The 100-KR-4 Operable Unit is along the Columbia River in the northern-central portion of the Hanford Site. Groundwater in 100-KR-4 was contaminated by waste releases associated with past operation of the deactivated KE and KW Reactors and from associated support facilities. At the end of 2011, ~30 percent of the waste sites were classified as closed, interim closed, no action, not accepted or rejected, with ~10 percent having undergone active remediation. Removing contaminants from the vadose zone eliminates secondary sources of contamination that could migrate to groundwater. Additional details about 100-KR-4 history, waste sites, and hydrogeology are provided in Chapters 1 and 3 of DOE/RL-2010-97, Remedial Investigation/Feasibility Study for the 100-KR-1, 100-KR-2, and 100-KR-4 Operable Units. Figure 2.3-1 shows locations of former waste sites, groundwater monitoring wells, and groundwater extraction and injection wells.

The unconfined aquifer in 100-KR-4 ranges from 5.2 to more than 32 meters thick. This aquifer is primarily present in the Ringold Formation unit E sand and gravel. This unit is overlain by the gravels and interbedded sand and silt of the Hanford formation, which comprise the bulk of the vadose zone. Near the northeastern end of the 116-K-2 Trench, a portion of the Hanford formation becomes saturated at high river stage. The vadose zone ranges from less than 1 meter thick near the Columbia River to 32 meters thick inland. The uneven surface of the silt- and clay-rich Ringold Formation upper mud unit forms the bottom of the unconfined aquifer.

Groundwater in 100-KR-4 flows generally to the northwest toward the Columbia River (Figure 2.3-2). With the installation of the new pump-and-treat system, groundwater flow is being altered. The increased extraction and injection of groundwater in the expanded pump-and-treat system has created depressions and mounds in the water table, affecting the local flow direction. The most prominent groundwater mound is inland of the 116-K-2 Trench, creating radial flow and affecting the hexavalent chromium contaminant distribution. Another mound, resulting from several injection wells, is in the southern part of 100-NR-2. A region in which the water table is low, resulting from extraction wells, is at the northern end of the 116-K-2 Trench. The extraction wells are along the river and capture contaminated groundwater before it discharges to the Columbia River.

Daily and seasonal fluctuations in the river stage also affect groundwater flow in 100-KR-4. As would be expected, longer term changes in the river stage produce more extensive and longer lived changes in the water levels, hydraulic gradient, and flow directions in the unconfined aquifer. The effect of river water migrating into the aquifer can cause lower contaminant concentrations in near-river and aquifer tubes (Section 2.1.2). Seasonal changes in hexavalent chromium concentrations are most evident in wells within 200 meters of the shoreline. The high river stage in the Columbia River observed in 2011 was the highest river stage in the past five years.

Contaminants of potential concern in the unconfined aquifer include hexavalent chromium, tritium, nitrate, strontium-90, carbon-14, and trichloroethene. Figure 2.3-3 illustrates changes in contaminant plume areas since 2003 for strontium-90, nitrate, hexavalent chromium, and tritium. In the unconfined
aquifer, the sizes of the individual contaminant plumes within 100-K have generally decreased since 2010, with the exception of strontium-90, because of remediation and natural processes. Wells completed in the first water-bearing unit within the Ringold Formation upper mud unit have exhibited low levels (less than 10 µg/L) of hexavalent chromium. As noted in Section 2.1, the 10 µg/L represents the ambient water quality standard for hexavalent chromium and is applicable in the hyporheic zone (i.e., the point at which groundwater discharges into the river). As defined in the current interim action ROD, the remedial action goal for hexavalent chromium is 20 µg/L in compliance wells.

### 2.3.1 Hexavalent Chromium

Hexavalent chromium is a mobile contaminant at 100-KR-4, and its presence resulted from historical releases of two different types of wastewater contaminated with chromium. The first type of release included spills, leaks, and limited intentional discharge of concentrated sodium dichromate dihydrate solutions used as feed chemicals for conditioning reactor cooling water. These releases apparently occurred near the chemical storage tank farms at the cooling water treatment head houses at the KE and KW Reactor complexes. The second type of release included spent reactor cooling water from retention basin leaks and intentional discharges to the 116-K-1 Crib and 116-K-2 Trench. The first release type consisted of relatively small volumes of high-concentration solutions; the second release type consisted of very large volumes of low-concentration cooling water effluent.

Figure 2.3-4 illustrates the distribution of hexavalent chromium in 100-KR-4 at high and low river stages in 2011. Several separate plumes are differentiated by geographic distribution, and by the location and nature of probable source areas. Plumes are present on both the southwestern and northeastern ends of the 116-K-2 Trench, the original source area. These plumes are the remnants of a single large plume that formerly extended the length of the 116-K-2 Trench, and now connect to the KE plume. Operation of the KR4 and KX pump-and-treat systems has resulted in several residual plume areas, which the KR4 and KX pump-and-treat systems are remediating.

Farther north, a few monitoring wells associated with the 100-NR-2 interest area are contaminated with low levels of hexavalent chromium. Modest amounts of sodium dichromate were used during the years immediately following startup of N Reactor (estimated at ~ 6,300 to 8,200 kilograms). Management and ultimate disposal of sodium dichromate solutions at 100-N may have contributed to some of the hexavalent chromium observed at 100-N. The hexavalent chromium plume observed northeast of 100-K and inland of 100-N most likely resulted from migration of reactor cooling water away from 116-K-2.

### 100-KR-4 at a Glance

<table>
<thead>
<tr>
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<tbody>
<tr>
<td>2011 Groundwater Monitoring</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Contaminant</th>
<th>Drinking Water Standard</th>
<th>Maximum Concentration</th>
<th>Plume Area (km²)</th>
<th>Shoreline Impact (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hexavalent Chromium</td>
<td>10/48&lt;sup&gt;b&lt;/sup&gt; µg/L</td>
<td>3,340 µg/L</td>
<td>2.5&lt;sup&gt;c&lt;/sup&gt;</td>
<td>1,300&lt;sup&gt;10&lt;/sup&gt;</td>
</tr>
<tr>
<td>Tritium</td>
<td>20,000 pCi/L</td>
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<td>Nitrate</td>
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<td>0</td>
</tr>
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<td>Strontium-90</td>
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<td>251 pCi/L</td>
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<td>0</td>
</tr>
<tr>
<td>Carbon-14</td>
<td>2,000 pCi/L</td>
<td>19,200 pCi/L</td>
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</tr>
<tr>
<td>Trichloroethene</td>
<td>5 µg/L</td>
<td>6.6 µg/L</td>
<td>0.007</td>
<td>0</td>
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</tbody>
</table>

### Remediation

- **Waste Sites (interim action):** ~ 10 percent remediated
- **Groundwater Remediation (interim ROD for hexavalent chromium):**
  - KX pump-and-treat: 2009–2011, removed 114 kg
- Final record of decision anticipated in 2012.

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<sup>a. Estimated area above listed water quality standard</sup>
<sup>b. 10 µg/L aquatic standard; 48 µg/L groundwater cleanup standard</sup>
<sup>c. At the 10 µg/L level</sup>
Trench during the period of operation of 105-KE and 105-KW Reactors. Subsurface geology also indicates a geologic contact trending to the north in that area which may be influencing contaminant migration. Although the monitoring well network within the hexavalent chromium-affected portion of the aquifer inland of 100-N is not extensive, the observed concentrations suggest that the hexavalent chromium plume exceeding 10 µg/L likely extends from well 199-K-182 all the way northeast to 100-D.

Inspection of groundwater monitoring data from inland wells between 100-K and 100-D indicates the long-term presence of hexavalent chromium in that area. Although sample analysis for hexavalent chromium as a specific analyte began relatively recently at numerous locations, historical analysis of total chromium in filtered and unfiltered aliquots started as early as the 1990s. Total chromium measurement in a filtered sample aliquot provides a good comparable value for hexavalent chromium.

Groundwater data indicate that at least four wells (i.e., 199-N-43, 699-87-55, 699-83-47, and 699-81-58) exhibited elevated hexavalent chromium in the 1990s. In recent samples, additional inland wells (i.e., 199-K-182, 199-N-71, 699-77-54, and 699-87-42A) still exhibit elevated hexavalent chromium in groundwater. Total chromium analyses performed on filtered and unfiltered groundwater samples in 2011 are consistent with the hexavalent chromium measurements.

The presence of hexavalent chromium in groundwater inland of 100-N Area, and between 100-K and 100-D Areas has been documented for ~ 20 years in groundwater samples collected from that area. The presentation of inferred hexavalent chromium plume maps that include coverage of both 100-K and 100-N Areas is intended to support the understanding that this condition most likely resulted from historical migration of chromium-contaminated groundwater in radial flow away from the large recharge mounds beneath 116-K-2 Trench with possible contribution from 116-DR-1 & 2 Cribs.

The K East plume extends from near the 183-KE Head House downgradient to the KX extraction wells 199-K-141 and 199-K-178. This plume originated from spills and leaks of high-concentration chromium solutions near the 183.1-KE Head House. The K West plume is near the KW Reactor and its associated water treatment facilities. The apparent sources were leaks and spills of high-concentration sodium dichromate solutions during unloading or storage at the 183.1-KW Head House. In 2012, the KW pump-and-treat system is remediating the K West plume.

2.3.1.1 116-K-2 Trench Hexavalent Chromium Plumes

Reactor coolant discharges to the 116-K-2 Trench between 1955 and 1971 raised the water table beneath 100-KR-4. The recharge mound that formed beneath the trench during operations extended for several kilometers in all directions. This extensive mound of contaminated water created a large hexavalent chromium plume with maximum concentrations similar to those of the reactor cooling water (i.e., up to 700 µg/L).

Overall distribution of hexavalent chromium in groundwater associated with the 116-K-2 Trench is consistent with the broad distribution of cooling water effluent being discharged to the trench. Pump-and-treat operations that began in 1997 have partially remediates the original plume, with the plume distribution showing the effect of the various remedial actions. Remedial activities divided the original plume into a southwestern segment, a central segment, and a northeastern segment along the length of the 116-K-2 Trench (Figure 2.3-4). Current evaluation of the northern segment indicates that it has been bifurcated by injection wells of the calcium polysulfide treatability test. In the south, the plume at the 183.1-KE Head house now combines with the southwestern portion of the 116-K-2 Trench plume.

The northeastern portion of the 116-K-2 Trench plume extends northeast into 100-NR-2. Well 199-N-189 was installed in 2011. Sampling during drilling detected hexavalent chromium concentrations of 35.5 µg/L at the water table, with concentrations of 38.9 µg/L deeper in the aquifer. This data point is not directly comparable to the other sample points, however, because the sample was collected during drilling and prior to well development. Additional monitoring of this well will be needed to substantiate the value. Well 199-N-74, which is located ~ 2.0 kilometers from the end of the trench and
farther north than 199-N-189, exhibits hexavalent chromium concentrations near 30 µg/L. Other wells inland from 100-N have also exhibited historical elevated hexavalent chromium in groundwater. These include well 699-87-55 (which historically exhibited total chromium up to 60 µg/L in a filtered sample in 1994), well 699-81-58 (which historically exhibited total chromium up to 25 µg/L in a filtered sample in 1991), and well 199-N-52 (which exhibited total chromium up to 10 µg/L in a filtered sample in 1990). These wells indicate that hexavalent chromium is relatively widespread inland of 100-N and downgradient of 100-K. Current hexavalent chromium concentrations at these wells are lower than historically measured.

The contamination in both locations likely resulted from migration of the plume at 116-K-2 Trench during the historical discharge period when radial flow away from the large discharge mound at the trench would have moved contaminated water toward 100-N in addition to the rest of the surrounding area. The historical use of sodium dichromate at 100-N was relatively small and of shorter duration than the historical treatment of cooling water at 100-K. Although there may be some contribution of hexavalent chromium to groundwater from historical 100-N activities, historical discharges of sodium dichromate-treated cooling water to 116-K-2 Trench is the most likely source of the elevated concentrations observed near 100-N. Even though the overall hexavalent chromium plume at concentrations over 20 µg/L near extraction wells is shrinking based on the current plume depictions, the detection of hexavalent chromium in wells 199-N-189 and 199-N-74 indicates that the plume associated with the 116-K-2 Trench extends farther to the northeast than previously thought (Figure 2.3-4). Recent measurements of hexavalent chromium in the vicinity inland of 100-N are not spatially or temporally continuous. The observed distribution of chromium in that area, however, is consistent with historical migration of contaminated groundwater radially away from the 116-K-2 Trench during the period of 100-K Reactor operations (i.e., 1955 to 1971). Recent observations of groundwater flow direction near 100-K indicate groundwater flows toward the Columbia River. The plume segments inland of 100-N are likely now isolated from the plume associated with 116-K-2 Trench and will likely migrate toward the river as well. To the south, the plume extends at least 1.5 kilometers from the river at well 199-K-193. Detections of hexavalent chromium at concentrations greater than 20 µg/L also are observed as far inland as well 699-77-54 (3.4 kilometers from the river). As with the hexavalent chromium near 100-N, the condition at 699-77-54 also is most likely a result of the historical migration of chromium-contaminated groundwater from 116-K-2 Trench. Data are not sufficient to determine whether the plume is continuous inland to well 699-77-54.

Hexavalent chromium concentrations in the northeastern 116-K-2 Trench plume have declined since 2009 (Figure 2.3-5). Concentrations in the northernmost extraction wells (Groups 5 and 6 on Figure 2.3-5) continued to decline in 2011, and many wells had concentrations below 20 µg/L. Concentrations were relatively low but variable in extraction wells near the central and southern part of the trench plume (Groups 1 through 4), and concentrations remained above 20 µg/L in some of these wells. Concentrations in extraction wells inland of the northeastern portion of the trench plume (Group 7) remained stable in 2011. Concentrations in monitoring wells (for example, Group 8) are similar to concentrations in extraction wells.

Hexavalent chromium concentrations in aquifer tubes downgradient from the 116-K-2 Trench plume have declined since groundwater remediation began in 1997. Concentrations are below the 10 µg/L ambient water quality standard in most of the aquifer tubes, but concentrations remain elevated in a few locations. The highest concentration in 2010 or 2011 was 57 µg/L in AT-K-3-D, near the southern end of the 116-K-2 Trench. This aquifer tube is located near existing extraction wells 199-K-198 and 199-K-199.
As of 2012, these wells are configured for extraction and it is recommended that they be connected to the KX pump-and-treat system.

Well 199-K-192 was sampled for characterization during drilling. Hexavalent chromium was detected at several intervals within the shallow unconfined aquifer unit, with a high concentration of 71 µg/L. The well was completed, however, within a water-bearing unit of the underlying Ringold Formation upper mud unit. No hexavalent chromium has been detected in this well since it was completed. Near the Columbia River, wells 199-K-197 and 199-K-199 showed the highest concentrations (31 and 38.5 µg/L) in the bottom half of the unconfined aquifer.

### 2.3.1.2 K East Hexavalent Chromium Plume

Hexavalent chromium distribution in the K East region is consistent with this plume’s having originated with the release of high-concentration chromium solutions that reached groundwater and subsequently migrated toward the river near the 183.1-KE Head House and associated facilities. The existing monitoring well network does not clearly define the dimensions of the K East hexavalent chromium plume, but the plume definitions has improved from previous years.

Upgradient of the 183.1-KE Head House, new RI/FS well 199-K-187 was installed to further delineate the K East plume. The plume (Figure 2.3-4) extends from the 183.1-KE Head House (i.e., near wells 199-K-36 and 199-K-188) toward the river (i.e., near extraction wells 199-K-141 and 199-K-178). Previous interpretations of the plume showed a smaller, less continuous area, and did not indicate a connection to the southern plume from the 116-K-2 Trench. In addition, the plume had a small area of contamination associated with the 183.2 KE Sedimentation Basin that was not connected to the main portion of the plume closer to the river. With the installation of additional wells and more data, the extent of the plume has been reevaluated.

During the low river stage, the plume is less continuous and much smaller. The shape of the plume during this period is consistent with previous interpretations of the plume shape. However, during periods of high river state, the plume extended south of the head house to new well 199-K-187 and connected to the southernmost portion of the 116-K-2 Trench plume. The extent of the plume to the south has been connected to well 199-K-23, which had a hexavalent chromium concentration of 97.4 µg/L in October 2011; this well had not been sampled for three years. Well 199-K-187 had a maximum concentration of 19 µg/L in July 2011. However, the duplicate sample had a lower concentration (10.8 µg/L), and an October sample had no detectable hexavalent chromium. The primary difference in the inferred distribution of hexavalent chromium near 105-KE between high and low river stages is driven by the observed concentration in well 199-K-187, which was non-detect in the data assembled for the low river stage and was 12.6 µg/L in the high river stage data set. Interpolation of the plume contours around this single point produces the observed inland extension of the plume in the high river stage map. Recent measurements in that well have exhibited low concentrations. The high river stage is not expected to have caused the observed condition at distance from the river. Continued monitoring of wells 199-K-187, 199-K-188, and 199-K-36 is recommended to investigate the variable hexavalent chromium concentrations in that area and better define the plume.

Two wells within the former water treatment chemical tank farm at the 183.1-KE Head House have elevated hexavalent chromium levels. Concentrations in new well 199-K-188 increased from 10.7 µg/L in January to 41.6 µg/L in June 2011. In nearby well 199-K-36, concentrations increased from 37.5 µg/L in December 2010 to more than 119 µg/L in June 2011. These levels indicate an increase from recent concentrations in both wells (Group 7, Figure 2.3-6). The recent increase may be related to demolition and vadose zone remediation activities near these wells, which increases the amount of water applied to the ground surface to provide dust suppression. Operation of the expanded pump-and-treat system may also be affecting flow directions and, therefore, contaminant concentrations at specific locations.

Groundwater remediation has reduced hexavalent chromium concentrations between the reactor building and the Columbia River. Concentrations declined sharply in well 199-K-141 after it was
converted to an extraction well and incorporated into the KX pump-and-treat system in 2009 (Group 5 on Figure 2.3.6). The concentrations remained above 20 µg/L in two of the extraction wells (199-K-141 and 199-K-178) associated with this plume in 2011.

Grab samples of groundwater were collected and analyzed during drilling of five monitoring wells as part of the 100-K RI/FS. Those samples, collected from wells 199-K-187, 199-K-188, 199-K-186, 199-K-189, and 199-K-190 (in order from most upgradient to most downgradient), indicated a slight increasing concentration trend with depth. All of the observed hexavalent chromium concentrations were less than 35 µg/L. Well 199-K-32B, completed in a confined water-bearing unit within the Ringold Formation upper mud unit, has exhibited low levels (less than 10 µg/L) of hexavalent chromium. No hexavalent chromium was detected in the confined water-bearing unit at well 199-K-192, also completed in the Ringold Formation upper mud unit. However, well 199-K-192 did exhibit hexavalent chromium in groundwater throughout the thickness of the overlying unconfined aquifer unit.

### 2.3.1.3 K West Hexavalent Chromium Plume

The distribution of the K West plume is consistent with the migration of hexavalent chromium historically released as high-concentration solutions near the chemical storage tank farm at the 183.1-KW Head House and related facilities. Releases of these solutions migrated downward through the vadose zone and affected groundwater.

The K West hexavalent chromium plume extends in a narrow band starting near the head house (Figure 2.3-4) and extending toward the river. The dimensions of this plume did not change between 2010 and 2011. The highest hexavalent chromium concentrations in 100-KR-4 in 2011 were in wells upgradient from the KW Reactor building.

Following the start of the KW pump-and-treat system in 2007, hexavalent chromium concentrations declined sharply in extraction wells and monitoring wells just upgradient from the KW Reactor (Group 3 on Figure 2.3-6). Levels continued to decline in these wells and in those farther downgradient (Groups 1 and 2) in 2011. Concentrations in one extraction well (199-K-165) remained stable, near 150 µg/L during most of the year.

**Maximum hexavalent chromium concentrations in K West extraction wells have decreased by more than 90 percent since the pump-and-treat system started in 2007. A new maximum concentration point was identified in 2011 (well 199-K-195).**

New RI/FS well 199-K-195 exhibited a hexavalent chromium concentration of 3,340 µg/L in April 2011, which is consistent with the concentrations found in depth-discrete samples collected during drilling. The highest concentration collected during drilling was 4,890 µg/L at a depth of 30.4 meters. This maximum value is much higher than the previously observed maximum of 771 µg/L detected in well 199-K-35 in 2010. Well 199-K-195 and adjacent well 199-K-35 were decommissioned to permit continued waste site remediation efforts around the former 183.1-KW Head House. A replacement well is recommended to monitor groundwater conditions near the Head House during continued remediation activities. The well could be configured as an extraction well to provide capability to extract groundwater for treatment from this source area.

The next downgradient monitoring well, 199-K-173, exhibited concentrations as high as 659 µg/L in 2011 (Figure 2.3-7). The presence of injection wells 199-K-175, 199-K-174, and 199-K-158 controls the upgradient edge of the plume. The plume does not extend inland past well 199-K-175, which had concentrations below 10 µg/L when the well was sampled before conversion to an injection well.
Grab samples of groundwater were collected and analyzed during the drilling of five monitoring wells. These results illustrate the variation in vertical distribution of chromium in this area. Sample results from wells 199-K-195, 199-K-173, 199-K-165, and 199-K-184 (in order from upgradient to downgradient) indicated varying distribution of hexavalent chromium with depth. The well nearest the apparent release point (i.e., 199-K-195) exhibited the highest concentration near the water table; the other wells exhibited elevated concentrations at varying depths. Well 199-K-165, an extraction well as of 2012, exhibited elevated hexavalent chromium over the entire aquifer thickness during drilling.

### 2.3.2 Tritium

Tritium is a highly mobile contaminant in 100-KR-4 groundwater at levels up to 290,000 pCi/L (well 199-K-18) in completed wells, a concentration above the 20,000 pCi/L drinking water standard. The major sources of tritium contamination included the following:

- Releases of reactor gas dryer condensate to the 116-KE-1 and 116-KW-1 Crib
- Release of fuel storage basin water to the 116-KE-3 and 116-KW-2 Crib
- Contaminated solid waste disposed of at the 118-K-1 Burial Ground

Another source of tritium was the release of contaminated reactor cooling water to the retention basins, the 116-K-1 Crib, and the 116-K-2 Trench.

At the 20,000 pCi/L drinking water standard, the plume has previously been interpreted to have two parts: a larger portion near the southwestern end of the 116-K-2 Trench and the 118-K-1 Burial Ground and a smaller portion near the KE Reactor. Based on current data, these plumes are now considered a single plume. Figure 2.3-8 shows the tritium distribution in groundwater in 2011.

Because of the active remediation of hexavalent chromium, extraction wells are also capturing tritium. Because tritium is present primarily as tritiated water, it is not affected by the treatment system. The current treatment for tritium is recirculation of the contaminated water within the aquifer until tritium has decayed. Tritium has a relatively short half-life of 12.32 years (RS, 2012), so recirculation has been considered an acceptable method of addressing the analyte. Because of recirculation, tritium is now in groundwater near the active injection wells at 100-K. Based on the design of the pump-and-treat system, this water will be captured by the downgradient extraction wells and will continue to decay. The plume is not reaching the river at levels above the drinking water standard, based on data from aquifer tubes. Tritium was detected in effluent water from the KX and KR-4 pump-and-treat systems. These effluent values were assigned to the injection wells associated with each system and included in the plume map. Note that there is now presented an area of tritium concentration greater than the 20,000 pCi/L MCL near the KR-4 system injection wells. Wells 199-K-29 and 199-K-30 formerly defined the highest concentration portion of the plume near the KE Reactor building and the 116-KE-1 Crib. Concentrations in those wells had declined from peak levels in the 1990s before the wells were decommissioned in January 2011 to permit access for demolition of the 117-KE filter facility. New well 199-K-189, downgradient from the reactor building and decommissioned wells 199-K-29 and 199-K-30, exhibited a maximum tritium concentration of 140,000 pCi/L in vertical profile sampling during drilling. A concentration of 42,600 pCi/L was detected in a sample collected after well completion in October 2011 (Figure 2.3-9).
A portion of the tritium plume at K East appears to have originated at 116-KE-1 Crib, with potential contribution from waste at the 118-K-1 Burial Ground. Concentrations have generally declined in the wells closest to the burial ground (199-K-111A and 199-K-157) but have increased in wells 199-K-18 and 199-K-145, located farther downgradient (Figure 2.3-9). This pattern is consistent with migration of contaminated groundwater downgradient from historical release points to locations where it is intercepted by extraction wells. Characterization sampling at 199-K-192 revealed elevated tritium concentration in the shallow unconfined aquifer, with a maximum observed concentration in a grab sample of 1,400,000 pCi/L. The concentrations observed in 199-K-18 and 199-K-145 are consistent with the elevated tritium concentration observed in the shallow unconfined aquifer at 199-K-192 during drilling.

Tritium concentrations in the K West region in 2011 were below the drinking water standard. However, concentrations as high as 430,000 pCi/L were measured in well 199-K-106A as recently as 2009 (with a historical maximum observed concentration of 2,240,000 pCi/L in 2005). It is unlikely that the plume has disappeared because the half-life of tritium is 12.32 years, but it is likely that the plume has migrated downgradient to a location without monitoring wells. The area downgradient from the 105-KW Reactor building is also under the capture influence of the active extraction wells of the 100-KW pump-and-treat system, which is affecting the migration of the tritium plume in this area.

Characterization samples collected during the drilling of RI wells showed that the tritium concentration declined with depth at some locations and increased with depth in others. Maximum concentrations were detected near the top of the aquifer in the two new wells with the highest tritium levels (199-K-189 [K East] and 199-K-192 [near the 116-K-2 Trench]). In addition, concentrations in 199-K-189 increased during October 2011, exceeding the drinking water standard with a concentration of 42,600 pCi/L.

Tritium plume behavior at 100-KR-4 is consistent with the downgradient migration of the plumes away from original source areas, modified by the effects of capture by groundwater extraction wells. The existing monitoring well network may not intercept the apparent maximum tritium concentrations in groundwater at K West.

### 2.3.3 Nitrate

Nitrate concentrations continued to exceed the drinking water standard (45 mg/L) in several 100-KR-4 wells in 2011. The nitrate observed in groundwater at 100-KR-4 originated from high concentrations of ammonia in reactor gas dryer condensate that was discharged to the 116-KE-1 and 116-KW-1 Cribs. Additional nitrate contributions to groundwater may have come from sanitary waste drain fields at various places within the 100-K Area. Figure 2.3-10 shows nitrate distribution in 2011. The size of the plume area exceeding the drinking water standard decreased between 2010 and 2011 (Figure 2.3-3), primarily because of migration and dispersion of the plume.

Well 199-K-198, downgradient from the southwestern end of the 116-K-2 Trench, had one sample with a nitrate concentration of 54.9 mg/L in the shallowest sample collected during drilling, but concentrations dropped quickly to lower levels (12 mg/L) in deeper strata. The average value for well 199-K-198 in 2011 was 19 mg/L. In October, new RI temporary wells 199-K-200 and 199-K-201 had maximum concentrations of 37 mg/L and 41 mg/L, respectively, both showing an increasing trend. At the same time, the concentration in well 199-K-18, located between well 199-K-200 and 199-K-198, declined to just below the standard for the first time in 2011.
In the K East region, only well 199-K-23 had a nitrate concentration above the drinking water standard in 2011 (46.5 mg/L). Concentrations are variable in this well, with no obvious increasing or decreasing trend since 1992. Recently decommissioned well 199-K-29 had a sharp increase in concentrations in 2010, with a value of 46.5 mg/L, and is included on Figure 2.3-10.

Three K West wells had nitrate levels above the drinking water standard in 2011: wells 199-K-34, 199-K-106A, and 199-K-108A. Two aquifer tubes downgradient from K West have had nitrate concentrations above the standard in recent years. Aquifer tube C6241 consistently has concentrations of 48 to 54 mg/L. The nitrate concentration in aquifer tube 17-D has been below the drinking water standard since 2009, when a maximum of 66.4 mg/L was observed. However, this aquifer tube exhibits substantial seasonal variations; and results may be directly linked to when the wells were sampled.

Characterization data from RI/FS wells indicate that nitrate concentrations decrease with depth in the aquifer at most locations in 100-KR-4. New RI well 199-K-185, which was installed in 2010, had nitrate levels at more than twice the drinking water standard at the top of the unconfined aquifer. Carbon-14 concentrations were also high in this well near the top of the aquifer. Because of the highly variable concentrations with depth, the average nitrate value for the well during drilling, shown on Figure 2.3-10, was below the drinking water standard. In addition, monitoring results in 2011 from this well, after completion and development, had a maximum value of 26.1 mg/L. However, this well was screened across the entire aquifer thickness, and while the sample was collected from the upper portion of the aquifer, results may not indicate the highest concentrations detected during drilling. Sealing off the lower section of this well would provide more representative values from the contaminated zone.

### 2.3.4 Strontium-90

Cooling water contaminated by fuel rod failures was held in the 107-KE or 107-KW retention basins and subsequently discharged to the 116-K-2 Trench. Fission products, including strontium-90, contaminated the discharged water. The fuel storage basins also had cooling water contaminated with strontium-90. Releases from the fuel storage basins and the discharges to the 116-K-2 Trench are the sources of the strontium-90 contamination in 100-KR-4 groundwater. Discharges to the 116-K-2 Trench resulted in strontium-90 distributed in groundwater at several locations along the length of the trench. Strontium-90 has also been released to groundwater via discharges to the 116-KW-2 and 116-KE-3 fuel storage basin cribs and reverse wells, or by direct leakage from the basins themselves.

Strontium-90 contamination in 100-KR-4 groundwater is found in numerous localized plumes (Figure 2.3-11). The areas with concentrations above the 8 pCi/L drinking water standard are limited in extent and do not extend to the Columbia River. Strontium-90 concentrations are near or below detection limits in most aquifer tubes. However, the maximum concentration for 2011 was 7.48 pCi/L in the September sample from aquifer tube 19-M, downgradient from the southern end of the trench.

The calculated historical area of the strontium-90 plume above the drinking water standard is subject to substantial uncertainty from the following aspects:

- The plume has not historically been delimited on the downgradient or cross-gradient directions from either of the fuel storage basin cribs.
- Historically, the plumes were allowed to diminish in size as concentrations at wells located near the release points declined. This is inconsistent with the apparent migration of strontium-90 away from those release areas.
The inferred plumes presented in this annual report reflect the best effort to extrapolate strontium-90 concentrations in groundwater and are consistent with the general approach to plume presentation in this report.

The strontium-90 plume areas for 2011 are larger than in previous years (Figure 2.3-3), and the apparent maximum concentrations are higher than in 2010.

Many of the wells monitoring the 116-K-2 Trench have detectable strontium-90, but most concentrations are below or near the drinking water standard of 8 pCi/L (Figure 2.3-11). The highest concentrations near the trench in 2011 were from new RI well 199-K-200, which was drilled through the former trench near the head end (southwest). Concentrations increased in this well after well construction to a maximum of 251 pCi/L in 2011 (Figure 2.3-12). A grab sample was collected in 2010 during the drilling of well 199-K-192, immediately downgradient from 199-K-200. The sample collected near the water table had the only detection of strontium-90 in the well, at 19 pCi/L. This observation further indicates that strontium-90 is in localized areas. This well was later completed and screened in the Ringold Formation upper mud unit, and has no detectable strontium-90 contamination. Concentrations in other wells in the 116-K-2 Trench region were consistently less than 30 pCi/L.

Well decommissioning related to structure demolition in the 100-K Area has removed monitoring wells near historical high concentrations (e.g., near 116-KE-3 Crib). In addition, existing downgradient monitoring wells do not exhibit the extremely high strontium-90 concentrations that were previously exhibited (e.g., ~18,000 pCi/L at well 199-K-109A). This condition results in considerable uncertainty in the expected extent of the strontium-90 plume in the area downgradient of both of the 100-K Reactors and the expected maximum concentration as concentrations declined in near-source upgradient wells. In previous analyses, historical concentrations in decommissioned wells were generally removed from the plume depiction. To account for this, a revised plume extrapolation process was applied to estimate the distribution of strontium-90 (and carbon-14, discussed in Section 2.3.5) in groundwater downgradient of the 105-KE and 105-KW Reactors.

The plume extrapolation process started with identifying groundwater flow paths away from the historical release points at 116-KE-3 and 116-KW-2 Cribs. The flow paths, including apparent gradient and flow direction based on groundwater elevation measurements, were aligned, by inspection, with downgradient wells that exhibit detections of strontium-90. An arithmetic, analytical solution was applied to the historical peak concentrations at wells near the release points, providing an estimation of downgradient concentrations, as affected by plume movement, contaminant interaction with aquifer solids (defined by a selected distribution coefficient), and radioactive decay. The product of this estimation was points of varying concentration along the axis of the flow path. These points were then combined with the existing measured strontium-90 concentrations at local wells to provide an estimate of the expected plume distribution and apparent maximum concentration in groundwater. The results of the plume extrapolation are integrated into the 2011 strontium-90 plume map for 100-K shown in Figure 2.3-11.

A high concentration strontium-90 plume is in the K East region. The heart of the plume formerly was represented by well 199-K-109A, which had a strontium-90 concentration of 1,120 pCi/L the last time the well was sampled in 2008 and historical maximum concentration of 18,600 pCi/L. This well historically exhibited strontium-90 concentration greater than 5,000 pCi/L from 1996 to 2000. This well was decommissioned to facilitate demolition activities. A nearby well, 199-K-189, has low to undetectable levels of strontium-90. However, the well is not directly downgradient from former well

The K East strontium-90 plume has migrated downgradient to extraction well 199-K-141. Wells and aquifer tubes closer to the river have detectable concentrations below the drinking water standard.
199-K-109A. About 120 meters directly downgradient from 199-K-109A, concentrations rose above the drinking water standard in extraction well 199-K-141 (Figure 2.3-13), with the increase beginning soon after starting groundwater extraction at that well. The increased concentration in extraction well 199-K-141 indicates part of the leading edge of the K East strontium-90 plume migrated downgradient in 2011. As of 2011, the leading edge of the plume is not well defined, and additional replacement wells would allow for monitoring the plume location as it migrates. Extrapolation of the estimated plume distribution downgradient of well 199-K-109A produced an estimated maximum groundwater concentration near 13,100 pCi/L, accounting for migration and radioactive decay.

Father downgradient, measured strontium-90 concentrations remained below the drinking water standard in 2011 at well 199-K-32A (maximum 7.4 pCi/L) and in aquifer tube 19-M (7.48 pCi/L). The observed decrease in strontium-90 concentration at 199-K-109A, as well as the arrival at downgradient wells 199-K-141 and 199-K-32A suggests that strontium-90 is migrating and may actually exhibit a substantially lower distribution coefficient in this vicinity. The inferred strontium-90 plume size and maximum concentration in groundwater are both indicated to be greater than was presented previously.

Two wells in the K West region consistently show strontium-90 concentrations above the drinking water standard (199-K-107A and 199-K-34). The maximum concentration of 50 pCi/L reported in early 2011 (well 199-K-34) was a slight increase from recent years. The concentrations are generally declining in well 199-K-107A (18.3 pCi/L in 2011). The concentrations in individual wells fluctuate, and the inferred plume size is indicated to be larger than indicated by previous analysis. This is due to the reinterpretation of potential downgradient migration away from the fuel storage basin cribs. Concentrations are near detection limits in wells farther downgradient.

Because of its limited mobility, strontium-90 contamination tends to be found in the upper part of the unconfined aquifer. This distribution is firmly established in 100-NR-2 (Section 2.4), and characterization data collected during installation of wells 199-K-189 and 199-K-192 in 100-KR-4 support this interpretation. Strontium-90 has not been detected in the water-bearing unit of the Ringold Formation upper mud unit.

The observed distribution of strontium-90 in groundwater at 100-KR-4 is consistent with the known releases at the fuel storage basin cribs and releases of contaminated cooling water to the 116-K-2 Trench.

2.3.5 Carbon-14

Carbon-14 in groundwater in 100-KR-4 (Figure 2.3-14) originated from historical discharges of reactor gas dryer regeneration condensate to the 116-KE-1 and 116-KW-1 gas condensate cribs. Shielding water in the KE and KW fuel storage basins also contained carbon-14. As with strontium-90 plumes described in the preceding subsection, the carbon-14 groundwater conditions were evaluated using a plume migration extrapolation to estimate the current plume configuration and apparent maximum concentration. The carbon-14 plumes associated with the reactor gas dryer condensate cribs (i.e., 116-KE-1 and 116-KW-1) were extrapolated using the historical maximum concentrations at wells 199-K-30 and 199-K-106A at KE and KW, respectively. As described previously for strontium-90, the historical carbon-14 maximum concentrations were migrated along selected downgradient flow paths, and the results were distributed using a distribution coefficient of 1.8 mL/g. Resultant migrated concentrations along the flow paths were selected for inclusion in the plume contouring analysis. This resulted in an enhanced estimate of the expected carbon-14 plume distribution and maximum concentrations in groundwater at 100-K. The highest residual carbon-14 concentrations in groundwater are associated with KW Reactor, where the estimated maximum concentration derived from the extrapolation is ~39,500 pCi/L. The extrapolated concentrations associated with KE Reactor are slightly lower, with the estimated maximum concentration of ~22,900 pCi/L. At both reactor areas, the resultant plume distribution exhibits an areal extent of concentrations exceeding the 2,000 pCi/L DWS that is larger than inferred in previous years.
Two wells in the K West region continued to exhibit concentrations above the 2,000 pCi/L drinking water standard: 199-K-34 and 199-K-106A. Both of these wells have exhibited an increasing trend in carbon-14 concentration since 2009, with concentrations in 199-K-106A reaching more than 10,000 pCi/L. The long-term trend in 199-K-34 shows more stable concentrations since 1996, with many yearly fluctuations. The highest concentration portions of this plume lie within the capture zone of groundwater extraction wells of the KW pump-and-treat system.

In new RI well 199-K-185, carbon-14 was detected in depth-discrete samples collected during drilling at levels as high as 2,390 pCi/L at the top of the unconfined aquifer. Monitoring results in 2011 from this well had a maximum value of 486 pCi/L. However, this well was screened across the entire aquifer thickness; and while the sample was collected from the upper portion of the aquifer, results may not indicate the highest concentrations detected during drilling. Sealing off the lower portion of the well would provide more representative sample results.

Detectable carbon-14 in groundwater extends downgradient to the river, where it has been detected in aquifer tubes at concentrations mostly below 100 pCi/L. Carbon-14 was detected at 162 pCi/L in aquifer tube C6241. This aquifer tube was not sampled in 2010, but the result is consistent with the result of 158 pCi/L in 2009.

A smaller carbon-14 plume exists in the K East region. The plume was formerly defined by wells 199-K-29 and 199-K-30, which have been decommissioned. In 2010, wells 199-K-29 and 199-K-30 had maximum concentrations of 3,120 and 6,900 pCi/L, respectively, which are above the drinking water standard. These wells had monitored conditions at the 116-KE-1 waste site. Monitoring well 199-K-109A, near the 116-KE-3 Crib, had concentrations at 118 pCi/L in 2008 prior to decommissioning, with an increasing concentration trend. The carbon-14 plume at K East may not lie completely within the expected capture zone of the operating extraction wells of the KX pump-and-treat system as of 2011. Additional monitoring wells are recommended to monitor the 116-KE-1 and 116-KE-3 areas, define the carbon-14 plume, and to track tritium, nitrate, and strontium-90 during remediation activities. None of the actively monitored wells had concentrations above the drinking water standard in 2011.

Carbon-14 has also been detected in aquifer tubes downgradient from K East. Aquifer tube C6247 had a carbon-14 result of 314 pCi/L in fall 2011. The other aquifer tubes in this cluster have not been sampled since 2008 but had similar results at that time.

The behavior of the carbon-14 plumes in groundwater at 100-K is consistent with historical releases of carbon-14 to the condensate cribs. Carbon-14 has moderate mobility in groundwater and is migrating downgradient toward the river; the highest concentrations have been consistently observed near the historical release points.

### 2.3.6 Other Contaminants

Trichloroethene continues to be detected in some 100-KR-4 wells, primarily in the K West region. Most concentrations were below the 5 µg/L drinking water standard (Figure 2.3-15) in 2011. The highest concentrations in routine samples in 2011 were 6.6 and 6.4 µg/L in wells 199-K-185 and 199-K-132, respectively. The sources of trichloroethene at 100-KR-4 are not apparent but are likely related to the use of solvents during equipment maintenance activities. As with other contaminants at 100-K, trichloroethene is detected in effluent water at the KW pump-and-treat system. The effluent concentrations were assigned to the injection wells, resulting in the presence of a more widespread low-concentration plume of trichloroethene in that area.
Technetium-99 is detected in groundwater at numerous locations within 100-KR-4 with concentrations consistently less than 100 pCi/L. Technetium-99 is a fission product, and it would be expected to have been present in cooling water contaminated by fuel ruptures and in the contaminated fuel storage basin water.

Total petroleum hydrocarbons have been encountered in the soil during the drilling of wells 199-K-167 (decommissioned), 199-K-173, and RI well 199-K-186. Total petroleum hydrocarbons were detected in groundwater during 2011 at a low concentration at only one location. A result of 8.61 µg/L gasoline range hydrocarbons was detected in well 199-K-137, and the result was qualified with a “J” flag, indicating the result was estimated. The overall results are consistent with previous sampling events.

Total organic carbon concentrations were elevated in wells at the location of a 2005 treatability test. Wells 199-K-133, 199-K-134, 199-K-135, and 199-K-136 showed total organic carbon at concentrations above 200,000 µg/L in 2008 and 2009. Levels subsequently declined, and samples were not analyzed for this constituent in 2011. The total organic carbon was a residual effect from the calcium polysulfide treatability test, when vegetable oil was injected to stimulate bacterial growth, to evaluate the effects of aquifer reduction on hexavalent chromium.

2.3.7 CERCLA Groundwater Activities

A ROD for the 100-KR-4 Operable Unit interim remedial action was issued in April 1996 (EPA/ROD/R10-96/134, Declaration of the Record of Decision for the 100-HR-3 and 100-KR-4 Operable Units, Benton County, Richland, Washington). The goal of the resulting interim remedial action is to prevent discharge of hexavalent chromium to the Columbia River.

The interim action goal was changed from 22 µg/L to 20 µg/L in August 2009 by an explanation of significant differences for the 100-HR-3 and 100-KR-4 Operable Units that sets a 20 µg/L threshold at onshore, near-river monitoring locations to achieve the ambient water quality standard of 10 µg/L (EPA et al., 2009b, Explanation of Significant Differences for the 100-HR-3 and 100-KR-4 Operable Units Interim Action Record of Decision: Hanford Site Benton County, Washington). As indicated in the interim action ROD (EPA/ROD/R10-96/134), an attenuation factor of 1:1 is expected before the groundwater would reach the aquatic receptor point of concern within the river substrate, ensuring that the ambient water quality criterion of 10 µg/L in the river substrate will be met.

The second CERCLA five-year review (DOE/RL-2006-20, The Second CERCLA Five-Year Review Report for the Hanford Site), published in 2006, identified four actions pertaining to 100-KR-4 groundwater. The actions involved installing new wells and expanding pump-and-treat systems. All of the actions have been completed. DOE finalized the third five-year review report (DOE/RL-2011-56) and submitted it to EPA in November 2011. These enhancements included installing the 100-KW and 100-KX pump-and-treat systems with their attendant extraction and injection wells and water conveyance systems.

Groundwater sampling under CERCLA includes monitoring interim remedial actions for effectiveness and monitoring wells throughout 100-KR-4 to track contamination. Appendix A lists wells and constituents monitored and the status of monitoring in 2011.

A subset of 100-KR-4 aquifer tubes is scheduled for annual sampling in the fall, and some tubes are sampled quarterly. The fall 2010 sampling event was delayed, and many tubes were sampled in 2011 instead. The fall 2011 sampling event was delayed into January and February 2012. Appendix D lists 2011 sampling dates for the aquifer tubes.

2.3.7.1 Remedial Investigation/Feasibility Study

In 2011, the sampling team completed drilling and sampling activities required by Integrated 100 Area Remedial Investigation/Feasibility Study Work Plan, Addendum 2: 100-KR-1, 100-KR-2, and 100-KR-4 Operable Units (DOE/RL-2008-46-ADD2) and implemented through the sampling and
analysis plan (DOE/RL-2009-41, as modified by TPA-CN-357, Change Notice for Sampling and Analysis Plan for the 100-K Decision Unit Remedial Investigation/Feasibility Study, DOE/RL-2009-41, Rev. 0). DOE/RL-2010-97 presents and discusses the results in detail. The field effort included the following:

- Installed nine monitoring wells in the unconfined aquifer, four monitoring wells into the Ringold Formation upper mud unit, and two vadose zone boreholes (all of which were completed as temporary wells)
- Conducted vadose zone and groundwater characterization sampling during drilling for all boreholes and wells
- Installed and sampled three aquifer tubes
- Sampled a selected set of 18 wells three times for temporal and spatial variation analysis

Data collected during the RI will support the selection of alternatives for final action site cleanup. The draft RI/FS report is undergoing public review in 2012.

2.3.7.2 Groundwater Remediation

DOE implemented three pump-and-treat systems to remediate hexavalent chromium contamination in 100-KR-4 groundwater and to protect the Columbia River. All three systems operated in 2011 and are continuing to operate in 2012, as follows:

- The KX pump-and-treat system has two focus areas: one at the northeastern end of the 116-K-2 Trench, where the hexavalent chromium plume migrated toward 100-NR-2, and the K East hexavalent chromium plume. The KX system began operating in 2009.
- The KW pump-and-treat system, which began operating in 2007, focuses on the hexavalent chromium plume at K West.

As of December 2011, 30 extraction wells and 17 injection wells were in use (Table 2.3-1, Appendix A). Combined, the three systems are capable of treating more than 4.6 million liters of groundwater per day. The combined pump-and-treat systems in 100-KR-4 removed 61.4 kilograms of hexavalent chromium from groundwater in 2011 (Table 2.3-1 and Figure 2.3-16). Since 1997, the 100-KR-4 pump-and-treat systems have removed 632 kilograms of hexavalent chromium from the aquifer. Calendar Year 2011 Annual Summary Report for the 100-HR-2 and 100-KR-4 Pump-and-Treat Operations, and 100-NR-2 Groundwater Remediation (DOE/RL-2012-02) provides additional detail.

Under the current configuration, the 100-KR-4 pump-and-treat systems are meeting remedial action objectives. Containment of the plumes addresses the first two objectives: (a) protect aquatic receptors in the river bottom from contaminants in groundwater entering the Columbia River, and (b) protect human health by preventing exposure to contaminants in the groundwater. Operation and refinement of the systems are also meeting the third objective, which is to provide information that will lead to the final remedy. Concentrations of hexavalent chromium in some compliance wells and extraction wells remained above the 20 µg/L remedial action goal, and the 100-KR-4 systems will continue to operate in 2012.

Thirty-one wells have been identified as compliance wells for the three operating pump-and-treat systems (i.e., KR, KW, and KX systems) at 100-K (TPA-CN-359, Change Notice for Modifying Approved Documents/Workplans In Accordance with the Tri-Party Agreement Action Plan, Section 9.0, Documentation and Records: DOE-RL-2006-75, Rev. 1, Reissue Supplement to the 100-HR-3 and 100-KR-4 Remedial Design Report and Remedial Action Workplan for the Expansion of the 100-KR-4 Pump and Treat System (As amended by TPA-CN-273, May 20, 2009) and DOE-RL-2006-52, Rev. 2, The KW Pump and Treat System Remedial Design and Remedial Action Work Plan, Supplement to the 100-KR-4 Groundwater Operable Unit Interim Action, October 2009). Most of these wells are operating.
extraction wells located on the riverward side of the inland hexavalent chromium plumes and have exhibited a strong downward concentration trends since 2010. During 2011, eighteen of these wells exhibited annual average measured hexavalent chromium concentrations below the 20 µg/L remedial action objective. Eight wells exhibited annual average hexavalent chromium concentrations between 20 and 30 µg/L, and five wells exhibited annual average concentrations of greater than 30 µg/L. Of the wells exhibiting hexavalent chromium concentrations greater than 30 µg/L, the maximum was well 199-K-18 with an annual average of 102 µg/L. The downward concentration trends in these wells are an indication of effective plume capture and chromium mass removal from the aquifer. Extraction well capture analysis indicates that the well network is effectively capturing the targeted plume areas. Continued operation of the pump-and-treat systems until they are augmented, or replaced, by the final remedial action system is expected to produce continued reduction in groundwater hexavalent chromium concentration at these wells.

The remedial action objectives for the 100-KR-4 Operable Unit (EPA/ROD/R10-96/134) are as follows:

- Protect aquatic receptors in the river bottom from contaminants in groundwater entering the Columbia River.
- Protect human health by preventing exposure to contaminants in the groundwater.
- Provide information that will lead to the final remedy.

The contaminant of concern is hexavalent chromium. The ROD specifies 20 µg/L as the concentration at compliance wells that is protective of aquatic organisms in the river environment.

2.3.8 K Basins Groundwater Monitoring

The fuel storage basins in the KW and KE Reactor buildings were used from 1955 to 1971 to store irradiated fuel generated at the K Reactors and from the late 1970s to 2004 to store irradiated fuel from the 100-N Reactor, along with other miscellaneous fuel recovered during remedial actions at other reactor areas. Each basin held ~ 4.9 million liters of shielding water that became highly contaminated with fuel residues and fission products (for example, strontium-90, cesium-137, and tritium). In addition, each basin was connected to a combined crib and reverse well (waste sites 116-KE-3 and 116-KW-2) designed to receive basin overflow water. These waste sites, as well as leaks around the KE Basin, contaminated the adjacent vadose zone and groundwater. KW Basin had no documented leaks.

Fuel rods and debris were removed from the K Basins by 2008; and the KE Basin, substructure, and crib were demolished in 2009. The reverse well associated with the 116-KE-3 Crib remains in place. Contaminated soil around the basin and crib was removed. Prior to demolition and remediation, downgradient groundwater monitoring wells around the KE Basin were decommissioned. The KW Basin has been emptied of fuel rods but remains a depository for contaminated sludge from the KE and KW Basins. The KW Basin and the 116-KW-2 Crib are scheduled for removal after 2015.

Based on reported contamination in the basin shielding water, the contaminants of concern for groundwater include tritium, carbon-14, technetium-99, and other less-mobile radionuclides such as strontium-90 and cesium-137. Tritium is considered to be the primary indicator of water loss from the fuel rod basin and crib system.
Groundwater Monitoring and Assessment Plan for the 100-K Area Fuel Storage Basins (PNNL-14033) specifies groundwater monitoring requirements. Although the basins are no longer filled with shielding water, a continuing sampling program is being maintained. Previous leakage at the KE Basin and the use of dust-suppression water during basin and vadose zone remediation warrant continued monitoring at downgradient wells for the near future. The well list has been modified to account for wells that have been decommissioned (Appendix B).

Tritium concentrations in wells downgradient from the KE Basins maintained previous trends (see Section 2.3.2), indicating no new releases. Strontium-90 concentrations increased in downgradient well 199-K-141 (an extraction well for the chromium pump-and-treat system; Section 2.3.4). This contamination could have originated in the KE Basins or the adjacent 116-KE-3 Crib. In the past, higher levels of strontium-90 were detected in 199-K-109A, adjacent to the crib, and it is likely that the decrease in concentration at 199-K-109A as well as the observed increase in 199-K-141 reflect movement of the plume.

Tritium and strontium-90 concentrations in wells downgradient from the KW Basins in 2011 were consistent with previous results (see Sections 2.3.2 and 2.3.4), indicating no new releases.

Table 2.3-1. 100-KR-4 Interim Action Pump-and-Treat Systems, 2011

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<th>Performance</th>
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<th>KX</th>
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<td>285</td>
<td>5,721</td>
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<td>Mass of hexavalent chromium removed (kilogram)</td>
<td>5.4</td>
<td>355</td>
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<td>Number of extraction wells</td>
<td>10</td>
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<tr>
<td>Number of injection wells</td>
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<tr>
<td>Total for All Systems, 1997 through 2011</td>
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<td>Plume area at 20 µg/L</td>
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<td>46%</td>
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Figure 2.3-1. Facilities and Groundwater Monitoring Wells in 100-KR-4

- Monitoring Well
- KR4 Extraction Well
- KR4 Injection Well
- KW Extraction Well
- KW Injection Well
- KX Extraction Well
- KX Injection Well
- Aquifer Tube

Well prefix ‘199’ omitted
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Figure 2.3-2. 100-KR-4 Water Table, March 2011
Figure 2.3-3. Changes to 100-KR-4 Plume Areas
Figure 2.3-4. Hexavalent Chromium Concentrations and Trends in 100-KR-4, Upper Part of Unconfined Aquifer, Spring and Fall 2011.
Figure 2.3-5. Hexavalent Chromium Trends in 116-K-2 Trench Plume
Figure 2.3-6. Hexavalent Chromium Trends in KE and KW Plumes

Note: Only trend plot locations shown on map.
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Figure 2.3-7. Hexavalent Chromium Trends in K West Monitoring Wells

Open symbols used for non-detect values, replicate data averaged.
Figure 2.3-8. Average Tritium Concentrations in 100-KR-4, Upper Part of Unconfined Aquifer, 2011
Figure 2.3-9. Tritium Trends in Wells Monitoring K East (Top) and 118-K-1 Burial Ground (Bottom)

Open symbols used for non-detect values, replicate data averaged.
Figure 2.3-10. Average Nitrate Concentrations in 100-KR-4, Upper Part of Confined Aquifer 2011
Figure 2.3-11. Average Strontium-90 Concentrations in 100-KR-4, Upper Part of Confined Aquifer 2011
Figure 2.3-12. Strontium-90 Trend in Well 199-K-200 in the 116-K-2 Trench

Figure 2.3-13. Strontium-90 Trend in Wells Downgradient of K East
Figure 2.3-14. Average Carbon-14 Concentrations in 100-KR-4, Upper Part of Unconfined Aquifer, 2011
Figure 2.3-15. Average Trichloroethene Concentrations in 100-KR-4, Upper Part of Unconfined Aquifer 2011
Figure 2.3-16. Volume of Groundwater Treated and Mass of Hexavalent Chromium Removed by 100-KR-4 Pump-and-Treat Systems, 1997 through 2011

Cumulative Mass Removed

Cumulative Volume Treated

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