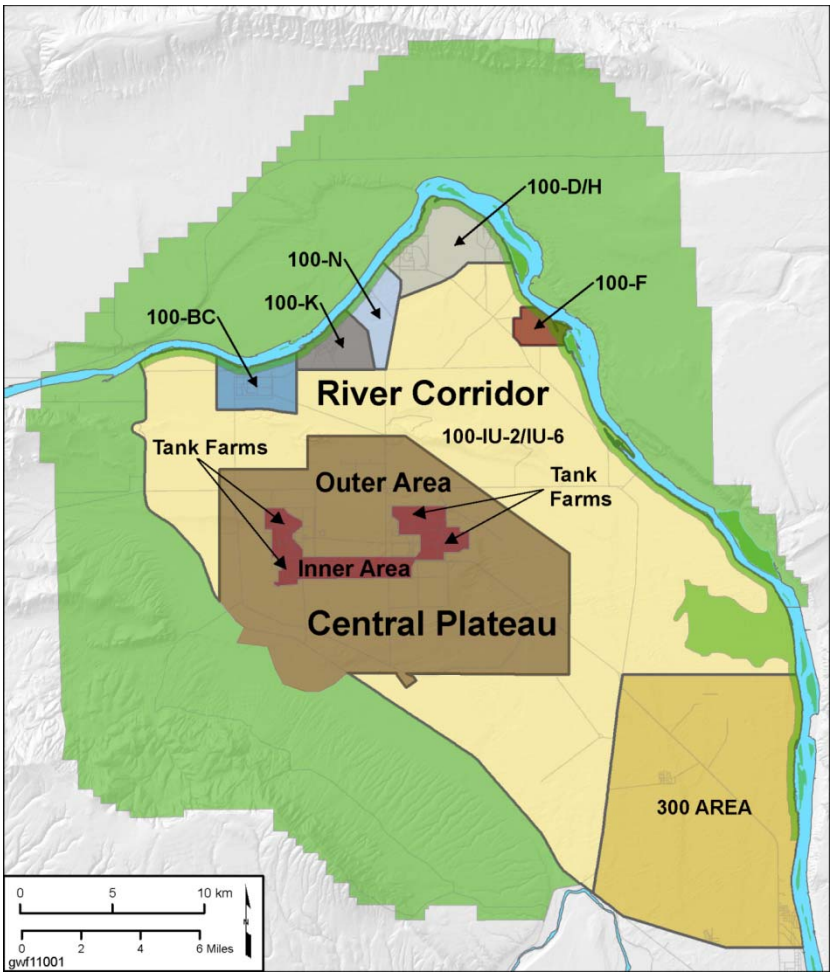
Executive Summary

M.J. Hartman and K.A. Ivarson

Introduction

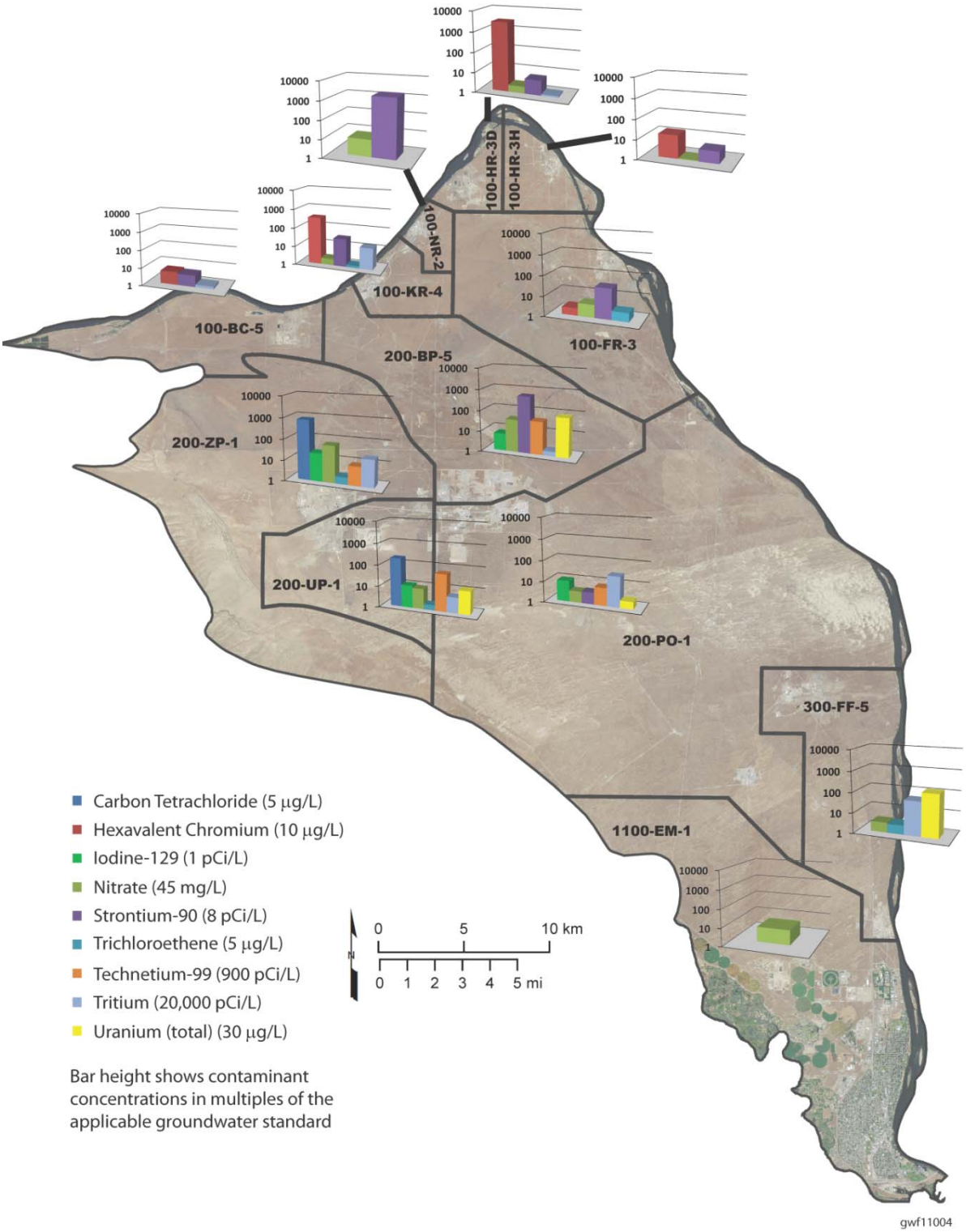
The Hanford Site, part of the U.S. Department of Energy's (DOE's) nuclear weapons complex, encompasses ~1,500 square kilometers northwest of the city of Richland along the Columbia River in southeastern Washington State. In 1943, as part of the top secret Manhattan Project, the federal government took possession of the Site to build the world's first large-scale plutonium production reactor, the B Reactor. This reactor was used to make the plutonium for the Trinity Test and the bomb that was dropped on Nagasaki, Japan in 1945. During the Cold War period (1945 to 1991), the government built a total of nine reactors along the Columbia River for the production of weapons-grade plutonium.



The Hanford Site is located in southeastern Washington State on the shore of the Columbia River. The River Corridor includes the 100 Area, where nine nuclear reactors formerly operated, and the 300 Area, where nuclear fuel assemblies were made. The Central Plateau includes the 200 Area, where chemical processing of nuclear fuel occurred.

During reactor operations, chemical and radioactive waste was released into the environment and contaminated the soil and groundwater beneath portions of the Hanford Site. Groundwater flows to the Columbia River and is the primary exposure route for contaminants to reach human, environmental, and ecological receptors.

Since the 1990s, DOE has worked to characterize, remove, treat, and dispose of contamination from past operations. DOE developed a plan to address groundwater and vadose (unsaturated) zone contamination in consultation with the U.S. Environmental Protection Agency (EPA) and the Washington State Department of Ecology (Ecology). Key elements associated with managing the Hanford Site's groundwater and vadose zone contamination are to (1) protect the Columbia River and groundwater, (2) develop a cleanup decision process, and (3) achieve final cleanup.



This map shows the maximum concentrations of groundwater contaminants in each groundwater interest area in 2011. The heights of the bars represent multiples of the applicable water quality standards. For example, if the maximum strontium-90 concentration was 80 pCi/L, the bar is 10 units high because the drinking water standard is 8 pCi/L.

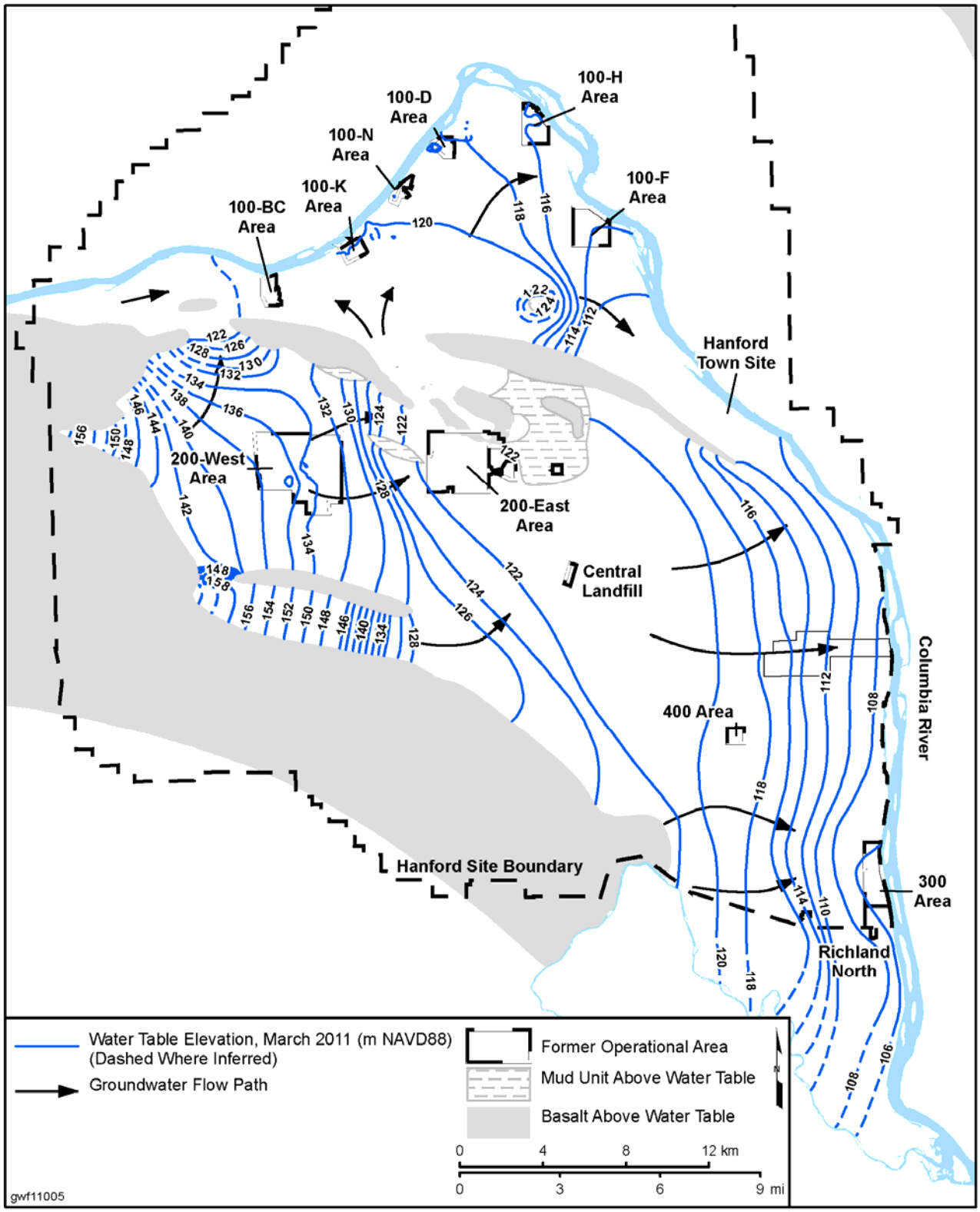
This document presents the results of Hanford Site groundwater monitoring for 2011. It describes monitoring results for Resource Conservation and Recovery Act of 1976 (RCRA) treatment, storage, and disposal units, for Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) groundwater operable units, where no active remediation is currently taking place, and for the Atomic Energy Act of 1954 (AEA), as required by DOE orders. This report provides a summary of vadose zone monitoring, investigations, and results, as well as well installation, remediation, and decommissioning activities. DOE publishes details on CERCLA remediation activities (for example, pump-and-treat operations) in separate reports that are summarized and referenced in this report. The data presented in this report—and information on well locations, construction, and screened intervals—can be found through the DOE's Environmental Dashboard Application at *http://environet.hanford.gov/EDA/*.

RCRA regulates the management of solid waste, hazardous waste, and certain underground storage tanks. It applies to active or recently-active treatment, storage, and disposal units. Monitoring is required at some units to determine if they are affecting groundwater quality in the uppermost aquifer. The uppermost aquifer is the unconfined aquifer beneath most of the Hanford Site. Groundwater monitoring requirements for the Site's RCRA units fall into one of two broad categories: interim status or final status. A permitted RCRA unit requires final status monitoring, as specified in WAC 173-303-645, "Dangerous Waste Regulations," "Releases from Regulated Units." The RCRA units not currently incorporated into a permit require interim status monitoring, as specified in WAC 173-303-400, "Dangerous Waste Regulations," "Interim Status Facility Standards" (based on 40 CFR 265, "Interim Status Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities"). Although the single-shell tank farms and inactive units are listed in Part A of the Hanford Facility Dangerous Waste Permit (WA7890008967, *Hanford Facility Resource Conservation and Recovery Act Permit, Dangerous Waste Portion, Revision 8C, for the Treatment, Storage, and Disposal of Dangerous Waste*), they are operated under interim status requirements until an approved operating permit for each unit is issued.

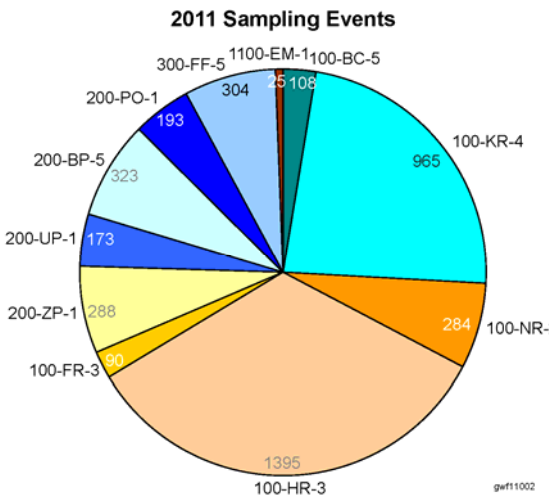
RCRA groundwater monitoring is conducted under one of three possible phases: (1) contaminant indicator evaluation (or detection) monitoring, (2) groundwater quality assessment (or compliance) monitoring, or (3) corrective action monitoring. In the interim-status contaminant indicator evaluation monitoring, four indicator parameters (pH, specific conductivity, total organic carbon, and total organic halides) are monitored and evaluated against statistically derived threshold values calculated from upgradient wells. In final status detection monitoring, site-specific indicators are evaluated using statistical methods identified in the respective permit. Groundwater quality assessment (interim status) or compliance (final status) monitoring occurs when a facility appears to have impacted groundwater quality. The objective of the monitoring program shifts from detection to assessing the nature and extent of the problem. Under corrective action monitoring, Ecology has stipulated some form of groundwater remediation. The goal of a corrective action groundwater monitoring program is to determine if the corrective action is effective.

CERCLA is the federal government's program to clean up the nation's uncontrolled hazardous and radioactive waste sites. Cleanup decisions are based on the results of environmental investigations that include the vadose zone and groundwater. CERCLA groundwater monitoring on the Hanford Site includes monitoring of contaminants and water levels, and monitoring the effectiveness of groundwater remedial actions, such as pump-and-treat systems.

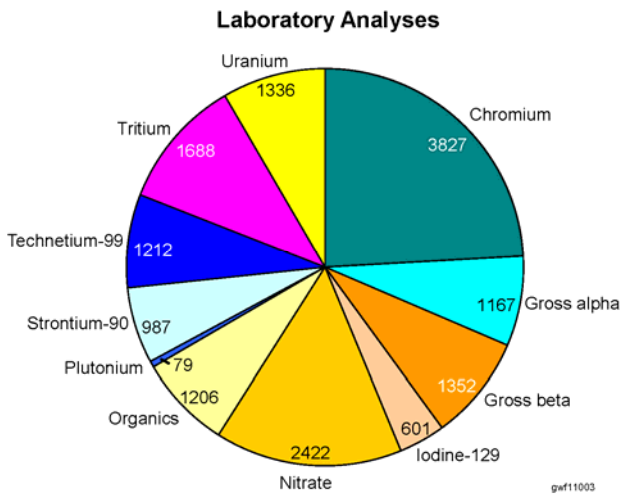
DOE Orders implement requirements of the AEA at DOE sites. These requirements include groundwater monitoring to detect, characterize, and respond to releases of radionuclides. This AEA monitoring is integrated with CERCLA and RCRA monitoring on the Hanford Site.



Groundwater flows from areas where the water table is high to where it is lower, and eventually discharges to the Columbia River.



DOE sampled 931 wells and 285 shoreline aquifer tubes in 2011. Many of the wells were sampled multiple times, for a total of 4,147 sampling events.



This chart shows the number of laboratory analyses run on Hanford Site groundwater samples for the most common constituents in 2011.

River Corridor

The Columbia River flows through the northern portion of the Hanford Site before turning south toward the City of Richland. The region of the Site along the shoreline is known as the River Corridor. Hanford Site groundwater flows toward the Columbia River, so groundwater is the primary exposure route for site contaminants to reach human and environmental receptors. Daily, monthly, and seasonal changes in river stage, controlled by operation of Priest Rapids Dam, affect the flow of nearby groundwater. During periods of high river stage, the river temporarily recharges the adjacent aquifer, whereas during periods of low or moderate river stage, groundwater discharges from the aquifer to the river. River stage changes cause a mixing zone to occur in the aquifer near the shore.

The table on the following page summarizes information about the River Corridor. In the 100 Area, groundwater contamination is related to past disposal of waste associated with water-cooled nuclear reactors. The primary groundwater contaminants are hexavalent chromium, strontium-90, nitrate, and tritium in the 100 Area, and uranium and tritium in 300-FF-5. Other contaminants of concern in the 100 Area include carbon-14 and trichloroethene. The primary sources of hexavalent chromium contamination were the routine disposal of reactor cooling water, which contained the corrosion inhibitor sodium dichromate, and unplanned spills and leaks of the high-concentration sodium dichromate stock solution.

DOE conducted intensive field studies in the River Corridor in 2010 and 2011. Results will be used to select methods for final remediation of soil and groundwater.

More than 60 percent of the waste sites near the river have been remediated or are classified as not requiring remediation under interim records of decision. Cleanup of the remaining sites is underway. Removal of contaminated soil reduces the potential for future groundwater contamination. Groundwater remediation systems in the 100 Area are limiting the amount of contamination reaching the Columbia River and reducing the mass of contaminants in the groundwater.

Interim cleanup of the River Corridor has achieved a great deal, but final decisions are yet to be made. CERCLA provides a process for making cleanup decisions. This process is known as a remedial

investigation/feasibility study (RI/FS), and the decision will be published in a record of decision (ROD). In 2010 and 2011, DOE conducted CERCLA investigations and drafted RI/FS reports for each of the river corridor units. DOE began submitting these reports to regulatory agencies for review in 2012.

River Corridor Overview

Area	Primary Operations	Status of Waste Site Remediation under interim ROD[(a)]	Groundwater Contamination: Maximum Concentration and Plume Area						
			Carbon-14	Hexavalent Chromium	Nitrate	Strontium-90	Trichloro-ethene	Tritium	Uranium
100-BC	Reactor operations – B Reactor 1944-69; C Reactor 1952-69	>90% complete	N		<DWS		<DWS		N
100-K	Reactor operations – KE Reactor 1955-71; KW Reactor 1955-70	>30% complete							<DWS
100-N	Reactor operations -- N Reactor 1963-87	>30% complete	<DWS				N	<DWS	<DWS
100-D & 100-H	Reactor operations – D Reactor 1944-67; DR Reactor 1950-64; H Reactor 1949-65	>45% complete	N				N	<DWS	<DWS
100-F	Reactor operations -- F Reactor 1945-65; Biological experiments until 1976	>85% complete	N					<DWS	
300	Nuclear fuel fabrication and research -- 1940s-1960s	>75% complete	N	N	(b)	<DWS			
1100	Vehicle maintenance, 1954-85; solid waste landfill --1950s-1970	100% (final ROD)	N	N	(b)	N	N	<DWS	<DWS
Standards			2000 pCi/L	10 ug/L	45 mg/L	8 pCi/L	5 ug/L	20,000 pCi/L	30 ug/L
Mobility in subsurface			High	High to Moderate	High	Slight	Moderate	High	Moderate

Legend

Colors indicate maximum concentration in 2011

- ≥1000 x standard
- ≥100 x standard and <1000 x standard
- ≥10 x standard and <100 x standard
- ≥Standard and <10 x standard
- N Not detected or not analyzed

Height of bar indicates plume area above standard (km^2)

- >10
- >1 and ≤ 10
- >0.1 and ≤ 1
- >0, ≤0.1

NOTES

(a) Approximate percentage by number of waste sites classified as closed, interim closed, no action, rejected, or not accepted (end of 2011).

(b) Nitrate in 300-FF-5 and 1100-EM-1 groundwater interest area originates from offsite sources, so plume are and maximum concentration are not shown

ABBREVIATIONS

COC Contaminant of concern
DWS Drinking water standard
ISRM
MNA
P&T Pump and treat system
ROD Record of decision

gwf11020

100-BC-5

Groundwater contamination in 100-BC-5 is related to disposal of solid and liquid waste associated with the operation of two water-cooled reactors. Contaminants include hexavalent chromium, which forms a large plume at relatively low concentrations (less than 50 µg/L). Concentrations appear to be declining very slowly in most wells. However, concentrations increased sharply in early 2012 downgradient of a large excavation at a contaminated waste site. Tritium and strontium-90 concentrations exceed the drinking water standards in several wells, and are declining overall.

Nearly all of the former waste sites have been excavated and backfilled under an interim record of decision. No groundwater interim action was required. Remedial investigation field studies were completed in 2011, and DOE is developing alternatives for remaining waste site and groundwater cleanup.

100-KR-4

The principal groundwater issues for 100-KR-4 are cleaning up hexavalent chromium in the groundwater, tracking contaminant plumes, and monitoring groundwater near the former KE and KW Fuel Storage Basins. Remediation of waste sites is underway. Groundwater contaminant plumes are decreasing in size due to remediation and natural processes including dispersion, discharge to the Columbia River, degradation and radioactive decay.

Pump-and-Treat systems in 100-KR-4 can process up to 4.6 million liters of contaminated groundwater every day. The systems have removed 632 kilograms of hexavalent chromium since 1997.

Hexavalent chromium is the primary contaminant of concern for groundwater. Three pump-and-treat systems operate as interim actions to remove hexavalent chromium from the groundwater. Between 1997 and 2011, 632 kilograms of hexavalent chromium have been removed, and the size of the plume (at the 20 µg/L contour) has shrunk by 32 percent.

Other groundwater contaminants in 100-KR-4 include tritium, carbon-14, strontium-90, nitrate, and trichloroethene. Tritium contamination is migrating downgradient from the 118-K-1 Burial Ground. The plume is intercepted by extraction wells near the river. Smaller tritium plumes are present near the KW and KE Reactors. Two wells in the K West region continued to have concentrations above the drinking water standard. The plume did not change significantly between 2010 and 2011. Few wells in 100-KR-4 had strontium-90 concentrations above the 8 pCi/L drinking water standard in 2011, and results were similar to 2010. A new, temporary well drilled through the 116-K-2 Trench had higher strontium-90 concentrations than other wells. The high concentrations have not migrated far from the source because strontium-90 has not been detected in downgradient wells. Nitrate continued to exceed the drinking water standard in a few wells in 100-K Area. Trichloroethene exceeded the drinking water standard in a single well in 2011.

The CERCLA process is underway to make final cleanup decisions for 100-KR-4. Remedial investigations in 2010 and 2011 included installing 15 wells and boreholes.

The concrete KE and KW Basins were integral parts of each reactor building. Until 2004, the water-filled basins were used to store irradiated fuel from the last run of N Reactor, as well as miscellaneous fuel fragments recovered during remedial actions at other reactor areas. Leaks at and around the basins have contaminated groundwater in the past. KE Basin was demolished, and soil remediation has begun. Demolition of the KW Basin is scheduled to begin after 2015. Groundwater monitoring in 2011 did not show new groundwater impacts from the basins.

Three pump-and-treat systems reduce the amount of hexavalent chromium entering the Columbia River from 100-KR-4. The concentrations and size of the main plume have declined as a result of remediation.

100-NR-2

Principal groundwater issues for 100-NR-2 include remediation of strontium-90 and RCRA monitoring. The major liquid waste sites have been remediated, and excavation is continuing at remaining waste sites.

The primary groundwater contaminant is strontium-90, which originated at the 116-N-1 and 116-N-3 waste sites. Strontium-90 tends to bind to sediment grains, and the shape and size of the plume does not change significantly from year to year. Pump-and-treat technology was found to be ineffective in cleaning up strontium-90; so DOE is applying an in situ technology, apatite sequestration. The goal is to create a reactive zone in the aquifer that captures strontium-90 as groundwater flows through it to the Columbia River. Apatite-forming chemicals were injected into a line of wells along the river shoreline several times since 2006. As the injected chemicals reacted with the aquifer and sediments, strontium-90 levels temporarily increased in downgradient wells and aquifer tubes. Subsequently, strontium-90 and gross beta concentrations declined. DOE expanded the barrier by 183 meters with additional injections in fall 2011.

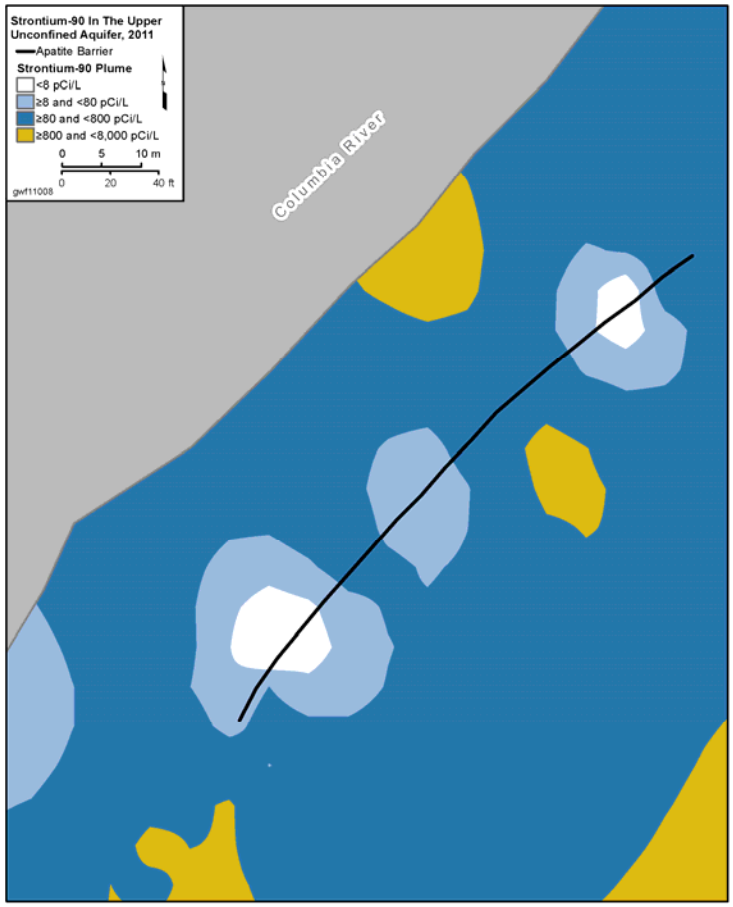
Other groundwater contaminants include nitrate and total petroleum hydrocarbons. Tritium concentrations have declined below the drinking water standard in recent years.

In 2011, RCRA monitoring continued under detection programs at the 1301-N, 1324-N/NA, and 1325-N facilities (waste sites 116-N-1, 120-N-1, 120-N-2, and 116-N-3). Results indicated no releases of dangerous waste constituents from the RCRA units.

In 2011, DOE released an RI/FS work plan addendum and drilled 8 boreholes that were completed as wells. Soil and water samples were collected from each of the boreholes during drilling.

100-HR-3

The 100-D and 100-H Areas, and the 600 Area between them, are combined into 100-HR-3. Remediation of waste sites continued in 2011. Hexavalent chromium is the primary contaminant of concern for groundwater, and a large plume extends from 100-D to 100-H Area. Hexavalent chromium also was detected at relatively high levels within the Ringold upper mud unit beneath 100-H, unlike elsewhere in the 100 Areas. Additional groundwater contaminants include strontium-90 and nitrate.



DOE injected chemicals into a line of wells along the river shore in 100-NR-2, creating a treatment zone in the aquifer. As contaminated groundwater flows through this zone, strontium-90 binds to the sediment grains before it can reach the river.

Pump-and-treat systems remove hexavalent chromium contamination from the groundwater as part of an interim action. Between 1997 and 2011, these systems removed 1,215 kilograms of hexavalent chromium. The new DX pump-and-treat system began to operate in December 2010 and the new HX system in October 2011. In 2011, the DX system alone removed nearly as much chromium as the older, lower-capacity 100-HR-3 system removed in its entire period of operation. Maximum concentrations have declined more than 75 percent in some areas.

DOE is remediating part of the southern 100-D Area hexavalent chromium plume using a permeable reactive barrier that immobilizes chromium in the aquifer. However, data from recent years indicate that contamination is breaking through in some areas of the barrier. New extraction wells downgradient of the barrier will remediate this contamination as part of the DX pump-and-treat system.

DOE expanded pump-and-treat systems in 100-HR-3 in 2010 and 2011. Treatment capacity is now 7.6 million liters per day. Since 1997, the systems have removed 1,215 kilograms of hexavalent chromium from the groundwater.

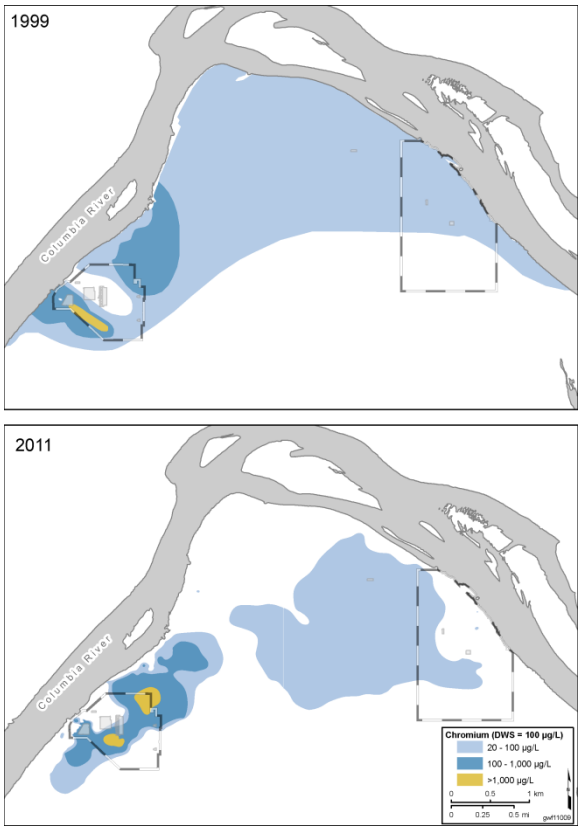
The CERCLA process is underway to make final cleanup decisions for 100-HR-3. Remedial investigations in 2010 and 2011 included installing 15 wells and 10 boreholes and characterizing the vadose zone and groundwater. During the remedial investigation, hexavalent chromium was identified farther south in 100-D Area than previously indicated. This new information will be evaluated in the FS.

The former 183-H solar evaporation basins (waste site 116-H-6) constitute the only RCRA site in 100-HR-3. The site is monitored in accordance with RCRA corrective action requirements during the post-closure period to track contaminant trends during operation of the CERCLA interim action for chromium. Concentrations of waste indicators increased in 2011.

100-FR-3

Groundwater contamination in 100-FR-3 originated from disposal of solid and liquid waste associated with operation of the water-cooled F Reactor and biological experiments. Nitrate concentrations in groundwater exceed the drinking water standard beneath much of the 100-F Area and a large region downgradient. Smaller plumes of hexavalent chromium, strontium-90, and trichloroethene are present. Strontium-90, hexavalent chromium, and trichloroethene concentrations are declining; and nitrate concentrations are stable. Uranium was detected at a level above the drinking water standard in a new well that was drilled through a former waste site.

Nearly all of the former waste sites have been excavated and backfilled under a ROD for interim action. No groundwater interim action was required. Remedial investigation field studies were completed in 2011, and DOE is developing alternatives for final waste site and groundwater cleanup.



A large hexavalent chromium plume is present in 100-HR-3. The size of the plume has decreased since 1999 due to groundwater remediation, discharge to the Columbia River, and dispersion. However, high concentrations remain in 100-D Area groundwater. DOE expanded the pump-and-treat systems in 2010 and 2011 to remediate the plumes.

300-FF-5

Three geographic regions comprise 300-FF-5: the 300 Area Industrial Complex, the 618-11 Burial Ground region, and a region including the 618-10 Burial Ground and 316-4 Cribs. Most of the liquid waste sites have been remediated.

Contaminants of concern in 300 Area groundwater are uranium, trichloroethene, and *cis*-1,2-dichloroethene. Uranium has persisted longer than expected, and concentrations remain above the drinking water standard (30 µg/L) in 300 Area groundwater. Another area of uranium contamination developed downgradient of a burial ground as a result of waste site remediation in 2007 and 2008. This plume has migrated downgradient and is merging with the larger uranium plume. Trichloroethene concentrations increased to levels above the drinking water standard in a few wells screened in the upper part of the unconfined aquifer in 2011. Higher concentrations were detected in groundwater samples collected from a deeper, finer-grained sediment during the RI, but only in a limited area. This sediment produces little water, so none of the monitoring wells are screened in it. However, at aquifer tube sites along the Columbia River, at least one aquifer tube is screened in this finer-grained sediment, and sampling reveals trichloroethene contamination.

Concentrations of uranium, trichloroethene, and cis-1,2-dichloroethene are relatively constant or gradually decreasing in 300-FF-5.

Groundwater downgradient of the 618-11 Burial Ground contains a high-concentration tritium plume, likely originating from irradiated material in the burial ground. Concentrations at a well adjacent to the burial ground have decreased from the peak values, and the plume has maintained its basic shape since its discovery in 1999. Concentrations are stable in the central portion of the plume, while increasing slightly at the downgradient edge of the plume, reflecting migration to the east.

Remedial investigation activities continued in 2011. Eleven wells and five boreholes were installed in 2010 and 2011. DOE issued a draft RI report and proposed plan in 2011 that will support remedy selection.

RCRA groundwater monitoring continued at the 300 Area Process Trenches (waste site 316-5). The unit is monitored in accordance with post-closure corrective action requirements. In June 2011, uranium concentrations increased sharply near the southern end of the trenches. The temporary increase likely was caused by mobilization of deep vadose zone contamination by the seasonal high water table.

The uranium plume in 300-FF-5 is attenuating slowly. DOE is investigating alternatives for more rapid remediation.

1100-EM-1

The only portion of the River Corridor for which final cleanup decisions have been made is 1100-EM-1. This operable unit was removed from the National Priorities List in 1996. The selected remedy for groundwater was monitored natural attenuation of volatile organic compounds, with institutional controls on drilling of new water supply wells. Trichloroethene was the primary contaminant of concern, but concentrations have remained below the cleanup level since 2001.

Wells in the North Richland Well Field are monitored frequently to detect any changes in potential Hanford Site contaminants near these wells. Tritium associated with the plume originating from sources in the 200 East Area has not been detected in these wells.

Uranium concentrations in wells downgradient of DOE's inactive Horn Rapids Landfill have slowly been increasing since 1996 but remained below the drinking water standard in 2011. The presence of uranium at these locations is likely associated with the plume moving northeast from an offsite facility.

Columbia River

Groundwater discharges to the Columbia River via riverbank springs and areas of upwelling in the river bed. DOE has taken actions to protect Columbia River and groundwater, including the following:

- Ceasing discharge of all unpermitted liquids in the central Hanford Site
- Remediating the former liquid waste sites in the 100 and 300 Areas to reduce the potential for future groundwater contamination
- Containing groundwater plumes and reducing the mass of primary contaminants through remedial actions such as pump-and-treat.

DOE samples Columbia River water, river sediment, and riverbank seeps to determine the extent of Hanford Site or other contaminants. The data provide a historical record of radionuclides and chemicals in the environment. Concentrations of tritium and uranium in river water downstream of the Site are slightly higher than upstream of the Site, but meet water quality standards. Concentrations of other contaminants are no higher in downstream samples.

The 100 Area and 300 Area component of DOE's River Corridor baseline risk assessment addresses post-remediation, residual contaminant concentrations in these areas, as well as the Hanford and White Bluffs town sites. The assessment is also investigating the risks related to the potential transport of Hanford Site contaminants into Columbia River riparian and near-shore environments adjacent to the operational areas.

DOE completed an investigation of Hanford Site contaminant releases in the Columbia River in 2010. Samples were collected of pore water (i.e., groundwater upwelling beneath the river bottom into the space between rocks and sediment of the river bed), river sediment, river water, fish, and island soil. Pore water in some of the 100 Area samples had concentrations of hexavalent chromium above the aquatic standard, and strontium-90 exceeded the drinking water standard in some 100-N Area samples. Tritium concentrations exceeded the drinking water standard in some pore water samples near the former Hanford town site, and uranium near the 300 Area. The information obtained from this investigation will ultimately be used to help make final cleanup decisions for Hanford Site contaminants that exist in and along the Columbia River.

Central Plateau

When the Hanford Site was operating, irradiated fuel reprocessing, isotope recovery, and associated waste management activities occurred in the 200 East and 200 West Areas in the central portion of the Site. For the purpose of Site cleanup, this region is defined as the Central Plateau and is divided into Inner and Outer Areas. The Inner Area is the final footprint area of the Hanford Site that will be dedicated to waste management and containment of residual contamination, while the Outer Area is the remainder of the Central Plateau. Contaminant sources included unlined cribs, trenches, and ponds, and leakage from underground storage tanks, and other unplanned releases. The table on the following page summarizes information about the Central Plateau.

Groundwater in the unconfined aquifer beneath the Central Plateau generally flows from upland areas in the west toward the regional discharge areas along the Columbia River. The flow of water divides

beneath the 200 East Area, with some water flowing toward the north through Gable Gap and some flowing southeast. Previous effluent discharges caused groundwater mounds to form beneath the 200 Area that significantly affected regional flow patterns in the past. These discharges largely ceased in the mid-1990s, and water levels declined; but remnants of groundwater mounds remain.

Central Plateau Overview

Area	Primary Operations	Status of Ground-water ROD	Groundwater Remedial Action	Groundwater Contamination: Maximum Concentration and Plume Area									
				Carbon Tetrachloride	Chromium	Cyanide	Iodine-129	Nitrate	Strontium-90	Trichloroethene	Technetium-99	Tritium	Uranium
200-ZP-1	T Plant (Pu separation) 1944-1956; Pu Finishing Plant: 1949-1989	Signed 2008	Interim action carbon tet. P&T: 1995-present; Soil vapor extraction 1991-present. Final remedy P&T to begin in 2012			<DWS			<DWS				<DWS
200-UP-1	REDOX Plant (Pu separa-tion) 1952-1967; U Plant (U recovery) 1952-1957	Expected 2012	Interim action U plant Tc-99 & U: 1994-2011; Interim action S-SX P&T to begin 2012	See 200-ZP-1		N			<DWS				
200-BP-5	B Plant Pu separation: 1945-1952; B Plant Sr and Cs recovery: 1967-1985	Expected 2016	Perched aquifer P&T test: 2011	N						<DWS			
200-PO-1	PUREX Plant Pu separation: 1956-1972 and 1983-1989	Expected 2016	Vadose zone desiccation test: 2011	<DWS	<DWS	<DWS				<DWS			
Standards				5 ug/L	48 ug/L	200 ug/L	1 pCi/L	45 mg/L	8 pCi/L	5 ug/L	900 pCi/L	20,000 pCi/L	30 ug/L
Mobility in subsurface				Multi-phase	High to Moderate	Moderate	High	High	Slight	Moderate	High	High	Moderate

Legend

Colors indicate maximum concentration in 2011

- ≥1000 x standard
- ≥100 x standard and <1000 x standard
- ≥10 x standard and <100 x standard
- ≥Standard and <10 x standard

N Not detected or not analyzed

Height of bar indicates plume area above standard (km^2)

>10 | >1 and ≤10 | >0.1 and ≤ 1 | >0, ≤0.1

ABBREVIATIONS

DWS Drinking water standard P&T Pump and treat system ROD Record of decision

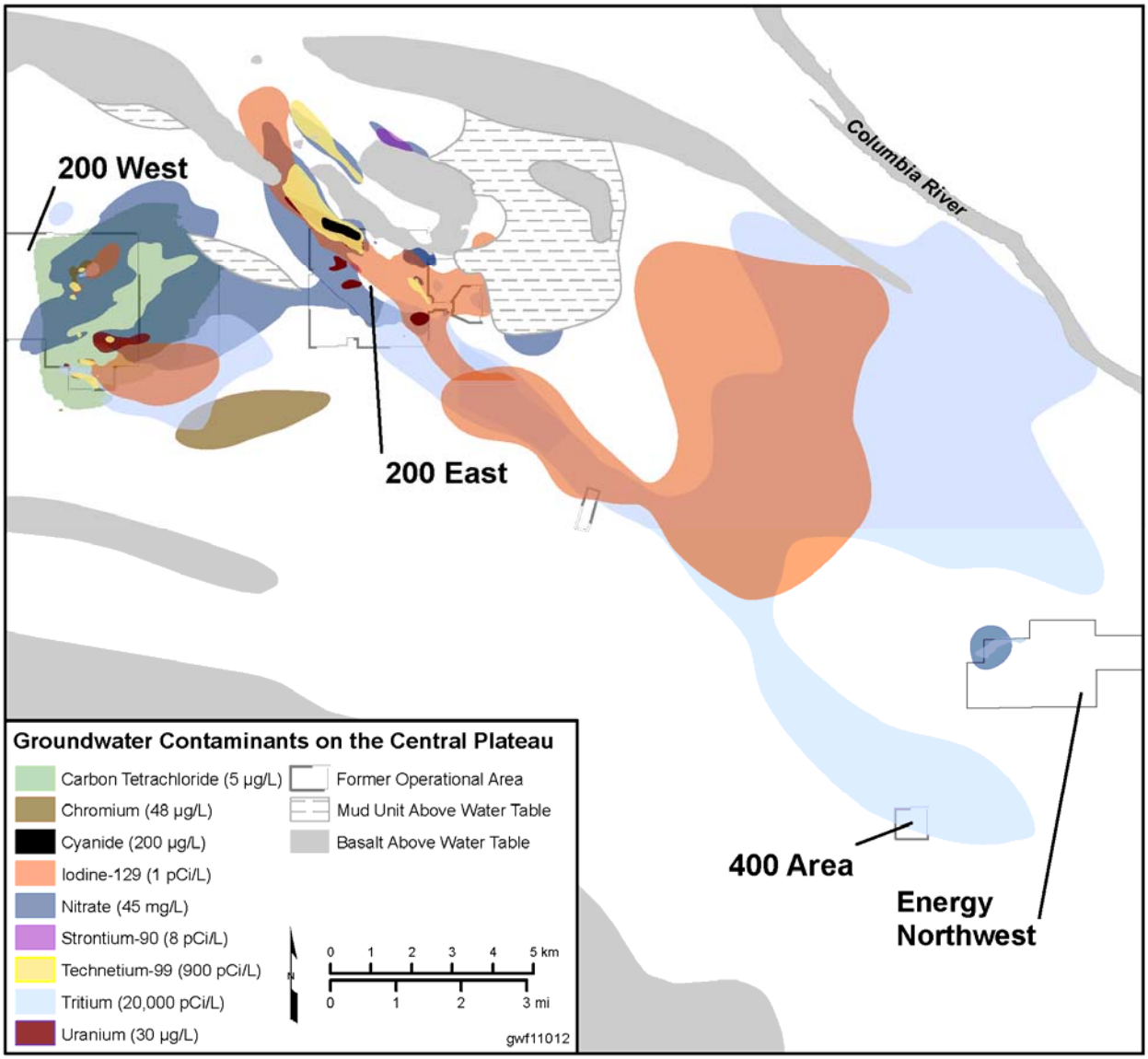
There are seven single-shell tank waste management areas in the 200 Area. Some of these tanks have leaked, contaminating the vadose zone and groundwater beneath the tanks. To minimize additional leaks, DOE has removed the drainable liquid in all of the single-shell tanks.

The vadose zone is up to 50 meters thick beneath the Central Plateau. Portions of it are contaminated with hazardous and radioactive waste. DOE is studying ways to clean up the deep vadose zone to prevent additional contaminants from reaching groundwater.

Waste sites in the Central Plateau currently are a lower priority for cleanup than waste sites in the River Corridor because they are farther from the Columbia River and pose less risk to human and ecological receptors. Remediation of the Central Plateau waste sites is expected to accelerate after River Corridor remediation is complete. Until then, cleanup activities on the Central Plateau focus on completing decision documents, remediating groundwater plumes, decontaminating and decommissioning facilities, and beginning to clean up waste sites in the Outer Area.

Groundwater contaminant plumes of tritium, iodine-129, and nitrate formed when the waste discharged to ponds and cribs reached the aquifer. These contaminants form regional plumes originating on the Central Plateau. The tritium and nitrate plumes have shrunk over the years as a result of dispersion

and radioactive decay. A large carbon tetrachloride plume originated in 200 West Area. This plume is expanding at the edges, but the high-concentration core is contained by a pump-and-treat system. Other groundwater contaminants in the Central Plateau include technetium-99, uranium, strontium-90, trichloroethene, and cyanide.



Large plumes of tritium and iodine-129 originated on the Central Plateau and moved to the east and southeast. Carbon tetrachloride and nitrate also form large plumes. Other contaminants are present in smaller areas.

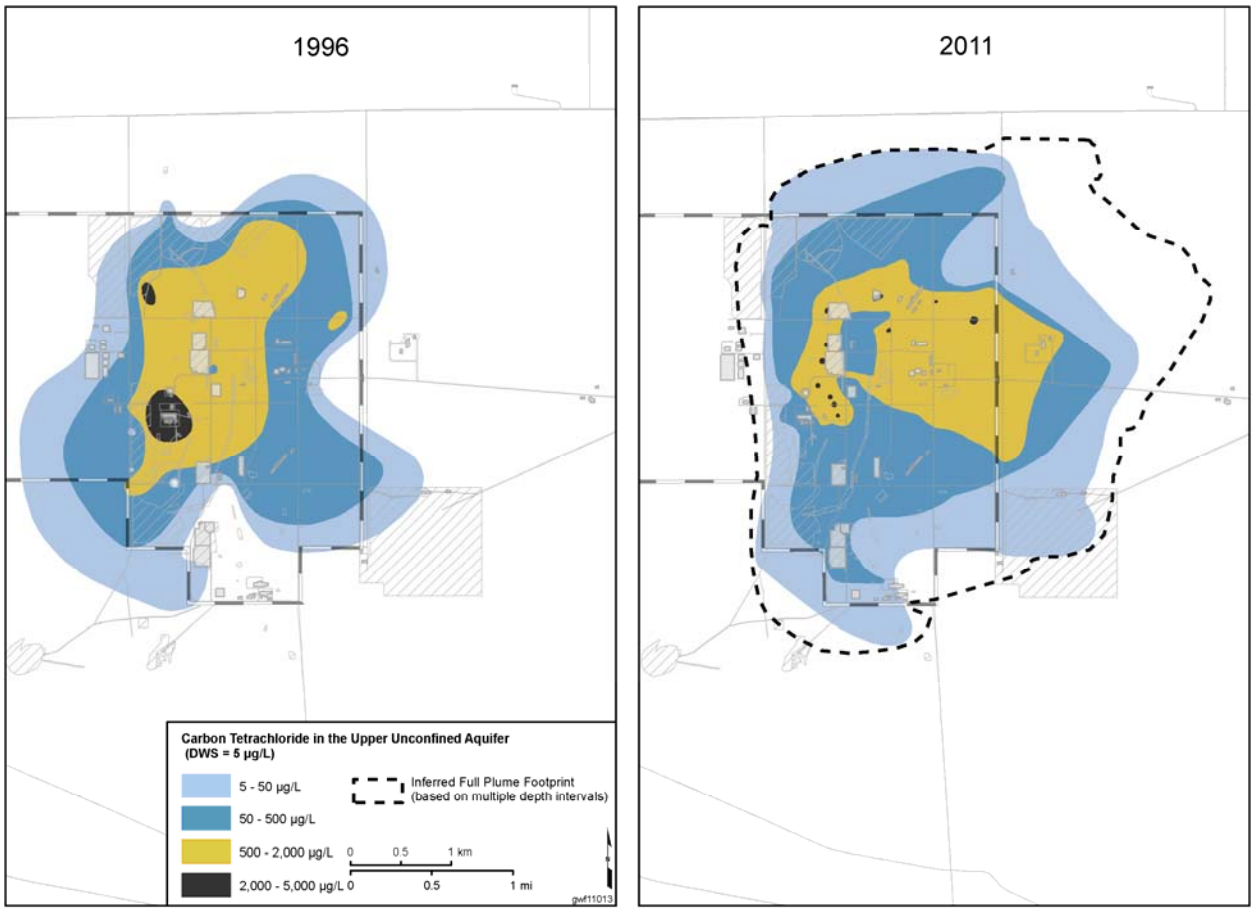
200-ZP-1

Contaminant sources in 200-ZP-1, located in 200 West Area, included cribs, ponds, and single-shell storage tanks. A final ROD for 200-ZP-1 groundwater identified carbon tetrachloride as the primary contaminant of concern. Other contaminants of concern are trichloroethene, iodine-129, technetium-99, nitrate, hexavalent chromium, total chromium, and tritium. Groundwater studies in recent years have improved DOE's knowledge of the complex, vertical distribution of carbon tetrachloride. Contamination occurs at increasing depth to the east (downgradient) of the source areas in 200-ZP-1.

Groundwater and vadose zone remediation systems have removed more than 93,000 kilograms of carbon tetrachloride from groundwater. That's equivalent to the weight of 30 full-size pickup trucks.

Drillers installed six injection wells in 2011 in support of the final ROD. When completed, the network will include 36 injection and extraction wells. These wells will support the new pump-and-treat system, which will remediate groundwater from the entire aquifer thickness. Construction activities for the new treatment facility were completed in 2011, and the system will be operational in 2012.

Since 1994, DOE has operated an interim action pump-and-treat system to prevent carbon tetrachloride in the upper portion of the aquifer from spreading. The system is limiting movement of the shallow, high-concentration portion of the plume but does not address contamination deeper in the aquifer and at the periphery of the plume. The system has removed 13,500 kilograms of carbon tetrachloride from groundwater. Soil vapor extraction systems have removed an additional 79,945 kilograms since 1992. Other pump-and-treat systems (200-UP-1 and Waste Management Area [WMA] T) have removed more than 220 kilograms.



The color shading on these maps of 200 West Area illustrates the carbon tetrachloride plume in the upper portion of the unconfined aquifer in 1996 (before interim remediation began) and in 2011. The dashed line on the 2011 map shows the full extent of the plume at all depths, based on data collected in recent years.

A second interim remediation, pump-and-treat test system has operated since 2007 to remove technetium-99 contamination downgradient of WMA T. During 2011, the system has extracted 13.3 grams (0.23 curies) of technetium-99, 57.9 kilograms of carbon tetrachloride, 6.9 kilograms of chromium, 405 grams of trichloroethene, and 23,024 kilograms of nitrate from the aquifer.

DOE conducted a treatability test in 2011 using one of the soil vapor extraction systems and associated vadose zone wells. The purpose of the test was to evaluate the flux of carbon tetrachloride from the vadose zone to the groundwater to assess the soil vapor concentrations to ensure that they are protective of groundwater. Results are currently being evaluated.

Two Low-Level Waste Management Areas (LLWMA) in 200-ZP-1 are monitored under RCRA interim-status, contaminant indicator parameter programs. At LLWMA-3, upgradient/downgradient comparisons have not been conducted in recent years because the upgradient wells were dry. A new upgradient well was installed in 2011, which will allow statistical evaluations to resume. No significant changes occurred at LLWMA-4 in 2011.

RCRA assessment monitoring continued at WMA T and WMA TX-TY. The concentrations and extent of dangerous waste constituents from these facilities are declining.

The State-Approved Land Disposal Site (SALDS) receives treated water from the Hanford Site's Effluent Treatment Facility. It is regulated under a state waste discharge permit. The declining water table in 200 West Area has caused several of the SALDS monitoring wells to go dry over the years, including two additional wells during 2011. This issue is being addressed during the permit renewal process.

200-UP-1

The southern portion of the 200 West Area and adjacent areas to the east and south comprise 200-UP-1. Contaminant sources included cribs, ponds, and single-shell tanks. Carbon tetrachloride, technetium-99, uranium, tritium, iodine-129, nitrate, and chromium plumes are present in groundwater. Strontium-90 and trichloroethene also exceed drinking water standards in some areas. Carbon tetrachloride originated from sources in 200-ZP-1. The technetium-99 plume area has decreased substantially at the U Plant pump-and-treat system, but the plume near WMA S-SX has grown. The tritium plume is attenuating due to dispersion and radioactive decay. The areal extents of other plumes have remained unchanged or have decreased slightly since 2003.

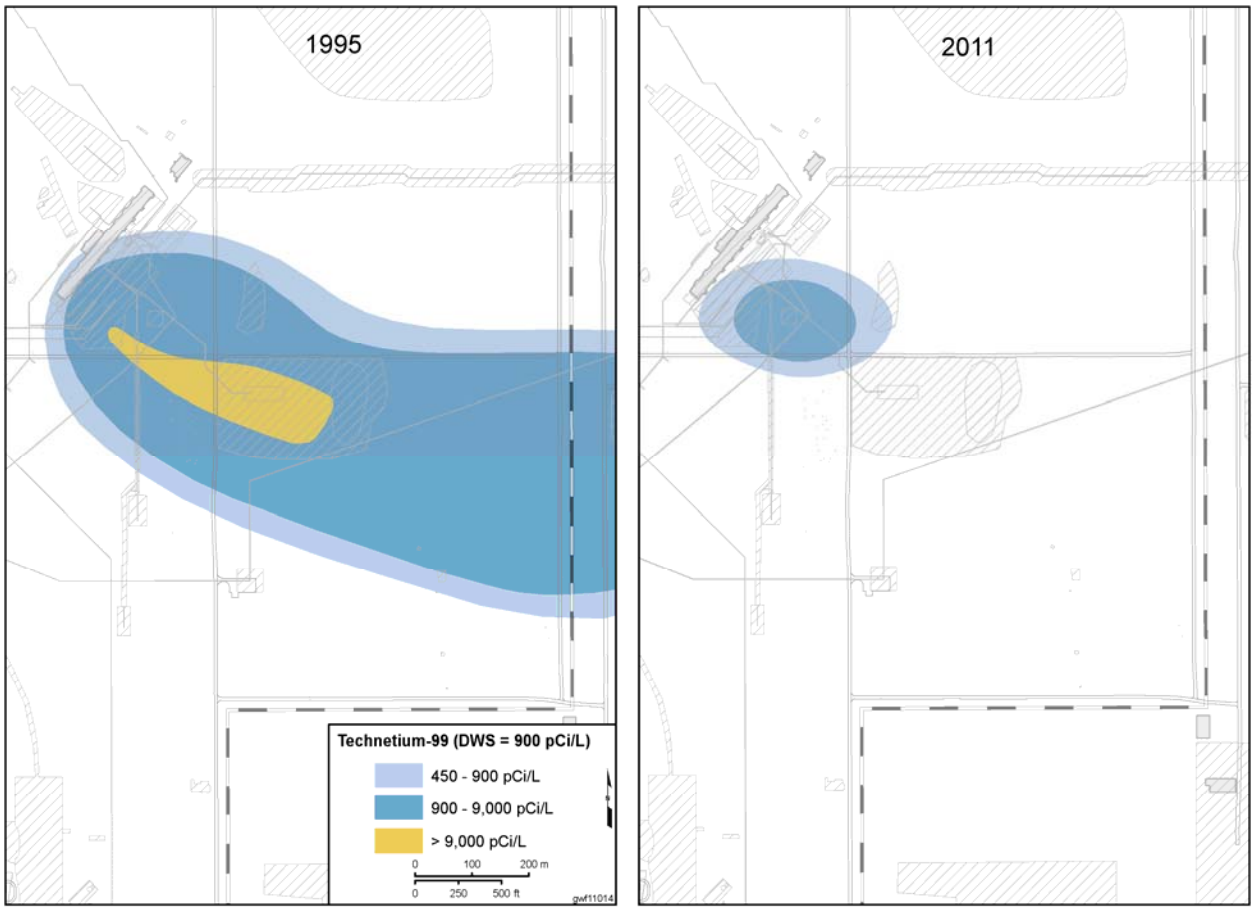
In 2011, DOE and EPA resolved comments concerning the technical approach and administrative strategy for remedial actions. Rather than including 200-UP-1 remedial actions in the existing 200-ZP-1 ROD (by amendment), DOE and EPA agreed that a separate ROD would be prepared for 200-UP-1. This ROD is expected to contain interim actions for all 200-UP-1 contaminants of concern.

Technetium-99 concentrations in 200-UP-1 groundwater are the highest on the Hanford Site. Pump-and-treat remediation has addressed one plume, but another plume near WMA S-SX has grown. A new pump-and-treat system will address that plume.

A CERCLA pump-and-treat system is being installed to remediate the technetium-99 plumes from WMA S-SX. Drillers installed three extraction wells in 2011. This system will replace extended purging of a monitoring well, which has removed ~0.011 curie (~0.63 gram) of technetium-99 since 2003.

During 2011, the U Plant interim action pump-and-treat system operated until March, when it was shut down in accordance with an agreement between DOE and EPA. Flow rates from extraction wells had decreased due to regional decline of the water table and reduced well efficiency. Since startup in 1994, the pump-and-treat system removed 220.5 kilograms of uranium and 127.4 grams of technetium-99. Overall, the U Plant pump-and-treat system achieved its objectives. The interim remedial action goal of

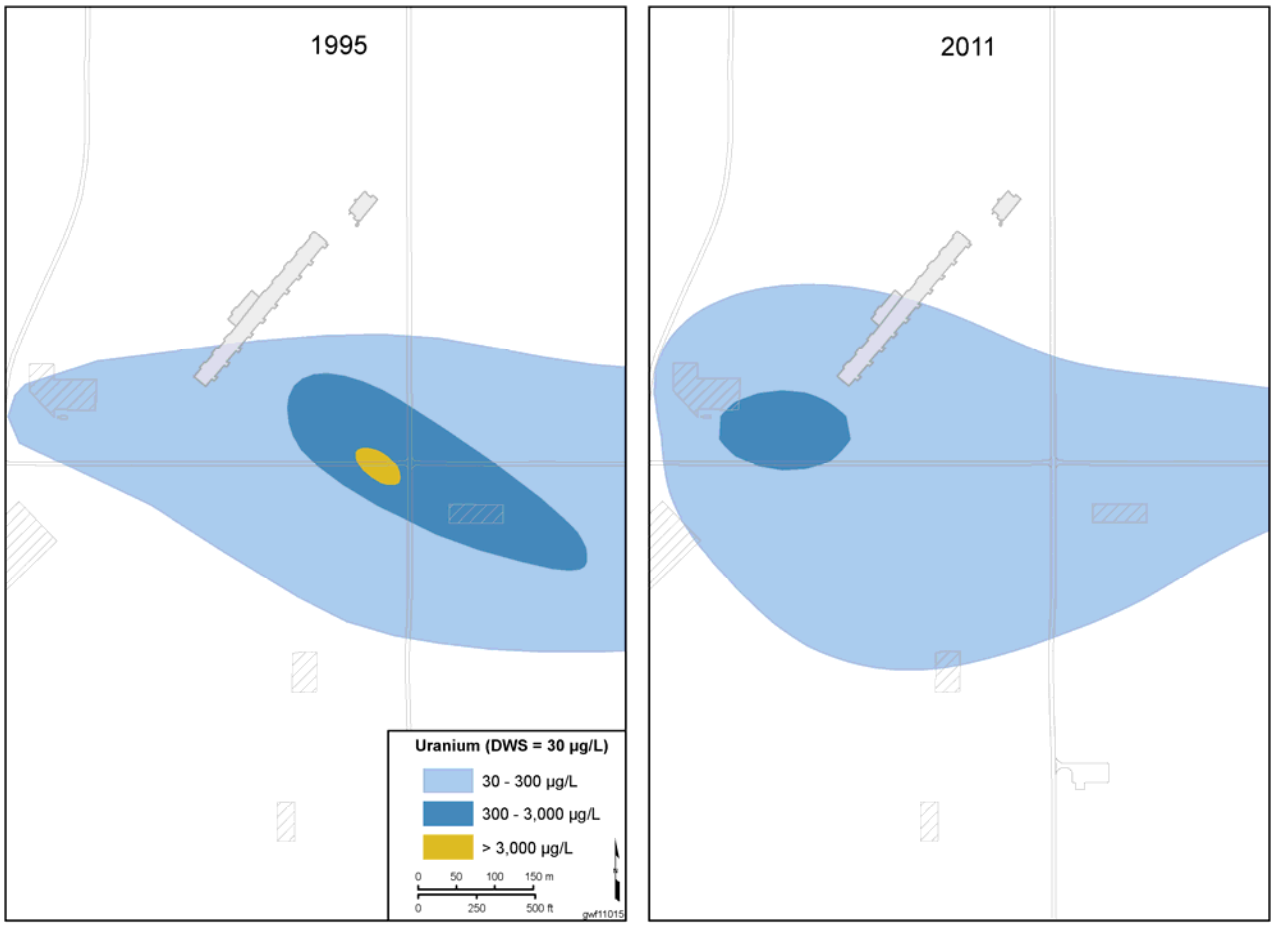
9,000 pCi/L for technetium-99 was achieved in 2005, and the goal of 300 µg/L for uranium was achieved in 2009. The final remedy for 200-UP-1 will address further remediation of the groundwater contaminant plumes.



A pump-and-treat system operated in 200-UP-1 as an interim action from 1994 until 2011. Remediation reduced the size of the technetium-99 plume.

RCRA monitoring in 200-UP-1 included interim status groundwater quality assessment monitoring at WMA S-SX and WMA U, and interim status indicator parameter evaluation monitoring at the 216-S-10 Pond and Ditch. Revised monitoring plans were implemented at WMA S-SX and WMA U in 2011. Monitoring results did not show major changes in the extent of contamination. Indicator parameters did not exceed statistical comparison values at the 216-S-10 Pond and Ditch during 2011.

The Environmental Restoration Disposal Facility is a low-level radioactive mixed waste landfill used for disposal of waste from surface remedial actions on the Hanford Site. The results of groundwater monitoring in 2011 continued to indicate that the facility has not adversely affected groundwater quality.



Uranium contaminant in 200-UP-1 did not respond to the pump-and-treat system as rapidly as technetium-99. Uranium interacts with aquifer sediment, slowing its movement and response to remediation. Interim remedial actions goals have been achieved for both contaminants.

200-BP-5

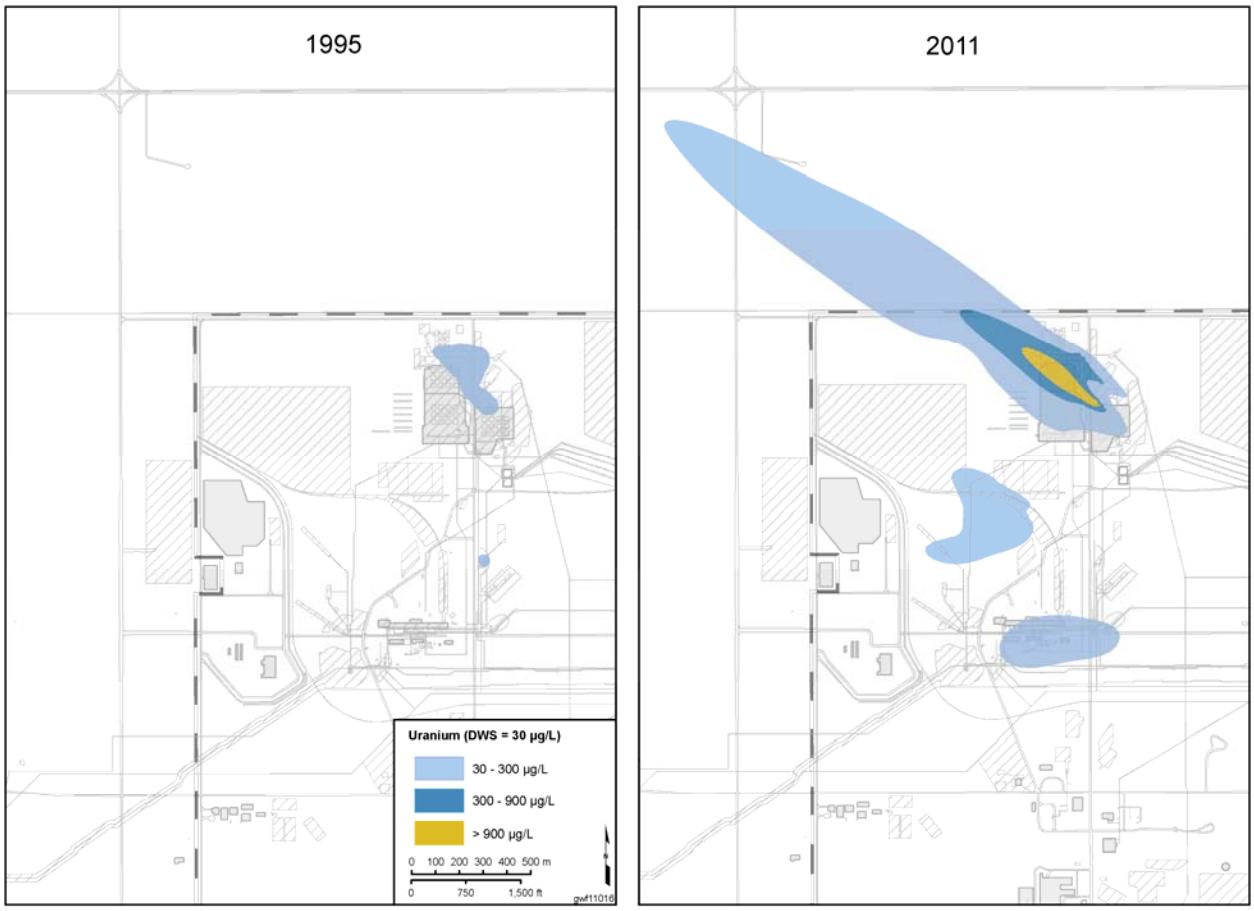
The 200-BP-5 operable unit includes groundwater beneath the northern 200 East Area and the region to the northwest where mobile contaminants have migrated between Gable Mountain and Gable Butte. Most of the groundwater contamination is concentrated beneath WMA B-BX-BY and adjacent waste sites in the northwestern portion of the 200 East Area. Cleanup decisions for 200-BP-5 are yet to be made, and preparation of a draft remedial investigation report began in 2011.

Wells in 200-BP-5 have the highest uranium concentrations in groundwater on the Hanford Site. DOE is testing methods to remove this contamination from the vadose zone and groundwater.

Nitrate, iodine-129, technetium-99, and tritium form the largest contaminant plumes in 200-BP-5. These mobile contaminants have migrated to the northwest as a result of past groundwater flow. The tritium plume has shrunk significantly, but the other large plumes have either grown or remained stable over the past decade. Cyanide and uranium are present in smaller plumes that have increased in size since 2002. A strontium-90 plume has decreased in size, and low-mobility contaminants cobalt-60, cesium-137, and plutonium-239/240 are present only near their former sources.

Scientists and engineers have designed a treatability test to evaluate pumping and treating groundwater to remediate uranium and technetium-99 contaminant plumes near WMA B-BX-BY. In 2011, drillers began to install an extraction well to support the test.

A fine-grained geologic unit beneath the B Plant region has created an area of saturated sediments (a "perched" aquifer) in the deep vadose zone above the regional water table. This perched water is contaminated with uranium and other contaminants at concentrations higher than in the underlying aquifer. In 2011, DOE began pumping to remove this perched water before it reaches groundwater. The pumping successfully removed ~95,000 liters of contaminated, perched water. Plans for a treatability test to use enhanced methods for continued pumping of perched water and pore water were completed in 2011.



A uranium plume with sources in WMA B-BX-BY began to develop in the late 1990s.

RCRA interim-status, indicator evaluation monitoring continued at LLWMA-1, LLWMA-2, and the 216-B-63 Trench with no significant changes in 2011. Assessment monitoring continued at WMA B-BX-BY, and WMA C; and results were consistent with previous years. The WMA B-BX-BY assessment plan will be revised in 2012 to incorporate the results of the recent CERCLA RI and the addition of new monitoring wells.

DOE monitors the Liquid Effluent Retention Facility under a RCRA final-status detection program. Monitoring results in 2011 indicated that all required constituents were undetected or below drinking water standards except for nitrate, which is from a regional plume. Drillers installed a new characterization well near this facility in 2011.

200-PO-1

The southern portion of the 200 East Area and a large region of the Hanford Site to the east and southeast comprise 200-PO-1. Disposal of large volumes of liquid waste created regional groundwater plumes of tritium, iodine-129, and nitrate. Concentrations of tritium are declining as the groundwater plume attenuates naturally as a result of radioactive decay and dispersion. The size of the tritium plume has decreased by one-third since 1980. The area of the iodine-129 plume above the 1 pCi/L contour has decreased slightly over the past decade, and maximum concentrations have declined significantly as a result of dispersion. Radioactive decay has not decreased the level of iodine-129 contamination noticeably because this isotope has a half-life of 15.7 million years. The nitrate plume covers a large area, with concentrations above background but mostly below the drinking water standard. Other contaminants in 200-PO-1 include strontium-90, technetium-99, and uranium in smaller areas near their sources.

DOE conducted a CERCLA remedial investigation in 200-PO-1 in 2008 and 2009. DOE submitted a draft RI report to Ecology in 2010 (DOE/RL-2009-85, *Remedial Investigation Report for the 200-PO-1 Groundwater Operable Unit*).

The tritium and iodine-129 plumes from sources in 200-PO-1 are the largest on the Hanford Site, having migrated more than 15 kilometers.

In 2011, a soil desiccation treatability test was conducted in an interval containing high moisture and associated technetium-99 contamination near the BC Cribs and Trenches. This technology is being considered as a remedy for contamination in the deep vadose zone. For approximately six months, nitrogen was injected into a well; and soil gas was extracted from another well. A combination of in situ sensors and geophysical measurements provided data to monitor performance. As anticipated, desiccation occurred more rapidly from higher-permeability sediment. The active portion of the test was completed, and DOE continues to monitor rewetting of the desiccated region. A comprehensive report will be issued in 2012.

RCRA assessment monitoring continued in 2011 at WMA A-AX, and data were consistent with previous results. RCRA indicator parameter monitoring continued at the 216-B-3 Pond. Monitoring results provided no indication of releases from this facility to groundwater.

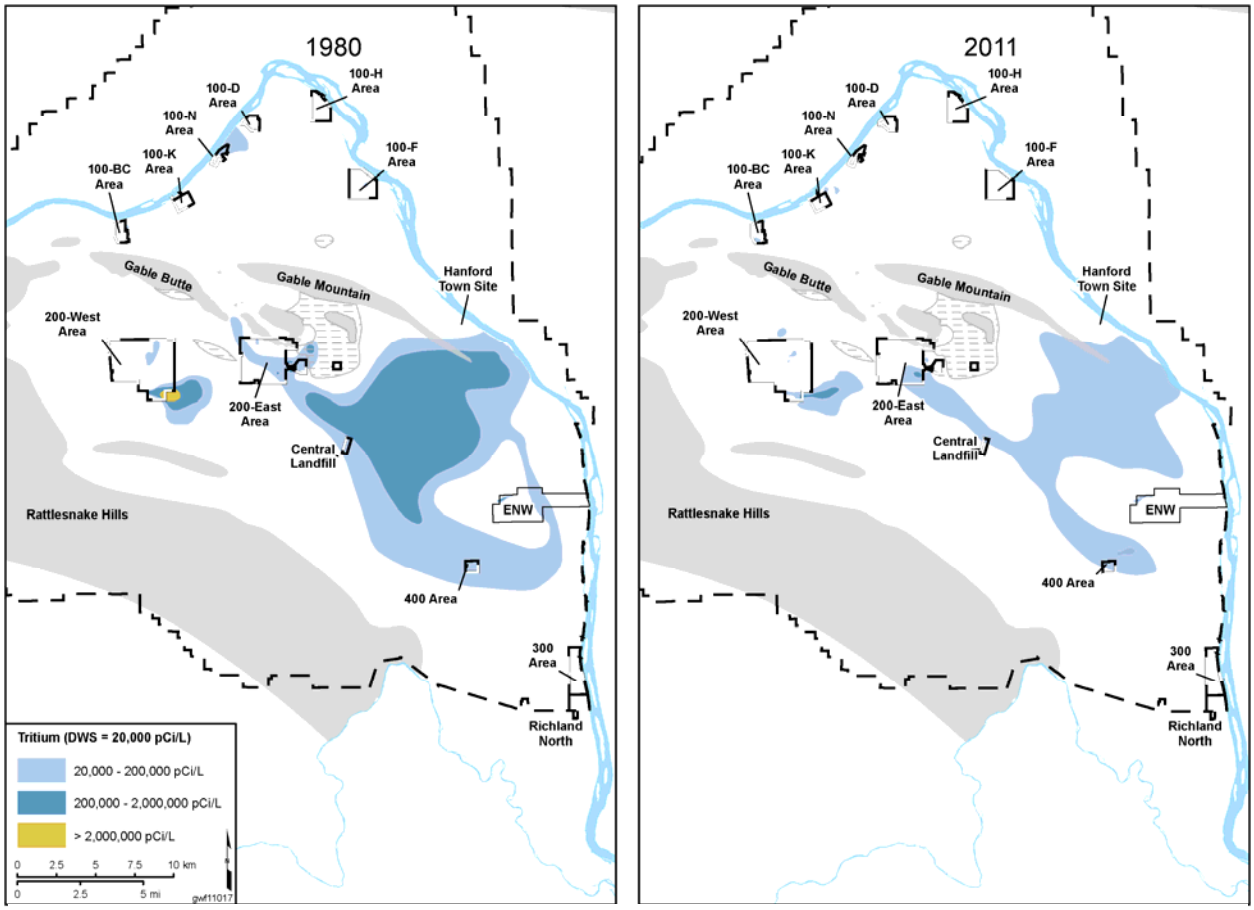
The Integrated Disposal Facility is an expandable, double-lined landfill that is regulated under RCRA and the AEA. It is not yet in use, and current groundwater monitoring is directed at obtaining baseline data.

New RCRA groundwater monitoring plans were implemented in 2011 at the 216-A-36B Crib and the 216-A-37-1 Crib. Background samples were collected so that critical mean values of contamination indicator parameters can be established.

The Treated Effluent Disposal Facility is a state-permitted liquid waste site. The uppermost aquifer beneath this facility is confined beneath the Ringold Formation lower mud unit. Groundwater monitoring is performed to demonstrate that the mud unit continues to protect the confined aquifer from potential impacts of discharges from the facility. The Permit is currently undergoing renewal; in the draft revised permit, it is proposed that groundwater monitoring be discontinued and the effluent monitored prior to discharge to the facility to comply with the Permit.

During 2010, DOE submitted a combination groundwater monitoring plan for the Nonradioactive Dangerous Waste Landfill and the adjacent Solid Waste Landfill to Ecology for review. Until that plan is approved and implemented, the Nonradioactive Dangerous Waste Landfill continues to be monitored under a RCRA detection program. Specific conductance in downgradient wells continued to exceed the

critical mean during 2011 but was previously determined to be caused by nonhazardous groundwater constituents from the nearby Solid Waste Landfill.



Hanford Site tritium plumes are gradually shrinking as concentrations decline as a result of radioactive decay, dispersion, and discharge to the Columbia River. Since 1980, the area of the plume has decreased by ~35%, and the maximum concentration has declined 90 percent.

The Solid Waste Landfill is regulated under Washington State solid waste handling regulations. As in previous years, some of the downgradient wells showed higher concentrations of regulated constituents than the statistically calculated background threshold values. Background threshold values exceeded during 2011 included coliform bacteria, pH, specific conductance, nitrite, sulfate, and total organic carbon.

Three water supply wells provide drinking water and serve as an emergency water supply for the 400 Area, which is in the footprint of 200-PO-1. Because the 400 Area is in the path of the Hanford Site-wide tritium plume, DOE routinely monitors the wells for tritium. These wells are screened deep in the unconfined aquifer, just above the Ringold lower mud unit. The 2011 sampling event was delayed until January 2012; concentrations were below the drinking water standard.

Confined Aquifers

Although most Hanford Site groundwater contamination is found in the unconfined aquifer, DOE monitors wells in deeper aquifers because of potential downward movement of contamination and potential migration of that contamination off site through the confined aquifers. There is no evidence of offsite migration via the confined aquifers.

One confined aquifer occurs within sand and gravel at the base of the Ringold Formation. Carbon tetrachloride, nitrate, and technetium-99 have contaminated this unit in a portion of 200 West Area where the upper confining unit is absent. New wells have been installed in recent years to monitor and remediate this contamination. The Ringold confined aquifer is the uppermost aquifer in a region east of 200 East (within portions of 200-BP-5 and 200-PO-1). Iodine-129 and tritium are detected in wells at this location, but the contamination has not migrated to wells farther downgradient.

In the northern Hanford Site, fine-grained sedimentary units informally called the Ringold upper mud confine deeper sediments in the Ringold Formation. This unit is contaminated with hexavalent chromium in some parts of 100-HR-3.

Groundwater within basalt fractures and joints, interflow contacts, and sedimentary interbeds make up the upper basalt-confined aquifer system. No significant contamination is detected in the basalt-confined aquifer, except in the northwestern 200 East Area, where poor well construction and temporary drilling effects allowed local migration of groundwater from the overlying unconfined aquifer.

Wells

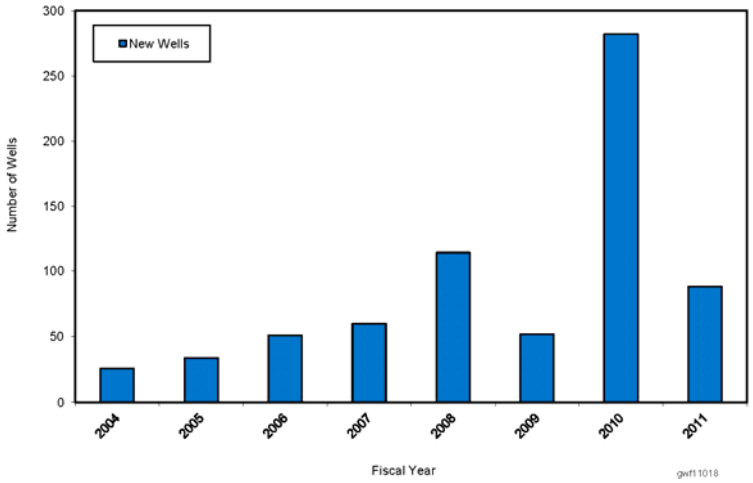
Over the lifetime of the Hanford Site, DOE has installed thousands of wells to monitor and remediate groundwater and provide geologic data. During 2011, DOE installed 89 new wells, primarily in support of RI studies or groundwater remediation.

During 2011, 49 direct-push and characterization boreholes were installed. The boreholes supported subsurface characterization of radiological constituents, volatile organics (e.g., carbon tetrachloride), or vadose zone properties (e.g., moisture content or grain-size distribution). The boreholes were decommissioned after data collection was complete.

DOE identifies wells, boreholes, or other subsurface installations for decommissioning when they are no longer needed. In 2011, 108 wells were physically decommissioned. This involved sealing the wells in compliance with Washington State groundwater protection laws. In additional to the physical decommissioning, 13 wells were administratively decommissioned. These wells could not be located and investigation showed they no longer exist.

Wells Installed in 2011

Location	Number of New Wells
100-BC-5	6
100-KR-4	15
100-NR-2	8
100-HR-3	25
100-FR-3	2
200-ZP-1	6
200-UP-1	4
200-BP-5	1
200-PO-1	2
300-FF-5	20
Total	**89**



New wells are installed to characterize, monitor, and remediate groundwater.

Conclusions

The items below highlight the primary conclusions based on Hanford Site groundwater monitoring in 2011.

- Decades of waste disposal have contaminated a large area of the Hanford Site's groundwater. The largest contaminant plume—tritium, from waste sites on the Central Plateau—is decreasing in size due to radioactive decay and dispersion. Hexavalent chromium is the primary concern in the River Corridor.
- Groundwater flows toward the Columbia River and is the primary exposure route for contaminants to reach human, environmental, and ecological receptors.
- More than half of the former waste sites in the River Corridor have been remediated or are classified as not needing remediation under interim records of decision. The rest of the waste sites will be remediated in the next few years. Thus, potential sources of additional groundwater contamination are being removed from the region that poses the greatest threat to the Columbia River. Remedial investigations have collected data to determine appropriate remedies for remaining vadose zone and groundwater contamination. The Tri Parties (Ecology, EPA, and DOE) will develop final RODs for the River Corridor units in coming years.
- Interim remediation of hexavalent chromium contamination in 100-KR-4 and 100-HR-3 continued in 2011. DOE has expanded pump-and-treat systems in these regions to control larger portions of the plumes. Chromium concentrations in compliance wells remained above cleanup goals, so remediation will continue.
- An in situ remediation method being applied in 100-NR-2 is reducing the amount of strontium-90 discharging to the Columbia River.
- On the Central Plateau, contamination is still present in many parts of the thick vadose zone, and may continue to drain into the groundwater. Remediation of the Central Plateau waste sites and vadose zone will accelerate after River Corridor remediation is complete. Meanwhile, DOE has been remediating groundwater and testing methods to remediate the deep vadose zone.
- Interim remediation of carbon tetrachloride contamination in 200-ZP-1, and the overlying vadose zone (200-PW-1), continued in 2011. Pump-and-treat is being used to clean up groundwater, and soil vapor extraction is being used to clean up the vadose zone. A second pump-and-treat system is being used in 200-ZP-1 to remove technetium-99.
- DOE continued to implement elements of the final remedy to clean up groundwater in 200-ZP-1. A total of 26 wells were installed between 2009 and 2011, and construction of the new groundwater treatment facility was completed in 2011. The new pump-and-treat system will begin to operate in 2012.
- Final cleanup decisions for 200-UP-1, 200-BP-5, and 200-PO-1 are yet to be made. Remedial investigation studies have gathered information to support cleanup decisions in coming years.
- Groundwater discharges to the Columbia River via springs and areas of upwelling. Contaminant concentrations in some springs are above applicable water quality standards. Concentrations are below these standards in river water samples.

Groundwater Contaminants on the Hanford Site

Contaminant	Primary Locations	Plume Area Above Standard (km^2)	Drinking Water Standard	Remediation in Place?	Mobility[a] and Half-Life
Carbon Tetrachloride	200-ZP-1	13.3	5 µg/L	Yes	Mobile and denser than water
Chromium (hexavalent)	100-KR-4, 100-HR-3	5.76	48 µg/L[b]	Yes	Mobile to moderate
Cyanide	200-BP-5	0.24	200 µg/L	No	Mobile
Iodine-129	200 Areas	60.1	1 pCi/L	No	Mobile; 17 million years
Nitrate (as NO_3^-)	200 Areas, 100-FR-3, 100-HR-3, 199-NR-2	37.7	45 mg/L	No[c]	Mobile
Strontium-90	100 Areas, 200-BP-5	1.51	8 pCi/L	Yes in 100-NR-2	Slightly mobile; 28.9 years
Technetium-99	200 Areas	3.1	900 pCi/L	Yes in 200 West[d]	Mobile; 213,000 years
Trichloroethene	100-FR-3, 200-ZP-1	0.90	5 µg/L	Yes in 200-ZP-1	Mobile to moderate
Tritium	200 Area, 300-FF-5, 100-BC-5, 100-KR-4	103	20,000 pCi/L	No	Mobile; 12.3 years
Uranium	200-UP-1, 200-BP-5, 300-FF-5	1.7	30 µg/L	No	Moderate; 240,000 years (U-234), 4.5 billion years (U-238)
Area of combined plumes[e]		**191**			

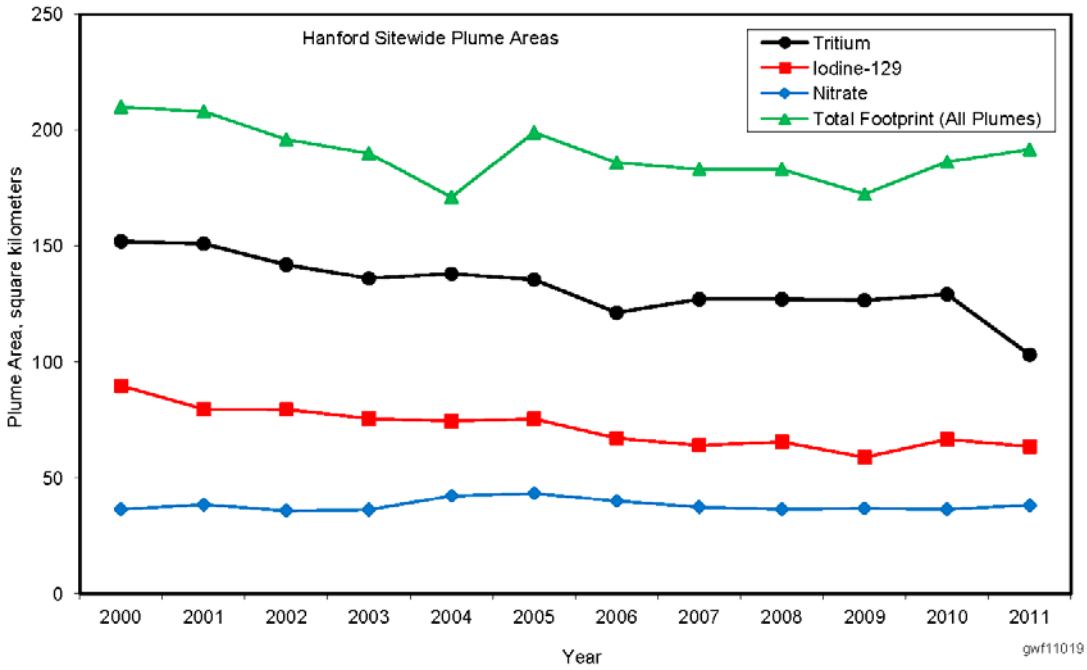
a. "Mobile" means a contaminant moves readily in groundwater. "Moderate" means a contaminant undergoes geochemical reactions in the aquifer and moves slower than the groundwater. "Slight" means a contaminant binds to sediment grains and moves much slower than the groundwater.

b. Washington State "Model Toxics Control Act—Cleanup" (WAC 173-340) groundwater cleanup level

c. Removed from treated water for the 200-ZP-1 pump-and-treat

d. 200-UP-1, WMA S-SX, and WMA T

e. Many plumes overlap so the area of combined plumes is less than the sum of the individual plume areas



The Hanford Site's largest contaminant plumes are tritium, iodine-129, and nitrate. The sizes of the Sitewide tritium and iodine-129 plumes have declined since 2000. Tritium has a half-life of approximately 12 years, so radioactive decay causes concentrations to decline. Iodine-129 has a half-life of 17 million years, so the decline in plume size was mainly caused by advection and dispersion. Nitrate plumes are present in all of the groundwater operable units. The total size of the nitrate plumes has changed very little since 2000.

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