PNNL-13022

Groundwater Quality Assessment Plan for Single-Shell Waste Management Area B-BX-BY at the Hanford Site

S. M. Narbutovskih

September 1999

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

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Pacific Northwest National Laboratory
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Contents

Figures

Tables

1.0 Introduction

Pacific Northwest National Laboratory conducted a first determination groundwater quality assessment at the Hanford Site. This work was performed for the U.S. Department of Energy, Richland Operations Office, in accordance with the Federal Facility Compliance Agreement during fiscal year (FY) 1996-1997. The purpose of the assessment was to determine if waste from the Single-Shell Tank (SST) Waste Management Area (WMA) B-BX-BY had entered the groundwater at levels above the drinking water standards (DWS). The resulting assessment report documented evidence demonstrating that waste from the WMA has impacted groundwater quality (Narbutovskih 1998).

The WMA is located in the northwest corner of the 200 East Area and consists of the 241-B, 241-BX, and 241-BY Tank Farms and ancillary waste systems (Figure 1.1). The unit is regulated under Resource Conservation and Recovery Act (RCRA) interim-status regulations (40 CFR 265, Subpart F) and was originally placed in assessment groundwater monitoring (40 CFR 265.93 [d]) in June 1996 when elevated conductivity in downgradient monitoring well 299-E33-32 was confirmed by verification sampling. A rise in conductivity was initially observed in this well in February 1996.

1.1 Statement of the Problem

During the course of the investigation, elevated technetium-99 and nitrate were observed above the DWS at well 299-E33-41, a well located between 241-B and 241-BX Tank Farms. In Narbutovskih (1998), observations of the groundwater contamination and tank farm leak occurrences combined with a qualitative analysis of possible solutions, led to the conclusion that waste from the WMA had entered the groundwater and were observed in this well.

Elevated technetium-99 and nitrate at well 299-E33-41 appeared to be related to remobilized tank waste from the WMA. The trend plot characteristics of high amplitude, high frequency events combined with the well's proximity to soil contamination from a known tank-leak and the documentation of ocal water driving forces indicate that this WMA contributed to the observed contamination. Well 299-E33-141, located 37 feet southwest of well 299-E33-41, marks the northwest extent of the known vadose zone plume associated with the 1970 leak from tank 241-BX 102 (Womark and Larkin 1971; DOE/GJ-Han-89). Data from the February 1997 sampling showed that technetium-99 was six times the DWS of 900 pCi/L. In early August 1997, technetium-99 was reported at 13 times the DWS or 12,000 pCi/L (Hartman and Dresel 1998). The level of technetium-99 at well 299-E33-41 is again rising. As of March 1998, the level was 2720 pCi/L.

Uranium has also risen above the DWS of 20 µg/L and above the local background value of 3.0 µg/L to a maximum of 81 µg/L in well 299-E33-41. The uranium trend displayed the same high amplitude, high frequency character seen in the technetium-99 and nitrate data for this well but the pattern occurred almost a year later.

In addition, high levels of nitrate, technetium-99, uranium and cyanide above the DWS have been found north and northeast of the WMA. Also, in February 1998, the DWS for technetium-99 and nitrate were also exceeded along the west boundary of the WMA. The source of rising trends of technetium-99 and nitrate seen on the western side of the WMA in wells 299-E33-42, 299-E33-31, 299-E33-32 and 299-E33-43 has not been determined. As evidenced with the February 1998 data, the contaminant levels are still fluctuating with both technetium-99 and nitrate rising above the DWS. Determination of the contamination source for these locations is part of the continued assessment for this WMA

Associated with source identification is determining the direction of contaminant flow (i.e., the direction of groundwater flow). Unfortunately the local water table is flat which negates use of the gradient to determine contaminant flow direction. Normally determination of contaminant flow direction is based on the maximum gradient of the water table. In the northwest corner of the 200 East Area, there is very little elevation change in the water table. Consequently the groundwater gradient and associated contaminant flow direction are difficult to determine accurately from water elevations. Hydrographs of local water elevations indicate that the WMA is located above a water table divide centered on wells 299-E33-13 and 299-E33-15. If the existence of this divide were true, the groundwater would have a southerly flow south of well 299-E33-13 and flow to the north on the north side of this well. There are no current surface operations that could release sufficient fluids to the ground to support an artificial mound. Thus the local direction of contaminant migration is presently unknown at this site.

Over the years groundwater plumes associated with the BY cribs indicate primarily north to north-west flow in this region (Hartman and Dresel 1998). A strategy to determine local flow directions is provided in this plan. It should be noted that there are currently no groundwater wells located along the southern border of either 241-BX Tank Farm or 241-B Tank Farm (Figure 1.1). Consequently, the state of the groundwater chemistry directly south of the WMA is unknown.

Presently it is not presently possible to eliminate either of these plumes as being tank-sourced. Consequently the further assessment will concentrate on three local areas of contamination:

1. A further assessment of technetium-99, nitrate and uranium contamination found at well 299-E33-41 focusing on matching contamination to source chemistry, monitoring contaminant levels, mapping contaminant extent over time and determining rate and direction of contamination movement.

2. Source determination for the technetium-99, nitrate and uranium contamination observed north and northeast of WMA B-BX-BY along with mapping contaminant levels and determining the extent, rate and direction of plume movement.

3. Source determination for the technetium-99, nitrate and uranium contamination observed along the west boundary of WMA B-BX-BY along with mapping contaminant levels and determining the extent, rate and direction of plume movement.

fig 1.1 (foldout)

Based on 40 CFR 265.93 [d] paragraph (7), the owner-operator must continue to make the minimum required determinations of contaminant level and of rate/extent of migrations on a quarterly basis until final facility closure. These continued determinations are required because the groundwater quality assessment was implemented prior to final closure of the facility.

1.2 Document Purpose

This document describes the plan used to implement a detailed assessment of the groundwater at WMA B-BX-BY as required by 40 CFR 265.93(d)(5). Although the original plan carried the assessment through the first determination (Caggiano 1996), this plan provides guidance for further assessment work. The minimum requirement in 40 CFR265.93 (d)(7) is to delineate the extent of the contamination, to track the concentration levels of contamination and to determine the rate of contamination migration in the groundwater. In addition to this minimum requirement, intensive studies will be conducted to further delineate the source of contamination still observed at well 299-E33-41.

This plan also provides guidelines for investigating the cause of contamination seen on the western side of the 241-BX and 241-BY Tank Farms and north/northeast of the 241-BY Tank Farm. During the first determination assessment, it was not possible to ascertain the source of contamination observed along the western, northern and northeastern WMA boundaries because the contaminant levels fluctuated over time and between wells. Also further information is needed concerning the nature of groundwater chemistry under surrounding liquid discharge facilities (Figure 1.1). In addition, ambiguities in the direction of local groundwater flow and thus, the direction of contamination migration obscure relationships between sources and groundwater plume locations. Consequently, a source determination study for these regions of the WMA is incorporated into this plan.

1.3 Scope of Investigation

The work plan for this assessment is guided, where appropriate, by the Data Quality Objectives (DQO) process developed by the U.S. Environmental Protection Agency (EPA 1994). A modified version of this process is used to develop specific objectives and identify data needs such that each aspect of the overall plan contributes to the main goal of source determination, delineation of the contaminant concentration and migration rate, and mapping the extent of migration in the ground water. Included with the migration rate is the direction of flow, needed for source determination and to predict the direction of contaminant transport.

Specific properties of the subsurface around both tank farms and surrounding cribs, trenches, tiles fields and reverse wells will be studied to differentiate sources related to these facilities from those of the nearby SST farms. In the past this has been a difficult problem. Consequently, a complete strategy, incorporating more information than the groundwater chemistry will be required. The scope of this strategy includes the following studies:

- A determination of groundwater flow velocity, both rate and direction, by reducing error in the water elevation measurements to improve our understanding of flow direction and by using a direct flow measurement device to provide corroboration of direction and to provide the rate of flow. This information provides insight on migration rate, direction to possible sources and locations of areas without adequate coverage.

- A spatial and temporal mapping of the contaminant plumes to provide the extent and level of contamination. Using past and present data, it may be possible to estimate rate and direction of contaminant movement from these maps.

- A source determination by conducting a covarying chemistry study that includes mixing curve analyses and isotopic/speciation studies. This task includes integrating the vadose zone contamination results with the groundwater results to locate vadose zone sources and using dispersion effects to estimate transport distance in the groundwater.

- A study of the existence, nature and extent of driving force sources that mobilize residual waste in the soil column and carry it to groundwater.

- The determination of an adequate sampling frequency. As evidenced from data presented in Narbutovskih 1998, semiannual sampling may not be adequate to accurately monitoring contaminants migrating from the tank farms. This study is aimed at providing a data set that will allow evaluation of the current monitoring frequency used for both assessment and detection monitoring.

These investigations are designed to provide information about the source of the contamination, the source of the driving force that carried the waste to groundwater or the nature of the contamination.

The SST farms and ancillary equipment, the location of usable groundwater wells and the surrounding past practice facilities determine the initial spatial limits for the assessment. As the extent of contamination is mapped, wells farther away from the immediate location of sources may be monitored or recommendations for new assessment wells may be made. Temporal limitations will be determined based on changes in groundwater chemistry, currently in a dynamic state across the site. If the flow is determined to have a southerly component, recommendations will be made early in the assessment process to provide coverage along the southern WMA border.

1.4 Report Plan

The following chapter explains the adaptation of the DQO process and how the conceptual model were used to develop the assessment plan. The spatial/temporal limits are explained within the modified DQO framework set forth in Chapter 2. Background information describing the results of the first determination is provided in Chapter 3 along with an update on current contamination levels at and around WMA B-BX-BY. In fourth chapter, each of the investigative studies provided above are presented with details of the specific problem, project objectives and information requirements. Reporting and project planning are described in Chapter 5.

The DQO Table of Investigative Studies is provided in Appendix A. This table allows the entire assessment plan to be view in a brief but concise format. A detail Sampling and Analysis Plan (SAP) is provided in Appendix B encompassing both a field sampling plan (FSP) and a quality assurance project plan (QAPP). The task schedule is included in Appendix B under the SAP. As-built diagrams of the assessment wells can be found in Appendix C.

2.0 Data Quality Objectives

This section will cover the general DQO requirements for the overall study, which is divided into a series of smaller investigations. First, the conceptual model is presented since this is a key element used to understand the parameters of contaminant source, migration pathways and driving forces. These parameters control the location and chemical nature of the groundwater contamination. This assessment plan is modeled after the DQO process. However, the process has been modified because this technically driven plan does not address risk or corrective actions which are beyond the scope of the assessment. The modifications are given below. The specifics relating to the DQO process are detailed for each individual investigation in Chapter 4.

2.1 Conceptual Model

The conceptual model of a hazardous waste storage facility provides a framework for guiding a RCRA assessment investigation. Any application of the DQO process should mesh with the conceptual model for the site. Consequently a brief description of the model for WMA B-BX-BY is given here. For a more complete discussion see Narbutovskih 1998.

A well-developed conceptual model integrates the characteristics of the hydrogeologic system and the waste management setting. This model includes the general waste types, the geology, the hydrogeology, and the geochemistry of the vadose zone and the unconfined aquifer. Hence, it is an aid used to develop hypotheses and qualitatively predict the movement of contaminants into and through the vadose zone to the unconfined aquifer. Specifically, the purpose of the conceptual model is to explore the complexity and spatial/temporal relationships of three important parameters: the contamination source, the driving force and the migration pathway.

The conceptual model for WMA B-BX-BY is shown in Figure 2.1. Various possible contamination sources and transport scenarios are depicted by different color schemes. The purple represents liquid tank waste at the time of the initial leak. The color shading from yellow to green depicts contaminant migration since the initial leak to its present location. Note that at WMA B-BX-BY contamination exists around some groundwater monitoring wells outside the farm boundaries.

Based on spectral gamma logs of dry wells inside the farm boundaries, it is known that cesium-137, cobalt-60 and uranium remain in the upper part of the soil column. This vadose zone contamination is related to direct leaks from tanks, from overflow of cascading transfer lines between tanks or from past surface spills. The depth of these plumes is presently unknown since the dry wells only extend to 100 to 150 feet. This leaves the bottom 100 feet of vadose zone unmapped. Existence of these plumes is documented in a 1997 DOE report (DOE/GJ-Han-89 1997). At present, there is little or no information on the nature of beta emitters in the vadose zone. Thus the existence of residual vadose zone plumes of technetium-99 is presently unknown.

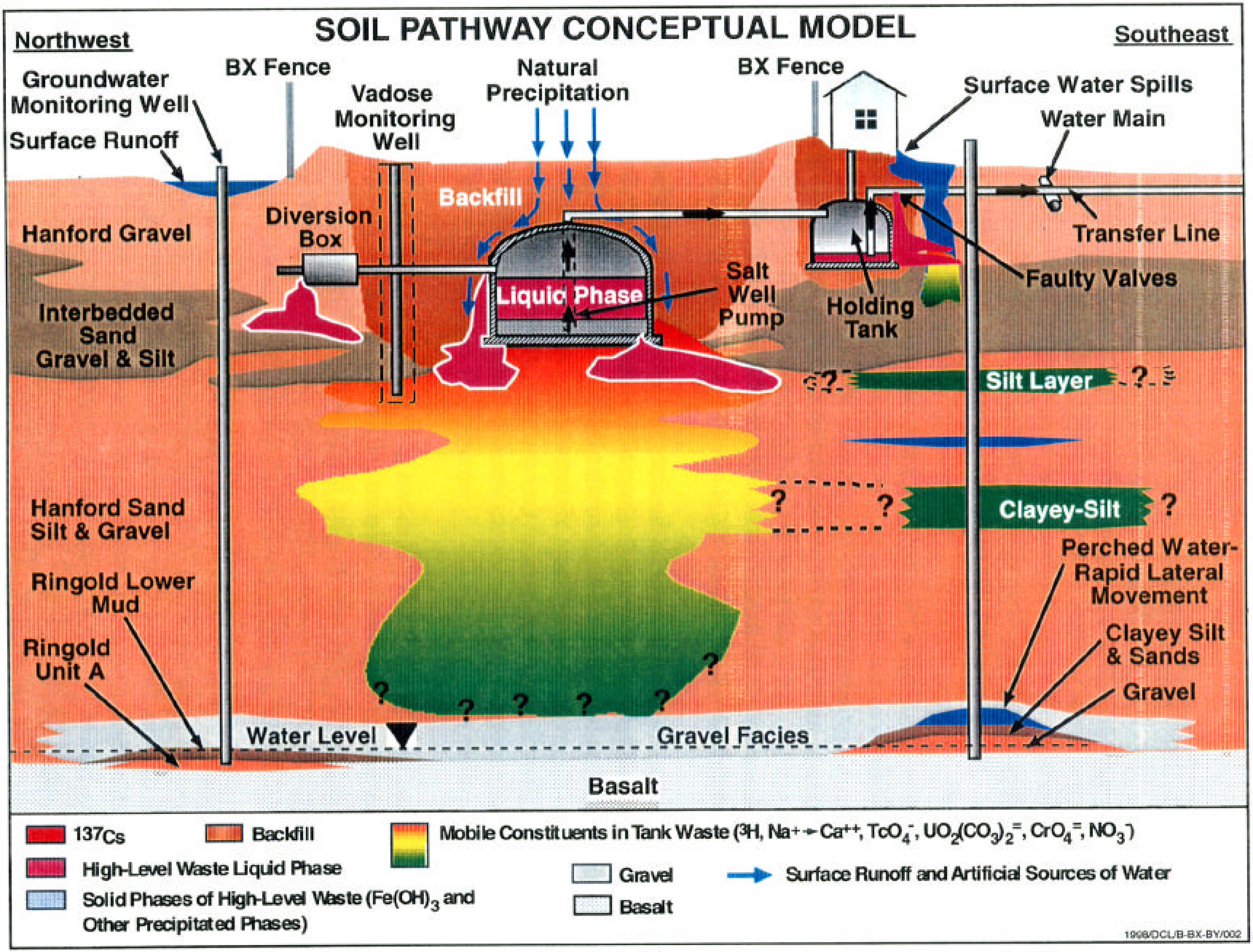

Figure 2.1. The Conceptual Model for Waste Management Area B-BX-BY in the 200 East Area

Migration of the contamination by infiltrating surface water could transport the mobile fraction of tank waste to groundwater, as illustrated in yellow to green in the central portion of the diagram. Near the holding tank, near surface water leaks or spills that encounter residual vadose zone waste may cause this waste to move rapidly down in near-vertical migration pathways, spreading the contamination to new regions. Alternatively, waste may have traveled by bulk transport through the vadose zone sediments, leaving a primarily vertical plume in the vadose zone. Waste liquid and mobile constituents from this scenario would tend to have some lateral movement via capillary forces or "wicking" into fine-grained sedimentary layers such as silt-rich zones. These layers are shown in green when they are contaminated. It is, however, not expected that lateral migration is as important in the 200 East Area as it is in the 200 West Area because well developed, continuous zones of low permeability are lacking in the upper vadose zone under this site.

2.2 The Modified Data Quality Objectives

The DQO process is used to identify the relationship between specific study goals and the corresponding data/information needs. These needs are then related to acquisition of new data where necessary. The purpose of this process is to focus on acquiring specific and necessary data. Consequently the process optimizes planning, and, if properly applied, can assist in avoiding unnecessary data acquisition and costs. The following discussion explains a modification of the formal DQO process that is applied individually to each study in Section 4.0.

2.2.1 Project Objectives

Each investigative study in this plan is designed to provide solutions or answers to problems of source determination, migration pathways and rate of transport, and the existence/nature of driving forces. Our knowledge and understanding of these components of the conceptual model support decisions on appropriate response actions such as prevention of further groundwater compromise, evaluation of environmental risk to the Columbia River, evaluation of risk to the groundwater involving tank remediation scenarios or implementation of escalated corrective action measures. The individual goal of each study and how it relates to the more general assessment objectives is discussed first under each study.

2.2.2 Decision Identification

In the DQO process, the objective of a field investigation is viewed as a choice between alternative response actions that are the consequence of making a "decision." But decisions concerning response actions based on the results of this assessment are beyond the scope of this assessment. Therefore this step is modified to address those decisions that are regulatory driven by 40 CFR 265 and pertain to determinations of contaminant source and level/rate of groundwater contamination. The individual study decision is presented for each investigation along with a discussion on how the specific study decision supports the overall assessment objectives, and an identification of data or informational needs to support the investigation. Currently available data sets are discussed with new data needs identified and justified.

2.2.3 Data/Information Requirements

Specific data or informational requirements are identified for each study along with a discussion on the manner in which an analysis of the data supports individual study objectives and resulting decisions. Currently available data sets are discussed with respect to data adequacy. New data needs and identified and justified.

2.2.4 Limits of Investigation

Currently the spatial boundaries of the study area are defined by the location of groundwater monitoring wells surrounding the WMA and nearby discharge facilities to the west, north and east. It should be noted that no groundwater chemistry information exists along the southern WMA boundary because there are no wells to provide information. With the present ambiguity concerning the direction of groundwater/contaminant flow, the spatial boundaries will be extended to cover this region, especially since the local water table indicates that flow may have a southerly component. As the current extent of groundwater plumes is mapped, the spatial limits of the assessment will be reevaluated and set accordingly.

Temporal limits, are defined as the time needed to make the technical decisions related to the overall project objectives. The levels of contamination observed in individual wells are, for the most part, either rising or fluctuating. Based, however, on the time required to collect, analyze and interpret sufficient data to answer pertinent questions, a minimum of 2.5 years may be required. A proposed assessment schedule is provided in Appendix B.

3.0 Background

The current state of contamination surrounding WMA B-BX-BY is presented in this section. Comparisons of data collected from RCRA groundwater wells are made with data from selected wells associated with or located near the surrounding liquid effluent discharge facilities (Figure 1.1). Observations based on these data are used to guide the objectives of investigative studies for further assessment work.

3.1 Conductivity Trends

Background field conductivity for groundwater under the 200 Areas plateau is about 344 µmhos/cm (Johnson et al. 1993). The statistical critical mean, calculated for use at the WMA during interim detection monitoring from July 1991 to June 1996, was 365.7 µmhos/cm (Figure 3.1). When conductivity values in well 299-E33-32 exceeded the critical mean in February 1996 (368 µmhos/cm) and verification sampling confirmed the high levels in June 1996 (427 µmhos/cm), the groundwater monitoring program was changed from detection-level monitoring to a groundwater quality assessment program. In August 1996 the conductivity dropped to 334 µmhos/cm in this well.

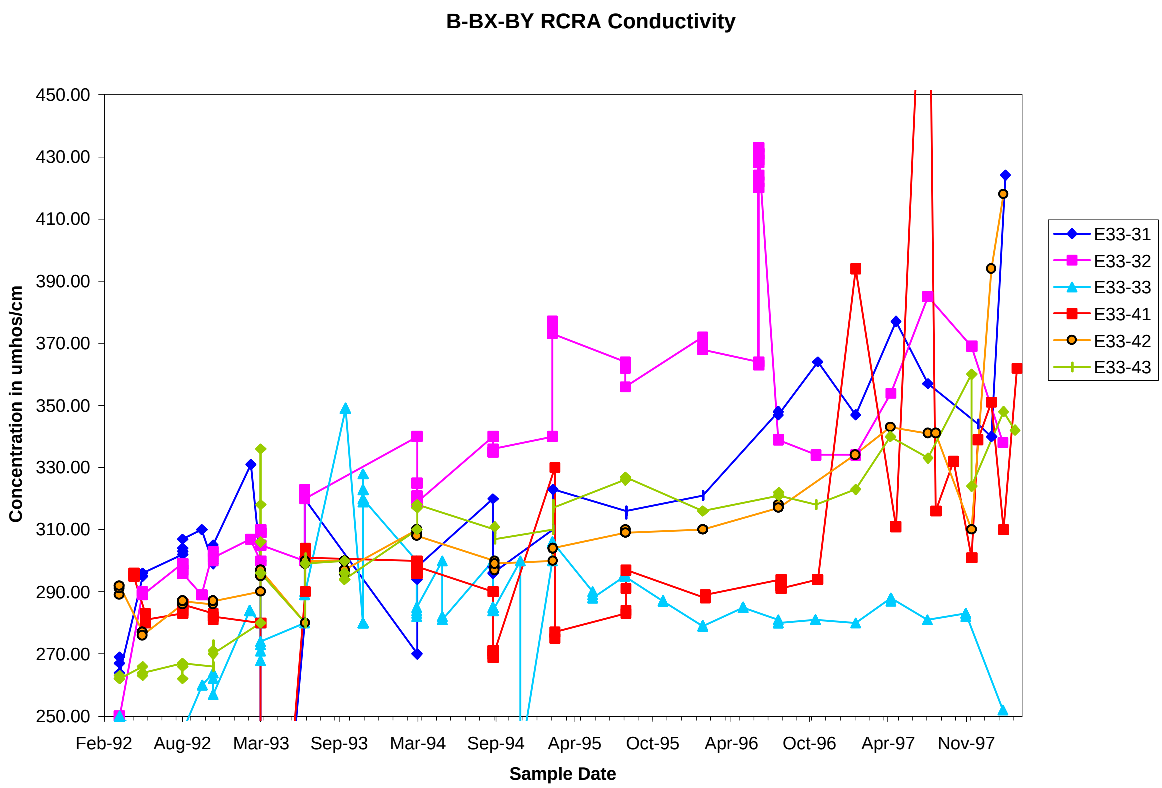

Figure 3.1. Conductivity Trend Plots for RCRA Network Wells. Note that some recent data are under review and thus, are questionable.

In February 1997 conductivity rose to 394 µmhos/cm in well 299-E33-41, then rose again in early August 1997 to 542 µmhos/cm. Three weeks later it dropped to 316 µmhos/cm. The high amplitude, high frequency, repeating character of the conductivity trend in Figure 3.1 was also observed for technetium-99 and the major anions during this time period (Figure 3.2). The WMA was kept in assessment because of exceedances in conductivity and technetium-99 in this well.

The following observations are pertinent to the assessment.

- Conductivity is currently rising at well 299-E33-41 with the March 1998 value at 362 µmhos/cm. Unlike the high amplitude, high frequency events observed earlier, this rise is occurring gradually from August 1997 to the present.

- Located on the western side of the WMA, wells 299-E33-31 and 299-E33-42 have sharply increased in conductivity to 424 µmhos/cm and 418 µmhos/cm respectively (see Figure 3.1). It is possible that this same increase occurred at well 299-E33-32 since nitrate and technetium-99 have risen in this well. The February 1998 conductivity value for this well is currently under investigation.

- The FY 1997 changes in contamination observed in well 299-E33-41 occurred over very short time intervals. If the WMA had been monitored semiannually, as required under detection monitoring,

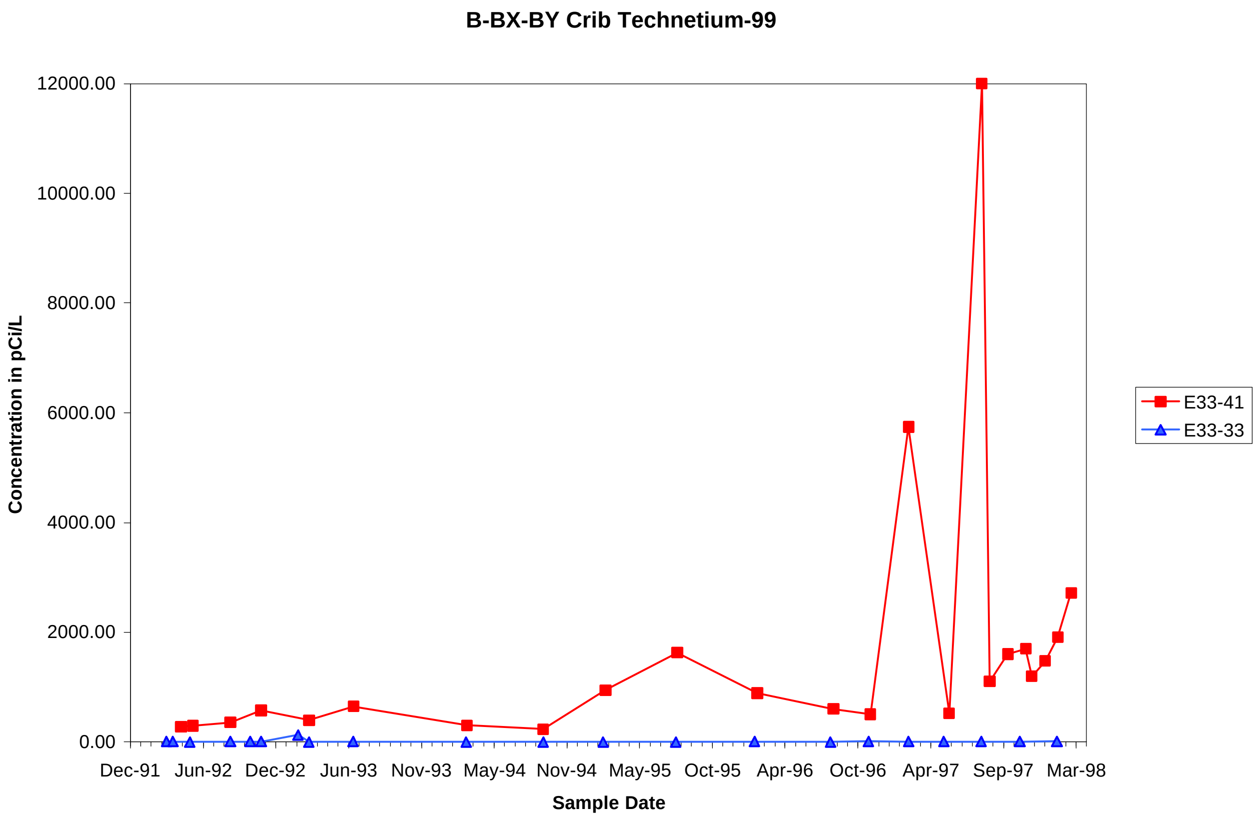

Figure 3.2. Trend Plots of Technetium-99 for RCRA Wells 299-E33-41 and 299-E33-33

neither of the high conductivity spikes and the corresponding technetium-99 contamination would have been observed (see Figure 3.2). The sudden drop in contamination from August 6 to August 24 provides further evidence that semiannual monitoring of this facility might be inadequate for detection monitoring.

- North of the WMA, in the southern part of the BY cribs, conductivity values ranged in February 1998 from 448 µmhos/cm in well 299-E33-5 to 568 µmhos/cm in well 299-E33-38. Northeast and east of the 241-BY Tank Farm, values for February 1998 range from 1132 µmhos/cm in well 299-E33-16, to 399 µmhos/cm in well 299-E33-39.

- Conductivity in the supposedly upgradient well for this area, well 299-E33-33, continues to remain stable at about 280 µmhos/cm.

The observed changes in conductivity are primarily a result of increases in nitrate along with some increases in sulfate and chloride. In February 1998, nitrate was in exceedance of the DWS of 45,000 µg/L on the west, north and northeast-east side of the WMA. Only wells 299-E33-41, 299-E33-43 and 299-E33-21 displayed nitrate data below the DWS. As there are no wells along the southern boundary of the WMA, contaminant conditions in this area are unknown.

The gradual rise in conductivity seen since the early 1990's in most of the RCRA wells is unlikely to be related to the declining water table intersecting vertical stratification of the groundwater contamination. A comparison of results from samples collected in well 299-E33-41 at depths of 2 inches (5 cm) and 5 feet (1.5 m) indicated that no significant stratification of groundwater is occurring at the this site.

3.2 Technetium-99

Comparison of technetium-99 trends between RCRA wells is shown on Figure 3.3. Data from well 299-E33-33, located southeast of the WMA, are included to allow comparison with a relatively uncontaminated, nearby area. In this well, technetium-99 has been less than 10 pCi/L since the earliest sample in March 1991. On the western side of the WMA, technetium-99 has been steadily rising in wells 299-E33-31, 299-E33-42 and 299-E33-32 since late 1996. In February 1998, technetium-99 was found in concentrations above the DWS of 900 pCi/L in well 299-E33-42 at 1240 pCi/L.

Recent data in well 299-E33-8 indicate that technetium-99 is in the groundwater further to the west of 241-BY Tank Farm. However, data from well 299-E33-21, located within the retention basins west of the WMA, indicate that currently there is very little technetium-99 to the southwest of the WMA. Data from this well bracket the technetium-99 plume in this area as of the February 1998 sampling event.

Comparisons of technetium-99 trends for well 299-E33-41 with selected non-RCRA wells are made in Figure 3.4. The highest technetium-99 concentration at 3010 pCi/L is found in well 299-E33-5 located north of the WMA in the BY cribs. Concentrations are also rising again in well 299-E33-41, currently at 2720 pCi/L as of March 1998. For a discussion of the high frequency, high amplitude spikes observed in the February and August 1997 data in this well, the reader is referred to Narbutovskih 1998.

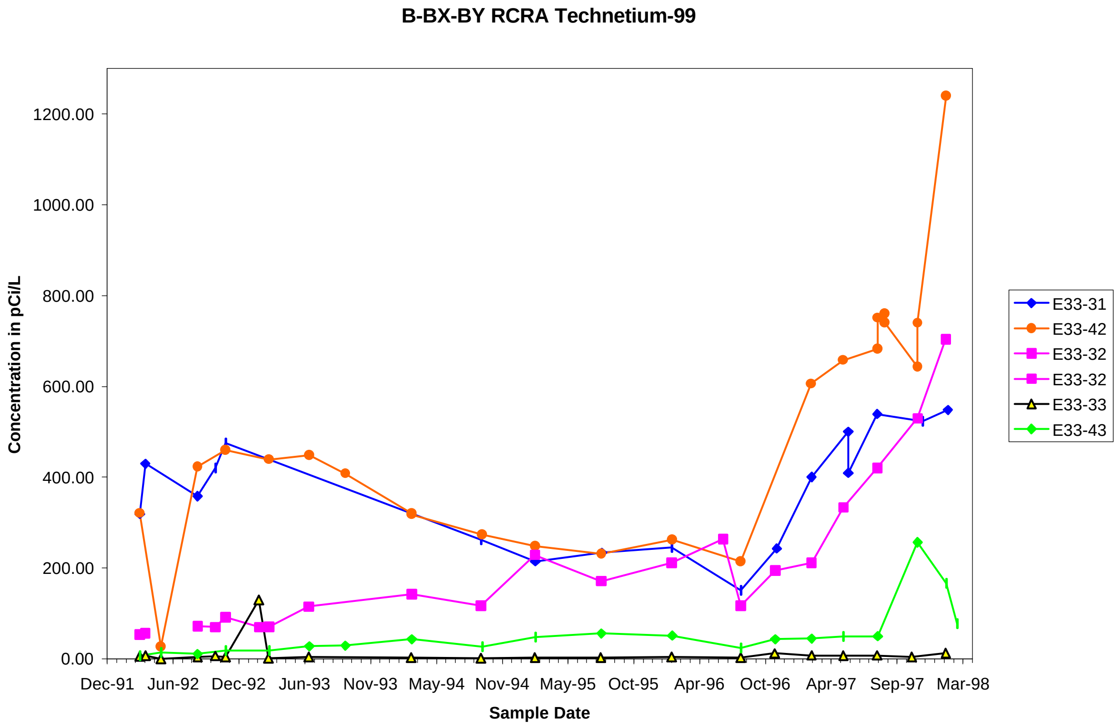

Figure 3.3. Trend Plots of Technetium-99 for RCRA Wells 299-E33-31, 299-E33-32, 299-E33-33, 299-E33-42, and 299-E33-43

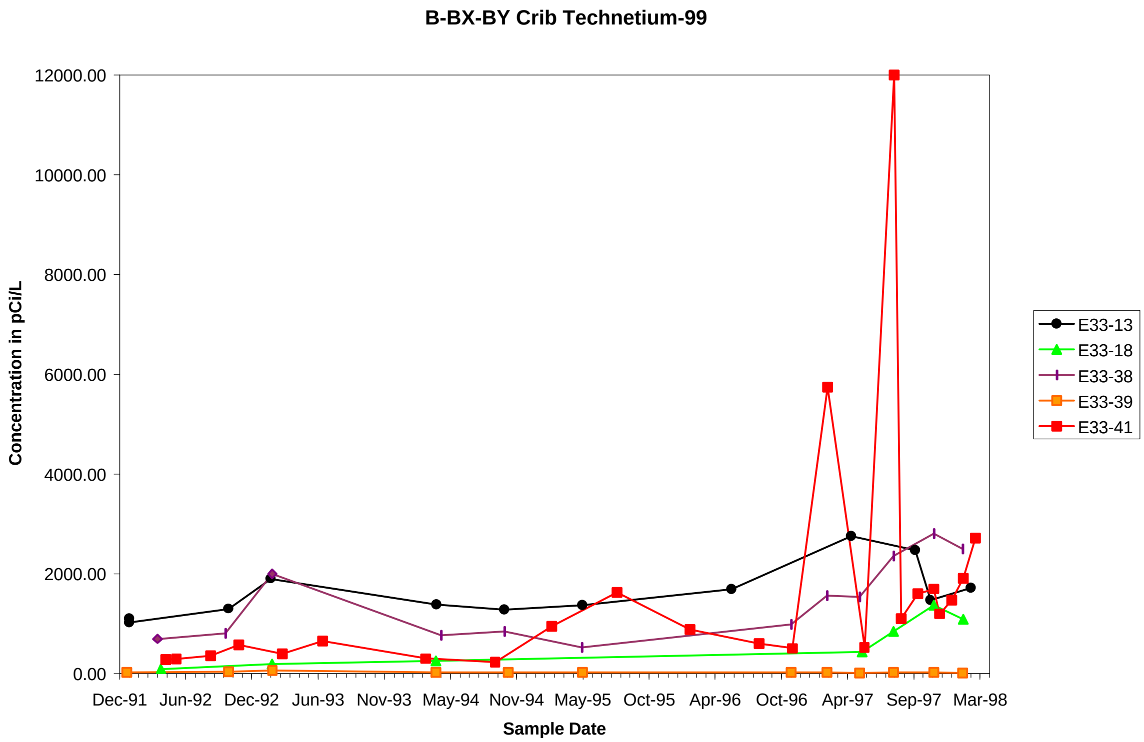

Figure 3.4. Trend Plot of Technetium-99 for Wells 299-E33-13, 299-E33-18, 299-E33-39, 299-E33-38, and 299-E33-41

Although there are significant amounts of technetium-99 found in wells 299-E33-16 and 299-E33-18, there is very little technetium-99 found in wells 299-E33-15, 17, 20, and 39. This produces a discontinuous technetium-99 pattern on the east side of the WMA. For most of these older non-RCRA wells, the historic data are sparse. The database is currently being built to better understand the nature and extent of the contamination in this area. The resulting picture of technetium-99 contamination at this site is confusing at best. Once the flow direction has been determined, coverage is provided on the south side of the WMA and mixing curves are developed, a hypothesis may be formed to explain these observations and to determine the source or sources for this contamination.

3.3 Uranium

Prior to 1995 uranium was sampled for the WMA RCRA network wells and select wells in the BY cribs managed under the 200-BP-1 CERCLA project. With the exception of well 299-E33-13, the uranium level in most wells was below 10 µg/L. The drinking water standard for uranium is 20 µg/L. Analyses for uranium were discontinued after early 1995 since the data indicated that, in general, uranium was not elevated in the area. With the appearance of high technetium-99 levels in well 299-E33-41 uranium analyses were resumed for the RCRA wells and for the expanded assessment network. These current uranium trends are shown in Figure 3.5 for wells with detectable uranium levels. Wells that were sampled but not shown in Figure 3.5 did not have detectable amounts of uranium in the groundwater.

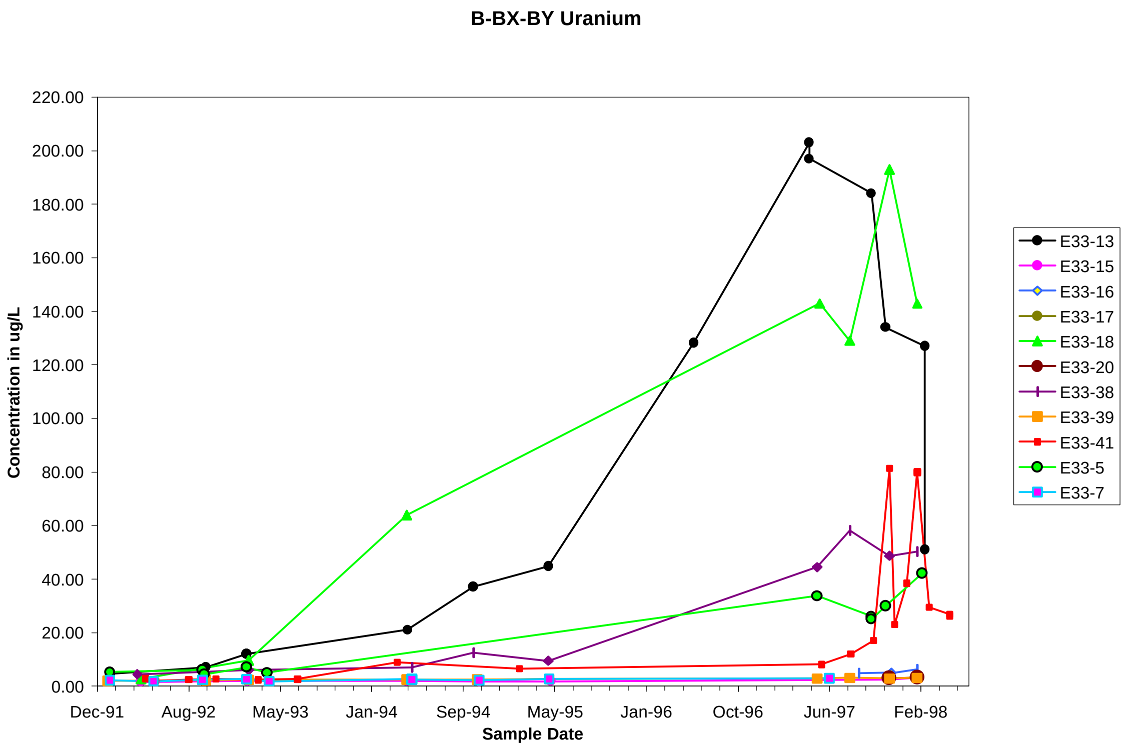

Figure 3.5. Trend Plot of Uranium for Wells 299-E33-13, 299-E33-18, 299-E33-33, 299-E33-38, and 299-E33-41

At WMA B-BX-BY, data from most wells show that uranium is at natural background levels from 2.5 to 3.0 µg/L. As shown in Figure 3.5, a small uranium groundwater plume is centered on well 299-E33-13. Elevated uranium has also been found in wells 299-E33-18, 38 and 5 along with well 299-E33-41. It should be noted that the uranium trend in well 299-E33-41 displays the same high amplitude, high frequency character seen in the technetium-99 and anion data for this well. The uranium pattern, however, has occurred at a later time than the corresponding technetium-99 contamination. The uranium found in this well is, most likely, related to the same event that caused the sudden increases in technetium-99. This implies not only a unique and different source for contamination in well 299-E33-41 with respect to nearby wells, but also that the uranium is traveling through the groundwater at a slower rate than the technetium-99 and associated anions.

It is difficult at this time to determine the source of the elevated uranium observed at wells 299-E33-13, 38, and 5. This is largely attributable to ambiguities in our knowledge of the local flow direction at WMA B-BX-BY. If the flow direction continues to have a strong northerly flow component, then a tank-related source is possible for this uranium contamination. If the flow direction has a primarily southerly direction, as indicated by direct flow measurements, then a tank-related source is less likely. Plans for determination of the local flow direction are given in the Chapter 4. If a northerly flow direction is determined, then a source determination investigation will be continued to identify the uranium source.

3.4 Other Constituents

Cyanide and cobalt-60 are possible key chemical constituents in this area. Potassium ferrocyanide and sodium ferrocyanide were added to tank waste along with nickel sulfate to precipitate selected radionuclides. The solid precipitate, nickel ferrocyanide settled, binding the cesium-137 in the tanks in a solid phase. The tank supernatant enriched with excess sodium or potassium ferrocyanide was discharged to the cribs. At the cribs the ferrocyanide complexed with cobalt-60 forming solid cobalt ferrocyanide, which most likely precipitated in the sediments. However this solid phase would be in equilibrium with the pore water leaving some relatively small activity of cobalt-60 and ferrocyanide as a mobile constituent. Thus, a crib source might be enriched in cyanide and cobalt-60 while a tank source might contain less of either constituent. Ferrocyanide scavenged waste was added primarily to tanks in the 241-BY Tank Farm.

As of November 1997 cyanide has been found in only three wells: 299-E33-13, 299-E33-38, and 299-E33-5 (Figure 3.6), all three located in or close to the BY cribs. There is no detectable cyanide in well 299-E33-41 or in the other RCRA wells at present. The lack of cyanide at well 299-E33-41 further distinguishes the contaminant source for this well as being tank waste. The maximum contaminant level allowed for cyanide is 200 µg/L. The analysis method has a detection threshold of 1.33 µg/L.

Based on the above discussion, cobalt-60 would be expected to co-vary with cyanide. Although cobalt-60 has been found in the groundwater at wells 299-E33-13, E33-16, 299-E33-38, and 299-E33-5 during the last year, the values are close to or below the limits of quantitation at 20.49 pCi/L. The historic data in these wells is not complete enough to provide ascertain any past events. For wells 299-E33-13, 299-E33-38, and 299-E33-5, the cobalt-60 has been co-varying with cyanide beginning in August 1997.

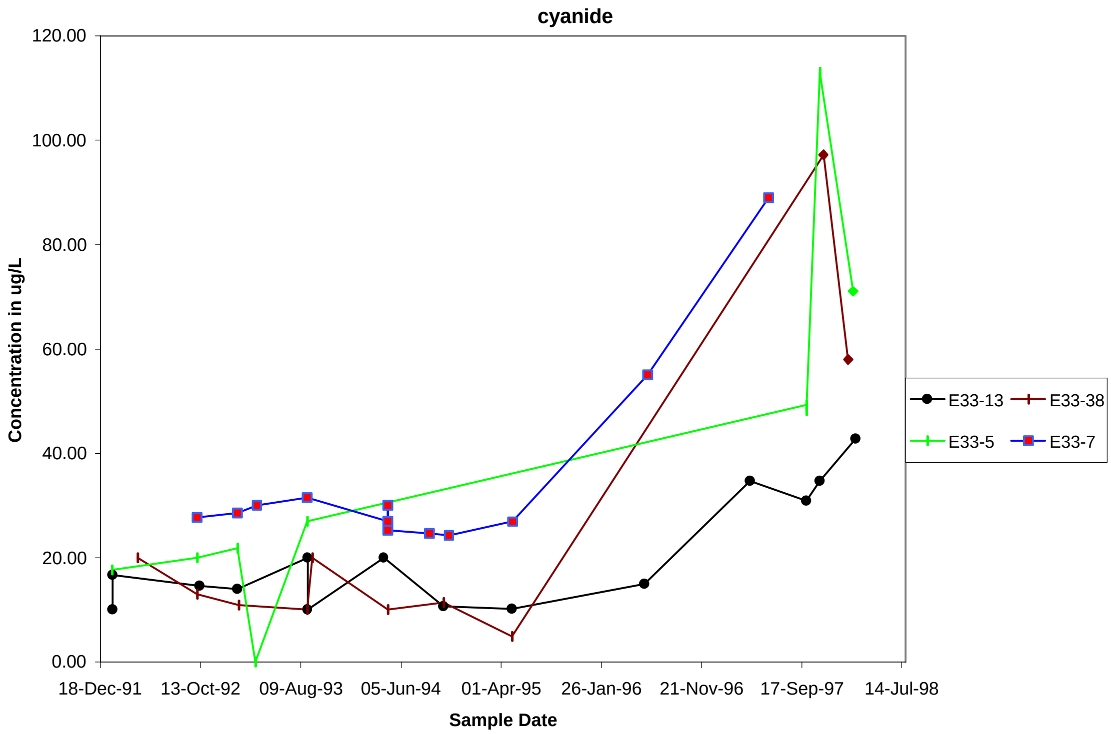

Figure 3.6. Trend Plot of Cyanide for Wells 299-E33-13 and 299-E33-7

For well 299-E33-16, there appears to be no corresponding cyanide to match the cobalt-60. This may be a data quality control problem and is under investigation. The interim DWS is 100 pCi/L for cobalt-60.

Although the assessment wells are monitored for cesium-137 and strontium-90, there are currently no known occurrences in the groundwater under 241-B-BX-BY Tank Farms. The lack of cesium-137 might be expected since field observations and experimental data suggest that cesium-137 is usually held in the upper part of the soil column close to the tanks.

4.0 Investigative Studies

This section explains the main tasks addressed by this assessment and provides the connection between each of these tasks and the general objectives of the assessment. For each individual investigative study, the specific problem and the modified DQO decision or objective is presented. The data or information required to provide a solution is discussed and new data needs are identified. A concise description of the assessment strategy can be found in the Table of Investigative Studies in Appendix B.

4.1 Groundwater Flow Velocity

This overall study addresses determination of the direction and rate of contamination migration. Currently there is considerable uncertainty in the velocity, both magnitude and direction, of groundwater flow in certain regions of the 200 East Area. At WMA B-BX-BY, the water table is nearly flat with a maximum of 7 inches (18 cm) change in water elevation across the Waste Management Area (Figure 4.1). The flat hydraulic gradient of 0.0001 reported in Hartman and Dresel (1998) makes the local flow direction difficult to ascertain. Plume maps of contamination from the late 1940s indicate that the original flow direction was south to south-southeast (Brown and Ruppert 1950). However, in the mid-1980's with the buildup of the B Pond mound, east of the 200 East Area, the flow direction at the BY cribs was artificially switched to the northwest as evidenced in regional plumes (Ford 993, WHC-SD-EN-TI-020). The RCRA groundwater network was originally designed prior to well installation in 1989 for this northwest flow (Jensen et al. 1989).

Currently the B-Pond mound is rapidly dissipating, and groundwater flow in the area of WMA B-BX-BY is expected to revert back to its original southerly direction. As can be seen in Figure 4.1, the water table is currently dropping in response to the declining B Pond mound. Aquifer thickness is approximately 10 feet at most locations. However there are local areas where the aquifer is less than 5 and other where is it is over 20 feet thick. This wide variation in thickness is a function of structure on the basalt surface. Based on original water depths in local wells drilled in the early 1950’s, the water table can be expected to drop at least another 2 to 5 feet before leveling out.

The hydrographs for RCRA wells indicate that some supposedly downgradient network wells may actually be higher in water elevation than the presumed upgradient wells, such as well 299-E33-33 (Figure 4.1). These data would suggest that southerly flow is already occurring.

In addition, in situ borehole measurements of flow direction conducted at the 216-BY cribs and along the west side of the WMA indicate that the current flow direction may be to the southwest (Kasza 1995, DOE/RL 1996). These measurements were made with a thermal perturbation probe. Although not in agreement with the past BY cribs plume movement to the northwest, the general southwest direction may be correct even though some error can be expected due to borehole effects (Drost et al. 1968). The southwesterly flow obtained by this method in 6 local wells is consistent with directions based on the local groundwater gradient.

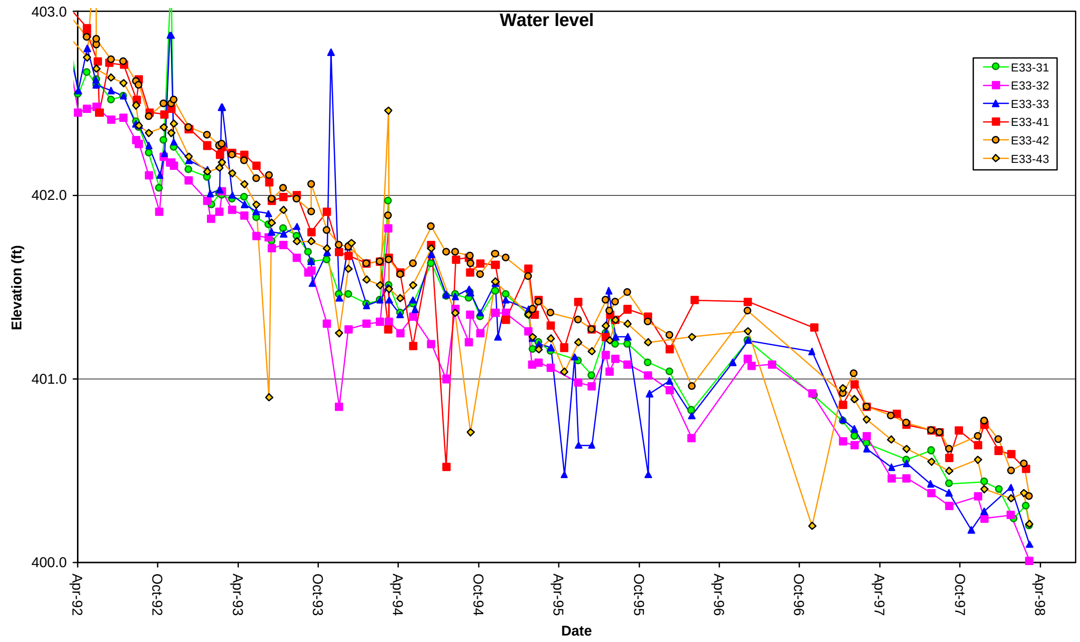

Figure 4.1. Hydrographs of the Wells that Comprise the RCRA Network. These data illustrate the flatness of the water table. Also shown are the consistent higher water levels of wells 299-E33-41 and 299-E33-42.

The relative difference between wells, indicating local southerly flow, has been similar since the wells were drilled in 1989/1990. That is, the “upgradient” well (299-E33-33) has had a lower water elevation than some of the “downgradient wells” (299-E33-41, for example). The elevation of wells 299-E33-13 and 299-E33-33 differs by about 7 inches (17.8 cm) (see Figure 1.1). There are numerous factors that can contribute to errors in water level data. They are as follows:

- Vertical survey error of well casings. Well locations are surveyed for map location and for elevation above mean sea level. Errors associated with the elevation of the tops of casings can results in consistent differences between wells.

- Water level measurements. Sources of error are related to stretch in the metal measuring tape, not measuring from the correct spot on the borehole each time and from error in reading the tape. The maximum data error for water level measurements is 1.4 inches (3.6 cm), with a typical error around 0.6 inches (1.5 cm). These errors are based on a maximum tape deviation of 1.2 inches (3.0 cm) with a measurement error of 0.24 inches (0.6 cm). The discrepancies in water table elevation differences are about 5 times the measurement error and taken alone, are not the source of this discrepancy.

- Vertical deviation effects of borehole casing. Occasionally a borehole is not plumb (vertically straight). This problem results in a longer depth to water and thus, a low water elevation. Errors may be close to a foot and would cause water elevations to appear consistently low. The discrepancy with the water elevations at this WMA is that several wells are too high. Consequently, this error is unlikely to be the cause of high water elevation measurements.

- Stratigraphic control. The water table may intersect sediments with widely varying permeabilities. Where sediments have a low permeability, the water table may be held slightly higher because of capillary action in fine-grained units. Slight local highs in the water table caused by impermeable sediments would continue over time provided the water table remained static.

- Barometric effects. Changing atmospheric pressures at the surface in response to changing weather conditions can cause the water elevation in wells located in unconfined aquifers to be temporally elevated or depressed. This may cause the relative differences in water elevations between wells to appear to change if the levels are measured at different times of the day. This effect would be more pronounced if water elevations are made on different days when the atmospheric pressure has changed due to varying weather conditions. Based on the consistent relative water elevation differences between wells over time, it is unlikely that barometric effects are causing these elevation differences.

Because the water level differences across the WMA are less than one foot, it is important to reduce the above sources of error to the degree possible. A strategy to improve water level measurements by reducing these sources of error or recognizing stratigraphic controls is given in the next section.

Calculations of flow rate using Darcy's Law, based on the local gradient indicate a maximum flow rate of 0.18 feet (0.11 m) per day (Hartman and Dresel 1997). Permeability, k, of 320 feet/day as reported by Newcomer et al. 1993 and a porosity of 20% were used in this calculation. The permeability was calculated from slug tests in well 299-E33-33, located southeast of the site (WHC 1990). Hydraulic testing in numerous other wells to the east and west of the WMA have provided permeability values that range from 4800 feet/day to 11,400 feet/day (Connelly et al. 1992). Using the value of 5300 feet/day from the well nearest of the WMA results in a flow rate of 3.0 feet/day. Results from the in situ thermal probe measurements provide values around 1.7 feet/day to 2.1 feet/day (DOE/RL 1996). Rates that were calculated with the greater permeability values are in agreement with those found using the in situ thermal probe but disagree with values calculated from slug test results. Thus, not only is the direction of flow in question but also the rate of flow.

As part of the continuing assessment under 40 CFR 265.93 [d], it is not only required that the rate of contamination but also the extent of contamination be determined. At present there are no monitoring wells along the south border of the WMA. If the current flow direction has taken on a southerly direction with the demise of B-Pond, then new wells may be needed along the southern border to provide downgradient coverage for the WMA. These wells have been proposed and two initial wells are planned for installation in FY1999.

Determination of the approximate flow direction is also needed to ascertain the source for contamination observed to the north and northeast of the WMA. Consequently an approximate knowledge of groundwater velocity is required as early as possible in the assessment process. If the flow direction can be determined within a quadrant, then initial conclusions can be drawn concerning the origin of contamination to the north and northeast.

4.1.1 Refinement of Water Elevations

A phased approach is adopted beginning with steps to refine the water elevations. The steps are numbered in the order that work will proceed. If the ambiguity in flow direction can be removed at any given time, it will not be necessary to proceed to the other studies. This will allow resources to be expended on other needed aspects of the assessment. Also if during the time that these studies are being conducted, the flow direction can be ascertained from observed changes in groundwater chemistry, then it will not be necessary to continue work on these tasks.

The refined water elevation tasks are designed to determine the approximate direction of groundwater flow, not the absolute direction. When the direction is determined within one quadrant, then possible sources can be identified and the need for additional monitoring wells in the south can be identified.

Tasks under this study are as follows:

1. Check survey history of wells in the area to determine if the reference point for individual wells is reported accurately. Check between surveys for consist well elevations. Calculate water elevations with the different surveys to find water table differences with respect to each survey. No new data is required unless the results indicate that mistakes in past well surveys warrants a new survey of the area. This is not anticipated at this time.

2. Refine depth to water measurements by taking accurate readings for the assessment wells. Measurements will be made with the same tape and by the same personal to reduce the actual measurement error. Each set of measurements will be made within a 3-hour period to reduce barometric effects. Three sets of measurements will be made over 3 months on days with limited changes in barometric pressure if possible. By having the water levels measured in one 3-hour period, barometric effects on water level elevations will be minimized.

3. Determine if borehole vertical deviation effects are great enough to cause the discrepancy observed in the water elevations. Initially, a comparison will be made between one “upgradient” well and one supposedly “downgradient” well. If these corrections eliminate the elevation discrepancies, then other key wells will be surveyed and depths to water corrected. Deviation from the vertical will be made with a downhole gyroscope or another adequate but less expensive method.

4. Construct a structure contour map of local stratigraphy across the WMA to ascertain if remnants of the Ringold “Lower Mud” or another relatively impermeable unit may be causing local ‘highs’ in the water table. As the water table has continues to drop, a greater degree of heterogeneity in permeability at the top of the water table may be forming a groundwater high thus affecting local flow directions.

5. Determine the magnitude of barometric effects on the water table. This study will be conducted in one “upgradient” well and one supposedly “downgradient” well to determine if daily changes in barometric pressure are great enough to cause the observed discrepancy in the water table gradient.

Pressure transducers will be place in the groundwater and at top of the well with continuous measurements made at 15 minute intervals. These pressure transducers will be coupled with downhole conductivity probes to provide data not only for this study but for those in Sections 4.4.2 and 4.5.

Once the above corrections are applied to water level measurements, the local flow direction can be more accurately inferred. Stratigraphic controls, if present, can compromise gradient information. Then the groundwater gradient is not useful to ascertain flow direction. Other approaches will be considered.

4.1.2 Flow Velocity From Direct Flow Measurements

The flow direction resulting from refined water elevation data will be checked with direct measurements in suitable wells with the colloidal borescope. The colloidal borescope is an in situ flow measurement device that detects the speed and direction of particulate matter moving with the water flowing through the well bore. These data are needed to provide an independent control on the groundwater flow direction. In addition, the boroscope data will provide information on the rate or magnitude of groundwater flow. For contaminants moving with the advective flow, this equates to determining the rate of contamination migration.

Prior to use of this tool, a scoping investigation will be conducted to determine the technical issues concerning the application of the borescope. As with any method that measures flow within the borehole, there are problems with flow deviation effects caused by the presence of the borehole itself. However, approximate flow directions within a quadrant are adequate for the purposes of the assessment. Thus some error can be tolerated. Results of this preliminary study will be used to assure that borescope measurements are properly made in as many wells as possible with respect to the well bore environment and local hydrogeology. Also, these findings will assure that borehole effects are mitigated. Furthermore, depending on the consistency of the results, this method may be deployed in a semi-permanent installation to watch for directional changes over time.

4.1.3 Decision Identification

Because of the important, potentially expensive decisions resulting from this assessment, it is required that the problem of flow direction be approached from all possible directions. The technical approach to flow determination is phased such that the simple, more direct possibilities are examined first.

Knowledge of the flow direction is used in making decisions concerning contaminant sources. Once the upgradient direction can be approximated, local waste facilities can be evaluated as possible sources for the groundwater contamination. For example, a northerly flow provides evidence that contamination seen to the north of 241-BY Farm may be from sources related to this WMA. On the other hand, if the flow direction is south, then recommendations will be made for groundwater monitoring coverage along the southern border of 241-B and 241-BX Tank Farms.

Other decisions relate to the rate at which the contamination is moving through the WMA. For example, a high flow rate of 2 to 3 feet/day (0.6 to 0.9 m/day) has implications for future risk analyses of the SST in this region.

4.2 Extent of Contamination

The objective of this study is to map the level and extent of contamination observed at the WMA. Groundwater chemistry data will be acquired from the assessment wells listed in Table 4.1. Although the decision to provide continuing information on contaminant levels and extent is required by 40 CFR 265.93, other uses will be made of these data. For example the resulting contaminant plume maps will be used to assess the need for additional monitoring wells. Also the acquired data will help locate the source of contamination found west, north and northeast of the WMA. As the plumes are mapped over time, information may be provided on groundwater flow velocity. In addition, these data will help determine an appropriate sampling frequency for continued monitoring and for closure network design.

4.2.1 Spatial/Temporal Mapping

Based on groundwater chemistry data, contaminant plumes maps will be prepared for the contaminants of interests and for associated constituents. Detailed, contaminant maps will be constructed for selected time intervals in the past and during the assessment to evaluate temporal relationships related to plume movement. Spatial relationships between contaminants will be compared to determine differences in plume chemistry. The plume maps will also be compared to results from Section 4.3 on source chemistry signature and vadose zone source locations to provide further evidence to define sources.

The groundwater plume maps and the local flow direction will be used to determine contaminant sources. When combined with a comparison of tank and crib chemistry, the source or sources of contamination observed to the west and north-northwest can be determined. This information may also provide insight relative to the points of entry to the groundwater as well as flow migration pathways within the unconfined aquifer.

The project limitations and study boundaries depend on the extent of the groundwater plumes, which presently are not defined. For example, on the western side of the WMA, there is some evidence that contamination does not extend underneath the south half of the retention basins (see Figure 1.1). Thus no further coverage is needed in this area yet. However, data from a well located on the northern edge of the trenches (i.e., northwest of the WMA) indicates that the plume may extend close to the B-57 crib. Consequently, the spatial boundary of the study will be extended to the northwest.

No contamination appears to the south of the WMA. However there are no wells in this area and consequently no groundwater data. Based on the present groundwater gradient direction, a minimum of two additional wells be installed along the southern boundary to support the assessment.

In addition to mapping the extent of the contamination, work will be conducted to detect little known, but mobile radioactive nuclides such as neptunium-237 and selenium-79, which are stable fission products of ruthenium isotopes. Certain waste streams contained limited quantities of these isotopes. Furthermore, samples will be analyzed for the isotopic abundance of U-235 and U-236. Over time, the abundance of U-236 in the waste streams was increased as the same uranium was reused and reacted repeatedly. Thus the amount of total U-236 in the waste may help to determine the age of waste released to the subsurface. Other isotopic work will be conducted on U-235 versus U-238 and determining if any U-233 is present in the groundwater.

4.2.2 Groundwater Monitoring Well Network

An expanded groundwater network has been developed for use while conducting this assessment. Both the original RCRA network wells and the additional non-RCRA wells are listed in Table 4.1 with locations shown in Figure 1.1. As-builts of the well construction are provided in Appendix C. Given in Table 4.1 are the two wells originally installed as upgradient wells for the network, wells 299-E33-33 and 299-E33-36. With the present uncertainty in groundwater flow direction, the terms “upgradient” and “downgradient” are obscure.

There are two types of wells used in the assessment. First are the original RCRA network wells plus wells 299-E33-38 and 299-E33-39, which were constructed to WAC 173-160 specification and thus, are RCRA compliant. These well were installed between 1989 and 1991 following the original groundwater-monitoring plan (Jensen et al. 1989) or during investigations for the 200-BP-1 operable unit. They have stainless steel, 4-inch diameters with 20-foot screens in a filter pack and full annular and surface seals (Caggiano 1992, 1993). The total depth of these wells is at or near the top of basalt.

The other wells are older non-RCRA wells constructed of carbon steel casing with perforations over different lengths within the unconfined aquifer. Many of these wells are located adjacent to cribs, trenches or reverse wells to provide monitoring for these facilities in the past. The data from these wells are used for supplemental monitoring during the assessment to determine differences in groundwater chemistry across the site and to map the extent of contamination.

Table 4.1. Groundwater Monitoring Assessment Wells at WMA B-BX-BY

Original RCRA Network Wells	**Assessment Network Wells**	
All wells have RCRA compliant construction	Non-RCRA compliant wells	RCRA compliant wells
299-E33-31	299-E28-8	299-E33-31
299-E33-32	299-E33-5	299-E33-32
299-E33-33	299-E33-7	299-E33-33
299-E33-36	299-E33-8	299-E33-36
299-E33-41	299-E33-15	299-E33-38
299-E33-42	299-E33-16	299-E33-39
299-E33-43	299-E33-17	299-E33-41
	299-E33-18	299-E33-42
	299-E33-20	299-E33-43
	299-E33-21	

Locations of other wells are provided in Figure 1.1 to show the wells in the area. However, not all these wells are suitable for sampling. For example, well 299-E33-27 has been plugged back to provide vadose zone monitoring only. Also well 299-E33-12 is screened in the confined aquifer which is the first basalt interbed. The well 299-E33-141 is a dry well used for gamma ray logging within the farm. Its location marks the northwest extent of the known vadose zone plume associated with the l970 leak from 241-BX Tank 102. These wells are included on the WMA B-BX-BY location map to facilitate future planning.

4.2.3 Sampling and Analysis

Depending on the location of a well with respect to known groundwater contamination, a well may be sampled monthly or quarterly. The current constituent list is given in Table 4.2. The constituent sampling frequency and total well list is provided in Appendix A. Although most wells are monitored for key constituents quarterly, wells that have displayed rapid rises in contamination are sampled monthly for anions, metals, technetium-99 and on the east side of the WMA, uranium. The observations reported in the PNNL-11826 show 10,000 pCi/L changes as great as 10,000 pCi/L in technetium-99 occurring over time intervals less than one month. Consequently, wells showing high or rapid changes on a quarterly interval are now sampled monthly. This sampling frequency is used not only to detect sudden, significant fluctuations in groundwater chemistry but also to provide a baseline data set to determine a more appropriate sampling interval at this WMA. The monthly sampling will also provide data sets for studying dispersion effects as described in Section 4.3.3. A few wells may be added or deleted during the course of the assessment as need is indicated by changes in the groundwater chemistry and to determine the outer limits of the contaminant plumes.

Overall quality assurance (QA) program requirements are defined by Article 31 of the Hanford Federal Facility Agreement and Consent Order (Ecology et al. 1994). Groundwater sampling procedures,

Table 4.2. Assessment Network Constituent List

Field-Analyzed Constituents	Laboratory-Analyzed Constituents	
	Quarterly/Monthly	Annually
pH	Alkalinity	Iodine-129
Conductivity	Anions	Stontium-90
Temperature	Cyanide	TOC
Turbidity	Gross Gamma Low level	TOX
	Tritium	
	Gross Alpha	
	Gross Beta	
	Metals	
	Technetium-99	
	Total Dissolved Solids	
	Uranium	

sampling collection documentation and chain-of-custody requirements are described in *Sampling Services Procedures Manual* (WMFS 1997) and the quality assurance project plan (QAPP) for sampling and analysis provided in PNNL QA Plan ETD-012 (1998).

Field sampling will be recorded in a proper field logbook as specified in EII 1.5 (WMNA 1998). The static water level will be measured and recorded prior to well sampling according to EII 10.2 (WMNA 1998). Based on the measured water level and well construction details, the water volume in the well will be calculated and documented on the well sampling form or field logbook. Each well will be purged according to the approved criteria as set forth in EII 5.8 (WMNA 1998).

Procedures for field measurements (pH, conductivity, turbidity, and temperature) are specified in the user's manuals for the field instruments. Laboratory analytical procedures are specified in PNNL (1998). Most of the analytical methods are selected from those provided in *Test Methods for Evaluating Solid Waste* (EPA 1986). For constituents with no analytical method specified by EPA (1982), other methods are selected as specified by PNNL (1997).

4.2.4 Decision Identification

The data collected in the study will be used to satisfy the 40 CFR-driven requirements of determining contaminant levels and extent. The analyses and interpretation of these data directly support decisions related to other investigative studies in this assessment plan. For example, the resulting maps for this study will support source determination for areas west, north and northwest of the WMA. If further groundwater data are needed, the use of the results will assist in locating new well. Also as the contamination is mapped through time, the direction of groundwater flow may be determined with greater certainty. In fact careful, detailed groundwater contaminant mapping over time may be the most reliable way to ascertain local flow. Finally the results of this study will assist in designing the closure monitoring networks well locations and sampling frequency.

4.3 Source Determination

This investigation contains three tasks. The first is related to characterization of a chemical signature associated with possible tank sources that may be identified in or matched to the groundwater chemistry. The second concerns the location of residual vadose zone plumes that may be acting as sources for continued groundwater contamination, and the third task is to relate contamination observed in a well to specific vadose zone sources and the local mobilizing driving force.

4.3.1 Source Chemistry Comparison

In other assessments it has been possible, by exploring co-contaminant chemical relationships of waste sources, to relate groundwater chemistry to nearby waste storage or disposal facilities (Hodges 1998; Johnson and Chou 1998). WMA B-BX-BY is in an area where waste effluent, related to SST tank contents, was discharged directly to the soil column and thus to the groundwater. In spite of this complexity, studying estimates of tank contents might establish pertinent co-contaminant relationships. These relationships can then be used to relate groundwater contamination to tank-sourced vadose zone plumes. Log-log or semi-log plots of co-contaminants ratios such as technetium-99 to nitrate formed from estimates of tank contents and from groundwater data may assist in identifying tank-sourced chemistry in the groundwater. In addition, similar studies will be made based on estimates of waste chemistry from surrounding cribs and retention trenches when these estimates are suitable.

Ideally direct measurements of residual vadose zone plume chemistry associated with both tank leaks and the surrounding crib discharges are needed to completely describe the source chemistry. Initially, Best Basis Data (BBD) and estimates of chemistry from Agnew 1997 will provide the bulk of the informational needs. An estimate of the waste chemistry when major leaks, overfills and surface spills occurred in the past would assist to make relationships more distinct. When these estimates become available, they will be incorporated into the overall chemistry study. Additionally, if suitable chemical estimates exist for nearby past practice effluent discharge facilities, these data will be incorporated into the overall study.

4.3.2 Groundwater/Vadose Zone Integral Mapping

It has been concluded in Phase I assessments that residual vadose zone plumes from past tank-related leaks have been remobilized, migrating through the vadose zone to the groundwater (Hodges 1998; Johnson 1998; Narbutovskih 1998). Thus, these vadose zone plumes are likely sources for the observed groundwater contamination. To relate these sources to associated driving forces and contamination at specific wells, it becomes necessary to map the location and extent, both vertically and laterally, of these vadose zone sources. It is also necessary to map residual plumes associated with the surrounding cribs, trenches and reverse wells, to the extent possible, to obtain a more complete understanding of the groundwater contamination. For example, the degree of lateral migration is important since candidate driving force sources must intersect these vadose zone sources to carry contaminants to the groundwater.

Geologic drilling logs, gross and spectral gamma ray logs, neutron moisture logs and moisture curves from drilling samples will be used to integrate vadose zone sources with groundwater contamination in a series of cross sections and planar maps. During the course of this study, new data needs may be identified based on the location of dry wells between 241-BY and 241-BX Tank Farms and in the southern part of 241-BX Tank Farm near the diversion boxes and vaults. At this time, however, no new data are required. Spatial boundaries on the region of interest are the same as in Section 4.3.1.

4.3.3 Use of Dispersion Effects

Probably the most obvious effect of dispersion in a steady-state porous flow system is to spread a contaminant mass beyond the region it would otherwise occupy as a result of advection alone (Figure 4.2). The degree to which a given volume of contamination spreads beyond its initial volume or the extent of longitudinal dispersion in any given flow system can be characterized by the variance, σ^2, of the contaminant distribution (Domenico and Schwartz 1990). The time variance of the breakthrough curve is

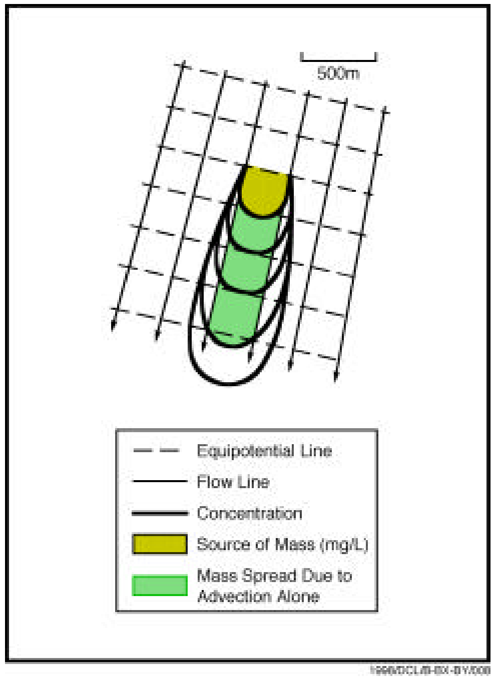

Figure 4.2. A Schematic of Mass Distributions Due to Advection Alone and Due to Advection-Dispersion. After Domenico and Schwartz 1990.

related to the spatial zone of mixing. Since the size of this zone, in turn, is related to the distance of contaminant migration, it may be possible to analyze the observed breakthrough curves to estimate the distance from the point of contaminant entry into the groundwater to the monitoring well. This estimation of migration distance may assist in identification of the source facility.

The objective of this study is to estimate the distance that discrete contaminant events have traveled in the groundwater prior to observation at a well. A discussion is presented to describe the principals of dispersion relevant to the assessment followed by a strategy for obtaining the desired results.

A good place to examine the concepts of dispersion is by studying a simple column experiment with the addition of a tracer or contaminant shown in Figure 4.3. The column represents a steady-state Darcy flow system with a controlled, continuous addition of tracer to an aqueous porous medium. The concentration value is given as the ratio the measured value, C, to that of the original source concentration, C_o. The distribution of this relative concentration over time seen at one point in space is the breakthrough curve shown in Figure 4.2a. As can be seen, the relative concentration was initially at zero when there was no contaminant in the groundwater. As the contaminant plume moved through the observation point, it rose to a maximum level equal to the undiluted source. The advective front, that is the point at which the groundwater is moving, is at the inflection point on the breakthrough curve. The relative concentration at the inflection point is 0.5.

A schematic representation of dispersion is shown in the column at three different times in Figure 4.4. A zone of mixing develops centered on the advective front as can be seen by the corresponding normal

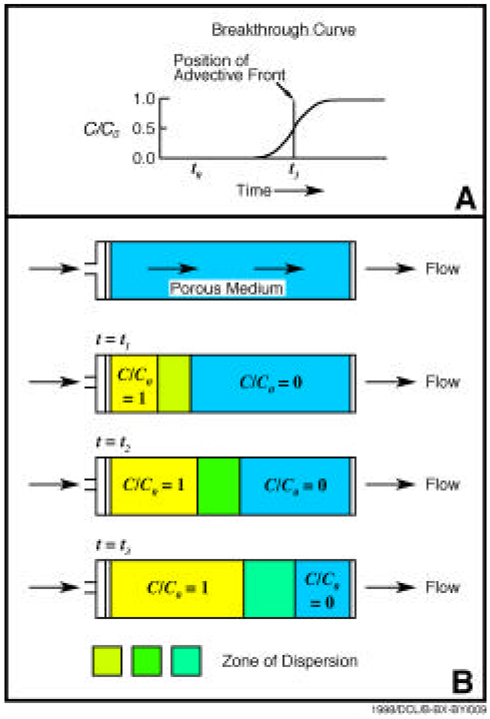

Figure 4.3. Schematic of Dispersion Within a Column of Porous Medium for a Continuous Contaminant Source. As the contaminant moves further through the column, the zone of mixing, shown in green, increases. Thus the slope on the breakthrough curve will decrease when the advective front is further from the source. After Domenico and Schwartz 1990.

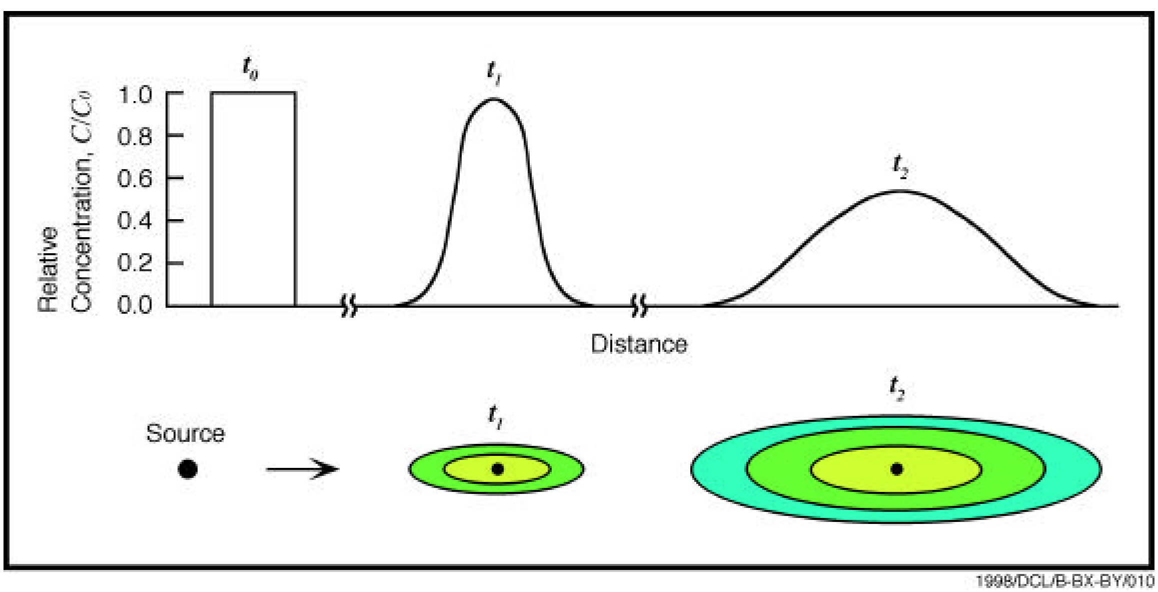

Figure 4.4. For a Constant Flow Velocity and a Pulse-Like Source, the Degree to Which a Plume is Dispersed Depends on How Far it has Traveled. After Domenico and Schwartz 1990.

curves shown for each time. As the advective front and the corresponding plume front move further from the initial point of entry into the system, the size of the zone of mixing increases. This, in turn, changes the slope on the spatial distribution curve and the corresponding breakthrough curve as shown in Figure 4.4. The distance is the location of the advective front with respect to the area where the contaminant entered the groundwater. Hence, it is the travel distance of the plume.

The fundamentals of dispersion may allow an estimate of how far the contamination has traveled in the groundwater without a prior knowledge of the source term, such as leak volume or initial contamination levels. A series of one-dimensional scenarios will be evaluated to approximate the distance of contaminant migration in the groundwater. These approximate values can then be correlated on a map with the location of residual vadose zone plumes and driving force sources. The results will provide evidence to support or disprove a particular source determination.

4.3.4 Decision Identification

The degree to which the results of these studies are useful to the overall assessment objectives will vary with the study. For example, utility of the source chemistry study will depend on how close the current estimates of tank chemistry are to the residual chemistry in the soil plume associated with that particular tank. If reasonable comparisons correlate a tank waste signature with that of the groundwater, this will indicate that tank waste may be the source of the groundwater contamination.

If residual vadose zone plumes can be mapped adequately, relationships will be sought to connect specific driving force sources to these residual plumes. Structural and isopach maps will also be used to search for possible stratigraphic controls on elevated water levels observed in certain “downgradient” wells.

Because the trends over time of observed groundwater chemistry data are not as complete as data collected in a controlled laboratory experiment, it may be difficult to adequately define a variance for a specific contaminant event. If, however, dispersion effects can used to provide reasonable estimates of contaminant migration distances, then possible locations for entry of the contamination into the groundwater can be identified. These results will be combined with results from the flow rate and direction effort, the integral mapping study and the driving force study to relate contamination events with vadose zone sources.

4.4 Driving Force Determination

Development of an accurate conceptual model tailored for a RCRA waste management site is an integral part of a RCRA assessment. The generalized information in the model provides guidance towards understanding the interaction between conditions resulting from the facility operations and the surrounding hydrogeologic environment. An integral part of a conceptual model is the identification of plausible forces/causes that drive the waste from a leak source, through the vadose zone to the groundwater. The objective of this task is to determine, to the extent possible, the existence, location and nature of recent driving forces in the vicinity of the WMA.

In general, there are three categories of driving forces operative in SST tank farm environments. The first is related to the leaking waste, which can migrate through the vadose zone by simple gravity drive, capillary action or by chemical interaction with the sediments. A residual waste plume is left behind in the soil pores or adhered to the soil particles. The second category pertains to the occurrence of water line leaks. As the water moves through the soil by either gravity or capillary action, it encounters the residual vadose zone waste left from the original tank leak and remobilizes it to the groundwater. The third category includes driving force sources related to natural precipitation. This category may have involved sudden snowmelts during the winter with rapid seepage into the ground or ponding of torrential rains causing the accumulation of small lakes in or around the farms.

This section contains two avenues for driving force documentation. The first is focused at documenting the existence and nature of driving force sources related to site operations (e.g., broken water lines) or related to the surface effects of naturally occurring sources (e.g., local ponding of rains or snow melts). The events providing these sources may have occurred in the past or may be presently occurring. The second avenue explores the possible effect of increased precipitation on the groundwater, searching for a frequency in the water elevations that may be related to an annual recharge from the surface.

4.4.1 Documentation

This study documents past and present occurrences of driving force sources related to the first two categories of driving force sources. Although the focus has been on leaks associated with either breached tanks or cascade lines, surface spills have at times contributed large volumes of waste to the subsurface. These direct leaks/spills have been documented over time and described adequately for use in the assessment (DOE 1993). On the other hand, it is more difficult to obtain information on driving force sources related to water line ruptures and leaks. Water line leaks related to farm operations should be documented in farm occurrence report. As might be expected, these reports focus on the effect that the water has on farm operations and not its potential to migrate waste to groundwater. Consequently there is little information on the total volume of a water line leak.

Water line leaks not related to farm operations may not be documented in written copy. Only site personnel that are engaged in reporting and fixing broken valves and pipes know of these occurrences. Also, ponding of water caused by natural precipitation is not routinely documented but can potentially provide significant driving force sources. Documentation of these occurrences will, of necessity, rely on verbal reports when written reports are not available.

There are two goals for this documentation. The first is to provide an understanding of the importance of these driving forces sources in terms of total volume, surface foot print and the time period the source was operative. The second is to identify, if possible, specific events that may be related to the migration of the waste presently observed in the groundwater. Documentation is easily obtained for brief descriptions of unusual occurrences that have happened at SST farms after FY 1990. Prior to that time occurrence reports were not computerized and are consequently more difficult to obtain. In some cases, there will be only oral communication.

4.4.2 Analyses of Transient Pressure Effects

Evidence exists that significant changes in groundwater chemistry can occur over periods less than a month (Narbutovskih 1998). It appears that these contamination fluctuations are related to driving forces that operate sporadically being turned on or off easily such as episodic use of a pipeline system with a large unknown leak. Another driving force is related to natural precipitation from years with exceptionally heavy snow falls as proposed by Johnson and Chou 1998. A cursory inspection of hydrographs from the RCRA groundwater monitoring network display a quasi-cyclic pattern that appears to contain an annual frequency (Figure 4.2) for the last few years. Although the amplitude is only a few inches, this may be significant given the high permeability values reported by Connelly et al. 1992.

The goal of this study is to determine the frequency of cyclic changes, if any, in water levels over time and to relate these cyclic events to possible driving force sources. The acquisition of pressure transducer data has been previously discussed in connection with studying barometric effects on the local groundwater gradient. The downhole pressure transducer data collected over a period of several years will provide the basic data sets for this study.

A spectral analysis will be accomplished by applying a Fourier transform to the transducer pressure data. This particular transform will take the pressure data from the time domain into the frequency domain, resulting in delineation of the frequency content of the data (Telford et al. 1976; Rohay 1996). Once the dominant frequencies of the water level changes are obtained, it may be possible to relate the periods to that of naturally occurring driving force sources. For example, by performing a spectral analysis of the corresponding atmospheric pressure data, direct correlation can be made between the period of water level changes, barometric pressure changes and the resulting amplitude of the water level changes associated with that frequency. If an annual frequency is observed, this would indicate that annual recharge may be reaching the groundwater.

Although this study involves utilizing new data, it is data that will be acquired in support of the flow direction investigation. Since the pressure will be monitored hourly over several years, the sampling frequency of the digital database will be sufficient to perform a computer-based digital transform.

4.4.3 Decision Identification

As in the previous studies, decisions for these studies are directed at relating the significance of the findings to the overall assessment objectives or to interpreting the results. Documentation of the driving forces will be used to assist in source determination for the groundwater contamination. In addition, the results will be applied towards refining the conceptual model for WMA B-BX-BY. If specific driving force sources can be related spatially to the mapped results of Section 4.3.2, then the confidence of identifying contaminant sources would be increased. If the frequency content of hydrographs indicates an annual fluctuation in water level, than recharge from natural precipitation should be considered a viable driving force source for migration of contamination through the vadose zone.

4.5 Sampling Frequency Determination

Semiannual monitoring required under RCRA regulations does not provide adequate temporal coverage. Large fluctuations in groundwater chemistry can occur in this region at a frequency of less than one month (Narbutovskih 1998). Under RCRA interim detection, the SST WMA sites are monitored semiannually. If samples had not been collected in August 1997 but in September 1997, or semiannually in May 1997 and December 1997, the increased levels of technetium-99 and nitrate concentrations would not have been observed. Although semiannual monitoring is the minimum required under RCRA regulations, these data indicate that this monitoring frequency does not provide adequate temporal coverage.

Based on the above discussion, the primary objective of this study is to determine an optimal sampling frequency to use at this WMA for routine monitoring. A secondary goal is to provide information on the feasibility of implementing a downhole screening apparatus to allow nearly continuous data acquisition of conductivity. A device of this nature would allow rapid screening of sudden contamination increases in near real-time. Thus additional sampling can then be performed providing laboratory analyses of co-varying contamination such as nitrate and technetium-99 without the expense of monthly sampling and analyses.

The study consists of combining the pressure transducer required to collect data in support of the transient water level effects with a conductivity probe. The resulting system, capable of automatically recording data from both sensors, would then be semi-permanently installed in a monitoring well. Weekly reviews of the data sets that display sudden fluctuations in conductivity would trigger collection of an extra groundwater sample for laboratory analyses.

Initially this dual sensor downhole apparatus will be deployed in one contaminated well and one relatively uncontaminated well. Once the sensors, data acquisition system and display/analyses method are functioning, a review of initial results will be performed. Data collected over several years should provide a temporal database to design an adequate sampling frequency for this site. Results from the contaminated well will be compared to the background well to evaluate data sets from two different chemical environments. The contaminated well will be chosen such that monthly sampling, as required under the assessment plan, will provide a comparative laboratory data set.

The results of this study will document the frequency with which contamination changes for a minimum of two years. The first year's data will be evaluated for data quality, usefulness and for cost-effectiveness. A comparison between the first and second year's data will be made to determine if the chemical signature contains any cyclic characteristics that might relate back to natural driving force sources.

4.5.1 Decision Identification

Based on the evaluation of the results from these two instrumented wells, an appropriate sampling frequency will be determine by decimating the data at regular time intervals until significant information is lost from the data set. Criteria of when this point is reached will be based on when the trend plot could not be used to identify important contamination changes occurring in the groundwater.

Decisions will also be made concerning the useful, practical, and cost effective nature of this monitoring method. If, after the first two installations have proven to be operative and the data useful, then monitoring wells may be instrumented at other SST sites to provide adequate spatially coverage for these WMAs. If the flow direction has been determined prior to the end of this study time, the instruments may be switched to more appropriate wells.

5.0 Assessment Reporting and Project Schedule

Based on technical requirements, the time period over which the series of investigative tasks is planned 2.5 years. Consequently the final report describing the interpretations and conclusions of the assessment will not be prepared until FY 2002. With the possible exception of the downhole conductivity monitoring and the analyses of transient pressure effects, all data acquisition, analyses and interpretation will be complete by the end of FY 2001. With the concluding report, recommendations will be made concerning assessment monitoring in out years.

The status of work done annually in support of the assessment will reported in the Annual Hanford Groundwater report beginning in FY 2000. Also in the quarterly RCRA reports submitted to DOE/ Ecology, a synopsis of groundwater chemistry changes at WMA B-B-X-BY will be included. Borehole completion packages will also be prepared for each new monitoring well installed to document compliance with WAC 173-160.

In Appendix A these tasks are summarized for easy reference. Table A.1 is organized by main tasks with objectives and data needs identified. The phased approach to defining the contaminant flow direction is shown along with investigative studies requiring data collection over a multiple year interval. The schedule and specific calendar for task is outlined in Table B.1 in Appendix B. The time period covered is from January 1999 to September 2002.

Project planning will be ongoing from year to year. This task involves ensuring that tasks are on track and that resources and personnel will be available when they are needed. Workarounds will be developed when schedule conflicts occur. Preparation of further assessment work plans and any subsequent revisions are also an important aspect of this task. Meetings with stakeholders and the integration project team leads will be conducted to ensure coordination with other projects.

6.0 References

40 CFR 265, Code of Federal Regulations, Title 40, Part 265. *Interim Status Standards for Owners and Operators of Hazardous Waste Treatment Storage and Disposal Facilities*.

Agnew, S. F. 1997. *Hanford Tank Chemical and Radionuclide Inventories*. LA-UR-96-3860, Los Alamos National Laboratory, Los Alamos, New Mexico.

Anderson, J. D. 1990. *A History of the 200 Area Tank Farms*. WHC-MR-0132, Westinghouse Hanford Company, Richland, Washington.

Brown, R. E., and H. G. Ruppert. 1950. *The Underground Disposal of Liquid Wastes at the Hanford Works, Washington*. General Electric Company, Richland, Washington.

Caggiano, J. A. 1996. *Assessment Groundwater Monitoring Plan for Single-Shell tank Waste Management Area B-BX-BY*. WHC-SD-EN-AP-002, Westinghouse Hanford Company, Richland, Washington.

Connelly, M. P., J. V. Borghese, C. D. Delaney, B. H. Ford, J. W. Lindberg, and S. J. Trent. 1992. *Hydrogeologic Model for the 200 East Groundwater Aggregate Area*. WHC-SD-EN-TI-019, Westinghouse Hanford Company, Richland, Washington.

DOE/RL-96-59. 1993. *B Plant Source Aggregate Area Management Study Report*. DOE/RL-92-05, Richland, Washington.

DOE/RL-96-59. 1996. *200_BP-5 Operable Unit Treatability Test Report*. DOE/RL-96-59, Richland, Washington.

Domenico, P. A., and F. W. Schwartz. 1990. *Physical and Chemical Hydrogeology*. John Wiley and Sons, New York, New York.

Ecology, EPA, and DOE. 1994. *Hanford Federal Facility Agreement and Consent Order*, Fourth Amendment, Washington State Department of Ecology, U.S. Environmental Protection Agency, and U.S. Department of Energy, Olympia, Washington.

EPA-600/4-82-055. 1983. *Methods for Chemical Analysis of Water and Wastes*. U.S. Environmental Protection Agency, Washington, D.C.

EPA. 1986. *Test Methods for Evaluating Solid Wastes*. Volume 1A, SW-846, U.S. Environmental Protection Agency, Washington, D.C.

EPA. 1994. *Guidance for the Data Quality Objectives Process*. EPA QA/G-4, U.S. Environmental Protection Agency, Washington, D.C.

Hartman, M. J., and P. E. Dresel. 1998. *Hanford Site Groundwater Monitoring for Fiscal Year 1997*. PNNL-11793, Pacific Northwest National Laboratory, Richland, Washington.

Hodges, F. N. 1998. *Results of Phase I Groundwater Quality Assessment for Single-Shell Tank Waste Management Areas T and TX-TY at the Hanford Site*. PNNL-11809, Pacific Northwest National Laboratory, Richland, Washington.

Jensen, E. J., S. P. Airhart, M. A. Chamness, T. J Gilmore, D. R. Newcomer, and K. R. Oster. 1989. *Interim Status Ground-Water Monitoring Plan for the Single-Shell Tanks*. WHC-SD-EN-AP-012, Rev. 0 Westinghouse Hanford Operations, Richland, Washington.

Johnson, V. G., and C. J. Chou. 1998. *Results of Phase I Groundwater Quality Assessment for Single-Shell Tank Waste Management Areas S-SX at the Hanford Site*. PNNL-11810, Pacific Northwest National Laboratory, Richland, Washington.

Kasza, G. L. 1995. *In Situ Flowmeter Results and Analysis for the 216-BY Cribs Vicinity*. Bechtel Hanford, Inc., Richland, Washington.

Narbutovskih, S. M. 1998. *Results of Phase I Groundwater Quality Assessment for Single-Shell Tank Waste Management Areas B-BX-BY at the Hanford Site*. PNNL-11826 UC-502, Pacific Northwest National Laboratory, Richland, Washington.

Newcomer, D. R., J. V. Borghese, and W. E. Cronin. 1990. *Hydrologic Testing at the Single-Shell Tanks, 1989*. Pacific Northwest Laboratory informal report to WHC, released as WHC-SD-EN-TI-147 (1993).

PNNL. 1997. *The Hanford Ground-Water Monitoring Project Quality Assurance Project Plan*. QA Plan ETD-012, Rev. 0, Pacific Northwest National Laboratory, Richland, Washington.

Rohay, V. J. 1996. *Field Tests of Passive Soil Vapor Extraction Systems at the Hanford Site, Washington*. BHI-00766, Rev. 0, OU: 200-ZP-2, TSD: N/A, ERA: CC14.

Telford, W. M., L. P. Geldart, R. E. Sheriff, and D. A. Keys. 1976. *Applied Geophysics*. Cambridge University Press, New York, New York.

U.S. Department of Energy (DOE). 1997. *Tank Summary Data Report for Tank BX-102*. GJ-HAN-89, MACTER-ERS, Richland, Washington.

WHC-SD-EN-TI-147. 1990. *Hydrologic Testing at the Single-Shelled Tanks, 1989*. D. R. Newcomer, J. V. Borghese, and W. E. Cronin. Westinghouse Hanford Company, Richland, Washington.

WMFS ES-SSPM-001. 1997. *Sampling Services Procedures Manual*, Waste Management Federal Services, Inc., Northwest Operations, Richland, Washington.

Womack, J. C., and D. J. Larkin. 1971. *Investigation and Evaluation of 102-BX Tank Leak*. ARH-2035, Atlantic Richfield Hanford Company, Richland, Washington.

Appendix A

DQO Table of Investigative Studies

Task	Objective	Problem	Existing Data/Information	New Data or New Information Needs	How New/Old Data Supports Solving the Problem?	Data Collection
GW flow direction	Determine direction/rate of migration for source determination.	What is direction/rate of migration? What is relationship of plumes to possible sources? Discrepancy exists between water elevation gradient calculations, direction from plume maps and direct flow measurements.	Flow direction determination from water elevations–not adequate due to lack of/ ambiguous gradient. Direction from plume maps not adequate due to a) possible change in flow direction back towards original direction b) localized extent of recent contamination-affected by non-uniform flow fields.	A. Refined water elevations 1. Check survey data 2. Make closely spaced water level measurements. 3. Borehole gyroscope measurements 4. Check for stratigraphic controls. 5. Measurement of transients effects such as seasonal fluctuations or barometric effects. B. Flow direction/rate studies with direct flow colloidal boroscope.	1. If survey corrections correct the problem, then use gradient to determine flow direction. 2. If closely spaced WL measurement do not fix the problem, then proceed with step 3. 3. If hole deviates from vertical sufficiently to remove elevation discrepancy, then survey the remaining wells to get accurate water elevations. If not, proceed with step 4. 4. If structural mapping does not indicate a structural control, then proceed with step 5. 5. If transient effects for two years (seasonal effects) are cause of “high” water elevations and can be removed sufficiently to allow a clear upgradient/downgradient direction to be determined over time (i.e., not just for one sampling event) then use adjusted gradient to assist in determining flow direction. If transient effects are not sufficient to account for ambiguous flow direction, then proceed with direct measurement of flow direction. If transient effects do account for ambiguous flow direction, then proceed with direct measurement	1. Check data base. 2. Take water level measurements. 3. Measure vertical deviation of one “high” well and one “upgradient” well. Survey others if initial results indicate it is useful. 4. N/A 5. Instrument one “high” well and one “upgradient” well with 2 pressure transducers each, one below water table to record transient effects on head and one at the surface to record barometric effects. Subtract out barometric, seasonal and tidal effects from water elevation data. Measure flow direction in wells located on at least three sides on the WMA to provide local direction of flow and rate of contamination migration.

Task	Objective	Problem	Existing Data/Information	New Data or New Information Needs	How New/Old Data Supports Solving the Problem?	Data Collection
					of flow direction to confirm these results and to provide the rate of contamination migration.. Results used to determine need/ location for new wells Results assist in predicting future extent/rate of migration of contamination. Results used to design strategy for monitoring future change in flow directions across the 200 East Area as B Pond mound dissipates. Allows better designs for closure monitoring networks	
GW Plume tracking (spatial and temporal) Groundwater sampling	40 CFR driven Determine contamination levels, rate of migration and extent of contamination.	What is the level of contamination, rate of migration and extent of contamination (e.g., E33-41)	Annual Quarterly Monthly	Quarterly (as required) Monthly (at times and for certain wells, as indicated by the current data)	1. Tracks contaminant levels through time 2. Gives extent of contamination spatially in wells not previously sampled, not sampled often enough, not sampled for constituents of interest- allows determining the extent of current contamination. 3. Assists in determining need for new wells and location of wells 4. May provide information on flow direction if "plumes" can be mapped over time.	Groundwater sampling in RCRA and surrounding older wells. Sampling program can be redefined when a) plume extent is defined and b) contaminant concentrations are static.
	40 CFR driven Determine source.	West, north and northeast of the WMA, nitrate and technetium-99 are rising. Both nitrate and technetium-99 were above the DWS, Feb. 98.			Although not directly related to rate and extent, these data will help to determine frequency of sampling necessary to determine contaminant source and identify possible driving forces.	

Task	Objective	Problem	Existing Data/Information	New Data or New Information Needs	How New/Old Data Supports Solving the Problem?	Data Collection
		What is the source?				
Source chemistry comparison	40 CFR driven Source determination	Do specific tank signatures match contamination seen in the groundwater? Does GW contamination trend delineate a mixing curve with the tank chemistry?	Agnew estimates. BBD from TWRS. Direct samples. Historic estimates for times in the past.	N/A	Determine if GW chemistry trends are delineating mixing curves between groundwater chemistry and tank chemistry. If tank wastes are indicated as the source, than redesign monitoring network to adequately monitor tank vadose zone sources in addition to tanks and ancillary equipment.	Acquire data from current estimates and direct measurements of waste available through TWRS. Acquire historic estimates of waste compositions for times when leaks supposedly occurred in the past. Compare relevant ratios of tank waste constituents to groundwater chemistry.
Integration of groundwater data with vadose zone plumes.	Source determination, Determine location of residual vadose zone plumes with respect to possible driving forces and GW wells. Attempt to locate possible regions of entry into the groundwater.	What is lateral extent of contamination in the soils, what controls might exist for directional spreading of contamination in the vadose, where might the contamination driven from the vadose zone be entering the GW?	Geologic logs. Gross and spectral gamma ray logs. Moisture curves (limited). Present data may not be adequate laterally in WMA away from tanks (e.g., near diversion boxes and vaults).	*New data needs will identified and passed on to the TWRS Vadose Zone team..	Existing vadose zone contamination is mostly likely source of current groundwater contamination. By knowing the lateral and depth extent of these vadose sources, relationships to water drivers and GW wells can be better defined to determine source. If definitive decisions can be made concerning source, then enough data has been collected. In addition the above, assist in defining WMA risk and designing better long term monitoring network for closure, and assist in new well locations.	N/A at this time.
Driving Forces Documentation.	Determine existence, location and nature of recent driving forces in the vicinity of the WMA (Source Determination)	What is the source of contamination and what are the migration pathways?	Some information exists as TWRS occurrence reports. Further information to be gathered from site operational personal, documents and records. Visually monitor ground surrounding farms during heavy rains.	No new data	Document causes for vadose migration leading to mitigation efforts. By determining location and nature of driving forces, it may be possible to relate driving forces to mapped plumes and to local GW contamination.	Screen occurrence reports, check water purveyor's records, obtain testimony from site operational personnel, document any natural or man-made water releases in the vicinity of the WMA.[1]
Sampling Frequency Determination	Document frequency of contaminant	What is frequency (period) of contaminant changes at the WMA?	Quarterly and some monthly groundwater trends.	Continuous conductivity measurements over time.	If contamination is fluctuating significantly at frequencies greater than 3 months, attempt to relate	Instrument 1 key wells with a continuously recording conductivity probe for 1 to 2 years.

* Input from TWRS characterization program

Task	Objective	Problem	Existing Data/Information	New Data or New Information Needs	How New/Old Data Supports Solving the Problem?	Data Collection
	changes in the vicinity of the WMA. Determine adequacy of sampling frequency. Obtain a continuous expression of contaminant changes with respect to conductivity. (Source Determination)	Evidence exists that significant changes in GW chemistry can occur over periods less than a month. Can these frequencies be related to driving forces? Source Determination			to past driving forces in the area to assist in determining source. If contamination is fluctuating close to critical mean concentrations (arbitrary) within one quarter, instrument keys wells closest to the WMA and one "upgradient" well with conductivity probes. If contamination is fluctuating within one quarter, consider special sampling for certain contaminants as indicated by probe results. Include continuous downhole probes for various chemical constituents in designs for current and final closure WMA monitoring network.	One year to capture seasonal effects, two ;years to confirm that these effects are repeatable (not a function of that particular year or well). Collect monthly sampling from this well for anions (and mobile rads) to confirm source of conductivity changes.
Use of Dispersion Effects	Estimate distance that contamination may have traveled in the GW for single well contamination events. (Source Determination)	How far has contamination traveled in the groundwater before impacting a well and can this travel distance be related to driving forces and residual vadose zone plumes? Can dispersion effects assist in backtracking to contaminant sources at this WMA and at others? Source Determination	Quarterly and Monthly groundwater trends.	No new data needed.	If variances can be adequately determined from current data trends, then calculations can be made to determine the travel distance in groundwater. Results would most likely include a range because a) the magnitude of flow is poorly known b) this approach assumes one-dimensional dispersion (might be possible to extend to 2-dimension dispersion) c) using real data not modeled data which introduces noise. However the approach, if it proves useful, could provide a powerful interpretation tool for all the sites.	N/A

Task	Objective	Problem	Existing Data/Information	New Data or New Information Needs	How New/Old Data Supports Solving the Problem?	Data Collection
Analyses of Transient Pressure Effects	Determine if an annual frequency exists in the water elevation data that might indicate a natural precipitation driving force through residual vadose zone plumes. (Source Determination)	With very high winter precipitation of recent years, it has been suggested that some component of the observed rise in contamination may be related to snow melting events/winter precipitation. Is there an annual component in the water elevation data?	Quarterly and monthly water elevation data for RCRA wells	Monthly groundwater elevation data. Downhole data (conductivity and pressures) discussed above.	If a dominant annual component exists in the water elevation data, than natural seasonal recharge should be considered a possible driver for remobilizing residual vadose zone contamination. If no clear annual frequency is found by curve matching techniques, this does not mean that surface precipitation did not or will not effect groundwater quality, just that this approach does not identify this mechanism as remobilizing vadose zone plumes.	Water elevations are collected with each sampling event. Pressure data will be collected along with continuous conductivity data. Analyzed by Spectral analysis to determine frequency/period content

Appendix B

Sampling and Analysis Plan

Appendix B

Sampling and Analysis Plan

This appendix consists of a field sampling plan (FSP) and a quality assurance project plan (QAPP). The FSP specifies the data collection design and the QAPP includes the procedures and project management controls intended to ensure the data collected and associated measurement errors are appropriate to meet the quantitative and qualitative needs of the study. Together these two plans form the Sampling and Analysis Plan (SAP). The SAP is used as the principal controlling document for conducting the work identified in Chapter 4 and summarized in Table A.1.

Activities that address similar or related information needs are grouped together where possible to allow the reader to relate the text to the charts. Data needs are not addressed in more than one task even though specific data sets may be used to satisfy more than one data need. The SAP should follow closely with the titles and listing in of data needs in Table A.1. The task schedule is included in Appendix B.1 (Figure B.1).

Appendix B.1

Field Sampling Plan

This appendix contains the data collection design and activity schedule for the continued WMA B-BX-BY groundwater quality assessment. The schedule for conducting specific tasks for this assessment is shown at the end of the appendix (Figure B.1). A brief description of each task as identified in the schedule (Figure B.1), by task title, is provided. Additional discussion and background information associated with the tasks are provided in the main body of the plan.

B.1.1 Task Descriptions

The tasks described are a subpart of the Hanford Groundwater Monitoring Project (#28023) managed for the Department of Energy (DOE) by Pacific Northwest National Laboratory (PNNL). Project management and organizational interfaces and procedures are described in Appendix B.2.

The dates indicated in the following task descriptions are approximate time periods or windows. Actual start and end dates may shift as detailed field plans for the multiple subprojects are planned and scheduled. It is recognized that conflicts may cause deferral or rescheduling of some of the proposed work in this plan. Scheduling conflicts for critical path work will be resolved by management prioritization and/or by use of subcontract labor as needed..

Velocity of Contaminant Migration

This task addresses determination of the direction and rate of contamination migration. It consists of various subtasks associated with flow rate and direction determination in an area with a flat watertable. The locally flat hydraulic dradient makes the local flow direction difficult to ascertain. The subtasks are described as follows.

Vertical Survey Error of Well Casings. Multiple surveys are available for well location and elevation above sea level for assessment wells at WMA B-BX-BY. The data from these surveys will be evaluated to determine the effect of survey error on well elevations, both within a survey and between the different surveys. Conclusions will be drawn concerning the overall effect of survey error on determining flow directions from water elevations and on which survey provides the most useful results.

Water Level Measurements. Errors associated with water level measurements can effect results when the gradient is of the same order as the error. Water level data will be collected using the same tape and personnel to provide a consistent data set for further analysis. Measurements will be made on one month intervals for three months. All data will be collected within 2 hours to reduce possible diurnal and storm-related pressure effects on the water elevation in the wells. Results from data collection will be used to produce a local water table map.

Vertical Deviation of Borehole Casing. If a borehole is not vertically straight, the depth to water will appear to be longer and the resulting water elevation is low. Critical wells that appear to have abnormally low water levels will be checked with a borehole gryroscope. Corrections will be made to the water level data as appropriate.

Stratigraphic Control. If the water table in a given well rests in a relatively impermeable geologic formation, it is possible that the water may be held artificially high at that location. A study of the local stratigraphy will be made to determine the nature of the aquifer at the water table across the site. As the water level continues to drop, the water table may rest in a formation different than the time of original well installation. A detail study of the stratigraphy will be performed to ascertain the nature of the soils at the water table. Drill cuttings will be obtained from the soils archive library to provide direct correlations of soil types with the local water table elevations. If a well is found to have the potential for stratigraphically controlled water elevations, it will be removed from the network for the purposes of determining the direction of groundwater flow.

Removal of Barometric Effects. Diurnal and storm-related events can cause small, temporary water level changes in wells. Although the effects are usually small, these temporary fluctuations may be great enough to cause confusion in the water level data masking the true flow direction. Removal of the elevation changes associated with these atmospheric pressure variations may help to delineate the true gradient across the site.

Direct Flow Measurements. The above studies will be conducted to refine water level measurements in an attempt to determine the true direction of contaminant flow. This is important in understanding the direction from which contaminants are entering the site, i.e., which wells are actually the upgradient wells. Given the extreme flatness of the water table and the level of error in each of the above steps, it is prudent to make direct measurements of flow within the wellbore to confirm the results obtained from water level measurements. The colloidal boroscope will be used for this purpose. This technology uses a magnifying glass and a downhole camera to view particulate material flowing through the wellbore. Perturbing effects on flow velocity associated with the presence of the wellbore will be reduced to the degree possible. It should be keep in mind that knowledge of the flow direction within a quadrant is sufficient for assessment purposes. In addition, the colloidal boroscope data will also be used to directly measure the magnitude of groundwater flow. This value is needed to determine the rate of contaminant migration.

Extent of Contamination

The objective is to determine the level and rate of contamination in the vicinity of the WMA over time and the rate/direction at which it is moving. The subtasks in support of this overall task are spatial and temporal mapping of contaminant plumes, new well drilling to track plume migration and groundwater sampling to track location and levels of contaminants over time.

Spatial/Temporal Mapping. Plume maps will be prepared for contaminants of interests and for associated constituents of concern. These maps will be used to document current contaminant extent and migration direction to the degree possible. Plumes migrating in a southward direction out from 241 B Tank Farm and from 241-BX Tank Farm will not be detected until sufficient coverage is provided along the southern border of the WMA. Interpretations of the mapped results will also be used in further source identification along with results from the source chemical signature study.

Well Drilling and Testing. Evaluation of the extent of groundwater contamination is required for this groundwater quality assessment (Table A.1). For this purpose, 2 new wells are planned for FY 1999 and at least an additional 6 in the out years. Two will be added in FY 1999 to track the apparent south-westward movement of contaminant activity and to increase downgradient spatial coverage at BX farm. Other wells in later years will be drilled to determine the nature of groundwater contamination at BX and B farms along the south and east WMA borders. The sampling results of these initial wells will be used to assist final well locations.

The wells drilled for this task will comply with the requirements for monitoring well design and construction as specified in 40 CFR 265.91(c). Specifications for well designs and procedures for performing the well installations are contained in Washington Administrative Code (WAC 173-160) and contractor/sub-contractor procedure manuals (see Appendix B.2). Only special conditions related to the RCRA groundwater assessment are described in this plan.

Geologic/Hydrologic Characterization. The following data collection conducted during and just after the drilling of these wells should be considered a minimum. The actually nature and types of data collected for geologic characterization may change prior to the spud date. As the assessment wells are drilled, the nature of the sediments will be classified and geologic logs constructed. In addition, sediments samples will be collected and archived for future use. Neutron moisture and spectral gamma logging will be conducted before the wells are completed. A slug test will be performed in each well to determine the local hydraulic conductivity.

Depth Distribution. There are two zones of interest: 1) the interface between the vadose or unsaturated zone and the water table or the capillary fringe zone; and 2) the maximum depth of contaminant occurrence in the unconfined aquifer.

Capillary Fringe Sampling. If contaminants enter the groundwater from beneath the tank farm under unsaturated conditions, they may be at their highest concentrations in the present day capillary fringe zone and in the uppermost layer of groundwater (especially close to the source). To evaluate this possibility, 1-liter samples of drill cuttings will be collected at 1-foot intervals beginning at 5 feet above the estimated static water level and up to 2 feet below the water level at the new BX farm wells. The samples will be refrigerated in air-tight containers until analyzed. The standard drilling sample archived at 5-foot intervals is not deemed adequate for this purposes and therefore, these extra samples will be collected. 1:1 water extracts of the jar samples of drill cuttings collected near the water table will be analyzed in the laboratory for major tank waste indicators (Ur, nitrate, technetium-99). The extracted sample media will be archived.

Top of Aquifer Sampling. Groundwater samples will be collected at the top of the aquifer in support of locating a highly concentrated layer of contamination just below the capillary fringe zone that might indicate contaminant migration through the vadose zone into the groundwater. The presence of such a layer would give credence to residual vadose zone plumes acting as new contaminant sources. After penetrating approximately 1 foot into the saturated zone, a portable pump (e.g., bladder pump) will be installed so that water can be extracted for analysis of tank waste constituents. To keep time to a minimum during sample acquisition, the water samples will be collected without development pumping or filtering. The water pumped to the surface will be transferred directly to two (analytical grade) five-gallon carboys, refrigerated, and taken to the lab for further analysis. After the suspended sediment settles, samples can be drawn for the standard set of analyses.

Saturated Zone Depth Sampling. Water samples will be collected near the base of the aquifer to check for the presence of high density salts that may have settled through the aqueous phase. This sampling will be conducted only on wells drilled in FY 1999 unless results are positive. The boreholes will be completed with up to 35 feet of screened interval if the aquifer proves to be that thick. During drilling of the saturated zone, the borehole will be advanced and sampled as indicated above for the top of aquifer sampling. A method to temporarily seal the drive shoe or cutting edge of the casing against the open borehole wall near the bottom of the hole must be used to eliminate movement of water from the annual space between the casing and the borehole wall. Also, the standing water in the borehole must be isolated. A packer assembly is typically used for this purpose. The water will be collected in the above fashion at 1 foot from the basalt basement. Multiple completion depths are not anticipated as needed at this site because the aquifer is thin (i.e., from 8 to 15 feet thick). It is unlikely that any significant chemical stratification exists.

Nature and Concentration of Contamination

Subtasks under this heading include determining the type and levels of contamination that exist in the groundwater surrounding the B-BX-BY WMA. The data on groundwater chemistry over time resulting from this overall task will be used as input to several of the tasks described below.

Quarterly Groundwater Sampling and Laboratory Analysis. Assessment sampling in the WMA B-BX-BY well network is an on-going activity funded under the groundwater monitoring project. Quarterly sampling is required by 40 CFR 265.93(d)(7)(i). The base list of constituents by analytical group with associated specific analytes of interest and detection limit requirements (MDL) for each quarterly sampling event are given below. Constituents for monthly sampling are a subset of the following list:

Chemical Constituents

- Anions, ion chromatography method (nitrate, chloride, bromide, and fluoride); MDL <500 μg/L

- Metals - filtered, ICP method (sodium, calcium, magnesium, potassium, chromium, iron, manganese, and aluminum); MDL <5 μg/L (Mn, Fe, Cr, and Al)

- Uranium – total or chemical (fluorometric), unfiltered; MDL <0.1 µg/L
- Cyanide; MDL <1.33 µg/L
- pH
- Specific conductance (lab method as well as field)

Radioactive Constituents

- Cobalt-60 – (unfiltered); low level gamma scan, MDA < ~ 10 pCi/L
- Gross beta – (unfiltered); gas flow proportional counter on dried samples, MDA <1 pCi/L
- Gross alpha – (unfiltered); gas flow proportional counter on dried samples, MDA <0.5 pCi/L
- Technetium-99 (unfiltered): ion exchange separation and liquid scintillation, MDA <10 pCi/L
- Tritium (unfiltered); MDA <400 pCi/L, liquid scintillation on evaporated samples

Isotope specific analyses will be requested (transuranics, and/or strontium-90) by the project scientist responsible for the RCRA assessment at this regulated unit under the following conditions. However, the low level gamma scan covers gamma-emitting isotopes such as cesium-137 and antimony-125.

1) gross alpha and beta results are above natural background,
2) or > upgradient concentrations,
3) or can not be accounted for by technetium-99 and/or uranium.

An important requirement, for use of gross alpha and gross beta measurements as surrogates for the more expensive isotope specific analyses, is reliable gross count measurements. One source of uncertainty in the gross or total count method is the effect of salt residue (self-absorption of the beta particles). Dissolved solids are not low in the vicinity of WMA B-BX-BY. Consequently, this may be a problem.

As indicated above, implementation of the surrogate approach places increased demands on the quality control aspects of the gross count measurements. It should be noted other methods will be relied on to assess the likely presence of alpha and beta emitters. For example, special ultra low-level isotopic analyses will be used to supplement the routine measurements.

The list of wells to be sampled quarterly can be found in Table B.1 at the send of this section. This list includes both RCRA and non-RCRA wells. As-builts for these wells, with the exception of 299-E33-44, can be found in Appendix C. Although the water level is decreasing in this region and the aquifer in the northern part of the WMA is thin (8 feet to 11 feet), the rate of decline is not as great as that in the 200 West Area. Early records of pre-Hanford water levels are not available. Consequently it is difficult to estimate the maximum drop in water level before the original water table is achieved. Based on the current rate of decline, the wells north of the 241-BY Tank Farm should be viable for at least 5 years. If the aquifer does thin to the point that wells cannot be pumped, a vadose zone monitoring system should be designed and implemented for further assessment and closure monitoring.

Sampling Procedures. Standard conditions for routine monitoring (pumping at ~1 gpm or less with a Hydrostar pump, removal of three bore volumes and stabilization of indicator parameters prior to sample collection) will be used. Procedures are defined in the QAPP, A.2. Pump depths will be maintained at ~5 feet below static water level to maintain comparability of results with previous monitoring data. The issue of variation with depth (i.e., shallow or microlayer at the top of the aquifer) is addressed elsewhere in this plan. If it is found that contaminant concentrations are much higher in the surface microlayer, the need for modifying the routine monitoring program will be considered.

Monthly Sampling. A quarterly frequency is required by 40 CFR 265.93(d)(7)(i). However, this frequency is not always adequate for assessing the nature and source of contaminant migration in the groundwater. Recent contaminant migration at WMA B-BX-BY has shown that high levels of technetium-99 and uranium can move through the near region of a well in less than a month (Narbutovskih 1998). Based on this time period, it has proven to be prudent to collect groundwater samples monthly for wells experiencing rapid changes.

Special Sampling. The specific sampling for this subtask will test for the presence of a high contaminant microlayer in the uppermost aquifer. As explained above, the presence of a highly concentrated contaminant layer at the capillary fringe/water table boundary could be an indication that contaminants are entering the groundwater by renew infiltration through the vadose zone. This sampling will be performed in pre-existing wells where the groundwater contamination appears to be related to surface recharge. The well pump will be removed, and at least 2 weeks will be allowed for the well to re-equilibrate. Kabis sampling (Mod II) will then be conducted. The Kabis must be lowered into position very slowly to minimize disturbance, especially near the surface of the water in the well. Analytes are limited to tritium, technetium-99, anions and ICP metals (portable membrane filter apparatus to be used for filtered metals). Due to the 1,200 cc volume of the Kabis Mod II, the sample volumes submitted to the lab may be less than normally specified. Initiation of the work as soon as possible after the quarterly samples have been collected will allow ample time to complete the work and re-install the sample pumps prior to the next regularly scheduled quarterly sampling event.

Source Determination

This task is aimed at delineating the various sources of contamination found in the groundwater at WMA B-BX-BY. The subtasks described below will, with the exception of the isotopic study, be ongoing as supporting data are received. In the event that groundwater contamination eventually becomes static at this WMA, the level of effort can be reduced. However, with the current dynamic state of contaminant change occurring across the site, it is necessary that maps and plots be updated frequently with resulting interpretations used to revise the working conceptual model.

Revision of Conceptual Model. The conceptual model of hazardous waste storage facility provides the framework for guiding the assessment and interpretation of data. As further information is collected and analyzed during the assessment process, the conceptual model will be updated to reflect this new information. This model integrates the characteristics of the subsurface (geology, hydrogeology, subsurface contamination) with that of the waste management unit setting. It attempts to incorporate the general waste types, facility equipment and storage configurations, the subsurface geology, hydrology and geochemistry of both the vadose zone and the unconfined aquifer. Use of the model allows exploring the complex spatial and temporal relationships of three important elements: 1) the contamination source, past and present, 2) the driving force that carries contaminants through the vadose zone to the groundwater, 3) the migration pathway of the contaminants through first the vadose zone and then the groundwater.

Spatial/Temporal Mapping of Historic Data. Although part of the work on this task will be done initially to fulfill the requirements of _, further work will be done to assist in source determination. Detailed contaminant maps will be constructed for various times in the past to study temporal relationships related to plume movement and to determine spatial relationships between the various contaminants over time. These plume maps will also be compared to tank/crib chemistry and to mapped vadose zone sources to provide insight relative to the entry points into the groundwater. They will also be used to map flow migration pathways within the unconfined aquifer.

Source Chemistry Characterization. By comparing co-contaminant chemical relationships of the waste sources to that of the groundwater chemistry, it may be possible to relate the groundwater chemistry to specific waste storage facilities. Also, as explained below, if proven useful for the assessment of WMA S-SX, analyses will be made on selected samples for specific isotopes of interest.

Chemical Mixing Curves. Currently the groundwater chemistry at WMA B-BX-BY reflects the complex nature of contaminant sources in and surrounding the WMA. With the regions lengthy history of waste storage along with the number and diversity of waste storage facilities in the immediate area, the amount and type of waste let to the ground and stored in the tanks is quite varied. Thus, determination of characteristic signatures for waste sources may be quite difficult. However a series of mixing curves will be developed for a co-contaminants found in the region. Comparisons will be made with possible source signatures to determine if relationships exist that would allow source identification.

Special Isotopic Analysis. Exploratory groundwater samples for ultra low-level isotopic analyses (e.g., plutonium-239/240, stable fission product isotopes, etc.) will be collected where tank waste indicators have recently appeared in wells at WMA S-SX. If the results of this isotopic study prove to be useful in delineating groundwater contamination associated with WMA S-SX from non-tank contamination, the same study may be applied at WMA B-BX-BY. The sampling at WMA B-BX-BY will be conducted during the regularly scheduled sampling event for the assessment wells at B-BX-BY. The timeframe of sampling will, of necessity, be set after results of the isotopic study at WMA S-SX are evaluated. The only additional expense involved for this preliminary or screening phase is preparation of off-site shipments. Because of the high sensitivity of the analytical methods to be employed, considerable care will be needed to prevent contamination of the samples during collection activities. This will be accomplished by 1) use of sterilized containers and 2) a portable glove box to minimize introduction of surface contamination from fugitive dust. Blanks and splits will be collected for quality control.

Vadose Zone Plume Mapping. Local maps will be constructed for a variety of depths from gamma ray borehole log data recently published by MACTEC (1998). The location and contaminant content of these maps will be compared to groundwater contamination and local driving forces to ascertain if it is possible that residual vadose zone plumes are the source of current groundwater contamination.

Use of Dispersion Effects. The specific objective of this task is to estimate or bracket the travel distance of discrete contaminant events prior to observation at a well. The fundamentals of dispersion may allow an estimate of how far the contamination has traveled in the groundwater without prior knowledge of the source term, such as leak volume or initial contaminant levels. These estimated distances, when correlated with residual vadose zone plume locations and driving force sources, could provide evidence to support or disprove a particular source determination.

Input will be acquired from monthly groundwater data and from continuous conductivity values acquired in support of borehole probe studies. A more complete discussion of the fundamentals related to this task can be found in Section 4.3.4.

Driving Force Determination

The objective of this subtask is to determine, to the extent possible, the existence, location and nature of recent driving forces in the vicinity of the WMA. In arid regions with substantial unsaturated zones, an important part of source determination is the identification of a viable mechanism that drives the waste from a leak source, through the vadose zone to the groundwater.

Driving Force Documentation. Documents and occurrence reports, related to direct tank/ancillary equipment and to broken water line leaks, will be compiled. This information will be used not only to revise the conceptual model but will be integrated with results from the whole source determination task to attempt relating groundwater contamination with specific sources.

Analysis of Transient Pressure Effects. As proposed by Johnson and Chou (1998), another driving force may be related to natural precipitation from years with exceptionally heavy precipitation. A cursory inspection of hydrographs from the RCRA groundwater monitoring network display a quasi-cyclic pattern that may contain an annual frequency for the last few years. The goal of this subtask is to identify and quantify the frequency of cyclic changes in water levels over time. Data collected in support of studying barometric effects will provide the basic data set. Because the goal is determine if an annual frequency is occurring in water levels, it will be necessary to collect the data over many periods. Hence data will be collected for at least four years. More detail can be found concerning the analysis and interpretation of these data in Section 4.4.2.

Evaluation of Sampling Frequency

The primary objective of this subtask is to determine the optimal sampling frequency to use at this WMA for routine monitoring. As observed in data presented in the first determination assessment report, large fluctuations in groundwater chemistry can occur in this area at frequencies of less than one month (Narbutovskih 1998). If this WMA had not been monitored such that samples were collected twice in

August 1997 or if it had been monitored in September 1997 and not August 1997, high levels of technetium-99 and nitrate would have been missed. These results bring forth the question of technically what is the best sampling frequency at this site to ascertain if waste related to the WMA is impacting groundwater, regardless of that set by 40 CFR 265.93.

Continuous conductivity data will be collected in a few wells using a borehole conductivity probe. These data will be gathered with the same data logger as that used in support of the barometric studies. A secondary goal is to provide information on the feasibility of implementing a downhole screening apparatus to allow nearly continuous data acquisition of conductivity. This would allow rapid screening of sudden contamination increases in near real-time, thereby eliminating the need for costly monthly sampling and analyses.

Reporting

Progress reports on current results of the groundwater quality assessment program must be submitted to Ecology no later than March 1 following each calendar year. The annual assessment progress for WMA B-BX-BY will be included in the Annual Hanford Groundwater report beginning in FY 2000. In addition, quarterly reports are submitted to DOE/Ecology, which include a synopsis of groundwater chemistry changes at each RCRA site in assessment. Borehole completion packages will also be prepared for each new monitoring well installed to document compliance with WAC 173-160.

Project Planning and Direction

This task involves ensuring that tasks are on track and that resources and personnel will be available when they are needed. Workarounds will be developed when schedule conflicts occur. Preparation of the further assessment work plans and any subsequent revisions are also an important aspect of this task. Meetings with stakeholders and the integration project team leads will be conducted to ensure coordination with other projects.

B.1.2 Schedule

The schedule for conducting the previously described tasks is shown in Figure B.1. The time period covered is from October 1998 to September 2002. Only start are shown for all tasks and subtasks. In general, these date correspond to times when data acquisition is scheduled to begin. It should be noted that for some tasks such as those related to continuous downhole measurement, data acquisition may be required for years. The end dates for tasks beyond FY 1999 are tentative at this time due to the uncertain nature of the WMA B-BX-BY assessment in relation to the upcoming TWRS RFI process. These ending dates will be revised annually as needed.

Sampling Schedule

Annual	Quarterly-A	Quarterly-B	Monthly-A	Monthly-B
299-E33-31	299-E33-31	299-E28-8	299-E33-13	299-E33-31
299-E33-32	299-E33-32	299-E33-13	299-E33-18	299-E33-32
299-E33-33	299-E33-33	299-E33-15	299-E33-41	299-E33-42
299-E33-36	299-E33-36	299-E33-16		299-E33-43
299-E33-38	299-E33-41	299-E33-17		299-E33-8
299-E33-39	299-E33-42	299-E33-18		
299-E33-41	299-E33-43	299-E33-20		
299-E33-42	299-E33-38	299-E33-21		
299-E33-43	299-E33-39			
		299-E33-5		
		299-E33-7		
		299-E33-8		
Planned Analysis				
Annual	**Quarterly-A**	**Quarterly-B**	**Monthly-A**	**Monthly-B**
Iodine-129	Alkalinity	Anions	Anions	Anions
Strontium-90	Anions	Cyanide	Gross Alpha	Gross Beta
TOX	Cyanide	Gamma Scan	Gross Beta	ICP Metals
	Gamma Scan	Gross Alpha	ICP Metals	Technetium-99
	Gross Alpha	Gross Beta	Technetium-99	
	Gross Beta	ICP Metals	Uranium	
	ICP Metals	Iodine-129		
	TOC	Technetium-99		
	Technetium-99	Uranium		
	TDS	Tritium		
	Uranium			
	Tritium			

Table B.1. List of Assessment Wells Currently in Use at WMA B-BX-BY Along with the Annual, Quarterly, and Monthly Constituents of Interest

299-E33-1A	299-E33-2	299-E33-3	299-E33-4	299-E33-5
299-E33-6	299-E33-7	299-E33-8	299-E33-9	299-E33-10
299-E33-11	299-E33-12	299-E33-13	299-E33-14	299-E33-15
299-E33-16	299-E33-17	299-E33-18	299-E33-19	299-E33-20
299-E33-21	299-E33-22	299-E33-23	299-E33-24	299-E33-25
299-E33-26	299-E33-27	299-E33-28	299-E33-29	299-E33-31
299-E33-32	299-E33-33	299-E33-36	299-E33-38	299-E33-39
299-E33-40	299-E33-41	299-E33-42	299-E33-43	299-E33-44
699-50-53A	699-49-55A	699-49-57A		

Appendix B.2

Quality Assurance Plan

The groundwater quality assessment investigation at WMA B-BX-BY is part of the RCRA groundwater monitoring project of the Hanford Site. The scope of the consolidated project includes: 1) groundwater monitoring; 2) groundwater velocity determination; 3) plume tracking; and 4) source/driving force determination. The project is administered by Pacific Northwest National Laboratory for the Richland Operations Office of the U.S. Department of Energy, Environmental Restoration (ER) Branch.

The consolidated groundwater project was established in 1996 when scope and personnel for the RCRA groundwater and related operational monitoring activities were transferred from Westinghouse Hanford Co. to PNNL. The Quality Assurance (QA) Plan ETD-012, Rev. 0, the Hanford Ground-Water Monitoring Project Quality Assurance Project Plan and associated subcontractor procedures/manuals for the consolidated project currently in place cover much of the work activities required for conducting the WMA B-BX-BY groundwater quality investigation. Accordingly, the primary emphasis of this appendix is on those activities not covered under the existing quality assurance plan. However, summaries of relevant sampling and analysis procedures, as well as, reference to other supporting and/or overarching documents, are included as needed to cover the planned activities described in the field sampling plan (Appendix B.1).

Project description, project organization and designated responsibilities, and project management interfaces between the Department of Energy and subcontractor organizations are described in the Hanford Ground-Water Monitoring Project Quality Assurance Project Plan (QA Plan, ETD-012, Rev. 0), here after referred to as the GW-QAPP. Also, because the Hanford Site now has numerous support contractors, some of the procedures referenced in this plan may be replaced by equivalent approved Project Hanford Management Contractor (PHMC) procedures.

B.2.1 Groundwater Sampling and Analysis Procedures

Sample Collection. Groundwater sampling procedures, sample collection documentation, sample preservation and shipment, and chain-of-custody requirements are described in subcontractor operating procedures/manuals and in the GW-QAPP. Quality requirements for sampling activities, including requirements for procedures, containers, transport, storage, chain of custody, and records requirements, are specified in a Statement of Work (SOW) to the performing subcontractor (currently Waste Management Northwest). To ensure that samples of known quality are obtained, the subcontractor is required to use contractor-controlled procedures based on standard methods for groundwater sampling whenever possible. Pacific Northwest National Laboratory (PNNL) will review these procedures for technical quality and consistency. In addition, periodic assessments will be performed by PNNL to further ensure that procedures are followed to maintain sample quality and integrity. A brief description of the sampling requirements is provided below.

Samples are generally collected after three casing volumes are withdrawn or after field parameters (pH, temperature, specific conductance and turbidity) have stabilized. Field parameters are measured in a flow-through chamber. Generally turbidities should be equal to or below 5 NTU (nephelometric turbidity units, 1 NTU = 1 mg/L of solids) prior to sample collection. The project scientist, depending on site-specific conditions and sampling objectives, however, could over ride this general requirement. For example, collection of water at the top of the aquifer during drilling necessarily involves turbid, unfiltered water, which will be processed further in the laboratory. Thus the 5 NTU requirement will be waived for these special water samples.

For routine groundwater samples, preservatives are added to the collection bottles in the laboratory prior to their use in the field. Duplicates, trip blanks and field equipment blanks are collected as part of the general quality control program. The sampling and analysis methods and procedures and associated quality control results are described in more detail in Hartman and Dresel (1998).

Analytical Procedures. Procedures for field measurements (pH, specific conductance, temperature, and turbidity) are specified in the manufacturer's manual for each instrument used. The laboratory approved for the groundwater monitoring program will operate under the requirements of current laboratory contracts and will use standard laboratory procedures as listed in the SW-846 (EPA 1986) or an alternate equivalent. Alternative procedures, when used, will meet the guidelines of SW-846, Chapter 10. Analytical methods and quality control for the RCRA groundwater monitoring activities are described in the GW-QAPP.

Data Storage and Retrieval. All contract analytical laboratory results are submitted by the laboratory in electronic form and loaded in the Hanford Environmental Information System (HEIS) database. Parameters measured in the field either are entered into HEIS manually or through electronic transfer. Data from the HEIS database may be downloaded to smaller databases, such as the Geosciences Data Analysis Toolkit (GeoDAT) for data validation, data reduction, and trend analysis. All field and laboratory hydrochemical results for this assessment will be entered in the publicly accessible HEIS database. Hard copy data reports and field records are considered to be the record copy of the data and are stored at PNNL.

B.2.2 Hydrologic Testing

Hydraulic conductivity will be determined using slug test procedures as specified in PNL-MA-567 ("Aquifer Testing"), or the most recent revision(s) of this document. Field data and other related information will be maintained in physical files at PNNL (Sigma V building). Hydraulic test results will be published under separate cover and not included in the annual updates of the Hanford Site groundwater monitoring report.

None of the wells included in this task (see Appendix B.1) are in a radiation control zone and thus no special radiological safety provisions are required.

B.2.3 Borehole Drilling and Testing

Bechtel Hanford Company (BHI) under their safety and related job control procedures manages borehole drilling and well installation. Data needs and objectives from this assessment plan are used as input to BHI who write the detailed specifications for the drilling contracts. The drilling and sampling activities and requirements associated with installation of two new RCRA compliant monitoring wells in FY 1999 for WMA B-BX-BY groundwater assessment and compliance purposes, are summarized as follows.

Subtask Descriptions and Related Procedures

The tasks involved in borehole drilling and sampling include:

- Activity preparation
- Location and designation of the borehole
- Drilling and geologic material sampling
- Sample handling
- Analysis of samples
- Documentation
- Borehole Gamma and Neutron Logging
- Well completion.

Activity Preparation. Preparation activities necessary before beginning fieldwork for borehole drilling include the following:

1. Coordinate with team members
2. Coordinate with support services
3. Evaluate drilling techniques
4. Obtain support documentation
5. Obtain monitoring and sampling equipment.

Borehole Locations. Two standard depth RCRA well will be installed in FY 1999. Additional compliance/assessment wells are anticipated for out years. The number of required wells is related to the change in flow direction that leaves no monitoring coverage along the south side of the WMA. These boreholes are designed to provide samples to 1) characterize the sediments in the vadose zone and saturated zone and 2) characterize the groundwater chemistry, both the nature and configuration of the chemistry. All borings will be constructed in accordance with Washington Administrative Code 173-160 requirements “Minimum Standards for Construction and Maintenance of Wells” and other appropriate Hanford requirements (e.g., WHC-S-014, Rev. 7 [WHC 1992]) or equivalent.

Boreholes are given designations that relate to the area in which they are located except in the 200 Areas. A permanent borehole number will be assigned once the well is installed and surveyed. Approximate locations are in the southwest corner of the WMA. The project scientist responsible for this assessment will also be responsible for "staking" the exact locations for the wells. Prior to final staking, ground penetrating radar will be used to assure that subsurface structures (water lines, electrical runs, waste transfer lines, etc.) are avoided. The drilling permit requirements dictate the level of pre-drilling survey needed.

Sample Handling.

Drilling and Coring Procedures. For wells in which coring will be performed, experience in Hanford sediments has shown that large diameter cores (10 cm) in the gravelly sand zones are more successful. A technique using casing advance has been successfully demonstrated for this purpose. In addition, drilling fluids will be avoided. These fluids are not desirable because measurement of the moisture content and matric potential are important TWRS data quality objectives.

Depending on borehole location and projected depth, a 6-m starter casing 20 to 30 cm in diameter will be used. Downsizing of well casing during drilling will be done at appropriate intervals depending on well conditions. In addition, precautions to minimize disturbance of subsurface materials and to prevent contamination of the subsurface and groundwater during drilling will be taken.

No drilling mud or fluids will be added to the borehole. Addition of other fluids such as water will be avoided unless absolutely necessary and approved by the project scientist. This is to allow for reliable determination of moisture content, make detection of moist zones or perched water zones easier, allow collection of representative moisture samples, and determine sorptive properties that are representative of actual subsurface conditions. Thus, considerable care must be take to avoid alteration of the natural state of the lithologic samples during the drilling and sample recovery process. Drilling the boreholes during the cooler months of the year aids in preserving the natural moisture content of the sample.

Flexible Drilling Contract Needed. Data quality can be significantly impacted if the appropriate type of drilling contract is not specified. It is of paramount importance to recognize that the two planned boreholes for FY 1999 are not simply for installation of new monitoring wells. Thus some "down time" (hourly rate schedule for drilling contractor) must be incorporated in the drilling plan for acquisition of core and groundwater samples as the borehole advances. It is difficult to predict the exact length or time this will take since the borehole will, at times, be advanced in a drill and test mode; i.e., field indicators will be analyzed during the saturated zone. The data quality objectives cannot be met with a cost-per-foot drilling contract. An hourly rate must be included to cover drill rig standby time when core samples and groundwater testing is conducted to meet the objectives defined in this assessment plan.

Sampling Activities. Drill cutting samples will be collected at 5-foot intervals throughout the vadose zone and below the static water level. After the geological logs are prepared, remaining sample will be kept for archival purposes. Digital photographs will be taken of contacts and significant changes in the nature of the sediments. Other sampling activities will be administered in accordance with applicable procedures in BHI-EE-01, *Environmental Investigations Procedures,* or WHC-CM-7-7, *Environmental Investigations and Site Characterization Manual* or equivalent Hanford Site approved procedure.

If continuous core samples are taken for the TWRS vadose characterization project 1) geologic description of fine structure and gross lithology, and 2) laboratory tests that includes saturated and unsaturated hydraulic conductivity, Kd, porosity and moisture content will be conducted.

Sub-samples of cuttings in the saturated zone will be extracted in the laboratory for key constituents in the PNNL, 300 Area laboratory by J. Serne using laboratory practice and procedures as described elsewhere (Myers et al. 1998). The standard drill cuttings archived at 5-foot intervals will be analyzed as deemed appropriate at a later time.

Core. If coring is conducted, all sampling will be conducted in accordance with procedure *Soil and Sediment Sampling* (BHI-EE-01, Procedure 4.0 or WHC-CM-7-7, EII 5.2, or equivalent, approved PHMC procedure). The well site geologist typically performs a description of the borehole sediments at the time of drilling to obtain a continuous lithologic record. However, with cores that are sealed in the plastic core liners, the physical description will have to be performed at a later date when the core liners are opened for processing. A sampling device, which can be advanced with the casing and be efficiently retrieved to the surface, will be used. The sampler will retrieve intact samples with a minimum outside diameter of 10 cm, have the ability to advance in 5-foot increments in downhole conditions, and will have Lexan (1/8-in. wall thickness) or equivalent liners for sample retention. The sample liners should be in two-foot long, individual segments.

The well site geologist will describe the samples in the field and record the descriptions on borehole logs per *Geologic Logging* (BHI-EE-01, Procedure 7.0, WHC-CM-7-7, EII 9.1) or equivalent, approved PHMC procedure. The field descriptions will be based on cuttings that are in excess of the core. Every sample collected will be recorded on a borehole log at the drill site because the cores will be immediately sealed. Detailed field lithologic descriptions of available material will include, if possible, color, texture, sorting, bulk mineralogy, roundness, relative calcium carbonate reactivity, consolidation, and cementation. All drilling and well construction data, sample depths, radiological and chemical survey points, etc. will be documented on the borehole logs.

Sample Handling. All sampling activities will be conducted in accordance with BHI, WHC procedures (BHI-EE-01 or WHC-CM-7-7 and WHC-CM-7-8), or an approved, equivalent PHMC or PNNL procedure unless specified otherwise. Special handling requirements may be associated with the type of analysis, laboratory procedures for the analysis, or regulatory requirements BHI procedure 3.0, “Chain of Custody,” and procedure 3.1, “Sample Packaging and Shipping.”

Samples obtained from the sampling process during drilling will be sealed as soon as they are retrieved from the downhole sampler. Cores will be sealed immediately in the field by placing end caps on the Lexan core liners. Teflon tape on plastic end caps is acceptable if Teflon caps are not available. The caps will be securely taped to the liner to achieve an airtight seal. Cored samples may be refrigerated in standard sample coolers with precautions to prevent moisture from the cooler impacting the sample.

Samples will be labeled with the borehole number, depth interval of the sample, and top and bottom of sample information. Samples, on which chemical tests are to be performed, will be transported to the appropriate laboratory for testing, after a field radiation and release survey is performed. Samples will be stored in refrigeration until analyzed

Archive samples will be delivered with a completed chain-of-custody form to the Hanford Geological Sample Library for archival after all samples have been taken from the core. All samples will receive a radiation release survey sticker prior to shipment.

B.2.4 Borehole Gamma and Neutron Logging

Gamma and neutron logging provides data comparison with core-derived data for stratigraphic interpretation, the vertical location of gamma-emitting radionuclides contamination, and relative moisture content of the sediments drilled. These logs will be used to determine *in situ* moisture content, help define hydrostratigraphic units and to correlate these units between boreholes. The boreholes will be logged in accordance with WHC-CM-7-7, EII 11.1 or equivalent, approved PHMC procedure. Logging sondes will include high-resolution spectral and gross gamma along with neutron moisture. Only proven techniques with procedures adequate to control the quality of the data will be used. After completion, each well will be re-logged with a germanium spectral gamma tool to provide a baseline for future radionuclide monitoring.

B.2.5 Well Completion

The two standard depth boreholes for FY 1999 will be completed as standard RCRA groundwater monitoring wells but with full length screens to allow for future declines in the water table. A screen length of 30 feet will be used for this purpose rather than the standard 20-foot screens. Also a 5 foot rat hole will be drilled to allow aquifer sampling if the head drops below two feet as the water table returns to its pre-Hanford levels. Approval from Ecology for this variance has been obtained. RCRA equivalent materials of construction will be used for the standard wells.

B.2.6 Groundwater Sampling Procedures and Points of Contact

This section supplements the description previously provided. The procedures for groundwater sample collection, water-level measurements, and field measurements include the following or equivalent, approved PHMC (Procedures SML-EP-001) or PNNL procedure:

- BHI-EE-01, Procedure 4.1 “Ground-Water Sampling”
- WHC-CM-7-8,6.1 “Disposal of Purgewater from Monitoring Wells”
- WHC-CM-7-8, 5.1 “User Calibration of Groundwater M&TE”

- WHC-CM-7-8, 5.2 “Groundwater M&TE Calibration by WHC Standard Lab”
- WHC-CM-7-7, EII 10.2 “Water-Level Measurement Procedure”
- WHC-CM-7-7, EII 1.2, 1.4 “Change Control Procedure”
- BHI-EE-01, Procedure 3.0 “Chain of Custody”
- BHI-EE-01, Procedure 4.0 “Soil and Sediment Sampling.”

All groundwater analyses will be done under the existing contract between PNNL and Quanterra (contract number MW6-SBB-A19981). All procedures, preservation requirements and techniques, accuracy and precision, and methods will follow the contract specifications.

Points of contact for the sampling and related drilling and analytical work are listed as follows:

Name	Affiliation	Responsibility	Phone
S. M. Narbutovskih	PNNL	Project Scientist	376-9235
F. N. Hodges	PNNL	Project Scientist Alternate	376-4627
D. G. Horton	PNNL	Geology	376-9932
S. P. Reidel	PNNL	Geology Alternate	373-6948
K. D. Reynolds	RFS	Drilling	372-8039
B. A. Williams	PNNL	Drilling Alternate	372-3799
V. G. Johnson	PNNL	Special Sampling	376-0916
R. Schalla	PNNL	Special Sampling Alternate	376-5064
D. L. Edwards	RFS	Sampling	372-2429
S. F. Conley	PNNL	Sampling Alternate	376-0550
F. A. Spane	PNNL	Hydrology	376-8329
D. R. Newcomer	PNNL	Hydrology Alternate	376-1054
D. L. Morgan	PNNL	Field Scheduling	376-9116
M. G. Gardner	RFS	Well Maintenance	372-8029
D. L. Stewart	PNNL	Laboratory Interface	376-5056

B.2.7 References

Bechtel Hanford Co. 1997. *Environmental Investigations Procedures*, Manual BHI-EE-01.

EPA. 1984. *Test Method for Determination of Inorganic Anions in Water by Ion Chromatography*, EPA-600/4-84-017, Environmental Monitoring and Support Laboratory, U.S. Environmental Protection Agency, Cincinnati, Ohio.

EPA. 1986. *Test Methods for Evaluating Solid Waste Physical/Chemical Methods*, 3rd Ed, EPA SW-846, U.S. Environmental Protection Agency, Washington, D.C.

EPA. 1993. *Data Quality Objectives Process for Superfund - Interim Final Guidance*, EPA/540-R-93-071, U.S. Environmental Protection Agency, Washington, D.C.

Hartman, M. J., and P. E. Dresel (eds.). 1998. *Hanford Site Groundwater Monitoring for Fiscal Year 1997*, PNNL-11793, Pacific Northwest National Laboratory, Richland, Washington.

Khaleel, R.. 1997. *Test Plans for Measurement and Analysis of Vadose Sone Hydraulic Properties for the Tank Waste Disposal Site*, Fluor Daniel Northwest report: FDNW-ENI-98-008.

PNL. 1989. *Procedures for Ground-Water Investigations*, PNL-6894, Pacific Northwest Laboratory, Richland, Washington.

Meyers, D. A., D. Moak, D. Parker, G. Gee, J. Serne, V. Johnson and G. Last. 1998. *Findings of the Extension of Borehole 41-09-39, 241-SX Tank Farm*, HNF-2855, Lockheed Martin Hanford Co., Richland, Washington.

WAC 173-160, *Minimum Standards for Construction and Maintenance of Wells*, Washington State Administrative Code, Olympia, Washington (as amended).

WHC, *Westinghouse Hanford Environmental Investigations and Site Characterization Manual*, WHC-CM-7-7, Westinghouse Hanford Company, Richland, Washington. (current version)

WHC, *Westinghouse Hanford Environmental Engineering and Technology*, WHC-CM-7-8, Westinghouse Hanford Company, Richland, Washington. (current version)

WHC. 1992. *Generic Specification -- Groundwater Monitoring Wells*, WHC-S-014, Rev. 7, Westinghouse Hanford Company, Richland, Washington.

Task Name	Start	Finish
B-BX-BY Assessment	**7/1/98**	**9/27/02**
Groundwater Flow Direction	**9/1/98**	**9/29/00**
Refined water levels	**9/1/98**	**9/29/00**
Survey check	12/1/98	3/1/99
Water Table Gradient	**9/1/98**	**10/1/99**
water level measurements	10/1/98	1/1/99
Local Water Table Map	9/1/98	10/1/99
Vertical boreholes deviations-Gyroscope	12/1/99	9/29/00
Stratigraphic control	4/1/99	9/1/99
Barometric effect	10/1/98	10/1/99
Flow direction/rate with direct flow measurements	4/1/99	6/30/00
Source Determination	**10/1/98**	**10/1/01**
Revision of Conceptual Model	10/1/98	10/1/01
Spatial/temporal mapping	10/1/98	1/1/01
Source chemistry characterization	**1/1/99**	**2/1/01**
Chemical Finger printing	1/1/99	12/1/00
Special Isotopic Analysis	2/1/99	9/1/99
Comparison with Process knowledge	3/1/99	2/1/01
Vadose Zone Plume mapping	6/1/99	12/1/00
Use of dispersion effects	10/1/99	6/1/01
Driving Force Determination	**12/1/98**	**1/1/02**
Driving force documentation	6/1/99	6/29/01
Analysis of transient pressure effects	12/1/98	1/1/02