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**Groundwater Monitoring Plan for
the Hanford Site 200 Area Treated
Effluent Disposal Facility**

D. B. Barnett

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Prepared for the U.S. Department of Energy
under Contract DE-AC06-76RLO 1830



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Pacific Northwest National Laboratory
Richland, Washington 99352



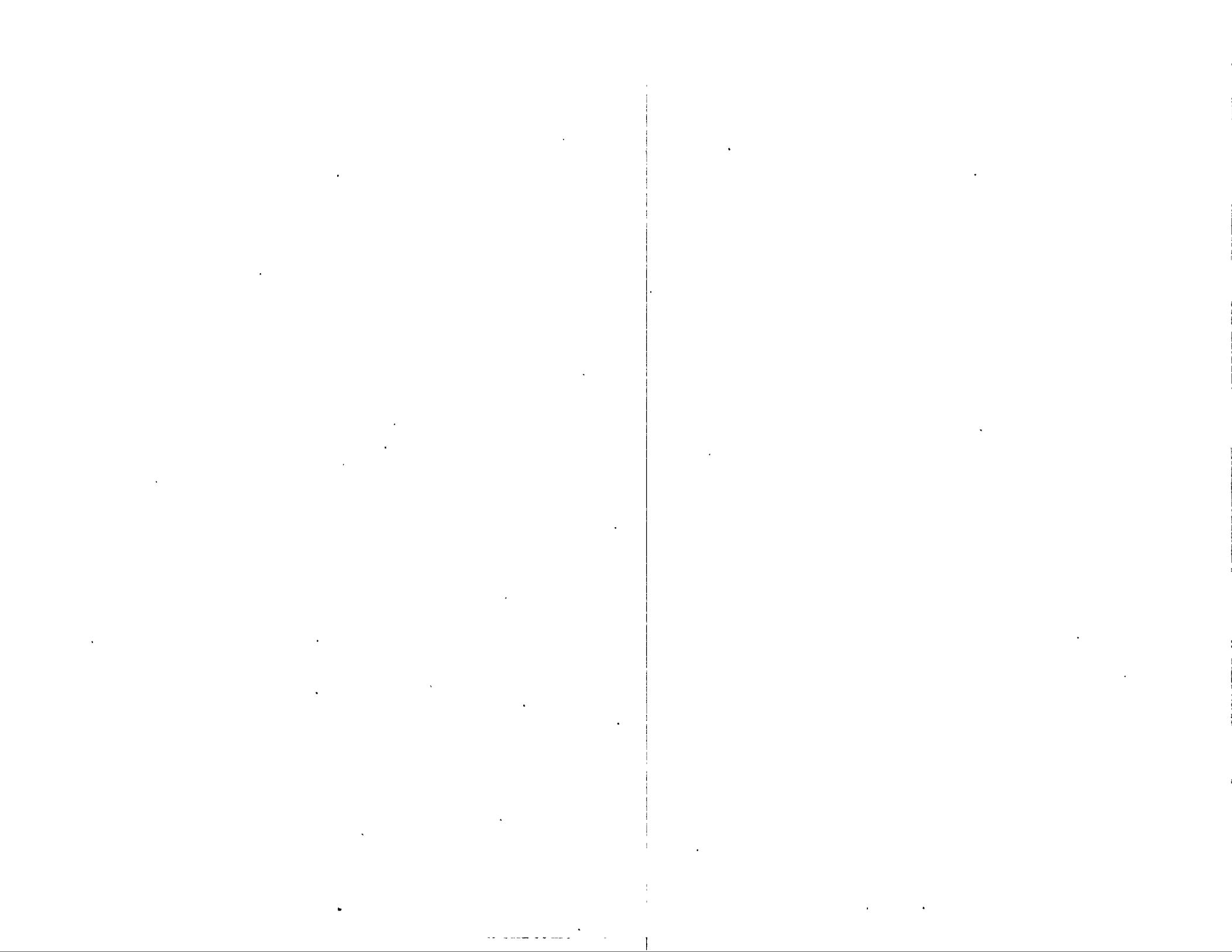
Summary

Seven years of groundwater monitoring at the 200 Area Treated Effluent Disposal Facility (TEDF) have shown that the uppermost aquifer beneath the facility is unaffected by TEDF effluent. Effluent discharges have been well below permitted and expected volumes. Groundwater mounding from TEDF operations predicted by various models has not been observed, and water levels in TEDF wells have continued declining with the dissipation of the nearby B Pond System groundwater mound.

Analytical results for constituents with enforcement limits indicate that concentrations of all these are below Practical Quantitation Limits, and some have produced no detections. Likewise, other constituents on the permit-required list have produced results that are mostly below sitewide background. Comprehensive geochemical analyses of groundwater from TEDF wells has shown that most constituents are below background levels as calculated by two Hanford Site-wide studies. Additionally, major ion proportions and anomalously low tritium activities suggest that groundwater in the aquifer beneath the TEDF has been sequestered from influences of adjoining portions of the aquifer and any discharge activities. This inference is supported by recent hydrogeologic investigations which indicate an extremely slow rate of groundwater movement beneath the TEDF.

Detailed evaluation of TEDF-area hydrogeology and groundwater geochemistry indicate that additional points of compliance for groundwater monitoring would be ineffective for this facility, and would produce ambiguous results. Therefore, the current groundwater monitoring well network is retained for continued monitoring.

A quarterly frequency of sampling and analysis is continued for all three TEDF wells. The constituents list is refined to include only those parameters key to discerning subtle changes in groundwater chemistry, those useful in detecting general groundwater quality changes from upgradient sources, or those retained for comparison with end-of-pipe discharge chemistry. Volatile and semivolatile organic compounds, ammonia, total organic carbon, oil and grease, and radium are removed from the constituent list. Annual analysis for low-level tritium is added to the constituent list to help confirm that groundwater beneath the TEDF remains isolated from operational influences.



Acknowledgments

The author extends his appreciation to Darrell R. Newcomer, Dr. Charissa J. Chou, Dr. V. G. Johnson, Phil M. Olson, and Kristi J. Lueck for their critical review of the document.



Acronyms

BAT/KART	Best Available Technology/All Known And Reasonable Treatment
CDL	contract detection limits
CFEST	Coupled Fluid, Energy, and Solute Transport
DMRs	Discharge Monitoring Reports
DOE/RL	Department of Energy, Richland Operations
DWS	Drinking Water Standards
Ecology	Washington State Department of Ecology
FADE	Factors of Attenuation and Dilution Efficacy
FH	Fluor Hanford
HEIS	Hanford Environmental Information System
LEMIS	Liquid Effluent Monitoring Information System
LWPF	Liquid Waste Processing Facilities (FH)
MODFLOW	MODular three-dimensional difference groundwater FLOW model
PNNL	Pacific Northwest National Laboratory
PQL	Practical Quantitation Limits
PUREX	Plutonium-Uranium Extraction (Plant)
QAPjP	Quality Assurance Project Plan
RCRA	Resource Conservation and Recovery Act of 1976
RDR	Requests for Data Review
ST-4502	Washington State Waste Discharge Permit for TEDF

TDS	total dissolved solids
TEDF	200 Area Treated Effluent Disposal Facility
VAM3DCG	Variably Saturated Analysis Model in Three Dimensions with Preconditioned Conjugate Gradient Matrix Solvers
WAC	Washington State Administrative Code
WESF	Waste Encapsulation and Storage Facility
WMH	Waste Management Hanford Company
WMFS	Waste Management Federal Services
WHC	Westinghouse Hanford Company

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1.0 Introduction

The 200 Area Treated Effluent Disposal Facility (TEDF) consists of a pair of infiltration basins that receive wastewater originating from the 200 East and 200 West Areas of the Hanford Site (Figure 1.1). In operation since 1995, the TEDF is regulated by State Waste Discharge Permit ST-4502 (ST-4502; Ecology 1995) under Washington State Administrative Code (WAC 173-216). The ST-4502 stipulates requirements for both effluent (end-of-pipe) and groundwater monitoring for the TEDF. Groundwater monitoring began in 1992 prior to TEDF construction to obtain background water quality data. The current ST-4502 expires in April 2000, and renewal will require an updated plan for groundwater monitoring. This document represents the plan, based on hydrologic and geochemical information collected since 1992. The document summarizes the operational history of the facility, the hydrogeology and groundwater geochemistry, and historical aspects of groundwater monitoring. This plan supercedes the groundwater monitoring plan of Barnett et al. (1995).

1.1 Background

The initial groundwater monitoring plan for the TEDF, *Groundwater Screening Evaluation/Monitoring Plan—200 Area Treated Effluent Disposal Facility (Project W-049H)* (Barnett et al. 1995), was effected in May 1995, shortly after the TEDF began operation in April 1995. The document presented historical groundwater monitoring results and statistical evaluations for the three TEDF wells that had been drilled ~3 years earlier (during 1992). During the 1992-1995 period, groundwater from these wells had been monitored in conjunction with the 216-B-3 Pond (B Pond System) RCRA facility, and the sampling/analysis schedule and list of analytes followed that of the B Pond System. When the 1995 plan was applied, a new, expanded list of analytes was adopted. That expanded list was used until April of 1997 when Ecology agreed to a reduced list of constituents. The details of historical groundwater monitoring at the TEDF are described in Section 1.4.

Groundwater sampling, analysis, and water level measurements have occurred on a quarterly basis at the TEDF since 1992. Analytical results are reported quarterly in Discharge Monitoring Reports (DMRs) issued by Fluor Hanford (FH) (formerly Waste Management Hanford Company [WMH]) and are summarized in annual reports on groundwater monitoring for the Hanford Site (e.g., Hartman and others 2000), and in annual reports specifically for the TEDF.

1.2 Objectives and Scope

This document presents an updated groundwater monitoring plan for the TEDF and supporting information. The supporting information includes a discussion of the current understanding of the hydrogeological and hydrogeochemical setting of the facility, an update of groundwater analytical results through April 1999, and a historical perspective of groundwater monitoring at the TEDF. The historical perspective is necessary to understand the rationale for various technical decisions during the past several years, and to clarify the strategy for continuation of monitoring. The resulting groundwater monitoring plan, presented in Section 5.0, is predicated upon this information. The plan governs only sampling and

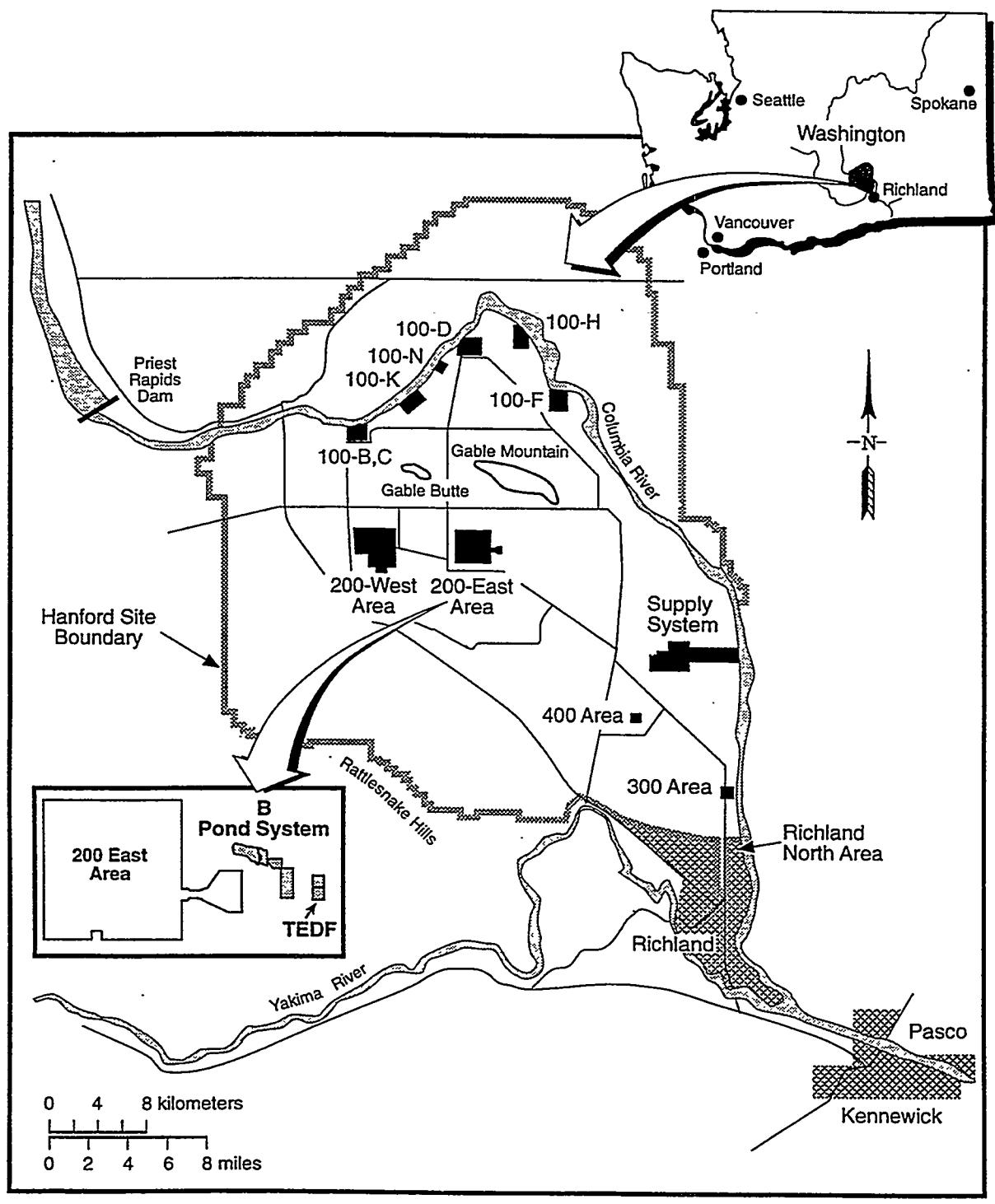


Figure 1.1. Location of the 200 Area Treated Effluent Disposal Facility (TEDF)

analysis for the three wells at the TEDF. This plan results in the elimination of some analytes from the list of constituents sought in the groundwater samples. Constraints for sampling and analysis for other Hanford Site groundwater monitoring are not implied, although data from these programs may be included in the supporting information. Requirements for monitoring and sampling/analysis of TEDF effluent are provided in the ST-4502 and the *Liquid Waste Processing Facilities Quality Assurance Project Plan (QAPjP)* (Olson 1997).

1.3 Facility Description and Operation

The TEDF system consists of a piping system, supporting structures (valves, housings, and instrumentation) and the actual disposal site (Figure 1.2). The TEDF disposal site is a pair of infiltration basins located approximately 3 km east of the 200 East Area of the Hanford Site. The TEDF disposal site has no treatment or retention capacity; all streams disposed to the TEDF are clean or receive any required treatment at the generating facilities. Details of the waste streams and generating facilities are presented by Crane (1998). Aerial and ground-level perspectives of the TEDF are shown in Plates 1.1 and 1.2.

1.3.1 Effluent Sources and Discharge History

Prior to TEDF construction, clean effluent streams from the 200 Area were directed to the RCRA clean-closed 3C expansion pond of the B Pond System (Figure 1.2). Some of these streams were redirected to the TEDF when it began operation in 1995. All remaining streams were sent to the TEDF in August 1997 when the 3C expansion pond was decommissioned.

Current sources of effluent discharging to the TEDF include: 242-A-81 Water Services Building waste water, Plutonium Finishing Plant waste water, T Plant waste water, 222-S Laboratory waste water, 284-W Power Plant, 284-E Power Plant, and WESF cooling water and wastewater, 241-A Tank Farm cooling water, 242-A Evaporator cooling water and steam condensate, 244-AR cooling water, and five package boilers (Crane 1998). All effluent stream generators have implemented Best Available Technology/All Known And Reasonable Treatment (BAT/AKART) at the generating facilities before the streams are discharged to the TEDF. Figure 1.2 schematically illustrates the collection system with major sources of effluent directed to the TEDF.

Effluent volumes to the TEDF have been well within permitted operating parameters since the beginning of operations in 1995. Regulated capacity of the TEDF for each of the two basins was initially approximately 2,820 L/min (750 gpm). In April 1997, a revised ST-4502 was issued that requires discharges not exceed 3,400 gpm (12,869 liters/min) on a monthly basis, averaged daily, or 1,200 gpm (4,542 liters/min) on an average annual basis. The permit revision also allowed for additional waste streams to be accepted by the facility. Figure 1.3 is a plot of monthly and cumulative discharge volumes to the TEDF through April 1999. Thus far, over 2.8 billion liters have been discharged to the facility. Although highly variable, actual discharge rates have averaged only $\sim 5.86 \times 10^7$ liters/month (1,346 liters/min) over the life of the facility, with a maximum of $\sim 3.75 \times 10^8$ liters (2,293 gpm [8,680 liters/min]) in September 1997, and a minimum monthly discharge of 3.0×10^6 (18 gpm [70 liters/min]) in April 1999. The high degree of variability in discharge volume is owing mostly to periodic campaigns of the 242-A Evaporator, which increase effluent flows dramatically.

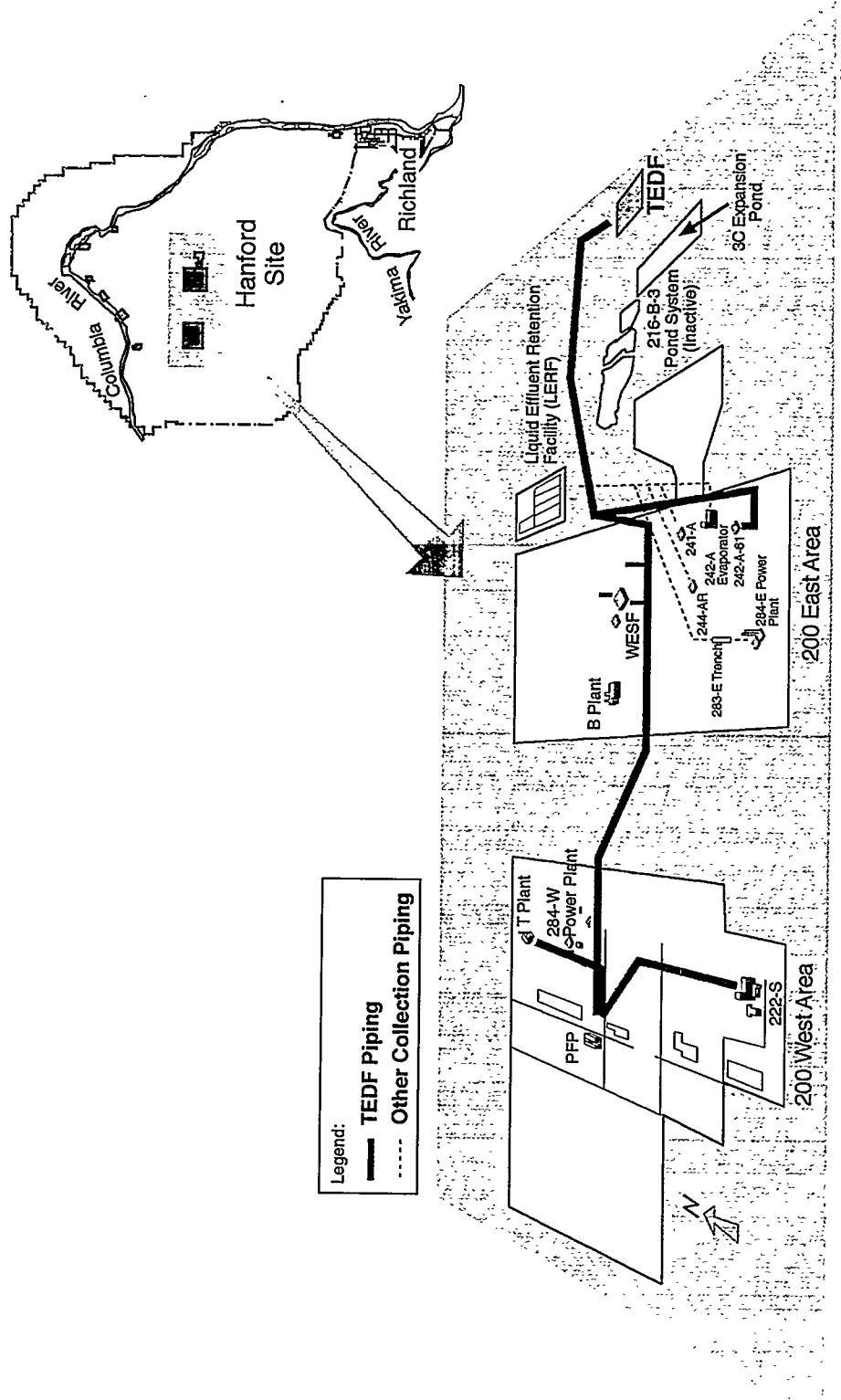
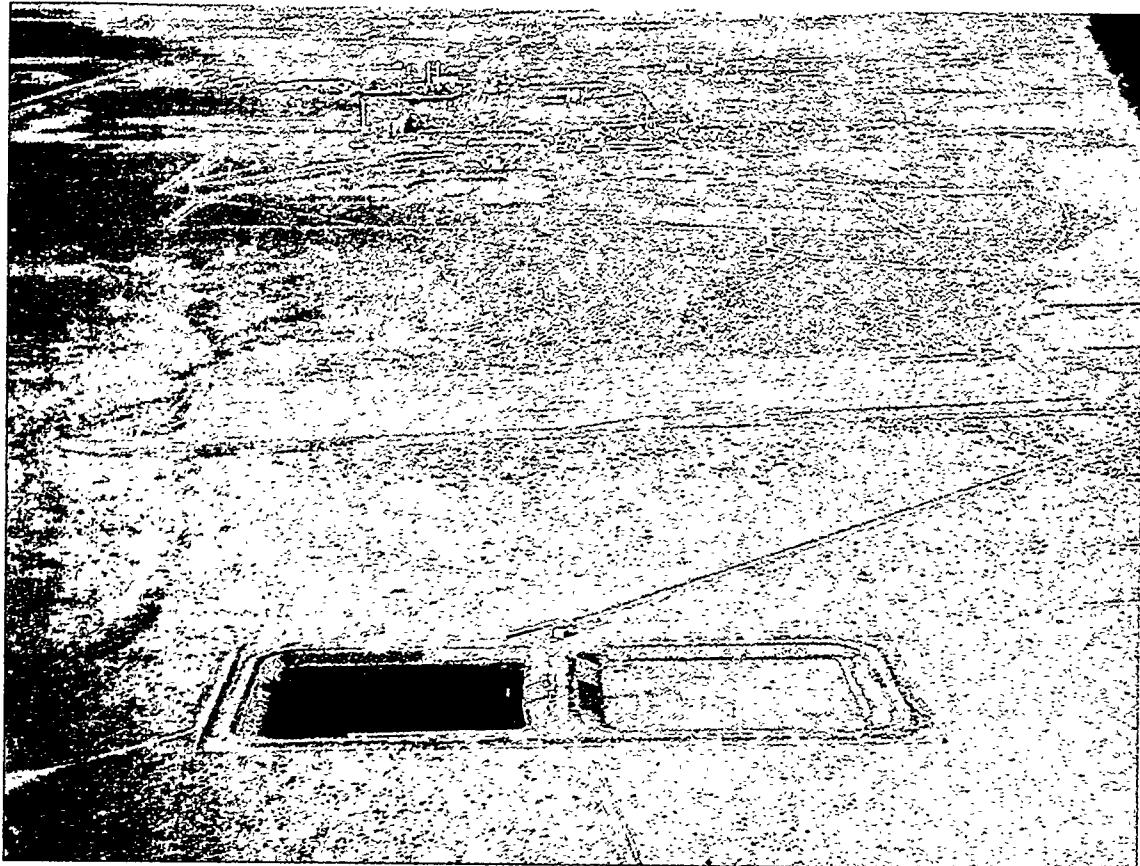


Figure 1.2. Schematic Diagram of the Effluent Collection System for the TEDF



Plates 1.1 and 1.2. (Top) Westward View of the TEDF with Southern Basin in Operation; 3C Expansion Pond of the B Pond System in Middle Distance, and 200 Areas in Background. (Bottom) Ground-Level View of TEDF Operation (Northern Basin).

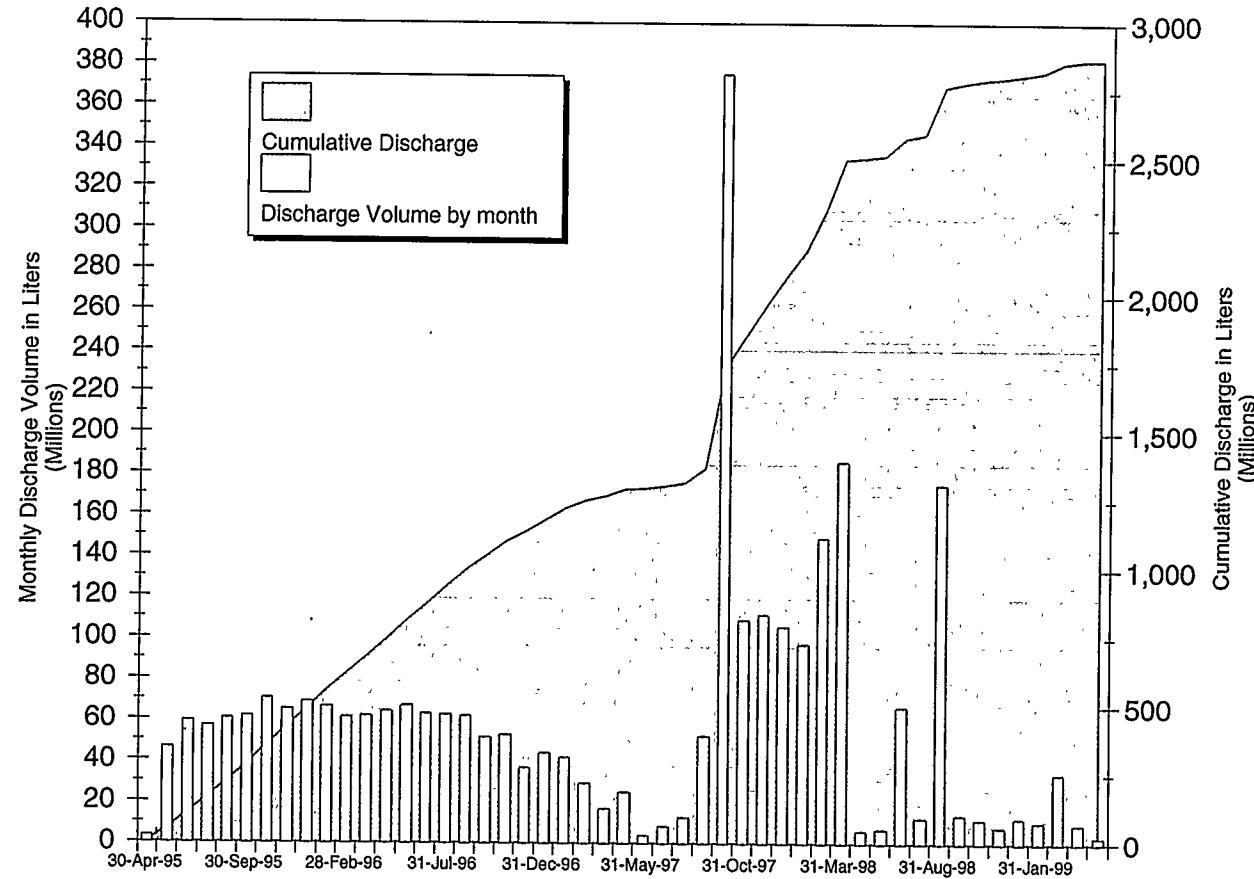


Figure 1.3. Monthly and Cumulative Effluent Discharges to the 200 Area TEDF Through April 1999

Chemical constituents of the waste stream are monitored at end-of-pipe at frequencies of one to four times per month, depending on the constituent. Flow, pH, and conductivity are monitored continuously near the discharge point. The ST-4502 (Sections S.3 and S.4) lists enforcement limits and early warning values in the effluent for several constituents of particular interest.

Analyses of TEDF effluent variability from July 1995 to April 1996 were statistically evaluated to 1) demonstrate compliance with ST-4502; 2) determine the variability of all constituents in the effluent that have enforcement limits, early warning limits, or monitoring requirements, and; 3) determine if concentrations of any of these constituents vary with season or other periodic events (Chou and Johnson 1996). Of the constituents regulated in the permit only iron and chloride were demonstrated to occur in concentrations in the effluent that may predictably exceed enforcement limits. All other constituents were shown to have less than 1 in 1 million probability of exceeding permit limits. A recent reevaluation of effluent variability, using four years of monitoring data (July 1995-June 1999) yields similar conclusions (Chou and Johnson 2000). In fact, only iron has exceeded permit limits since TEDF operations began. Iron exceedences occurred three times; during the April-to-July period of 1996, during the January-to-March period of 1997, and in June 1999. The elevated iron is thought to be a result of rust particles originating from conveyance piping.

1.3.2 Groundwater Monitoring

Groundwater monitoring at the TEDF began in late 1992 upon completion of three test wells, which were constructed as RCRA-compliant monitoring wells. From 1992 until early 1995 these three wells were monitored under the RCRA program as part of the 216-B-3 Pond System network. When operation of the TEDF began in April 1995, groundwater monitoring continued under the provisions and schedule dictated by the ST-4502. Locations of the wells (699-40-36, 699-41-35, and 699-42-37 [upgradient]) are shown in Figure 1.4. Enforcement limits are set for six constituents in the ST-4502 for the two down-gradient wells (see Sections 1.4 and 3.1). Rationale for selection of well location and well construction is discussed in Section 2.2.4. The larger, square perimeter surrounding the active basins in Figure 1.4 represents the bounds of the site evaluated during the site-selection and characterization process (WHC 1992; Davis and Delaney 1992). A expanded account of historical groundwater monitoring at the TEDF is provided in Section 1.4.

1.4 Chronology of Groundwater Monitoring at the TEDF

Groundwater monitoring in the vicinity of the TEDF began with interim-status RCRA monitoring at the B Pond System in 1988 (Figure 1.4). The wells monitored in this early effort are located near the main and 3B expansion ponds of the B Pond System (e.g., Luttrell in Fruland and Lundgren 1989). In the succeeding years, through 1992, several additional wells were installed at the B Pond System. Some of these wells are near the 3C expansion pond, immediately west of the TEDF site. Although not a formal component of the TEDF monitoring network, groundwater data from these wells has helped characterize groundwater geochemistry and hydrogeology in the general region of the TEDF. These B Pond System wells were sampled for a comprehensive list of constituents and parameters (see Appendix A.1) under the

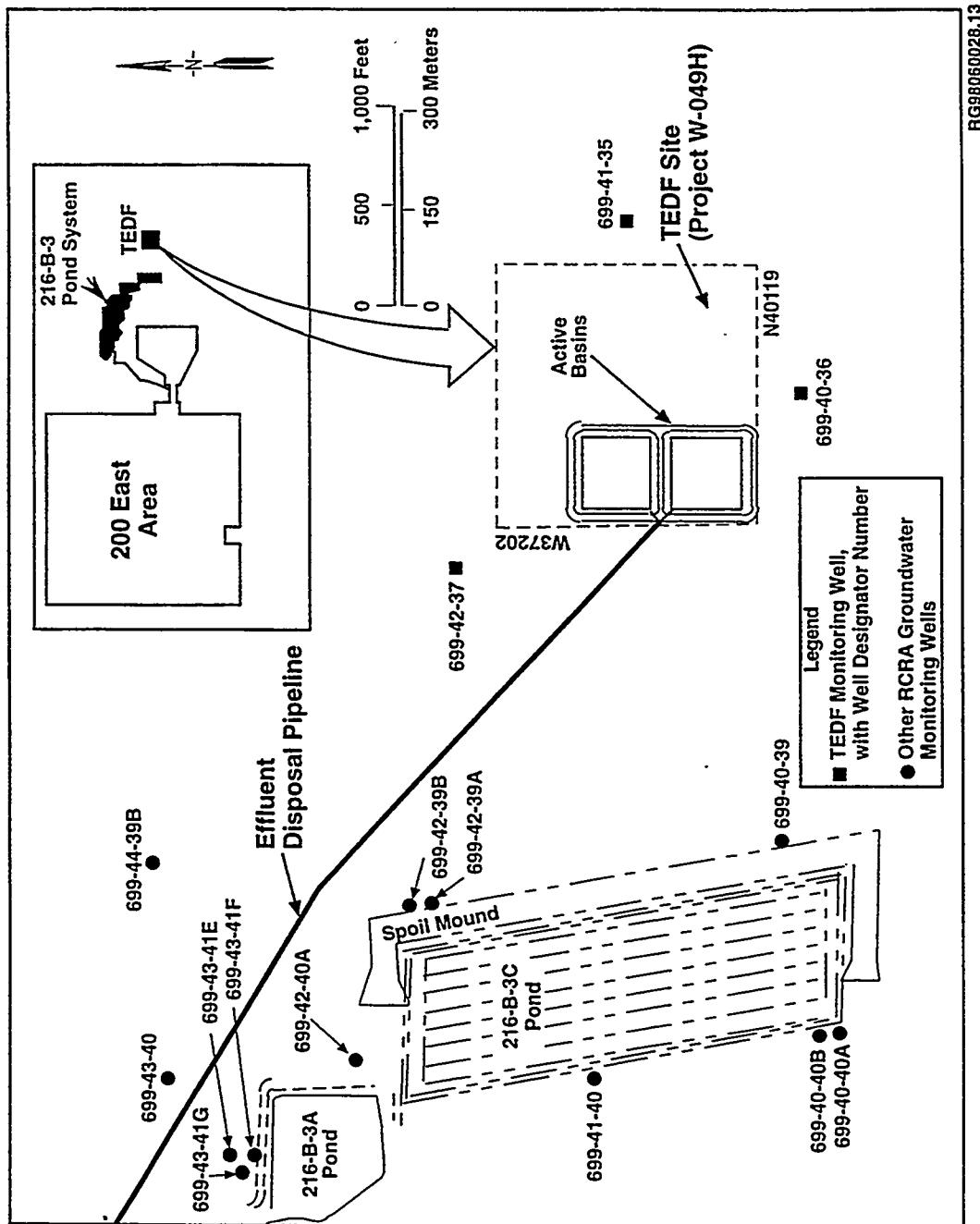


Figure 1.4. Location of Groundwater Monitoring Wells in the Vicinity of the TEDF

RCRA program. Discussions of analytical results from B Pond System wells are found in annual ground-water reports for Hanford Site RCRA facilities (e.g., DOE/RL 1993) and specific reports or plans for the B Pond System (e.g., Barnett and Teel 1997; Barnett and Chou 1998).

During 1992, three wells were installed in anticipation of TEDF construction; upgradient well 699-42-37 and downgradient wells 699-40-36 and 699-41-35. All three wells were completed as "RCRA-compliant," resource-protection wells (WAC 173-160). General construction parameters and stratigraphy for the three facility wells are shown in Appendix B. Drilling and hydrologic testing of these wells also allowed hydrogeologic characterization of the aquifer and vadose zone at this site (Davis et al. 1993). Following emplacement and testing of the three TEDF monitoring wells, it was recognized that peculiar hydrogeologic conditions existed at the site that may eventually require alternative planning for groundwater monitoring. Section 2.0 elaborates on the hydrogeologic framework of the facility and the rationale for well locations and groundwater monitoring. All three TEDF wells are hydraulically down-gradient from the B Pond System, and for this reason were included informally in this facility's well network for sampling and analysis of groundwater from 1992 through early 1995. The TEDF wells were thus sampled quarterly for the same constituents as wells in the B Pond System during this period. The constituent list for the 1992-1995 period is shown in Appendix A.1.

In May 1995, the *Groundwater Screening Evaluation/Monitoring Plan—200 Area Treated Effluent Disposal Facility (Project W-049H)* (Barnett et al. 1995) was approved by Ecology to guide groundwater sampling and analysis at the TEDF for determining pre-operational background groundwater quality. The constituents required by this document, as guided by the ST-4502, are listed in Appendix A.2. Groundwater monitoring requirements for the TEDF were initially determined to be similar to RCRA-regulated facilities (40 CFR 265, [subpart F]). Thus, the list of Table A.2 was derived from the existing RCRA program list and additional parameters approved by Ecology. The list represents a comprehensive suite of parameters for evaluating background groundwater quality at the site and screening for anomalous geochemical conditions. The list was applied quarterly until 1996.

In July 1996, the list of analytes for groundwater samples from TEDF wells was again revised following completion of 3 quarters of groundwater background evaluation under the comprehensive list. Several constituents were eliminated from the list in Table A.2, but the lists of metals and anions were somewhat expanded. Analytes consistently below detection were also eliminated from the list, and quarterly Discharge Monitoring Reports (DMRs) were adopted as a medium to track and report quarterly groundwater monitoring results from TEDF. Ecology approved these revisions in accordance with discretionary latitude provided by the ST-4502, Section S.8. The revisions resulted in the most recent list of analytes for the TEDF groundwater monitoring shown in Appendix A.3. Of the constituents in Appendix A.3, six (total trihalomethanes, 1,1,1 trichloroethane, total cadmium, total cyanide, total lead, and pH) were assigned enforcement limits in groundwater. Total trihalomethanes was also assigned an early warning criterion. Samples for these constituents and water level measurements are currently collected quarterly.

In September 1998, the report *Evaluation of Groundwater Monitoring Results at the Hanford Site 200 Area Treated Effluent Disposal Facility* (Barnett 1998) examined historical groundwater geochemical

results, and proposed recommendations for revision of the constituent list and groundwater sampling schedule. These proposed revisions are refined and incorporated into the groundwater monitoring plan in this document, described in Section 5.0.

2.0 Hydrogeology of the TEDF Site

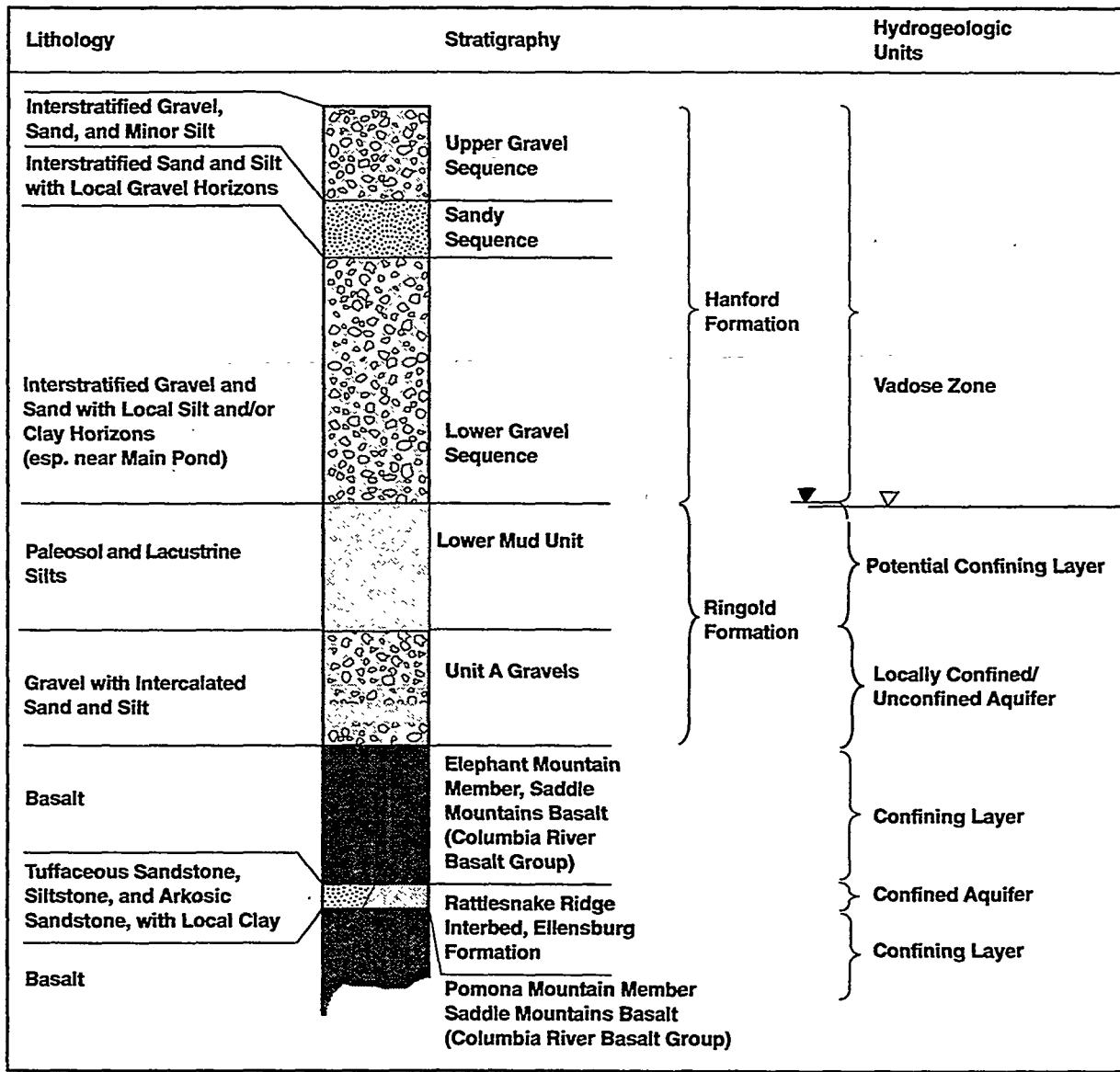
This section describes the hydrogeologic setting of the TEDF, based on historical and ongoing characterization efforts for the 200 East Area and vicinity, and studies directed specifically at the TEDF. Baseline information on the physical setting of the TEDF site was derived primarily from *Site Characterization Report: Results of Detailed Evaluation of the Suitability of the Site Proposed for Disposal of 200 Areas Treated Effluent* (Davis et al. 1993). Groundwater hydrology and related geochemistry for the site is described in detail by Davis et al. (1993), and more recent information is provided by Barnett (1998) and Hartman and Dresel (1999). Stratigraphy of the 200 East Area adjoining the TEDF is described in greatest detail by Lindsey et al. (1992) and Connelly et al. (1992). Williams et al. (2000) revisit the stratigraphy and hydrogeology of the 200 East Area and vicinity, and present a revised interpretation of groundwater flow potential in the vicinity of TEDF.

2.1 Geologic and Stratigraphic Framework

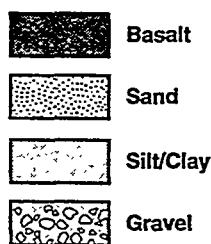
The principal geologic units beneath the TEDF include the Miocene Columbia River Basalt Group, the Pliocene Ringold Formation fluvial deposits, and the Pleistocene Hanford formation glacial flood deposits. A representative stratigraphic column of these units, as they occur beneath the TEDF, is shown in Figure 2.1. A diagrammatic cross section of the stratigraphy in the vicinity of the TEDF is shown in Figure 2.2. Appendix B also illustrates TEDF stratigraphy in the form of drilling lithologic logs for each of the three monitoring wells. Davis et al. (1993) describe these lithologic units in the vicinity of the TEDF in detail, and refer to other reports that provide additional information. A synopsis of this information is provided here.

The Elephant Mountain Member of the Saddle Mountains Formation basalt is the uppermost basalt flow of the Columbia River Basalts beneath the TEDF. Immediately beneath the Elephant Mountain basalt is the Rattlesnake Ridge sedimentary interbed, which is one of the areally-extensive sedimentary interbeds of the Ellensburg Formation. On the Hanford Site, this unit consists largely of tuffaceous sandstone and siltstone (Reidel and Fecht 1981). The Rattlesnake Ridge interbed comprises an important portion of the uppermost of several basalt confined aquifers in the TEDF area.

Ringold Formation fluviacustrine sediments average ~45 m thick beneath the TEDF and consist of (in ascending stratigraphic order): 1) unit A gravel and 2) lower mud unit. The lower mud unit and unit A correspond to units 8 and 9, respectively, of Thorne et al. (1994). The Ringold unit A gravel ranges in thickness from ~25 m in well 699-40-36, south of the TEDF to ~37 m in well 699-42-37, north of the facility. This unit is mainly composed of a silty sandy gravel with secondary lenses and interbeds of gravelly sand, sand, and muddy sands to clay/silt. In the TEDF area, a prominent stratum of silty clay occurs approximately midway between the top of unit A and the underlying basalt. Judging from the uniform occurrence of this fine-grained horizon, as represented in other wells in the area, it is probably continuous beneath the TEDF.



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▼ Potentiometric Surface

▼ Potential Perching Layer

Figure 2.1. Representative Stratigraphic Column for Suprabasalt Sediments Beneath the TEDF

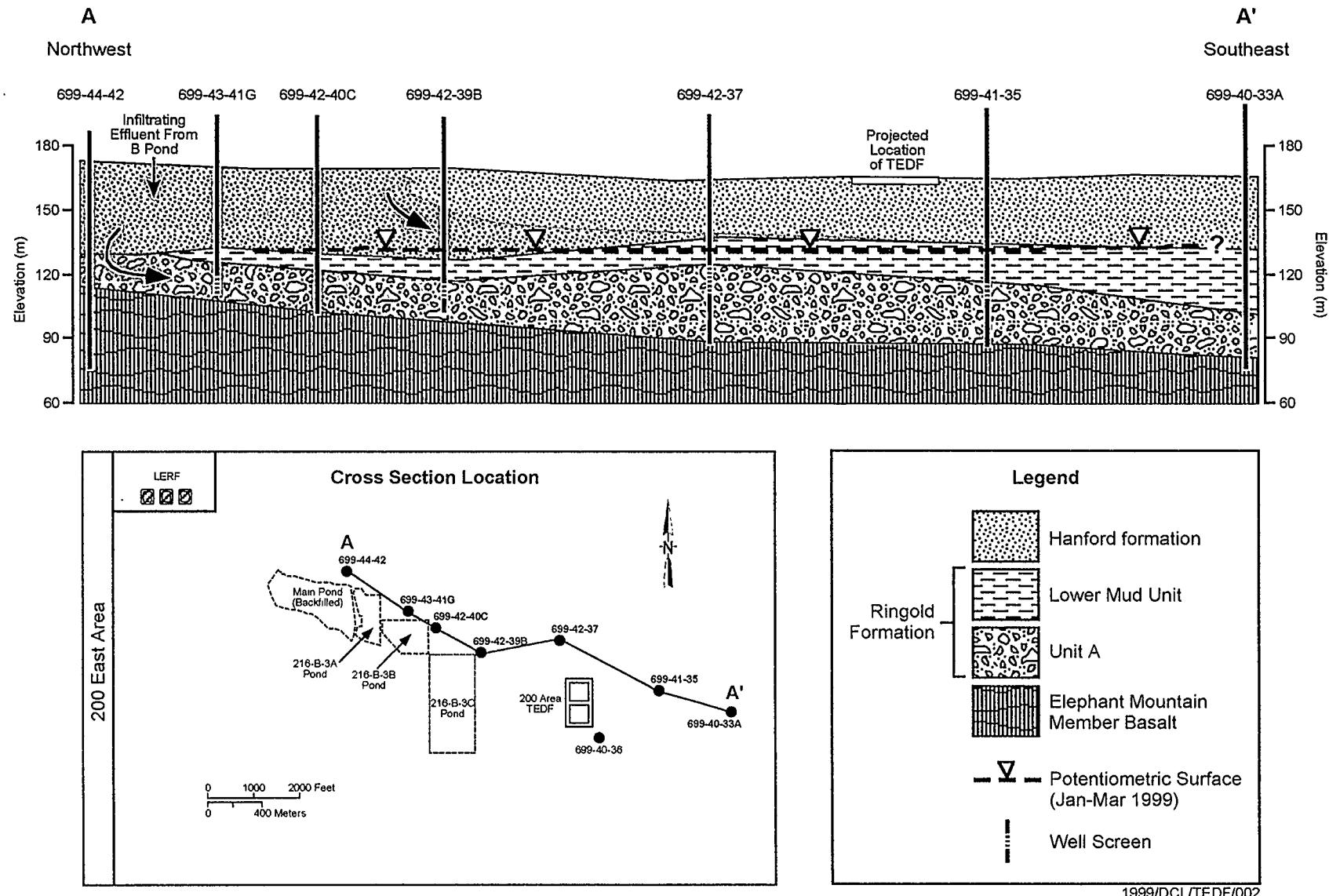


Figure 2.2. Schematic Cross Section of Suprabasalt Sediments in the B Pond/TEDF Area. Blue indicates interpreted pathways of B Pond System effluent, showing marginal penetration of effluent into the Ringold unit A aquifer. Some wells are shown for stratigraphic control only. The potentiometric surface is based on those wells in the diagram that are screened below the lower mud unit.

The Ringold lower mud sequence ranges in thickness from 26 m in well 699-40-36 (south) to slightly more than 11 m in well 699-42-37 north of the TEDF. The lower mud unit consists of clay, silt, and various mixtures of silt and clay. This unit is particularly important to effluent infiltration and groundwater hydrology beneath TEDF, and is discussed in greater detail in Section 2.2.

The Hanford formation is approximately 30 m thick beneath the TEDF. This unit (corresponding to unit 1 of Thorne et al. 1994) is represented by three facies, in ascending stratigraphic order: 1) lower gravel sequence, 2) sandy sequence, and 3) upper gravel sequence (subdivisions after Lindsey et al. 1992). All of these strata are poorly-cemented or non-cemented, and highly permeable compared with the underlying units of the Ringold Formation. A relatively thin veneer of dune sand overlies the Hanford formation to the land surface.

2.2 Groundwater Hydrology

The uppermost aquifer beneath the facility occurs primarily within sediments of the Ringold Formation, with the Hanford formation comprising the vadose zone. The Elephant Mountain basalt acts as the regional lower boundary for the uppermost aquifer. Although generally unconfined across the Hanford Site, drilling data and hydrologic tests (Davis et al. 1993) indicate that the uppermost aquifer is under confining pressure beneath the TEDF. This confinement apparently increases gradually from an unconfined condition near the main pond of the B Pond System to progressively more confined in south and southeasterly directions. Artesian head recorded during well construction ranged from ~8.5 m in upgradient well 699-42-37 to ~25 m in downgradient well 699-40-36. The implications of these conditions for TEDF operation and groundwater monitoring are discussed in Sections 2.2.4 and 4.0.

As illustrated in Figure 2.2, the potentiometric surface nearly coincides with the upper surface of the Ringold lower mud unit. Figure 2.3 is the potentiometric map for the uppermost aquifer in the vicinity of TEDF for March 1999. The hydraulic head in this region is dominated by the remnants of a groundwater mound generated from past discharges to the nearby B Pond System. This mound has been decaying since at least the late 1980's when discharges to the B Pond System were greatly reduced. This subsidence is reflected in wells throughout the area (see Barnett and Chou 1998), and is apparent in hydrographs of the three TEDF wells (Figure 2.4). A more pronounced rate of decline began in late 1996 in all three wells. The greatest rate of decline since 1996 is within upgradient well 699-42-37, presumably because this well is the nearest of the three TEDF wells to the source of the mounding.

Linear calculations of the rates of water level decline indicate that several decades of service are yet available from the TEDF wells. Based on the most recent ~1 year of data, the calculations of water level decline indicate that well 699-40-36 will have ~108 years of potential service; ~99 years for 699-41-35, and ~55 years for 699-42-37. The calculations indicate that water levels in all three wells are currently falling at a rate of about 0.3 m yr^{-1} (~1 ft yr^{-1}). An explanation of these calculations, along with related well data are tabulated in Table B.1, Appendix B.

The configuration of the potentiometric surface in the TEDF area has changed significantly during the past ~2 years. Figure 2.5 illustrates an interpretation of the potentiometric surface in June 1997, clearly illustrating the presence of the groundwater mound from B Pond System operations. Comparing 1997

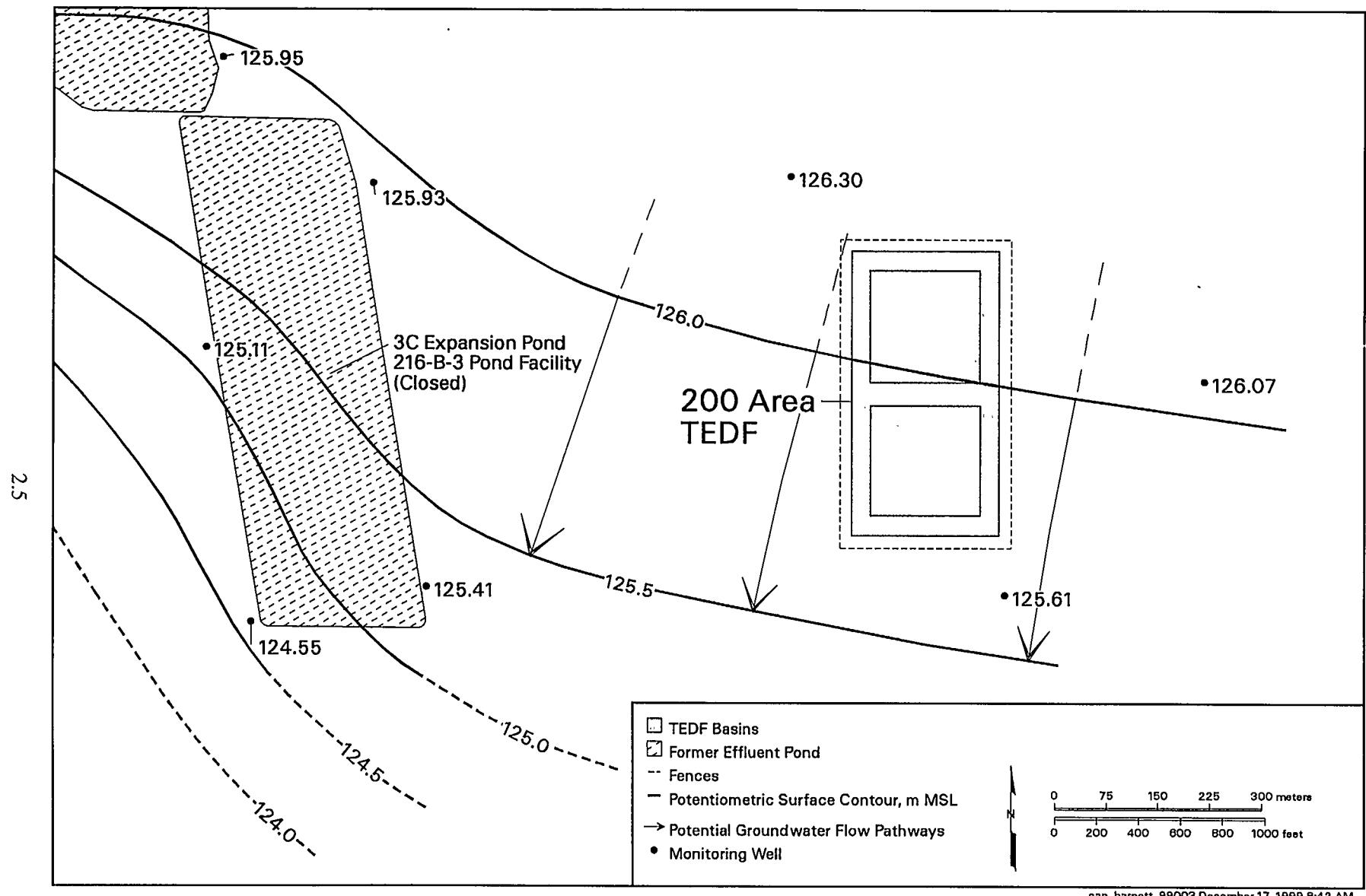


Figure 2.3. Potentiometric Map for the Uppermost Aquifer in the TEDF Area, March 1999. Arrows orthogonal to equipotential lines indicate interpreted groundwater flow direction.

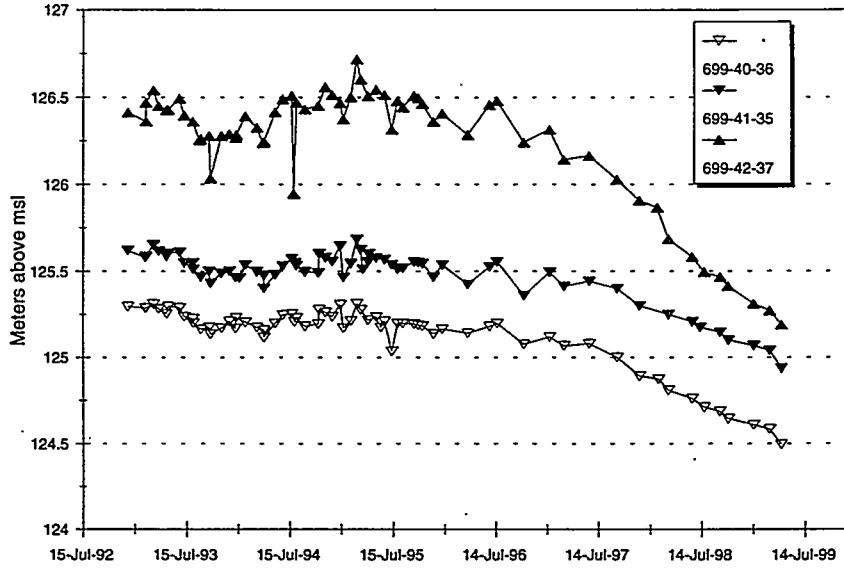


Figure 2.4. Hydrographs of TEDF Wells Through April 1999

and 1999 (Figure 2.3) interpretations indicates a shift in groundwater flow potential (orthogonal to equi-potential lines) beneath TEDF from southeast in 1997 to south-southwest in March 1999. The shift in flow potential in the uppermost aquifer has altered the relative hydraulic positions of the TEDF basins and monitoring wells. Most notably, well 699-41-35 is no longer downgradient of the TEDF with respect to the uppermost aquifer. The implications of this condition are discussed in subsequent sections.

Vertical groundwater flow potential between the uppermost aquifer and the upper-basalt confined aquifer is also changing in the vicinity of the TEDF (see Barnett 1998). Wells monitoring both of these aquifers at the nearby B Pond System suggest an impending reversal from downward to upwardly-directed flow potential between the two aquifers in the B Pond area. Hydraulic heads are falling in both aquifers, but more rapidly in the unconfined aquifer, as a result of the diminishing influence of past wastewater discharges to the B Pond System. It is possible that an upwardly-directed flow potential already exists further east, beneath the TEDF.

2.2.1 Aquifer and Vadose Zone Hydraulic Characteristics

The uppermost aquifer beneath the TEDF is hosted by the Ringold Formation unit A. Samples of this material produced saturated hydraulic conductivities (K_s) of $\sim 1.0 \text{ E-}07 \text{ cm}\cdot\text{sec}^{-1}$, but constant-rate pumping tests yield K_s values as high as $1.3 \text{ E-}03 \text{ cm}\cdot\text{sec}^{-1}$ (Swanson in Davis et al. 1993). The confined condition of the aquifer beneath the TEDF is attributed to the presence of the Ringold lower mud unit and its low degree of permeability. This 11 to 26 m-thick stratum of fine-grained sediment forms an effective aquitard and potential perching horizon. Although saturated throughout most of its vertical extent at the TEDF site, the lower mud unit probably allows very little horizontal or vertical groundwater movement. Saturated hydraulic conductivity (K_s) averaged $5.5 \text{ E-}07 \text{ cm sec}^{-1}$ in five samples of lower mud unit taken

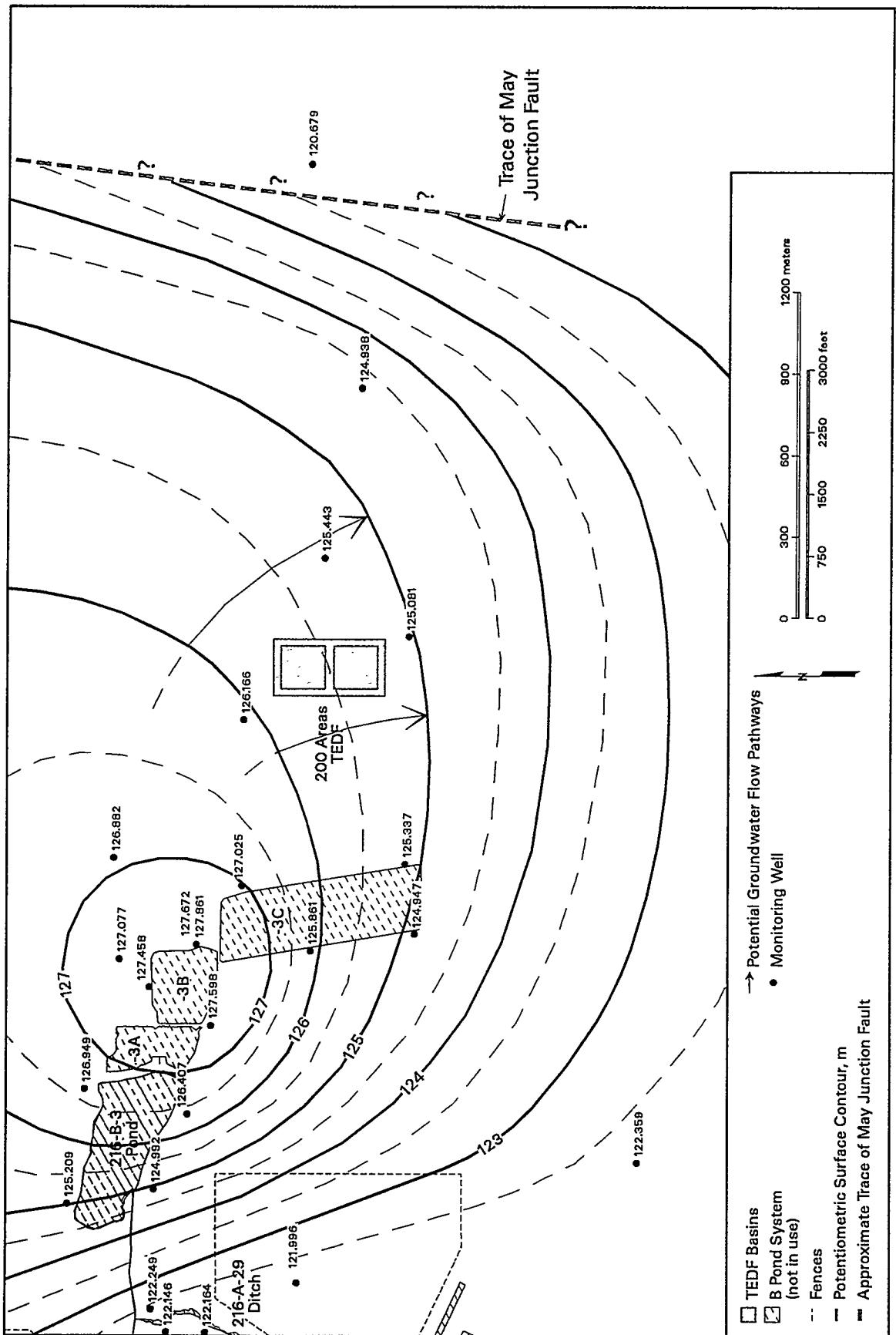


Figure 2.5. Potentiometric Map of the TEDF/B Pond Area for June 1997. Arrows orthogonal to equipotential lines indicate interpreted groundwater flow direction.

from the TEDF wells during drilling and testing (Davis et al. 1993). One lower mud K_s was estimated at $7.5 \text{ E-09 cm sec}^{-1}$. In contrast, samples from the superjacent Hanford formation produced K_s estimates as high as $1.3 \text{ E-01 cm sec}^{-1}$.

2.2.2 Groundwater Flow

Groundwater movement in the aquifer beneath the TEDF was calculated using the Darcy equation and estimates of effective porosity, hydraulic conductivity, and horizontal gradient. This relationship is denoted by $\bar{v} = K_s J/n_e$, where \bar{v} is the horizontal component of average linear flow velocity, K_s is the saturated hydraulic conductivity, J is the horizontal component of hydraulic gradient, and n_e is the effective porosity of the aquifer material. By this method, average linear flow velocity was estimated in 1995 to be from 0.03 to 0.6 m day^{-1} in a southeasterly direction (Barnett et al. 1995). Using a recent estimate of hydraulic gradient (J) beneath the TEDF of ~ 0.001 (from March 1999 water level measurements in the TEDF wells), the most reliable parameters for K_s derived from constant-rate pumping tests by Swanson in Davis et al. (1993) of 3.6 ft/day ($1.3 \text{ E-03 cm sec}^{-1}$), and an n_e of 0.25 (Graham et al. 1981; Graham et al. 1984; Cole et al. 1997), produces an average linear flow velocity of $\sim 0.004 \text{ m/day}$. Contouring of hydraulic head in the region immediately surrounding TEDF for March 1999 (Figure 2.3) indicates a south-southwesterly directional flow potential beneath the TEDF.

2.2.3 Summary of Groundwater Modeling Results

Numerous conceptual and numerical groundwater models with direct or indirect implications for TEDF operation have been published during the last several years. Studies with the entire Hanford Site or large portions thereof as a focus produced conceptual hydrogeologic models for the unconfined aquifer system (e.g., Connelly et al. 1992; Thorne et al. 1994). Other studies provide predictive numerical simulations of groundwater and contaminant movement in the unconfined aquifer system on the Hanford Site, which include the area of the TEDF (e.g., Chairamonte et al. 1996; Cole et al. 1997). Three groundwater numerical simulations were conducted specifically for the TEDF prior to the beginning of operation. This section summarizes the salient results of these numerical simulations and the broader predictions yielded by other applicable site-wide groundwater models.

2.2.3.1 Large-Scale Modeling Predictions Involving the TEDF Area

Recent Hanford Site-wide groundwater numerical modeling efforts have focused on prediction of future water table configurations, flow paths across the site from various sources, and contaminant-transport potential. Protection of the Columbia River from potential Hanford Site contamination sources is the ultimate aim of the studies.

Chariamonte et al. (1996) used the *Variably Saturated Analysis Model in Three Dimensions with Preconditioned Conjugate Gradient Matrix Solvers* (VAM3DCG) finite element code (developed by HydroGeoLogic Inc., Herndon, Virginia) to simulate groundwater flow and contaminant transport across the Hanford Site for a period of 200 years, beginning with 1995. Assumptions included a combined B Pond/TEDF discharge of 820 gpm ($3,105 \text{ liter/min}$) for 30 years (about twice the rate of actual average annual discharge thus far—see Section 1.3.1). Results of this model indicated the presence of a hydraulic

mound in the B Pond/TEDF area influencing groundwater flow in this region through at least the year 2015. During this period, groundwater (represented by instantaneous velocity streamlines) appears to flow slowly southward ~1-2 km from the B Pond/TEDF area before turning eastward and accelerating toward the Columbia River. After 2015, flow across this area is predicted to be nominally west to east, without any apparent remnant effects of TEDF/B Pond discharges. Predictions for the year 2005 (ten years into the simulation) show that effluent originating from the TEDF/B Pond area appears to take >120 years to reach the Columbia River. By 2015 and subsequent years, groundwater movement along this flowpath is shown to consume in excess of 300 years to reach the river. Decreased head and lowering of the water table into the less permeable Ringold Formation causes the apparent, progressive slowing of groundwater flow in some areas.

In 1997, Cole et al. used the three-dimensional Coupled Fluid, Energy, and Solute Transport (CFEST) code (Gupta et al. 1987) to predict groundwater contaminant plume movement and the potential effects of low-level waste disposal on the Hanford Site. The model assumes an average discharge to the TEDF of 3409 m³/day (2,367 liters/min) from 1997 through 2026 (~1,021 liters/min more than the actual average thus far—see Section 1.3.1). Results of the simulation suggest that the water levels in the unconfined aquifer beneath the B Pond facility, immediately west of the TEDF, will drop as much as 4 to 10 m over the modeled period of 350 years. On a Hanford sitewide scale, groundwater flow in the vicinity of the TEDF is shown to maintain a generally southeasterly direction until far into the future; presumably because of remnant effects of discharge to the TEDF. By year 2350, the model forecasts that the flow in this area has resumed a pre-Hanford west-to-east direction toward the Columbia River.

2.2.3.2 TEDF Site Groundwater Modeling Results

The first site-specific simulation was conducted as a part of the final site-selection process for the TEDF. McMahon (in Davis 1992) used *MODular three-dimensional difference groundwater FLOW model* (MODFLOW) to estimate the hydrologic effects of TEDF operation at four locations on the Hanford Site, including the location east of the B Pond System where the TEDF now resides. The three-layered model, representing the Ringold unit A, Ringold lower mud unit, and Hanford formation, used two alternate values each for hydraulic conductivities in the Hanford formation and Ringold lower mud unit, and two alternate TEDF discharge scenarios. The higher, assumed value for hydraulic conductivity in the Hanford formation (10,000 ft/d) coupled with the lowest assumed discharge rate (5,670 L/min [1,500 gpm]) resulted in a barely-perceptible simulated groundwater mound beneath the facility. Conversely, when the lower value for hydraulic conductivity (1,000 ft/d) was combined with the highest discharge scenario (56,700 L/min [15,000 gpm]), the simulation produced a groundwater mound approximately 3 m high beneath the TEDF in the uppermost aquifer. Results indicated that groundwater mounding would occur beneath and north of the TEDF, and that this mound “would tend to block flow toward the Columbia River from the B Pond Complex...”. It was this expectation of mounding, and the consequent beneficial blocking of potential contaminant plumes from the 200 East Area and vicinity from reaching the Columbia River, that contributed to the selection of the current TEDF site.

In 1993, McMahon, in Davis et al. (1993), used a VAM3DCG model to estimate travel times of TEDF effluent to the Columbia River within a 40-year simulation period (30 years of operation and 10 years of reequilibration). McMahon simulated four scenarios—a combination of two average annual

discharge rates at TEDF, 2,270 and 8,700 L/min (600 and 2,300 gpm), and two average combined annual discharge rates at the 3B and 3C expansion ponds of the B Pond System; 265 and 795 L/min (70 and 210 gpm). In reality, discharges to the expansion ponds were permanently discontinued in August 1997. Results from the four simulations produced a relatively narrow range of effluent travel times from the TEDF to the Columbia River; 8 to 9.7 years. However, the scenarios using the higher discharge rate to the TEDF (8,700 L/min [2,300 gpm]) resulted in a substantially larger hydraulic mound in the area of the facility than did the lower discharge estimate (2,270 L/min [600 gpm]). The larger discharge scenario also predicted a large hydraulic mound would develop in the unconfined aquifer just north of the TEDF, particularly in the Hanford formation. The lower discharge estimate produced a barely perceptible mound. Discharges of 265 to 795 L/min (70 to 210 gpm) to the B Pond System had no material effect on the mound size or travel times. Ten years after simulated discharges to the TEDF ceased, a small mound still remained with the higher discharge scenario. Within the anticipated range of long-term (permitted) rates of discharge (at that time ~2,820 L/min [745 gpm]), travel time to the Columbia River was predicted to be 9.6 years (current permitted rates of discharge are now 4,500 L/min (1,200 gpm) (see Sections 1.2 and 1.3). The model also predicted that the existing groundwater mound beneath the B Pond System (see Figure 2.5) would become unrecognizable within 10 years of the beginning of TEDF operations.

Collard, in Barnett et al. (1995), combined the low-volume scenario (2,270 L/min [600 gpm]) of the McMahon VAM3DCG model (Davis et al. 1993) with constituent transport information to predict travel of potential contaminants from the TEDF under steady-state conditions. Using empirically-derived coefficients of distribution (K_d) and constituent half-lives, Collard generated Factors of Attenuation and Dilution Efficacy (FADE) for several constituents of concern at the TEDF, including metals and organic compounds. With K_d values ranging from near 0 mL g^{-1} for very conservative (mobile) species (e.g., sulfate or nitrate) to 30 mL g^{-1} for relatively non-mobile species (e.g., iron, manganese), Collard predicted breakthrough (the point in the system at which 0.1% of the initial concentration is observed) times to the bottom of the vadose zone from <1 year to >2,000 years, depending on the mobility of the species and horizontal distance from the TEDF. Breakthrough times for the top of the aquifer ranged from 42 years for the most conservative species at an observation point closest to the facility to 7,200 years for a $K_d = 30$ species 200 m downgradient of the facility. In summation, Collard states that FADE values for even the relatively coarse-grained Hanford formation provides "significant" protection of the uppermost aquifer, and notes that the FADEs would likely be orders of magnitude larger if transient, instead of steady-state, conditions were applied. In Collard's assessment, very little risk is posed to the aquifer by a hypothetical contaminant release from the facility, even in quantities far exceeding those reasonably expected in an unplanned release.

2.2.4 Discussion of Hydrogeology and Modeling Predictions

Hydrogeology. Williams et al. (2000) surmise that although head response in the TEDF wells and other nearby wells in the confined portions of the uppermost aquifer reflect the pressure effects of the B Pond System, the actual movement of groundwater (or effluent) from B Pond operation has been minimal in the direction of the TEDF. A major portion of infiltrating B Pond System effluent was either intercepted by the Ringold lower mud unit ("umbrella effect") and then moved south-southeastward along the top of this unit in the Hanford formation, or was diverted southwestward into more permeable units immediately south of the main pond. Very minimal migration has apparently occurred within the

confined portion of the uppermost aquifer in the vicinity of the TEDF (see Figure 2.2). This is substantiated by the low groundwater flow rate calculated for the aquifer beneath TEDF ($\sim 0.004 \text{ m day}^{-1}$) and the fact that tritium and other conservative constituents have remained virtually unchanged in concentration (allowing for decay/dilution) in some wells northwest of the TEDF near the B Pond System. Additionally, geochemical evidence from these wells support the supposition that groundwater in the vicinity of the TEDF is comparatively stagnant or flowing at a very slow rate (see Section 3.1.2). Apparent changes in directional flow potential beneath the TEDF indicated between 1997 and 1999 (Figures 2.3 and 2.5) are likely the result of the subsidence of the B Pond groundwater mound and the consequent relief of hydrostatic pressure within the confined portion of the aquifer.

Thus far, no hydraulic effects resulting from TEDF discharges have been detected in groundwater wells. Given the extreme contrasts in hydraulic conductivities between the Hanford formation and the underlying Ringold lower mud unit, it is reasonable to assume that TEDF effluent is mostly, if not wholly, restricted to movement in the Hanford formation vadose zone sediments immediately above the lower mud unit.

Groundwater Modeling. Because no hydraulic or other effects from the TEDF have yet been observed in groundwater, accuracies of model predictions concerning TEDF operational effects are not strictly verifiable. However, based on a refined understanding of the hydrogeology in the TEDF region that has been gained in recent years, some reevaluation of the models and their assumptions in portraying groundwater flow is possible.

Actual discharge volumes to the TEDF have been substantially less, thus far, than assumed in modeling efforts. This factor may have some minor bearing on the lack of model accuracy. By far a larger factor, however, are the hydrostratigraphic assumptions—i.e., to which stratigraphic unit(s) the effluent from TEDF will actually migrate and where lateral flow will occur. To illustrate this; predicted travel times from the TEDF region to the Columbia River are considerably longer in the site wide models than in site-specific models by McMahon. This is primarily because McMahon used the high hydraulic conductivities associated with the Hanford formation in calculating flow rates. Conversely, the site-wide models assume that flow occurs predominantly within the Ringold Formation near the TEDF area, resulting in greatly increased travel times.

Predictions of mounding in the uppermost aquifer by some models, due to TEDF discharges, have not been borne out thus far, primarily because of incorrect hydrostratigraphic assumptions. It was proposed by Davis (1992) that TEDF mounding could provide a protective hydraulic barrier from the effects of B Pond System discharges moving toward the Columbia River. This proposal was apparently based on the assumption that the lower mud unit did not materially separate the confined aquifer in the Ringold Formation from the Hanford formation. However, site characterization showed that only traces of perched water existed in one well (699-40-36) in the Hanford formation (vadose zone) at TEDF, and that the uppermost aquifer was confined within the Ringold unit A by the lower mud unit. No monitoring points are available in the Hanford formation near the TEDF discharge point to detect any potential mounding in that unit. However, in view of the high hydraulic conductivities of the Hanford formation at this location and lower-than-predicted TEDF discharge rates, it is doubtful that significant mounding has occurred.

The model by Collard (Barnett et al. 1995) is the only TEDF model that incorporates constituent transport and calculates retardation of hypothetical contaminants. No contaminants are disposed to the TEDF; transport modeling was performed merely as a risk-evaluation measure. A high degree of conservatism is built into the model, most notably that it relies on steady-state conditions rather than transient. Also, a large hydraulic head was assumed to exist above the lower mud unit, and factors of attenuation were purposely downplayed. Despite these assumptions the model indicated that even the Hanford formation would provide a high degree of protection from contamination entering the uppermost aquifer. The separation of the TEDF effluent and the uppermost aquifer by the lower mud unit provides an even greater degree of protection.

2.2.5 Hydrogeologic Rationale for Monitoring Well Locations

When the three facility wells (699-40-36, 699-41-35, 699-42-37) were drilled, it was discovered that the Ringold Formation lower mud unit formed an essentially impermeable layer at the base of the vadose zone, and that this unit was also a confining horizon for the uppermost aquifer beneath the TEDF (see discussion in Section 2.2.1). Only a trace of perched water was discovered in one well (699-40-36) immediately above the lower mud unit. When this unit was penetrated, the static water level rose in each well to near the top of the lower mud, representing an artesian head of ~15 m (45 ft) in upgradient well 699-42-37 to ~21 m (70 ft) in downgradient well 699-40-36. Provisions were discussed for installation of additional monitoring points should such a layer be discovered during well installation (Davis and Delaney 1992). However, after consultation with regulators, it was decided that the existing, uppermost aquifer was the correct point of compliance for groundwater, and that the lower mud unit would serve as an additional protective feature for the uppermost aquifer in the vicinity of the TEDF. Monitoring groundwater in this aquifer would help confirm the integrity of the lower mud unit and its continued effectiveness in preventing direct migration of TEDF effluent into the uppermost aquifer. Thus, these wells are screened below the Ringold Formation lower mud confining unit and monitor groundwater in the upper portion of the Ringold Formation unit A gravel. Because the TEDF is located hydraulically downgradient of the B Pond System, an upgradient well and two downgradient wells were selected to differentiate the effects of TEDF operation from the potential effects of B Pond System operations.

Figures 2.3 and 2.5 illustrate that the direction of groundwater flow (or potential for flow) beneath the TEDF has recently changed significantly. Well 699-41-35 is no longer downgradient with respect to the TEDF and the uppermost aquifer. However, well 699-42-37 remains upgradient of the facility and the two downgradient wells. It is recognized in the previous section that none of the three TEDF wells have been in the potential flow path of effluent discharged from the facility, but are completed in the uppermost aquifer in the immediate vicinity of the TEDF; this aquifer being isolated from the TEDF effluent by the low-permeability Ringold lower mud unit. Thus, these wells are used to demonstrate that no direct routes to groundwater exist between the TEDF discharge basins and the uppermost aquifer. This application of the wells is not altered by the change in flow potential in uppermost aquifer. Because the TEDF effluent presumably spreads laterally (or "radially") across the surface of the lower mud unit, the TEDF wells will still be capable of detecting an incursion of effluent if it occurs across the lower mud unit in the vicinity of the TEDF. Well 699-42-37 is still upgradient of the facility, and will help in providing data to discriminate between the effects of TEDF and any upgradient sources (i.e., B Pond System).

3.0 Groundwater Geochemistry

To date, over 15,000 groundwater geochemical results have been produced from the TEDF wells. Most of these results were recently evaluated by Barnett (1998). That document examined analytical results for all constituents reported at least once above Practical Quantitation Limits (PQL) in the three wells since groundwater monitoring began at the facility in 1992, through March of 1998. Major ion concentrations in the groundwater in the vicinity of TEDF were examined to compare groundwater geochemical characteristics with average hydrogeochemical conditions elsewhere in the unconfined aquifer, and to determine if TEDF or B Pond System effluent had affected groundwater beneath the facility. The combined results of the 1998 evaluation and an updated discussion including groundwater analytical results through April 1999 are presented in this section. The complete range of these data, including non-detections, can be viewed through the Hanford Environmental Information System (HEIS). Data collected since 1995 may also be viewed through the Liquid Effluent Monitoring Information System (LEMIS) in conjunction with discharge chemistry.

3.1 Summary of Comprehensive Data Evaluation

As discussed in Section 1.4, the constituent list for sampling and analysis of groundwater at TEDF has changed significantly since groundwater monitoring began at the TEDF in 1992. The results of comprehensive groundwater analyses from the three TEDF wells, beginning with the first background sampling program in 1992 through March 1998, were evaluated by Barnett (1998), with emphasis on results since 1995. The results were tabulated to show the number of analyses obtained, maximum, and mean values, and standard deviation of results. A recapitulation of relevant portions of the 1998 evaluation is presented here with an updated tabulation and discussion, incorporating analytical results through April 1999. The tabulation consists of all constituents with at least one result above the PQL listed in the original, comprehensive list of constituents for TEDF groundwater monitoring (Appendix A.2). These results are compared with applicable enforcement limits (ST-4502) and existing Hanford Site background values derived by Johnson (1993) and DOE/RL (1997), and are presented in Appendix C.

None of the constituents and parameters with enforcement limits in the ST-4502 have ever exceeded early-warning values, enforcement limits, or PQLs. Constituents with enforcement limits, and the maximum detected concentrations through April 1999, are as follow:

total trihalomethanes (no detections—48 analyses; PQL = 20 µg/L)
1,1,1 trichloroethane (no detections—83 analyses; PQL = 5 µg/L)
total cadmium: maximum = 1.41 µg/L, April 1999, well 699-41-35; (PQL = 5 µg/L)
total cyanide: maximum = 31.4 µg/L, Oct. 1996, well 699-40-36 (PQL = 50 µg/L)
total lead: maximum = 4.6 µg/L, July 1995, well 699-40-36 (PQL = 10 µg/L)
pH: (all within range [6.5 to 8.5]).

Total trihalomethanes (the sum of CHCl_3 , CHBrCl_2 , CHBr_2Cl , and CHBr_3) is the only parameter assigned an early-warning value for groundwater in the ST-4502. Thus far, all analytical results for this parameter have been below the PQL (20 $\mu\text{g/L}$), and hence, well below the early-warning value of 50 $\mu\text{g/L}$.

Average values for dissolved metals in groundwater samples from TEDF wells are mostly below Hanford Site provisional background levels as determined by Johnson (1993) and by DOE/RL (1997). Some metals, notably chromium, manganese, and iron, have periodically exceeded primary or secondary Drinking Water Standards (DWS) in all three wells in either filtered or unfiltered samples. Elevated levels of these metals have been attributed to well construction materials and natural aquifer conditions, and are generally observed across the Hanford Site (Johnson 1993). Upgradient well 699-42-37 has the greatest number of highest averages for metals between the three TEDF wells. However, most metals are within, to significantly below, sitewide background values. Calcium and magnesium concentrations in TEDF wells are only a fraction of sitewide background.

Average concentrations of aluminum, in all three TEDF wells from both filtered and unfiltered samples, substantially exceed background values for this metal. These elevated averages reflect a period of anomalous results reported for all three wells for the January and April sampling periods in 1994. Without these anomalies, the averages for aluminum would be nominal with background values.

Total metals results are predictably higher than those for filtered samples for most metals. The exception to this is calcium averages in well 699-41-35, which reveal a slightly higher average for filtered samples than for unfiltered. The plausible explanation for this occurrence is that all calcium is dissolved, and the range of error is large enough in both types of analyses that the average for filtered results falls coincidentally (albeit slightly—<2%) above the unfiltered results. Averages for both calcium and magnesium in all three TEDF wells are significantly lower than sitewide background values.

Anions (chloride, nitrate, and sulfate) are also notably higher in well 699-42-37 than in the two downgradient wells. The average result for nitrate is roughly an order of magnitude higher in this well than in 699-41-35 and 699-40-36. Likewise, the average for sulfate is 4 to 5 times higher in well 699-42-37 than in the two downgradient wells. These higher nitrate and sulfate averages approach average values observed in the nearby B Pond System wells to the immediate northwest (see Figure 1.4 for location). However, anion averages in all three wells are still far below sitewide backgrounds provided by Johnson (1993) and DOE/RL (1997). Additional calculations and comparisons of ionic concentrations are presented in Section 3.2.

Few organic constituents have been detected in TEDF wells. Those listed in Tables C.1 through C.3 are mostly attributed to common laboratory contaminants, with some exceptions. In early 1993, traces of motor oil or fuel were supposedly observed by field crews on a pump removed from well 699-40-36. Subsequent total oil and grease analyses indicated elevated levels of this constituent in a groundwater sample from this well. When groundwater monitoring began under the ST-4502 in 1995, initial results for oil and grease were reported as below detection. In the July 1995 sampling event, all three wells around the facility showed elevated levels of oil and grease. This constituent remained elevated in these wells until April 1996, whereupon all results fell to below detection simultaneously in all three wells and

have remained so since. Analyses of gasoline produced only one result above detection; this occurred in well 699-41-35, also in July 1995. The supposed source of the contamination was never resolved, but was thought to be related to equipment used to remove the pumps from the wells in preparation for hydrologic testing. These parameters have remained on the list of constituents for groundwater sampling at the TEDF. However, the coincidental disappearance of detectable oil and grease from all three wells at the same time draws into question the validity of earlier results or sample integrity.

Several radionuclides or radionuclide indicators were sought in the comprehensive list of Appendix A.2, but only radium, uranium, gross alpha, and gross beta have produced results above contract detection limits (CDL). Gross alpha and gross beta averages fell below background for all wells, but maximum results in each well exceeded gross alpha background, and maximum results for gross beta exceeded background in well 699-40-36. This well displayed coincident events of elevated gross alpha and gross beta in early 1994. Higher-than-average values of gross alpha also occurred during this period in wells 699-41-35 and 699-42-37. Gross beta values appear to generally decrease in all three wells beginning in early 1994. An anomalous gross beta result (23 pCi/L) was also produced in October 1998 from well 699-42-37, but a duplicate analysis on the same date produced a result (3.2 pCi/L) in line with historic averages. No specific alpha (e.g., U or ^{226}Ra) or beta emitters were identified during the periods of elevated gross alpha and gross beta. Furthermore, all results for ^{226}Ra and most results for U are below Johnson's (1993) provisional background values for these radionuclides, and all results for U and most results for gross alpha and beta are below sitewide backgrounds defined by DOE-RL (1997). Problematic detections occurred for ^{125}Sb (15.2 ± 14.9 pCi/L—well 699-42-37) and ^{137}Cs (7.13 ± 5.4 pCi/L—well 699-41-35) during 1993 (prior to TEDF operations), but detections of these radionuclides were isolated and not correlatable to gross beta results.

Tritium had not been detected in any of 52 analyses that were performed on groundwater from the TEDF wells from late 1992 through early 1998. Beginning in July 1998, tritium analyses were performed annually on samples from the three wells and TEDF end-of-pipe discharge using low-detection methods. Results for tritium in all three wells were near or below minimum detectable activities (MDA). The highest groundwater result thus far (8.69 ± 2.26 pCi/L) was obtained from well 699-42-37 in July 1999. Well 699-41-35 produced a maximum result of 6.54 ± 2.24 pCi/L and in well 699-40-36 results have all been below MDA (MDA average = 4.90 pCi/L). These levels of tritium activity are considered exceptionally low for the suprabasalt aquifer system, which has an estimated background concentration of 102 pCi/L (DOE/RL 1997). The end-of-pipe discharge sample from 1998 produced a result of 65 ± 11 pCi/L tritium, which is within the expected range of activities for Columbia River water near the Hanford Site (Dirkes and Hanf 1998). The maximum end-of-pipe result for 1999 was 133 ± 6.8 pCi/L.

3.2 Major Ion Chemistry

Averaged results for major ionic species in groundwater (Na+K, Ca, Mg, Cl, HCO_3^- , and SO_4^{2-}) were calculated and plotted in milliequivalents as Stiff diagrams for 12 wells in the vicinity of TEDF and for TEDF effluent (Figure 3.1). The results of these calculations showed that: 1) bicarbonate dominates the anion abundance in all wells examined; 2) effluent from the TEDF closely resembles groundwater from wells 699-42-40A and 699-44-39B, with notably lower Na+K and HCO_3^- proportions compared with

other wells in the vicinity; and 3) wells in the south to southeast portion of the map have a higher proportion of Na+K cations than those to the west and northwest.

With the exception of wells 699-42-40A and 699-44-39B, ionic concentrations for the wells in the vicinity of the TEDF and B Pond appear to be generally representative of groundwater at these locations over the averaged periods for the wells. Well 699-42-40A is an older well located near the discharge site for effluent sent to the 216-B-3C expansion pond during the past 4 years (discontinued in August 1997). It is likely that this well, and possibly well 699-44-39B, have been significantly affected by dilute discharges to the pond. A check of charge balance showed a slight electrical imbalance in groundwater in wells 699-40-33A and 699-41-35, but not great enough to invalidate the analyses (Barnett 1998).

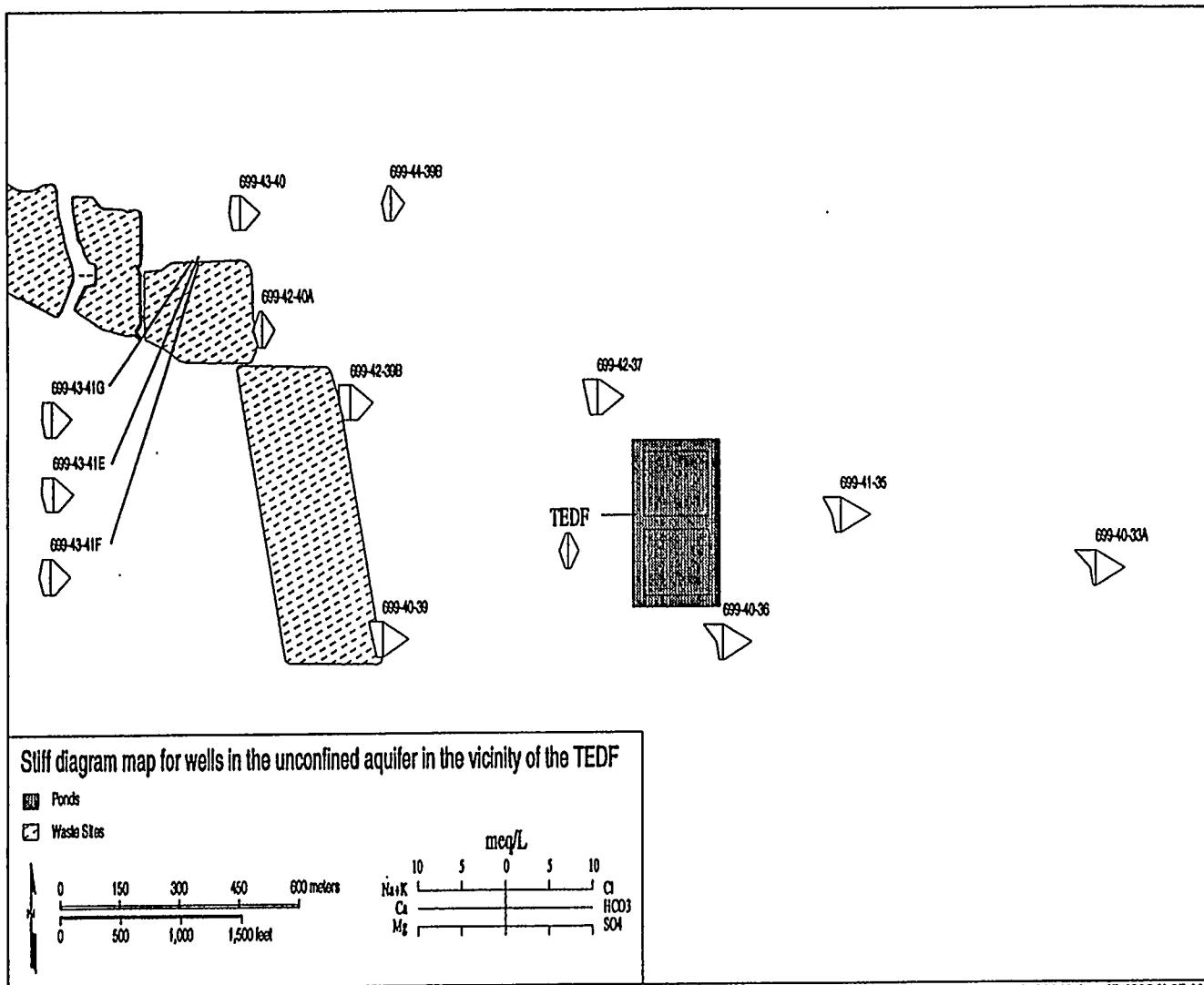
3.3 Discussion of TEDF Groundwater Geochemistry

Groundwater in wells nearest the B Pond System is predominantly of a calcium-bicarbonate type, but southward and eastward of this area, particularly east of TEDF, sodium-bicarbonate becomes more dominant. Johnson, in DOE-RL (1992), and Spane and Webber (1995) describe major ion chemistry from the upper basalt confined aquifer system. These two studies indicate that groundwaters from the upper basalt confined aquifer system are predominantly sodium-bicarbonate waters, particularly in eastern portion of the Hanford Site. Johnson (DOE 1992) also notes that with increased age of the groundwater, sodium bicarbonate waters become predominant in the confined aquifer system. Stiff diagrams constructed for several wells in this aquifer system closely resemble the gross proportions of Stiff diagrams around and east of the TEDF.

Except for areas near the center of the hydraulic mound generated by the B Pond System (see Figure 3.6), the vertical component of hydraulic potential in the eastern portion of Hanford Site is directed upward, from the upper basalt confined system to the unconfined aquifer (Spane and Webber 1995). Webber^(a) has suggested that similarities in the major ion chemistry between waters from some wells in the Rattlesnake Ridge Interbed confined aquifer and those within wells near TEDF may indicate discharge of groundwater from the upper basalt confined system to the unconfined aquifer. This could occur through structural discontinuities in the basalt, at the base of the unconfined aquifer. Alternatively, this chemistry may reflect a relatively stagnant condition within this portion of the uppermost (Ringold Formation) aquifer, thereby promoting an in-situ evolution of the groundwater chemistry.

Ionic strength and total dissolved solids (TDS) are lowest in both the effluent discharged to the TEDF and groundwater sampled from wells 699-42-40A and 699-44-39B. These wells are near the former discharge point of effluent sent to the B Pond System for the past few years, and near an interpreted area of discontinuities in the Ringold lower mud unit. Discharge to that facility ended in August 1997 (see Section 1.2), and the effluent was redirected to the TEDF. In fact, most effluent now sent to TEDF is of the same (non-contaminated) origins as that formerly sent to the 3C expansion pond of the B Pond System. Hence, it is expected that the ionic character of groundwater near the former discharge point at the B Pond facility resembles that for the end-of-pipe at TEDF (Figure 3.1).

(a) W. D. Webber personal communication.



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Figure 3.1. Stiff Diagrams for Wells in the Uppermost Aquifer in the Vicinity of the TEDF

Elevated nitrate concentrations and tritium activities in groundwater within the upper basalt confined aquifer have been suggested as indicators for intercommunication with the overlying unconfined aquifer (Spane and Webber 1995). Recent analyses for tritium in the three TEDF wells indicate tritium activities near, or below low-detection limits (~4.90 pCi/L). In contrast, farther west and northwest near the B Pond System, tritium activities exceed 50,000 pCi/L in several wells. Likewise, nitrate is atypically low for the uppermost aquifer (lower than sitewide background) in the area of TEDF, and has been low even before operations began at this facility. Upgradient well 699-42-37 is nearer the B Pond System and is the exception, with an average nitrate concentrations significantly above the two downgradient wells (Table D.3). These circumstances would tend to lend additional credence to the ion chemistry data, which suggests that upward incursion of groundwater may be occurring from the upper basalt confined aquifer system into the uppermost (Ringold Formation) aquifer, or that this water may be characteristic of a relatively stagnant uppermost (Ringold Formation) aquifer at this location, considering the slow rate of groundwater movement calculated (see Section 2.2.2).

4.0 Conceptual Model for Groundwater Monitoring at the TEDF

Several years of groundwater monitoring at or near the TEDF have provided abundant information on groundwater hydrology, hydrochemistry, and contaminant occurrence/transport. Recent work by Barnett (1998) and Williams et al. (2000) have helped to more precisely characterize the aquifer beneath the TEDF and the potential for effluent migration from the facility, and to gauge the potential effects of the nearby B Pond System operation. The sum of this information is synthesized in this section to construct a conceptual model for the purpose of formulating an effective groundwater monitoring approach. Figure 4.1 is a schematic illustration of salient factors that govern the conceptual model.

4.1 Hydrogeologic Criteria

The infiltration basins of the TEDF are built within the permeable sand and gravel strata of the Hanford formation (Figure 4.1). Drilling and subsequent testing of these sediments indicated a high saturated hydraulic conductivity (Section 2.2.1). Drilling data also indicate that the Ringold lower mud unit is up to 26 m thick in the vicinity of the TEDF and no discontinuities in the unit were observed in drill holes within ~1 km of the facility. The lower mud unit is relatively impermeable; K_s estimates are as low as $7.5E-09 \text{ cm} \cdot \text{sec}^{-1}$ (see Section 2.2.1). The unit is saturated for nearly its entire thickness in the vicinity of TEDF, to within ~1 m of its contact with the overlying Hanford formation. The extreme contrast in hydraulic conductivities between the Ringold lower mud unit and the overlying Hanford formation suggests that effluent will have a strong impetus to move preferentially laterally through the Hanford formation, rather than downward through the relatively impermeable lower mud unit. Hydrographs of the three TEDF wells reflect the decline in the hydraulic mound at the B Pond System. In fact, the most pronounced decline in water levels in TEDF wells began in 1996, several months after the startup of TEDF operations. This decline has not perceptibly abated since then, and has even accelerated, especially in well 699-42-37 (Figure 2.4). Thus, groundwater flow potential (observed hydrostatic head gradient) in the uppermost aquifer beneath TEDF is a result of past B Pond System operations, and does not reflect TEDF operation. TEDF effluent may eventually reach the southern, southeastward, or northern limit of the lower mud unit and mingle with groundwater in the uppermost aquifer.

Hydraulic head data for the uppermost aquifer and the upper basalt confined aquifer system indicate that an upwardly-directed flow potential could currently exist between these aquifers in the region of the TEDF. If so, this could explain the anomalous groundwater geochemical characteristics determined from samples from the TEDF wells, which are screened in the uppermost aquifer (Ringold Formation) (see Section 4.2).

Estimates of average linear groundwater flow rates in the aquifer beneath the TEDF are on the order of 0.004 m/day (Section 2.2.2). Groundwater moving at this rate would take in excess of 370 years to travel from upgradient well 699-42-37, beneath the TEDF to the downgradient side of the active basins of the TEDF. Less-mobile contaminants entrained in the groundwater would take considerably longer to travel this same distance because of retardation.

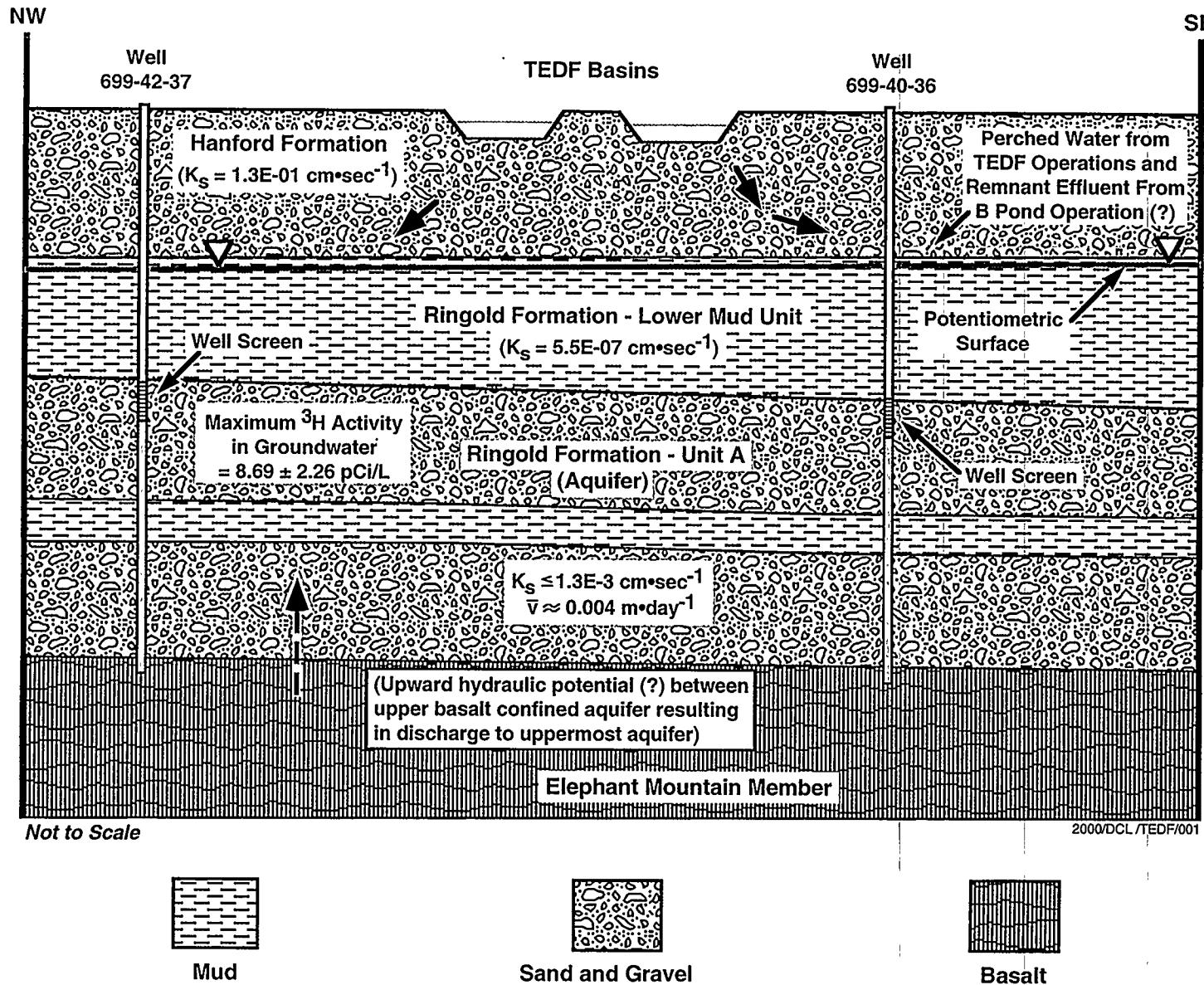


Figure 4.1. Schematic Representation of Hydrogeologic and Operational Relationships at the TEDF. All wells backfilled and sealed below the levels of screened intervals.

Recent work by Williams et al. (2000) describes a potential “umbrella effect” for historical discharges entering the ground near the B Pond System. This effect, illustrated in the left portion of the schematic diagram of Figure 2.2, implies that a portion of the effluent migrating to groundwater near the B Pond System was intercepted by the Ringold lower mud unit and diverted generally southward along the surface of this unit. If this occurred, potentially contaminated water could have migrated beneath the TEDF along the lower mud unit at the base of the Hanford formation. Remnants of these discharges could still be present. Hence, groundwater monitoring of TEDF effluent in this horizon may be nonrepresentative of TEDF effects, because of the possibility that residual effluent or contamination from the B Pond System remains.

4.2 Geochemical Criteria

Comparison of constituents in groundwater from TEDF wells with two independent determinations of background concentrations for these constituents (compare Tables D.1 through D.3 with Johnson 1993; DOE-RL 1997) indicate that most parameters fall below background concentrations determined for the Hanford Site. Sodium (total and dissolved) is the exception. This condition is distinct from groundwater in wells around the nearby B Pond System, which show concentrations of most constituents more in line with Hanford Site background values.

Upgradient well 699-42-37 has produced results for some constituents that average considerably higher than the two downgradient wells. The simplest conclusion is that this well is nearer the edge of the confined portion of the upper most aquifer and its degree of isolation from the effects of the adjoining groundwater (e.g., in the B Pond area) is significantly less than the other two wells. It is possible that the increased head associated with B Pond System operations has forced groundwater from the unconfined portions of the aquifer toward the TEDF area; the location of well 699-42-37 may represent a mixing zone for the two chemically-distinct portions of the aquifer. However, the fact that tritium in this well remains anomalously low, and concentrations of several other constituents (though higher than downgradient wells) are below estimated Hanford Site background values, may demonstrate that the actual effluent from the B Pond System never penetrated into the confined portion of the aquifer as far as well 699-42-37.

Plots of major ion proportions in groundwater (Stiff diagrams) indicate that the groundwater in the immediate vicinity of the TEDF is significantly enriched in sodium and relatively depleted in the calcium ion, producing a dominantly sodium bicarbonate groundwater type. This proportion is characteristic of groundwater that has been sequestered or in transit for a long period of time, and is generally atypical for the uppermost unconfined aquifer on the Hanford Site. Supporting this inference is the anomalously low tritium activities (maximum = 8.69 ± 2.26 pCi/L) from the TEDF wells. Brief appearances of elevated gross alpha and gross beta results in early 1994 are problematic.

4.3 Conclusions

The remnants of a groundwater mound from B Pond System operations continue to dominate hydrostatic heads in the aquifer beneath the TEDF. Mounding due to TEDF discharges, which was predicted by some numerical models has not occurred. The high hydraulic conductivity of the Hanford formation,

the impermeable character of the Ringold lower mud unit, and the less-than-expected discharge volumes to the facility have prevented any discernable mounding. In fact, aside from the lower mud unit, the greatest protective feature is the uppermost aquifer itself in the Ringold unit A. Hydraulic conductivity in this unit and, consequently, groundwater flow rates are extremely low. Groundwater geochemical results support this conclusion. A sodium-bicarbonate groundwater, anomalously low tritium activities, and other constituents occurring significantly below sitewide background values, suggest that groundwater beneath TEDF has been isolated from adjoining portions of the uppermost aquifer. It is possible that the relatively elevated levels of some constituents in well 699-42-37, compared with the other two TEDF wells, may indicate the distal extent of geochemical influence of the B Pond System.

Vadose-zone monitoring (in-the-Hanford-formation)-downgradient-of-TEDF would be ineffective because of the potential contamination introduced into this zone by operation of the B Pond facility, and thus, not be representative of TEDF effects. As shown in Figure 2.2, effluent from the B Pond System operations have most likely affected the Hanford formation in the vicinity of TEDF, and remnants or residues of these discharges could remain along the surface of the Ringold lower mud unit.

Approximately 1-2 km south of TEDF the uppermost aquifer occurs within the Hanford formation (Williams et al. 2000). It is assumed that effluent from TEDF will merge with the groundwater in the unconfined aquifer somewhere in this region after flowing for a considerable distance in a southerly direction along the surface of the Ringold lower mud unit. The region of merging is interpreted by Williams et al. (2000) to be an area of high hydraulic conductivity and groundwater flow velocity, and based on tritium plume movement, conveys groundwater from the 200 East area rapidly toward the Columbia River. Monitoring groundwater for the TEDF at this location would be ineffectual in discerning any unique effects from the facility because of the overprint of contamination or potential contamination from the 200 East Area. Thus the effects from these two sources may be indistinguishable in the aquifer south of the TEDF. Likewise, results from areas north of the TEDF would be potentially confused with the effects of discharges from the B Pond System.

No hydrologic or geochemical effects of TEDF operation have been observed in groundwater. The existing TEDF well network will continue to help provide confirmation that TEDF effluent is not taking a *direct* route to the uppermost aquifer near the facility, but is being diverted laterally in the vadose zone by the extreme contrasts in hydraulic conductivities between the Hanford formation (vadose zone) and the Ringold lower mud unit (confining/perching horizon). However, these wells are not within the flowpath of TEDF effluent and will not provide conventional upgradient/downgradient geochemical comparisons. Water introduced into the Hanford formation at TEDF should spread radially to some degree, then flow dominantly south to southeast along the structural dip of the lower mud unit.

5.0 Groundwater Monitoring Program

The groundwater monitoring program defined in this section is based on precepts of groundwater protection embodied in the original ST-4502, updated interpretations of groundwater hydrology and geochemistry as described in Sections 2.0 through 4.0 of this document, TEDF effluent characteristics, and the requirements of the revised ST-4502. The fundamental change in this groundwater monitoring program from the former program is the refined constituents list. This change is prefaced on the revised conceptual model of hydrogeology and geochemistry of the aquifer beneath the TEDF site, and related effects of TEDF operation.

5.1 Monitoring Objectives and Scope

The primary objective of the groundwater monitoring program is to provide compliance validation for early warning and enforcement limits in the permit, and to detect any impact of the TEDF operations on the uppermost aquifer. This determination will be made by comparison with background values for groundwater constituents, trending and/or statistical analysis of results, and comparison with the appropriate regulatory standards (e.g., WAC 173-200) and the revised ST-4502 requirements. Secondary objectives include the monitoring of specific analytes that will provide insight to general groundwater quality or hydrologic conditions beneath the site, thus lending insight to potential impacts or influence from other sites. Of primary concern is the ability to distinguish potential impacts from TEDF operation from those of other facilities or conditions. No provisions are included in this document for routine effluent monitoring, which is guided by ST-4502.

5.2 Monitoring Well Network

The groundwater monitoring well network will consist of the three existing wells drilled initially for TEDF monitoring: downgradient wells 699-40-36, 699-41-35, and upgradient well 699-42-37. Although they are not within the direct flowpath of TEDF effluent, these wells represent the most advantageous points for determining the potential effects of the TEDF operation on the uppermost aquifer (see discussion in Section 4.3). Groundwater data from additional nearby wells, such as those around the B Pond System RCRA facility, may be evaluated on an as-needed basis to gain further insight into hydrogeologic and geochemical conditions around the TEDF.

5.3 Sampling and Analysis Plan

This section describes all activities pertaining to the collection, analysis, interpretation, and reporting of groundwater data from the three TEDF wells. Where possible, these efforts will be coordinated with other Hanford Site groundwater programs to maintain maximum technical and resource efficiency.

5.3.1 Sampling Schedule

The sampling frequency for all constituents is quarterly, except for low-level tritium analyses, which will occur annually. Although refined estimates of groundwater flow rates suggest that groundwater movement beneath the TEDF is extremely slow (see Section 2.2), and recent corroborating geochemical evidence (Section 3.0) indicates that a lower sampling frequency is adequate, quarterly sampling will continue as an added precaution until a larger data set is established.

5.3.2 Constituents to be Analyzed

The first permit-driven constituent list, in use since 1995, is shown in Appendix A, Table A.3. The new constituent list for groundwater sample analyses, to take effect in spring of 2000, is shown in Table 5.1. This list is based upon recent reevaluations of extensive effluent chemistry data, an updated evaluation of groundwater geochemistry, and a comparison of known Hanford Site background conditions with historical analytical results from TEDF wells (see Section 3.0). Some constituents have been replaced with indicator parameters (e.g., gross alpha substituting for ^{226}Ra). Most changes are based on a lack of historic significance of a constituent/parameter in groundwater and effluent and the calculated low flow rates in the aquifer, thus resulting in the elimination of a constituent or the substituting of a screening parameter for a specific constituent. Hence, the following are **dropped** from the list of constituents:

- all volatile and semivolatile organic compounds
- ammonia
- total organic carbon
- oil and grease
- radium 226
- total radium (sum of radium-226 and radium-228).

Anion concentrations will be sought because of the importance of major ion proportions in determining overall groundwater character. Major ion chemistry will serve as a potential early-warning tool to detect subtle changes in groundwater quality. Likewise, total and dissolved metals by method SW-846 6010 (or equivalent) will be determined to provide the cationic complement to the anionic component of major ion chemistry.

Alkalinity and total dissolved solids are also key indicators of baseline groundwater conditions and will be retained. Sample turbidity is a key indicator of sample quality, particularly when total metals are of concern. Field determinations of sample turbidity will occur at each sampling event to ensure the effects of pumping are kept to a minimum, and as a check against total metals results (see Section 5.3.3).

Tritium activity has not been a routine parameter of groundwater monitoring at TEDF. Historical results indicated that tritium was not present in significant concentrations in the groundwater beneath TEDF. In 1998, low-level tritium analyses were conducted for all three wells and the TEDF effluent. The results of these and subsequent analyses in 1999 demonstrated that tritium was exceptionally low in groundwater beneath the TEDF (see Section 3.0), and suggest it is isolated from the operational effects of

Table 5.1. Analytical Parameters and Schedule for Groundwater Monitoring at the 200 Area TEDF

Constituent ^(a)	Method ^(b)	Schedule
Metals (Total and Dissolved)		
Arsenic, cadmium (5 µg/L), chromium, mercury, lead (10 µg/L) Iron, manganese	EPA 200.8 SW-846 6010	Quarterly Quarterly
Anions		
Chloride, fluoride, nitrate as N, sulfate	EPA 300.0	Quarterly
Miscellaneous Parameters		
Alkalinity, conductivity, pH (6.5 - 8.5), temperature Total dissolved solids Turbidity Tritium (low detection) Gross Alpha Gross Beta Water level measurement	Field analyses 40 CFR 136 160.1 Standard Methods 214A (Field Analysis) RICH-RC-5024 Gross Alpha (DGPC) Gross Beta (DPC) Field	Quarterly Quarterly Quarterly Annual Quarterly Quarterly Quarterly at time of sampling
<p>(a) Constituents with permit groundwater limitations (in downgradient wells 699-40-36 and 699-41-35) are indicated in bold.</p> <p>(b) Other methods with equal or superior detection capabilities may be substituted.</p>		

the TEDF and other sources of effluent—i.e., virtually sequestered from Hanford Site influences. Because of the value of this parameter in demonstrating the isolated nature of the groundwater, low-level tritium analyses for all three wells is added to the constituent list on an annual basis. These will be compared with annual low-level tritium analyses from the TEDF effluent.

5.3.3 Quality Assurance and Control

Provisions for groundwater sampling, analysis, and data validation procedures and criteria are governed by the *Liquid Waste Processing Facilities Quality Assurance Project Plan* (QAPjP) (Olson 1997). Analytical methods are performed by an accredited laboratory as authorized by WAC 173-50 *Accreditation of Environmental Laboratories* (Ecology 1990), and are a reflection of *Test Methods for Evaluating Solid Wastes, Physical/Chemical Methods* (EPA 1986) and *Implementation Guidance for the Groundwater Quality Standards* (Ecology 1996). Additional or alternative procedures are compliant with SW-846, Chapter 10. Details of analytical methods are described in *Standard Methods for the Examination of Water and Wastewater* (Eaton et al. 1995). All required constituents will be analyzed to within or below the PQL for each constituent as listed in ST-4502, S2(c). Procedures for field analyses are specified in the subcontractor's or instrument manufacturer's manuals and are specifically described in *Sampling Services Procedure Manual* (WMFS 1998). Field personnel will perform sampling and field measurements according to the manual and this Groundwater Monitoring Plan.

5.3.4 Well Purging and Sample Collection

Prior to sample collection, each well will be purged of one well volume of groundwater. Following purging, a sample may be collected when field parameters (pH, conductivity, temperature, turbidity) have stabilized. Pumping rates for purging and sampling should be sufficiently low such that sample turbidity is kept to a minimum. Turbidity must be ≤ 5.0 NTU prior to sample collection. If this turbidity criterion cannot be achieved, field personnel will contact the project scientist in charge of data interpretation (PNNL) or the project engineer in charge of data validation (FH).

All water purged from the TEDF wells meets criteria for discharge to ground surface, and need not be contained. If future analyses indicate containment is necessary procedures for containment and disposal will follow *Strategy for Handling and Disposal of Purgewater at the Hanford Site* (DOE-RL 1990).

5.4 Groundwater Flow Determination

Groundwater elevations in the three TEDF wells will be measured quarterly at the time of sample collection. Determination of groundwater flow rate and direction will be made annually, at minimum, for the purpose of ensuring adequate understanding of hydrologic conditions in the aquifer beneath the TEDF. Groundwater flow rate will be determined using the average linear flow equation derived from the Darcy relationship, as presented in Section 2.2.2 of this document. The direction of groundwater flow will be estimated by the mapping of hydrostatic head in the aquifer beneath and in the vicinity of the TEDF.

5.5 Data Management, Evaluation, and Reporting

Groundwater analytical results will be received from the laboratory on electronic medium or hard copy (mostly field parameters). These data are validated and entered into the Liquid Effluent Monitoring Information System (LEMIS) by the Data Manager at Liquid Waste Processing Facilities. After an initial inspection and qualification, these data are copied in whole to the Hanford Environmental Information System (HEIS).

Groundwater data are evaluated using application-specific databases such as the HEIS Groundwater Data Evaluator, which allows trend analyses, data screening, and other comparisons. The project scientist will evaluate the data (hydrologic and geochemical) for each quarterly analytical period for trend departures, anomalous or erroneous data, or suspect results. This evaluation is used to assess the potential vulnerability of groundwater to TEDF operation, or to detect the influence in the aquifer of other, upgradient sources that may interfere with the TEDF groundwater interpretations.

Groundwater analytical results will be evaluated quarterly, at minimum, to screen for anomalous results, unexpected trends, exceedences in permit groundwater limitations, and comparison with historical results. Requests for Data Review (RDR) are used by PNNL to initiate a detailed examination of anomalous

groundwater analytical results or results suspected of error. All such results will be subject to RDRs. All results will also be reviewed annually and compared with background values, permit groundwater limitations, or historical results.

LWPF publishes quarterly Discharge Monitoring Reports (DMRs) that contain all analytical results for both effluent and groundwater for the TEDF. Groundwater analytical data will continue to be reported, as they become available, in the DMRs. Groundwater data will appear quarterly in the DMR, reflecting the quarterly sampling/analysis schedule. A report detailing all significant groundwater results from the TEDF will be published biannually. This report will include a discussion of departures from historical trends in analytical results and hydrogeological information (see Section 5.4). In addition, a summary of TEDF groundwater monitoring results is published annually in the Hanford Site Groundwater Monitoring report (e.g., Hartman and Dresel 1999).

5.6 Statistical Evaluation of Data

Basic measures of central tendency and variability will be determined annually for the groundwater analytical data, such as presented in Appendix C, and will be compared with permit groundwater limitations and historical values (e.g., Special Condition S.1). Additional statistical analyses may include the application of control charts for constituents of particular interest (e.g., conductivity) should trending suggest a departure from historical values.

5.7 Contingencies for Future Groundwater Monitoring

The plan presented above represents a conservative approach to groundwater monitoring at the TEDF. Several factors, such as the demonstrated consistency in cleanliness of the effluent, the natural protection afforded the uppermost aquifer by an impermeable stratum, and other unique aspects of the hydrogeologic setting of the TEDF, indicate that the scope of groundwater monitoring at this facility could be reduced without the loss of detection capability.

The results of groundwater and effluent monitoring at the TEDF should be reevaluated after at least one year of monitoring under the plan presented in this document. If results of groundwater analyses remain within historical ranges and show no indications of upward trends in concentrations of constituents related to TEDF operation, a contingency plan should be considered for reducing the frequency of sampling and analysis for groundwater monitoring at the facility. The contingency may include a deferral of future groundwater monitoring in the three TEDF wells to the Hanford sitewide groundwater monitoring program on an annual or less frequent basis.

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Appendix A

Groundwater Constituents Lists for the 200 Area TEDF

Appendix A

Groundwater Constituents Lists for the 200 Area TEDF

The following tables are the lists of constituents sought in samples from TEDF groundwater monitoring wells during the years 1992 through present (1999). The new list of constituents for the groundwater monitoring program is presented in Section 5.3.1, (Table 5.1) in the main body of the document.

Table A.1. Initial Groundwater Constituent List for the TEDF, 1992-1995

Contamination Indicator Parameters		
pH	Total organic carbon	
Specific conductance	Total organic halogens	
Groundwater Quality Parameters		
Chloride	Manganese	Sodium
Iron	Phenols	Sulfate
Drinking Water Parameters		
2,4-D	Fluoride	Nitrate
2,4,5-TP	Gross alpha	Radium
Arsenic	Gross beta	Selenium
Barium	Lead	Silver
Cadmium	Lindane	Silvex
Chromium	Mercury	Toxaphene
Coliform bacteria	Methoxychlor	Turbidity
Endrin		
Site-Specific Parameters		
Ammonium	Hydrazine	Tritium
Assessment Monitoring Parameters		
Anions ^(a)	Polychlorinated biphenyls	
Herbicides	Volatile, semi-volatile organic compounds	
Pesticides		

(a) As shown for groundwater quality and drinking water parameters.

Table A.2. Groundwater Screening List of Constituents for the TEDF, 1995-1996

Part 1A. Volatile Organic Constituents			
Constituent ID	Constituent Name	Group ^(a)	PQL (µg/L) ^(b)
71-55-6	1,1,1-Trichloroethane	SW-846 8240/8260	5
79-00-5	1,1,2-Trichloroethane	SW-846 8240/8260	5
75-34-3	1,1-Dichloroethane	SW-846 8240/8260	5
75-35-4	1,1-Dichloroethylene	SW-846 8240/8260	5
106-93-4	1,2-Dibromoethane	SW-846 8240/8260	5
107-06-2	1,2-Dichloroethane	SW-846 8240/8260	5
78-87-5	1,2-Dichloropropane	SW-846 8240/8260	5
591-78-6	2-Hexanone	SW-846 8240/8260	5
108-10-1	4-Methyl-2-pentanone	SW-846 8240/8260	5
67-64-1	Acetone	SW-846 8240/8260	5
107-13-1	Acrylonitrile	SW-846 8240/8260	5
71-43-2	Benzene	SW-846 8240/8260	5
75-27-4	Bromodichloromethane	SW-846 8240/8260	5
75-25-2	Bromoform	SW-846 8240/8260	5
56-23-5	Carbon tetrachloride	SW-846 8240/8260	5
108-90-7	Chlorobenzene	SW-846 8240/8260	5
67-66-3	Chloroform	SW-846 8240/8260	5
124-48-1	Dibromochloromethane	SW-846 8240/8260	5
100-41-4	Ethylbenzene	SW-846 8240/8260	5
78-83-1	Isobutyl alcohol	SW-846 8240/8260	5
74-87-3	Methyl chloride	SW-846 8240/8260	5
78-93-3	Methyl ethyl ketone	SW-846 8240/8260	5
80-62-6	Methyl methacrylate	SW-846 8240/8260	5
75-09-2	Methylene chloride	SW-846 8240/8260	5
110-86-1	Pyridine	SW-846 8240/8260	5
100-42-5	Styrene	SW-846 8240/8260	5
127-18-4	Tetrachloroethylene	SW-846 8240/8260	5
108-88-3	Toluene	SW-846 8240/8260	5
79-01-6	Trichloroethene	SW-846 8240/8260	5
75-01-4	Vinyl chloride	SW-846 8240/8260	5
1330-20-7	Xylenes (total)	SW-846 8240/8260	5
10061-01-5	cis-1,3-Dichloropropene	SW-846 8240/8260	5
109-99-9	Tetrahydrofuran	SW-846 8240/8260	100
156-60-5	trans-1,2-Dichloroethylene	SW-846 8240/8260	5
10061-02-6	trans-1,3-Dichloropropene	SW-846 8240/8260	5

Table A.2. (contd)

Part 1B. Non-Halogenated Volatile Organic Constituents			
Constituent ID	Constituent Name	Group ^(a)	PQL (µg/L) ^(b)
123-91-1	1,4-Dioxane	Super SW-846 8015	150
71-36-3	1-Butanol	Super SW-846 8015	50,000
141-78-6	Ethyl acetate	Super SW-846 8015	50,000
60-29-7	Diethyl ether	Super SW-846 8015	50,000
78-83-1	Isobutyl alcohol	Super SW-846 8015	50,000
78-93-3	Methyl ethyl ketone	Super SW-846 8015	100,000
64-17-5	Ethyl alcohol	Super SW-846 8015	5,000,000
107-21-1	Ethylene Glycol	Super SW-846 8015	100,000
---	WTPH-G	SW-846 8015 (modified)	1,000

Part 2. Semivolatile Organic Constituents			
Constituent ID	Constituent Name	Group ^(a)	PQL (µg/L) ^(b)
130-15-4	1,4-Naphoquinone	SW-946 8270 Appx IX	10
134-32-7	1-Naphthylamine	SW-946 8270 Appx IX	10
88-06-2	2,4,6-Trichlorophenol	SW-946 8270 Appx IX	10
121-14-2	2,4-Dinitrotoluene	SW-946 8270 Appx IX	10
606-20-2	2,6-Dinitrotoluene	SW-946 8270 Appx IX	10
95-57-8	2-Chlorophenol	SW-946 8270 Appx IX	10
91-59-8	2-Naphthylamine	SW-946 8270 Appx IX	10
91-94-1	3,3'-Dichlorobenzidine	SW-946 8270 Appx IX	20
119-93-7	3,3'-Dimethylbenzidine	SW-946 8270 Appx IX	10
106-44-5	4-Methylphenol	SW-946 8270 Appx IX	10
98-86-2	Acetophenone	SW-946 8270 Appx IX	10
62-53-3	Aniline	SW-946 8270 Appx IX	10
140-57-8	Aramite	SW-946 8270 Appx IX	20
50-32-8	Benzo(a)pyrene	SW-946 8270 Appx IX	10
100-51-6	Benzyl alcohol	SW-946 8270 Appx IX	20
111-44-4	Bis(2-chloroethyl) ether	SW-946 8270 Appx IX	10
117-81-7	Bis(2-ethylhexyl) phthalate	SW-946 8270 Appx IX	10
85-68-7	Butylbenzylphthalate	SW-946 8270 Appx IX	10
510-15-6	Chlorobenzilate	SW-946 8270 Appx IX	10
218-01-9	Chrysene	SW-946 8270 Appx IX	10
84-74-2	Di-n-butylphthalate	SW-946 8270 Appx IX	10
117-84-0	Di-n-octylphthalate	SW-946 8270 Appx IX	10
2303-16-4	Diallate	SW-946 8270 Appx IX	10
84-66-2	Diethyl phthalate	SW-946 8270 Appx IX	10
131-11-3	Dimethyl phthalate	SW-946 8270 Appx IX	10

Table A.2. (contd)

118-74-1	Hexachlorobenzene	SW-946 8270 Appx IX	10
67-72-1	Hexachloroethane	SW-946 8270 Appx IX	10
78-59-1	Isophorone	SW-946 8270 Appx IX	10
72-43-5	Methoxychlor	SW-946 8270 Appx IX	10
108-39-4	m-Cresol	SW-946 8270 Appx IX	10
924-16-3	N-Nitrosodi-n-butylamine	SW-946 8270 Appx IX	10
55-18-5	N-Nitrosodiethylamine	SW-946 8270 Appx IX	10
62-75-9	N-Nitrosodimethylamine	SW-946 8270 Appx IX	10
86-30-6	N-Nitrosodiphenylamine	SW-946 8270 Appx IX	10
10595-95-6	N-Nitrosomethylethylamine	SW-946 8270 Appx IX	20
91-20-3	Naphthalene	SW-946 8270 Appx IX	10
98-95-3	Nitrobenzene	SW-946 8270 Appx IX	10
87-86-4	Pentachlorophenol	SW-946 8270 Appx IX	50
108-95-2	Phenol	SW-946 8270 Appx IX	10
106-50-3	o-Phenylenediamine	SW-946 8270 Appx IX	10
110-86-1	Pyridine	SW-946 8270 Appx IX	10
126-73-8	Tributyl Phosphate ^(c)	SW-946 8270 Appx IX	NA
629-50-5	Tridecane	SW-946 8270 Appx IX	10

Part 3. Pesticide, Herbicide, and PCB Constituents

Constituent ID	Constituent Name	Group	PQL (µg/L)
72-54-8	4,4'-DDD	SW-846 8080	50
72-55-9	4,4'-DDE	SW-846 8080	10
50-29-3	4,4'-DDT	SW-846 8080	2
319-84-6	Alpha-BHC	SW-846 8080	2
12674-11-2	Aroclor-1016	SW-846 8080	50
11104-28-2	Aroclor-1221	SW-846 8080	50
11141-16-5	Aroclor-1232	SW-846 8080	50
53469-21-9	Aroclor-1242	SW-846 8080	50
12672-29-6	Aroclor-1248	SW-846 8080	50
11097-69-1	Aroclor-1254	SW-846 8080	50
11096-82-5	Aroclor-1260	SW-846 8080	50
57-74-9	Chlordane	SW-846 8080	50
319-86-8	Delta-BHC	SW-846 8080	2
959-98-8	Endosulfan I	SW-846 8080	2
33213-65-9	Endosulfan II	SW-846 8080	10
1031-07-8	Endosulfan sulfate	SW-846 8080	10
72-20-8	Endrin	SW-846 8080	10
7421-93-4	Endrin Aldehyde	SW-846 8080	2

Table A.2. (contd)

72-43-5	Methoxychlor	SW-846 8080	2
8001-35-2	Toxaphene	SW-846 8080	50
58-89-2	gamma-BHC (Lindane)	SW-846 8080	2
93-72-1	2,4,5-TP	SW-846 8150	2
94-75-7	2,4-D	SW-846 8150	12
Part 4. Metallic Constituents (total and dissolved)			
Constituent ID	Constituent Name	Group	PQL (µg/L)
7429-90-5	Aluminum	SW-846 6010	500
7440-36-0	Antimony	SW-846 6010	300
7440-39-3	Barium	SW-846 6010	20
7440-41-7	Beryllium	SW-846 6010	10
7440-42-8	Boron	SW-846 6010	100
7440-43-9	Cadmium	SW-846 7131A	5
7440-70-2	Calcium	SW-846 6010	500
7440-47-3	Chromium	SW-846 7191/EPA 200.8	20
7440-48-4	Cobalt	SW-846 6010	70
7440-50-8	Copper	SW-846 6010	60
7439-89-6	Iron	SW-846 6010	100
7439-93-2	Lithium	SW-846 6010	100
7439-95-4	Magnesium	SW-846 6010	1,000
7439-96-5	Manganese	SW-846 6010	50
7439-98-7	Molybdenum	SW-846 6010	100
7440-02-0	Nickel	SW-846 6010	75
7440-09-7	Potassium	SW-846 6010	5,000
7440-21-3	Silicon	SW-846 6010	450
7440-22-4	Silver	SW-846 6010	70
7440-23-5	Sodium	SW-846 6010	1,000
7440-62-2	Vanadium	SW-846 6010	80
7440-66-6	Zinc	SW-846 6010	20
7440-67-7	Zirconium	SW-846 6010	100
7440-31-5	Tin	SW-846 7870	8,000
7439-92-1	Lead	SW-846 7421	10
7439-97-6	Mercury	SW-846 7470/7471	2
7440-38-2	Arsenic	SW-846 7060	15
7782-49-2	Selenium	SW-846 7740	20

Table A.2. (contd)

Part 5. Miscellaneous Indicators and Inorganic and Organic Constituents			
Constituent ID	Constituent Name	Group	PQL ($\mu\text{g/L}$) ^(b)
14798-03-09	Ammonia	40 CFR 136 350.1/2/3	50
57-12-5	Cyanide	40 CFR 136 335.1/2/3	50
ALKALINITY	Alkalinity	FIELD ANALYSIS	500
CONDUCTANCE	Specific conductance (in $\mu\text{mhos/cm}$)	SW-846 9050/EPA 120.1	10
NTU	Turbidity in NTU	Std. Methods 214A	1
pH	pH in pH units	SW-846 9040A/EPA 150.1	0.1
TDS	Total Dissolved Solids	40 CFR 136 160.1	10,000
TOX	Total Organic Halogen	SW-846 9020	50
TOC	Total Organic Carbon	SW-846 9060	1,000
--	Anions by ion chromatograph per anion	EPA 300.0	500
--	Nitrate/Nitrate as N	EPA 353.1/2/3	50
12595-89-0	Chloride	EPA 300.0	1,000
14265-44-2	Phosphorus as PO_4	EPA 300.0	500
14797-55-8	Nitrate as N	EPA 300.0	100
14808-79-8	Sulfate	EPA 300.0	10,000
16984-48-8	Fluoride	EPA 300.0	500
24959-67-9	Bromide	EPA 300.0	500
TEMPERATURE	Temperature in degrees Celsius	EPA 170.1	0.1
18496-25-8	Sulfide	SW-846 9030	1,000
--	Oil and Grease-Gasoline Range	SW-846 9070	10,000
TSS	Total Suspended Solids	40 CFR 160.2	4,000
Part 6. Radionuclides			
Constituent ID	Constituent Name	Group	CDL pCi/L ^(d)
10028-17-8	Tritium	LAB SPECIFIC	400
10098-97-2	Strontium-90	LAB SPECIFIC	2
15046-84-1	Iodine-129	LAB SPECIFIC	5
7440-14-4	Radium-228+226 (total)	LAB SPECIFIC	5
13982-63-3	Radium-226	LAB SPECIFIC	1
7440-61-1	Uranium (gross) $\mu\text{g/L}$	LAB SPECIFIC	0.1
ALPHA	Gross Alpha	LAB SPECIFIC	3
BETA	Gross Beta	LAB SPECIFIC	4
15117-48-3	Plutonium-239/240	LAB SPECIFIC	1
10045-97-3	Gamma Energy Analysis Cesium-137	LAB SPECIFIC	15
14683-23-9	Gamma Energy Analysis Europium-152	LAB SPECIFIC	50

Table A.2. (contd)

15585-10-1	Gamma Energy Analysis Europium-154	LAB SPECIFIC	50
14391-16-3	Gamma Energy Analysis Europium-155	LAB SPECIFIC	50
13967-48-1	Gamma Energy Analysis Ruthenium-106	LAB SPECIFIC	75
<p>(a) Tentatively Identified Compound (TICs) were reported.</p> <p>(b) PQL-Practical Quantitation Limit per 40 CFR 264, Appendix IX. Note: where no PQL was available, value was established at 10 times method detection limit. Values are expressed as micrograms per liter ($\mu\text{g}/\text{L}$) unless otherwise noted.</p> <p>(c) Constituent was specifically requested on analysis request forms.</p> <p>(d) CDL-Contract Detection Limit which is expressed in pico curies per liter (pCi/L).</p>			

Table A.3. Constituent and Parameters List for Quarterly Groundwater Monitoring at the 200 Area TEDF (effective through April 2000)

Constituent	Method
Metals (Total) Arsenic, cadmium, chromium, mercury, lead, uranium	EPA 200.8
Barium, calcium, iron, magnesium, manganese, potassium, silicon, sodium, zinc	SW-846 6010
Anions Nitrate, sulfate, chloride, fluoride, nitrite as N	EPA 300.0
Volatile and Semivolatile Organic Compounds Bis (2-hexylethyl) phthalate, phenol,	SW-846 8270
Total trihalomethanes, carbon tetrachloride, methylene chloride, 1,1,1 trichloroethane, chloroform	SW-846 8260
WTPH-G	SW-846 8015M
Miscellaneous Parameters Ammonia	40 CFR 136 350.1/2/3/EPA 300.7
Alkalinity, conductivity, pH, temperature	Field analyses
Cyanide (total)	40 CFR 136 335.1/2/3/EPA 335.3
Total dissolved solids	40 CFR 136 160.1
Turbidity	Standard Methods 214A (Field Analysis)
Total Organic Carbon	SW-846 9060
Oil and Grease	SW-846 9070
Gross alpha	Gross Alpha (DGPC)
Gross beta	Gross Beta (DPC)
Radium 226	Radium-226 (AEA)
Radium 226+228	Radium-228 (GEA)

Appendix B

Construction and Serviceability Information for TEDF Wells

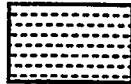
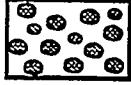
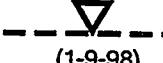
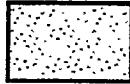
Appendix B

Construction and Serviceability Information for TEDF Wells

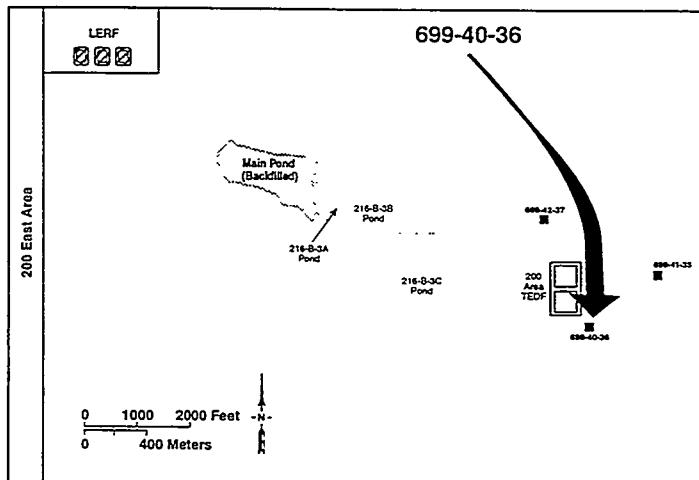
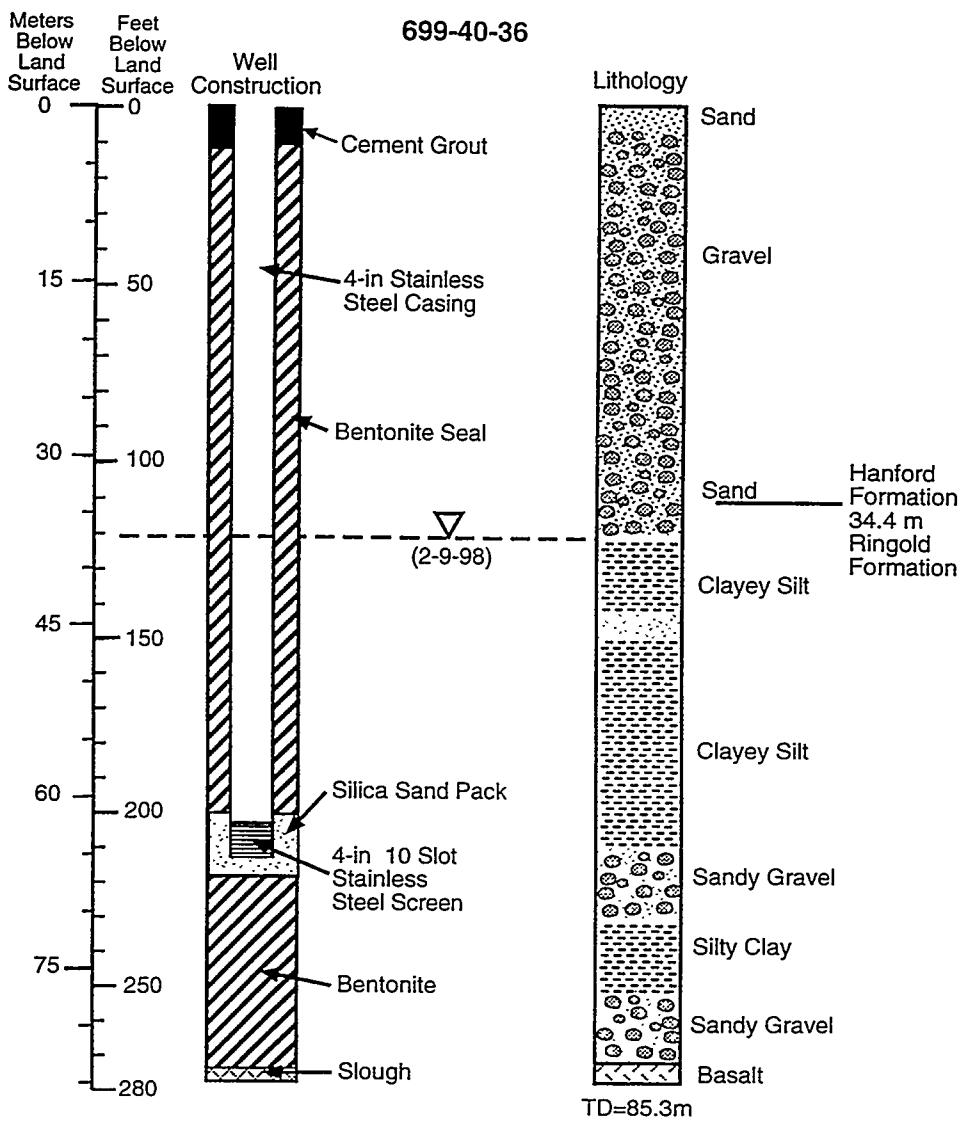
Appendix B.1 presents a graphic summary of lithologic and construction information for the three TEDF wells. This information is abstracted from more detailed well lithologic/construction logs presented in Davis et al. (1993).

Table B.1 provides predictions of well serviceability calculated from water level data. The table represents a linear calculation of water level decline in the three TEDF wells for the most recent ~1 year of data, ending in April 1999. The predicted years of service are based on the water remaining in the well divided by the rate of decline, assuming a minimum of 1 ft of water must remain in the well to be serviceable. DTW = depth to water, WT Elev = water table elevation, REF Elev = elevation reference point (measuring point). All distances are in feet, as they appear in the HEIS database.

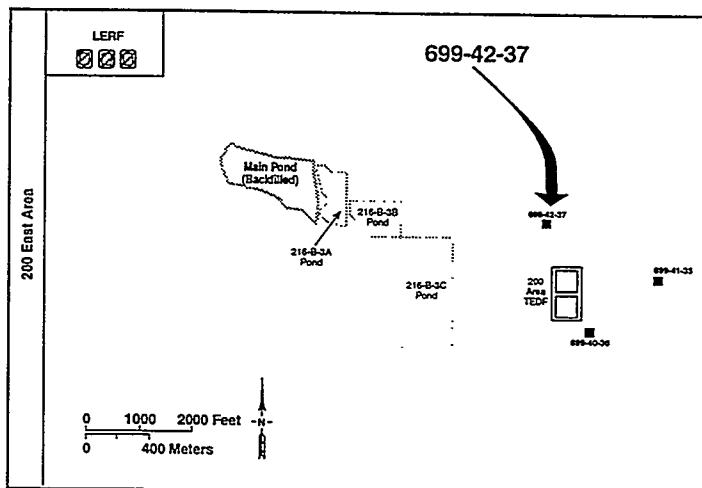
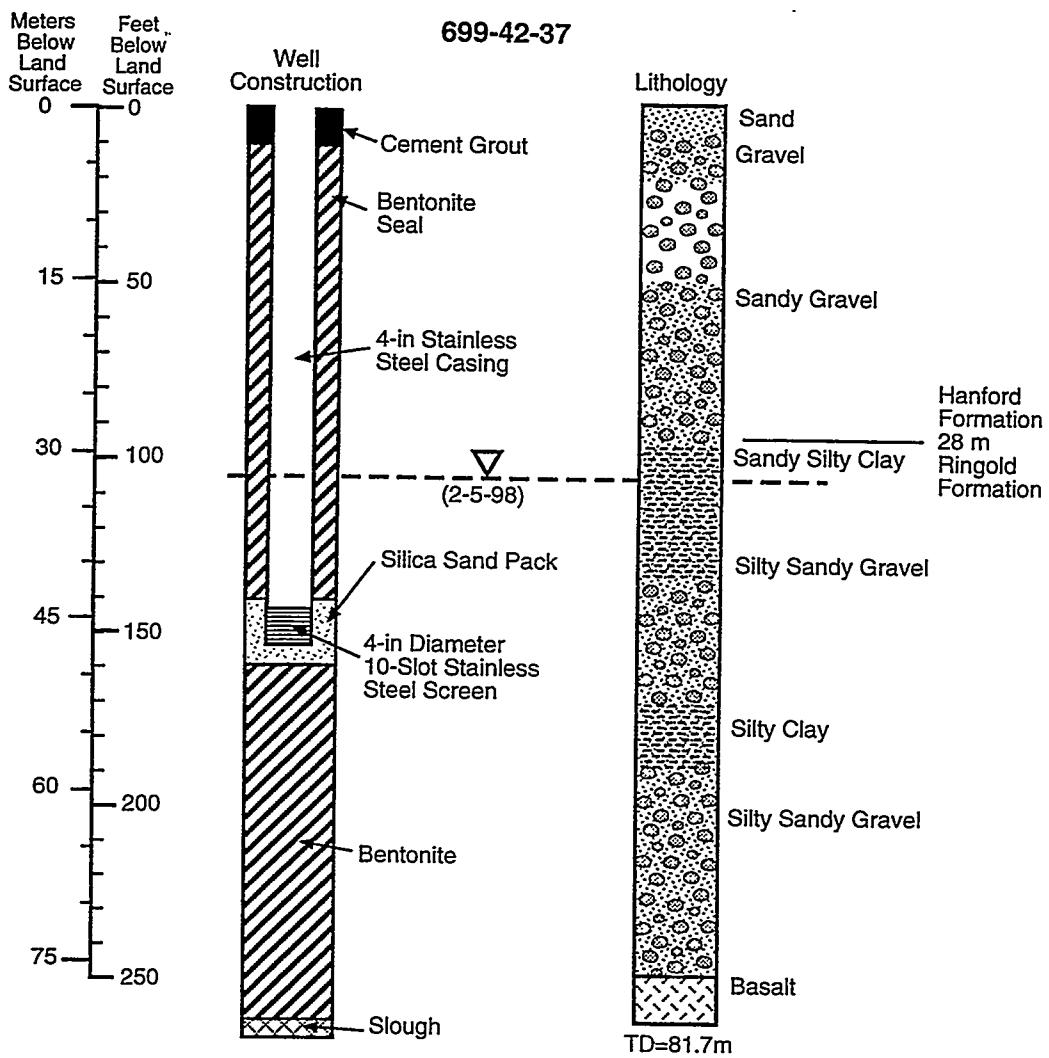
Legend

Lithologies	Well Construction
	clay or silt
	sand
	gravel
	basalt
	Water Table or potentiometric surface with date of measurement (1-9-98)
	
	Bentonite Seal
	
	Artificial Sand Pack
	
	Well Screen Interval
	
	Cement Grout
	
	Slough

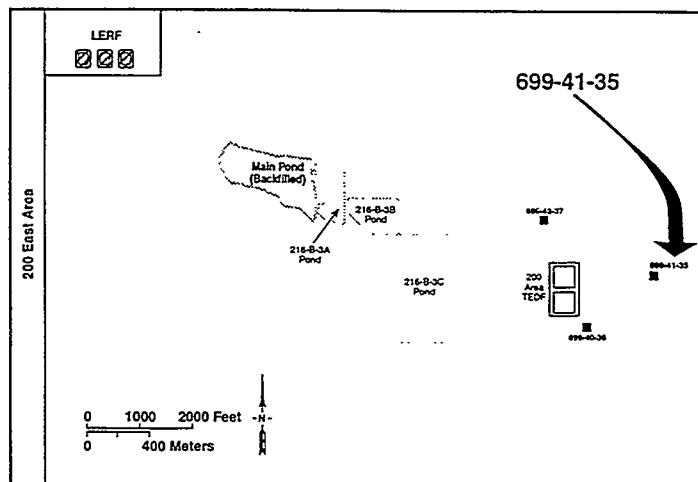
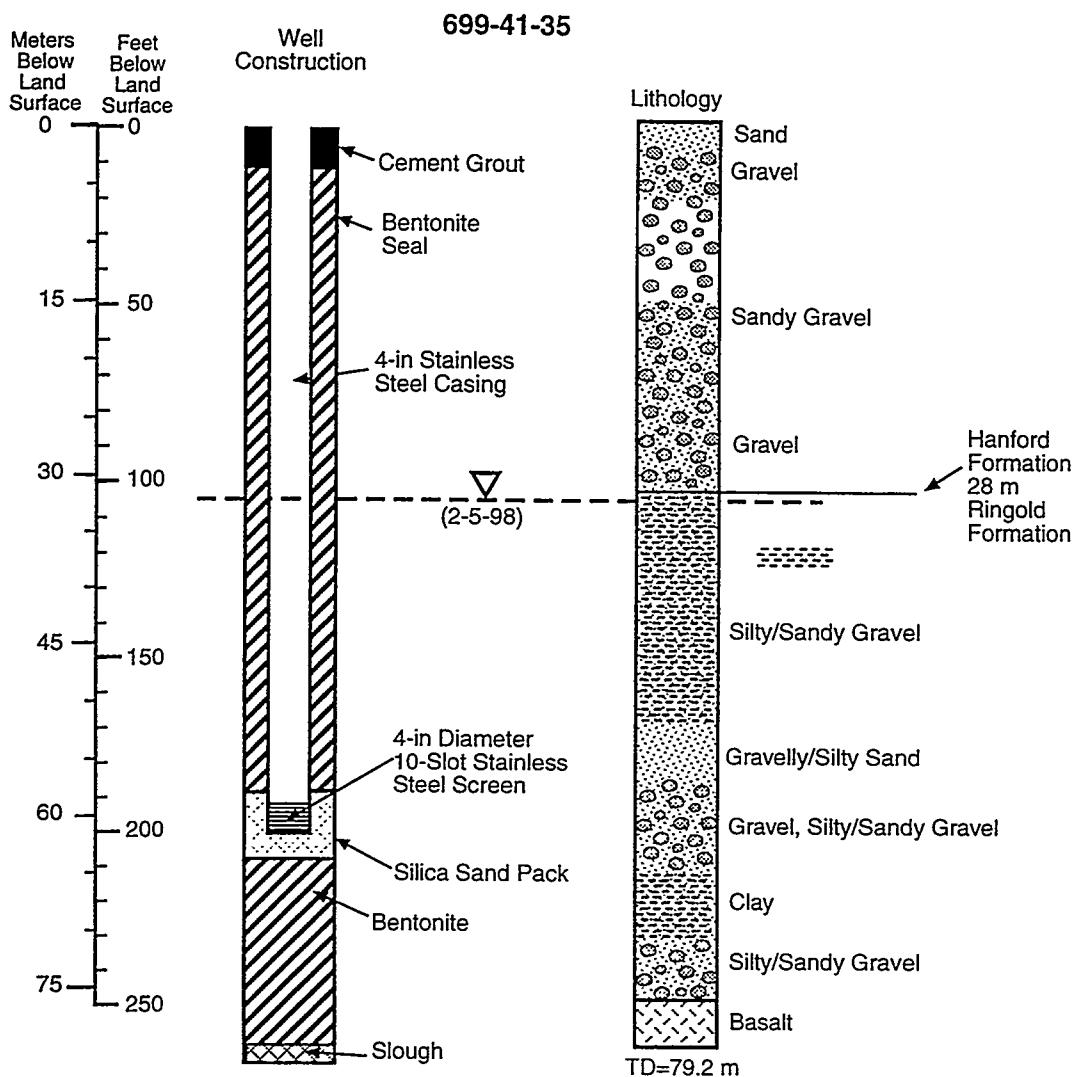
RG98060028.12



RG96080028.11



RG98060028.7



RG98060028.8

Table B.1.

Well	98 Meas. Date	99 Meas. Date	98 DTW (ft)	99 DTW (ft)	Wt. Elev. (ft)	Ref. Elev. (ft)
699-40-36	17-Mar-98	19-Apr-99	119.44	120.47	408.45	528.92
699-41-35	17-Mar-98	19-Apr-99	109.45	110.48	409.9	520.38
699-42-37	17-Mar-98	19-Apr-99	107.7	108.69	410.73	519.42

Well	Depth of Well Screen Bottom (ft)	Depth of Pump Intake (ft)	Water Left Above Intake (ft)	Amount Pump can be Lowered (ft)	Annual Rate of Decline (ft)	Years of Service Left
699-40-36	222.95	216.75	96.28	6.20	0.94	108.5
699-41-35	203.80	201.37	90.89	2.43	0.94	98.8
699-42-37	158.60	154.39	45.70	4.21	0.91	55.0

Appendix C

Summary Tables of Geochemical Analytical Results for TEDF Wells

Appendix C

Summary Tables of Geochemical Analytical Results for TEDF Wells

The following summary tables present numbers of analyses, means, standard deviations, maxima, and related comments for all constituents occurring at least once above the PQLs, as shown in the comprehensive list of Appendix A.2. Included are all results through April 1999. Hanford Site background values for groundwater in the unconfined aquifer, as calculated by Johnson (1993; [“B1” column]) and DOE/RL (1997; [“B2” column]) are listed for comparison, where available. Summary data and discussions for constituents with specific enforcement limits are presented in Section 3.0 in the document.

Table C.1. Constituents from the Original TDF Analyte List with at Least One Result Exceeding PQL in Well 699-40-36

Constituent	n ^(a)	Mean ^(b)	sd ^(b)	Maximum Result ^(b)	B1 ^(c)	B2 ^(d)	Comments
Bis(2-hexylethyl) phthalate	5	2.2	2.2	6.0	na	na	Estimated value—common lab contaminant
Butylbenzyl phthalate	1	--	--	17.00	na	na	
Aluminum	F = 6	78.2	115.2	310	<200	11.7	Unfiltered max. is suspect result
	U = 26	1269.5	5,252.9	27,000	na	15.3	
Barium	F = 25	65.4	5.4	80	68.5	149	
	U = 36	74.8	40.7	310	na	154	
Calcium	F = 23	15,083	896	17,400	63,600	78,770	
	U = 34	15,576	1,836	24,000	na	81,319	
Chromium	F = 13	3.9	4.1	8.4	<30	3.17	
	U = 34	14.7	27.8	120	na	4.55	
Iron	F = 17	37	24	80	86	227	Unfiltered max. is suspect result
	U = 32	340	317	38,000	na	535	
Magnesium	F = 23	5,367	241	5,860	16,480	31,051	Unfiltered max. is suspect result
	U = 33	5,435	266	13,000	na	32,233	
Manganese	F = 28	56.5	41.7	160	24.5	86.4	Unfiltered max. is suspect result
	U = 35	83	128.2	780	na	99.8	
Nickel	F = 0	--	--	--	<30	1.98	
	U = 4	50	31	83	na	4.16	
Potassium	F = 23	7,733	608	8,800	7,975	na	Unfiltered max. is suspect result
	U = 34	7,804	916	12,000	na	na	
Silicon	F = 16	22,019	874	25,200	26,500	na	Unfiltered max. is an estimated value
	U = 26	22,862	1,352	38,300	na	na	
Sodium	F = 23	46,648	2,190	54,000	33,500	37,958	
	U = 34	46,188	1,646	50,000	na	38,730	
Uranium	F = 9	3.2	0.2	3.7	3.43	14.4	
	U = 25	4.67	0.23	3.8	na	13.9	
Vanadium	F = 21	15.1	5.2	26.4	15	19.3	
	U = 29	18	14	87	na	20.2	

Table C.1. (contd)

Constituent	n ^(a)	Mean ^(b)	sd ^(b)	Maximum Result ^(b)	B1 ^(c)	B2 ^(d)	Comments
Zinc	F = 15	24.8	30.8	97.5	<50	48.9	
	U = 31	121.3	165.8	690	na	111	
Ammonia	3	64	14	80	<120	154	"Q" flag
Alkalinity	24	144,620	4,008	153,000	210,000	156,367	
Specific conductance (conductivity)	106	315.1	9.2	333	539	430	Units in μ hos/cm
Turbidity	51	18.8	104.5	750	na	na	In nephelometric turbidity units (NTU); Most recent 1 yr. mean = 3.7 NTU
pH	101	8.0	0.2	Maximum = 8.27 Minimum = 7.34	6.90 to 8.24	8.07	In pH units
Total dissolved solids	27	204,926	21,281	242,000	na	277,190	
Total organic carbon	32	462	328	1,820	1,610	3,336	
Nitrate (includes N in NO_3)	27	143	120.8	332	12,400	41,723	
N in NO_2	14	14.86	10.7	40	na	40	
Chloride	32	3,350	154	3,830	8,690	17,370	
Sulfate	32	5,234	3,292	17,000	90,500	54,950	
Fluoride	32	831	158	1,200	775	539	
Total suspended solids	8	6,750	6,408	17,000	na	na	
Radium-226	13	0.121	0.05	0.23	na	39.4	pCi/L (filtered)
Gross alpha	32	3.59	3.51	21	5.79	3.48	pCi/L
Gross beta	32	12.10	23.10	130	12.62	9.73	pCi/L; Maximum result suspected error—mean without maximum result = 8.03, s = 6.24
Oil and grease	7	9,414	14,379	41,800	na	na	See text for explanation of results

(a) Results are from unfiltered samples unless denoted by "F" (filtered) and "U" (unfiltered).

(b) All results in $\mu\text{g}/\text{L}$ unless otherwise indicated.

(c) Hanford Groundwater Background by Johnson 1993, 95th percentile, $\mu\text{g}/\text{L}$.

(d) Hanford Groundwater Background by DOE/RL, 1997, 95th percentile, $\mu\text{g}/\text{L}$.

na = no results available for background.

Table C.2. Constituents from the Original TEDF Analyte List with at Least One Result Exceeding PQL in Well 699-41-35

Constituent	n ^(a)	Mean ^(b)	sd ^(b)	Maximum Result ^(b)	B1 ^(c)	B2 ^(d)	Comments
Bis(2-hexylethyl) phthalate	6	25.3	36.9	100.00	na	na	Includes estimated values; common lab contaminant
Butylbenzyl phthalate	1	--	--	1.0	na	na	Estimated value
Aluminum	F = 5	59.9	79.5	200	<200	11.7	
	U = 9	543.8	986.1	2,800	na	15.3	
Barium	F = 24	142	12.7	170	68.5	149	
	U = 6	144.5	7.6	160	na	154	
Calcium	F = 24	19,265	1,190	23,000	63,600	78,770	Unfiltered max. is estimated value
	U = 34	18,940	827	20,300	na	81,319	
Chromium	F = 12	3.7	2.1	8.6	<30	3.17	
	U = 31	14.8	24.4	110	na	4.55	
Iron	F = 20	44.4	85.4	400	86	227	Filtered max. is suspect result
	U = 29	339	894	4,100	na	535	
Magnesium	F = 23	7,082	440	8,300	16,480	31,051	
	U = 35	7,045	253	7,390	na	32,233	
Manganese	F = 27	59.2	49.0	170	24.5	86.4	
	U = 37	58.5	52.0	210	na	99.8	
Nickel	F = 2	15.5	2.1	17	<30	1.98	
	U = 4	36	21	55	na	4.16	
Potassium	F = 23	6,427	683	8,000	7,975	na	
	U = 34	6,373	466	7,300	na	na	
Silicon	F = 16	20,500	1,113	21,900	26,500	na	
	U = 28	20,914	1,177	23,600	na	na	
Sodium	F = 23	42,435	2,814	53,000	33,500	37,958	
	U = 35	41,994	1,548	47,000	na	38,730	
Uranium	F = 3	5.13	0.21	5.8	3.43	14.4	
	U = 23	5.02	0.38	5.8	na	13.9	
Vanadium	F = 15	9.9	3.7	15.4	15	19.3	
	U = 17	10.0	3.4	15.3	na	20.2	

C.4

Table C.2. (contd)

Constituent	n ^(a)	Mean ^(b)	sd ^(b)	Maximum Result ^(b)	B1 ^(c)	B2 ^(d)	Comments
Zinc	F = 9	15.1	7.9	27.3	<50	48.9	
	U = 26	28.3	32.6	150	na	111	
Ammonia	5	61	32	100	<120	154	
Alkalinity	25	146,760	4,772	160,000	210,000	156,367	
Specific conductance (conductivity)	104	323.5	6.8	344	539	430	Units in μ hos/cm
Turbidity	55	3.5	7.7	42	na	na	In nephelometric turbidity units (NTU); most recent 1 yr. mean = 1.5 NTU
pH	107	8.0	0.2	Maximum = 8.45 Minimum = 7.45	6.90 to 8.24	8.07	In pH units
Total dissolved solids	28	202,893	19,651	263,000	na	277,190	
Total organic carbon	20	397	285	1,120	1,610	3,336	
Nitrate (includes N in NO_3)	30	296	185	668	12,400	41,723	
N in NO_2	13	13	9	30	na	40	
Chloride	31	3,392	293	4,480	8,690	17,370	
Sulfate	33	6,608	914	8,800	90,500	54,950	
Fluoride	31	777	134	1,100	775	539	Most recent 1 yr. results are estimated
Total suspended solids	6	3,333	2,582	6,000	na	na	
Radium-226	16	0.24	0.26	1.2	na	39.4	pCi/L (filtered)
Gross alpha	31	4.01	1.42	7.4	5.79	3.48	pCi/L
Gross beta	30	6.15	2.55	11.4	12.62	9.73	pCi/L
Oil and grease	7	19,979	26,731	63,000	na	na	See text for discussion
Gasoline	1	--	--	118,000	na	na	See text for discussion

(a) All results from unfiltered samples unless denoted by "F" (filtered) and "U" (unfiltered).

(b) All results in $\mu\text{g/L}$ unless otherwise indicated.

(c) Hanford Groundwater Background by Johnson 1993, 95th percentile, $\mu\text{g/L}$.

(d) Hanford Groundwater Background by DOE/RL, 1997, 95th percentile, $\mu\text{g/L}$.

na = no results available for background.

Table C.3. Constituents from the Original TEDF Analyte List with at Least One Result Exceeding PQL in Well 699-42-37

Constituent	n ^(a)	Mean ^(b)	sd ^(b)	Maximum Result ^(b)	B1 ^(c)	B2 ^(d)	Comments
Bis(2-hexylethyl) phthalate	1	--	--	1.0	na	na	Estimated value; common lab contaminant
Butylbenzyl phthalate	1	--	--	1.0	na	na	Estimated value
Aluminum	F = 5	39.0	30.4	88	<200	11.7	
	U = 15	419.2	901.1	3,500	na	15.3	
Barium	F = 23	56.0	4.7	70	68.5	149	
	U = 32	58.2	6.8	85	na	154	
Calcium	F = 22	24,186	1,674	29,900	63,600	78,770	
	U = 31	24,661	1,379	29,600	na	81,319	
Chromium	F = 15	4.5	2.7	10	<30	3.17	
	U = 33	22.3	31.0	150	na	4.55	
Iron	F = 17	31	16	72	86	227	
	U = 27	468	1,064	5,800	na	535	
Magnesium	F = 22	10,373	738	12,900	16,480	31,051	
	U = 31	10,574	515	12,000	na	32,233	
Manganese	F = 19	39.1	41.4	120	24.5	86.4	Unfiltered max. is suspected result
	U = 28	38.5	48.9	170	na	99.8	
Nickel	F = 3	21.7	4.0	26	<30	1.98	
	U = 12	30.1	21.2	80	na	4.16	
Potassium	F = 22	4,814	485	5,970	7,975	na	Filtered max. is estimated value Unfiltered max. error = 5,740 µg/L
	U = 31	4,914	472	6,000	na	na	
Silicon	F = 15	20,613	1,687	24,900	26,500	na	
	U = 23	21,004	1,398	23,800	na	na	
Sodium	F = 22	36,550	2,620	45,200	33,500	37,958	
	U = 31	36,452	1,418	38,800	na	38,730	
Uranium	F = 9	6.39	0.45	6.84	3.43	14.4	
	U = 23	6.38	0.54	7.6	na	13.9	
Vanadium	F = 21	24.4	5.3	36.5	15	19.3	
	U = 30	25.6	4.1	35.5	na	20.2	

Table C.3 (contd)

Constituent	n ^(a)	Mean ^(b)	sd ^(b)	Maximum Result ^(b)	B1 ^(c)	B2 ^(d)	Comments
Zinc	F = 7	22.9	18.7	63	<50	48.9	
	U = 19	35.6	37.3	140	na	111	
Amonnia	5	52	22	80	<120	154	
Alkalinity	25	136,520	4,145	144,000	210,000	156,367	
Specific conductance (conductivity)	105	356.0	16.1	393	539	430	Units in $\mu\text{mhos}/\text{cm}$
Turbidity	48	8.9	20.6	110	na	na	In nephelometric turbidity units (NTU); most recent yr. mean = 3.8 NTU
pH	98	8.1	0.3	Maximum = 8.31 Minimum = 7.64	6.90 to 8.24	8.07	In pH units
Total dissolved solids	26	227,808	16,940	270,000	na	277,190	
Total organic carbon	22	413.5	293.6	1,430	1,610	3,336	
Nitrate (includes N in NO_3)	29	3,588	3,195	17,000	12,400	41,723	Max. is suspect result; mean without max. included = 3,109 $\mu\text{g}/\text{L}$
N in NO_2	10	14	9	20	na	40	
Chloride	29	7,930	287	8,599	8,690	17,370	
Sulfate	29	24,000	2,122	32,000	90,500	54,950	
Fluoride	29	716	174	1,100	775	539	
Total suspended solids	4	2,750	2,582	5,000	na	na	
Radium-226	12	0.19	0.23	0.99	na	39.4	pCi/L (filtered)
Gross alpha	31	5.16	1.23	8.26	5.79	3.48	pCi/L
Gross beta	31	6.04	3.85	23.0	12.62	9.73	pCi/L; max is suspect result; mean without max is 5.47 pCi/L
Oil and grease	6	11,137	17,980	47,700	na	na	See text for discussion

(a) "F" (filtered) and "U" (unfiltered) metals; all other results are unfiltered.

(b) All results in $\mu\text{g}/\text{L}$ unless otherwise indicated.

(c) Hanford Groundwater Background by Johnson 1993, 95th percentile, $\mu\text{g}/\text{L}$.

(d) Hanford Groundwater Background by DOE/RL, 1997, 95th percentile, $\mu\text{g}/\text{L}$.

na = no results available for background.

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