Appendix D

Confined Aquifers

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D Confined Aquifers

This chapter describes groundwater flow and groundwater quality in confined aquifers within the Ringold Formation and the upper portion of the Columbia River Basalt Group.

D1 Ringold Confined Aquifers

Numerous wells at the Hanford Site monitor confined, water-bearing units in the Ringold Formation (Figure D-1). The most widespread Ringold confined aquifer is where the Ringold lower mud unit confines the underlying sediment of Ringold unit A. Approximately 40 wells are screened in Ringold unit A, although not all of these have been sampled in recent years. Most of the wells are located in or near the Central Plateau; others are located in the southern Hanford Site (including the 300 Area), and one well is in the 100 Area.

Local, water-bearing units in or beneath the Ringold upper mud unit exist in the northern Hanford Site. These are not believed to be interconnected into a regional aquifer. Nineteen wells in the 100 Area are screened in water-bearing units within or beneath this unit.

D1.1 Groundwater Flow in Ringold Confined Aquifers

This subsection describes groundwater flow in the confined aquifer of Ringold unit A in the region near the 200 Area and farther south. The elevation of this Ringold confined aquifer varies from 34 m (111.5 ft) above mean sea level (NAVD88, *North American Vertical Datum of 1988*) southwest of the 200 West Area (Plate 3 of PNNL-13858) to more than 128 m (420 ft) (NAVD88) northeast of the 200 East Area (Plate 3 of PNNL-12261). There are insufficient data from unit A in the northern part of the Hanford Site to interpret groundwater flow directions. Groundwater flow in the Ringold upper mud is not characterized because the water-bearing units are not known to be interconnected.

Figure D-2 presents the March 2014 potentiometric surface for a portion of the confined aquifer in the Ringold Formation unit A. This map is subject to uncertainty because only a few wells monitor this aquifer. However, generalized flow patterns can be inferred from available data when the hydrogeologic framework (that is, the extent of the confined unit, presence of basalt subcrops, and influence of the May Junction Fault) is considered.

Groundwater flow in the Ringold confined aquifer is generally west to east near the 200 West Area and west to east along the southern boundary of the aquifer near the Rattlesnake Hills. This flow pattern indicates that recharge occurs west of the 200 West Area in upgradient areas within the Cold Creek Valley, as well as in the Dry Creek Valley, and possibly the Rattlesnake Hills. Near the 200 East Area, flow in the Ringold confined aquifer converges from the west, south, and east before discharging to the unconfined aquifer where the Ringold Formation lower mud is absent (Section 4.2.3 of PNNL-12261). This water is thought to flow southeast over the top of the confining unit (Section 2.4.3 of DOE/RL-2008-59).

Three of the injection wells for the 200 West pump and treat system are screened beneath the Ringold lower mud unit. The 130 m (426.5 ft) contour in Figure D-2 illustrates the higher potentiometric surface around those wells. This was derived by simulation of groundwater injection at these wells (ECF-Hanford-14-0050, *Preparation of the March 2014 Hanford Site Water Table and Potentiometric Surface Maps*).

Artificially elevated water levels are present in the Ringold confined aquifer to the northeast of the 216-B-3 Pond (B Pond). The high water levels reflect mounding from past wastewater discharges and subsequently cause a southwest flow beneath B Pond where mounding is not as prevalent. Eastward flow away from the region of elevated water levels does not occur due to the north-south trending May Junction Fault, located east of the B Pond area (Section 2.4.3 of DOE/RL-2008-59). Hydraulic head and water chemistry differences across this fault indicate it is a barrier to groundwater flow in the confined aquifers (Sections 4.2.3 and 4.3.2 in PNNL-12261). While impermeable units have been juxtaposed against permeable units along part of the fault, the mud units may also have smeared along the fault zone and sealed it (Plates 8 and 9 in PNNL-12261). South of the B Pond area, the flow of water divides, with some flow moving northwest toward the 200 East Area and some flow moving east or southeast. The exact location of the flow divide is not known because of a lack of water-level data in this area and uncertainty regarding the southward extent of the May Junction Fault.

The potentiometric contours for the Ringold confined aquifer (Figure D-2) are similar to the potentiometric surface contours for the upper basalt-confined aquifer system, indicating that flow patterns in the central portion of the Hanford Site are similar in both aquifers. Basalt bedrock from the topographic low area at Gable Gap near the 200 East Area was eroded significantly by late Pleistocene catastrophic flooding (Section 7.0 of PNNL-19702), which facilitates intercommunication between the unconfined and confined aquifers. The 200 East Area is a discharge area for both of the confined aquifers, which explains the similar flow patterns.

The potentiometric surface responds to increased or reduced loading of the confined aquifer caused by water-level changes in the overlying unconfined aquifer. Hydraulic head declined in the confined aquifer between 2013 and 2014, continuing longer term trends. Small declines were evident in wells near 200 East and in the southeast part of the Hanford Site (0.02 to 0.09 m [0.066 to 0.295 ft] between 2013 and 2014). The largest declines were observed in 200 West Area (e.g., 0.54 m [1.77 ft] in Well 299-W22-24P, located in southern 200 West).

Hydraulic head east of 200 West Area has varied in recent years. Three pump and treat injection wells that are screened in the Ringold confined aquifer increased the head in 2013, interpreted as a “mound” in the potentiometric surface with a high head in nearby monitoring Well 699-43-69. The “mound” nearly dissipated in 2014 with a 2.28 (7.48 ft) decline in Well 699-43-69. The water level in 2014 was in line with the longer term, declining trend due to reduced loading in the overlying unconfined aquifer in this region.

D1.2 Groundwater Quality in Ringold Confined Aquifers

Wells monitoring Ringold confined aquifers are sampled in accordance with the objectives of the groundwater operable units in which they are located. The main text of this report discusses monitoring results and highlights are summarized in the following text.

With few exceptions, groundwater in the Ringold upper mud unit is not contaminated (Table D-1). Nineteen wells screened in this unit were sampled at least once between 2012 and 2014. Hexavalent chromium concentrations are greater than the 48 µg/L “Model Toxics Control Act—Cleanup” (WAC 173-340) standard in some Ringold upper mud wells in 100-H Area (higher than currently observed in the unconfined aquifer) and in one well in the Horn. It appears that portions of this unit east of 100-D Area were eroded, allowing contaminated cooling water into water-bearing units within the mud. This water moves more slowly than unconfined groundwater so the contamination persists.

Tritium and chromium concentrations are elevated in Ringold mud Well 199-N-80 (see 100-NR section of this report), although tritium levels are below the drinking water standard (DWS). This is the only well in 100-NR screened in the mud. Attempts to install another well in a similar, water-bearing zone in 2011 were unsuccessful; no water-bearing zone was encountered during drilling.

Twenty wells screened in unit A were sampled at least once between 2012 and 2014. The region just east of the 200 West Area is contaminated with carbon tetrachloride, chromium, and nitrate. These contaminants apparently reached unit A in a region of the 200 West Area where the lower mud unit is absent. As the groundwater continues to flow toward the east where the lower mud is present, it becomes confined. The 200-ZP section of this report discusses contaminant distribution with depth in the 200 West Area.

The Ringold confined aquifer (unit A) is the uppermost aquifer in a region east of 200 East (200-BP and 200-PO groundwater interest areas). Regional contaminants iodine-129 and tritium are detected in wells monitoring this aquifer (Table D-1). Contamination has not been observed in wells located downgradient of the contaminated wells, indicating it is of limited extent.

D2 Upper Basalt-Confined Aquifer

The upper basalt-confined aquifer groundwater system occurs within basalt fractures and joints, interflow contacts, and sedimentary interbeds within the upper Saddle Mountains Basalt. The thickest and most widespread sedimentary unit in this system is the Rattlesnake Ridge interbed, which is present beneath much of the Hanford Site. Groundwater also occurs within the Levey interbed, which is present only in the southern portion of the Hanford Site. A small interflow zone occurs within the Elephant Mountain Member of the upper Saddle Mountains Basalt and may be significant to the lateral transmission of water. The upper basalt-confined aquifer system is confined by the dense, low-permeability interior portions of the overlying basalt flows and in some places by silt and clay units of the lower Ringold Formation that overlie the basalt. Approximately 50 wells screened in the upper basalt-confined aquifer have been sampled or had water levels measured in recent years (Figure D-3).

An area of intercommunication between the unconfined and upper basalt-confined aquifers exists near the 200 East Area where the confining layers are eroded away or fractured. Several basalt-confined wells have shown evidence of intercommunication with the overlying unconfined aquifer (Section 3.0 of PNL-10817, *Hydrochemistry and Hydrogeologic Conditions within the Hanford Site Upper Basalt Confined Aquifer System*).

D2.1 Groundwater Flow in Upper Basalt-Confined Aquifer

Figure D-4 presents the interpreted March 2014 potentiometric surface for the upper basalt-confined aquifer system south of Gable Butte and Gable Mountain, based on measurements from 38 monitoring wells. The region to the north of Gable Butte and Gable Mountain was not contoured because of an insufficient number of wells in this area. Plate 1 of PNL-8869, *Preliminary Potentiometric Map and Flow Dynamic Characteristics for the Upper-Basalt Confined Aquifer System*, provides a generalized potentiometric surface map of this area. The upper basalt-confined aquifer system does not exist in the Cold Creek Valley and along the west portion of the Gable Mountain and Gable Butte structural area because of the absence of the Rattlesnake Ridge interbed.

Recharge to the upper basalt-confined aquifer system likely occurs from upland areas along the margins of the Pasco Basin and results from the infiltration of precipitation and surface water where the basalt and interbeds are exposed at or near ground surface. Recharge may also occur from the overlying aquifers (that is, the unconfined aquifer or confined aquifer in the Ringold Formation) in areas where the hydraulic gradient is downward and from deeper basalt aquifers where an upward gradient is present. The Yakima River may also be a source of recharge to this aquifer system. The Columbia River represents a discharge area for this aquifer system in the southeastern portion of the Hanford Site where the river has a lower head than the upper basalt-confined aquifer, but not for the northern portion of the site where the river head is higher (Section 3.2 of PNL-8869). Discharge also occurs to the overlying aquifers in areas where the hydraulic gradient is upward. Discharge to the overlying unconfined aquifer near the Gable Butte and Gable Mountain structural area is believed to occur through windows eroded in the basalt.

South of Gable Butte and Gable Mountain, groundwater in the upper basalt-confined aquifer system generally flows from west to east across the Hanford Site, toward the Columbia River. The north-south trending May Junction Fault, located east of B Pond, acts as a barrier to groundwater flow in the unconfined aquifer and the confined aquifer within the Ringold Formation (Section 2.4.3 of DOE/RL-2008-59). It may also impede the movement of water in the upper basalt-confined aquifer system by juxtaposing permeable units opposite impermeable units. As with the Ringold confined aquifer, a flow divide is interpreted to exist southeast of the 200 East Area and B Pond in the upper basalt-confined aquifer system, but the exact location of this divide is uncertain because of a lack of wells in the area.

Groundwater flow rates within the Rattlesnake Ridge interbed have been estimated between 0.7 and 2 m/yr (2.3 and 6.6 ft/yr) (Section 4.2 of PNL-10817), which is a considerably lower flow rate than most estimates for the overlying unconfined aquifer system. The sediment comprising the interbed consists mostly of sandstone (with silts and clays) and is much less permeable than the sediment in the unconfined aquifer. In addition, the magnitude of the hydraulic gradient is generally lower than in the unconfined aquifer.

The vertical hydraulic gradient between the upper basalt-confined aquifer system and the overlying aquifer varies spatially, as shown by comparison of observed heads (Figure D-5). An upward gradient exists beneath most of the Hanford Site. A downward gradient exists in the western portion of the Hanford Site and near the B Pond recharge mound, as well as in regions north and east of the Columbia River. Near the B Pond, the vertical head gradient between the unconfined aquifer system and the upper basalt-confined aquifer system has diminished in recent years but remains downward. In 2014, the area of upward gradient beneath a portion of 200 West Area grew in response to groundwater extraction, which reduced heads in the unconfined aquifer.

In the 200 East Area, the potentiometric surface (Figure D-4) is similar to the potentiometric surface for the Ringold confined aquifer (Figure D-2). The basalt in this area was significantly eroded by late Pleistocene catastrophic flooding, which facilitates aquifer intercommunication (Section 7.0 of PNNL-19702). In the 200 East Area and to the immediate north, the vertical hydraulic gradient between the upper basalt-confined aquifer system and the overlying aquifer is upward. It is likely that the upper basalt-confined aquifer system currently discharges to the overlying aquifer in this region.

The 2014 potentiometric surface map (Figure D-4) shows flexures in the contours beneath 200 West and the region to the east. This interpretation shows the influence of groundwater mounds (injection) and depressions (extraction) in the overlying unconfined and Ringold confined aquifers.

Water levels declined slightly in most of the basalt-confined wells in 200 East and 200 West Areas between 2013 and 2014. The decreases ranged from less than 0.1 m (0.33 ft) in wells near the 200 East Area to 0.68 m (2.23 ft) in Well 699-47-80AP, north of the 200 West Area. The latter well is located near unconfined injection wells. The water level rose significantly between 2012 and 2013, but resumed its downward trend in 2014.

In the northern part of 200 East Area the basalt confined aquifer is in communication with the overlying unconfined aquifer. Hydraulic head in the confined aquifer resumed its declining trend in this region in 2014. Head had increased in 2013 in response to higher than normal Columbia River stage during the summers of 2011 and 2012, which affected head in the overlying unconfined aquifer. The overall decline in the potentiometric surface is a response to reduced loading of the confined aquifer (i.e., a reduction in external stress) caused by water-level declines in the overlying unconfined aquifer and Ringold confined aquifer. Where the basalt is not confining, the water-level declines in the deeper aquifer are directly due to the declining water table. The water table in the unconfined aquifer is declining in response to reduced effluent disposal activities in the 200 Areas.

D2.2 Groundwater Quality in Upper Basalt-Confined Aquifer

The U.S. Department of Energy (DOE) monitors groundwater quality in the upper basalt-confined aquifer system because of the potential for downward migration of contaminants from the overlying unconfined aquifer in areas where confining units are absent or fractured. The upper basalt-confined aquifer system is not affected by contamination as much as the unconfined aquifer. Contamination found in the upper basalt-confined aquifer system is most likely to occur in areas where the confining units have been eroded away or were never deposited, and where past disposal of large amounts of wastewater resulted in downward hydraulic gradients. Researchers have identified areas of intercommunication between the contaminated unconfined aquifer and the upper basalt-confined aquifer by geochemical signatures and the presence of nitrate and tritium in groundwater in some basalt-confined wells near the 200 East Area (Chapter 3.0 of PNL-10817). However, groundwater monitoring data do not indicate that contamination has migrated into the upper basalt-confined aquifer. Because of poor seals in wells constructed prior to implementation of WAC 173-160 ("Minimum Standards for Construction and Maintenance of Wells"), intercommunication between aquifers has permitted groundwater flow from the unconfined aquifer to the underlying confined aquifer in the past, increasing the potential to spread contamination (e.g., at Well 299-E33-12, discussed below). Section 2.14.2 of DOE/RL-2008-01 further discusses communication between the upper basalt-confined aquifer system and the overlying aquifers.

Eighteen wells screened in the upper basalt-confined aquifer were sampled between 2012 and 2014. Concentrations of contaminants are far below DWSs in the basalt-confined aquifer (Table D-2), except in a single well (299-E33-12) where past drilling practices and well construction allowed migration of groundwater from the overlying unconfined aquifer. The highest concentrations of contaminants continued to be observed in Well 299-E33-12 in the northwestern 200 East Area. This well was drilled in 1953 and was uncased from just above the bottom of the unconfined aquifer through the Rattlesnake Ridge interbed. Contamination is believed to have migrated from the unconfined aquifer, down the open borehole, to the Rattlesnake Ridge interbed (Section 2.14.2 of DOE/RL-2008-01). The well was sealed from the unconfined aquifer in 1979 with an additional seal placed in the well in 1990 to shorten the open interval. Concentrations of waste indicators cyanide, nitrate, technetium-99, and tritium continued to be elevated in samples from this well, and possibly in a small area of the confined aquifer. Well 299-E33-50, located near 299-E33-12, consistently shows levels of technetium-99 between 25 and 50 pCi/L. Other confined wells in this region showed no contamination. The hydraulic gradient is upward in this region (Figure D-5).

Tritium is detected at a concentration below the DWS in Well 699-42-40C, located east of 200 East (200-BP interest area) and concentrations generally are declining. The hydraulic gradient in this region remains downward (Figure D-5).

Groundwater in basalt-confined wells in other regions of the Hanford Site is uncontaminated, based on data from a small number of available wells that were sampled in recent years (Table D-2).

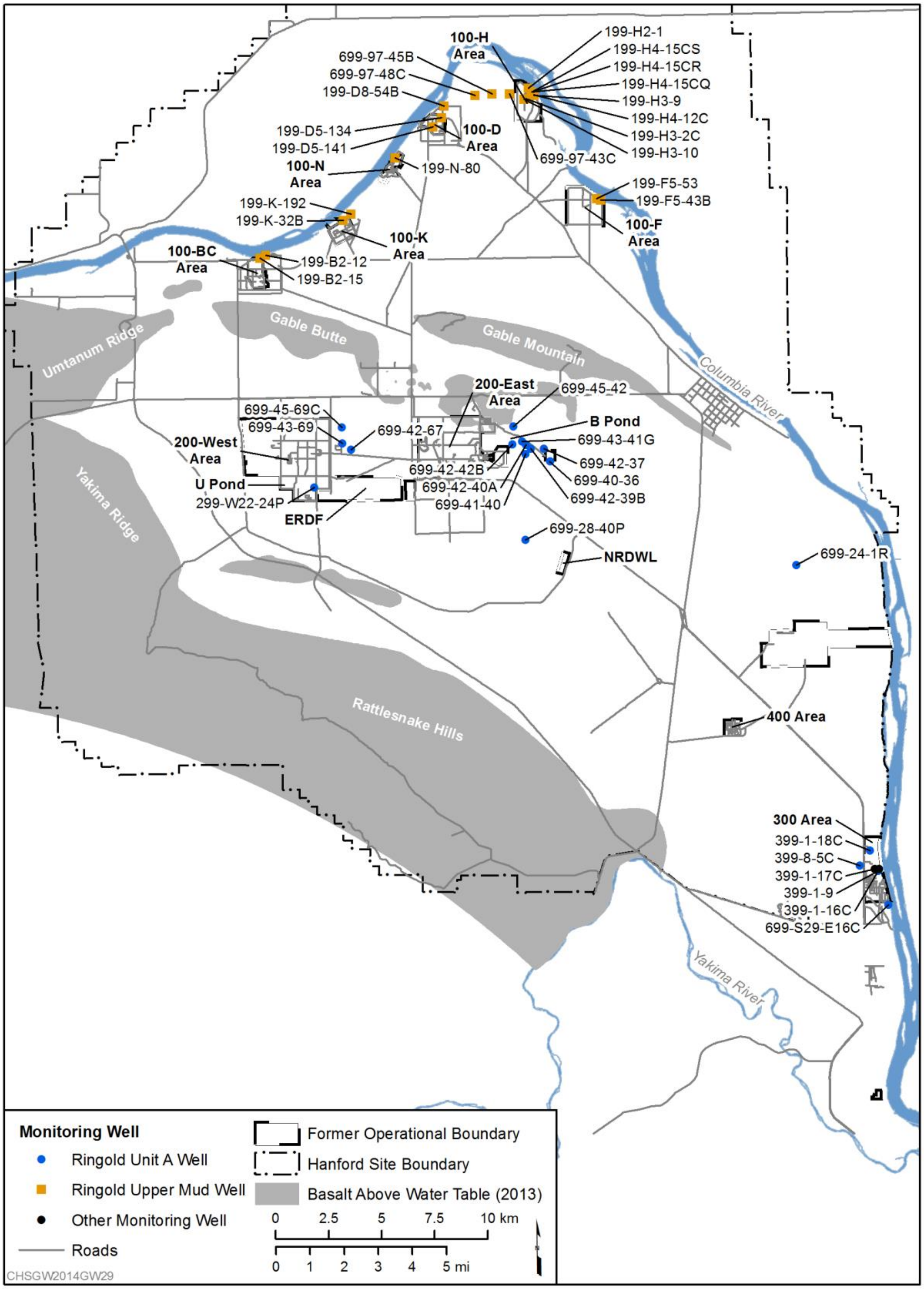

Figure D-1. Ringold Confined Monitoring Wells

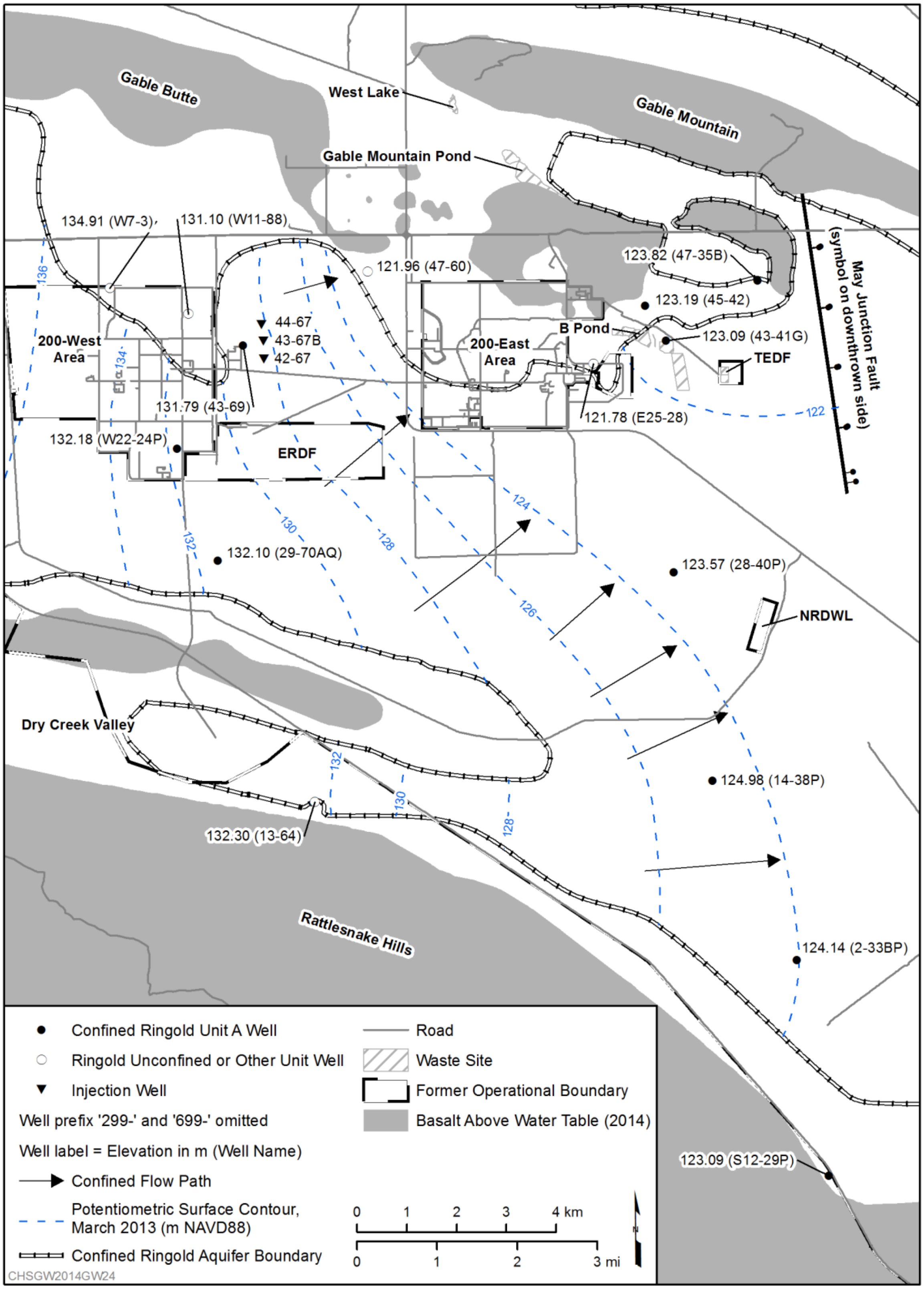

Figure D-2. Potentiometric Surface for Ringold Unit A, March 2014

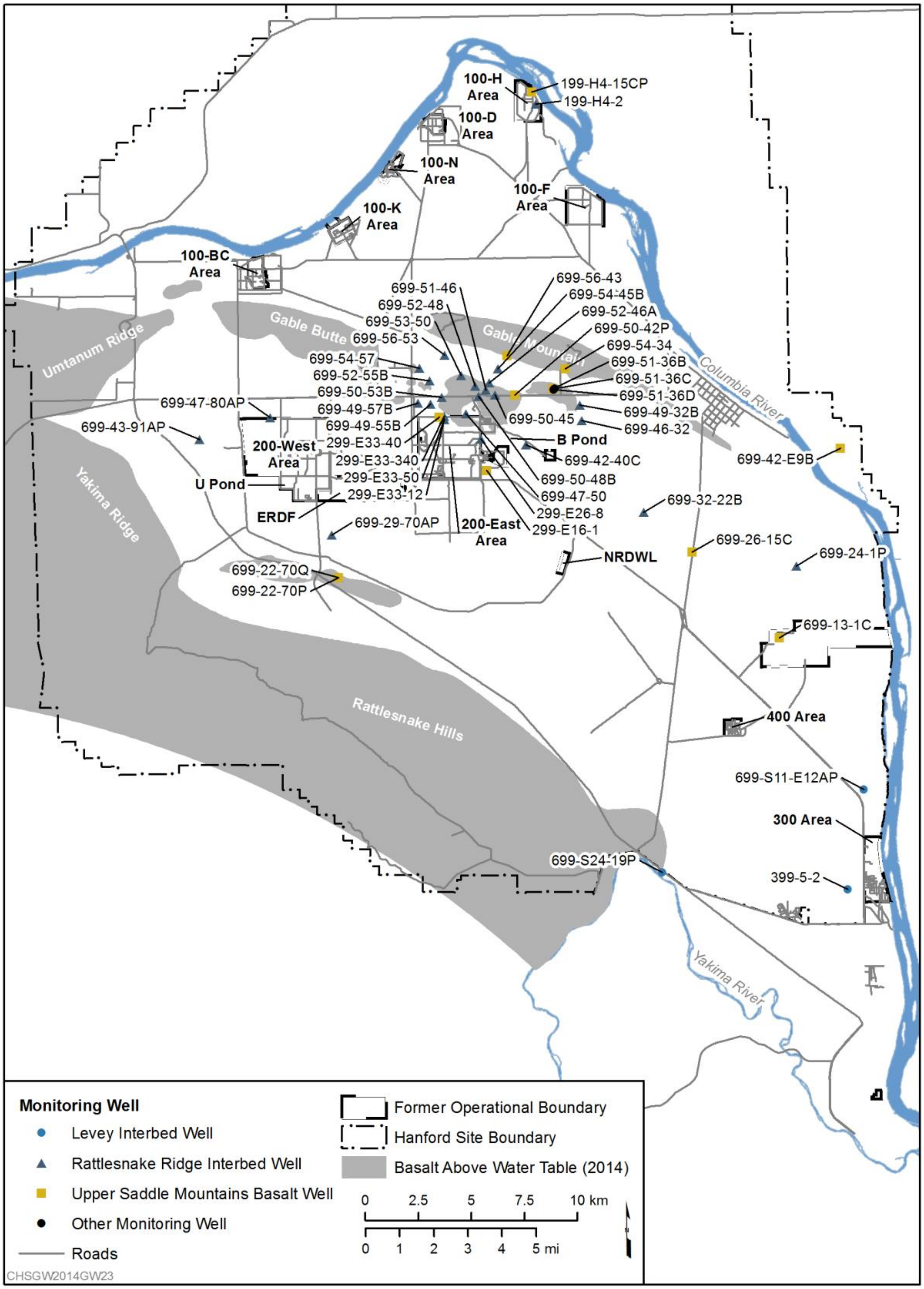

Figure D-3. Basalt-Confined Monitoring Wells

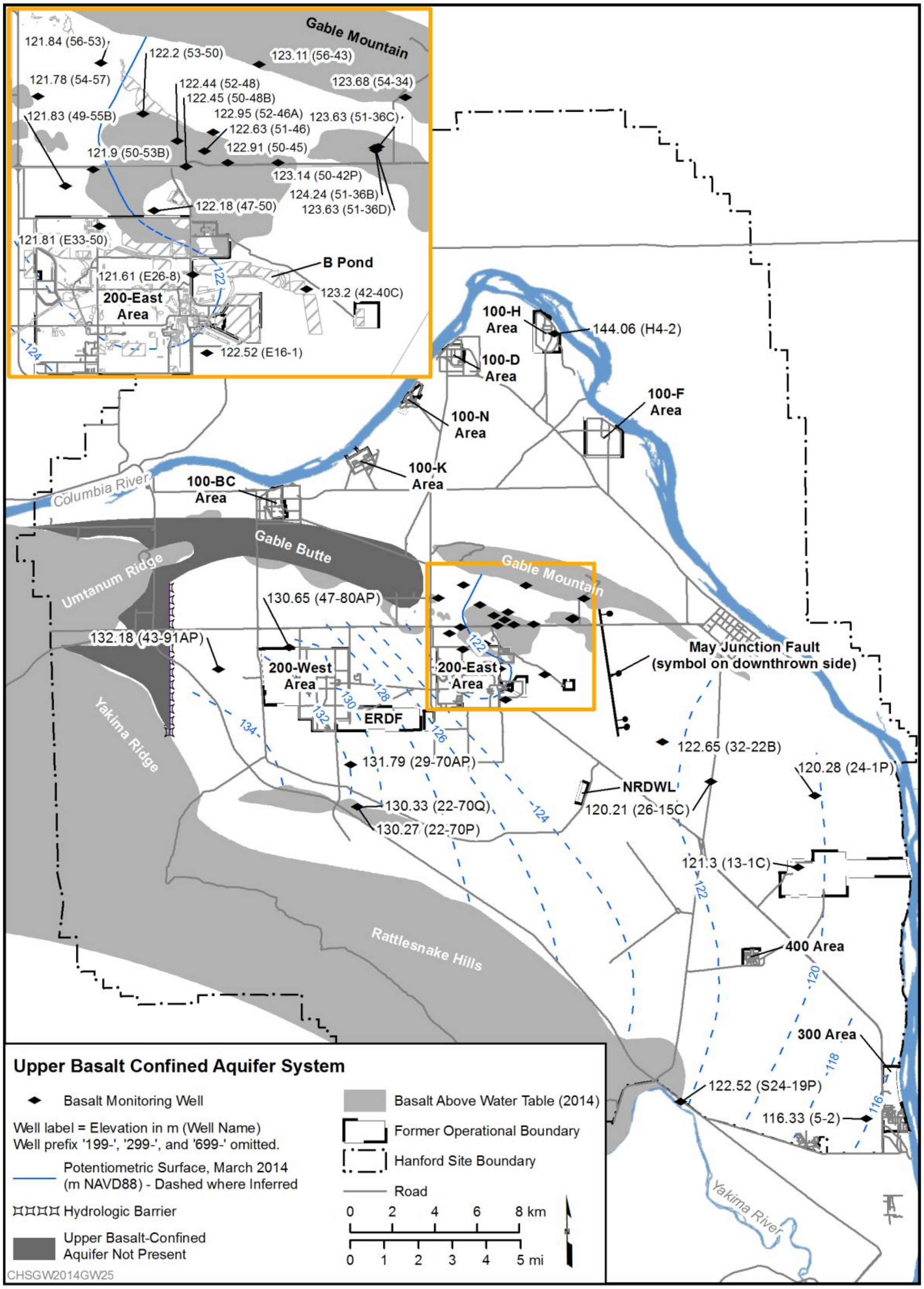

Figure D-4. Potentiometric Surface for Upper Basalt-Confined Aquifer, March 2014

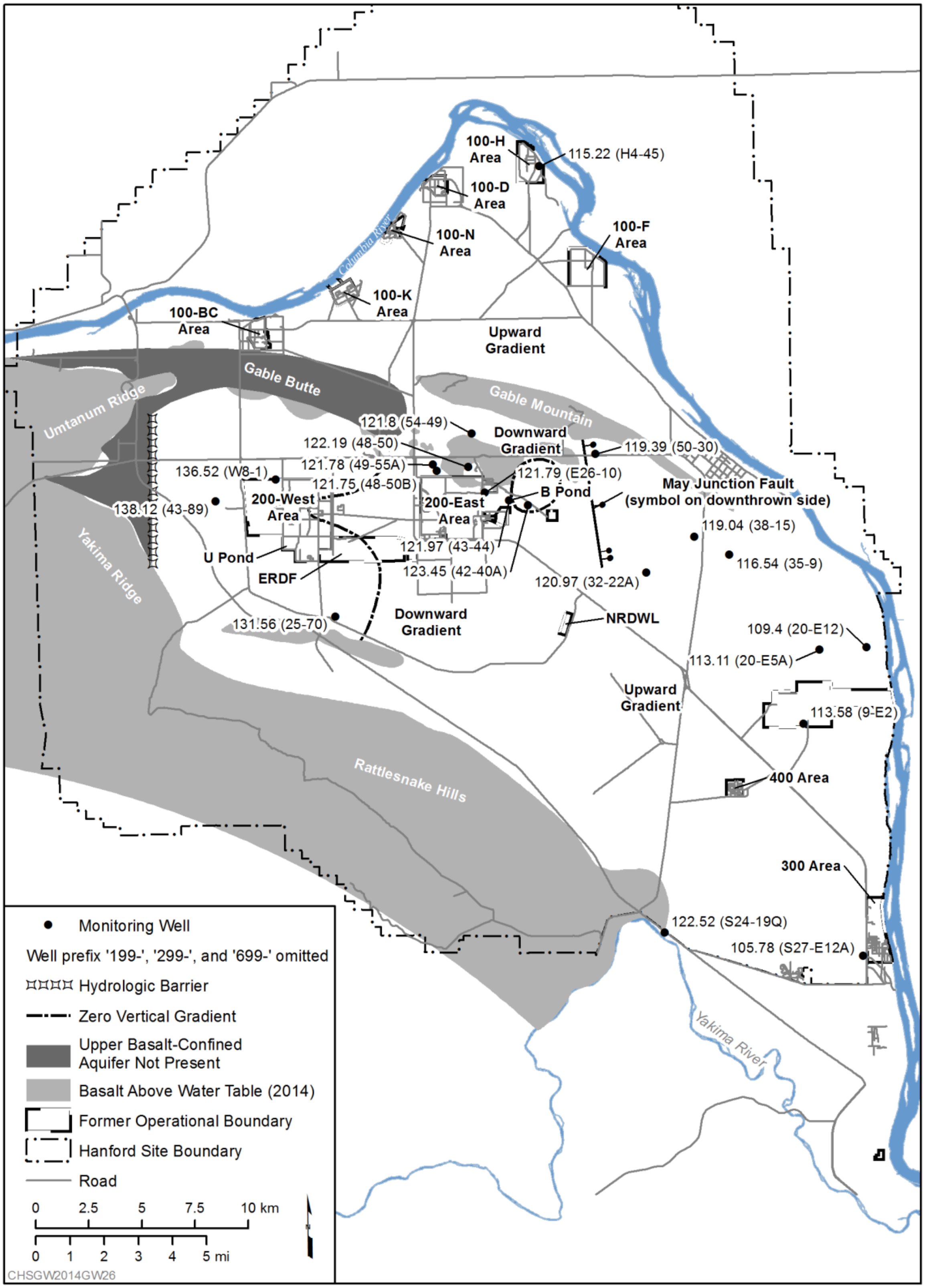

Figure D-5. Comparison of Observed Heads for Upper Basalt-Confined Aquifer and Overlying Unconfined Aquifer, 2014

Table D-1. Groundwater Quality in Ringold Confined Aquifers

Groundwater Interest Area	Wells Sampled	Groundwater Contamination[a] (DWS)
Wells Screened in Ringold Upper Mud Unit		
100-BC	199-B2-12, 199-B2-15	None
100-KR-4	199-K-32B, 199-K-192	None
100-NR	199-N-80	Hexavalent chromium (48 µg/L): up to 182 µg/L Tritium (20,000 pCi/L): up to 13,000 pCi/L
100-HR-D and 100-HR-H	199-D5-134, 199-D5-141, 199-D8-54B, 199-H2-1, 199-H3-10, 199-H3-2C, 199-H3-9, 199-H4-12C, 199-H4-15CS, 199-H4-90, 199-H4-91, 699-97-43C, 699-97-45B, 699-97-48C	Hexavalent chromium (48 µg/L): up to 179 µg/L
100-FR	199-F5-43B, 199-F5-53	None
Well Screened in Ringold Unit B		
100-HR-H	199-H4-15CR	None
Wells Screened in Ringold Unit A		
100-HR-H	199-H4-15CQ	None
200-ZP[b]	699-43-69, 699-45-69C	Carbon tetrachloride (5 µg/L) : up to 580 µg/L Chromium (filtered) (48 µg/L): up to 45.6 µg/L Nitrate (45 mg/L): up to 198 mg/L
200-UP	299-W22-24P, 699-42-67	Carbon tetrachloride (5 µg/L): up to 72 µg/L Nitrate (45 mg/L): up to 25.7 mg/L
200-BP	699-42-40A, 699-43-41G, 699-45-42	Iodine-129 (1 pCi/L): up to 2.2 pCi/L Tritium (20,000 pCi/L): up to 42,000 pCi/L
200-PO	699-24-1R, 699-28-40P, 699-40-36, 699-41-40, 699-42-37, 699-42-39B, 699-42-42B	Iodine-129 (1 pCi/L): up to 2.2 pCi/L Tritium (20,000 pCi/L): up to 34,000 pCi/L
300-FF	399-1-16C, 399-1-17C, 399-1-18C, 399-1-9, 399-8-5C, 699-S29-E16C	None

a. Evaluation based on data from 2012 through 2014.

b. Other wells in 200-ZP are screened in unit A where the lower mud is not present: 299-W6-6, 299-W7-3, 299-W11-88, 299-W12-2, 299-W12-3, 299-W14-73, and 299-W14-74. The aquifer is not confined at these locations, and results are not reported here.

Table D-2. Groundwater Quality in Upper Basalt-Confined Aquifer

Groundwater Interest Area	Wells Sampled	Groundwater Contamination[a]
100-H	199-H4-15CP	None
200-BP	299-E26-8, 299-E33-12, 299-E33-340, 299-E33-40, 699-42-40C, 699-49-55B, 699-49-57B, 699-50-45, 699-52-46A, 699-52-55B, 699-54-45B, 699-56-53	Cyanide: 27 µg/L[c] Iodine-129: undetected Nitrate: Up to 35.5 mg/L[c] Technetium-99: up to 1,000 pCi/L[c] Tritium: up to 3,200
200-PO	299-E16-1, 699-13-1C, 699-24-1P, 699-32-22B, 699-S11-E12AP, 699-S24-19P	None
300-FF	399-5-2	None
Offsite	699-42-E9B	None

a. Evaluation based on data 2011 through 2013.

b. Suspected corrosion product.

c. Not representative of basalt-confined aquifer. Migrated down wellbore from unconfined aquifer; see text.