ADDENDUM D

GROUNDWATER MONITORING PLAN

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GROUNDWATER MONITORING PLAN

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D GROUNDWATER MONITORING PLAN, LIQUID EFFLUENT RETENTION FACILITY

This document describes a groundwater monitoring program for the Liquid Effluent Retention Facility (LERF). The LERF is a regulated unit under the *Hazardous Waste Management Act* [*Revised Code of Washington* (RCW) 70.105] and is subject to groundwater monitoring requirements pursuant to *Washington Administrative Code* [(WAC) 173-303-645].

D.1 Introduction

This plan describes the LERF groundwater monitoring program, including the monitoring network, constituent list, sampling schedule, sampling and analysis protocols, and data evaluation and reporting methods for LERF groundwater monitoring. Four monitoring wells at LERF (299-E26-10, 299-E26-11, 299-E26-77, and 299-E26-79) establish a monitoring network compliant with the requirements of the Permit (WAC 173-303-645).

D.1.1 History of Groundwater Monitoring at the Liquid Effluent Retention Facility

A groundwater monitoring program was established at LERF in 1990 before final construction of the regulated unit. Samples were collected quarterly from four monitoring wells (one upgradient and three down-gradient from the LERF), and evaluation of indicator parameters began before waste was transferred to the basins. Analytes listed in 40 *Code of Federal Regulations* (CFR) 264, Appendix IX; groundwater quality parameters; and several site-specific constituents were analyzed the first year of sample collection. Total organic carbon, total organic halides, pH, and specific conductivity (indicator parameters) were also analyzed during the first year; upgradient/downgradient comparison values were calculated for these parameters based on requirements of 40 CFR 265 Subpart F- Groundwater Monitoring. Detection monitoring continued on a semi-annual schedule. Two wells, 299-E26-9 and 299-E35-2, could no longer yield representative samples of groundwater in 1999 and 2001, respectively, due to declining water levels. These wells went dry in 2002 and 2005. Inter-well statistical evaluation of LERF groundwater monitoring data has not been performed since 2001. Sampling continued at former down-gradient well 299-E26-10 and former upgradient well 299-E26-11. Wells 299-E26-77 and 299-E26-79 were drilled and construction was completed in 2008 (*Borehole Summary Report for the Installation of RCRA Wells, FY 2008* [Sexton 2008]). These wells are located west and south of LERF, respectively, and were sampled concurrently with existing wells beginning in January 2009.
A groundwater evaluation was conducted during and subsequent to installation of the new wells, and the results indicate that the four wells form an adequate monitoring network capable of yielding representative samples of the uppermost hydrostratigraphic unit laterally continuous under the LERF basins (*Liquid Effluent Retention Facility Characterization Report* [Smoot 2009]).

D.1.2 Facility Description

This section provides an overview of the physical structures, operational history, and waste characteristics for the LERF. Additional details are provided in Chapter 3.0, Waste Analysis and Chapter 4.0, Process Information.

D.1.3 Physical Structure

The LERF is located in the central portion of the Hanford Site on the eastern boundary of the 200 East Area (Figure D.1). Construction of the LERF was completed in 1991. The LERF consists of three dangerous waste management units classified as a surface impoundment: Basins 42, 43, and 44.

The LERF is a 15.8-hectare (39-acre) site with three 2.9 x 10^7-liter (7.7-million-gallon) capacity basins. The basins are arranged side by side with 18.2-meter (60-feet) separation between each basin. The dimensions of each basin (cell) are 100.5 by 82.2 meters (330 by 270 feet), with a maximum fluid depth of 6.7 meters (22 feet). The side slopes of the basin have a slope ratio of 3:1.

The primary liner for each basin is a 60-mil, high-density polyethylene (HDPE) geomembrane laid directly over a manufactured geotextile/bentonite carpet layer. The secondary liner is also a 60-mil HDPE geomembrane laid directly on 0.9 meters (36 inches) of a soil/bentonite mixture. The liners are

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separated by a synthetic drainage geonet laid on the sides of the basins, with 0.3 meters (12 inch) of drainage gravel at the bottom. The sides slope to a sump, which is pumped when the liquid level reaches approximately 28 centimeters (11 inches) and shuts off when it drops to 18 centimeters (7 inches).

D.1.4 Operational History

The LERF was constructed to manage 242-A evaporator process condensate. Since the completion of the 200 Area Effluent Treatment Facility (ETF), the LERF stores liquid wastes for operations at the ETF and related activities. The LERF basins have also been identified to provide storage capacity for other Hanford Site projects involving contaminated waste streams.

The first 242-A evaporator waste reduction campaign, and transfer of wastewater to LERF, began in April 1994. Future waste streams will be identified for management in LERF as cleanup activities at Hanford progress.

D.1.5 Waste Characteristics

The ETF was designed to treat a variety of aqueous wastes containing both chemical and radiological contaminants. They include, but are not limited to, the following Hanford wastes: 242-A evaporator process condensate; contaminated groundwater from pump-and-treat remediation activities; laboratory aqueous waste from unused samples and sample analyses; and leachate from landfills, such as Trenches 31 and 34 in 218-W-5 burial ground, and the Environmental Restoration Disposal Facility. Waste characteristics acceptable for management at LERF and the 200 Area ETF are defined by the requirements of Chapter 3.0, Waste Analysis Plan.

Influent samples from the ETF and the 242-A Evaporator effluent, and basin samples provide information on the types and concentrations of dangerous constituents in the wastes. These data are maintained in the Hanford Facility Operating Record, LERF and 200 Area ETF file, and in the Hanford Environmental Information System (HEIS) database and were reviewed to evaluate and select dangerous constituents, as well as indicator parameters for groundwater monitoring at LERF. If the waste acceptance criteria for the LERF basins are modified, the LERF Groundwater Monitoring Plan will be evaluated and if necessary, a permit modification will be requested.

D.2 Hydrogeology and Groundwater-Chemistry

This section describes the geology, hydrogeology, and groundwater chemistry beneath the LERF area.

D.2.1 Geology

The geology near the LERF consists of Columbia River Basalt overlain by a series of sedimentary units of the Ringold Formation and Hanford formation. This discussion is primarily based on information from *Geology and Hydrology of the Hanford Site: A Standardized Text for Use in Westinghouse Hanford Company Documents and Reports* (Delaney et al. 1991); *Site Characterization Report for the Liquid Effluent Retention Facility* (Sweeney et al. 1994); *Revised Hydrogeology for the Suprabasalt Aquifer System, 200-East Area and Vicinity, Hanford Site, Washington* (Williams et al. 2000); and on the results from the groundwater evaluation performed in 2008 and 2009 (Smoot 2009). The terrain surrounding the LERF is flat to slightly undulating, and the average elevation is approximately 195 meters (640 feet) above mean sea level (msl). The LERF lies in the Pasco Basin, between the axis of the Umtanum-Gable Mountain anticlinal ridge and the axis of the Cold Creek syncline.

The stratigraphy beneath the LERF is interpreted from the four boreholes drilled to construct the original groundwater monitoring network, in addition to the two new wells constructed in 2008. Correlations were also made with data from nearby sites. The thickness of the sediments near the LERF basins is about 61 meters (200 feet). Three principal stratigraphic units present near the LERF are the Hanford formation, the Ringold Formation, and the Elephant Mountain Member of the Saddle Mountains Basalt.

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D.2.1.1 Hanford Formation

The Hanford formation in the vicinity of the LERF ranges from approximately 59 to 61 meters (193 to 200 feet) thick and consists predominantly of a loose, sandy, pebble-cobble gravel; and a gravelly sand, with occasional layers of sand and/or muddy sand. The Hanford formation is subdivided into an upper gravel sequence (Hug), a sandy sequence (Hs), and a lower gravel sequence (Hlg) in some areas. The sandy sequence is present locally, and where it is missing, the single sequence of gravel-dominated facies exists, designated as undifferentiated (Hun) on the cross-sections.

The LERF is located along the southern flank of a major west-northwest/east-southeast trending cataclysmic flood channel. Because of multiple flood events and the turbulence and extremely high-energy associated with these floods, it is difficult to correlate individual strata within flood sequences. In outcrops of the Hanford formation elsewhere in the Pasco Basin, for example, it is common to see changes from gravel-dominated sediments to sand and silt-dominated sediments over a distance of a few tens of meters.

D.2.1.2 Ringold Formation

The Ringold Formation represents ancient fluvial and lacustrine deposits associated with the ancestral Columbia River and the formation exhibits consolidation and weathering. Isolated, erosional remnants of the Ringold Formation may exist locally between the Hanford formation and the basalt beneath the LERF. The *200 East Groundwater Aggregate Area Management Study Report* (U.S. DOE 1993) reported approximately 2.74 meters (9 feet) of the Ringold Lower Mud Unit in well 299-E26-11 and mapped the Lower Mud Unit extending to this location from the east. This also has been interpreted as a possible saprolite (residual mud) resulting from weathering of the Elephant Mountain Member flow top. Thin (few meters or less) pockets of Ringold Formation also occur to the south near well 299-E25-9.

D.2.1.3 Elephant Mountain Member

The nature and extent of the Elephant Mountain Member basalt is better understood as the result of characterization performed in 2008 near the LERF basins. This is one of the youngest members of the Saddle Mountains Basalt and is the uppermost basalt in this area. In the immediate vicinity of the LERF basins, the basalt surface consists of a ridge on approximately the same trend as Gable Mountain and Rattlesnake Mountain. This portion of basalt appears to be fractured, vesicular, and permeable, suggesting that it is basalt flow top. The Elephant Mountain Member basalt was encountered in all six wells drilled near the LERF. The Elephant Mountain Member basalt dips to the south with a gradient of approximately 2×10^{-2}.

The Elephant Mountain Member flow top is composed of basalt rubble, reddish-brown weathered basalt, broken or cracked basalt, and vesicular basalt. Results of drilling and sampling of wells 299-E26-77 and 299-E26-79 in 2008 indicate the presence of permeable basalt in the lower portion of the unconfined aquifer. The thickness of the flow top ranges from 2 meters (6.5 feet) at well 299-E26-77 (west of the LERF) to 3.2 meters (10.5 feet) at well 299-E26-79 (south of the LERF), and 1.5 meters (5 feet) at well 299-E26-11 (east of LERF).

The interior of the Elephant Mountain Member is intact. Observations of drilling at wells 299-E26-77 and 299-E26-79, where drilling slowed dramatically approximately 5.5 to 6.1 meters (18 to 20 feet) below the first encounter of basalt, indicated the presence of competent basalt colonnade or entablature. This observation is confirmed regionally in other wells, including 699-47-42 and 299-E26-8.

D.2.2 Groundwater Hydrology

The vadose zone beneath the LERF is in the Hanford formation and portions of the Elephant Mountain Member basalt above the water table, as well as potentially some of the Ringold Formation near well 299-E26-11. There are no perched water table conditions observed near the LERF basins. The uppermost aquifer directly beneath the LERF consists of thin aquifer(s) in the Hanford formation, and Elephant Mountain Member flow top. The aquifer in the Hanford formation is unconfined; however, recent analysis of water-level data for barometric pressure responses indicates that the aquifer near well

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299-E26-11 is semi-confined. Well 299-E26-11 is still considered capable of yielding representative samples from the same hydro-stratigraphic unit as the other three wells associated with the LERF groundwater monitoring program.

Well construction details are discussed in Section D.2.4. New wells 299-E26-77 and 299-E26-79 were drilled into and completed in the Elephant Mountain Member flow top. The wells produce 22.7 to 30.3 liters per minute (6 to 8 gallons per minute), which is sufficient for geochemical sampling, and the flow top is sufficiently permeable for adequate hydraulic connection with the overlying sediments.

Basalt flow top fracturing, brecciation, and/or weathering provide localized zones of higher permeability. Where these conditions exist and are in hydraulic communication with overlying saturated sediments, the basalt flow top is part of the overlying unconfined aquifer system. Based on evaluations of drill cuttings, drilling rates, and water production noted during drilling wells 299-E26-77 and 299-E26-79, the Elephant Mountain Member flow top functions as a component of the unconfined aquifer and forms a laterally continuous aquifer beneath the LERF.

The uppermost aquifer increases in thickness to the south (Figure D.1) due to the south-dipping structure of the Elephant Mountain Member. The flow interior of the Elephant Mountain Member represents the lower boundary of the uppermost aquifer. This was verified by observations of drilling at wells 299-E26-77 and 299-E26-79, as discussed in Section D.2.1.3. The revised aquifer thickness map reflecting results of drilling and sampling in 2008 is shown in Figure D.1.

D.2.2.1 Aquifer Properties

Transmissivity values determined from early tests conducted in the LERF wells were reported in Sweeney et. al. (1994). Values ranged from 11 to 230 meters^2 per day (118 to 2,476 feet^2 per day) for well 299-E26-9 (now dry), resulting in equivalent hydraulic conductivity of approximately 6 to 120 meters per day (20 to 394 feet per day), assuming an aquifer thickness of 2 meters (6.6 feet). The transmissivity value for both wells 299-E26-11 and 299-E35-2 (now dry) was 6 meters^2 per day (64.6 feet^2 per day). Data were not obtained for well 299-E26-10 during these early testing activities.

Hydrologic tests were conducted in 2003 at wells 299-E26-10 and 299-E26-11. An analysis of the results of slug tests indicates that hydraulic conductivity at well 299-E26-10 ranged from 35 to 55 meters per day (115 to 180 feet per day); and well 299-E26-11 had a hydraulic conductivity of approximately 5 to 7 meters per day (16 to 23 feet per day). A constant-rate discharge test conducted in well 299-E26-10 resulted in a hydraulic conductivity value of approximately 36 meters per day (118 feet per day) and a specific yield of 0.13. No hydraulic boundaries or response characteristics indicative of detachment or perched-water conditions were exhibited during the performance of the constant-rate pumping test. These results suggest that the saturated sediments of the Hanford formation at this location are part of the larger, site wide unconfined aquifer system. Detailed discussions pertaining to these tests are contained in *Results of Detailed Hydrologic Characterization Tests – Fiscal Year 2003* (Spane and Newcomer 2004).

Hydrologic tests were conducted in the two new wells and in well 299-E26-11. Water-level drawdown was also measured during well development. Slug testing was performed in November 2008, and the results of the tests were analyzed.

In well 299-E26-77, a total of 1,442 liters (381 gallons) were pumped during development, at a maximum rate of 22 liters per minute (5.8 gallons per minute), for a total of 59 minutes. Drawdown, measured using an electronic water meter, ranged from 0.9 to 1.1 meters (2.9 to 3.5 feet) at the maximum rate of 22 liters per minute (5.8 gallons per minute). Slug test results indicated hydraulic conductivity approximately several tens of meters per day (e.g. 10 – 30 m/day).

In well 299-E26-79, a total of 1,271.9 liters (336 gallons) were pumped over a period of 42 minutes at a continuous flow rate of 30.2 liters per minute (8 gallons per minute). Drawdown, measured using a pressure transducer and data logger, ranged from 0.2 to 0.5 meters (0.8 to 1.6 feet). Slug test results again indicated hydraulic conductivity approximately several tens of meters per day (e.g. 10 – 30 m/day).

Slug test results for well 299-E26-11 indicated a hydraulic conductivity value of approximately 10 meters per day (33 feet per day), which is somewhat lower than the tests performed in the new wells. This value is within the same range of the results previously reported for this well (5 to 7 meters per day [16 to 23 feet per day]).

The hydraulic characteristics of all four monitoring wells do not vary widely (total range from 5 to 55 meters per day [16 to 180 feet per day]) and indicate similar hydraulic conductivity beneath the LERF.

D.2.2.2 Flow Dynamics

Regional groundwater flow was initially from west to east but was impacted by groundwater mounding resulting from wastewater discharges; these impacts continue to the present to a smaller degree. The water table elevation for wells in 200 East Area for March 2008 is shown in Figure D.1.

Groundwater flow conditions were re-evaluated after installation of the two new wells. A preliminary evaluation of water levels in the uppermost aquifer (Hanford formation and/or Elephant Mountain Member flow top) was conducted using static water levels measured at the four LERF wells during the first and second quarters of fiscal year 2009. The results of the evaluation are presented in Smoot (2009) and are summarized in Table D.2, as well as the results of trend-surface analyses conducted and documented by Spane and Newcomer (2004). The evaluation included gyroscope surveys in the completed wells to determine the deviation of the holes from vertical. The water level in a deviated borehole would appear to be deeper than it actually is because it is measured at an angle to vertical. In addition, the wells have been surveyed at the highest precision practical and tied into the local surveying network to minimize error in the surface elevation.

To determine the hydraulic gradient at the LERF, three-point computations were made using recent water-level measurements collected from the three down-gradient wells: 299-E26-10, 299-E26-77, and 299-E26-79. Well 299-E26-11 has a higher water-level elevation compared to the other three wells (McDonald 2007, *Water-Level Barometric Response Analysis for the Liquid Effluent Retention Facility Monitoring Wells*). Therefore, calculations with water levels from well 299-E26-11 result in a westerly flow direction.

Well bore deviation surveys and highly accurate (within 2 mm) casing elevation surveys were performed on the down-gradient wells to minimize errors in water-level measurements. The results indicated the difference between the measured depth to water and the true vertical depth to water, which allowed the water-level measurements to be corrected for deviations of the well bores from vertical. For well 299-E26-10, the difference between the measured and true depth to water was 1.2 centimeters (0.5 inches). The difference was larger for the two new wells: 26 centimeters (10.2 inches) for well 299-E26-77, and 46.9 centimeters (18.5 inches) for well 299-E26-79.

Water-level measurements were collected during November 2008 and in February and March 2009. The measurements from November contained an outlier, so the gradient computation was only performed on the February and March measurements. The results for February indicated a direction of 254 degrees azimuth (west-southwest) and a magnitude of 9.7×10^{-5} meter per meter. The flow direction calculated from the February measurements confirms previous results from Spane and Newcomer (2004) that groundwater flow is toward the west-southwest. The results for March were 177 degrees azimuth (south) at a magnitude of 2.1×10^{-4} meter per meter. The difference between these results reflects the uncertainty remaining in the measurements, which may be partly due to barometric pressure fluctuations. Monthly measurements and annual evaluation will continue according to the requirements of this plan to reduce uncertainty in the measurements and resulting flow direction calculations.

An analysis was performed in wells 299-E26-10 and 299-E26-11 to assess barometric pressure effects on well water-level elevation measurements (*Water-Level Barometric Response Analysis for the Liquid Effluent Retention Facility Monitoring Wells, Hanford Site* [McDonald 2007]). Pressure transducers were installed in the wells from April to July 2007 to measure well water-level elevations (other wells used in the trend-surface analysis were dry or were not accessible). Hourly well water-level elevations were

measured and recorded, and hourly barometric pressure data for 200 East Area was obtained from the Pacific Northwest National Laboratory meteorological station.

The multiple regression method in *Identifying and Removing Barometric Pressure Effects in Confined and Unconfined Aquifers* [Rasmussen and Crawford 1997]) was used to analyze the well water-level responses to barometric pressure fluctuations. The water-level response characteristics indicated that the aquifer is unconfined at well 299-E26-10 and leaky confined at well 299-E26-11. This suggests that a low hydraulic conductivity layer may be causing locally confined conditions in the aquifer as dewatering occurs.

Assuming a hydraulic conductivity of 30 meters per day (98.4 feet per day), a gradient of 10^{-4} (west end of the basins), and an effective porosity of 0.1, groundwater travel time would be approximately 10 meters per year (33 feet per year) in the vicinity of the LERF basins. Factoring in well 299-E26-11, the gradient is closer to 10^{-3} and the travel time is approximately 100 meters per year (328 feet per year).

D.2.3 Groundwater Chemistry

Groundwater chemistry in the uppermost aquifer beneath the LERF was affected by several years of diluted liquid waste discharge to the 216-B-3 Pond System, which ceased in 1997.

Groundwater samples were collected at the new LERF wells during drilling in 2008 and during sampling of all four LERF wells in January 2009. Water quality parameters in the January 2009 samples from wells 299-E26-11 and 299-E26-79 show a clear correlation demonstrated by relatively low levels of the major cations and anions and a sodium-carbonate-type signature; the similarity suggests substantial hydraulic communication. Water quality parameters for the January 2009 samples at the other two wells (299-E26-10 and 299-E26-77) show the same basic signature as the first two wells, with the addition of calcium and sulfate. These results are documented in the groundwater evaluation report/Liquid Effluent Retention Facility Characterization Report (Smoot 2009). These parameters are collected to evaluate hydrogeologic conditions and are not related to specific waste constituents.

Water quality parameters for the four wells show similarities. The identified disparity (i.e., higher calcium sulfate content in the two westernmost down-gradient wells) may be explained by the presence of a regional sulfate plume (*Hanford Site Groundwater Monitoring for Fiscal Year 2008* [U.S. DOE 2009]) originating to northwest of the LERF site. Thus, available chemistry data support the conclusion that the four wells are completed in the same aquifer. Water quality parameters will continue to be collected semiannually for purposes of further evaluating the conclusion reached via the aquifer characterization study: that the four wells yield representative samples of the uppermost hydrostratigraphic unit that is continuous under the LERF Basins. See Table D.5.

D.2.4 Well Completions and Conditions

The basic well information is summarized in Table D.1 and in Figures D.2 through D.5. All four wells extend beyond 61 meters (200 feet) in depth. Although the new wells extend 5.5 to 6.1 meters (18 to 20 feet) into the Elephant Mountain basalt, the screened intervals in all four wells intercept the unconfined aquifer.

The initial LERF groundwater monitoring wells were installed in 1990 and included three down-gradient wells on the west end of the facility boundary and one upgradient well at the east end of the facility. This configuration was based on the east-to-west groundwater flow direction, caused by the recharge mound created by years of liquid effluent disposal to B Pond. Wells 299-E26-9, 299-E26-10, and 299-E35-2 were originally installed as down-gradient wells and well 299-E26-11 as an upgradient well. Wells 299-E26-77 and 299-E26-79 were installed in 2008. Well 299-E26-77 is adjacent to the location of well 299-E26-9, and well 299-E26-79 is south of LERF between Basins 42 and 43 (Figure D.1). Well 299-E26-10 (Figure D.2) has a 4.5-meter (15-feet) screen, screening the wells across the entire aquifer column. The well screen in 299-E26-10 penetrates approximately 0.5 meters (1.8 feet) into the basalt. Well 299-E26-11 (Figure D.3) was completed with a 1.5-meter (5-feet)-long channel-pack screen placed

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completely within the basalt flow top and includes a sand pack that extends 1.3 meters (4.4 feet) above the screen top.

Well 299-E26-77 encountered groundwater at approximately 63.4 meters (208 feet) below ground surface and was drilled to a total depth of 71 meters (232.8 ft) below ground surface (Figure D.4). The well is constructed with 7.6 meters (25 feet) total length of screen installed across approximately 1.4 meters (4.6 feet) of sediments and 6.2 meters (21.4 feet) of basalt flow top. Well 299-E26-79-encountered groundwater at 61.5 meters (201.7 feet) below ground surface and was drilled to a total depth of 68.5 meters (224.8 feet) below ground surface (Figure D.5). The well is constructed with 7.6 meters (25 feet) total length of screen installed across approximately 3.7 meters (12 feet) of sediments and 3.9 meters (13 feet) of basalt flow top. The screens are 10-centimeters (4-inches) in diameter, 20-slot, stainless-steel wire-wrap. Both wells have a 1-meter (3-foot) blank sump below the screens. The casing from the top of the screen to land surface is 10-cenimeter (4-inch)-diameter stainless steel.

The longevity of the operable monitoring lifetime for the remaining LERF wells is an ongoing concern as water levels continue to decline. Well 299-E26-10 is projected to provide samples until approximately 2019, while well 299-E26-11 is projected to provide samples beyond 2024. This assumes that the wells can be sampled until the water reaches a minimum sampling depth of 0.5 meters (1.6 feet) above the bottom of the well and a constant, linear decline in the water table. Wells 299-E26-77 and 299-E26-79 are not expected to go dry based on the current rates of water-level decline, the maximum extent of decline, and the available screened interval. Water-level trends will continue to be evaluated.

D.3 Groundwater-Monitoring Program

Groundwater monitoring at LERF consists of wells 299-E26-10, 299-E26-11, 299-E26-77, and 299-E26-79 and is compliant with the requirements of WAC 173-303-645(8)(a). More specifically, this network is capable of yielding ground water samples from the uppermost aquifer that:

- Represent the quality of background water that has not been affected by leakage from a regulated unit;
- Represent the quality of ground water passing the point of compliance;
- Allow for the detection of contamination when dangerous waste or dangerous constituents have migrated from the waste management area to the uppermost aquifer.

Characterization conducted in 2008 and 2009 indicates that the characteristics of the hydrostratigraphic units underlying the LERF basins constitute an aquifer unit that is continuous beneath the LERF basins and is capable of yielding representative groundwater samples.

Since the close proximity of the three LERF basins to one another prevents separate groundwater monitoring networks for each of the three basins, the waste management area is described by an imaginary line encompassing the three LERF basins, as provided for in WAC 173-303-645(6)(b).

D.3.1 Objectives of Dangerous Waste Groundwater Monitoring

A groundwater monitoring program, in accordance with the requirements of WAC 173-303-645, is designed to determine whether there is statistically significant evidence of contamination in the uppermost aquifer attributable to the LERF basins. The statistical approach at LERF uses intra-well statistical comparisons of groundwater quality changes.

The action leakage rate has not been exceeded during operations, and results of the LERF groundwater monitoring program to date suggest that the LERF basins have not impacted groundwater quality beneath the site. The monitoring results for wells 299-E26-10 and 299-E26-11, and recent results from new wells 299-E26-77 and 299-E26-79, have not indicated dangerous constituents above background levels, with the exception of carbon tetrachloride. This constituent was reported at 2.3 µg/liter in well 299-E26-77 and at 2.4 µg/liter in well 299-E26-79 however, these analyses are suspect due to possible instrument contamination. Additional carbon tetrachloride sample results will be necessary to determine whether this constituent is actually present in groundwater; if it is not (which is the current assumption), a detection

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monitoring program in accordance with WAC 173-303-645(9) is appropriate for the site to provide compliance with the requirements of WAC 173-303-645.

D.3.2 Dangerous Constituents

A list of dangerous and/or mixed aqueous waste that can be accepted in LERF is defined by the requirements of Chapter 3.0, Waste Analysis Plan.

Dangerous constituents and suitable indicator parameters that provide a reliable indication of the presence of dangerous constituents in groundwater for purposes of groundwater monitoring were selected based on the target parameter constituents from Chapter 3.0, Waste Analysis Plan, and results of LERF basin water samples collected between July 1999 and August 2009. Several target parameters in the Waste Analysis Plan occur in the LERF basin data and were evaluated relative to the dangerous constituents (groundwater monitoring list in Chemical Test Methods for designating Dangerous Waste, Appendix 5, as provided in WAC 173-303-110(7). Dangerous constituents measured as part of routine liquid sampling in the LERF basins were included as chemical parameters. Constituents that have a primary drinking water standard that exceeded one-half of the maximum contamination levels in any sample were included, regardless of whether they are dangerous constituents. Ammonia was included because it degrades to nitrate in the environment.

The dangerous constituents for groundwater monitoring and evaluation are shown in Table D.3. These were further evaluated to identify the groundwater monitoring indicator parameters (based on the dangerous constituents), which are provided in Section D.3.6.1.

D.3.3 Concentration Limits

A series of events that triggers the shift from detection monitoring to compliance monitoring is prescribed in WAC 173-303-645. If there is statistically significant evidence of contamination, as required in WAC 173-303-645(9)(f), groundwater protection standards and concentration limits will subsequently be established in accordance with WAC 173-303-645(9)(g)(iv)(D). Section D.3.13, Evaluation and Notification, provides the process and schedule for actions, notification, and permit modification, if necessary.

If a tolerance limit or control chart limit is exceeded at a statistically significant level, additional measurements shall be conducted to verify that a detection event has occurred. If the detection of a dangerous constituent is verified, as discussed in Section D.3.13, compliance monitoring will be implemented in accordance with WAC 173-303-645(10).

D.3.4 Groundwater Monitoring System and Point of Compliance

The groundwater monitoring system for the LERF will consist of four wells. Wells 299-E26-10, 299-E26-11, 299-E26-77, and 299-E26-79 will be monitored in accordance with the requirements provided in this monitoring plan. The point of compliance for the LERF groundwater monitoring plan will be represented by the vertical surface between the four monitoring wells that extends down into the uppermost aquifer underlying the waste management area, based on WAC 173-303-645(6)(a). The waste management area is described by an imaginary line encompassing the three LERF basins, as provided for in WAC 173-303-645(6)(b).

D.3.5 Compliance Period

Any compliance period will be established by the Washington State Department of Ecology (Ecology) in accordance with WAC 173-303-645 (7) if the Permittee is required to establish a compliance monitoring program pursuant to WAC 173-303-645 (10).

D.3.6 Sampling and Analysis

This section describes the sampling and analysis program for the three LERF regulated units (Basins 42, 43, and 44) that are the waste management area, including monitoring parameters, analytical methods, monitoring frequency, and sampling protocols.

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D.3.6.1 Monitoring Parameters

Monitoring parameters include the indicator parameters and geochemical parameters.

As identified in section D.3.2, arsenic (Basins 42, 43, and 44), n-nitrosodimethylamine (NDMA) (primarily Basin 42), carbon tetrachloride (Basin 43), and total organic halogen are the indicator parameters and dangerous constituents that provide a reliable indication of the presence of dangerous constituents in groundwater, subject to statistical evaluation to fulfill requirements of the groundwater monitoring plan. Table D.4 provides the constituents to be analyzed and the frequency of sampling. These were derived from evaluating the dangerous constituents provided in Section D.3.2, and as discussed below.

Nitrate was initially proposed because ammonia/ammonium is present in large quantities in the waste stream and degrades to nitrate in the environment through nitrification. However, there are numerous nitrate sources near the LERF basins, and groundwater chemistry results indicate high concentrations and recent changes in nitrate. Thus, changes in nitrate concentration alone will not be a reliable indicator of LERF performance, and will not be monitored as an indicator parameter.

Arsenic is proposed because it has been detected in the basin effluent in all three of the LERF basins. It is persistent and relatively mobile in the environment, and it has a low detection level with current analytical methods. Therefore, arsenic will be monitored as a dangerous constituent that provides an indication of groundwater contamination.

Analysis of the effluent streams into the LERF basins indicates that organic constituents are present in Basins 42 and 43; however, detectable quantities of organic constituents are not observed in Basin 44. N-nitrosodimethylamine (NDMA) is found in the effluent in LERF Basin 42, and may be relatively mobile in Hanford soils; however, biodegradation may remove NDMA under aerobic conditions. NDMA has a low detection level using currently available analytical methods. Therefore, NDMA will be monitored as a dangerous constituent that provides an indication of groundwater contamination.

Other organic constituents in the Basin 42 effluent consist primarily of alcohols and ketones, with lesser amounts of ethers, phenols, and phthalates. In general, most of these constituents degrade readily and have half-lives in the environment in the order of hours to a few days.

Halogenated hydrocarbons are present in Basin 43. Carbon tetrachloride is observed in the Basin 43 leachate at several times the drinking water standard. These relatively small concentrations will likely be degraded in the environment, but the generally aerobic condition in the Hanford vadose zone is likely to inhibit dehalogenation. Carbon tetrachloride and total organic halogen therefore, are proposed as indicators of halogenated organic contamination.

D.3.6.2 Sampling Frequency

Samples will be collected quarterly for two years from wells 299-E26-10, 299-E26-11, 299-E26-77, and 299-E26-79 to establish background conditions for dangerous constituents identified in section D.3.6.1 for the statistical evaluation (presented in Section D.3.13). After background data are obtained, the Permittee will continue to collect samples quarterly and to evaluate the data in accordance with the statistical methods.

Samples will be collected for analysis of major anions, cations, and alkalinity semiannually to evaluate groundwater geochemistry.

D.3.6.3 Sampling Procedures

Groundwater sampling procedures, sample collection documentation, sample preservation and shipment, and chain-of-custody requirements are described below. The Permittees will develop, maintain, and conduct work according to procedures consistent with, and no less stringent than, those described to be conducted. The Permittees will maintain current copies of these procedures in the Hanford Facility Operating Record, LERF and 200 Area ETF file, as required by Permit Condition II.I.1.

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Samplers fill out groundwater sample report forms as they purge and sample each well. Field personnel measure water levels in each well before sampling and then purge stagnant water from the well. Field personnel also record time of sampling which allows correlation with barometric pressure measurements at the Hanford Meteorological Station. Water levels are typically measured with laminated-steel electrical sounding tapes with a precision of 2 mm. Procedures require sample collection after three casing volumes of water have been purged from the well and after field parameters (pH, temperature, specific conductance, and turbidity) have stabilized. Field parameters are measured in a flow-through chamber. Both filtered and unfiltered samples are collected for metals analyses. Filtering is performed in the field with 0.45-micron, in-line, disposable filters to ensure that results represent dissolved metals and do not include particulates. Dissolved trace metals analysis (from filtered samples) will be used for statistical analyses of trace metal arsenic.

Sample preservation techniques will follow generally accepted practices (e.g. U.S. Environmental Protection Agency [EPA]-approved guidelines such as *Test Methods for Evaluating Solid Wastes, Physical/Chemical Methods* [SW-846], Table 11-1, or equivalent) and will be documented in sample authorization forms generated by the Sample and Data Management organization. Preservatives are added to collection bottles before use in the field. A chemical preservative label is affixed to the sample container listing the specific preservative. The preservative's brand name, lot number, concentration, and date opened are recorded.

D.3.6.4 Sample Chain-of-Custody

Groundwater samplers use chain-of-custody forms to document the integrity of groundwater samples from the time of collection through data reporting. The forms are generated during scheduling and are managed through a documented procedure. Required information recorded on the forms includes the following:

- Sampler's name
- Method of shipment and destination
- Collection date and time
- Sample identification numbers
- Analysis methods
- Preservation methods

Samples are labeled and sealed with evidence tape, wrapped with bubble wrap, and placed in a U.S. Department of Transportation-approved container with ice, as appropriate. The packaging parameters for samples are determined by associated hazards. Samples for offsite laboratories are shipped according to U.S. Department of Transportation regulations. A chain-of-custody form accompanies all samples.

When samples are transferred from one custodian to another (e.g., from sampler to shipper, or from shipper to analytical laboratory), the receiving custodian inspects the form and the samples, noting any deficiencies. Each transfer of custody is documented by the printed names and signatures of the custodian relinquishing the samples and the custodian receiving the samples, as well as the time and date of transfer. Commercial shippers do not sign chain-of-custody forms, but the forms are signed by the receiving laboratory, and sample integrity is verified by inspecting the bottle seals.

D.3.7 Decontamination of Drilling and Sampling Equipment

The following information is included relative to well drilling equipment if new wells are installed at LERF for this Permit. Well drilling equipment is decontaminated using high temperature and pressure washing. The equipment then is rinsed with clean water.

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Equipment for collecting soil samples during drilling for later chemical analysis is decontaminated. Equipment is washed with phosphate-free detergent, rinsed three times with de-ionized water, rinsed once with nitric acid (glass or stainless-steel equipment only), rinsed three more times with de-ionized water, and then finally rinsed with hexane. After heat drying, equipment is wrapped in unused aluminum foil and sealed with tape until needed. The tape shall not come into contact with the equipment to avoid any contamination from the materials in the tape.

Monitoring wells for the LERF shall be equipped with dedicated sampling pumps. Sample pumps are placed at approximately mid-depth within the screen interval. Water-level measuring tapes are cleaned with potable or deionized water and a clean towel. Sample manifolds used at the well head require decontamination as follows: wash with a phosphate-free detergent, rinse three times in high-purity water, rinse in a 1 M solution of nitric acid, rinse three more times in high-purity water, then rinse in hexane, and finally dry in drying chamber. These are done in accordance with established procedures.

D.3.8 Quality Objectives and Criteria

The quality control program is designed to assess and enhance the reliability and validity of groundwater data, and to document whether the resulting data are of the quantity and quality necessary for the intended decision-making purpose. In groundwater detection monitoring, the primary decision-making purpose is to determine whether a statistically significant increase in a dangerous constituent concentration is observed in groundwater down-gradient from the permitted site. Consequently, data quality is monitored by evaluating the results of quality control samples, conducting audits, validating groundwater data, and comparing these results to data quality requirements established in this groundwater monitoring plan. Accuracy, precision, and detection are the primary parameters used to assess data quality. Data for these parameters are obtained from two categories of quality control samples: (1) those that provide checks on field and laboratory activities (field quality control), and (2) those that monitor laboratory performance (laboratory quality control). Table D.6 summarizes the types of samples in each category and the sample frequencies and characteristics evaluated.

D.3.9 Analytical Procedures

Instruments for field measurements (e.g., pH, specific conductance, temperature, and turbidity) are verified using standard solutions before use. These include, for pH, 4, 7, and 10 buffer/standard solutions; for specific conductance, 445 uS/cm and 1413 uS/cm solutions; and for turbidity, Gelex standards 0-10, 0-100, and 0-1000 NTU. Instruments are operated in accordance with the manufacturer's instructions. Each instrument is assigned a unique number that is tracked via field and verification documentation.

Laboratory analytical methods are specified in Table D.7, and reflected in contracts with the laboratories and are standard methods from SW-846 (1986, as revised), *Methods for Chemical Analysis of Water and Wastes* (U.S. EPA 1979, as revised), or *Standard Methods for the Examination of Water and Wastewater, 20th Edition* (APHA/AWWA/WEF 1998, as revised). Analytes, analytical methods, and required maximum practical quantitation limits are shown in Table D.7.

D.3.9.1 Quality Control

Quality control data are evaluated based on acceptance criteria for each quality control sample type, as summarized by constituent in Table D.8. These criteria limits are intended to provide confidence that the analytical and field methods are in control and provide reliable data. For field and method blanks, the acceptance limit is two times the instrument detection limit (metals) or method detection limit (other chemical parameters), except for common laboratory contaminants acetone, methylene chloride, 2-butanone, and phthalate esters where the limit is five times the method detection limit. Groundwater samples that are associated (i.e., collected on the same date and analyzed by the same method) with out-of-limit field blanks shall be flagged with a "Q" in the HEIS database to indicate a potential problem, and then recorded in the Hanford Facility Operating Record, LERF and 200 Area ETF file pursuant to Permit Condition III.3.D.1.b.

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Field duplicates must agree within 20% (as measured by relative percent difference) to be acceptable. Only those field duplicates with at least one result greater than five times the appropriate detection limit shall be evaluated. In the case where one result is a non-detect, the detection limit is used to calculate the relative percent difference. Unacceptable field duplicate results are flagged with a "Q" in the database and recorded in the Hanford Facility Operating Record, LERF and 200 Area ETF file.

The acceptance criteria for laboratory duplicates, matrix spikes, matrix spike duplicates, surrogates, and laboratory control samples are defined in Table D.8 and are in accordance with EPA SW-846. The acceptance criteria for the associated parameter data shall be analyzed and recorded in accordance with Section D.3.10.2.

Table D.9 lists the acceptable accuracy for the double-blind standards for carbon tetrachloride and total organic halides. These samples are prepared by spiking Hanford background well water (currently, wells 699-19-88 and 699-49-100C) with known concentrations of constituents of interest. Spiking concentrations range from the detection limit to the upper limit of concentration determined in groundwater on the Hanford Site. Investigations shall be conducted for double-blind standards that are outside of acceptance limits in accordance with Section D.3.10.2. The results from these standards shall be used to determine acceptability of the associated parameter data. Recommended holding times depend on the analytical method, as specified in EPA SW-846 or (U.S. EPA 1979). The holding times shall be specified in laboratory contracts pursuant to permit requirements. Data associated with exceeded holding times are flagged with an "H" in the HEIS database and noted in the Hanford Facility Operating Record, LERF and 200 Area ETF file. Data exceeding holding times shall be maintained but potentially may not be used in statistical analyses, in accordance with Section D.3.10.2.

Additional quality control measures include laboratory audits and participation in nationally based performance evaluation studies. Audit results are used to improve performance. Summaries of audit results and performance evaluation studies shall be incorporated into the Hanford Facility Operating Record, LERF and 200 Area ETF file as appropriate to substantiate data quality objectives and data acceptance criteria.

D.3.9.2 Data Management

This section describes data management practices.

D.3.9.3 Loading Data

The contract laboratories report analytical results electronically and in hardcopy. The electronic results shall be loaded into the HEIS database as they are received from the laboratories. The appropriate sections of the Hanford Environmental Information System shall be incorporated by reference into the Hanford Facility Operating Record, LERF and 200 Area ETF file to satisfy Permit Condition III.3D.1.b. Field data (e.g., specific conductance, pH, temperature, turbidity, and depth to water) are recorded on field records. Data management staff enters these into the HEIS database manually through data-entry screens and verify each value against the hardcopy. An electronic field data collection system may be implemented soon, which would replace the manual field data collection and the manual data entry process when it is implemented.

Data not available electronically may also include well logbooks, borehole videos, geologic descriptions, field screening data, or other information.

D.3.9.4 Data Review, Verification, Validation, and Usability

The final data review shall determine whether data meet the criteria specified below. The work activities shall follow documented procedures and processes for data validation and verification, as summarized below. Validation of groundwater data involves assessing whether the data collected and measured truly reflect aquifer conditions. Verification involves assessing data accuracy, completeness, consistency, availability, and internal control practices to determine overall reliability of the data collected. Other data quality objectives that shall be met include the proper chain-of-custody, sample handling, use of proper

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analytical techniques for each constituent, and the quality and acceptability of the laboratory analyses conducted.

Groundwater monitoring staff performs checks on laboratory electronic data files for formatting, allowed values, data flagging (qualifiers), and completeness. Hardcopy results are verified to check for (1) completeness; (2) notes on condition of samples upon receipt by the laboratory; (3) notes on problems that arose during the analysis of the samples; and (4) correct reporting of results. If data are incomplete or deficient, staff will work with the laboratory to correct the problem discovered during the analysis.

The data validation process provides the requirements and guidance for validating groundwater data that are routinely collected. Validation is a systematic process of reviewing verified data against a set of criteria (listed in Table D.8) to determine whether the data are acceptable for their intended use.

Results of laboratory and field QC evaluations, double-blind sample results, laboratory performance evaluation samples, and holding-time criteria are considered when determining data usability. Staff review the data to identify whether observed changes reflect changes in groundwater quality or potential data errors, and they may request data reviews of laboratory, field, or water-level data for usability purposes. The laboratory may be requested to check calculations or reanalyze the sample, or the well may be resampled. Results of the data reviews are used to flag the data appropriately in the HEIS database (e.g., "R" for reject, "Y" for suspect, or "G" for good) and/or to add comments.

Upon final data acceptance, both the raw data and the accepted/validated data shall be incorporated into the Hanford Facility Operating Record, LERF and 200 Area ETF file.

D.3.9.5 Data Review Corrective Actions

The responses to data quality defects are identified through the verification/validation process. Corrective actions are shown in Table D.8.

D.3.9.6 Statistical Analysis of Groundwater Monitoring Data

Groundwater monitoring constituents have been identified for the LERF basins and are listed in Table D.3. The dangerous constituents and indicator parameters used to indicate the presence of contamination (WAC 173-303-645(9)(a)) and subject to statistical evaluation are listed in Table D.4 and include arsenic, n-nitrosodimethylamine, carbon tetrachloride, and total organic halides.

To establish background conditions, eight samples will be collected during the first two years (quarterly sampling frequency) in accordance with the Permit. Once the baseline has been established, the sample collection and analysis will continue on a quarterly basis.

The statistical method for comparing baseline (background) groundwater quality with compliance-point groundwater quality is the combined Shewhart/CUSUM control chart provided for by WAC 173-303-645(8)(h)(iv) and recommended by EPA as a core strategy for detection monitoring in Unified Guidance *Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities*, (U.S. EPA, 2009). Applying this intra-well statistical procedure will enable monitoring in the existing wells based on the following justification:

The methods can be used when no upgradient well is available or the upgradient well is suspect (such as at LERF); when an upgradient well exists but there is a high degree of spatial variability in groundwater chemistry among wells; or there is considerable uncertainty in groundwater flow direction as is the condition at LERF.

The methods may be applied to each well individually while maintaining the desired site wide false-positive and false-negative error rates (this method is effective). Spatial variations that may adversely affect the analysis of variance procedure do not play a role under these methods. (Note: Elimination of spatial variability decreases the uncertainty in measured concentrations, making intra-well comparisons more sensitive to a real release (*Standard Guide for Developing Appropriate Statistical Approaches for Ground-Water Detection Monitoring Programs* [ASTM 1998].)

The statistical method uses a combined Shewhart-CUSUM control chart approach, first referenced in *Combined Shewhart-CUSUM Control Chart for Improved Quality Control in Clinical Chemistry* (Westgard et al. 1977) and further developed in *Combined Shewhart-CUSUM Quality Control Schemes* (Lucas 1982). This method is an EPA recommended core strategy for detection monitoring, as provided and described in *Unified Guidance Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities* (US EPA 2009).. The power of the control chart method is enhanced by the combined Shewhart and CUSUM procedures. The Shewhart procedure is sensitive to sudden shifts, and the CUSUM procedure is sensitive to gradual changes in the mean concentrations. A combined Shewhart and CUSUM procedure, therefore, is well designed to detect both types of changes.

The method is a sequential testing procedure to test for an upward shift in the mean concentration of a constituent of interest. The Shewhart portion of the test checks for any sudden upward shift in groundwater quality parameters based on a single observation, while the CUSUM checks for any gradually increasing trend in the groundwater monitoring parameters. The combined Shewhart–CUSUM method can be implemented following a baseline of eight or more independent samples for a given well (US EPA 2009; ASTM 1998). The method assumes that the groundwater background data and future observations will be independent and normally distributed in accordance with WAC 173-303-645(8)(g)(i). The most important assumption is that the data are independent. The aquifer properties and flow rates suggest that quarterly sampling will assure independent samples are collected. The assumption of normality can usually be met by log transforming the data or by other Box-Cox transformations.

The combined Shewhart-CUSUM procedure can be implemented as follows: Let x'_i be a series of independent baseline observations i = 1…. b (b = 8). Let x_i be a series of future monitoring measurements i = 1, 2, 3…. Then, using the baseline data, the following steps are applied:

First, determine if the x'_i can be assumed to follow a normal distribution with mean μ and standard deviation σ using the Shapiro-Wilk test for normality (US EPA 2009). If not, transform the x'_i using the appropriate Box-Cox transformation and work with the transformed data.

Next, use the baseline measurements to compute the estimates:

$$\bar{x}' = \sum_{i=1}^{b} x'_i/\text{b for } \mu \text{ and } s' = \sqrt{\sum_{i=1}^{b} (x'_i - \bar{x}')^2 /(b-1)} \text{ for } \sigma.$$

Determine the upper Shewhart control limit (SCL) for the procedure by calculating $SCL = \bar{x}' + z_s s'$, where z_s is a percentile from the standard normal distribution used to set the false-negative, and false-positive values of the SCL. The value of z_s that is most often suggested for groundwater use is 4.5 by Lucas, 1982, and (ASTM 1998). The EPA Unified Guidance uses a value of 5 in its example (US EPA 2009), but does not provide specific recommendations. The value 4.5 is more conservative than 5. Other values may also be used, depending on the sampling scheme and whether verification sampling is used to modify the false-positive and false-negative error rates. If less than 15% of the background measurements are non-detects, the non-detects will be replaced with half the MDL and the s' calculated as usual. If more than 15% of the background measurements are non-detect, a Kaplan-Meier, robust regression on order (ROS), or Cohen's method (US EPA 2009) will be implemented to estimate the mean and standard deviation of the background samples. If all eight background samples are non-detect, the laboratory Reporting Limit (RL) will be used as the SCL in the Shewhart test.

Determine the upper CUSUM control limit (CCL), with $CCL = z_c$. The value of z_c suggested by Lucas, 1982) is $z_c = 5$. This value can also be adjusted to reach desired false-negative and false-positive error rates. In practice setting $z_c = z_s = 4.5$ results in a single limit with no compromise in leak detection capabilities (ASTM 1998, US EPA 2009).

Determine the amount of increased shift in the mean of the water quality parameter of interest to detect an upward trend. This value is referenced as "k" and is usually measured in σ units of the water quality

parameter. Starks (1988) suggests a value of k = 1, if there are less than 12 baseline observations, and a value of k = 0.75 if there are 12 or more baseline observations. The Unified Guidance (US EPA 2009) also cites these values.

Using the monitoring data after the baseline has been established:

Compute the CUSUM statistic as $S_i = \max\{0, (x_i - \overline{x}')/s' - k + S_{i-1}\}$ as each new monitoring measurement, x_i becomes available, where i = 1,2,3,…, max{a, b} is the maximum of a and b, and $S_0 = 0$.

As each new monitoring measurement becomes available, compute the Shewhart and CUSUM tests. A verification sampling will be conducted if either $x_i \geq$ SCL or $S_i \geq$ CCL. A well is declared to be out of control only if the verification result also exceeds the SCL or the CCL. If both $x_i <$ SCL and $S_i <$ CCL, then continue monitoring.

As monitoring continues and the process is shown to be in control, (i.e., there is no statistically significant evidence of facility impact to groundwater) the baseline mean and standard deviation should be updated periodically (e.g., every 1 or 2 years) to incorporate the new data (US EPA 2009). This reduces uncertainty in the background, and helps adjust for groundwater influences from outside sources. This updating process should continue for the lifetime of the monitoring program.

If an exceedance occurs, resampling will be undertaken to verify or refute the original exceedance. The analytical result from the resample is substituted into the above formulas in place of the original value obtained, and the CUSUM statistic is updated. (Note: In the above combined test, the Shewhart portion of the test will quickly detect extremely large deviations from the baseline period. The CUSUM portion of the combined test is sequential. Thus, a small shift in the mean concentration over the baseline period will slowly aggregate in the CUSUM statistic and eventually cause the test to exceed the CCL.)

If resampling does not confirm the exceedance of the control limit, and *if the exceedance can be shown to be a measurement in error or a confirmed outlier, it should be excluded from the revised background. Otherwise, any disconfirmed exceedances (including any resamples that exceed the background limit but are disconfirmed by other resamples) should probably be included when updating the background. The reason is that background limits designed to incorporate retesting are computed as low as possible to ensure adequate statistical power* (US EPA 2009).

D.3.10 Reporting and Recordkeeping

Reporting of monitoring evaluations for LERF will be carried out through the annual dangerous waste (RCRA) groundwater monitoring report.

Pertinent information for groundwater monitoring and electronic files for groundwater data shall be maintained in the Hanford Facility Operating Record, LERF and 200 Area ETF file required by Permit Condition II.I.1. Records may be stored in either electronic or hardcopy format.

The Hanford Facility Operating Record, LERF and 200 Area ETF file will also include, consistent with Permit Condition III.3.D.1.b, the following:

- Groundwater sample reports
- Chain-of-custody forms
- Sample receipt records.

D.3.11 Evaluation and Notification

Groundwater flow rate and direction in the uppermost aquifer will be evaluated and reported annually. Groundwater chemistry data collected under this permit will be reviewed semi-annually to determine if there is statistically significant evidence of contamination (in accordance with WAC 173-303-645[9][f]) using the statistical method provided in Section D.3.11. The results of the statistical evaluation and associated information will be submitted to Ecology annually, beginning after the second full year of sampling and analysis under this groundwater monitoring program (WAC 173-303-645(9)(c)).

If statistically significant evidence of contamination is determined for one or more of the dangerous constituents or indicator parameters, at any monitoring well at the compliance point, the owner or operator may resample within one month and repeat the analysis for the detected compounds in accordance with WAC 173-303-645(9)(g)(ii). The resample data will be compared with the control limit. If resampling confirms statistically significant evidence of contamination, the following will be performed in accordance with WAC 173-303-645(9)(g):

- Notify Ecology in writing within 7 days of the finding, indicating which chemical parameters have shown statistically significant evidence of contamination.
- Sample the groundwater in all monitoring wells and determine if constituents included in *Chemical testing Methods for Designating Dangerous Waste*, Appendix 5 are present, and if so, in what concentration. For any of these compounds detected, the owner or operator may resample within one month of receiving the results and repeat the analysis for those compounds detected. If the constituents are detected in the second analysis, they will form the basis for compliance monitoring.
- If dangerous constituent(s) are detected, submit an application for a Permit modification to Ecology within 90 days to establish a compliance monitoring program in accordance with WAC 173-303-645(9)(g)(iv).
- If dangerous constituents are not detected, continue to monitor in accordance with the detection monitoring program.

In the case that a source other than the LERF caused the contamination or the detection is an artifact caused by an error in sampling, analysis, or statistical evaluation or natural variation in groundwater (as allowed by WAC 173-303-645[9][g][vi]), the following will apply:

- Notify Ecology in writing within 7 days of the finding (i.e., exceedance) and indicate the intent to make a demonstration to this effect.
- Submit a report to Ecology within 90 days. The report should demonstrate that a source other than the regulated unit caused the contamination, or that the contamination resulted from an error in sampling, analysis, evaluation, or natural variation in groundwater chemistry.
- Continue monitoring in accordance with the detection monitoring program.

If it is determined, in accordance with WAC 173-303-645(9)(h), that the detection monitoring program no longer satisfies the requirements of WAC 173-303-645(9), submit an application to Ecology for a Permit modification within 90 days to make any appropriate changes to the program.

D.4 Compliance-Monitoring Program

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D.5 Corrective-Action Program

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Table D.1 Pertinent Information for Monitoring Wells in LERF

Well	Top of Casing Elevation (m), MSL (NAVD88)	Well Water Level Record Period	Saturated Well Screen Section Elevation (m), MSL (NAVD88)	Comments
299-E26-10	184.42	10/90 – 5/09	122.37 - 120.69 (1.7)	Top of basalt, approximately 121.2 m MSL
299-E26-11	183.88	10/90 - 5/09	123.32 - 120.25 (3.1)	Top of basalt, approximately 122.6 m MSL
299-E26-77	184.771	8/08 – 5/09	123.54 - 115.99 (7.5)	Screened in permeable basalt
299-E26-79	183.114	8/08 – 5/09	123.60 - 115.98 (7.6)	Screened in permeable basalt

MSL = mean sea level
NAVD88 = North American Vertical Datum of 1988

Table D.2 Groundwater Flow Characterization Results Based on Trend Surface Analysis or Three-Point Solution of Well Water Level Measurements in LERF and Surrounding Area

Date	Maximum Observed Well Water-Level Elevation Difference (m)	Flow Direction, (0° = N; 90° = E)	Hydraulic Gradient (m/m)	Comments
6/10/97	1.308	266°	1.04×10^{-3}	
6/8/98	1.222	264°	9.81×10^{-4}	
3/8 - 9/99	1.186	257°	9.67×10^{-4}	
3/22 - 23/00	1.173	269°	9.09×10^{-4}	
3/13 - 14/01	1.096	270°	8.71×10^{-4}	
3/19/02	1.110	264°	9.04×10^{-4}	Well 299-E34-3 measured on 5/1/02
3/19/03	1.068	273°	8.75×10^{-4}	Well 299-E26-9 dry; no measurement available
2/09	NA	254	9.57 x 10-5	
3/09	NA	177	2.1 x 10-4	
Average Values (Standard Deviation)	1.166 (±0.083)	266° (±5.2°)	9.35×10^{-4} ($\pm 6.3 \times 10^{-5}$)	

(a) The well network for 6/10/97 and 3/19/03 included 299-E26-9, 299-E26-10, 299-E26-11, 299-E27-10, 299-E34-3, 299-E34-7, and 299-E35-2. The well network for 2/09 and 3/09 included wells 299-E26-10, 299-E26-77, and 299-E26-79.

NA = not applicable

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Table D.3 Dangerous Constituents for Groundwater Monitoring Based on Comparisons to Basin 42, 43, and 44 Chemistry

Chemical Constituent	Range of Basin 42, 43, and 44 Water Analysis Results
Acetone	Non-detect (1 - 20)[a] to 5,900 µg/L
Ammonia/ammonium (as nitrogen)	48 to 769 mg/L
Antimony	0.5 to 32 µg/L
Arsenic	0.53 to 8.9 µg/L
Barium	1 to 108 µg/L
Bis(2-ethylhexyl) phthalate (DEHP)	12 to 230 µg/L
Carbon tetrachloride	13 to 490 µg/L
Chloroform	2 to 7.6 µg/L
Chloromethane	1.5 µg/L (one measurement)
Chromium	0.4 to 95.9 µg/L
Copper	0.86 to 818 µg/L
Cresol (o, p, m)	Non-detect (0.59 - 1) to 49 µg/L
Lead	Non-detect (0.05 - 0.1) to 94.6 µg/L
Mercury	Non-detect (0.04 – 0.05) to 1.22 µg/L
Nickel	Non-detect (4 – 8) to 22.2 µg/L
Nitrate (as nitrogen)	342 µg/L to 4,780 µg/L
Nitrite (as nitrogen)	68 µg/L to 2,820 µg/L
N-nitrosodimethylamine	12 µg/L to 2,760 µg/L
Selenium	Non-detect (0.3 – 0.4) to 5.5 µg/L
Silver	2.3 µg/L to 33 µg/L
Zinc	Non-detect (2 – 12) to 79.9 µg/L
[a] Method detection limits varied over the time in which these analyses were performed.	

Table D.4 Dangerous Constituents and Indicators to be Analyzed as Indicators of Groundwater Contamination at the LERF Basins

Constituent	Sample Frequency	Comment
• Arsenic • N-nitrosodimethylamine • Carbon tetrachloride • Total organic halides	Samples collected quarterly for two years to establish background. Samples collected quarterly for ongoing statistical evaluations after background is established.	Subject to statistical evaluation, based on the standard sampling plan outlined in WAC 173-303-645(8)(g)(i) and WAC 173-303-645(8)(g)(ii).

Table D.5 Constituents to be Analyzed for Geochemical Evaluation of Groundwater

Constituent	Sample Frequency	Comment
• Major anions • Major cations • Alkalinity	Semiannually	Aid geochemical evaluation

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Table D.6 Quality Control Samples

Sample Type	Primary Characteristics Evaluated	Frequency
Field Quality Control		
Full trip blank	Contamination from containers or transportation	One per 20 well trips
Field transfer blank	Airborne contamination from the sampling site	One each day volatile organic compound samples are collected
Equipment blank	Contamination from non-dedicated sampling equipment	As needed[a]
Duplicate samples	Reproducibility	One per 20 well trips
Laboratory Quality Control		
Method blank	Laboratory contamination	One per batch
Laboratory duplicates	Laboratory reproducibility	[b]
Matrix spike	Matrix effects and laboratory accuracy	[b]
Matrix spike duplicate	Laboratory reproducibility and accuracy	[b]
Surrogates	Recovery/yield	[b]
Laboratory control sample	Method accuracy	One per batch

a. For portable Grundfos pumps, equipment blanks are collected 1 per 10 well trips. Whenever a new type of non-dedicated equipment is used, an equipment blank is collected every time sampling occurs until it can be shown that less frequent collection of equipment blanks is adequate to monitor the decontamination procedure for the non-dedicated equipment.

b. As defined in the laboratory contract or quality assurance plan and/or analysis procedures.

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Table D.7 Preservation Techniques, Analytical Methods Used, and Current Required Quantitation Limits for Chemical Constituents

Constituent	Collection & Preservation[a,b]	Analysis Methods[c]	Method Quantitation Limit (µg/L)[d]
Metals			
Arsenic	P, HNO_3 to pH<2	SW-846[e] Method 6010,or EPA/600 Method 200.8	4
Barium			5
Calcium			1,000
Sodium			500
Potassium			4,000
Magnesium			750
Anions by Ion Chromatography			
Nitrate	P, none	EPA/600 Method 300.0[f]	250
Sulfate			500
Chloride			200
Nitrite			250
Volatile Organics			
Carbon tetrachloride	G, no headspace	SW-846 8260	2
Semi Volatile Organics			
N-nitrosodimethylamine	G, no headspace	SW-846 8270D	10
Total Organic Halides			
Total Organic Halides	G, no headspace	SW-846 9020	20
Alkalinity			
Alkalinity	G/P, none	EPA Standard Method[g] 2320 EPA/600 Method 310.1 EPA/600 Method 310.2	5,000

a. P = plastic; G = glass.
b. All samples will be cooled to 4ºC upon collection.
c. Constituents grouped together are analyzed by the same method, unless otherwise indicated.
d. Detection limit units, except where indicated.
e. SW-846, Methods for Evaluation of Solid Waste: Physical/Chemical Methods. EPA/600/4-84-017).
f. Analytical method adapted from Method 300.0, Test Methods for Determination of Inorganic Anions in Water by Ion Chromatography (EPA-600/4-84-017).
g. Standard Methods for the Examination of Water and Wastewater (AWWA/APHA 1998).

EPA = U.S. Environmental Protection Agency
N/A = not applicable

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Table D.8 Field and Laboratory Quality Control Elements and Acceptance Criteria

Constituent[a]	QC Element	Acceptance Criteria	Corrective Action
General Chemical Parameters			
Alkalinity	MB	<MDL	Flagged with "C"
	LCS	80-120% recovery[c]	Data reviewed[d]
	DUP	<20% RPD[c]	Data reviewed[d]
	MS[e]	75-125% recovery[c]	Flagged with "N"
	EB, FTB	<2 times MDL	Flagged with "Q"
	Field duplicate	<20% RPD[f]	Flagged with "Q"
Anions			
Anions by IC	MB	<MDL	Flagged with "C"
	LCS	80-120% recovery[c]	Data reviewed[d]
	DUP	<20% RPD[c]	Data reviewed[d]
	MS	75-125% recovery[c]	Flagged with "N"
	EB, FTB	<2 times MDL	Flagged with "Q"
	Field duplicate	<20% RPD[f]	Flagged with "Q"
Metals			
Arsenic Barium ICP metals	MB	<CRDL	Flagged with "C"
	LCS	80-120% recovery[c]	Data reviewed[d]
	MS	75-125% recovery[c]	Flagged with "N"
	MSD	<20% RPD[c]	Data reviewed[d]
	EB, FTB	<2 times MDL	Flagged with "Q"
	Field duplicate	<20% RPD[f]	Flagged with "Q"
Volatile Organic Compounds			
Carbon tetrachloride	MB	<MDL	Flagged with "B"
	LCS	Statistically derived[g]	Data reviewed
	MS	Statistically derived[g]	Flagged with "N"
	MSD	Statistically derived[g]	Data reviewed[d]
	SUR	Statistically derived[g]	Data reviewed[d]
	EB, FTB, FXR	<2 times MDL	Flagged with "Q"
	Field duplicate	<20% RPD[f]	Flagged with "Q"
Semivolatile Organic Compounds			
N-nitrosodimethylamine	MB	<2 times MDL	Flagged with "B"
	LCS	Statistically derived[g]	Data reviewed
	MS	Statistically derived[g]	Flagged with "N"
	MSD	Statistically derived[g]	Data reviewed[d]
	SUR	Statistically derived[g]	Data reviewed[d]
	EB, FTB	<2 times MDL	Flagged with "Q"
	Field duplicate	<20% RPD[f]	Flagged with "Q"

a. Refer to Table D.7 for specific analytical methods.
c. Laboratory-determined, statistically derived control limits may also be used. Such limits are reported with the data.
d. After review, corrective actions are determined on a case-by-case basis. Corrective actions may include a laboratory recheck or flagging the data as suspect ("Y" flag) or rejected ("R" flag).
e. Applies to total organic carbon and total organic halides only.
f. Applies only in cases where one or both results are greater than 5 times the detection limit.
g. Determined by the laboratory based on historical data. Control limits are reported with the data.

Data flags:
B, C = possible laboratory contamination (analyte was detected in the associated method blank)
N = result may be biased (associated matrix spike result was outside the acceptance limits)
Q = problem with associated field QC sample (blank and/or duplicate results were out of limits)

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Table D.8 Field and Laboratory Quality Control Elements and Acceptance Criteria

Abbreviations:

CRDL	=	contract-required detection limit
DUP	=	laboratory matrix duplicate
EB	=	equipment blank
FTB	=	full trip blank
FXR	=	field transfer blank
GC	=	gas chromatography
ICP	=	inductively coupled plasma
ICP/MS	=	inductively coupled plasma/mass spectrometry
LCS	=	laboratory control sample
MB	=	method blank
MDA	=	minimum detectable activity
MDL	=	method detection limit
MS	=	matrix spike
MSD	=	matrix spike duplicate
PCB	=	polychlorinated biphenyl
RPD	=	relative percent difference
SUR	=	surrogate

Table D.9 Blind-Standard Constituents and Schedule

Constituents	Frequency	Accuracy (%)[a]	Precision (% RSD)[a]
Carbon tetrachloride	Quarterly	±25%	<25%
Total organic halides[b]	Quarterly	±25%	<25%

If the results are less than 5 times the required detection limit, then the criterion is that the difference of the results of the replicates is less than the required detection limit.

Two sets of spikes for total organic halides will be used. The spiking compound for one set should be 2,4, 5-trichlorophenol. The spiking compound for the second set should include the constituents used for the volatile organic compounds sample (carbon tetrachloride).

RSD = relative standard deviation

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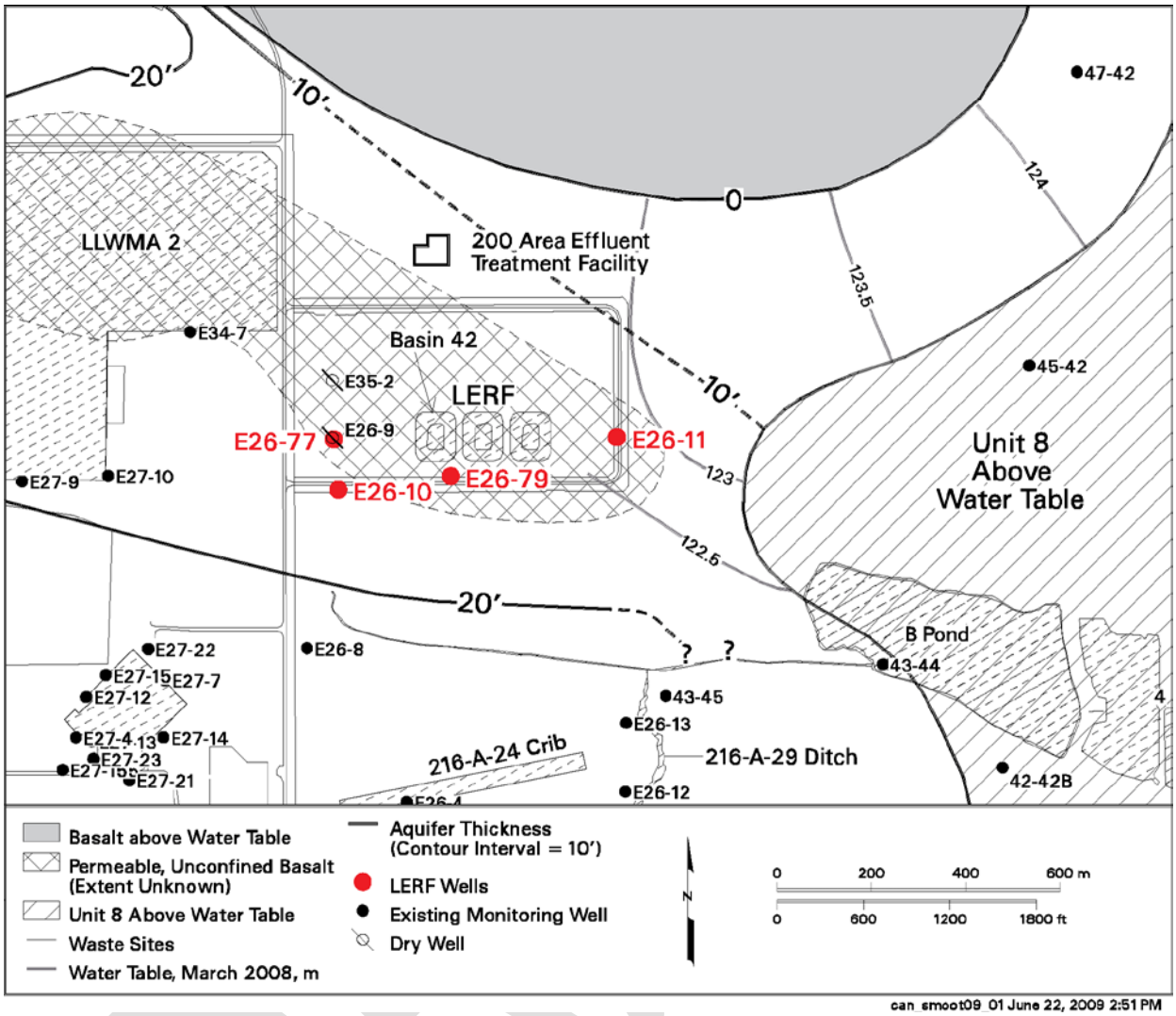


Figure D.1 LERF Location Map Showing Revised Unconfined Aquifer Thickness

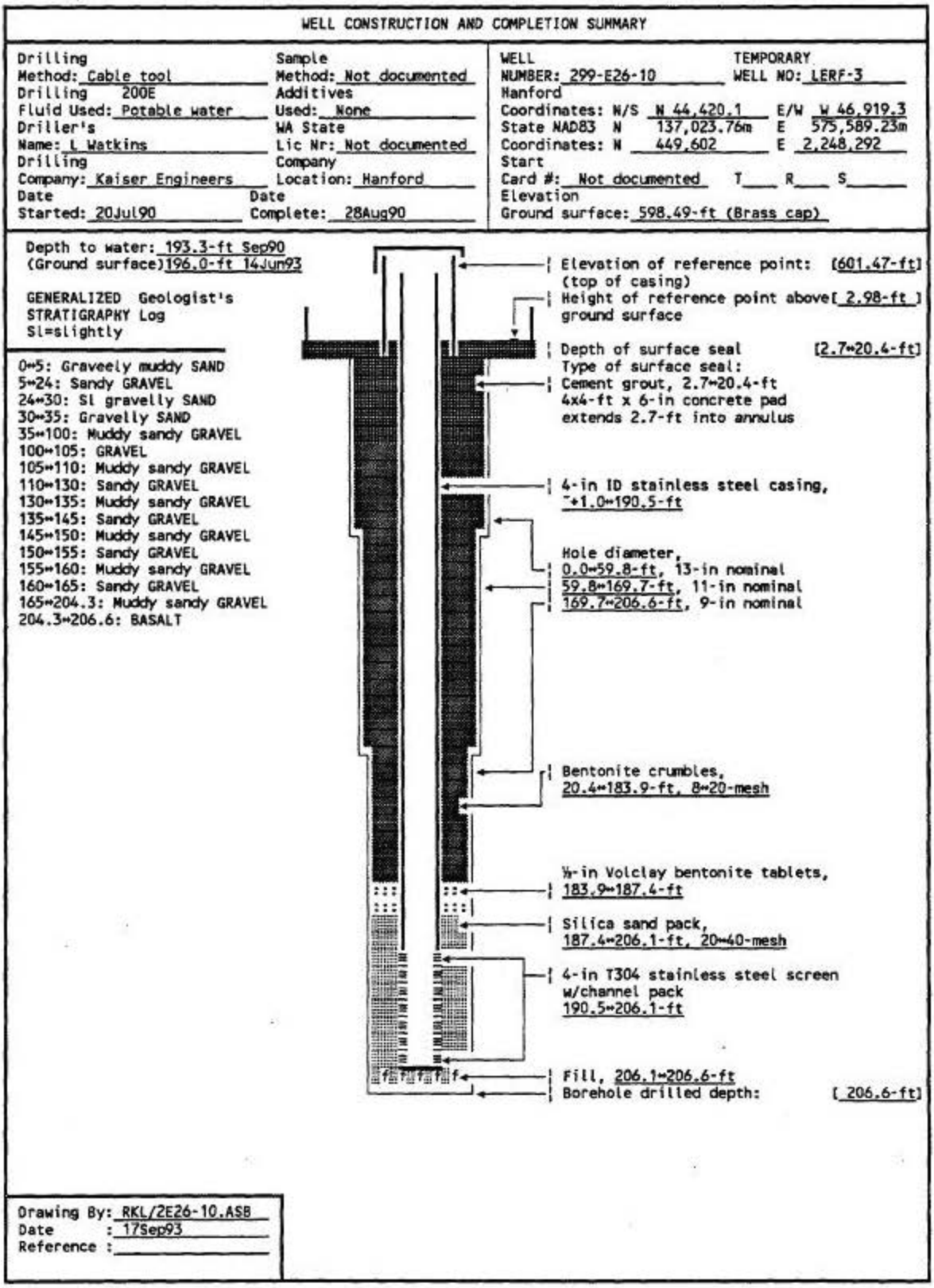


Figure D.2 Well Construction Diagram for Well 299-E26-10 in LERF Groundwater Monitoring Network

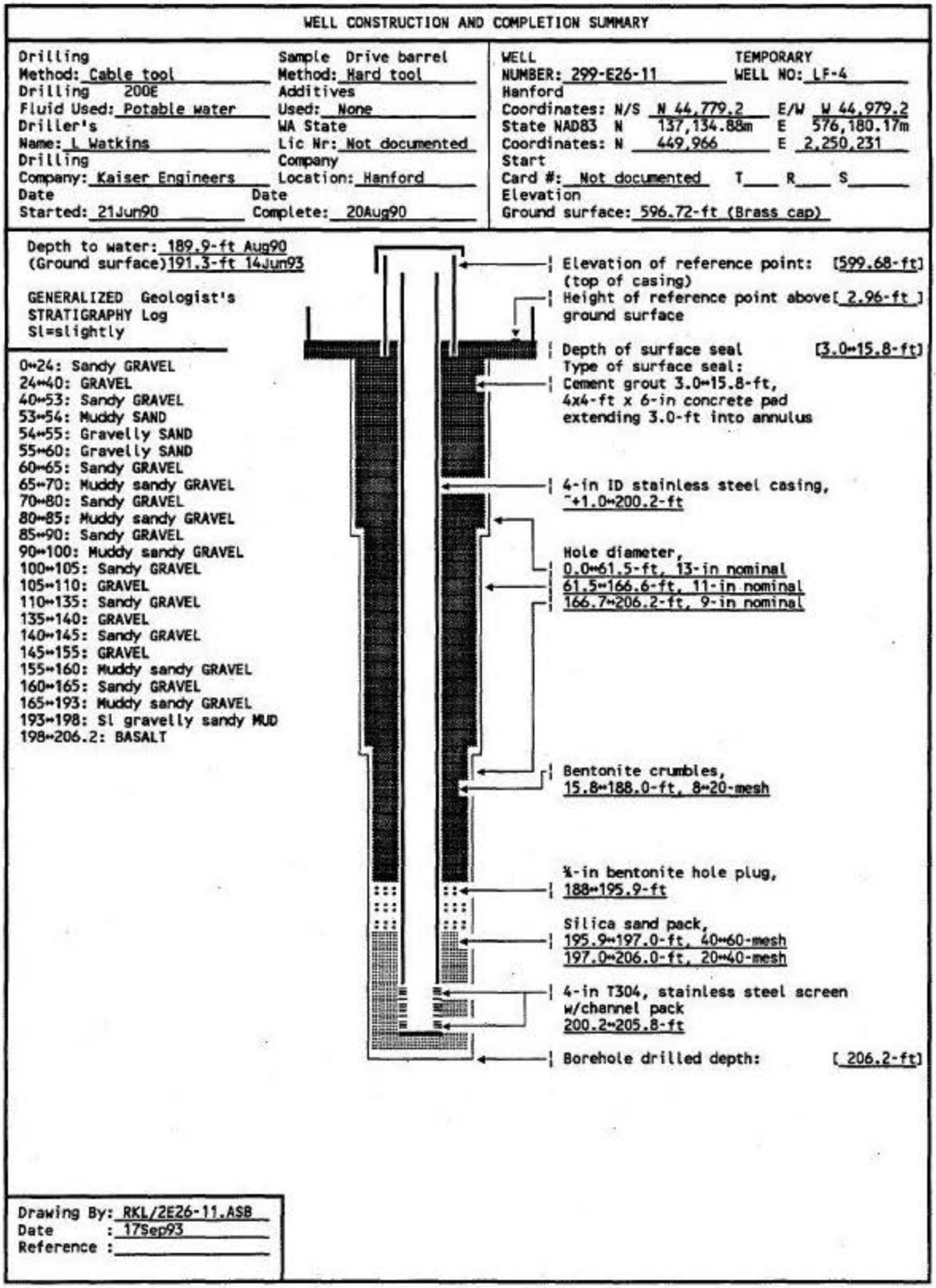


Figure D.3 Well Construction Diagram for Well 299-E26-11 in LERF Groundwater Monitoring Network

WELL SUMMARY SHEET

Start Date: 08/12/2008
Finish Date: 09/05/2008
Page 1 of 2

Well ID: C6455
Well Name: 299-E26-77
Location: Inside fence, LERF 200 E
Project: M-24 RCRA Wells (LERF)
Prepared By: S. Sexton
Date: 9/08/08
Reviewed By: L. D. Walker
Date: 10/13/08
Signature:
Signature:

CONSTRUCTION DATA

Description

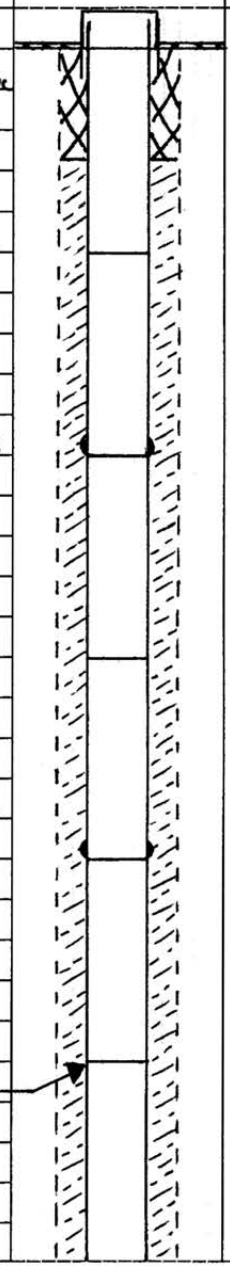
6" x 4' x 4' concrete pad
6" stainless steel protective monument:

4" ID Sch. 10 stainless steel casing: 1.96 ft ags to 200.85 ft bgs
4" stainless steel wire wrap screen, 0.020": 200.85 to 225.6 ft bgs
4" Sch. 10 stainless steel sump: 225.6 to 228.6 ft bgs

Portland cement grout: 0 to 11.05 ft bgs
Bentonite granules: 11.05 to 189.0 ft bgs
Bentonite pellets: 189.0 to 194.6 ft bgs
10-20 silica sand: 194.6 to 232.8 ft bgs

casing joint

Diagram



GEOLOGIC/HYDROLOGIC DATA

Depth in Feet: 0, 20, 40, 60, 80, 100

Graphic Log

Lithologic Description

0-0.5: gravel drill pad
0.5-5: gravelly Silt (gM)
5-34: silty Gravel (mG)
34-38: gravelly silty Sand (gmS)
38-43: silty sandy Gravel (msG)
43-45.5: gravelly Sand (gS)
45.5-52: silty Sand (mS)
52-75: silty sandy Gravel (msG)
75-123: sandy silty Gravel (smG)

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Figure D.4 Well Summary Sheet for Well 299-E26-77 in LERF Groundwater Monitoring Network

WELL SUMMARY SHEET

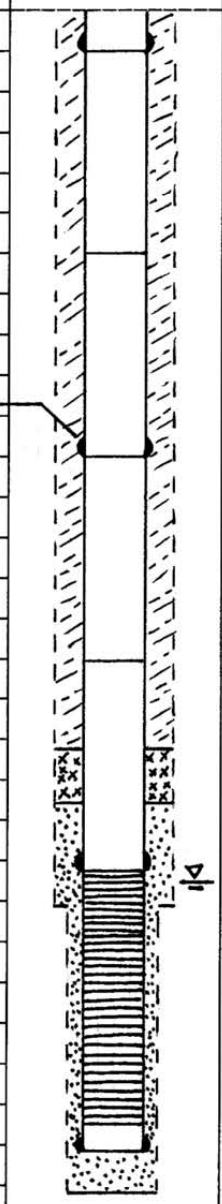
Start Date: 08/12/2008
Finish Date: 09/05/2008
Page 2 of 2

Well ID: C6455	Well Name: 299-E26-77
Location: Inside fence, LERF, 200E	Project: M-24 RCRA Wells (LERF)
Prepared By: S. Sexton — Date: 9/08/08	Reviewed By: L.J. Walker — Date: 10/13/08
Signature:	Signature:

CONSTRUCTION DATA

Description

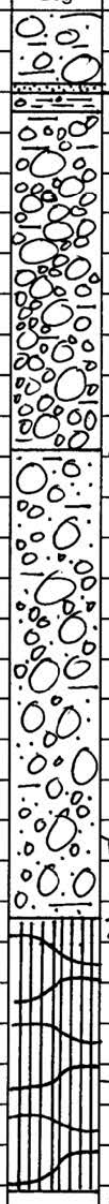
Diagram



GEOLOGIC/HYDROLOGIC DATA

Depth in Feet

Graphic Log



Lithologic Description

123-124: Sand (s)
124-126: gravelly Silt (gM)
126-159: silty Gravel (mG)
159-205.5: silty sandy Gravel (msG)
DTW = 201.9 ft bgs on 08/27/2008
205.5-233: basalt
TD = 232.8' bgs on 08/26/2008
All depths recorded in feet "below ground surface" (bgs)

A-6003-643 (03/03)

Well Summary Sheet for Well 299-E26-77 in LERF Groundwater Monitoring Network (cont.)

WELL SUMMARY SHEET

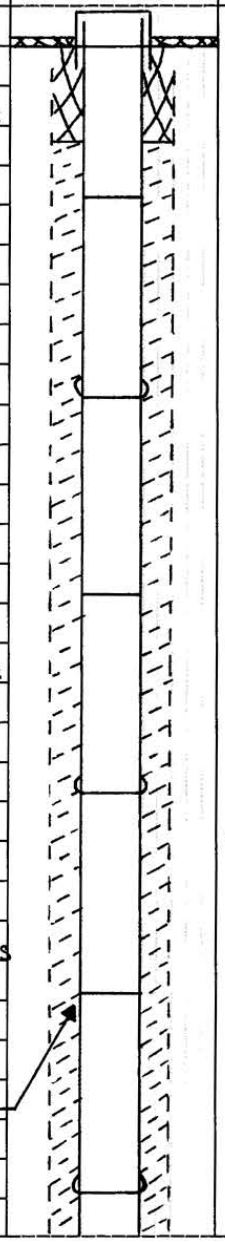
Start Date: 09/09/2008
Finish Date: 10/02/2008
Page 1 of 2

Well ID: C6826	Well Name: 299-E26-79
Location: Inside fence, LERF, 200E	Project: M-24 RCRA Wells (LERF)
Prepared By: S. Sexton — Date: 10/6/08	Reviewed By: L.D. Walker — Date: 10/13/08
Signature:	Signature:

CONSTRUCTION DATA

Description:
6" x 4' x 4' concrete pad
6" stainless steel protective monument: 3.0' bgs to 3.1' ags
4" stainless steel Sch. 10 casing: 2.3 ft ags to 195.2 ft bgs
4" stainless steel wire wrap screen, 0.020": 195.2 to 220.2' bgs
4" stainless steel Sch. 10 sump: 220.2 to 223.2 ft bgs
Portland cement grout: 0 to 10.3 ft bgs
Bentonite granules: 10.3 to 183.0 ft bgs
Bentonite pellets: 183.0 to 187.8 ft. bgs
10-20 silica sand: 187.8 to 224.76 ft bgs
Casing joint

Diagram:



GEOLOGIC/HYDROLOGIC DATA

Depth in Feet: 0, 20, 40, 60, 80, 100

Graphic Log:

Lithologic Description:
0-1: gravel drill pad
1-27: sandy silty Gravel (smG)
27-27.5: sandy Silt (sM)
27.5-29: silty Gravel (mG)
29-32: sandy Silt (sM)
32-54: silty Sand (mS)
54-79: silty sandy Gravel (msG)
79-119: sandy silty Gravel (smG)

A-6003-643 (03/03)

Figure D.5 Well Summary Sheet for Well 299-E26-79 in LERF Groundwater Monitoring Network

WELL SUMMARY SHEET

Start Date: 09/09/2008
Finish Date: 10/02/2008
Page 2 of 2

Well ID: C6826
Well Name: 299-E26-79
Location: Inside fence, LERF, 200E
Project: M-24 RCRA Wells (LERF)
Prepared By: S. Sexton Date: 10/6/08
Reviewed By: L. D. Walker Date: 10/13/08
Signature:
Signature:

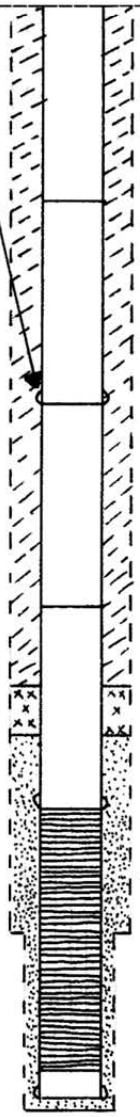
CONSTRUCTION DATA

Description

Centralizer

All temporary casing removed from borehole

Diagram



GEOLOGIC/HYDROLOGIC DATA

Depth in Feet: 120, 140, 160, 180, 200, 220

Graphic Log

Lithologic Description

119-135: silty sandy Gravel (msG)
135-152: Gravel (G)
152-200: silty sandy Gravel
DTW = 201.7 ft bgs on 09/22/2008
200-203: sandy Gravel (sG)
203-206: gravelly Sand (gS)
206-207: modified clay
207-224.76: basalt
TD = 224.76 ft bgs on 09/23/2008
All depths recorded in feet "below ground surface" (bgs)

A-6003-643 (03/03)

Well Summary Sheet for Well 299-E26-79 in LERF Groundwater Monitoring Network (cont.)

D.6 References

40 CFR 141. "National Primary Drinking Water Regulations", "Radionuclides; Proposed Rule". U.S. Environmental Protection Agency, *Code of Federal Regulations*.

40 CFR 264, Appendix IX. "Ground-Water Monitoring List". U.S. Environmental Protection Agency, *Code of Federal Regulations*.

APHA/AWWA/WEF. (1998). *Standard Methods for the Examination of Water and Wastewater, 20th Edition*, as revised, American Public Health Association, American Water Works Association, and Water Environment Federation, Washington, D.C., ISBN: 0875530478.

ASTM. (1998). *Standard Guide for Developing Appropriate Statistical Approaches for Ground-Water Detection Monitoring Programs*. ASTM D 6312-98, American Society for Testing and Materials, West Conshohocken, Pennsylvania.

Delaney, C. D., K. A. Lindsey, and S. P. Reidel. (1991). *Geology and Hydrology of the Hanford Site: A Standardized Text for Use in Westinghouse Hanford Company Documents and Reports*. WHC-SD-EN-TI-003, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

Gibbons, R. D. (1994). *Statistical Methods for Groundwater Monitoring*. John Wiley & Sons, New York.

Gilbert, R. O. (1987). *Statistical Methods for Environmental Pollution Monitoring*, Van Nostrand Reinhold, New York.

Lucas, J. M. (1982). "Combined Shewhart-CUSUM Quality Control Schemes". In *Journal of Quality Technology*, 14:(2)51-59.

McDonald, J. P. (2007). *Water-Level Barometric Response Analysis for the Liquid Effluent Retention Facility Monitoring Wells, Hanford Site*. SGW-35756, Rev. 0, Fluor Hanford, Richland, Washington.

Montgomery, D. C., and E. A. Peck. (1982). *Introduction to Linear Regression Analysis*., John Wiley & Sons, New York.

Rasmussen, T. C., and L. A. Crawford. (1997). "Identifying and Removing Barometric Pressure Effects in Confined and Unconfined Aquifers". In *Ground Water*, 35: 502-511.

RCW 70.105. "Public Health and Safety", "Hazardous Waste Management". Washington State Department of Ecology, *Revised Code of Washington*.

Resource Conservation and Recovery Act of 1976, 42 U.S.C.6901, et seq.

Sen, P. K. (1968). "Estimates of the Regression Coefficient Based on Kendall's Tau". In *Journal of the American Statistical Association* 63:1379-1389.

Sexton, S. M. (2008). Borehole Summary Report for the Installation of RCRA Wells 299-E26-77 (C6455), 299-E26-79 (C6826), 299-E25-236 (C6542), and 199-N-165 (C6693), FY 2008. SGW-39344, Rev. 0, CH2M Hill Plateau Remediation Company, Richland, Washington.

Smoot, J. L. (2009). *Liquid Effluent Retention Facility Characterization Report*. SGW-41072, CH2M Hill Plateau Remediation Company, Richland, Washington.

Spane, F. A., and Newcomer, D. R. (2004). *Results of Detailed Hydrologic Characterization Tests - Fiscal Year 2003*. PNNL-14804, Pacific Northwest National Laboratory, Richland, Washington.

Starks TH. (1988). *Evaluation of Control Chart Methodologies for RCRA Waste Sites*, (EPA/600/4-88/040), U.S. Environmental Protection Agency Office of Research and Development, Las Vegas, Nevada.

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SW-846. (1986). *Test Methods for Evaluating Solid Wastes: Physical/Chemical Methods*, 3rd Edition, as amended. U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response, Washington, D.C.

Sweeney, M. D., K. A. Lindsey, J. S. Schmid, and J. V. Borghese. (1994). *Site Characterization Report for the Liquid Effluent Retention Facility*. WHC-SD-EN-EV-024, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

U.S. DOE. (1993). *200 East Groundwater Aggregate Area Management Study Report*. DOE/RL-92-19, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

U.S. DOE. (2009). *Hanford Site Groundwater monitoring for Fiscal Year 2008*. DOE/RL-2008-66, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

U.S. EPA. (1979). *Methods for Chemical Analysis of Water and Wastes*. EPA-600/4-79-020, as revised, U.S. Environmental Protection Agency, Washington, D.C.

U.S. EPA. (2009), *Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities - Unified Guidance*. EPA 530-R-09-007, U.S. Environmental Protection Agency, Washington, D.C.

Westgard, J. O., T. Groth, T. Aronson, and C. De Verdier. (1977). "Combined Shewhart-CUSUM Control Chart for Improved Quality Control in Clinical Chemistry". In *Clinical Chemistry*, 28(10):1881-1887.

Williams, B. A., B. N. Bjornstad, R. Schalla, and W. D. Webber. (2000). *Revised Hydrogeology for the Suprabasalt Aquifer System, 200-East Area and Vicinity, Hanford Site, Washington*. PNNL-12261, Pacific Northwest National Laboratory, Richland, Washington.

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