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Revision 0

Path Forward Recommendations Report for the Uranium Contamination in the B Area

Prepared for the U.S. Department of Energy
Assistant Secretary for Environmental Management

Contractor for the U.S. Department of Energy
under Contract DE-AC06-08RL14788

CH2MHILL
Plateau Remediation Company
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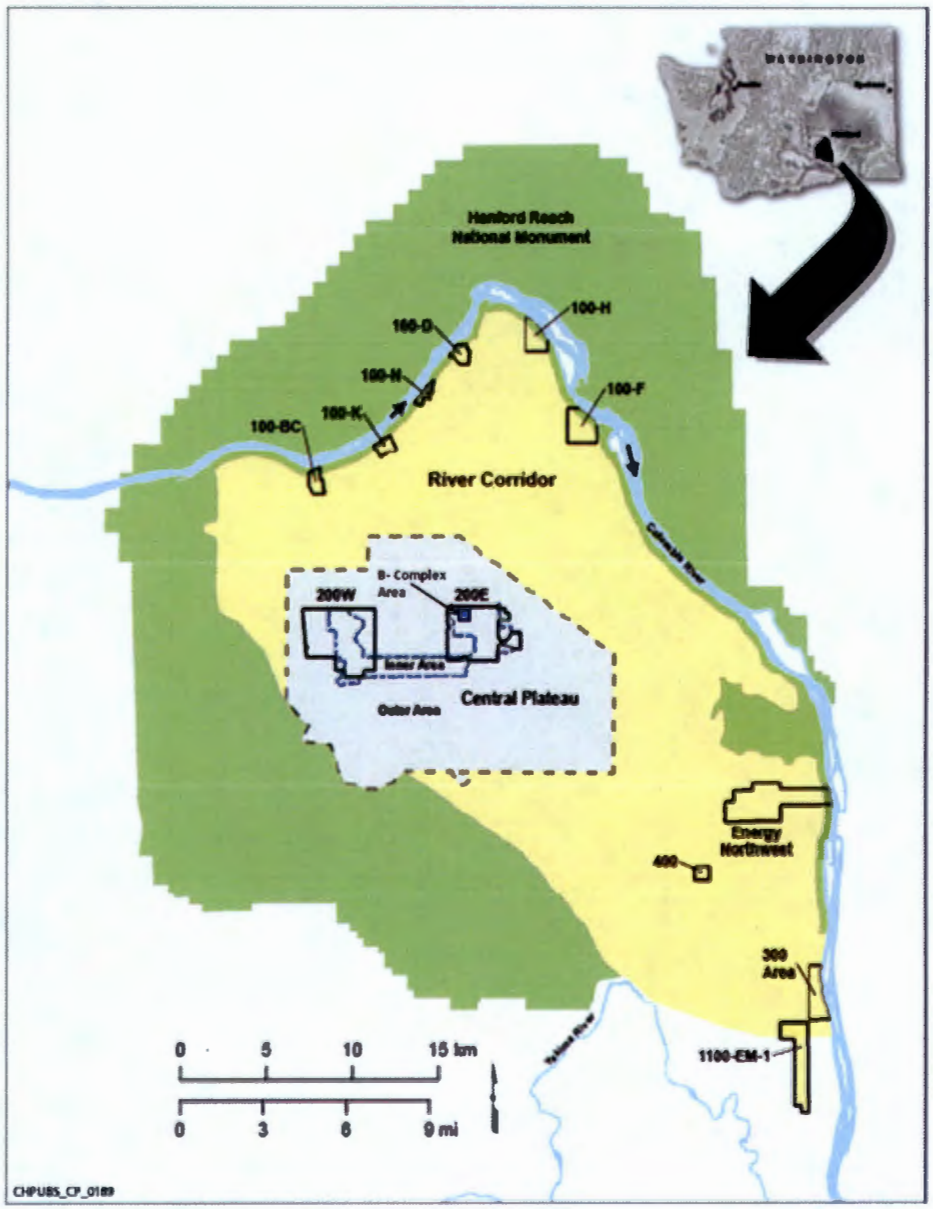
Terms

AMSL	above mean sea level
CERCLA	*Comprehensive Environmental Response, Compensation, and Liability Act of 1980*
CCU	Cold Creek Unit
CRBG	Columbia River Basalt Group
CSM	conceptual site model
DOE	U.S. Department of Energy
DOE-ORP	U.S. Department of Energy – Office of River Protection
ETF	Effluent Treatment Facility
H1 Unit	Hanford formation—gravel-dominated sequence
H2 Unit	Hanford formation—sand-dominated sequence
OU	Operable Unit
RCRA	*Resource Conservation and Recovery Act of 1976*
WRPS	Washington River Protection Solutions LLC

1 Introduction

Contaminated perched water is present in the deep vadose zone at the B Complex Area located in the 200 East Area of the Hanford Site (Figure 1). The B Complex Area includes waste sites in the 200-DV-1 Operable Unit (OU) and the B, BX, and BY single shell tank farms in Waste Management Area B-BX-BY (Figure 2). The perched water, which contains uranium, technetium-99, and nitrate at concentrations that have exceeded 70,000 µg/L, 45,000 pCi/L, and 100,000 µg/L, respectively, is a continuing source of contamination to groundwater in the underlying unconfined aquifer. Characterization and remediation of the perched water is being conducted as part of the 200-DV-1 OU, which was created in 2010 to support remedy selection for waste sites with deep vadose zone contamination.

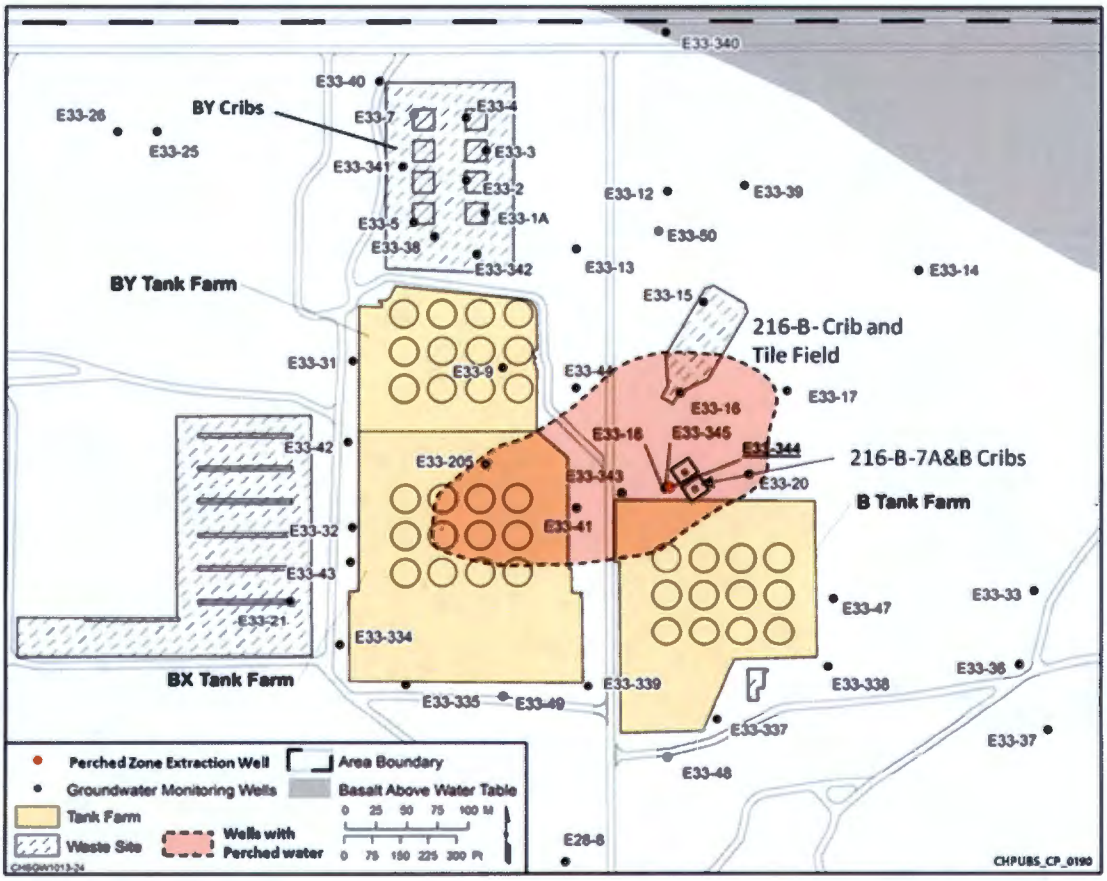


Source: Modified from DOE/RL-2011-118, *Hanford Site Groundwater Monitoring for 2011*.

Figure 1. Location of the B-Complex Area on the Hanford Site

The perched water zone extends from the east-central portion of the BX Tank Farm northeast to the 216-B-8 Crib and includes the northwest portion of the B Tank Farm (Figure 2). Perched water has been detected in this area since 1991 during drilling of wells to characterize groundwater contamination. Most recently, perched water was encountered during drilling of Well 299-E33-344 in January 2008 (Figure 2). This well was planned to be drilled through the unconfined aquifer as part of the *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA) remedial investigation for the 200-BP-5 Groundwater OU, but the drilling was terminated in the deep vadose zone because high levels of radiological contamination were detected in the perched water. The well was completed as a monitoring well in the perched zone (SGW-39626, *Borehole Summary Report for the Installation of Seven Groundwater Monitoring Wells at the 200-BP-5 Operable Unit, CY 2008*).

Extraction of the contaminated perched water began in 2011 to collect information on the perched water and to reduce impacts to the unconfined aquifer. Well 299-E33-344 was configured for use as the extraction well. As of September 2012, approximately 246,000 L (65,000 gal) of perched water containing approximately 13 kg of uranium, 0.1 g of technitium-99, and 132 kg of nitrate have been removed from the perched zone.



Source: Modified from PNNL-19277, *Conceptual Models for Migration of Key Groundwater Risk Contaminants Through the Vadose Zone and Into the Unconfined Aquifer Below the B-Complex* (Figure 1.1).

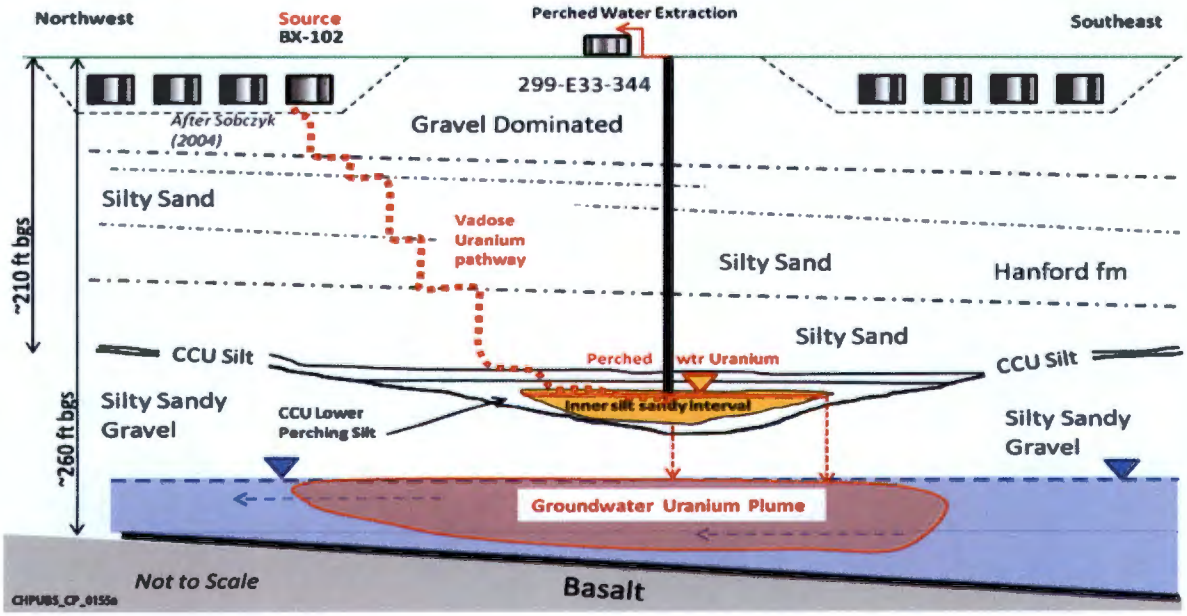
Figure 2. Location of Waste Sites, Tank Farms, and Wells in the B-Complex Area

2 Purpose

The purpose of this white paper is to update the conceptual site model (CSM) for the perched water and provide recommendations for additional characterization of the perched water zone as part of the 200-DV-1 OU remedial investigation. This CSM along with the characterization tasks outlined in this paper will be included in the 200-DV-1 OU work plan.

3 Conceptual Site Model

The integration and interpretation of borehole hydrogeologic, geochemical, and geophysical data sets were used to help resolve the nature of the perching horizon and the location and extent of the contaminated perched water within the perching zone. The resulting CSM indicates that the contaminated perched water is contained within a localized sand lens deposited in a structural low within a low permeability silt layer (CCU_z) in the Cold Creek Unit (CCU) (Figure 3). The top of the sand lens is approximately 72 m (235 ft) below ground surface; the maximum thickness of the sand lens is approximately 4.6 m (15 ft). The lateral and vertical extent of the perched water is limited to the presence of the sand lens and is approximately 4.6 m (15 ft) above the unconfined aquifer at its lowest point. The underlying silt layer forms a natural barrier that slows contaminant migration from the sand layer to the aquifer. Liquid wastes containing uranium, technetium-99, and nitrate have migrated vertically and laterally in the subsurface and accumulated within this sand lens. The sources of the contaminated water were the nearby 200-DV-1 OU waste sites (216-B-7A&B and 216-B-8 cribs), which were used for subsurface infiltration of liquid wastes, and the 241-BX-102 single shell tank, which released liquid waste to the subsurface when it was inadvertently overfilled.



Source: CP-51879, *200-DV-1 Operable Unit, B-Complex Perched Contamination Conceptual Site Model and Proposed Path Forward* (Page 20).

Figure 3. Conceptual Site Model of the Cold Creek Unit Perching Zone

The perched water extraction system has been operated for 212 days since full-scale pumping began in September 2011. The removal of 246,000 L (65,000 gal) during that time has lowered the elevation of the perched water by approximately 0.46 m (1.5 ft). The 246,000 L (65,000 gal) recovered represents

between 5 and 20 percent of the 1.25 to 5.03 million L (1.330 to 0.330 million gal) of perched water estimated to be contained within the sand layer. Following the initiation of pumping, the concentrations of uranium and technetium-99 increased significantly in samples of the perched water (Figure 4). The initial extraction of perched water from this well is thought to have removed the lower concentration residual water that had accumulated from disposal operations that occurred many decades ago at the 216-B-7A&B and 216-B-8 cribs which are located on the eastern margin of the perching silt layer. The large volumes of waste water disposed to these cribs most likely created the perched water zone, and subsequent perched water pumping pulled higher concentrations of uranium and technetium-99 from the west side of the perched zone, nearest the 241-BX-102 tank release, toward the extraction well.

Data are not available to estimate the capture zone from pumping this perching horizon. There are no observation wells and no hydraulic tests have been performed on samples from this zone or within wells drilled through the perched zone.

The CSM for the perched water zone provides the basis for identifying uncertainties associated with the nature and extent of the contaminated groundwater. Additional characterization of the extent and thickness of the sand layer will help to refine the extent of the perched water zone and the estimate of the volume of remaining perched water.

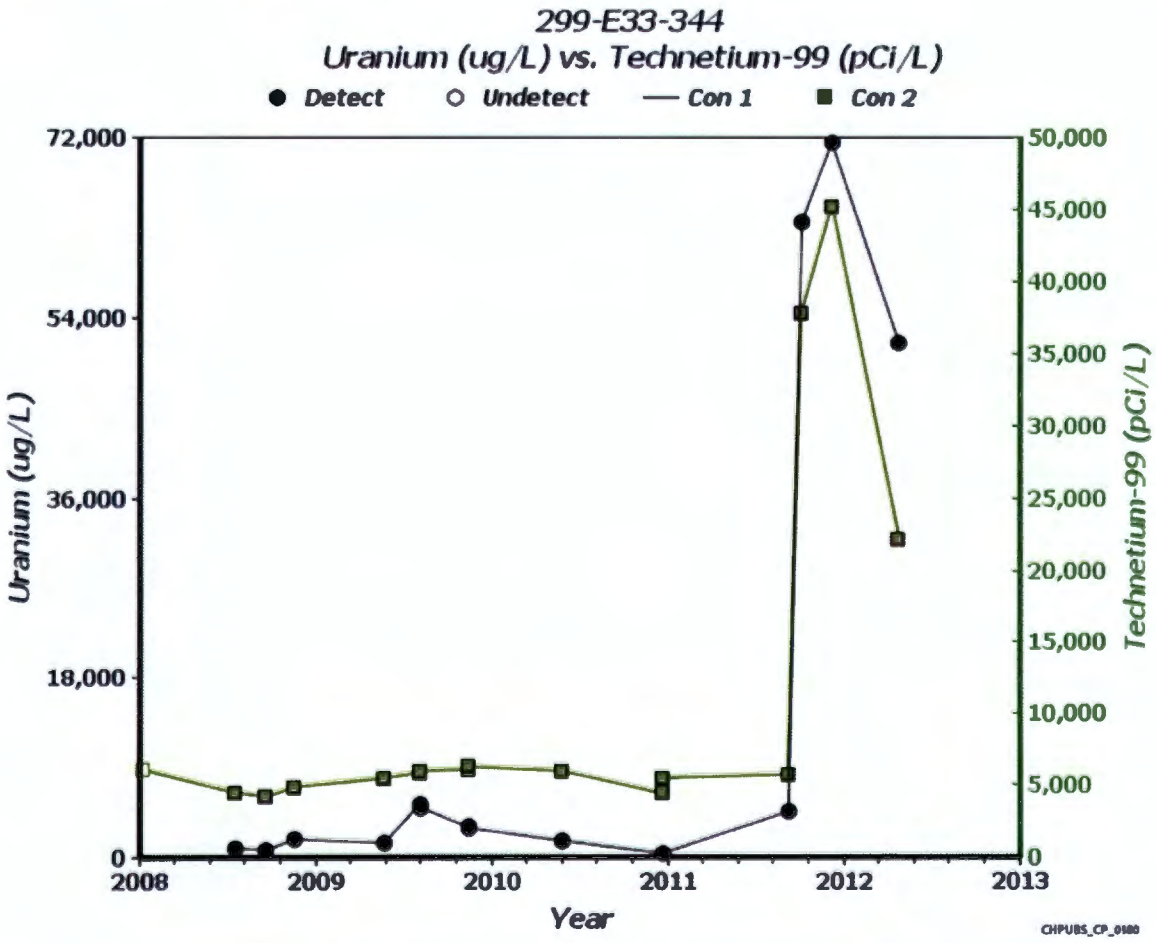


Figure 4. Increase in Uranium and Technetium-99 Concentrations in Well 299-E33-344 After Pumping Began in September 2011

4 Recommendations for Additional Activities for the Perched Water

The following characterization activities were developed to support the 200-DV-1 OU remedial investigation of the perched water zone:

- Continued perched water extraction
- Continued geophysical logging evaluation of wells in the vicinity of the perched zone
- Potential decommissioning of groundwater Well 299-E33-18 and installation of a replacement groundwater monitoring well
- Surface geophysical data evaluation
- Installation of additional perched water wells to characterize the nature and extent of the perched CCU interval and to accelerate recovery of contaminated perched water

4.1 Continued Perched Water Extraction

Extraction of the highly contaminated perched water will be continued using Well 299-E33-344 to remove the primary source of uranium contamination to the underlying groundwater in the B Complex Area. If left untreated, the uranium contamination in the perched water will continue to contribute contamination to the aquifer by slow leakage through the perching CCU_z silt layer. Groundwater samples will be collected during the pumping operation to better understand the mass of contaminants removed and extent of the perched water contamination. Monitoring of the pumping rate and recovery intervals will be used to support estimates of the volume and extent of water in the perched zone. These characterization and remediation activities will be continued as part of the 200-DV-1 remedial investigation at the B Complex Area.

The need to apply a vacuum to enhance the pumping rate will be evaluated as extraction continues. Vacuum-enhanced recovery of the perched water, followed by pore water extraction, would be implemented as a treatability test in accordance with DOE/RL-2011-40, *Field Test Plan for the Perched Water Pumping/Pore Water Extraction Treatability Test.*

4.2 Geophysical Logging Evaluation

Borehole geophysical logging will be used to assess the vertical extent and concentration of uranium contamination within the perched zone in the CCU in selected boreholes in the B Complex Area. Periodic spectral gamma logging profiles show changes in uranium concentration and extent; neutron moisture logging profiles show changes in vadose zone moisture content. These data will be used to evaluate locations and magnitudes of ongoing uranium contributions to groundwater and to assess the effectiveness of the perched water extraction to reduce perched liquid and uranium mass.

Following initiation of perched water extraction from Well 299-E33-344, the concentrations of uranium and technetium-99 increased in groundwater samples from Well 299-E33-18. Well E33-18 was drilled in 1950 and constructed without annular seals. The pumping may have caused contaminated perched water to migrate to Well 299-E33-18 and then to the groundwater along a preferential pathway. A subsequent neutron survey of the inside of the well casing has indicated that it was dry. However, the annular space around the outside of the casing may have provided the pathway. Geophysical logging of Well 299-E33-18 is scheduled for 2012 to evaluate/update the uranium contaminant profile in the deep vadose zone at this location.

4.3 Decommissioning of Well 299-E33-18

Well 299-E33-18 is one of the oldest wells in the area of the lower, perching CCU_z silt layer (Figure 2). Groundwater samples from this well contain the highest concentrations of uranium in the B Complex Area. Well 299-E33-18 was installed as an unsealed well through the CCU interval and appears to be providing a preferential pathway for contaminant migration from the perched zone to the unconfined aquifer. If geophysical logging, groundwater monitoring, and perched water monitoring indicate that Well 299-E33-18 is providing a preferential pathway to groundwater, the well will be decommissioned to remove the potential for continued contributions to groundwater contamination. Because of its key location in the area of highest uranium groundwater contamination, a new groundwater monitoring well will be installed to replace it. Well 299-E33-18 is tentatively scheduled to be decommissioned in 2017.

4.4 Surface Geophysical Data Evaluation

Existing surface geophysical data (seismic and resistivity lines) are available for the area and can be re-evaluated to support characterization of the lower CCU_z perching layer. Initially, short segments of geophysical profiles collected in the vicinity of the B Complex perched water will be reprocessed to determine whether the reprocessed data are able to identify geologic reflectors at the depth of the CCU (Page 33 of Appendix B). If this method is successful, additional segments of geophysical profiles will be reprocessed. Reprocessing will use a depth to basalt (the bedrock base of the unconfined aquifer) typical for the B Complex Area. Check shots will be performed in wells to refine the vertical profile of seismic travel times to support the reprocessing.

The reprocessed geophysical data will be used to delineate the lateral and vertical extents of the CCU_z silt interval and the CCU saturated zone. In addition, the data will be used to optimize the locations for additional perched water wells, if needed.

4.5 Installation of Additional Perched Water Wells for Characterization and Remediation

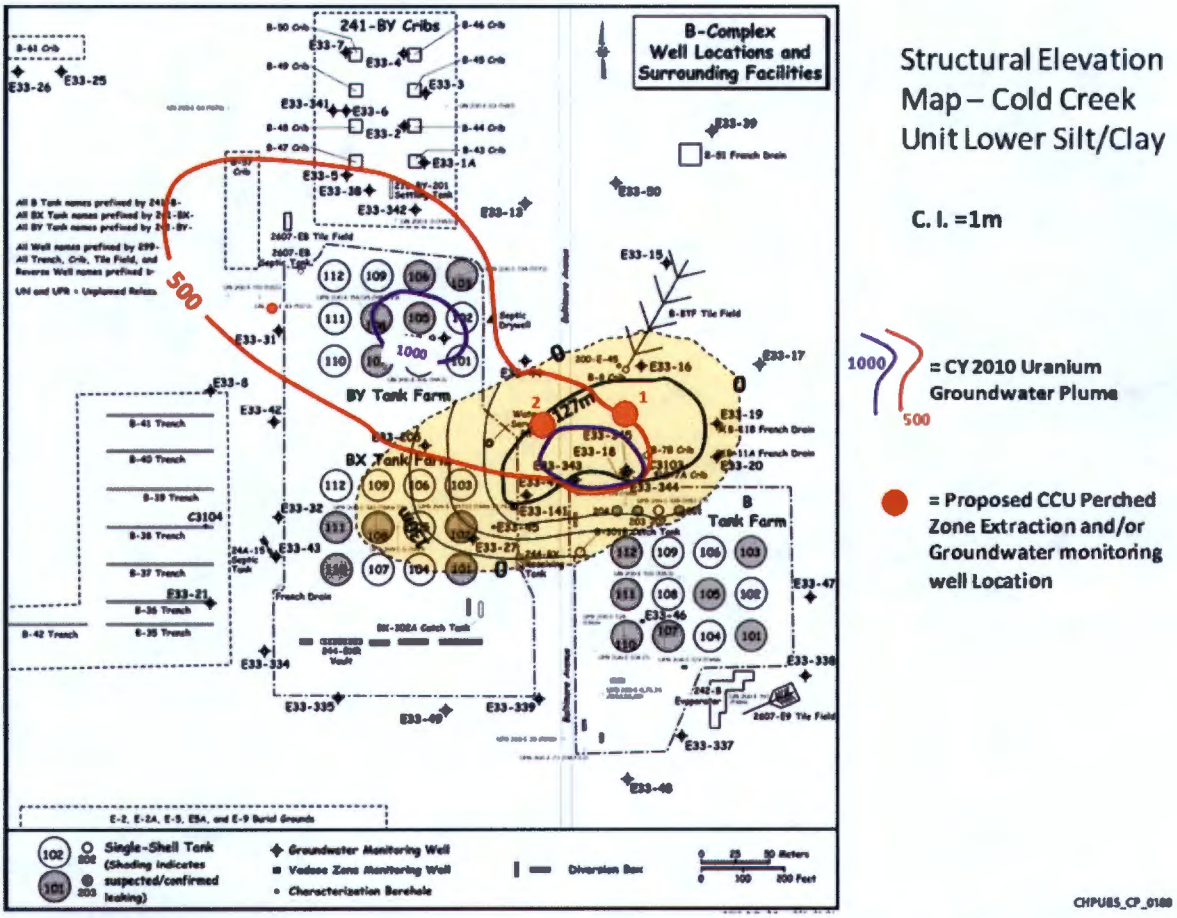
Two additional perched water wells are recommended to be installed to help characterize and remediate the perched water zone at the B Complex Area. Data collected during drilling will improve the understanding of the vertical and lateral extents of the CCU_z silt, which will then support better delineation of contaminant sources. After construction, the wells will be used to extract contaminated perched water, accelerating removal of the source of continuing uranium contributions to groundwater, or to monitor perched water during extraction from Well 299-E33-344.

The highest priority well is located north of Well 299-E33-344 between the 241-B Tank Farm and the 216-B-8 Crib (Figure 5). This location is potentially where the structural low in the CCU is deepest and the sand lens is the thickest. It is near the highest concentrations of uranium and technetium-99 in groundwater underlying the perched zone (Figure 5 and page 27 in Appendix B). Data collected during drilling at this location will support characterization of the northeastern extent of the sand lens within the CCU_z silt layer and will support evaluation of the 216-B-8 Crib as a source of water and contaminants in the perched zone.

The second well is located between Well 299-E33-344 and the 241-BX Tank Farm. This location is potentially in the path followed by the contaminated liquids that were released from the 241-BX-102 tank and accumulated in the CCU sand lens. It is near the highest concentrations of uranium and technetium-99 in groundwater underlying the perched zone (Figure 5 and page 27 in Appendix B). Data collected during drilling at this location will support characterization of the northwestern extent of the sand lens

within the CCU_z silt layer and will support evaluation of the 241-BX-102 tank as a source of water and contaminants in the perched zone.

Both wells will be drilled through the CCU to characterize the CCU interval. Samples of deep vadose zone sediments and perched water will be collected during drilling. In addition, a perched zone hydraulic test will be attempted to determine hydraulic conditions and improve recovery calculations. The highest priority well will be used to establish a perched water zone extraction/monitoring well between the 216-B-8 Crib and perched water extraction Well 299-E33-344. The second well will be used to provide additional extraction/monitoring capacity as needed.



Source: CP-51879, *200-DV-1 Operable Unit, B-Complex Perched Contamination Conceptual Site Model and Proposed Path Forward* (Page 35).

Figure 5. Proposed Well Locations for the Perched Water Zone at the B Complex Area

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Appendix A

B Complex Perched Water Conceptual Site Model Supporting Information

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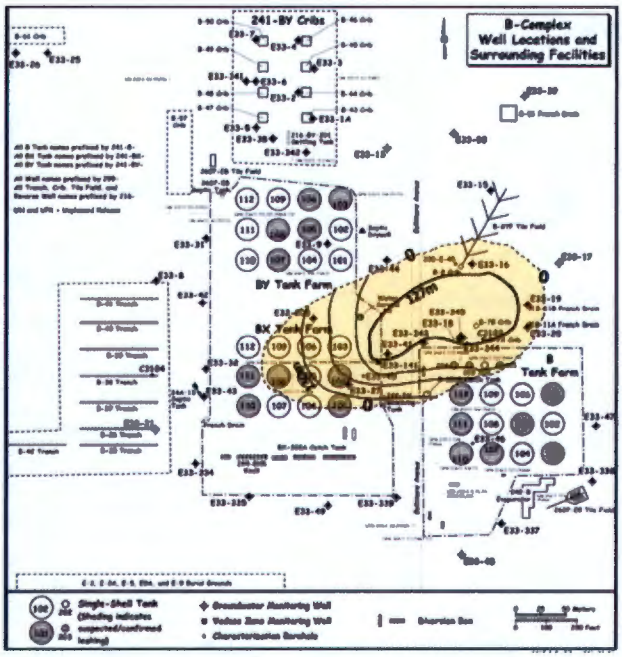
Appendix A

A1 Background

Perched water was identified and partially characterized during installation of *Resource Conservation and Recovery Act of 1976* (RCRA) tank farm groundwater monitoring wells as early as 1991 (e.g., Well 299-E33-41). Most recently, perched water was encountered during drilling of Well 299-E33-344 in January 2008 (Figure A-1). The well was planned to be drilled through the unconfined aquifer as part of the *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA) remedial investigation for the 200-BP-5 Groundwater OU, but the drilling was terminated in the deep vadose zone because high levels of radiological contamination were detected in the perched water. The well was completed as a monitoring well in the perched zone (SGW-39626, *Borehole Summary Report for the Installation of Seven Groundwater Monitoring Wells at the 200-BP-5 Operable Unit, CY 2008*). A replacement well (299-E33-345) was drilled through the aquifer and completed as a groundwater monitoring well to meet the 200-BP-5 remedial investigation requirements. Well 299-E33-345 is approximately 2.25 m (7.5 ft) northwest of Well 299-E33-344 and encountered the perching horizon in approximately the same depth interval.

The saturated portion of the perched zone at this location was encountered at approximately 68.3 m (224 ft) below land surface and is approximately 4 m (13 ft) thick. The perched water thickness is based on the difference between the perched water elevation in Well 299-E33-344 and the top of the underlying low permeability perching zone identified in sediment characterization samples and confirmed by nearby replacement Well 299-E33-345 (Figure A-2). The unconfined aquifer is approximately 5.2 m (17 ft) below the bottom of the perched water zone in Well 299-E33-344, based on comparison of the water table elevation in Well 299-E33-345 to the top of the perched zone silt in Well 299-E33-344.



Source: Modified from PNNL-19277, *Conceptual Models for Migration of Key Groundwater Risk Contaminants Through the Vadose Zone and Into the Unconfined Aquifer Below the B-Complex* (Figure 1.1).

Figure A-1. Location of Waste Sites, Tank Farms, and Wells in the B Complex Area and Approximate Extent of the Perched Water

A2 Characterization

Geologic descriptions of the various stratigraphic units beneath the B Complex Area are provided in Sections 2.3 and 2.5 of PNNL-19277, *Conceptual Models for Migration of Key Groundwater Risk Contaminants Through the Vadose Zone and Into the Unconfined Aquifer Below the B-Complex*. This white paper provides a more detailed discussion of the lower vadose zone stratigraphy, hydrology, and contaminant distribution with a focus on the Cold Creek hydrogeologic interval that creates the perched water condition and contaminant zone affecting the unconfined aquifer.

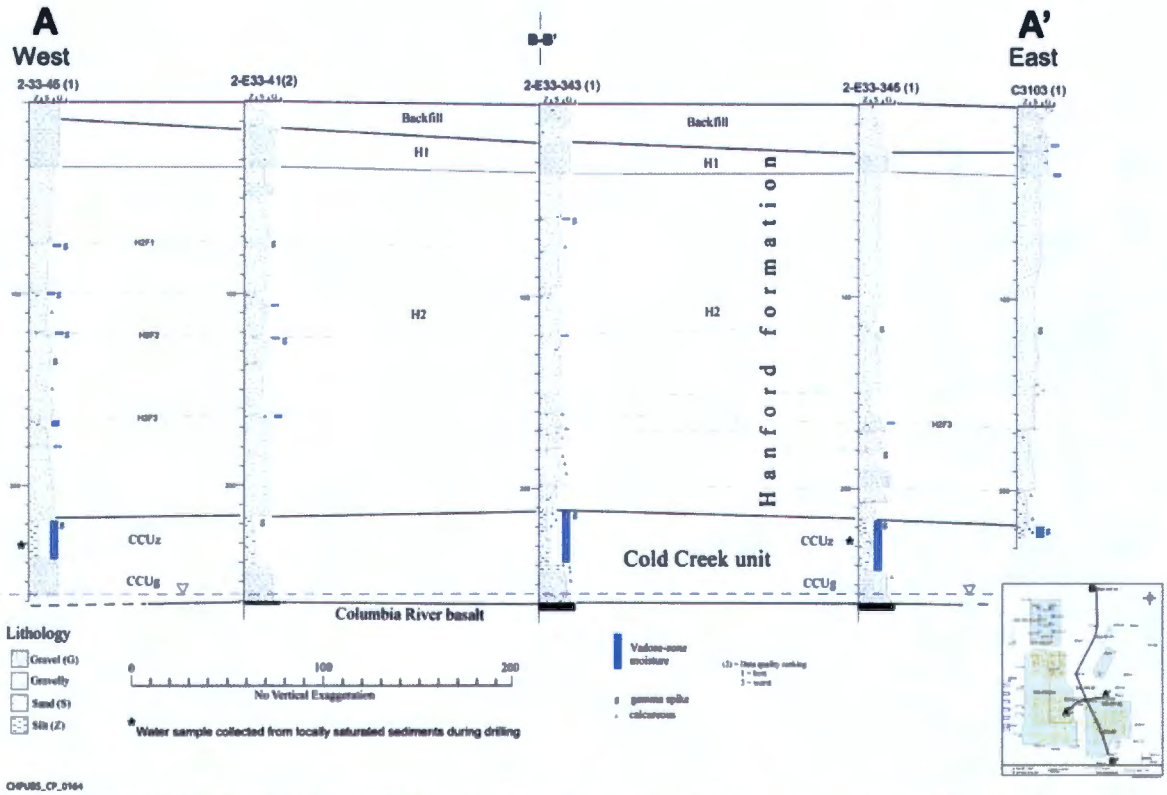
A2.1 Hydrogeology

As summarized from PNNL-19277, the geology beneath the B Complex Area is composed of five stratigraphic units, defined below in descending order as:

- Hanford formation—gravel-dominated sequence (H1 unit)
- Hanford formation—sand-dominated sequence (H2 unit)
- Cold Creek unit silt—fine grained (CCU_z)
- Cold Creek unit gravel—coarse grained (CCU_g)
- Columbia River Basalt Group—bedrock (CRBG)

Recent backfill material was added to the surface during construction of the tanks, cribs, and trenches used for liquid waste storage or disposal. The Hanford H1 unit underlies disturbed and manmade structures and consists of highly permeable gravel-dominated basaltic sediment. The Hanford H2, a sand-dominated unit, underlies the H1 unit, extends vertically through approximately two thirds of the vadose zone, and is the thickest of the units; the H2 contains several thin, fine-grained silty lenses that promote horizontal spreading of waste liquids that accumulate and migrate through the vadose zone (Figure A-2). The Cold Creek unit (CCU), which contains the perching interval, underlies the H2 and is the focus of this paper. The Columbia River Basalt Group (CRBG) forms the bedrock and bottom of the unconfined aquifer and lies just a few meters (feet) below the bottom of the CCU perching silt layer (CCU_z). Highly transmissive, coarse-grained gravelly deposits (CCU_g) overlie basalt and form the sediment interval containing the unconfined aquifer. Groundwater within the unconfined aquifer is known to contain uranium, technetium, and nitrate contaminants from past operations and leaks at the B-Complex. A detailed discussion of the stratigraphy and hydrology of the perching CCU is provided below.

The Cold Creek unit (CCU_z and CCU_g) consists of one or more silt and fine sand layers (CCU_z) and an underlying gravel layer (CCU_g). The unconfined aquifer lies within the CCU_g. The overlying CCU_z silt layer is believed to be overbank-flood plain alluvium from the ancestral Columbia River, while the gravel layer represents fluvial deposits of the ancestral Columbia River. Within the B Complex Area, the overall CCU_z silt interval is up to 7.6 to 8.5 m (25 to 28 ft) thick (in Wells 299-E33-16, E33-18, E33-343, and E33-345 [Figure A-3]), and is composed of at least two well-sorted silt intervals separated by fine-to-coarse silty sand. The CCU_z silt interval is deposited on the underlying CCU_g which directly overlies CRBG bedrock; the CCU_g ranges from approximately 4.6 m (15 ft) to 18 m (60 ft) thick (Figure A-2) across the B Complex. Within the B Complex, the CCU_z silt interval thickens within structural lows formed on the surface of the underlying CCU_g. Some portion of the CCU_z can be traced across most of the B Complex. However, the thickest CCU_z interval and the lower CCU_z silt strata that forms the perching horizon, allowing perched water to accumulate, is localized in a CCU_g low that trends southwest to northeast across the BX and B Tank Farms (Page 18 in Appendix B). Elsewhere in the B Complex Area the CCU_z was either subsequently eroded or not deposited. The top of the CCU_z interval dips slightly toward the northeast (PNNL-19277, Section 2.5.3).

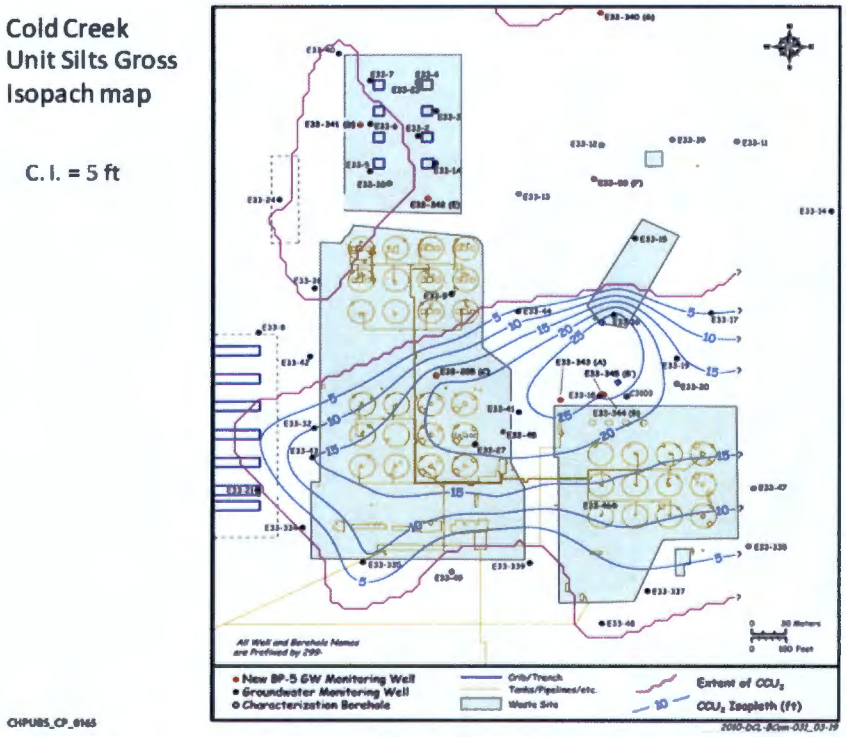


Source: PNNL-19277, *Conceptual Models for Migration of Key Groundwater Risk Contaminants Through the Vadose Zone and Into the Unconfined Aquifer Below the B-Complex* (Figure 2.2).

Figure A-2. Hydrogeology of the Vadose Zone Showing the Cold Creek Unit in the Perched Water Area

A cross section from the north central portion of BX Tank Farm to the northwestern portion of the B Tank Farm is shown in Figure A-2. The cross section illustrates the entire vadose zone thickness and includes zones of elevated moisture associated with thin, fine-grained layers in the Hanford H2 unit, the gross CCU_z silt interval, the CCU_g sandy gravel, the underlying CRBG bedrock, and the relatively thin unconfined aquifer.

The correlation of the CCU interval in the B Complex Area was refined in 2012 to more precisely define and evaluate the extent of the perched zone contamination (CP-51879, *200-DV-1 Operable Unit, B-Complex Perched Contamination Conceptual Site Model and Proposed Path Forward*). Geologic borehole data (geologic descriptions and core), along with borehole geophysical logging results, were integrated in the evaluation and provide a detailed interpretation. Results show that the CCU_z interval locally consists of an upper and lower silt layer separated by a more permeable, coarser-grained silty sand layer. The lower silt layer forms the perching horizon, and is limited in extent to the area defined by the structural trough formed on the underlying CCU_g surface (Page 18 in Appendix B). Coarser grained silty sand overlying the lower CCU_z silt interval becomes saturated with liquid waste that accumulates, creating a perched aquifer. The uppermost silt layer has a much greater lateral extent, but data indicate that this upper layer doesn't have the same hydraulic properties conducive to perching.

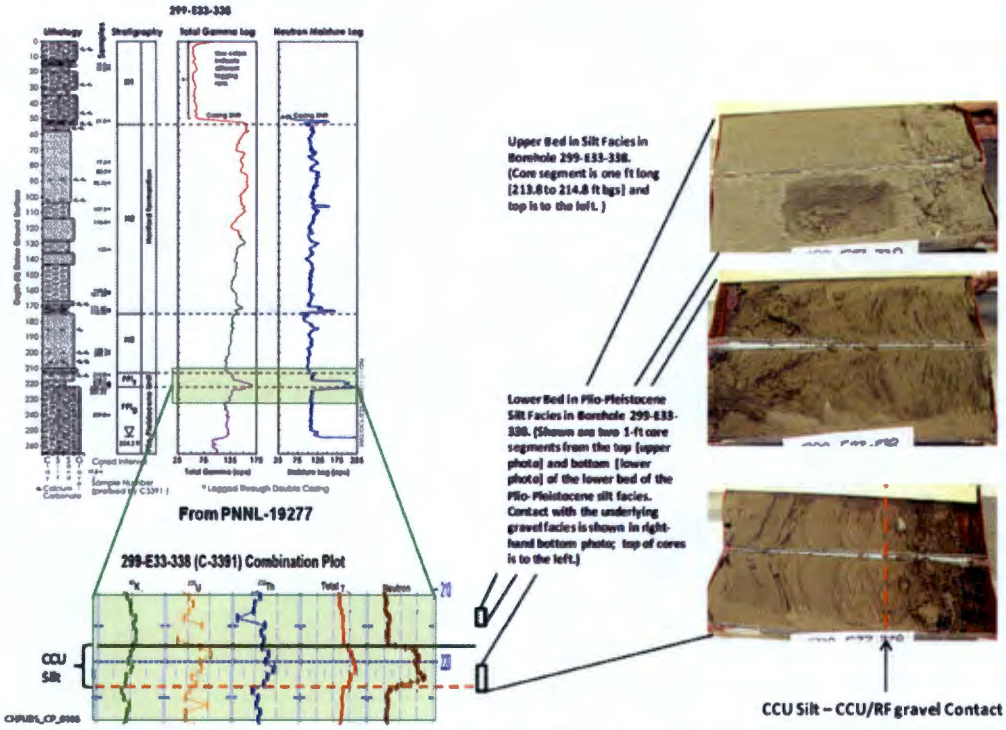


Source: PNNL-19277, *Conceptual Models for Migration of Key Groundwater Risk Contaminants Through the Vadose Zone and Into the Unconfined Aquifer Below the B-Complex.*

Figure A-3. Isopach Map of Cold Creek Unit

The geologic descriptive data, and observations of the borehole drill cuttings and core samples, have been used to delineate the overall gross CCU_z interval, the underlying CCU_g, and basalt. The geophysical borehole log data provide improved and detailed fine-grained strata delineation, moisture zone identification (including saturated conditions), and the identification and vertical distribution of gamma emitting man-made contamination (e.g., uranium). In addition these data allow detailed well-to-well correlation. Figure A-4 (and Page 5 in Appendix B) illustrates the CCU_z hydrogeologic correlation in Well 299-E33-338, which is located outside of the perched water contamination area southeast of the B Tank Farm. Geologic core and geophysical borehole log data are used to complete this interpretation and illustrate the vertical location of the CCU_z overlying the CCU_g. The intact sediment core photographs corroborate the interpretation, illustrating the much finer-grained silt unit overlying the CCU_g and the increased moisture within the silt zone, which is also precisely delineated using the geophysical borehole neutron moisture log data. The hydrogeologic evaluation of each of the B Complex boreholes was completed using all available information; highlights of some of these are further discussed below. In some cases, older well data were limited to driller logs, or to limited geologic and older geophysical log data.

The hydrogeologic interpretation (Well 299-E33-345) near the northwest corner of the B Tank Farm, where the overall CCU is thickest, shows that a sand lens occurs between the two silt layers of the Cold Creek unit (Figure A-5, and Page 6 of Appendix B). The geologic data and geophysical gamma and neutron moisture logs are used to identify these layers. The neutron moisture log indicates that both silt zones as well as the bounded sand layer contain elevated moisture levels. The gamma log data define these silt layers and also the radiological anomaly caused by the manmade uranium contamination which can be defined within the saturated sand layer. These data show the sand layer is also saturated, is contaminated with uranium, and is perched on the lower silt layer.



Source: PNNL-19277, *Conceptual Models for Migration of Key Groundwater Risk Contaminants Through the Vadose Zone and Into the Unconfined Aquifer Below the B-Complex.*

Figure A-4. Cold Creek Unit Identification and Correlation in Well 299-E33-338

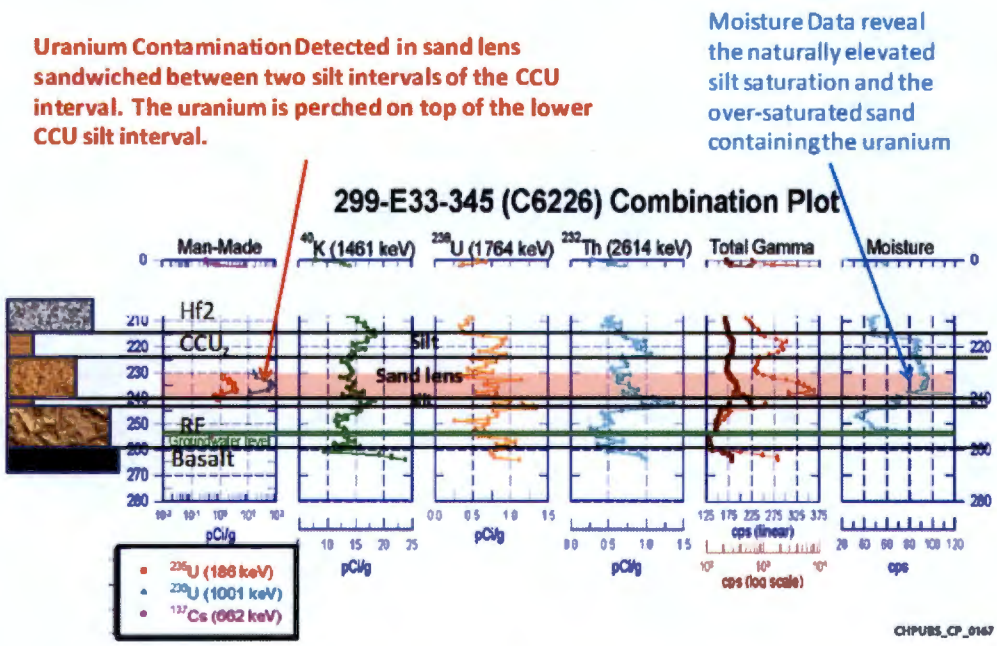


Figure A-5. Lower Vadose and Cold Creek Unit Hydrostratigraphy and Contaminant Identification

The hydrostratigraphic correlation and contaminant zone identification is continued in the perched zone extraction well (Well 299-E33-344), which has a depth-limited and reduced dataset, by correlating to the deeper, more complete nearby Well 299-E33-345 (Figure A-6 and Page 7 in Appendix B). The CCU upper and lower silt layers, interlayered sand lens, underlying CCU_g, and CRBG bedrock can be correlated between Wells 299-E33-345 and 299-E33-344 (approximately 2 m to the southeast of Well 299-E33-345) by correlating and extrapolating the geophysical log characteristics identified in Well 299-E33-345 to Well 299-E33-344. These data illustrate the continuity of the perching lower CCU_z layer, the overlying contaminated and saturated sand lens, and the overlying upper CCU_z layer. Based on the sediment samples and the neutron moisture log correlations, the data also show there is no perched, or saturated condition existing on top of the upper CCU_z silt layer that forms the top of the overall CCU interval.

The hydrostratigraphic correlation was continued to surrounding wells, including recently drilled Well 299-E33-343 (approximately 37 m to the west of Well 299-E33-345) (Figure A-7 and Page 8 in Appendix B). The Cold Creek unit upper and lower silts show an increase in total gamma activity; the sand has a lower total gamma activity. The upper and lower silt and interlayered sandy lens have elevated moisture concentrations. In Wells 299-E33-345 and 299-E33-343, the moisture content is highest near the top of the lower silt (Well 299-E33-344 was not logged below the top of the sand interval).

Well 299-E33-18, which is approximately 3 m southwest of Well 299-E33-345, was drilled in 1950 during active liquid disposal at nearby cribs. Changes in the gamma activity between geophysical logging results in 1959 and 1976 suggest that contaminated perched water may have been present in the lower Hanford formation on top of the CCU and the lower CCU_z silt and sand during 1959. The interpretation of the presence of the Cold Creek unit upper and lower silt and interlayered sand is based on Well 399-E33-343, which is 35 m to the west (Figure A-8 and Page 9 in Appendix B).

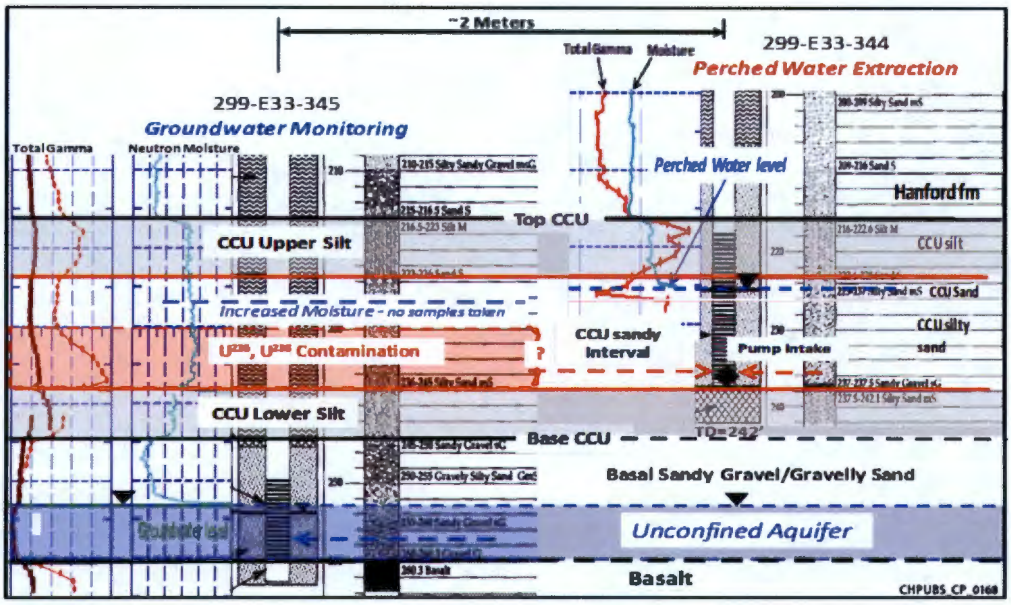


Figure A-6. Detailed Cold Creek Unit Hydrostratigraphy and Contaminant Identification in Perched Water Extraction Well 299-E33-344

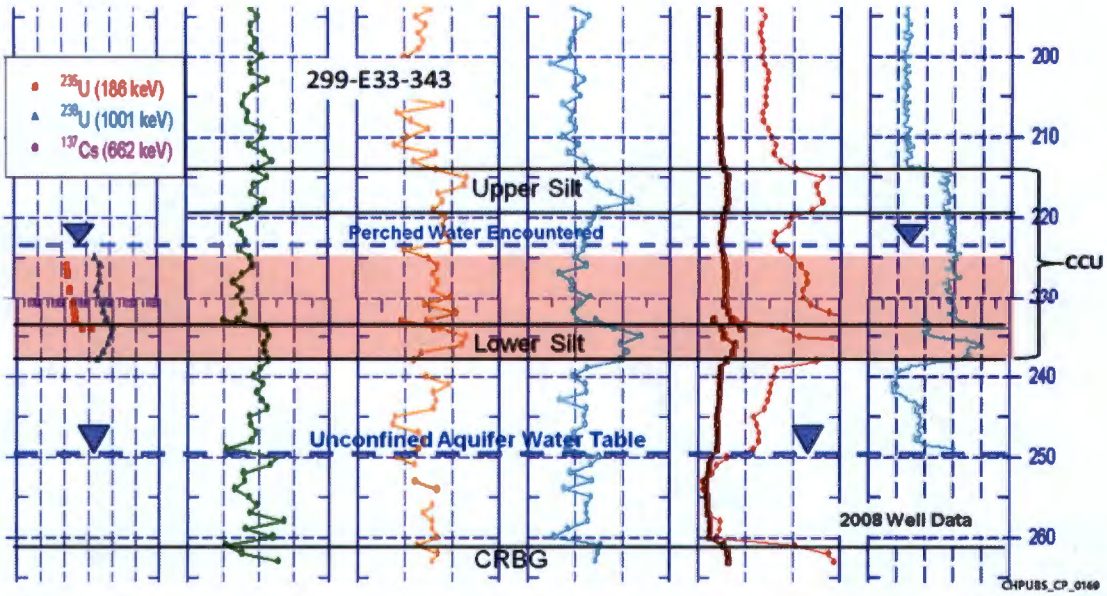


Figure A-7. Detailed Cold Creek Unit Hydrostratigraphy and Contaminant Identification in Well 299-E33-343

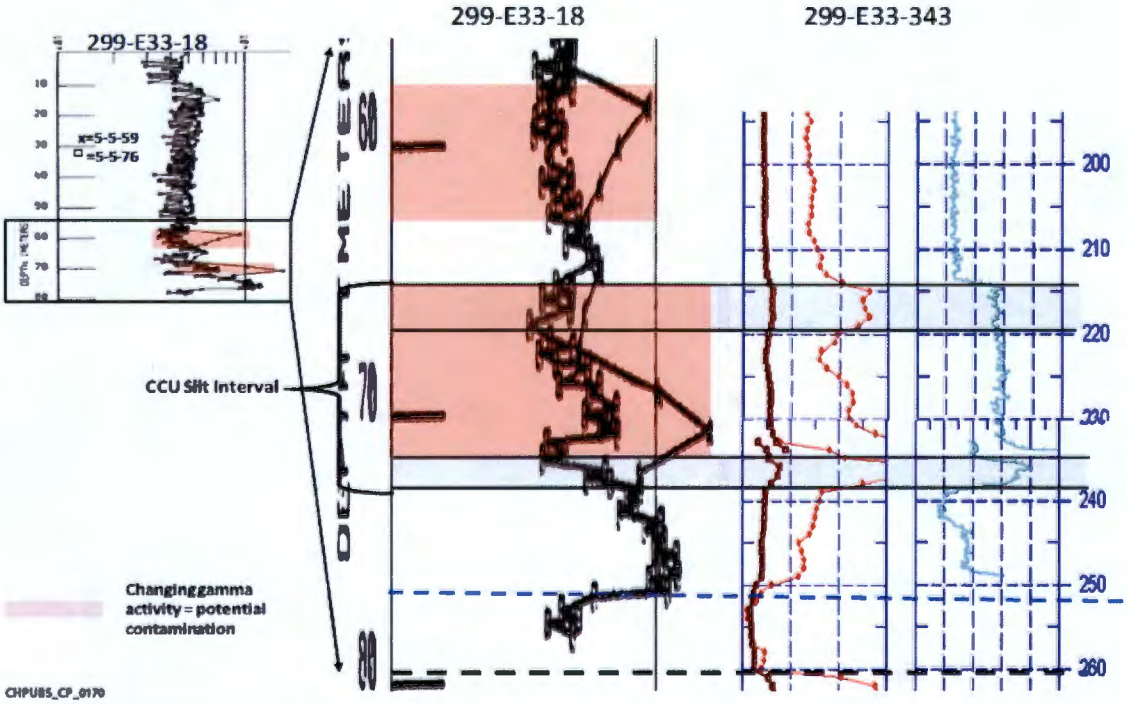


Figure A-8. Geophysical Borehole Log Comparison and Correlation in Well 299-E33-18, Highlighting Changes in Gamma Signal (i.e., Contamination) Between 1959 and 1976

Well 299-E33-45, at the eastern perimeter of BY Tank Farm, was drilled and logged in 2001, before extensive perched zone characterization had occurred. The total gamma activity profile of the CCU can be used to interpret the presence of the upper and lower silt units separated by the sand layer (Page 10 in Appendix B). Perched water was encountered in this well during drilling. Based on the refined hydrogeologic interpretation, the perched zone was in the sand layer overlying the lower silt (Page 11 in Appendix B). Interestingly, man-made gamma contamination was not encountered at that time in the perched water zone or CCU even though it was saturated, but uranium contamination was detected shallower in the vadose zone within the overlying H2 sand-dominated interval (Page 10 in Appendix B). This well is very close to the single shell Tank 241-BX-102 that is the presumed source of the uranium contamination, and the shallow detection of that contamination indicates the contamination has either not migrated vertically downward to the CCU perched zone, or has migrated laterally into other regions of the vadose zone and continued to descend to the CCU elsewhere.

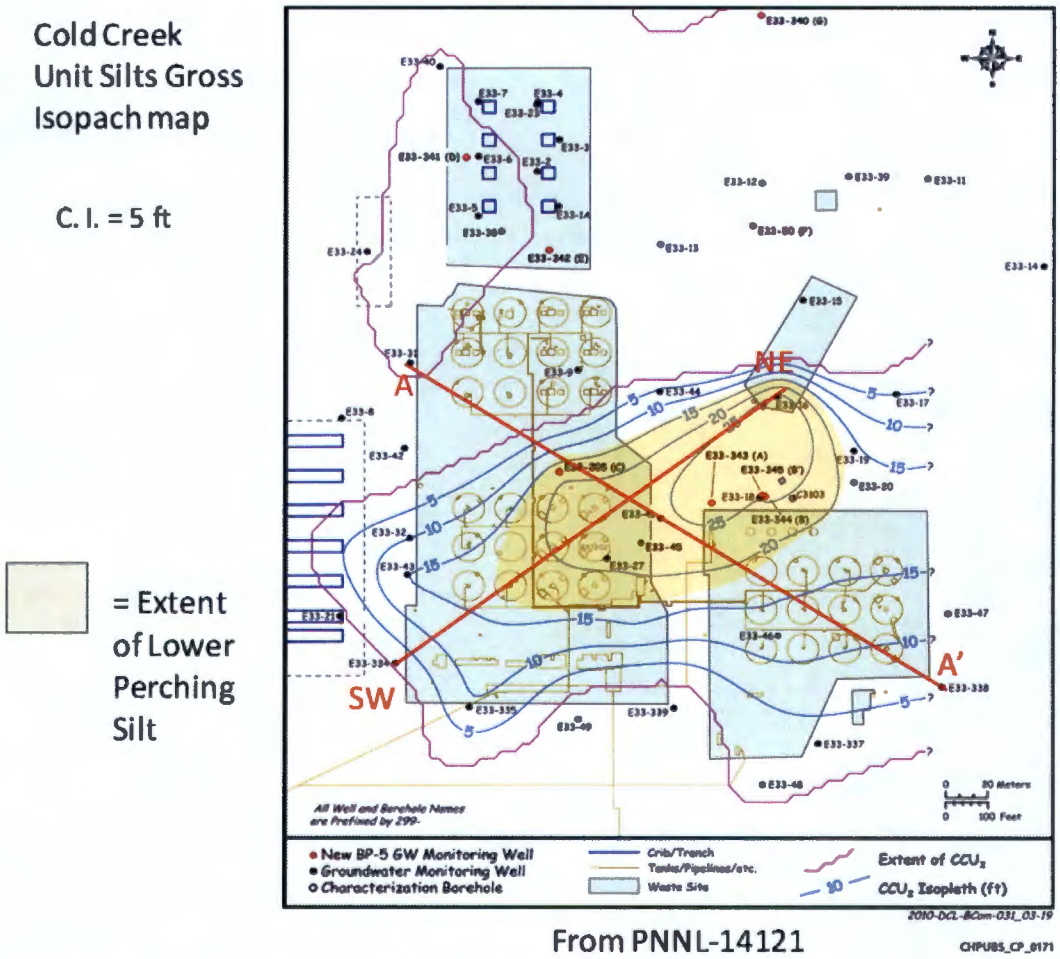
Well 299-E33-41 was drilled as a RCRA groundwater monitoring well on the eastern perimeter of BY Tank Farm in 1991. This well is located further east, away from single shell Tank 241-BX-102 and well 299-E33-45, which encountered contamination at shallower depths in the H2 unit. Based on the refined interpretation of the 1991 geophysical log data (gross and man-made gamma activity), the Cold Creek unit was identified in Well 299-E33-41 and includes the upper and lower silt layers separated by the sand layer. Man-made uranium contamination was detected in the geophysical logs over an extensive vadose interval that includes the deep H2 unit and the CCU. This well location and the distribution of uranium within the vadose zone support the interpretation that contaminated fluids from the 241-BX-102 overfill event migrated vertically and laterally along silt zones within the H2 unit, eventually reaching the CCU. Based on the geophysical log data, the contamination is contained within the CCU and overlying H2 unit and does not affect the unconfined aquifer at this location.

Based on the refined interpretation of the Cold Creek unit in the B Complex Area boreholes where the Cold Creek unit is present, the lateral extent of the lower CCU_z silt unit is shown in Figure A-9. Where the lower CCU_z silt layer is present, it is overlain by the sand layer and the upper silt unit. Outside of this area, the sand layer is not present, and only one silt layer is present. The perched water occurs within the sand layer and is perched on the top of the lower CCU_z silt layer. The northwest to southeast hydrogeologic cross section A-A' (Figure A-10) illustrates the occurrence of the perched water zone within the sand layer overlying the lower CCU_z silt layer.

The extent of the CCU_z lower silt and overlying sand layer roughly corresponds to the extent of a lower elevation trough formed by the underlying CCU_g surface (Page 18 in Appendix A). The structural low in the gravel is oriented southwest-northeast. The surface of the lower silt layer reflects the surface of the underlying gravel layer and also forms a trough oriented southwest-northeast (Page 19 in Appendix B).

A2.2 Perched Water

Wells have been drilled in the B Complex Area to characterize and monitor the groundwater. Perched water conditions or highly elevated vadose zone moisture levels were encountered in several wells in the area during drilling. The wells within the area with detectable levels of elevated moisture in the vadose zone and/or perched water are identified in Table A-1.

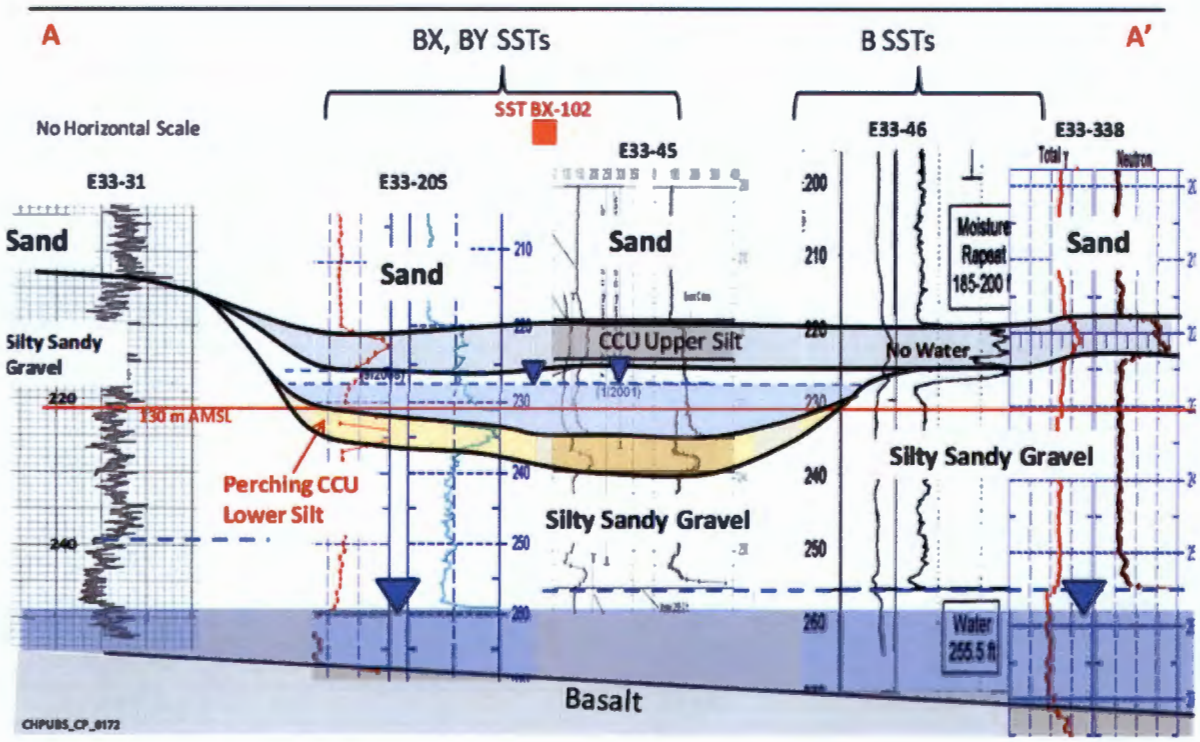


Sources: CP-51879, *200-DV-1 Operable Unit, B-Complex Perched Contamination Conceptual Site Model and Proposed Path Forward.*

PNNL-14121, *Characterization of Vadose Zone Sediment: RCRA Borehole 299-E33-338 Located Near the B-BX-BY Waste Management Area.*

Figure A-9. Extent of Cold Creek Unit Lower Silt Layer

Well 299-E33-344 is the only well completed within the perched water zone. Between July 2008 and December 2010, the elevation of the perched water in Well 299-E33-344 was measured ten times (Figure A-11). The first measurement of the perched water was 130.60 m (428.48 ft) above mean sea level (amsl) (227.4 ft below top of casing) on July 15, 2008. The last measurement was 130.65 m (428.64 ft) amsl (227.3 ft below top of casing) on December 19, 2010. The water level elevation was approximately 0.3 m (1 ft) lower in August 2009, but the overall net change was an increase in the water level elevation of approximately 0.05 m (0.2 ft). These water level measurements were taken before the well was converted to an extraction well; withdrawal of perched water began during September 2011. The perched water level appears to have remained relatively stable over this 2.5 year period without any apparent long-term decreasing trend.



Source: CP-51879, *200-DV-1 Operable Unit, B-Complex Perched Contamination Conceptual Site Model and Proposed Path Forward.*

Figure A-10. Hydrogeologic Cross Section Illustrating Upper and Lower Cold Creek Unit Silt Layers (see Figure A-9 for location)

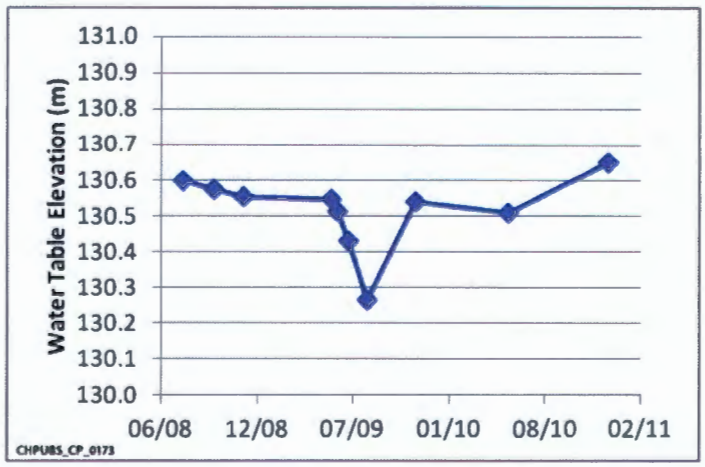


Figure A-11. Water Level Measurements in Well 299-E33-344 Before Extraction of Perched Water

Table A-1. Wells in B Complex Area with Indications of Perched Water

Well Name	Date Drilled	Cold Creek Unit Interval of Elevated Moisture		Basis for Determination of Elevated Moisture
		Top (ft bgs)	Bottom (ft bgs)	
299-E33-45	2001	227	233	Perched water encountered and sampled during drilling (RPP-7921, Appendix H)
299-E33-41	1991	223	~240	Perched water encountered during drilling (see well records).
299-E33-46	2001	No perched water detected		RPP-8633. Borehole Log descriptions, Neutron Moisture Log reveals CCU_z zone
299-E33-343	2008	223	235	Perched water encountered during drilling (SGW-39626. Section 2.2.4.1). HGLP-LDR-195 (neutron moisture log reveals CCU interval is saturated.)
299-E33-16	1947	215	225	Inferred from drillers log and more recently detected contaminant extent defined in MACTEC Log data report
299-E33-18	1950	225	239	HGLP-LDR-076, and drilling records
299-E33-19	1956	Not determined	Not determined	HGLP-LDR-429
299-E33-344	2008	225	238 (based on extrapolation from E33-345)	Perched water encountered during drilling reported in borehole log (SGW-39626, Section 2.2.5.1)
		216	225	HGLP-LDR-197; moisture logging was terminated at approximately 225 ft at the bottom of the borehole.
299-E33-345	2008	226	236	Increased moisture noted in borehole log, perched water samples not taken during drilling (SGW-39626, Section 2.2.6.1); however, neutron moisture geophysical logging indicates saturated zone (CP-51879; HGLP-LDR-196).
		217	244	HGLP-LDR-196 defines entire CCU as saturated.
C3103	2001	219	NDE	Borehole log, Well reached total depth in the upper CCU and was not drilled deep enough.

Sources: CP-51879, *200-DV-1 Operable Unit, B-Complex Perched Contamination Conceptual Site Model and Proposed Path Forward.*

HGLP-LDR-076, *299-E33-18 (A4844) Log Data Report.*

HGLP-LDR-195, *299-E33-343 (C5858) Log Data Report.*

HGLP-LDR-196, *299-E33-345 (C6226) Log Data Report.*

HGLP-LDR-197, *299-E33-344 (C5859) Log Data Report.*

HGLP-LDR-429, *299-E33-19 (A4845) Log Data Report.*

RPP-7921, *BX-102 Borehole Completion Report.*

RPP-8633, *Summary Report 241-B-110 Well (C3360) 299-E33-46.*

SGW-39626, *Borehole Summary Report for the Installation of Seven Groundwater Monitoring Wells at the 200-BP-5 Operable Unit, CY 2008.*

A2.3 Groundwater

In the B Complex Area, the unconfined aquifer occurs within the unconsolidated sand and gravel of the Hanford formation, and locally within the sand and gravel (CCU_g) of the Cold Creek unit, which overlies the basalt bedrock. The uppermost surface of the basalt defines the lower surface of the unconfined aquifer. Because the water table is nearly flat (i.e., the local gradient is too small to be measured) and the uppermost surface of the basalt is irregular, the unconfined aquifer in this area exhibits variable thickness. The inferred aquifer saturated thickness ranges from 0.3 m (1 ft) to approximately 4.5 m (15 ft) in the B Complex Area (DOE/RL-2010-74, *Treatability Test Plan for the 200-BP-5 Groundwater Operable Unit*, Section 1.3). The thin aquifer and irregular base likely result in some channeled/preferential flow of groundwater within the aquifer.

Well 299-E33-18 was drilled in 1950 near the northwest corner of the B Tank Farm. Water table elevations measured from 1950 through 2012 illustrate the development of a groundwater mound during operations (until 1986) with subsequent, continuing decline (Figure A-12). The primary source of the groundwater mounding in the 200 East Area was the liquid effluent discharged to the B Ponds to the east of the B Complex Area. This semi-regional groundwater mound was centered under B ponds and created a groundwater divide; the groundwater gradient under the B Complex Area was to the northwest toward Gable Gap. The maximum water level measured in 299-E33-18 exceeded 124.65 m amsl. The peak of the B Complex Area water table mound would have been at an elevation that contacted the lower perching CCU_z silt interval. As liquid waste discharges around the 200 East Area declined and then terminated toward the end of the 1990s, the artificial groundwater mound quickly dissipated and the water table became relatively flat across a broad region including the B Complex Area. Subsequently, the groundwater flow velocity has continued to decrease because of the high transmissivity of the gravel deposits coupled with the relatively flat water table in this area.

Although the groundwater flow direction under the B Complex Area remains primarily to the north-northwest, temporary reversal of flow to the south was documented in 2008-2009 and in 2011 (DOE/RL-2011-118, *Hanford Site Groundwater Monitoring for 2011*, Section 3.4). The flow reversal was attributed to higher heads caused by an influx of Columbia River water to the aquifer northwest of Gable Butte as a result of high river stage in the spring. The current unconfined aquifer elevation is approximately 9 m (29.5 ft) below the top of the perched water table and approximately 2.9 m (9.5 ft) below the bottom of the lower perching CCU_z silt interval.

A2.4 B-Complex Source(s) of Water

In December 2011, Washington River Protection Solutions LLC (WRPS) and U.S. Department of Energy Office of River Protection (DOE-ORP) researched the status of potable and raw water lines, as well as other pertinent information, in the vicinity of the B Complex Area to investigate additional sources of water that could potentially mobilize contaminants within the vadose zone. They concluded that there are no active fire suppression lines in the vicinity and no reason to suspect leaking pipelines. No further work is required to evaluate pipelines as a potential current source of water to the subsurface.

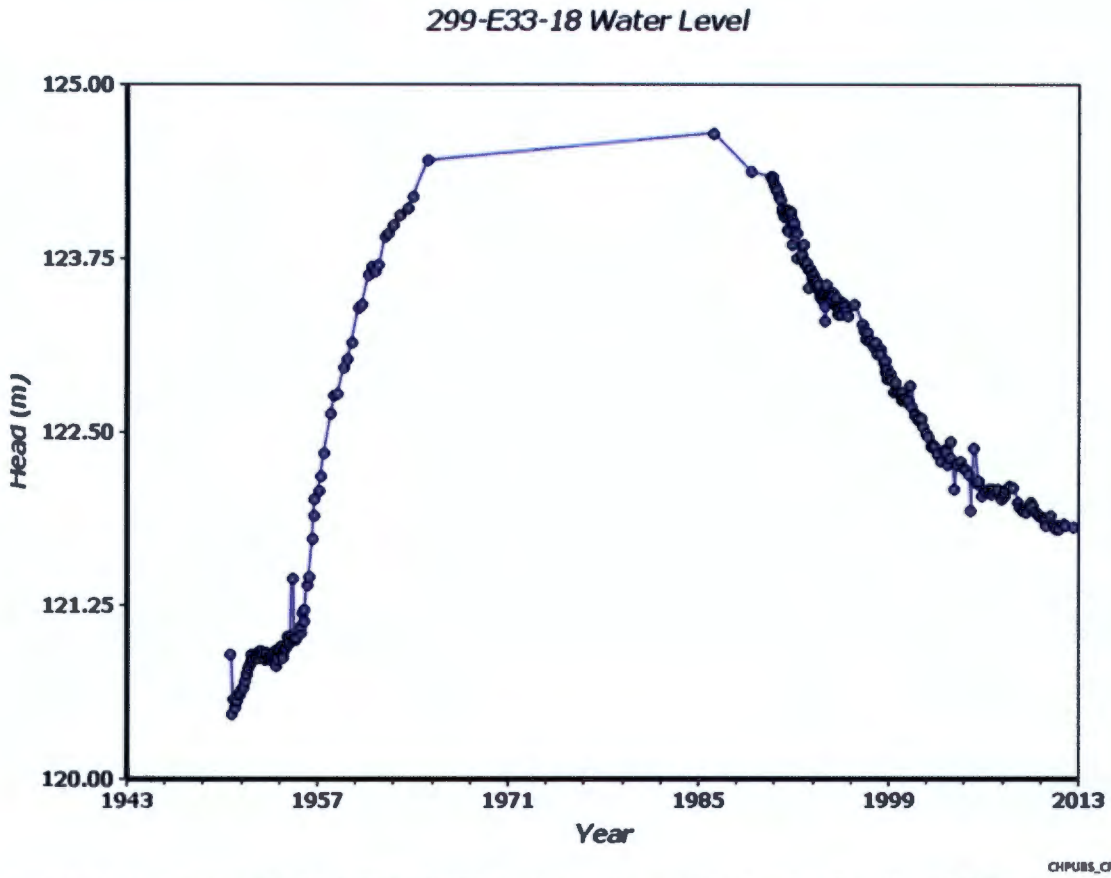


Figure A-12. Hydrograph for Well 299-E33-18 Illustrating Changes in Aquifer Elevation at the B Complex Area

Stiff diagrams, which illustrate the chemical signature of a water sample, can be used to evaluate (1) potential sources of contamination in the perched water zone by comparing the chemistry of the perched water to the chemistry of liquid wastes; (2) leakage of perched water to the aquifer by comparing the chemistry of the perched water to the chemistry of the underlying groundwater; and (3) the nature and extent of different sources of contamination in the perched zone by comparing the evolution of the perched water chemistry before and after extraction began in the perched water extraction well. Based on Stiff plots of perched water samples, there are at least two probable sources for the water in the perched zone: (1) residual water from routine liquid waste discharges to the 216-B-7A&B Crib (in use from 1947 through 1967) and the 216-B-8 Crib and Tile Field (in use from 1951 through 1952); and (2) water from the unplanned release of liquid from the overfill event at tank 241-BX-102 in 1951.

Background groundwater chemistry data are available from wells located generally outside of the B Complex Area (southeast) away from the major contaminant plumes. Groundwater from Well 299-E33-338, located near the southeast corner of the B Tank Farm (Figure A-13), is relatively uncontaminated, as shown by the low concentrations of major anions and cations (Figure A-14). This well has been evaluated for perched water (Figure A-10) and none was found within the CCU_z interval, which is at a higher elevation than the CCU_z perched zone lower silt and is away from any shallow vadose water sources. The groundwater contaminant plumes are currently northwest of this well. Stiff plots for groundwater from wells within the contaminant plumes and more closely associated with the contaminant sources show higher ionic concentrations (Figure A-13).

Figure A-13 illustrates Stiff chemistry plots for the perched water from Well 299-E33-344 and for groundwater from surrounding wells. Before pumping, the perched water had a relatively high sodium/potassium signature and relatively lower concentrations of other ionic constituents (yellow Stiff plot #1 on Figure A-13 and Figure A-15). The dashed blue line on Figure A-13 approximates the area of groundwater that has similar high sodium/potassium concentrations and that therefore appears to have been affected by residual leakage from the perched zone into the unconfined aquifer near Well 299-E33-344. Uranium, technetium-99, and nitrate are also presumed to have been added to the aquifer during this time through leakage from the perched zone in this area (Figure A-16).

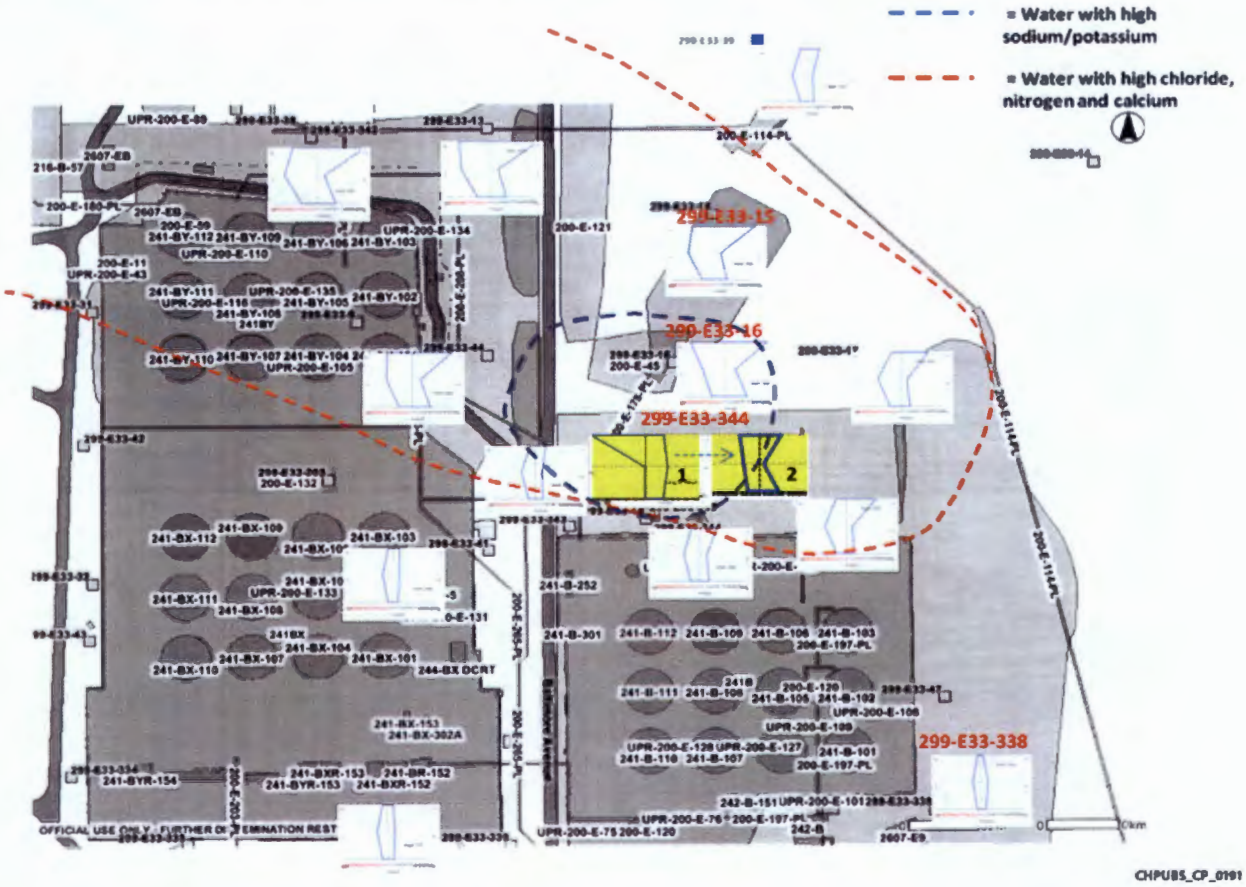


Figure A-13. B Complex Area Comparison of Groundwater and Perched Water Chemistry (Stiff) Plots (Yellow Plots are Perched Water)

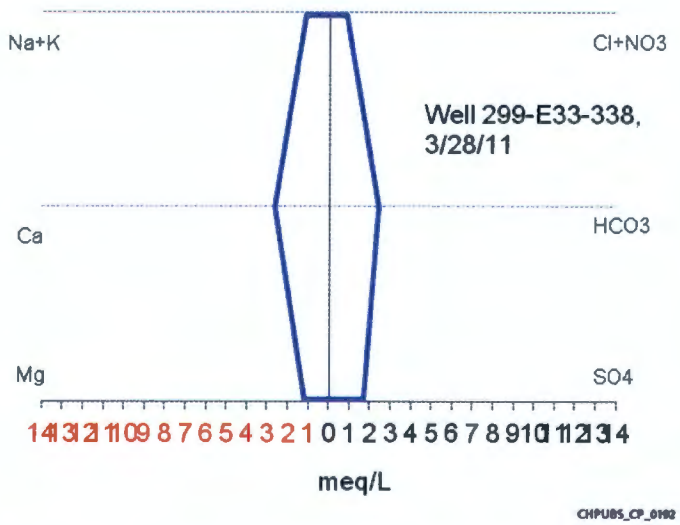


Figure A-14. Stiff Groundwater Chemistry Plot for Well 299-E33-338 Illustrating Relatively Uncontaminated Groundwater

The chemistry of the perched water changed significantly after initiation of perched water extraction (Figure A-15). The earlier Stiff plot, based on data from a perched water sample taken before extraction operations, is used to illustrate relatively static/stable conditions within the perched water interval. The high sodium/potassium concentration and relatively lower concentrations of other ionic constituents are believed to reflect water primarily disposed decades ago to the 216-B-7A&B disposal site located immediately east of the well (299-E33-344). These early impacts to the vadose zone, attributed to liquid effluent disposal at the 216-B-7A&B Crib and/or the 216-B-8 Crib, are supported by interpretations of old borehole geophysical logs (299-E33-18) provided in Figure A-8, which illustrate temporal gamma log changes occurring at the interval correlated to the CCU. These log changes indicate contaminated liquids were moving into the zone at that time. Well 299-E33-18 is located very close to the 216-B-7A&B Crib. The relatively low ionic concentrations of the perched water appears to be similar in concentration to effluent disposed to the 216-B-7A&B Crib.

Effluent disposed to the 216-B-7A&B Crib most likely migrated vertically to the perching CCU_z located beneath the waste site and saturated the perched zone, effectively occupying the entire volume of the perched interval including the vicinity of Well 299-E33-344.

After startup of perched zone extraction, the chemistry of the perched water decreased in sodium/potassium and bicarbonate and increased in calcium, magnesium, and chloride (Figure A-13 yellow Stiff plot #2 and Figure A-15). In addition, the major contaminants uranium, nitrate, and technetium-99 all increased significantly in concentration in the perched water extracted from this well (Figure A-16). The only source for these elevated concentrations of uranium and technetium -99 in this area is the 241-BX-102 overfill release event. Previous work has shown that contamination from the 241-BX-102 release has affected the perched zone (PNNL-19277). This increase in contaminant concentration and change in perched water chemistry is attributed to arrival of 241-BX-102 contamination that had been in the westernmost part of the perched zone. The volume of water contaminated by the 241-BX-102 release was smaller and did not completely displace the sodium-rich water that had already filled the perched zone from the earlier 216-B-7-A&B waste disposal that was of much greater volume. The perched water extraction caused a drawdown of the perched water table as the sodium-contaminated perched water was removed, thus expanding the perched water capture zone increasingly outward from the extraction well and capturing the perched water contaminated by the

241-BX-102 release. The dashed red line in Figure A-13 illustrates the area of groundwater in the B Complex Area that is similar in chemistry to the current perched water chemistry (Figure A-13 yellow Stiff plot #2). The uranium groundwater plume occupies approximately the same area enclosed by the dashed red line. These Stiff plots illustrate the link between the vadose zone perched water and the larger groundwater plumes.

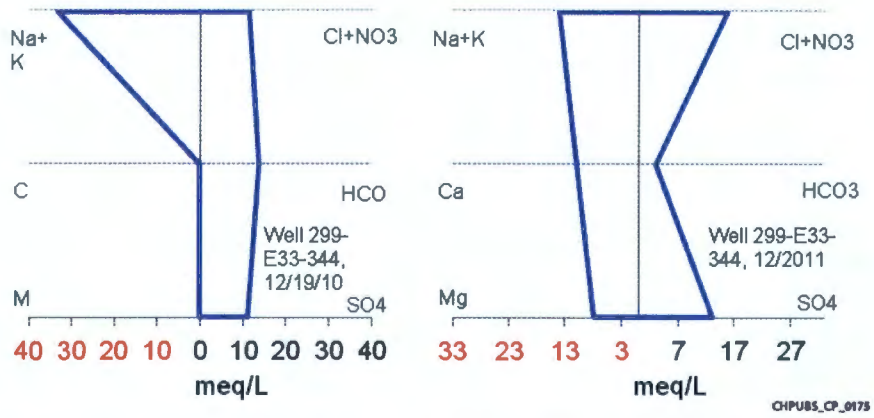


Figure A-15. Stiff Diagrams for Water Samples Collected from Well 299-E33-344 on December 19, 2010 Before Extraction Began and on December 5, 2011 During Extraction

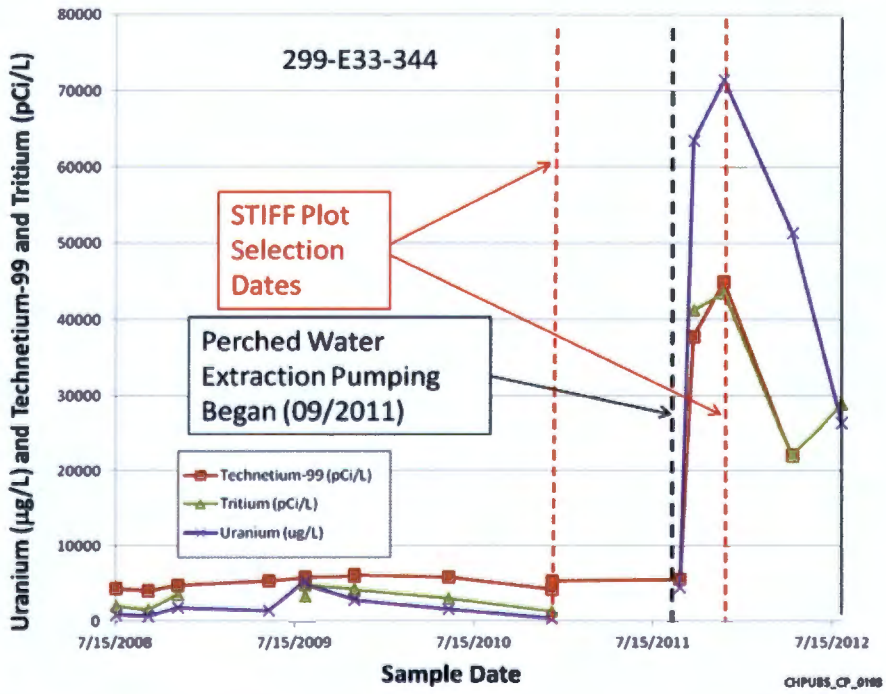


Figure A-16. Radiological Contaminant Concentration Changes in Perched Water from Well 299-E33-344

A3 Source(s) of Contamination

In the B Complex Area, the primary source of uranium in the subsurface was the 1951 overfill event at Tank 241-BX-102 that released 20,000 kg of uranium (RPP-RPT-47562, *Hanford BX-Farm Leak Assessments Report*). Lesser amounts of uranium were associated with routine waste discharges to the BY Cribs (216-B-43, 216-B-44, 216-B-45, 216-B-46, 216-B-47, 216-B-48, and 216-B-49 Cribs) and 216-B-7A&B/216-B-8 Cribs (Pages 28 and 29 in Appendix B). Even though uranium was discharged to the BY Cribs, it does not appear that uranium from these cribs is contributing much, if any, uranium to the groundwater since the water-extractable uranium in the vadose zone is found only in shallow sediments far above the water table (PNNL-19277, page 9-8).

In the B Complex Area, the primary source of technetium-99 in the subsurface was the routine waste discharges to the BY Cribs from 1954 to 1955 (Pages 23 and 24 in Appendix B). Lesser amounts of technetium-99 were associated with the 241-BX-102 overfill and unplanned releases from the B and BY Tank Farms.

The sources of nitrate in the B Complex subsurface are the 216-BY Cribs and the 216-B-7A&B/216-B-8 Cribs (PNNL-19277, Table 9-1).

The observed water-extractable fluoride and chromium in the CCU_z silt pore water and chromium in groundwater in nearby wells support the conclusion that liquid waste from the 216-B-7A&B Crib and/or the 216-B-8 Crib and Tile Field is present in the pore water in the CCU_z silt unit. However, uranium isotopic signature data suggest that fluids from the 216-B-7A Crib are not a significant contributor to the uranium found in the groundwater in the vicinity (PNNL-19277, page 9-9).

The leak loss studies at B Tank Farm (RPP-RPT-49089, *Hanford B-Farm Leak Inventory Assessments Report*), BX Tank Farm (RPP-RPT-47562), and BY Tank Farm (RPP-RPT-43704, *Hanford BY-Farm Leak Assessments Report*), evaluated only the tanks. The cascade lines and other tank infrastructure could also be evaluated for potential leaks. However, reassessment of the tank farm lines has not been completed at this time.

A4 Perched Water Nature and Extent of Contamination

Available data from most of the wells that are within the boundary defined by the lower CCU_z silt zone can be shown to contain higher levels of moisture and detectable uranium contamination. However, wells within the lower CCU_z zone that are structurally higher or upgradient from the tank farm release source do not show significant increased moisture in the CCU_z interval and do not contain detectable uranium contamination (e.g., Well 299-E33-205).

The perched uranium contamination originated near the 241-BX-102 overfill source leak. Previous studies illustrate the vertical movement and lateral migration of uranium contaminated liquids (primarily identified by vadose zone geophysical logging results) from near 241-BX-102 tank in the shallow vadose and extending in a northeastward direction following down dipping fine grained lenses within the H2 sand dominated sediments, ultimately contributing uranium to the groundwater plume beneath the B Complex. Figure A-17 illustrates the lower vadose zone, including the CCU interval, from the area southwest of the 241-BX-102 tank to the area near the 216-B-8 Crib. Wells closest to the 241-BX-102 tank have detectable uranium contamination only in the H2 unit above the CCU and within the CCU, whereas wells further northeast and down dip of the presumed 241-BX-102 source only contain contamination within and/or below the upper CCU_z silt. This data support the 241-BX-102 source determination and also indicate that the contaminated liquid effluent most likely encountered the CCU near the source at approximately the location of Well 299-E33-41, contaminating the vadose zone above

and within the CCU as the effluent perched and migrated through the upper CCU_z interval. The liquid effluent was contained within the silty sand perched above the lower CCU_z silt, saturating the silty sand interval between the CCU_z upper and lower silt layers and subsequently spreading laterally, flowing downgradient on the lower CCU_z at least as far northeast as Well E33-345.

In Well 299-E33-345, there is no detectable uranium contamination to indicate the upper CCU_z silt layer was ever contaminated (Page 6 in Appendix B). The sand layer beneath the upper CCU_z silt contains uranium contamination, which is perched on the lower CCU_z silt layer. Also, the uranium contamination is found in the sand above the lower CCU_z silt in Well 299-E33-344, which is only two meters to the east. Geophysical data also show that some uranium has migrated below the contaminated sand layer partially into the less permeable lower CCU_z silt in Well 299-E33-343 (Page 8 in Appendix B).

When Well 299-E33-45, located east of the 241-BX-102 tank, was drilled and logged in 2001, uranium contamination was detected in the Hanford H2 unit, but not in the Cold Creek unit silt (Page 10 in Appendix B). Well 299-E33-41 was drilled at the eastern perimeter of the BY Tank Farm in 1991. More recent geophysical logging using a spectral gamma logging system showed uranium contamination in the H2 unit sand and extending to the lower CCU_z silt. The southwest to northeast hydrogeologic cross section (Figure A-17) illustrates the occurrence of the perched uranium contamination within the Cold Creek unit in the B Complex Area.

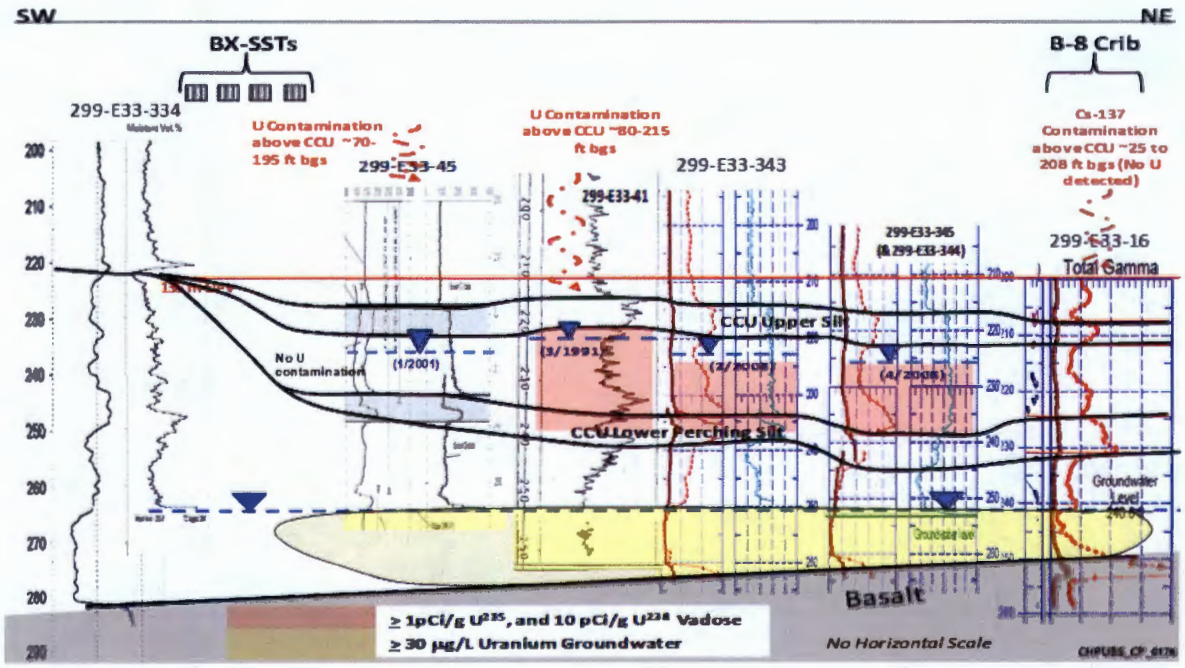


Figure A-17. Hydrogeologic Cross Section Illustrating Upper and Lower Cold Creek Unit Silt Layers and Perched Uranium Contamination (see Figure A-9 for location)

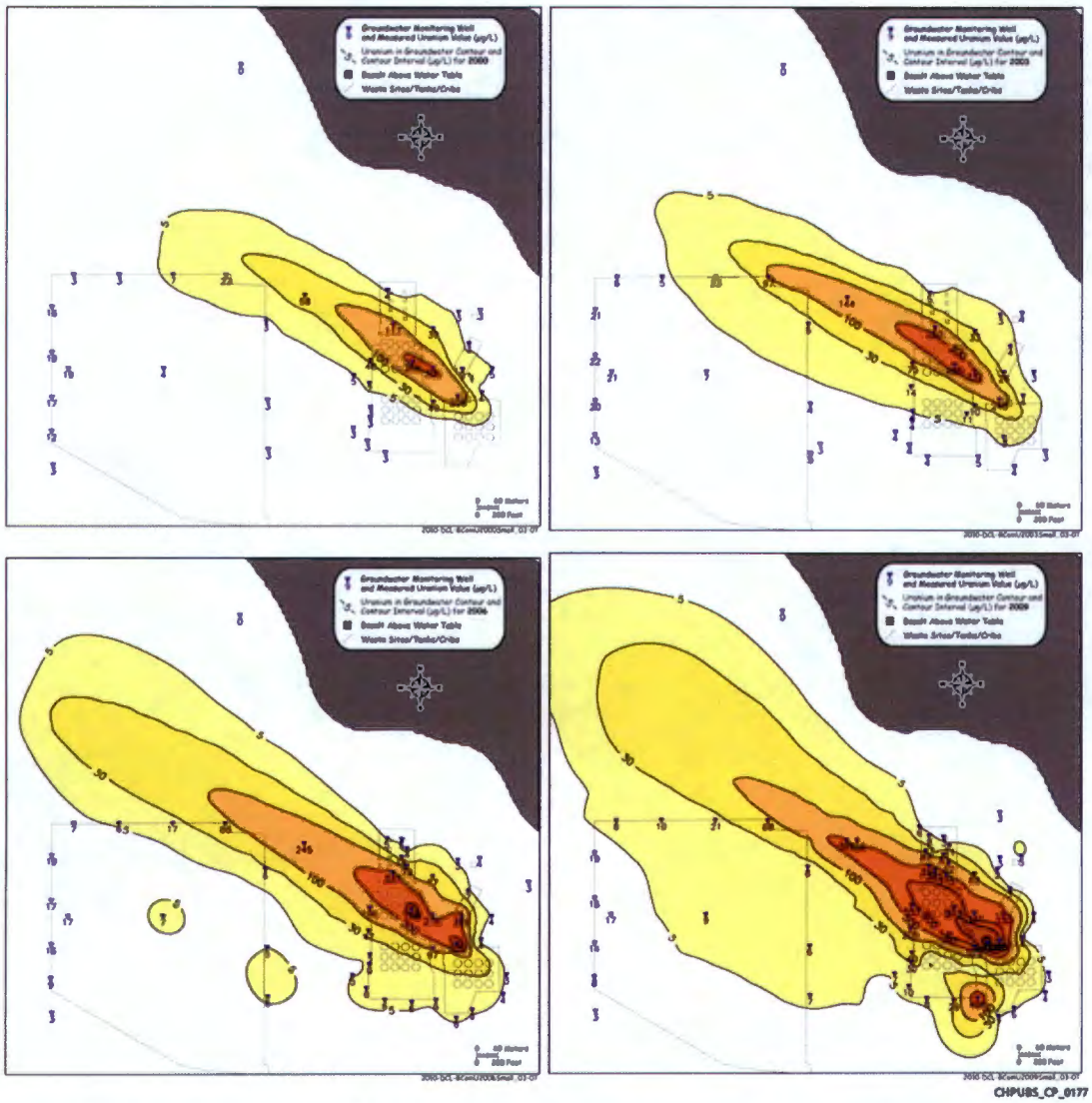
A5 Groundwater Nature and Extent of Contamination

The uranium and technetium-99 groundwater plumes in the B Complex Area for 2000, 2003, 2006, and 2009 are shown in Figure A-18 and Figure A-19, respectively. The uranium plume originates in an area that coincides with the areal extent of the lower CCU_z silt zone. Initially, during the time of predominant northwest groundwater flow, the plume hot spot increased near the mapped extent of the down dip edge of the lower CCU_z, near Well 299-E33-44, eventually becoming more centered and expanding in

concentration to the southeast near the Well 299-E33-18. This area is the approximate center of the low formed by the base of the lower CCU_z interval and indicates the perched uranium contamination is the probable source of the groundwater plume.

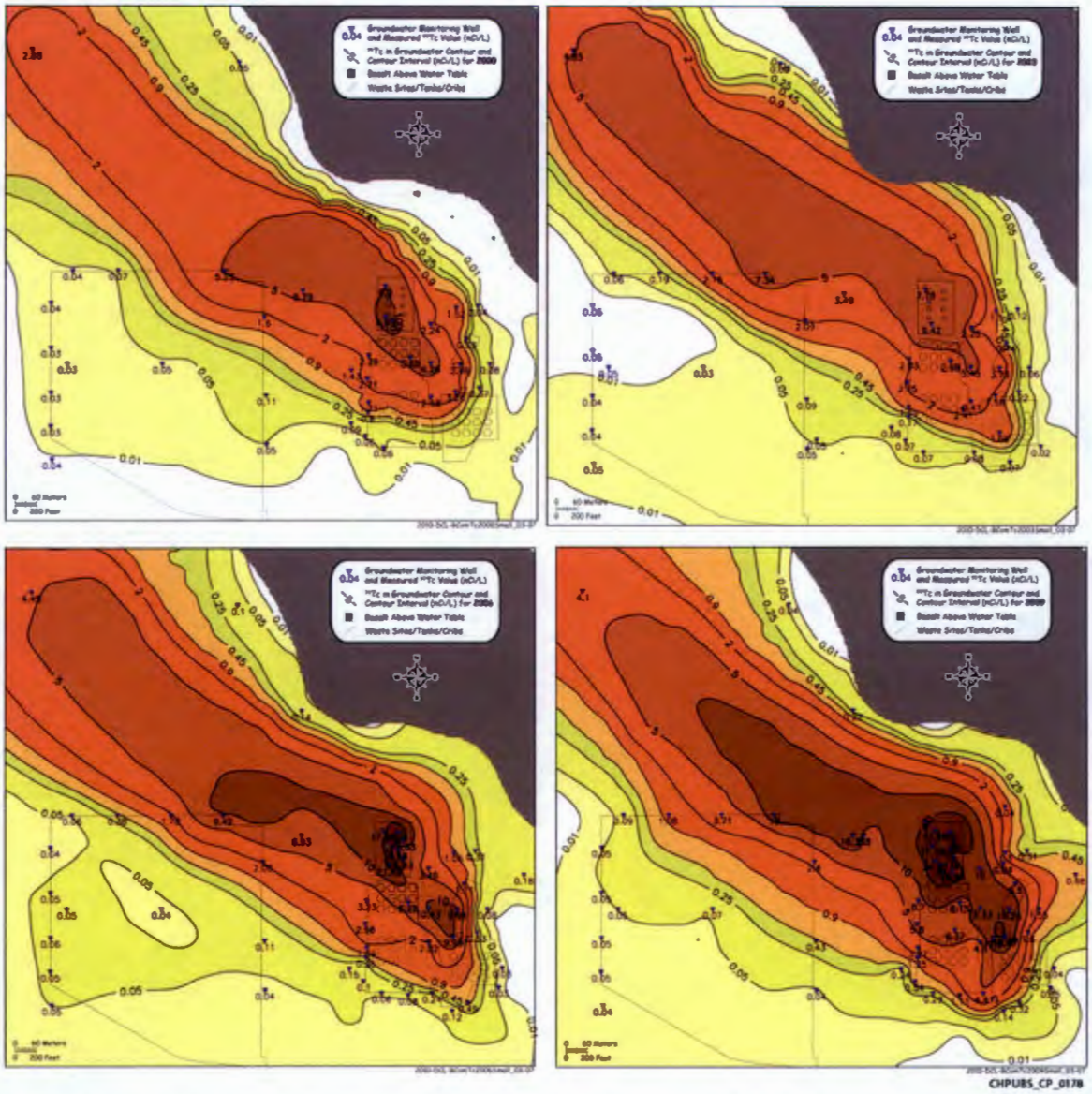
Based on current interpretations, there appear to be two vadose zone source areas contributing to the uranium plume in the B Complex Area groundwater (Figure A-20) and two vadose zone source areas contributing to the technetium-99 plume in the B Complex Area groundwater (Figure A-21).

Well 299-E33-18 is one of the oldest wells in the area that contains the lower, perching CCU_z silt layer. This well is also located in the area containing the highest concentrations of uranium in groundwater. Well 299-E33-18 was installed as an unsealed well through the CCU interval, and data indicate that it is probably providing a preferential pathway for contaminant migration from the perched zone to the unconfined aquifer (Figure A-22 and Figure A-23).



Source: PNNL-19277, *Conceptual Models for Migration of Key Groundwater Risk Contaminants Through the Vadose Zone and Into the Unconfined Aquifer Below the B-Complex* (Figures 5-41, 5-42, 5-43, and 5-44).

Figure A-18. Uranium Groundwater Plume in the B Complex Area, 2000 through 2009



Source: PNNL-19277, *Conceptual Models for Migration of Key Groundwater Risk Contaminants Through the Vadose Zone and Into the Unconfined Aquifer Below the B-Complex* (Figures 5-18, 5-19, 5-20, and 5-21).

Figure A-19. Technetium-99 Groundwater Plume in the B Complex Area, 2000 through 2009

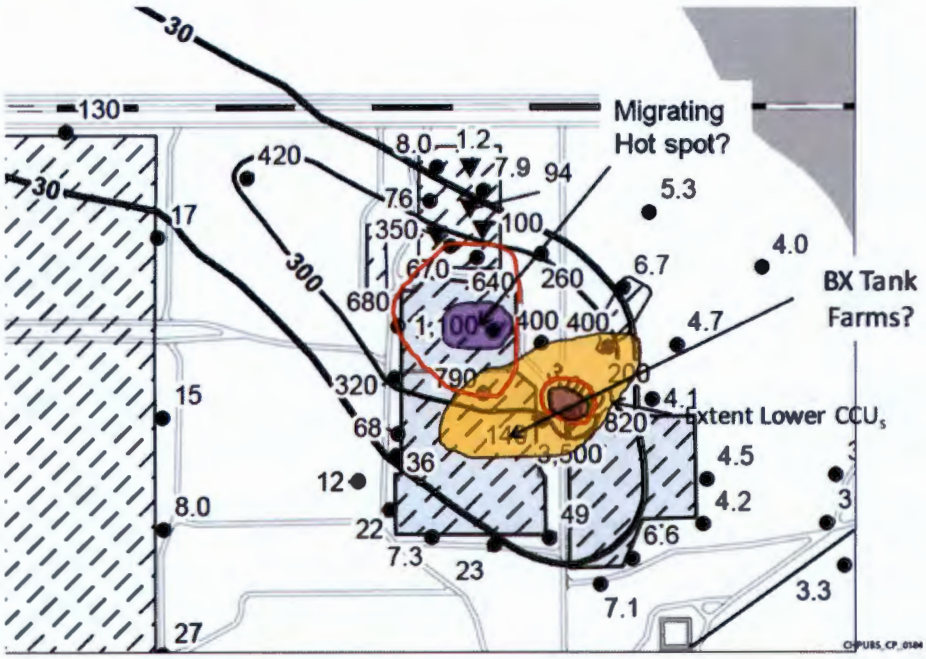


Figure A-20. Potential Sources of Uranium Contamination Contributing to the Groundwater Plume in the B Complex Area

CY 2010 TECHNETIUM-99 GROUNDWATER PLUME

Two Source Areas?

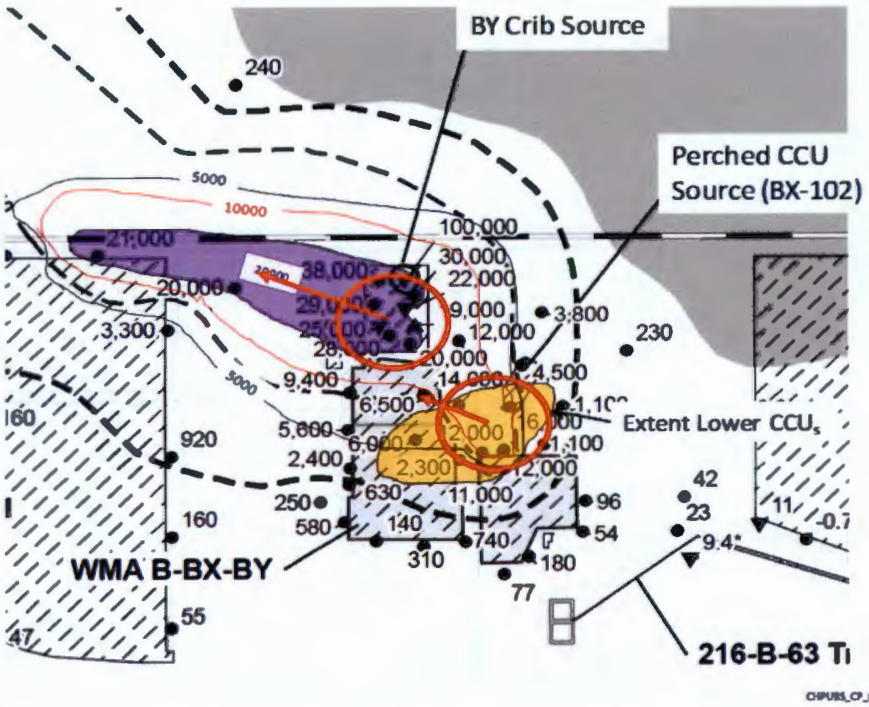


Figure A-21. Potential Sources of Technetium-99 Contamination Contributing to the Groundwater Plume in the B Complex Area

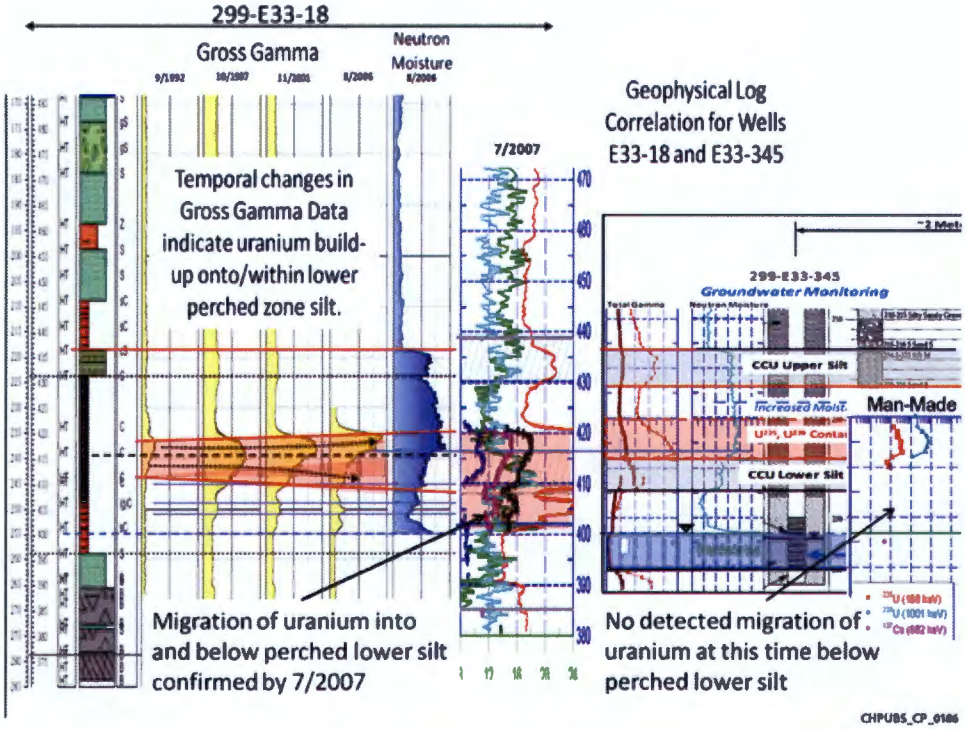


Figure A-22. Vertical Migration of Uranium Detected in Well 299-E33-18

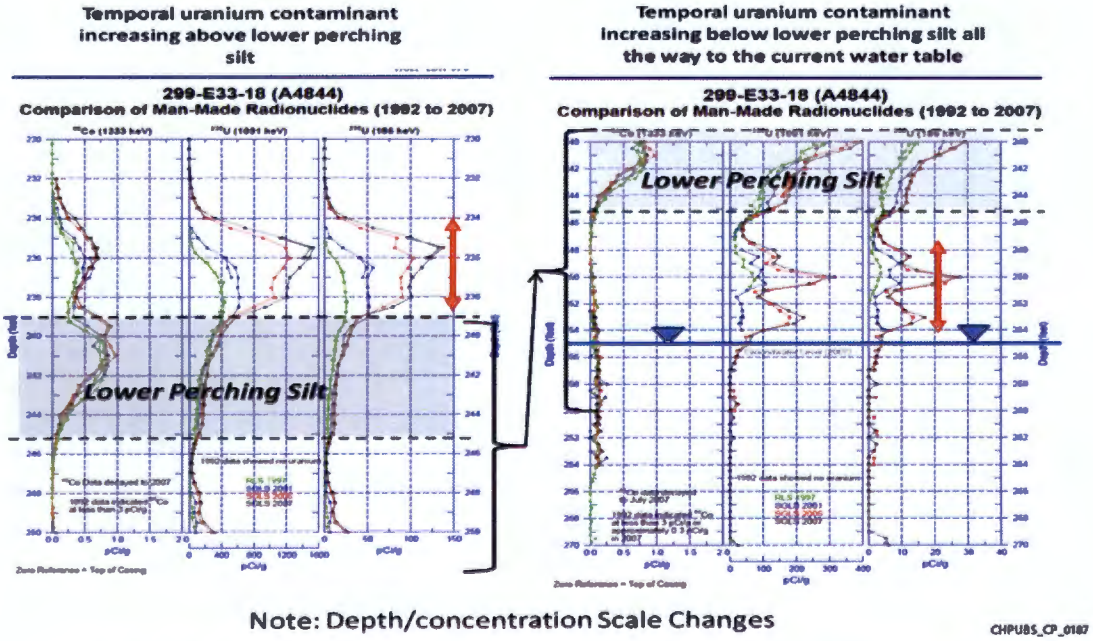


Figure A-23. Increasing Uranium Concentrations Above and Below Lower (Perching) Silt Layer in Well 299-E33-18

A6 Extraction

Extraction of the contaminated perched water from Well 299-E33-344 was initiated on August 30, 2011. A dedicated submersible pump was installed in Well 299-E33-344 with automatic on-off pump control provided by a water level sensor. When the perched water level in Well 299-E33-344 reached the high level set-point, the pump was turned on and the water was pumped into a water collection system located near the wellhead. Once pumping lowered the water level to the low level set-point, the pump was shut-off to allow the well to recover. This on-off cycle is repeated for the duration of the extraction period. The configuration of the perched water extraction site is shown in Figure A-24.

Figure A-24. Configuration of the Perched Water Extraction Site (October 2011)

For the first month of operations, the pump was operated during the day shift to allow workers to evaluate and optimize the pumping rates and water level set points. On September 26, 2011, continuous operations (24 hr/day, 7 days/wk) began using an average pumping rate of approximately 0.76 L (0.2 gal)/min, yielding approximately 1,136 L (300 gal)/day. The perched water level slowly declined with continued pumping, necessitating downward adjustment of the set point for turning on the pump to provide a reasonable pumping rate. The extracted water was collected in a 13,249 L (3,500 gallon) tank; the water in the tank was transferred weekly to the Effluent Treatment Facility (ETF) for treatment.

Before initiation of perched water removal, between July 2008 and September 2011, the perched water in Well 299-E33-344 was sampled nine times. The uranium concentrations ranged from 788 to 5,300 µg/L; the technetium-99 concentrations ranged from 4,130 to 6,200 pCi/L; and the nitrate concentrations ranged from 417,000 to 580,000 µg/L (Table A-2). On October 4, 2011, the first perched water sample was collected after the initiation of pumping. The concentrations of all three of these contaminants were higher in the October 4th sample. The increases in uranium and technetium -99 were dramatic (Figure A-25). Concentrations also increased in nearby groundwater Wells 299-E33-345 (Figure A-26) and 299-E33-18 (Figure A-27). Recent sampling has indicated the uranium and technetrium-99

concentrations in the perched water well are decreasing, but are still above the pre-pumping concentrations (Table A-2 and Figure A-25).

Table A-2. Well 299-E33-344 Perched Water Constituent Data

Sampling Date	Nitrate (µg/L)	Technetium-99 (pCi/L)	Uranium (µg/L)
07/15/08	436,000	4,400	897
09/19/08	522,000	4,130	788
11/18/08	483,000	4,800	1,820
06/26/09	474,000	5,400	1,460
08/04/09	478,000	5,900	5,300
08/04/09	483,000	5,800	4,940
11/12/09	417,000	6,200	2,980
11/12/09	433,000	6,000	2,910
05/24/10	469,000	5,900	1,660
10/04/11	604,000	37,800	63,600
12/05/11	810,000	45,100	71,500
04/23/12	456,000	22,100	51,500
08/02/12	522,000	12,200	26,600

On December 7, 2011, upon receipt of the October 4, 2011 sample results, the pumping system was temporarily shut down to evaluate the process and the treatment options for extracted water with the increased contaminant concentrations. After confirming that the water could continue to be transferred to ETF for treatment, it was determined that the submersible pump had failed, resulting in an extended shutdown until it was replaced. The system was restarted on April 11, 2012.

Pumping continued until April 26, 2012, when it was observed that algae were present in the collected water at concentrations that prevented its disposal to ETF. Residual water in the collection tank since the December shutdown had been subjected to increasing ambient temperature that facilitated the algae growth. On May 17, 2012, a copper sulfate ($CuSO_4$) solution was added to the collection tank, using a newly installed metering system, to control algae growth, and perched water pumping resumed. Despite failure of the $CuSO_4$ solution metering pump on June 6, 2012, collected water has remained acceptable for treatment at ETF. Pumping of the perched water continued until September 19, 2012, when the pumping system was turned off.

Figure A-28 shows perched water extraction history. The overall trends are (1) a decline in the daily volume collected; (2) an increase in the time to recharge following pumping; and (3) a relatively constant water level. A relatively low daily volume removed typically was a result of the system being down for maintenance.

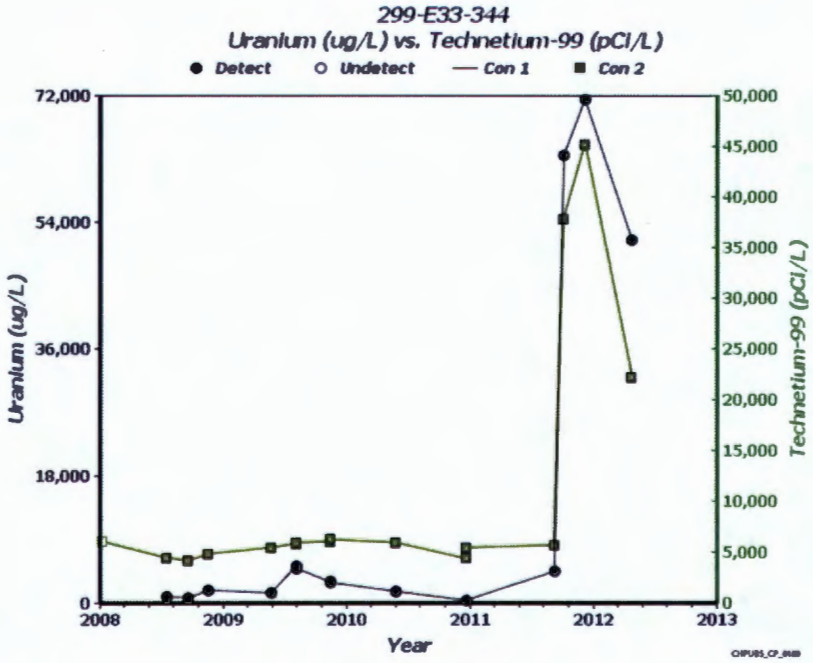


Figure A-25. Increase in Uranium and Technetium-99 Concentrations in Perched Water Well 299-E33-344 After Pumping Initiated

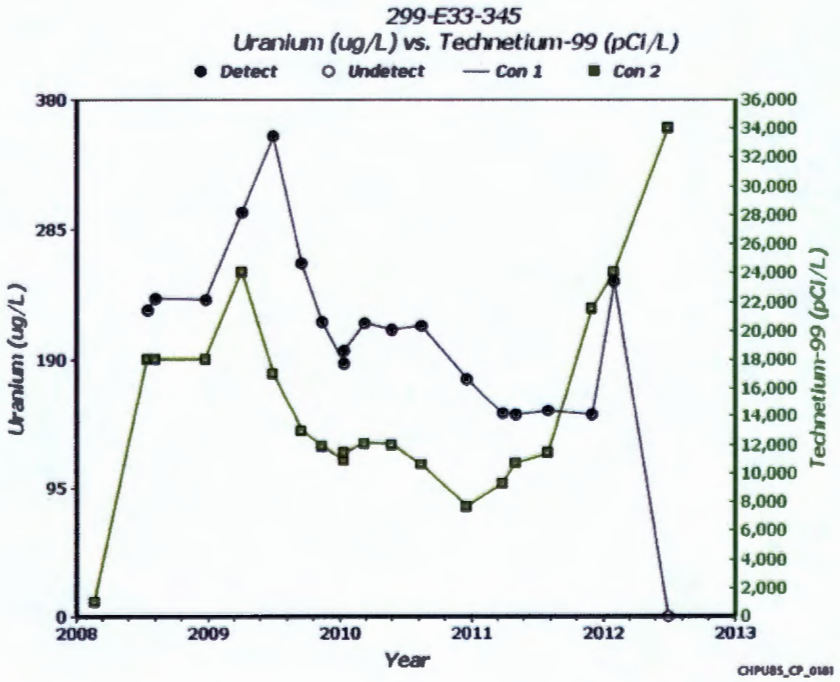


Figure A-26. Increase in Uranium and Technetium-99 Concentrations in Groundwater Monitoring Well 299-E33-345 After Pumping Initiated from Well 299-E33-344

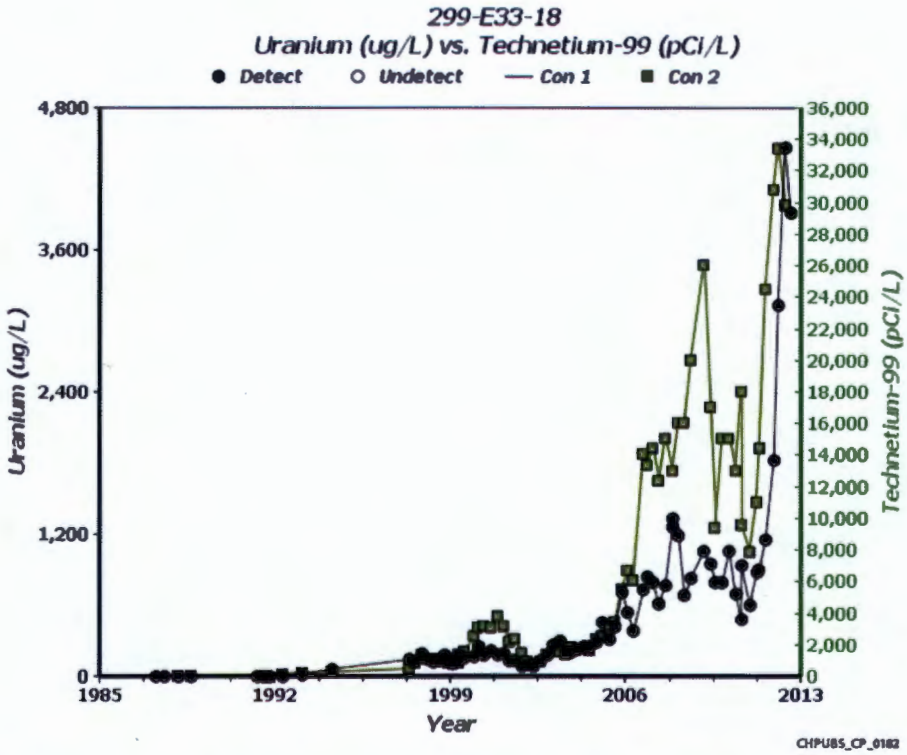


Figure A-27. Increase in Uranium and Technetium-99 Concentrations in Groundwater Monitoring Well 299-E33-18 After Pumping Initiated from Well 299-E33-344

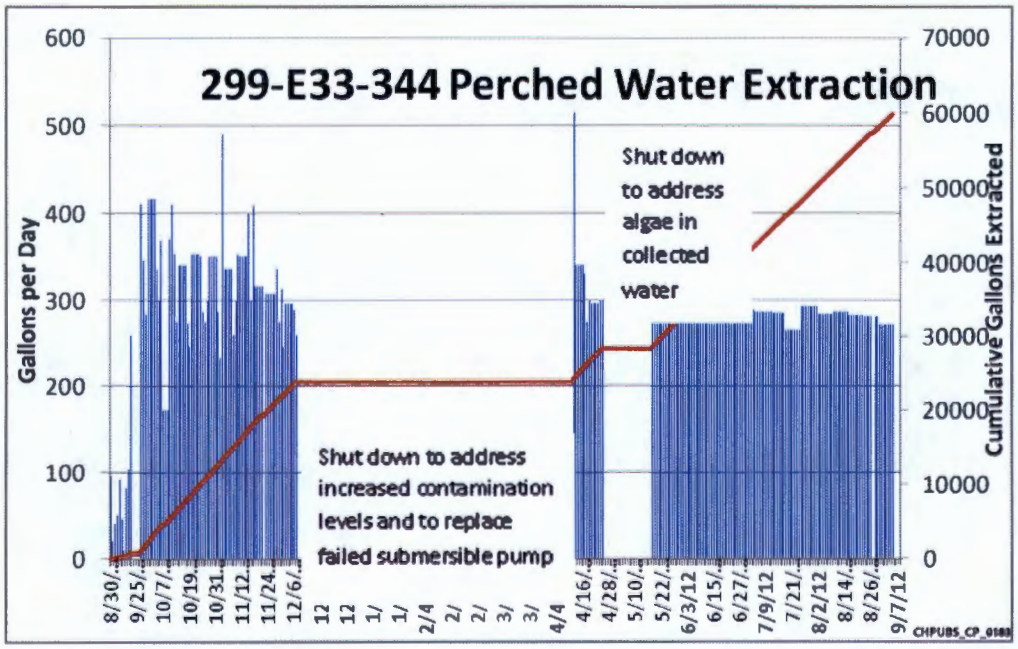


Figure A-28. Well 299-E33-344 Perched Water Extraction History

Since pumping began, approximately 246,000 L (65,000 gal) of perched water have been extracted. Based on sampling data, approximately 131.8 kg of nitrate, 13.34 kg of uranium, and 0.118 g of technetium -99 have been removed from the perched zone. Since the start of continuous operations in September 2011, the water level in Well 299-E33-344 has declined approximately 0.46 m (1.5 ft).

With continued extraction, the duration of the pump cycle has increased (Figure A-29). One pump cycle is defined as the time when the pump is off (to allow the water in the well to recover) followed by the time when the pump is on (to remove the water). The increase in the cycle time indicates that it is taking progressively longer for additional perched water to re-fill the well after it has been pumped.

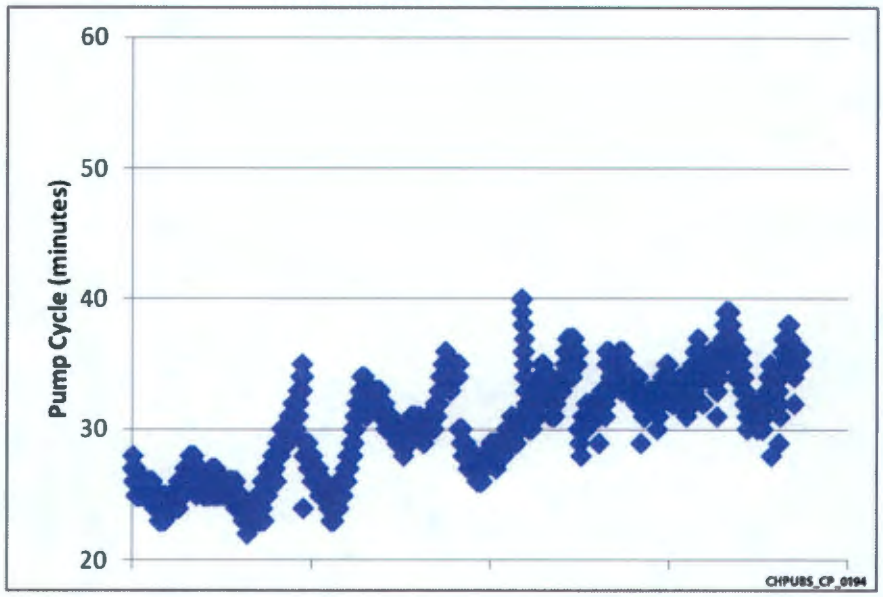


Figure A-29. Duration of Pump Cycle with Continued Extraction October 2011 to August 2012

In September 2011, the pump was programmed to begin operations when the water level in the well reached 2.4 m (8 ft) (i.e., the high set point) and to cease operations when the water level in the well fell to 0.12 m (0.4 ft) (i.e., the low set point). On September 13, 2012, the high set point was lowered to 2.1 m (7 ft) to reduce the length of time that the pump was not operating. After the high set point was lowered, the time between pumping cycles was reduced from 43 minutes to 27 minutes.

A7 Conceptual Site Model

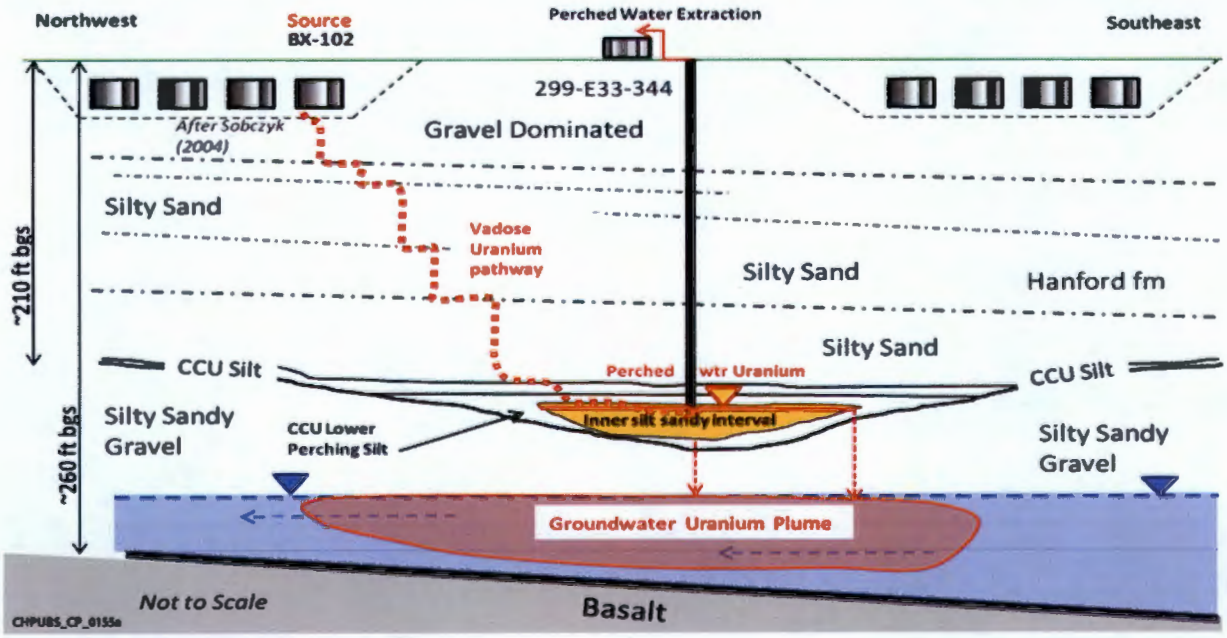
The integration and interpretation of various borehole hydrogeologic, geochemical, and geophysical data sets obtained during drilling facilitated the delineation of the perching horizon and determination of the nature and extent of the perched contamination. Integration of the borehole geologic and geophysical logs defined the structural elevation and thickness of the perching low permeability silt interval. Borehole geophysical moisture logs, gamma logs, and sample data allowed detailed determination of the elevation and thickness of the oversaturated zone above the perching horizon, and the extent and magnitude of the radiological uranium contamination within the perching interval. Together, these data sets resolved the nature of the perching horizon and the location and extent of the contaminated perched water within the perching zone, allowing an estimation of remaining contaminant extent.

The resulting conceptual model indicates that the contaminated perched water is contained within a localized sand lens deposited in a structural low on top of a low permeability CCU_z silt layer (Figure A-30). The top of the sand lens is approximately 72 m (235 ft) below ground surface; the

maximum thickness of the sand lens is approximately 4.6 m (15 ft). The lateral and vertical extent of the perched water is limited to the presence of the sand lens and is approximately 4.6 m (15 ft) above the unconfined aquifer at its lowest point. Liquid wastes containing uranium and technetium-99 that were discharged decades ago to nearby engineered structures for subsurface infiltration and that leaked from the 241-BX-102 single shell tank overfill have migrated vertically and laterally and are accumulating within this CCU sand layer above the lower perching silt, which forms a natural barrier that slows contaminant migration to the aquifer.

Initially, extraction of water from Well 299-E33-344 removed the lower concentration residual water that accumulated in the perched zone from routine disposal operations at the nearby 216-B-7A&B and 216-B-8 cribs; this perched effluent most likely occupied most of the perched water zone. Ongoing removal of the perched water began to widen the perched water capture zone to the western side of the perched zone and caused the higher concentration tank leak perched water to flow toward the extraction well.

The perched water extraction system has been operated for 212 days since full-scale pumping began in September 2011. The removal of 246,000 L (65,000 gal) during that time has lowered the elevation of the perched water by 0.46 m (1.5 ft). The 246,000 L (65,000 gal) recovered represents a range between 5 and 20 percent of the 5 to 1.25 million L (1.330 to 0.330 million gal) of perched water estimated to be contained within the sand layer. Following the initiation of pumping, the concentrations of uranium and technetium-99 increased significantly in samples of the perched water (Figure A-25).



Source: CP-51879, *200-DV-1 Operable Unit, B-Complex Perched Contamination Conceptual Site Model and Proposed Path Forward* (Page 20).

Figure A-30. Conceptual Site Model of the Cold Creek Unit Perching Zone

A8 References

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Appendix B

200-DV-1 Operable Unit, B Complex Perched Contamination Conceptual Site Model and Proposed Path Forward (CP-51879)

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CP-51879

CH2MHILL
Plateau Remediation Company

200-DV-1 OU, B-Complex Perched Contamination Conceptual Site Model and Proposed Path Forward

Presented to: Ecology

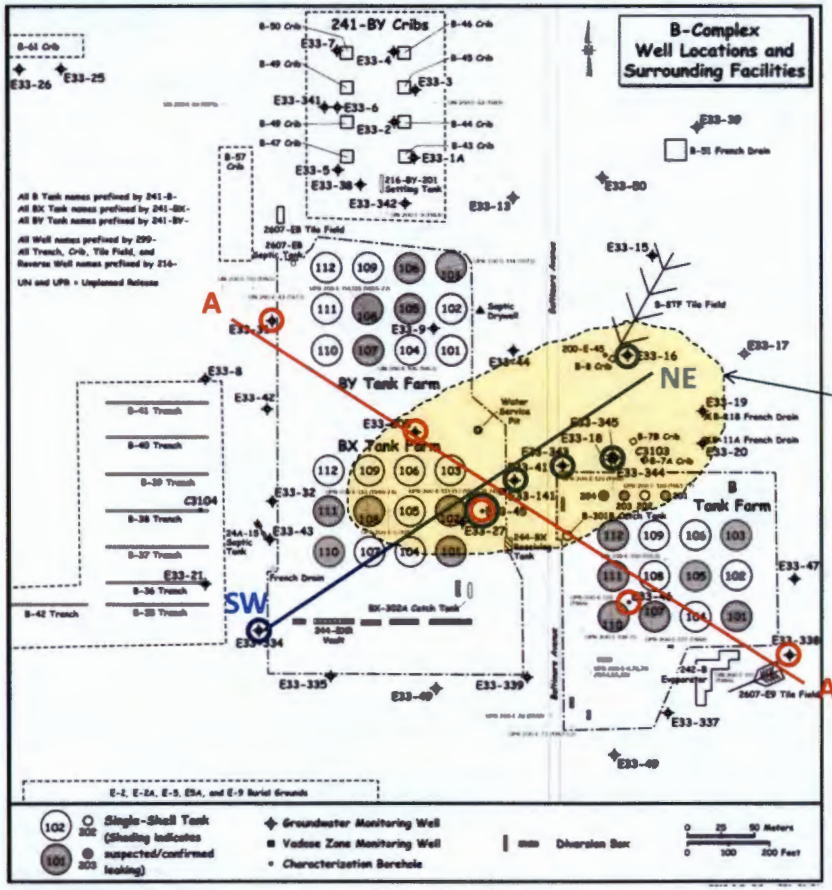
February 22, 2012

Presented by: Bruce Williams

U.S. DEPARTMENT OF ENERGY

One Team. One Culture.

B-Complex Study Area
200 East Area



Cross Section Orientation Map

Wells in Cross Section

Approximate Extent of CCU Lower Perching Silt/Clay Layer

Cold Creek Unit = CCU

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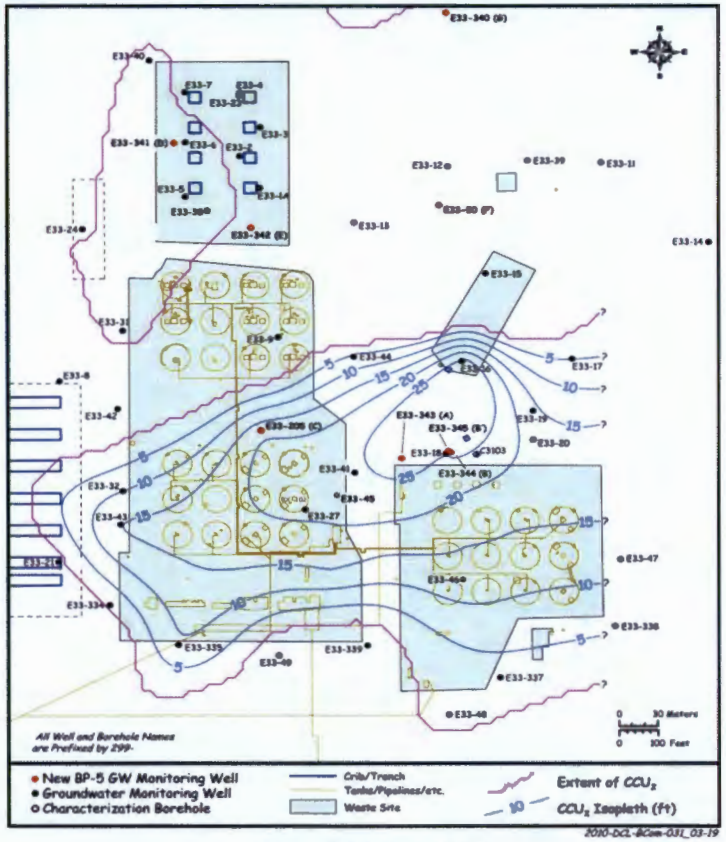
Gross Isopach - Cold Creek Unit Silt (Vadose Zone Perching Interval)

Cold Creek Unit Silts Gross Isopach map

C. I. = 5 ft



From PNNL-14121

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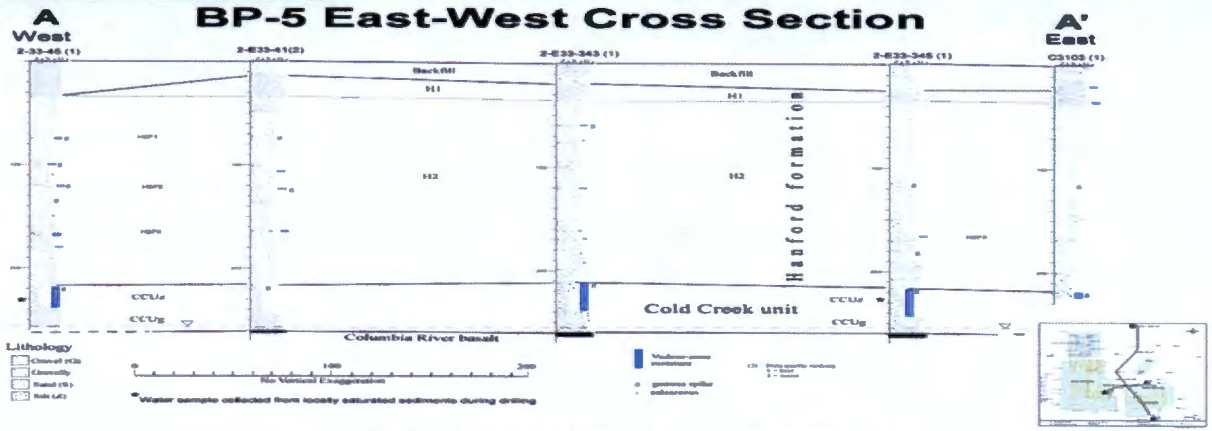
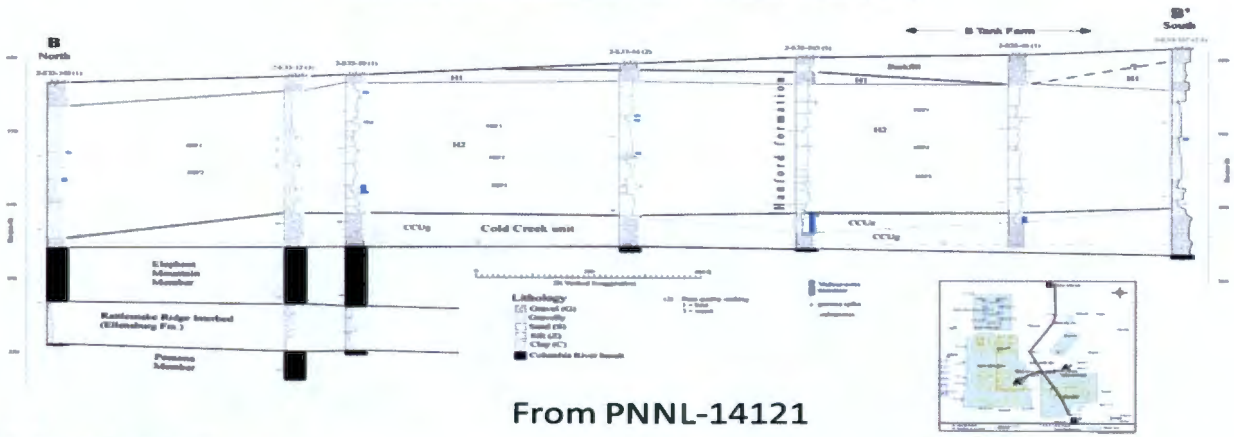
Geologic Cross Sections Illustrating Cold Creek Unit, B-Complex





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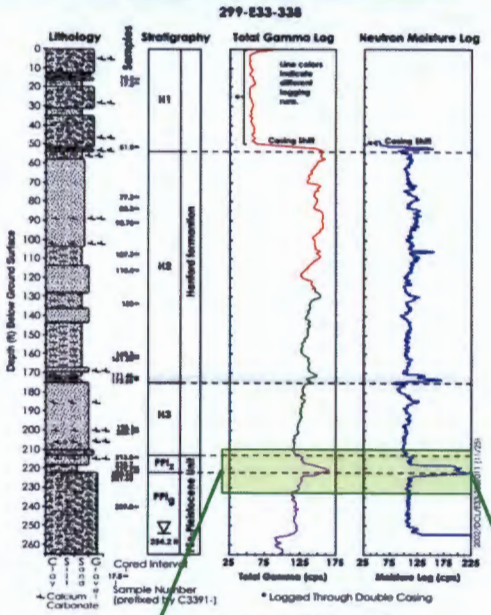
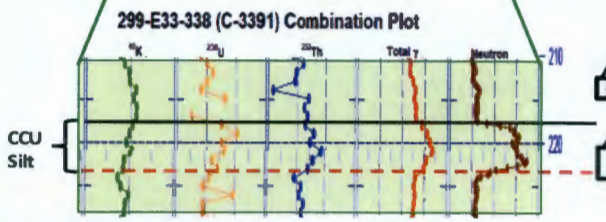
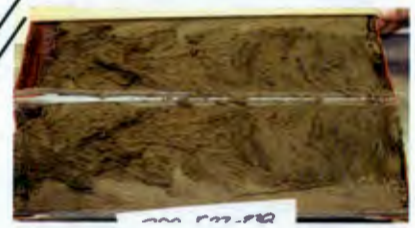
Example - Geologic-Geophysical Correlation of Cold Creek Unit Silt



From PNNL-14121



Upper Bed in Silt Facies in Borehole 299-E33-338. (Core segment is one ft long [213.8 to 214.8 ft bgs] and top is to the left.)



Lower Bed in Plio-Pleistocene Silt Facies in Borehole 299-E33-338. (Shown are two 1-ft core segments from the top [upper photo] and bottom [lower photo] of the lower bed of the Plio-Pleistocene silt facies. Contact with the underlying gravel facies is shown in right-hand bottom photo; top of cores is to the left.)

CCU Silt – CCU/RF gravel Contact

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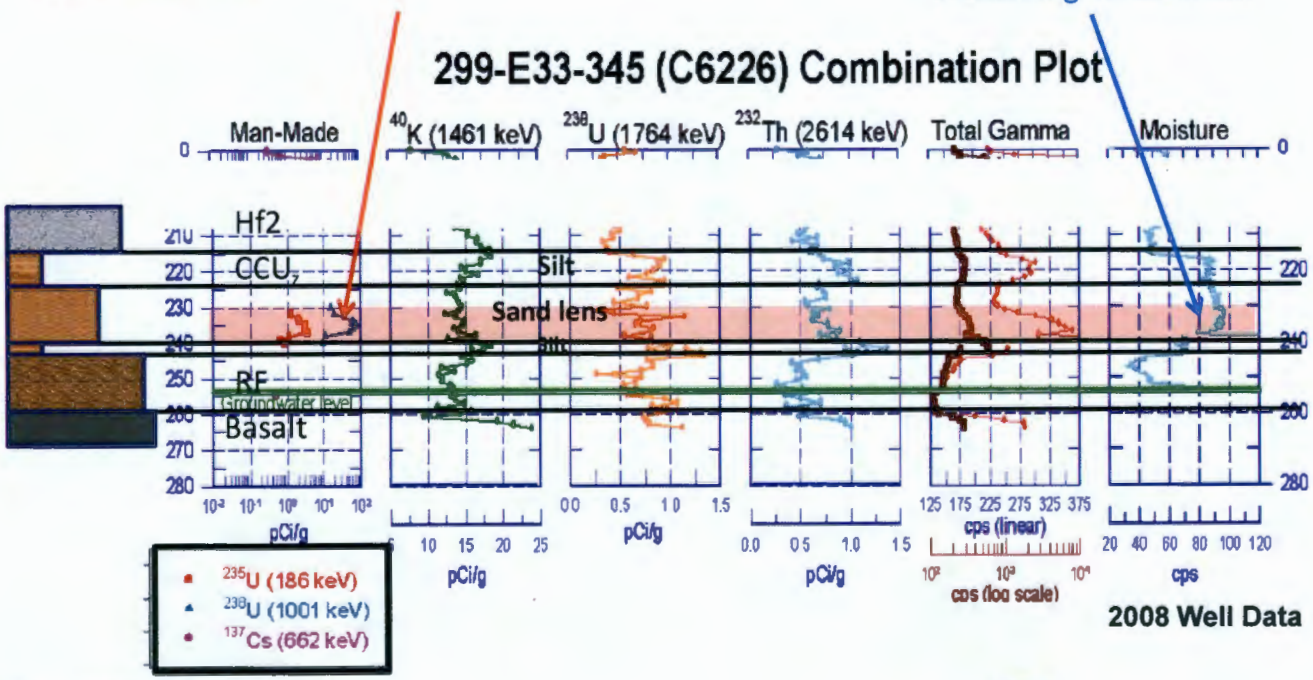
Geophysical Log Contaminant / Moisture Identification and Geologic Correlation

Uranium Contamination Detected in sand lens sandwiched between two silt intervals of the CCU interval. The uranium is perched on top of the lower CCU silt interval.

Moisture Data reveal the naturally elevated silt saturation and the over-saturated sand containing the uranium



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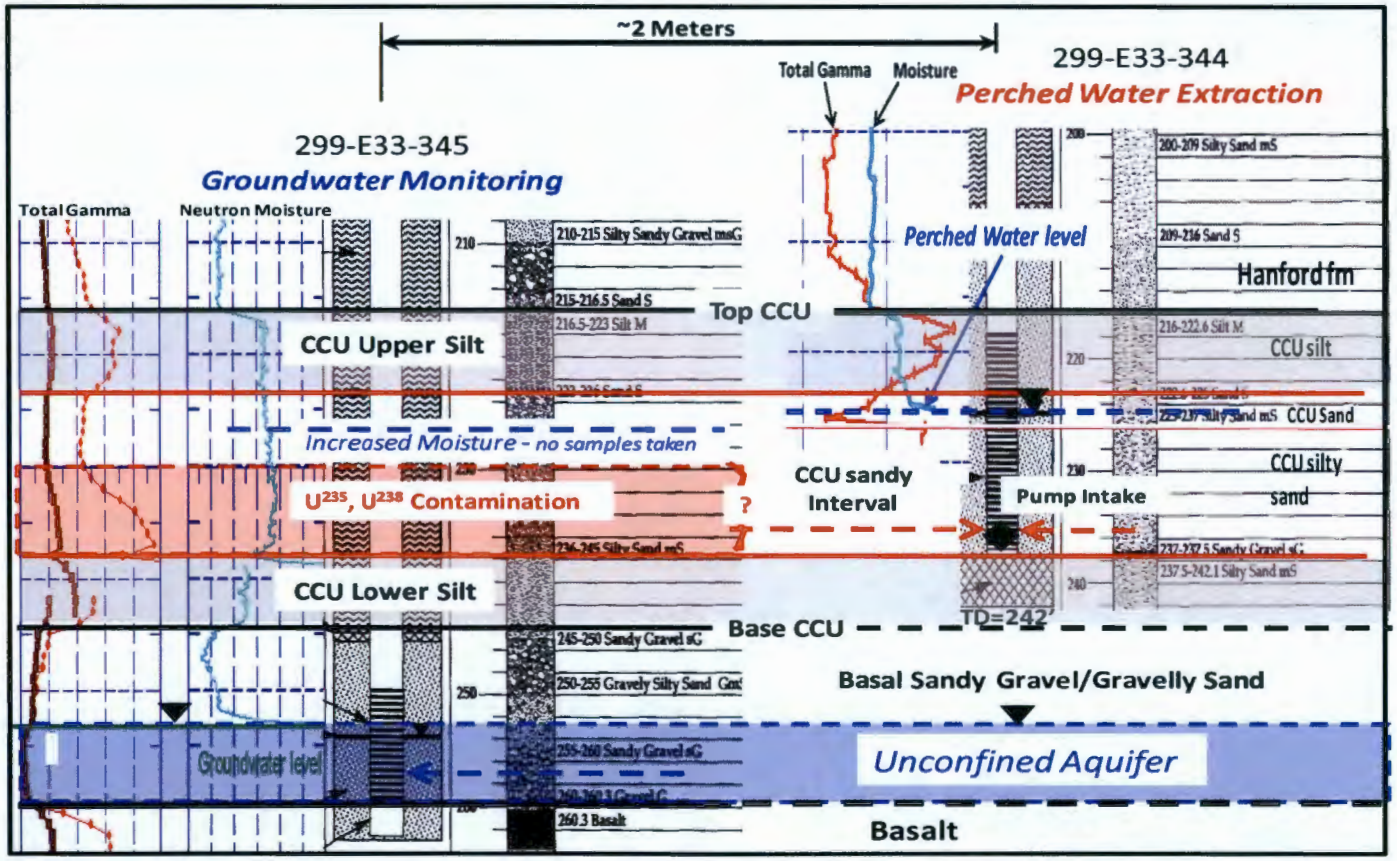
Multi-Borehole Cold Creek Unit Perched Zone Correlation



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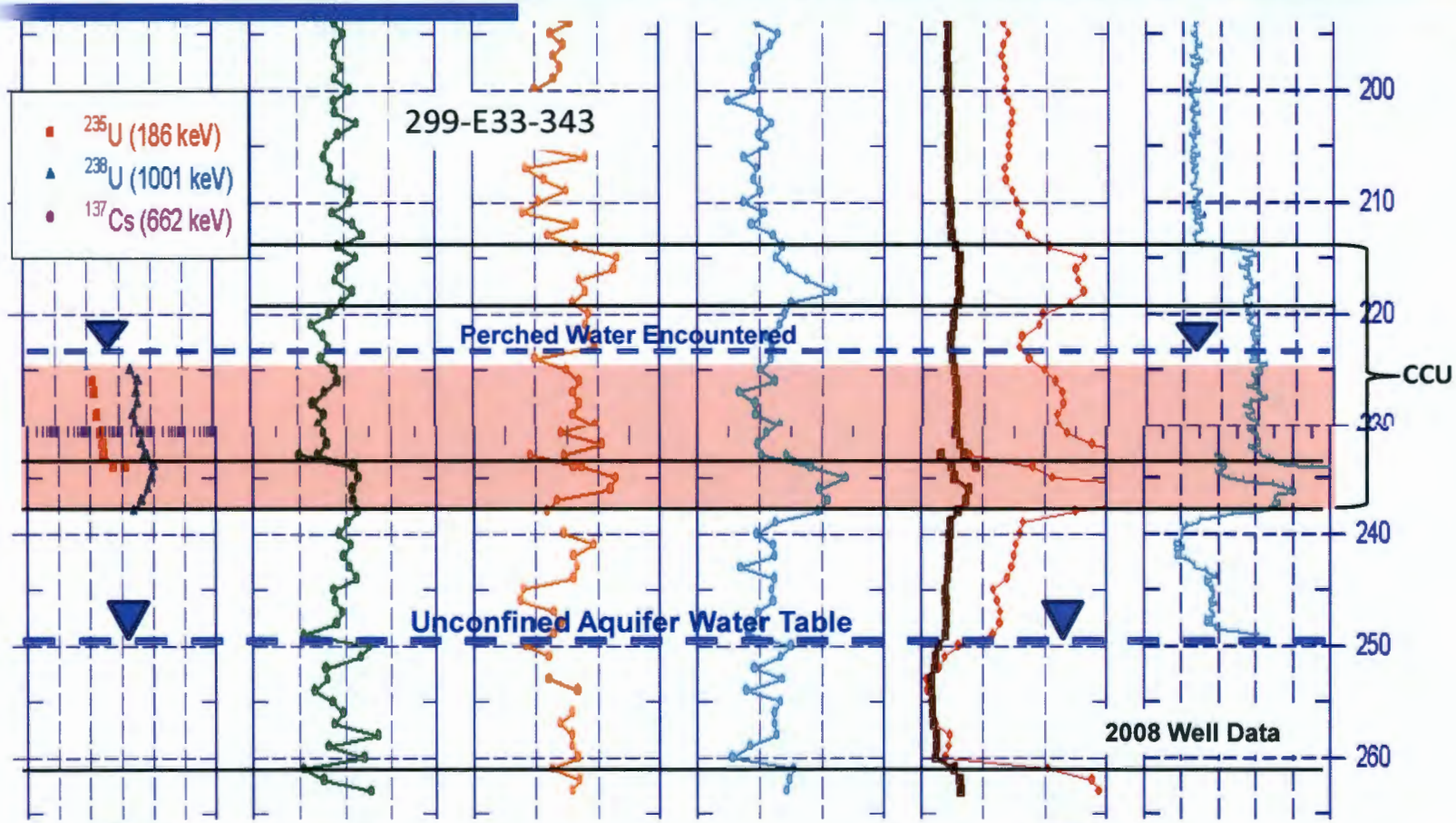
Manmade Uranium Detected on Top and within Lower CCU Silt Layer



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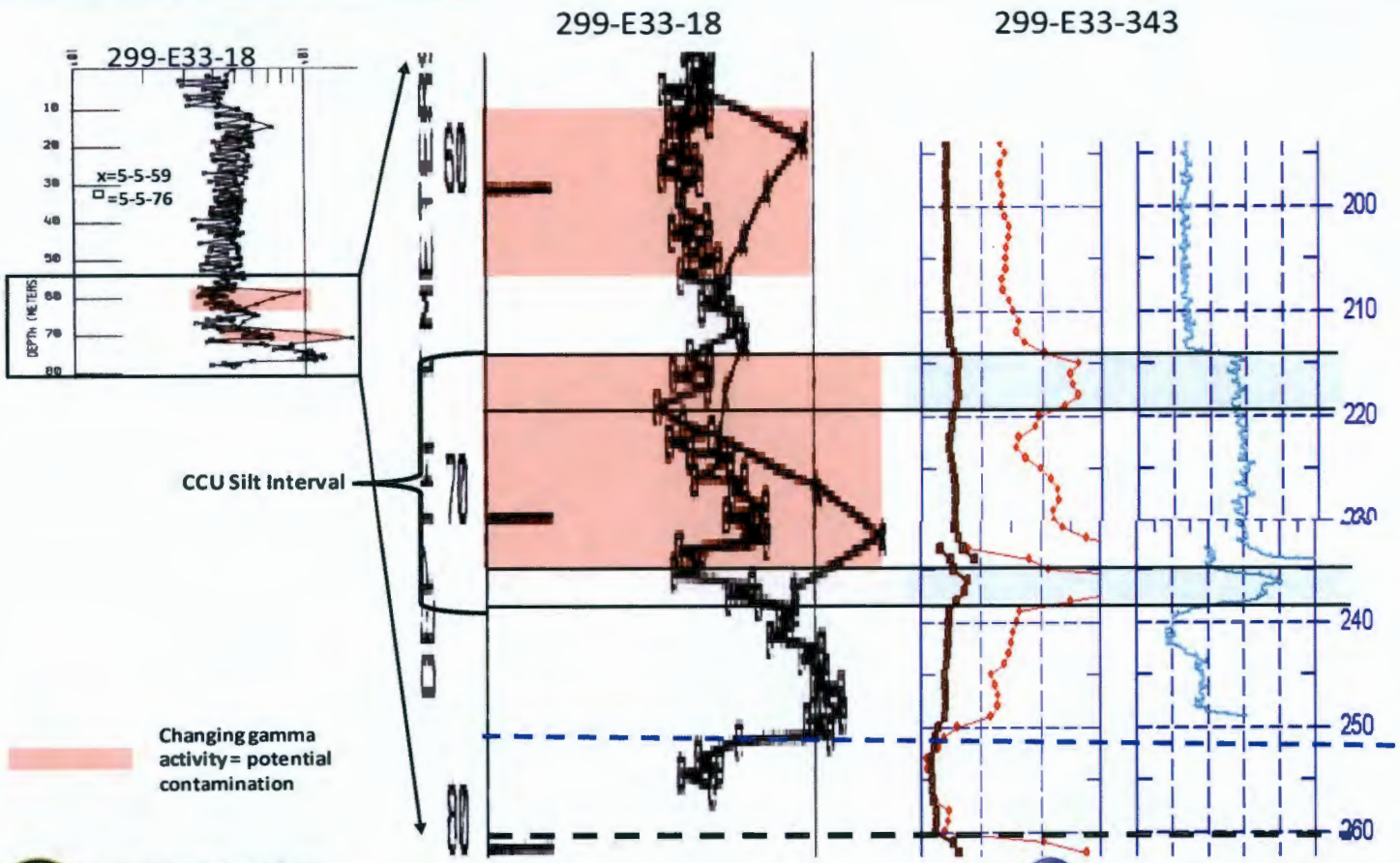
Temporal Geophysical Logging Data Indicating Perching During 1959 Crib Operations (B-7A/ B?)



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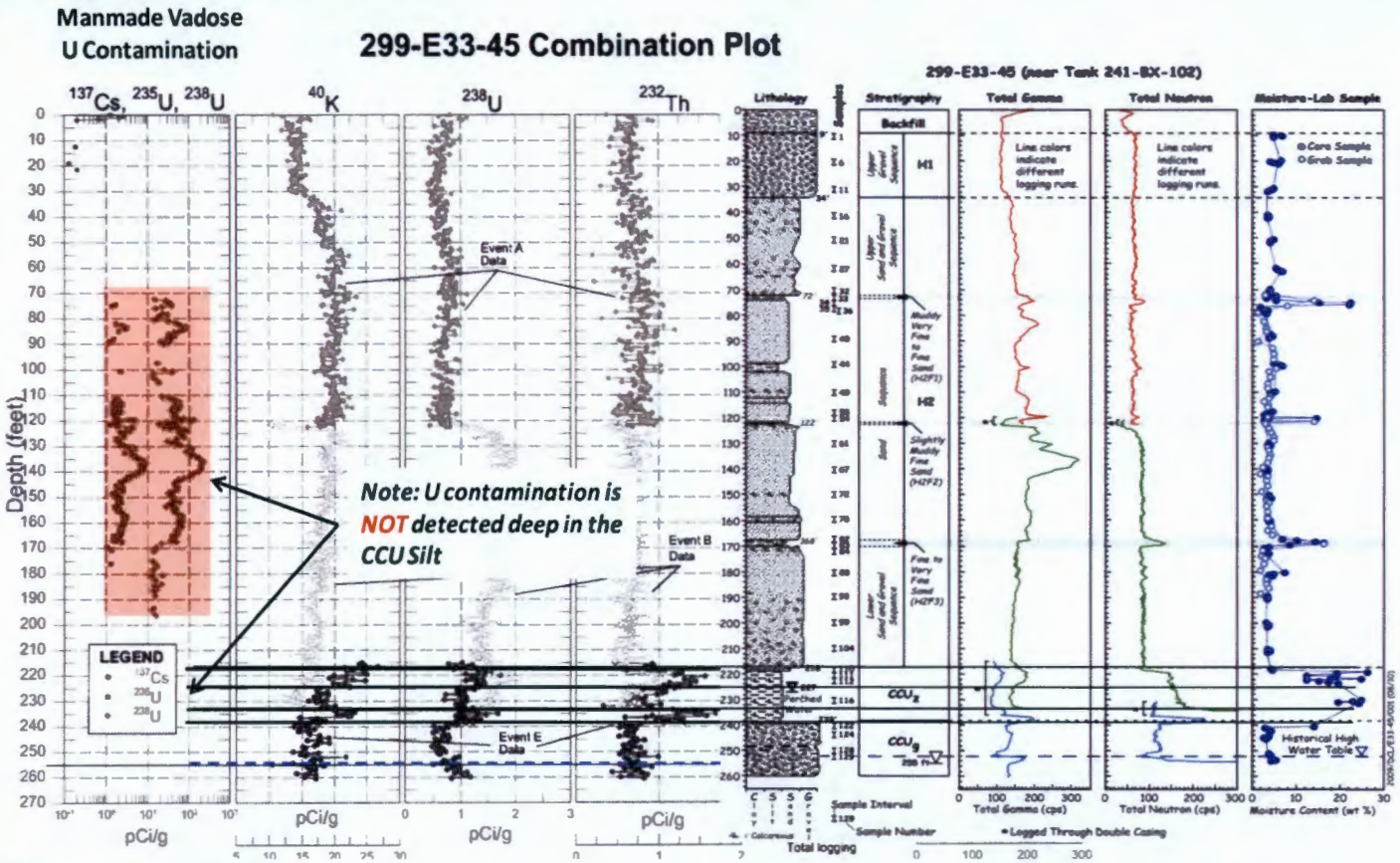
9

Example Geophysical-Geologic Correlation and Contaminant Identification Dataset (299-E33-45)



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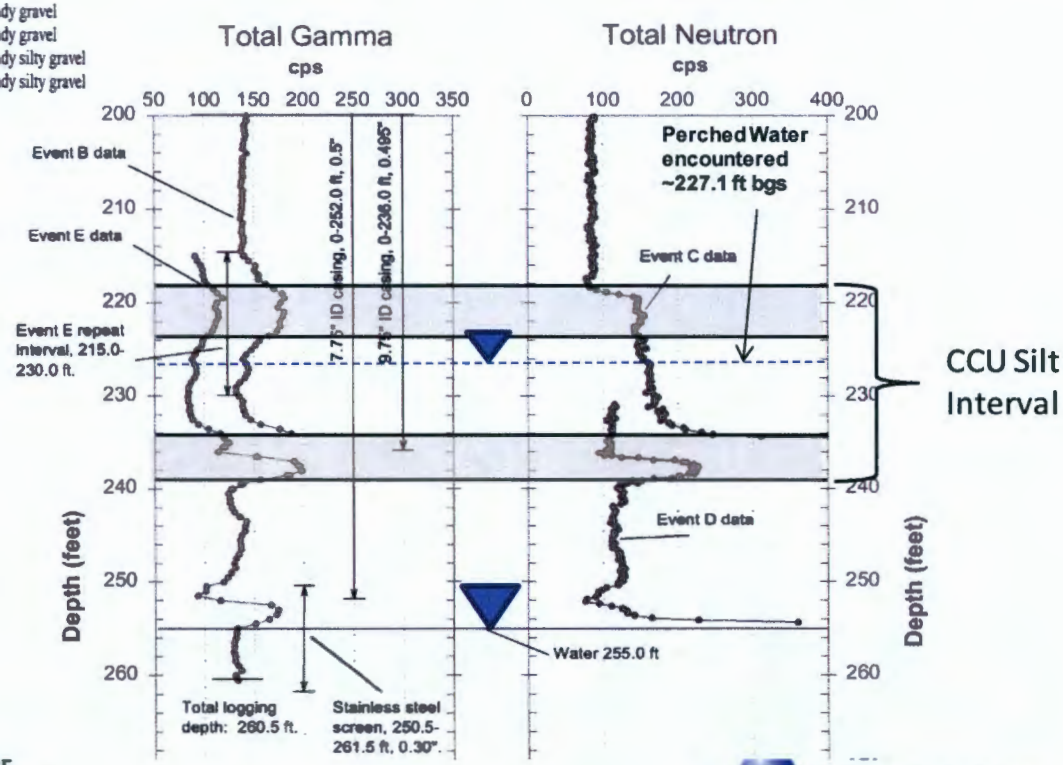
299-E33-45 Cold Creek Unit Geologic-Geophysical Correlation

[illegible]	Sand, slightly gravely
[illegible] to [illegible]	Sand, slightly gravely
217.8 to 220	sand/silt contact
219.97 to 222.2	Silt
222.2 to 224.1	Silt
229.7 to 231.9	Silt
240.1 to 242.3	Sandy gravel
243.5 to 245.7	Sandy gravel
250.1 to 252.3	Sandy silty gravel
251.9 to 254.1	Sandy silty gravel

From RPP-7921, Rev.0

Depth Datum: Ground Level



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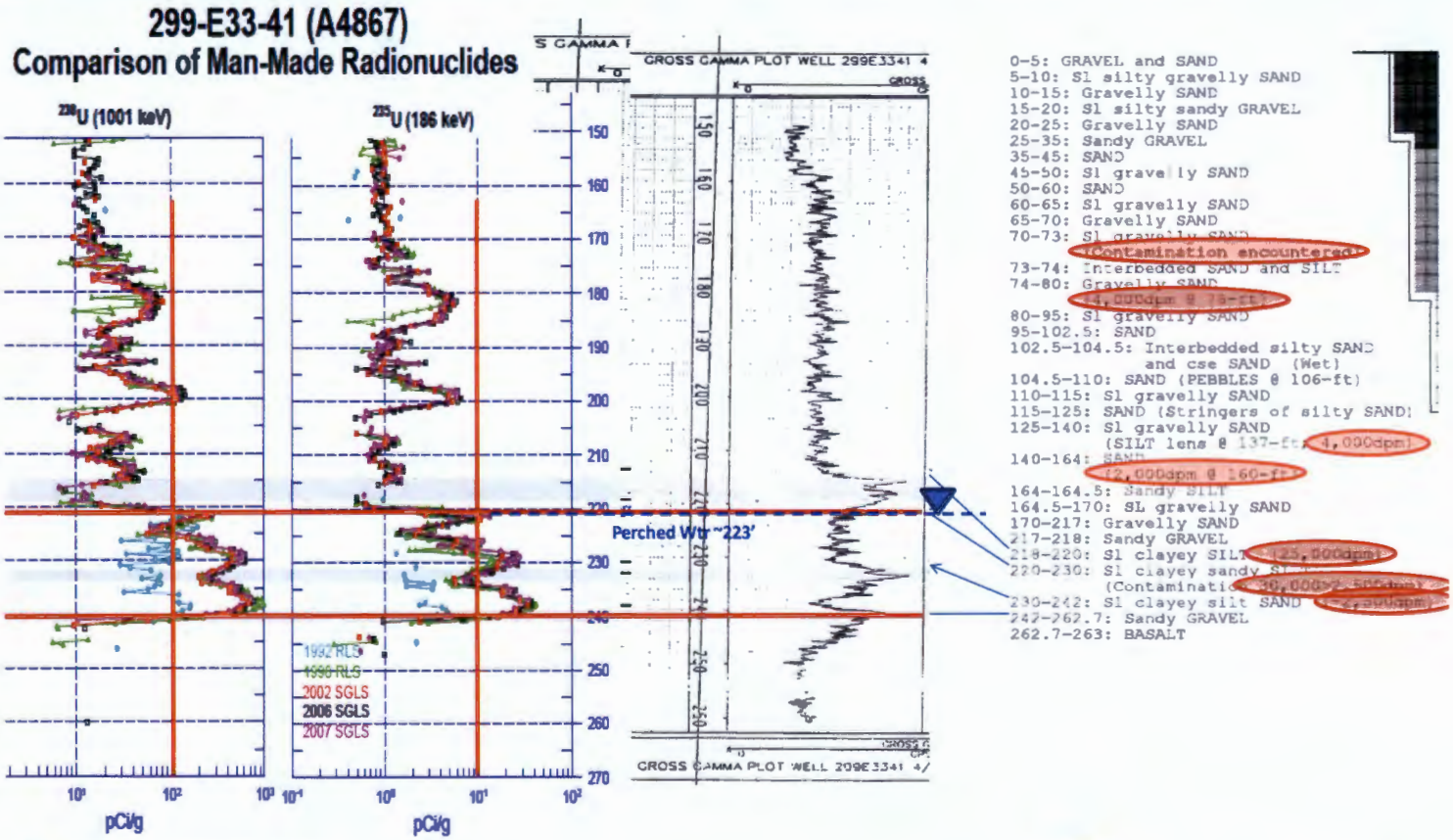
Example CCU-U Contamination Interpretation/Correlation



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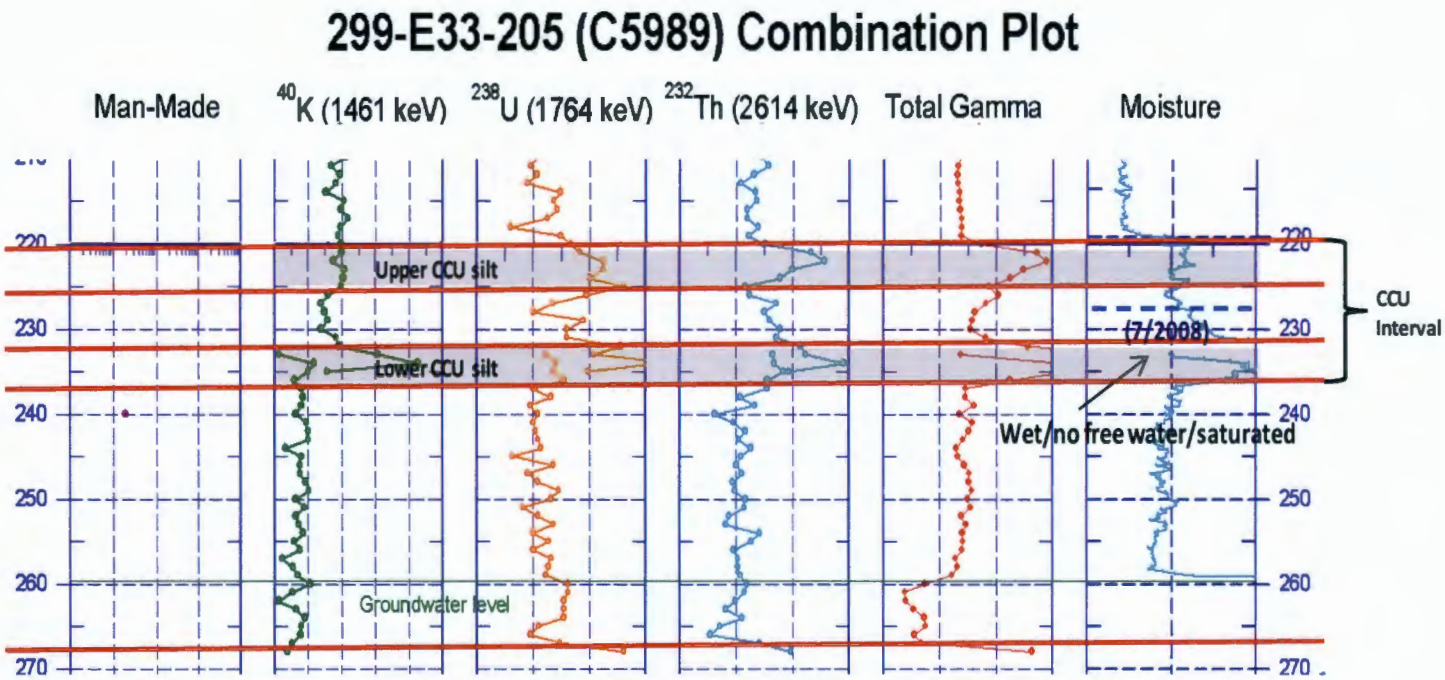
Example CCU Correlation in Well with No Uranium Contamination



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CCU Correlation in Well at B-8 Crib – Cesium-Cobalt Contamination (Throughout)

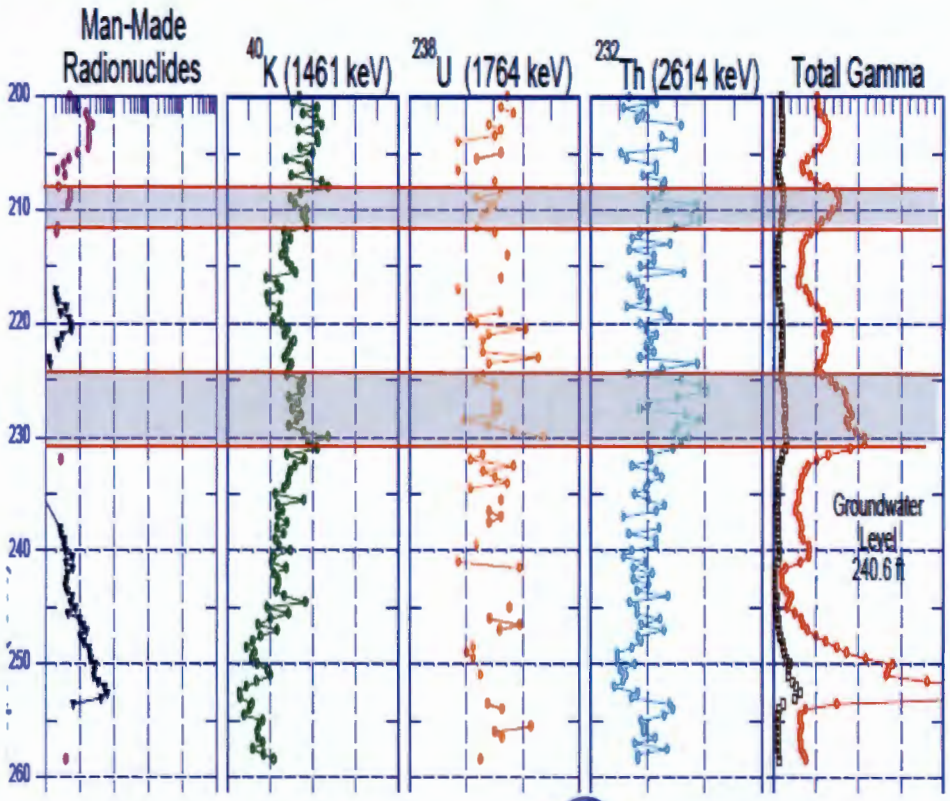
DRILLING		CORING		TYPE SOIL	
Time	Depth	Time	Depth		Time
					7:45-8:
8:30-8:45	208'	Heavy silt			
8:45-8:50	209'	Heavy silt			
8:50-9:00	210'	Heavy silt			
9:00-9:15	211'	Heavy silt			
9:15-9:25	212'	Heavy silt			
9:25-9:40	213'	Heavy silt			
9:40-9:55	215'	Shale and silt.			9:55-10
10:25-10:55	217'	Shale, silt and fine black gravel.			
10:55-11:10	219'	Shale, silt and fine black gravel.			
11:10-11:30	221'	Heavy silt			11:30-1
12:50-1:10	223'	Heavy silt			12:00-1

REMARKS

Ran out of bet stuff at 208'

Left the heavy silt between 226' and 227' picked up gravel and sand.

299-E33-16 (A6855) Combination Plot



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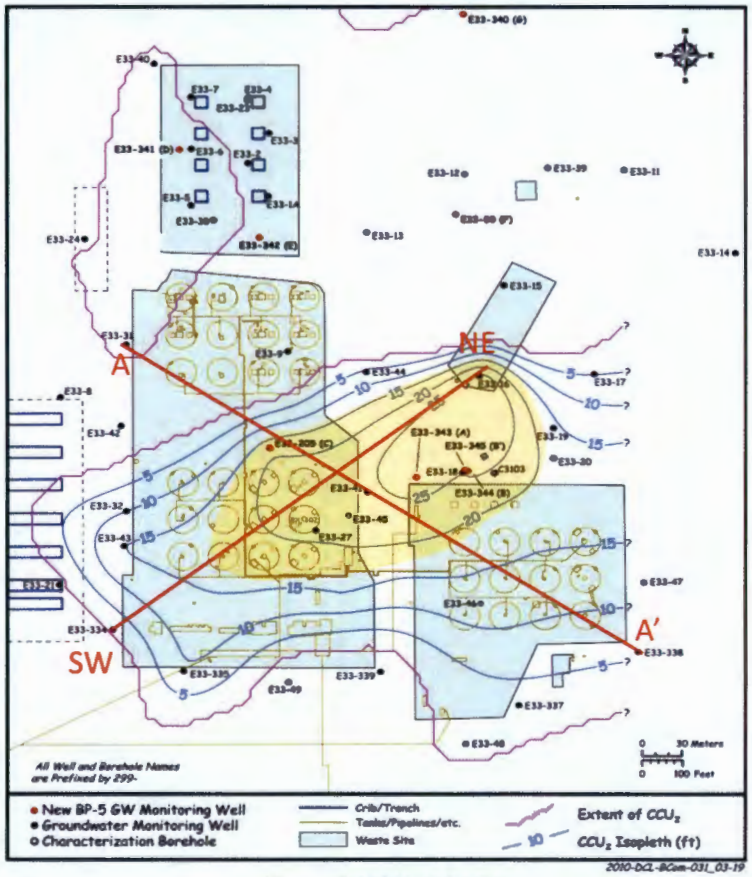
Areal Extent of CCU Lower Silt Layer

Cold Creek Unit Silts Gross Isopach map

C. I. = 5 ft

= Extent of Lower Perching Silt



From PNNL-14121

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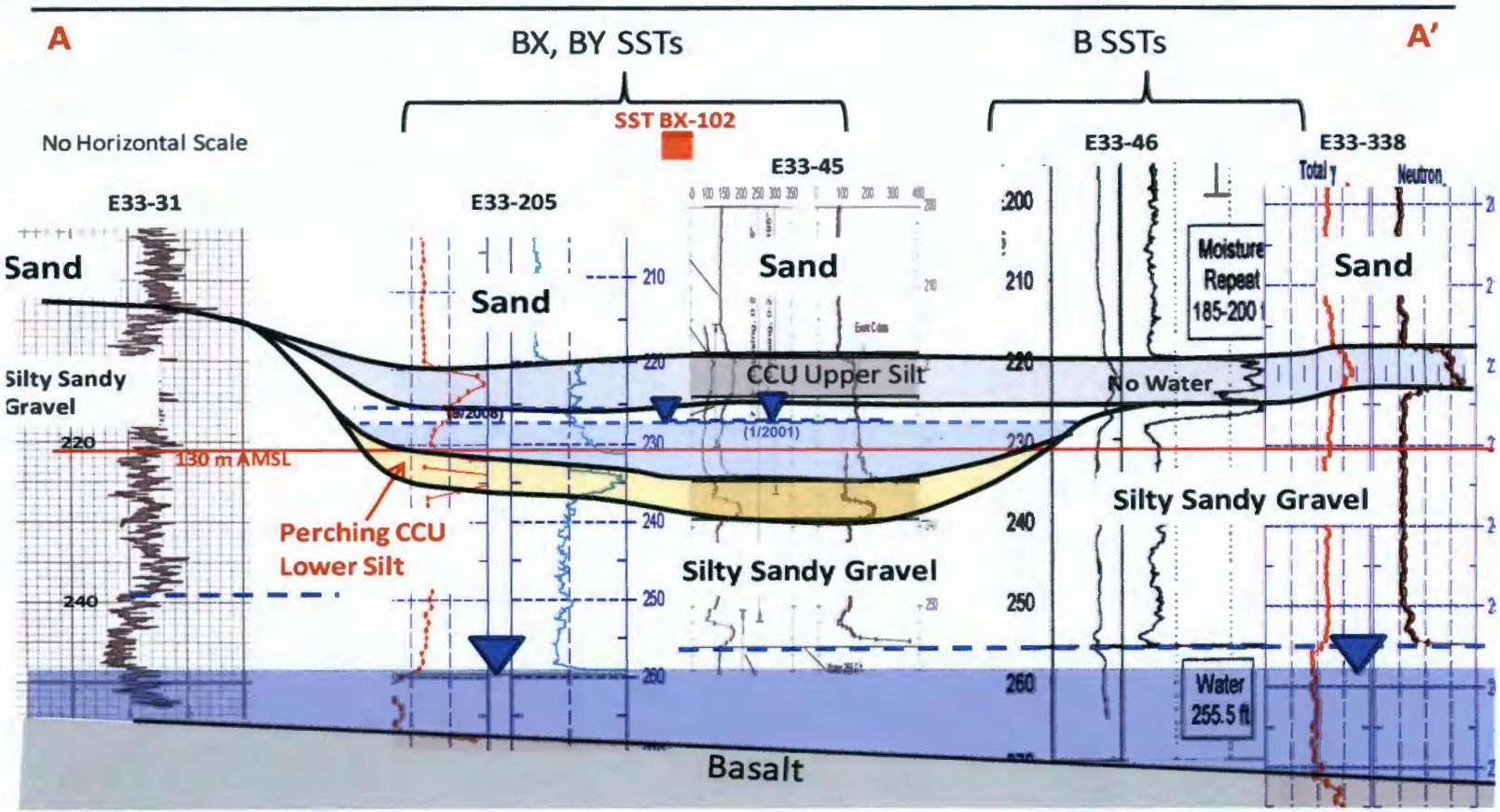
Hydrogeologic Cross Section A-A' Illustrating Upper and Lower CCU



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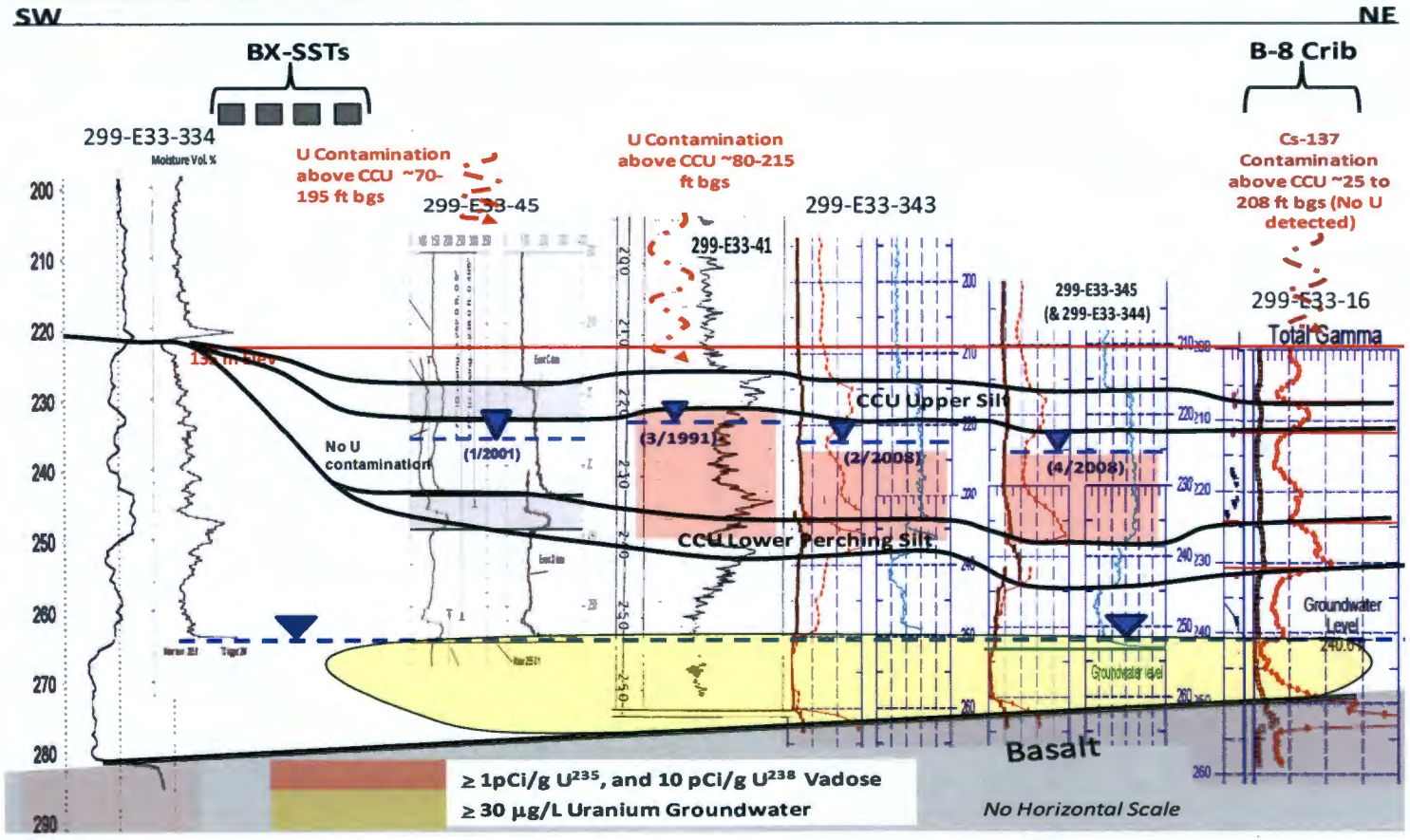
Hydrogeologic Cross Section SW-NE Illustrating CCU and Perched Uranium



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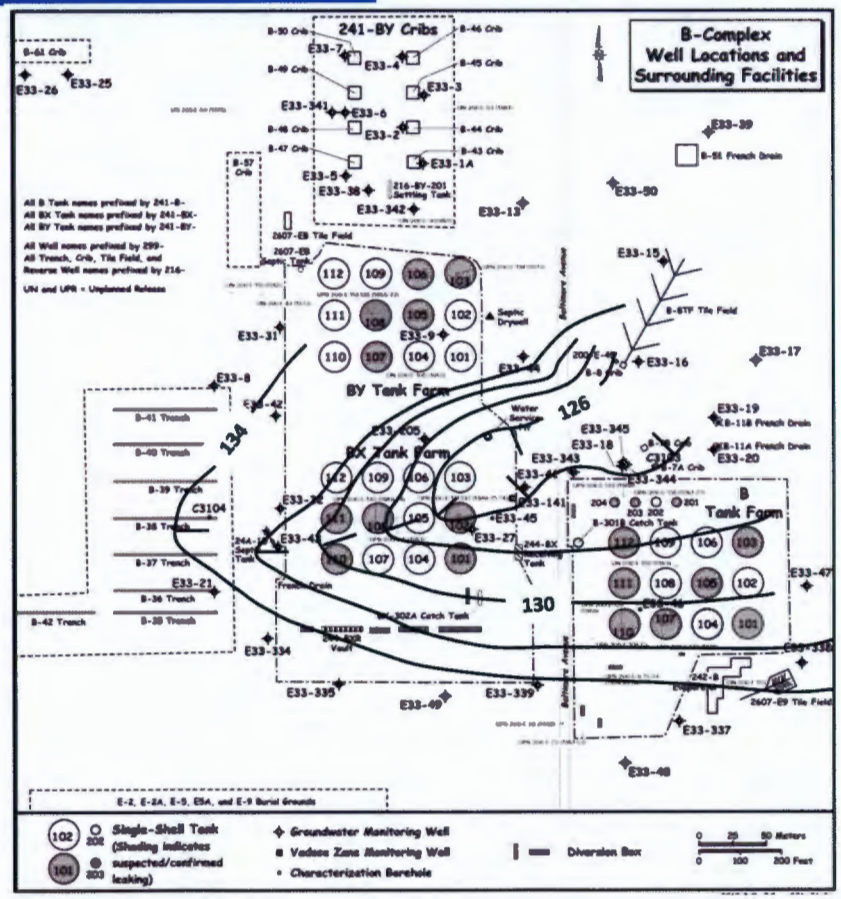
Structural Elevation Map of Top of Basal CCU Gravel Dominated Interval



Structural Elevation Map – Top of Basal CCU_{gravel}

C. I. = 2 meters

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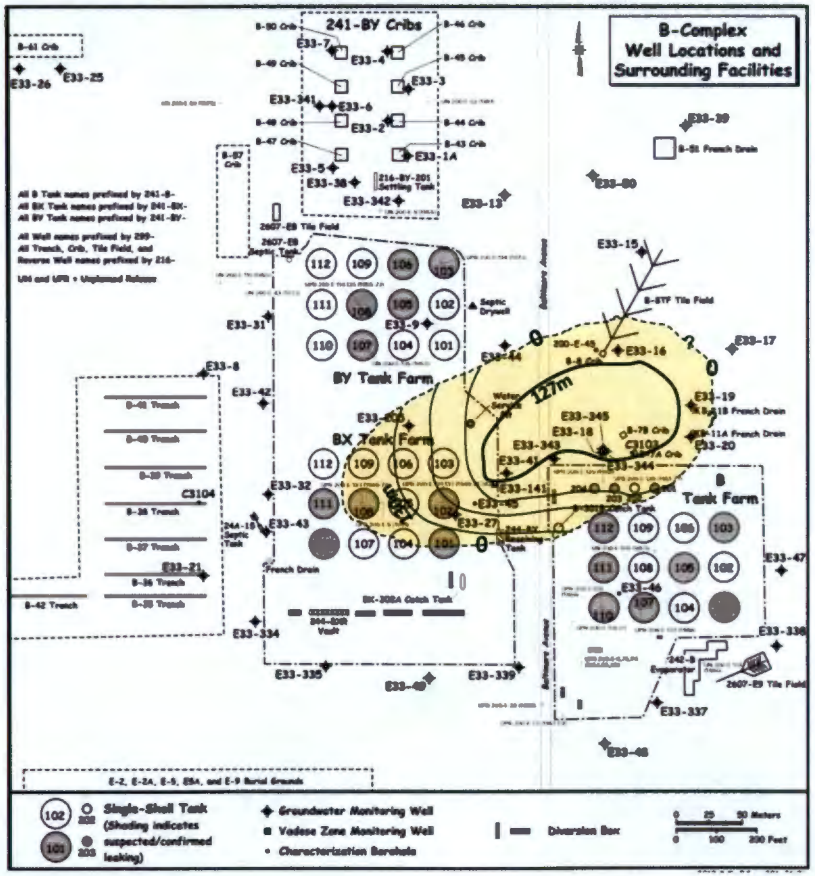
Structural Elevation Map –Cold Creek Unit - Lower Silt/Clay Layer



Structural Elevation Map – Cold Creek Unit Lower Silt/Clay

C. I. =1m

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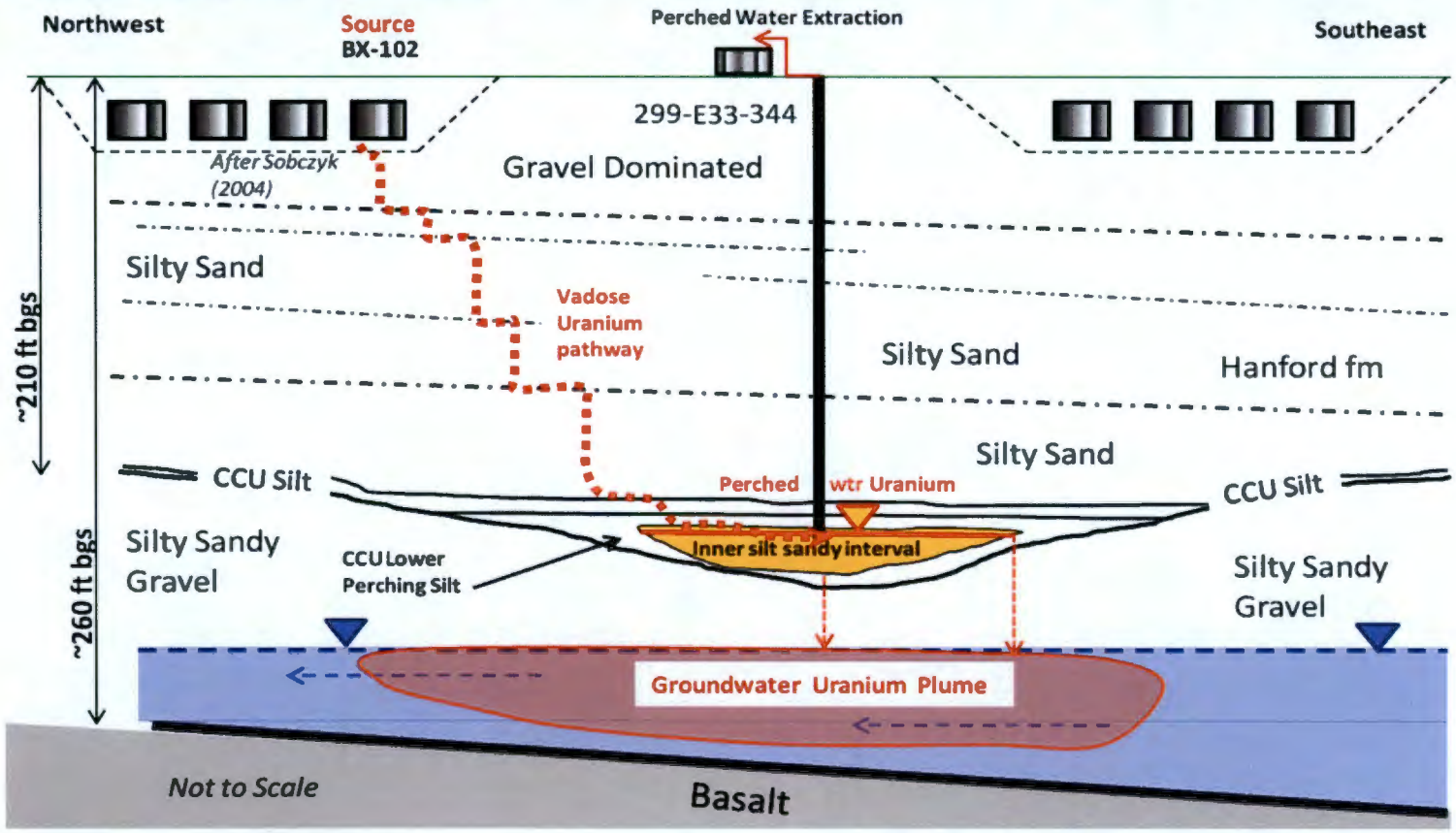
Cold Creek Unit Perching Zone Conceptual Site Model, B-Complex, 200 East Area



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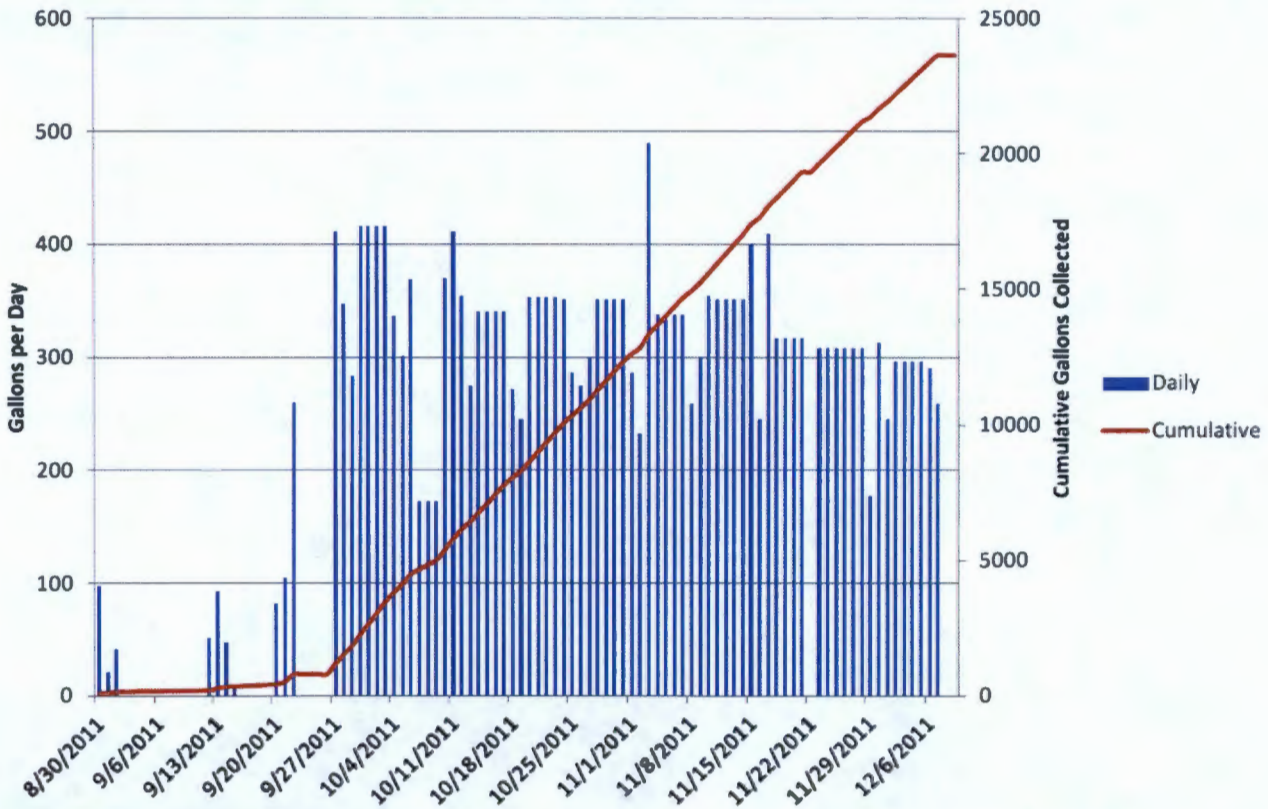
Perched Water Well Performance Data – Daily and Total Gal. Removed



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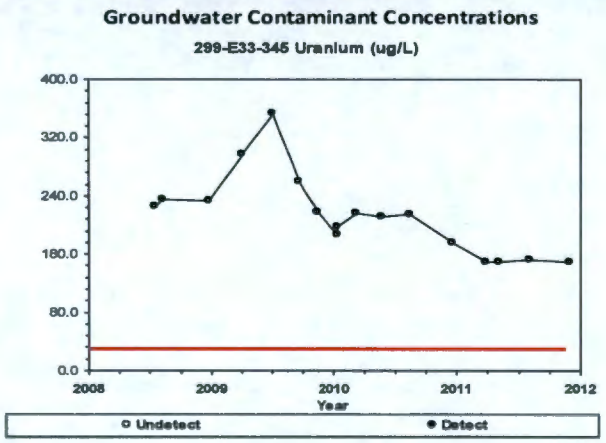
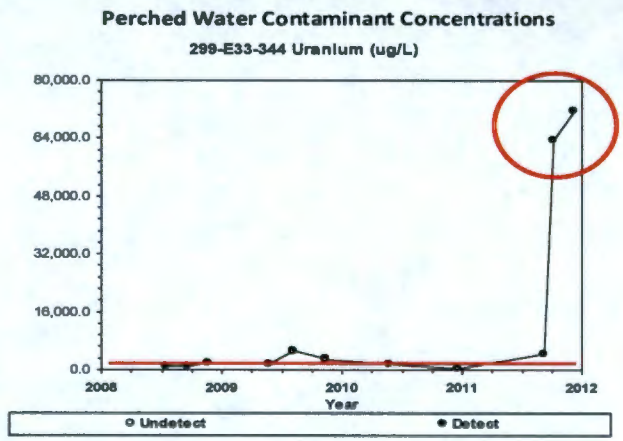
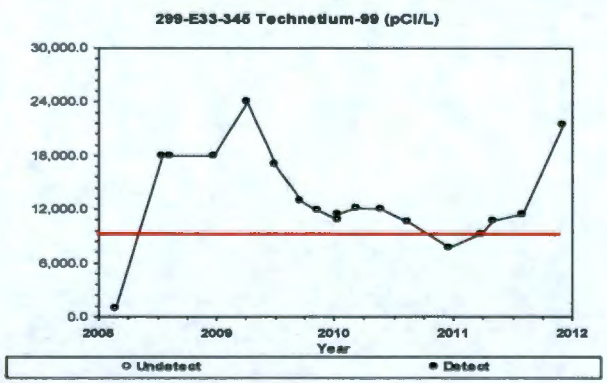
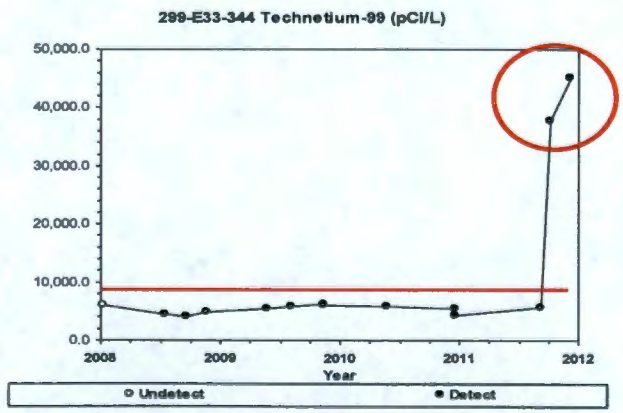
Uranium and Technetium-99 Concentrations in Groundwater and Perched Vadose Zone Water









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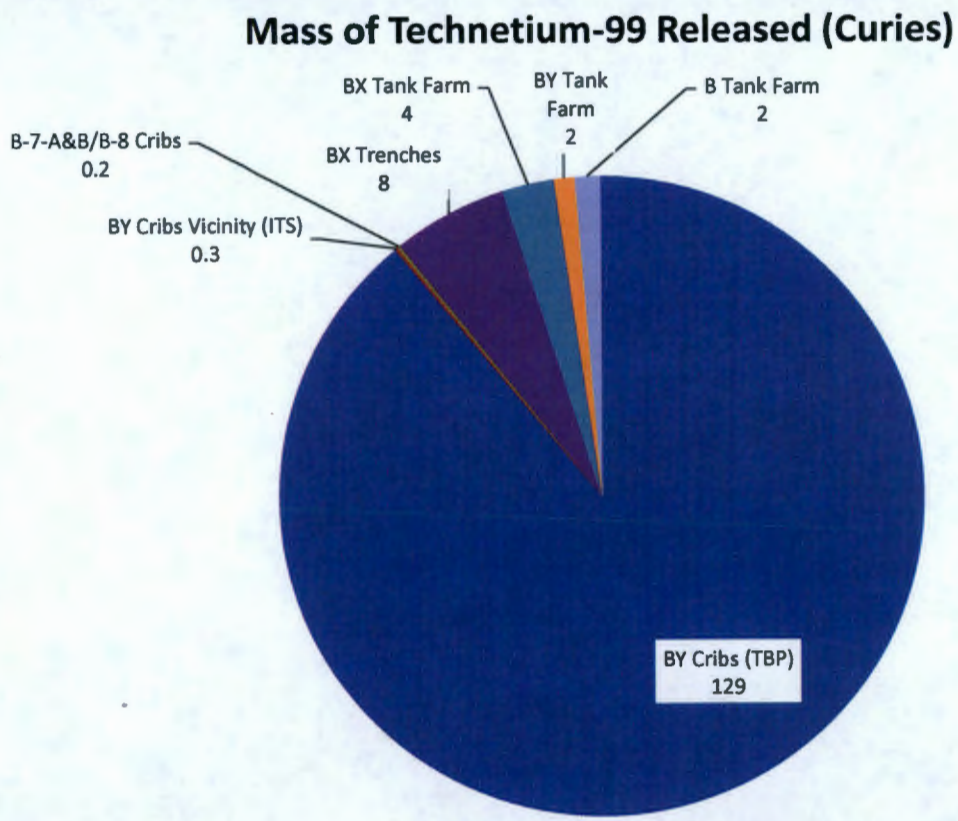
Technetium-99 Released to Subsurface



(PNNL-19277, Table 3.25)

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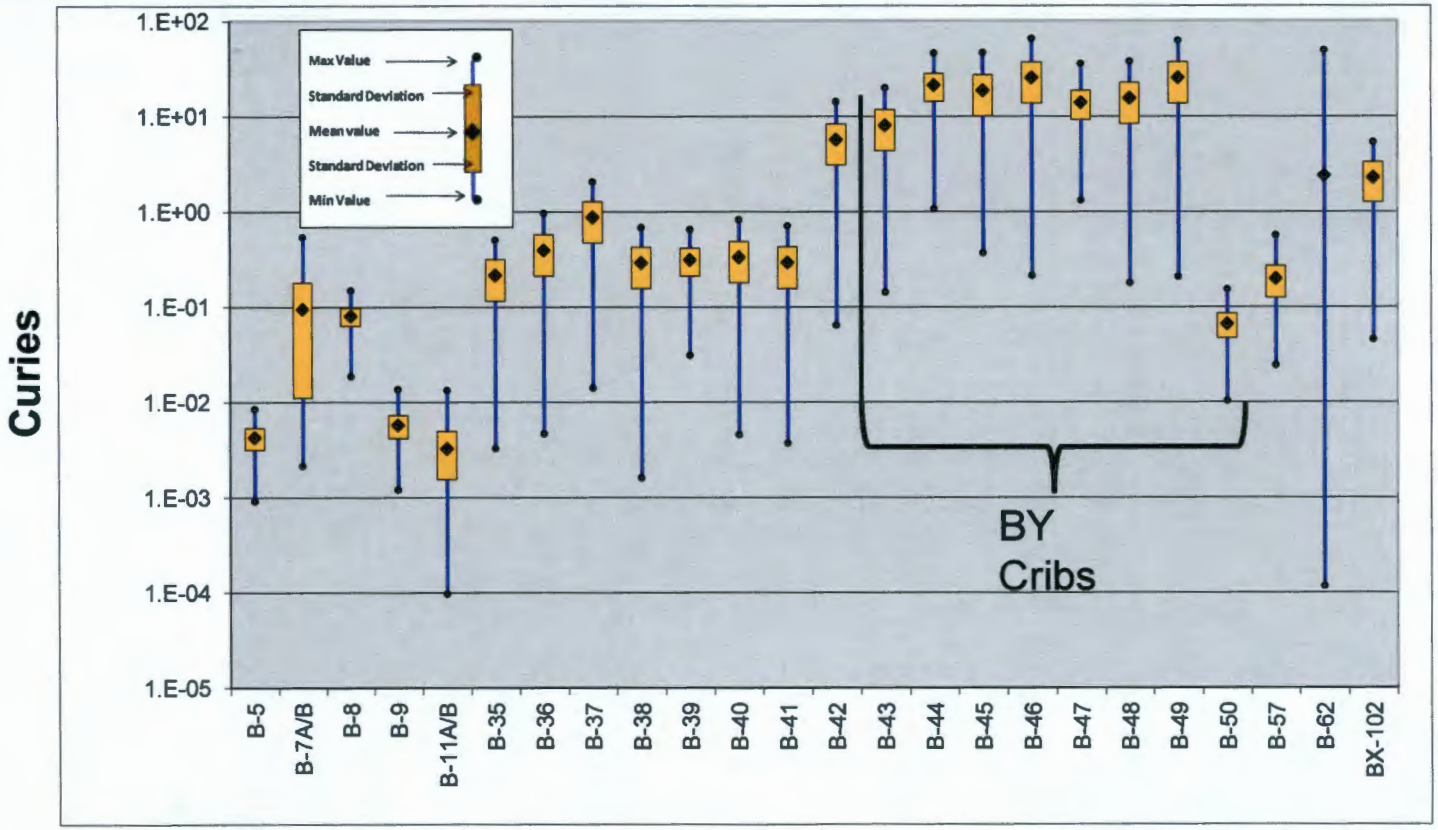
Technetium-99 Inventory for 200-DV-1 (B-Area Complex)



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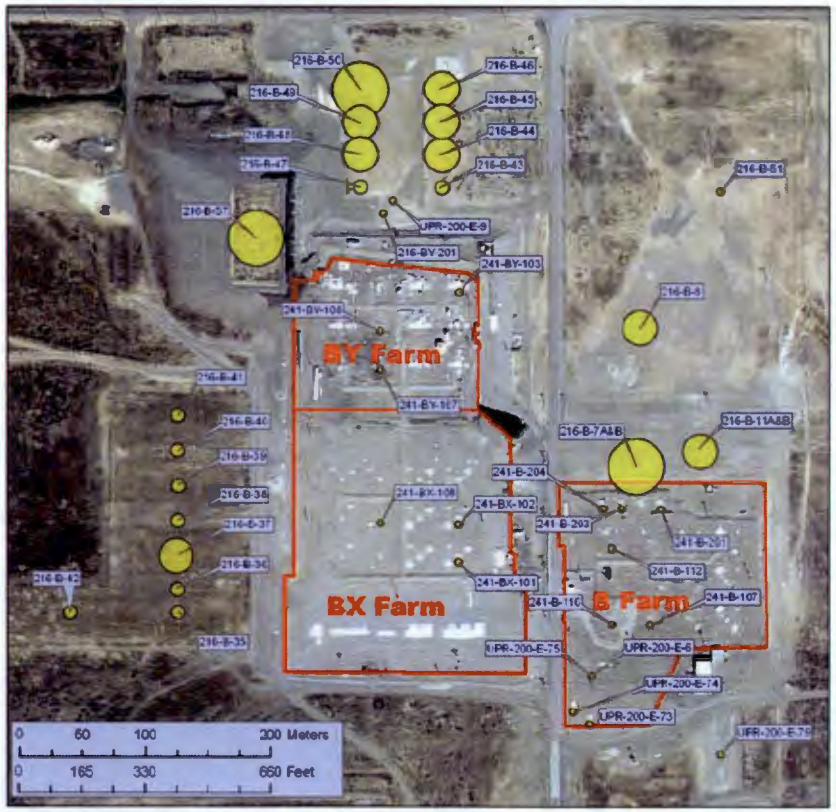
Disposal/Leak Volumes by Waste Site



Total Disposal Volume in Millions of Gallons

- 0.0 - 0.1
- 0.2 - 1.0
- 1.1 - 10.0
- >10

After RPP-34690

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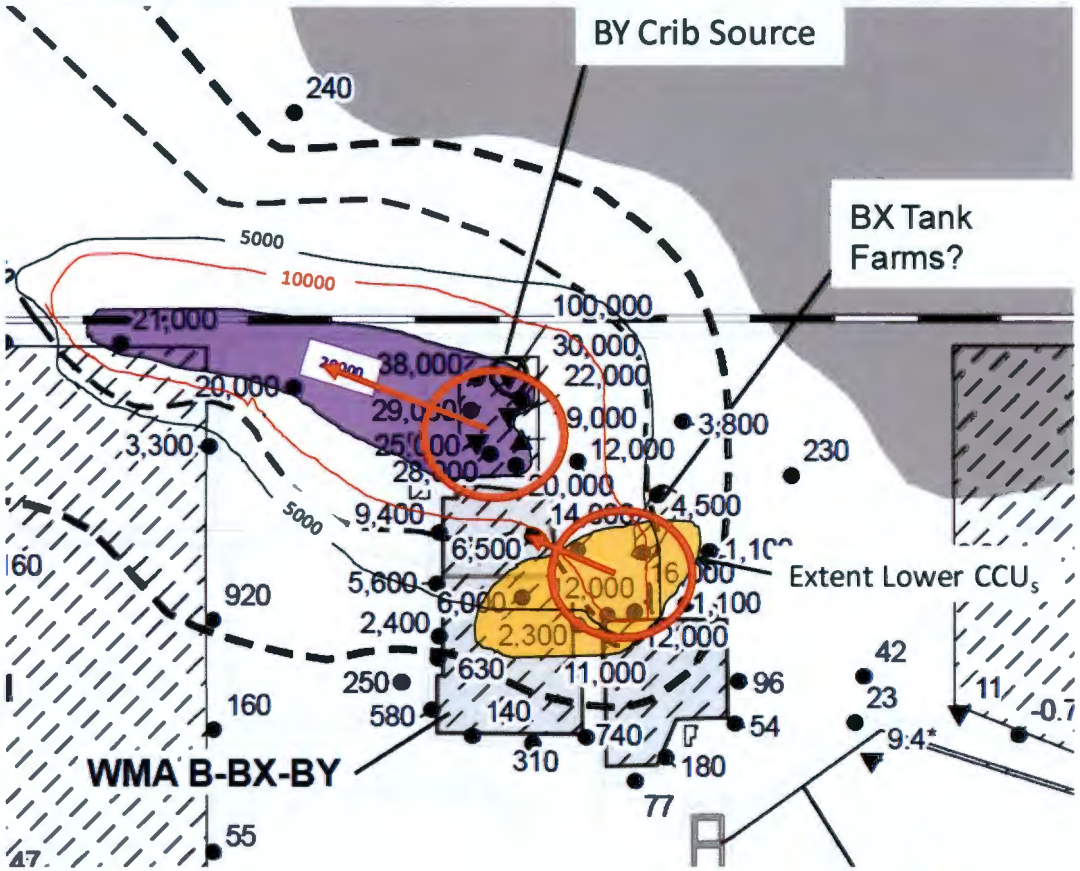
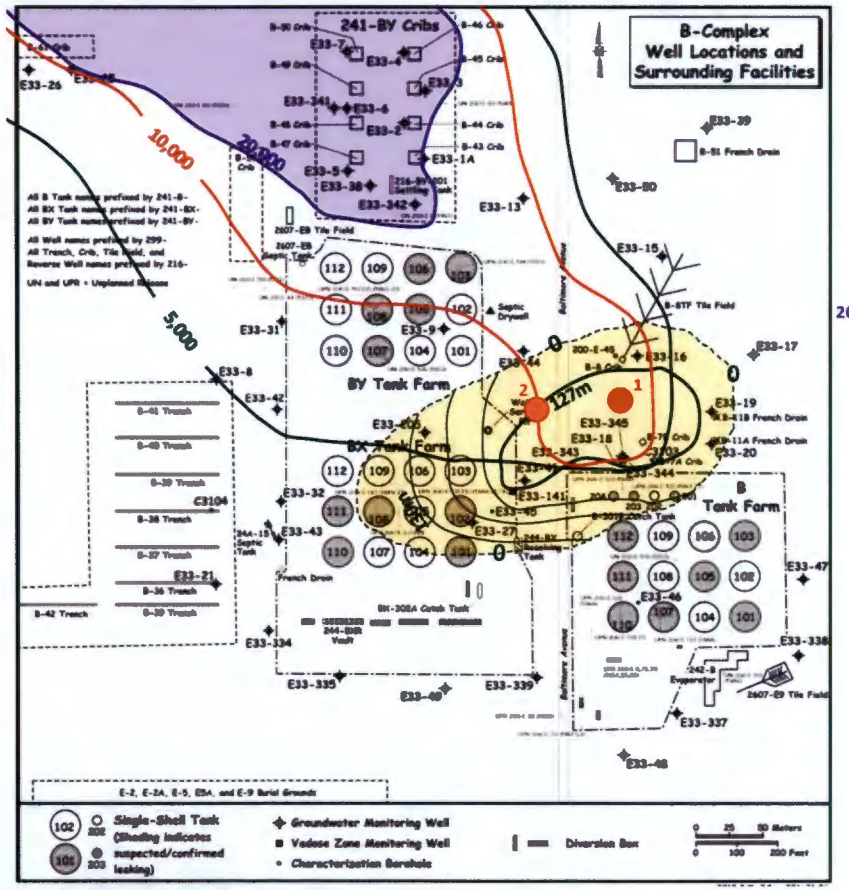
CY 2010 Technetium-99 Groundwater Plume Two Source Areas?

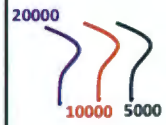


Proposed Well Locations-Deep Vadose Perched Zone Overlain on Technetium-99 GW Plume



Structural Elevation Map – Cold Creek Unit Lower Silt/Clay

C. I. =1m



= CY 2010 Technetium-99 Groundwater Plume

= Proposed CCU Perched Zone Extraction and/or Groundwater monitoring well Location

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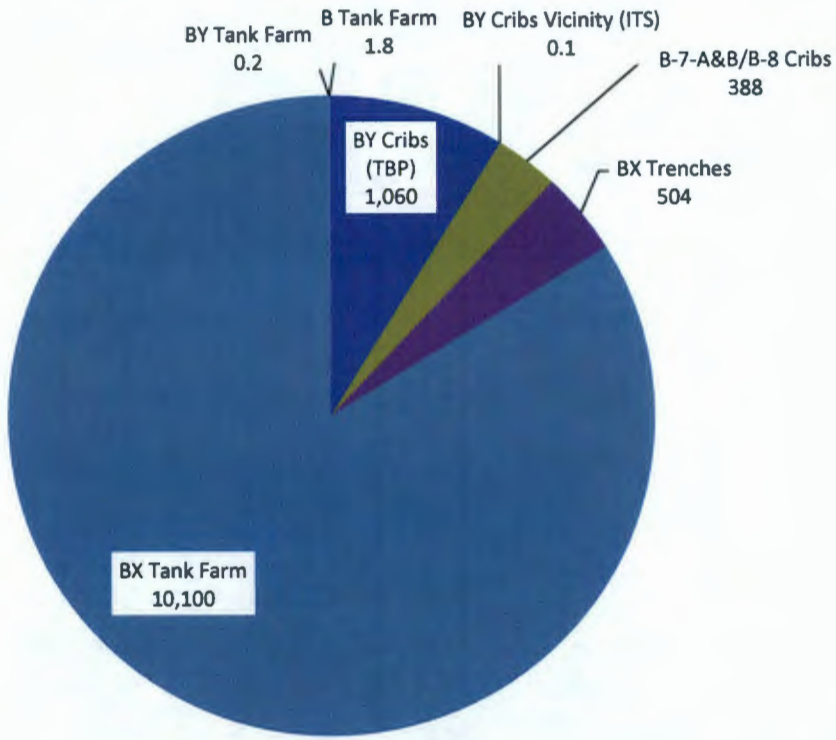
Uranium Released to Subsurface

Mass of Uranium Released (kilograms)



(PNNL-19277, Table 3.25)

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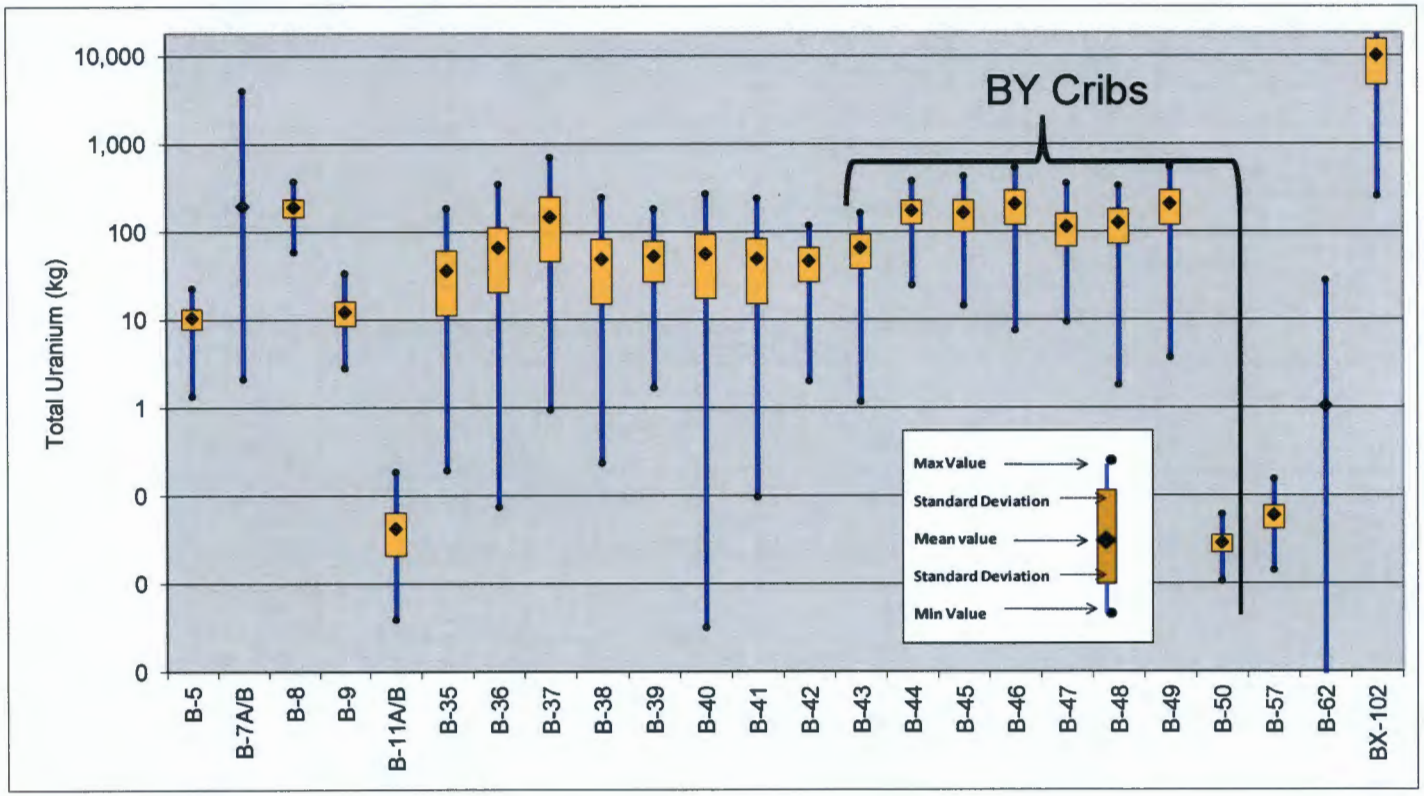
Uranium Inventory for 200-DV-1 (B-Area Complex)



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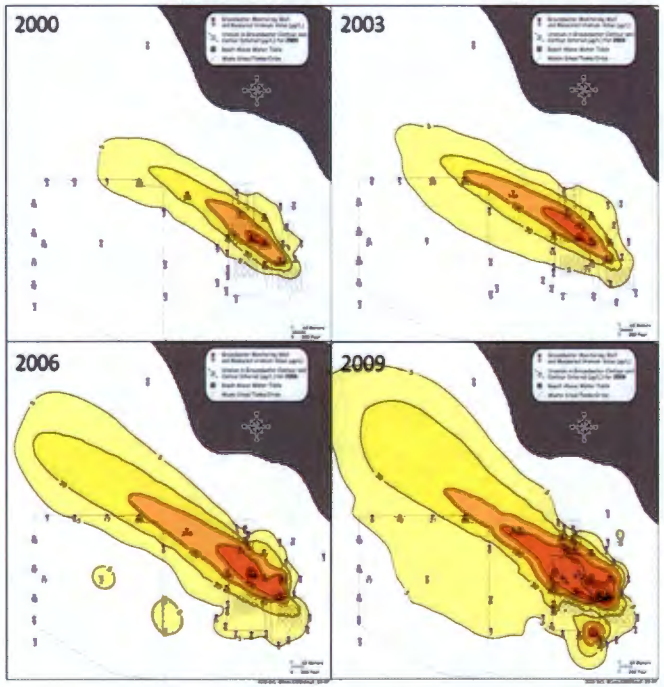
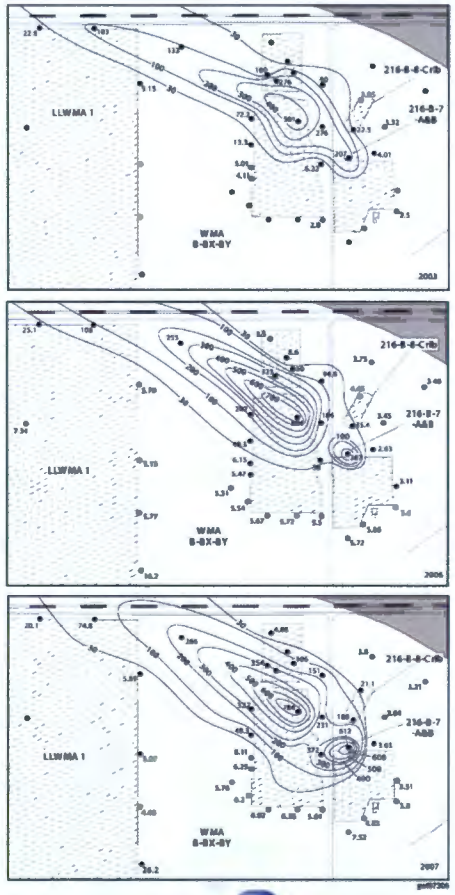
Uranium Groundwater Plume Interpretations 2000-2009

Published Uranium Plume Maps 2000-2009



From PNNL-19277, 2010



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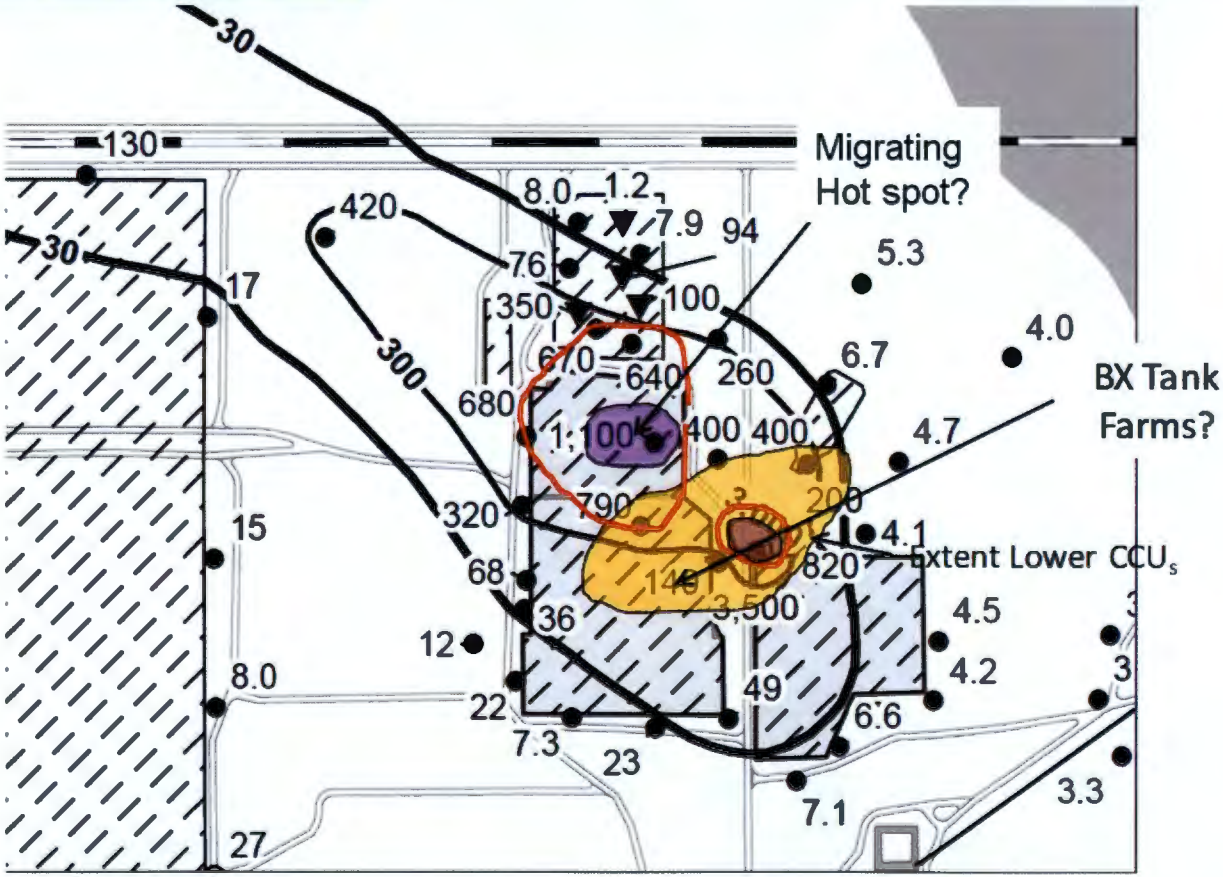
CY 2010 Uranium Plume at B-Complex Two Potential Sources?



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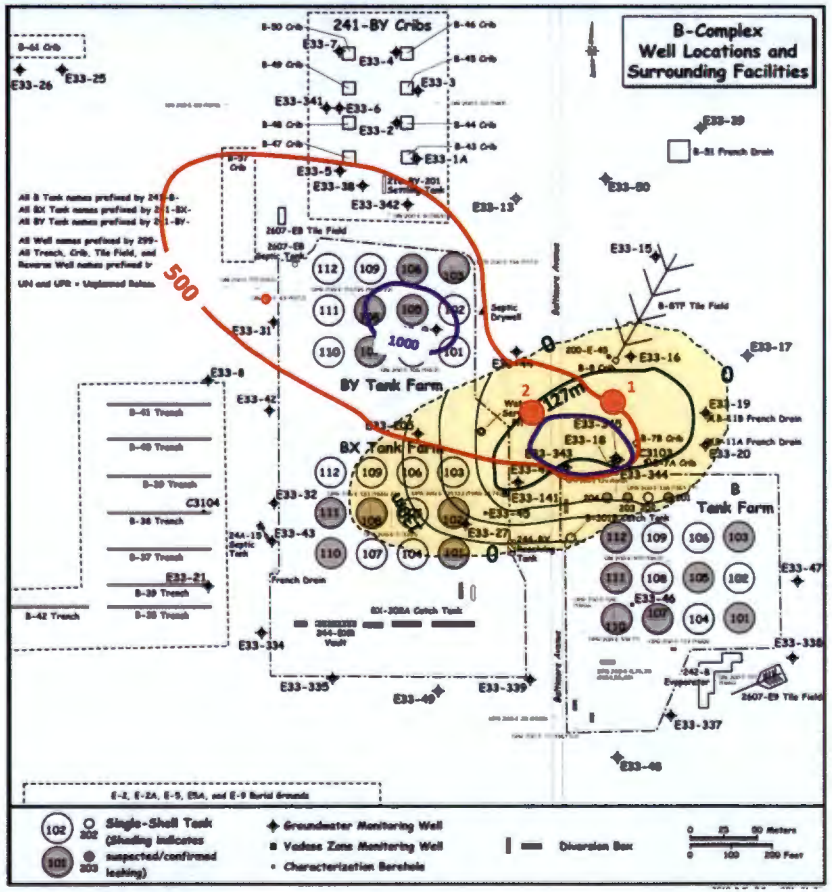
Proposed Well Locations-Deep Vadose Perched Zone Overlain on Uranium Groundwater Plume



Structural Elevation Map – Cold Creek Unit Lower Silt/Clay

C. I. =1m

1000 500 = CY 2010 Uranium Groundwater Plume

= Proposed CCU Perched Zone Extraction and/or Groundwater monitoring well Location

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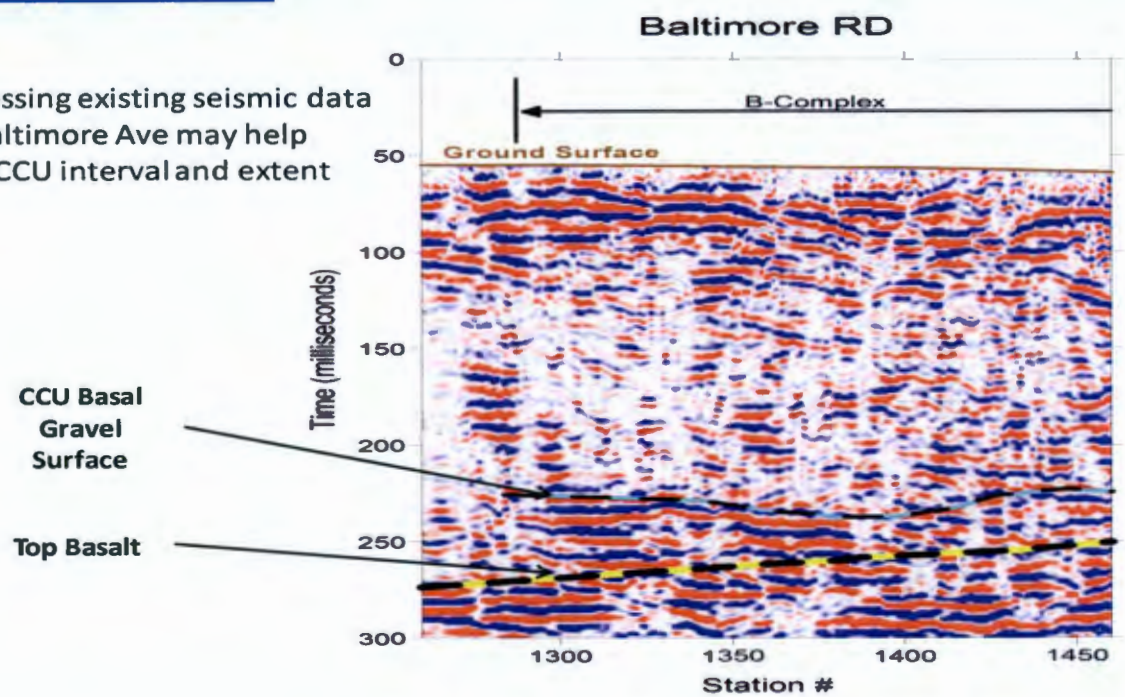
Geophysical Techniques May Improve Interpretation of CCU Extent

Reprocessing existing seismic data along Baltimore Ave may help resolve CCU interval and extent



Check Shot in 299-E33-340 places 210-250-ft depth in the seismic travel-time range of 220 ot 235 ms. Light-Blue and Black Dashed Line is in this range

Top-Basalt = Black-Yellow Dashed

Well 299-E33-339 near Station 1350
Well 299-E33-343 near Station 1435

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Possible Geophysics Work Scope East/Northeast of the B-Complex to Attempt to Map CCU Perched Water Zone

Scope	Limitations
PNNL re-analysis of the B-Area SGE data with a focus on the perched water	Reprocessing the existing data does not have sufficient resolution to delineate the perched water zone at this depth. Data results discussed during the 2/14/12 MPT meeting.
HGI reprocess existing SGE data in the B Area	See PNNL limitations above.
Collection of new SGE data based on the results of the above two items	Unknown, method is depth limited.
Perform check shot(s) and reprocess existing seismic data • go/no-go decision point: based on reprocessing of short segments on Baltimore Road and 12th Street profiles, determine ability of reprocessed seismic data to identify reflectors at the appropriate depth of the CCU	To be "visible", the perched water zone needs to be approximately 5 ft thick and extend 40-50 ft laterally. Method may be able to delineate the saturated/unsaturated zone, silt/gravel, and basalt contact.
Collect and process new time-domain electromagnetic (TDEM) data • go/no-go decision point: based on collection and evaluation of approximately 5 new TDEM stations, determine whether subsurface changes identified by TDEM correlate with presence of perched water zone	Perched water zone may be difficult to image separately from saturated water zone (aquifer), based on their vertical proximity. Infrastructure would potentially overwhelm the TDEM response.

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Proposed 200-DV-1 OU Perched Water Path Forward/Scope

Geophysical Data Evaluation-

Purpose a) Delineate CCU Silt interval extent

b) Delineate CCU saturated zone extent

c) Optimize Proposed New Well Location(s)

- Re-process Existing Seismic Data (including well check shot surveys).

Install Two Wells-

Purpose a) Evaluate the extent of the CCU.

b) Delineate contaminant sources (SSTs BY, BX, B-8, etc)

c) Capture additional contaminated perched water.

- Well 1 - Drill/characterize through CCU with focus on CCU interval. Obtain perched water/soil samples. Establish perched zone extraction/monitoring well between B-8 Crib and current extraction well (E33-344).

- Well 2 – Drill/characterize through CCU with focus on CCU interval. Obtain perched water/soil samples. Establish perched water extraction dependent on available quantity.

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