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Section 1 of 2

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SUBSURFACE CONDITIONS DESCRIPTION OF THE C AND A-AX WASTE MANAGEMENT AREA

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ASTM	American Society for Testing and Materials
CRBG	Columbia River Basalt Group
CWP	PUREX Coating Waste
CWP2	PUREX cladding waste
DOE	U.S. Department of Energy
Ecology	Washington State Department of Ecology
EPA	U.S. Environmental Protection Agency
FIR	Field Investigation Report
HDW	Hanford defined waste
IP	intrusion prevention
IS	interim stabilized or isolated
ITS	in-tank solidification
OWW	organic wash waste
PAS	PUREX acidified sludge
PAW	PUREX acid waste
PI	partially interim isolation
PSN	PUREX supernate waste
PSPL	Preliminary Safety Analysis Report
PUREX	Plutonium-Uranium Extraction Plant
Qfg	Quarternary flood gravels
Qfs	Quarternary flood sands
RCRA	Resource conservation and Recovery Act of 1976
REDOX	reduction-oxidation
SST	single-shell tank
TBP	tributyl phosphate
WIDS	Waste Information Data Base System
W MA	Waste Management Area
UPR	unplanned release
UR	Uranium Recovery

1.0 INTRODUCTION

This document, *Subsurface Conditions Description of the C and A-AX Waste Management Areas*, discusses the subsurface conditions relevant to the occurrence and potential migration of contaminants in the groundwater underlying the C, A, and AX Tank Farms. These tank farms, located in the 200 East Area of the Hanford Site, make up the C and A-AX Waste Management Areas (WMAs). This document describes the available environmental contamination data and contains a limited, qualitative interpretation of the data as they apply to contaminant behavior.

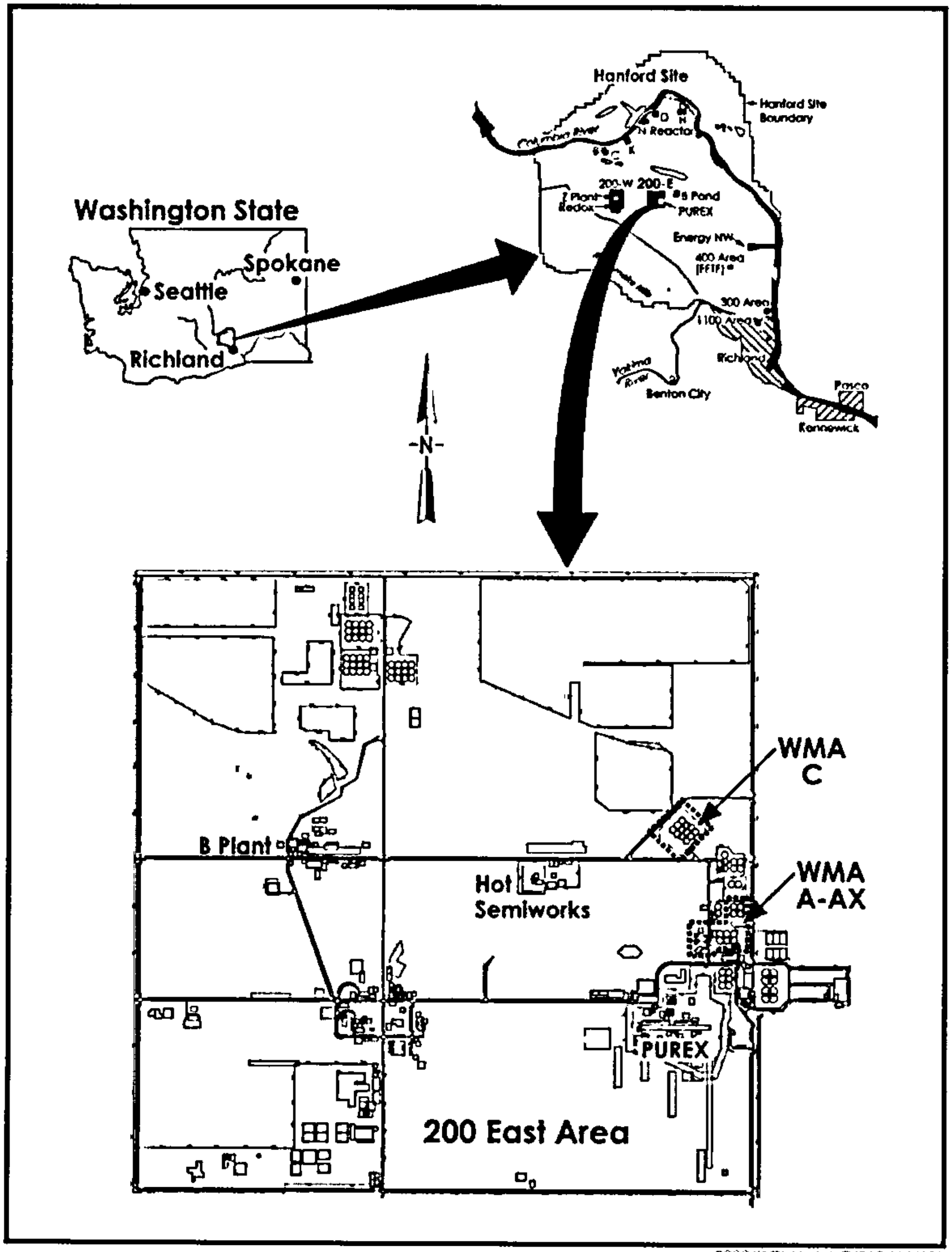
1.1 BACKGROUND

Figure 1-1 shows the locations of the C and A-AX WMAs, and some other facilities in the 200 East Area. To facilitate *Resource Conservation and Recovery Act of 1976* (RCRA) groundwater monitoring programs, the A and AX Tank Farms were grouped into one WMA. Figures 1-2 and 1-3 provide more detail on the C and A-AX WMAs, respectively. Surrounding area facilities are also shown. In Figure 1-2 (C tank farm), other auxiliary tank farm structures are shown including the 244-CR vault, the C-301 catch tank and four small processing tanks, C-201 through C-204. In Figure 1-3 (A and AX Tank Farms), auxiliary structures (244-AR vault, A-350 Catch tank) and nearby liquid discharge facilities (cribs, trenches, retention basins and french drains) are shown.

Evaluation of vadose zone contamination under C and A-AX Tank Farms by tank waste is being evaluated as an extension of similar activities that have been completed for several other single shell tank farm WMAs including S-SX, B-BX-BY, T, and TX-TY WMAs. Subsurface Conditions Description Reports (SCDR) have been issued for these WMAs: *Subsurface Physical Conditions Description of the S-SX Waste Management Area* (Johnson et al. 1999), *Subsurface Conditions Description of the B-BX-BY Waste Management Area* (Wood et al. 2000), and *Subsurface Conditions Description of the T and TX-TY Waste management Areas* (Wood et al. 2001). The previous investigations were initiated because the source of some nearby groundwater contamination was attributed to a tank waste source in the vadose zone underlying these WMAs. Consequently, the Washington State Department of Ecology (Ecology), the U.S. Environmental Protection Agency (EPA) and the U.S. Department of Energy (DOE) negotiated the *Hanford Federal Facility Agreement and Consent Order* (Tri-Party Agreement) *Change Control Form, Form No. Draft M-45-98-03* (Ecology et al. 1999). The proposed Tri-Party Agreement milestones mandated a series of activities addressing these WMAs. The goal of the activities was to determine the need for corrective action to mitigate the impact of contamination from single-shell tanks (SST) on the surrounding environment.

The C and A-AX WMAs were not included in this action because there has been no indication that vadose contamination in these WMAs is a source of current nearby groundwater contamination. However, it has become clear from previous investigations that if vadose zone contamination is present under a WMA, future groundwater contamination from these sources is plausible. In order to complete remediation of these WMAs and achieve final closure of the facility, the potential environmental impacts of these sources must be evaluated. Information generated by these and future characterization activities will support waste management decisions for SST waste retrieval, and SST closure.

Figure 1–1. Location Map of the C and A-AX Waste Management Areas and Related Facilities.



2002/DCL/A-AX-C/013 (06/10)

Figure 1–2. Location Map of the C WMA (C Tank Farm and Surrounding Facilities).

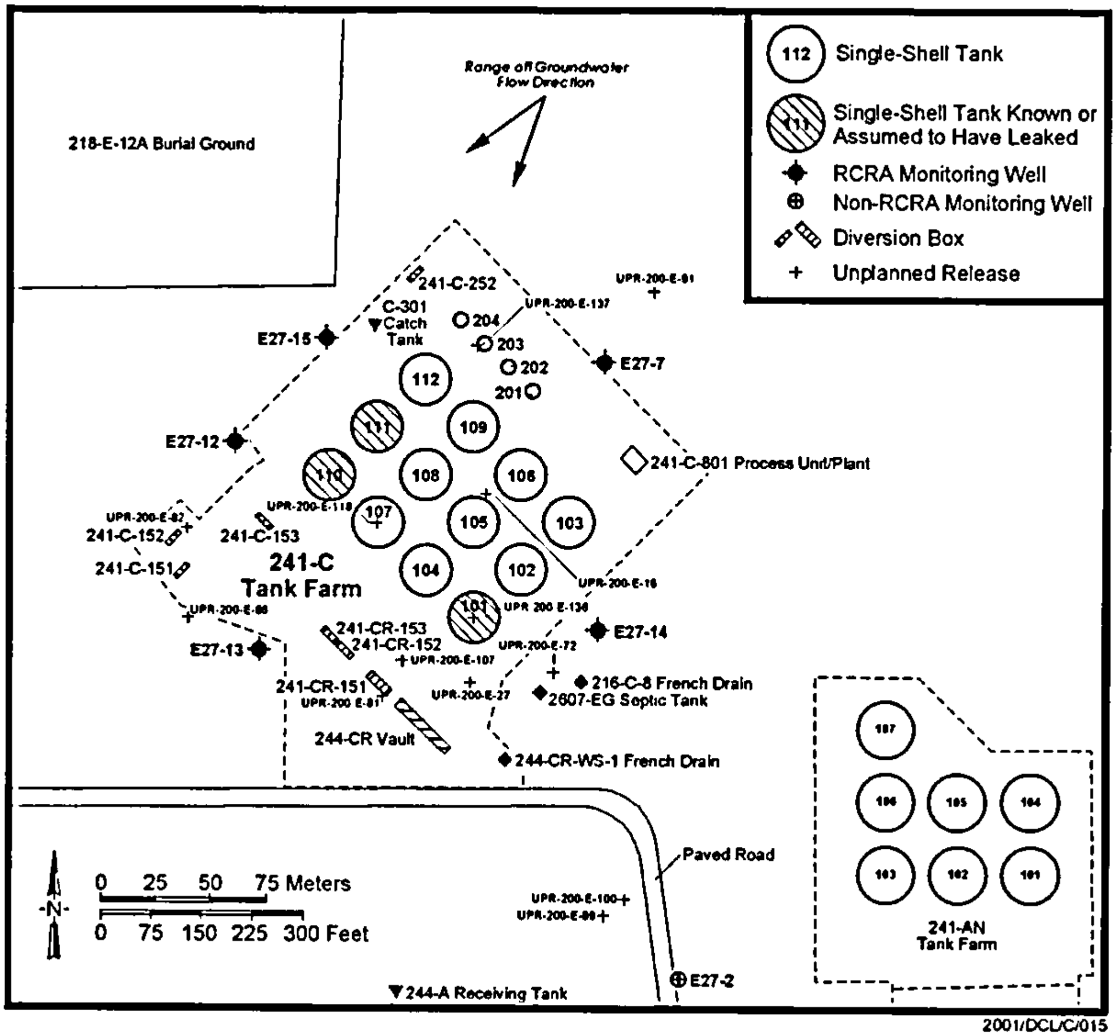
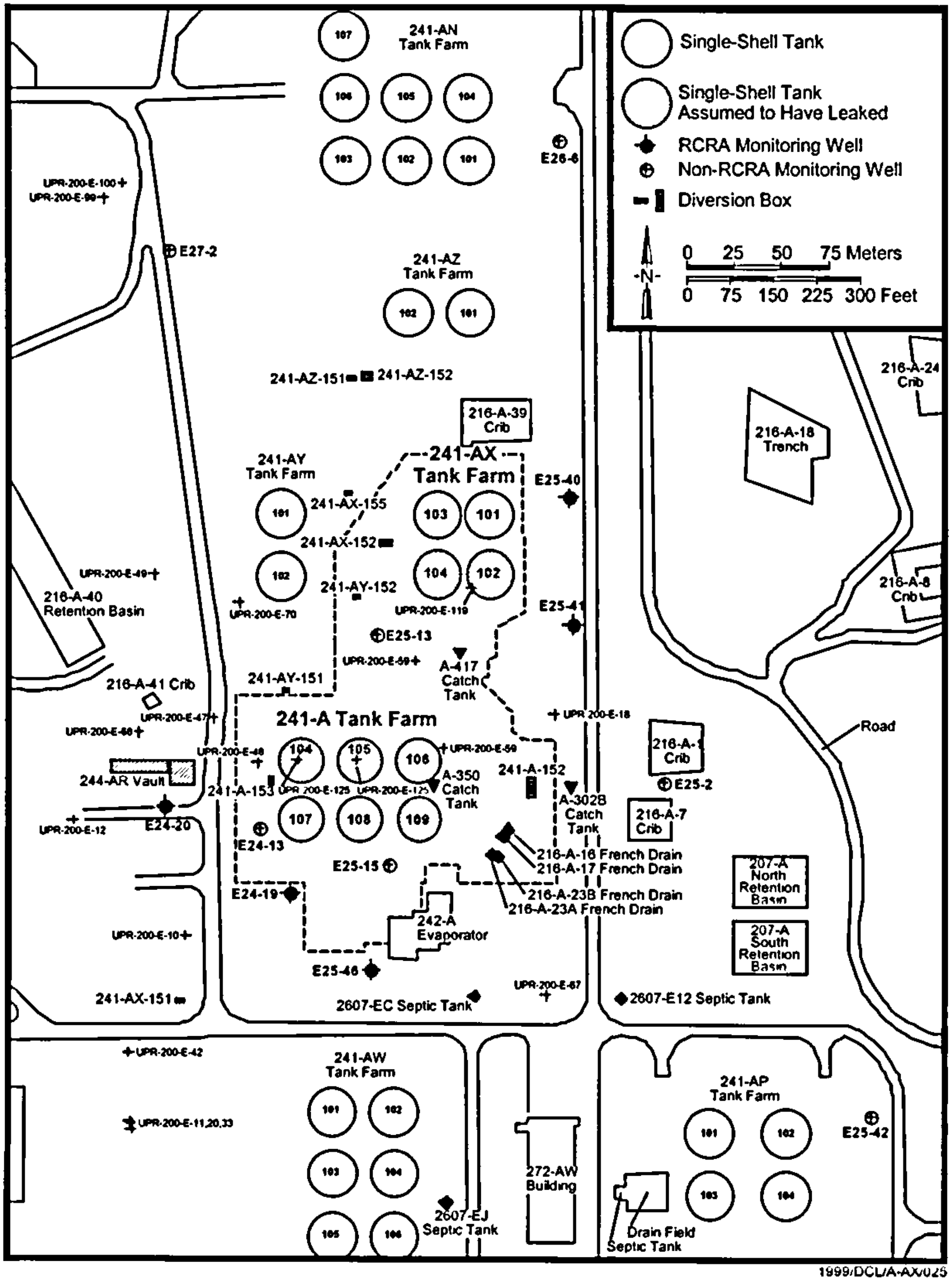


Figure 1–3. Location Map of the A-AX WMA (A and AX Tank Farms and Surrounding Facilities).



1.2 PURPOSE

Within the context of the characterization and evaluation program, this document fulfills several purposes. To aid in selecting a characterization approach, this document is focused on site-specific data that define the occurrence and migration of contaminants within the system to date. This document includes a concise description and limited interpretation of these critical data. A systematic description of the environmental conditions affecting contaminant migration still is needed to identify data gaps, recognize significant relationships among different data types, and organize data inputs to contaminant migration models. This document provides a framework for completing a systematic description as more data are collected, interpreted, and integrated with currently available information. This document supports the creation of a work plan addendum to the *Phase I RCRA Facility Investigation/Corrective Measures Study Work Plan for Single-Shell Tank Waste Management Areas* (DOE/RL-99-36 1999).

1.3 SCOPE

The first part of this document describes the two primary components of the subsurface condition database: the physical setting of the C and A-AX WMAs and the contaminants contained within the WMAs. Chapter 2 describes the physical setting, which includes the tank farm infrastructure, geology, hydrology and infiltration mechanisms, and geochemistry. The tank farm infrastructure description emphasizes those parts of the system that allowed fluids to discharge into the soil column and the periods during which these parts were operational. The geology description emphasizes the impact of the geologic strata on fluid movement. The hydrology and infiltration discussion emphasizes infiltration mechanisms, infiltration history, and hydrologic properties of the geologic strata that control fluid movement. The geochemistry section emphasizes the characteristics that control contaminant movement, particularly in relation to fluids.

The second component of the subsurface characterization database is the description of contaminant occurrences and movement within the vadose zone. This is presented in Chapter 3. First, contamination events are summarized to orient the reader to the historical sequence. Second, the synthesis of the historical and spectral gamma database for the C, A and AX Tank Farms is summarized. These data are unique because of their extent, both temporally and spatially. The overview demonstrates the observed spatial variability of contaminant concentration and provides the most comprehensive indication of the diversity among various contaminating events. Distinct sources or similar types of sources within the vadose zone of the WMAs organize the remainder of the discussion in Chapter 3. The key data in this discussion include tank waste inventory and chemistry information derived from process history, the corroborating gamma data, and soil sample data where available.

Chapter 4 contains a brief qualitative integration of the data and relates the data to a conceptualization of the contamination events. Because the events are diverse, database interpretations are given for each specific contaminating occurrence or type of occurrence.

Key uncertainties and data gaps that are important to understanding potential future contamination of the unconfined aquifer are identified in Chapter 5. Chapter 5 also provides recommendations for resolving these uncertainties.

Six appendices also are provided. Appendix A contains the text of the C and A-AX WMA historical summary document *Historical Vadose Zone Contamination from A, AX, and C Tank Farm Operations* (Williams 2001). Appendix B provides additional tank infrastructure, operating history information and unplanned releases descriptions. Appendix C provides supporting geologic data. Appendix D provides supporting hydrologic data. Appendix D summarizes the analyses of spectral gamma logging data. Appendix E summarizes the analyses of gross gamma logging data. Appendix F summarizes field characterization work completed for two unplanned releases of tank waste from transfer lines in the southwest part of the C WMA.

2.0 PHYSICAL SETTING

2.1 C AND A-AX WMA INFRASTRUCTURE AND OPERATIONS HISTORY

This section discusses the infrastructure and briefly summarizes the C, A and AX Tank Farm operations history, including the use of ancillary equipment and nearby cribs, trenches and wells. A more detailed historical review is provided in Williams (2001), which is provided as Appendix A. This section identifies the infrastructure elements known or suspected to have discharged fluids to the vadose zone, along with elements that remain capable of future discharges.

2.1.1 C and A-AX WMA Infrastructure

The three tank farms, C, A and AX are divided into two WMAs, with the C Tank Farm in one and the A and AX Tank Farms in the other. Within the C Tank Farm, the primary structures through which tank waste was stored, transported and discharge are the 12 primary tanks (C-101 through C-112) and four secondary tanks (C-201 through C-204). The primary tanks are 23 m (75 ft) in diameter and 4.9 m (16 ft) deep with a capacity of 2 million liters (530,000 gal). Each ancillary tank is 6.1 m (20 ft) in diameter and 11 m (37 ft) deep with a capacity of 0.2 million liters (55,000 gal). Primary and secondary tank configurations and dimensions are provided in Appendix B, Figures B-1 and B-2. The 12 primary tanks were divided into 4 sets of 3 tanks each (e.g., tanks C-101, C-102, and C-103) with cascade lines attaching set so that waste would flow from southwest to northeast by gravity feed. The C Tank Farm also contains an assortment of ancillary equipment used to move tank waste during operations. These include seven diversion boxes, the 244-CR process vault and numerous waste transfer lines (see Figure 1-2).

Within the A-AX WMA, the primary structures are two tank farms containing a total of 10 tanks (tanks A-101 through A-106 and tanks AX-101 through AX-104). Each tank is 23 m (75 ft) in diameter and 9.1 m (30 ft) deep with a capacity of 3.8 million liters (1 million gal). Tank configurations and dimensions are provided in Appendix B, Figure B-3. The tanks were connected by overflow lines but did not cascade. The A Tank Farm was underlain by laterals connected to caissons as a leak detection system because the tank farm was designed to store boiling waste. The AX tanks included a grid of drain slots beneath the shell liner bottom and a leak detection well that could collect potential leakage. Ancillary equipment included diversion boxes and catch tanks inside the WMA and the 244-AR vault just west of A Tank Farm. Outside the A and AX Tank Farms are several liquid discharge facilities: retention basin 216-A-40 west of AX Tank Farm, crib 216-A-39 north of AX Tank Farm, crib 216-A-38 east of AX Tank Farm, crib 216-A-41 west of A Tank Farm, and cribs (216-A-1 and 216-A-7) and retention basins (207-A North and South) east of A Tank Farm (see Figure 1-3).

2.1.2 Operations History

The C, A and AX Tank Farm complexes received waste generated by essentially all of the major chemical processing operations that occurred at Hanford including bismuth phosphate fuel processing, uranium recovery, Plutonium-Uranium Extraction Plant (PUREX) fuel processing, fission product recovery and tank farm interim stabilization and isolation activities. Only C Tank Farm was operational during the bismuth phosphate and uranium recovery processes.

2.1.2.1 Bismuth Phosphate and Uranium Recovery Operations. The C Tank Farm was constructed between 1943 and 1944 and first received metal waste and first cycle waste from B Plant beginning in 1946. Ultimately, tanks C-101 through C-106 received metal waste and tanks C-107 through C-112 received first cycle waste. All tanks were filled with bismuth phosphate waste by the end of 1948. The 200 series tanks also received metal waste. To free up tank space, in 1952 first cycle waste was transferred to the 242-B evaporator. Metal waste was also removed from C Tank Farm beginning in 1952 and transferred to U plant for uranium recovery. Ancillary equipment involved in the metal waste transfer included the 244-CR vault and diversion boxes 241-CR-151, -152 and –153. Subsequently, tributyl phosphate (TBP) waste, a byproduct of the uranium recovery process, was returned to C Tank Farm. The 244-CR vault was modified in 1955 to scavenge TBP waste (that is, to separate cesium-137 from the supernate by precipitation) that was present in tanks C-107 through C-112. The scavenged slurry was redeposited in tanks C-109 and C-112 to settle and the resultant supernate was discharged to the BC cribs.

2.1.2.2 PUREX Processing Operations. The A Tank Farm was constructed in 1955 to support the PUREX processing plant operations, which ultimately produced the greatest amount of plutonium during Hanford processing history. The PUREX process produced three major waste streams, PUREX Coating Waste (CWP), PUREX acid waste (PAW) which contained about 99% of the fission products, and organic wash waste (OWW). These wastes were neutralized, as needed, and stored in the C and A Tank Farms at various times. Beginning in 1956, neutralized PAW and OWW were sent to A Tank Farm and CWP was sent to C Tank Farm. Beginning in 1957 CWP in C Tank Farm was routed to the B-BX-BY Tank Farms. AX Tank Farm was constructed in 1963 and received PAW from 1965 through 1969. From 1962 until 1969 tank C-102 was designated as the receiver tank for CWP and all CWP from PUREX was sent there and in 1968, OWW was separated from PAW and also sent to tank C-102. The CWP and OWW wastes were routed to the in-tank solidification operations in the BY Tank Farm.

Both intentional and unintentional discharges to ground occurred during this time period. Tank condensate and cooling water were deliberately discharged to several cribs, ditches, french drains and ponds beginning in 1956. Several liquid discharge facilities received enough waste to reach their radiological capacity, released contaminants to groundwater and were decommissioned. Crib 216-A-8 was abandoned in 1958 but then reused from 1966 to 1976 when crib 216-A-24 reached its capacity and was abandoned in 1966. Crib 216-A-5 and ditch 216-A-10 received process condensate from 1956 until 1961 and from 1961 to 1978, respectively before groundwater contamination forced their abandonment.

Several unintentional PUREX waste releases to the environment occurred during this time period. In 1969, CWP leaked from a transfer line (V051) near diversion box 241-CR-151 to which it was connected. CWP also leaked from a transfer line between tanks C-105 and C-108 some time between 1956 and 1959. An estimated 190 L (50 gal) was lost. In early 1965, a violent steam discharge event occurred in tank A-105. A 30-minute steam release was associated with this event. The initial assessment was that up to 10 to 12 thousand gallons of waste might have been lost during the event. Subsequent investigation showed a bulge in the tank liner bottom providing an estimate void volume between the liner and the concrete shell of 19,000 to 57,000 L. Additional leakage was noted in 1967 (UPR-200-E-126).

2.1.2.3 Isotope Recovery Programs. By the late 1950s, it was clear that a number of SSTs had likely leaked and the long-term storage of large volumes of liquid radioactive wastes was untenable. Hanford Site contractors were directed to convert liquid radioactive waste to saltcake as soon as practicable. Conversion of the supernatant to saltcake required removal of much of the Cs-137 and Sr-90. As treatment processes were developed and implemented, PUREX waste streams depleted in strontium-90 and Cs-137 were stored at various times in some C farm tanks. Strontium-90 depleted PAW was stored in tanks C-107 through C-109 after Strontium Semiworks startup in 1961. In 1963, PUREX supernate waste (PSN) previously stored in tank C-103 was transferred to 241-C-801 facility for cesium-137 removal and subsequently returned to tank C-102. Eventually, this waste and commingled CWP in tank C-102 was transferred to BY Tank Farm. From 1963 to 1967 strontium-90 recovery processes were being developed at B Plant and the depleted wastes were stored in C Tank Farm and in tank AX-101.

The conversion of high-fission product radioactive waste supernatants into saltcake required both a 3 to 5 year cooling-off period to allow short-lived radionuclides to decay (thus, the need for boiling waste tanks in the S, SX, A, and AX Tank Farms) and removal of a significant amount of the longer-lived heat-generating radionuclides such as strontium-90 and cesium-137. In 1967, B Plant was reactivated to support an isotope recovery program. Beginning in 1967, PUREX current acid wastes were processed through B Plant for cesium-137 and strontium-90 recovery, prior to the 3 to 5 year cooling-off period. Aged PUREX supernatants and sludges were recovered from the tanks and processed through the B Plant for strontium-90 and cesium-137 recovery. The aged reduction-oxidation (REDOX) supernatants were transferred to 200 East Area tanks and processed through B Plant for cesium-137 recovery. Tank C-105 was the receiver tank for all supernatants going to B Plant for Cs-137 recovery. After cesium-137 removal, REDOX supernatants were transferred back to the 200 West Area for saltcake production in the T and S Evaporators.

After the cesium-137 was removed (or at least greatly reduced) in the aged PUREX supernatants, the wastes were transferred to various tanks in the B/BX/BY and C farms, leading to conversion of supernatants into saltcake using the BY farm in-tank solidification (ITS) process. In the ITS process, heater units were installed in three tanks in the BY Tank Farm. Waste supernatants were rotated through the ITS process tanks and out to the B-BX-BY tanks so as to produce saltcake. The available tank space in the B-BX-BY farms was filled with saltcake using the BY ITS process.

By 1967, all cesium-137 and strontium-90 removal from PSN was being done at B Plant and the primary transfer sequence was initial storage of PSN in AX Tank Farm followed by transfer through tank C-105. In the late 1960s, OWW was combined with CWP and stored in tank C-102 and subsequently transferred to BX Tank Farm for interim tank stabilization. PUREX sludges were also sluiced from A Farm tanks (A-101 in 1968, A-104 in 1969 and A-106 in 1970) and transferred to 244-AR vault for acidification, then to 244-CR vault as PUREX acidified sludge (PAS) and B Plant. Depleted wastes from B Plant were returned to AX Tank Farm for storage. This cycle ran until 1978 when the last of the PUREX waste in A and AX Tank Farm had been treated. Tanks deemed to be sound in C, A and AX Tank Farms (primarily tanks A-103, C-103 and C-104) stored all variety of wastes not segregated by waste type.

Intentional discharges during the waste fractionation period included slightly contaminated fluids from the 244-AR vault to crib 216-A-41 (1968 to 1974) and uncontaminated cooling water to Gable Mountain Pond. Unintentional releases included PSN losses from transfer lines V122 near diversion box 241-C-152 in 1970 (UPR-200-E-82) and line 812 near diversion box 241-C-151 in 1971 (UPR-200-E-86). In AX Tank Farm, three small releases occurred surface contamination around diversion box 241-AX-151 in 1972, (UPR-200-E-42), a pump pit leak at 241 AX-103 in 1974 (UPR-200-E-115), and a small spill created at 241-AX-104 in 1969 created by cable movement (UPR-200-E-119).

In the mid 1970s, a decision was made put all the single shell tanks out of service. At C, A and AX Tank Farms, saltwell jet pumping was employed to remove much of the liquid waste present in the tanks. Tanks C-103 and A-102 were designated as the receiver tanks for C farm and A-AX Tank Farms, respectively and pumping began in 1976. Currently, the majority of liquid wastes have been removed from these tanks. The most recent sluicing event occurred at tank C-106 in 1999.

2.2 GEOLOGY

This section summarizes the geologic setting and presents an updated conceptual geohydrologic model of the area in the vicinity of A-AX and C Waste Management Areas (WMAs), located in the east-central portion of Hanford's 200 East Area. This analysis is based on a total of 49 boreholes (Table 2-1) located within 1000 ft (300 m) of A-AX and C WMAs (Figure 2-1) and contains an update of previous geologic descriptions given for these areas (Caggiano and Goodwin 1991; Williams et al. 2000; Narbutovskih and Horton 2001; and Horton and Narbutovskih 2001). The resulting conceptual model was compared to regional studies to assure coherence within the larger framework of stratigraphic interpretations. The information in this section provides the framework for subsequent consideration of stratigraphic and structural controls on moisture and waste movement through the vadose zone to groundwater.

Figure 2-1. Well/Borehole Location Map.

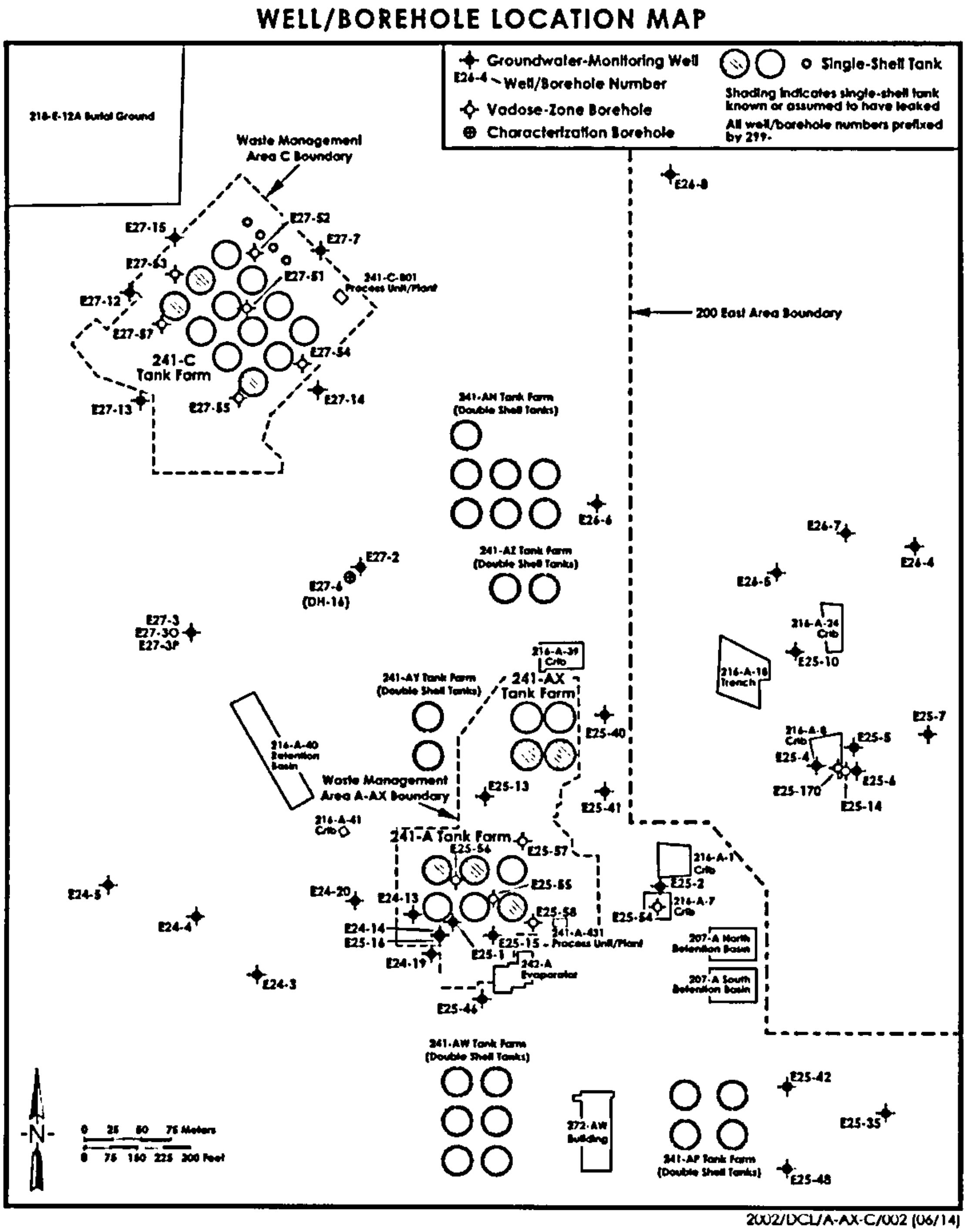


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Table 2-1. Descriptive Characteristics of Boreholes within 1000 ft of the C and A-AX WMAs. (3 sheets)

Borehole Name	Borehole ID	Quality Rating[1]	Included on Cross Section	Associated Facility	Drill Method[2]	Easting (m)	Northing (m)	Source	Casing Stick Up (ft ags)	Ground-Surface Elevation (ft)	Reference Point	Well Survey	Total Depth (ft)	Year Drilled	Open Interval (ft bgs)	Depth to Water (ft bgs)	Date of Water-Level Measurement	Lithologic Log[3]	Geophysical Log[4]	Moisture Data (Depth Interval in ft)	Particle-Size Distribution (Depth Interval in ft)	Calcium Carbonate (Depth Interval in ft)	Purpose of Borehole	Comments
299-E24-03	A5897	3		A Tank Farm	HT	575165.15	135983.20	USACE(JFCA)	1.67	700.35[b]	Top of Casing	NAVD88	333.0	1956	Perforated 0-135, 277-331			D	G, N, D		5-330	5-330	Groundwater well	
299-E24-04	A5898	3	B-B'	A Tank Farm	HT	575112.42	136035.20	USACE(JFCA)	1.43	700.38[b]	Top of Casing	NAVD88	330.0	1956	Perforated 0-135, 272-298	297.20	August-98	D	G, N, D, T		5-305	5-305	Groundwater well	
299-E24-05	A5899	3	B-B'	A Tank Farm	HT	575037.90	136063.46	USACE(JFCA)	1.76	698.55	Ground Surface	NAVD88	329.0	1956	Perforated 0-135, 274-327	298.20	April-02	D	G, N, D, T		5-329	5-329	Groundwater well	
299-E24-13	A4749	4	B-B'	A Tank Farm	HT	575300.61	136037.32	USACE(JFCA)	4.00	694.36	Brass Cap	NAVD88	340.0	1969	Perforated 0-20, 90-260, 270-338	289.10	July-93	D			5-340	5-340	Groundwater well	
299-E24-14	A4750	4		A Tank Farm	DB/HT	575323.85	136018.81	KEH	0.40	694.65	Brass Cap	Converted to NAVD88 from NGVD29	343.0	1969	Perforated 270-318	289.30	July-93	D			15-300		Groundwater well	
299-E24-19	A4754	2		A Tank Farm	DB/HT	575316.95	136003.51	USACE(JFCA)	2.80	694.44	Brass Cap	NAVD88	303.0	1989	Well screen 279.6-300.7	295.80	March-02	G	G	5 - 265			Groundwater well	
299-E24-20	A4756	3	B-B'	A Tank Farm	DB/HT	575251.10	136049.40	KEH	3.44	689.37	Brass Cap	Converted to NAVD88 from NGVD29	304.0	1991	Well screen 279.2-299.7	291.10	March-02	G	G	5 - 25, 265 - 290			Groundwater well	
299-E25-01	A4759	3	A-A'	A Tank Farm	HT	575336.03	136030.88	USACE(JFCA)	0.33	693.80	Brass Cap	NAVD88	322.0	1955	Perforated 0-20, 90-270	288.50	July-93	D	G		30-322	30-322	Groundwater well	
299-E25-02	A4766	3	E-E'	A Tank Farm	HT	575513.76	136061.87	USACE(JFCA)	2.00	677.02[b]	Top of Casing	NAVD88	375.0	1955	Perforated 0-235, 276-316	277.70	March-02	D	G, T, N, D		5-360	5-330	Groundwater well	
299-E25-04	A4788	5		216-A-8 Crib	HT?	575648.83	136169.12	USACE(JFCA)	2.42	662.71[b]	Top of Casing	NAVD88	289.0	1956	Perforated 239-281	258.80	June-93	D	SG, G, T, N, D				Groundwater well	Two contradictory driller's logs
299-E25-05	A6025	4		216-A-8 Crib	HT?	575681.24	136184.94	USACE(JFCA)		661.5[a]	Top of Casing	NAVD88	293.0	1956	Perforated 235-291			D	G, N, D				Groundwater well	
299-E25-06	A4796	3	B-B'	216-A-8 Crib	HT	575683.76	136163.97	USACE(JFCA)	2.42	662.33	Brass Cap	NAVD88	290.0	1956	Perforated 234-288	264.40	April-02	D	SG, G, N, D		5-290	5-290	Groundwater well	
299-E25-07	A6026	4	B-B'	AN Tank Farm	HT	575745.61	136197.87	USACE(JFCA)	2.50	660.38[b]	Top of Casing	NAVD88	290.0	1956	Perforated 235-290			D	G, N, D				Groundwater well	
299-E25-10	A4760	2		A-29 Ditch	HT	575630.06	136267.59	USACE(JFCA)	1.90	657.73	Brass Cap	NAVD88	293.0	1958	Perforated 226-291	254.90	June-96	D	SP, N, G, T				Groundwater well	
299-E25-13	A4762	3		AX Tank Farm	DB/HT	575362.87	136140.43	USACE(JFCA)	0.33	685.66[b]	Top of Casing	NAVD88	317.0	1963	Perforated 0-20, 90-236, 256-315	280.30	July-93	D			5-305	5-305	Groundwater well	
299-E25-14	A6029	4			DB/HT	575673.69	136164.47	299E_local		681.52	Top of Casing	Converted to NAVD88 from NGVD29	208.0	1966				D	G, N, D				Vadose-zone monitoring	
299-E25-15	A4763	4		A Tank Farm	DB/HT	575368.82	136018.65	USACE(JFCA)	0.43	692.55[b]	Top of Casing	NAVD88	340.0	1969	Perforated 0-20, 90-260, 270-338	287.70	June-93	D			5-300		Groundwater well	
299-E25-16	A6030	5		A Tank Farm	CT	575323.66	136018.54	USACE(JFCA)	4.00	694.51	Brass Cap	NAVD88	340.0	1969	Perforated 270-338			D					Groundwater well	
299-E25-35	A4783	3	A-A'	Grout	DB/HT	575708.34	135864.69	USACE(JFCA)	3.38	674.57	Brass Cap	NAVD88	285.0	1988	Well screen: 260-281			G	G, N, D				Groundwater well	
299-E25-40	A4789	2		AX Tank Farm	DB	575464.68	136212.32	USACE(JFCA)	3.22	666.40	Brass Cap	NAVD88	274.0	1989	Well screen: 252-273	276.50	March-02	G	G	5 - 270			Groundwater well	
299-E25-41	A4790	2	B-B'; E-E'	AX Tank Farm	DB/HT	575466.06	136145.93	USACE(JFCA)	3.15	671.72	Brass Cap	NAVD88	279.0	1989	Well screen: 255.3-276.3	267.80	March-02	G	G	5 - 220			Groundwater well	
299-E25-42	A4791	3	A-A'; E-E'	AP Tank Farm	DB/HT	575622.80	135887.60	KEH	3.58	679.74	Brass Cap	NAVD88	294.7	1991	Well screen 267.6-288.9	273.30	March-02	G	G				Groundwater well	
299-E25-46	A4793	2	A-A'	A Tank Farm	DB	575359.73	135963.50	USACE(JFCA)	3.01	695.16	Brass Cap	NAVD88	310.3	1992	Well screen 286.0-306.3			G	G	5 - 300			Groundwater well	

Table 2-1. Descriptive Characteristics of Boreholes within 1000 ft of the C and A-AX WMAs. (3 sheets)

Borehole Name	Borehole ID	Quality Rating[1]	Included on Cross Section	Associated Facility	Drill Method[2]	Easting (m)	Northing (m)	Source	Casing Stick Up (ft ags)	Ground-Surface Elevation (ft)	Reference Point	Well Survey	Total Depth (ft)	Year Drilled	Open Interval (ft bgs)	Depth to Water (ft bgs)	Date of Water-Level Measurement	Lithologic Log[3]	Geophysical Log[4]	Moisture Data (Depth Interval in ft)	Particle-Size Distribution (Depth Interval in ft)	Calcium Carbonate (Depth Interval in ft)	Purpose of Borehole	Comments
299-E25-48	A4795	4	E-E'	Grout Treatment Facility	AR/DB	575623.85	135815.69	USACE(JFCA)	2.64	683.05	Brass Cap	NAVD88	287.5	1992	Well screen 274.3-294.6	296.60	March-02	G	SG, Mag				Groundwater well	
299-E25-54	A6043	3		216-A-7 Crib	CT	575512.44	136043.48	USACE(JFCA)	1.33	679.31[b]	Top of Casing	NAVD88	150.0	1955		284.00	March-02	D	SG, N, G				Vadose-zone monitoring	
299-E25-55	A6044	3		A Tank Farm	CT	575369.18	136050.83	USACE(JFCA)		692.14	Brass Cap	NAVD88	151.0	1955				D	G				Vadose-zone monitoring	
299-E25-56	A6045	4		A Tank Farm	CT	575337.65	136066.77	USACE(JFCA)		689.9[a]	Top of Casing	NAVD88	151.0	1955				D	G				Vadose-zone monitoring	
299-E25-57	A6046	3	B-B'	A Tank Farm	CT	575394.96	136101.62	USACE(JFCA)		688.7[a]	Top of Casing	NAVD88	150.0	1955				D	G				Vadose-zone monitoring	
299-E25-58	A6047	3		A Tank Farm	CT	575402.68	136029.42	USACE(JFCA)		691.17	Brass Cap	NAVD88	151.0	1958				D	G				Vadose-zone monitoring	
299-E25-170	A6585	5		A Tank Farm	CT	575667.76	136166.57	USACE(JFCA)					204.0	1966				NA					Vadose-zone monitoring	
299-E26-04	A4804	3	C-C'	216-A-24 Crib	HT	575733.96	136360.88	USACE(JFCA)	2.05	649.50	Brass Cap	NAVD88	283.0	1958	Perforated 225-281	250.20	March-02	D	SG		5-283	5-283	Groundwater well	
299-E26-05	A6641	4	C-C'	216-A-24 Crib	HT	575614.42	136337.77	USACE(JFCA)		651.70	Brass Cap	NAVD88	292.5	1958	Perforated 237-273, 277-290.5	243.50	June-88	D	SG, G, N, D		5-290	5-290	Groundwater well	
299-E26-06	A6642	4	C-C'	AN Tank Farm	HT	575459.84	136397.86	USACE(JFCA)		653.5[a]	Top of Casing	NAVD88	290.0	1960	Perforated 250-290			D			5-290	5-290	Groundwater well	
299-E26-07	A6643	4		216-A-24 Crib	DB/HT	575673.17	136373.30	CONVERTED					245.0	1965	None documented			D	G, N, D				Groundwater well?	
299-E26-08	A4805	3	D-D'	216-B-3-3 Ditch	HT/AR	575522.23	136687.23	USACE(JFCA)	2.70	620.79	Brass Cap	NAVD88	400.0	1982	Well screen. 326-396	222.00	March-02	D	SG, G, T, D, Mag, SP&R, Sonic, Cal				Groundwater well	Monitors Rattlesnake Ridge Interbed
299-E27-02	A6670	4		AN Tank Farm	HT	575254.18	136341.95	CONVERTED		666.30		Reported in as-built	312.0	1948	Perforated 262-313			D, G					Groundwater well	
299-E27-03	A6671	3	C-C'	North of PUREX	HT	575108.94	136284.23	USACE(JFCA)	1.40	684.54	Ground Surface	NAVD88	360.0	1958	Perforated 265-348			D	G, T, N		5-360	5-360	Groundwater well	
299-E27-06	A6673	2	A-A', C-C', E-E'	North of PUREX	DB/DC	575245.07	136332.48	CONVERTED		670.00	Ground Surface	Asbuilt	353.0	1977	Perforated 0-20			D			5-290	5-290	Ringold Characterization	Same as DH-16
299-E27-07	A4816	5		C Tank Farm	HT	575220.59	136619.40	USACE(JFCA)	0.50	636.93	Brass Cap	NAVD88	281.0	1982	Well screen 241-281	237.10	March-02	D					Groundwater well	
299-E27-12	A4810	2		C Tank Farm	DB	575054.14	136583.53	USACE(JFCA)	3.40	661.26	Brass Cap	NAVD88	270.0	1989	Well screen. 246.5-267.6	263.10	March-02	G	G	5 - 258			Groundwater well	
299-E27-13	A4811	2	D-D'	C Tank Farm	DB/HT	575064.92	136489.23	USACE(JFCA)	2.70	669.61	Brass Cap	NAVD88	275.6	1989	Well screen 253.6-274.7	270.90	March-02	G	G	5 - 240			Groundwater well	
299-E27-14	A4812	2	A-A', D-D'	C Tank Farm	DB/HT	575217.34	136498.24	USACE(JFCA)	3.00	658.95	Brass Cap	NAVD88	266.8	1989	Well screen. 245.8-266.8	260.50	March-02	G	G	5 - 240			Groundwater well	
299-E27-15	A4813	2	A-A'	C Tank Farm	DB/HT	575095.26	136630.36	USACE(JFCA)	2.83	653.45	Brass Cap	NAVD88	262.5	1989	Well screen 238-259	255.20	March-02	G	G	5 - 245			Groundwater well	

Table 2-1. Descriptive Characteristics of Boreholes within 1000 ft of the C and A-AX WMAs. (3 sheets)

Borehole Name	Borehole ID	Quality Rating[1]	Included on Cross Section	Associated Facility	Drill Method[2]	Easting (m)	Northing (m)	Source	Casing Stick Up (ft ags)	Ground-Surface Elevation (ft)	Reference Point	Well Survey	Total Depth (ft)	Year Drilled	Open Interval (ft bgs)	Depth to Water (ft bgs)	Date of Water-Level Measurement	Lithologic Log[3]	Geophysical Log[4]	Moisture Data (Depth Interval in ft)	Particle-Size Distribution (Depth Interval in ft)	Calcium Carbonate (Depth Interval in ft)	Purpose of Borehole	Comments
299-E27-51	A6676	4	A-A'	C Tank Farm	CT	575155.58	136568.87	USACE(JFCA)		647.5[a]	Top of Casing	NAVD88	150.0	1944	Perforated 48-148			D	G				Vadose-zone monitoring	
299-E27-52	A6677	4		C Tank Farm	CT	575162.73	136618.71	USACE(JFCA)		646.7[a]	Top of Casing	NAVD88	150.0	1944	Perforated 48-148			D	G				Vadose-zone monitoring	
299-E27-53	A6678	5		C Tank Farm	CT	575093.53	136598.34	USACE(JFCA)					150.0	1944	Perforated 48-148			D					Vadose-zone monitoring	
299-E27-54	A6679	4		C Tank Farm	CT	575204.73	136519.90	USACE(JFCA)					155.0	1944	Perforated 54-154			D	G				Vadose-zone monitoring	
299-E27-55	A6680	4		C Tank Farm	CT	575148.53	136491.34	USACE(JFCA)					154.0	1944	Perforated 53-153			D	G				Vadose-zone monitoring	
299-E27-57	A6682	5		C Tank Farm	CT	575083.31	136555.50	USACE(JFCA)					150.0	1944	Perforated 51-151			D	G				Vadose-zone monitoring	

[1] 1 = best, 5 = worst

[2] CT = cable tool, HT = hard tool, DB = drive barrel, AR = air rotary, DC = diamond core

[3] D = driller's log, G = geologist's log

[4] SP = spontaneous potential, G= natural gamma; N = neutron-neutron; D = density; T = temperature, SG = spectral gamma; mag = Magnetic, Cal = caliper

[a] Stick-up unknown, subtracted 2 ft from top of casing as estimate of ground surface

[b] Ground surface = casing elevation minus stick up

NA = not available   Bold = hole to top of basalt

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2.2.1 Geomorphology

A-AX and C WMAs lie along Cold Creek bar, a large compound flood bar formed during Pleistocene Ice Age floods (DOE 1988, Wood et al. 2000). The upper surface of the bar in the 200 East Area forms a broad plain extending westward for several miles. The northern boundary of the bar is defined by a series of northwest-southeast trending flood channels. WMA A-AX is near the apex of the bar at an elevation of about 690 ft (210 m) whereas WMA C lies along the gently sloping, north flank of the bar at an elevation of about 650 ft (198 m).

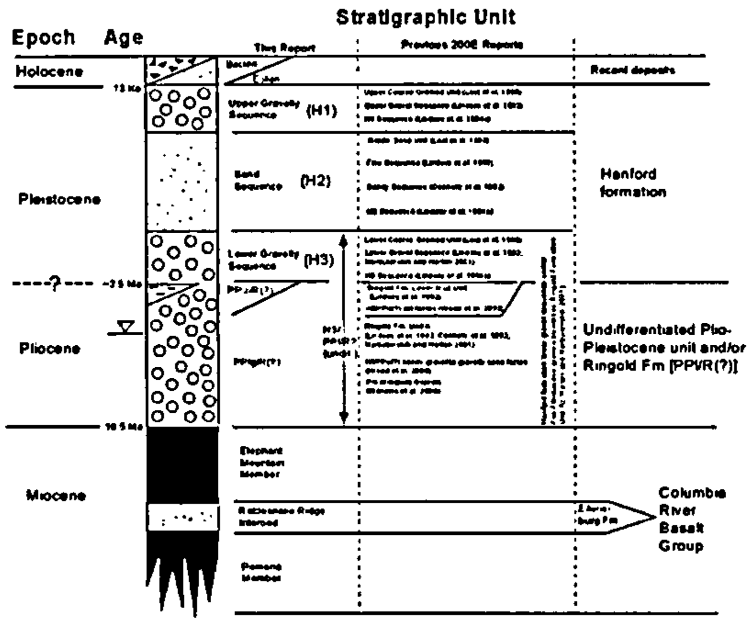
2.2.2 General Stratigraphy

The regional geologic setting of the Pasco Basin and the Hanford Site has been described by *Geology and Hydrology of the Hanford Site: A Standardized Text for Use in Westinghouse Hanford Company Documents and Reports* (Delaney et al. 1991), "Geohydrologic Setting of the Hanford Site, South-Central Washington" (Lindsey et al. 1994b), and DOE (1988). *Geology of the Separation Areas, Hanford Site, South-Central Washington* (Tallman et al. 1979) and more recently *Geologic Setting of the 200 East Area: An Update* (Lindsey et al. 1992), *Geologic Setting of the Low-Level Burial Grounds* (Lindsey et al. 1994a), Last et al. (1989), and Williams et al. (2000) described the geology of the 200 East Area. The geology specific to WMA A-AX was first described by Price and Fecht in *Geology of the 241-A Tank Farm* (1976a) and *Geology of the 241-AX Tank Farm* (1976b) followed by *Fate and Transport of Constituents Leaked from Tank 241-A-105* (Caggiano and Goodwin 1991). Most recently, the WMA A-AX geology was summarized in *A Summary and Evaluation of Hanford Site Subsurface Contamination* (Jones et al. 1998), and Narbutovskih and Horton (2001). The geology specific to WMA C was first described in *Geology of the 241-C Tank Farm* (Price and Fecht 1976c) followed by Caggiano and Goodwin (1991). Most recently the WMA C geology was summarized by Jones et al. (1998) and Horton and Narbutovskih (2001).

A total of seven stratigraphic units lie within the A-AX and C Waste Management Areas (Figure 2-2). These units are represented on hydrogeologic cross sections and isopach and structure-contour maps (Appendix C):

- Recent deposits
- Hanford formation - upper gravelly sequence (H1 unit)
- Hanford formation – sand sequence (H2 unit)
- Hanford formation - lower gravelly sequence (H3 unit)
- Undifferentiated Plio-Pleistocene silt (PPlz) and/or Ringold Formation mud? [PPlz/(R)?]
- Undifferentiated Plio-Pleistocene unit gravel (PPlg) and/or Ringold Formation UnitA? [PPlg/(R)?]
- Columbia River Basalt Group

Figure 2-2. Stratigraphic Units.



A-AX and C WMAs were constructed in the near-surface sediments that overlie the Columbia River Basalt Group (i.e., bedrock) on the north limb of the Cold Creek syncline. The oldest suprabasalt sediments in the vicinity of A-AX and C WMAs include, (1) a gravelly sequence belonging to undifferentiated Ringold Formation member of Wooded Island (Unit A) and/or younger fluvial gravel facies of the Plio-Pleistocene unit (PPlg), referred to in this report as PPlg/R(?), overlain by (2) undifferentiated Ringold Formation mud and/or Plio-Pleistocene silt (PPlz), abbreviated here as PPlz/R(?). These deposits predate Pleistocene cataclysmic flooding, which blanketed the area with mostly coarse sand and gravel. Cataclysmic flood deposits, collectively referred to as the Hanford formation, include a lower and upper gravelly sequence, separated by a sand-dominated sequence in the study area. Recent deposits of eolian silty sand and man-made backfill locally overlie flood deposits.

The thickness of the vadose zone beneath the study area ranges from 235 ft (72 m) in the vicinity of WMA C to 295 ft (90 m) around WMA A-AX (Narbutovskih and Horton 2001; Horton and Narbutovskih 2001). The unconfined aquifer is relatively thin (60-90 ft [18-27 m]) and resides mostly within the undifferentiated Plio-Pleistocene gravels/Ringold Formation Unit A sequence (see Appendix C).

2.2.3 Methodology

The sources of available geologic data, the quality of these data, and how they are used to develop the conceptual geohydrologic model for C and A-AX WMAs are described in the following paragraphs. The quality of data available from the boreholes varies considerably depending on when the boreholes were drilled, the drill method(s) used, and intended purpose of the borehole.

2.2.3.1 Data Sources. Borehole data consisting of driller's logs, geologist's logs, archived samples, and geophysical logs, as well as limited laboratory characterization data (grain-size distribution, $CaCO_3$, and moisture content), are the principal data sets used to interpret subsurface geology. In addition, numerous reports describing the geology of the area create the foundation from which the model has evolved (e.g. Tallman et al. 1979; DOE 1988; Last et al. 1989; Lindsey et al. 1992, Connelly et al. 1992, Horton and Narbutovskih 2001, and Narbutovskih and Horton 2001). A summary of the types of data available for the 49 boreholes within 1000 ft (300 m) of A-AX and C WMAs is presented in Table 2-1. Interpretations in this report are biased in favor of the higher-quality boreholes, which have one or more of the following characteristics: 1) recent installation, 2) available geologist logs, 3) available geophysical logs, and 4) available moisture, grain-size, and other characterization data.

Initially, well-site geologists' logs or drillers' logs were examined and compared to geophysical logs from boreholes. The quality of drilling logs differs because many wells and boreholes were drilled without a geologist present at the site; this is generally true for all boreholes drilled prior to the mid-1980's. Up until that time, driller's would collect sediment samples every 5 ft (1.5 m) and provide general descriptions of the formation materials and problems encountered during drilling. Most of the archived sediment samples from these early (pre-1980) borings were subsequently analyzed in the laboratory for grain-size distribution and $CaCO_3$ content; these results reside in a database called ROCSAN, which is available but no longer maintained. For this study, grain-size distribution and wt% $CaCO_3$ plots were generated after manually reentering the data into EXCEL spreadsheets from ROCSAN printouts.

The quality of the grain-size distribution data largely depends on the drill method used. Most boreholes were drilled via the percussion cable-tool method, either with a hard tool or with a drive barrel. Those intervals drilled with a hard tool tend to produce more fines because of the pulverizing action of the solid hard-tool bit. The drive-barrel, on the other hand, better preserves the original grain-size distribution, but also can result in some pulverization. The suprabasalt sediments in only two boreholes within the study area were drilled by alternative methods (Table 2-1). Borehole 299-E25-48 was drilled using the air rotary method, which also has a pulverizing effect, and borehole 299-E27-6 (DH-16) was drilled via diamond core below the 100 ft depth (Webster 1977). Of all the methods, diamond core produces the best-quality samples from which to evaluate the subsurface geology.

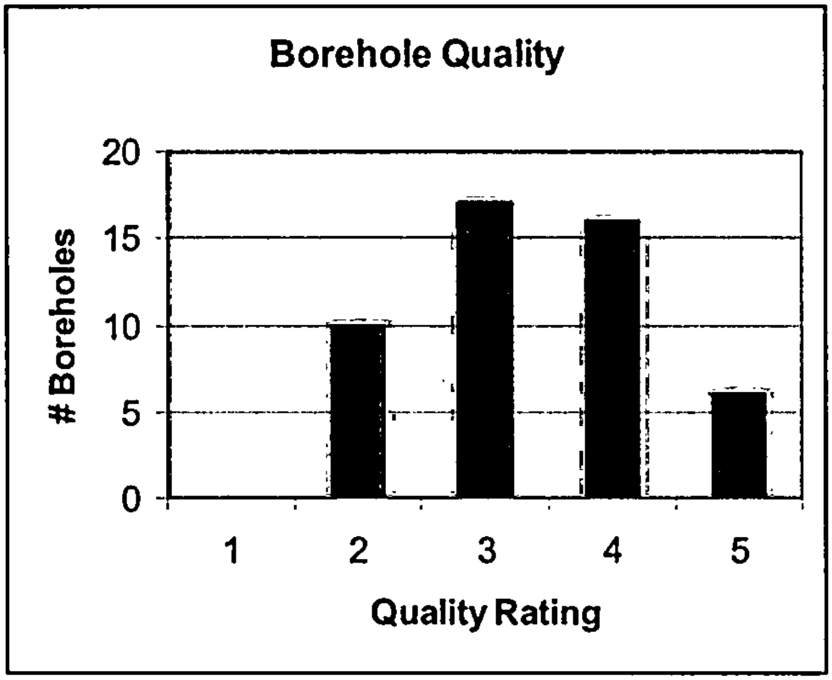
Beginning in the mid-1980's, geologists were assigned the responsibility for providing lithologic descriptions during drilling and samples were no longer routinely analyzed in the laboratory. Therefore, most boreholes drilled after the mid-1980's were not analyzed quantitatively in the laboratory for grain-size distribution and wt% $CaCO_3$; qualitative estimates of these parameters were provided on geologists logs, however.

Geophysical logs (e.g., gross-gamma ray), available for most of the boreholes, differ in quality but are useful for identifying some, but not all, stratigraphic contacts. Geophysical logs sometimes show lithologic differences because of differing amounts of natural gamma-ray emitters (most commonly ^{40}K). The proportion of ^{40}K generally increases with decreasing grain size. The gross-gamma log is often more useful than physical samples for accurately determining the depths of fine-grained layers, especially those more than about 3 ft (1 meter) thick. However, very thin clay and/or silt layers commonly go undetected on gross gamma logs.

When available, the neutron-moisture log is useful for identifying zones of higher moisture, which are often associated with capillary boundaries including fine-grained intervals. Within the vadose zone, moisture content frequently increases along sedimentary interfaces between materials with contrasting grain size or lithology. Other geophysical logs listed in Table 2-1 (e.g., density, temperature, magnetic, caliper) have not proven particularly useful for stratigraphic interpretation.

2.2.3.2 Development of Geohydrologic Model. The process of building the physical geohydrologic model followed a series of investigative steps that were designed to honor the data and give preferential treatment to the boreholes with the highest quality data available. Boreholes near the C and A-AX WMAs are rated in Table 2-1 according to the quality of data and degree of certainty in the interpretation of the geology of the borehole. The rating scale ranges 1 to 5 (Figure 2-3), with boreholes rated #1 having the highest confidence in the geologic interpretation. Those boreholes rated #5 (least confidence and highest uncertainty) are associated with those boreholes with only a driller's log available. None of the 49 boreholes within 1000 ft (300 m) of the C and A-AX WMAs (Table 2-1) are rated #1, as none of the holes have a complete set of high-quality characterization data. Boreholes rated #1 are those with a complete geologist's log accompanied by a gross-gamma and moisture logs, as well as grain-size, $CaCO_3$, and/or other characterization data. Only 10 boreholes are rated #2 (Figure 2-3). Number 2 rated boreholes have a geologists log, accompanied by a gamma log and either a neutron-moisture log, or laboratory measurements of moisture, grain size, and/or $CaCO_3$. The majority of the boreholes in the study area has limited data sets (drillers log only, perhaps with a gamma log and/or grain size/$CaCO_3$ data) and therefore has a quality rating of only 3 or 4. Six of the boreholes are rated #5 (no useful geologic information or questionable drillers log only) and thus of no use for geologic interpretation.

Figure 2-3. Quality Rating for 49 Boreholes within 1000 ft (300 m) of the C and A-AX WMAs. Boreholes rated #1 provide the highest quality geologic information while those rated #5 provide the lowest quality.



Five cross sections were constructed in the study area that included as many higher-quality boreholes (rating =2 or 3) that best represented the study area and especially the tank farms. These cross sections, located on Figure 2-4, are presented in Appendix C. Stratigraphic contacts for the various units and facies were identified on these cross sections. Elevations and thicknesses for the seven major stratigraphic units (Figure 2-2) were calculated and plotted onto structure-contour and isopach maps, as a way to determine if the contacts are realistic and make sense geologically. If the interpreted depths of contacts are chosen correctly, the data should plot as relatively smooth surfaces transitioning from one borehole to another. Isolated, large, steep-gradient "bull's eyes" on contour maps indicate that the contact may be mislocated; in those cases the interpreted stratigraphic contact would be reevaluated and adjusted as necessary. Final picks for stratigraphic units are presented in Table 2-2 and the final isopach and structure-contour maps are presented in Appendix C.

Figure 2-4. Cross Section Location Map.

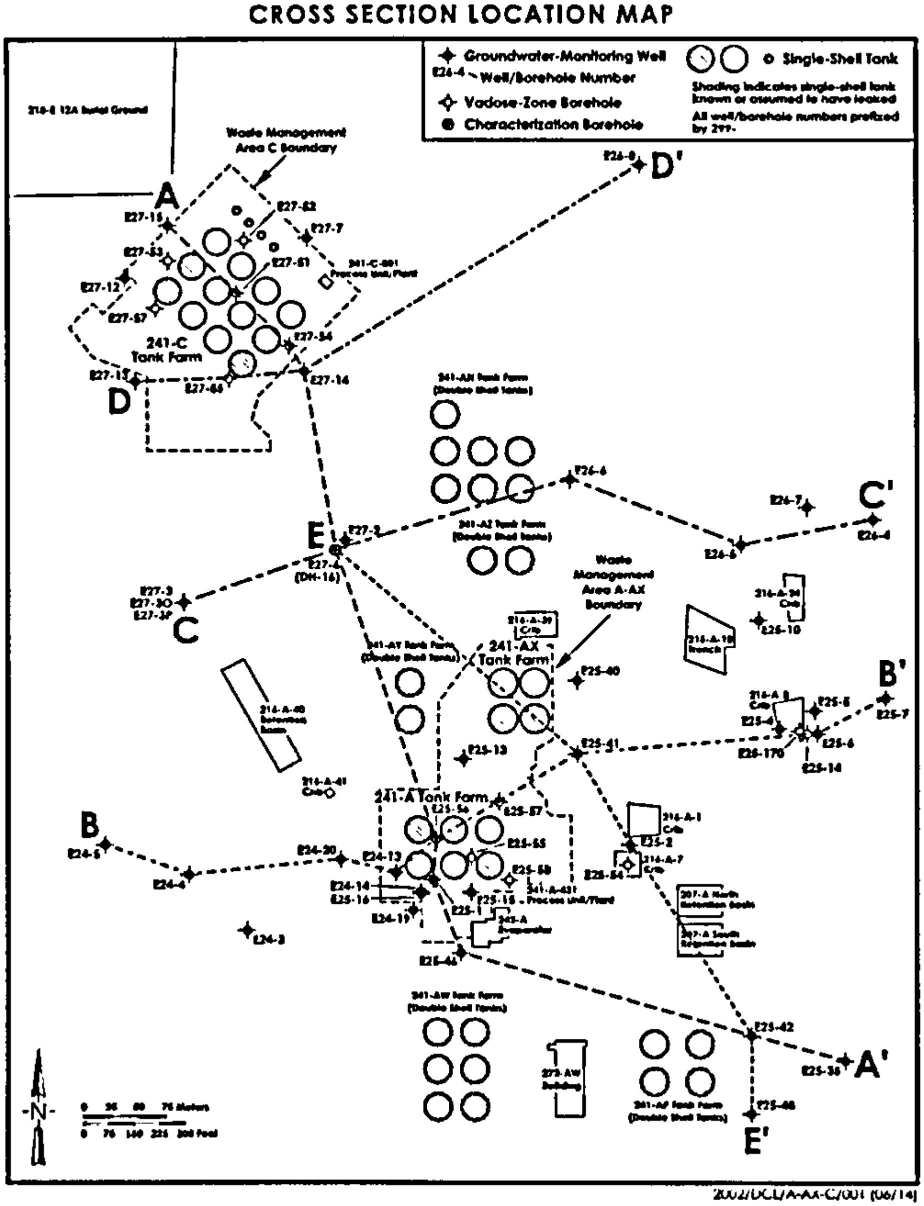


Table 2-2. Stratigraphic Contacts for Boreholes within 1000 ft of WMA (2 sheets).

Borehole Name	Quality Rating[1]	Ground-Surface Elevation (ft amsl)	Total Depth (ft)	TOB	Top of PPlg/R?	Top of PPlz/R(?)	Top of H3	Top of H2	Top of H1	TOB	Top of PPlg/R?	Top of PPlz/R(?)	Top of H3	Top of H2	Top of H1	PPlg/R(?)	PPlz/R(?)	H3	H2	H1	Recent Deposits (Type[2])
299-E24-03	3	700.35	333.0		?	NP?	NP?	107	0		?	NP?	NP?	593	700		NP?	NP?	?	107	
299-E24-04	3	700.38	330.0		?	NP?	NP?	70	15		?	NP?	NP?	630	685		NP?	NP?	?	55	15 (BF)
299-E24-05	3	698.55	329.0		?	NP?	NP?	8	NP		?	NP?	NP?	691	NP		NP?	NP?	?	NP	8 (E)
299-E24-13	4	694.36	340.0		287	263	NP	120	10		407	431	NP	574	684		24	NP	143	110	10 (BF)
299-E24-14	4	694.65	343.0		290	275	NP	60	0		405	420	NP	635	695		15	NP	205	60	
299-E24-19	2	694.44	303.0		285	277	NP	125	10		409	417	NP	569	684		8	NP	152	115	10 (F)
299-E24-20	3	689.37	304.0		280	275	NP	115	0		409	414	NP	574	689		5	NP	160	115	
299-E25-01	3	693.80	322.0		280	265	NP	125	20		414	429	NP	569	674		15	NP	140	105	20 (BF)
299-E25-02	3	677.02	375.0	356	265	255	205	118	15	321	412	422	472	559	NP	91	10	50	137	103	15 (E)
299-E25-04	5	662.71	289.0																		
299-E25-05	4	661.50	293.0																		
299-E25-06	3	662.33	290.0		270	264	170	28	5		392	398	492	634	667		6	94	142	23	5 (E)
299-E25-07	4	660.38	290.0		?	?	180	0	NP		?	?	480	660	NP			?	180	NP	
299-E25-10	2	657.73	293.0																		
299-E25-13	3	685.66	317.0		280	256	NP	65	20		406	430	NP	621	666		24	NP	191	45	20 (E)
299-E25-14	4	683.52	208.0				205	120	0				479	564	684				145	120	
299-E25-15	4	692.55	340.0		284	275	NP	80	0		409	418	NP	613	693		9	NP	195	80	
299-E25-16	5	694.51	340.0		286	265	NP	60	0		409	430	NP	635	695		21	NP	205	60	
299-E25-35	3	674.57	285.0		270	257	210	75	8		405	418	465	600	667		13	47	135	67	8 (E)
299-E25-40	2	666.40	274.0		257	248	195	100	0		409	418	471	566	666		9	53	95	100	
299-E25-41	2	671.72	279.0		270	253	195	100	0		402	419	477	544	672		17	58	95	100	
299-E25-42	3	679.74	294.7		255	246	220	80	20		425	434	460	600	660		9	26	140	60	20 (BF)
299-E25-46	2	695.16	310.3		278.5	273	NP	80	7		417	422	NP	615	688		6	NP	193	73	7 (E)
299-E25-48	4	683.05	287.5		280	266.5	NP	86	20		403	417	NP	597	663		14	NP	181	66	20 (E)
299-E25-54	3	679.31	150.0																		
299-E25-55	3	692.14	151.0					100	20					592	672					80	20 (BF)
299-E25-56	4	689.90	151.0					85	50					605	640					35	50 (BF)
299-E25-57	3	688.70	150.0					120	50					569	639					70	50 (BF)

Table 2-2. Stratigraphic Contacts for Boreholes within 1000 ft of WMA (2 sheets).

Borehole Name	Quality Rating[1]	Ground-Surface Elevation (ft amsl)	Total Depth (ft)	TOB	Top of PPlg/R?	Top of PPlz/R(?)	Top of H3	Top of H2	Top of H1	TOB	Top of PPlg/R?	Top of PPlz/R(?)	Top of H3	Top of H2	Top of H1	PPlg/R(?)	PPlz/R(?)	H3	H2	H1	Recent Deposits (Type[2])
299-E25-58	3	691.17	151.0					122	30					569	661					92	30 (BF)
299-E25-170	5		204.0																		
299-E26-04	3	649.50	283.0		230	220	180	0	NP		420	430	470	650	NP		10	40	180	NP	
299-E26-05	4	651.70	292.5		?	?	190	8	NP		?	?	462	644	NP			?	182	NP	8 (E)
299-E26-06	4	653.50	290.0		247	243	NP	60	16		407	411	NP	594	638		4	NP	183	44	16 (E)
299-E26-07	4		245.0				176	14	0						0						
299-E26-08	3	620.79	400.0	250	NP	NP	136	10	NP	371	NP	NP	485	611	NP			?	126	NP	10 (E)
299-E27-02	4	666.30	312.0		263	255	NP	50	0		403	411	NP	616	666		8	NP	205	50	
299-E27-03	3	684.54	360.0	349	?	NP?	255	35	10	336	?	NP?	430	650	675			?	220	25	10 (E)
299-E27-06	2	670.00	353.0	343	266	257	NP	85	10	327	404	413	NP	585	660	77	9	NP	172	75	10 (E)
299-E27-07	5	636.93	281.0		?	?	210						427						?		
299-E27-12	2	661.26	270.0		?	NP	230	35	5		?	NP	431	626	656				195	30	5 (E)
299-E27-13	2	669.61	275.6		?	NP	240	40	0		?	NP	430	630	670				200	40	
299-E27-14	2	658.95	266.8		?	NP	230	40	10		?	NP	429	619	649				190	30	10 (E)
299-E27-15	2	653.45	262.5		?	NP	230	20	10		?	NP	423	613	643				190	30	10 (E)
299-E27-51	4	647.50	150.0																		
299-E27-52	4	646.70	150.0																		
299-E27-53	5		150.0																		
299-E27-54	4		155.0																		
299-E27-55	4		154.0																		
299-E27-57	5		150.0																		

[1] 1 = best, 5 = worst

[2] BF = backfill, E = eolian

NP = not present

2.2.4 Uncertainty

Sources of uncertainty for location of contacts between stratigraphic units in boreholes and correlations between boreholes include:

- Borehole-Related Uncertainty. This includes the drilling method, source and quality of the borehole and geophysical logs, and borehole spacing;
- Sampling-Related Uncertainty. This includes the method of drilling and sampling, sampling frequency, and bias induced by the sampling techniques;
- Geologic-Related Uncertainty. This includes the three-dimensional shape of the sedimentary features, lateral facies changes in relative proportion of sand, silt and gravel, and bed-form properties of the sediment layers.

2.2.4.1 Borehole-Related Uncertainty. Most boreholes near A-AX and C WMAs have been drilled using cable-tool percussion techniques. Cable tool drilling has been the standard technique from earliest drilling at Hanford because of its effectiveness at penetrating loose, gravelly sediments. Cable-tooled boreholes are advanced via a drive barrel or hard tool while driving a temporary string of welded casing. The technique generally provides good sample control and has proven successful, especially in the unconsolidated gravel-dominated facies of the Hanford formation. There are several disadvantages to cable tool technique, however. These include:

- Limited sample size;
- Samples can be difficult to retain in the drive barrel, in the vadose zone. Often, water must be added to give the sample cohesive strength so that it will stay in the drive barrel.
- Gravels are not easily retrieved because they are not easily retained in the drive barrel;
- The depth of the sample is difficult to control.
- Cemented units or zones with large gravel clasts must be drilled with a "hard tool" which pulverizes the material and alters the grain-size distribution of the recovered samples. Pulverization occurs to a lesser degree with the drive barrel.

Most boreholes drilled prior to the 1980s were drilled without a well-site geologist to log the samples. Thus, the only records of early drilling are driller's logs that vary in the quality of the sample description. The quality of the geologist's logs also varies from borehole to borehole because of different procedures being used as well as variable experience and expertise between geologists.

Many boreholes were completed without the benefit of being geophysically logged. Geophysical logging is sometimes a useful tool for determining the depth of lithologic changes. Finally, borehole coverage is usually dictated by factors other than addressing geologic questions. Therefore, the spacing and distribution of boreholes is often inadequate to confidently address geologic problems.

2.2.4.2 Sampling-Related Uncertainty. The type and quantity of data collected varies substantially from one borehole to another, which adds uncertainty and complicates stratigraphic correlations based on different data sets of different data quality. Sample collection in the unconsolidated vadose-zone formations (i.e., Hanford formation) is often challenging because the samples are typically dry and are not easily retained in the drive barrel.

The most-important factor affecting quality of the geologic data is the borehole log. Prior to 1980 geologists were generally not present during drilling activities at the Hanford Site. Most often, drillers were the only personnel on site, which meant they were responsible for sample collection (one lithologic sample collected into a glass jar every 5 ft), completion of borehole log, and drilling of the hole. Because of widely different experience and backgrounds, and lack of training in geologic descriptions, the quality of drillers logs is variable and geologically inconsistent. The quality and consistency of borehole logs improved significantly in the 1980's when the responsibility for geologic logging and sampling of the boreholes shifted to geologists.

The quality of the geophysical logging (i.e., gross-gamma log) has also varied over the years. Earlier logs were often uncalibrated to a standard and/or run at rapid rates, which adversely affected data quality. However, the older logs are still useful for qualitative comparison and definition of lithologic contacts.

2.2.4.3 Geologic-Related Uncertainty. In addition to the uncertainty in borehole data, there is uncertainty in the geometric shape and distribution of sediment bodies. Because of the scale and dynamic nature of the cataclysmic flooding that produced the Hanford formation, very few analogs are available to compare the geologic model at the C and A-AX WMAs to an analog field locality. Nearby surface excavations, such the 218-E-12B Burial Ground, in the northeast 200 East Area provide valuable information on the types and scales of natural heterogeneity within the Hanford formation, which cannot be interpreted from boreholes alone (Wood et al. 2000).

2.2.5 Columbia River Basalt Group

The Columbia River Basalt Group (CRBG) forms the bedrock base of the unconfined aquifer under the C and A-AX WMAs. Sedimentary interbeds between CRBG flows belong to the Ellensburg Formation (Figure 2-2). The Elephant Mountain Member of the Saddle Mountains Basalt formation is a medium to fine-grained tholeiitic basalt with abundant microphenocrysts of plagioclase (DOE 1988). The Elephant Mountain Member has been dated by the K/Ar method at 10.5 Ma (McKee et al. 1977) and consists of two flows beneath the 200 East Area. The Elephant Mountain Member represents the youngest basalt flows in the study area; the top of the member lies at depths between 250-360 ft (75-110 m) bgs within the study area. The top of basalt dips south toward the axis of the Cold Creek syncline (Connelly et al. 1992). Up to 50 ft (15 m) of topographic relief (Figure C-6) exists on the basalt surface as a result of tectonic deformation and/or erosion. In general, upper lava flows of the CRBG, as well as the Ellensburg Formation and overlying suprabasalt sediments, thicken to the south toward the axis of the Cold Creek syncline (DOE 1988).

Only four boreholes (299-E25-2, -E26-8, -E27-3, and -E27-6) within the study area extend to the top of basalt. One borehole (299-E26-8) fully penetrated the Elephant Mountain Member and advanced through the first sedimentary interbed (Rattlesnake Ridge) into the underlying Pomona Member of the CRBG (Figure C-4). In this borehole, the Elephant Mountain Member and the Rattlesnake Ridge Interbed were 90 ft (27 m) and 50 ft (15 m) thick, respectively.

2.2.6 Undifferentiated Plio-Pleistocene Unit/Ringold Formation

Where not eroded away, the Ringold Formation overlies Columbia River basalt in the central Pasco Basin (DOE 1988). The Ringold Formation in this area consists of multilithic, clast-supported to matrix-supported, variably cemented and/or limonitic-stained, sandy gravel sequences. Ringold Formation gravel sequences are occasionally separated by thinner sequences of horizontally laminated, ripple laminated and/or massive, locally calcareous sand, silt, and clay in various shades of blue, olive, gray, and brown (Lindsey 1995). Sands are generally well-sorted and predominantly quartzo-feldspathic (i.e., light colored). The gravels represent fluvial channel-fill and braidplain deposits while intervening, fine-grained deposits are interpreted as lacustrine and/or fluvial overbank-paleosol deposits.

At present it is uncertain how much, if any, of the Ringold Formation is present beneath the C and A-AX WMAs. This area lies at or near the axis of a paleochannel that removed most or all of the Ringold Formation from the northern half of the 200 East Area (Williams et al. 2000). Thus, most or all the Ringold Formation may have been removed from beneath the study area, either by fluvial processes that postdate the Ringold Formation and/or by Ice Age cataclysmic flooding. Some previous workers, however, include erosional remnants of the Ringold Formation beneath the A-AX and C WMAs (Lindsey et al. 1992, Connelly et al. 1992, Narbutovskih and Horton 2001).

The southeast-trending paleochannel underlying WMAs A-AX and C postdates regional incision of the Ringold Formation and marks the path of the ancestral Columbia River as it flowed through a topographic low at Gable Gap starting sometime after 3.4 Ma (Fecht et al. 1987). The shift of the Columbia River to its present path along the north side of Gable Mountain probably occurred at the onset of the Ice Age and associated cataclysmic flooding. These floods, which began about the beginning of the Pleistocene Epoch 1.5 to 2.5 million years ago as documented in "Long History of Pre-Wisconsin, Ice Age Cataclysmic Floods: Evidence from Southeastern Washington State (Bjornstad et al. 2001), led to further erosion as well as development and progradation of flood bars over the former course of the river. Prior to the Ice Age floods, however, there was a 1-2 million-year period where "normal" fluvial processes might have occurred within the central basin where the ancestral Columbia River continued to flow through Gable Gap and to the southeast. It is during this period that the Plio-Pleistocene unit deposits developed locally, either on the eroded Ringold Formation or directly on top of basalt bedrock within the study area.

Similar to the Ringold Formation, Plio-Pleistocene unit deposits in the central basin consist of multilithic, clast-supported sandy gravel. These deposits, previously referred to as Pre-Missoula Gravels in *Skagit/Hanford Nuclear Project, Preliminary Safety Analysis Report* (PSPL 1982) and Lindsey (1995), have more recently been included as a mainstream-alluvial facies of the Plio-Pleistocene unit (Lindsey et al. 1994b). Unlike the Ringold Formation, mainstream facies of the Plio-Pleistocene unit are generally unconsolidated, have a "whitish" or "bleached" appearance and lack limonitic staining, characteristic of the Ringold Formation. Because mainstream facies of the Plio-Pleistocene unit consists of essentially reworked fluvial sands and gravels of the Ringold Formation, it is often difficult to distinguish the two units from one another.

Another facies of the Plio-Pleistocene unit beneath the 200 East Area consists of a well-sorted silt to fine sand, which is locally up to 35 ft (10.5 m) thick beneath the B Tank Farm (Wood et al. 2000). The thickness of this unit, referred to as the Hf/PPu(?) silt by Wood et al. (2000), appears be too great for the Hanford formation and thus is probably entirely of Plio-Pleistocene age. A fine-grained layer, at about the same relative depth, is also present beneath most of WMA A-AX. The fine-grained layer is discontinuous, however, between this area and northern portion of the 200 East Area as it is missing beneath WMA C. Some of the sample descriptions of the fine-grained unit from WMA A-AX are more like those for the lacustrine/overbank/paleosol facies of the Ringold Formation (i.e., gray-, blue-, or green clay). In other boreholes, however, sample descriptions are more like those for the Plio-Pleistocene silty facies (brown silt to fine sand) (Figure 2-5). Therefore, it is uncertain at this time as to whether this fine-grained unit beneath WMA A-AX represents fine-grained facies of the Ringold Formation or Plio-Pleistocene unit, or both.

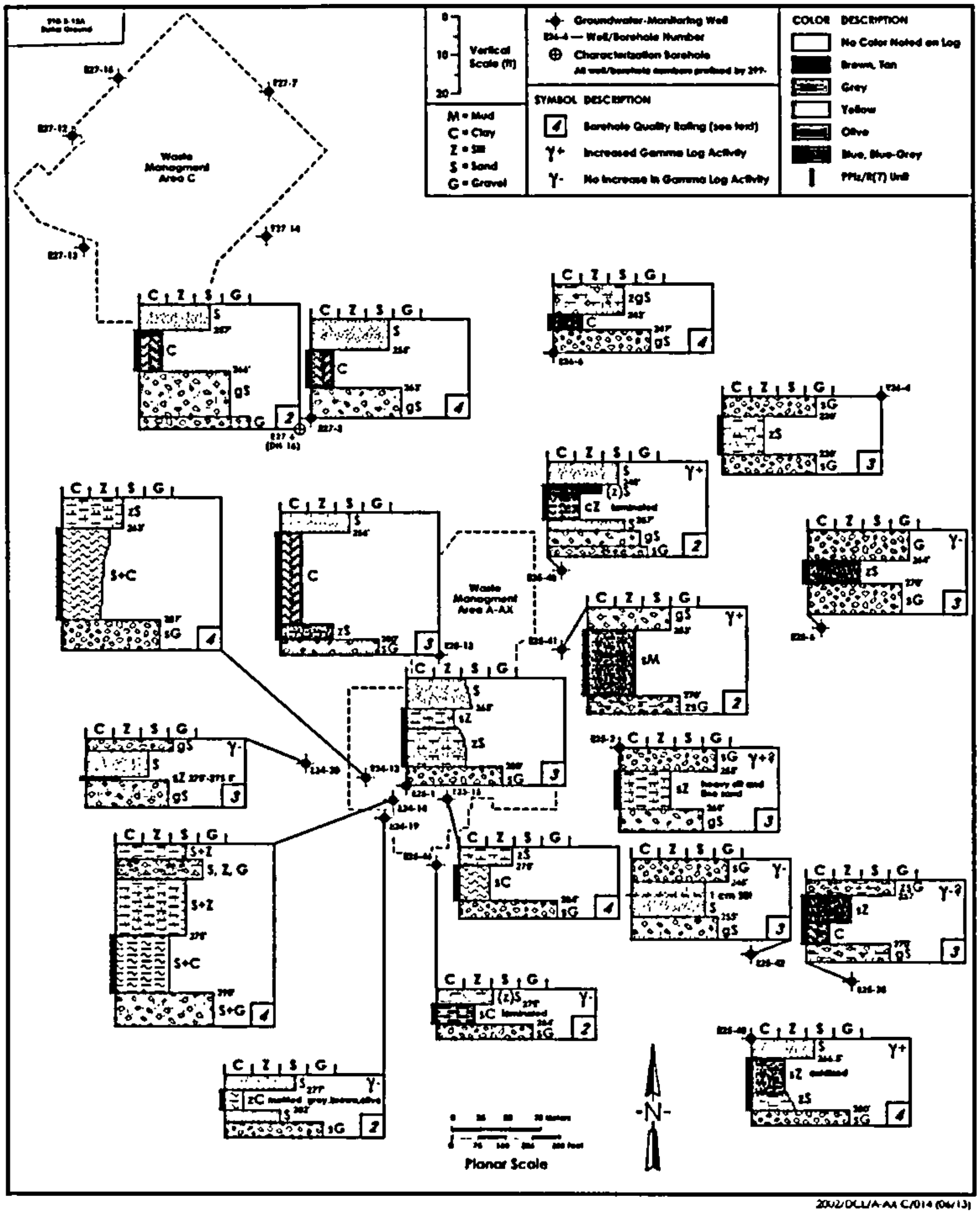
Where present, the top of the fine-grained unit, near the 250 ft (75 m) depth, defines the top of the undifferentiated Plio-Pleistocene silt/Ringold Formation mud unit (PPlz/R(?)) and the base of overlying flood deposits of the Hanford formation. Below the PPlz/R(?) unit is an undifferentiated sequence of Plio-Pleistocene gravel and/or Ringold Formation Unit A, designated PPlg/R(?). Where the fine-grained layer is missing, (e.g., beneath WMA C) it is not possible to differentiate between similar, coarse-grained facies of the Ringold Formation, Plio-Pleistocene unit, and flood gravels of the Hanford formation with the information available.

While these units have similar lithologic characteristics, their transport properties are believed to be very different. Whether this gravel sequence is Ringold, Plio-Pleistocene unit, and/or Hanford formation has important implications for the permeability and flow rate of groundwater in the unconfined aquifer. Overall, Hanford formation gravels are significantly (10 to 100 times) more permeable than gravel sequences in the Ringold Formation. Plio-Pleistocene-age gravels are probably intermediate between the Ringold and Hanford formations. The differences in permeability are attributed mainly to the higher degree weathering and matrix cementation and induration common in the Ringold sediments (Wurstner et al. 1995).

2.2.6.1 Undifferentiated Plio-Pleistocene Unit Gravel and/or Ringold Formation Unit A [PPlg/R(?)]. Gravelly facies immediately overlying basalt within the study area belong to either the Ringold Formation Unit A and/or the Plio-Pleistocene unit. An exception is to the northeast near borehole 299-E26-8 (Figure C-4), where the top of basalt rises above the depth of post-Ringold-age scouring by Ice Age floods. It is probable that the PPLg/R(?) unit was completely removed during flooding so that flood deposits of the Hanford formation lie directly on top of basalt bedrock.

The PPLg/R(?) unit consists of predominantly sandy pebble- to cobble-sized gravel with occasional boulders. As a whole the unit shares characteristics of both coarse-grained facies of the Ringold Formation and the Plio-Pleistocene unit. In some boreholes the unit is described as tight, cemented, and brown colored with oxide coatings (characteristics of the Ringold Formation), whereas other boring logs describe the unit as loose, caving to heaving, losing water, gray colored, and clean/unweathered (more characteristic of the Plio-Pleistocene unit). Mineralogically, the sand fraction consists of 15-60% basalt grains with generally less than 1 wt% $CaCO_3$. The total thickness of this unit is ≤90 ft (27 m), based on a limited number of boreholes where the upper and lower boundaries are represented. The top of PPLg/R(?) unit ranges from about 390-425 ft (120-130 m) elevation amsl (Figure C-7).

Figure 2-5. Heterogeneity within the Undifferentiated Plio-Plestocene Silt/Ringold Formation Mud? [PPlz/R(?)] Unit at Boreholes near the C and A-AX WMAs.



2.2.6.2 Undifferentiated Plio-Pleistocene Silt and/or Ringold Formation Mud? [PPlz/R(?)]. A fine-grained unit, occurring at a depth of about 250 ft (75 m), is described for most boreholes beneath WMA A-AX (Figure 2-5). The fine-grained unit is described on borehole logs of cuttings and samples as clay, silt, sandy silt, and/or silty sand. Some gross gamma-ray logs show a reported increase in activity occasionally accompanied by an increase in moisture. No perched water was noted on top of the sequence (Caggiano and Goodwin 1991), but the water table was higher in the past. Thus, the increased moisture content may be a remnant of a higher water table.

The PPlz/R(?) unit is thickest (up to 24 ft [7.3 m]) near WMA A -AX (Figure C-8). This unit disappears to the north and is absent beneath the WMA C. Descriptions of this unit on drilling and geologic logs vary significantly (Figure 2-5), which may be due to: 1) different subjective descriptions/interpretations by different drillers and geologists, 2) heterogeneities within the unit, which may include multiple lithologic units (e.g., Plio-Pleistocene unit silts overlying Ringold Formation muds), or 3) a combination of these. Where present, this fine-grained unit is described in about half the boreholes as a blue-, gray- or olive-colored clay or mud; remaining boreholes describe the unit as a tan to brown sandy silt to "heavy" silt, which may display a laminated to mottled structure. The former description fits that of Ringold Formation paleosol facies (DOE 1988), whereas the latter fits descriptions for the Plio-Pleistocene silt facies (Wood et al. 2000), interpreted as eolian-overbank in origin. Unlike most other fine-grained units in the 200 Areas, the PPlz/R(?) unit is generally noncalcareous, containing only a few weight percent or less $CaCO_3$.

The top of the PPlz/R(?) unit ranges from about 400-435 ft elevation (Figure C-9). The top of the PPlz/R(?) unit was probably scoured and eroded during Ice Age flooding as suggested by a southeast-trending trough present at the top of this unit. The PPlz/R(?) unit may have extended further north prior to flooding but was subsequently removed during Ice Age flooding near WMA C.

2.2.7 Hanford Formation

The Hanford formation (informal name) overlies the Ringold Formation and consists of glaciofluvial sediments deposited by Ice Age cataclysmic floods from glacial Lake Missoula, pluvial Lake Bonneville, and perhaps other ice-margin lakes. Cataclysmic floods were released during major glacial events that occurred during the Pleistocene starting as early as 1.5 to 2.5 Ma (Bjornstad et al. 2001). The Hanford formation consists of pebble- to boulder-size gravel, fine- to coarse-grained sand, and silt (Baker et al. 1991). These deposits are generally divided into three facies associations: 1) gravel-dominated, 2) sand-dominated, and 3) interbedded sand and silt-dominated. The Hanford formation is present throughout the Hanford Site below elevations of about 1000 ft (300 m). The Hanford formation reaches its maximum thickness of 300 ft (100 m) between the 200 East and 200 West Areas beneath the Cold Creek flood bar.

1. GRAVEL-DOMINATED FACIES. This facies generally consists of poorly sorted mixtures of pebble to boulder gravel, fine- to coarse-grained basaltic sand, with variable amounts of silt. Gravel-dominated facies may display massive bedding, horizontal to low-angle bedding,

and/or large-scale, planar-tabular cross bedding in outcrop, as well as scour-and-fill channels. An open-framework fabric is also observed in outcrop, characterized by clast-supported basalt-rich gravel without little or no matrix-filling sand/silt. Discontinuous sand and silt beds may be interbedded throughout sequences of gravel-dominated facies. Gravel clasts are dominantly basalt with lesser amounts of reworked, Ringold Formation clasts such as granite, quartzite, and gneiss (Lindsey 1992). The gravel-dominated facies was deposited by high-energy floodwaters in or immediately adjacent to the main cataclysmic flood channels (Baker et al. 1991).

2. SAND-DOMINATED FACIES. This facies consists of fine- to coarse-grained sand and pebbly gravel. The sands typically display a high basalt content (30-70%) with color commonly described as black, gray, or "salt-and-pepper" like. Sand-dominated facies may contain isolated matrix-supported pebbles and rip-up clasts, as well as discontinuous beds of pebble-gravel and/or silty interbeds generally less than 3 ft (1 m) meter thick. The silt content of the sands is variable, but when low, the sands are clean and well sorted. In outcrop this facies commonly displays horizontal to subhorizontal lamination and bedding. The sand-dominated facies was deposited adjacent to main flood channels during the waning stages of flooding (Baker et al. 1991). The facies is transitional between the gravel-dominated and the interbedded sand and silt-dominated facies associations.

3. INTERBEDDED SAND AND SILT-DOMINATED FACIES. This facies consists of thin-beds of interbedded, horizontal- to ripple cross-laminated fine- to coarse-grained sand and silt. Beds are typically a meter or less thick and commonly display normally graded-bedding. Unlike the other facies associations, in outcrop, individual "rhythmite" beds may be traced laterally for hundreds of meters or more. Sediments of this facies were deposited under slack-water conditions and in back-flooded areas during cataclysmic flooding (DOE 1988; Baker et al. 1991). This facies association is generally absent within the A-AX and C Waste Management Areas.

Coarser-grained sand and gravel fractions of the Hanford formation generally consist of about equal amounts of basaltic and quartzo-feldspathic material (Tallman et al. 1979). This mineral assemblage gives the Hanford formation its characteristic "salt and pepper" appearance, often noted in driller and geologist's logs. The non-basaltic component consists of predominantly quartz and feldspar with some samples containing greater than 10% pyroxene, amphibole, mica, chlorite, ilmenite and magnetite. The silt- and clay-sized fractions consist of mostly quartz, feldspar, mica and smectite.

The Hanford formation makes up the majority of the suprabasalt sedimentary sequence beneath the C and A-AX WMAs, ranging in thickness from 43 to 73 m (140 to 240 ft). The Hanford formation has been divided into three informal units (H1, H2, and H3) in the 200 East Area. The Hanford formation H1 and H3 units are gravelly units consisting of predominantly sandy gravel to gravelly sand. The H2 unit is predominantly sand, with occasional beds of slightly gravelly sand. The Hanford formation H1 and H3 units contain a higher percentage of flood gravel, associated with deposition within and along the main Ice Age flood channelways. The sand-dominated H2 unit was deposited under less-energetic currents, perhaps further away from the main channelway. The third facies association of the Hanford formation, the interbedded sand and silt-dominated facies, are absent in C and A-AX WMAs.

2.2.7.1 Lower Gravelly Sequence (H3 Unit). The Hanford formation lower gravelly sequence (H3 unit) locally overlies undifferentiated Plio-Pleistocene/Ringold deposits (Figure 2-2). This sequence is equivalent to the lower coarse-grained unit of the Hanford formation of Last et al. (1989) and the lower gravel sequence of Lindsey et al. (1992), the Hanford formation H3 sequence of Lindsey et al. (1994a) and the Quarternary flood gravels (Qfg) deposits of *Geologic Map of the Pries Rapids 1:100,000 Quadrangle, Washington* (Reidel and Fecht 1994).

The H3 unit consists of predominantly gravelly facies of clast-supported, sandy, pebble to boulder gravel to matrix-supported pebbly sand. The maximum $CaCO_3$ measured is ~2.5 wt%. The sand fraction ranges from 15-70% basalt grains, but most often is reported as 40-50% basalt. This unit appears to be present everywhere except within the central and southwest portions of the study area; it is generally missing from beneath most of WMA A-AX (Figure B-5). The unit is probably absent from these areas because of lateral facies changes that take place between gravel-dominated facies to the north and sand-dominated facies to the south away from the primary flood channel that exists north and east of the study area. The greatest thickness [(94 ft 28.7 m)] occurs several hundred feet east of WMA A-AX. The exact thickness of the Hanford formation H3 unit beneath WMA C, on the other hand, is uncertain because the underlying PPLz/(R)? Unit, used to define the base of the unit, is missing.

A structure-contour map of the top of the Hanford formation H3 unit is shown in Figure C-11. The surface of this unit slopes to the south and west with the highest elevations occurring in the northeast and east portions of the study area. Coarser-grained facies are more common to the east and north along the axes of flood channels. About 20 m (70 ft) of relief (420-490 ft) exists on the surface of the H3 unit beneath WMAs A-AX and C.

2.2.7.2 Sand Sequence (H2 Unit). The Hanford formation sand sequence overlies the lower gravel sequence (H3 unit). This sand sequence is equivalent to the middle sand unit (Last et al. 1989), the fine sequence of Lindsey et al. (1992), the sandy sequence of Connelly et al. (1992), the Hanford formation H2 sequence of Lindsey et al. (1994a), and to Quaternary flood sands (Qfs) of Reidel and Fecht (1994).

The H2 unit consists of predominantly sand-dominated facies of the Hanford formation. Fine- to coarse-grained sand dominates with lenses of silty sand to slightly gravelly sand. Minor sandy gravel to gravelly sand beds occur sporadically. Consolidation ranges from loose to compact. Cementation is very minor or absent, and total $CaCO_3$ content is generally only a few weight percent or less. The sand fraction ranges from 10-70% basalt grains but most often a basalt content of 30-40% is reported. Silt lenses and thinly interbedded zones of silt and sand are common but are not abundant in the Hanford formation H2 unit. These thin (< 1 ft [0.3 m]) fine-grained zones generally cannot be correlated among boreholes and are not reflected in the gross gamma-ray logs or moisture data. This is probably because moisture samples are normally collected every 5 ft (1.5 m) during drilling; this sampling interval is too large to detect most thin zones. The fine structure observed in some older gross gamma-ray logs may reflect changes in the silt content that were not detected during drilling.

The Hanford formation sand sequence (H2 unit) underlies the entire area beneath WMAs A-AX and C. The base of the Hanford formation H2 unit is identified as the top of gravelly H3 unit or the top of the fine-grained PPlz/R(?) unit, if the H3 unit is missing. The H2 unit thickens to south and west (Figure C-12), except beneath WMA A-AX, where the upper portion may have been scoured by a southeast trending Ice Age flood channel, perhaps associated with deposition of the overlying gravelly sequence (HI unit). This is indicated by a south to southeast-trending trough present at the top of the H2 unit (Figure C-13). Furthermore, over 100 ft (30 m) of relief exists on top of the H2 unit along this trough.

2.2.7.3 Upper Gravelly Sequence (H1 unit). The Hanford formation upper gravel sequence overlies the Hanford formation sand sequence (H2 unit). This sequence is equivalent to the upper coarse-grained unit of Last et al. (1989), the upper gravel sequence of Lindsey et al. (1992), the Hanford formation H1 sequence of Lindsey et al. (1994a), and to Qfg of Reidel and Fecht (1994).

The Hanford formation H1 unit consists of predominantly loose, sandy gravel to gravelly sand, with minor beds of sand to silty sand. Coarser beds may contain boulder-sized materials. Only a few weight percent or less $CaCO_3$ has been measured in this unit. Sand fractions range from 10-80% basalt, although 40-50% basalt is most commonly reported. The Hanford formation H1 unit consists of mostly high-energy, coarse-grained gravel and sand deposits. Occasional thin, discontinuous lenses of fine sand and silt may also be present.

The isopach map of the Hanford formation H1 unit (Figure C-14) suggests the unit thickens along a northwest-southeast trending trough, which includes WMAs A-AX and C. The H1 unit appears to be missing in the northeast and extreme southwest portions of the study area. The maximum thickness (~100 ft[30 m]) of the H1 unit underlies WMA A-AX. The H1 unit is thinner in the immediate vicinity of the tanks because much of the Hanford formation H1 unit was removed and replaced with backfill during tank-farm operations.

2.2.8 Recent Deposits

Two types of recent deposits are present in the C and A-AX WMAs: 1) eolian sand and silt, and 2) backfill material. Fine to medium sand to silty sand naturally caps the sedimentary sequence in the C and A-AX WMAs. These relatively fine-grained deposits are derived from the reworking of uppermost flood deposits by winds since the last Ice Age flood (~13,000 years B.P.). These poorly sorted eolian deposits contain up to 10-wt% $CaCO_3$ associated with recent soil development.

Eolian sand and silt, forms a relatively thin [up 20 ft (6.1 m)] blanket over the study area (Figure C-15). The thickness of the eolian deposits appears greater along a northwest to southeast trend extending from the WMA AX toward the southeast (Figure C-15). Most or all of the eolian material has been removed and replaced with backfill in the immediate vicinity of tank-farm operations.

Backfill materials consist of unstructured, poorly sorted mixtures of gravel, sand, and silt removed during tank excavation, and then later used as fill around the tanks. Backfill materials extend to depths of 50 ft within the tank farms (Figure C-15).

2.2.9 Clastic Dikes

Clastic dikes are vertical to subvertical sedimentary structures that crosscut normal sedimentary layering. Clastic dikes are a common geologic feature of the Hanford formation in the 200 Areas, especially in the sand- and silt-dominated facies. Clastic dikes are much less common in the gravel-dominated facies of the Hanford formation.

Clastic dikes occur in swarms and form four types of networks (Fecht et al. 1999): 1) regular-shaped polygonal-patterns, 2) irregular-shaped, polygonal-patterns, 3) pre-existing fissure fillings, and 4) random occurrences. Clastic dikes in WMAs A-AX and C probably occur randomly in the gravel-dominated facies (Hanford formation Units H1 and H3) and as regular-shaped polygons in the sand sequence (Hanford formation unit H2). Regular polygonal networks resemble 4- to 8-sided polygons and the dikes defining the polygons typically range from 3 cm to 1 m in width, from 2 m to greater than 20 m in depth, and from 1.5 to 100 m along strike. Smaller dikelets, sills, and small-scale faults and shears are commonly associated with master dikes that form the polygons.

In general, a clastic dike has an outer skin of clay with coarser infilling material. Clay linings are commonly 0.03 mm to 1.0 mm in thickness, but linings up to about 10 mm are known. The width of individual infilling layers ranges from as little as 0.01 mm to more than 30 cm and their length can vary from about 0.2 m to more than 20 m. Infilling sediments are typically poor- to well-sorted sand, but may contain clay, silt, and gravel.

2.3 RECHARGE SOURCES AND EVENTS

The facility infrastructure, infiltration of water from natural and tank farm operation sources, and hydrologic properties of the stratigraphic units beneath the study area control the moisture and waste movement through the vadose zone to groundwater. This section summarizes available information on infiltration from natural resources; discharges caused by tank farm operations and observed spatial and temporal effects on subsurface hydrologic properties. Supporting data tables and figures are provided in Appendix D.

Fluid infiltration into the soil column from the natural and tank operation sources, which are discussed in Sections 2.3.1 and 2.3.2, respectively, had a substantial effect on current environmental contamination conditions in the A-AX and C WMAs at the Hanford Site (Figure 1-1). Temporal changes in vadose zone moisture distribution and water table elevation in response to historical variations in natural and artificial recharge (Section 2.3.3), combined with hydrologic properties (Section 2.4), account for the rate and direction of contaminant dispersal in the aquifer.

2.3.1 Infiltration from Natural Sources

The tank farm surface characteristics and infrastructure create an environment conducive to enhanced general recharge and transient, high-intensity events. Natural infiltration, runoff events, and rapid snowmelt are discussed in Sections 2.3.1.1 through 2.3.1.3.

2.3.1.1 Infiltration. No direct measurements of the natural infiltration rate under the A-AX and C WMAs have been made. However, observations from similar, disturbed, gravel-covered areas at the Hanford Site indicate that as much as 10 cm/year (3.9 in./year) can infiltrate a vegetation-free coarse gravel surface (Gee et al. 1992; Fayer and Walters 1995; Fayer et al. 1996). This represents about 60 percent of the average annual precipitation (rainfall plus snowmelt). Fayer and Walters (1995) indicate that the C and A-AX WMAs are in an area estimated to have about of 5 cm/year to 10 cm/year (1.97 to 3.9 in./year) of infiltration. This estimate of infiltration is based on soil type, lack of vegetation, and land use. Actual recharge is significantly different and not uniform because of the presence of the tanks and the disturbed soil surrounding the tanks. Recharge is blocked and "shed" by the tank domes and flows into the disturbed soil near the tanks. Thus, infiltration rates near tank edges and between rows of tanks are likely manifold higher than average areal infiltration rates.

2.3.1.2 Runoff Events. Transient saturation from collection of runoff in low spots may be more significant as a driving force than average annual infiltration. For example, rapidly melting snow is one natural event that can lead to surface flooding. This type of occurrence has been documented at the T Tank Farm in *Results of Phase I Groundwater Quality Assessment for Single-Shell Tank Waste Management Areas T and T-TX at the Hanford Site* (Hodges 1998), but no similar record is available for either C or A-AX WMAs. Runoff controls, berms and gutter sand diversions were installed around the C and A-AX WMAs in calendar year 2002.

2.3.1.3 Rapid Snowmelt. Records of snowmelt have been made since 1981 at the Hanford Meteorology Station, located between the 200 West and 200 East Areas. Figure 2-6 summarizes the total snowmelt per month for a 24-hour period. These records indicate likely periods when unusual accumulations or ponding of water may have resulted in transient saturation events, possibly leading to transport of contaminants through the vadose zone to groundwater. In addition to the February 1979 snowmelt ponding event mentioned in the previous runoff event section several additional events are likely to have occurred over the last 20 years as evidenced in Figure 2-6. The snowmelt events, as well as maximum monthly precipitation since 1946 (Appendix D, Table D-1), are shown on a time line with groundwater contamination occurrences, tank leaks and unplanned releases in Figures 2-7 and 2-8 for C and A-AX WMAs, respectively.

Figure 2-6. Monthly Summaries of Rapid Snowmelt Events, 1981 Through 1997.

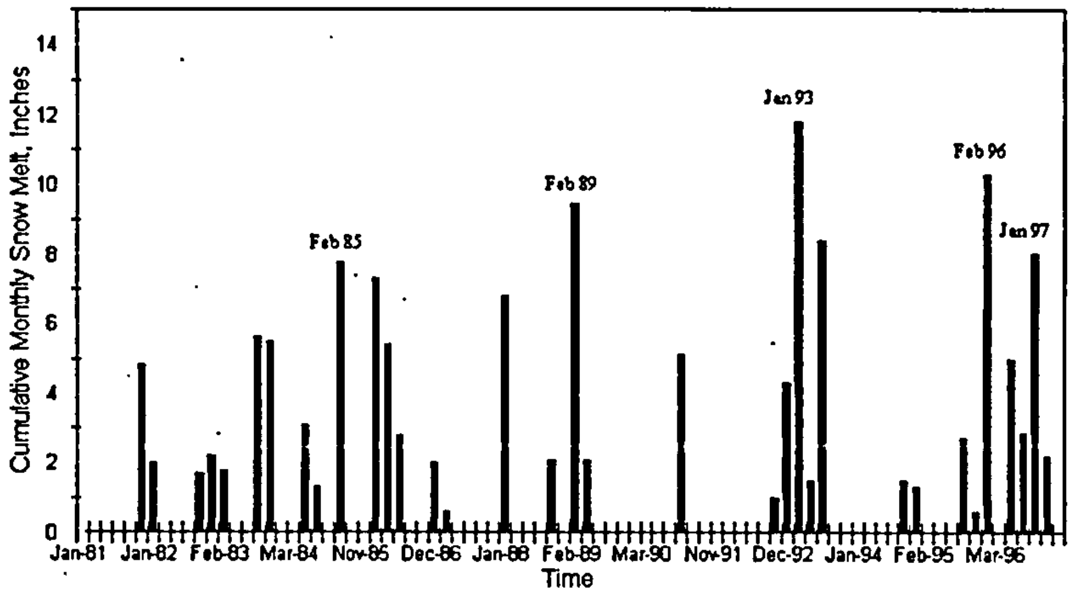


Figure 2-7. Timeline of Hydrologic and C Tank Farms Operational Events.

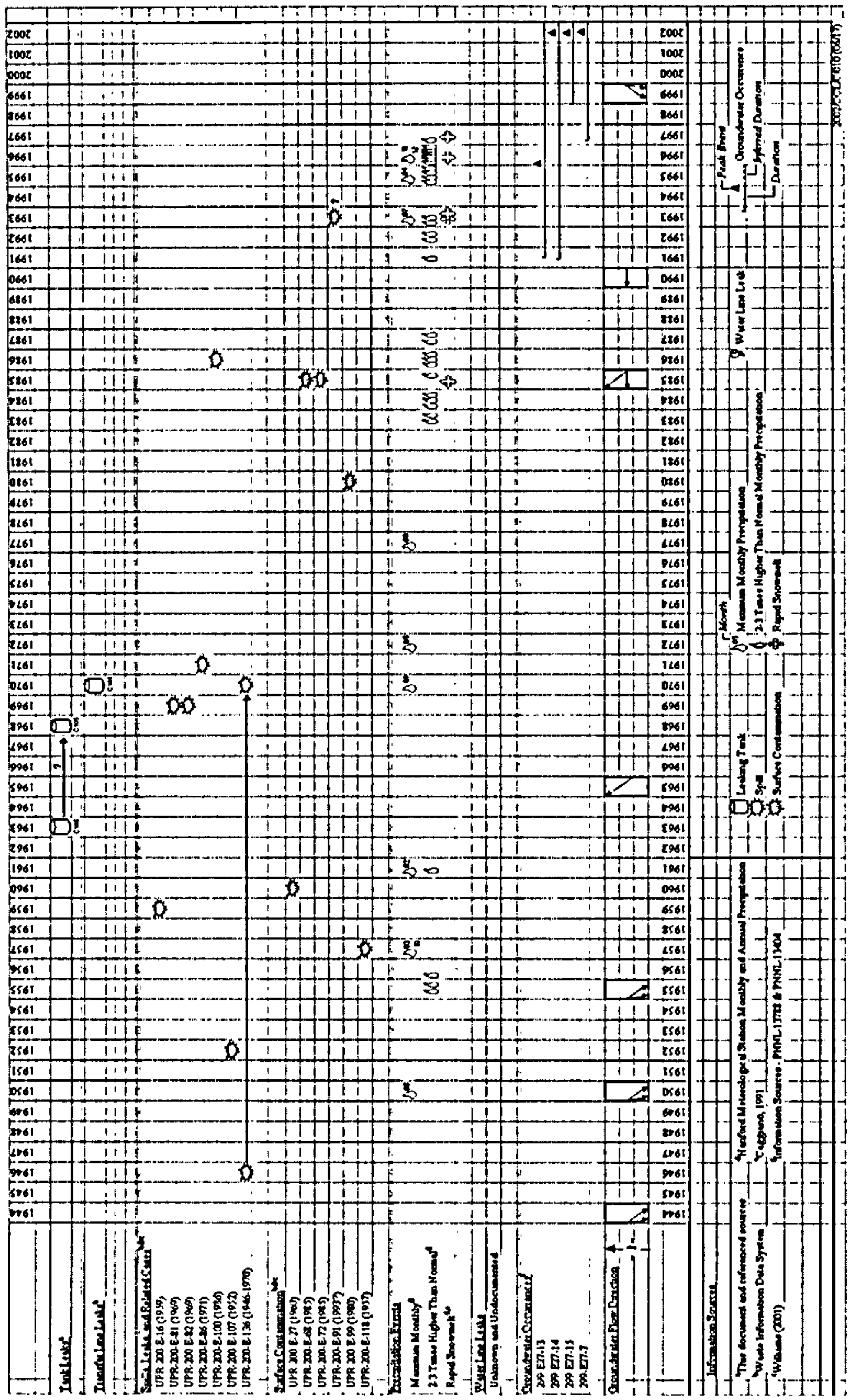


Figure 2-8. Timeline of Hydrologic and A and AX Tank Farms Operational Events