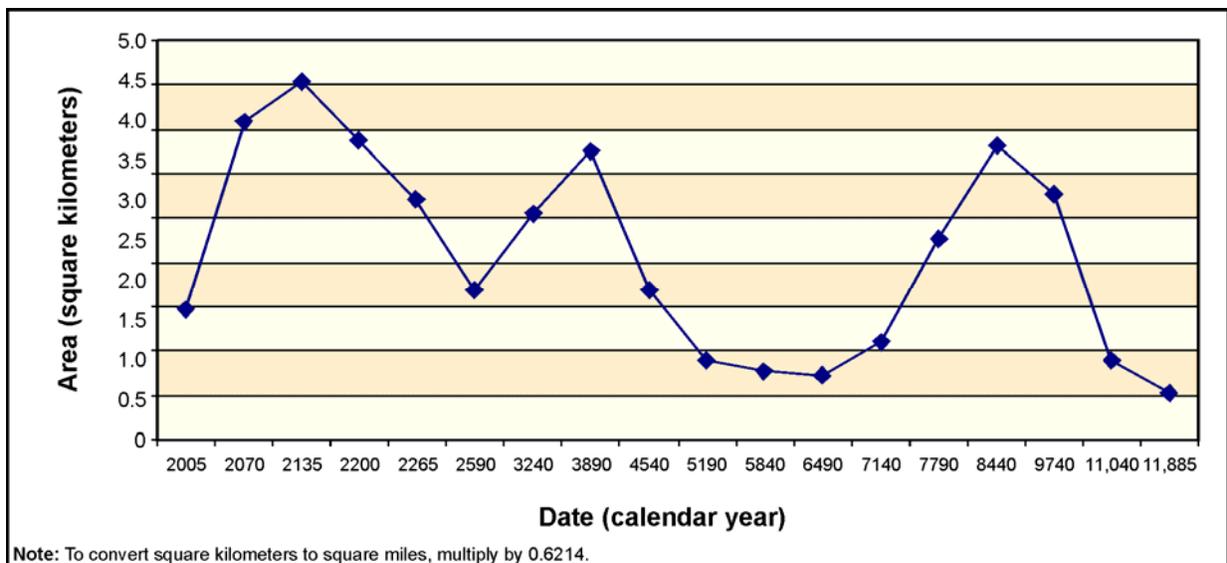


Figure 6–53. Alternative Combination 2 Total Area for Which Cumulative Groundwater Concentrations of Technetium-99 Exceed the Benchmark Concentration as a Function of Time

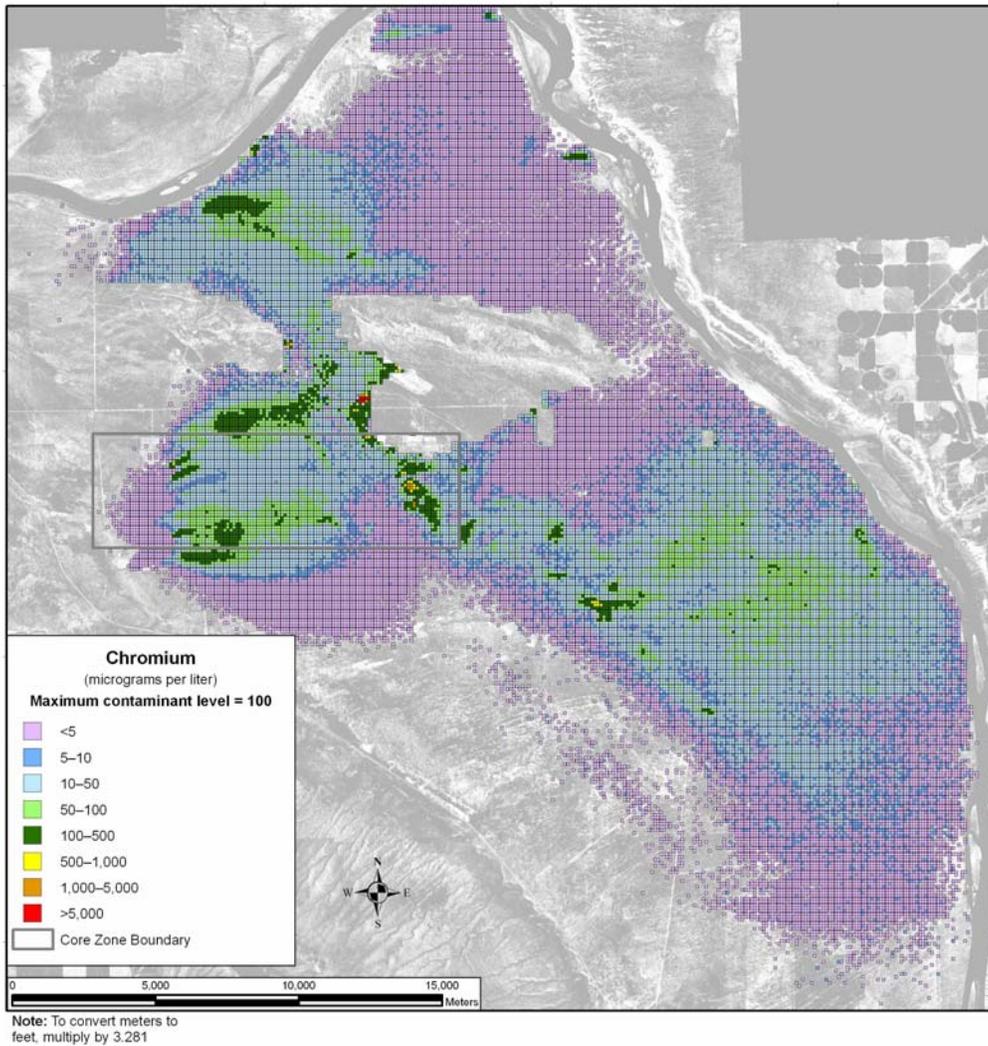


Figure 6-54. Alternative Combination 2 Spatial Distribution of Cumulative Groundwater Concentration for Chromium During Calendar Year 2005

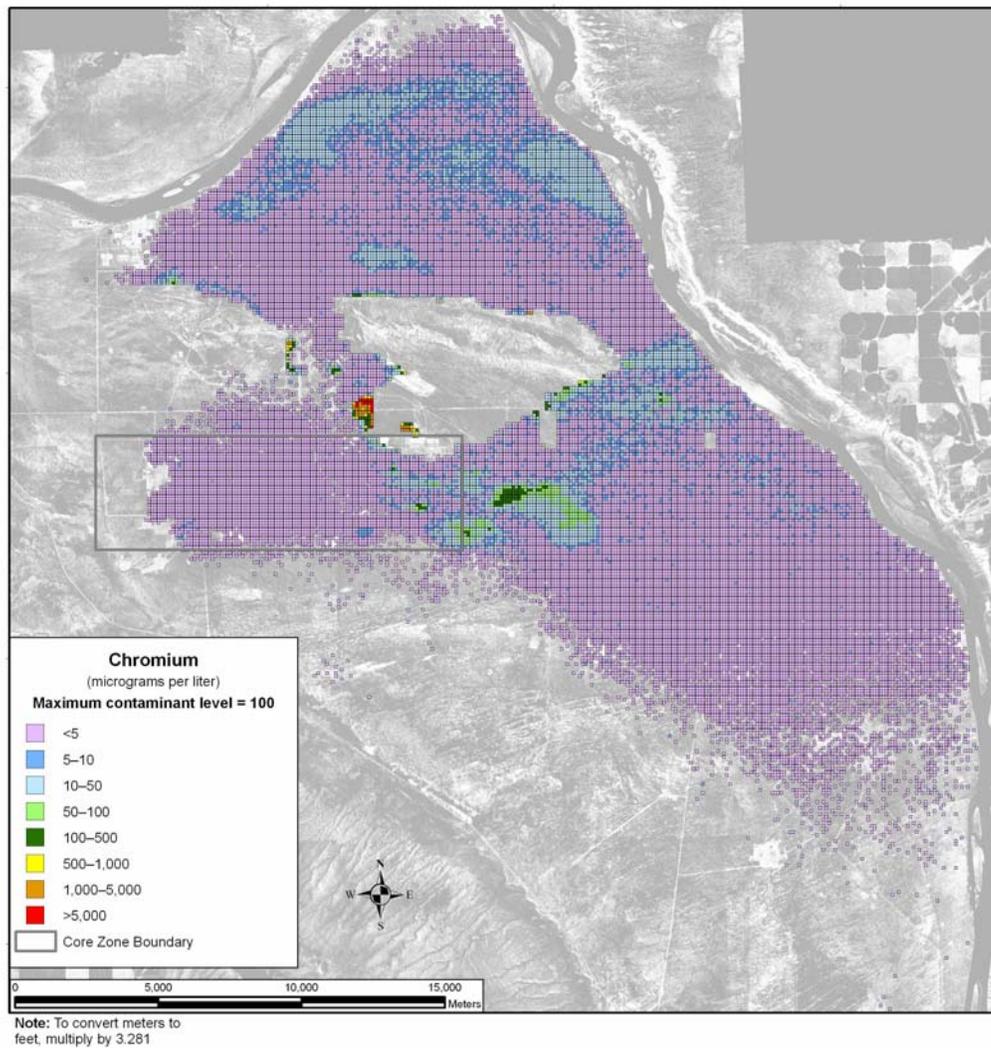


Figure 6-55. Alternative Combination 2 Spatial Distribution of Cumulative Groundwater Concentration for Chromium During Calendar Year 3890

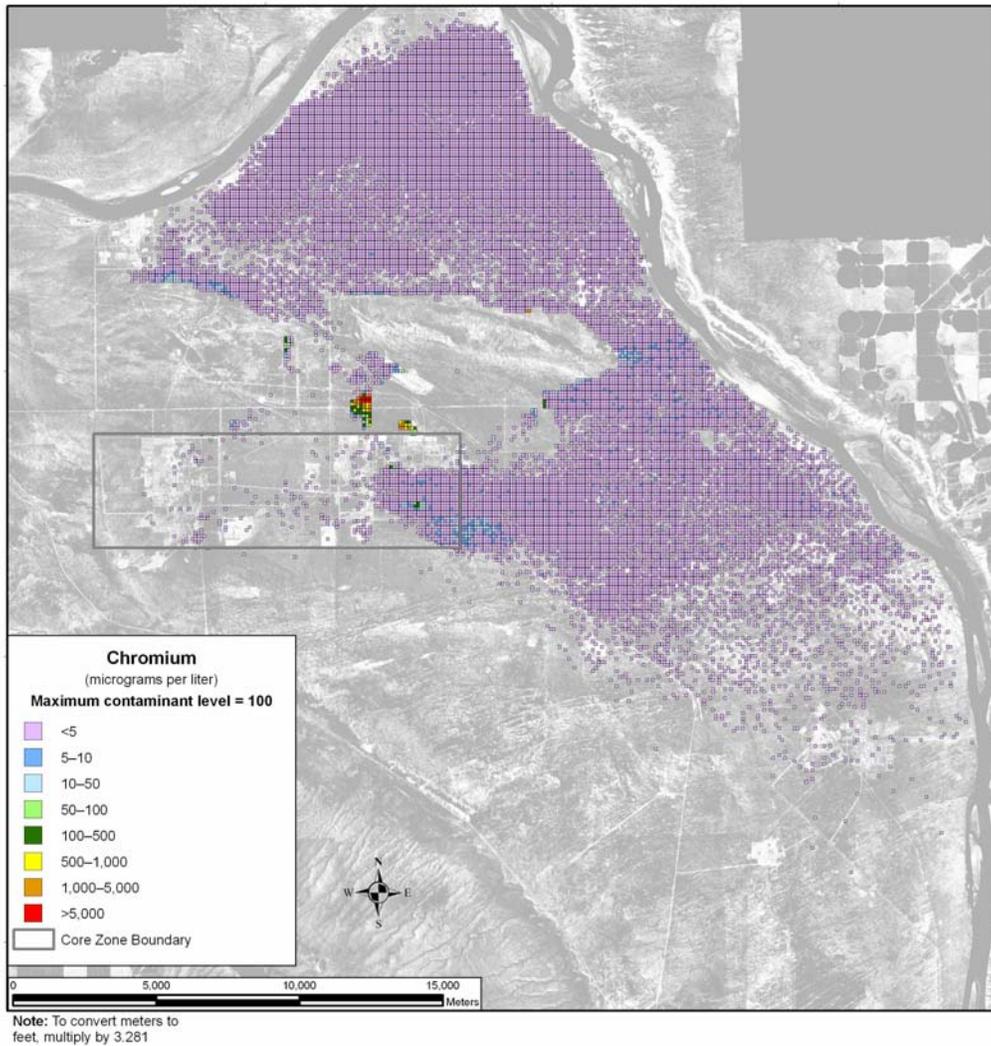


Figure 6-56. Alternative Combination 2 Spatial Distribution of Cumulative Groundwater Concentration for Chromium During Calendar Year 7140

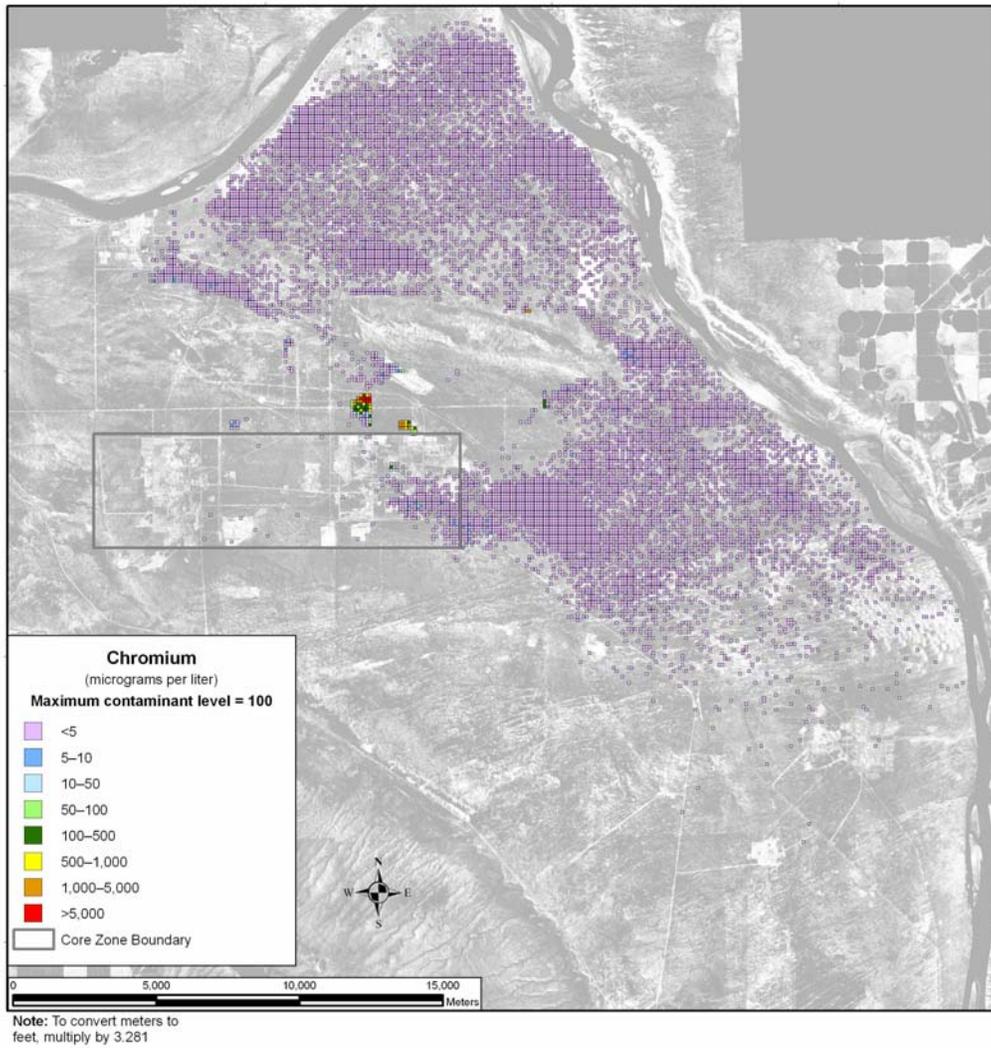


Figure 6-57. Alternative Combination 2 Spatial Distribution of Cumulative Groundwater Concentration for Chromium During Calendar Year 11,885

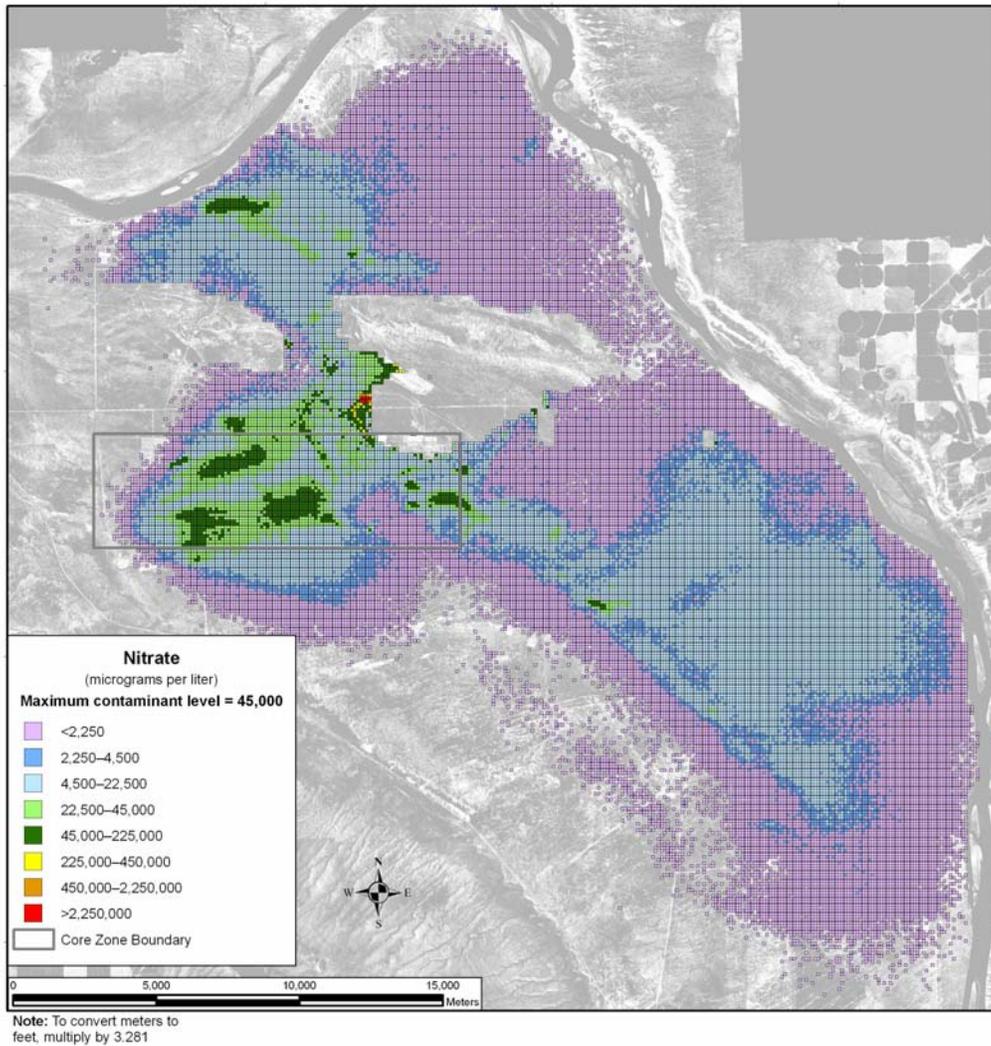


Figure 6-58. Alternative Combination 2 Spatial Distribution of Cumulative Groundwater Concentration for Nitrate During Calendar Year 2005

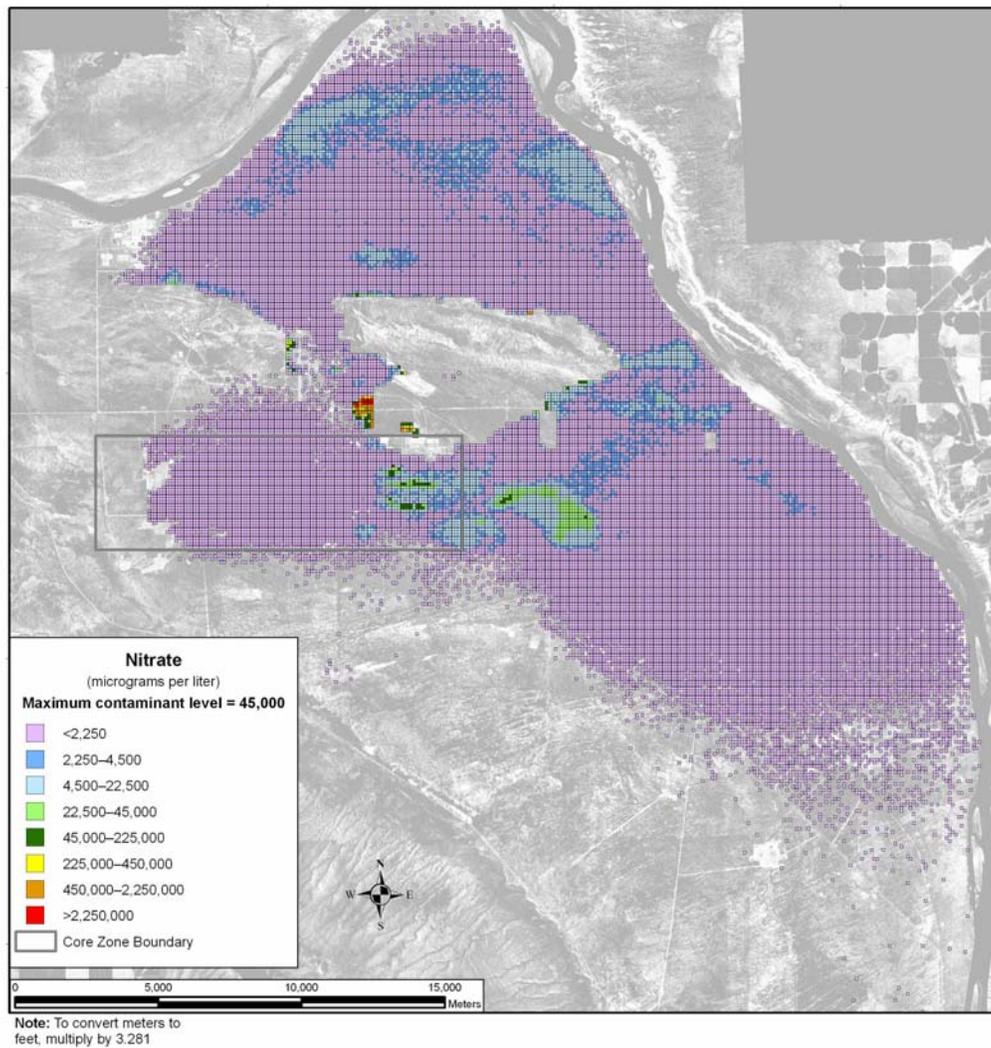


Figure 6–59. Alternative Combination 2 Spatial Distribution of Cumulative Groundwater Concentration for Nitrate During Calendar Year 3890

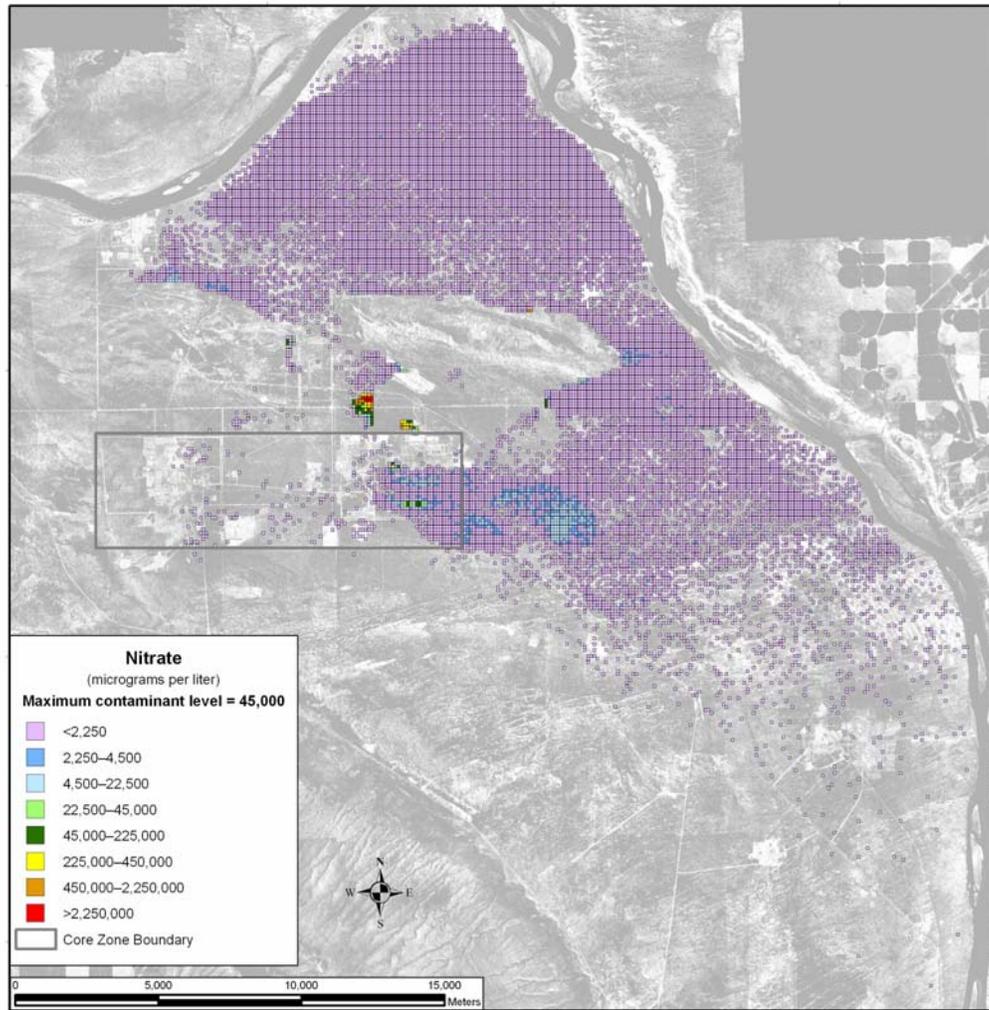


Figure 6–60. Alternative Combination 2 Spatial Distribution of Cumulative Groundwater Concentration for Nitrate During Calendar Year 7140

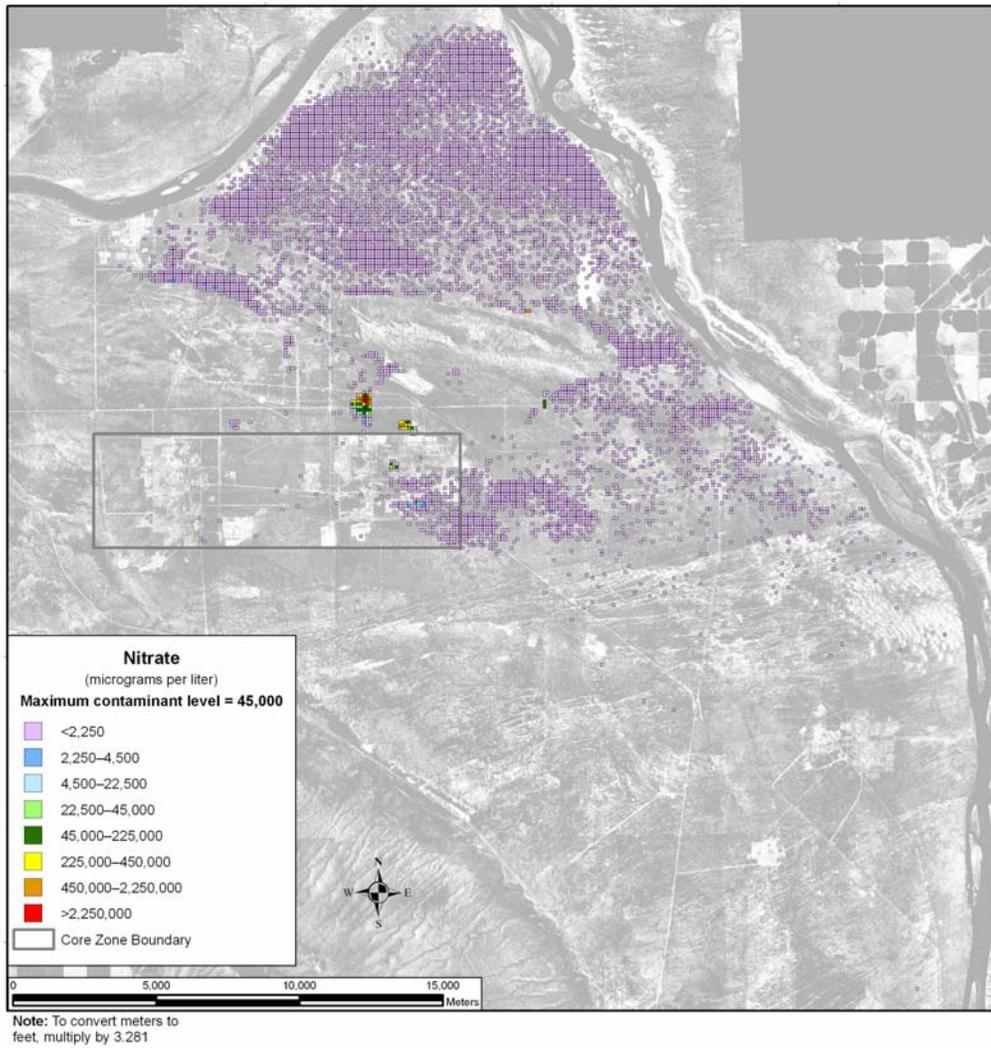


Figure 6–61. Alternative Combination 2 Spatial Distribution of Cumulative Groundwater Concentration for Nitrate During Calendar Year 11,885

The carbon tetrachloride distribution is dominated by non-TC & WM EIS sources associated with the Z Area within the 200-West Area. The spatial distribution during CY 2005, shown in Figure 6–62, is a large plume covering most of the 200-West Area, with peak concentrations over an order of magnitude greater than the benchmark concentration. Note that this model result does not include the effects of carbon tetrachloride removal and containment in the 200-West Area. Figures 6–63 and 6–64 show the dissipation of the plume over time at CY 2135 and CY 3890, respectively.

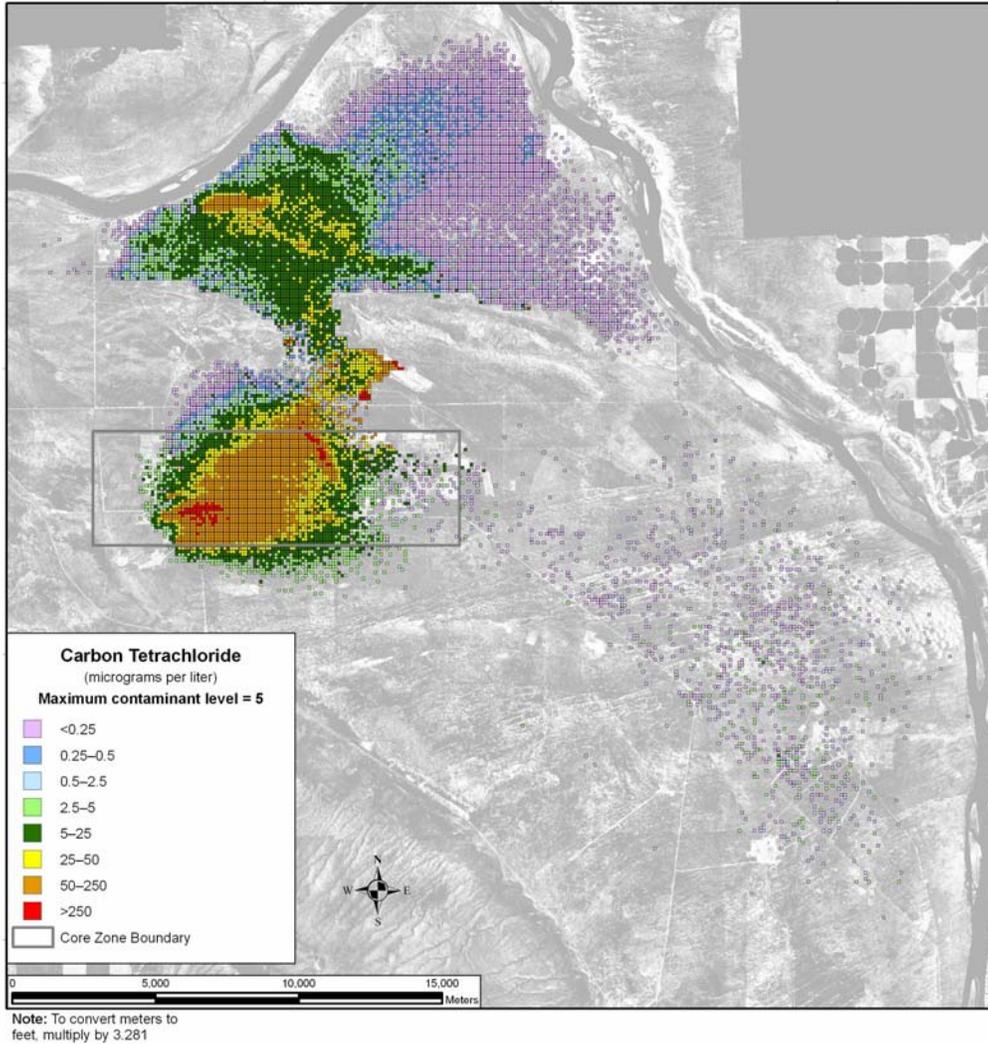


Figure 6–62. Alternative Combination 2 Spatial Distribution of Cumulative Groundwater Concentration for Carbon Tetrachloride During Calendar Year 2005

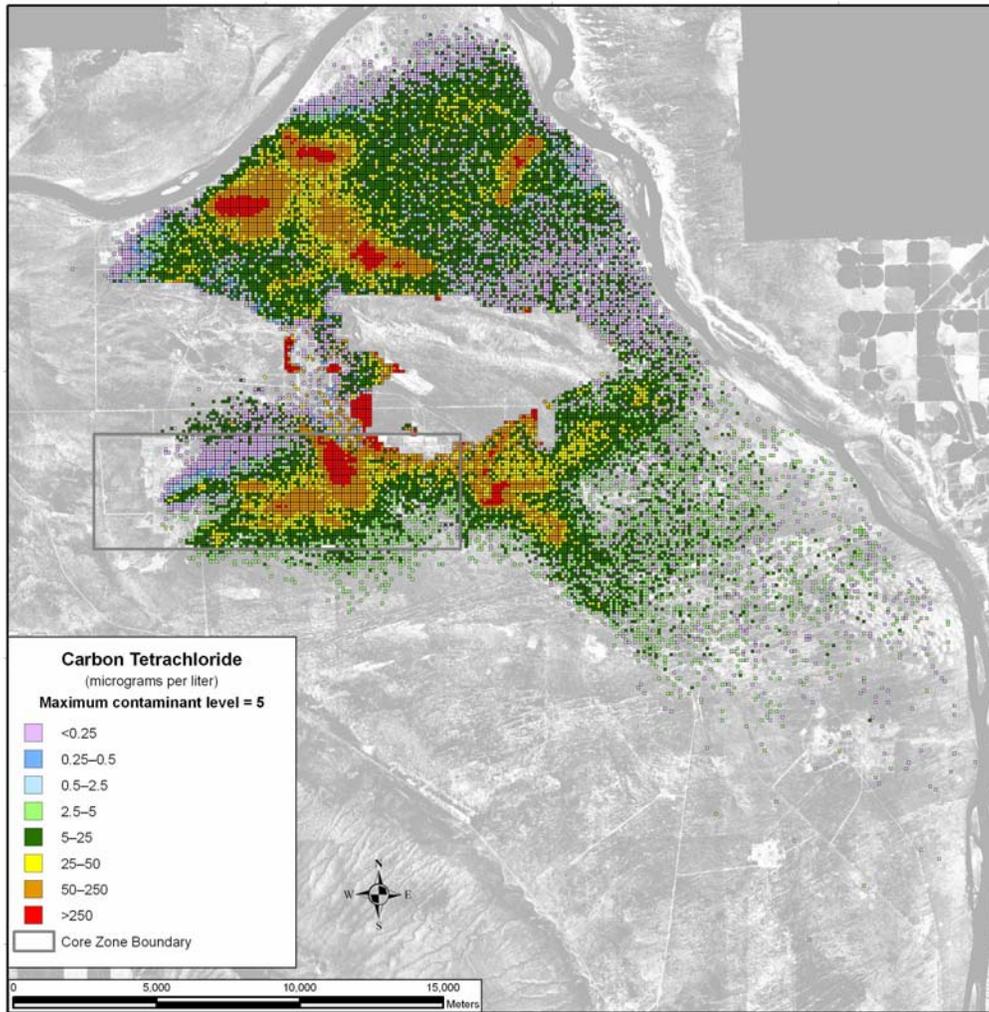


Figure 6-63. Alternative Combination 2 Spatial Distribution of Cumulative Groundwater Concentration for Carbon Tetrachloride During Calendar Year 2135

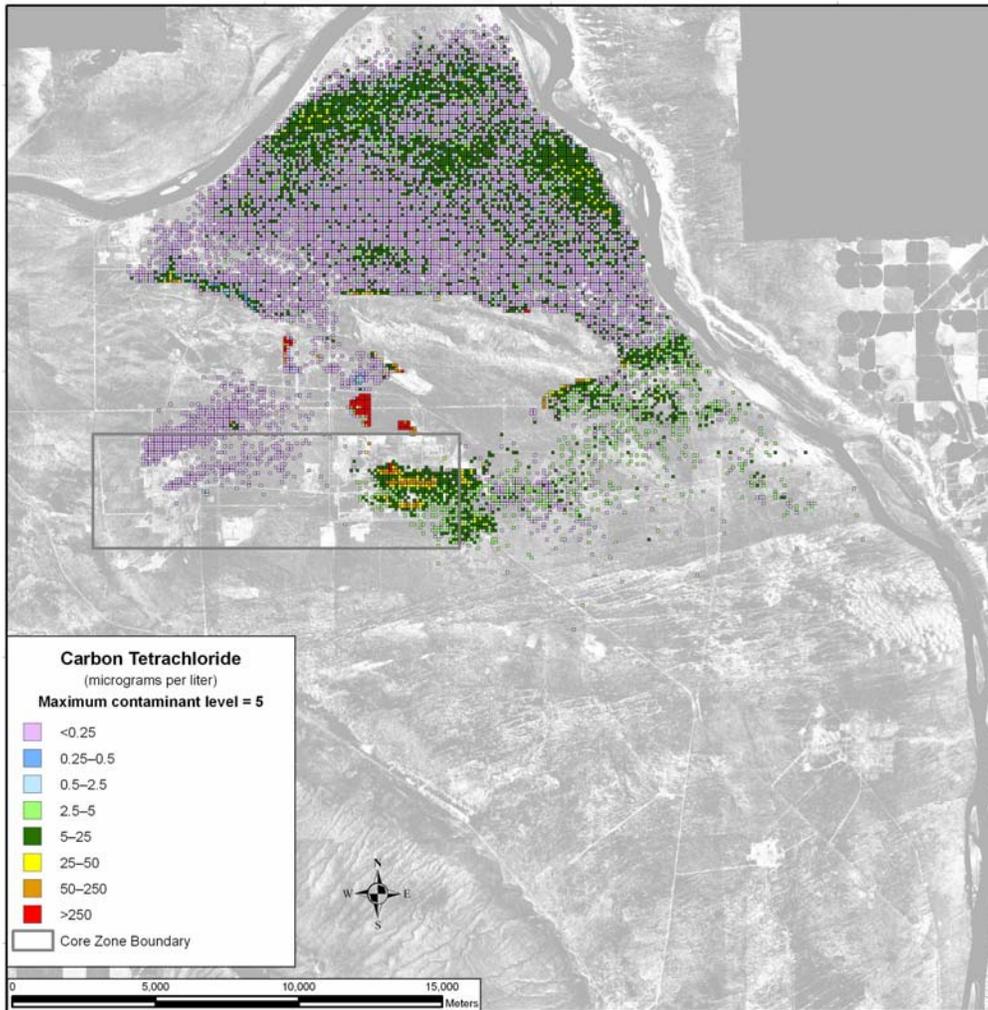


Figure 6-64. Alternative Combination 2 Spatial Distribution of Cumulative Groundwater Concentration for Carbon Tetrachloride During Calendar Year 3890

Uranium-238 and total uranium show a different spatial distribution over time. These COPCs are not as mobile as those discussed above, moving about seven times slower than the porewater velocity. As a result, travel times through the vadose zone are longer, release to the aquifer is delayed, and travel times through the aquifer to the Columbia River are longer. Figure 6–65 shows the distribution of uranium-238 during CY 2135. There are two plumes associated with releases from the ponds (non-TC & WM EIS sources) in the 200-East and 200-West Areas with peak concentrations that exceed the benchmark by an order of magnitude. By CY 3890 (see Figure 6–66) these plumes have dissipated, but releases from other tank farm sources (primarily within the A Barrier) have produced a second plume east of the Core Zone, with peak concentrations about an order of magnitude greater than the benchmark. At CY 11,885 (see Figure 6–67) the plumes from other tank farm sources have extended this plume and produced additional plumes in the 200-West Area. Figure 6–68 shows the total area for which groundwater concentrations of uranium-238 exceed the benchmark concentration as a function of time. The area of exceedance is largest early in the analysis (non-TC & WM EIS sources, primarily ponds) with an upward trend toward the end of the period of analysis (other tank farm sources). Figures 6–69 through 6–71 show the corresponding spatial distributions for total uranium.

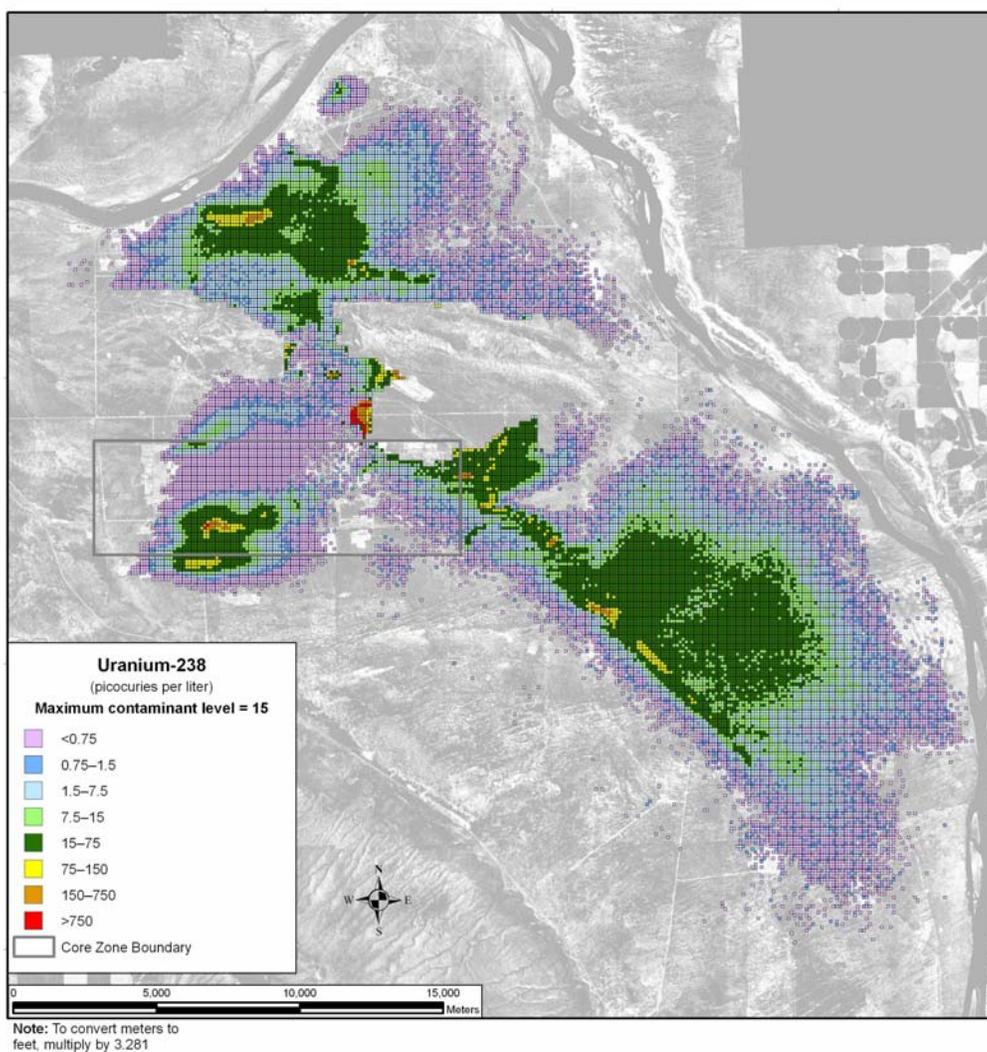


Figure 6–65. Alternative Combination 2 Spatial Distribution of Cumulative Groundwater Concentration for Uranium-238 During Calendar Year 2135

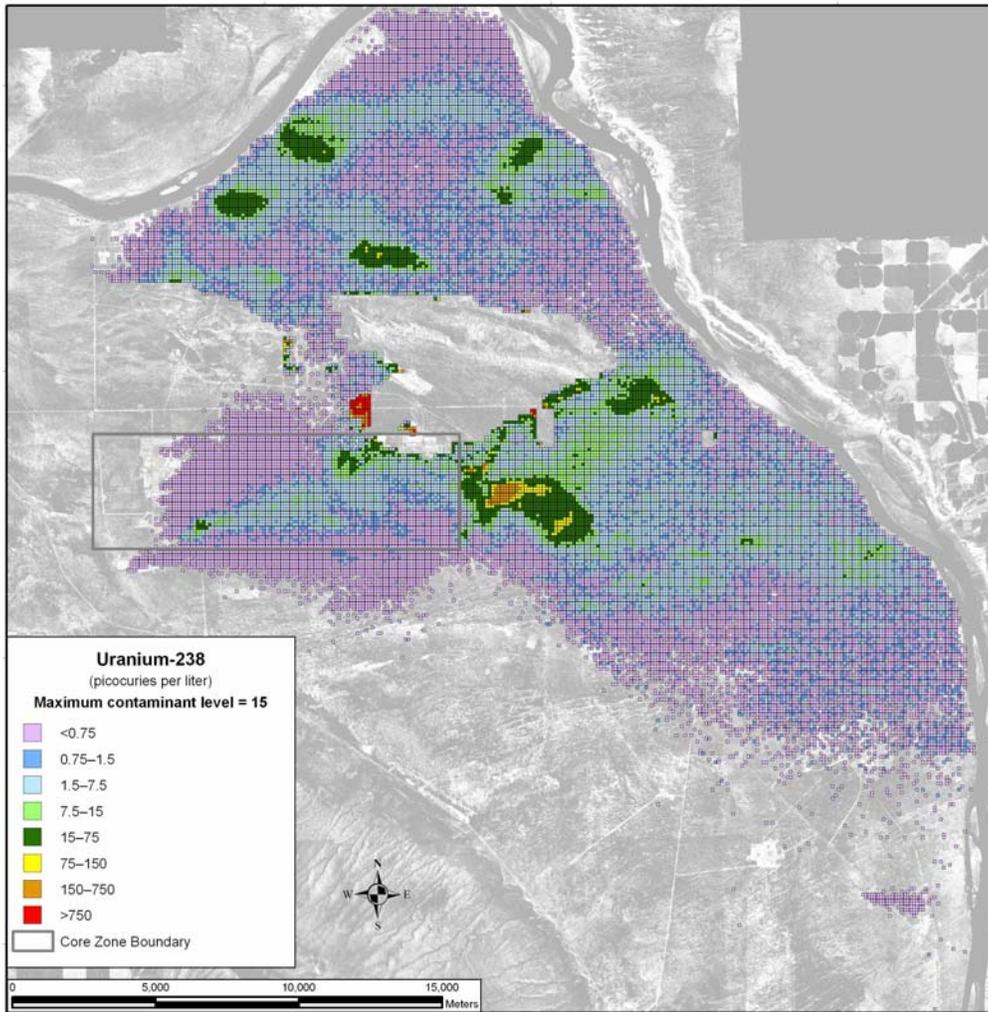


Figure 6-66. Alternative Combination 2 Spatial Distribution of Cumulative Groundwater Concentration for Uranium-238 During Calendar Year 3890

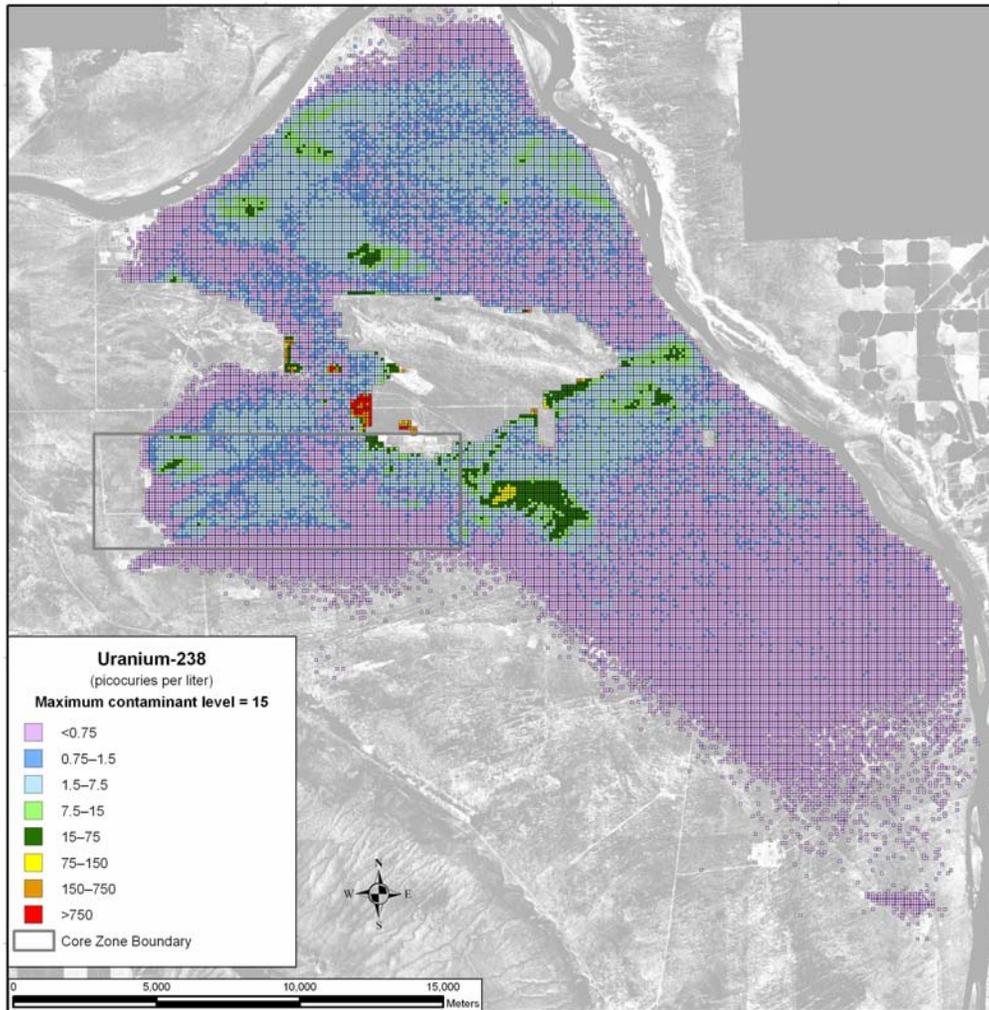


Figure 6-67. Alternative Combination 2 Spatial Distribution of Cumulative Groundwater Concentration for Uranium-238 During Calendar Year 11,885

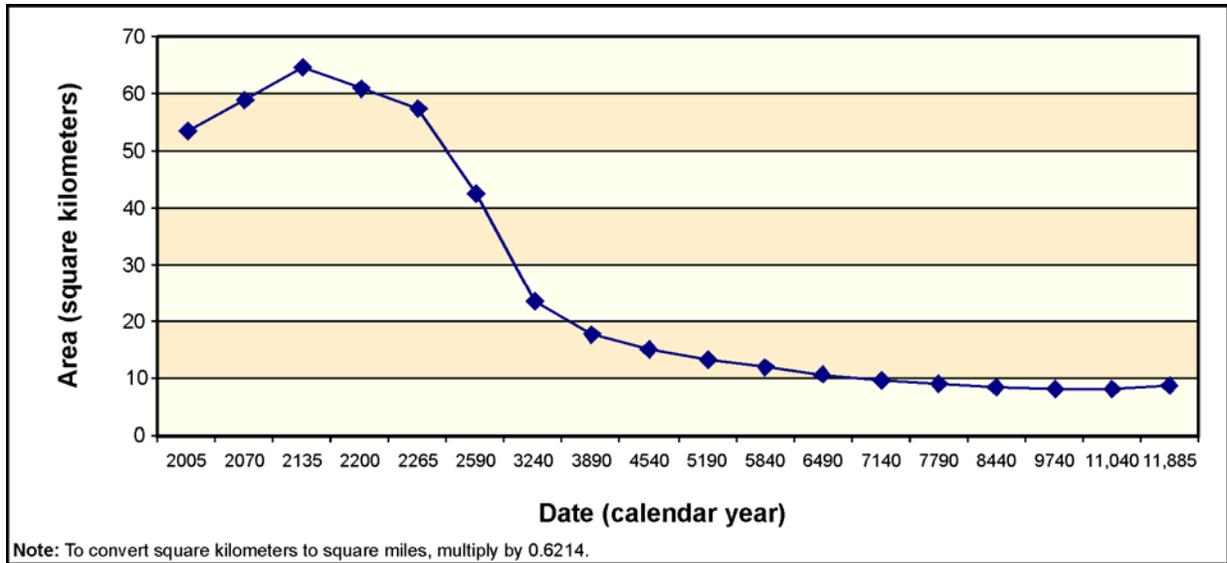


Figure 6–68. Alternative Combination 2 Total Area for Which Cumulative Groundwater Concentrations of Uranium-238 Exceed the Benchmark Concentration as a Function of Time

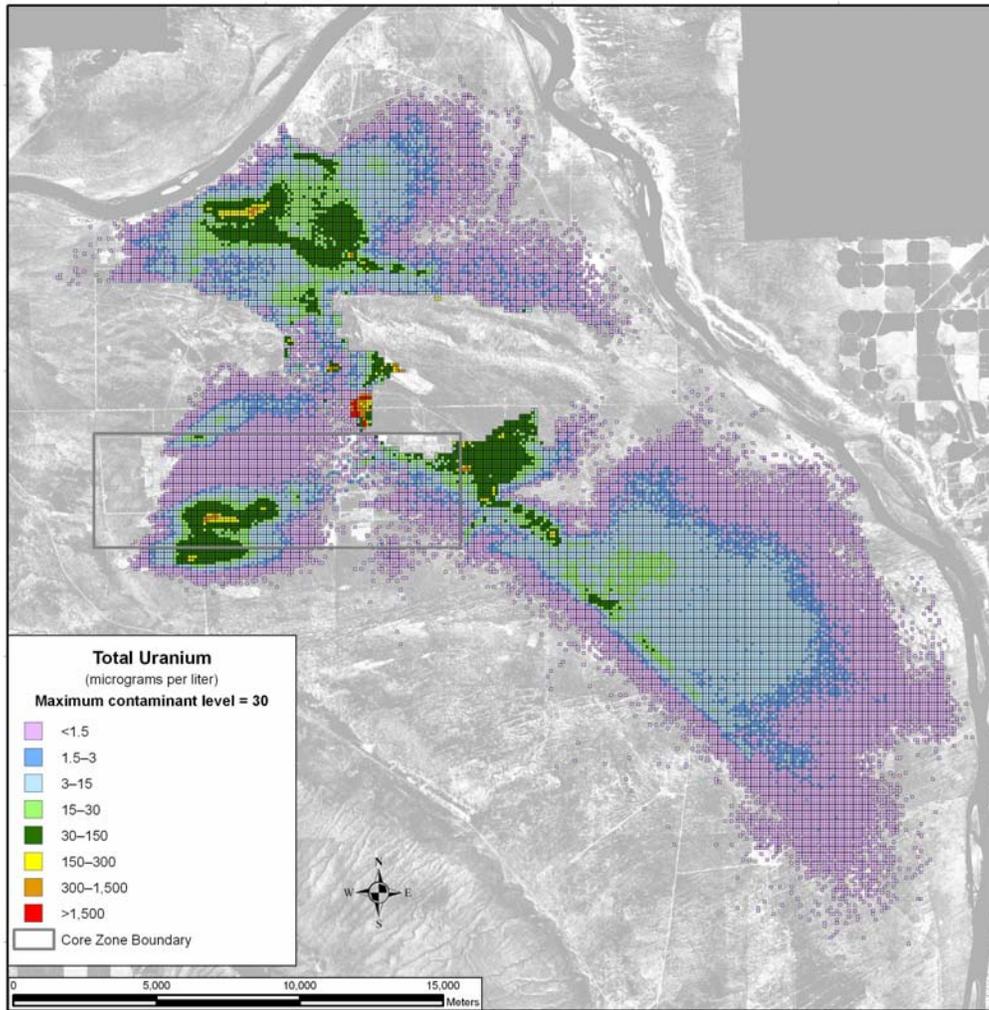


Figure 6-69. Alternative Combination 2 Spatial Distribution of Cumulative Groundwater Concentration for Total Uranium During Calendar Year 2135

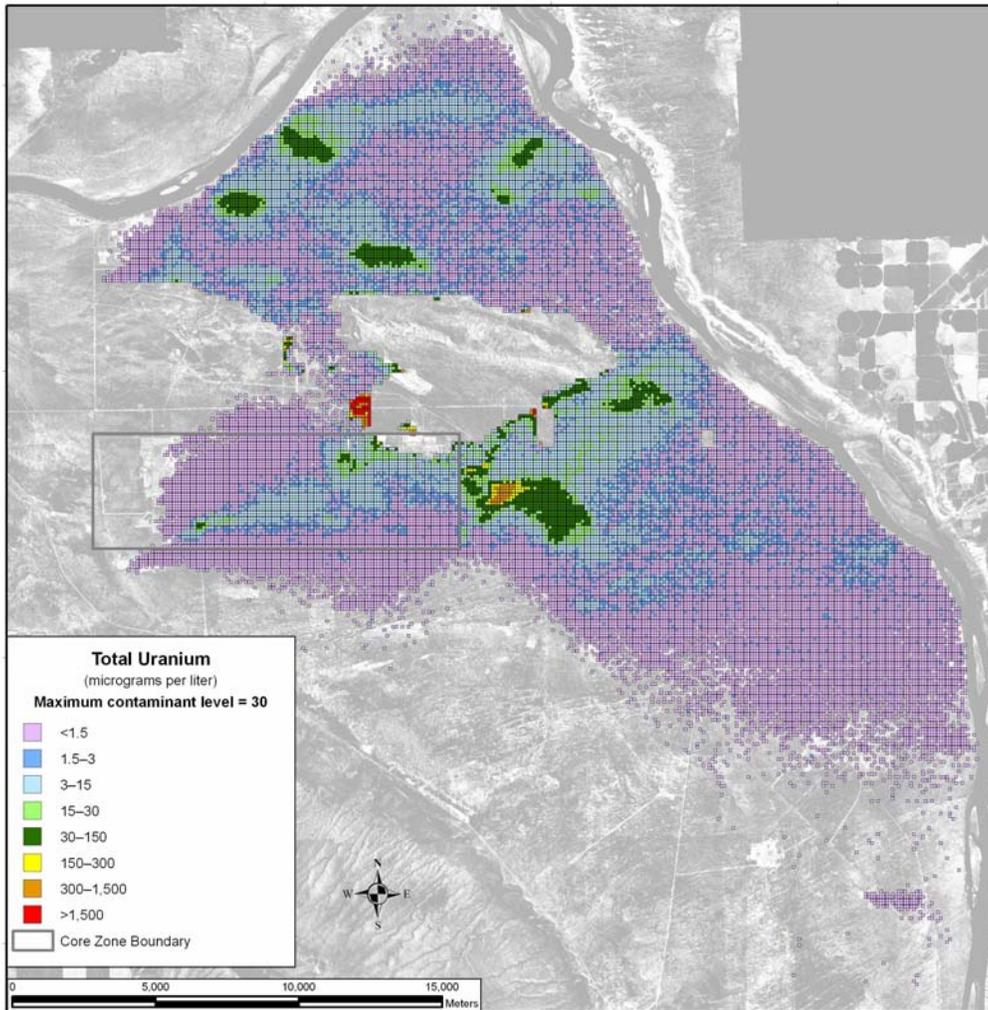


Figure 6-70. Alternative Combination 2 Spatial Distribution of Cumulative Groundwater Concentration for Total Uranium During Calendar Year 3890

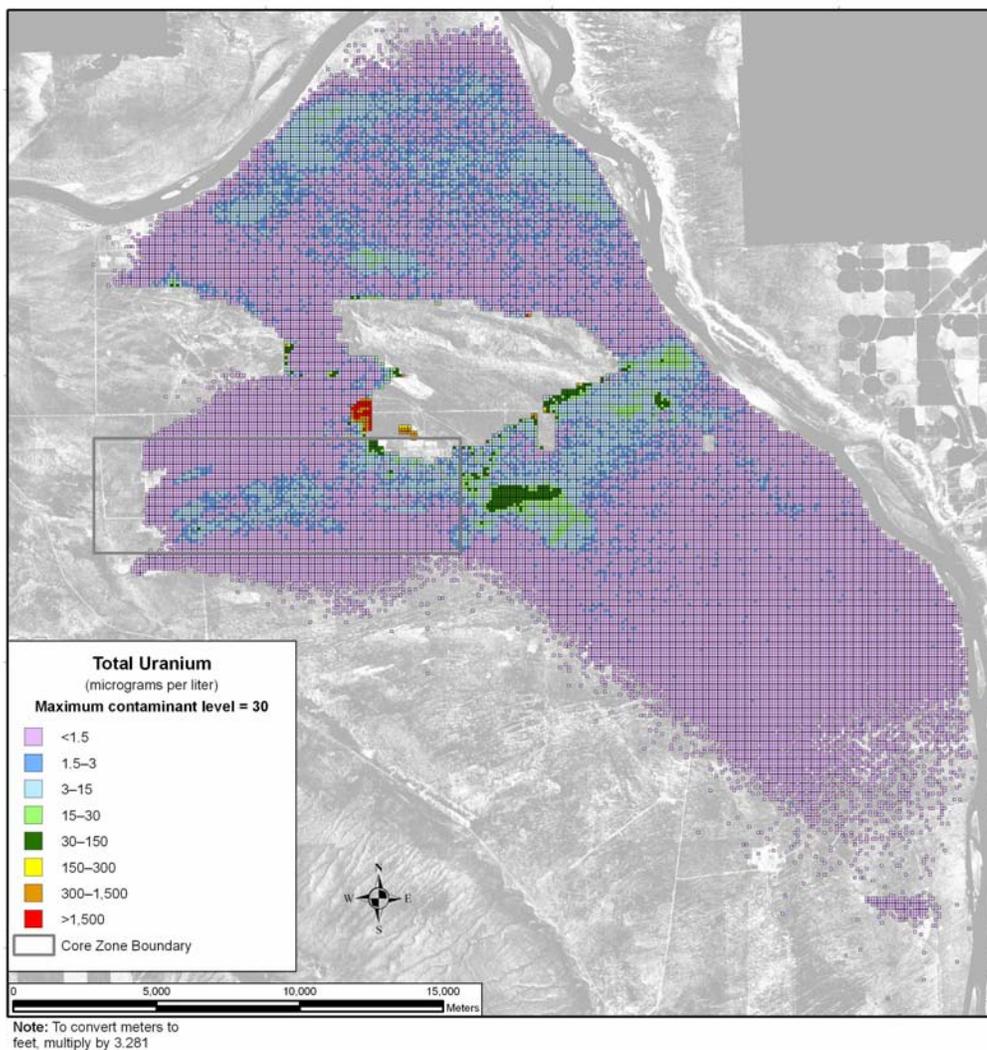


Figure 6–71. Alternative Combination 2 Spatial Distribution of Cumulative Groundwater Concentration for Total Uranium During Calendar Year 11,885

6.4.1.2.4 Summary of Impacts

The cumulative long-term impacts for Alternative Combination 2 and non-*TC & WMEIS* sources are dominated by non-*TC & WMEIS* sources (tritium, uranium-238, carbon tetrachloride, chromium, and total uranium); a combination of non-*TC & WMEIS* sources and Waste Management alternative sources (iodine-129); a combination of non-*TC & WMEIS* sources and tank closure sources (nitrate); or all three (technetium-99). Contributions from FFTF Decommissioning Alternative 2 sources account for well under 1 percent of the total amount released to the environment.

For iodine-129, technetium-99, carbon tetrachloride, chromium, and nitrate, concentrations at the Core Zone Boundary exceed benchmark standards by an order of magnitude during most of the period of analysis. Concentrations at the Columbia River are somewhat lower. The intensities and areas of these groundwater plumes peak between CY 3200 and CY 4000.

For tritium, concentrations at the Core Zone Boundary exceed the benchmark by about three orders of magnitude during the first 100 years of the period of analysis. Concentrations at the Columbia River exceed the benchmark by about two orders of magnitude during this time. Attenuation by radioactive

decay is a predominant mechanism that limits the intensity and duration of groundwater impacts by tritium. After CY 2100 tritium impacts are essentially negligible.

For uranium-238 and total uranium, discharges from the ponds (non-*TC & WM EIS* sources) are the dominant contributors during the early period of the analysis. Other tank farm sources are a secondary contributor, for which limited mobility is an important factor governing the time frames and scale of groundwater impacts.

6.4.1.3 Alternative Combination 3

This section presents the results of the cumulative long-term groundwater impacts analysis including Alternative Combination 3. This section focuses on the combined long-term groundwater impacts of Alternative Combination 3 and non-*TC & WM EIS* sources, which are discussed in Chapter 5, Section 5.4. All of the non-*TC & WM EIS* sources discussed in Appendix S are included.

This discussion of long-term impacts is focused on the following COPC drivers:

- radiological risk drivers: tritium, iodine-129, technetium-99, and uranium-238
- chemical hazard drivers: carbon tetrachloride, chromium, nitrate, and total uranium

The COPC drivers were obtained from the combination of the COPC drivers for the three individual alternatives that compose the Alternative Combination and the COPC drivers for the non-*TC & WM EIS* sources. They fall into three categories. Iodine-129, technetium-99, carbon tetrachloride, chromium, and nitrate are all mobile (i.e., move with groundwater) and long-lived (relative to the 10,000-year period of analysis) or stable. Tritium is also mobile, but short lived. The half-life of tritium is about 12.3 years, and tritium concentrations are strongly attenuated by radioactive decay during travel through the vadose zone and groundwater systems. Finally, uranium-238 and total uranium are long-lived or stable, but are not as mobile as the other COPC drivers. These constituents move about seven times more slowly than groundwater. The other COPCs that were analyzed do not significantly contribute to risk or hazard during the period of analysis because of limited inventory, high retardation factors (i.e., retention in the vadose zone), short half-lives (i.e., rapid radioactive decay), or a combination of these factors. The level of protection provided for the drinking water pathway was evaluated by comparison against the maximum contaminant levels provided in 40 CFR 141 and other benchmarks presented in Appendix O.

6.4.1.3.1 Analysis of Release and Mass Balance

This section presents the total amount of the COPC drivers released to the vadose zone, to groundwater, and to the Columbia River. Releases of radionuclides are totaled in curies, and releases of chemicals are totaled in kilograms. Both are totaled over the 10,000-year period of analysis.

Table 6–19 lists the release to the vadose zone for the COPC drivers. For Alternative Combination 3, the release to the vadose zone is controlled by a combination of inventory and waste form. For tank closure and FFTF decommissioning sources, the entire inventory was released to the vadose zone during the period of analysis. For some waste management sources (e.g., ILAW glass) some of the inventory was not released to the vadose zone during the 10,000-year period of analysis because of retention in the waste form. The release to the vadose zone for Alternative Combination 3 and non-*TC & WM EIS* sources is dominated by sources associated with non-*TC & WM EIS* sources for tritium, uranium-238, chromium, and total uranium; by non-*TC & WM EIS* and waste management sources for iodine-129; by non-*TC & WM EIS* sources and tank closure sources for nitrate; and a combination of all three types of sources for technetium-99.

Table 6–19. Alternative Combination 3 Release to Vadose Zone for COPC Drivers

	Radiological COPCs (curies)				Chemical COPCs (kilograms)		
	Hydrogen-3 (Tritium)	Iodine-129	Technetium-99	Uranium-238	Chromium ^a	Nitrate	Total Uranium
Other activities	3.43×10 ⁶	2.49×10 ¹	7.33×10 ²	3.13×10 ³	3.35×10 ⁵	7.38×10 ⁷	2.53×10 ⁵
Tank Closure Alternative 2B Base	4.59×10 ⁴	8.35×10 ⁻¹	4.53×10 ²	2.59×10 ¹	9.07×10 ⁴	2.56×10 ⁷	2.93×10 ⁴
FFTF Decommissioning Alternative 2	1.73×10 ⁻⁵	0	2.72×10 ¹	0	0	0	0
Waste Management Alternative 2 Disposal Group 1-A	6.29×10 ⁴	1.84×10 ¹	2.53×10 ³	3.30×10 ²	6.48×10 ³	9.38×10 ⁶	1.27×10 ⁴
Total	3.54×10 ⁶	4.41×10 ¹	3.75×10 ³	3.48×10 ³	4.32×10 ⁵	1.09×10 ⁸	2.95×10 ⁵

^a It was assumed, for the purposes of analysis, that all chromium was hexavalent.

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

Key: COPC=constituent of potential concern; FFTF=Fast Flux Test Facility.

Table 6–20 lists the release to groundwater for the COPC drivers. In addition to the inventory consideration discussed in the previous paragraph, release to groundwater is controlled by the transport properties of the COPC drivers and by the rate of moisture movement through the vadose zone. For iodine-129, technetium-99, chromium, and nitrate, the amount released to groundwater is essentially equal to the amount released to the vadose zone. For tritium, the amount released to groundwater is attenuated by radioactive decay during transit through the vadose zone. About 60 percent of the tritium released to the vadose zone reaches the unconfined aquifer. Because of retardation, less than 35 percent of the uranium-238 and total uranium released to the vadose zone reaches the unconfined aquifer during the period of analysis.

Table 6–20. Alternative Combination 3 Release to Groundwater for COPC Drivers

	Radiological COPCs (curies)				Chemical COPCs (kilograms)		
	Hydrogen-3 (Tritium)	Iodine-129	Technetium-99	Uranium-238	Chromium ^a	Nitrate	Total Uranium
Other activities	2.06×10 ⁶	2.48×10 ¹	7.12×10 ²	1.48×10 ²	3.40×10 ⁵	7.42×10 ⁷	1.05×10 ⁵
Tank Closure Alternative 2B Base	3.23×10 ⁴	7.49×10 ⁻¹	4.08×10 ²	7.31×10 ⁻¹	9.27×10 ⁴	2.64×10 ⁷	2.42×10 ²
FFTF Decommissioning Alternative 2	2.58×10 ⁻⁸	0	2.62×10 ¹	0	0	0	0
Waste Management Alternative 2 Disposal Group 1-A	0	1.68×10 ¹	2.27×10 ³	2.68×10 ⁻⁷	6.46×10 ³	9.36×10 ⁶	4.64×10 ⁻⁴
Total	2.09×10 ⁶	4.23×10 ¹	3.42×10 ³	1.49×10 ²	4.39×10 ⁵	1.10×10 ⁸	1.05×10 ⁵

^a It was assumed, for the purposes of analysis, that all chromium was hexavalent.

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

Key: COPC=constituent of potential concern; FFTF=Fast Flux Test Facility.

Table 6–21 lists the release to the Columbia River for the COPC drivers. Release to the Columbia River is controlled by the transport properties of the COPC drivers in the unconfined aquifer. For iodine-129, technetium-99, chromium, and nitrate, the amount released to Columbia River is essentially equal to the amount released to groundwater. For tritium, the amount released to the Columbia River is attenuated by radioactive decay. Overall, only about 5 percent of the tritium released to groundwater reaches the Columbia River. Because of retardation, about 90 percent of the uranium-238 and total uranium released to groundwater during the period of analysis reaches the Columbia River.

Table 6–21. Alternative Combination 3 Release to Columbia River for COPC Drivers

	Radiological COPCs (curies)				Chemical COPCs (kilograms)		
	Hydrogen-3 (Tritium)	Iodine-129	Technetium-99	Uranium-238	Chromium ^a	Nitrate	Total Uranium
Other activities	1.11×10 ⁵	2.46×10 ¹	7.26×10 ²	1.40×10 ²	3.51×10 ⁵	7.47×10 ⁷	9.28×10 ⁴
Tank Closure Alternative 2B Base	8.70×10 ²	7.23×10 ⁻¹	3.94×10 ²	2.44×10 ⁻¹	9.23×10 ⁴	2.63×10 ⁷	7.87×10 ¹
FFTF Decommissioning Alternative 2	0	0	2.72×10 ¹	0	0	0	0
Waste Management Alternative 2 Disposal Group 1-A	0	1.63×10 ¹	2.20×10 ³	0	6.22×10 ³	9.21×10 ⁶	3.05×10 ⁻⁵
Total	1.12×10 ⁵	4.16×10 ¹	3.35×10 ³	1.40×10 ²	4.50×10 ⁵	1.10×10 ⁸	9.29×10 ⁴

^a It was assumed, for the purposes of analysis, that all chromium was hexavalent.

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

Key: COPC=constituent of potential concern; FFTF=Fast Flux Test Facility.

6.4.1.3.2 Analysis of Concentration Versus Time

This section presents the contaminant concentrations in groundwater versus time at the Core Zone Boundary and the Columbia River. Because of the discrete nature of the concentration carried across a barrier or the river, a line denoting the 95th percentile upper confidence limit of the concentration is included on several of these graphs. This confidence interval was calculated to aid in interpreting data with a significant amount of random fluctuation (noise). The confidence interval was calculated when: the concentration had a reasonable degree of noise, the concentration trend was level, and the concentrations were near the benchmark. The benchmark concentration for each radionuclide and chemical is also shown. Note that the concentrations are plotted on a logarithmic scale to facilitate visual comparison of concentrations that vary over five orders of magnitude. Table 6–22 lists the maximum concentrations for the COPCs at the peak year for the Core Zone Boundary and the Columbia River nearshore.

Table 6–22. Alternative Combination 3 Maximum Concentrations for COPCs^a

Contaminant	Core Zone Boundary	Columbia River Nearshore	Benchmark Concentration ^b
Radionuclide (picocuries per liter)			
Hydrogen-3 (Tritium)	104,000,000 (1996)	4,190,000 (1986)	20,000
Carbon-14	46,700 (1998)	196 (2013)	2,000
Strontium-90	181,000 (1998)	4,160,000 (1991)	8
Technetium-99	144,000 (1956)	2,870 (1999)	900
Iodine-129	190 (1956)	9.4 (4540)	1
Cesium-137	0 ^c (1997)	1,310,000 (1985)	200
Uranium isotopes (includes U-233, -234, -235, -238)	2,200 (1991)	22,400 (1973)	15

Table 6–22. Alternative Combination 3 Maximum Concentrations for COPCs^a (continued)

Contaminant	Core Zone Boundary	Columbia River Nearshore	Benchmark Concentration ^b
Radionuclide (picocuries per liter) (continued)			
Neptunium-237	114	16	15
	(2066)	(2004)	
Plutonium isotopes (includes Pu-239, -240)	2,660	4,250	15
	(11,848)	(2983)	
Chemical (microgram per liter)			
1-Butanol	17,200	49	3,600
	(1998)	(11243)	
Carbon tetrachloride	3,350	60.7	5
	(2270)	(2527)	
Chromium ^d	28,800	16,100	100
	(1956)	(1978)	
Dichloromethane	0.7	0.1	5
	(3286)	(4711)	
Fluoride	90,200	14,500	4,000
	(2003)	(1982)	
Hydrazine/Hydrazine Sulfate	0.030	0.088	0.022
	(3343)	(3627)	
Lead	0 ^c	9,080	15
	(2021)	(2374)	
Manganese	392	242	1,600
	(8610)	(2286)	
Mercury	183	25.5	2
	(2015)	(1997)	
Nickel (soluble salts)	0 ^c	8,310	700
	(11871)	(3877)	
Nitrate	13,100,000	505,000	45,000
	(1956)	(1973)	
Total Uranium	3,290	15,400	30
	(1991)	(1964)	
Trichloroethylene (TCE)	0.1	0.2	5
	(3404)	(3764)	

^a The peak cumulative concentration for some constituents occurs in the past. The relationship of past to future cumulative constituent concentrations is presented in the time versus concentration plots in Figures 6–72 through 6–79.

^b The sources of the benchmark concentrations are provided in Appendix O, Section O.3.

^c Values that are less than 0.001 are reported as zero.

^d It was assumed, for the purposes of analysis, that all chromium was hexavalent.

Note: To convert from liters to gallons, multiply by 0.26417.

Key: COPC=constituent of potential concern.

Figure 6–72 shows concentration versus time for tritium. Note that for visual clarity, the time period shown on this figure is from 1940 through 2540 rather than the full 10,000-year period of analysis. Concentrations at the Core Zone Boundary exceed the benchmark concentration by about three orders of magnitude for a short period of time during the early part of the period of analysis. During this time groundwater concentrations at the Columbia River nearshore peak at about two orders of magnitude above the benchmark concentration. Because the half-life of tritium is less than 13 years, radioactive decay rapidly attenuates groundwater concentration, and tritium is essentially not a factor at times later than CY 2100.

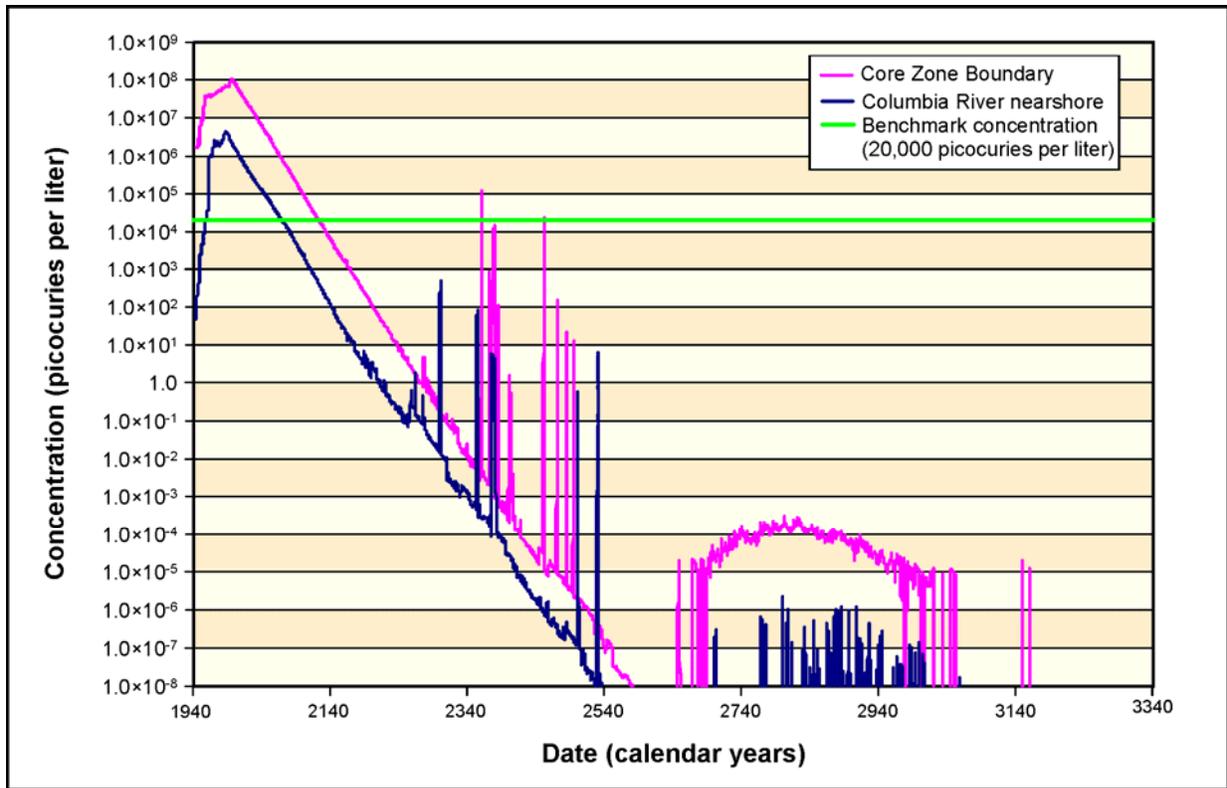


Figure 6-72. Alternative Combination 3 Cumulative Concentration Versus Time for Tritium

Figures 6–73 through 6–77 show concentration versus time for iodine-129, technetium-99, carbon tetrachloride, chromium, and nitrate. Groundwater concentrations of iodine-129 exceed benchmark concentrations by more than an order of magnitude during the first several thousand years of the analysis. During this time groundwater concentrations at the Columbia River nearshore exceed the benchmark concentration by about an order of magnitude. During later times in the analysis the concentrations are on the same order of magnitude as the benchmark at the Core Zone Boundary and the Columbia River nearshore. Technetium-99, carbon tetrachloride, chromium, and nitrate concentrations show a similar curve, with technetium-99, chromium and nitrate concentrations at the Columbia River nearshore dropping below the benchmark concentrations.

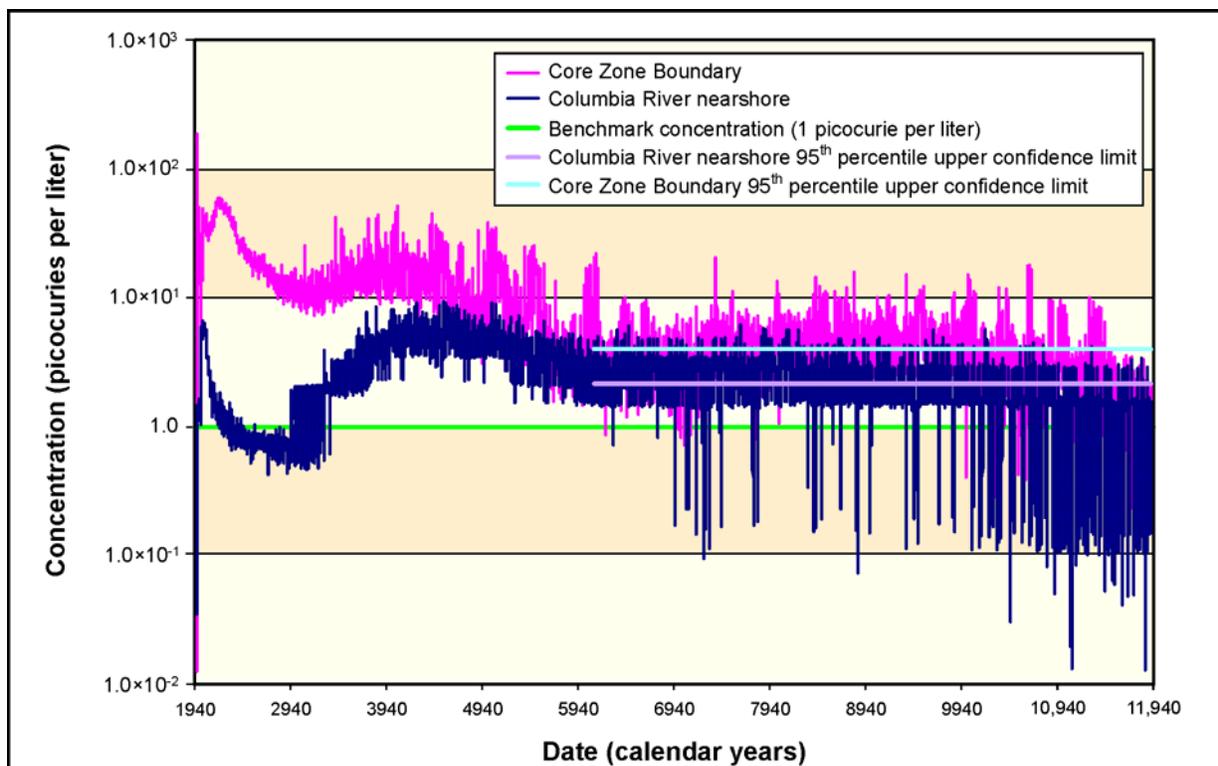


Figure 6–73. Alternative Combination 3 Cumulative Concentration Versus Time for Iodine-129

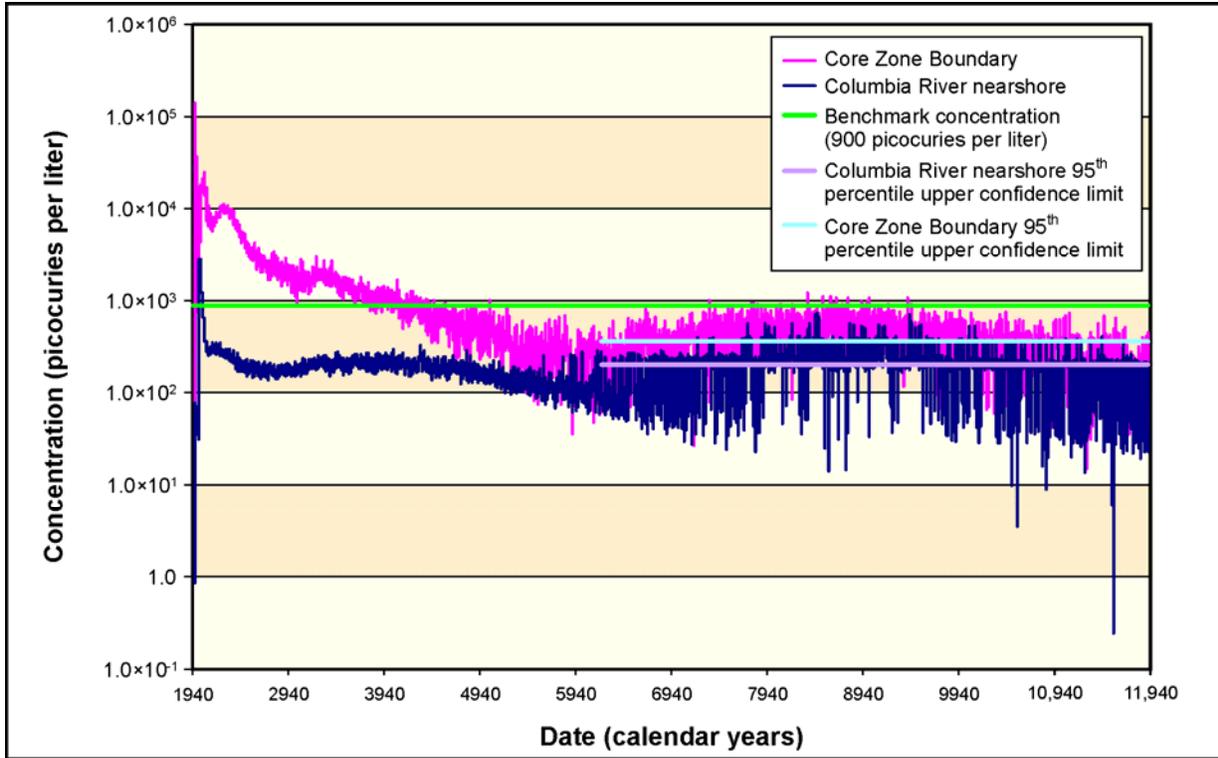


Figure 6-74. Alternative Combination 3 Cumulative Concentration Versus Time for Technetium-99

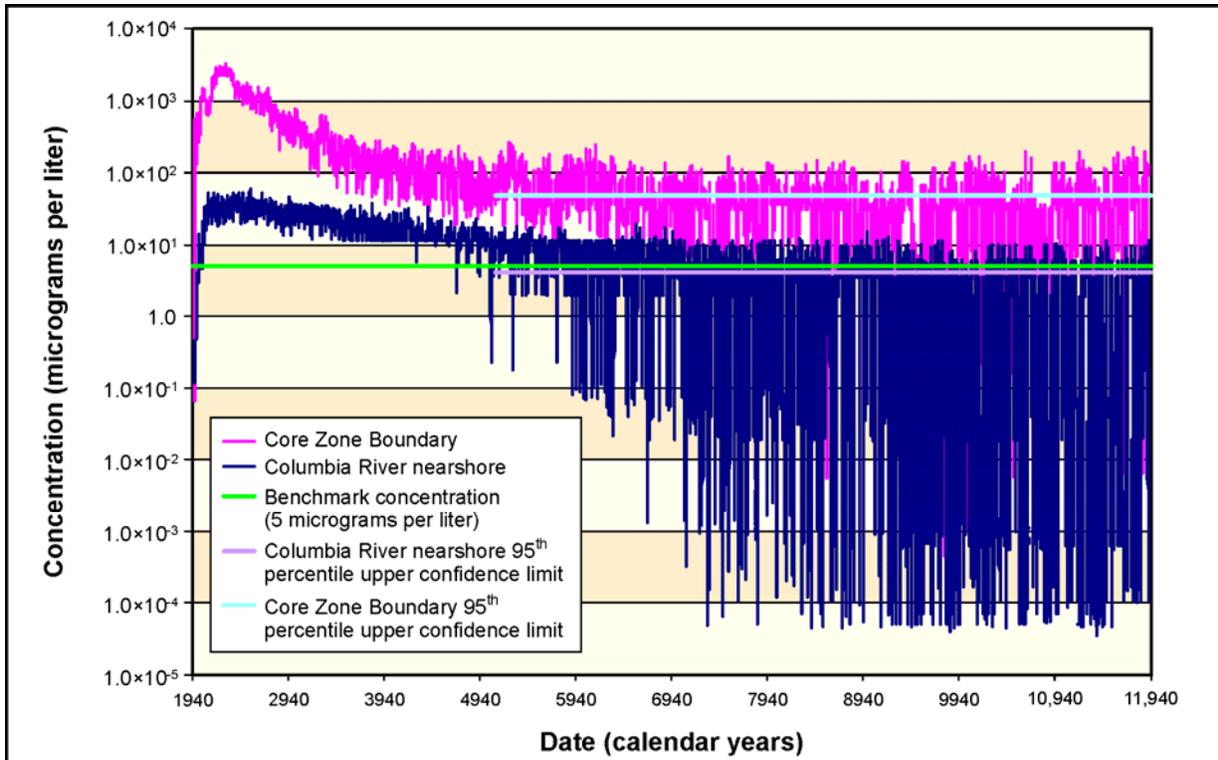


Figure 6-75. Alternative Combination 3 Cumulative Concentration Versus Time for Carbon Tetrachloride

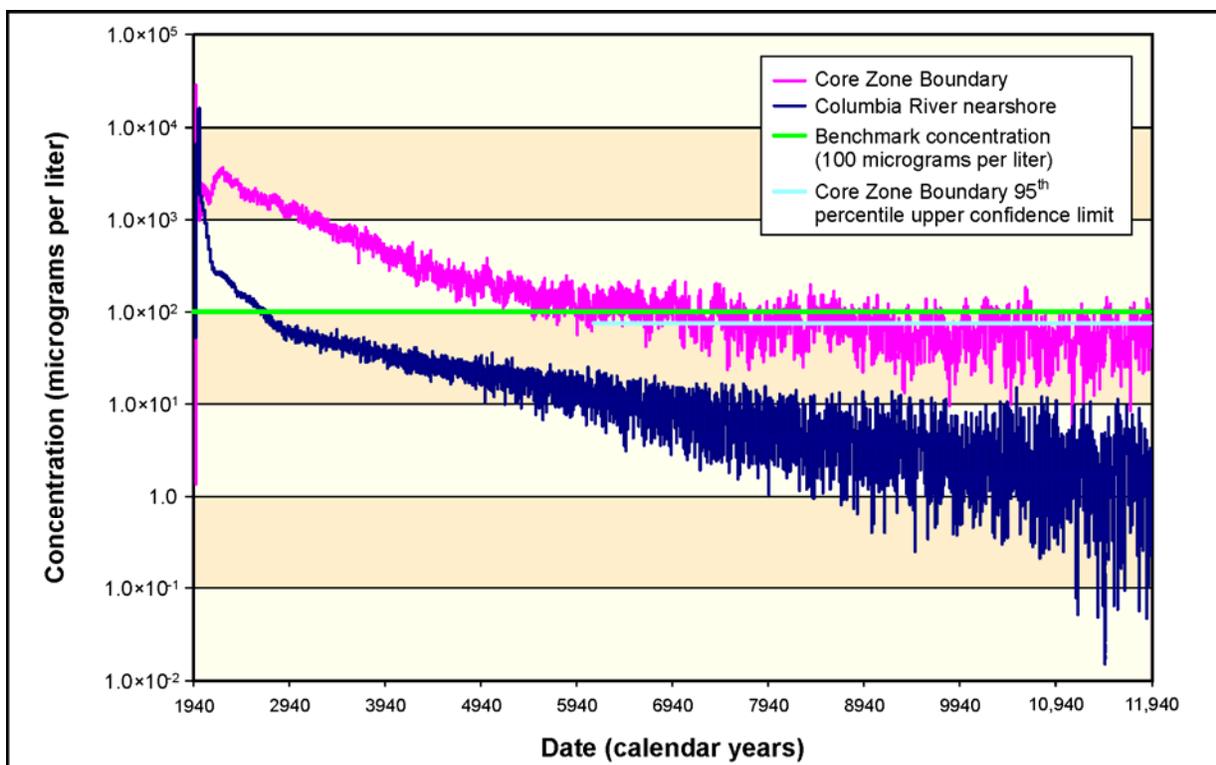


Figure 6–76. Alternative Combination 3 Cumulative Concentration Versus Time for Chromium

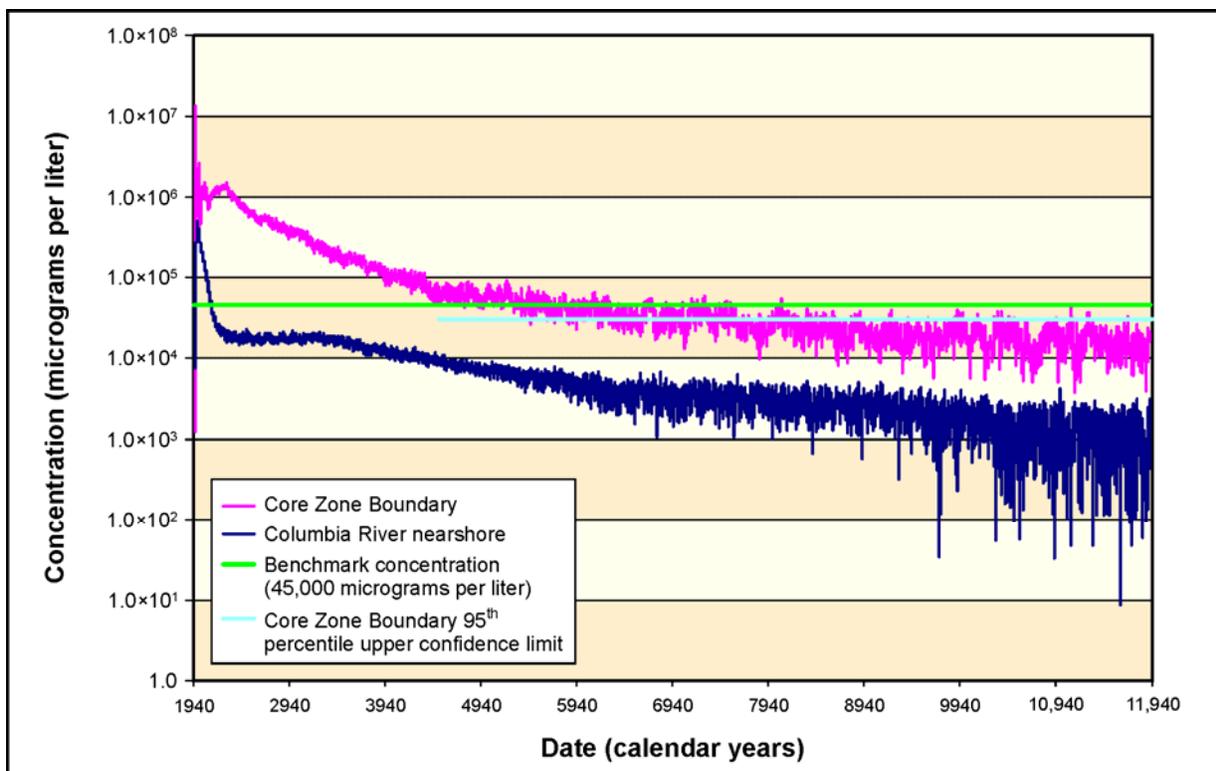


Figure 6–77. Alternative Combination 3 Cumulative Concentration Versus Time for Nitrate

Figures 6–78 and 6–79 show concentration versus time for uranium-238 and total uranium. Concentrations of uranium-238 and total uranium peak early in the period of analysis, and then maintain relatively constant for the remainder of the period of analysis. The travel times of these COPCs from the source locations to the Core Zone Boundary and Columbia River is slowed relative to groundwater flow by a factor of about seven. After about 1,000 years, concentrations of both uranium-238 and total uranium exceed the benchmark concentration at the Core Zone Boundary by about an order of magnitude. Groundwater concentrations at the Columbia River nearshore remain within an order of magnitude of the benchmark during this time.

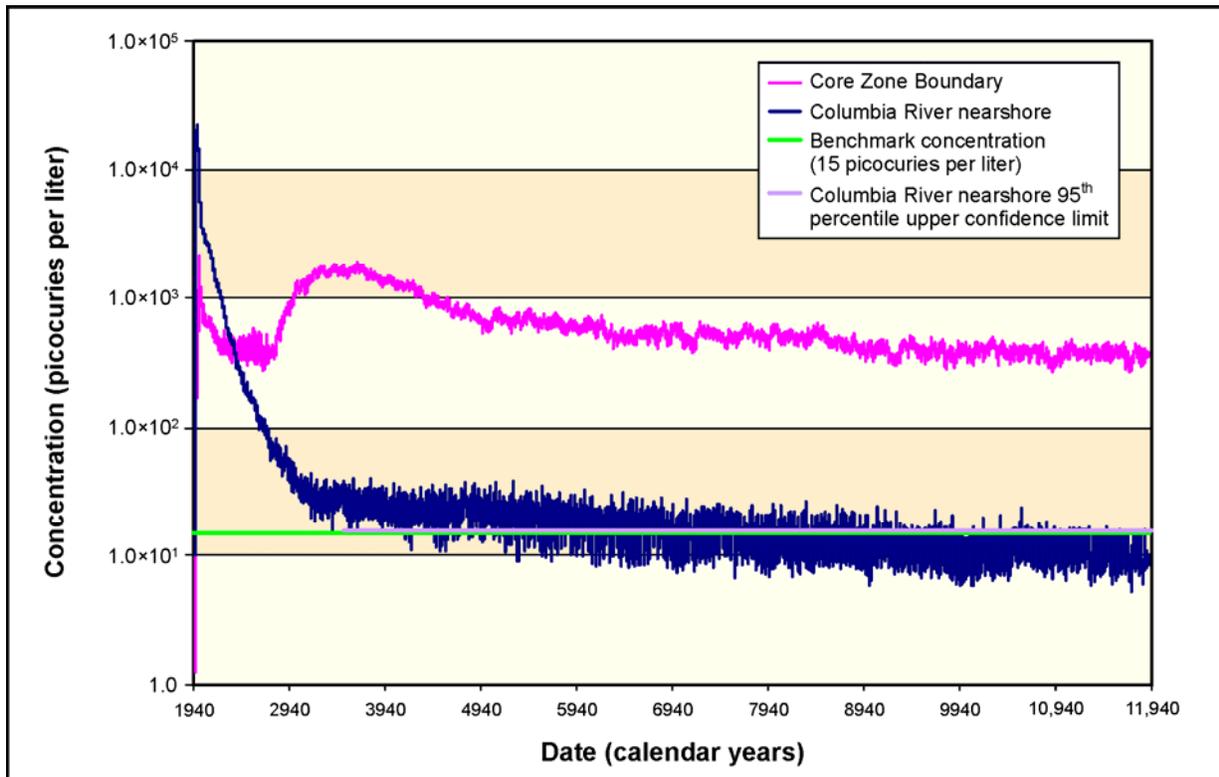


Figure 6–78. Alternative Combination 3 Cumulative Concentration Versus Time for Uranium-238

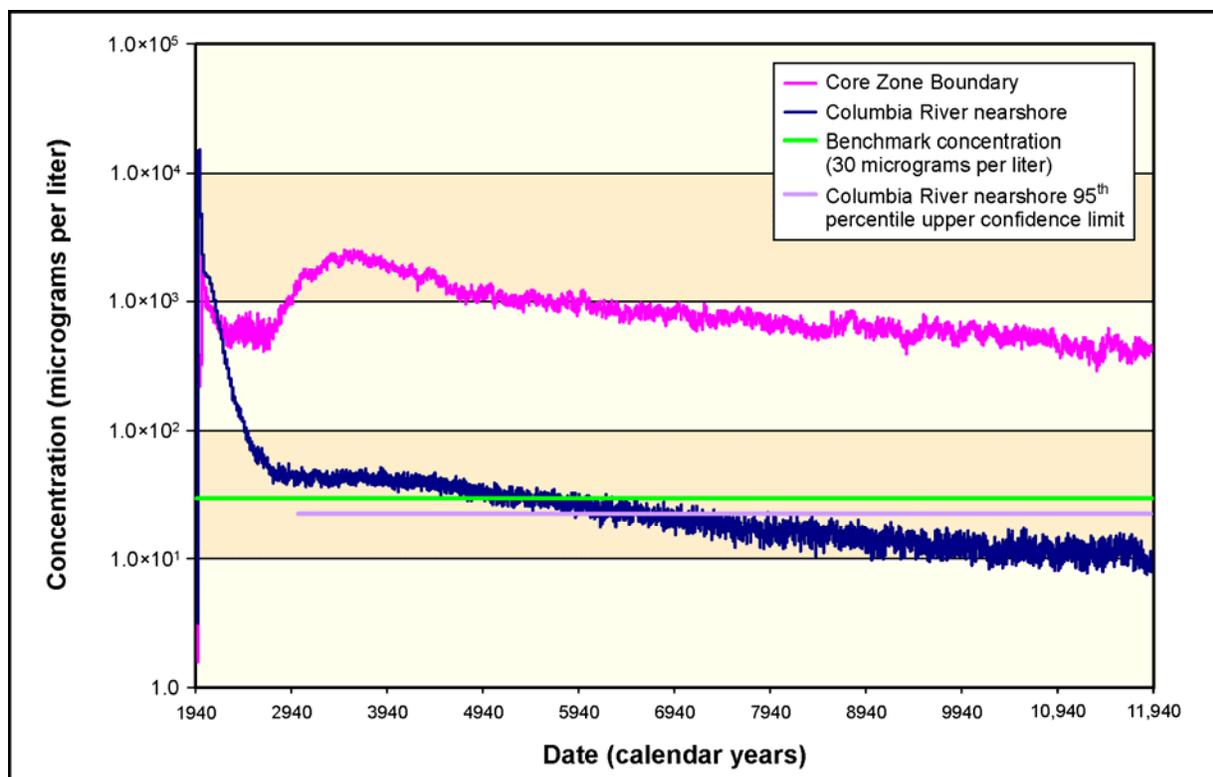


Figure 6–79. Alternative Combination 3 Cumulative Concentration Versus Time for Total Uranium

6.4.1.3.3 Analysis of Spatial Distribution of Concentration

This section presents the spatial distribution of groundwater concentrations at selected times. Concentrations for each radionuclide and chemical are indicated by a color scale which is relative to the benchmark concentration. Concentrations greater than the benchmark concentration are indicated the fully saturated colors green, yellow, orange, and red in order of increasing concentration. Concentrations less than the benchmark concentration are indicated the faded colors green, blue, indigo, and violet in order of decreasing concentration. Note that the concentrations ranges are on a logarithmic scale to facilitate visual comparison of concentrations that vary over three orders of magnitude.

Figure 6–80 shows the spatial distribution of groundwater concentration for tritium during CY 2005. Releases from cribs and trenches (ditches), primarily associated with non-TC & WM EIS sources within the PUREX Plant and the REDOX Facility areas, result in groundwater concentration plumes (exceeding the benchmark concentration) that extend from the southern part of the 200-West Area across the Core Zone, and extending from the eastern part of the Core Zone southeast to the Columbia River. Peak concentrations in this plume are about ten to fifty times greater than the benchmark. Tritium concentrations are attenuated by radioactive decay to levels less than one twentieth of the benchmark concentration by CY 2135.

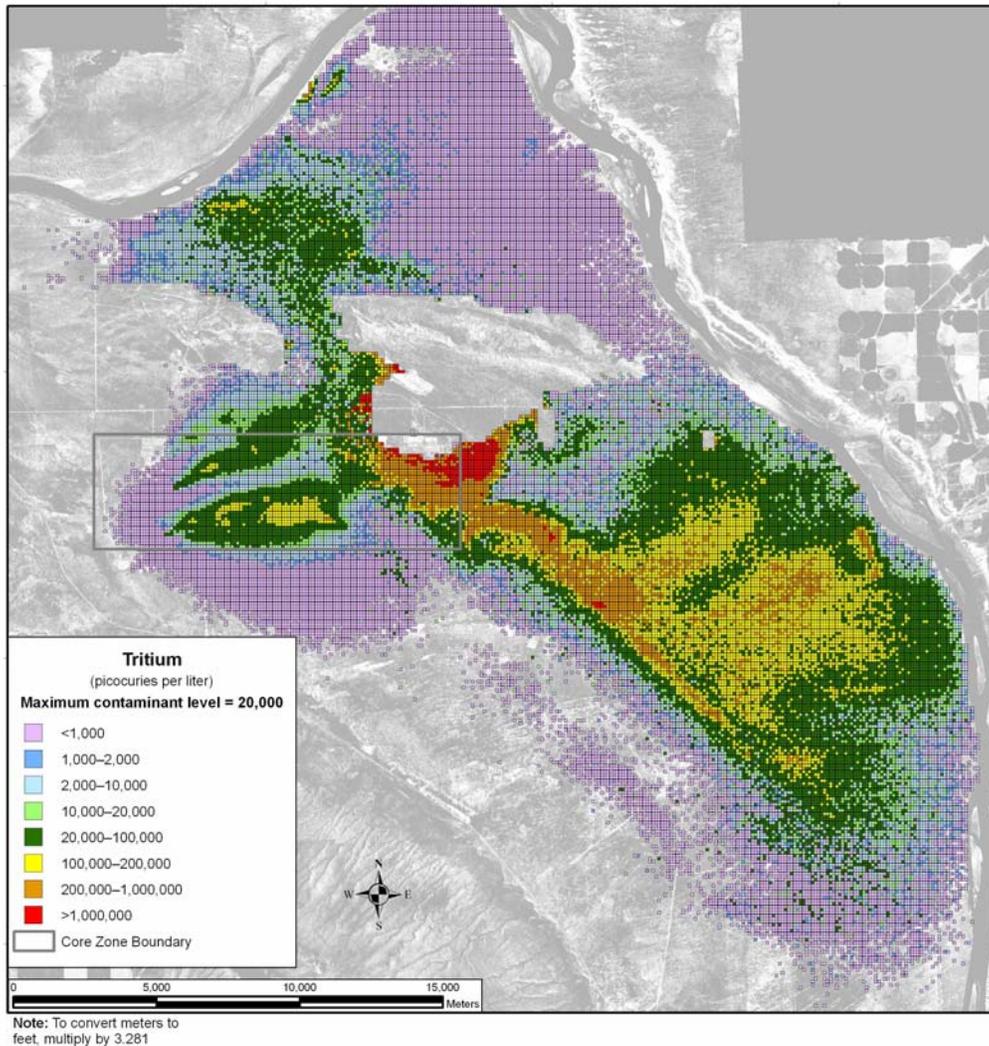


Figure 6–80. Alternative Combination 3 Spatial Distribution of Cumulative Groundwater Concentration for Tritium During Calendar Year 2005

Figure 6–81 shows the spatial distribution of groundwater concentration for iodine-129 during CY 2005. Releases from cribs and trenches (ditches) and past leaks result in groundwater concentration plumes that exceeding the benchmark concentration associated with the T Barrier, the B Barrier, and the A Barrier. Peak concentrations in this plume are about 10 to 50 times greater than the benchmark, and mostly contained within the Core Zone. Releases from the PUREX Plant area (non-TC & WM EIS sources) produce a plume extending south and east of the Core Zone with peak concentrations about 1 to 5 times the benchmark concentration. Around CY 3890 releases from other tank farm sources create an iodine-129 plume east of the Core Zone Boundary (see Figure 6–82). By CY 7140 the groundwater concentration distribution is driven primarily by waste management sources located at the IDF in the 200-East Area (see Figure 6–83). The impact is characterized by a plume exceeding the benchmark concentration by more than an order of magnitude that is located east of the Core Zone. Because of retention in the waste forms, this impact lasts to the end of the 10,000-year period of analysis (see Figure 6–84). Figure 6–85 shows the total area for which groundwater concentrations of iodine-129 exceed the benchmark concentration as a function of time. After an early peak related to releases from the PUREX Plant area, the area of exceedance peaks between CY 3240 and CY 4540 driven primarily by releases from other tank farm sources. A secondary peak at later times results from releases at IDF. Figures 6–86 through 6–90 show the spatial distribution at the same three times and the total area of

exceedance versus time for technetium-99. The spatial distribution of technetium-99 does not include contributions from the PUREX Plant sources (compare to iodine-129 distributions) and is dominated by releases from other tank farm sources and IDF. Chromium (see Figures 6–91 through 6–94) and nitrate (see Figures 6–95 through 6–98) show similar spatial distributions to technetium-99.

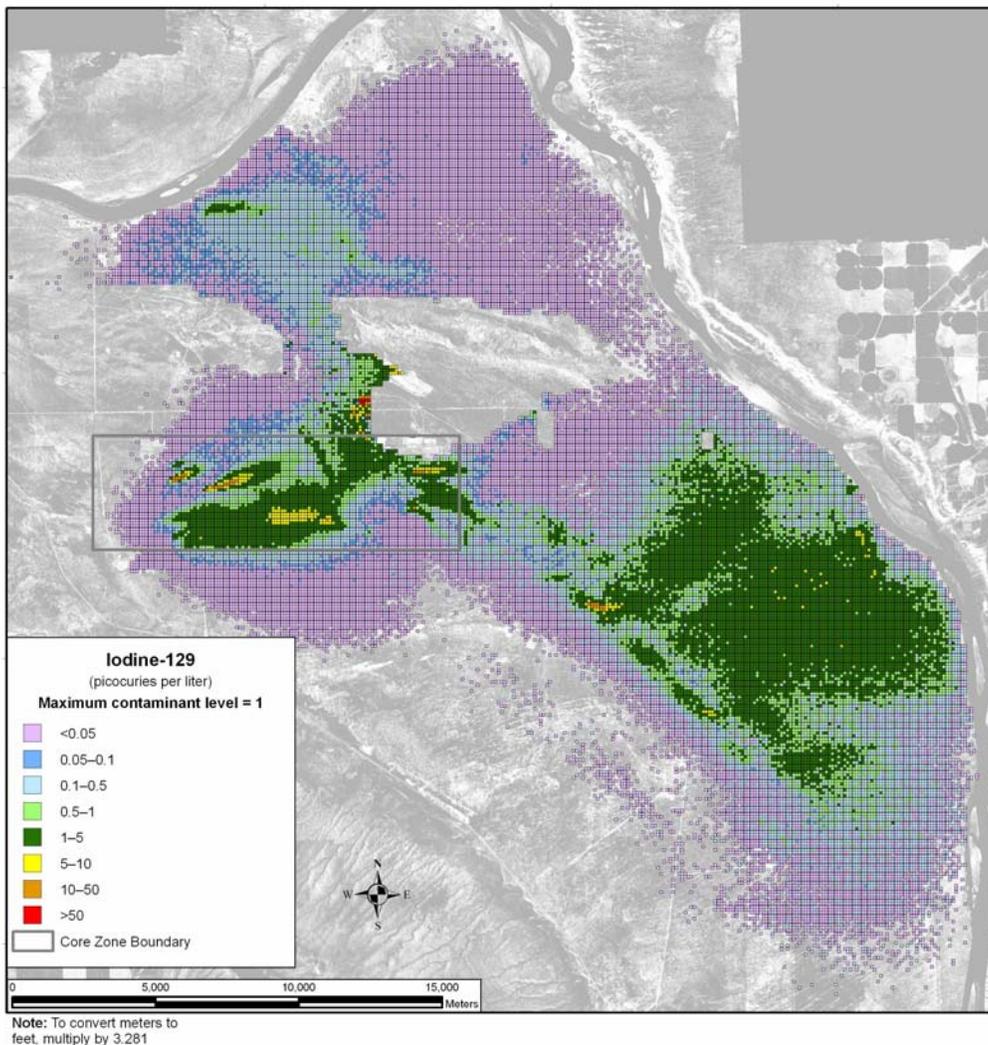


Figure 6–81. Alternative Combination 3 Spatial Distribution of Cumulative Groundwater Concentration for Iodine-129 During Calendar Year 2005

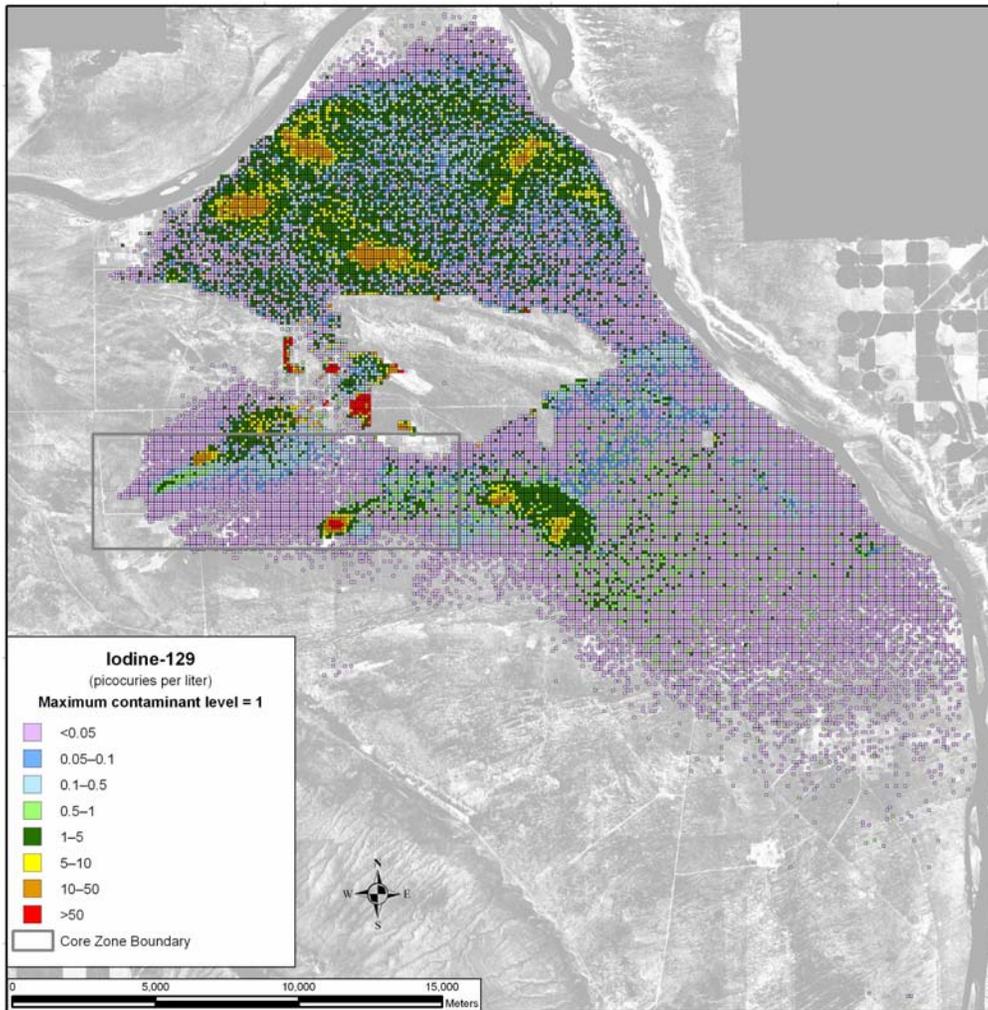


Figure 6–82. Alternative Combination 3 Spatial Distribution of Cumulative Groundwater Concentration for Iodine-129 During Calendar Year 3890

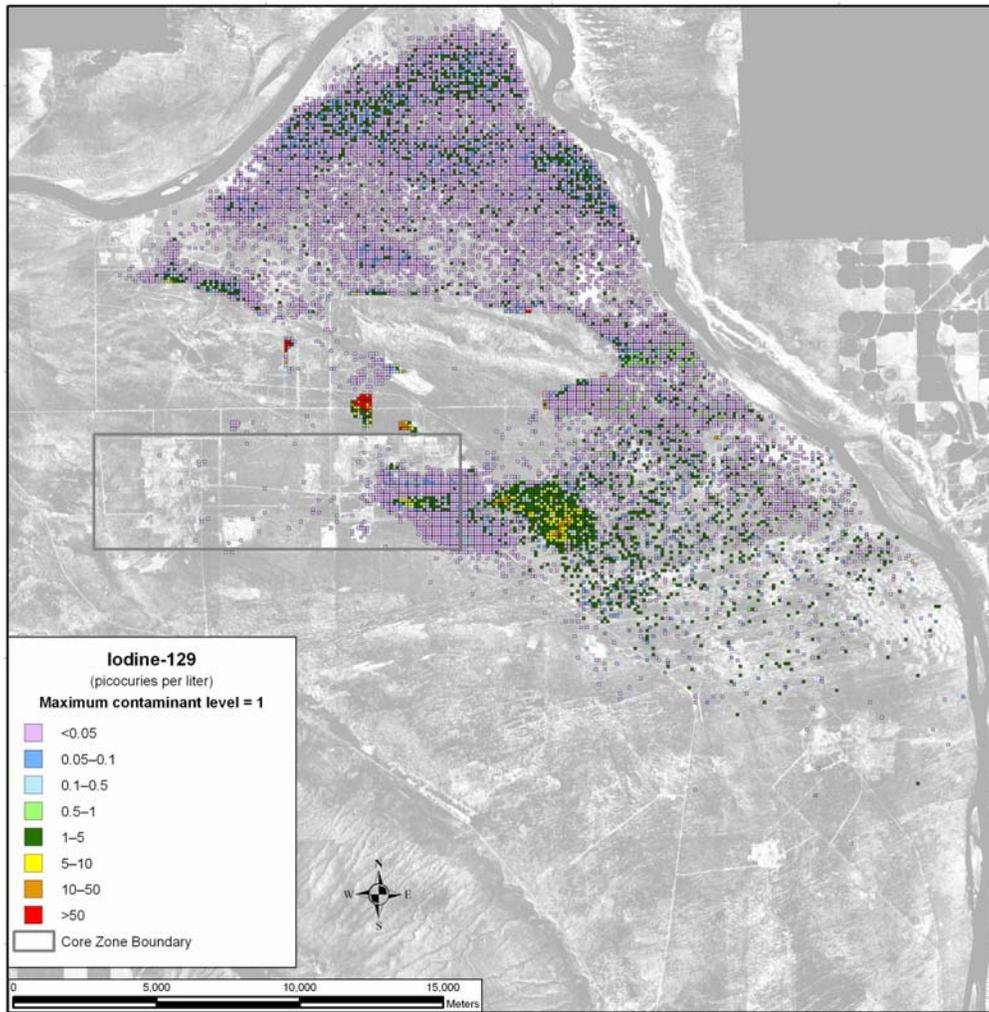


Figure 6–83. Alternative Combination 3 Spatial Distribution of Cumulative Groundwater Concentration for Iodine-129 During Calendar Year 7140

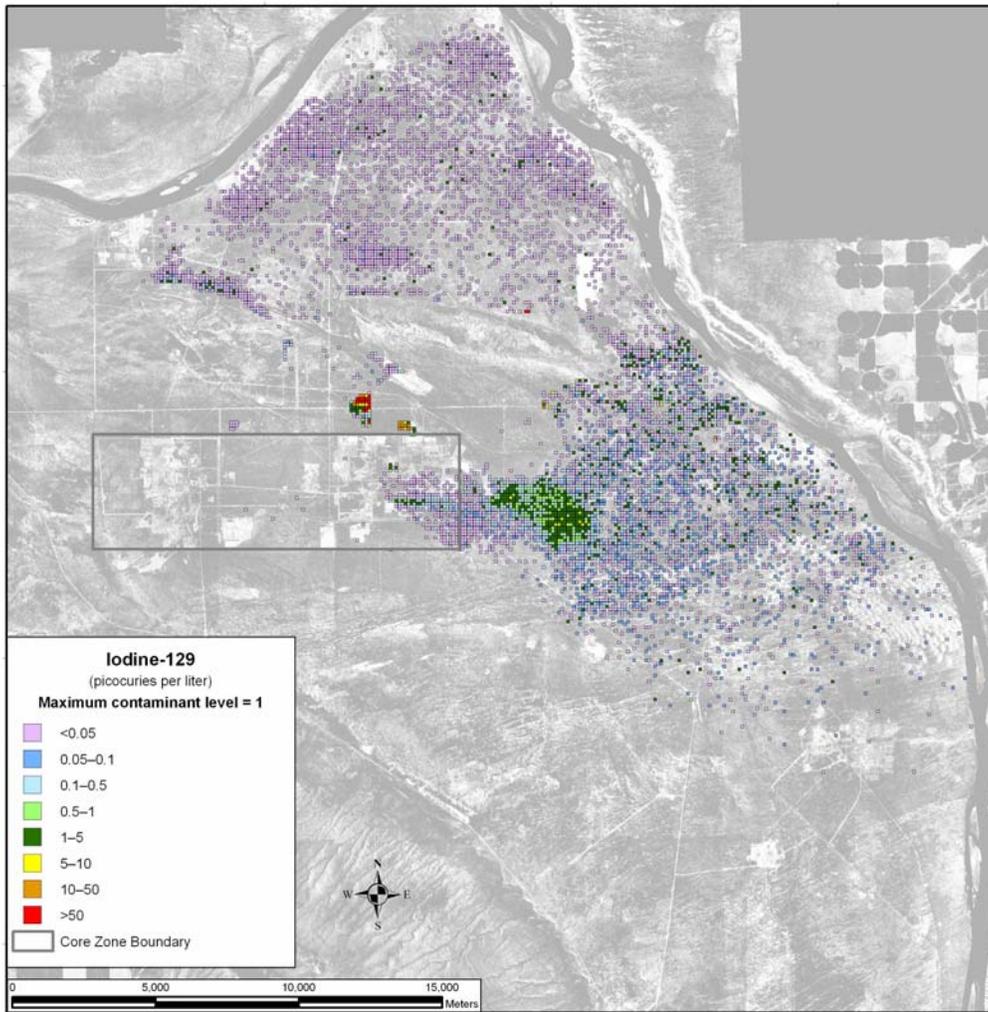


Figure 6–84. Alternative Combination 3 Spatial Distribution of Cumulative Groundwater Concentration for Iodine-129 During Calendar Year 11,885

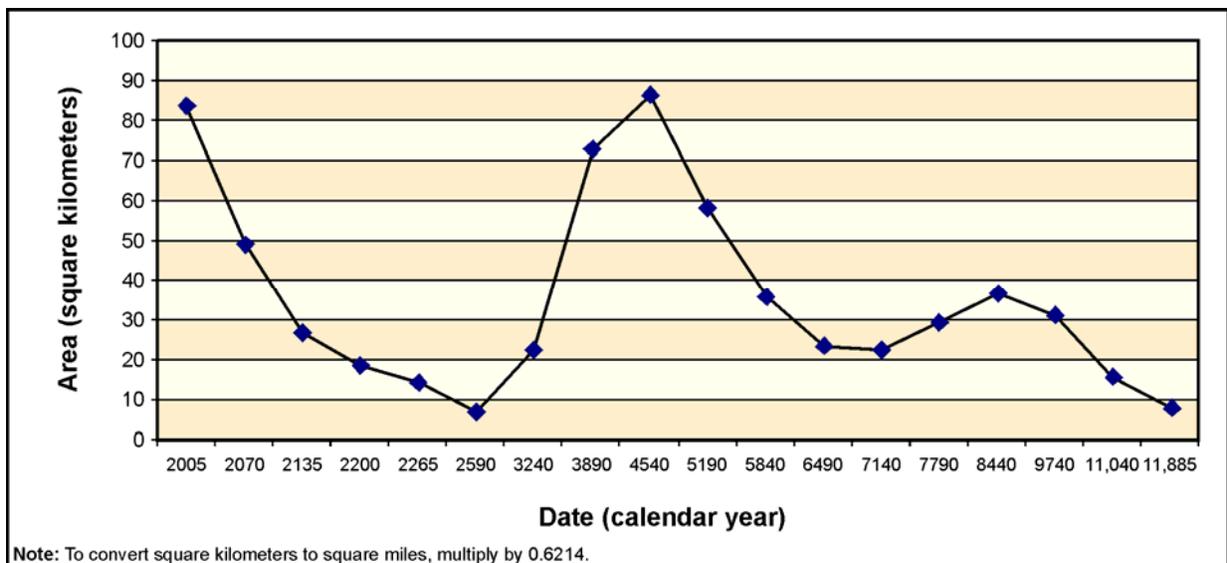


Figure 6–85. Alternative Combination 3 Total Area for Which Cumulative Groundwater Concentrations of Iodine-129 Exceed the Benchmark Concentration as a Function of Time

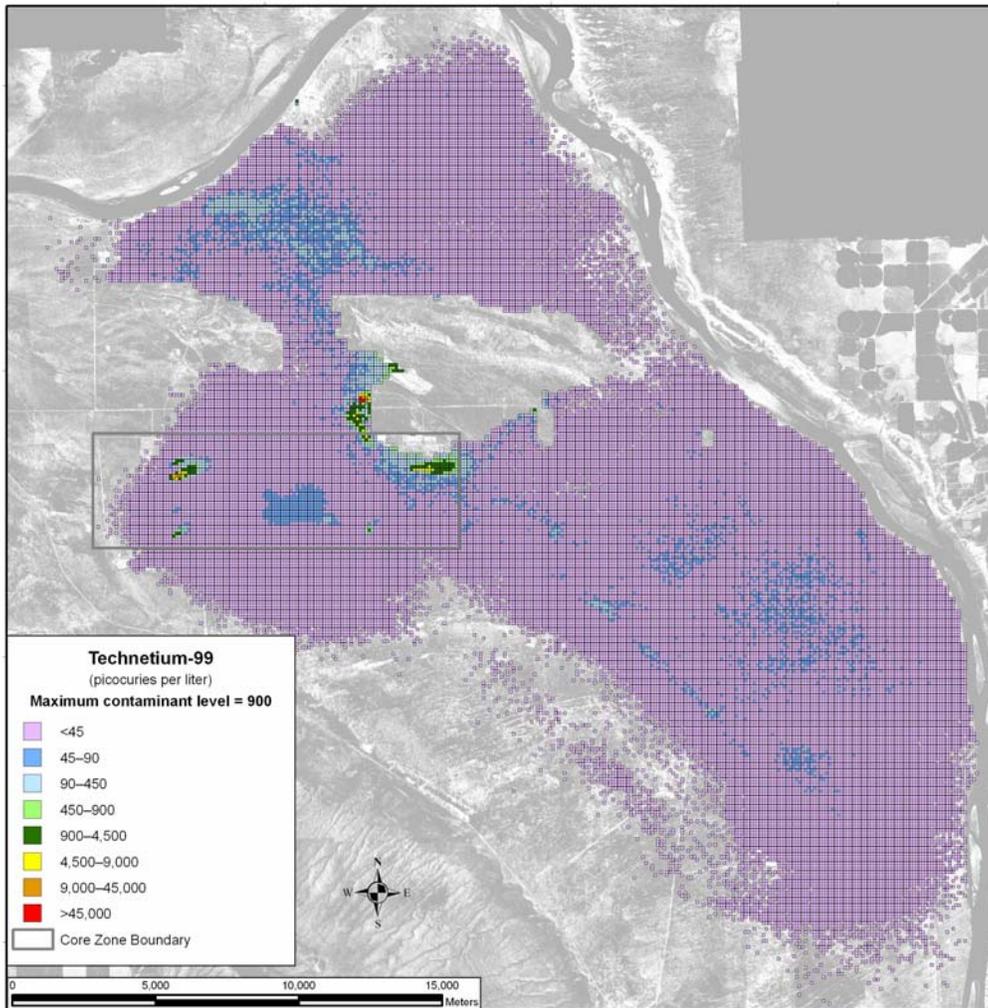


Figure 6-86. Alternative Combination 3 Spatial Distribution of Cumulative Groundwater Concentration for Technetium-99 During Calendar Year 2005

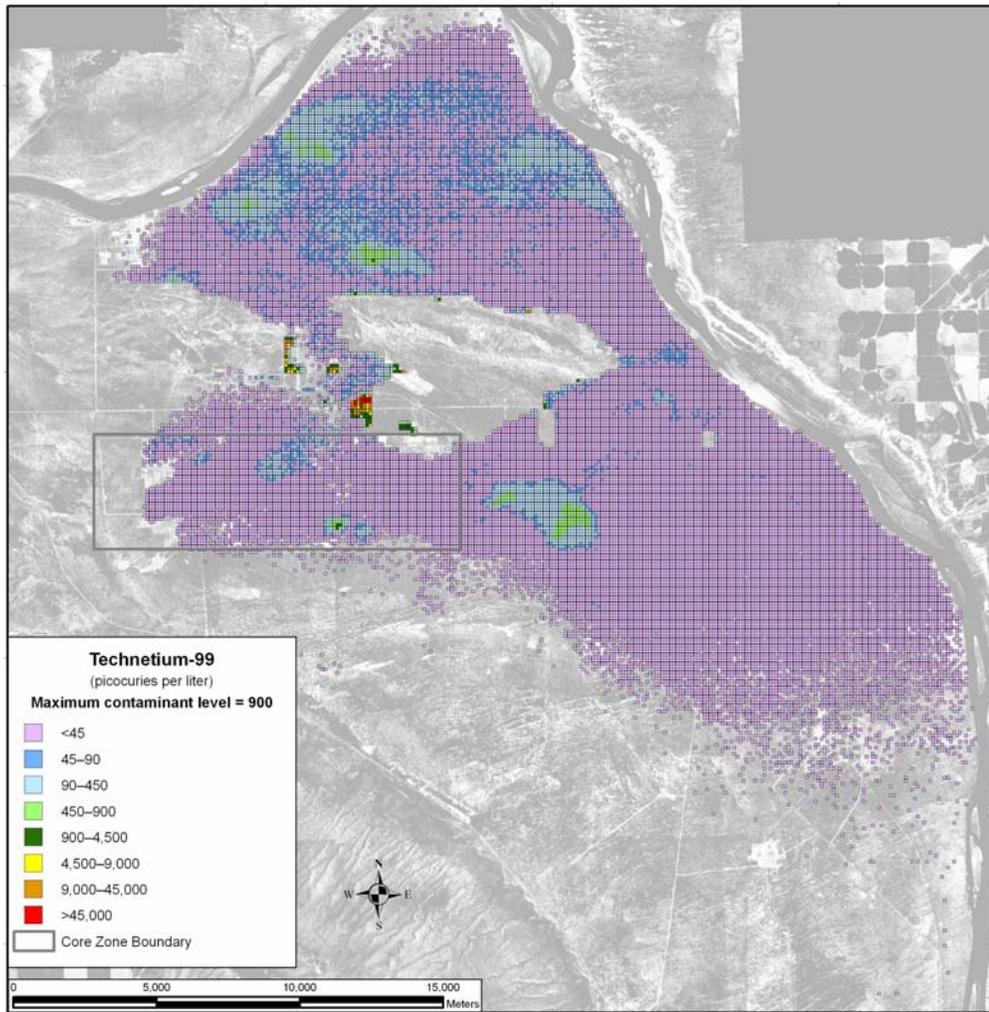


Figure 6-87. Alternative Combination 3 Spatial Distribution of Cumulative Groundwater Concentration for Technetium-99 During Calendar Year 3890

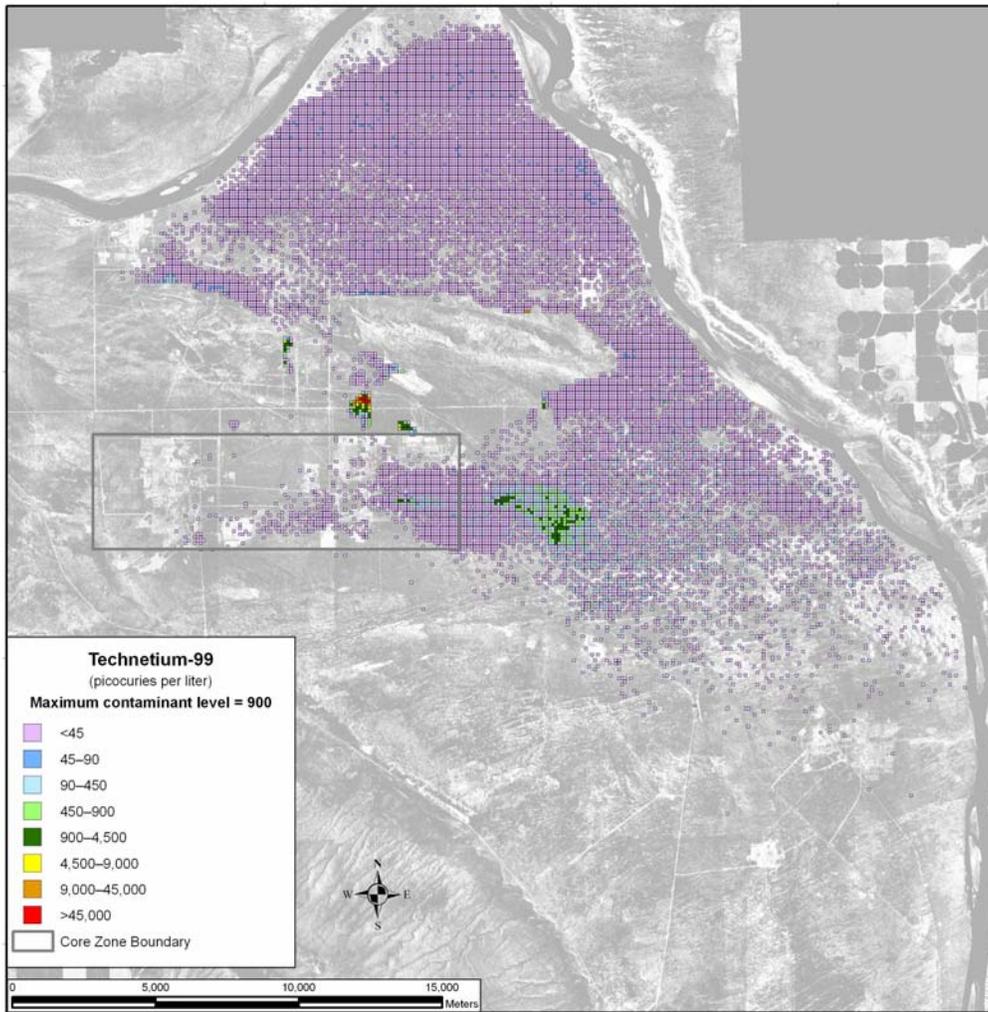


Figure 6-88. Alternative Combination 3 Spatial Distribution of Cumulative Groundwater Concentration for Technetium-99 During Calendar Year 7140

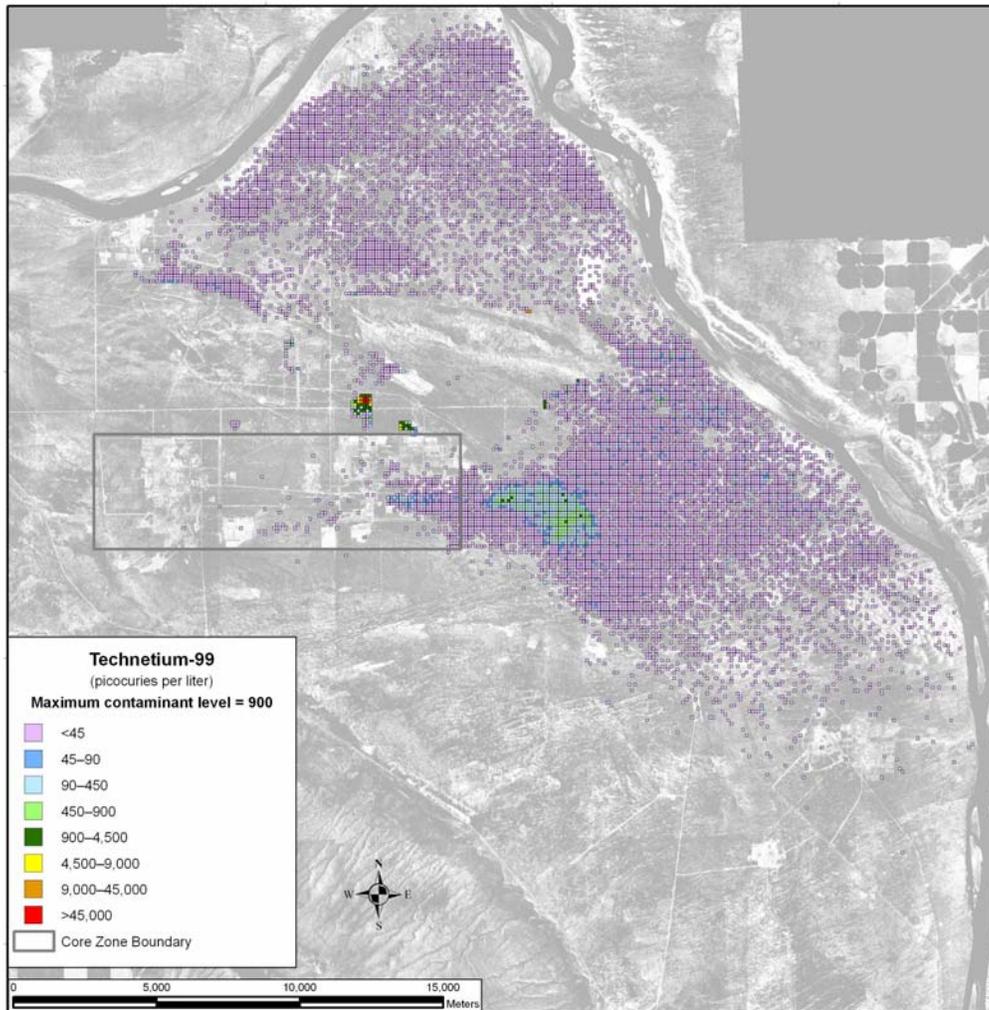


Figure 6-89. Alternative Combination 3 Spatial Distribution of Cumulative Groundwater Concentration for Technetium-99 During Calendar Year 11,885

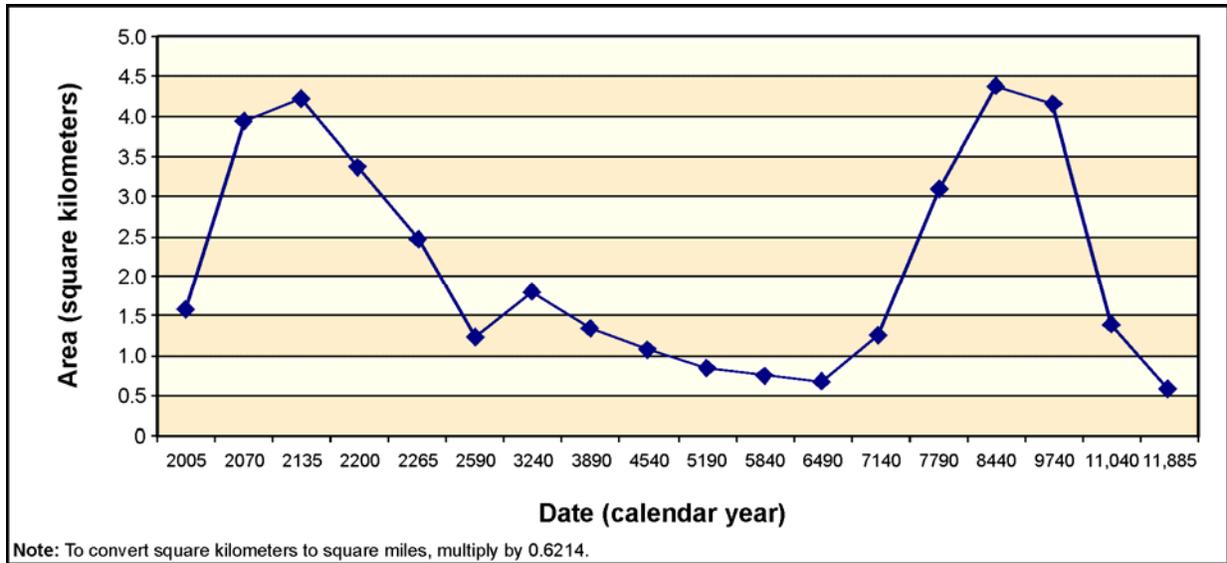


Figure 6-90. Alternative Combination 3 Total Area for Which Cumulative Groundwater Concentrations of Technetium-99 Exceed the Benchmark Concentration as a Function of Time

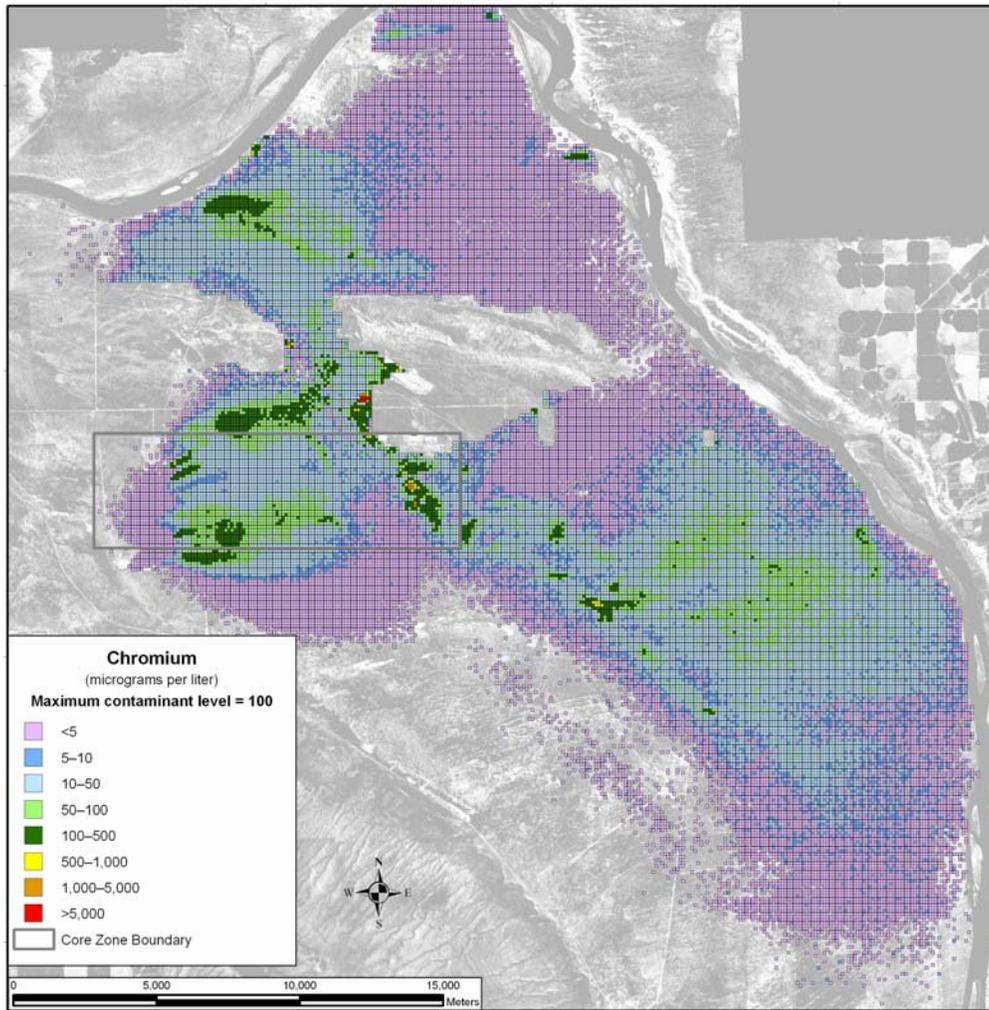


Figure 6-91. Alternative Combination 3 Spatial Distribution of Cumulative Groundwater Concentration for Chromium During Calendar Year 2005

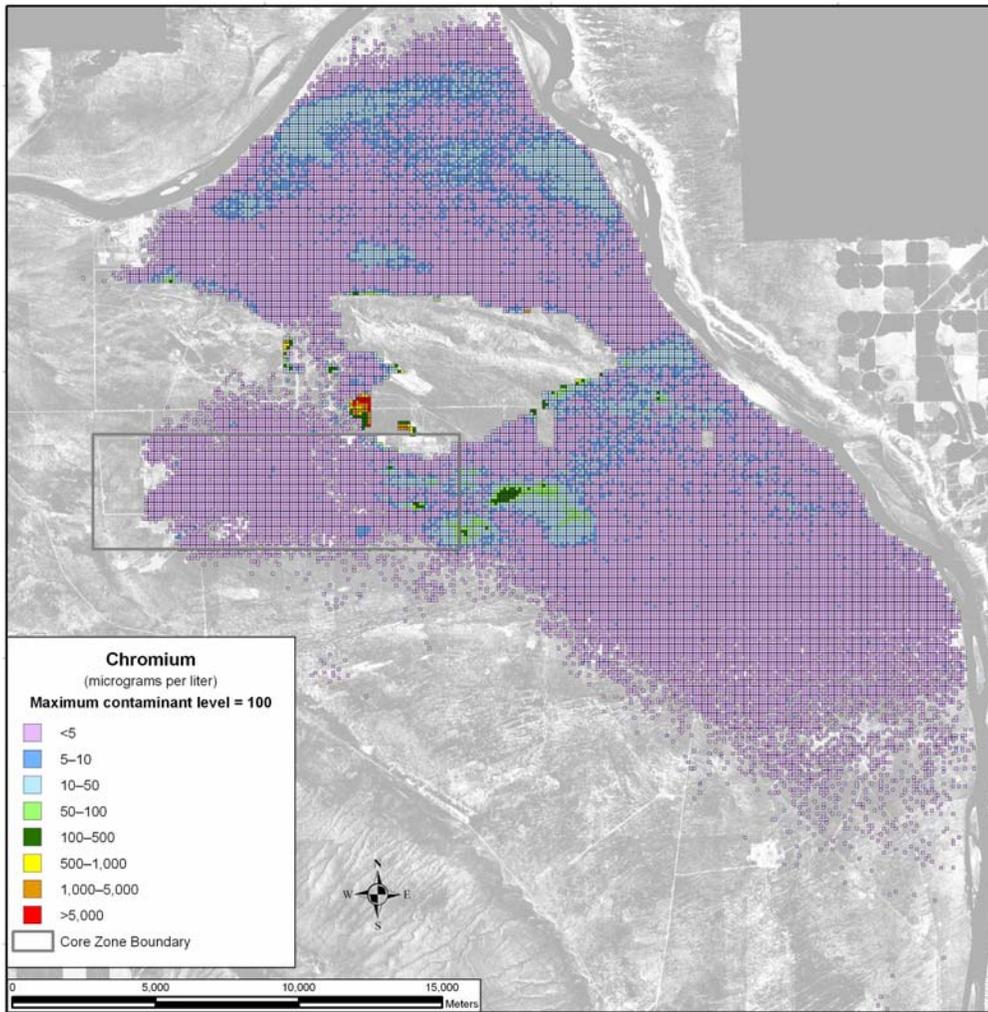


Figure 6-92. Alternative Combination 3 Spatial Distribution of Cumulative Groundwater Concentration for Chromium During Calendar Year 3890

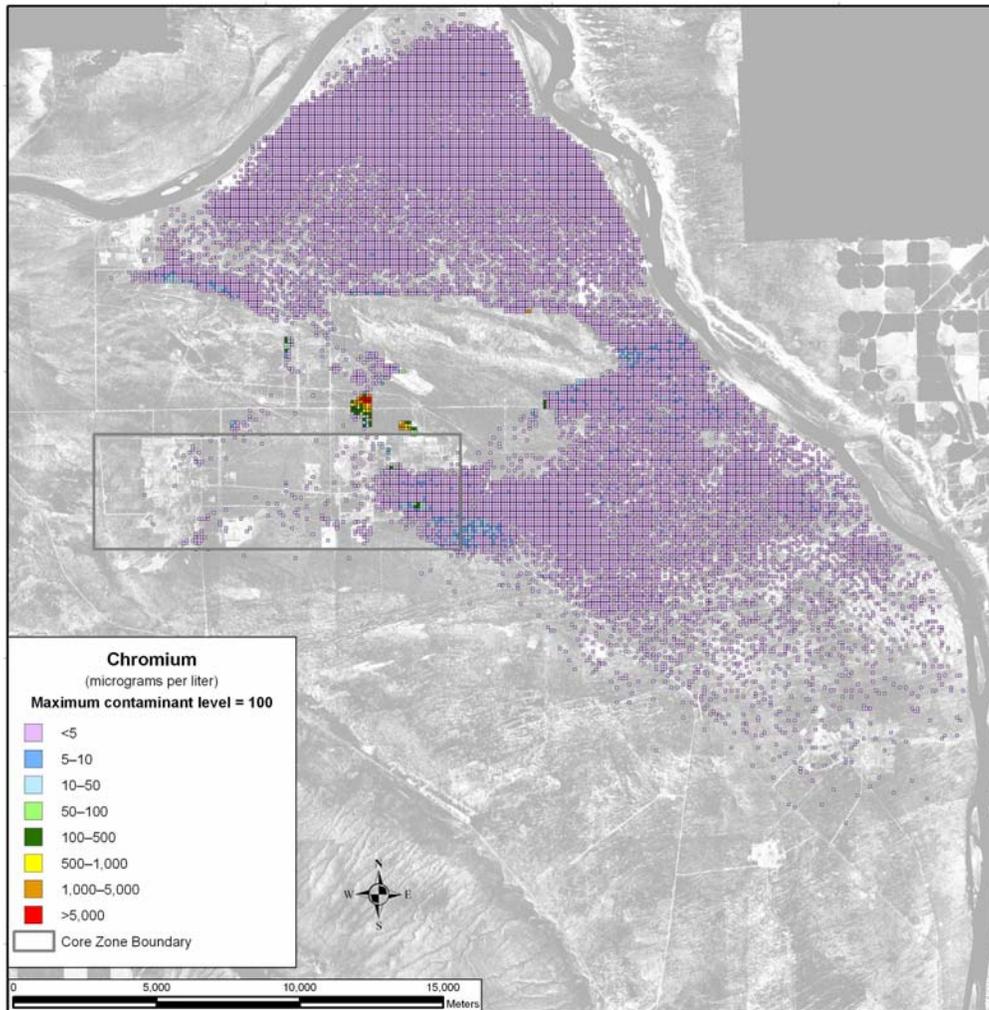


Figure 6-93. Alternative Combination 3 Spatial Distribution of Cumulative Groundwater Concentration for Chromium During Calendar Year 7140

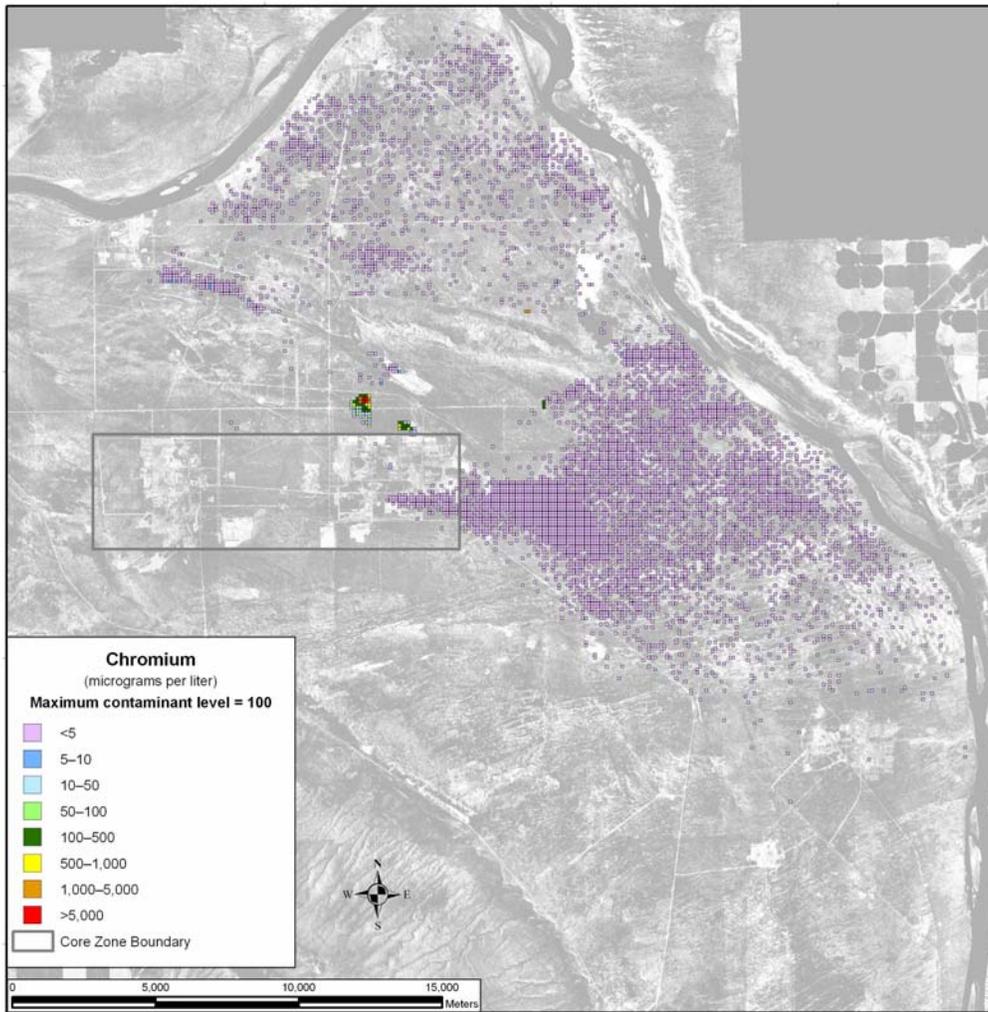


Figure 6-94. Alternative Combination 3 Spatial Distribution of Cumulative Groundwater Concentration for Chromium During Calendar Year 11,885

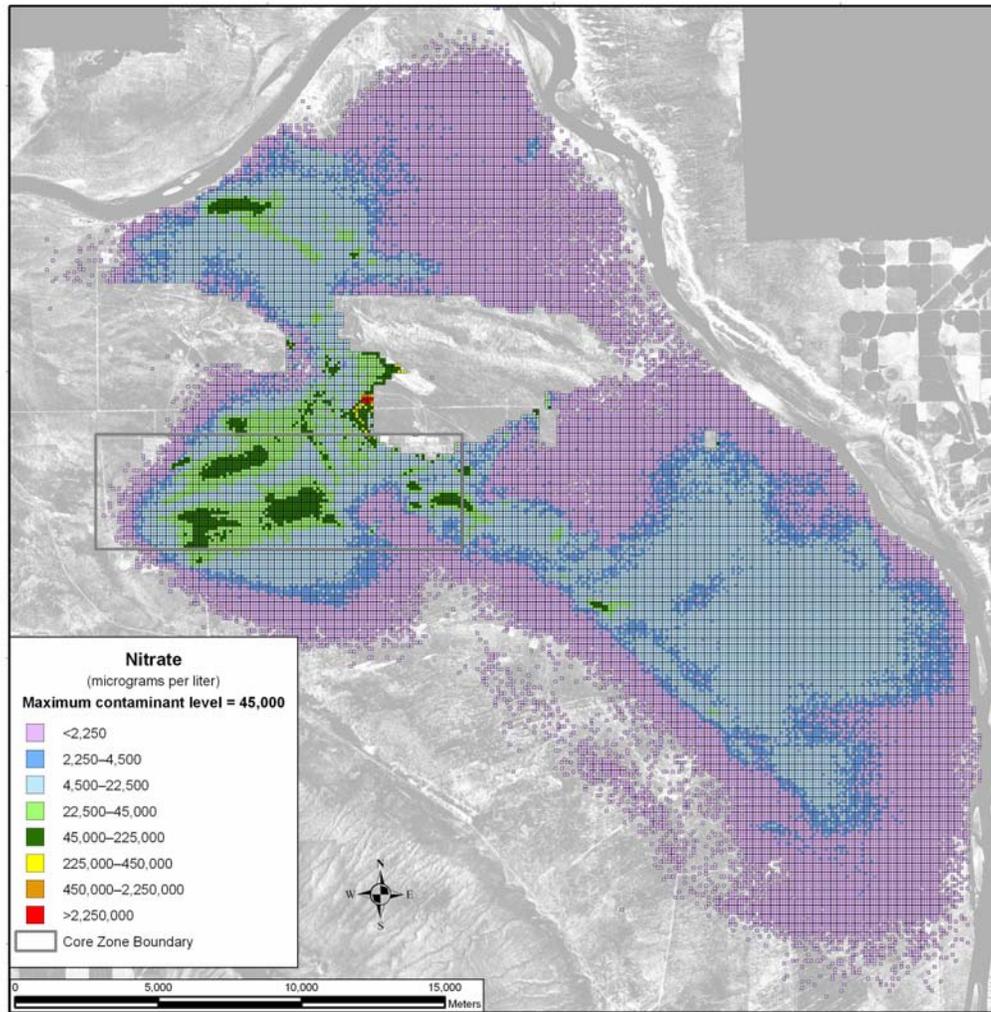


Figure 6-95. Alternative Combination 3 Spatial Distribution of Cumulative Groundwater Concentration for Nitrate During Calendar Year 2005

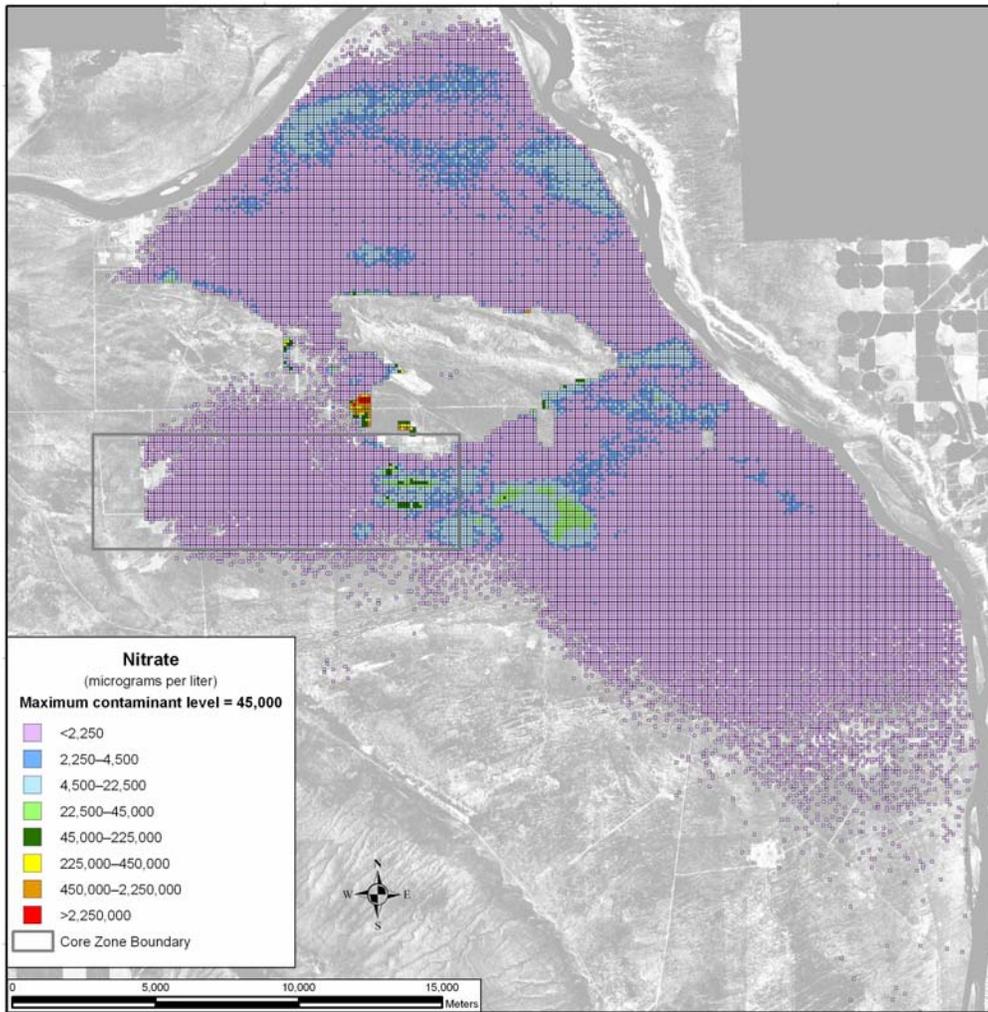


Figure 6–96. Alternative Combination 3 Spatial Distribution of Cumulative Groundwater Concentration for Nitrate During Calendar Year 3890

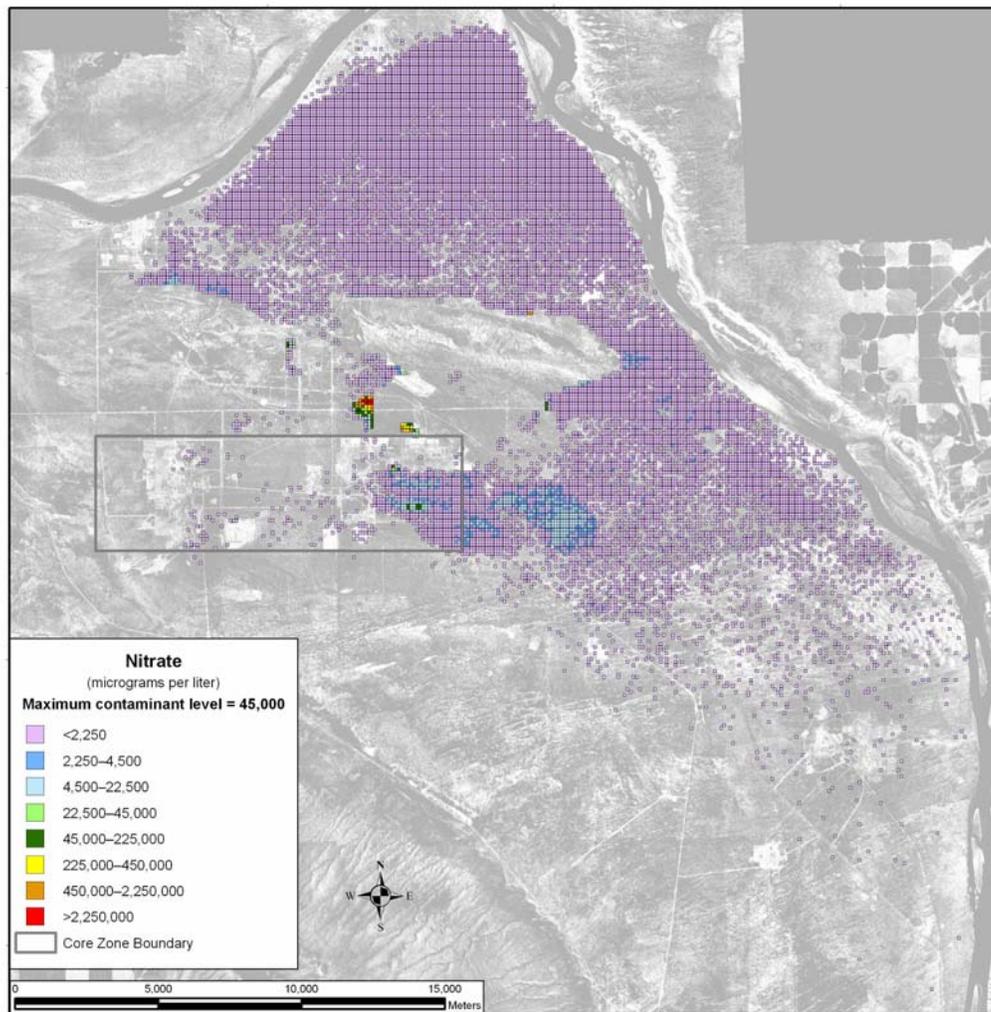


Figure 6–97. Alternative Combination 3 Spatial Distribution of Cumulative Groundwater Concentration for Nitrate During Calendar Year 7140

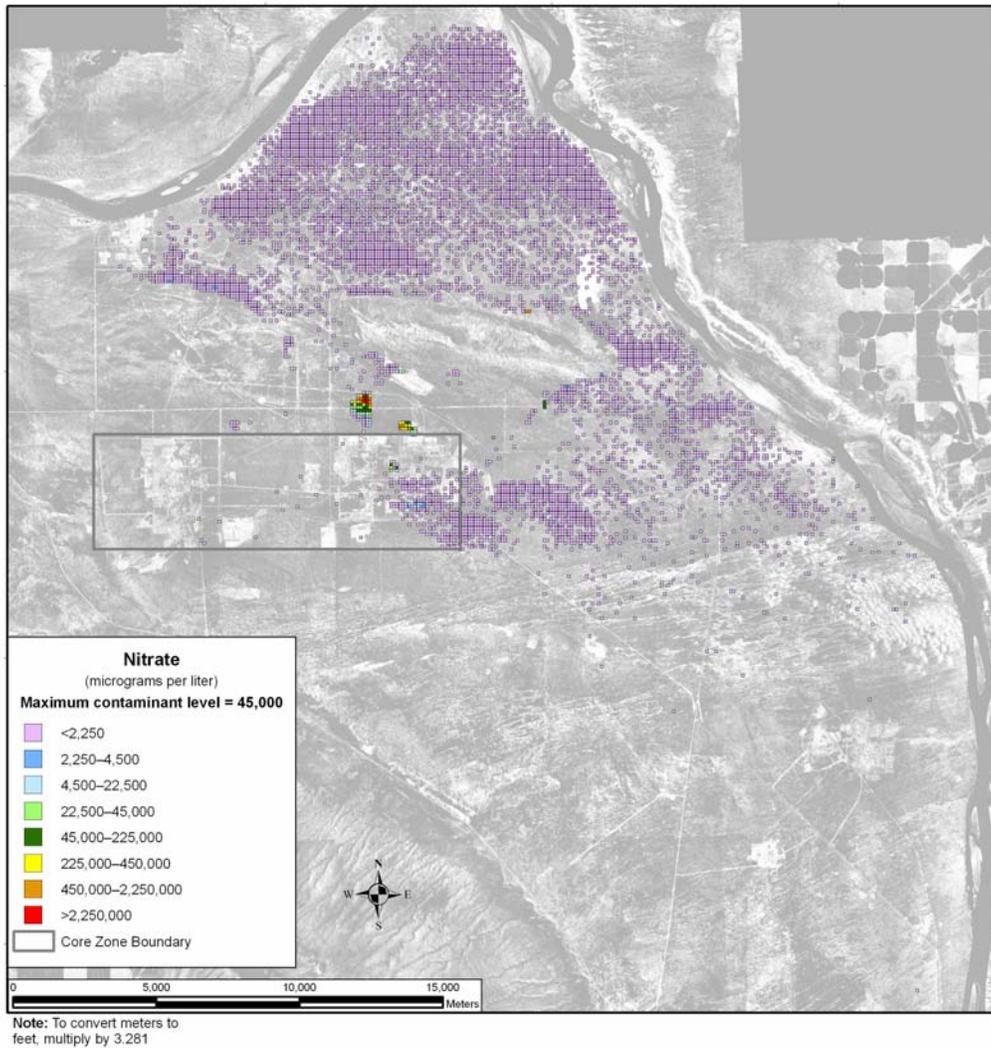


Figure 6–98. Alternative Combination 3 Spatial Distribution of Cumulative Groundwater Concentration for Nitrate During Calendar Year 11,885

The carbon tetrachloride distribution is dominated by non-TC & WM EIS sources associated with the Z Area within the 200-West Area. The spatial distribution during CY 2005, shown in Figure 6–99, is a large plume covering most of the 200-West Area, with peak concentrations over an order of magnitude greater than the benchmark concentration. Note that this model result does not include the effects of carbon tetrachloride removal and containment in the 200-West Area. Figures 6–100 and 6–101 show the dissipation of the plume over time at CY 2135 and CY 3890, respectively.

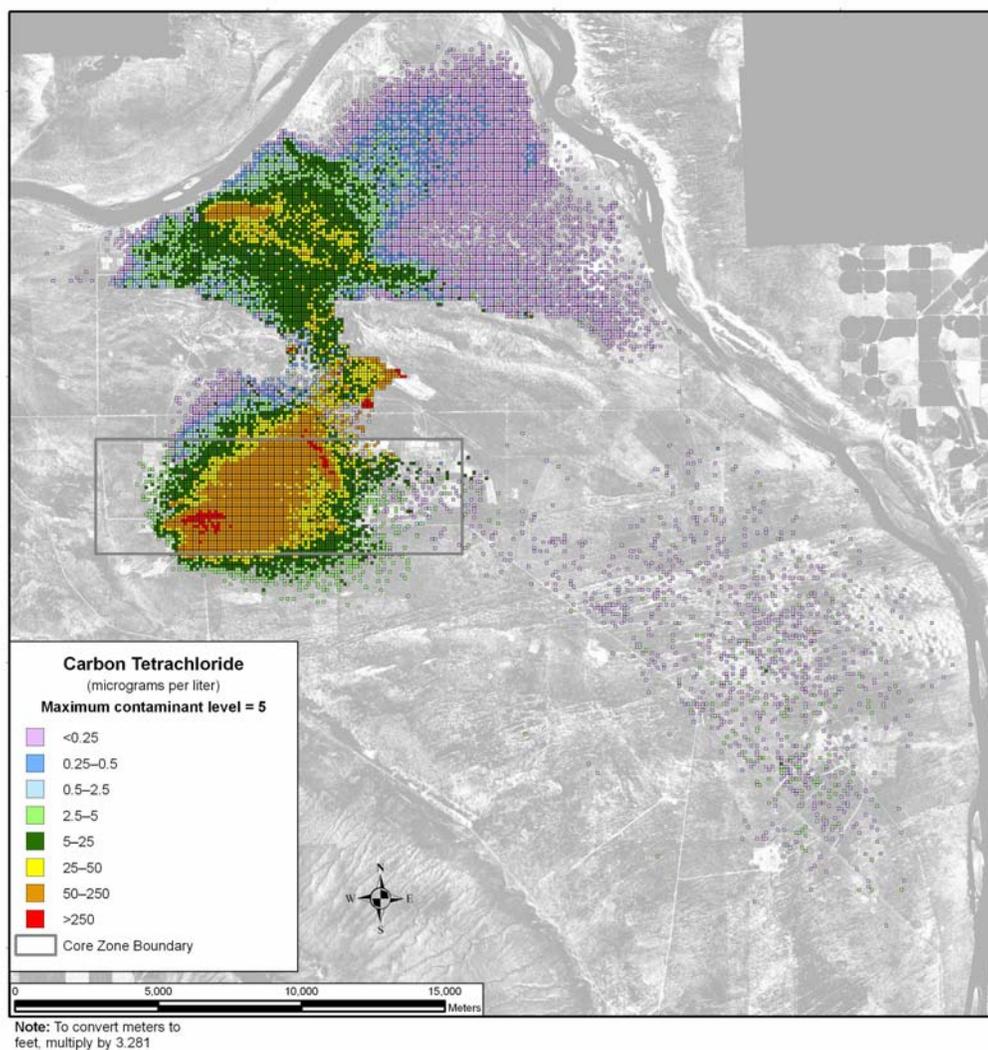


Figure 6–99. Alternative Combination 3 Spatial Distribution of Cumulative Groundwater Concentration for Carbon Tetrachloride During Calendar Year 2005

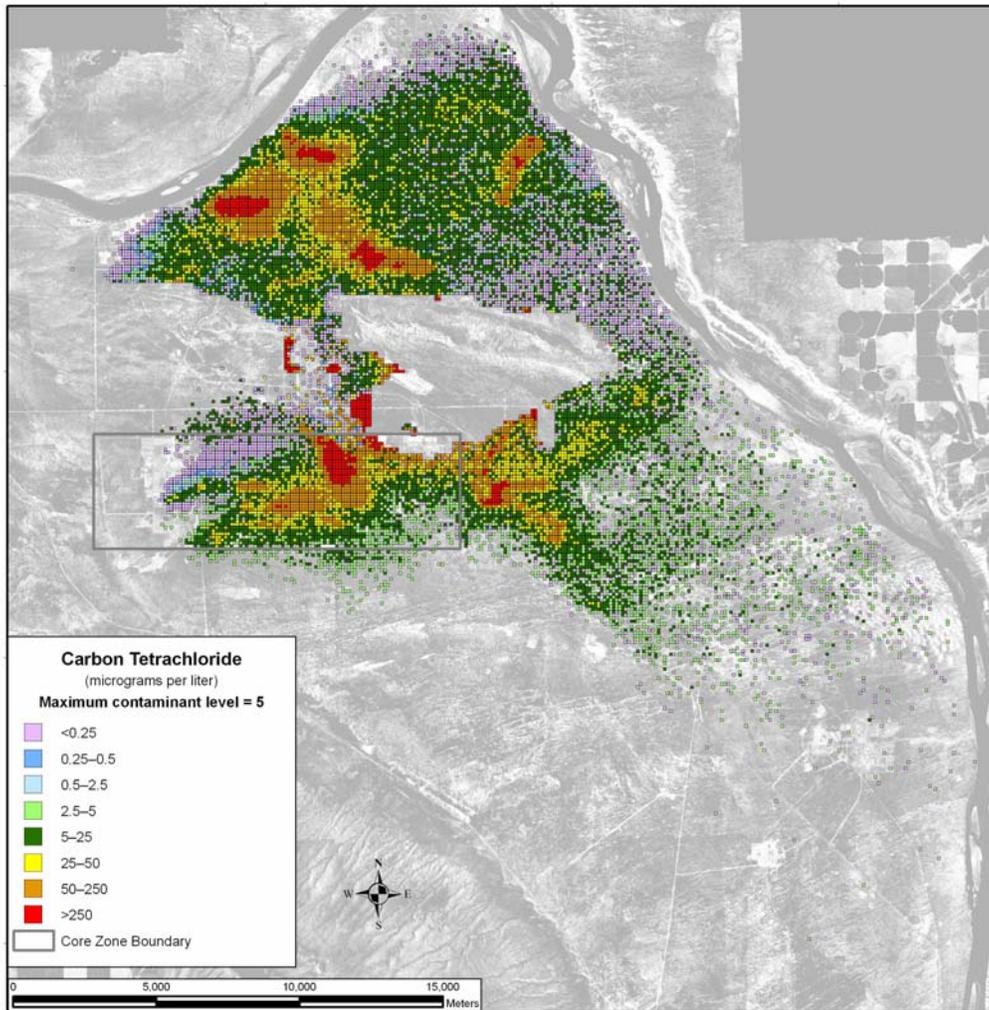


Figure 6-100. Alternative Combination 3 Spatial Distribution of Cumulative Groundwater Concentration for Carbon Tetrachloride During Calendar Year 2135

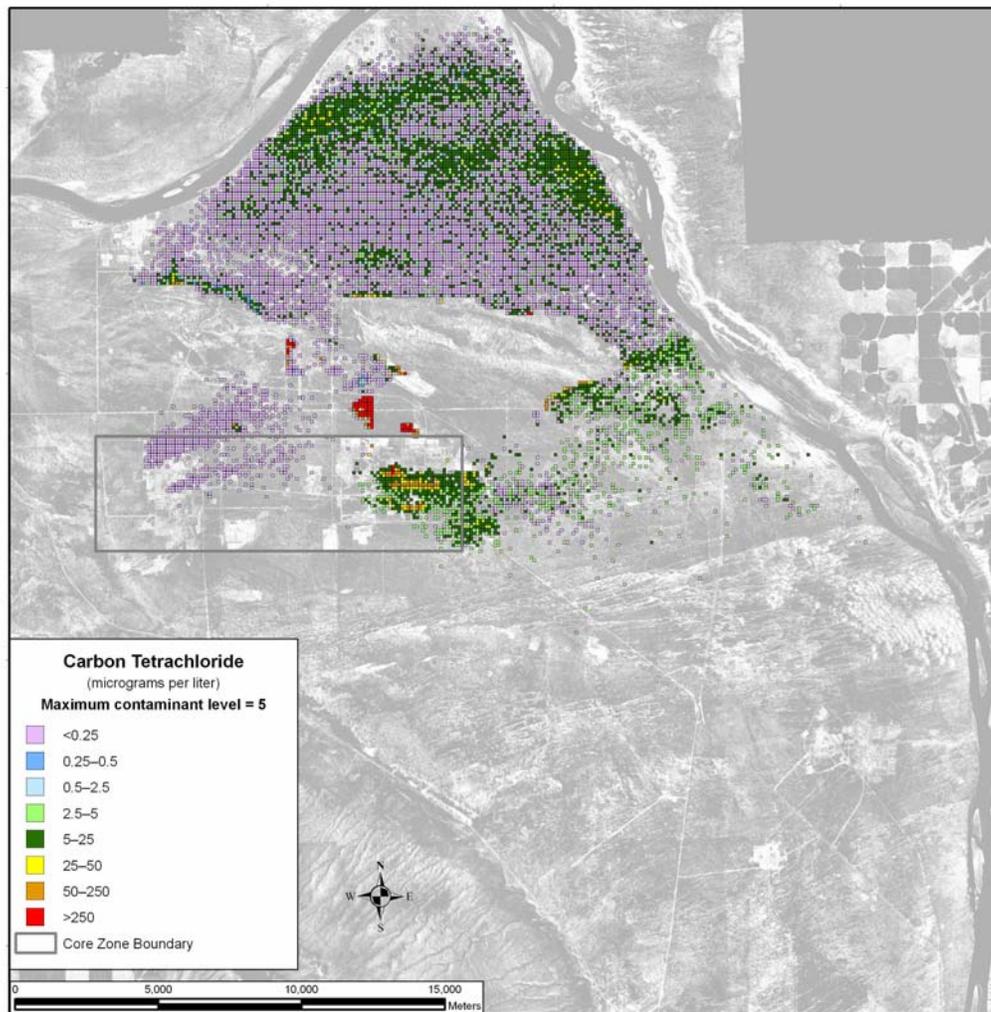


Figure 6-101. Alternative Combination 3 Spatial Distribution of Cumulative Groundwater Concentration for Carbon Tetrachloride During Calendar Year 3890

Uranium-238 and total uranium show a different spatial distribution over time. These COPCs are not as mobile as those discussed above, moving about seven times slower than the porewater velocity. As a result, travel times through the vadose zone are longer, release to the aquifer is delayed, and travel times through the aquifer to the Columbia River are longer. Figure 6–102 shows the distribution of uranium-238 during CY 2135. There are two plumes associated with releases from the ponds (non-TC & WM EIS sources) in the 200-East and 200-West Areas with peak concentrations that exceed the benchmark by an order of magnitude. By CY 3890 (see Figure 6–103) these plumes have dissipated, but releases from other tank farm sources (primarily within the A Barrier) have produced a second plume east of the Core Zone, with peak concentrations about an order of magnitude greater than the benchmark. At CY 11,885 (see Figure 6–104) the plumes from other tank farm sources have extended this plume and produced additional plumes in the 200-West Area. Figure 6–105 shows the total area for which groundwater concentrations of uranium-238 exceed the benchmark concentration as a function of time. The area of exceedance is largest early in the analysis (non-TC & WM EIS sources, primarily ponds) with an upward trend toward the end of the period of analysis (other tank farm sources). Figures 6–106 through 6–108 show the corresponding spatial distributions for total uranium.

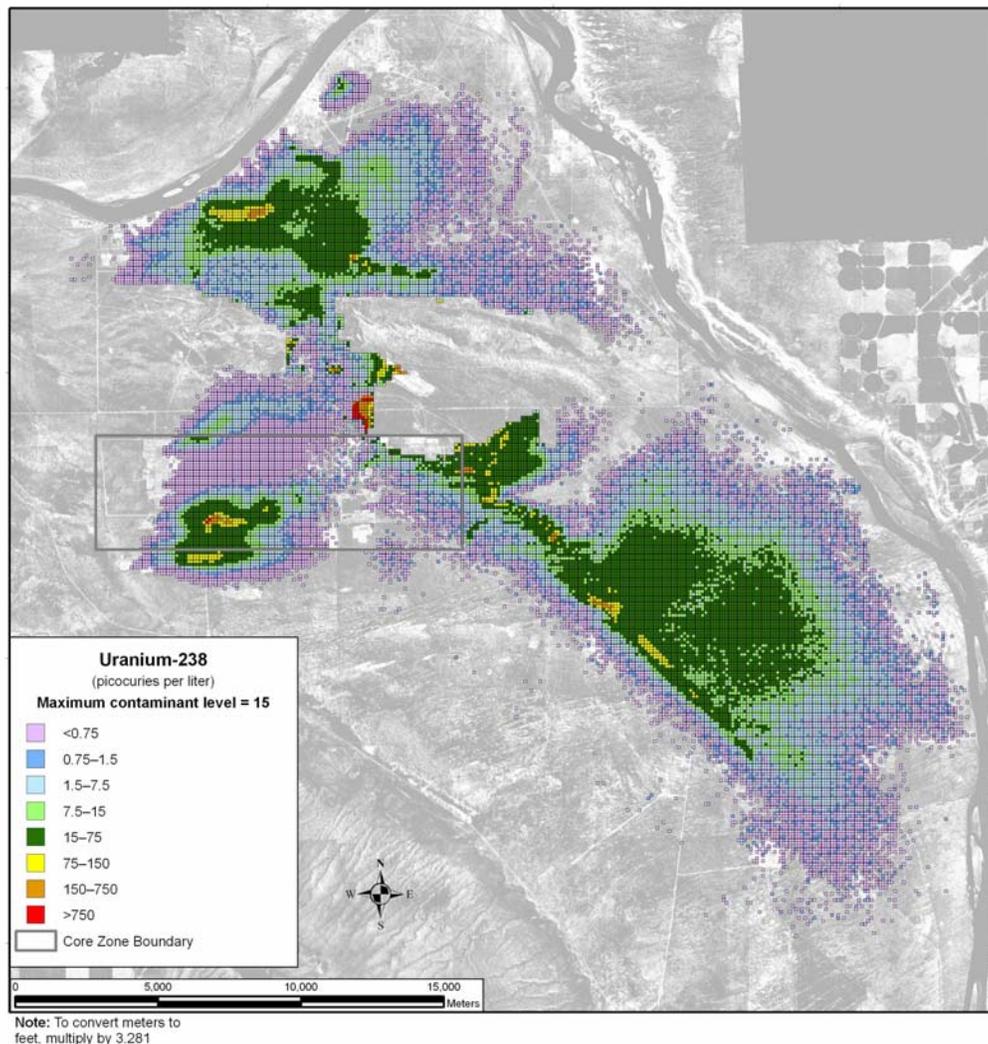


Figure 6–102. Alternative Combination 3 Spatial Distribution of Cumulative Groundwater Concentration for Uranium-238 During Calendar Year 2135

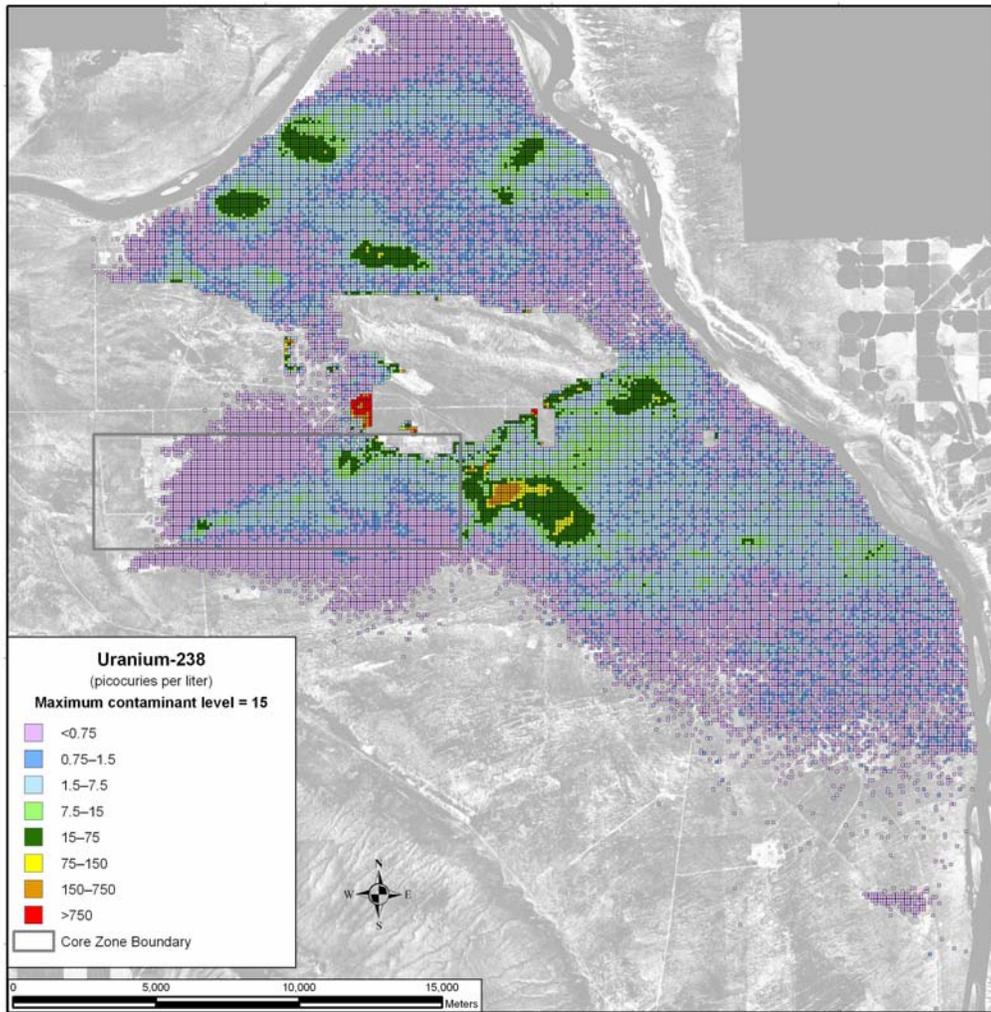


Figure 6-103. Alternative Combination 3 Spatial Distribution of Cumulative Groundwater Concentration for Uranium-238 During Calendar Year 3890

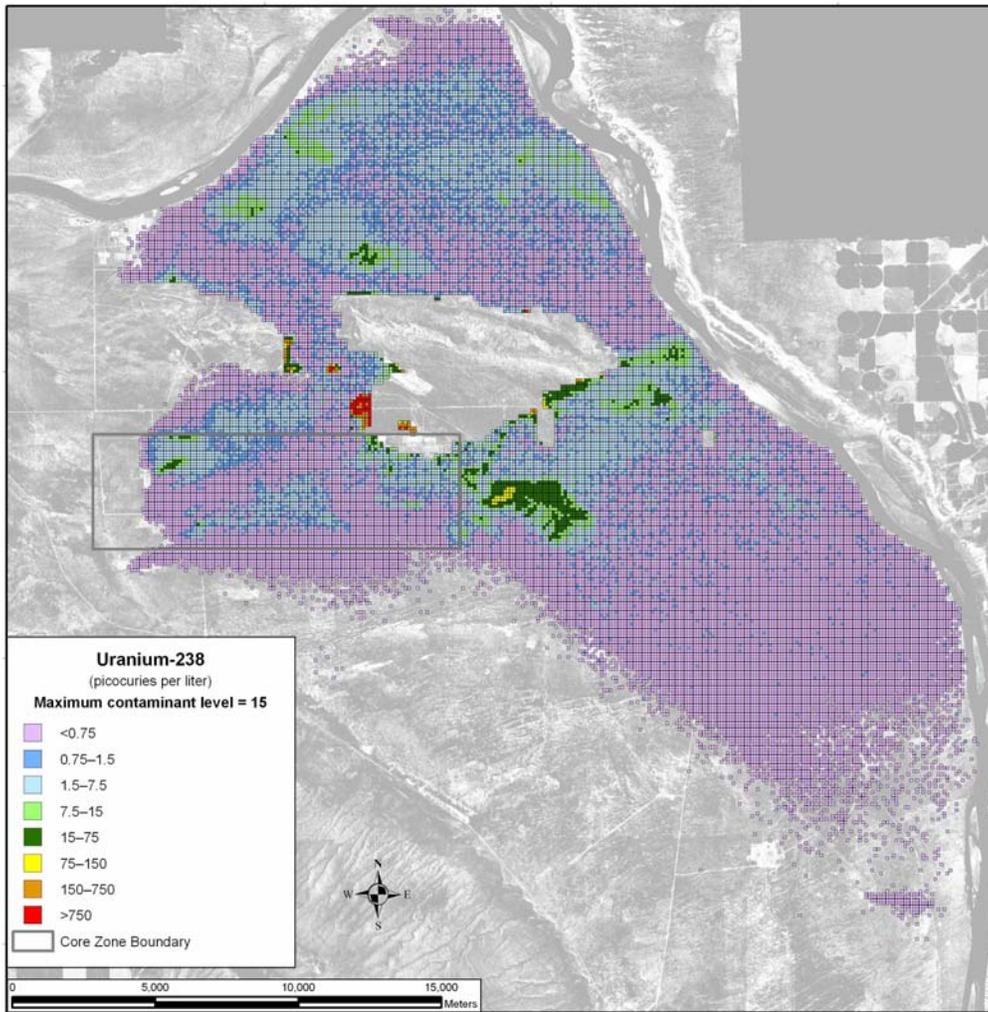


Figure 6-104. Alternative Combination 3 Spatial Distribution of Cumulative Groundwater Concentration for Uranium-238 During Calendar Year 11,885

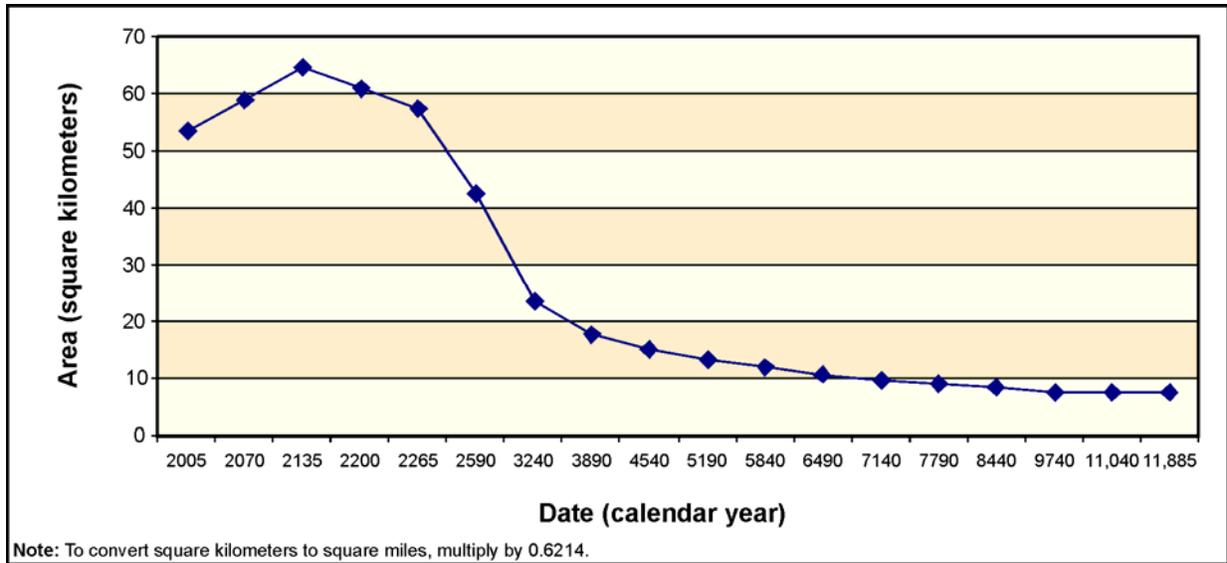


Figure 6-105. Alternative Combination 3 Total Area for Which Cumulative Groundwater Concentrations of Uranium-238 Exceed the Benchmark Concentration as a Function of Time

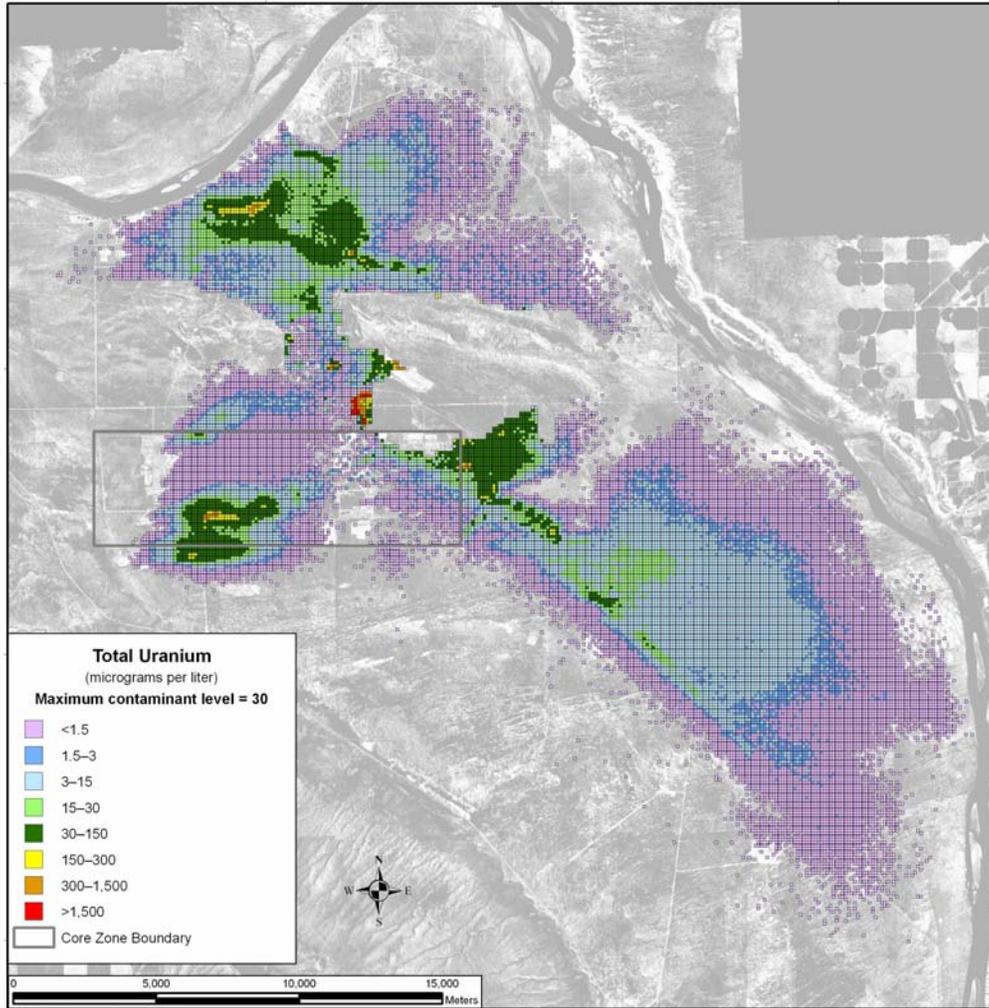


Figure 6-106. Alternative Combination 3 Spatial Distribution of Cumulative Groundwater Concentration for Total Uranium During Calendar Year 2135

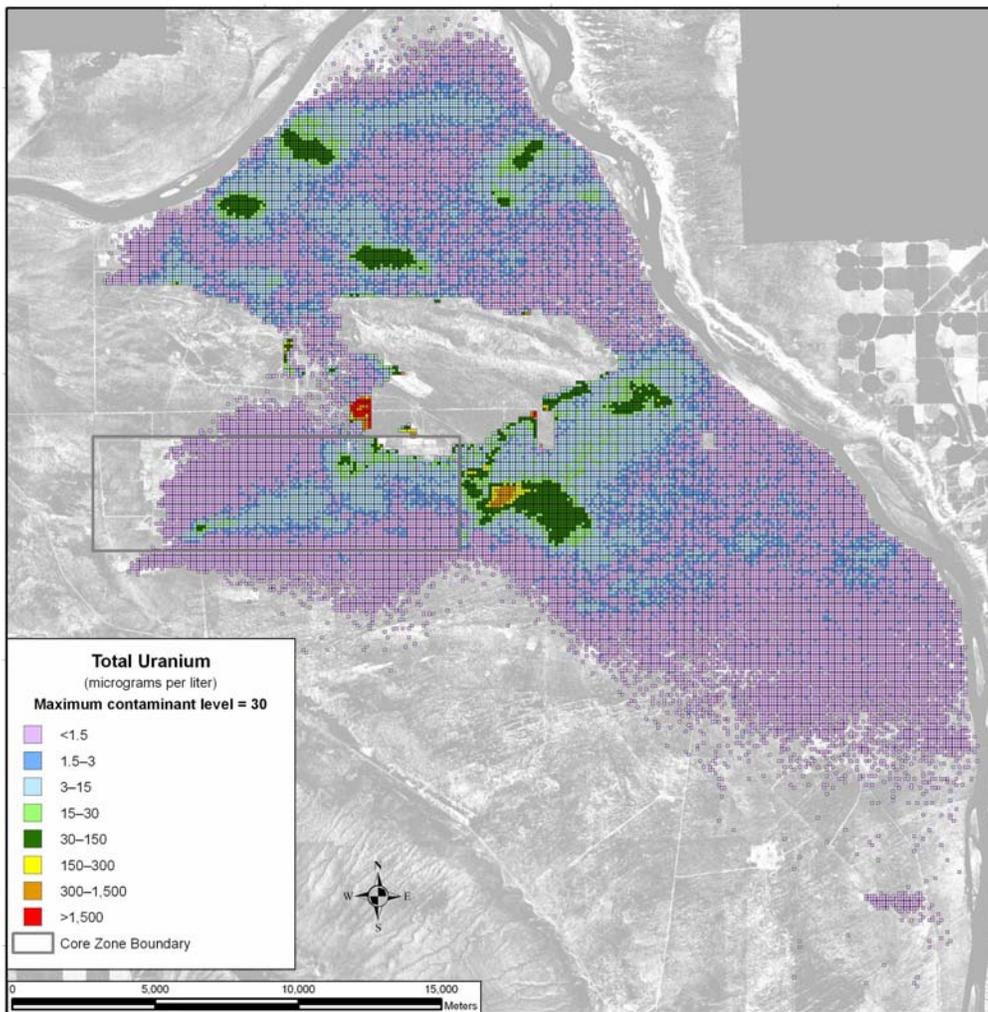


Figure 6-107. Alternative Combination 3 Spatial Distribution of Cumulative Groundwater Concentration for Total Uranium During Calendar Year 3890

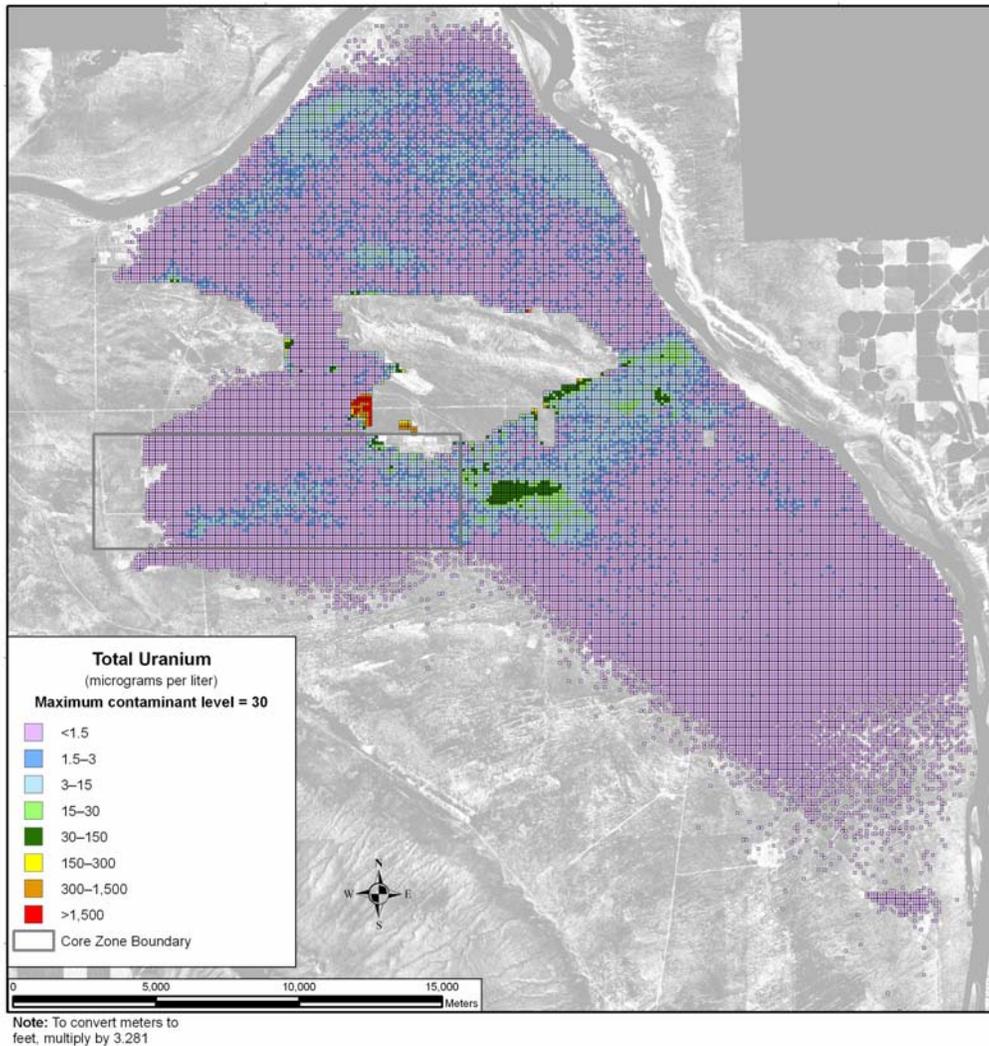


Figure 6-108. Alternative Combination 3 Spatial Distribution of Cumulative Groundwater Concentration for Total Uranium During Calendar Year 11,885

6.4.1.3.4 Summary of Impacts

The cumulative long-term impacts for Alternative Combination 3 and non-TC & WMEIS sources are dominated by non-TC & WMEIS sources (tritium, uranium-238, carbon tetrachloride, chromium, and total uranium); a combination of non-TC & WMEIS sources and Waste Management alternative sources (iodine-129); a combination of non-TC & WMEIS sources and tank closure sources (nitrate); or all three (technetium-99). Contributions from FFTF Decommissioning Alternative 3 sources account for well under 1 percent of the total amount released to the environment.

For iodine-129, technetium-99, carbon tetrachloride, chromium, and nitrate, concentrations at the Core Zone Boundary exceed benchmark standards by an order of magnitude during most of the period of analysis. Concentrations at the Columbia River are somewhat lower. The intensities and areas of these groundwater plumes peak at various times during the 10,000-year period of analysis, depending on the combination of alternative-related and non-alternative-related sources.

For tritium, concentrations at the Core Zone Boundary exceed the benchmark by about three orders of magnitude during the first 100 years of the period of analysis. Concentrations at the Columbia River

exceed the benchmark by about two orders of magnitude during this time. Attenuation by radioactive decay is a predominant mechanism that limits the intensity and duration of groundwater impacts by tritium. After CY 2100 tritium impacts are essentially negligible.

For uranium-238 and total uranium, discharges from the ponds (non-*TC & WM EIS* sources) are the dominant contributors during the early period of the analysis. Other tank farm sources are a secondary contributor, for which limited mobility is an important factor governing the time frames and scale of groundwater impacts.

6.4.2 Human Health Impacts

This section presents the results of the long-term cumulative impacts analysis for 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, including estimates of the impacts of radiological and chemical constituents on each receptor, location, and alternative for the year of peak impact. Supporting information for the analysis of cumulative impacts on human health, including contributions from the major radionuclides and chemical constituents at the year of peak cumulative impact, is presented in Appendix U, Section U.2.

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

As with the individual *TC & WM EIS* alternatives, four measures of human health impacts were considered in this analysis: lifetime risks of developing cancer from radiological constituents, lifetime risks of developing cancer from chemical constituents, dose from radiological constituents, and Hazard Indices from chemical constituents. These measures were calculated for each year over 10,000 years for applicable receptors at three locations of analysis (i.e., the Core Zone Boundary, Columbia River nearshore, and Columbia River surface water). This large amount of information must be summarized to allow an interpretation of results. The method chosen was to present the dose for the year of maximum dose, the risk for the year of maximum risk, and the Hazard Index for the year of maximum Hazard Index. This choice was based on regulation of radiological impacts as dose and the observation that peak risk and peak noncarcinogenic impacts expressed as a Hazard Index may occur at times other than that of peak dose.

The three onsite locations of analysis were the Core Zone Boundary, the Columbia River nearshore, and the Columbia River. The offsite locations of analysis were population centers downstream of Hanford. The total offsite population assumed for this analysis was 5 million people. Consistent with DOE guidance (DOE Guide 435.1-1), the potential consequences of loss of administrative or institutional controls were considered by estimating the impacts on onsite receptors. Because DOE does not anticipate loss of control of the site, these onsite receptors were considered hypothetical and were applied to develop estimates for past and future time periods.

Four types of hypothetical receptors were considered. The first type, a drinking-water well user, uses groundwater as a source of drinking water. The second type, a resident farmer, uses groundwater for drinking water consumption and irrigation of crops. It was assumed that garden size and crop yield were adequate to produce approximately 25 percent of average requirements of crops and animal products. The third type, an American Indian resident farmer, uses groundwater for both drinking water

consumption and irrigation of crops. In this case, it was assumed that garden size and crop yield were 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, which drink surface water.

The significance of the dose impacts was evaluated by comparing doses with the 100 millirem per year all-pathway standard specified for protection of the public and the environment in DOE Order 5400.5, *Radiation Protection of the Public and Environment*. Perspective on the radiological dose to the offsite population of 5 million individuals potentially using water from the Columbia River is provided by comparison with the background dose for the average individual of 365 millirem per year. The level of protection provided for the drinking water pathway was evaluated by comparison against the applicable drinking water standards presented in Chapter 5, Section 5.1.1. The significance of noncarcinogenic chemical health impacts was evaluated by comparison with a Hazard Index guideline value of less than unity.

6.4.2.1 Other Past, Present, and Reasonably Foreseeable Future Actions

The potential cumulative human health impacts of the past, present, and reasonably foreseeable future actions due to releases from non-TC & WM EIS sources are summarized in Table 6–23, for the drinking-water well user and resident farmer and Table 6–24 for the American Indian resident farmer and American Indian hunter-gatherer. The key radiological constituents contributing to human health risk are tritium, carbon-14, strontium-90, technetium-99, iodine-129, cesium-137, uranium isotopes, neptunium-237, and plutonium isotopes. The chemical risk and hazard drivers are 1-butonal, carbon tetrachloride, chromium, fluoride, hydrazine/hydrazine sulfate, manganese, mercury, nickel (soluble salts), nitrate, total uranium, and trichloroethylene. For all locations and all receptors, the peak radiological dose and risk have already occurred. For the peak Hazard Index and nonradiological risk, the peak has either already occurred or would occur between the years 2200 and 2500. For the period 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. For the period after calendar year 2000, risks remain high, with values between 1×10^{-3} and 1×10^{-2} . The estimated offsite population dose of 215 person-rem per year for the year of peak dose is approximately 0.01 percent of the average background dose for the population.

Table 6–23. Summary of Peak Impacts of Releases from Non-TC & WM EIS Sources for the Drinking-Water Well User and Resident Farmer Receptors

Location	Receptor									
	Drinking-Water Well User					Resident Farmer				
	Dose at Year of Peak Dose (millirem per year)	Hazard Index at Year of Peak Hazard Index (unitless)	Radiological Risk at Year of Peak Radiological Risk (unitless)	Nonradiological Risk at Peak Nonradiological Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)	Dose at Year of Peak Dose (millirem per year)	Hazard Index at Year of Peak Hazard Index (unitless)	Radiological Risk at Year of Peak Radiological Risk (unitless)	Nonradiological Risk at Peak Nonradiological Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)
On Site										
Core Zone Boundary	2.55×10 ⁴	1.84×10 ²	3.38×10 ⁻¹	5.33×10 ⁻³	3.39×10 ⁻¹	3.65×10 ⁴	9.13×10 ²	5.22×10 ⁻¹	3.35×10 ⁻²	5.24×10 ⁻¹
Columbia River Nearshore	3.42×10 ⁵	2.17×10 ²	1.0	9.66×10 ⁻⁵	1.0	4.51×10 ⁶	2.21×10 ²	1.0	6.07×10 ⁻⁴	1.0
Columbia River	N/A	N/A	N/A	N/A	N/A	4.29×10 ⁻²	1.14×10 ⁻³	7.71×10 ⁻⁷	3.41×10 ⁻⁸	8.04×10 ⁻⁷

Note: The total risk for the year of peak total risk may not equal the sum of the radiological and nonradiological risks for the year of peak risk, because the peak radiological and nonradiological risks are likely to occur at different times.

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

Table 6–24. Summary of Peak Impacts of Releases from Non-TC & WM EIS Sources for the American Indian Resident Farmer and American Indian Hunter-Gatherer Receptors

Location	Receptor									
	American Indian Resident Farmer					American Indian Hunter-Gatherer				
	Dose at Year of Peak Dose (millirem per year)	Hazard Index at Year of Peak Hazard Index (unitless)	Radiological Risk at Year of Peak Radiological Risk (unitless)	Nonradiological Risk at Peak Nonradiological Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)	Dose at Year of Peak Dose (millirem per year)	Hazard Index at Year of Peak Hazard Index (unitless)	Radiological Risk at Year of Peak Radiological Risk (unitless)	Nonradiological Risk at Peak Nonradiological Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)
On Site										
Core Zone Boundary	6.42×10 ⁴	3.83×10 ³	1.0	1.46×10 ⁻¹	1.0	N/A	N/A	N/A	N/A	N/A
Columbia River Nearshore	1.31×10 ⁷	3.05×10 ²	1.0	2.95×10 ⁻³	1.0	8.56×10 ⁶	6.71×10 ¹	1.0	5.95×10 ⁻³	1.0

Note: The total risk for the year of peak total risk may not equal the sum of the radiological and nonradiological risks for the year of peak risk, because the peak radiological and nonradiological risks are likely to occur at different times.

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

6.4.2.2 Alternative Combination 1

The potential cumulative human health impacts associated with Alternative Combination 1, together with the impacts of past, present, and reasonably foreseeable future actions (discussed above), are summarized in Table 6–25 for the drinking-water well user and resident farmer and Table 6–26 for the American Indian resident farmer and American Indian hunter-gatherer. The key radiological constituent contributors to human health risk are tritium, carbon-14, strontium-90, technetium-99, iodine-129, cesium-137, uranium isotopes, neptunium-237, and plutonium isotopes. The chemical risk and hazard drivers are 1-butanal, acetonitrile, boron and boron compounds, carbon tetrachloride, chromium, fluoride, hydrazine/hydrazine sulfate, manganese, mercury, nickel (soluble salts), nitrate, total uranium, and trichloroethylene. The impacts of Alternative Combination 1 are dominated by the impacts of releases from the non-*TC & WM EIS* sources. The estimate of the offsite population dose of 215 person-rem per year for the year of peak dose is approximately 0.01 percent of the average background dose for the population.

**Table 6–25. Alternative Combination 1 Summary of Peak Cumulative Impacts
for the Drinking-Water Well User and Resident Farmer Receptors**

Location	Receptor									
	Drinking-Water Well User					Resident Farmer				
	Dose at Year of Peak Dose (millirem per year)	Hazard Index at Year of Peak Hazard Index (unitless)	Radiological Risk at Year of Peak Radiological Risk (unitless)	Nonradiological Risk at Peak Nonradiological Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)	Dose at Year of Peak Dose (millirem per year)	Hazard Index at Year of Peak Hazard Index (unitless)	Radiological Risk at Year of Peak Radiological Risk (unitless)	Nonradiological Risk at Peak Nonradiological Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)
On Site										
Core Zone Boundary	2.55×10 ⁴	5.42×10 ²	3.38×10 ⁻¹	5.33×10 ⁻³	3.39×10 ⁻¹	3.66×10 ⁴	9.34×10 ²	5.22×10 ⁻¹	3.35×10 ⁻²	5.25×10 ⁻¹
Columbia River Nearshore	3.42×10 ⁵	2.17×10 ²	1.0	9.66×10 ⁻⁵	1.0	4.51×10 ⁶	2.21×10 ²	1.0	6.07×10 ⁻⁴	1.0
Columbia River	N/A	N/A	N/A	N/A	N/A	4.30×10 ⁻²	1.24×10 ⁻³	7.73×10 ⁻⁷	3.41×10 ⁻⁸	8.05×10 ⁻⁷

Note: The total risk for the year of peak total risk may not equal the sum of the radiological and nonradiological risks for the year of peak risk, because the peak radiological and nonradiological risks are likely to occur at different times.

Key: N/A=not applicable.

**Table 6–26. Alternative Combination 1 Summary of Peak Cumulative Impacts
for the American Indian Resident Farmer and American Indian Hunter-Gatherer Receptors**

Location	Receptor									
	American Indian Resident Farmer					American Indian Hunter-Gatherer				
	Dose at Year of Peak Dose (millirem per year)	Hazard Index at Year of Peak Hazard Index (unitless)	Radiological Risk at Year of Peak Radiological Risk (unitless)	Nonradiological Risk at Peak Nonradiological Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)	Dose at Year of Peak Dose (millirem per year)	Hazard Index at Year of Peak Hazard Index (unitless)	Radiological Risk at Year of Peak Radiological Risk (unitless)	Nonradiological Risk at Peak Nonradiological Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)
On Site										
Core Zone Boundary	6.42×10 ⁴	3.86×10 ³	1.0	1.47×10 ⁻¹	1.0	N/A	N/A	N/A	N/A	N/A
Columbia River Nearshore	1.31×10 ⁷	3.05×10 ²	1.0	2.95×10 ⁻³	1.0	8.56×10 ⁶	6.76×10 ¹	1.0	5.95×10 ⁻³	1.0

Note: The total risk for the year of peak total risk may not equal the sum of the radiological and nonradiological risks for the year of peak risk, because the peak radiological and nonradiological risks are likely to occur at different times.

Key: N/A=not applicable.

6.4.2.3 Alternative Combination 2

The potential cumulative human health impacts including Alternative Combination 2, together with the impacts of past, present, and reasonably foreseeable future actions (discussed above), are summarized in Table 6–27 for the drinking-water well user and resident farmer and Table 6–28 for the American Indian resident farmer and American Indian hunter-gatherer. The key radiological constituent contributors to human health risk are tritium, carbon-14, strontium-90, technetium-99, iodine-129, cesium-137, uranium isotopes, neptunium--237, and plutonium isotopes. The chemical risk and hazard drivers are 1-butonal, boron compounds, carbon tetrachloride, chromium, fluoride, hydrazine/hydrazine sulfate, manganese, mercury, nickel (soluble salts), nitrate, total uranium, and trichloroethylene. The impacts of Alternative Combination 2 are dominated by the impacts of releases from the non-*TC & WM EIS* sources. The estimate of the offsite population dose of 215 person-rem per year for the year of peak dose is approximately 0.01 percent of the average background dose for the population.

Table 6–27. Alternative Combination 2 Summary of Peak Cumulative Impacts for the Drinking-Water Well User and Resident Farmer Receptors

Location	Receptor									
	Drinking-Water Well User					Resident Farmer				
	Dose at Year of Peak Dose (millirem per year)	Hazard Index at Year of Peak Hazard Index (unitless)	Radiological Risk at Year of Peak Radiological Risk (unitless)	Nonradiological Risk at Peak Nonradiological Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)	Dose at Year of Peak Dose (millirem per year)	Hazard Index at Year of Peak Hazard Index (unitless)	Radiological Risk at Year of Peak Radiological Risk (unitless)	Nonradiological Risk at Peak Nonradiological Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)
On Site										
Core Zone Boundary	2.55×10^4	5.27×10^2	3.38×10^{-1}	5.33×10^{-3}	3.39×10^{-1}	3.66×10^4	9.34×10^2	5.22×10^{-1}	3.35×10^{-2}	5.25×10^{-1}
Columbia River Nearshore	3.42×10^5	2.17×10^2	1.0	9.66×10^{-5}	1.0	4.51×10^6	2.21×10^2	1.0	6.07×10^{-4}	1.0
Columbia River	N/A	N/A	N/A	N/A	N/A	4.30×10^{-2}	1.25×10^{-3}	7.73×10^{-7}	3.41×10^{-8}	8.05×10^{-7}

Note: The total risk for the year of peak total risk may not equal the sum of the radiological and nonradiological risks for the year of peak risk, because the peak radiological and nonradiological risks are likely to occur at different times.

Key: N/A=not applicable.

Table 6–28. Alternative Combination 2 Summary of Peak Cumulative Impacts for the American Indian Resident Farmer and American Indian Hunter-Gatherer Receptors

Location	Receptor									
	American Indian Resident Farmer					American Indian Hunter-Gatherer				
	Dose at Year of Peak Dose (millirem per year)	Hazard Index at Year of Peak Hazard Index (unitless)	Radiological Risk at Year of Peak Radiological Risk (unitless)	Nonradiological Risk at Peak Nonradiological Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)	Dose at Year of Peak Dose (millirem per year)	Hazard Index at Year of Peak Hazard Index (unitless)	Radiological Risk at Year of Peak Radiological Risk (unitless)	Nonradiological Risk at Peak Nonradiological Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)
On Site										
Core Zone Boundary	6.42×10^4	3.86×10^3	1.0	1.46×10^{-1}	1.0	N/A	N/A	N/A	N/A	N/A
Columbia River Nearshore	1.31×10^7	3.05×10^2	1.0	2.95×10^{-3}	1.0	8.56×10^6	6.74×10^1	1.0	5.95×10^{-3}	1.0

Note: The total risk for the year of peak total risk may not equal the sum of the radiological and nonradiological risks for the year of peak risk, because the peak radiological and nonradiological risks are likely to occur at different times.

Key: N/A=not applicable.

6.4.2.4 Alternative Combination 3

The potential cumulative human health impacts of Alternative Combination 3, together with the impacts of past, present and reasonably foreseeable future actions (discussed above), are summarized in Table 6–29 for the drinking-water well user and resident farmer and Table 6–30 for the American Indian resident farmer and American Indian hunter-gatherer. The key radiological constituent contributors to human health risk are tritium, carbon-14, strontium-90, technetium-99, iodine-129, cesium-137, uranium isotopes, neptunium-237, and plutonium isotopes. The chemical risk and hazard drivers are 1-butonal, boron and boron compounds, carbon tetrachloride, chromium, fluoride, hydrazine/hydrazine sulfate, manganese, mercury, nickel (soluble salts), nitrate, total uranium, and trichloroethylene. The impacts of Alternative Combination 3 are dominated by the impacts of releases from the non-*TC & WM EIS* sources. The estimate of the offsite population dose of 215 person-rem per year for the year of peak dose is approximately 0.01 percent of the average background dose for the population.

Table 6–29. Alternative Combination 3 Summary of Peak Cumulative Impacts for the Drinking-Water Well User and Resident Farmer Receptors

Location	Receptor									
	Drinking-Water Well User					Resident Farmer				
	Dose at Year of Peak Dose (millirem per year)	Hazard Index at Year of Peak Hazard Index (unitless)	Radiological Risk at Year of Peak Radiological Risk (unitless)	Nonradiological Risk at Peak Nonradiological Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)	Dose at Year of Peak Dose (millirem per year)	Hazard Index at Year of Peak Hazard Index (unitless)	Radiological Risk at Year of Peak Radiological Risk (unitless)	Nonradiological Risk at Peak Nonradiological Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)
On Site										
Core Zone Boundary	2.55×10 ⁴	5.27×10 ²	3.38×10 ⁻¹	5.33×10 ⁻³	3.39×10 ⁻¹	3.66×10 ⁴	9.33×10 ²	5.22×10 ⁻¹	3.35×10 ⁻²	5.25×10 ⁻¹
Columbia River Nearshore	3.42×10 ⁵	2.17×10 ²	1.0	9.66×10 ⁻⁵	1.0	4.51×10 ⁶	2.21×10 ²	1.0	6.07×10 ⁻⁴	1.0
Columbia River	N/A	N/A	N/A	N/A	N/A	4.30×10 ⁻²	1.25×10 ⁻³	7.73×10 ⁻⁷	3.41×10 ⁻⁸	8.05×10 ⁻⁷

Note: The total risk for the year of peak total risk may not equal the sum of the radiological and nonradiological risks for the year of peak risk, because the peak radiological and nonradiological risks are likely to occur at different times.

Key: N/A=not applicable.

Table 6–30. Alternative Combination 3 Summary of Peak Cumulative Impacts for the American Indian Resident Farmer and American Indian Hunter-Gatherer Receptors

Location	Receptor									
	American Indian Resident Farmer					American Indian Hunter-Gatherer				
	Dose at Year of Peak Dose (millirem per year)	Hazard Index at Year of Peak Hazard Index (unitless)	Radiological Risk at Year of Peak Radiological Risk (unitless)	Nonradiological Risk at Peak Nonradiological Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)	Dose at Year of Peak Dose (millirem per year)	Hazard Index at Year of Peak Hazard Index (unitless)	Radiological Risk at Year of Peak Radiological Risk (unitless)	Nonradiological Risk at Peak Nonradiological Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)
On Site										
Core Zone Boundary	6.42×10 ⁴	3.86×10 ³	1.0	1.46×10 ⁻¹	1.0	N/A	N/A	N/A	N/A	N/A
Columbia River Nearshore	1.31×10 ⁷	3.05×10 ²	1.0	2.95×10 ⁻³	1.0	8.56×10 ⁶	6.74×10 ¹	1.0	5.95×10 ⁻³	1.0

Note: The total risk for the year of peak total risk may not equal the sum of the radiological and nonradiological risks for the year of peak risk, because the peak radiological and nonradiological risks are likely to occur at different times.

Key: N/A=not applicable.

6.4.3 Ecological Risk

This section presents the results of the analysis of cumulative long-term impacts on ecological resources from exposure to chemicals and radionuclides released to the environment as a result of past, present, and reasonably foreseeable future actions. The cumulative impacts analysis incorporates estimated cumulative concentrations of chemicals and radionuclides in soil and estimated peak concentrations in air, water, and sediment from the ecological risk analysis for the *TC & WM EIS* alternatives. Detailed information on the ecological risk analysis for the *TC & WM EIS* alternatives appears in Appendix P.

As described in Appendix R, cumulative impacts are evaluated in an ROI that includes the proposed *TC & WM EIS* action areas, Hanford, and the Hanford Reach of the Columbia River. A general description of ecological resources at Hanford and within the region is presented in Chapter 3, Section 3.2.7. The long-term ecological risk from releases to air and groundwater as a result of the three combinations of Tank Closure, FFTF Decommissioning, and Waste Management alternatives is summarized in Chapter 5, Section 5.4. Section 6.3.7 presents the analysis of cumulative impacts to ecological resources that may occur as a result of land use changes in the ROI.

The analysis of long-term cumulative impacts to ecological receptors presented here focuses on risk from exposure to chemicals and radionuclides released to air and groundwater as a result of DOE actions at Hanford. The releases to air from Waste Treatment Plant operations are summarized in Chapter 2, Section 2.8.3.4. The releases to groundwater are summarized in Chapter 2, Section 2.9.1. The cumulative impacts analysis assumes impacts from contaminant releases of a given type (air or groundwater) from different sources coincide, even though many would not. This provides the most conservative estimate of cumulative impacts. The combined cumulative long-term impacts of releases to air and groundwater were not analyzed because groundwater impacts to ecological resources are not expected to occur until hundreds or thousands of years after the air impacts.

For air releases, cumulative impacts were evaluated by combining estimated media concentrations resulting from *TC & WM EIS* alternative combinations with reported baseline media concentrations resulting from past and current practices. Maximum soil concentrations from samples collected by Hanford environmental monitoring program (Poston et al. 2006, 2007; Poston, Hanf, and Dirkes 2005) were used to estimate baseline conditions. Estimated media concentrations for the *TC & WM EIS* alternative combinations came from models of transport and deposition of contaminants released to air and deposited on soil, sediment and surface water. There are no comparable estimated concentrations of chemical and radiological contaminants in air or soil from other future DOE actions at Hanford and non-DOE actions in the ROI. Therefore, estimated concentrations for the *TC & WM EIS* alternative combinations were added to reported maximum measured baseline concentrations. The addition of estimated *TC & WM EIS* alternative combinations to measured baseline concentrations focuses attention on those instances where the cumulative impacts pose a potential risk when there is little to no risk from either measured baseline conditions or the *TC & WM EIS* alternative combinations separately. No such cases were found (see Section 6.4.3.1).

For groundwater releases, cumulative impacts were estimated as the sum of impacts from predicted contaminant releases associated with *TC & WM EIS* alternative combinations (see Appendix D) and from past, present, and reasonably foreseeable future non-*TC & WM EIS*-related releases at Hanford as captured in the cumulative contaminant inventory (see Appendix S). Estimated media concentrations for the *TC & WM EIS* alternative combinations and cumulative impacts analysis came from models of release and transport through the vadose zone, groundwater transport, and eventual discharge of contaminants to the Columbia River and its riparian zone. Hazard Quotients were calculated for the cumulative impacts under the three Tank Closure, FFTF Decommissioning, and Waste Management alternative combinations (see Appendix P). Cumulative impacts for groundwater are discussed in Section 6.4.3.2.

6.4.3.1 Air

The cumulative long-term impacts on ecological receptors of estimated media concentrations resulting from air releases and actual media concentrations are not different from their separate long-term impacts. Where there is not already a potential risk from either actual media concentrations or the *TC & WM EIS* alternative combination, there would be no risk from the cumulative impacts. Where there would be a potential risk to ecological receptors, the risk would result from either concentrations from actual media concentrations or the estimated concentrations from the *TC & WM EIS* alternative combination, but not both.

Table 6–31 presents the maximum concentrations for select *TC & WM EIS* chemical and radiological COPCs with corresponding data from Hanford Site Environmental Surveillance Data Reports for 2004, 2005, and 2006 (Poston et al. 2006, 2007; Poston, Hanf, and Dirkes 2005). The selected COPCs are those with the highest Hazard Quotients under the three alternative combinations: mercury for receptors exposed to soil and air at the onsite maximum-impact location (see Chapter 5, Table 5–6), and mercury and benzene for receptors exposed to sediment and Columbia River surface water. For these analytes, only the estimated cumulative concentrations of mercury in onsite surface soil for Alternative Combinations 2 and 3 pose a potential for adverse impacts to ecological receptors. Comparing the estimated mercury soil concentrations for Combinations 2 and 3 to the maximum mercury concentration reported for the Hanford monitoring program shows that the latter is three orders of magnitude smaller than the estimated value and does not pose a risk to ecological receptors. Conversely, maximum baseline concentrations of mercury and benzene (as well as ammonia) in Columbia River surface water could potentially have adverse impacts on ecological receptors because they exceed published benchmarks (e.g., maximum Hazard Quotient = 172 for side-blotched lizard) (see Table 6–32), but the estimated concentrations resulting from the *TC & WM EIS* alternative combinations would contribute insignificantly to the risk. Maximum baseline concentrations of mercury in sediment, which are nearly 20 times larger than those estimated for Combinations 2 and 3, are nearly equal to the benchmark.

Table 6–31. Potential Cumulative Impacts on Ecological Risk from Releases to Air

Action/Activity	Concentration of COPC in the Environmental Medium			
	Mercury			Benzene
	Soil (mg/kg)	Surface Water (mg/L)	Sediment (mg/kg)	Surface Water (mg/L)
TC&WM EIS Alternative Combinations^a				
Alternative Combination 1	0	0	0	5.1×10^{-8}
Alternative Combination 2	2.46	2.4×10^{-9}	8.9×10^{-3}	4.6×10^{-8}
Alternative Combination 3	2.56	3.7×10^{-9}	9.2×10^{-3}	6.9×10^{-8}
Other DOE Actions at the Hanford Site				
Hanford Site baseline ^a	7.0×10^{-3}	6.3×10^{-6}	2.0×10^{-1}	1.7×10^{-4}
Other DOE Actions Subtotal	7.0×10^{-3}	6.3×10^{-6}	2.0×10^{-1}	1.7×10^{-4}
Cumulative Totals^b				
Alternative Combination 1	7.0×10^{-3}	6.3×10^{-6}	2.0×10^{-1}	1.7×10^{-4}
Alternative Combination 2	2.47	6.3×10^{-6}	2.1×10^{-1}	1.7×10^{-4}
Alternative Combination 3	2.57	6.3×10^{-6}	2.1×10^{-1}	1.7×10^{-4}
Benchmark Concentration^c	1.5×10^{-2}	2.8×10^{-6}	2.0×10^{-1}	3.16×10^{-5}

^a Maximum onsite and Columbia River values in Hanford Site Environmental Reports for calendar years 2004, 2005, and 2006 (Poston, Hanf, and Dirkes 2005; Poston et al. 2006, 2007).

^b Sum of *TC & WM EIS* and Hanford Site baseline values.

^c From Table 6–32.

Note: Concentrations exceeding the benchmark values are shown in **bold** text. To convert kilograms to pounds, multiply by 2.2046; liters to gallons, by 0.26417.

Key: COPC=constituent of potential concern; DOE=U.S. Department of Energy; mg/kg=milligrams per kilogram; mg/L=milligrams per liter; *TC & WM EIS*=*Tank Closure and Waste Management Environmental Impact Statement for the Hanford Site, Richland, Washington*.

Source: Poston, Hanf, and Dirkes 2005; Poston et al. 2006, 2007.

Table 6–32. Toxicity Benchmark Concentrations for Ecological Receptors Exposed to Chemicals in Soil, Water, and Sediment

Chemical	Water (mg/L)		Soil (mg/kg)		Sediment (mg/kg)	
	Value	Source	Value	Source	Value	Source
Chromium ^a	2.7×10^{-4}	Suter and Tsao 1996 ^b	–	–	–	–
Lead	–	–	–	–	3.1×10^1	EPA 1999
Mercury	2.8×10^{-6}	EPA 1999 ^c	1.5×10^{-2}	c, d	2.0×10^{-1}	EPA 1999 ^c
Uranium	–	–	–	–	1.3×10^1	e
Benzene	3.16×10^{-5}	Suter and Tsao 1996 ^f	–	–	–	–

^a It was assumed, for the purposes of analysis, that all chromium was hexavalent.

^b Sensitive Species Test 20 percent Effect Concentration for chromium.

^c Value for methyl mercury.

^d Soil mercury concentration producing $HQ = 1$ for side-blotched lizard: $C_{soil} = TRV / (IR_{food} \times BAF-S + IR_{soil})$; $TRV = 0.0064$ mg/kg body weight/day (Sample, Opresko, and Suter 1996); $IR_{food} = 0.05$ kg food/kg body weight/day (Sample et al. 1997); $BAF-S = 8.5$ kg dry soil/kg tissue (EPA 1999); $IR_{soil} = IR_{food} \times SF$; $SF = 0.011$ kg dry soil/kg food (DOE 1998b).

^e Sediment uranium concentration producing $HQ = 1$ for raccoon: $C_{sediment} = TRV / (IR_{food} \times BASF + IR_{sediment})$; $TRV = 3.07$ mg/kg body weight/day (Sample, Opresko, and Suter 1996); $IR_{food} = 0.26$ kg food/kg body weight/day (Sample et al. 1997); $BASF = 0.893$ kg dry sediment/kg tissue (EPA 1999); $IR_{sediment} = IR_{food} \times SF$; $SF = 0.018$ kg dry soil/kg food (DOE 1998b).

^f Acute lowest observed adverse effect level for rainbow trout $\times 0.1$ acute-to-chronic conversion factor.

Note: To convert liters to gallons, multiply by 0.26417; kilograms to pounds, by 2.2046.

Key: BAF=bioaccumulation factor; BAF-S=soil-to-soil invertebrate BAF; BASF=sediment-to-benthic-invertebrate BAF; C=concentration; HQ=Hazard Quotient; IR=ingestion rate; mg/kg=milligrams per kilogram; mg/L=milligrams per liter; TRV=toxicity reference value.

Source: DOE 1998b; EPA 1999; Sample, Opresko, and Suter 1996; Sample et al. 1997, Suter and Tsao 1996.

The relationship between reported data for non-DOE facilities in or near the ROI and the estimated cumulative values for this *TC & WM EIS* is similar to that for the Hanford onsite baseline data. Soil grab samples at the AREVA NP fuel fabrication facility between 2000 and 2005 did not exceed 3.75 picocuries per gram uranium (AREVA 2006), which is 10 times smaller than the maximum estimated onsite soil concentration for *TC & WM EIS* alternative combinations (Alternative Combination 1, onsite soil, 32.2 picocuries per gram). Plant stack data for air emissions from the Perma-Fix Northwest (formerly known as Pacific EcoSolutions) low-level radioactive and mixed waste processing facilities in 2006 did not exceed 0.0042 picocuries per cubic meter cobalt-60 (Pacific EcoSolutions 2007), which is over 10 times less than the maximum estimated onsite air concentration for the *TC & WM EIS* alternative combinations (Combination 1, onsite air, 0.096 picocuries per cubic meter). Soil samples at the US Ecology Commercial Low-Level Radioactive Waste Disposal Facility have activities less than the maximum estimated *TC & WM EIS* values and Hanford baseline values for all radiological COPCs (Ecology and WSDOH 2004); with the exception of total uranium for 1998 (maximum 0.8 picocuries per cubic meter), which exceeded the baseline uranium-238 value (maximum 0.31 picocuries per cubic meter). Tritium in water (Stormwater Outfall Sample 101) from the Energy Northwest Columbia Generating Station was measured as high as 17,100 picocuries per liter (Energy Northwest 2006b), exceeding the Hanford baseline maximum by a factor of 25 (594 picocuries per liter) and the estimated *TC & WM EIS* value by a factor of 240,000 (0.07 picocuries per liter). Not one of these cobalt-60, tritium and uranium activities pose a risk to ecological receptors (see Chapter 5, Section 5.4), thus, there is unlikely to be a cumulative impact. Moravek Biochemicals reported 2004 air releases of tritium and carbon-14 within permissible levels (Moravek 2005). Future releases from the Moravek facility could potentially add to impacts from estimated air emissions of tritium and carbon-14 for the *TC & WM EIS* alternatives.

Cumulative impacts from air emissions from construction projects and operation activities off site could potentially increase impacts to ecological receptors exposed to nitrogen oxides and sulfur oxides from burning diesel fuel. Emissions of volatile organic carbon compounds such as acetaldehyde, acetic acid, ethyl acetate, formaldehyde, ethanol, and methanol from biofuel plants (e.g., the Columbia Ethanol Plant) may have impacts on ecological receptors. The magnitude of those impacts cannot be estimated using the available information. In general, potential offsite sources of air emissions (see Appendix R, Table R-5) are not expected to contribute significantly to cumulative ecological risk at Hanford.

6.4.3.2 Groundwater

Cumulative impacts on ecological resources from releases to groundwater were calculated for the three *TC & WM EIS* alternative combinations. The largest risk indices for each aquatic and riparian receptor exposed to chemical COPCs in groundwater discharging at the Columbia River are summarized in Table 6-33. Impacts are presented in Table 6-33 for the three *TC & WM EIS* alternative combinations and the cumulative releases (i.e., releases associated with the three alternative combinations plus non-*TC & WM EIS*-related releases). Impacts from radiological COPCs are never as high as those from chemical COPCs.

Table 6-33. Summary of Long-Term Impacts of Alternative Combinations and Cumulative Impacts on Aquatic and Riparian Resources at the Columbia River Resulting from Contaminant Releases to Groundwater

	Hazard Quotient for Maximum Reasonably Foreseeable COPC						
	Benthic Invertebrate	Muskrat	Spotted Sandpiper	Raccoon	Least Weasel	Bald Eagle	Aquatic Biota/Salmonids
Alternative Combinations							
	Chromium ^a			Uranium	Nitrate	Chromium ^a	
Alternative Combination 1	1.20×10 ⁻¹	4.71×10 ⁻³	8.17×10 ⁻¹	2.95×10 ⁻¹	6.31×10 ⁻¹	2.08×10 ⁻²	2.14×10¹
Alternative Combination 2	2.56×10 ⁻²	1.00×10 ⁻³	1.74×10 ⁻¹	2.88×10 ⁻²	6.43×10 ⁻¹	1.51×10 ⁻²	2.22×10¹
Alternative Combination 3	2.60×10 ⁻²	1.02×10 ⁻³	1.77×10 ⁻¹	2.72×10 ⁻³	6.44×10 ⁻¹	1.52×10 ⁻²	2.23×10¹
Cumulative Impacts with Alternative Combinations							
	Lead						Chromium ^a
Alternative Combination 1	2.64×10²	2.42×10¹	1.29×10⁵	3.68×10⁴	4.76×10²	1.71×10²	2.28×10²
Alternative Combination 2	2.64×10²	2.42×10¹	1.29×10⁵	3.68×10⁴	4.76×10²	1.71×10²	2.29×10²
Alternative Combination 3	2.64×10²	2.42×10¹	1.29×10⁵	3.68×10⁴	4.76×10²	1.71×10²	2.29×10²

^a It was assumed, for the purposes of analysis, that all chromium was hexavalent.

Note: Hazard Quotient is unitless. Values greater than 1 are shown in **bold** text.

Key: COPC=constituent of potential concern.

The highest risk indexes for the alternative combinations for benthic invertebrates, muskrat, spotted sandpiper, bald eagle and aquatic biota, including salmonids, are those for chromium. The highest index for raccoons is that for uranium in sediment, and the highest for the least weasel is that for nitrate in seeps at the Columbia River. Chromium in aquatic biota, including salmonids, is the only COPC with an Hazard Quotient exceeding 1 for the alternative combinations. Hazard Quotients less than 1 indicate no risk to the receptor.

The highest risk index for the cumulative impacts would result from lead for all receptors except aquatic biota and salmonids. For the latter, the highest risk index for the cumulative impact analysis would be

from chromium. All of the maximum risk indices for the cumulative impacts would exceed 1. Other COPCs identified in the cumulative impacts analysis as potentially causing adverse impacts on aquatic and riparian receptors (risk index greater than 10) would include the chemicals fluoride, mercury, nickel, and uranium, as well as the radionuclides cesium-137, plutonium-239 and uranium-238 (see Table 6–34).

**Table 6–34. Risk Indices for Aquatic and Riparian Receptors
and Selected Chemical and Radiological Constituents of Potential Concern –
Cumulative Impacts with Alternative Combinations**

Constituents of Potential Concern	Benthic Invertebrate	Muskrat	Spotted Sandpiper	Raccoon	Bald Eagle	Least Weasel	Aquatic Biota/ Salmonids
Cumulative Impacts with Alternative Combination 1							
Chemical COPCs							
Carbon tetrachloride	6.19	8.55×10 ⁻³	No TRV	1.63	No TRV	4.44×10 ⁻²	2.29×10 ⁻¹
Chromium ^a	1.19×10¹	4.65×10 ⁻¹	8.06×10¹	9.76	9.05×10 ⁻¹	8.92×10 ⁻¹	2.28×10²
Fluoride	No TRV	4.64×10 ⁻²	1.54×10²	1.65×10¹	1.65	1.22	No TRV
Lead	2.64×10²	2.42×10¹	1.29×10⁵	3.68×10⁴	1.71×10²	4.76×10²	1.74×10 ⁻¹
Mercury	1.27×10²	7.96×10 ⁻²	1.22×10³	1.03×10²	2.29	1.86	3.97×10 ⁻¹
Nickel	3.38×10¹	1.66×10 ⁻²	4.63	2.59	8.85×10 ⁻³	4.35×10 ⁻²	1.21×10 ⁻³
Nitrate	No TRV	1.04×10 ⁻¹	No TRV	3.34×10 ⁻¹	No TRV	1.51	No TRV
Uranium	No TRV	5.02×10 ⁻¹	2.38×10²	5.35×10²	2.96×10 ⁻¹	6.02	4.20
Radiological COPCs							
All radionuclides combined (rad/d) ^b	1.58×10²	1.03×10 ⁻¹	4.07×10²	1.92×10²	4.12×10 ⁻¹	1.58	1.76
Cesium-137	5.12×10¹	5.02×10 ⁻²	3.85×10²	1.83×10²	3.90×10 ⁻¹	1.49	1.70
Plutonium-239	2.25×10¹	5.60×10 ⁻⁷	1.39×10 ⁻²	5.97×10 ⁻³	1.23×10 ⁻⁵	5.21×10 ⁻⁵	2.16×10 ⁻⁵
Strontium-90	7.53	2.51×10 ⁻³	2.79	1.20	3.48×10 ⁻³	1.38×10 ⁻²	1.40×10 ⁻³
Uranium-238	7.72×10¹	9.60×10 ⁻⁴	1.88×10¹	8.11	1.76×10 ⁻²	7.34×10 ⁻²	5.75×10 ⁻²
Cumulative Impacts with Alternative Combination 2							
Chemical COPCs							
Carbon tetrachloride	6.19	8.55×10 ⁻³	No TRV	1.63	No TRV	4.44×10 ⁻²	2.29×10 ⁻¹
Chromium ^a	1.18×10¹	4.61×10 ⁻¹	8.00×10¹	9.69	8.99×10 ⁻¹	8.86×10 ⁻¹	2.29×10²
Fluoride	No TRV	4.64×10 ⁻²	1.54×10²	1.65×10¹	1.65	1.22	No TRV
Lead	2.64×10²	2.42×10¹	1.29×10⁵	3.68×10⁴	1.71×10²	4.76×10²	1.74×10 ⁻¹
Mercury	1.27×10²	7.96×10 ⁻²	1.22×10³	1.03×10²	2.29	1.86	3.97×10 ⁻¹
Nickel	3.38×10¹	1.66×10 ⁻²	4.63	2.59	8.85×10 ⁻³	4.35×10 ⁻²	1.21×10 ⁻³
Nitrate	No TRV	1.01×10 ⁻¹	No TRV	3.26×10 ⁻¹	No TRV	1.52	No TRV
Uranium	No TRV	5.01×10 ⁻¹	2.38×10²	5.35×10²	2.96×10 ⁻¹	6.01	4.19
Radiological COPCs							
All radionuclides combined (rad/d) ^b	1.58×10²	1.03×10 ⁻¹	4.07×10²	1.92×10²	4.11×10 ⁻¹	1.58	1.76
Cesium-137	5.12×10¹	5.02×10 ⁻²	3.85×10²	1.83×10²	3.90×10 ⁻¹	1.49	1.70
Plutonium-239	2.25×10¹	5.60×10 ⁻⁷	1.39×10 ⁻²	5.97×10 ⁻³	1.23×10 ⁻⁵	5.21×10 ⁻⁵	2.16×10 ⁻⁵
Strontium-90	7.53	2.51×10 ⁻³	2.79	1.20	3.48×10 ⁻³	1.38×10 ⁻²	1.40×10 ⁻³
Uranium-238	7.72×10¹	9.59×10 ⁻⁴	1.88×10¹	8.11	1.76×10 ⁻²	7.34×10 ⁻²	5.75×10 ⁻²

Table 6–34. Risk Indices for Aquatic and Riparian Receptors and Selected Chemical and Radiological Constituents of Potential Concern – Cumulative Impacts with Alternative Combinations (*continued*)

Constituents of Potential Concern	Benthic Invertebrate	Muskrat	Spotted Sandpiper	Raccoon	Bald Eagle	Least Weasel	Aquatic Biota/Salmonids
Cumulative Impacts with Alternative Combination 3							
Chemical COPCs							
Carbon tetrachloride	6.19	8.55×10^{-3}	No TRV	1.63	No TRV	4.44×10^{-2}	2.29×10^{-1}
Chromium ^a	1.18×10^1	4.61×10^{-1}	8.00×10^1	9.69	8.99×10^{-1}	8.86×10^{-1}	2.29×10^2
Fluoride	No TRV	4.64×10^{-2}	1.54×10^2	1.65×10^1	1.65	1.22	No TRV
Lead	2.64×10^2	2.42×10^1	1.29×10^5	3.68×10^4	1.71×10^2	4.76×10^2	1.74×10^{-1}
Mercury	1.27×10^2	7.96×10^{-2}	1.22×10^3	1.03×10^2	2.29	1.86	3.97×10^{-1}
Nickel	3.38×10^1	1.66×10^{-2}	4.63	2.59	8.85×10^{-3}	4.35×10^{-2}	1.21×10^{-3}
Nitrate	No TRV	1.01×10^{-1}	No TRV	3.26×10^{-1}	No TRV	1.53	No TRV
Uranium	No TRV	5.01×10^{-1}	2.38×10^2	5.35×10^2	2.96×10^{-1}	6.01	4.18
Radiological COPCs							
All radionuclides combined (rad/d) ^b	1.58×10^2	1.03×10^{-1}	4.07×10^2	1.92×10^2	4.11×10^{-1}	1.58	1.76
Cesium-137	5.12×10^1	5.02×10^{-2}	3.85×10^2	1.83×10^2	3.90×10^{-1}	1.49	1.70
Plutonium-239	2.25×10^1	5.60×10^{-7}	1.39×10^{-2}	5.97×10^{-3}	1.23×10^{-5}	5.21×10^{-5}	2.16×10^{-5}
Strontium-90	7.53	2.51×10^{-3}	2.79	1.20	3.48×10^{-3}	1.38×10^{-2}	1.40×10^{-3}
Uranium-238	7.72×10^1	9.59×10^{-4}	1.88×10^1	8.11	1.76×10^{-2}	7.34×10^{-2}	5.75×10^{-2}

^a It was assumed, for the purposes of analysis, that all chromium was hexavalent.

^b Includes the contribution from radiological COPCs not shown in the table.

Note: Risk indices exceeding 1 are shown in **bold** text; risk indices are unitless.

Key: COPC=constituent of potential concern; rad/d=rads per day; TRV=toxicity reference value.

Estimated impacts from groundwater releases that are not associated with the *TC & WM EIS* alternatives, e.g., past leaks, are greater than estimated impacts from releases associated with the *TC & WM EIS* alternatives. For example, impacts from estimated concentrations of uranium in sediment and chromium in surface water that are associated with the *TC & WM EIS* alternatives would represent a small fraction of the cumulative impacts (see Table 6–35). Estimated concentrations resulting from groundwater releases that are not associated with the *TC & WM EIS* alternatives are approximately 10 times the estimated concentrations associated with the *TC & WM EIS* alternatives for chromium and several orders of magnitude greater than estimated concentrations of uranium. Other COPCs showing this pattern are fluoride and uranium-238. Nitrate concentrations in groundwater associated with the *TC & WM EIS* alternatives are estimated to be about 2 to 5 percent of the concentrations in groundwater due to releases not associated with the *TC & WM EIS* alternatives. Lead is not estimated to occur in groundwater discharging at the Columbia River under the *TC & WM EIS* alternative combinations, but it is a source of cumulative impact to aquatic and riparian receptors exposed to sediment as a result of past leaks (see Table 6–35). Other constituents showing this pattern are mercury, nickel, cesium-137, and plutonium-239.

Estimated cumulative long-term impacts from chromium, lead, and uranium releases exceed benchmark concentrations. The cumulative impacts from these COPCs in groundwater result from the high concentrations associated with non-*TC & WM EIS*-related releases (see Table 6–35). For groundwater releases associated with the *TC & WM EIS* alternative combinations, only chromium exceeds toxicity benchmarks.

**Table 6–35. Summary of Long-Term Impacts of Alternative Combinations
and Cumulative Impacts on Aquatic and Riparian Resources at the Columbia River
Resulting from Contaminant Releases to Groundwater**

Action/Activity	Concentration of COPCs in Environmental Medium			
	Groundwater (mg/L Nitrate)	Sediment (mg/kg Uranium)	Surface Water (mg/L Chromium ^a)	Sediment (mg/kg Lead)
This TC & WM EIS				
Alternative Combination 1	23.5	3.8	0.0057	0
Alternative Combination 2	11.0	0.37	0.0059	0
Alternative Combination 3	11.7	0.035	0.0059	0
Other DOE Actions at Hanford				
Past Leaks and Other ^b	502	6,927	0.055	8,176
Other DOE Actions Subtotal	502	6,927	0.055	8,176
Cumulative Total^c				
Alternative Combination 1	526	6,931	0.06	8,176
Alternative Combination 2	513	6,927	0.06	8,176
Alternative Combination 3	514	6,927	0.06	8,176
Benchmark^d	No data	13	0.00027	31

^a It was assumed, for the purposes of analysis, that all chromium was hexavalent.

^b Difference of concentrations for TC & WM EIS alternative combinations and Past Leaks and Other releases combined and concentrations for TC & WM EIS alternative combinations.

^c Sum of TC & WM EIS alternative combinations and other DOE actions.

^d From Table 6–32.

Note: Concentrations exceeding the benchmark concentrations are shown in **bold** text.

Key: COPC=constituent of potential concern; DOE=U.S. Department of Energy; Hanford=Hanford Site; mg/kg=milligrams per kilogram; mg/L=milligrams per liter; TC & WM EIS =Tank Closure and Waste Management Environmental Impact Statement.

Impacts from releases to groundwater from upstream sources are discussed in Section 6.4.2. These releases are not expected to contribute substantially to impacts to the Hanford Reach of the Columbia River given the distances and river-flow volumes. In addition, the proposed Black Rock Reservoir could change the groundwater flow field, which could, in turn, alter the contaminant concentrations and timing of discharges of peak concentrations to the Columbia River (see Appendix V).

6.4.4 Environmental Justice

This section presents the cumulative impacts analysis for environmental justice. Sections 6.4.1 and 6.4.2 evaluate cumulative groundwater impacts and associated potential human health effects. The receptors analyzed with the potential for environmental justice concerns include a resident farmer, an American Indian resident farmer, and an American Indian hunter-gatherer. The hypothetical resident farmer and American Indian resident farmer were both assumed to use only groundwater for drinking water ingestion and crop irrigation. While only a portion of the food consumed by the resident farmer was assumed to come from crops and animal products exposed to contaminated groundwater, all of the food consumed by the American Indian resident farmer was assumed to come from crops and animal products exposed to contaminated groundwater. The American Indian hunter-gatherer does not cultivate crops, but rather gathers food from indigenous plants and harvests fish from the Columbia River; he is assumed to be exposed to a combination of surface water and groundwater. Based on these assumptions, the two American Indian receptors would be most at risk from contaminated groundwater.

As demonstrated by Tables 6–14, 6–18, and 6–22, which show the maximum cumulative concentrations of the COPCs, as well as Figures 6–2 through 6–9, 6–35 through 6–42, and 6–72 through 6–79, which show cumulative concentrations versus time, for all locations and all receptors, the peak radiological

impacts have already occurred. Cumulative releases of radiological materials results in the doses to the resident farmer, the American Indian resident farmer, and the American Indian hunter-gatherer exceeding regulatory standards at the applicable Core Zone Boundary and the Columbia River nearshore locations. In all instances, these releases exceed regulatory limits by several orders of magnitude.

Peak nonradiological impacts have either already occurred or would occur between the years 2200 and 2500. Releases of nonradiological materials from cumulative analysis sources result in Hazard Index guidelines being exceeded for the resident farmer, the American Indian resident farmer, and the American Indian hunter-gatherer at the applicable Core Zone Boundary and the Columbia River nearshore locations.

The human health risk analysis determined that releases from cumulative analysis sources would result in impacts in excess of regulatory limits only if an individual were located on site at the Core Zone Boundary and the Columbia River nearshore location and if all of their food and water were exposed to contaminated groundwater and surface water. There are no such onsite receptors currently at Hanford. The onsite exposure scenarios do not currently exist and have never existed during Hanford operations. Therefore, the estimated high health risks for past years are hypothetical risks only; no persons were ever exposed at these levels. While it is possible for these receptor scenarios to develop in the future, none are expected within a reasonably foreseeable timeframe because the Core Zone is designated for Industrial-Exclusive use, the Columbia River nearshore location is designated for Preservation (Hanford Reach National Monument), and the area between them is designated for Conservation (Mining) (DOE 1999a). Therefore it is unlikely that cumulative releases would pose a disproportionately high and adverse long-term human health risk to the American Indian population. As discussed in Chapter 5, the alternative combination with the greatest impact on long-term human health would be Alternative Combination 1. Cumulative impacts, including Alternative Combination 1, would be dominated by impacts due to releases from past, present, and reasonably foreseeable future non-TC & WM EIS-related actions.

6.5 REGIONAL AND GLOBAL CUMULATIVE IMPACTS

6.5.1 Ozone Depletion

The TC & WM EIS alternatives are not expected to use or discharge substantial quantities of any ozone-depleting compounds. Construction and operations activities would be accomplished using materials and equipment formulated to be compliant with laws and regulations to reduce the use of ozone-depleting compounds. Any release of ozone-depleting compounds would be incidental to the conduct of the TC & WM EIS activities, such as releases that might occur during demolition of older air conditioning systems that contain unrecovered, ozone-depleting compounds. Emissions of carbon tetrachloride from groundwater plume vapor extraction in the 200-West Area are below reportable quantities (Poston et al. 2007:10.10). Emissions of ozone-depleting compounds would be very small and would represent a negligible contribution to the destruction of the Earth's protective ozone layer.

6.5.2 Global Climate Change

The “natural greenhouse effect” is the process by which part of terrestrial radiation is absorbed by gases in the atmosphere, warming the Earth's surface and atmosphere. This greenhouse effect and the Earth's radiation balance are affected largely by water vapor, carbon dioxide, and trace gases, which absorb infrared radiation and are referred to as greenhouse gases. Other greenhouse gases include nitrous oxide, halocarbons, and methane.

There is consensus among scientists, including those on the Intergovernmental Panel on Climate Change (IPCC), that increases in atmospheric concentrations of certain pollutants can produce changes in the Earth's atmospheric energy balance and thereby influence global climate. These pollutants are commonly referred to as greenhouse gases, and this warming effect is referred to as global warming. Water vapor

(1 percent of the atmosphere) is the most common and dominant greenhouse gas; only small amounts of water vapor are produced as the result of human activities. The principal greenhouse gases resulting from human activities are carbon dioxide, methane, nitrous oxide, and halocarbons. Halocarbons include chlorofluorocarbons; hydrofluorocarbons, which are replacing chlorofluorocarbons as refrigerants; and perfluorocarbons, which are a byproduct of aluminum smelting. Other gases of concern include sulfur hexafluoride, which is widely used in insulation for electrical equipment. These gases are released in different quantities and have different potencies in their contributions to global warming (IPCC 2007a; Justus and Fletcher 2006).

Sources of anthropogenic carbon dioxide include combustion of fossil fuels such as natural gas, oil, gasoline, and coal. It is estimated that carbon dioxide atmospheric levels have risen by more than 35 percent since the preindustrial period (since 1750) as a result of human activities. Emissions of other greenhouse gases have also risen. Annual global emissions of carbon dioxide are estimated to be 26.4 billion metric tons from fossil fuel use (IPCC 2007a:3). Carbon dioxide is the most important anthropogenic greenhouse gas and is therefore of primary concern in this EIS.

The IPCC concluded that warming of the earth's climate system is unequivocal, and that most of the observed increase in global average temperatures is very likely due to the observed increase in anthropogenic greenhouse gas concentrations. The IPCC reports potential impacts from warming of the climate system, including expansion of sea water volume; decreases in mountain glaciers and snow cover resulting in sea level rise; changes in arctic temperatures and ice; changes in precipitation, ocean salinity, and wind patterns; and changes in extreme weather (IPCC 2007a:3-8).

As described in Appendix G, the *TC & WM EIS* alternatives could produce 2.75 metric tons (under FFTF Decommissioning Alternative 1 over a period of 100 years) to 0.246 million metric tons (under Tank Closure Alternative 6A, Option Case, over a period of 257 years) of carbon dioxide per year. Based on Hanford fuel use in 2006 (see Chapter 3, Section 3.2), baseline carbon dioxide emissions are 14,200 metric tons per year. Based on fuel consumption averages for INL (see Chapter 3, Section 3.3), baseline carbon dioxide emissions are 35,200 metric tons per year. The emissions under the alternatives would add to global annual emissions of carbon dioxide, which are estimated to be 26.4 billion metric tons from fossil fuel use worldwide (IPCC 2007a:3). The emission estimates for the *TC & WM EIS* alternatives account for facility specific fuel-burning and process sources from construction and operations activity and mobile source emissions from material and waste shipments. Emissions from employee vehicles and indirect emissions from electricity use were not estimated. Table 6-36 summarizes the estimated annual average carbon dioxide emissions by *TC & WM EIS* alternative.

Cumulative impacts of the emission of carbon dioxide and other greenhouse gases from *TC & WM EIS* alternatives and other activities at Hanford and throughout the region would contribute to changes related to global climate discussed above. Although the cumulative emissions of greenhouse gases and the impacts on the global climate and the resulting environmental, economic, and social consequences could be significant, there is currently no threshold or standard against which to evaluate the significance of such emissions from a specific local project.

Greenhouse gas emissions in the Hanford region include carbon dioxide from multiple sources, including the burning of natural gas and fuel oil for home and commercial heating and the use of gasoline and diesel fuel to power automobiles, trucks, construction equipment, and other vehicles. Generation of electricity results in carbon dioxide emissions in parts of the State of Washington and the

Table 6–36. Estimated Annual Average Carbon Dioxide Emissions by Alternative

Alternative	Emissions (metric tons per year)
Tank Closure (TC)	
TC Alternative 1	1.07×10^4
TC Alternative 2A	7.03×10^4
TC Alternative 2B	7.59×10^4
TC Alternative 3A	3.53×10^4
TC Alternative 3B	3.6×10^4
TC Alternative 3C	5.39×10^4
TC Alternative 4	3.92×10^4
TC Alternative 5	8.29×10^4
TC Alternative 6A, Base Case	2.39×10^5
TC Alternative 6A, Option Case	2.46×10^5
TC Alternative 6B, Base Case	5.81×10^4
TC Alternative 6B, Option Case	6.85×10^4
TC Alternative 6C	7.61×10^4
FFTF Decommissioning	
FFTF Decommissioning Alternative 1	2.75
FFTF Decommissioning Alternative 2 ^a	1.98×10^3
FFTF Decommissioning Alternative 3 ^a	1.54×10^2
Waste Management (WM)	
WM Alternative 1	1.23×10^3
WM Alternative 2	4.1×10^4
WM Alternative 2, Disposal Group 1	4.11×10^3
WM Alternative 2, Disposal Group 2	2.02×10^4
WM Alternative 2, Disposal Group 3	2.33×10^4
WM Alternative 3	4.1×10^4
WM Alternative 3, Disposal Group 1	5.03×10^3
WM Alternative 3, Disposal Group 2	2.11×10^4
WM Alternative 3, Disposal Group 3	2.38×10^4

^a Including emissions for options at Idaho National Laboratory.

Key: FFTF=Fast Flux Test Facility.

United States. In the region near Hanford, most of the electricity (97 percent) is supplied by a combination of hydroelectric dams, nuclear power plants, and wind turbines (BPUD 2006). These types of power production generate little carbon dioxide. The *TC & WM EIS* alternative combinations could require a total of 0.0032 megawatt-hours (under FFTF Decommissioning Alternative 2) to 188 million megawatt-hours (under Tank Closure Alternative 6A, Option Case) of electricity. The State of Washington has implemented regulations to mitigate emissions of carbon dioxide from certain fossil-fueled thermal electric generating facilities larger than the station-generating capability of 25 megawatts of electricity. Recently adopted amendments to these regulations are intended to establish goals for statewide reduction of greenhouse gases emissions and immediately reduce greenhouse gas emissions from electric power generation (WAC 173-407). Participation of Washington State in the Western Climate Initiative's proposed Cap-and-Trade Program may also result in a reduction in greenhouse gas emissions (Ecology 2009).

There also are emissions of chlorofluorocarbons and hydrofluorocarbons, which are used locally in refrigeration and air conditioning units at residential, commercial, industrial, and government facilities.

A number of opportunities for reductions in greenhouse gases at Hanford have been pursued, including the reduction and phaseout of chlorofluorocarbon use and the reduction of carbon dioxide emissions and other trace gases through energy conservation. Other potential mitigation technologies that are currently available and could be applicable at Hanford include alternative fuels and renewable heat and power sources, carbon capture and storage, more fuel-efficient vehicles, cleaner diesel vehicles, hybrid vehicles, biofuels, efficient lighting and daylighting, more-efficient electrical equipment, improved insulation, passive and active solar design for heating and cooling, and use of alternative refrigeration fluids (IPCC 2007b).

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