

100-NR

100-NR Overview

Among the Hanford Site plutonium-production reactors, the design of N Reactor was unique (Map NR.1). The N Reactor, which operated in 100-N from 1964 to 1986, was a dual-purpose reactor that produced plutonium for defense purposes and steam for commercial electrical power generation. Groundwater contamination in 100-N is primarily associated with waste produced by the reactor and associated processes. Additional details about 100-N history and waste sites are provided in Section 1 of the U.S. Department of Energy/Richland Office (DOE/RL) ([DOE/RL-2008-46-ADD5](#), *Integrated 100 Area Remedial Investigation/Feasibility Study Work Plan, Addendum 5: 100-NR-1 and 100-NR-2 Operable Units*).

Strontium-90 is the principal groundwater contaminant. Other groundwater contaminants include nitrate, total petroleum hydrocarbon-diesel, and chromium. A summary of 100-NR-2, including key contaminants is shown in Table NR.1. Strontium-90 and total petroleum hydrocarbon-diesel are being remediated under a *Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA)* interim action U.S. Environmental Protection Agency (EPA) ([EPA/ROD/R10-99/112](#), *Interim Remedial Action Record of Decision for the 100-NR-1 and 100-NR-2 Operable Units, Hanford Site, Benton County, Washington*). An apatite permeable reactive barrier was installed between 2006 and 2011 to enhance attenuation of the strontium-90 in groundwater moving toward the Columbia River. Groundwater is monitored at four waste sites to meet requirements of the *Resource Conservation and Recovery Act of 1976 (RCRA)* and [WAC-173-303](#), "Dangerous Waste Regulations."

The vadose zone in 100-N is 0 to 23 meters thick and is composed of gravels and sands of the Hanford formation and upper Ringold Formation unit E (Figure NR.1). The unconfined aquifer is approximately 6.5 to 14 meters thick. When the Columbia River stage is high, the water table can rise into the Hanford formation in wells near the shoreline. The Ringold upper mud forms the base of the unconfined aquifer.

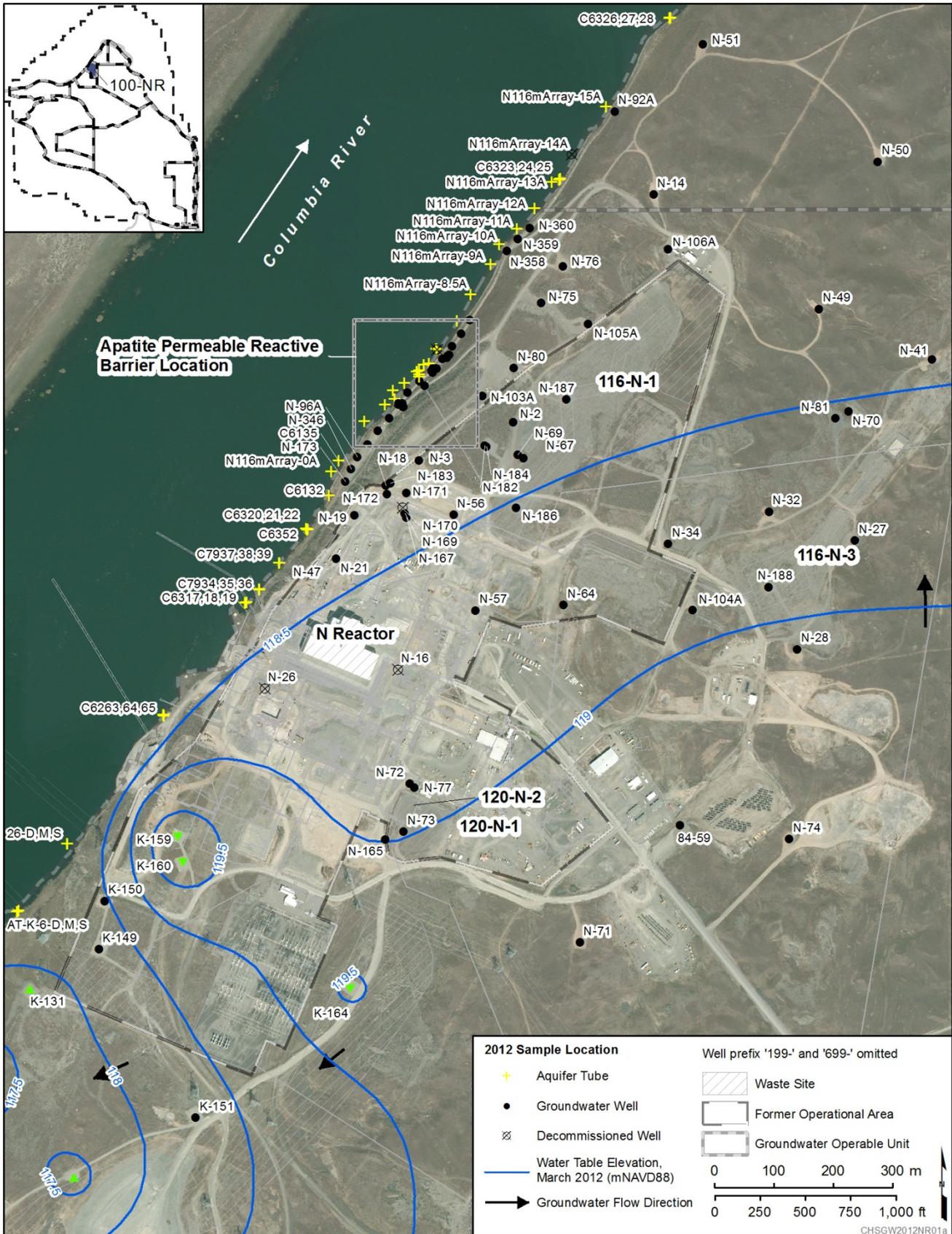
Groundwater in 100-N generally flows northwest toward the Columbia River. As shown in Map NR.1, the magnitude of the change in groundwater hydraulic head across 100-N in March 2012 was about 1 meter. Groundwater flow was influenced in 2012 by groundwater extraction and injection for the KX pump-and-treat remediation system located in the southwest portion of 100-N. A small groundwater mound approximately 1 meter high surrounding the KX injection well creates local radial flow.

In 2012, the river stage peaked in late June and remained high into mid-July; high river stage was approximately 3 meters higher than low river stage. Water levels in well 199-N-2, 170 meters inland from the river, rose approximately 2.5 meters with a lag time of a few days. Changing river stage influences groundwater elevations over 1 kilometer inland from the river (Section 3.6 of [DOE/RL-2012-15](#), *Remedial Investigation/Feasibility Study for the 100-NR-1 and 100-NR-2 Operable Units*).

Figure NR.2 illustrates how the estimated areas of the contaminant plumes have changed since 2003.

Table NR.1 100-NR-2 at a Glance

N Reactor Operations: 1963–1987				
2012 Groundwater Monitoring				
Contaminant	Water Quality Standard	Maximum Concentration	Plume Area ^a	Shoreline Impact (m)
Strontium-90	8 pCi/L	15,000 pCi/L (199-N-187)	0.61 km ²	620
Nitrate	45 mg/L	149 mg/L (199-N-186)	0.63 km ²	150
Diesel (as Total Petroleum Hydrocarbons)	0.5 mg/L	4.6 mg/L (199-N-171)	0.006 ^b	0
Tritium	20,000 pCi/L	35,000 pCi/L (199-N-186)	NC ^d	0
Remediation				
Waste Sites (interim action): >40% complete ^c				
Groundwater (interim action):				
<ul style="list-style-type: none"> • Pump-and-treat: 1995-2006, 1.8 Ci strontium-90 removed • Apatite permeable reactive barrier: 2006-2012 				
Final record of decision anticipated in 2014				
a. Estimated area at a concentration greater than the water quality standard.				
b. Area at 200 µg/L.				
c. Waste sites with status of closed, interim closed, no action, not accepted, or rejected.				
d. Plume area not calculated due to infrequent detection of tritium greater than 20,000 pCi/L.				



Map NR.1 100-NR Overview Map with Groundwater Flow

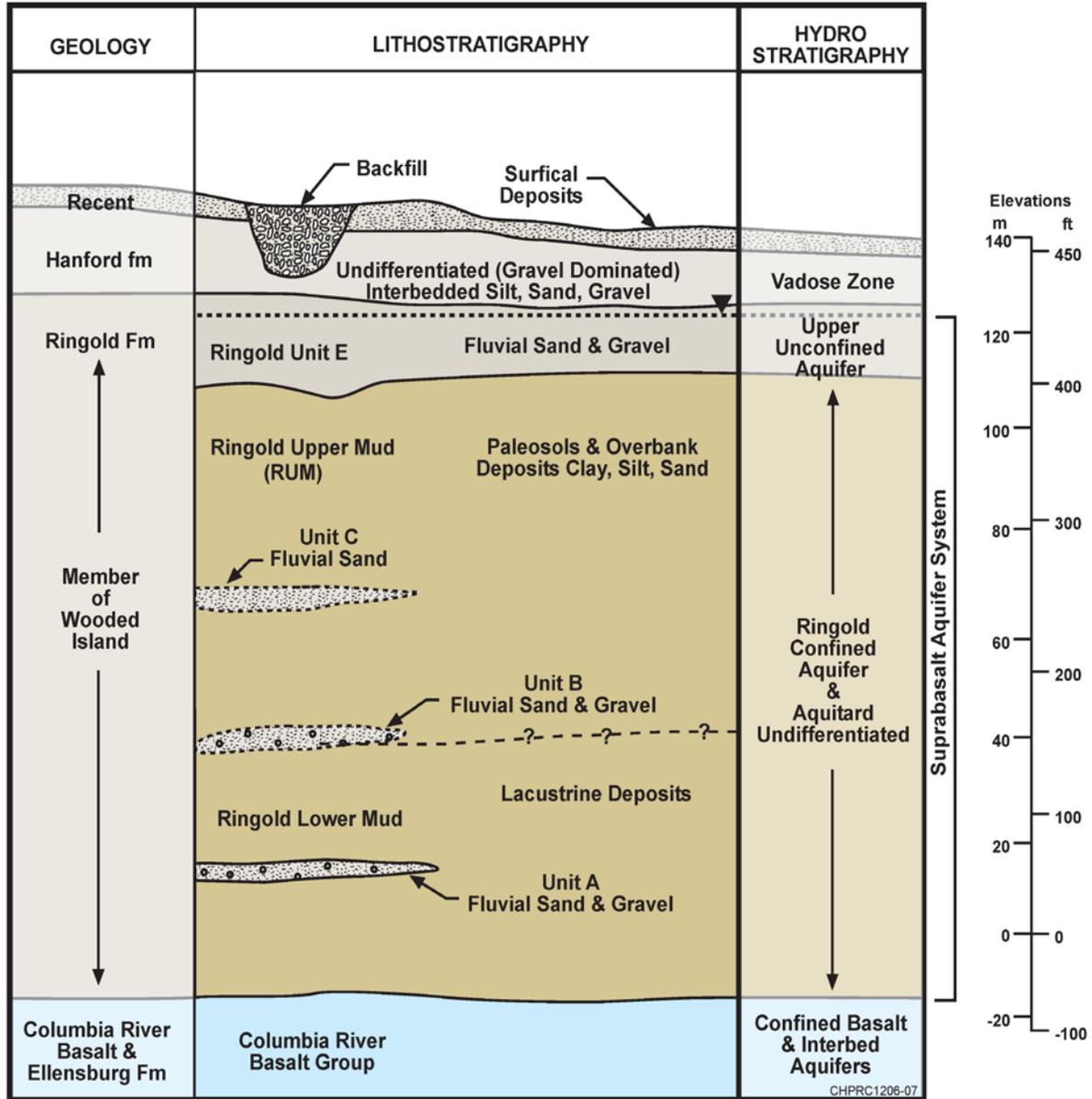


Figure NR.1 100-NR Geology

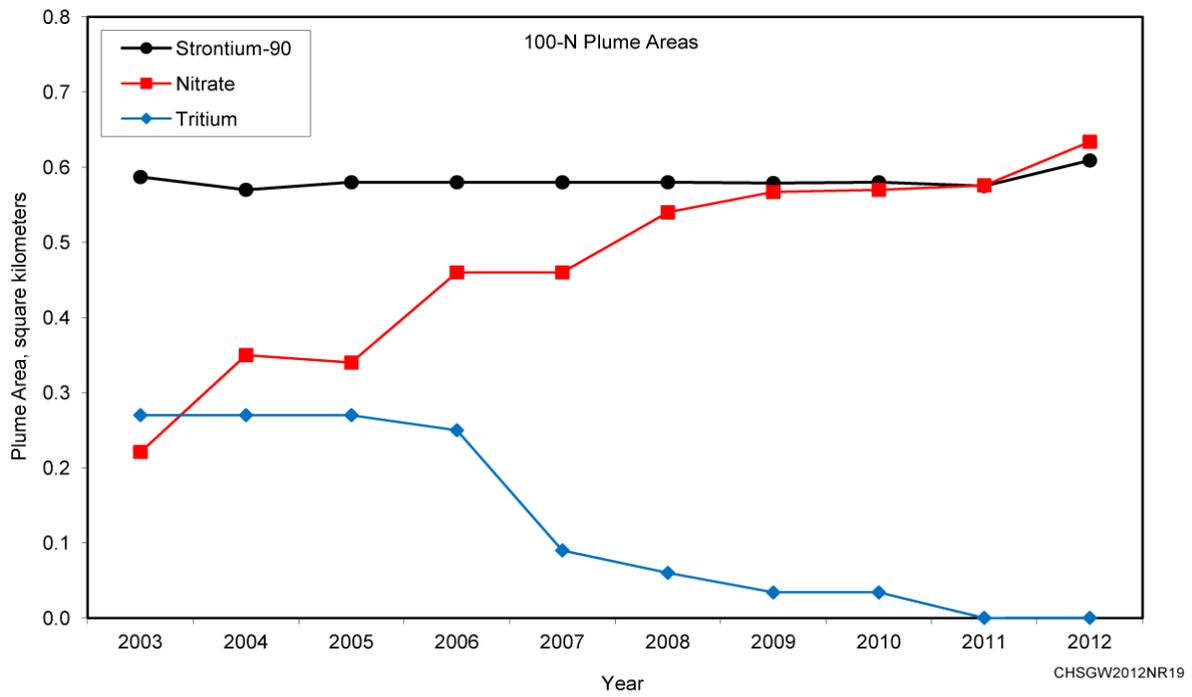


Figure NR.2 100-N Plume Areas

100-NR CERCLA Activities

CERCLA activities for 100-NR-2 in 2012 included continued groundwater monitoring, preparation of the remedial investigation/feasibility study (RI/FS) report, and continued interim remediation of strontium-90 and total petroleum hydrocarbon-diesel contamination.

CERCLA Groundwater Monitoring

Wells (Map NR.2) and constituents monitored for the 100-NR-2 Operable Unit (OU) under CERCLA in 2012 were defined in the following documents:

- *Remedial Design Report/Remedial Action Work Plan for the 100-NR-2 Operable Unit* ([DOE/RL-2001-27](#)), as modified by *Change Notice For Modifying Approved Documents/Workplans in Accordance with the TPA Action Plan Section 9.0 Documentation and Records DOE/RL-2001-27 Rev. 0 Remedial Design Report/Remedial Action Work Plan for the 100-NR-2 Operable Unit and the Interim Action Waste Management Plan for the 100-NR-2 Operable Unit DOE/RL-2000-41 Rev. 1* ([TPA-CN-256](#))
- *Strontium-90 Treatability Test Plan for 100-NR-2 Groundwater Operable Unit* ([DOE/RL-2005-96](#)), as modified by *Change Notice for Modifying Approved Documents/Workplans in Accordance with the Tri-Party Agreement Action Plan Section 9.0 Documentation and Records Treatability Test Plan Addendum for the 100-NR-2 Groundwater Operable Unit DOE/RL-2005-96 Addendum* ([TPA-CN-271](#))
- *Design Optimization Study for Apatite Permeable Reactive Barrier Extension for the 100-NR-2 Operable Unit* ([DOE/RL-2010-29](#))
- *Integrated 100 Area Remedial Investigation Feasibility Study Work Plan Addendum 5, 100-NR-1 and 100-NR-2 Operable Units* ([DOE/RL-2008-46-ADD5](#)) and associated *Sampling and Analysis Plan for the 100-NR-1 and 100-NR-2 Operable Units Remedial Investigation/Feasibility Study* ([DOE/RL-2009-42](#))
- *Sampling and Analysis Plan for Aquifer Sampling Tubes* ([DOE/RL-2000-59](#)), as modified by *Change Notice For Modifying Approved Documents/Workplans in Accordance with the TPA Action Plan Section 9.0 Documentation and Records DOE/RL-2000-59 Rev. 1 Sampling and Analysis Plan for Aquifer Tubes* ([TPA-CN-353](#))

The CERCLA sampling is conducted primarily in September, with selected wells monitored in March. A summary of the wells scheduled and sampled is provided in Appendix A.

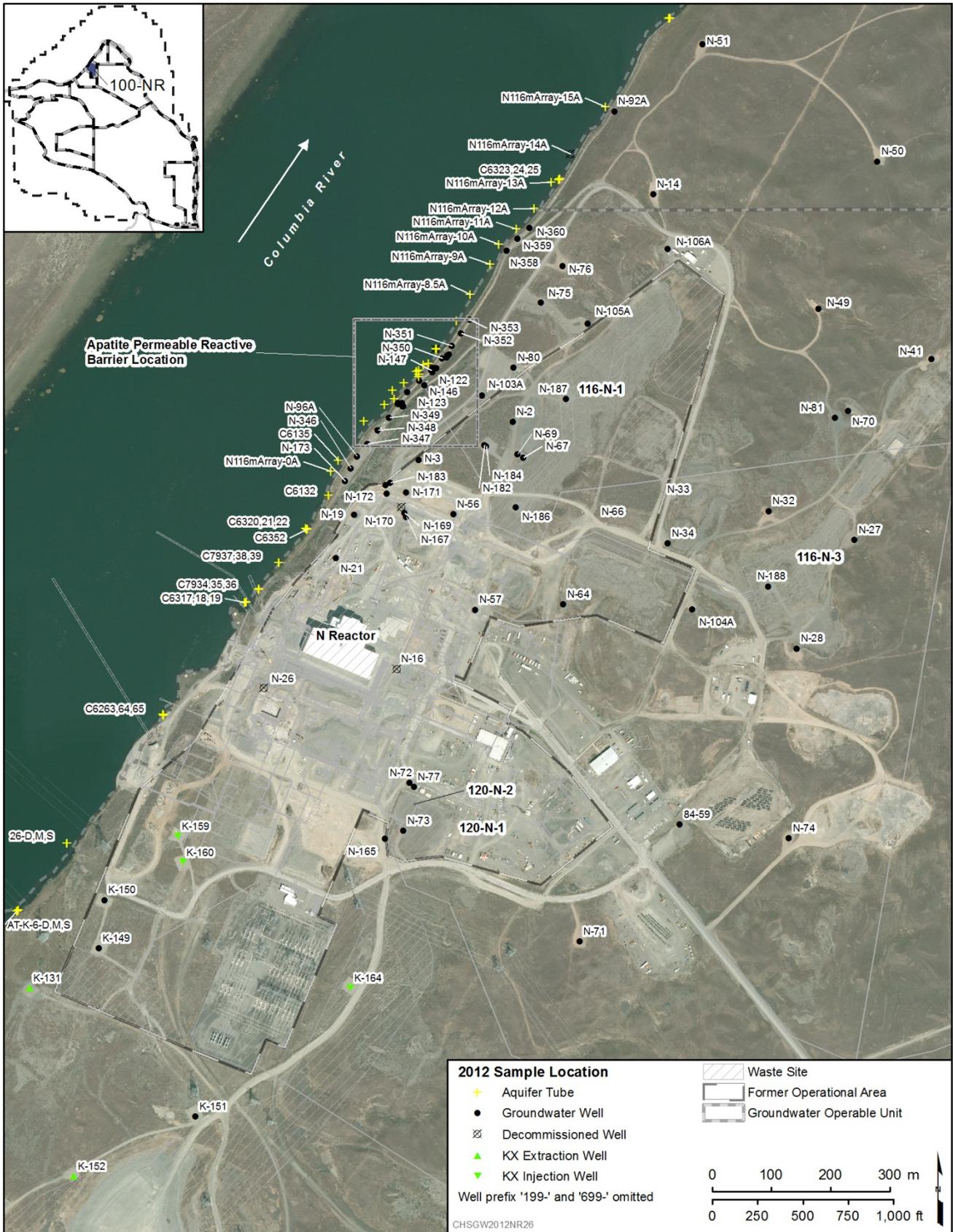
Remedial Investigation/Feasibility Study

The RI/FS work plan ([DOE/RL-2008-46-ADD5](#)) and sampling and analysis plan ([DOE/RL-2009-42](#)) for 100-N were issued in March 2011 and December 2010, respectively. In 2011, eight boreholes were drilled, sampled, and completed as wells as part of the RI. These new wells have been incorporated into the CERCLA groundwater monitoring program. Initial sampling of the wells began in March 2012.

Data collected for the RI were used to update the conceptual site model for the vadose zone and groundwater, support the baseline risk assessment, and identify and evaluate technologies for remedial alternatives. Details regarding sample collection and analysis and data interpretation are provided in the 100-N Area RI/FS report ([DOE/RL-2012-15](#)); Draft A of the RI/FS report will be submitted for review to the Washington Department of Ecology (Ecology), the lead regulatory agency for the 100-NR-1 and 100-NR-2 OUs, in June 2013. The RI/FS information will be used to make decisions for remediation of waste sites and groundwater. The record of decision (ROD) for these OUs, which will identify the remedies for cleanup of waste sites and groundwater, is anticipated in 2014.

Groundwater Remediation

Interim actions are being conducted for cleanup of strontium-90 and total petroleum hydrocarbon-diesel contamination in 100-NR-2. The activities and results for 2012 are summarized in this section. Additional details are available in DOE/RL-2013-13, *Calendar Year 2012 Annual Summary Report for the 100-NR-2 and 100-KR-4 Pump-and-Treat Operations, and 100-NR-2 Groundwater Remediation*. Interim actions are being conducted for cleanup of strontium-90 and total petroleum hydrocarbon-diesel contamination in 100-NR-2. The activities and results for 2012 are summarized in those sections.



Map NR.2 100-NR 2012 Sample Locations

100-NR Strontium-90

The primary source of the strontium-90 contamination in 100-N was liquid waste disposal to the 116-N-1 and 116-N-3 waste sites. The size and shape of the strontium-90 plume changes very little from year to year, except near the apatite permeable reactive barrier (Map NR.3). The plume extends from beneath the 116-N-1 and 116-N-3 waste sites to the Columbia River at concentrations exceeding the drinking water standard (8 pCi/L) (Map NR-3). The highest concentration portion of the strontium-90 groundwater plume (i.e., the area with concentrations exceeding 800 pCi/L) primarily underlies the 116-N-1 Trench and the 116-N-3 Crib. The inferred highest concentration is found beneath, and downgradient of, 116-N-1. The lateral distribution of the groundwater plume with concentrations between 8 and 800 pCi/L is found peripheral to the highest concentration in a distribution consistent with historical radial flow away from the two trenches and elongated toward the river.

The highest strontium-90 groundwater concentration detected at 100-N in 2012 was 15,000 pCi/L in a sample from well 199-N-187, which was drilled through the 116-N-1 site. Concentrations exceeding 100 pCi/L are limited to the very upper portion of the aquifer. Strontium-90 contamination is either not detected or is detected at very low concentrations in wells monitoring the base of the unconfined aquifer or the Ringold upper mud unit.

Water levels were higher beneath the 116-N-1 and 116-N-3 waste sites when discharges were occurring. As the water level declined, strontium-90 remained sorbed in the lower vadose zone. As a result, when the water table rises beneath these former waste sites, strontium-90 from the vadose zone may be remobilized, increasing the concentrations in groundwater. Strontium-90

concentrations in well 199-N-81 downgradient of the 116-N-3 trench have declined since the late 1990s. However, a high water table in 2012 caused a slight increase in the strontium-90 concentration in the fall 2012 sample (Figure NR.3). Concentrations are expected to decline as the water table returns to lower elevations. Strontium-90 concentrations in well 199-N-67 near the 116-N-1 crib show no obvious long-term decline, but generally increase when the water level is elevated and decrease when it is lower (Figure NR.4). The positive variation of concentration with water level may be more pronounced at wells near the 116-N-1 waste site, which received a much larger mass of strontium-90 than the 116-N-3 waste site and presumably has more residual strontium-90 in the lower vadose zone.

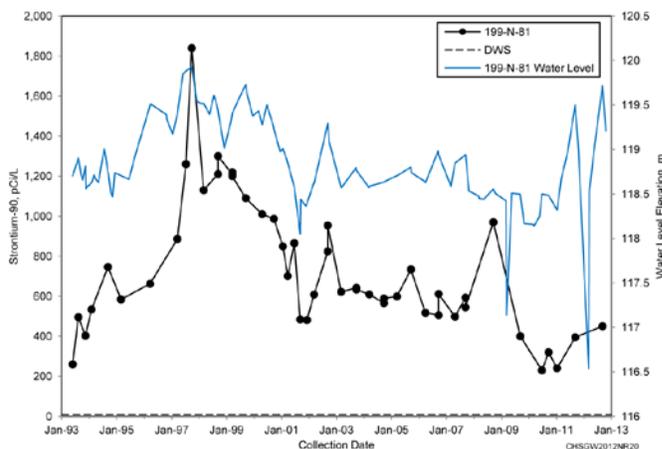


Figure NR.3 100-NR Strontium-90 Data for well 199-N-81

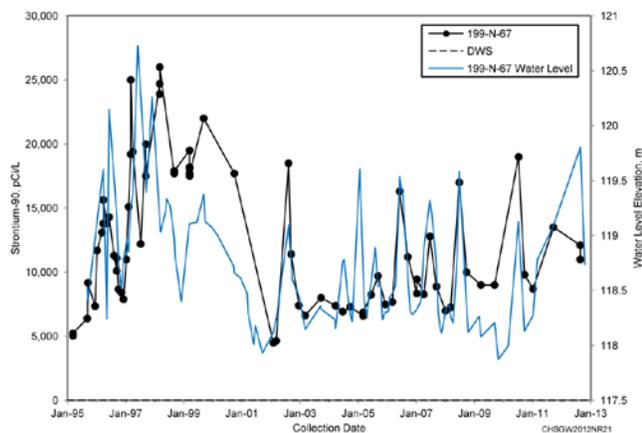
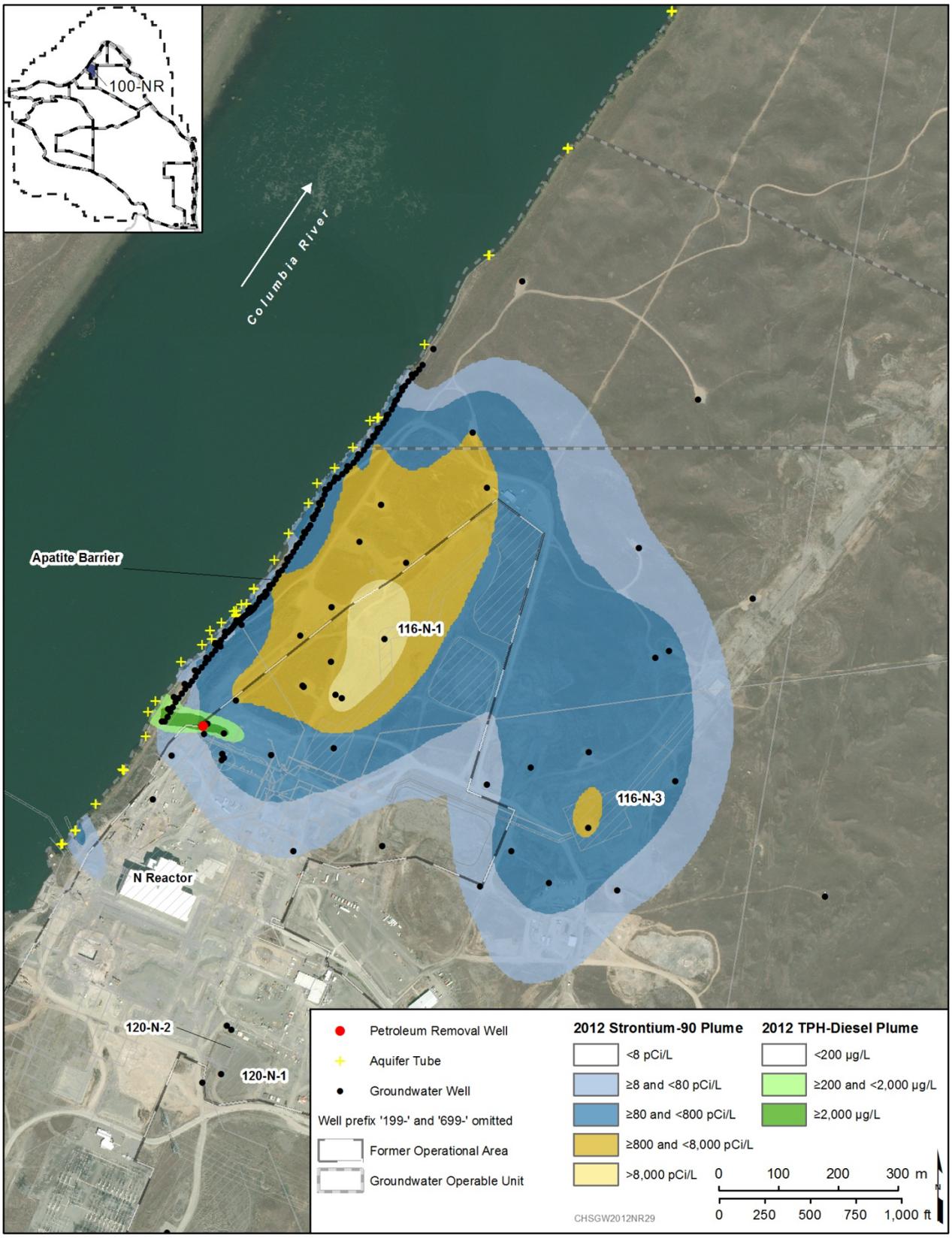


Figure NR.4 100-NR Strontium-90 Data for well 199-N-67

concentrations have increased in all four former extraction wells downgradient of the 116-N-1 waste site (199-N-103A, 199-N-105A, 199-N-106A, 199-N-75). The increases are attributed to the rebound of the water table into contaminated portions of the aquifer after pumping ceased (2006) and to much higher seasonal increases in the water table in 2011 and 2012. Strontium-90 concentrations at the apatite permeable reactive barrier are discussed in a separate section of 100-N. Strontium-90 concentrations in aquifer tubes are consistent with those seen in monitoring wells. The only strontium-90 detections outside the area where the strontium-90 groundwater plume intersects the Columbia River are at aquifer tube cluster C7934/C7935/C7936. These aquifer tubes are in the engineered fill around the 1908-N Outfall, which indicates that outfall construction created a preferential pathway for migration of contaminated groundwater to the river (Section 4.2 of SGW-49370, Columbia River Pore Water Sampling in the 100-N Area, December 2010).



Map NR.3 100-NR 2012 Strontium-90 Plume

100-NR Nitrate

Nitrate exceeds the drinking water standard (45 mg/L) in groundwater beneath the 116-N-1 and 116-N-3 waste sites and the 100-N Reactor area to the southwest (Map NR.4). The highest concentration detected in 2012 was 149 mg/L in well 199-N-186 in the 116-N-1 crib. The 116-N-1 and 116-N-3 waste sites are implicated as the primary source of nitrate based on the persistent groundwater plume beneath them.

Nitrate concentrations were relatively low during disposal operations at the 116-N-1 and 116-N-3 sites (Figures NR.5 and NR.6). The highest nitrate concentrations were detected following remediation activities at these two sites from 2000 to 2006, which included excavation, application of dust suppression water and stabilizing chemicals, and backfill. Decreasing concentrations since 2011 appear to be the result of higher water table elevations.

Nitrate concentrations near the 120-N-1 waste site were very low when the waste site was in use, but began to increase in the mid-1990s (Figure NR.7). Only low levels of nitrate (approximately 1 mg/L) were detected in the 120-N-1 effluent (Section 2.4.4 of [DOE/RL-96-39](#)). These factors suggest that the 120-N-1 site was not the source of the nitrate plume in the southwest region of 100-N. Past releases from upgradient septic systems could provide the source for this nitrate. The 2012 nitrate plume has a more limited extent to the southwest than in previous years because of the impact of treated water entering the aquifer through nearby 100-K injection wells.

Nitrate concentrations are anomalously low in wells in the area of the total petroleum hydrocarbon-diesel groundwater plume, centered around well 199-N-18. The lower concentrations are caused by the chemical reduction of nitrate during biodegradation of the total petroleum hydrocarbon-diesel contamination. Low dissolved oxygen levels, lower pH, detectable nitrite, and elevated concentrations of iron and manganese support the interpretation of reducing conditions in this part of the aquifer.

Nitrate concentrations are highest in the upper part of the unconfined aquifer. Wells 199-N-69 and 199-N-70, screened near the bottom of the aquifer, consistently have lower concentrations than the adjacent, shallow wells.

Nitrate concentrations in several aquifer tubes in southwestern 100-N exceeded the drinking water standard in 2012.

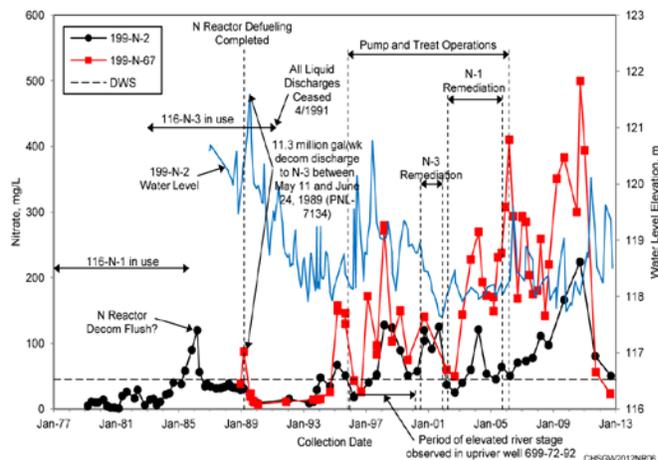


Figure NR.5 100-NR Nitrate Data for wells 199-N-2 and 199-N-67

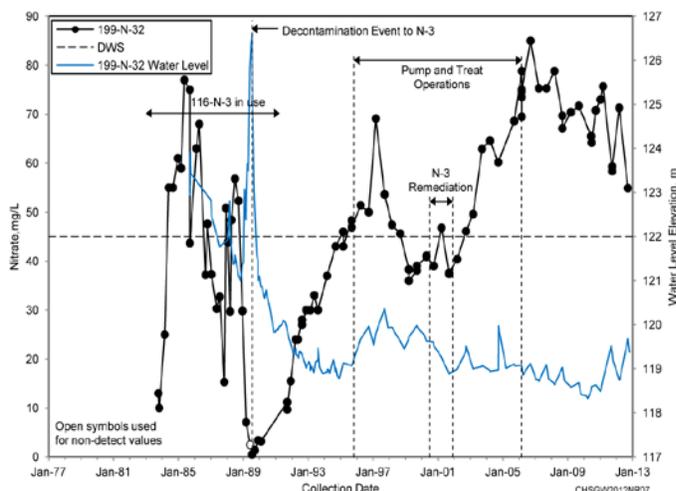


Figure NR.6 100-NR Nitrate Data for well 199-N-32

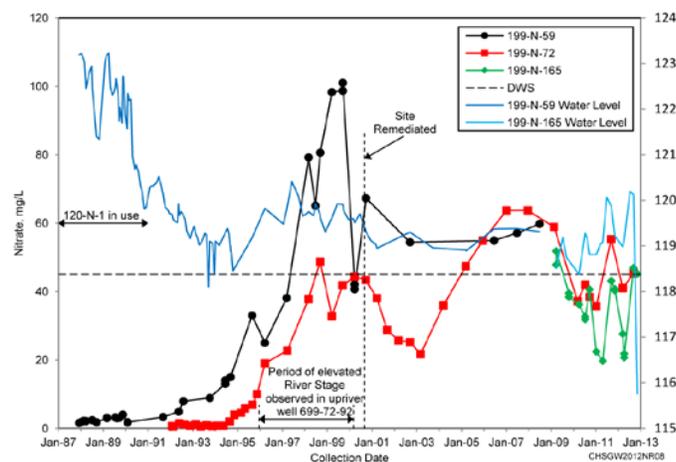


Figure NR.7 100-NR Nitrate Data for wells 199-N-59, 199-N-72, and 199-N-165

100-NR Total Petroleum Hydrocarbons - Diesel

The source of the total petroleum hydrocarbon-diesel groundwater contamination is a 1966 diesel fuel spill (UPR-100-N-17). A small, well-defined groundwater plume extends downgradient of the spill to the river (Map NR.5). The highest groundwater concentration in 2012 was 4,620 µg/L (Well 199-N-171), which is a substantial decrease from the 2011 and 2010 maximum concentrations of 48,000 and 420,000 µg/L, respectively. This reduction in concentration is attributed primarily to the bioventing pilot test conducted by Washington Closure Hanford in 2010 and 2011 for remediation of diesel in the deep vadose zone at UPR-100-N-17 ([WCH-490](#), *UPR-100-N-17: Bioventing Pilot Plant Performance Report*).

In situ bioventing introduces oxygen to promote in situ aerobic biodegradation of the total petroleum hydrocarbon-diesel in the deep vadose zone to carbon dioxide and water. The data from the bioventing pilot test were used to support the design of a full-scale bioventing system. Full scale bioventing system operations began at UPR-100-N-17 in December 2012 using three injection wells (199-N-167, 199-N-172, and 199-N-173) and five monitoring wells (199-N-166, 199-N-168, 199-N-169, 199-N-170, and 199-N-171).

Some natural biodegradation of diesel occurs in groundwater, as shown by the anomalously low nitrate groundwater concentrations in this area (discussed in the 100-NR nitrate section).

If present as a non-aqueous phase (free product), the total petroleum hydrocarbon-diesel in groundwater is found in the shallowest portion of the aquifer or floating on top of the water table (Section 4.4 of [DOE/RL-2011-25](#), *Calendar Year 2010 Annual Summary Report for the 100-HR-3 and 100-KR-4 Pump-and-Treat Operations and 100-NR-2 Groundwater Remediation*). Removal of free product from well 199-N-18 continued in 2012 in accordance with the interim action ROD ([EPA/ROD/R10-99/112](#)). The diesel is removed using a polymer “smart sponge” that selectively absorbs petroleum products from the surface of the water within the well. Approximately every two months, two sponges are lowered to surface of the aquifer in well 199-N-18 and left to soak up the diesel. The sponges are weighed prior to placement in the well and again after removal. The weight difference between the two measurements is the amount of diesel fuel removed from the well. In 2012, 600 grams of diesel were removed from well 199-N-18 (Table NR.2). Removal of petroleum product from well 199-N-18 will continue in 2013.

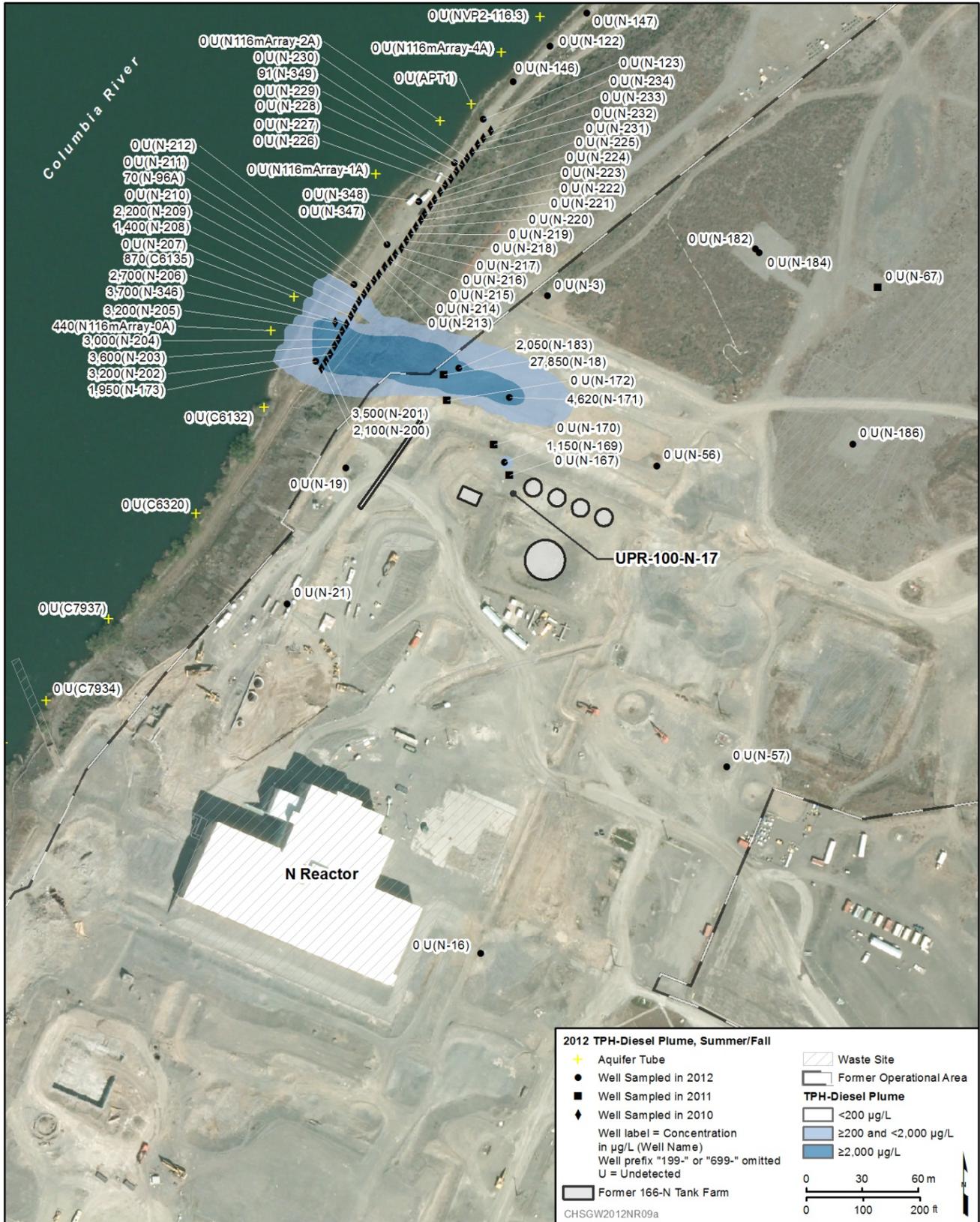
In 2012, two of the three aquifer tubes sampled for total petroleum hydrocarbon-diesel concentrations near the intersection of the groundwater plume and the Columbia River showed detections of total petroleum hydrocarbon-diesel (C6135 and N116mArray-0A [Map NR.5]).

Table NR.2 100-NR Hydrocarbon Product Removal from Well 199-N 18, 2003-2012

Year	Product Removed (gram)	Notes
2003 ^a	~1,200 ^b	Estimate provided per information given in table note; data records lost when original work package was lost in the field.
2004	3,475	Changed out twice per month.
2005	780	Changed approximately every two months.
2006	1,370	Changed every two months.
2007	1,294	Changed every two months.
2008	920	Changed every two months.
2009	1,380	Changed approximately every two months.
2010	225.5	Changed only twice prior to June 2010; smart sponge broke apart in well. No removal for second half of 2010.
2011	500	Changed every two months.
2012	600	Changed in January, April, June, and August 2012
Total		12,014.5 grams (approximately 12 kilograms) removed through end of 2012

a. [DOE/RL-2004-21](#), *Calendar Year 2003 Annual Summary Report for the 100-HR-3, 100-KR-4, and 100-NR-2 Operable Unit (OU) Pump & Treat Operations*, reports that product removal started in October 2003.

b. [DOE/RL-2005-18](#), *Calendar Year 2004 Annual Summary Report for the 100-HR-3, 100-KR-4, and 100-NR-2 Operable Unit Pump-and-Treat Operations*, states that the average mass removal for fiscal year 2004 (October 2003 through October 2004) was approximately 0.4 kilogram per month; therefore, an estimate is provided for the 3 months missing in 2003.



Map NR.5 100-NR Total Petroleum Hydrocarbons-Diesel Plume, Summer/Fall 2012

100-NR Chromium

Sodium dichromate was used in N Reactor operations only from 1964 to 1972 and in lesser amounts than in the other 100 Area reactors because of the design of the N Reactor cooling system and the use of corrosion-resistant metals (such as zircaloy) in the fuel and facility (Section 1.3.2 of DOE/RL-2012-15). Although chromium was present in the effluent discharged to the 116-N-1 waste site, it was never detected in samples of the effluent (Section 3.1.1.4 of DOE/RL-90-22, *RCRA Facility Investigation/Corrective Measures Study Work Plan for the 100-NR-1 Operable Unit, Hanford Site, Richland, Washington*). Given the mobility and nonsorbing nature of chromium in solution, the high continuous discharge rates and high temperatures while chromium was being delivered to the 116-N-1 waste site, and the fact that liquid discharges to 116-N-1 continued for another 10 years after use of sodium dichromate had ceased, the mobile portion of chromium was thoroughly flushed from the subsurface and into the Columbia River by the end of the N Reactor's operational period (Section 4.8.1.4 of DOE/RL-2012-15).

Only one well in 100-NR-2 had chromium concentrations above the drinking water standard (100 µg/L) in 2012 (Map NR.6). The dissolved (filtered) chromium concentration in well 199-N-80, which was completed in a thin, confined water-bearing zone in the upper portion of the Ringold upper mud unit, was 189 µg/L, consistent with previous results and relatively unchanged since monitoring began (Figure NR.8). This water-bearing zone is not laterally continuous and does not pose a significant threat of releasing contamination to the unconfined aquifer (Section 4.4.3. of DOE/RL-2012-15).

The chromium detected in well 199-N-80 is likely the result of past disposal of chromium-bearing liquid waste that was driven into this confined interval during extremely high unconfined aquifer heads and today remains relatively stagnant (Section 4.8.1.4 of DOE/RL-2012-15). Recent well maintenance activities confirmed stainless steel well screen corrosion was occurring, which could also release chromium.

In 2012, chromium continued to be detected below the drinking water standard in wells approximately 750 meters inland from N Reactor and not associated with a waste site. This chromium contamination migrated inland while the 100-K-2 Trench was in use and a groundwater mound was present. A portion of this 100-K chromium plume has migrated northward into 100-N near wells 199-N-74 and 199-N-189. Chromium concentrations were near or below detection limits in 100-N aquifer tube samples in 2012. All were below the 10 µg/L ambient water quality standard.

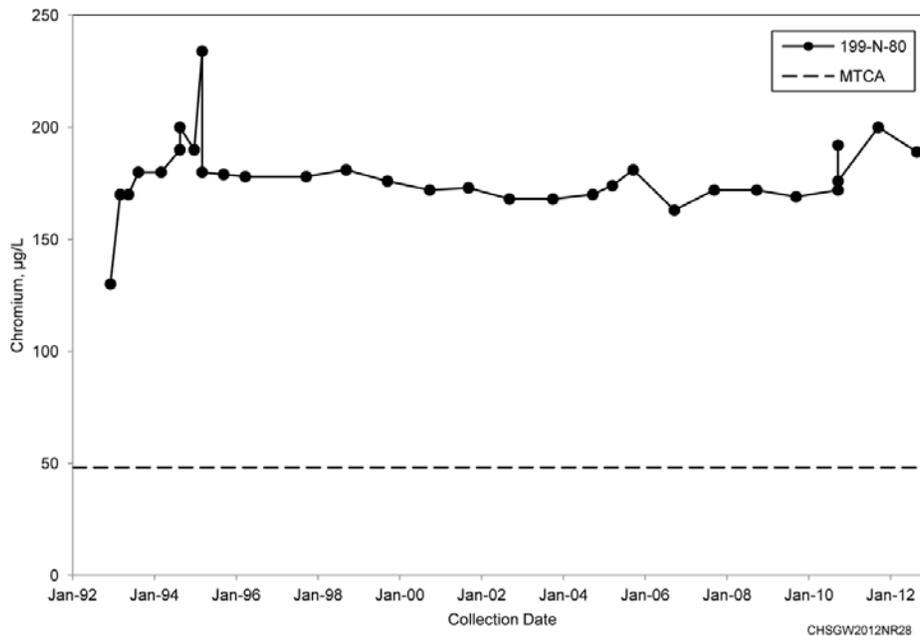
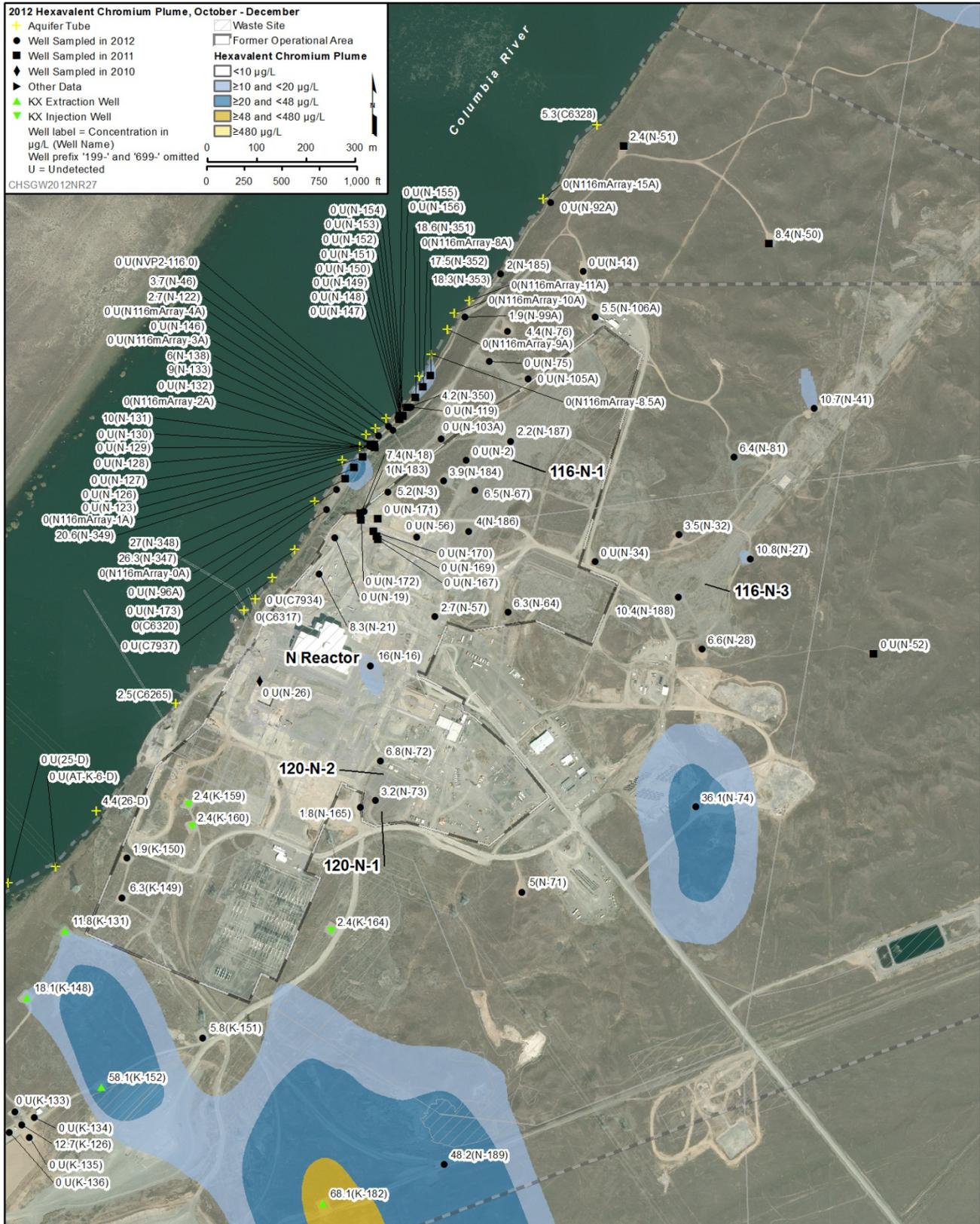


Figure NR.8 100-NR Chromium Data for well 199-N-80



Map NR.6 100-NR 2012 Hexavalent Chromium Plume

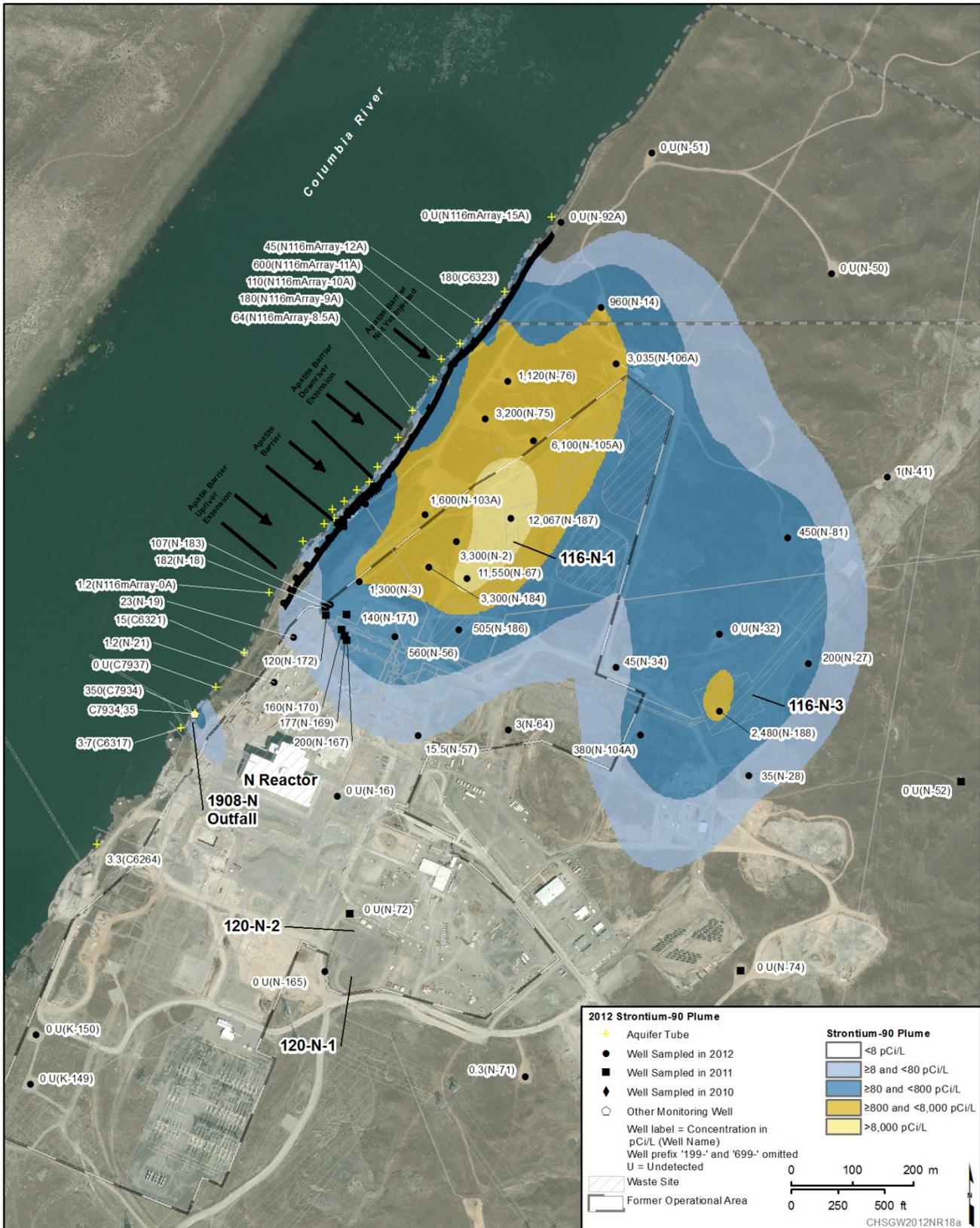
100-NR Remedies – Introduction

Interim actions are being conducted for cleanup of strontium-90 and total petroleum hydrocarbon-diesel contamination in 100-NR-2 (Map NR.7). The activities and results for 2012 are summarized in this section. Additional details are available in DOE/RL-2013-13, *Calendar Year 2012 Annual Summary Report for the 100-NR-2 and 100-KR-4 Pump-and-Treat Operations, and 100-NR-2 Groundwater Remediation*.

The CERCLA remediation of strontium-90 in groundwater is identified in the interim action ROD ([EPA/ROD/R10-99/112](#)). When the Interim Action ROD was issued in 1995, the interim action for remediation of strontium-90 in groundwater was pump-and-treat. The 100-NR-2 groundwater pump-and-treat system operated from 1995 until 2006. The system removed approximately 1.8 Ci of strontium-90 from the aquifer, which was less than the amount removed by radioactive decay during the same period. Because strontium-90 binds strongly to the sediment, the pump-and-treat system was not effective in the cleanup of strontium-90 from the aquifer.

One of the requirements of the Interim Action ROD was to evaluate alternative technologies for groundwater cleanup. Therefore, in 2006, Ecology, EPA, and DOE approved placing the pump-and-treat system in cold-standby status and constructing a permeable reactive barrier. A 90-meter-long apatite permeable reactive barrier was completed as a treatability test in accordance with [DOE/RL-2005-96](#). Based on the treatability test results ([PNNL-17429](#), *Interim Report: 100-NR-2 Apatite Treatability Test: Low-Concentration Calcium-Citrate-Phosphate Solution Injection for In Situ Strontium-90 Immobilization*), the apatite technology showed promise as a remediation option. As a result, the Interim Action ROD was amended in 2010 to allow for expansion of the apatite barrier and permanent decommissioning of the 100-N pump-and-treat system.

The CERCLA interim action for remediation of total petroleum hydrocarbon-diesel in groundwater is identified in the interim action ROD ([EPA/ROD/R10-99/112](#)). The Interim Action ROD specifies that petroleum hydrocarbons (free product) will be removed if observed in a monitoring well. The removal of the total petroleum hydrocarbon-diesel is discussed in the 100-NR Total Petroleum Hydrocarbon-Diesel section.



Map NR.7 100-NR Remedy Plumes

100-NR Remedies – Apatite Barrier

The original, 90-meter-long apatite permeable reactive barrier was created by injection of apatite-forming solutions into 16 wells from 2006 through 2008. The expanded apatite permeable reactive barrier well network was installed between late 2009 and early 2010, extending the original barrier upriver and downriver for a total well network length of 760 meters (Map NR.8). In fall 2011, two segments of the extended well network, one upriver and one downriver of the original barrier, were injected to expand the apatite treat portion of the barrier approximately 300 meters. The barrier was expanded in accordance with the design optimization study ([DOE/RL-2010-29](#), *Design Optimization Study for Apatite Permeable Reactive Barrier Extension for the 100-NR-2 Operable Unit*).

Apatite Permeable Reactive Barrier Technology

The apatite permeable reactive barrier is formed by injecting a calcium-citrate-phosphate solution into the aquifer through a network of vertical wells. After the solution is injected, biodegradation of the citrate results in apatite (a calcium phosphate mineral $[\text{Ca}_5(\text{PO}_4)_3(\text{F}, \text{Cl}, \text{OH})]$) precipitation. Strontium-90 (and strontium) ions in groundwater substitute for calcium ions via cation exchange and eventually become trapped as part of the mineral matrix during apatite crystallization (Section 1.3 of [PNNL-16891](#), *Hanford 100-N Area Apatite Emplacement: Laboratory Results of Ca-Citrate-PO4 Solution Injection and Sr-90 Immobilization in 100-N Sediments*). The strontium-90 is sequestered within the apatite permeable reactive barrier, where it will naturally decay.

Apatite Permeable Reactive Barrier Performance Monitoring

Performance monitoring at the apatite barrier was performed twice in 2012. Groundwater samples were collected from performance monitoring wells and aquifer tubes during high river stage in May and during low river stage in September and October. A comparison fall 2012 measurement data to baseline conditions is shown in Table NR.3.

Semiannual performance monitoring (high and low river stages) will continue for the apatite permeable reactive barrier in 2013.

Design Optimization Study

The design optimization study ([DOE/RL-2010-29](#)) had seven objectives for evaluating barrier implementation and effectiveness. As described in [DOE/RL-2011-118](#), *Hanford Site Groundwater Monitoring for 2011*, and [DOE/RL-2012-02](#), *Calendar Year 2011 Annual Summary Report for the 100-HR-3 and 100-KR-4, Pump-and-Treat Operations, and 100-NR-2 Groundwater Remediation*, five of the seven objectives have been met. The following two objectives had not been completed prior to 2012:

- Further evaluate the high-concentration calcium-citrate-phosphate solution impact on the release of strontium-90 and other metals from previously untreated sediments to groundwater.
- Evaluate whether the permeable reactive barrier can achieve up to a 90 percent reduction in strontium-90 flux to the Columbia River.

The first of these two objectives was tested in 2011 following injection of the apatite solution into the wells in the upriver and downriver barrier extensions. Samples were collected to determine how long the release of strontium-90 and other metals occurs after the initial injections. A separate report will provide the details and results of the apatite barrier expansions and testing results.

After the apatite injections ceased in 2008 in wells in the central (original) segment of the barrier, strontium-90 and gross beta concentrations declined steadily in the sampled wells, with very few exceptions (Figure NR.9). The second of these two objectives will require the collection of data over the next few years to determine whether the 90 percent reduction of strontium-90 has occurred in the permeable reactive barrier monitoring wells. Strontium-90 is a beta-emitter. Gross beta concentrations (x2) are used to approximate equivalent strontium-90 concentrations. The wells showed temporary, higher strontium-90 concentrations immediately following the injections of the apatite solution, which had a higher ionic strength than groundwater and temporarily mobilized cations and anions, causing their concentrations in groundwater to increase. As of September and October 2012, the strontium-90 and gross beta values were still considerably lower in all wells and aquifer tubes monitored along this segment of the barrier than before the injections started in 2006. However the 2012 data indicate that the barrier has been slightly less effective at reducing strontium-90 concentrations in groundwater compared to previous years. In 2012, the strontium-90 concentrations had been reduced by 66 to 84 percent. Additional apatite injections are needed to bring the network into compliance with the 90 percent reduction performance criteria in the test plan (Section 4.4.3 of [DOE/RL-2005-96](#)) and the 8 pCi/L drinking water standard (remedial action goal in the amended Interim Action ROD).

One year after the injections into the upriver and downriver barrier extension wells were completed, performance monitoring in September and October 2012 indicated that three of the four upriver barrier segment compliance monitoring wells have achieved approximately 80 percent or better reduction of strontium-90 concentrations in groundwater; the well in the highest concentration portion of this barrier segment has achieved a 95 percent reduction. All four of the downriver barrier segment compliance monitoring wells have essentially achieved 90 percent reduction in strontium-90 concentrations in groundwater. Ongoing monitoring will allow the determination of the continued effectiveness of the apatite treatment along the expanded barrier and support decisions regarding additional future apatite treatments.

Table NR.3 Performance Monitoring at the Apatite Permeable Reactive Barrier, 100-NR-2 OU				
Upriver Apatite PRB				
	199-N-96A	199-N-347	199-N-348	199-N-349
Baseline (maximum)	37.9	7.0	1800.0	230.0
Sr-90 Concentration (pCi/L) Fall 2012	4.6	10.0	88.0	50.0
Percent Reduction^a	88	-43	95	78
Central (Original) Apatite PRB				
	199-N-122	199-N-123	199-N-146	199-N-147
Baseline (maximum)	4530.0	1180.0	985.0	1842.0
Sr-90 Concentration (pCi/L) Fall 2012	900.0	230.0	330.0	300.0
Percent Reduction^a	81	81	66	84
Downriver Apatite PRB				
	199-N-350	199-N-351	199-N-352	199-N-353
Baseline (maximum)	240.0	350.0	580.0	83.0
Sr-90 Concentration (pCi/L) Fall 2012	26.0	29.0	29.0	3.4 U
Percent Reduction^a	89	92	95	100
Drinking Water Standard for Sr-90 is 8 pCi/L.				
a – Percent reduction in Sr-90 concentration from maximum baseline to Fall 2012				

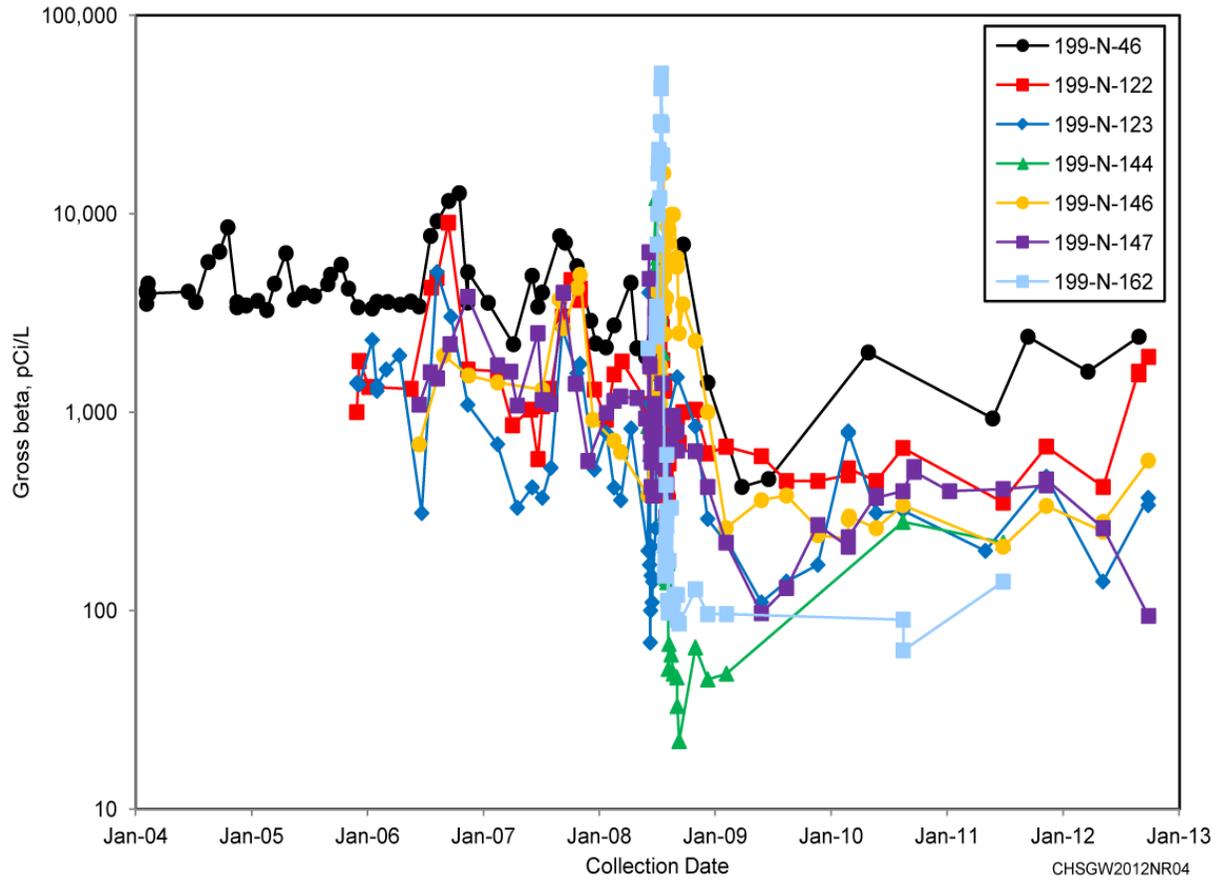


Figure NR.9 100-NR Gross Beta Data for wells near the Apatite Barrier

100-NR RCRA – Introduction

This section describes the monitoring results for the following four RCRA facilities at 100-N (Map NR.9): the 116-N-1 Crib and Trench (1301-N Liquid Waste Disposal Facility), the 116-N-3 Crib and Trench (1325-N Liquid Waste Disposal Facility), the 120-N-1 Pond (1324-NA Percolation Pond), and the 120-N-2 Surface Impoundment (1324-N Surface Impoundment). Groundwater is monitored at these facilities to meet the requirements of RCRA and [WAC 173-303](#) for dangerous waste constituents. Groundwater data for these facilities are available in the Hanford Environmental Information System database and in the data files accompanying this report. [SGW-55438](#) includes well and constituent lists, flow rates, and statistical tables for the four RCRA units at 100-N.



Map NR.9 100-NR RCRA Facility Location

100-NR RCRA – 116-N-1 Crib and Trench

The 116-N-1 waste site (1301-N Liquid Waste Disposal Facility [Map NR.10]) was an unlined crib and trench used for disposal of liquid effluent from the 1960s through 1985. The effluent contained small quantities of dangerous waste in addition to the large volume of radioactive waste. The waste site has been excavated to remove shallow vadose zone sediment (where most of the radionuclide contamination resided) and was backfilled with clean fill.

The direction of groundwater flow beneath the 116-N-1 site in 2012 remained the same as in 2011; the area is under the influence of groundwater injection in 100-KR-4 to the south. In spring (March/April 2012), the water table gradient beneath the 116-N-1 site is to the north-northwest at 1.9×10^{-3} m/m, and estimates of the groundwater flow rate ranged from 0.04 to 0.71 meter per day ([SGW-55438](#)).

Two upgradient wells (199-N-34 and 199-N-57) and three downgradient wells (199-N-2, 199-N-3, and 199-N-105A) monitor the 116-N-1 waste site ([SGW-55438](#)). No changes to the monitoring network were made in 2012.

The 116-N-1 facility is included in the Hanford Facility RCRA Permit ([WA7890008967](#), *Hanford Facility Resource Conservation and Recovery Act Permit, Dangerous Waste Portion, Revision 8C, for the Treatment, Storage, and Disposal of Dangerous Waste*), which states that RCRA monitoring during closure activities will follow the requirements of [BHI-00725](#), *100-N Pilot Project: Proposed Consolidated Groundwater Monitoring Program*. That plan, and a supplemental plan ([PNNL-13914](#), *Groundwater Monitoring Plan for the 1301-N, 1324-N/NA, and 1325-N RCRA Facilities*), are similar to an interim status indicator evaluation program ([40 CFR 265.93\[b\]](#), “Interim Status Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities,” “Preparation, Evaluation, and Response”), as referenced by [WAC 173-303-400](#), “Dangerous Waste Regulations,” “Interim Status Facility Standards.”

Upgradient and downgradient wells are scheduled for sampling twice each year for RCRA contamination indicator parameters (that is, pH, specific conductance, total organic carbon, and total organic halides) and once for groundwater quality and site-specific parameters. The wells were sampled as scheduled during 2012, and there were no critical mean exceedances (Table 3-3, [SGW-55438](#)).



Map NR.10 100-NR RCRA 116-N-1 Monitoring Well Locations

100-NR RCRA – 116-N-3 Crib and Trench

The 116-N-3 waste site (1325-N Liquid Waste Disposal Facility, Map NR.11) was an unlined crib and trench used to dispose of liquid effluent from 1983 through 1991. The effluent contained small quantities of dangerous waste in addition to the large volume of radioactive waste. The waste site was excavated to remove shallow vadose zone material (which contained the highest concentrations of radionuclides) and was backfilled.

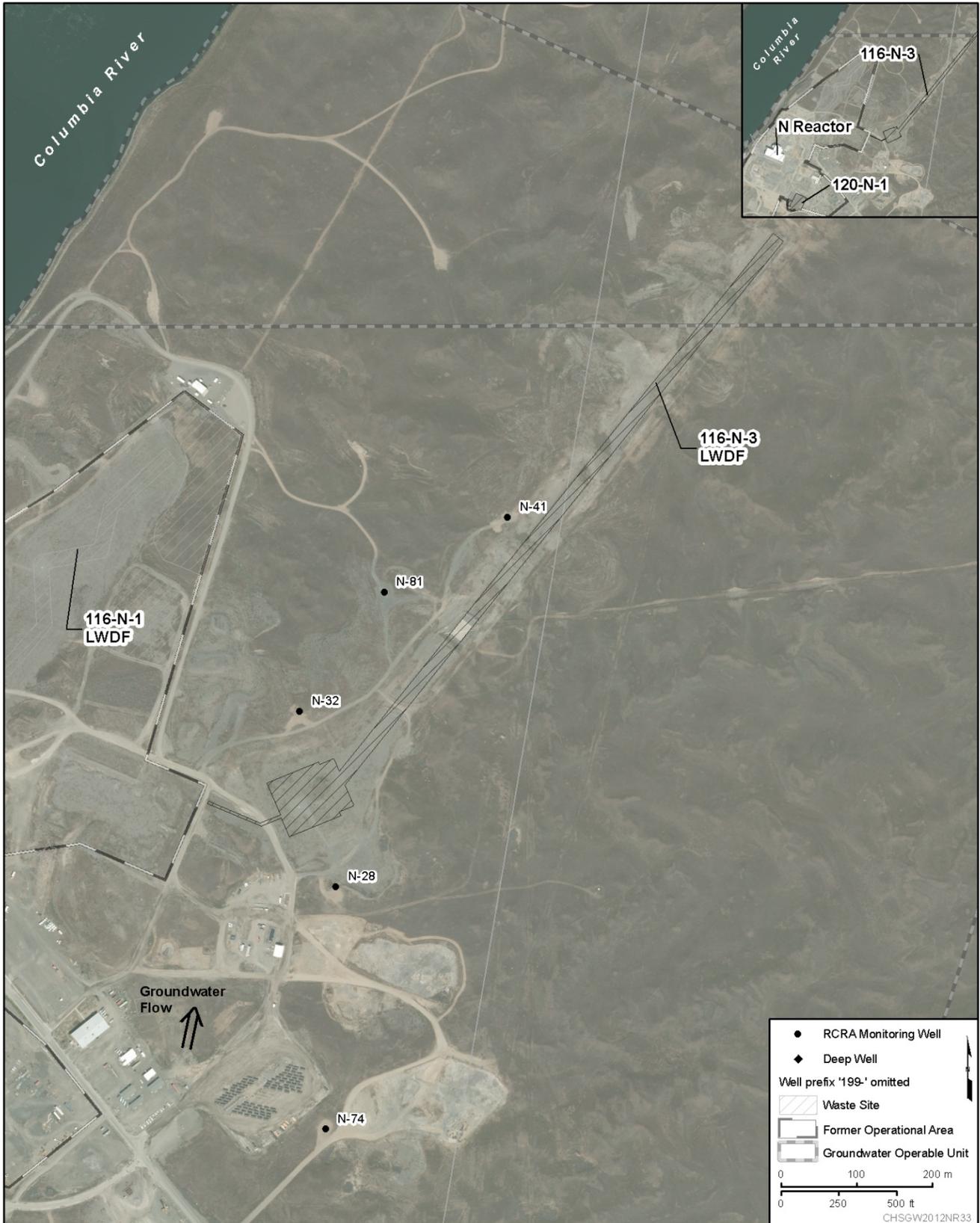
Groundwater flows to the north beneath the 116-N-3 site, turns to the northwest, and discharges to the Columbia River. The hydraulic gradient in March 2012 was to the north at 1.21×10^{-3} m/m with the groundwater flow rate estimated from 0.03 to 0.46 meter per day ([SGW-55438](#)).

The 116-N-3 facility is included in the Hanford Facility RCRA Permit ([WA7890008967](#)), which states that RCRA monitoring during closure activities will follow the requirements of BHI-00725. BHI-00725 and a supplemental plan ([PNNL-13914](#)) are similar to an interim status indicator evaluation program ([40 CFR 265.93\[b\]](#)), as referenced by [WAC 173-303-400](#).

Upgradient well 199-N-74 and downgradient wells 199-N-32, 199-N-41, and 199-N-81 monitor the 116-N-3 waste site. Well 199-N-28 is monitored for supporting information, but its data are not evaluated statistically. No changes to the monitoring network were made in 2012.

All five wells in the RCRA network were sampled as planned during 2012, twice for RCRA contamination indicator parameters (that is, pH, specific conductance, total organic carbon, and total organic halides) and once for groundwater quality and site-specific parameters.

Average specific conductance values in all three of the downgradient wells (199-N-41, 199-N-81, and 199-N-32) exceeded the 2012 critical mean of 463 $\mu\text{S}/\text{cm}$ ([SGW-55438](#)). This is a continuation of previous exceedances noted from 1999 through 2011. The assessment report for the original 1999 exceedance (at well 199-N-41) concluded that the exceedance was caused by past discharges of nonregulated contaminants to the 120-N-1 site ([00-GWVZ-054](#), *Results of Assessment at the 1325-N Facility*). Recent data indicate that this conclusion in the 1999 assessment report ([00-GWVZ-054](#)) remains valid. No other critical mean exceedances occurred during the reporting period.



Map NR.11 100-NR RCRA 116-N-3 Monitoring Well Locations

100-NR RCRA – 120-N-1 and 120-N-2

The 120-N-1 waste site (1324-NA Percolation Pond) and the 120-N-2 waste site (1324-N Surface Impoundment) were used to treat and dispose of corrosive, nonradioactive waste from 1977 to 1990. Both facilities have been remediated and backfilled.

The 120-N-1 and 120-N-2 facilities (Map NR.12) are included in the Hanford Facility RCRA Permit ([WA7890008967](#)), which states that RCRA monitoring during closure activities will follow the requirements of [BHI-00725](#), [BHI-00725](#) and a supplemental plan ([PNNL-13914](#)) are similar to an interim status indicator evaluation program ([40 CFR 265.93\[b\]](#)), as referenced by [WAC 173-303-400](#). The two units are monitored as a single site (waste management area) because of their proximity and similar waste types.

Upgradient well 199-N-71 and downgradient wells 199-N-72, 199-N-73, 199-N-77, and 199-N-165 monitor the 120-N-1 and 120-N-2 waste sites. Well 199-N-77 is screened at the base of the unconfined aquifer, and statistical comparisons are not performed on data from this well. No changes to the monitoring network were made in 2012.

All five of the monitoring wells for these sites were sampled as planned during 2012, twice for RCRA contamination indicator parameters and groundwater quality, and once for site-specific parameters ([SGW-55438](#)).

100-KR-4 injection wells south and west of the 120-N-1 and 120-N-2 sites affected groundwater flow in 2012 (Map NR.1). In March 2012, the hydraulic gradient was to the north-northwest at 8.3×10^{-4} m/m, and estimated flow rates ranged from 0.02 to 0.31 meter per day.

Average specific conductance values in downgradient wells 199-N-72, 199-N-73, and 199-N-165 continued to exceed the critical mean value of approximately 585 $\mu\text{S}/\text{cm}$ in 2012. A previous groundwater quality assessment indicated that the high specific conductance is caused by the nonregulated constituents sulfate and sodium ([WHC-SD-EN-EV-003](#), *Results of Groundwater Quality Assessment Monitoring at the 1301-N and 1324-N/NA Facilities*). These constituents along with calcium, nitrate, other ions, and the indicator specific conductance increased during the time of unusually high water levels in the aquifer over the past two years. The constituents concentration dropped coincident with lower water table levels. These data suggest that residual contamination may be present in the lower vadose zone near the water table beneath the 120-N-1 and 120-N-2 and is released into the aquifer during unusually high water levels that saturated the normally unsaturated lower vadose zone. Recent data indicate that this conclusion in the 1992 assessment report ([WHC-SD-EN-EV-003](#)) remains valid.

The average total organic carbon concentration increased above the critical mean value of 860 $\mu\text{g}/\text{L}$ in well 199-N-165 in September 2011. In 2012, the average total organic carbon concentration had decreased and remained below the Limit of Quantitation in the March and September samples. The maximum concentration during the temporary increase exceeded 6,000 $\mu\text{g}/\text{L}$. None of the other RCRA wells monitoring 120-N-1 and 120-N-2 had critical mean exceedances for total organic carbon during September 2011 or thereafter. Because there is no record of organic waste discharged to these facilities, it was believed the exceedance was not caused by releases from the 120-N-1 and 120-N-2 waste sites.

In accordance with the letter from DOE to Ecology regarding the exceedance ([12-AMCP-0041](#), "Groundwater Indicator Parameter Exceedance at 1324-N/NA"), DOE planned additional sampling and analyses to evaluate and confirm the source of the elevated total organic carbon concentrations. Sampling was planned for March 2012, the next RCRA sampling period at 120-N-1 and 120-N-2, and an expanded analyte list was selected to test for the presence of constituents that could help identify the potential source of the total organic carbon. Based on the sampling results, the source for the elevated total organic carbon was not a volatile organic analyte or a polyaromatic hydrocarbon and was not related to septic releases (coliform bacteria), fuel spills (total petroleum hydrocarbon-diesel or total petroleum hydrocarbon-gasoline), or polychlorinated biphenyls ([169299](#), "100 & 300 Area Unit Manager Meeting Minutes," Attachment 8). Based on the available information, the conclusion of the evaluation was that the elevated total organic carbon concentrations are not attributed to the 120-N-1 or 120-N-2 waste sites.



Map NR.12 100-NR RCRA 120-N-1 and 120-N-2 Monitoring Well Locations

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