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Monitoring the Prototype Hanford Barrier – Fiscal Year 2017 Report

September 2017

ZF Zhang
JN Thomle
RE Clayton

U.S. DEPARTMENT OF ENERGY
Prepared for the U.S. Department of Energy under Contract DE-AC05-76RL01830

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Pacific Northwest National Laboratory
Richland, Washington 99352

Executive Summary

After a decade of development activities from 1983 to 1993, the 2.5-ha (6.2 acres) Prototype Hanford Barrier (PHB) was constructed between late 1993 and 1994 over the 216-B-57 Crib in the 200 East Area (46°34’01.23”N, 119°32’28.43”W) at the Hanford Site in southeastern Washington State as part of a *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA) treatability test of barrier performance for the 200-BP-1 Operable Unit. The CERCLA treatability test included an enhanced precipitation stress test during the water years 1995 to 1997 to determine barrier response to extreme precipitation events and a controlled fire test in 2008 to examine the recovery of vegetation under the natural condition and the performance of the barrier with limited vegetation.

The barrier was monitored extensively between November 1994 and September 1998 to evaluate surface-barrier constructability, construction costs, and hydrologic and structural performance at the field scale. From fiscal year 1998 (FY98) to FY13, monitoring focused on a more limited set of water balance, stability, and biotic parameters to evaluate the barrier’s hydrologic, structural, and ecological performance. The design, test, and performance of the PHB till 2015 were summarized in DOE-RL (2016). There were no monitoring activities from FY14 to FY16.

In 2016, the Department of Energy requested that monitoring of the PHB be resumed to lengthen the record of performance, continue to follow the recovery following a controlled burn in 2008, and collect data specific to extreme events that have a greater chance of occurring during a longer monitoring period.

The hydrological monitoring at the PHB was resumed in FY17. The current strategy for the monitoring is to monitor water balance approximately quarterly. The structural and ecological monitoring was scheduled for a future time and at a less frequent rate (approximately once every several years) because the barrier structure and ecological state are not expected to change over this time frame. The primary activities have included 1) preparing water balance monitoring using a new neutron probe and a newly designed double-tipping-bucket drainage monitoring system; and 2) removing the unused instruments and supporting accessories from the site. This report statuses these activities, and will release monitoring data in FY18, once the data have been fully qualified.

Reference

DOE-RL. 2016. Prototype Hanford Barrier 1994 to 2015, DOE/RL-2016-37, Rev. 0, U.S. Department of Energy Richland Operations Office. Richland, Washington. Available at http://www.hanford.gov/c.cfm/sgrp/DOE-RL-2016-37/DOE-RL-2016-37_R0.pdf and http://www.hanford.gov/c.cfm/sgrp/DOE-RL-2016-37/Appendices.pdf (Accessed on September 12, 2017).

Acknowledgments

This document was prepared by the Deep Vadose Zone − Applied Field Research Initiative at Pacific Northwest National Laboratory. Field activities were coordinated by the CHPRC. Funding for this work was provided by the U.S. Department of Energy (DOE) Richland Operations Office. The Pacific Northwest National Laboratory is operated by Battelle Memorial Institute for the DOE under Contract DE-AC05-76RL01830.

Acronyms and Abbreviations

Acronyms	Description
AC	asphalt concrete
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act of 1980
DOE	Department of Energy
DOE-RL	Department of Energy Richland Operations Office
DTB	double-tipping-bucket
ETC	evapotranspiration-capillary
FGB	fiberglass block
FY	Fiscal Year
HDI	How Do I…?
HMS	Hanford Meteorological Station
NP	neutron probe
PHB	Prototype Hanford Barrier
QA	Quality Assurance
TB	tipping bucket
TDR	time domain reflectometry

Contents

Figures

Tables

1.0 Introduction

1.1 Background

After a decade of development activities from 1983 to 1993, the 2.5-ha (6.2 acres) Prototype Hanford Barrier (PHB, Figure 1.1) was constructed between late 1993 and 1994 over the 216-B-57 Crib in the 200 East Area (46°34’01.23”N, 119°32’28.43”W) at the Hanford Site in southeastern Washington State as part of a *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA) treatability test of barrier performance for the 200-BP-1 Operable Unit (DOE-RL 2016). The CERCLA treatability test included an enhanced precipitation stress test during the water years 1995 to 1997 to determine barrier response to extreme precipitation events and a controlled fire test in 2008 to examine the recovery of vegetation under the natural condition and the performance of the barrier with limited vegetation. The barrier was monitored extensively between November 1994 and September 1998 to evaluate surface-barrier constructability, construction costs, and hydrologic and structural performance at the field scale. From fiscal year 1998 (FY98) to FY13, monitoring focused on a more limited set of water balance, stability, and biotic parameters to evaluate the barrier’s hydrologic, structural, and ecological performance.

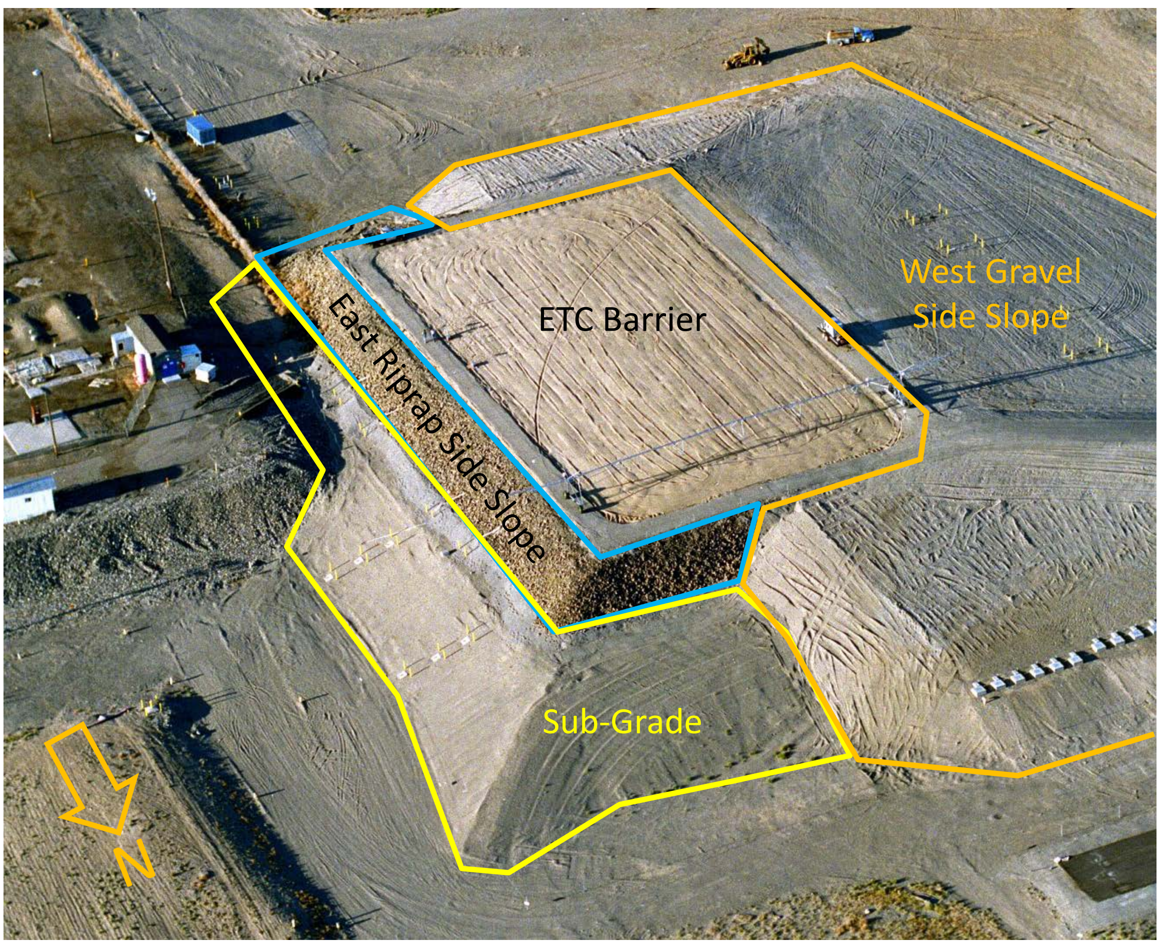

Figure 1.1. Plan view of the Prototype Hanford Barrier after completion of construction. (Photo taken on August 9, 1994. The lines show the approximate boundaries of the main barrier components.)

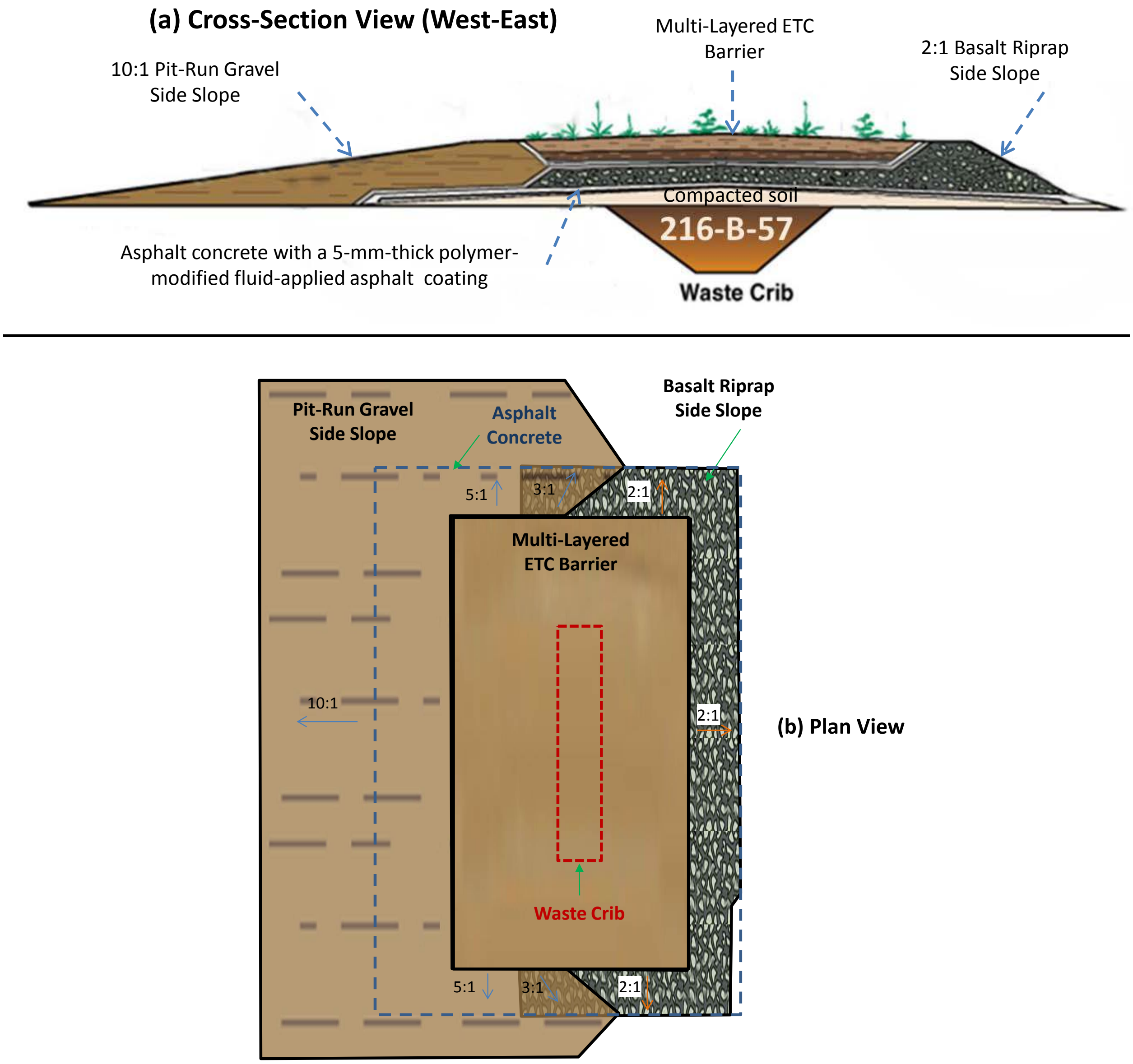

Figure 1.2. Schematic of the PHB: (a) cross-section view (west-east) and (b) plan view (approximate scale).

The PHB consists of four main components (Figure 1.2): (1) An evapotranspiration-capillary (ETC) barrier that consists of a silt loam evapotranspiration layer and an underlying capillary break (CB) consisting of gravels grading into large basalt, which is intended to prevent intrusion; (2) an asphalt concrete (AC) barrier with a polymer-modified fluid applied asphalt coating and a compacted soil layer beneath it; (3) a gentle pit-run gravel side slope in the west (10:1); and (4) a steep basalt riprap side slope in the east (2:1). The ETC barrier is the portion of the PHB that sits directly above but is larger than the waste zone. The role of the ETC barrier is to store precipitation and release the stored water into the atmosphere and to deter intrusion from the barrier surface by plants, animals, or humans. The AC barrier diverts drainage, hinders intrusion, and thus acts as a backup to the ETC barrier should the functionality of the latter be compromised. The two side slopes maintain barrier stability so that the ETC barrier remains intact and retains its functionality.

1.2 PHB Performance from 1994 to 2015

The design, test, and performance of the PHB till 2015 were summarized in DOE-RL (2016) based on a comprehensive review and analysis of the data collected at the site. The information in DOE-RL (2016) has also been published in several peer-reviewed journal papers. Zhang (2015) analyzed the field water retention of the silt loam layer at four depths and 12 water balance stations using in situ measurements of water content and pressure from 1995 to 2003. In Zhang (2017a), the drainage from the riprap side slope is evaluated with respect to the side slopes influence on the effectiveness of a long-term barrier. Additionally, Zhang (2017b) evaluated the performance of the neutron probe used in monitoring the soil water content at the PHB, and Zhang et al. (2017) discussed the surface-barrier design and performance of the PHB under conditions of enhanced and natural precipitation and no vegetation. The main findings with respect to the performance of the barrier components are as follows:

- The ETC barrier of the PHB performed much better than the drainage design goal of 0.5 mm yr^{-1}.
  - During each winter season, the silt loam layer was recharged by precipitation. The capillary break considerably enhanced the barrier’s storage capacity.
  - During each summer season, all of the summer precipitation and nearly all of the stored water from the winter season was returned to the atmosphere by evapotranspiration. These seasonal observations were consistent year to year and thus explained why average drainage (0.005 mm yr^{-1}) was so much lower than the design goal.
  - After the controlled fire in September 2008, significantly less vegetation re-established in the burned section of the PHB than in the unburned section. The re-established grasses still removed nearly all the stored water in the burned section, but at a slower rate than in the unburned section, which had fully grown shrubs. Initially after the fire, the soil showed decreased wettability, but gradually returned to normal in the years that followed.
  - No detectable settlement or compression of the ETC barrier occurred.
  - The number and sizes of animal holes on the barrier surface were small and did not discernibly affect barrier function.
- Both side slopes remained stable and well-drained.
- The AC barrier remained stable and allowed negligible water percolation.

In summary, from 1994 to 2013—during which time the barrier experienced 3 years of enhanced precipitation, three 1000-year return, 24-hour simulated rainstorms, and a controlled fire—the monitoring data demonstrate that the barrier satisfied nearly all objectives in the past two decades. The PHB far exceeded the *Resource Conservation and Recovery Act* criteria, functioned in Hanford’s semiarid climate, limited drainage to well below the 0.5 mm yr^{-1} performance criterion, limited runoff, and minimized erosion and bio-intrusion.

1.3 Long-Term Barrier Monitoring Strategy

One of the challenges facing deployment of surface barriers is convincing stakeholders that the technology will be effective and long-lasting. A longer period of performance monitoring will help to address this challenge. Hence, DOE-RL (2016) recommended the continuation of the barrier monitoring for several reasons:

- The two-decade monitoring period accounts for only 2% of the 1000-year design life. Extrapolation of past performance into the future is subject to significant uncertainty, including the possible effects of climate change.

- Extreme events happen very infrequently, perhaps on time scales of decades or longer. Extending the monitoring period increases the likelihood that extreme events will occur and barrier performance will be observed.

- The vegetation on the north section of the PHB was still dominated by the shallow-rooted grasses 4 years after the controlled burn. Precipitation levels during this period were normal and were never high enough to stress the barrier. Extending the monitoring period allows for more-complete observation of vegetation recovery and PHB performance.

Per the recommendation in DOE-RL (2016), the hydrological monitoring of the PHB performance was planned to resume in FY16. However, radioactive rabbit droppings were found at the site during the monitoring gap between FY13 and FY16. This finding required necessary procedures be established and delayed the monitoring activities to FY17. The monitoring strategy is to monitor water balance approximately quarterly. The structural and ecological monitoring was scheduled for a future time and at a less frequently rate (approximately once several years) because the barrier structure and ecological state are not expected to change substantially across years. The monitoring components in the past, FY17, and the future are listed in Table 1.1.

The last structural monitoring was in FY12 and the last ecological monitoring was in 2011. In the next 1 to 2 years, it is expected to complete the calibration of primary instruments and test procedures. The runoff plot will be refurbished and the structural and ecological monitoring resumed.

1.4 Scope of the Report

Section 2 describes the monitoring system including monitoring plots and stations, monitoring methods, and instrument calibration. Section 3 presents the activities in FY17. Section 4 describes the quality assurance program and Section 5 summarizes the activities in FY17. Data collected in FY17 will be released in the FY18 report, once the data have been fully qualified.

Table 1.1. Past, FY17, and Future Monitoring Components at the Prototype Hanford Barrier

Monitoring Purpose	Monitoring Components	Methods	FY15 to FY13	FY17	Future
Hydrology – Primary	Precipitation	Mini-lysimeters	x		
	Surface runoff and erosion	Runoff flume	x		x
	Water content profile	Neutron probe	x	x	x
	Drainage off the asphalt concrete	Drainage vaults	x	x	x
Hydrology - Secondary	Water content at the bottom of the silt loam and beneath the asphalt layer	Neutron probe	x	x	x
	Soil water pressure and temperature	Heat dissipation units	x		
	Soil water pressure	Fiberglass blocks	x		
Structural Stability	Barrier settlement	Settlement markers	x		x
	Barrier elevation	Element markers	x		x
	Riprap side slope stability	Creep gauges	x		x
	Wind erosion	Wind stations	x		
	Overall barrier conditions	Areal-photos	x		x
Ecological Monitoring	Vegetation characteristics (i.e., floristics composition, plant cover and spatial distribution, plant height, and canopy characteristics)	Field survey	x		x
	Gas exchange rate, roots, shrub survivorship, reproduction, and xylem pressure potential	A variety of methods	x		
	Animal activities	Surface inspection, measurement of the counts and dimension of animal burrows, and direct observation using traps	x		

2.0 Monitoring System

This section describes the monitoring system including monitoring zones, stations, and methods.

2.1 Monitoring Plots and Stations

The PHB was divided into 12 monitoring plots to address the spatial variability of water balance and hydrologic processes. Figure 2.1 shows the plots, which are denoted as 1W through 6W for those located in the west half and 1E through 6E in the east half. The 12 plots represent three main types of barrier structure:

1. Silt loam plots: 3W, 3E, 6W, and 6E
2. Side slope plots:
    a. 1W and 4W for the west gravel side slope
    b. 1E and 4E for the east riprap side slope
3. Transitional or silt loam boundary plots: 2W, 2E, 5W, and 5E

Not all the components were monitored in all of the plots, depending on the primary hydrological processes and the function of the components. Drainage through all 12 plots was monitored with 12 drainage vaults. Each of the 12 curbed zones collected water beneath the plot, which was discharged to a concrete vault. Each collection zone with a vault is equivalent to a drainage lysimeter. The vaults were installed to the north and downgradient from the AC to allow the movement of water by gravity.

For water balance, the focus was on the silt loam, which serves as the media for water storage and vegetation growth. The riprap side slope has very little water storage capacity while the gravel side slope has some level of water storage. 14 monitoring stations, denoted as S1 through S14, were established. Twelve of the fourteen monitoring stations were installed in the four silt loam plots (Figure 2.1)—three stations each in 6W and 6E in the north section and 3W and 3E in the south section—to allow the water processes and balance of these plots to be thoroughly evaluated. Two stations were installed in the two gravel plots, i.e., 1W and 4W, respectively, at the west side slope. There was no water balance monitoring of the east riprap side slope or the four small transition plots because the riprap has little water holding capacity and the transition plots are less important than others.

Water content of the soil 0.15 m above the bottom of the silt loam storage zone was monitored with eight horizontally oriented NP access tubes (AA1 through AA8 in Figure 2.2) to examine how the side boundaries and the CB at the bottom affected water movement. Water content beneath the AC was monitored with six horizontally oriented NP access tubes (BA1 through BA6 in Figure 2.2) installed at the depths of 1, 2, and 3 m below the AC.

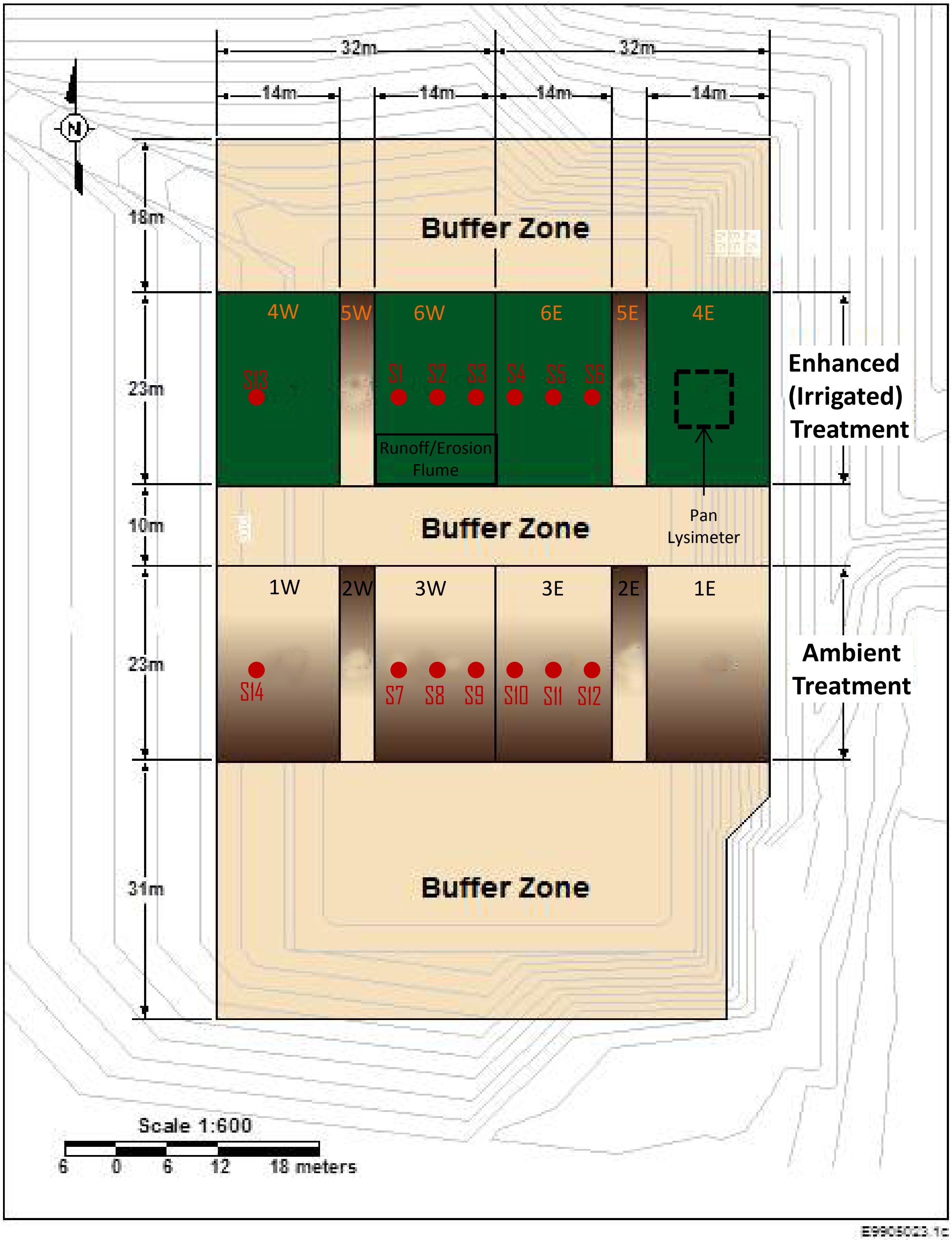

Figure 2.1. Plan view of the Prototype Hanford Barrier showing the 14 water balance monitoring stations (marked as S1 through S14), 12 plots for drainage monitoring (marked as 1W through 6W and 1E through 6E), and the runoff/erosion flume.

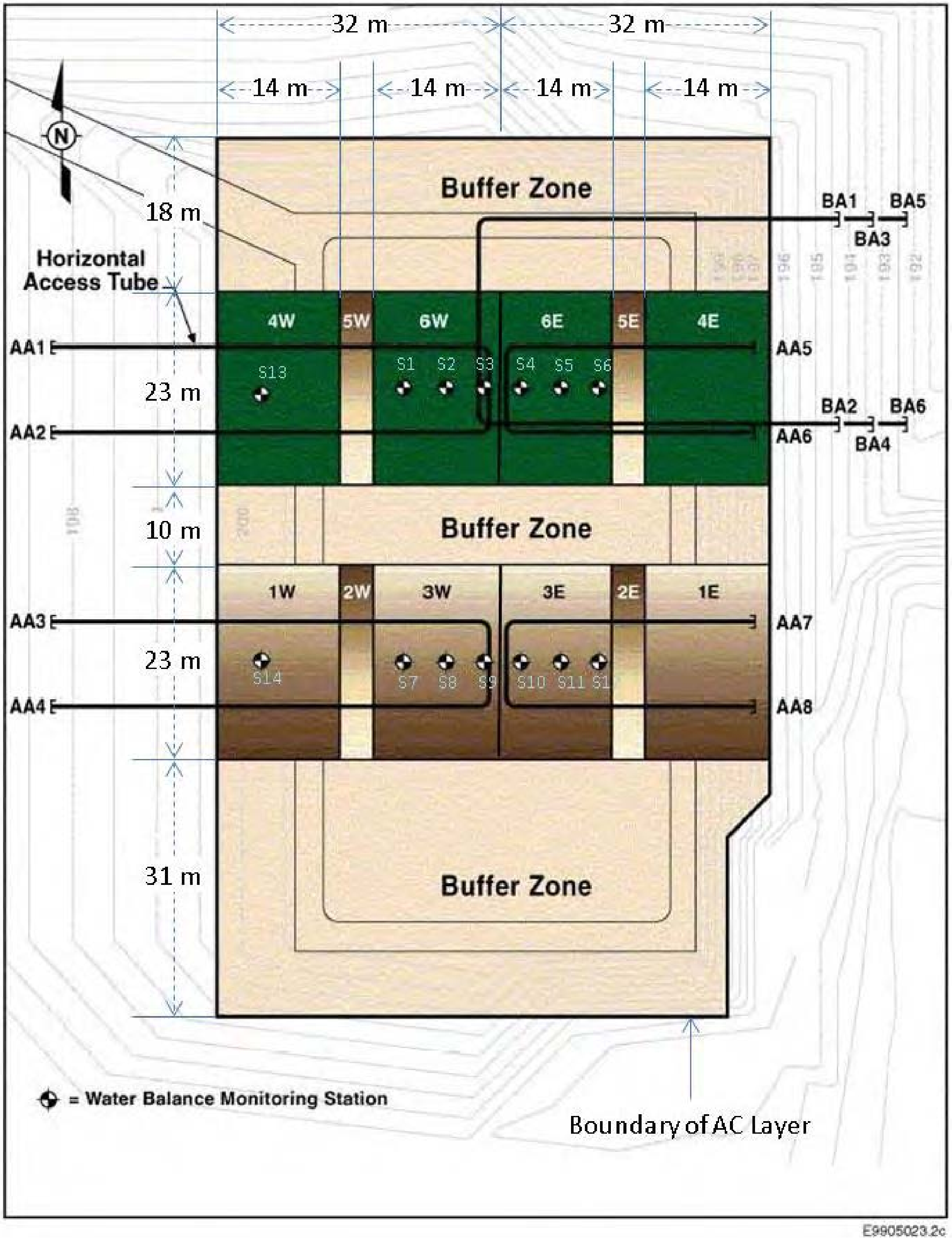

Figure 2.2. The horizontal neutron access tubes shown by the U-shaped lines. Tubes AA1 through AA8 are located near the bottom of the silt loam, slightly above the silt-sand interface. Tubes BA1 and BA2 are 1 m below the asphalt concrete, BA3 and BA4 are 2 m below, and BA5 and BA6 are 3 m below.

2.2 Drainage Monitoring

Within each of the 12 drainage vaults, the old drainage measurement system (which included a tipping bucket, a pressure transducer, and a dosing siphon) will be replaced with a double-tipping-bucket (DTB) measuring system (Figure 2.3). The DTB system is composed of one small Pronamic Rain-O-Matic Small PCB No. 9602 tipping bucket (TB; Pronamic APS, Ringkobin, Denmark; approximate 5 ml per tip) sitting above a large HS TB6/40 (Hyquest Solutions P/L, Liverpool, NSW, Australia; approximate 40 ml per tip) TB. Drainage from the monitored plot flows first through the small TB and then the large TB and hence is measured twice. The drainage water then flows out of the vault through a hole on the existing pipe of the old siphon system.

The DTB system is used for two reasons. First, the flow rates are highly variable both seasonally and between plots, easily covering several orders of magnitude. The maximum flow rate ever recorded at the PHB is 1.3 L min^{-1}, which occurred at the riprap side slope plot 4E on March 29, 1996. The lower and upper bounds of the small TBs are roughly one order of magnitude smaller than those of the large TBs. The upper bound of the small TB is approximately 0.5 L min^{-1} (0.09 mm hr^{-1} for the full plots; 0.33 mm hr^{-1} for the transitional plots) and that for the large TB is 3 L min^{-1} (0.56 mm hr^{-1} for the full plots; 1.96 mm hr^{-1} for the full plots). Second, both TBs should function normally except, in rare cases, high drainage rate from the side slopes could exceed the upper limit of the small TB. Data from the two TBs in the same drainage vault can serve as a check of the functionality and accuracy of the each other. Another advantage of the DTB system is that it can be removed from the vault for repair or replacement when it fails. The procedures to calibrate the DTB will be prepared.

The 12 assembled DTB systems will be installed in the 12 existing drainage vaults, respectively (Figure 2.4). The total height of the assembled DTB system is about 5 feet. This height can be adjusted as needed.

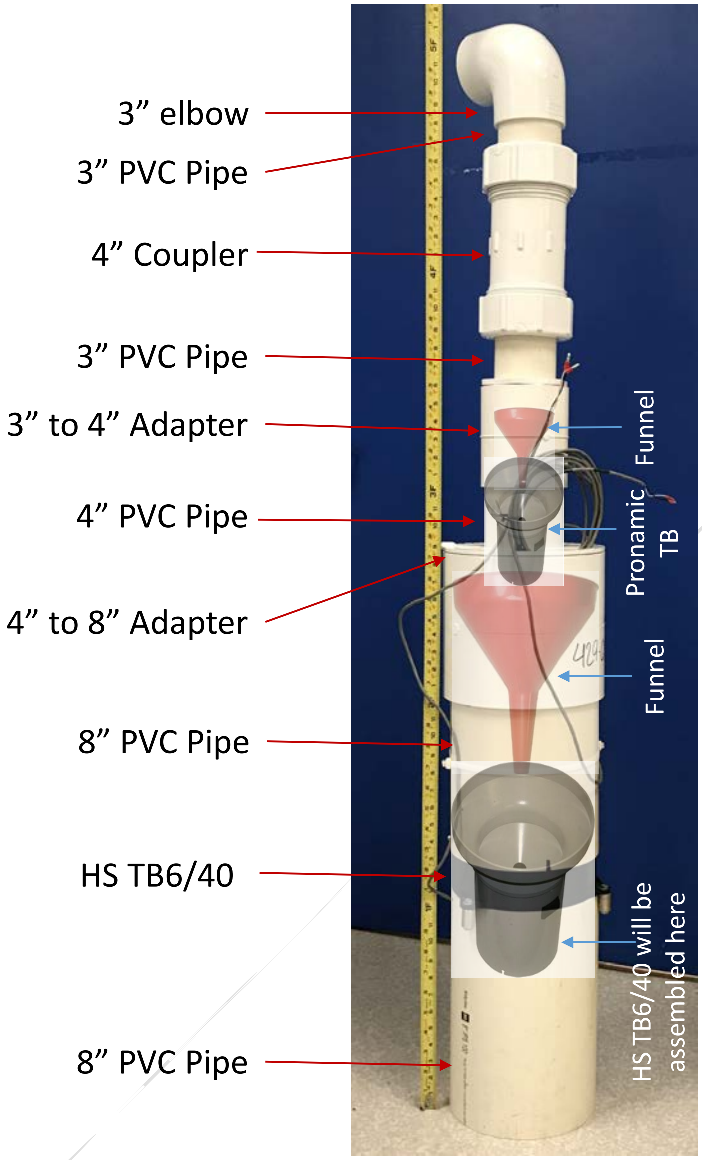

Figure 2.3. The assembled double-tipping-bucket system. The red arrows point to the PVC pipes or adapters. The blue arrows point to the items inside the pipes. The images of the funnels and tipping buckets are not those of the actual items used in the DTB system and not to scale.

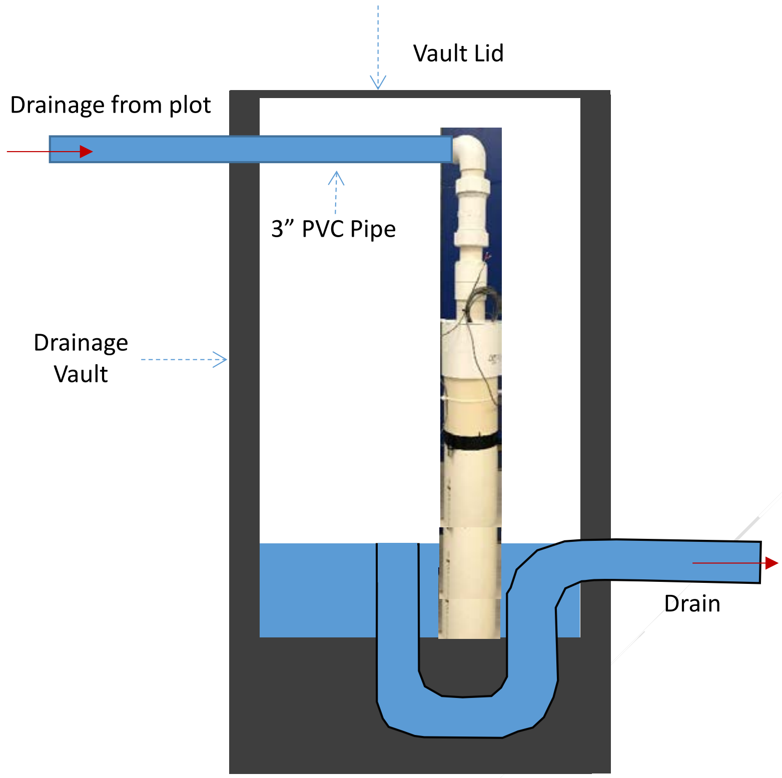

Figure 2.4. Schematic showing the installation of a DTB system in a drainage vault (Not to scale).

2.3 Runoff and Precipitation

Only one runoff plot (Figure 2.1) was established for runoff monitoring because runoff was not expected to be a major component of the water balance as reported in DOE-RL (2016). If runoff occurred within that plot, it was assumed that the rate would be applicable to the remaining barrier surface. Any short-distance runoff within the ETC barrier can become run-on in a different location within the ETC. This within-the-barrier runoff cannot be detected by the runoff flume.

Precipitation is not measured on site. The measurement at the nearby Hanford Meteorological Station (HMS) is used in the analysis. The HMS is located near the center of the Hanford Site between the 200 West and 200 East Areas and is about 3 miles west of the PHB.

3.0 Field Activities

This section describes the monitoring activities in FY17.

3.1 Neutron Probe Calibration

The neutron probe (CPN 503DR Hydroprobe, S/N H33115140) used from FY95 to FY13 exceeded its design life and was retired. A newer neutron probe (CPN 503DR Hydroprobe, S/N 50200) was used in FY17 and will be used in the future. A cross calibration between the two probes was conducted at the Hanford site in 2011 so the logged neutron counts can be converted and compared after the complete of the quality assurance of the data.

The neutron probe (S/N 50200) was calibrated in the silt loam for the 2-inch and 3-inch aluminum access tubes during the period between February and September 2017. Each calibration was based on the data from three containers located near the PHB, which represented the low, intermediate, and high water content condition, respectively. The vessel for the low water content soil was a 4-foot-diameter, 5-foot-tall stainless steel container packed with well mixed silt loam from a soil pile near the PHB and was covered to prevent any gain or loss of water. The container for the intermediate water content soil was a 4-foot-diameter, 5-foot-deep lysimeters, which was filled with silt loam years earlier and was open to the air. A 2-inch and a 3-inch access tube, about 1 foot apart, were installed vertically near the center of each of these containers. The high water content was achieved in two 200 gallon drums, one of which contained a vertically installed 2-inch aluminum tube and the other a 3-inch tube. The drums initially were filled with saturated silt loam two decades ago at the time the PHB was constructed and was covered. Some water has lost from these drums but the water content was still high.

At the time of neutron probe calibration, after neutron loggings were taken, soil samples were taken from multiple depths from three boreholes around each access tube for water content and bulk density measurements. A sleeve was used to keep the probe assembly in the middle during the calibration in the 3-inch tube. Due to the lack of an appropriate test facility, the neutron probe was not calibrated in a 3-inch aluminum tube in sand. Calibration results will be released once the data qualification has been completed.

3.2 Neutron Logging

In FY17, neutron probe logging was conducted approximately quarterly in the silt loam and annually in the sand below the PHB. The functionality of the neutron probe was verified on each logging day before and after the logging. Note that the neutron probe measures neutron counts and hence the neutron loggings are independent of the calibration relationships. However, the neutron counts cannot be converted into water content if the calibration relationship is not available.

The logging scheme was essentially the same as the past except that 1) the logging was repeated 4 times on each logging day instead of just once as in the past (from FY95 to FY13); and 2) the horizontal neutron loggings were extended to the side slopes so that the edge effect can be revealed more clearly. The logging scheme with 4 repetitions provides an opportunity to identify outliers, which are excluded from further data analysis. Repetitions also provide the opportunity to separate unexpected field processes (e.g., very wet condition at just one location) from accidental observation error.

3.3 Removal of Unused Instruments

The surface and near surface units of the unused instruments at the 14 monitoring stations were removed in FY17. These instruments include mini-lysimeters, heat dissipation units (HDUs), fiberglass blocks (FGBs), time domain reflectometry (TDR) probes, and capacitance probe access tubes. The holes after the removal were filled with the same silt/pea gravel admix from the soil pile outside of PHB. To protect the integrity of the surface barrier and minimize the disturbance of the barrier, the wires for HDUs, FGBs, and the TDR probes were cut off approximately 5 cm below ground surface, while the sensors with the rest of the buried wire were left in the soil. For the segmented TDR probes, only the top-most probe of the three-probe profile was removed in each of the monitoring station; the intermediate and deepest TDR probes (0.6-m long Type K probe of Environmental Sensors, Inc.) were left in the soil. The instruments left for current or potential future monitoring at each of the 12 (i.e., S1 through S12) monitoring stations in the ETC barrier are a neutron access tube and a root observation tube.

Off the barrier surface, the surface units for the pan lysimeter (Figure 2.1) were installed before barrier construction below the AC were removed, while the buried wires, pipes, and pan lysimeter were left in place. The old tipping buckets, pressure transducers, and top portion of the siphon systems installed in the 12 drainage vaults were removed.

3.4 Test of the DTB System in the Field

The DTB system for drainage monitoring was tested in the field. Upon the approval of quality assurance of the procedures, the system will be installed for drainage monitoring.

3.5 Runoff Monitoring System Checkup

The runoff monitoring system was found to be nonfunctional in FY17 because the battery was dead. Additionally, the pipe that guides the runoff to the monitoring station was broken.

4.0 Quality Assurance

The PNNL Quality Assurance (QA) Program is based upon the requirements as defined in the United States Department of Energy (DOE) Order 414.1D, Quality Assurance and 10 CFR 830, Energy/Nuclear Safety Management, Subpart A -- Quality Assurance Requirements. PNNL has chosen to implement the following consensus standards in a graded approach:

- ASME NQA-1-2000, Quality Assurance Requirements for Nuclear Facility Applications, Part 1, Requirements for Quality Assurance Programs for Nuclear Facilities.
- ASME NQA-1-2000, Part II, Subpart 2.7, Quality Assurance Requirements for Computer Software for Nuclear Facility Applications, including problem reporting and corrective action.
- ASME NQA-1-2000, Part IV, Subpart 4.2, Guidance on Graded Application of Quality Assurance (QA) for Nuclear-Related Research and Development.

The procedures necessary to implement the requirements are documented through PNNL's "How Do I…? (HDI), a system for managing the delivery of laboratory-level policies, requirements and procedures.

The *DVZ-AFRI Quality Assurance Plan* (QA-DVZ-AFRI-001) is the minimum applicable QA document for DVZ-AFRI projects under the NQA-1 QA program. This QA Plan also conforms to the QA requirements of DOE Order 414.1D, *Quality Assurance*, and 10 CFR830, Subpart A, *Quality Assurance Requirements*. The DVZ-AFRI is subject to the *Price Anderson Amendments Act* (PAAA).

The implementation of the DVZ-AFRI quality assurance program is graded in accordance with NQA-1-2000, Part IV, Subpart 4.2, *Guidance on Graded Application of Quality Assurance (QA) for Nuclear-Related Research and Development.*

Three technology levels are defined for this DVZ-AFRI QA Program:

Basic Research consists of research tasks that are conducted to acquire and disseminate new scientific knowledge. During basic research, maximum flexibility is desired in order to allow the researcher the necessary latitude to conduct the research.

Applied Research consists of research tasks that acquire data and documentation necessary to assure satisfactory reproducibility of results. The emphasis during this stage of a research task is on achieving adequate documentation and controls necessary to be able to reproduce results.

Development Work consists of research tasks moving toward technology commercialization. These tasks still require a degree of flexibility and there is still a degree of uncertainty that exists in many cases. The role of quality on development work is to make sure that adequate controls to support movement into commercialization exist.

Research and Development Support Activities are those which are conventional and secondary in nature to the advancement of knowledge or development of technology, but allow the primary purpose of the work to be accomplished in a credible manner. An example of a support activity is controlling and maintaining documents and records. The level of quality for these activities is the same as for developmental work.

Within each technology level, the application process for quality assurance controls is graded such that the level of analysis, extent of documentation, and degree of rigor of process control are applied commensurate with their significance, importance to safety, life cycle state of a facility or work, or programmatic mission. The work for this report was performed under the technology level of Development.

5.0 Summary

After a monitoring gap from late FY13 to FY16, the monitoring of the performance of the Prototype Hanford Barrier resumed in FY17. The strategy for the monitoring is to monitor water balance approximately quarterly. The structural and ecological monitoring was scheduled for a future time and at a less frequently rate (approximately once ever several years) because the barrier structure and ecological state are not expected to change substantially in a single year. In FY17, a new neutron probe was calibrated for the silt loam used for constructing the PHB with 2- and 3-inch access tubes and was used in the monitoring. A double-tipping-bucket drainage monitoring system was designed as a replacement of the old system because a fraction of the old system was not functioning normally. The unused instruments at the surface or near surface and supporting accessories were removed from the site. Neutron logging was conducted in the silt loam and in the sand below the asphalt layer. The runoff monitoring system was found to be nonfunctional and in need of repair.

References

10 CFR 830. *Energy/Nuclear Safety Management, Subpart A -- Quality Assurance Requirements, Code of Federal Regulations, as Amended*, Code of Federal Regulations.

ASME NQA-1-2000. *Quality Assurance Requirements for Nuclear Facility Applications*, A.S.O.M. Engineers, New York, New York.

DOE-RL. 2016. *Prototype Hanford Barrier 1994 to 2015*, DOE/RL-2016-37, Rev. 0, U.S. Department of Energy Richland Operations Office. Richland, Washington. Available at http://www.hanford.gov/c.cfm/sgrp/DOE-RL-2016-37/DOE-RL-2016-37_R0.pdf and http://www.hanford.gov/c.cfm/sgrp/DOE-RL-2016-37/Appendices.pdf (Accessed on September 12, 2017).

DOE Order 414.1D. *Quality Assurance*, U.S.D.O. Energy, Washington, D.C.

Zhang ZF. 2015. "Field Soil Water Retention of the Prototype Hanford Barrier and Its Variability with Space and Time," *Vadose Zone Journal*, 14(8):1-10. doi:10.2136/vzj2015.01.0011.

Zhang ZF. 2017a. "Long-Term Drainage from the Riprap Side Slope of a Surface Barrier," *Water*, 8:156-164.

Zhang ZF. 2017b. "Should the Standard Count Be Excluded from Neutron Probe Calibration?," ***Soil Sci. Soc. Am. J.***, (in press).

Zhang ZF, CE Strickland, and SO Link. 2017. "Design and Performance Evaluation of a 1000-Year Evapotranspiration-Capillary Surface Barrier," *Journal of Environmental Management*, 187:31-42.

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