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T-Area Technetium-99 Data Quality Objectives Summary Report

Prepared for the U.S. Department of Energy
Assistant Secretary for Environmental Management

Project Hanford Management Contractor for the
U.S. Department of Energy under Contract DE-AC06-96RL13200

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Richland, Washington

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Fluor Hanford, Inc.

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LIST OF TERMS

AA	alternative action
AEA	*Atomic Energy Act of 1954*
ASA	American Society of Agronomy
ASTM	American Society for Testing and Materials
BBI	best-basis inventory
bgs	below ground surface
CEC	cation exchange capacity
CERCLA	*Comprehensive Environmental, Response, Compensation, and Liability Act of 1980*
CFR	*Code of Federal Regulations*
CHG	CH2M Hill Hanford Group, Inc.
CLARC	Cleanup Levels and Risk Calculations
COC	contaminant of concern
COPC	contaminant of potential concern
CRCIA	Columbia River comprehensive impact assessment
CRDL	contract-required detection limit
CSM	conceptual site model
DO	dissolved oxygen
DOE	U.S. Department of Energy
DOE-EM	U.S. Department of Energy, Office of Environmental Management
DQO	data quality objective
DR	decision rule
DS	decision statement
DST	double-shell tank
DWS	drinking water standard
Ecology	Washington State Department of Energy
Eh	oxidation potential
EIS	environmental impact statement
EMSP	Environmental Management Science Program
EPA	U.S. Environmental Protection Agency
EQM	Environmental Quality Management, Inc.
FH	Fluor Hanford, Inc.
FS	feasibility study
FY	fiscal year
GC	gas chromatography
HAB	Hanford Advisory Board
HEIS	Hanford Environmental Information System
HFSUWG	Hanford Future Site Uses Working Group
HLW	high-level waste
HRR	high-resolution resistivity
IC	ion chromatography
ICP	inductively coupled plasma
IX	ion exchange
K_d	partition coefficient

LLW	low-level waste
MCL	maximum contaminant level
MDC	minimum detectable concentration
MS	mass spectrometry
N/A	not applicable
NABIR	Natural and Accelerated Bioremediation Research
NTU	nephelometric turbidity unit
ORP	U.S. Department of Energy, Office of River Protection
OU	operable unit
PFP	Plutonium Finishing Plant
PID	photo ionization detector
PNNL	Pacific Northwest National Laboratory
PRG	preliminary remediation goal
PSQ	principal study question
PUREX	plutonium-uranium extraction
QC	quality control
RBC	risk-based concern
RCRA	*Resource Conservation and Recovery Act of 1976*
REDOX	reduction-oxidation
RI	remedial investigation
RL	U.S. Department of Energy, Richland Operations Office
ROD	Record of Decision
SALDS	State-Approved Land Disposal Site
SAP	sampling and analysis plan
SIM	Soil Inventory Model
SST	single-shell tank
STOMP	Subsurface Transport Over Multiple Phases
TBD	to be determined
TBP	tributyl phosphate
TCE	trichloroethene
TIC	total inorganic carbon
TOC	total organic carbon
Tri-Party Agreement	*Hanford Federal Facility Agreement and Consent Order*
TSD	treatment, storage, and disposal
UO_3	uranium trioxide
UPR	unplanned release
URP	uranium recovery process
WAC	*Washington Administrative Code*
WIDS	Waste Information Data System
WMA	waste management area
XRD	x-ray diffraction

METRIC CONVERSION CHART

Into Metric Units		
If You Know	*Multiply By*	*To Get*
Length		
inches	25.4	millimeters
inches	2.54	centimeters
feet	0.305	meters
yards	0.914	meters
miles	1.609	kilometers
Area		
sq. inches	6.452	sq. centimeters
sq. feet	0.093	sq. meters
sq. yards	0.0836	sq. meters
sq. miles	2.6	sq. kilometers
acres	0.405	hectares
Mass (weight)		
ounces	28.35	grams
pounds	0.454	kilograms
ton	0.907	metric ton
Volume		
teaspoons	5	milliliters
tablespoons	15	milliliters
fluid ounces	30	milliliters
cups	0.24	liters
pints	0.47	liters
quarts	0.95	liters
gallons	3.8	liters
cubic feet	0.028	cubic meters
cubic yards	0.765	cubic meters
Temperature		
Fahrenheit	subtract 32, then multiply by 5/9	Celsius
Radioactivity		
picocuries	37	millibecquerel

Out of Metric Units		
If You Know	*Multiply By*	*To Get*
Length		
millimeters	0.039	inches
centimeters	0.394	inches
meters	3.281	feet
meters	1.094	yards
kilometers	0.621	miles
Area		
sq. centimeters	0.155	sq. inches
sq. meters	10.76	sq. feet
sq. meters	1.196	sq. yards
sq. kilometers	0.4	sq. miles
hectares	2.47	acres
Mass (weight)		
grams	0.035	ounces
kilograms	2.205	pounds
metric ton	1.102	ton
Volume		
milliliters	0.033	fluid ounces
liters	2.1	pints
liters	1.057	quarts
liters	0.264	gallons
cubic meters	35.315	cubic feet
cubic meters	1.308	cubic yards
Temperature		
Celsius	multiply by 9/5, then add 32	Fahrenheit
Radioactivity		
millibecquerel	0.027	picocuries

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PREFACE

The data quality objectives (DQO) process is a strategic planning approach based on the scientific method and used to prepare for a sampling data collection activity (*Guidance for the Data Quality Objectives Process* [EPA 2000]). The process provides a systematic procedure for defining the criteria that the data collection design should satisfy, including when to collect samples, where to collect samples, the tolerable level of decision errors for the study, and how many samples to collect.

By using the DQO process, the type, quantity, and quality of environmental data used in decision making will be appropriate for the intended application. In addition, resources will not be committed to data collection efforts that do not support a defensible decision.

The DQO process consists of seven steps. The output from each step influences the choices that will be made later in the process. The final step of the process involves developing the data collection design.

The DQO process ensures that characterization activities address identified data needs. However, although the DQO process is intended to limit redundant or unnecessary activities, it will not preclude additional characterization activities that may be prompted by new information or technological advances.

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1.0 STEP 1 – STATE THE PROBLEM

The purpose of this data quality objectives (DQO) process is to support decision-making activities as they pertain to the evaluation of technetium-99 in the unconfined aquifer in the Hanford Site's T Area.

The T Area includes the *Resource Conservation and Recovery Act of 1976* (RCRA)-regulated Waste Management Area T (WMA-T) and adjacent *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA) past-practice liquid disposal sites. WMA-T encompasses to the 241-T Tank Farm (hereinafter referred to as T Tank Farm) and the associated pipes and catch basins. The term "T Area" is used to refer to the entire study area, which includes WMA-T, as well as the cribs and trenches in the surrounding area and the area covered by the 900 pCi/L technetium-99 isopleth at the water table, as shown in Figure 1-1.

The *Remedial Investigation/Feasibility Study Work Plan for the 200-ZP-1 Groundwater Operable Unit* (hereinafter referred to as the 200-ZP-1 remedial investigation/feasibility study [RI/FS] work plan) (DOE-RL 2004) and *Hanford Site Groundwater Monitoring for Fiscal Year 2004* (PNNL 2005) have previously documented the presence of a technetium-99 plume at the water table in T Area groundwater at concentrations up to 27,400 pCi/L (Figure 1-1). Elevated concentrations of technetium-99 (181,900 pCi/L) recently have been measured in well 299-W11-25B at 10 m (32.8 ft) below the water table. The extreme concentrations found in well 299-W11-25B had not been previously encountered in T Area groundwater, and the contaminant had not been detected at the observed depth below the water table.

The goal of this DQO process is to understand how much technetium-99 is present below the water table in the unconfined aquifer to a depth approximately 61 m (200 ft) below the water table, to determine the lateral and vertical concentrations of the contaminant, and, if possible, to determine the source(s). The study area shown in Figure 1-1 encompasses the area defined by the 900 pCi/L isopleth at the water table and was selected as a reasonable focus for initial investigations of groundwater contamination and potential sources.

Development of the sampling design in Step 7 of this DQO process has been divided into two phases. Phase I is focused on the initial groundwater investigation to generate an enhanced understanding of the nature and extent of technetium-99 contamination. Phase II will be focused on any additional groundwater investigations required to enhance the information generated through Phase I and on the source investigation. The phased DQO process was developed to support (1) reconsideration of additional groundwater investigation locations and priorities based on results from the initial groundwater investigation, and (2) coordination of the source investigation data needs with data required to support waste site remediation and tank farm vadose zone characterization.

The sampling design in this DQO summary report addresses the Phase I activities. It is anticipated that development of the sampling design for the Phase II activities will be initiated in the fall/winter of 2007, resulting in a revision to this DQO summary report. During the DQO process to support Phase II activities, new data acquired after completion of the Phase I DQO process will be used to refine the conceptual model of the technetium-99 contamination and to revise the study area boundary, as appropriate.

The objective of DQO Step 1 is to use the information gathered from the DQO scoping process, as well as other relevant information, to clearly and concisely state the problem to be resolved.

1.1 PROJECT OBJECTIVES

The objective of this DQO process is to establish an approach to characterize the extent of technetium-99 contamination in the groundwater beneath the T Area. The Washington State Department of Ecology (Ecology) and the U.S. Environmental Protection Agency (EPA) requested that the U.S. Department of Energy (DOE) develop a schedule for detailed characterization and remediation at WMA-T and its associated groundwater. Elevated concentrations of technetium-99 and co-contaminants were recently observed in the groundwater at well 299-W11-25B, which is located near the eastern boundary of the T Tank Farm (Figure 1-1). Technetium-99 was known to exist in the T Area at the water table; however, high concentrations (over 180,000 pCi/L) had not been previously encountered in this area, and the contaminant had not been detected at a depth of 10 m (32.8 ft) below the water table.

Potential sources of the technetium-99 contamination include adjacent past-practice liquid disposal waste sites, adjacent unplanned release (UPR) sites, and WMA-T facilities. The DOE Richland Operations Office (RL) will conduct additional groundwater characterization activities as part of the CERCLA RI of the 200-ZP-1 Groundwater Operable Unit (OU). These activities will be coordinated with ongoing RCRA investigation and assessment activities at WMA-T.

The DQO process will be used to develop the technical documentation and activities for detailed characterization and potential remediation of the technetium-99 and associated groundwater contamination observed in well 299-W11-25B and other nearby wells. The DQO activities (Phases I and II) will, at a minimum, address the following:

- RCRA groundwater quality assessment requirements
- Identification (to the extent practicable) of the source(s) and driving forces of the contaminants exceeding drinking water standards (DWSs) in these wells
- Delineation of the vertical and lateral extent of the groundwater plumes for technetium-99, chromium, and other contaminants identified as contaminants of concern (COCs)
- The potential for the plumes to migrate from the 200 Area Central Plateau
- Data required to plan and implement groundwater remediation activities (if needed)
- Data required to assess the effectiveness of remediation technologies (if needed).

These project objectives comply with DOE's response to the request from Ecology and EPA for a project schedule (Klein 2005). The T Area study area boundary is shown in Figure 1-1 and is further discussed in Section 4.0. The decision makers requested during the DQO interviews that the T Area be placed in context; therefore, Figure 1-2 provides a perspective of the other areas that surround the T Area.

1.2 PROJECT ASSUMPTIONS

For purposes of this DQO process, it is assumed that RL will integrate RCRA and CERCLA compliance activities for the 200-ZP-1 OU, as well as for other affected projects in the T Area. This assumption is discussed in detail in Section 1.3.

1.3 PROJECT ISSUES

The following discussion identifies the policy and/or regulatory issues that govern project activities, as well as the technical issues that provided a basis for decisions.

1.3.1 Global Issues

Global issues are those concerns that are not solved by gathering data, but are policy or regulatory issues that govern the project goals and set the "rules" for gathering data. The primary global issue identified by the decision makers was that all of the vadose zone and groundwater projects must improve integration between RCRA and CERCLA program activities, as well as among the organizations performing the work. In addition, the decision makers indicated the need to improve the integration of schedules related to characterization/ remediation of contaminant source(s) and groundwater plumes.

While this DQO process cannot govern the integration and schedules for all source units and groundwater projects, the project is planning to integrate information from the following relevant sources:

- RCRA characterization studies from WMA-T and, as appropriate, from WMA-TX/TY
- CERCLA characterization data from the 216-T-3, 216-T-6, 216-T-14 through 216-T-17, and 216-T-32 Cribs in the 200-TW-2 OU, as well as nearby cribs and trenches in other OUs, including the 216-T-12, 216-T-5, 216-T-7, and 216-T-36 Cribs
- CERCLA characterization data from the 200-ZP-1 Groundwater OU.

Because the global issue identified above concerns multiple groundwater OUs and multiple source OUs external to this project, the team agreed not to hold a global issues meeting. The scheduling concern is being discussed between EPA, Ecology, RL, and the DOE Office of River Protection (ORP). If resolution of the schedules is achieved prior to completion of this DQO summary report, the relevant schedules will be included in this report.

Although the DQO process did not formally address integration concerns, output from the following RCRA- and CERCLA-based activities will be integrated into this DQO process:

- The RCRA Corrective Actions Project issued a field investigation report for WMA-T and WMA-TX/TY in July 2005 (Myers 2005] in fulfillment of the *Hanford Federal Facility Agreement and Consent Order* (Tri-Party Agreement) (Ecology et al. 2003) Milestone M-45-55-T-3. Information contained in the field investigation report will be incorporated in the compilation of background data supporting this DQO process.
- The RCRA Corrective Actions Project will issue a RCRA facility investigation report in support of Tri-Party Agreement Milestone M-45-55, a RCRA corrective measures study in support of Milestone M-45-58, and a RCRA corrective measures work plan in support of Milestone M-45-60. The RCRA Corrective Actions Project will participate in this DQO process to ensure that the sampling and analysis plan (SAP) resulting from the DQO process will generate data that will support future RCRA activities.
- The WMA integration study for WMA-T was issued in June 2005 (Schaus and Seeley 2005) in support of Tri-Party Agreement Milestone M-45-00B. The document describes the approach for remediation of WMA-T, including integration with CERCLA activities for waste sites and groundwater.

- The Hanford Site Groundwater Performance Assessment Project issued a groundwater assessment monitoring plan for WMA-T in 2006 (Horton 2006). The plan fulfills the requirements of 40 *Code of Federal Regulations* (CFR) 265.93(d)(7) for continued groundwater quality assessment of (1) the rate and extent of migration of the hazardous waste or hazardous waste constituents in the groundwater, and (2) the concentration of hazardous waste or hazardous waste constituents in the groundwater. The data needs outlined in the assessment plan will be considered during the DQO process for the technetium-99 characterization activities. Also, appropriate data collected during implementation of the SAP resulting from the DQO activities will be incorporated into the RCRA groundwater assessment at WMA-T.
- The Waste Sites Remediation Project will issue CERCLA RI/ FS reports for adjacent past-practice liquid disposal waste sites and UPRs in the 200-TW-2, 200-CW-4, and 200-SC-1 OUs in support of Tri-Party Agreement Milestone M-15-00C. The Waste Sites Remediation Project will participate in the technetium-99 DQO activities to ensure that data resulting from the subsequent characterization activities will support the waste sites remediation activities, as appropriate.
- The Groundwater Remediation Project will issue a CERCLA RI report in September 2006 for groundwater underlying the northern portion of the 200 West Area and a FS report in March 2008 in support of Tri-Party Agreement Milestone M-15-00C. The Groundwater Remediation Project will participate in the technetium-99 DQO activities to ensure that data resulting from the characterization activities, performed as identified in the SAP associated with this DQO summary report, will support future groundwater remediation activities, as appropriate.

In addition, available data from the following future characterization activities will be integrated into Phase II of the DQO process and resulting SAP:

- **Results from surface high-resolution resistivity (HRR) studies being conducted over WMA-T and adjacent past-practice disposal facilities.** The data, as well as information generated from the installation and sampling of new wells, will support the siting of the next round of groundwater wells and the SAP. The data may also aid in locating additional wells, if needed.
- **Results from drilling and sampling of a new, deep (i.e., approximately 61 m [200 ft] below the water table) characterization borehole in November 2005.** Well 299-W11-45, also known as "T-2" (Figure 1-1), was drilled approximately 80 m (262.5 ft) downgradient of well 299-W11-25B. The purpose of the well was to help determine the horizontal extent of the elevated technetium-99 concentrations discovered in well 299-W11-25B (PNNL 2006). The maximum technetium-99 concentration found during drilling of well 299-W11-45 was 15,646 pCi/L at 9.1 m (29.9 ft) below the water table (PNNL 2006), indicating that the deep technetium-99 plume extends into this area.

- **Results from drilling and sampling of a new, deep characterization borehole in February 2006.** Well 299-W11-47, also known as "T-3" (Figure 1-1), was drilled near the southeast corner of WMA-T, near existing well 299-W11-41. The well was installed to determine the lateral extent of the elevated technetium-99 contamination. Preliminary results suggest that the maximum technetium-99 concentrations in this well range from approximately 3,000 to 4,000 pCi/L at depths of 9.8 to 15.6 m (32.3 to 51.3 ft) below the water table, indicating much lower concentrations of technetium-99 contamination than found in well 299-W11-25B.

1.3.2 Technical Issues and Proposed Resolutions

The policy issues discussed above provide a context for decisions. The following section establishes the technical basis for decisions that will be the subject of the DQO process.

The following technical issues will be addressed and/or included in this DQO summary report:

- Determine the source of the technetium-99 contamination in the aquifer

  NOTE: Technetium-99 sources being considered include the tanks in WMA-T (T Tank Farm), trenches and cribs in the area, UPRs, or a combination of these.
- Determine whether ratios of isotopes and/or nonradioactive constituents may assist in identification of the source of the technetium-99
- Determine how best to develop a mass balance of the technetium-99 in the groundwater and provide a best estimate of the contaminant inventory
- Determine how best to use the results of vadose zone sampling in the conceptual site model (CSM)
- Use HRR data to better define sampling locations
- Identify the data needed for future remediation decisions
- Identify the potential for a continuing source of technetium-99 in the T Area
- Include recharge from the rainfall and snowmelt in models predicting the technetium-99 movement
- Evaluate whether the berms around the tank farm may cause the rain/snowmelt to remain over the tank area, thus increasing the driver into the vadose zone
- If possible, develop a "moisture model" that can be used to predict future technetium-99 movements in the vadose zone.

1.4 EXISTING REFERENCES

Table 1-1 presents a list of all of the references that were reviewed as part of the scoping process, as well as a summary of the pertinent information contained within each reference. These references are the primary source for the background information presented in Section 1.5. Numerous additional references are available and are considered and cited in this document, as appropriate.

1.5 SITE BACKGROUND INFORMATION

This section provides a background of the operations history for the facilities that potentially contributed contaminants to the investigation area(s), as well as the studies that have been conducted to date.

There are two CERCLA groundwater OUs in the 200 West Area: the 200-UP-1 OU to the south, and the 200-ZP-1 OU to the north. The T Area is within the northern portion of the 200-ZP-1 OU. RL monitors groundwater within the 200-ZP-1 OU to assess the performance of an interim action pump-and-treat system for carbon tetrachloride contamination, to track other contaminant plumes, and to monitor compliance at four RCRA units (including WMA-T within the T Area) and the State-Approved Land Disposal Site (SALDS). Data from facility-specific monitoring activities are integrated into CERCLA groundwater investigations for the 200-ZP-1 OU. The major, local contamination plumes specific to the T Area include technetium-99, chromium, and fluoride. In addition, more dispersed plumes of carbon tetrachloride, trichloroethene (TCE), nitrate, and tritium exist beneath the T Area. The study area for this DQO process and the resulting data will be considered as part of documentation and milestones for the 200-ZP-1 OU and decisions will be incorporated into the Record of Decision (ROD) for the OU.

Figure 1-1 shows the general layout of the T Area. WMA-T is a RCRA-regulated facility in the southwestern portion of the T Area. WMA-T includes T Tank Farm, piping, and catch basins. Groundwater samples from a recently drilled (in 2005) groundwater monitoring well near the northeastern corner of WMA-T (well 299-W11-25B) showed technetium-99 concentrations above anticipated levels and prompted further investigation of the sources of technetium-99 in and around the T Area. This DQO summary report addresses the data needs required to answer questions dealing with the technetium-99 sources, locations, and concentrations that may be found in the soils and groundwater below WMA-T. This section of the DQO summary report provides background information on the facilities that potentially contributed to the technetium-99 contamination in the T Area, as well as a review of past and ongoing investigations to characterize the source(s) and extent of the groundwater plume.

The first three decades of Hanford operations were (for the most part) driven by high demand for plutonium production for cold war defense purposes. During the first decade or more of this period, the requirements for recordkeeping, particularly for waste management, were not as stringent as the requirements implemented in later years of Hanford operations. Furthermore, during the late 1940s through the 1950s, plutonium demand plus uranium recovery from the waste tanks (B and T Plant bismuth-phosphate plutonium processing did not recover uranium) required waste tank space that simply was not available, at least to any significant degree. Tank construction was ongoing but could not keep up with the demand for tank space. Consequently, a combination of evaporator operations and liquid waste disposal to the soil column was used to free up tank space for the higher priority production operations. Soil disposal did consider the ion-exchange (IX) properties of the soil and was specifically intended to keep contamination out of the environment and aquifer. However, as noted below, technetium was not a radioisotope of concern during those years of operation from either a production or waste disposal viewpoint; thus, its behavior in the soil column was neither known nor tracked.

Chemical processing during these years was primarily concerned with plutonium production, uranium recovery, and isolation of those isotopes (primarily cesium and strontium) that complicated waste tank operations and/or provided high personnel exposure to Hanford

operations and maintenance personnel. Technetium-99 was not needed for defense purposes and was not present in the wastes in high enough concentrations to result in significant tank storage or personnel exposure issues and, thus, was not routinely monitored. In fact, the chemistry of technetium throughout the plutonium production, uranium recovery, and isotope recovery operations is not well known or understood. Thus, the concentrations of technetium in any waste type are estimated based on present-day knowledge of technetium chemistry and not due to any technetium recordkeeping during the years of interest.

The operational factors discussed above resulted in a large amount of waste transfers to and from tanks, within and between tank farms, to and from the evaporators, and liquid waste disposal to multiple soil sites to free up tank space for higher priority tasks. Combining this with incomplete recordkeeping (and/or the loss of records over the decades and prime contractor changes) and lack of knowledge or interest in technetium, the information needed to define the wastes in the tanks and of wastes disposed to the soil at any given time is less than adequate. The information in the following subsections is the best information available at this time. Specific dates and volumes of waste types disposed to specific waste sites are provided below where available, but the information should not be interpreted to necessarily be the *only* waste that was stored, transferred, or disposed to any given site during these periods of time. The information should be understood as qualitative, and not necessarily quantitative, and is provided so the reader will have an understanding of the waste disposal patterns and approximate quantities of waste disposed in the 200 West Area around WMA-T.

1.5.1 Hanford Chemical Process Overview

This section provides an overview of Hanford processes and facilities that potentially contributed technetium-99 to soil and/or groundwater in the T Area, as well as those operations that may have helped to mobilize technetium-99 that was already present in the soil or groundwater. The *RCRA Assessment Plan for Single-Shell Tank Waste Management Area T* (Horton 2006), the *Field Investigation Report for Waste Management Areas T and TX-TY* (Myers 2005), and *Subsurface Conditions Description of the T and TX-TY Waste Management Areas* (CHG 2001) provide extensive discussions of site conditions to assist in the evaluation of T Area contamination. The descriptions provided below draw heavily from these documents.

The Hanford Site's primary mission was materials production (primarily plutonium) for weapons manufacturing. In addition, during the late 1940s and early 1950s, the uranium stored in the waste tanks was more than the total uranium that existed in the world at that time. Consequently, uranium recovery from the wastes was needed for recycle to support ongoing reactor operations for plutonium production. Technetium was a byproduct from the fuel-reprocessing program at Hanford and had no purpose in the defense mission or any commercial utility; therefore, there was little, if any, reason for operators to become familiar with its chemistry or to monitor it in the processes. In the mid- to late 1960s, the Hanford operators learned that technetium generally remained with the uranium and/or in the aqueous supernates from fuel processing/reprocessing and waste management processes such as uranium recovery and isotope separations activities.

Hanford facilities used three different chemical processes to support their mission:

- The bismuth-phosphate process, which was used from 1944 until 1956 (T Plant from 1944 to 1956, and B Plant from 1945 to 1952)

- The reduction-oxidation (REDOX) process, which was used from 1952 until 1967
- The plutonium-uranium extraction (PUREX) process, which was used from 1956 until all Hanford fuel reprocessing was halted in 1988.

The T Plant bismuth-phosphate process was the only fuel reprocessing operation that used the T Tank Farm and related facilities (e.g., diversion boxes, trenches, cribs, retention basin, etc.). In addition to the T Plant bismuth-phosphate process, the uranium recovery process (URP) performed at U Plant (from 1952 to 1958) and various isotope separations processes (primarily isolation of cesium-137 and strontium-90) performed in a myriad of Hanford facilities, including a refurbished B Plant, also used the T Tank Farm for pre- and post-process "staging." The isotope recovery processes began in the late 1940s and continued until approximately 1983. These additional operations have resulted in a very complex mixture of contents in the tanks at T Tank Farm from a number of "non-T Plant" sources.

It is likely that the REDOX Plant and B Plant neutralized waste disposed to the T Tank Farm included technetium, although the concentrations are unknown. B Plant cesium and strontium processing during the PUREX Plant's operating periods likely included upwards of 75% of the PUREX-produced technetium in their process liquids. This estimate is based upon PUREX laboratory tests of uranium recovered and sent to the Uranium Trioxide (UO_3) Plant for recycle to Fernald, Ohio. The impact of B Plant processing for cesium and strontium removal from the waste stream and tank supernates on technetium-99 concentrations, and the final destination of the technetium that passed through B Plant, is unknown. Considering the small amount of B Plant low-level waste (LLW) that was disposed at T Tank Farm (as compared to 200 East Area disposals), it is likely that the majority of the technetium produced in PUREX went to and remains in 200 East Area tanks, cribs, and trenches.

The "volume-reduction" processes, primarily the evaporators, also transferred waste solutions into and out of T Tank Farm. Because the temperature at which technetium would have volatilized is well above the operational temperatures of the evaporators, the majority of the technetium processed through the evaporators would have remained in the evaporators' "bottoms." The evaporator bottoms contain high-salt liquids remaining after much of the water has been evaporated. These bottoms were usually returned to the single-shell tanks (SSTs). As production needs demanded additional tank space, however, these bottoms were ultimately disposed to the retention trenches. In the 200 West Area, these trenches included 216-T-14 through 216-T-17 (northeast of T Tank Farm) and 216-T-21 through 216-T-25 (to the southwest of the TY Tank Farm). These evaporator bottoms are likely to have contained significant levels of technetium.

The decontamination activities performed at T Plant from 1958 through the 1990s were the final processes that used the T Tank Farm directly. During the 1960 to 1969 time interval, decontamination wastes were sent to cribs in the T Area for disposal. After that time, these wastes were sent to the T Tank Farm tanks for storage. This decontamination waste is not likely to have contained much, if any, technetium. Figure 1-3 provides a timeline of the processes that potentially contributed technetium-99 to the soils and groundwater beneath the T Area. Descriptions of the major processes are provided in the following subsections.

1.5.1.1 Bismuth-Phosphate Operations, 1944-1956. T Plant used the bismuth-phosphate process to separate plutonium from irradiated fuel slugs. The process was based on the principle that bismuth phosphate is similar in crystal structure to plutonium phosphate. The operation was

a batch precipitation process that achieved plutonium separation by varying the valence state of the plutonium-239 and then repeatedly dissolving and centrifuging the plutonium-bearing solutions. The first step in the process involved dissolving the aluminum fuel jackets from the uranium fuel elements. This was followed by an extraction step that separated the plutonium-239 from the uranium; this processing step also removed an estimated 90% of the fission products into what was called the metal waste solution (WHC 1996). Additional steps of dissolution, precipitation, and centrifuging decontaminated the plutonium, with the liquids disposed as waste. Liquid waste that was sent to the tank farms was cascaded from one tank to the next in a series; each series contained three tanks. Each tank in the series would receive a lower percentage of solids due to settling in the preceding tank(s). After the third tank, the supernate liquid was disposed to a crib. The bismuth-phosphate process produced five waste streams:

- Metal waste was the byproduct from the plutonium-separation phase of the bismuth-phosphate process. Metal waste contained unfissioned uranium and the majority (approximately 90%) of the fission products, including technetium-99, of the irradiated fuel.
- First-cycle (1C) waste was the byproduct from the first plutonium decontamination cycle of the bismuth-phosphate process. This waste contained a fraction (approximately 10%) of the fission products and technetium-99 of the irradiated fuel.
- Second-cycle (2C) waste was the byproduct from the second and last plutonium decontamination cycle of the bismuth-phosphate process. This waste contained less than 0.1% of the fission products and technetium-99 of the irradiated fuel.
- The "224 waste" was low-level liquid waste from the 224-T Plutonium Concentrator Building. This waste stream was the primary contributor to plutonium contamination of the soil. This waste was routed to the 241-T-361 settling tank and then discharged to the 216-T-3 reverse well near T Plant. It was later routed to the 200-series tanks for settling and discharged to the 216-T-32 Crib.
- The "5-6 waste" was low-level liquid waste from floor drains in individual process cells in T Plant. This waste was discharged to the 216-T-4 Pond during the T Plant startup testing "cold run" but was routed to the 5-6 tank in T Plant when processing of irradiated fuel began in December 1944. Waste stored in the 5-6 tank was discharged along with 224 waste to the 241-T-361 tank and the 216-T-3 reverse well.

The metal waste stream contained most (approximately 90%) of the technetium-99 and originally was placed in tanks 241-T-101, 241-T-102, and 241-T-103. Beginning in 1953, after the U Plant URP operations began (see discussion below), the metal waste was routed directly from T Plant to U Plant for uranium recovery, bypassing the T Tank Farm.

The first-cycle waste stream containing approximately 10% of the fission products and technetium was placed in all of the T Tank Farm tanks, either directly from T Plant discharges or indirectly as a result of evaporator operations from the evaporator bottoms.

Recent laboratory-scale work performed by Pacific Northwest National Laboratory (PNNL) to simulate the bismuth-phosphate precipitation process indicated that nearly all (>98%) of the technetium should have remained in the metal waste solution that was disposed to tanks (PNNL 2006). However, for the purposes of this investigation, the previous estimate that

approximately 90% of the technetium remained with the metal waste solution will be used. This approach will ensure that disposal sites for first-cycle waste streams, which might contain higher levels of technetium if the bismuth-phosphate operating parameters varied from specifications, are included as potential sources.

The second-cycle, 5-6, and 224 waste streams contained very little fission products or technetium-99 and will not be further considered in this DQO process as a source of technetium-99. These waste streams were eventually disposed to the soil column and may have contributed to the mobilization of the technetium-99 already in the soil column from spills, leaks, or direct discharge.

1.5.1.2 Uranium Recovery Operations, 1952-1958. The bismuth-phosphate fuel process separated plutonium from irradiated reactor fuel but did not separate the uranium. The Manhattan Project, and subsequently the Atomic Energy Agency, planned to recover uranium from the waste, but the wartime exigencies sent the uranium to the waste tanks for storage with the remainder of the fission products and other wastes.

Beginning in 1952, metal waste sludge was sluiced from T Tank Farm, treated in the 244-TXR process vault, and then transferred to U Plant for uranium recovery. The U Plant operation relied on tank waste and T Plant metal waste as its source material. These URP source materials included waste containing technetium-99 as a component. Metal waste sludge from the C, B (200 East Area), and U Tank Farms was also sent to U Plant for uranium recovery. From 1952 until T Plant was shut down in 1956, T Plant operations sent newly generated metal waste directly to U Plant for uranium recovery.

The waste tank supernates were transferred to an empty waste tank for temporary storage while the sludge was mobilized and transferred to U Plant for uranium recovery. Due to the high pH of the waste tank supernates, the supernates would have contained a substantial majority of the technetium, while the uranium sludge would have contained the remainder. Thus, the uranium recovery processing, in itself, did not have a significant impact on the majority of the technetium-99 that was in the tanks or that was released to the soils. Storage needs to support this processing, coupled with ongoing plutonium processing, required additional tank space, which resulted in existing in-tank supernates and evaporator bottoms being directly disposed to the soils. This decision ultimately resulted in a significant fraction of the T Plant-produced technetium being discharged to the soil column in and around the T, TX and TY Tank Farms, but the concentrations of the technetium in each waste discharge is unknown and, thus, cannot be accurately estimated.

Despite additional tank farm construction and ongoing volume-reduction efforts, tank space was not sufficient to support both the URP and plutonium production. To reduce the volume of stored waste, tributyl phosphate (TBP) waste (originating from URP operations) from T Tank Farm was concentrated in the 242-T evaporator beginning in July 1953. Additionally, a ferrocyanide-scavenging process was developed to remove the principal long-lived fission products cesium-137 and strontium-90 from the TBP waste to enable disposal of the waste supernate to the cribs. This waste was primarily disposed in the 216-T-19 Crib, south of the TX Tank Farm (Figure 1-2). A small amount of this waste was disposed to the 216-T-18 Crib, south of WMA-T and east of the TY Tank Farm (Figure 1-2). However, the majority of the supernate disposal required to support URP was to the B/C Cribs and trenches in the 200 East Area and not in the 200 West Area.

The only other disposal of URP waste streams to 200 West Area soil was disposal to the 216-T-25 and 216-T-26 Trenches. Disposal of evaporator bottoms in the 216-T-25 Trench (west of the TX Tank Farm) (Figure 1-2) very likely contained some level of technetium. In addition, the 216-T-26 Crib (east of TY Tank Farm) received scavenged TBP and first-cycle waste during URP (12 million L [3.2 million gal]). The volume of first-cycle liquids released directly to the specific retention trenches (216-T-14 through 216-T-17 and 216-T-21 through 216-T-26) to make tank space available for T Plant operations and URP (see Section 1.5.1.5), however, is very likely one source of the technetium-99 found in the soils in the T Area. Figure 1-4 provides an overview of the bismuth-phosphate and URP timelines of interest, as well as the location of the technetium-99 during that interval. From initial T Plant operation until the metal waste was directly routed to U Plant for the URP, the supernate soil disposal after T Tank Farm tank cascading (e.g., tanks 241-T-101 to 241-T-102 to 241-T-103) very likely released the majority of the technetium produced in T Plant to the soils around the T Tank Farm during this time period. In addition, the direct crib/trench disposal of the first-cycle wastes, also in support of the various T and U Plant operations, are likely additional sources of the T Area technetium-99 soil inventory.

1.5.1.3 Central Decontamination and In-Tank Solidification Operations, 1960-1974. Following the end of plutonium-separation operations, T Plant was converted in 1958 into a central decontamination facility. The 2706-T decontamination annex was built in 1959. Waste was sent to the 241-T-112 tank for settling, and supernate was discharged to the TY Cribs beginning in February 1960. The TY Crib inlet line was re-routed from the TY Tank Farm to tank 241-T-112 for this purpose; however, these decontamination wastes are not likely to have contained much, if any, technetium.

1.5.1.4 Stabilization and Isolation, 1975-Present. Interim stabilization is the process of removing all supernatant liquid and as much drainable liquid as possible from a waste storage tank. This process began in 1972. The T Tank Farm tanks were interim stabilized beginning in 1976, with pumpable liquids transferred to receiver tank 241-TX-107 and from there to the 242-S evaporator. The evaporator bottoms were transferred to the double-shell tanks (DSTs). Following interim stabilization, the SSTs were isolated by establishing at least one physical barrier between the tank contents and the environment to preclude inadvertent addition of liquid. Cutting and blanking of all process piping to and from the tank, blanking all risers, and equipping the tank with a filtered ventilation system accomplished the necessary isolation.

1.5.1.5 Evaporator Operations, 1951-1953. The 242-T evaporator was built to reduce the volume of first-cycle waste, and operations began in late April 1951. Cooling water from the evaporator was sent to the 216-T-4 Pond via the 207-T retention basin.

When the 242-T evaporator was needed for TBP waste (i.e., U Plant operations), ground disposal of first-cycle waste was pursued. In May 1953, direct disposal of first-cycle waste to specific retention trenches was approved at a maximum discharge rate of 5,280 L/m^2 (150 gal/ft^2). This level of release was chosen to ensure retention of the wastes in the soil. Evaporation of first-cycle waste was discontinued in June 1953; approximately 17 million L (4.5 million gal) of first-cycle waste from the 200 East and 200 West Areas had not been evaporated at that time. Consequently, 2.9 million L (766,099 gal) of first-cycle waste were sent to the 216-T-14 and 216-T-17 specific retention trenches via an over-ground line from 241-T-106 between January and June 1954. This disposal also contained the evaporator bottoms and thus would have

contained up to 10% of the technetium-99 produced from T Plant during the period from startup to 1954.

1.5.2 Waste Management Area T Overview

The RCRA-regulated WMA-T is located within the T Area and includes the T Tank Farm, which is considered a potential source of the technetium-99 contamination. This section provides an overview of waste management at WMA-T.

The T Tank Farm includes twelve 100-series (2,006,000-L [530,000-gal]) SSTs and four 200-series (208,000-L [55,000-gal]) SSTs. The 100-series tanks are arranged in four east-west rows of three tanks each (Figure 1-1). The tanks are numbered 241-T-101 through 241-T-112, with tank 241-T-101 in the northeast corner. The northernmost row of tanks includes 241-T-101 (on the east), 241-T-102 (in the middle), and 241-T-103 (on the west). The next row of tanks to the south includes 241-T-104 (on the east), 241-T-105, and 241-T-106 (on the west). The next row of tanks to the south includes 241-T-107 (on the east), 241-T-108, and 241-T-109 (on the west). The southernmost row of tanks includes 241-T-110 (on the east), 241-T-111, and 241-T-112 (on the west). The four 200-series tanks are arranged in a single north-south row about 15 m (50 ft) to the west of the block of 100-series tanks and are numbered sequentially from 241-T-201 (on the north end) to 241-T-204.

Select tanks in WMA-T leaked to the vadose zone. In order to understand the vadose zone contamination, one must understand the tanks' contents. Waste management operations have created a complex intermingling of the tank wastes, as previously discussed. In addition to the intermixing and processing of tank wastes, nonradioactive chemicals have been added to the tanks, and varying amounts of waste and heat-producing radionuclides have been removed from the tanks. In addition, natural processes have caused settling, stratification, and segregation of waste components. Waste also was cascaded (i.e., allowed to flow by gravity from one tank to another) through a series of tanks; cooling and precipitation of radionuclides and solids occurred in each tank of the cascade. Supernatant from the last tank in a cascade was sent to cribs because of a shortage of tank storage capacity and the belief that these wastes posed little risk to the environment. As a result, combined with incomplete records from the earlier years of waste operations, it is very difficult to estimate the composition of the wastes remaining in the tanks through operational records.

Table 1-2 provides a general depiction of the wastes routed to the T Tank Farm, including the waste sources disposed to individual tanks over time. The table shows the complexity of the tank waste and identifies the tanks that initially received the T Plant bismuth-phosphate metal waste, which contained the majority (approximately 90%) of the technetium produced from that process. Table 1-2 also identifies the remaining volume of waste in the tanks and the estimated technetium-99 inventory associated with the waste.

Appendix A includes an estimated current inventory for entrained liquids in WMA-T tanks, including three tanks (241-T-101, 241-T-102, and 241-T-103) that initially received the bulk of wastes containing technetium-99. Because tank contents were cascaded and blended many times over their history, and because the solubility of technetium-99 in tank waste is not well understood, inventory estimates for a given tank vary depending on which model was used to determine the estimate. Estimates in this DQO summary report are based upon computer

modeling performed by *HDW Rev. 4.1, User Interface*[1] (Agnew 1998), as described in *Hanford Tank Chemical and Radionuclide Inventories: HDW Model, Rev. 4* (Agnew 1997). Laboratory analysis of 34 samples from WMA-T tanks yields technetium-99 concentrations of up to 0.399 μCi/g (241-T-105) in the solid phase and up to 0.0858 μCi/mL (241-T-107) in the drainable liquid of a solid sample. Average results were 0.047 μCi/mg (solids) and 0.037 μCi/mL (drainable liquids).

Monitoring test wells (dry wells) were drilled in each tank farm as part of their original construction to check for tank leakage using gamma logging. Most of the WMA-T dry wells, including most of those closest to the tanks, were constructed in the early 1970s and were not available for logging during bismuth-phosphate and URP operations. To avoid groundwater contamination, these test wells were drilled to only 46 m (150 ft) below ground surface (bgs) and did not extend to the upper aquifer (approximately 76 m [250 ft]) bgs. Wells were checked weekly for contamination. (Note that the gamma logging does not detect technetium-99, which is a beta emitter; only gamma emitters were detected.)

The DOE reported in 1993 that leaks from the T, TX, or TY Tank Farms contaminated the vadose zone but not the unconfined aquifer. Investigations of releases from the WMA-T site are discussed in Section 1.5.3.

1.5.3 Liquid Waste Discharges Overview

This section provides an overview of techniques that were employed onsite to discharge liquid wastes into the soil column.

The following facilities located in the T Area are potential sources of technetium-99 contamination to the soil and groundwater or received waste streams that could have mobilized technetium-99 deposited in the vadose zone from other sources:

- 207-T retention basin and 216-T-12 pit (located east of T Tank Farm)
- Piping for salt-well pumping (located throughout the T complex)
- 216-T-3 reverse well and 216-T-6 Crib (located east of T Tank Farm)

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[1] Although a more recent version (Revision 5) of the HDW model is available (*Hanford Defined Waste Model Revision 5.0* [Higley 2004]), tank waste inventories in the newer version are calculated by waste type and not on a tank-by-tank basis, as was the case with Revision 4 and older versions. A user/computer interface is not available for Revision 5, making inventory calculations for individual tanks difficult. Revision 4 has a user interface that facilitates calculation of current and historical tank inventories. Technetium-99 inventories across the tank farms overall have decreased approximately 23% between HDW model Revision 4 and Revision 5 due to modeling of process losses. However, newer technetium-99 inventory estimates for tanks in WMA-T are substantially higher overall. The best-basis inventory (BBI), which uses HDW model Revision 5 as a basis for much of its technetium-99 inventory estimates in WMA-T, indicates the total estimated inventory of WMA-T as 150 Ci as opposed to 15 Ci for HDW model Revision 4. However, the BBI is not as useful for determining concentrations of technetium-99 during a potential leak because BBI is a bulk inventory (i.e., it is in terms of total tank inventory in the combined waste phases, not analyte concentration in each waste phase). The BBI also cannot easily be used to determine historical inventories. For these reasons, Revision 4 was used to produce estimates of tank waste inventories in this DQO summary report. Estimated current inventories for entrained liquids in WMA-T tanks are provided in Appendix A. In addition, historical estimates are given for liquids in three tanks (241-T-101, 241-T-103, and 241-T-106) that have leaked or overflowed; these estimates are given for the end of the calendar quarter nearest to the time of the leak.

- 216-T-5 Trench, 216-T-7 Crib, and 216-T-32 Crib (located just to the west of T Tank Farm) and 216-T-36 Crib (southwest of T Tank Farm)
- T Trenches (216-T-14 through 216-T-17) (located northeast of T Tank Farm)
- Three TY Cribs (216-T-26 through 216-T-28) and the 216-T-18 test crib (located east of TY Tank Farm)
- Five specific retention trenches (216-T-21 through 216-T-25) (located west of TX Tank Farm).

Select TY and TX Cribs/Trenches have been evaluated in this DQO process to ensure that all of the liquid release sites that could have some likelihood of introducing technetium-99 to the groundwater below the T Area are considered in the evaluation. No sampling of cribs and trenches in the TX-TY Tank Farms was considered in this DQO process, as this was not part of the scope.

Ground disposal of aqueous industrial waste, which relied on the IX properties of the soil to decontaminate the water as it percolated to the aquifer, was a commonly used practice in the 1940s. From 1944 until 1979, when the last WMA-T tank was taken out of service (the T Farm remains a RCRA treatment, storage, and disposal (TSD) facility but has not received new waste since 1979), plant operators sent high-activity liquid wastes to underground storage tanks within the T Tank Farm. Initial storage allowed many of the radionuclides from some waste types to settle out of solution and form sludge on the bottom of the tank. The pH of the tank supernates was maintained very high by addition of significant quantities of sodium hydroxide (NaOH), as necessary, prior to discharge to tanks to limit corrosion of the carbon steel liners. The presence of sodium is significant because it competes with cesium (and other metals) for sorption sites in the soil and because it undergoes cation exchange in soils that have calcium present as calcium carbonate ($CaCO_3$). Because technetium is more soluble in alkaline conditions, the majority of the technetium is likely to have remained in the supernates. After settling in tanks, these supernates were often discharged to the soil column in engineered facilities such as cribs, drain fields, specific retention trenches, and reverse wells, as described below:

- Storage tanks were intended to receive liquids and hold them for settling (i.e., separation of the particulates from the liquids) and eventual further processing. Based on the belief that the stored liquids would be addressed in the near term, first-generation SSTs (e.g., WMA-T SSTs) were built for a 20-year lifespan.
- Cribs are shallow excavations that were either backfilled with permeable material or held open by wooden structures. Cribs usually had an additional layer of an impermeable substance, which directed the waste flow into the backfilled material or covered space, and into the vadose zone soils approximately 61 to 91 m (200 to 300 ft) above the water table. Designs for cribs included the following:
  - Underground caverns constructed by cross-stacking 30.5–cm by 30.5–cm by 6.1–m (12-in. by 12-in. by 20-ft) timbers
  - Circular concrete culverts

- Rectangular, concrete "box" structures
- Buried gravel and sand.

- Specific retention trenches are shallow, long, narrow, unlined excavations. Trenches received limited quantities of liquid wastes that were usually higher in activity than the wastes sent to the cribs. Trenches often were located in close proximity to one another (e.g., 216-T-14, 216-T-15, 216-T-16, and 216-T-17 Trenches). These facilities received liquid until a specific retention volume or radionuclide capacity was met. The specific IX capacity of the soils underlying the crib was considered when determining how long a trench would be used, taking into account the specific isotope(s) and isotopic concentrations of interest (which did not include technetium) that were to be released. After the addition of wastes, the trenches were backfilled with the excavated soil. The volume of fluids discharged to specific retention trenches was limited to approximately 10% of the available soil pore volume between the trench bottom and the groundwater table.
- Reverse injection wells were usually encased holes with the lower end perforated or open to allow liquid to seep to the soil column. These wells injected waste into the vadose soil at depths greater than the other disposal sites. Injection wells were used for the disposal of early liquid wastes from T, B, U, and Z Plants.

Waste from the cooling water and steam condensate streams contained very low levels of either radionuclide or chemical waste constituents. These streams usually were combined and sent to large surface impoundments (e.g., 216-T-4 Pond and 216-U-10 Pond). The impoundments were known as "swamps" or ponds, and waste was routed from the processing facilities to the impoundments through piping and open, unlined ditches. The concentration of technetium-99 in these normal releases would be near zero, but during process upset conditions, the radionuclide inventory (and technetium-99) of the releases might be higher. It should be noted here that the first trench that supplied the 216-T-4 Pond (T Pond) was 216-T-4-1. This trench/ditch was closed and backfilled after receiving its estimated maximum radioisotope load, and a second trench/ditch (216-T-4-2) was put into service. Since the effluents introduced into these trenches/ditches were ostensibly clean, how and from what source did 216-T-4-1 receive the radionuclides that resulted in its closure? It is likely that the radionuclides were the result of process upsets, and these upsets may have included technetium as one of the components. Thus, the trenches feeding the T Pond, as well as the T Pond itself, may have been an additional source of T Area technetium.

1.5.3.1 Cribs and Trenches. The T Area includes eight liquid disposal sites, which consist of open trenches or buried cribs that received effluent from the T Tank Farm or other types of effluent, such as steam condensate, decontamination waste, or miscellaneous wastes from 221-T (T Plant), 221-U (U Plant), or 2706-T (decontamination facility). These sites are described below:

- Liquid disposal sites 216-T-5 and 216-T-14 through 216-T-17 were open trenches supplied by overland pipelines from T Tank Farm. Each of these sites was backfilled after use. The 216-T-7 and 216-T-32 Cribs were permanent underground disposal sites consisting of wooden crib boxes supplied by an underground pipeline. The 216-T-7 Crib box overflowed to a tile field. The 216-T-36 Crib, located southwest of T Tank Farm, includes a single vitreous clay pipe resting in a gravel-backfilled trench (see Figure 1-1).

The 216-T-36 Crib received approximately 520,000 L (137,369.5 gal) of decontamination water from T Plant and U Plant.

- The 207-T retention basin is a concrete structure, divided into two sections, with a 3,800,000-L (1,000,000-gal) capacity. The bottom dimensions for each basin are 32.3 m by 32.3 m (106 ft by 106 ft). The basin received cooling water effluent from 221-T and 224-T Facilities. There was an inlet structure on the east side and an outlet structure on the west side, adjacent to the outside walls of the basins. Two 40.6-cm (16-in.)-diameter, cast-iron pipes connected to two 0.9-m (3-ft) sumps, one for each basin. The basin effluent was released to the 216-T-4-1 and 216-T-4-2 Ditches. Approximately 1,830 m (6,000 ft) of 61-cm (24-in.)-diameter vitrified clay pipeline was used to convey wastewater to and from the basin (see Figure 1-1).
- Site 216-T-12 was a small trench dug next to the northeast corner of the 207-T retention basin. It received approximately 10 m^3 (350 ft^3) of sludge dredged during the cleanout of the retention basin and was backfilled (see Figure 1-1).
- Although slightly outside of the area of interest, the 216-T-3 and 216-T-6 disposal sites east of WMA-T are included because of their potential impact on groundwater in the T Area. Figure 1-5 shows the locations of the 216-T-3 and 216-T-6 Cribs.

  The 216-T-3 reverse well was drilled in November 1944 to a depth of 62.8 m (206 ft) bgs, which was above the water table at the time of drilling. The well was constructed of casings with varying diameters. The deepest casing is 20 cm (8 in.) in diameter, and the middle portion of the casing is 25 cm (10 in.) in diameter. The casing, from the surface to 30 m (100 ft) below the surface, is 30 cm (12 in.) in diameter. A new well (216-T-3) was drilled several feet away to a shallower depth. The new well was used for waste disposal, and the old well was used as a groundwater monitoring well (redesignated as 299-W11-22). The reverse well was active from June 1945 to August 1946 and received effluent from the 241-T-361 settling tank. When the use of reverse wells was discontinued in 1949, both wells were used as vadose zone monitoring wells. The site was deactivated by blanking the inlet pipe when the effluent flow rate exceeded the infiltration rate. The effluent was re-routed to the 216-T-6 Crib.

  The 216-T-6 Crib consists of two wooden crib boxes, and each box is set into a pit with sloping sides. The two 4.3-m (14-ft) square crib boxes are set 19 m (62 ft) apart and are connected in series by a pipe, with one crib overflowing into the other. Each box has two risers extending from the top of the crib boxes. After construction, the excavations were backfilled to grade.
- Although slightly outside of the area of interest, the 216-T-26 Crib (south of WMA-T) is included because of its likely contribution of technetium to groundwater. Figure 1-5 shows the location of the 216-T-26 Crib.

  The 216-T-26 Crib is an inactive liquid waste disposal site that received T Plant and U Plant effluents from August 1955 to November 1956. The 216-T-26 Crib is the northernmost crib of the 216-T-26, 216-T-27, and 216-T-28 Crib series (Figure 1-5). A 36-cm (14-in.) steel inlet pipe reduces to a 25-cm (10-in.) pipe located approximately 3 m (9 ft) below grade. The smaller section of pipe branches into four 20-cm (8-in.) steel pipes that feed the large-diameter vertical concrete pipes, which are approximately 1.2 m (4 ft) long and 1.2 m (4 ft) in diameter. The piping lies within a 9-m by 9-m by 4.6-m

(30-ft by 30-ft by 15-ft)-deep excavation. The base of the crib was placed at 4.6 m (15 ft) bgs, and the excavation was filled with approximately 2.4 m (8 ft) of gravel followed by approximately 2.4 m (8 ft) of earthen backfill.

The 216-T-26 Crib received approximately 12 million L (3.2 million gal) of liquid waste that originated at the T Plant as metal waste and first-cycle waste that had been recovered through the URP and scavenged at U Plant. The waste first was transferred to the TY Tank Farm to allow the sludge to settle; the liquid effluent then was discharged to the crib. Waste disposed at this unit includes ferrocyanide complexes, fluoride, nitrate, nitrite, phosphate, sodium, sodium aluminate, sodium hydroxide, sodium silicate, sulfate, cesium-137, ruthenium-106, strontium-90, plutonium, and uranium. Since technetium usually followed the uranium and remained in the supernates of alkaline solutions, it is likely that this crib is one source for technetium-99 in the groundwater.

Table 1-3 identifies the most significant discharges to the T Area's engineered facilities, including those that would have contained appreciable levels of technetium-99. The pore volumes in Table 1-3 are from *Waste Site Grouping for 200 Areas Soil Investigations* (DOE-RL 1997). Section 1.5.11 provides the technetium-99 soil inventory of these locations.

Test wells were drilled near the cribs as part of original construction to monitor vadose zone contamination. Typically, wells would be drilled to 46 m (150 ft) bgs, but major disposal sites had at least one 92-m (300-ft)-deep well to check for radionuclide migration to groundwater. Typically, these early dry wells and groundwater monitoring wells were constructed using cable-tool methods, which did not include placement of annular seals. Any well lacking such a seal is a potential preferential pathway for contaminant migration.

1.5.3.2 Discharges to Ponds. Although not within the T Area, two ponds, or swamps, existed in the 200 West Area that affected the flow of the groundwater beneath this area. Due to the significant volume of discharges to these two ponds (T Pond and 216-U-10 Pond [U Pond]), they each created groundwater mounds that significantly affected groundwater flow direction and rate over time. These ponds are discussed below to help in understanding the groundwater flow and contaminant migration history below the T Area.

The T Pond was located northwest of the T Area (Figure 1-1). T Plant, the 200 West Area evaporators, and for a brief period the UO_3 Plant were the primary sources of effluent to T Pond. The ditch shown supplying the pond (216-T-4-2 Ditch) is the second ditch that fed this pond. The original 216-T-4-1 Ditch was closed and backfilled after receiving its estimated radionuclide loading from the effluents routed through the ditch. Based on available documentation, it is unclear whether the effluent disposed to T Pond from the evaporators included evaporator bottoms. If T Pond received evaporator bottoms, which likely contained some levels of technetium-99, it might be a source of technetium-99 found in the groundwater at the north of the T Tank Farm. The T Pond was in use from 1944 until 1957, and then from 1960 until it was permanently closed in 1995. The total effluent received by this pond is estimated to be 42.5 billion L (over 11.2 billion gal) over its lifetime.

The U Pond was located south of the T Area and south of the Plutonium Finishing Plant (PFP). The U Pond received effluent mostly from the PUREX Plant, Z Plant (i.e., PFP), S Plant (i.e., REDOX Plant), U Plant (i.e., TBP Plant), the 200 West Area evaporators, the laundry, and the 200 West Area steam plant, as well as other smaller effluent streams. The ditch that supplied U Pond (216-U-14) originated near the center of the 200 West Area (at the steam plant) and

terminated at the U Pond, which is in the southwest corner of the 200 West Area. This ditch was unlined and effluents undoubtedly percolated into the vadose zone on the way through this ditch. The U Pond was in use from 1944 until 1984, and then it was permanently closed. The total effluent received by this pond is estimated to be 165 billion L (over 43.6 billion gal) over its lifetime.

Section 1.5.6 discusses the influence of the ponds on the groundwater flow in greater detail.

1.5.3.3 T Area Unplanned Release Sites. In addition to the intentional discharges discussed above, accidental discharges of liquids to the soil column contributed to vadose and groundwater contamination.

Recent analyses of borehole data (Horton 2006) indicate that very large tank leaks, large UPRs (e.g., broken water lines or transfer lines), and operational releases of clean or low-concentration contaminated water are the most likely sources of groundwater contamination in the T Area. The large tank leaks and transfer line leaks introduced contaminants into the vadose zone, and if of sufficient volume, may have directly impacted groundwater. Releases of clean or minimally contaminated water had the potential to mobilize contaminants already present in the vadose zone and transport them downward to groundwater. Table 1-4 identifies the known releases from sources other than tanks, including those that conceivably might have contained appreciable quantities of technetium-99. The following provides an overview of the releases and their potential contributions of liquid waste to the vadose zone:

- UPR-200-W-14 occurred in October 1952 along the waste line connecting the 242-T Evaporator Building and the 207-T retention basin. The release was detected when contaminated water rose to the ground surface above the waste line. The waste line was repaired and the contaminated soil was covered with approximately 0.3 m (1 ft) of soil. The line carried steam condensate from the 242-T evaporator to the 207-T retention basin (information obtained from the Waste Information Data System [WIDS] database). The volume of the release is unknown.
- UPR-200-W-29 occurred in November 1954 at a cave-in approximately 23 m (75 ft) east of Camden Avenue and 23 m (75 ft) south of 23rd Street, between the 241-T-152 and 241-TX-153 diversion boxes. The UPR resulted from the failure of an uncased line connecting the diversion boxes. First-cycle supernatant waste from the 241-T-105 SST was released with dose rates of 11.5 R/hr at 5 cm (2 in.). The area was hosed down with water and backfilled. A second spill (UPR-200-W-62) occurred at the same location in May 1966 due to re-use of the same line (information obtained from WIDS). Since first-cycle waste contained roughly 10% of the T Plant produced technetium, this is a likely source for some of the T Area technetium. The waste volume is estimated in the Soil Inventory Model (SIM) as 3,785 L (1,000 gal). However, since the technetium concentration is unknown, the amount of technetium involved is also unknown. Compared to the volumes of other sources of technetium that have been identified, even if this liquid release contained significant quantities of technetium, the total technetium released in this event(s) is not believed to have been significant; however, no characterization data exist to support this assumption.

- UPR-200-W-62 occurred in May 1966 at the southeast corner of 23rd Street and Camden Avenue, south to near 22nd Street. Liquid waste was released from a broken underground line, which surfaced and then crossed Camden Avenue but did not run down the side of the road. Surface contamination at 600 counts/min was detected. The surface contamination was removed to a depth of 0.9 m (3 ft). This event occurred when the broken waste line causing UPR-200-W-29 was mistakenly placed back into service. The waste released to the soil consisted of a high-salt, neutral-to-basic liquid tank waste solution containing approximately 10 Ci of fission products. The waste consisted of second-cycle bismuth-phosphate waste from the 241-T-107 tank. The maximum surface dose rate was 5 R/hr beta-gamma, with 3 R/hr being gamma radiation (information obtained from WIDS). The waste volume is estimated in the SIM as 1,996 L (527 gal). This site also is referred to as UPR-200-W-97. Based on the estimated volume, this event is likely to have released a small amount of technetium, but is expected to be essentially insignificant relative to this study. Currently, no characterization data exist to support this assumption.
- *Results of Phase I Groundwater Quality Assessment for Single-Shell Tank Waste Management Areas T and TX-TY at the Hanford Site* (Hodges 1998) suggests that the cable-tool drilling of well 299-W11-27 near the northeast corner of WMA-T (and adjacent to the 61-cm [24-in.] vitrified clay pipe draining the 207-T retention basin to the 216-T-4-2 Ditch) may have damaged the pipe, causing a leak of indeterminate volume. Such a leak would have the potential to transport residual vadose zone contamination it encountered toward groundwater; it might also result in accelerated mechanical dispersion of contaminants already present in the groundwater, effectively diluting contaminant concentrations at this well.

Borehole data from the area around 241-T-106 (discussed in Section 1.5.6) appear to show that contamination associated with line leaks or near-surface spills does not migrate to any significant depth in the soils unless those leaks occur immediately adjacent to a borehole or tank. In this instance, the leak will reach the groundwater only in those cases where a substantial amount of water is released in the same area at the same time or subsequent to the original leak. Those isotopes and/or chemicals that do not react with the Hanford soils (e.g., technetium-99, nitrates, tritium, and ruthenium-106) are not subject to these conditions for soil movement, as these isotopes will migrate to groundwater with very little additional water as a "driver."

1.5.3.4 Tank Leaks. Tank leaks constitute a special type of UPR due to the potentially significant volume and contaminant inventory associated with the tanks.

Seven of the tanks in WMA-T have been declared as leakers (based on liquid-level monitoring data that suggested unexplained liquid losses) (Hanlon 2004). Table 1-5 provides a summary of the T Tank Farm tank leaks. In accordance with the Hanford operating policy at the time, DOE expedited liquid waste removal from tanks of questionable integrity, and the seven tanks were removed from service. Interstitial liquid was removed by salt-well jet pumping.

Hanlon (2004) provides estimated leak volumes for tanks 241-T-107, 241-T-108, 241-T-109, and 241-T-111 based on observed variances in liquid levels in the tanks. To date, other data collected and evaluated, including spectral-gamma logging data (DOE-GJO 1999, 2000) and tank waste transfer records, show no clear evidence that a release has occurred at any of these

four tanks (Jones et al. 2002). Conservatism applied to waste tank operations in place at the time resulted in these tanks being identified as "leakers."

Corroborating well log data indicate that tanks 241-T-101, 241-T-103, and 241-T-106 did actually leak. The 241-T-101 leak is thought to have been an "overfill" that resulted in supernate passing from the tank to the soils via an open pipe and not by an actual tank failure/leak. The three tanks are believed to have leaked 28,400 L (7,500 gal), less than 3,800 L (1,000 gal), and 435,000 L (115,000 gal), respectively. Appendix A provides estimated supernate inventories for each of these tanks at the time of the leaks, as well as estimated current entrained liquid radioisotope inventories.

1.5.4 Geology and Hydrogeology

In order to evaluate the migration patterns of contaminants in the soil and groundwater beneath the T Area, it is necessary to first understand the geology and hydrogeology of the site. This section provides an overview of the current understanding of the site.

The geology of WMA-T has been extensively characterized in order to support the environmental compliance activities for this regulated waste site. The geology for WMA-T is generally representative of the conditions for the remainder of the T Area and provides the basis for much of the following discussion. A clear understanding of the geology and hydrogeology is necessary to better understand mobility of technetium-99 from the vadose zone to groundwater.

Geology, Hydrogeology, Geochemistry, and Mineralogy Data Package (Reidel et al. 2005) provided an update on previous work on WMA-T geology, including observations from four new downgradient wells and one new upgradient well at WMA-T. The geologic profiles for these wells are comparable to descriptions found in recent studies (Williams et al. 2002, CHG 2001), and use the updated, standardized stratigraphic nomenclature and interpretations of the suprabasalt sediments (DOE-RL 2002). The information presented below is primarily from Reidel et al. (2005), as summarized in Horton (2006).

The vadose zone beneath the T Area is approximately 68 to 74 m (223 to 243 ft) thick and consists of the Hanford formation, the Cold Creek unit, the Taylor Flats member of the Ringold Formation, and the upper portion of Unit E of the Wooded Island member of the Ringold Formation. The water table within Unit E is at an elevation of about 136.5 m (448 ft). The unconfined aquifer beneath the T Area is estimated to be about 53 m (174 ft) thick, based on March 2004 water levels and the depth of the Ringold Lower Mud Unit, as described for well 299-W10-24. Figure 1-6 depicts the generalized stratigraphic column for the T Area. Wells and cross-section locations are shown in Figure 1-7, while Figures 1-8 through 1-10 provide stratigraphic cross-sections through the T Area. The Ringold Lower Mud Unit becomes thinner to the northeast and east of the T Tank Farm area and is locally discontinuous or absent in this area. Where the Lower Mud Unit is absent, groundwater from the unconfined aquifer is in communication with groundwater from the Ringold Formation confined aquifer (Williams et al. 2002).

Unit E was fully penetrated by three wells in the T Area (299-W10-24, 299-W10-25B, and 299-W10-01) and is between 83 and 86 m (272 and 282 ft) thick; many wells in the T Area penetrate the top of Unit E. Based on the elevation of the upper boundary of Unit E, the unit dips slightly toward the west or southwest beneath the T Area. The Taylor Flats member ranges in thickness from 1.2 to 10.3 m (3.9 to 34 ft) beneath T Area but is generally thicker than

3 m (9.8 ft) and averages 5.5 m (18 ft). Like the underlying units, the Taylor Flats member has a general, gentle dip toward the southwest.

The Cold Creek unit calcic paleosol sequence occurs in all wells at the T Area. The sequence ranges in thickness from 2.4 to 9.8 m (7.9 to 32.2 ft), with an average thickness of 5.3 m (17.4 ft) under the T Area. The Cold Creek fluvial and/or eolian sequence is between 1.8 and 6.7 m (5.9 and 22 ft) in thickness and averages 3.6 m (11.8 ft) in thickness at the T Area. The surface of the unit dips gently to the southwest.

The Hanford formation sand sequence (H2) ranges from about 4 to 18 m (13.1 to 59 ft) and averages 13 m (42.7 ft) in thickness beneath the T Area. Thin, silt lenses cap some individual beds within the Hanford formation sand-dominated sequence. These lenses are generally 15 cm (5.9 in.) or less in thickness but range up to about 30 cm (11.8 in.) thick. Although the silt lenses generally cannot be correlated among boreholes, one thin, silt lens can be traced among three boreholes along the northern edge of the T Area (Figure 1-11).

The Hanford formation gravel-dominated sequence (H1) varies from 6 to 17 m (19.7 to 55.8 ft) thick in the T Area and averages about 11 m (36.1 ft) thick. The entire unit was largely excavated from most, if not all, of the tank farm area during construction and replaced as backfill around the tanks. An east-to-west cross-section from *Characterization of Vadose Zone Sediments Below the T Tank Farm: Boreholes C4104, C4105, 299-W10-196, and RCRA Borehole 299-W11-39* (Serne et al. 2004) shows the extent of the backfill in the T Tank Farm area and the adjacent undisturbed Hanford formation gravel-dominated sequence (Figure 1-11).

The *Geology of the 241-T Tank Farm* (Price and Fecht 1976) states that clastic dikes were detected in the T Tank Farm during construction, although they could not be mapped. Although not encountered during drilling of the RCRA wells at WMA-T or in the T Area, these features are present in the area and could influence contaminant migration in the vadose zone, providing preferential pathways for downward transport of contaminated liquids. Characterization data collected to date show no evidence of clastic dikes in the immediate vicinity of identified releases.

1.5.5 Groundwater

The following subsections provide an overview of groundwater concerns and the current understanding of groundwater conditions and flow beneath the T Area.

RL has implemented interim actions within the 200-ZP-1 OU for remediation of carbon tetrachloride, chloroform, and TCE in groundwater. Because the contaminant plumes are distinct from the technetium-99 contamination, these activities are only indirectly related to the activities of concern to this DQO summary report. Remediation of other groundwater contaminants will be determined through the RI/FS process in accordance with Section 5.5 of the Tri-Party Agreement (Ecology et al. 2003). RL prepared the 200-ZP-1 RI/FS work plan (DOE-RL 2004) in fiscal year 2004 (FY04), which was implemented in FY05. The evaluation of T Area technetium-99 contamination, which is the focus of this DQO summary report, is a component of the 200-ZP-1 RI/FS work plan.

The following subsection provides an overview of groundwater flow in the T Area, as well as historical and ongoing monitoring and characterization activities that are directly relevant to the technetium-99 evaluation.

1.5.5.1 Groundwater Hydrology. In April 1963, DOE drilled well 299-W11-13 to the unusual depth of 152 m (500 ft). In the 1970s, additional wells were drilled in all three of the tank farms to monitor groundwater contamination. These wells provide a record of groundwater levels and data over a fairly extensive period of Hanford operations. *Single-Shell Tank Farms Interim Remedial Corrective Actions* (Gaddis 1999) provides an extensive discussion of monitoring wells inside the tank farms. Additional information can be found in the annual groundwater reports prepared by PNNL, as well as from numerous site investigations and work plans.

Water levels in the unconfined aquifer beneath the T Area increased as much as 13.5 m (44.3 ft) above the pre-Hanford Site natural water table because of artificial recharge from liquid waste disposal operations that were active between the mid-1940s and 1995. The largest volumes of discharge were to the T Pond system and U Pond system. Figure 1-12 provides hydrographs of selected wells in the northern portion of the 200 West Area.

The liquid waste disposal operations also had a significant impact on groundwater flow directions in the northern portion of the 200 West Area (Figure 1-13). Pre-Hanford Site (circa 1942) groundwater flow direction was toward the east (Kipp and Mudd 1974). By the early 1950s, groundwater flow in the study area had shifted toward the south as a result of the disposal of large volumes of liquid to the T Pond system, located north of the T Area. By 1957, groundwater flow had shifted to the northeast because of the increasing influence of the groundwater mound under U Pond (to the south of the study area) and a decreasing influence of the mound under T Pond. Discharges to T Pond were substantially reduced after 1976 and ended in 1995. When discharges to U Pond declined in the early 1980s, groundwater flow shifted to a more northward direction as the groundwater mound began to decrease and discharges to the 216-U-14 Ditch continued. Discharges continued at U Pond until 1984. These changes in groundwater flow direction resulting from the rise and fall of water table mounds were slow and transitional, rather than abrupt, and occurred over months to years.

All non-permitted discharges to the ground ceased and the influence of the U Pond mound on the groundwater beneath the T Tank Farm diminished in 1995. Circa 1997, groundwater flow had essentially reverted to its original (pre-operations) easterly gradient, where it is expected to stabilize. Recently, two trend-surface analyses conducted in August and September 2002 yielded groundwater flow directions of 6 degrees to 8 degrees south of east and a water-table gradient between 0.00114 and 0.00132 (Spane et al. 2002). An earlier trend-surface analysis yielded a flow direction of 5 degrees north of east and a water-table gradient of 0.00172 (Spane et al. 2001). Figure 1-14 provides a current water table map for the T Area.

Recent tracer-dilution test results provide evidence for downward, vertical hydraulic gradients within the upper portion of the aquifer in wells 299-W11-39 and 299-W11-40. Hydraulic properties are discussed in detail in several reports on the results of detailed hydrologic characterization tests for FY99, FY01, and FY02 (Spane et al. 2001, 2002, 2003, respectively) and are presented in Tables 1-6 and 1-7.

Myers 2005 provided the following summary of recharge in WMA-T:

> *Tank farm surfaces are covered with gravel to prevent vegetation growth and provide radiation shielding for site workers. Bare gravel surfaces, however, enhance the net infiltration of meteoric water compared to undisturbed, naturally vegetated surfaces. Infiltration is further enhanced in the tank farms by the effect of percolating water being diverted by the impermeable sloping surface of the tank*

domes. An umbrella effect is created by the 23-m-diameter buried tank domes. Water that is shed from the tank domes flows down the tank walls into the underlying sediments. Sediments adjacent to the tanks, while remaining unsaturated, can attain elevated moisture contents. Enhanced infiltration from a gravel-covered tank dome can provide the potential for faster transport of contaminants to the water table.

Although there has been no direct measurement of recharge on tank farm backfill, Myers (2005) estimates that it should range between 70 and 100 mm/yr based on infiltration studies of Hanford Site soils similar to the backfill at WMA-T.

Run-off has presented a concern for surface water infiltration at the T Tank Farm. A quick snowmelt in February 1979 inundated parts of the tank farm. Pictures of the event show Hanford workers standing in water up to their ankles. Many of the dry wells were submerged; a number were uncapped, providing a direct pathway for infiltration at tens of feet below grade. The T Tank Farm is located at the bottom of a topographic depression and receives surface run-off from the surrounding area, so this type of flooding has likely occurred in the past. The DOE recently installed earthen berms to minimize the potential for external sources of run-off to inundate the surface adjacent to the T Tank Farm. Installation of the berms has created a concern that they may trap precipitation, thereby inducing recharge adjacent to the tanks.

1.5.5.2 Groundwater Contamination and Plumes in T Area. The groundwater COCs for the 200-ZP-1 OU are defined in the 200-ZP-1 RI/FS work plan (DOE-RL 2004). The COCs for the T Area are discussed below:

- **Carbon tetrachloride:** Carbon tetrachloride contamination is found at levels greater than the DWS (5 μg/L) in the groundwater under most of the 200 West Area (Figure 1-15). The main sources are believed to be the 216-Z Cribs and Trenches that received waste from the PFP; other possible carbon tetrachloride sources exist in the northern portion of the OU. Carbon tetrachloride remediation is the subject of the *Declaration of the Interim Record of Decision for the 200-ZP-1 Operable Unit* (EPA et al. 1995). The depth and areal distribution of carbon tetrachloride is part of an ongoing investigation under the 200-ZP-1 RI/FS and is not a focus of this DQO summary report.
- **Nitrate:** Nitrate is present in groundwater at concentrations in excess of the DWS (45 mg/L) beneath much of the 200-ZP-1 OU (Figure 1-16). The nitrate contamination is more widespread than tritium, iodine-129, or technetium-99 contamination, as discussed in the Hanford groundwater monitoring annual report for FY05 (PNNL 2006). There are likely multiple sources of nitrate in this area, including the cribs near WMA-T. The maximum concentration detected in this vicinity during FY05 was 3,540 mg/L in well 299-W10-4, which is near the 216-T-36 Crib (south of WMA-T). The average nitrate concentration for FY05 in well 299-W10-4 was 3,000 mg/L. Nitrate concentrations increased rapidly in this well through FY04, but the concentration remained relatively stable in FY05.
- **Chromium:** Chromium contamination is found at levels above the DWS (100 μg/L) in filtered samples in the immediate vicinity of WMA-T (Figure 1-17). The highest levels are found west (upgradient) and south of WMA-T. The highest detected chromium concentration was 722 μg/L and the average concentration was 666 μg/L, which was

found in well 299-W10-4 during FY05. Chromium concentrations peaked in this well in October 2004 and have declined since that time. Chromium at lower levels extends downgradient toward or past the 200 West Area boundary. The chromium plume in the vicinity of WMA-T has changed little in size over the past decade, although the extent of lower concentrations beyond the 200 West Area fence line is uncertain due to the lower density of monitoring wells.

Figure 1-17 shows a plume map depicting the FY05 average chromium concentration for samples from wells in the T Area. The highest chromium concentrations are in wells 299-W10-28 and 299-W10-4 where chromium reached 316 and 772 µg/L, respectively, in 2005. When groundwater flow direction was toward the north prior to 1997, several wells on the north (then downgradient) side of WMA-T had relatively high chromium concentrations. Well 299-W10-1 (which was lateral to the tank farm with respect to groundwater flow direction but downgradient of the 216-T-5 Trench, the 216-T-7 Crib and tile field, and the 216-T-32 Crib) also had chromium concentrations exceeding 200 µg/L prior to 1997. In about 1997, as groundwater flow was gradually reverting back to an easterly direction, chromium concentrations dropped to <40 µg/L in well 299-W10-1, decreased in all of the northern wells, and began increasing in well 299-W10-4 (see the chromium trend plots in Figure 1-18). The most likely source for the chromium west and north of WMA-T is one or more of the disposal facilities located upgradient of WMA-T (e.g., the 216-T-5 Crib received 3,920 kg of chromium, and the 216-T-32 Crib received 2,490 kg of chromium). The northerly groundwater flow direction that existed for several years prior to 1997 would have carried chromium from these facilities toward well 299-W10-1. However, as the flow direction slowly shifted toward the east, contaminant transport in the study area was increasingly eastward, such that by 1997, contaminants from these facilities would have been carried eastward, across the northern wells and the remainder of the WMA.

- **Fluoride:** Fluoride contamination is seen in a restricted area around WMA-T at levels greater than the primary DWS (4 mg/L). Although fluoride occurs naturally in the groundwater, lanthanum fluoride was used in the bismuth-phosphate process, and the discharge or release of related liquid wastes may be responsible for elevated fluoride concentrations. In FY05, samples from two wells north of WMA-T had average fluoride concentrations greater than the DWS (Figure 1-19); one other well had individual results above the DWS. All wells had average concentrations below the DWS in FY04. A fluoride plume, exceeding the secondary DWS of 2,000 µg/L, extends from the southwest to the north and east of WMA-T; however, the extent of the plume remains almost unchanged from the previous year.

- **Tritium:** Tritium contamination at levels greater than the DWS (20,000 pCi/L) is mainly restricted to a plume extending northeast from waste disposal facilities in the vicinity of WMA-T and WMA-TX/TY. There are multiple potential sources of tritium in this vicinity. Overall, tritium levels in the 200-ZP-1 OU are fairly low, with a few wells having average concentrations greater than the 20,000 pCi/L DWS in FY05.

- **Technetium-99:** Technetium-99 within the 200-ZP-1 OU groundwater is found at levels above the DWS (900 pCi/L) only on the east/northeast (downgradient) side of WMA-T and on the east and south sides of WMA-TX/TY (Figure 1-20). Evidence points to multiple sources of technetium-99 within those areas.

Technetium-99 began to increase in well 299-W11-23 (located east of well 299-W11-27) in November 1997, coinciding with the change in groundwater flow to a more eastward direction. It increased to a high of 8,540 pCi/L in November 1998 (Figure 1-21). Technetium-99 values subsequently fluctuated between 7,110 and 840 pCi/L. The last sample from this well, collected in December 2000, indicated a technetium-99 concentration of 4,470 pCi/L. Sampling of replacement well 299-W11-39 in 2001 detected technetium-99 concentrations between 4,160 and 5,010 pCi/L, indicating contamination of the upper portion of the aquifer at this well. The technetium-99 concentration in this well rose to a high of 21,400 pCi/L in August 2004.

In early 2002, technetium-99 concentrations began to increase in well 299-W11-42 (south of well 299-W11-39) and in early 2003, technetium-99 began to increase in well 299-11-41 (south of well 299-W11-42) (Figure 1-22). These increases suggest that a second technetium-99 plume or a portion of the technetium-99 plume first detected in the northeast corner of T Tank Farm is being detected along the entire east and downgradient side of WMA-T.

Sampling during drilling of well 299-W10-24 in 1998 (Figure 1-21) showed that the highest technetium-99 concentrations were at or very near the water table at the northeast side of WMA-T, and concentrations decreased rapidly with increasing depth in the aquifer at the time the well was drilled. This suggested a nearby source for the technetium-99 because the contaminant had not traveled far enough to disperse vertically in the aquifer (Hodges 1998).

Technetium-99 concentrations near the T Area decreased slightly during the first part of FY05 before increasing during the latter part of the FY. Well 299-W11-39 (Figure 1-21), near the northeast corner of WMA-T, had the highest concentration in samples collected near the water table, with values in FY05 ranging from 12,000 to 27,400 pCi/L.

1.5.5.3 Recent Investigations of Wells 299-W11-25B, 299-W11-45, and 299-W11-47. The DOE installed two new RCRA assessment monitoring wells in this area during calendar year 2005. The first new well (299-W11-25B [also known as "T-1"]) was installed adjacent to well 299-W11-39 in February and March 2005 to assess the vertical extent of contamination near the northeast corner of the WMA. The well was drilled to the top of the Ringold Lower Mud Unit at approximately 125 m (410 ft) bgs (approximately 51 m [167 ft] below the water table). Unexpectedly high concentrations of technetium-99 and chromium were found in groundwater samples collected during drilling of the well. Well 299-W11-25B was damaged during construction, and well 299-W11-46 was drilled and constructed as a replacement.

The DOE collected and analyzed groundwater samples from well 299-W11-25B during drilling in February and March 2005. Two types of samples were collected: air-lifted and pumped. All samples were analyzed for technetium-99, chromium, and nitrate. The air-lifted slurry samples were collected every 1.5 m (4.9 ft) throughout the drilled portion of the aquifer. These samples were collected in 3.8–L (1-gal) jars and sat overnight to allow the particulates to settle. The following day, the samples were pumped through a filter into sample bottles and delivered to the laboratory. Pumped samples were collected every 6.1 m (20 ft) throughout the drilled portion of the aquifer. A pump was lowered into the borehole and the borehole was purged for at least 1 hour prior to sampling.

Figure 1-23 shows the depth distribution of technetium-99 in well 299-W11-25B. The maximum detected technetium-99 concentration is 181,900 pCi/L at 10 m (32.8 ft) below the water table. The technetium-99 concentration decreases abruptly between 12 and 14 m (39.4 and 45.9 ft) below the water table and gradually decreases to the bottom of the well. However, concentrations at the bottom of the well remain quite high, in the 20,000 to 30,000 pCi/L range.

The open points in Figure 1-23 represent pumped samples, and the solid points represent air-lifted samples. The differences between the pumped and air-lifted values suggest that some of the technetium-99 is being reduced in the air-lifted samples while the groundwater sits overnight in contact with freshly crushed rock.

Figure 1-24 shows the depth distribution of nitrate and technetium-99 in well 299-W11-25B. The maximum nitrate concentration (663,540 μg/L) coincides with the depth of the maximum technetium-99 concentration, at 10 m (32.8 ft) below the water table. The concentrations of both technetium-99 and nitrate track each other throughout the upper portion of the aquifer.

Well 299-W11-25B was to be constructed with a 6-m (19.7-ft) screen centered at the depth of the maximum technetium-99 concentration. The well was damaged during construction, however, and well 299-W11-46 was drilled as a replacement, 2.5 m (8.2 ft) from well 299-W11-25B. Well 299-W11-46 has a 6-m (19.7-ft) screen centered at 9.1 m (29.9 ft) below the water table. The first routine, quarterly sampling of the well was scheduled for November 2005.

The second new well (299-W11-45 [also known as "T-2"]) was drilled and sampled during September through November 2005. Well 299-W11-45 is located approximately 80 m (262 ft) downgradient of well 299-W11-46 (and 299-W11-25B). The well was installed to define the horizontal extent of the very high technetium-99 concentration encountered in well 299-W11-25B. DOE sampled groundwater from well 299-W11-45 every 1.5 m (4.9 ft) throughout the upper 56 m (511.8 ft) of the aquifer. Figure 1-25 shows the technetium-99 and nitrate concentrations found during drilling.

The maximum technetium-99 concentration found during drilling of well 299-W11-45 was 15,646 pCi/L, at 9.1 m (29.9 ft) below the water table. The depths of the maximum concentrations are similar in wells 299-W11-25B and 299-W11-45. Although the technetium-99 concentration is very high in well 299-W11-45, it is much less than the 181,900 pCi/L maximum found in well 299-W11-25B. This suggests that if the technetium-99 found in the two wells is from the same plume, the front edge of the plume is likely a short distance east of well 299-W11-45.

Although the nitrate and technetium-99 concentrations tracked each other in well 299-W11-25B, this does not seem to be the case in well 299-W11-45 (Figure 1-25). The maximum nitrate concentration (590,000 μg/L) in well 299-W11-45 roughly coincides with the maximum technetium-99 concentration, but the nitrate has a much broader high-concentration interval before gradually decreasing. Since both wells are located within the regional nitrate plume (Figure 1-15), perhaps the regional nitrate masks the nitrate associated with the technetium-99 at lower technetium-99 concentrations (and presumably lower associated nitrate concentrations).

The third new well at WMA-T (299-W11-47 [also known as "T-3"]) was drilled and sampled during January through March 2006. Well 299-W11-47 is located along the downgradient side of WMA-T adjacent to existing well 299-W11-41, where recent sampling and analysis has shown increasing technetium-99 concentration in groundwater. The well was installed to determine the extent of the technetium-99 contamination in that area. Preliminary results suggest

that the maximum technetium-99 concentrations in this well range from approximately 3,000 to 4,000 pCi/L at depths of 9.8 to 15.6 m (32.3 to 51.3 ft) below the water table.

1.5.5.4 Data Analysis. The ratios of constituents in the inventory can be used to assist in determining the source of the waste. Each process and the wastes from that process have a relatively unique chemical/radionuclide signature that establishes specific ratios among the contaminants. PNNL has conducted considerable studies to identify the ratios for the various process and tank wastes at the Hanford Site. This work has resulted in the development of profiles that allow an evaluation of contaminant ratios within a waste to assist in identifying the source(s). This work has resulted, for example, in the development of a technetium-99/nitrate ratio, as well as a technetium-99/chromium ratio for each geographic group of wells (i.e., profiling the water quality in the wells from a specific part of the site). Ratios for these constituents from samples collected at wells near the northeastern corner of WMA-T are similar to the ratios for wastes from the 241-T-101 and 241-T-106 tanks, implicating those tanks as potential sources for the contaminants in that area.

Figure 1-18 shows the concentrations of technetium-99 and chromium in selected wells from the T Area. The relative concentrations of technetium-99 and chromium track each other through time in upgradient wells at WMA-T (Figure 1-18-A) and wells north of WMA-T (Figure 1-18-B).

The technetium-99 and chromium concentration relationship in wells located at the northeast corner (Figure 1-18-C) and east of WMA-T (Figure 1-18-D) is different from what is found in samples from wells to the west and north. On the east and northeast sides, the concentrations of the two constituents do not appear to track each other; this is especially evident in wells to the east. The trends in Figures 1-18-C and 1-18-D suggest that there are two different sources for either the technetium-99 or the chromium, or both.

The technetium-99/chromium concentration ratios in samples of groundwater from selected wells at WMA-T compared to the estimated ratios for two tank leaks and for discharges to several nearby cribs and trenches are shown in Figure 1-26. The inventory estimates for the tank leaks and crib/trench discharges used in this figure were updated in 2005. (Previous comparisons [e.g., in PNNL 2005] were based on inventory estimates from 2001.) As was previously concluded (PNNL 2005), the figure shows that groundwater in the northeast part of WMA-T (Figure 1-26-C), and probably the more recent samples from the east side of WMA-T (Figure 1-26-D), have technetium-99/chromium concentration ratios similar to those in the fluids leaked from tanks 241-T-101 and 241-T-106. Based on the updated inventory estimates, however, the groundwater in the southwest, west, and north parts of WMA-T (Figures 1-26-A and 1-26-B) now do not appear to have been influenced to any great extent by waste disposed to the nearby cribs and trenches located upgradient of WMA-T, as was previously concluded (PNNL 2006).

Studies have shown that it can be beneficial to use ruthenium-106 to aid in the evaluation of sources for technetium-99. While ruthenium-106 is chemically similar to technetium-99, it has a one-year half-life, as opposed to 212,000 years for technetium-99. Using this trait of the ruthenium-106 can assist in determining potential waste source locations. In addition, there is a definite variation in the abundance of ruthenium isotopes (101/102/104), depending on the source (i.e., natural/background, uranium-235 fission, and plutonium-239 fission). Based on the ratios of ruthenium isotopes, samples collected from well 299-W11-25B are indicative of waste

from a plutonium-239 source (consistent with specific material processed at PUREX), more so than samples from along the eastern boundary wells and wells from around 241-T-106 (similar to material from REDOX and PUREX Plants) (Figure 1-27).

1.5.6 Tank 241-T-106 Soil Contamination Investigation

The largest leak of HLW occurred in 1973 when 435,000 L (approximately 115,000 gal) escaped from tank 241-T-106. The tank 241-T-106 leak is the largest, most thoroughly documented SST leak at the Hanford Site. The first extensive study of this leak was conducted shortly after the leak occurred (ARH 1973), and a follow-up study was completed in 1978 (Routson et al. 1979). More recently, DOE completed an extensive sampling and analysis program on soil samples taken from a borehole near the center of the tank 241-T-106 leak to improve understanding of the nature and extent of contamination in the vadose zone produced by this event (BHI 1994).

Because they were significantly larger than background fluctuations, the liquid-level drops from tank 241-T-106 were unambiguous and permitted an unusually reliable estimate of the leakage volume (435,000 L [115,000 gal]) and leak rate. DOE installed a dense array of drywells to quantify the soil contamination caused by this leak. Gross gamma logging data were collected routinely from many of these wells from 1973 through the mid-1990s, providing the most complete characterization data set of any tank farm leak on the Hanford Site.

The following summary of the vadose zone investigations of this leak are from Myers (2005) and Serne et al. (2004):

- Two boreholes were drilled in areas contaminated by the tank 241-T-106 leak to evaluate the nature and extent of mobile constituents in the vadose zone, particularly technetium-99.
  - Borehole C4104 (total depth of 38.7 m [127 ft] bgs) was drilled near the source of the 241-T-106 leak, about 6.1 m (20 ft) away from the southeast part of the tank wall and near a characterization borehole (299-W10-196) completed in 1993, which is sometimes referred to as the "GAO borehole." The C4104 borehole data were generally consistent with data collected at borehole 299-W10-196 and showed that mobile tank waste constituents (nitrate and technetium-99) are concentrated in the Cold Creek unit and the underlying Taylor Flats member of the Ringold Formation (see Figure 1-9 for stratigraphy). Comparison of nitrate and technetium-99 distribution patterns in the two sets of borehole sediments suggests very limited vertical migration over the last 10 years (Figures 1-28 and 1-29).
  - The second borehole, C4105 (total depth of 39.6 m [130 ft] bgs), was drilled about 27.4 m (90 ft) west of borehole C4104. Compared to their distribution in boreholes C4104 and 299-W10-196, nitrate and technetium-99 are more evenly distributed over a larger depth interval, including the H2 subunit of the Hanford formation, the lower subunit of the Cold Creek unit, and Taylor Flats member of the Ringold Formation (Figures 1-30, 1-31, and 1-32). These data, along with analysis of historical gamma data, suggest that lateral migration has been a significant part of vadose zone migration since the 1973 leak event.

The effect of geologic units on vertical migration of tank waste in the vadose zone is best illustrated by a comparison of technetium-99 and nitrate distributions in borehole 299-W10-196 and borehole C4104 (Table 1-8). Because the boreholes are close together, similar changes in mobile constituent distribution with depth are believed to accurately represent the nature of vertical migration of tank waste contaminants at this location. Technetium-99 and nitrate, the most mobile constituents, are present in these boreholes at similar concentrations at depth. Maximum technetium-99 activities of about 4,800 and 6,100 pCi/g were measured at 35.7 and 35.4 m (117 and 116 ft) bgs in boreholes C4104 and 299-W10-196, respectively. The true maximum at borehole 299-W10-196 may be at 33.5 m (110 ft) bgs, however, where no technetium-99 measurements were taken but where the maximum nitrate value was measured. Slightly higher technetium-99 activities were measured between 35.4 to 35.7 m (116 to 117 ft) bgs and at the bottom of the C4101 borehole (activities ranged from 61 to 572 pCi/g between 35.4 and 39 m [116 and 128 ft] bgs) relative to the values from borehole 299-W10-196 (activities ranged from 5 to 50 pCi/g between 36.6 and 44.2 m [120 and 145 ft] bgs).

The more substantive change in technetium-99 distribution occurs between 30.5 and 39.6 m (100 and 130 ft) bgs in both boreholes (Table 1-8). While the major fraction of technetium-99 is present within this range (96% and 86% in boreholes C4104 and 299-W10-196, respectively), a significantly higher fraction is present between 33.5 and 39.6 m (110 and 130 ft) bgs in Taylor Flats member of the Ringold Formation at the C4104 borehole compared to borehole 299-W10-196 (92% versus 58%). Nitrate distributions show essentially the same trends as technetium-99 in these two boreholes. Thus, contaminant migration through the Hanford formation and the upper Cold Creek unit over the last 10 years has occurred as expected from historical migration rates, but the lower Cold Creek unit and the Taylor Flats member of the Ringold Formation are apparently impeding vertical migration of fluid and mobile constituents and causing concentration buildup in these layers.

The thick, fine-grained nature of the lower Cold Creek unit and perhaps the fine-grained nature of the Taylor Flats member of the Ringold Formation are thought to cause impedance to vertical flow. Under unsaturated flow conditions, these sediment characteristics encourage lateral movement of water at the expense of further vertical migration. In addition, and perhaps more importantly, these units overlie a more coarse-grained stratigraphic layer, the Wooded Island member of the Ringold Formation, thereby forming a natural corollary to an engineered capillary break system. Under unsaturated conditions, capillary forces prevent significant water breakthrough from the fine-grained to the coarse-grained layer until the fine-grained layer is at or near saturation. If these mechanisms are operating, insufficient moisture has collected in the lower Cold Creek unit and the Taylor Flats member of the Ringold Formation to allow more than minor breakthrough.

Serne et al. (2004) provided in situ desorption distribution coefficient (K_d) values for nitrate, cobalt-60, technetium-99, uranium, and chromium based on the difference between acid (for cobalt-60, direct sediment gamma activities were used) and water extracts of the contaminated sediments. For bounding modeling purposes, Serne et al. (2004) recommended using K_d values of 0 mL/g for nitrate, cobalt-60, and technetium-99; a value of 0.1 mL/g for uranium near borehole C4104; 10 mL/g for uranium near borehole C4105; and 1 mL/g for chromium to represent the entire vadose zone profile from the bottoms of the tanks to the water table.

While technetium-99 cannot be detected by gamma logging, other gamma-emitting isotopes are detected and may be used as surrogates if their presence correlates with the presence of technetium-99. Cobalt-60 is a gamma emitter and is detected by the gross-gamma and spectral-gamma logging; although it has a relatively short half-life (5.27 years), it may be an effective surrogate and warrants evaluation. Because cobalt-60 and technetium-99 have K_ds of essentially zero, these may be located at similar depths. Visualizations of cesium-137, cobalt-60, and europium-154 plumes for the T Tank Farm show good control on the lateral extent of contamination but poor control on vertical extent. The Cold Creek unit may act as a barrier to downward flow, but available log data suggest that it is not very effective. Geologic characteristics would suggest that it certainly has an effect on contaminant migration, but log data and groundwater samples show that it is likely more of a "speed bump" than a barrier. Cobalt-60 has been shown in the boreholes near leaking tank 241-T-106 at and below the Cold Creek layer. Cobalt-60 was detected in groundwater in well 299-W11-46 at the northeastern corner of T Tank Farm.

Figure 1-33-A shows the results of spectral-gamma logging in the shallow borehole drilled during the GAO investigation of the leak in tank 241-T-106. The bulk of the contamination occurs above the Cold Creek layer, likely because that is where it was deposited. Figures 1-33-B and 1-33-C show the results of spectral-gamma logging in the two recent vadose zone boreholes. The logs from all three boreholes clearly show significant amounts of cobalt-60 extending below the Cold Creek unit.

1.5.7 Liquid Waste Site Investigation

Liquid waste site investigations are critical to understand the information related to the movement of technetium-99 to the groundwater. There is a high probability that some combination of tank leakage and waste site deposition has moved the technetium-99 plume to approximately 9.1 m (30 ft) below the water table. Thus, understanding the data that have been collected to date from the liquid waste sites is the key to better understanding the conceptual site model.

As noted in Section 1.5.3, some cribs may have contaminated the unconfined aquifer, based on soil porosity and volume of waste discharged. Gross-gamma logging of test wells in the vicinity of the cribs was conducted to verify contamination. The 216-T-7 Crib and the TY Cribs (216-T-21 through 216-T-25) were shown to have contaminated the uppermost aquifer based on this evaluation. The 216-T-18 test crib, the 216-T-19 Crib, and the 216-T-12 pit have the potential to contaminate the uppermost aquifer, but no gamma logging was performed to verify whether this has, in fact, occurred. The 216-T-3 reverse well, 216-T-6 Crib, 216-T-32 Crib, the 216-T-34 and 216-T-35 Trenches, and the 216-T-5 Crib also have the potential to contaminate the uppermost aquifer, but gamma logging indicates that this has not occurred.

The 200-TW-1 OU waste sites received scavenged waste from URP and the ferrocyanide processes at U Plant, which recovered the uranium from the metal waste streams at the B and T Plants. The scavenged waste discharges contributed perhaps the largest liquid fraction of contaminants to the ground in the 200 Areas. RL conducted RI activities on one representative site for the 200-TW-1 OU (216-T-26 Crib) from June to October 2001. This investigation included drilling one borehole (C3102) through the crib and collecting split-spoon soil samples of the vadose zone sediments (DOE-RL 2003).

Figure 1-34 shows the contaminant distribution model of the 216-T-26 Crib. Radiological contamination was not detected in soil samples collected from the surface to a depth of 5.5 m (18 ft) bgs, which corresponds to the base of the crib. The main zone of radiological contamination extends from 5.5 to 11 m (18 to 36.5 ft) bgs. The predominant radionuclides in this zone are contaminants that generally are assumed to be immobile or only slightly mobile (e.g., americium-241, cesium-137, europium-154, europium-155, plutonium-238, plutonium-239/240, and strontium-90). The maximum concentrations of the other contaminants occurred in the 10.4- to 11-m (34- to 36.5-ft) sample interval, with concentrations for the remainder of the borehole only slightly elevated above the detection limit.

More mobile radiological contaminants (e.g., cobalt-60, technetium-99, tritium, and uranium isotopes) were detected in soil samples to a depth of 28.8 m (94.5 ft), which is the approximate top of the Cold Creek unit (formerly the Plio-Pleistocene unit). Only technetium-99 and tritium were detected at depths greater than 28.8 m (94.5 ft); however, concentrations of these contaminants were less than 4 pCi/g each in this zone.

1.5.8 Soil Inventory Model

The Hanford Soil Inventory Model (SIM) is a stochastic model used to develop a Sitewide inventory of soil contamination across the Hanford Site (Corbin et al. 2005). The SIM considers the uncertainties in both waste stream composition (i.e., contaminant concentration) and discharge volumes to estimate the quantities of contaminants in the soil column at individual waste sites. Table 1-9 provides the inventory data set for the most significant radionuclides in the T Area, tying the radionuclides to the cribs, trenches, basins, tanks, and UPRs that contributed to the soil and groundwater contamination in this area.

The inventory reveals that the highest concentrations of technetium-99 (approximately 8.0E+7 pCi/L) are associated with past tank leaks, while the T Area trenches contain concentrations of technetium-99 in excess of 2.7E+5 pCi/L. Table 1-9 indicates that approximately 93% of the technetium-99 inventory in the soils in the T Area is from past tank leaks, with the most significant portion from tank 241-T-106. Tank 241-T-106 also is responsible for approximately 47% of the iodine-129 inventory. The data also indicate that the T Area swamp contains approximately 36% of the uranium-234/238 inventory.

1.6 DATA QUALITY OBJECTIVE TEAM MEMBERS AND KEY DECISION MAKERS

Individual members of the DQO team were carefully selected to participate in the seven-step DQO process based on their ability to provide expertise in all of the technical areas needed to meet the task objectives.

The key decision makers include representatives from RL and EPA Region 10. The role of the key decision makers is to make final decisions related to the sampling design.

Tables 1-10 and 1-11 identify each of the individual members of the DQO team and the key decision makers, respectively. These tables also identify the organization that each DQO team member or key decision maker represents, as well as their technical area of expertise.

1.7 PROJECT BUDGET AND CONTRACTUAL VEHICLES

The budget for all of the task activities associated with the development and implementation of the sampling program, the performance of laboratory analyses, the performance of the data quality assessment, and the evaluation and reporting of investigation results will be agreed upon after the DQO summary report identifies the additional data requirements.

1.8 DATES

Table 1-12 presents the dates for the completion of all task activities associated with the development of the sampling program. Dates for the implementation of the sampling program, additional technical data evaluation, performance of laboratory analyses, performance of a data quality assessment, and evaluation and reporting of investigation results will be determined after the sampling plan is completed.

1.9 CONTAMINANTS OF CONCERN

The following subsections describe the process that was used to identify the contaminants to be evaluated through this DQO process.

A list of the COCs for the site under investigation was generated by initially listing all of the contaminants of potential concern (COPCs) based on historical process operations. The COPCs were then evaluated by the DQO team members to establish those to be included in the site investigation.

1.9.1 Total List of Contaminants of Potential Concern

Several documents have already extensively evaluated the groundwater COPCs for the 200-ZP-1 OU, for WMA-T, or for vadose zone characterization. Some of these documents are listed below:

- *Remedial Investigation/Feasibility Study Work Plan for the 200-ZP-1 Groundwater Operable Unit* (DOE-RL 2004)
- *Characterization of Vadose Zone Sediments Below the T Tank Farm: Boreholes C4104, C4105, 299-W10-196 and RCRA Borehole 299-W11-39* (Serne et al. 2004)
- *Sampling and Analysis Plan for Two New Deep Wells in the 200-ZP-1 Operable Unit at Single-Shell Tanks, Waste Management Area T, Calendar Year 2005* (DOE-RL 2005)
- *RCRA Assessment Plan for Single-Shell Tank Waste Management Area T* (Horton 2006).

The COPCS from the above documents were used as the starting points for this DQO process. Note that the COCs in the 200-ZP-1 RI/FS work plan (DOE-RL 2004) that were selected for groundwater were based on an evaluation of constituents detected in the vadose zone from the facilities, cribs, and trenches above the groundwater OU. In addition, groundwater data from wells in the T Area, listed below, were obtained from Hanford Environmental Information System (HEIS) database:

- 299-W10-1
- 299-W10-4
- 299-W10-8
- 299-W10-12
- 299-W10-15
- 299-W10-16
- 299-W10-22
- 299-W10-23
- 299-W10-24
- 299-W10-28
- 299-W11-7
- 299-W11-12
- 299-W11-15
- 299-W11-18
- 299-W11-23
- 299-W11-24
- 299-W11-25B
- 299-W11-27
- 299-W11-28
- 299-W11-39
- 299-W11-40
- 299-W11-41
- 299-W11-42.

All of the COPCs from the aforementioned wells were screened against the corresponding limits determined for the 200-ZP-1 Groundwater OU. Appendix B lists the COPCs that were evaluated from the HEIS data for the T Area wells. Appendix B presents a list of analytes that exceeded the limits by well number, along with the number of exceedances, the maximum and minimum detections, standard deviations, and the screening value. Appendix C, which is based on the SAP found in Appendix A, Table A1-7 of the 200-ZP-1 RI/FS work plan (DOE-RL 2004), provides the limits determined for the 200-ZP-1 OU. The limits for evaluation of contamination for the entire 200-ZP-1 OU were approved by RL and EPA via approval of the RI/FS work plan. The selected limits are also referred to as the screening values or preliminary remediation goals (PRGs). Appendix D provides a list of all constituents that were analyzed in samples from the T Area wells, including summary statistics regarding minimum and maximum detections and analytical methods.

1.9.2 Contaminants of Concern Addressed by Concurrent Activities

The scope of a DQO summary report prepared to support remediation activities typically assumes the responsibility for all media at the site. In this case, however, DOE has performed vadose zone characterization and groundwater characterization before this DQO process began. Table 1-13 presents a list of the COCs that have been found through other characterization activities or COCs that are currently listed in sampling plans that are underway for the T Area. These sampling plans and any available results will be considered when establishing the SAP for this DQO process. This DQO process will identify sample data that will be generated from other SAPs to ensure that the needed data have been tracked and captured.

1.9.3 Other Contaminant of Concern Exclusions

Table 1-14 presents a list of COCs to be excluded from this DQO investigation. The table also provides the specific rationale for the exclusion of each of the identified COPCs.

1.9.4 Final List of Contaminants of Concern

Table 1-15 presents the final list of COCs for T Area groundwater to be carried through the remainder of the DQO process. Sulfate, common cations (e.g., sodium, calcium, potassium, and magnesium), pH, and specific conductance were added as water quality indicators to allow better assessment of anion/cation balance and the assessment of the ionic strength of the water.

Ruthenium, although not a COC, may be included in the site investigation to aid in the evaluation of sources for technetium-99, as discussed in Section 1.5.5.4. Table 1-16 lists all of the constituents and parameters that will be analyzed in groundwater.

1.9.5 Distribution of Contaminants of Concern

The key COC, technetium-99, arrived at the site from one, or a combination, of the following sources:

- Tank leaks (most likely from 241-T-101 or 241-T-106) to the vadose zone.
- Cribs and trenches near the WMA-T area are not currently considered to contain sufficient quantities of technetium-99 to cause the concentrations seen at the northeastern corner. The technetium-99 content of the decontamination waste disposed to the 216-T-36 Crib cannot be quantified, however, and a well very close to 216-T-36 has significant concentrations of technetium-99. In addition, the 216-T-26 Crib (east of the TY Tank Farm) received large volumes of liquids that could have contained technetium-99. This crib may be one source of the technetium-99. Liquids disposed to cribs and trenches could have facilitated the movement of contaminants in the vadose zone that were derived from other sources.
- The volumes discharged to the T Area cribs and trenches are small when compared to U Pond and T Pond discharges (Figure 1-3). The U and T Pond water did not contain technetium-99, but the large volumes disposed to these sites changed the direction of the groundwater flow.

The UPRs are considered a less likely source of the technetium-99. The volumes are very small, generally on or near the soil surface, and are not as likely to cause the observed concentrations in groundwater.

The focus of this study is technetium-99. Figure 1-26 presents the concentration of technetium-99 over time from the wells of interest. It is evident that the technetium-99 concentration is high on the northeastern side and is increasing along the entire east side of WMA-T. Preliminary results of sample analyses from well 299-W11-45 indicate that the elevated concentration of technetium-99 at approximately 10 m (32.8 ft) below the water table extends into that area of the site.

The following known plumes are already well documented in the area: carbon tetrachloride, nitrate, chromium, shallow aquifer technetium-99, and tritium. The iodine-129 plume is located east of WMA-T and, given the current easterly groundwater direction, should not extend to this area.

1.10 CURRENT AND POTENTIAL FUTURE LAND USE

The current and potential future land uses in the immediate vicinity of the T Area will provide input later in the DQO process to support the evaluation of decision error consequences. Land use will help establish target risk levels that are necessary to establish adequate analytical and field methods.

DOE worked for several years with cooperating agencies and stakeholders to define land-use goals for the Hanford Site and to develop future land-use plans through the efforts of the Hanford Future Site Uses Working Group (HFSUWG) (*The Future for Hanford: Uses and Cleanup, the*

Final Report of the Hanford Future Site Uses Working Group [HFSUWG 1992]). The cooperating agencies and stakeholders included the National Park Service, Tribal Nations, the states of Washington and Oregon, local county and city governments, economic and business development interests, environmental groups, and agricultural interests. These efforts were reported initially by HFSUWG (1992) and culminated in the *Final Hanford Comprehensive Land-Use Plan Environmental Impact Statement* (DOE 1999) and the associated ROD (64 FR 61615) that were issued in 1999.

HFSUWG (1992) identified the following nine general recommendations:

- Protect the Columbia River
- Deal realistically and forcefully with groundwater contamination
- Use the Central Plateau wisely for waste management
- Do no harm during cleanup or with new development
- Cleanup of areas of high future use value is important
- Clean up to the level necessary to enable the future-use option to occur
- Transport waste safely
- Capture economic development opportunities locally
- Involve the public in future decisions about the Hanford Site.

Specific to the 200 Area Central Plateau, the findings and recommendations from the HFSUWG (1992) are as follows:

- The Central Plateau is unique.
- Some type of government presence or oversight should be assumed for the foreseeable future.
- Waste from other Hanford Site locations should be concentrated in the 200 Areas.
- Waste management, storage, and disposal activities should be concentrated within the 200 Areas, whenever feasible, to minimize the amount of land devoted to these activities, and adverse impacts to clean areas also should be minimized.
- Wastes generated in or coming to the 200 Areas from the remainder of the Site will not necessarily be permanently disposed of in the 200 Area. Offsite shipments are occurring and may continue. New technologies may be applied to waste in the future.
- Waste and contaminants within the 200 Areas should be treated and managed to prevent migration from the 200 Areas to other areas or off the Hanford Site.
- Access to the "exclusive" areas, including "exclusive buffers," will be restricted to personnel who are properly trained and monitored.

The HFSUWG identified a single cleanup scenario for the Central Plateau. This scenario assumes that future uses of the surface, subsurface, and groundwater in and immediately surrounding the 200 East and 200 West Areas will be industrial (exclusive).

Consistent with the HFSUWG (1992), the core zone (which includes the 200 East and 200 West Areas) has been designated as industrial (exclusive) in the comprehensive land-use plan environmental impact statement (EIS) (DOE 1999). The industrial exposure scenario is used to evaluate each site.

Human health risks are evaluated for an industrial exposure scenario using site-specific data and exposure assumptions obtained from state and Federal guidance documents. The land surrounding the 200 East and 200 West Areas was designated as industrial-exclusive in the comprehensive land-use plan EIS (DOE 1999). The T Area is located in this industrial-exclusive land-use area.

The Tri-Parties (i.e., EPA, Ecology, and RL) undertook the task of developing a risk framework to support risk assessments in the Central Plateau. Representatives from DOE, EPA, Ecology, the Hanford Advisory Board (HAB), the Tribal Nations, the state of Oregon, and other interested stakeholders completed a series of workshops in 2002. The workshops focused on the different programs involved in activities in the Central Plateau and the need for a consistent application of risk assessment assumptions and goals. The results of the risk framework are documented in letter HAB #132, *Exposure Scenarios Task Force on the 200 Area* (HAB 2002a); in the Tri-Parties' response to *Consensus Advice #132: Exposure Scenarios Task Force on the 200 Area* (Klein et al. 2002); and in *Report of the Exposure Scenarios Task Force* (HAB 2002b). The following items summarize the risk framework description from the Tri-Parties' response to the HAB. Clarifications have been added to the original response language:

- The core zone (200 Areas, including B Pond [main pond] and S Ponds) will have an industrial land-use scenario for the foreseeable future.
- The core zone will be remediated and closed, allowing for "other uses" consistent with an industrial land-use scenario (environmental industries) that will maintain an active human presence in this area, which in turn will enhance the ability to maintain the institutional knowledge of waste left in place for future generations. Exposure scenarios used for this zone should include a reasonable maximum exposure to a worker/day user, to possible Native American users, and to intruders.
- DOE will follow the required regulatory processes for groundwater remediation (including public participation) to establish the points of compliance and remedial action objectives. It is anticipated that groundwater contamination under the core zone will preclude beneficial use for the foreseeable future, which is at least the period of waste management and institutional controls (150 years). It is assumed that the tritium and iodine-129 plumes beyond the core zone boundary will exceed the DWSs for the next 150 to 300 years (less for the tritium plume). It is expected that other groundwater contaminants will remain below, or be restored to, drinking water levels outside the core zone.
- No drilling for water use or otherwise will be allowed in the core zone. An intruder scenario will be evaluated for assessing the risk to human health.
- An industrial land-use scenario will set cleanup levels on the Central Plateau. Waste sites outside the core zone but within the Central Plateau (i.e., 200-N Area, Gable Mountain Pond, and B/C Crib controlled area) will be remediated and closed based on an evaluation of multiple land-use scenarios to optimize institutional-control cost and long-term stewardship.

- Other land-use scenarios (e.g., residential or recreational) may be used for comparison purposes to support decision making, especially for the following:
  - The post-institutional controls period (> 150 years)
  - Sites near the core zone perimeter to analyze opportunities to "shrink the site"
  - Early (precedent-setting) closure/remediation decisions.

This framework does not deal with the tank waste retrieval decision.

Because the T Area is located in the 200 Area core zone, this description serves as the basis for the risk assessment activities. The risk assessment will follow the risk guidelines identified through the risk framework workshops, as documented in the Tri-Parties' response to HAB Advice #132 (Klein et al. 2002). Risk evaluations for possible Native American users and intruder scenarios may be considered in the FS for informational purposes.

Future risk evaluation for the for the 200 Area OUs will be based on these guidelines, as well as on EPA and Washington State risk assessment guidance. Radiological constituents are addressed through a dose evaluation, which then is converted to a risk value. Hypothetical human health risks are calculated for industrial exposure scenarios using inputs developed from other Hanford Site OUs, site-specific data, and guidance documents.

Nonradiological constituents from the shallow zone soil, 0 to 4.6 m (0 to 15 ft) bgs, are screened to industrial soil, risk-based concentrations (RBCs) and industrial air RBCs for direct contact and inhalation of ambient air, respectively. Nonradiological constituents from the deep-zone soil (0 m to water table) are compared with the soil RBCs for protection of groundwater. For purposes of planning data collection to support future RI/FS reports, analytical methods' detection limits may be compared to RBCs developed under CERCLA guidance (EPA 1991) using the excess lifetime cancer risk range of 10^{-4} to 10^{-6} and a hazard quotient of 1.0, using an industrial land-use scenario for nonradiological contaminants. Because the waste sites in this OU are within the core zone, RBCs used for screening correspond to a 10^{-5} risk level.

The WMA-T is a RCRA TSD unit and will be closed in accordance with applicable requirements, as implemented through the framework provided by the Tri-Party Agreement.

1.11 PRELIMINARY ACTION LEVELS

The action limits/PRGs from the 200-ZP-1 RI/FS work plan (DOE-RL 2004) are used as the basis for the action limits presented here. This approach allows this project to be consistent with CERCLA remediation for the entire OU. These PRGs were updated with the new limits from the *Cleanup Levels and Risk Calculations Under the Model Toxics Control Act Cleanup Regulation (CLARC III)* (CLARC) (Ecology 2005) database and the information used from EPA's Integrated Risk Information System database, as documented via e-mails from Ecology as of August 26, 2005. The COCs are those presented in previous sections and are listed in Table 1-16.

1.12 CONCEPTUAL SITE MODEL

This section describes the current CSMs for describing technetium-99 contamination in the groundwater beneath the T Area. These models will be modified as new data become available and new understanding is developed. However, the current CSM for the T Area illustrates the

complexity and the spatial and temporal relationships of five important parameters: contaminant sources, driving forces, migration pathways to groundwater, changes in groundwater flow direction and flow rate, and the current contaminant distributions in the aquifer.

1.12.1 Conceptual Models

Eight conceptual models are presented below. All of the conceptual models have been presented in previously published documents (Serne et al. 2004, Myers 2005, Horton 2006, Hodges 1998, DOE-RL 2003) and/or described in the course of interviews with technical staff to explain three-dimensional and temporal distributions of contamination in the study area and potential pathways to the groundwater. Conceptual models #1 through #4 primarily address mechanisms and potential sources by which the contamination may have entered the groundwater. Understanding these pathways is important in order to focus potential remediation efforts on any continuing sources of technetium-99 to the groundwater. Models #5 through #8 address the issues specifically related to the vertical distribution of contamination in the groundwater. Understanding the variability in contaminant concentrations with depth in the groundwater is important to establish the quantity and extent of contamination and to potentially provide information about vadose and groundwater transport mechanisms. Each of the conceptual models fits some of the available data and provides valuable insight into potential groundwater contamination mechanisms. There also are problematic issues that arise with each. The various conceptual models and a brief discussion of identified issues associated with each are presented below:

- **Model #1:** The technetium-99 plume resulted from tank leaks in WMA-T that migrated through the vadose zone to groundwater. This model is based largely on the amount of technetium-99 in the tank waste and known leaks that have occurred, as well as work with contaminant and isotopic ratios. Several reports (Horton 2006, CHG 2001, Hodges 1998, Hodges and Chou 2001) have surmised that the technetium-99 contamination may have come from T Tank Farm leaks that migrated through the vadose zone to groundwater.

  Discussion on model #1: Studies that have looked at contaminant and isotopic ratios (Horton 2006, Brown et al. 2005) suggest that tank waste has impacted some of the wells proximal to the northeast corner of WMA-T and, to varying degrees, other wells east of WMA-T. Available data from borehole logging, the volume of tank fluids released (Serne et al. 2004, Myers 2005), and models of migration through the vadose zone, however, do not support breakthrough of contamination to the groundwater at the time of the various tank leaks or in subsequent years. For example, Serne et al. (2004) performed an extensive analytical characterization of sediment samples from two boreholes cored near tank 241-T-106. It was concluded that between 1993 and 2003, nitrate had migrated vertically about 1.8 m (5.9 ft) and cobalt-60 had migrated about 3 to 4.6 m (9.8 to 15.1 ft). The deepest cobalt-60 detected was at 34.4 m (112.9 ft), and the deepest nitrate was at about 38.7 m (127 ft) bgs. The depths of the boreholes do not allow a definitive conclusion that the contamination has not reached the groundwater; however, concentrations of mobile constituents were decreasing markedly at the deepest depth sampled. Even assuming that the release did make it to groundwater in 1973, the groundwater flow directions and velocities do not support a technetium-99 plume that reaches wells in the sequence observed. Data from groundwater measurements generally

show that wells just outside the northeast corner of the tank farm first indicated a technetium-99 plume in about 1995. Wells in a southerly direction (299-W11-42 and 299-W11-41) subsequently indicated the arrival of a technetium-99 plume over the next several years, beginning in about 2000. Well 299-W11-41, at the southeastern edge of the tank farm, has shown a marked and continuing increase since about 2000. Because there is no southerly component to the groundwater flow in that area and there has been none in the timeframe that tanks 241-T-106 or 241-T-101 or any other of the WMA-T tanks were known to have leaked, it is difficult to reconcile the temporal pattern of contamination observed in the northeast wells followed by wells increasingly to the south if the contamination is from the tank farms (presumably tanks 241-T-101 or 241-T-106). It has been noted in discussions with technical staff that more complex scenarios involving multiple plumes or specific plume shapes and/or heterogeneities in the hydrogeologic properties could be invoked to explain the temporal pattern of contamination.

If the observed groundwater contamination is from the tank farm vadose contamination plume as a whole, and a hypothetical release to the groundwater occurred so the groundwater plume was not moved north, then the release would have to have occurred after 1995, when the primary direction of groundwater flow changed from north to east. A release after 1995 would not allow enough time for the plume to reach the easterly wells (at various dates after 1995) given the measured/calculated groundwater velocities. It also would not allow technetium-99 from a leak from tank 241-T-106 or other tanks to reach the wells on the eastern side of the T Tank Farm in the sequence indicated by the analytical data from the various wells. Well 299-W11-39 showed the leading edge of a plume in about 2002, although a nearby well (299-W11-23) that it replaced showed a marked rise in technetium-99 concentration as early as 1998. A leak from a tank close to the easterly boundary (e.g., tank 241-T-101) could have reached well 299-W11-39 (approximately 72 m [236.2 ft] east of 241-T-101) in 2002 with an easterly flow rate from 1996 of about 12 m/yr (39.4 ft/yr). This is significantly faster than a recently estimated easterly flow rate of about 4.6 m/yr (15.1 ft/yr) (Horton 2006) in that era, based on current and historical groundwater-level measurements.

Horton (2006) noted that when comparing the ratios of technetium-99/nitrate and technetium-99/chromium in groundwater to those in tank waste, there is evidence that the wells proximal to the northeast corner of the T Tank Farm have been impacted by tank waste. Although the earliest contamination in the southern wells along the eastern perimeter of the tank farm did not appear to be tank waste, later contamination may be from tank waste. The composition is changing such that currently the groundwater ratios are approaching tank waste ratios. This work was recently re-evaluated due to a revision of disposal site inventory estimates (Corbin et al. 2005). Technical staff reviewed contaminant ratios (technetium-99/chromium, and technetium-99/nitrate) in groundwater samples from a number of wells near WMA-T, including 299-W10-4, 299-W11-39, 299-W11-41, and 299-W11-42 against predicted ratios for tank, crib, and trench waste. Consideration of data from about 1997 through 2005 indicates that the dominant source of the technetium-99 plume in well 299-W11-39 would appear to be tank waste, while the contaminant ratios in well 299-W10-4 are not consistent with a tank farm source. The contamination ratios in wells 299-W11-41 and 299-W11-42 indicate a crib and trench source when looking at technetium-99/nitrate ratios but show evidence of increasing

influence from a tank source when considering technetium-99/chromium ratios. These data indicate a plume in the T Area that is likely the result of several sources.

Recent work by PNNL (Brown et al. 2005) compared the stable ruthenium isotope ratios in groundwater to the ruthenium isotope ratios in vadose zone porewater samples collected near tank 241-T-106. The isotopic ratios in shallow groundwater samples were in close agreement with most 241-T-106 vadose zone porewater samples. Deeper groundwater samples showed somewhat different isotopic ratios, suggesting a different source. Nuclear model calculations and the time of waste discharge indicate that most of the cribs to the west of the tank farm were unlikely to be sources of the ruthenium in either the shallow or deep groundwater; however, the 216-T-36 Crib could not be ruled out on this basis. No vadose zone porewater samples from the cribs were analyzed. It was noted that the data were not conclusive and further studies are needed.

It should also be noted that well 299-W10-4, approximately 60 m (196.8 ft) south of the T Tank Farm boundary and approximately 180 m (590.5 ft) west of well 299-11-25B, has shown an increase in the concentration of technetium-99 that essentially mirrors wells 299-W11-39, 299-W11-41, and 299-W11-42, which are along the eastern boundary of the T Tank Farm. The magnitude of the increase is significantly less than in the wells along the eastern boundary, but follows the same temporal pattern. Concentrations of technetium-99 remained relatively constant in well 299-W11-12 (approximately 30 m [98.4 ft] south of the southeastern corner of WMA-T), which was sampled for technetium-99 from 1998 through 2005. It would appear as though a component of the contamination observed in wells 299-W11-39, 299-W11-41, and 299-W11-42 is part of the same plume that impacted well 299-W10-4, based on temporal variability in the technetium-99 analytical results, in contrast to the conclusions reached by evaluation of the contaminant ratios in the groundwater.

- **Model #2:** The technetium-99 plume resulted from historical discharges to cribs and ditches in the T Area that migrated through the vadose zone to groundwater.

  Discussion on model #2: Considering the timeframe of the discharges to the 216-T-7 and 216-T-32 Cribs in the T Area, the direction of groundwater movement, and potential velocities over the years, there is no known sequence of events that would allow a high-concentration technetium-99 plume to reach wells in the northeastern corner of WMA-T from cribs and ditches in the T Area without impacting wells north of WMA-T in previous years. In addition, the current estimate of technetium-99 concentration in the waste that has been disposed to these two cribs (maximum of 1,771 pCi/L) (Corbin et al. 2005) is far too dilute to have been a major contributor to the high-concentration technetium-99 plume (over 180,000 pCi/L). There is evidence (Brown et al. 2005, Horton 2006) that a portion of the technetium-99 groundwater plume is from crib and trench releases, so it is likely that cribs and trenches contributed to the existing groundwater technetium-99 plume, but it is unlikely that they are the sole contributors.

  Considering the timeframe of the discharges, as well as the direction of movement and potential groundwater velocities over the years (Horton 2006), the 216-T-36 Crib is the only local source of an external crib discharge that could likely have impacted the wells in the sequence indicated by available measurements. The volume disposed in that crib (approximately 500,000 L [132,086 gal] between 1967 and 1969) would not have been

expected to reach groundwater; however, groundwater data from well 299-W10-4 indicate that contamination reached the groundwater in 1969 (Jones et al. 2002). In 1969, over 600 pCi/L of cesium-137 and cobalt-60, as well as an increase in gross alpha concentrations, were observed in water samples from this well (Jones et al. 2002, HEIS data). The technetium-99 concentration in the waste that has been disposed to the 216-T-36 Crib (417 pCi/L) is far too dilute to have been a significant contributor to the current high-concentration groundwater technetium-99 plume downgradient of WMA-T (Corbin et al. 2005). However, there is significant uncertainty as to the exact nature of the T Plant decontamination waste disposed to the 216-T-36 Crib (Jones et al. 2002).

Recent work by PNNL (Brown et al. 2005) compared the ruthenium isotope ratios in the groundwater to ruthenium isotope ratios predicted in waste discharged to cribs and could not yet rule out a contribution to groundwater from the waste discharged to the 216-T-36 Crib. These studies did suggest, however, that other cribs were not the source of waste that contaminated the groundwater at well 299-W11-25B. It was noted that the ruthenium isotope data were limited in the number of groundwater samples analyzed and even more limited in the number of vadose zone porewater samples available and analyzed. Vadose zone porewater from below any of the cribs and trenches was not available for analysis; data were only available for sediments impacted by the 241-T-106 tank leak. Thus, the available data are not conclusive for determining sources and further studies are needed.

- **Model #3:** The technetium-99 plume resulted from historical discharges to cribs outside of the study area that may have migrated through the vadose zone to groundwater and migrated with groundwater to the study area. This model is specifically included to help explain the concentrations of carbon tetrachloride and TCE, as well as components of the nitrate and chromium, in the groundwater under the study area.

  Discussion on model #3: The various documents that were reviewed generally agree that the carbon tetrachloride, TCE, and portions of the nitrate in the groundwater indicate that a plume from the south, likely from PFP and/or other sources, have migrated north and forms a broad, underlying plume within which smaller, more localized plumes may exist. The most likely source for the chromium west and north of WMA-T is one or more of the disposal facilities located upgradient of WMA-T (Horton 2006). Chromium from these facilities would have been moving north across well 299-W10-1 prior to 1997, then east across the northern wells and the remainder of the WMA after 1997.

  It is generally accepted that carbon tetrachloride and TCE were not discharged to the vadose zone from the WMA-T tank leaks or the cribs and ditches in the T Area. While there is a source of TCE near T Plant, east of WMA-T and outside of the study area, historical groundwater flow directions (Horton 2006) clearly indicate that it would not have impacted the wells proximal to the eastern boundary of WMA-T. Finding carbon tetrachloride, TCE, and nitrate contamination at depth in the aquifer (compared to finding technetium-99 at higher concentrations near the top of the aquifer in wells 299-W10-24 and 299-W14-13) provides support for the concept that some of the technetium-99 is the result of local, relatively recent contamination of groundwater. However, the findings in wells 299-W11-25B and 299-W11-45 do not support that assumption for the whole area. Based on the information from these recent wells, the maximum technetium-99

contamination in the area east of WMA-T appears to be at approximately 10 m (32.8 ft) below the water table.

- **Model #4:** The technetium-99 plume resulted from vadose zone contamination from tank leaks, crib discharges, or UPRs that was driven to the groundwater as a result of pipeline breaks, leaks, or other discharges or via natural precipitation. The difference between this model and the preceding models is that the contamination may not have reached the groundwater at the time of the initial leak or discharge but would have been driven from the vadose zone to the groundwater via relatively clean water from a subsequent unrelated release. The tank leaks or the cribs were the mechanism by which contamination reached the vadose zone, but subsequent events provided the driver that moved the contamination to the groundwater.

  Discussion on model #4: If contamination was driven to the groundwater by rainfall and snowmelt run-off, it would be expected to have impacted the groundwater over a fairly large area, based on the lateral extent of contaminant plumes in the vadose zone as established by numerous investigations (Myers 2005). The length of time for contamination to have reached the groundwater would have depended on factors such as the volume of water introduced to the vadose zone, the frequency of occurrence of flooding scenarios, and the migration pathway (e.g., through interstitial drainage or short circuits along preferential pathways). From 1973 (the estimated time of the 241-T-106 tank leak) until 1982, groundwater traveled primarily in a northeast direction. From 1983 to 1995, the groundwater primarily traveled northwest, and from 1997 to present, the groundwater has been traveling primarily to the east.

  Recent drilling established that technetium-99 is at high concentrations at 10 m (32.8 ft) below the water table in well 299-W11-45, near the southern end of the 216-T-15 Trench (approximately 185 m [607 ft] east of the 241-T-106 tank). In order for a plume from the 241-T-106 leak to reach well 299-W11-45, it would have to travel at a rate of at least 20 m/yr (65.6 ft/yr). This estimate of the probable velocity of groundwater assumes that the leaked contaminants reached groundwater directly under the tank and that the contamination did not impact the groundwater until 1996, after which time there was no significant westward or northward movement of the plume. It also assumes that the 241-T-106 release did not move a significant distance laterally within the vadose zone, that preferential vertical migration pathways were not involved, and that there was no impact from a potential breach of the pipeline from the 207-T retention basin. In all likelihood, well 299-W11-45 does not indicate the eastern edge of the plume. Therefore, the required groundwater flow rate for a 241-T-106 leak to impact well 299-W11-45 in 2005 is likely greater than 20 m/yr (65.6 ft/yr). Tank 241-T-101 is about 75 m (246 ft) further east than 241-T-106, but the plume would have to travel over 12 m/yr (39.4 ft/yr) from 241-T-101 to reach 299-W11-45 in 2005.

  Another estimate of the velocity of the plume can be made by assuming that well 299-W11-39 data indicate when the high-concentration plume from tank 241-T-106 or tank 241-T-101 reached the location. The significant rise in technetium-99 concentrations in well 299-W11-39 began in about 2002. The distance from well 299-W11-39 to well 299-W11-45 is about 60 m (196.8 ft). This also would indicate a plume velocity of about 20 m/yr (65.6 ft/yr), based on the same assumptions as noted above, and is likely a low estimate for the same reasons as noted above.

A groundwater velocity of 12 or 20 m/yr (39.4 or 65.6 ft/yr) is significantly greater than the estimated horizontal velocity of 4.6 m/yr (15.1 ft/yr) or 32 m (105 ft) easterly travel distance between 1997 to 2004, as estimated by Horton (2006). A flow rate of 20 m/yr (65.6 ft/yr) is also greater than the flow rates estimated from 1954 through 1957 under the influence of the T Pond during its heaviest use. It is, however, within the upper range of estimated horizontal groundwater velocities measured in wells near the northeastern corner of the T Tank Farm. Individual well measurements ranged from 6 to 102 m/yr (19.7 to 334.6 ft/yr), with the median at 17 m/yr (55.8 ft/yr).

The breaking of a water transfer line while drilling well 299-W11-27 in 1992 has been proposed as a potential explanation for the low specific conductance that was observed in the well (Hodges 1998, Hodges and Chou 2001). It is further surmised that when discharge to the 216-T-4-2 Ditch (via the potentially broken pipeline) was terminated in 1995, the dilution caused by a local water mound ceased and the observed concentrations of many constituents rose, including technetium-99. This series of events assumes that the technetium-99 plume had reached the location of well 299-W11-27 prior to its installation but escaped detection after the well was drilled due to dilution from leaks in the broken water line. This could explain the observed time-series behavior of measured constituents in the well. If it is assumed that the technetium-99 concentration increase seen in 1996 was the leading edge of a technetium-99 plume, however, and not the result of removing a water source, then the estimated groundwater velocity needed to place the technetium-99 plume approximately 70 m (229.7 ft) away in 2005 at well 299-W11-45 in 2005 is 7.8 m/yr (25.6 ft/yr), which is less than half of the velocity needed for other wells in the area (see discussion above). Nearby well 299-W11-23 revealed a sharp rise in technetium-99 activity beginning in 1998. The velocity required for the leading edge of the plume to travel east for 60 m (196.8 ft) to well 299-W11-45 by 2005 is about 7.1 m/yr (23.3 ft/yr). It has been surmised that the leaking pipe may have also affected the distribution of technetium-99 in the aquifer (Horton 2006). Others (Hodges 1998, Hodges and Chou 2001) have speculated that a small mound might have formed in the vicinity of the leak. However, discussion with technical staff has noted that there is no evidence, based on water level measurements, of a groundwater mound during or after the era of the leak.

- **Model #5:** The depth of the technetium-99 maximum concentrations in the aquifer may have been enhanced by higher density, salt-laden effluents entering the upper aquifer and then dispersing at the 10 m (32.8 ft) depth.

  Discussion on model #5: Changes in contaminant concentrations with depth are significant because of their impact on the determination of quantity and extent of contamination and because of information that they may provide about vadose transport mechanisms. As noted by Hodges (1998), there are two potential causes of contaminant stratification within the aquifer. One potential cause is brines (i.e., high-salt waste), with densities significantly greater than 1 g/cm^3, sinking within the aquifer. The second potential cause of stratification within the aquifer is recharge with little, or incomplete, vertical mixing resulting in layering at the top of the aquifer. If the high-concentration plume of technetium-99 was from tank waste that had directly reached groundwater after a leak, the waste density would be much greater than that of the groundwater and would be expected to sink quickly. Similarly, if the tank waste reached the groundwater as

a result of floods or other effluent recharge over a relatively short time, the initial contamination that reached the groundwater would be expected to have a relatively high density due to dissolved salts. Most previous evaluations of vertical contaminant distribution have assumed that contamination near the water table indicates that the contamination has not traveled far and/or has not entered the aquifer as a high-density solution. The data from wells 299-W11-45, 299-W11-46, and 299-W11-25B (i.e., all of the wells for which recent technetium-99 depth profile data exist in this area) would indicate that the contamination is not at a maximum at the water table. In these wells, the conclusion would be that the contamination was either from a nearby source that intercepted the groundwater as a higher density stream, or that the technetium-99 was from a distant source and has had time to mix vertically. With the exception of those few wells, other monitoring wells in the area are screened from the water table to a depth of about 9.1 m (30 ft) and are not useful in determining to what depth the contamination may extend. Several wells in the area (299-W10-24, 299-W14-11, and 299-W14-13) indicated that the highest concentrations of technetium-99, nitrate, and iodine-129 were at the water table when the wells were first installed. Thus, it remains to be determined if the maximum technetium-99 concentrations are generally deep in other wells.

It was also noted (Horton 2006) that the permeability of the various strata within the aquifer are markedly different and not readily related to descriptions in drilling logs. This may limit the ability to obtain representative samples at different depths in the screened interval of any of the wells and may result in samples that are not representative of the entire screened interval.

- **Model #6:** The depth of the maximum technetium-99 concentrations in the aquifer may have resulted from technetium-99 that was from a source external to the T Area. Therefore, the plume has migrated a long distance and has had time to be dispersed into a deeper part of the aquifer.

  Discussion on model #6: Previous discussions of contaminant depth distribution have asserted that since the technetium-99 was shallow in well 299-W10-24, the contamination came from a nearby source. This is not consistent with current findings in wells 299-W11-25B (approximately 30 m [98.4 ft] southeast) or 299-W11-45, where it is apparent that the highest concentrations of technetium-99 occur at about 10 m (32.8 ft) below the water table. Other wells in the T Area are screened from the water table to a depth of about 9.1 m (30 ft), and positive technetium-99 results were assumed to be confirming the presence of shallow contamination. An evaluation of the data in HEIS for well 299-W10-24 showed initial measurements in late 1998 of less than 500 pCi/L and a subsequent maximum of 3,660 pCi/L in 1999. Subsequent to those evaluations, data from recently drilled wells 299-W11-45 and 299-W11-25B have shown the contamination to be much deeper than previously thought. Based on the data from these more recent wells, the conclusion would be that the high-concentration technetium-99 contamination was either from a nearby vadose zone source that intercepted the groundwater as a higher density stream, or that the technetium-99 was from a distant source and has had time to mix vertically. The lower technetium-99 concentration portions of the groundwater plume may have also been affected by the depth of the water table during initial waste disposal, as discussed in model #8 below.

- **Model #7:** The depth of the maximum technetium-99 concentrations in the aquifer may have resulted from changing water levels and flow directions, which created or exacerbated conditions (e.g., vertical gradients) that accelerated vertical mixing, compared to an aquifer that was undisturbed. The history of effluent disposal practices indicates that the groundwater flow direction and elevation has changed over time (Horton 2006). The groundwater flow direction and water-table elevation varied depending on the disposal volumes to the ponds/cribs/trenches in different eras. Flow was to the south from 1954 through 1956, to the northeast from 1957 through 1982, to the north-northwest from 1983 through 1995, and to the east from 1997 through 2003. Changes in flow directions and water-table elevations were slow and transitional.

  Discussion on model #7: Consideration of the direction, velocity, and era of groundwater flow make it difficult to hypothesize a tank leak (e.g., from 241-T-106 or 241-T-101) that is able to impact wells just off of the northeast corner and the east boundary of the T Tank Farm fence line at the time and in the sequence that have been observed from time-series groundwater measurements. The distances that plumes appear to have traveled are not consistent with the measured horizontal flow rates noted in Hodges (1998) or the horizontal flow rates estimated from historical water-level measurements in Horton (2006). Assuming that a technetium-99 plume began traveling east from 241-T-101 (i.e., the furthest east tank) in 1997, when groundwater flow was essentially to the east, a plume would have to travel approximately 17 m/yr (55.8 ft/yr) to cover the approximately 133 m (436.4 ft) to well 299-W11-45, even if the plume had just barely reached that area when the well was drilled in November 2005. In addition, as noted by Hodges (1998), the interpretation of sampling results of monitoring wells may be complicated by the generally falling groundwater levels that are observed in the area since discharges to the ground have been eliminated. By sampling with a pump set at a fixed depth, there is the possibility, in a vertically stratified aquifer, that sample results do not reflect the highest contaminant concentrations or are missing the contaminants completely. Until recently, almost all of the monitoring wells were screened from the water table to about 9.1 m (30 ft) below the water table. Limited data are available describing vertical distribution of contaminants in the T Area. The data that are available (wells 299-W11-45, 299-W11-46, and 299-W11-25B) indicate significant stratification, with peak concentrations near the bottom of the normally screened interval. Hodges (1998) reported the first preliminary vertical sampling results at well 299-W11-27 and indicated a vertical gradient for technetium-99 and other constituents in the upper portion of the aquifer. Hodges (1998) also noted that the presence of vertical gradients within the aquifer is significant for understanding vadose transport mechanisms because of the possibility of both density-driven transport and surface-infiltration driven transport (Ward et al. 1997). As noted by Horton (2006), recent measurements in several wells near the northeastern corner of the T Tank Farm revealed a vertical flow gradient in some of the wells. While it is not possible to relate the measured gradients directly to vertical mixing rates in the aquifer, it is of interest and may indicate vertical gradients in the aquifer in at least some locations.

- **Model #8:** The depth of the maximum technetium-99 concentrations in the aquifer may have resulted from the water table rising above existing technetium-99 contamination in the groundwater. Wastewater containing technetium-99 was delivered to the water table. The water table subsequently rose and the contamination was moved and distributed in such a way as to result in the presently observed technetium-99 contamination at depth in the groundwater.

  Discussion on model #8: Discharges to the soil from cribs and trenches in the T Area began as early as 1945, as previously discussed (e.g., Table 1-3). The groundwater levels rose significantly from about 1949 through about 1956 (Figure 1-11), with the result that waste deposited at the water table in the early years could eventually be 10 m (32.8 ft) or more below the surface of the water table at its high point. The cessation of liquid waste disposal to the soil column over the ensuing years has resulted in the decline of the water table to levels near (approximately 1 to 5 m [3.3 to 16.4 ft] above) those in the early days of disposal. The net result would be contamination of the soil column at depths below the current water table and might have contributed to the observed technetium-99 contamination at depth.

  As noted in the previous discussion, there is evidence of more than one source for the technetium-99 plume in the T Area. It seems likely that cribs and trenches have contributed to the technetium-99 groundwater plume in some wells (Horton 2006, Brown et al. 2005) near WMA-T. It should also be noted that there is significant uncertainty in the exact composition of the multiple waste streams that were disposed to the major cribs, such as 216-T-7 (Stenner et al. 1988). The cribs and trenches at WMA-T are generally thought to have received dilute waste with concentrations of technetium-99 that are lower (Corbin et al. 2005) than those observed in the high-concentration portion of the plume found in wells proximal to the northeastern corner of WMA-T. Pending the results of additional wells and sampling, it is not known if there is a deep, low-concentration technetium-99 component in some wells that would be consistent with the type of waste that the cribs and trenches are thought to have received. Thus, while cribs and trenches could have contributed to the groundwater plume based on the technetium-99 disposed in them, it is clear that unless the concentrations of waste disposed to the cribs and trenches is significantly under-estimated, they could not be a major contributor to the high-concentration portions of the plume. In addition, net groundwater movement over the life of any of the cribs and trenches near WMA-T is generally thought to be north and east (Horton 2006). The temporal occurrence of high-level technetium-99 contamination in various wells also makes it unlikely that the sources of the high-concentration groundwater technetium-99 plume in the northeastern corner of the T Area are the result of discharges to the cribs and trenches.

1.12.2 Summary

All non-permitted, liquid discharges were terminated at the Hanford Site in 1995. Therefore, although no flushing of contaminants to groundwater will result from future intentional discharges, residual porewater and associated contaminants remain in the vadose zone beneath the T Area. This residual contamination is expected to slowly bleed into the aquifer for the foreseeable future through natural infiltration. Non-tank sources (i.e., cribs and trenches) have contributed mobile contaminants to the groundwater in the past, but it is not clear if these sources

are still a vadose zone source for the mobile contaminants. Specific retention trenches that received lower volumes of waste may still have mobile contaminants present in the vadose zone; more characterization is needed of the sediments underneath these facilities.

High levels of gross beta in wells that are located near some of the cribs and trenches west of WMA-T provided the earliest evidence of groundwater contamination in 1955 (Serne et al. 2004). This early groundwater contamination pre-dates any reported tank leak from the T Tank Farm. Thus, it is likely that a portion of the present T Area technetium-99 plume did not originate from the tank farms, based on historical well data and groundwater flow. Information obtained from analysis of both ruthenium ratios (Brown et al. 2005) and contaminant ratios (Horton 2006; Hartman et al. 2003, 2004; PNNL 2005) has shown that a plume of technetium-99 appears to have originated near the 216-T-36 Trench and moved in a northeastern trajectory. The movement of a plume from the 216-T-36 Trench area to the wells near the northeastern corner of WMA-T is also consistent with groundwater velocities and movement since the use of this trench ended in 1969. Although there is significant uncertainty in the exact nature of the waste disposed to this trench, current 216-T-36 inventory estimates (Corbin et al. 2005) do not indicate sufficient technetium-99 to support 216-T-36 to provide a source for the higher concentration technetium-99 plume.

The UPRs in the T Tank Farm (see Section 1.5.3), or other discharges or leaks resulting from waste transfers, etc., may have contributed large amounts of contaminants to the vadose zone, where they accumulated in thin, fine-grained lenses. Later, driving forces such as pipeline breaks or floods may have driven contaminants into the aquifer. This may have occurred by driving contaminants from the vadose zone to the groundwater along preferential pathways (e.g., poorly cased wells, fissures, or sub-vertical geologic formations) or, if the driving forces were large enough, directly through the fine-grained units and surrounding sands to groundwater.

There are regional sources for most of the tritium, carbon tetrachloride, and nitrate found in the groundwater beneath the T Area, with the exception of a probable local source for the extremely high nitrate near well 299-W10-4 and the high nitrate concentrations associated with technetium-99 found in well 299-W11-25B. As noted above, increases in a number of contaminants and their concentrations, including technetium-99, began around 1997 coincident with a groundwater-flow direction change from northwest to east. Results of contaminant ratio analysis (Horton 2006, Brown et al. 2005) indicate that (1) tank waste from WMA-T may have impacted groundwater at the northeastern corner and along the eastern boundary of WMA-T; and (2) past-practice cribs, trenches, and tile fields upgradient of WMA-T do not appear to have impacted groundwater southwest, west, or north of WMA-T.

The most obvious source for the tank waste in groundwater northeast and east of WMA-T is WMA-T itself. Several studies discussed in the models above have concluded, however, that there is no clear scenario and driver for the leaked tank waste in the tank farm to have moved from the vadose zone in the tank farm to the groundwater. Additional difficulties arise when trying to reconcile the apparently rapid rate of eastward movement of the hypothetical plume whose source is tanks 241-T-101 or 241-T-106, or any of the other tanks in WMA-T that do not appear to have leaked.

The concentration of technetium-99 in wells 299-W11-25B and 299-W11-46 was significantly higher than had been previously measured in other monitoring wells. If all or part of the contamination plume that has been detected on the northeastern corner of WMA-T is from

T Tank Farm leaks, then the leaks would likely have contained high salt content and would have exhibited a density much greater than the groundwater. Similarly, if run-off events or water from pipe breaks have driven the tank waste from the vadose zone to the groundwater, the higher density liquid front (containing waste salts and mobile contaminants) reaching the aquifer would likely sink until natural turbulence and mixing resulted in a local density approximately that of the groundwater.

Recently installed (November 2005) well 299-W11-45 was sampled at various depths to determine the vertical profile of technetium-99, as well as to determine how far east the plume may have moved. The well was drilled about 60 m (196.8 ft) east of wells 299-W11-25B and 299-W11-46, and just south and west of the 216-T-15 Trench. Preliminary field-screening data show that the vertical location of the peak technetium-99 concentration (approximately 9.1 m [30 ft]) is similar to that found in well 299-W11-25B. The magnitude of the peak concentration (15,646 pCi/L) is significantly lower than that found in 299-W11-25B (over 180,000 pCi/L). The results from this well indicate that the technetium-99 plume has moved more rapidly to the east than was anticipated. The preliminary data from new well 299-W11-47 (south of well 299-W11-41) show that the maximum technetium-99 concentrations in this well range from approximately 3,000 to 4,000 pCi/L at depths of 9.8 to 15.6 m (32.3 to 51.3 ft) below the water table, indicating that the elevated technetium-99 concentrations are not present at this location to the south.

As noted in the discussions above, well 299-W11-25B was damaged during completion and was replaced by well 299-W11-46, approximately 3 to 5 m (9.8 to 16.4 ft) to the west. The new well was screened in the same interval (6.1 to 12.2 m [20 to 40 ft] below the water table) as the peak concentration of contaminants found in well 299-W11-25B. Although the two wells are only 3 to 5 m (9.8 to 16.4 ft) apart and both were screened in the same interval (6.1 to 12.2 m [20 to 40 ft] below the water table), the highest concentration of technetium-99 in the replacement well has been about 36,000 pCi/L, which is significantly lower than the comparable sample results from the same interval in well 299-W11-25B. This seemingly large difference may relate to the highly variable permeability observed for various strata in wells in the vicinity and/or to sampling techniques. Furthermore, the technetium-99 concentration in the replacement well (299-W11-46) may rise with subsequent samples, as was observed for well 299-W10-24 after installation. Acknowledgment of the significant heterogeneity in the aquifer properties such as permeability, vertical gradients, and horizontal groundwater speed based on measurements and calculations should be a part of any conceptual model that is used to explain the details of the technetium-99 plume.

1.13 STATEMENT OF THE PROBLEM

Recent analytical data for well 299-W11-25B revealed technetium-99 concentrations that were not only an order of magnitude higher than any previously identified near WMA-T, but also were further below the surface of the water table than anticipated. These findings suggest that the technetium-99 mass and distribution in the unconfined aquifer beneath the T Area, and the processes that generated this contamination, are not well understood. The lateral and vertical distribution of the technetium-99 in the aquifer is needed to support remedial decisions.

Technetium-99 has been found in well 299-W11-25B at concentrations exceeding 180,000 pCi/L at 10 m (32.8 ft) below the water table. This unexpectedly high concentration has not been seen previously in the T Area. Well 299-W11-25B is located at the northeastern corner of WMA-T.

Additional data from other nearby wells indicate that concentrations of technetium-99 are higher below the water table. Data indicate that the high-concentration plume may be more extensive and deeper in the unconfined aquifer than previously thought.

Conceptual groundwater models indicate that the technetium-99 is likely from some combination of tank leaks, cribs, trenches, and UPRs. Until the technetium-99 source(s) is/are better understood, the probability of additional technetium-99 contamination and the extent of the high-concentration portions of the technetium-99 groundwater plume cannot be evaluated. In addition, until the vertical and lateral distribution and movement of technetium-99 is better understood, it is not possible to assess the risk to humans or the environment, nor is it possible to adequately evaluate remedial actions.

Complicating the technetium-99 problem are other known contaminants that exceed regulatory limits. In particular, carbon tetrachloride, TCE, nitrate, and chromium plumes exist below the T Area. These and the other COCs identified need to be considered when evaluating technetium-99 risks and remedial opportunities.

Figure 1-1. T Area Location Map.

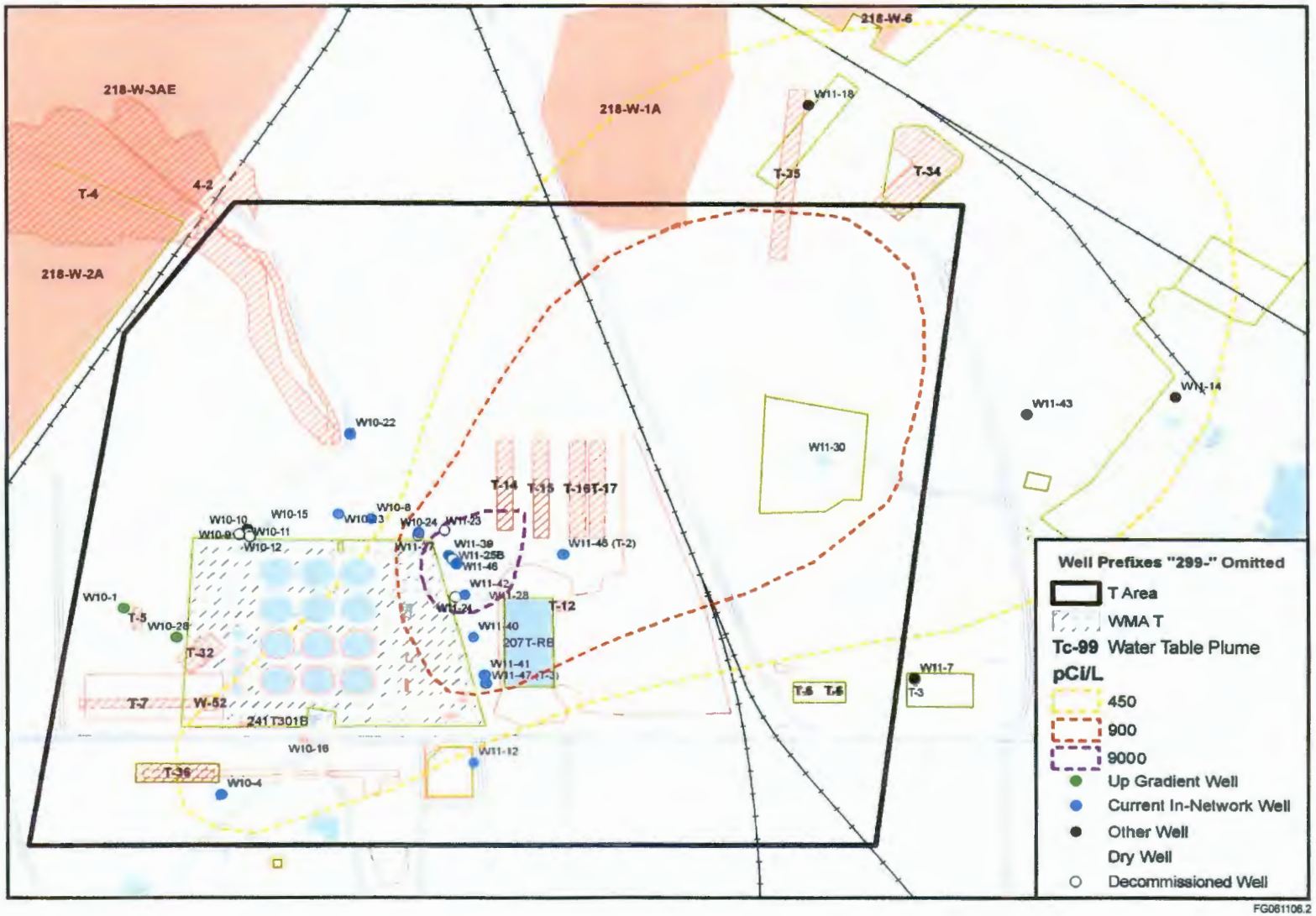
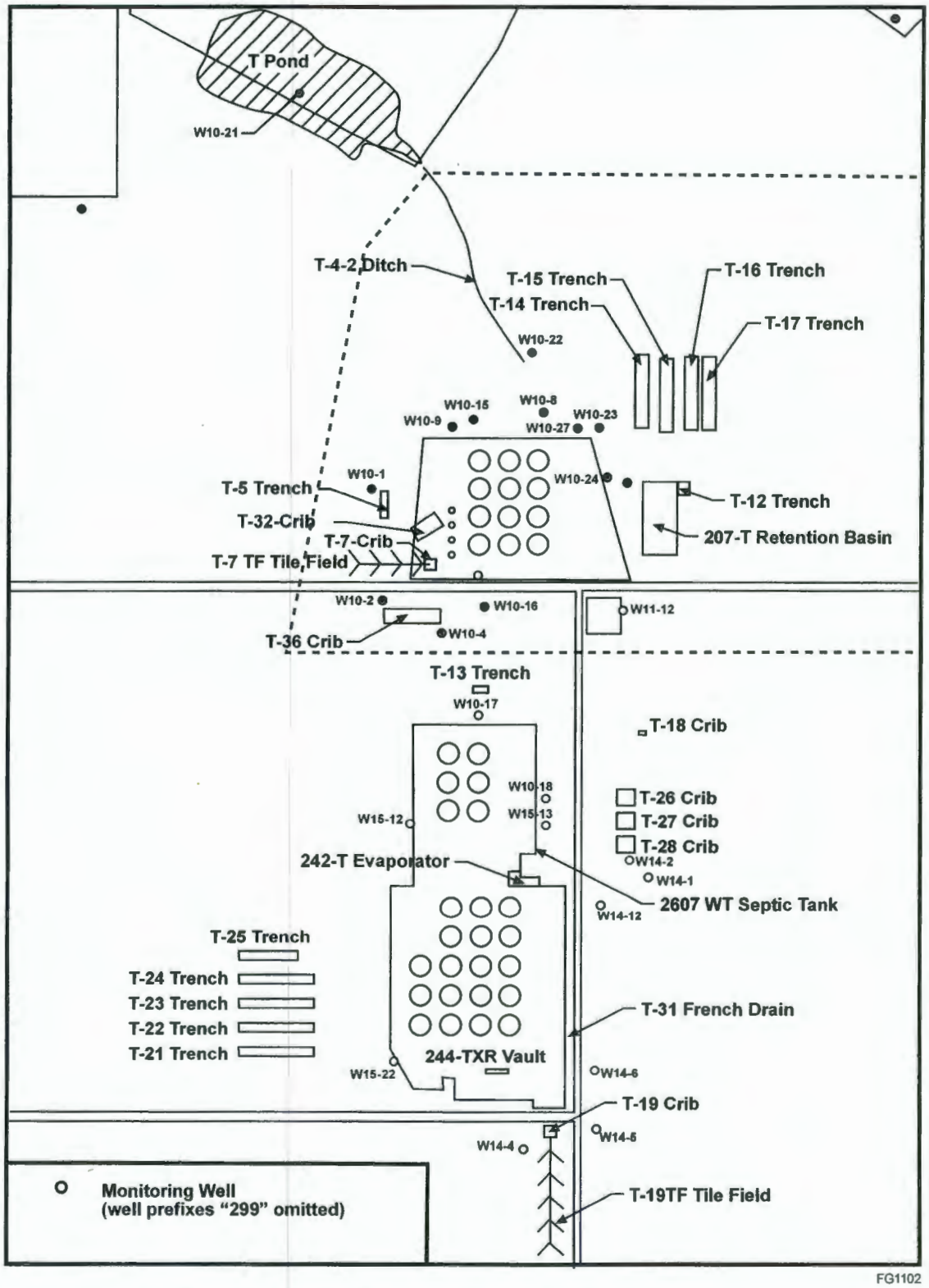


Figure 1-2. 200 West Area, Including the T, TX, and TY Tank Farms.



NOTE: Dashed line shows the study area boundary for the T Area.

Figure 1-3. Liquid Waste Discharges Timeline.

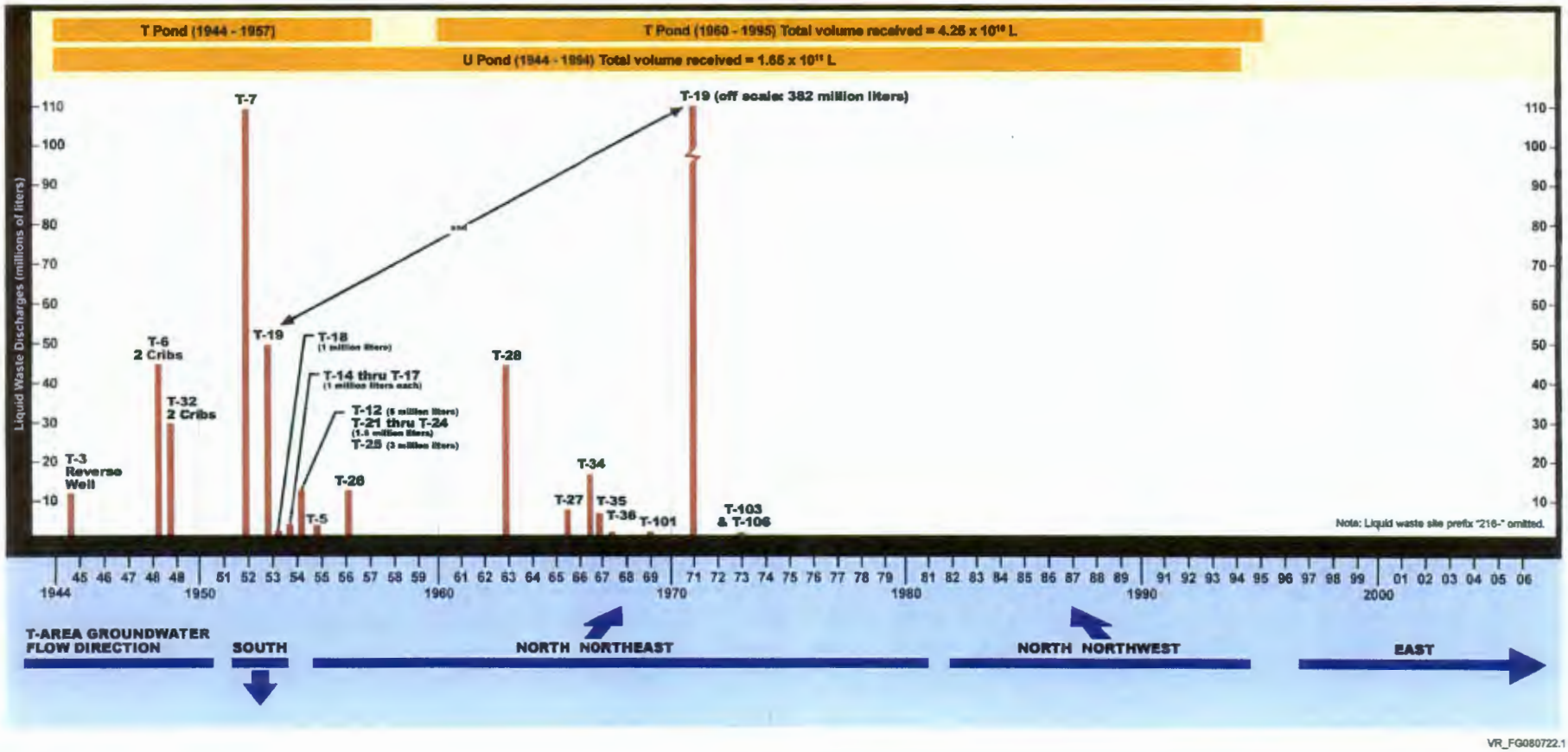


Figure 1-4. Technetium-99 Timeline (Bismuth-Phosphate and Uranium Recovery).

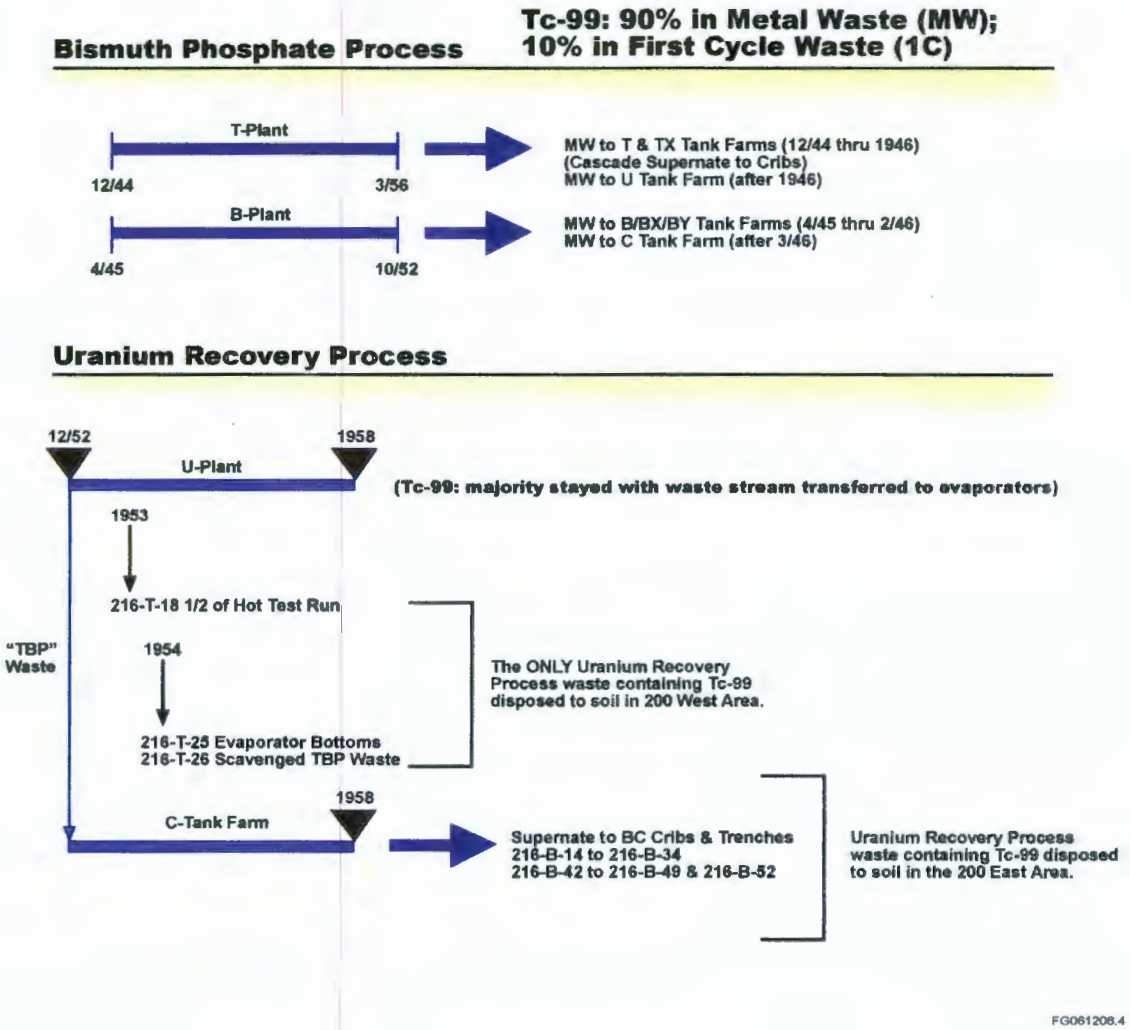
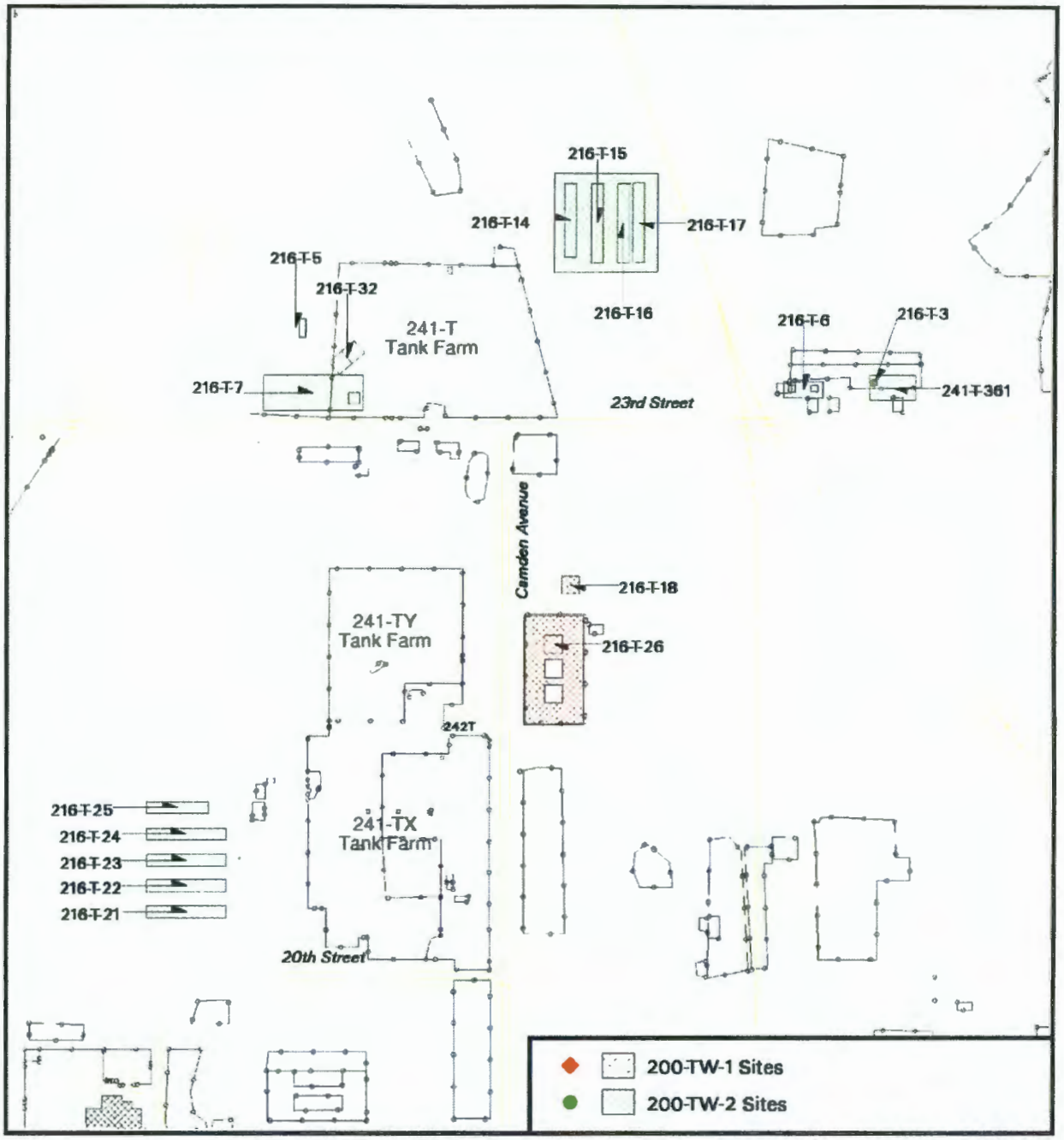
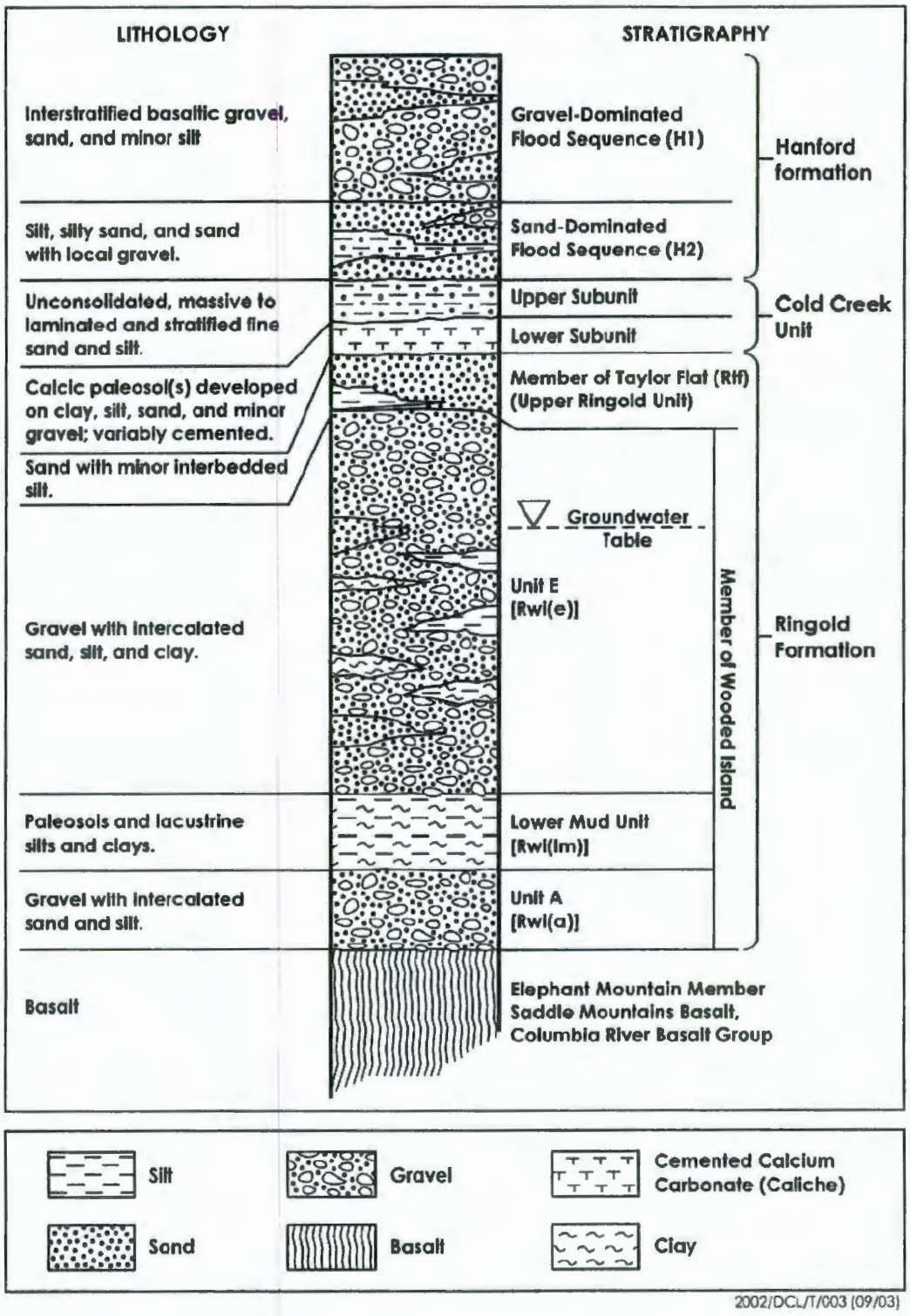


Figure 1-5. Location Map of the 216-T-26 Crib, South of T Area.[a]



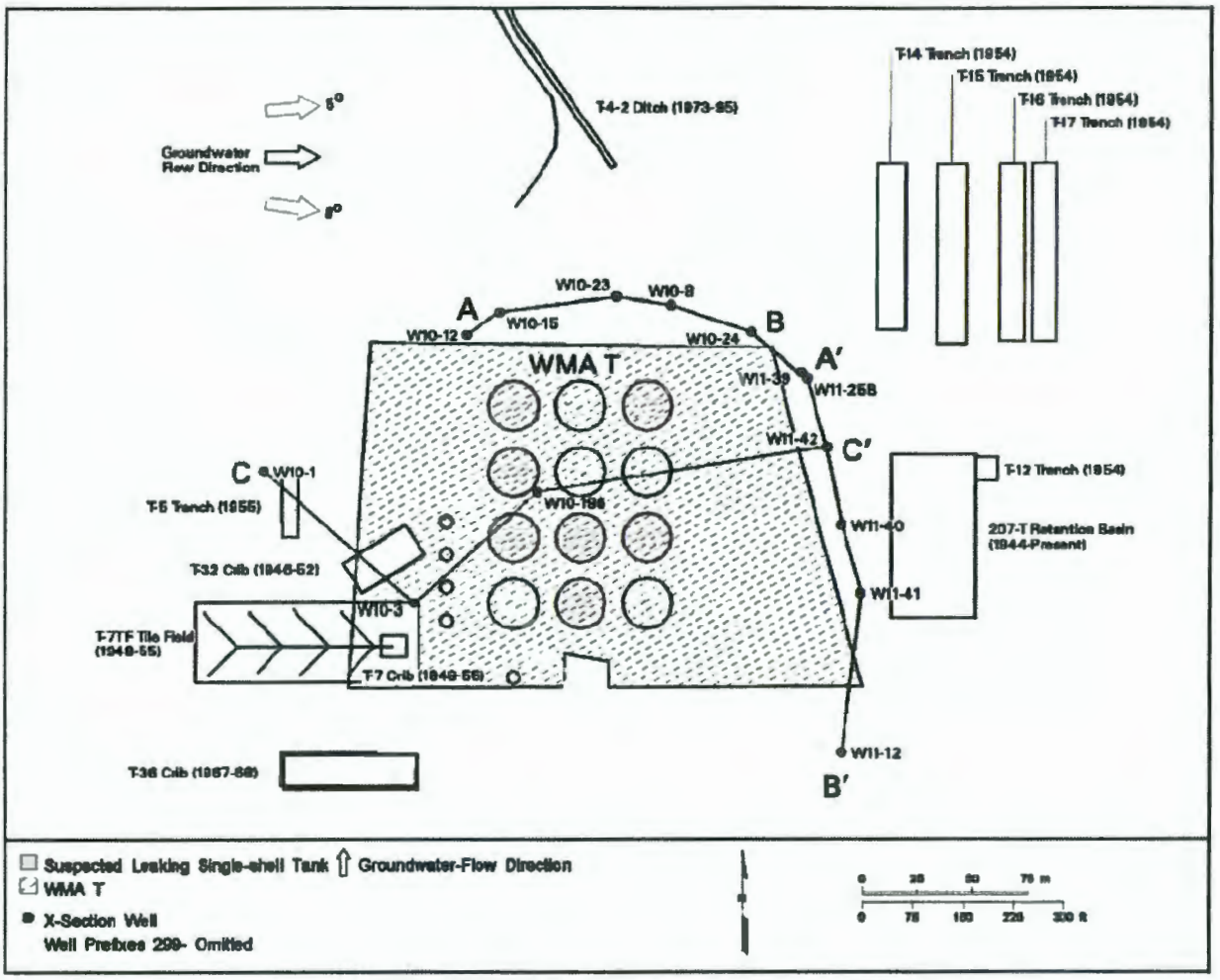
[a] From *Remedial Investigation Report for the 200-TW-1 and 200-TW-2 Operable Units (Includes the 200-PW-5 Operable Unit)*, DOE/RL-2002-42, Rev. 0 (DOE-RL 2003).

Figure 1-6. Generalized Stratigraphy of Suprabasalt Sediments at T Tank Farm.[a]



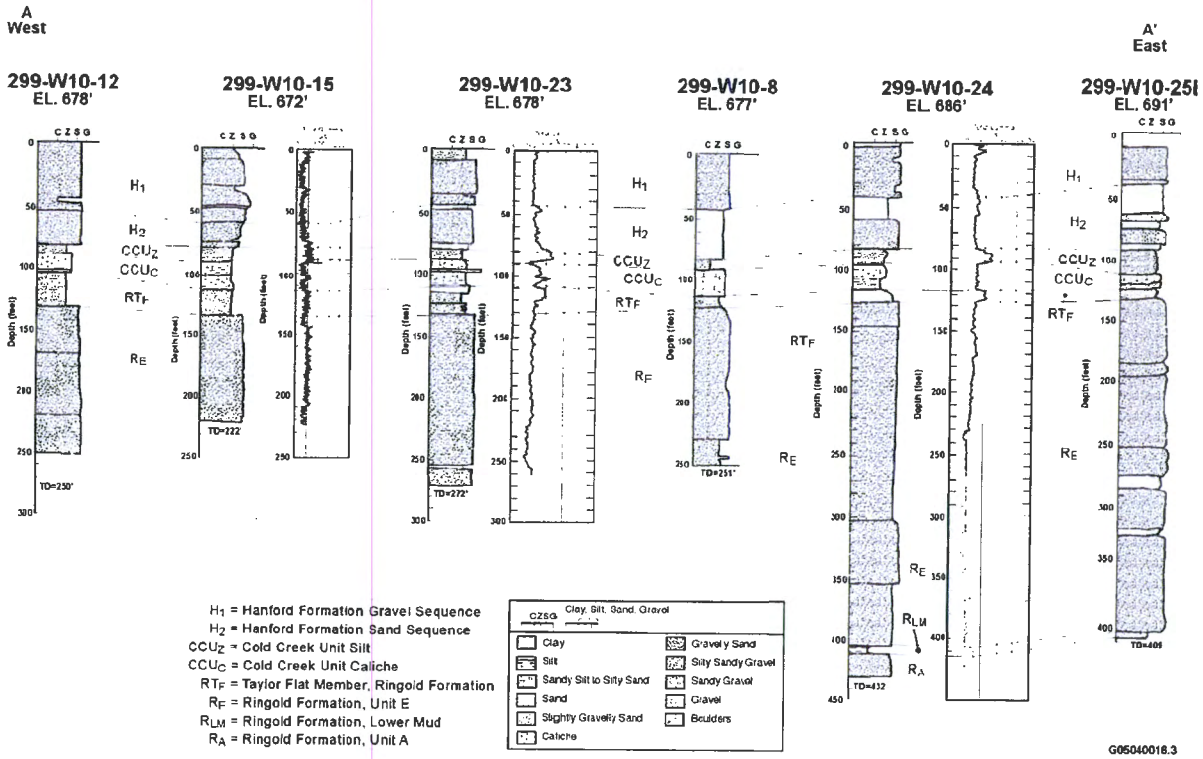
[a] From *Characterization of Vadose Zone Sediments Below the T Tank Farm: Boreholes C4104, C4105, 299-W10-196, and RCRA Borehole 299-W11-39*, PNNL-14849, Rev. 0 (Serne et al. 2004).

Figure 1-7. Location of Wells and Cross-Sections Around Waste Management Area T.[a]



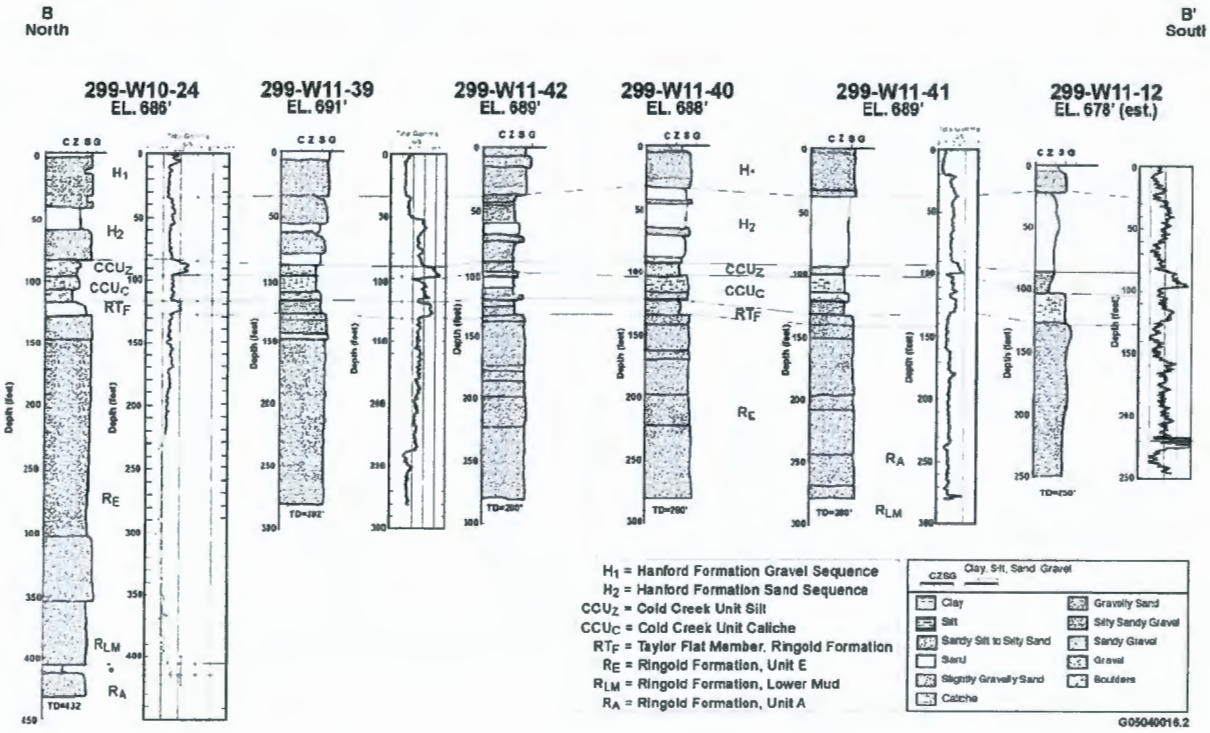
[a] This figure has been slightly modified from *RCRA Assessment Plan for Single-Shell Tank Waste Management Area T*, PNNL-15301, Rev. 0 (Horton 2006).

Figure 1-8. Cross-Section North of Waste Management Area T.[a]



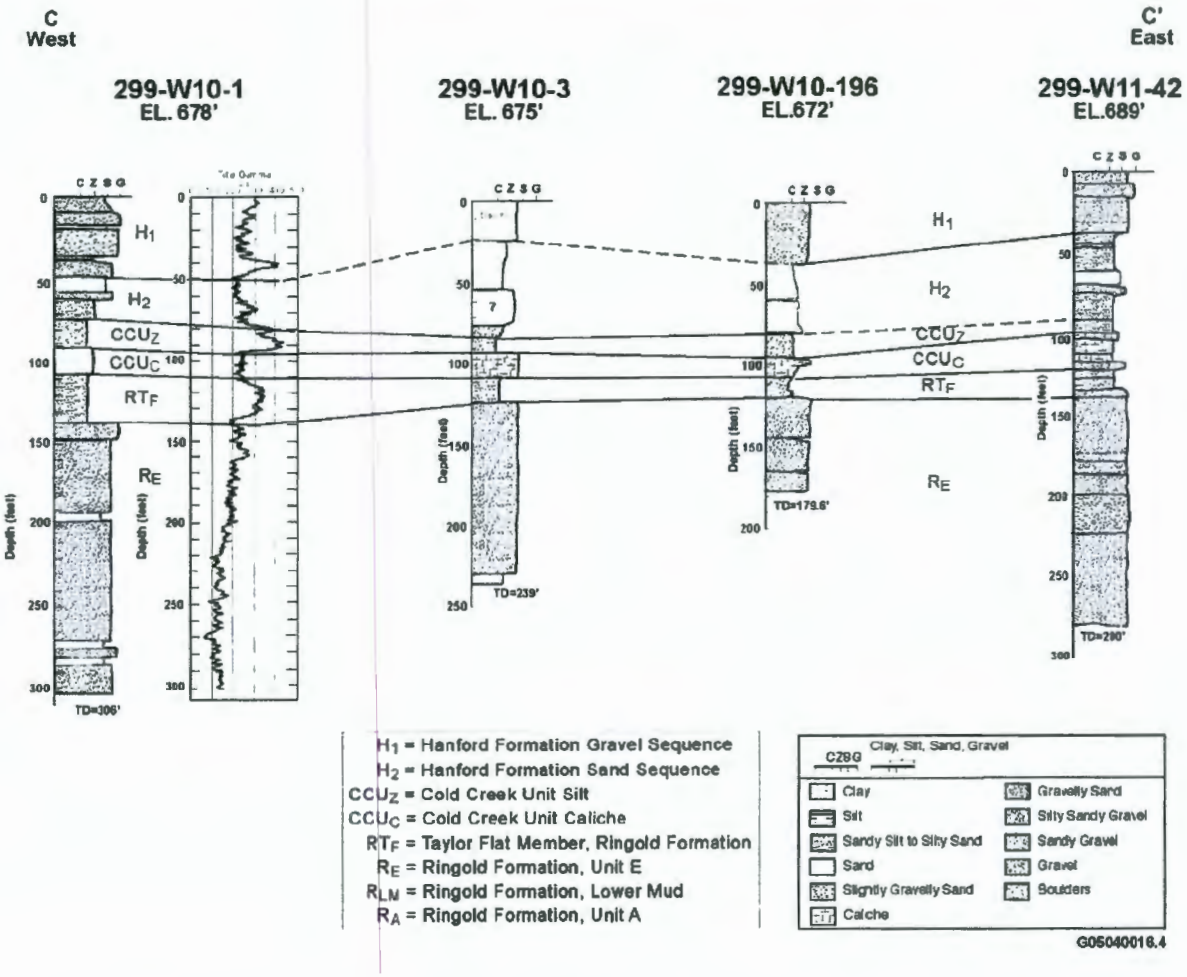
[a] From *RCRA Assessment for Single-Shell Tank Waste Management Area T*, PNNL-15301, Rev. 0 (Horton 2006).

Figure 1-9. Cross-Section East (Downgradient) of Waste Management Area T.[a]



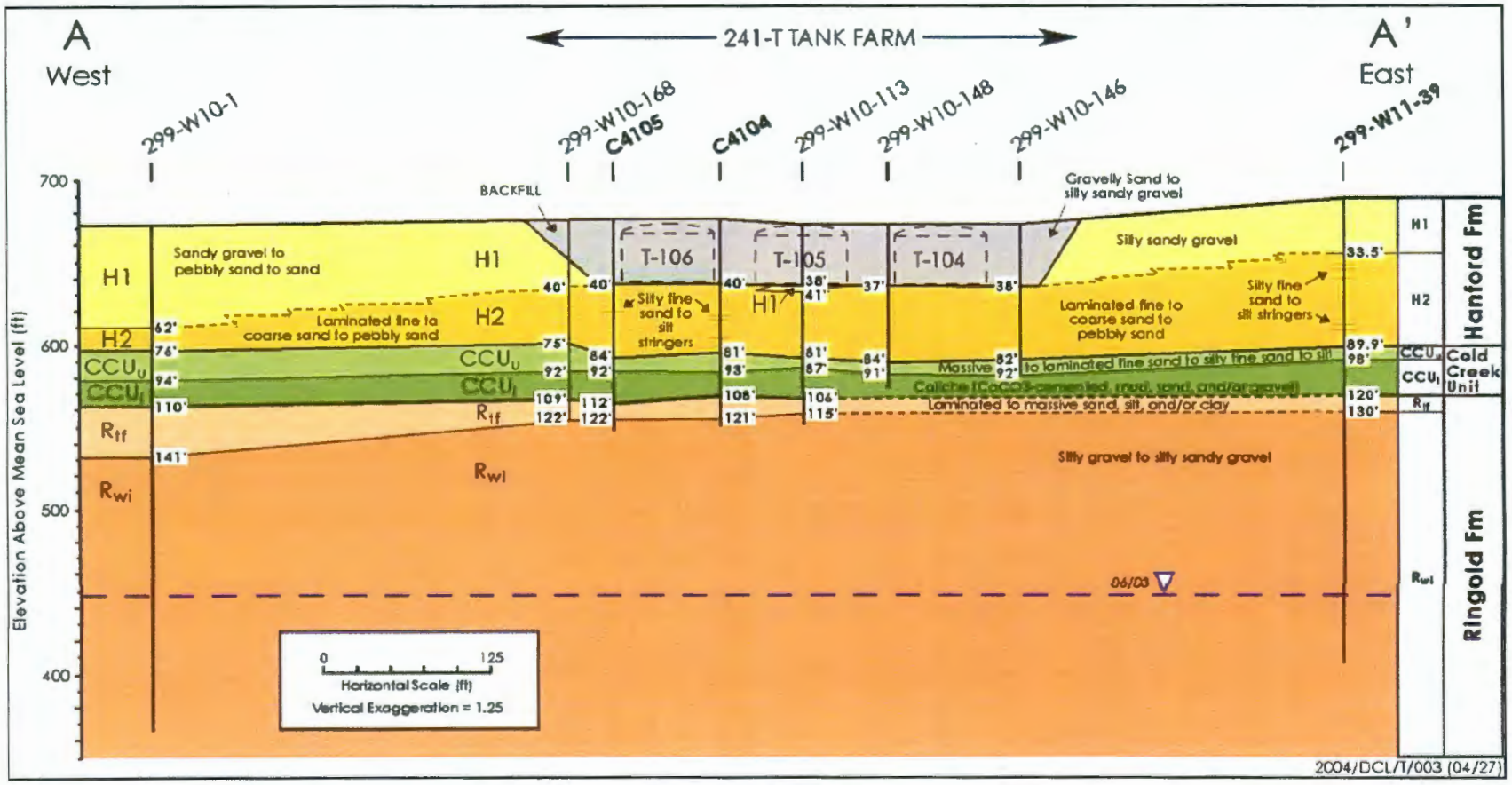
[a] From *RCRA Assessment Plan for Single-Shell Tank Waste Management Area T*, PNNL-15301, Rev. 0 (Horton 2006).

Figure 1-10. Cross-Section Beneath Waste Management Area T.[a]



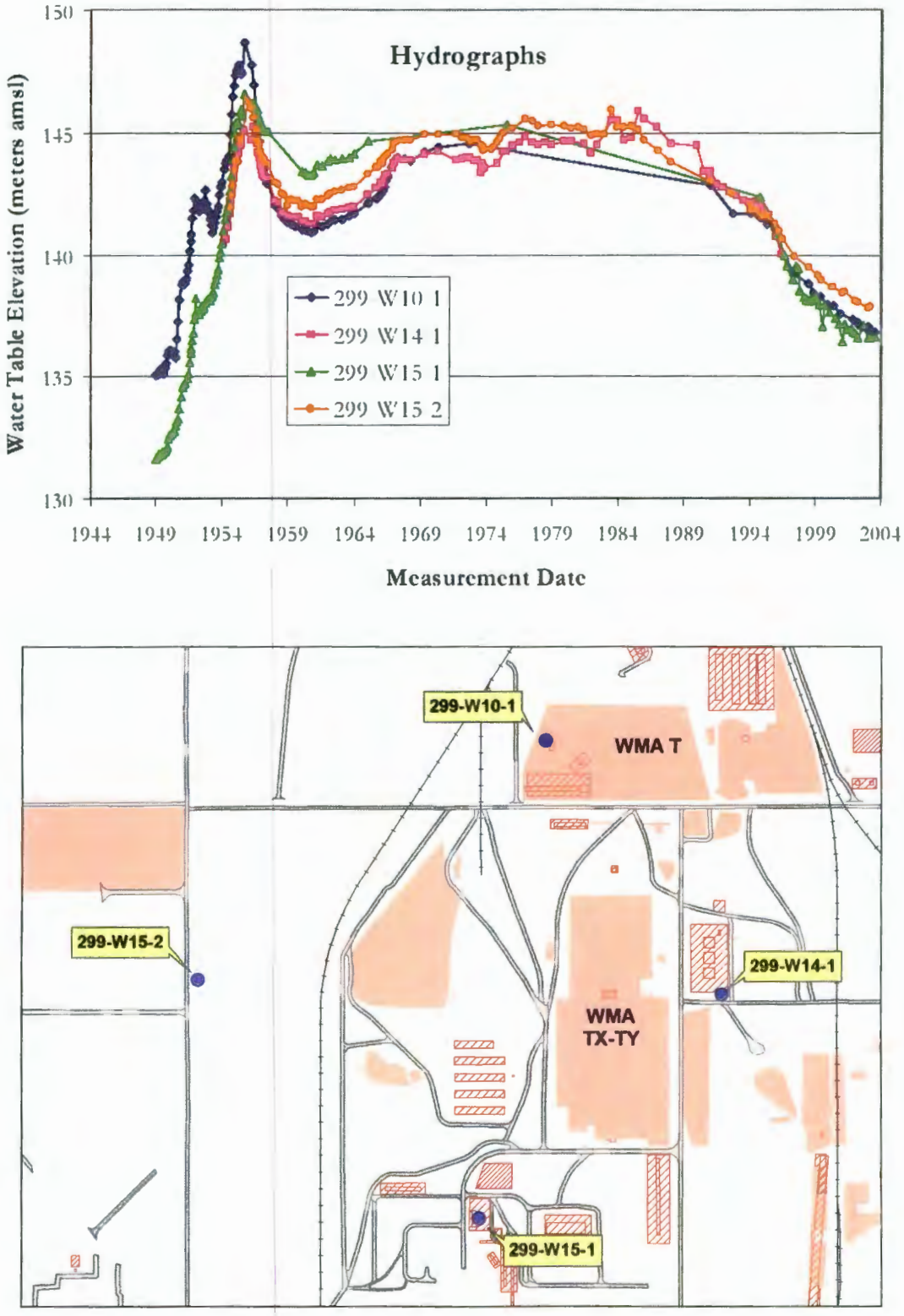
[a] From *RCRA Assessment Plan for Single-Shell Tank Waste Management Area T*, PNNL-15301, Rev. 0 (Horton 2006).

Figure 1-11. Hydrogeologic Cross-Section of the T Tank Farm Showing Backfill Around the Tanks.[a]



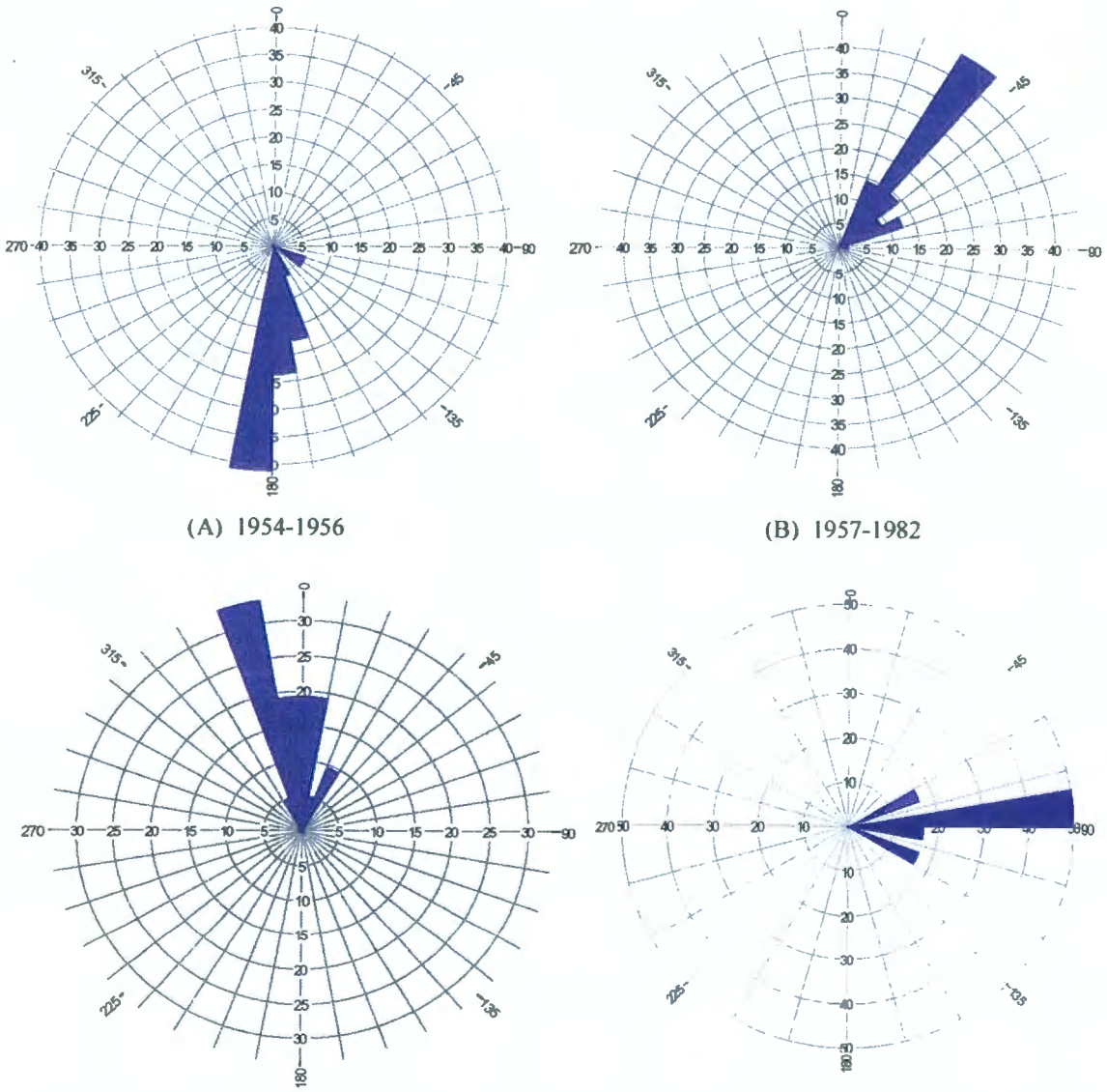
[a] From *Characterization of Vadose Zone Sediments Below the T Tank Farm: Boreholes C4104, C4105, 299-W10-196, and RCRA Borehole 299-W11-39*, PNNL-14849, Rev. 0 (Serne et al. 2004).

Figure 1-12. Hydrographs of Selected Wells in the Northern Portion of the 200 West Area.[a]



[a] From *RCRA Assessment Plan for Single-Shell Tank Waste Management Area T*, PNNL-15301, Rev. 0 (Horton 2006).

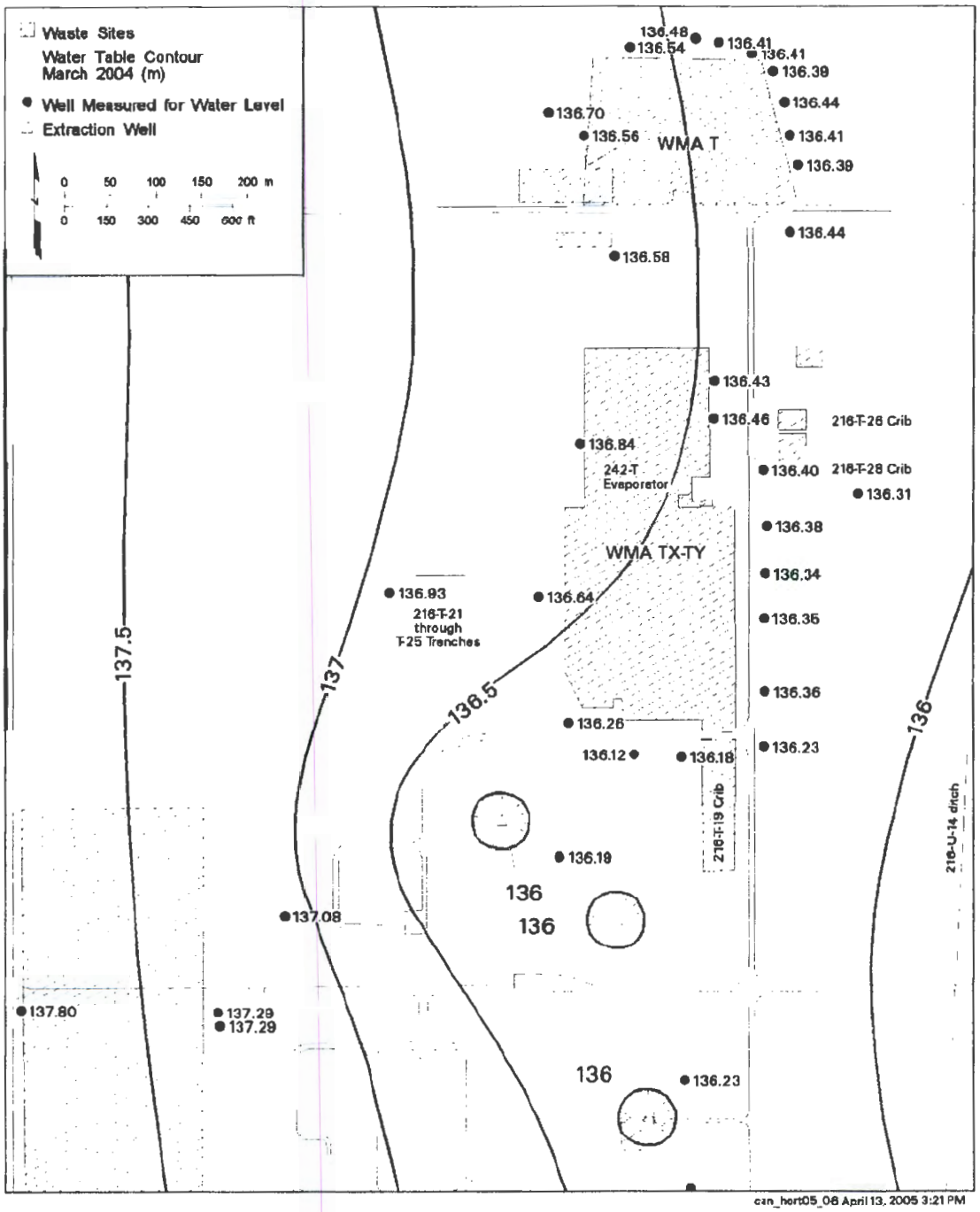
Figure 1-13. Groundwater Flow Directions in the Northern Portion of the 200 West Area.[a]



(A) 1954 to 1956, 1 well triplet, 17 measurements;
(B) 1957 to 1982, 2 well triplets, 56 measurements;
(C) 1983 to 1995, 4 well triplets, 21 measurements;
(D) 1997 to 2003, 3 well triplets, 6 measurements.

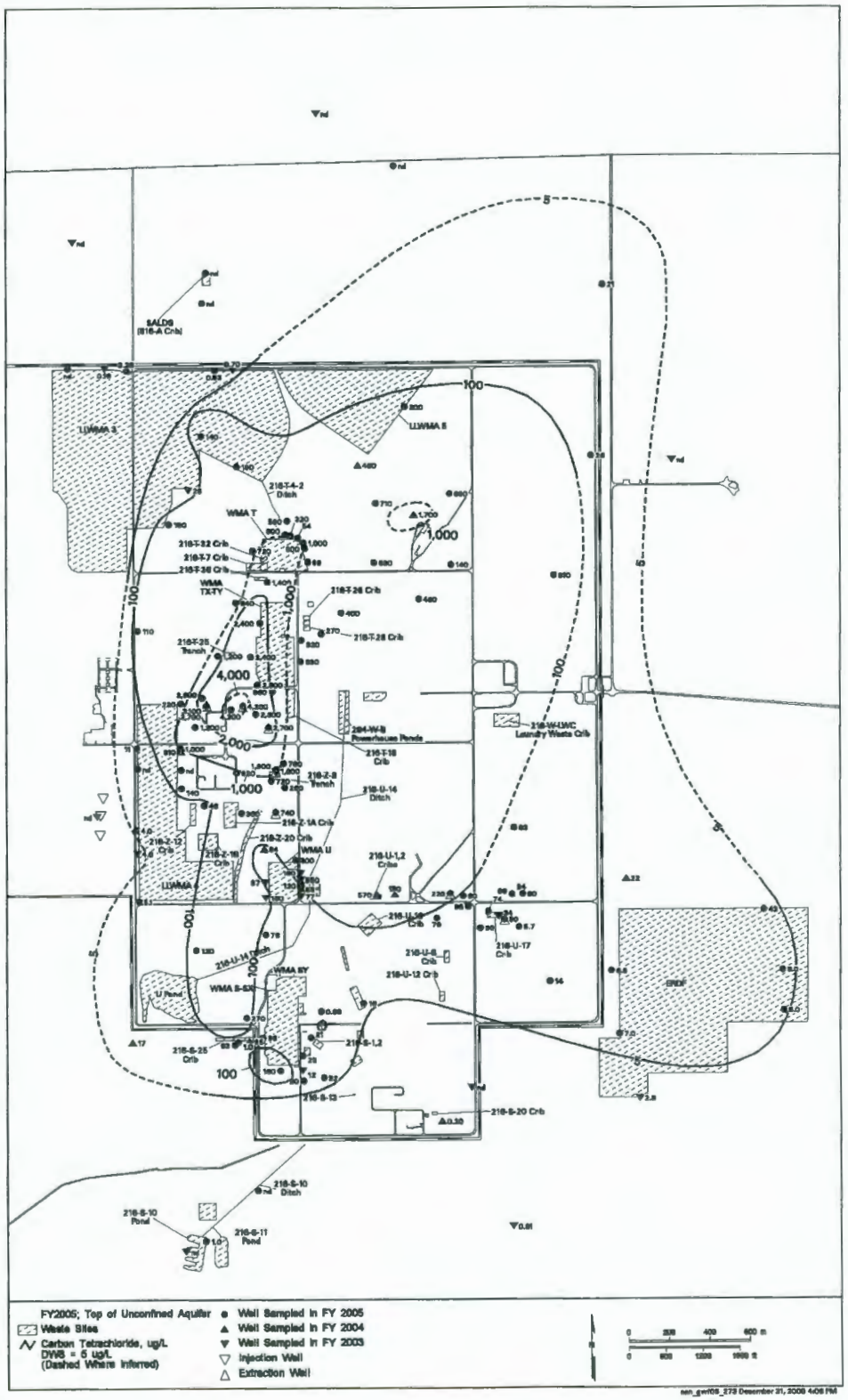
[a] From *RCRA Assessment Plan for Single-Shell Tank Waste Management Area T*, PNNL-15301, Rev. 0 (Horton 2006).

Figure 1-14. March 2004 Water Table Map of the T Area.[a]



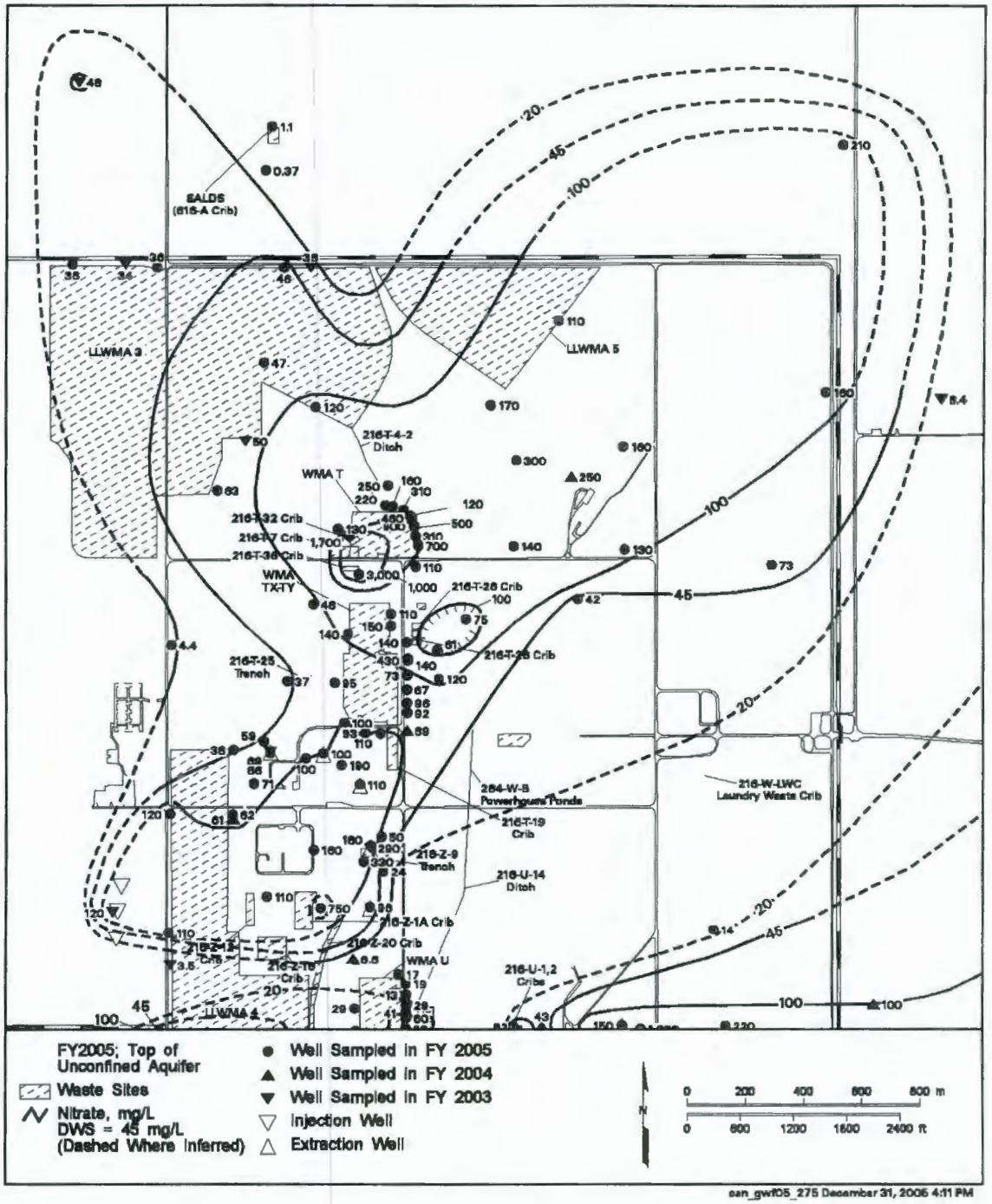
[a] From *RCRA Assessment Plan for Single-Shell Tank Waste Management Area T*, PNNL-15301, Rev. 0 (Horton 2006).

Figure 1-15. Average Carbon Tetrachloride Concentrations in 200 West Area, Top of Unconfined Aquifer.[a]



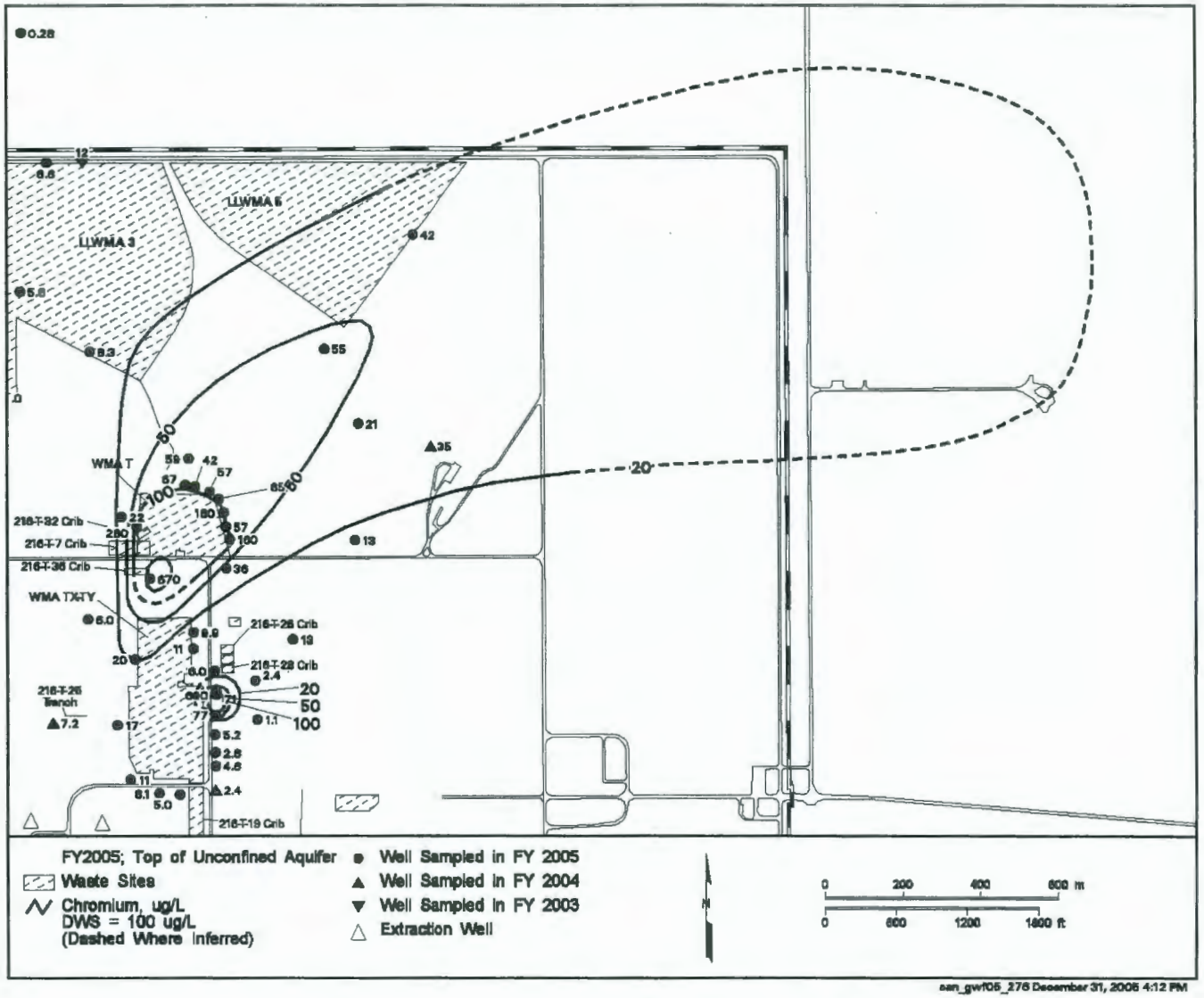
[a] From *Hanford Site Groundwater Monitoring for Fiscal Year 2005*, PNNL-15670, Rev. 0 (PNNL 2006).

Figure 1-16. Average Nitrate Concentrations in Central and North 200 West Area, Top of Unconfined Aquifer.[a]



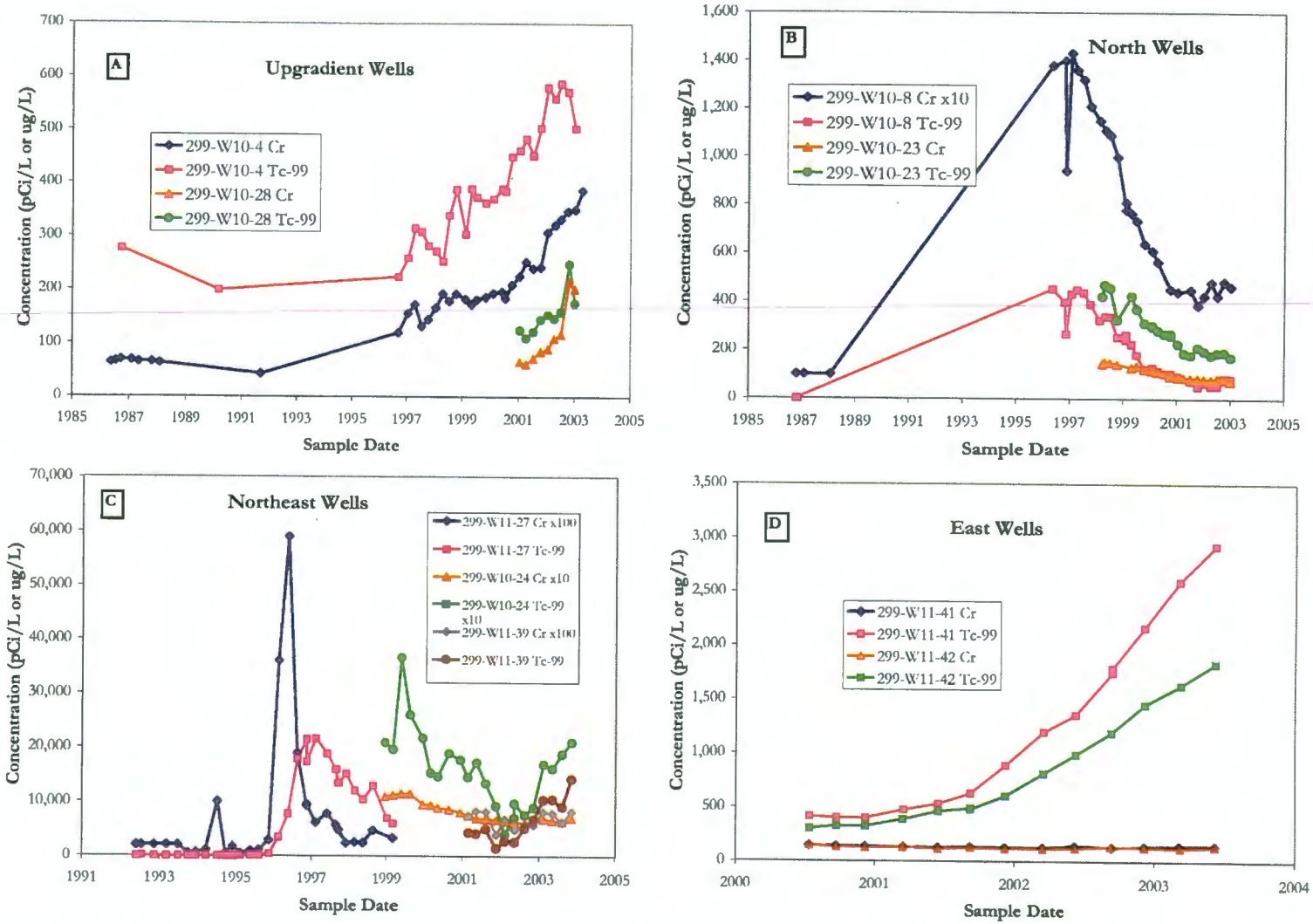
[a] From *Hanford Site Groundwater Monitoring for Fiscal Year 2005*, PNNL-15670, Rev. 0 (PNNL 2006).

Figure 1-17. Average Concentration of Chromium in the T Area, Top of the Unconfined Aquifer.[a]



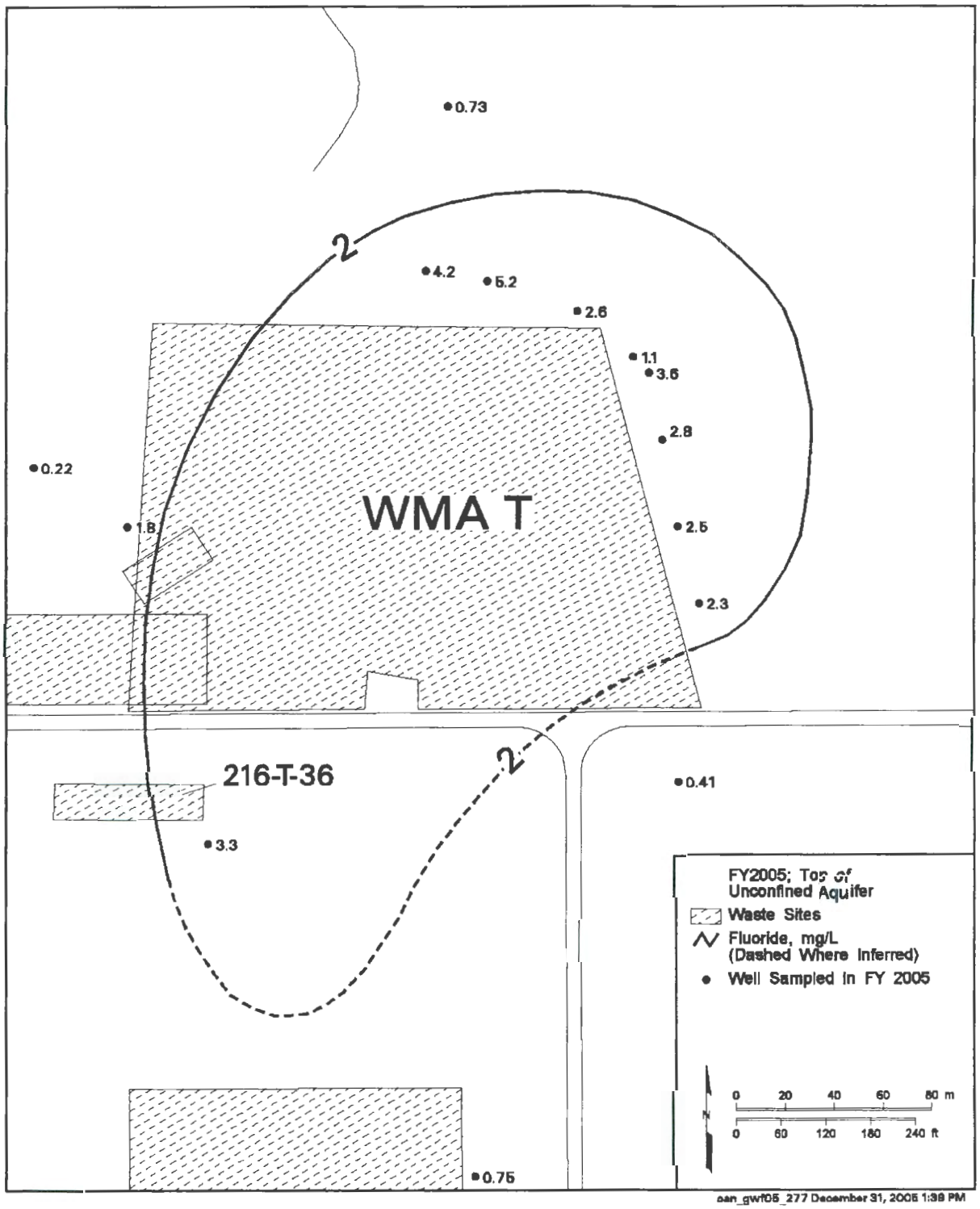
[a] From *Hanford Site Groundwater Monitoring for Fiscal Year 2005*, PNNL-15670, Rev. 0 (PNNL 2006).

Figure 1-18. Technetium-99 and Chromium Concentrations in Selected Wells at Waste Management Area T.[a]



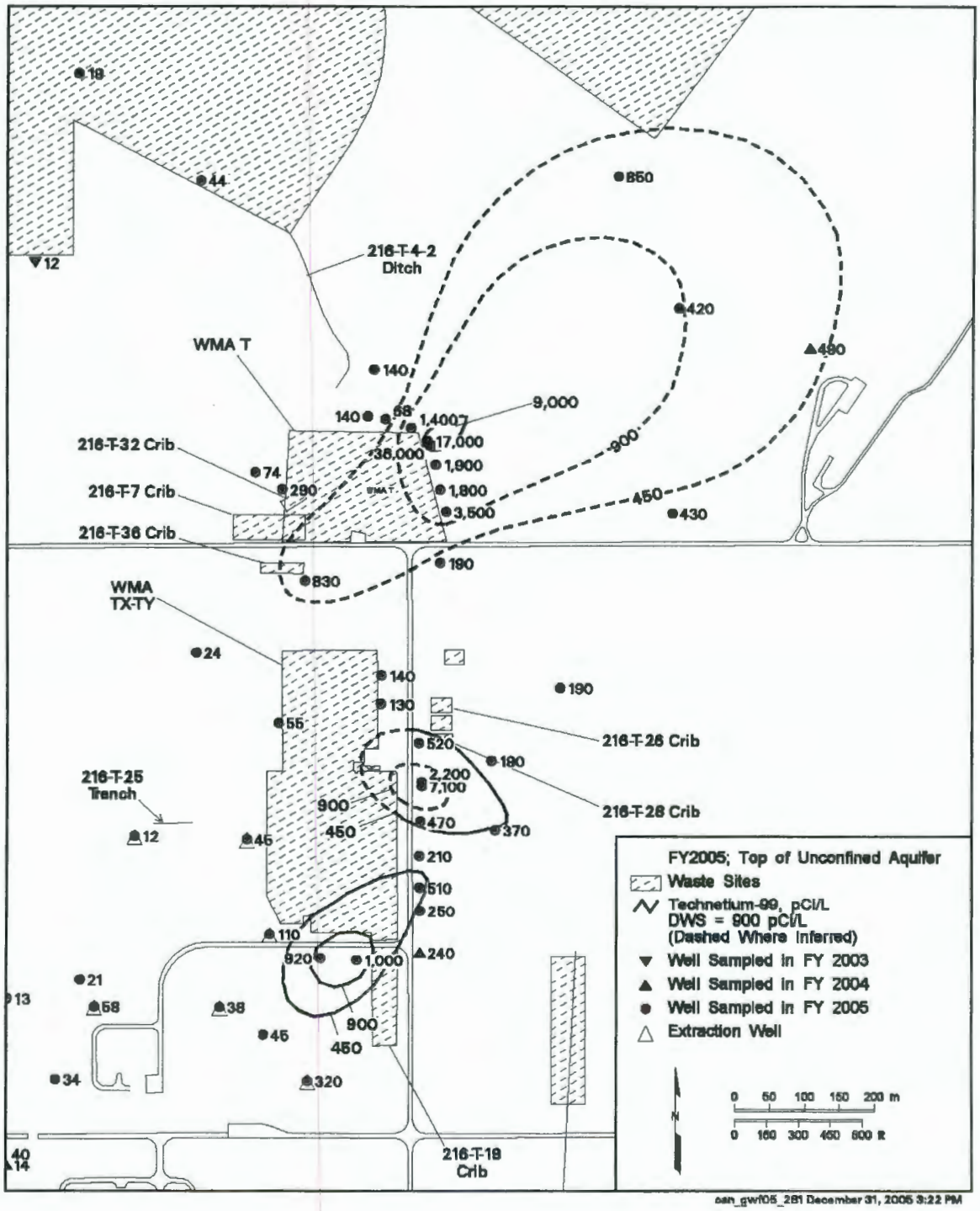
[a] From *RCRA Assessment Plan for Single-Shell Tank Waste Management Area T*, PNNL-15301, Rev. 0 (Horton 2006).

Figure 1-19. Average Fluoride Concentrations Near the T Area in North 200 West Area, Top of the Unconfined Aquifer.[a]



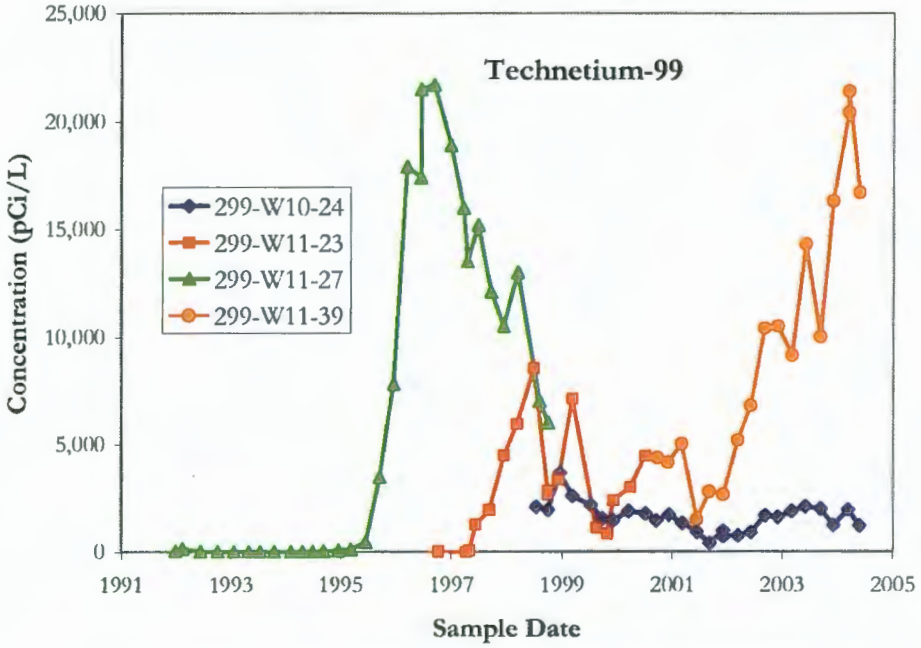
[a] From *Hanford Site Groundwater Monitoring for Fiscal Year 2005*, PNNL-15670, Rev. 0 (PNNL 2006).

Figure 1-20. Average Technetium-99 Concentrations in North 200 West Area, Top of Unconfined Aquifer.[a]



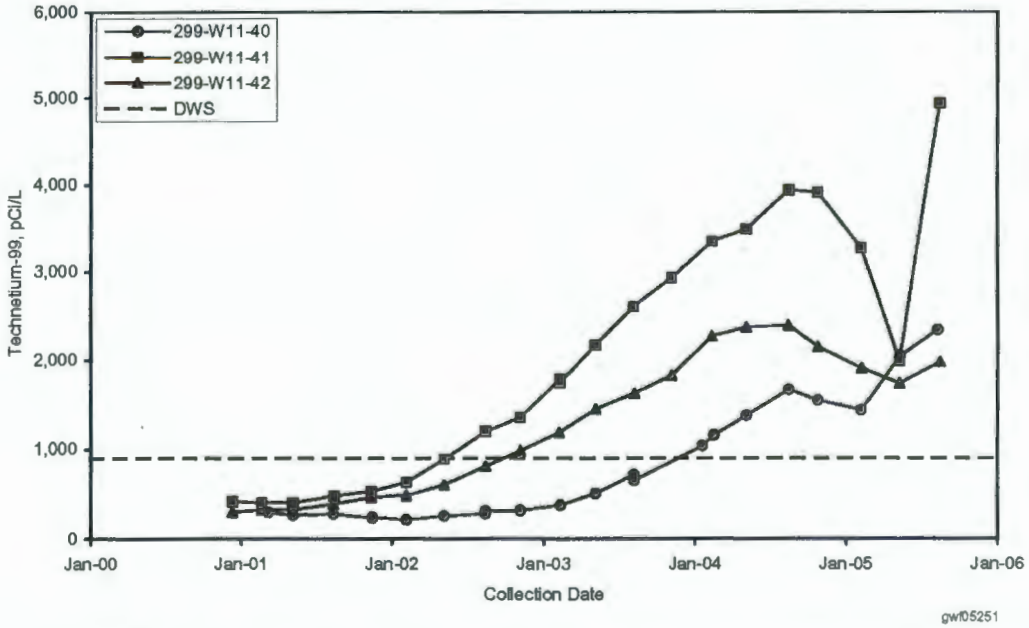
[a] From *Hanford Site Groundwater Monitoring for Fiscal Year 2005*, PNNL-15670, Rev. 0 (PNNL 2006).

Figure 1-21. Technetium-99 Concentrations in Wells at the Northeastern Corner of Waste Management Area T.[a]



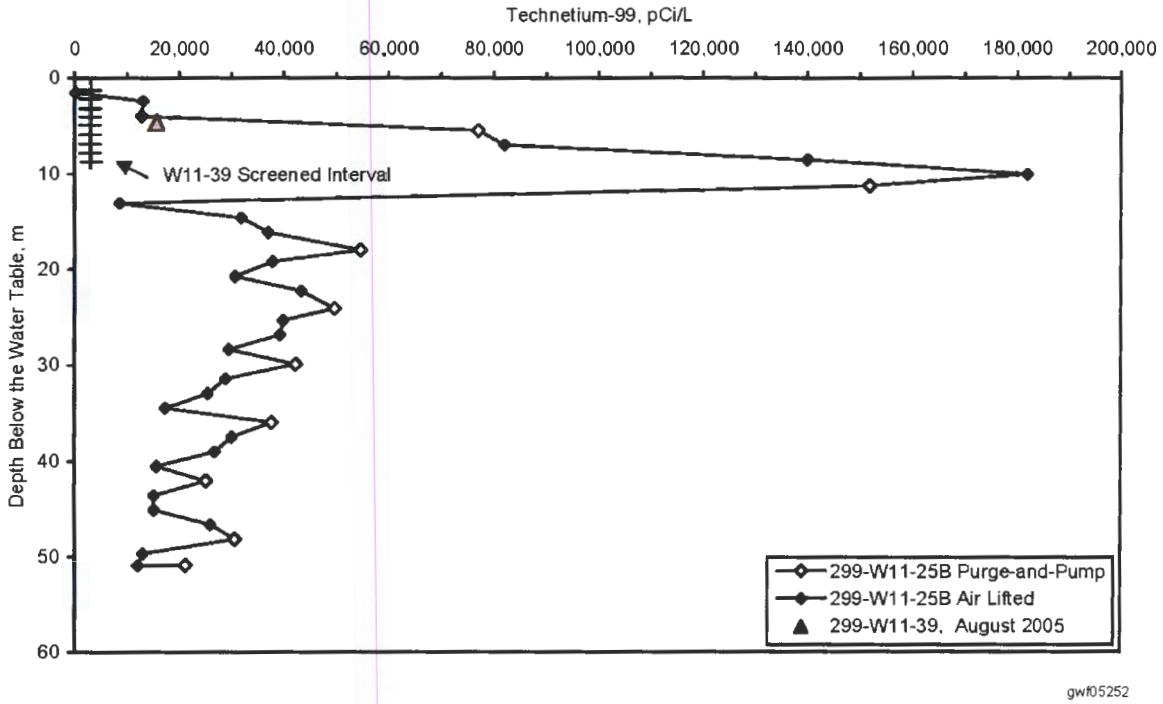
[a] From *RCRA Assessment Plan for Single-Shell Tank Waste Management Area T*, PNNL-15301, Rev. 0 (Horton 2006).

Figure 1-22. Technetium-99 Concentrations in Selected Eastern Wells at Waste Management Area T.[a]



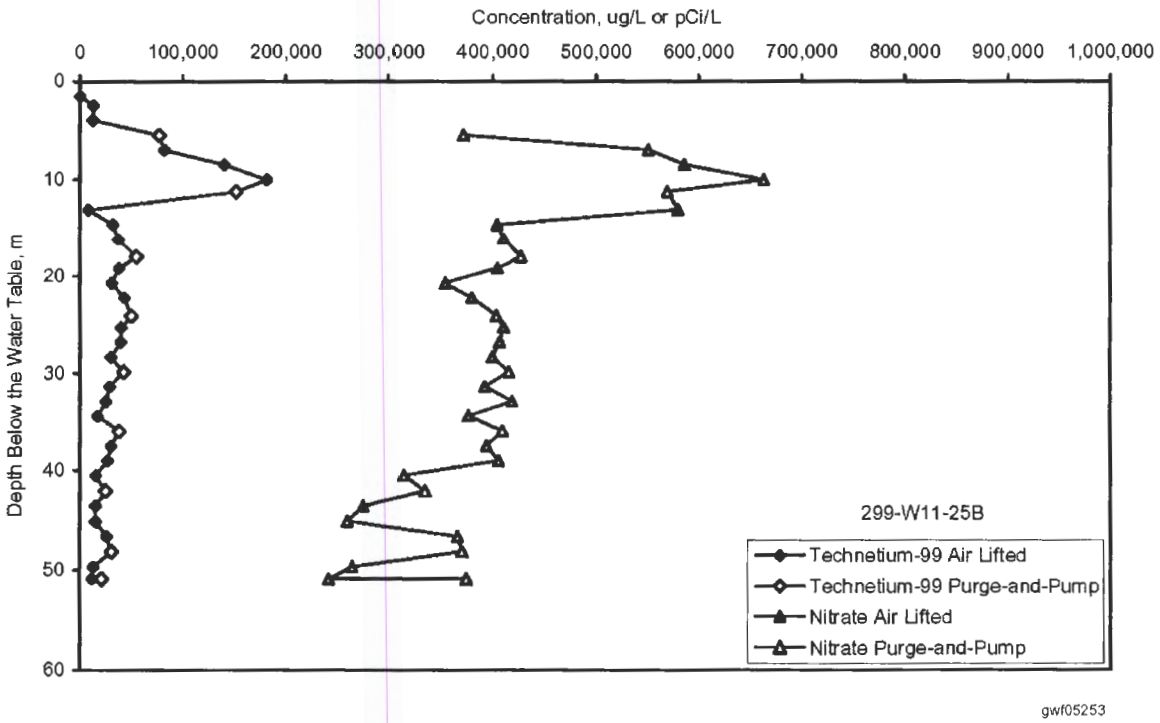
[a] From *RCRA Assessment Plan for Single-Shell Tank Waste Management Area T*, PNNL-15301, Rev. 0 (Horton 2006).

Figure 1-23. Technetium-99 Concentrations at Well 299-W11-25B.[a]



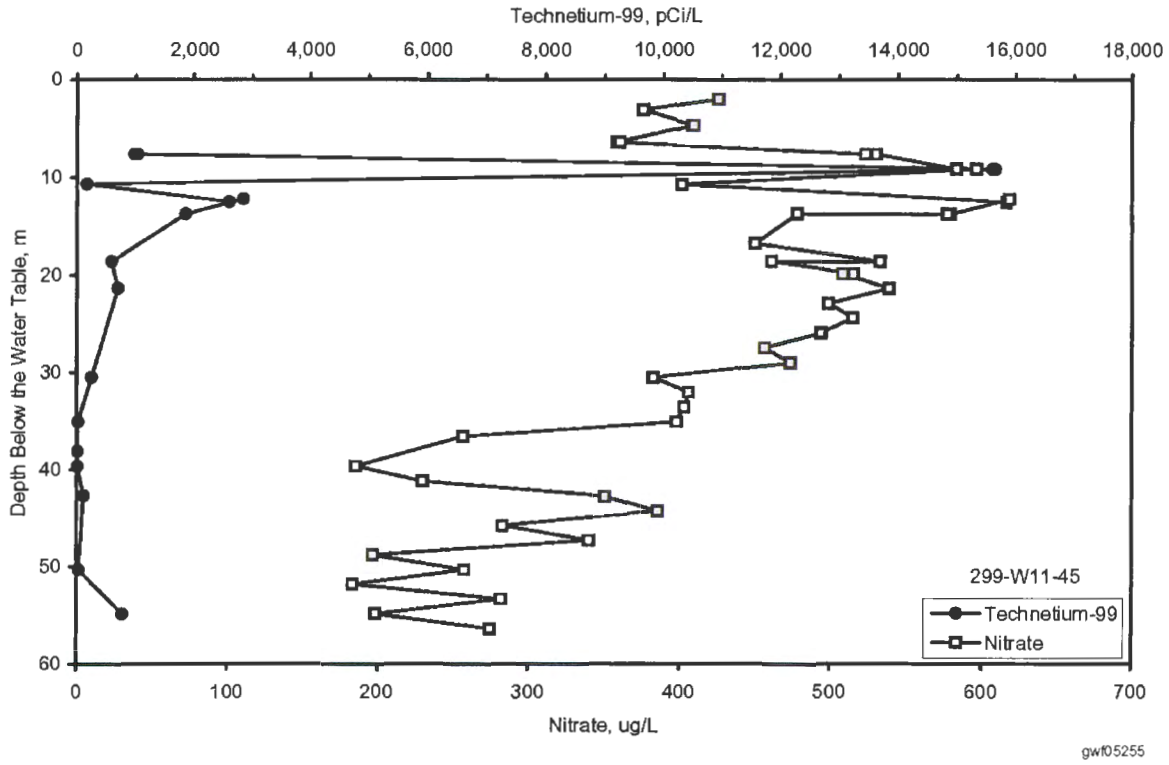
[a] From *Hanford Site Groundwater Monitoring for Fiscal Year 2005*, PNNL-15670, Rev. 0 (PNNL 2006).

Figure 1-24. Depth Distribution of Technetium-99 and Nitrate at Well 299-W11-25B.[a]



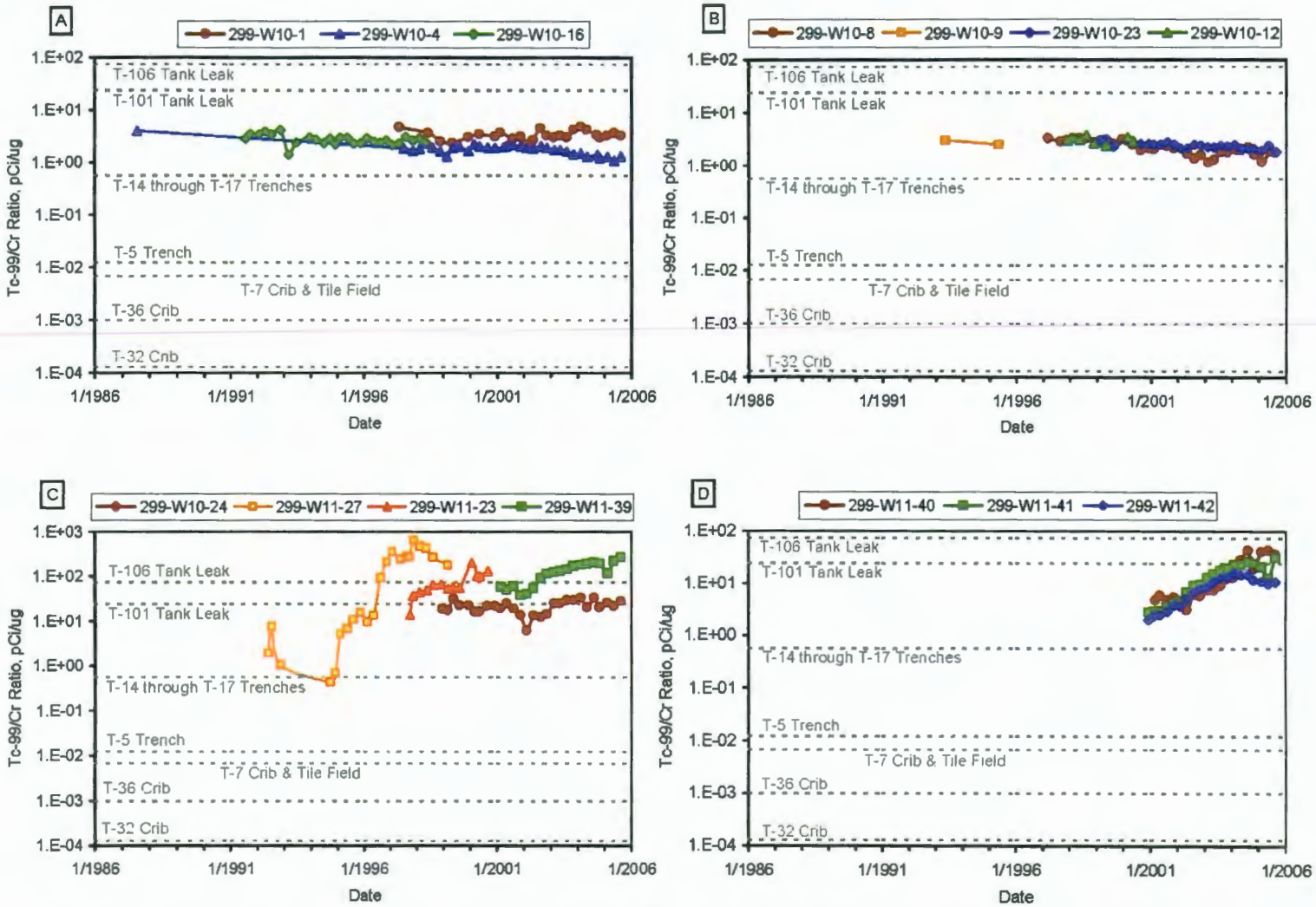
[a] From *Hanford Site Groundwater Monitoring for Fiscal Year 2005*, PNNL-15670, Rev. 0 (PNNL 2006).

Figure 1-25. Technetium-99 and Nitrate Concentrations Encountered During Drilling of Well 299-W11-45.[a]



[a] From *Hanford Site Groundwater Monitoring for Fiscal Year 2005*, PNNL-15670, Rev. 0 (PNNL 2006).

Figure 1-26. Technetium-99/Chromium Concentration Ratios in Samples from Selected Wells at Waste Management Area T.[a]



NOTE: (A) = western wells; (B) = northern wells; (C) = northeastern wells; (D) = eastern wells

[a] From *Hanford Site Groundwater Monitoring for Fiscal Year 2005*, PNNL-15670, Rev. 0 (PNNL 2006).

Figure 1-27. Ruthenium Isotope Ratios in Relationship to Different Processing Plants.

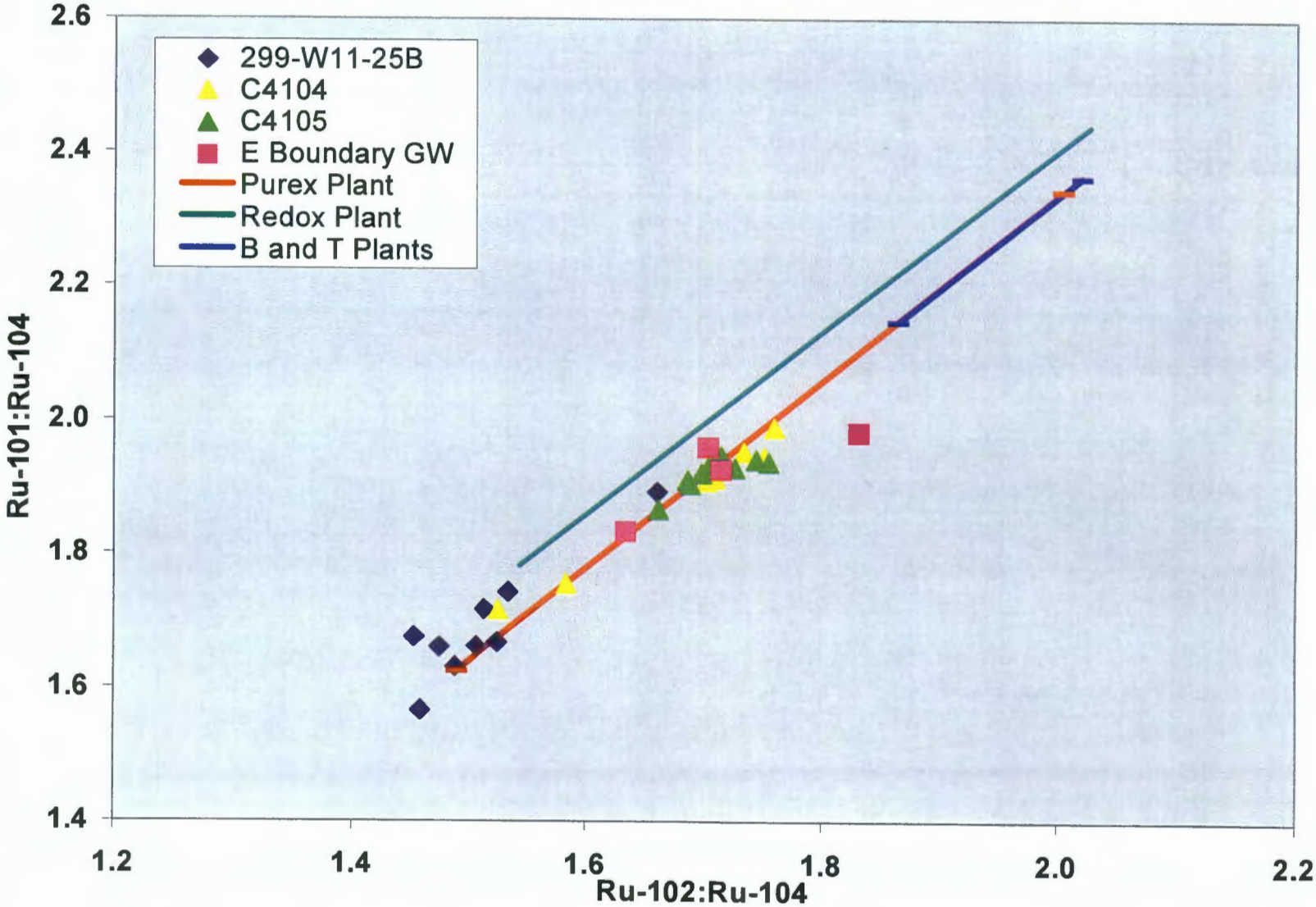
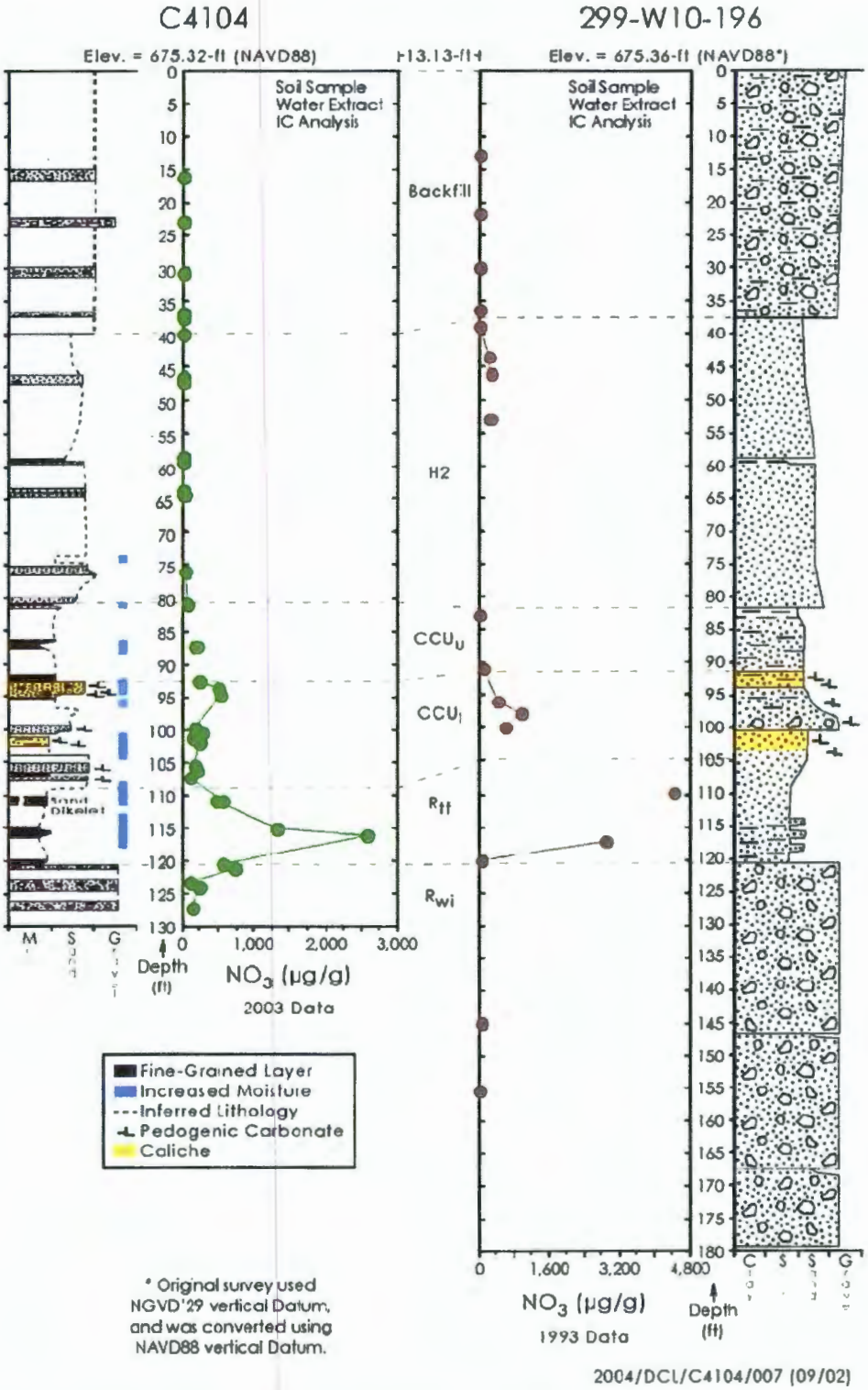
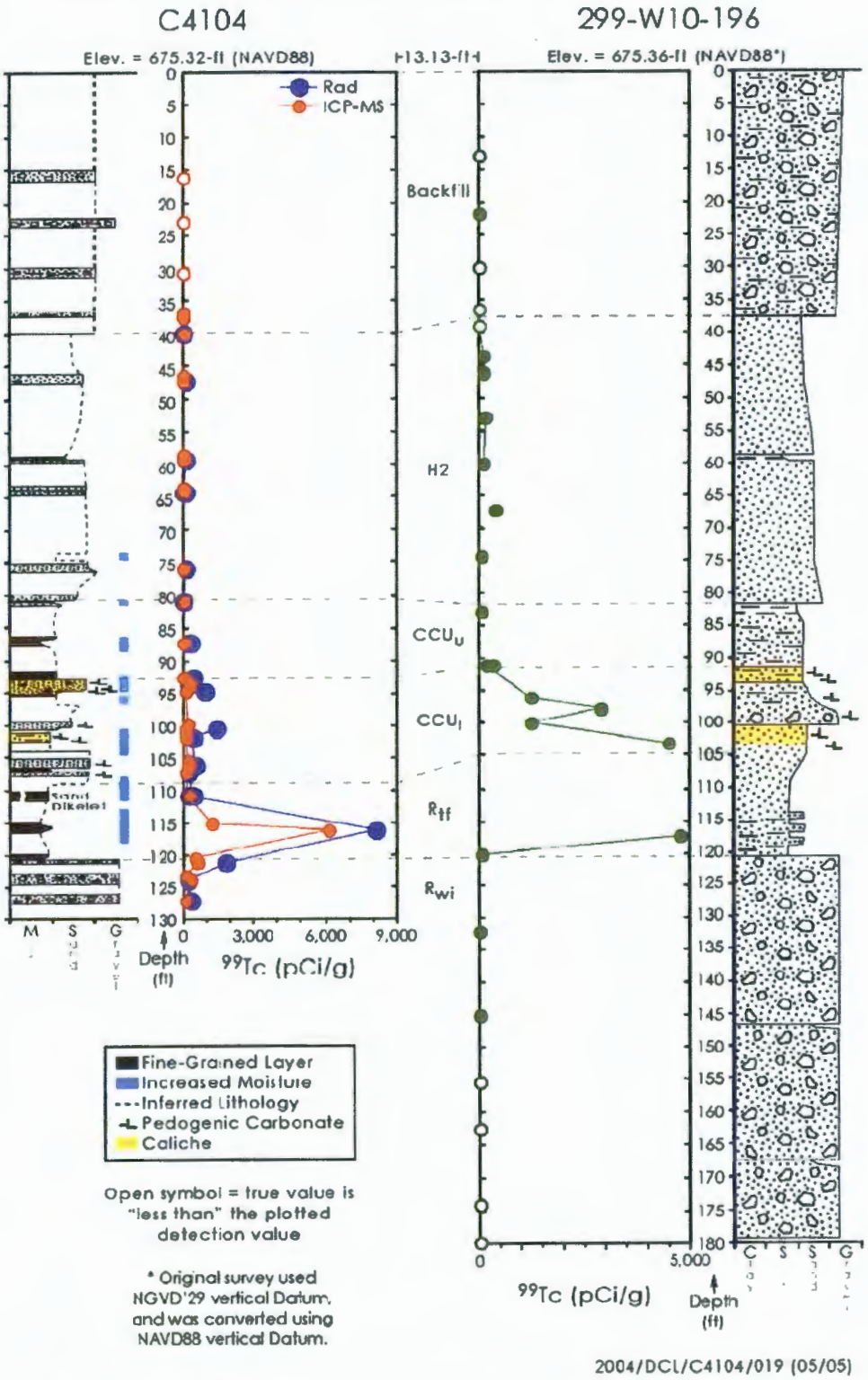


Figure 1-28. Comparison of Nitrate Content in Boreholes C4104 (in 2003) and 299-W19-196 (in 1993).[a]



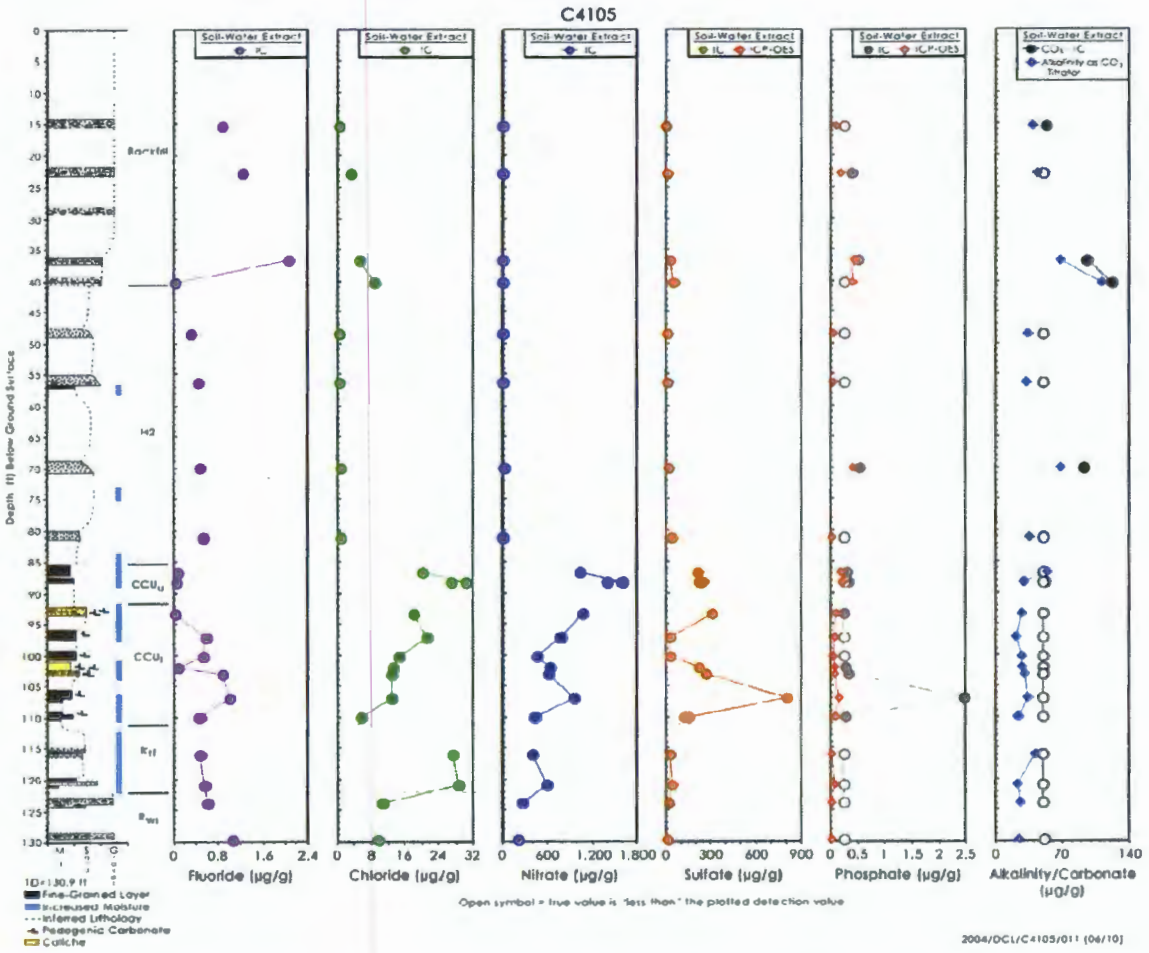
[a] From *Characterization of Vadose Zone Sediments Below the T Tank Farm: Boreholes C4104, C4105, 299-W10-196, and RCRA Borehole 299-W11-39*, PNNL-14849, Rev. 0 (Serne et al. 2004).

Figure 1-29. Comparison of Tc-99 Content in Boreholes C4104 (in 2003) and 299-W19-196 (in 1993).[a]



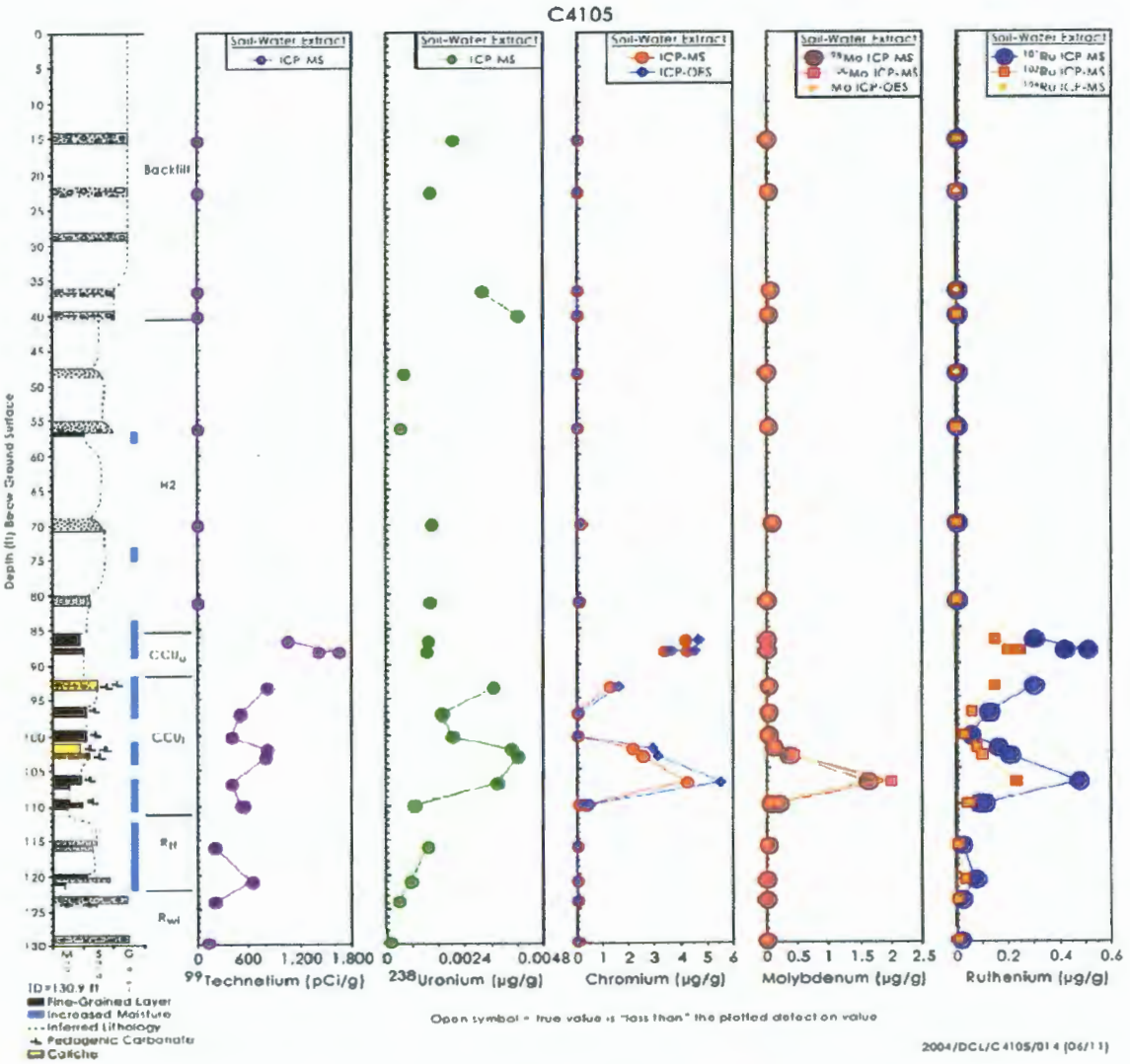
[a] From *Characterization of Vadose Zone Sediments Below the T Tank Farm: Boreholes C4104, C4105, 299-W10-196, and RCRA Borehole 299-W11-39*, PNNL-14849, Rev. 0 (Serne et al. 2004).

Figure 1-30. C4105 Borehole Water-Extractable Anions (µg/g Dry Sediment).[a]



[a] From *Characterization of Vadose Zone Sediments Below the T Tank Farm: Boreholes C4104, C4105, 299-W10-196, and RCRA Borehole 299-W11-39*, PNNL-14849, Rev. 0 (Serne et al. 2004).

Figure 1-31. Distribution of Mobile Metals in Water Extracts of C4105 Vadose Zone Sediments.[a]



[a] From *Characterization of Vadose Zone Sediments Below the T Tank Farm: Boreholes C4104, C4105, 299-W10-196, and RCRA Borehole 299-W11-39*, PNNL-14849, Rev. 0 (Serne et al. 2004).

Figure 1-32. Location of New Characterization Boreholes Installed Adjacent to the 1993 GAO Borehole.

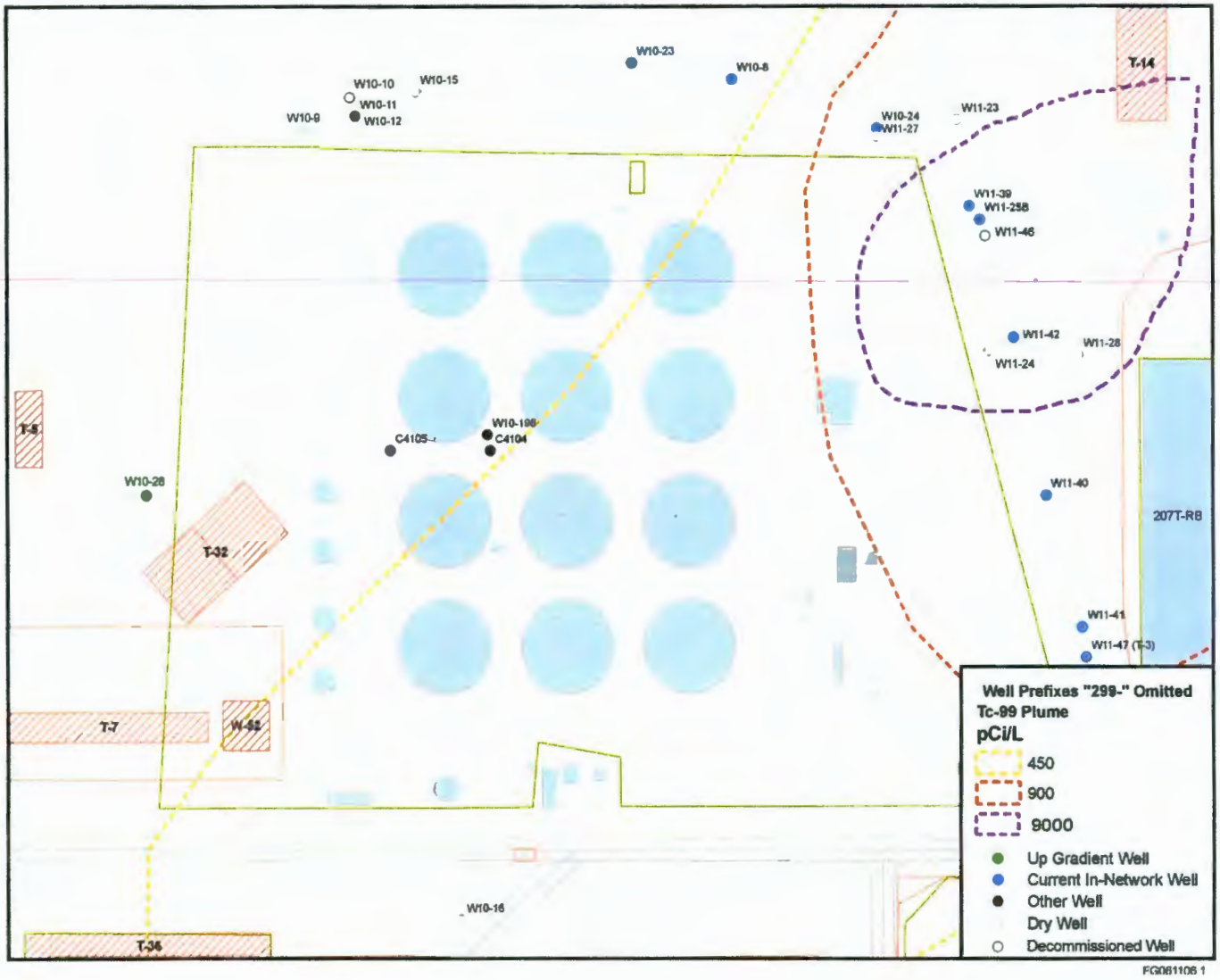


Figure 1-33. Spectral-Gamma Logs from the GAO, C4104, and C4105 Boreholes Around 241-T-106.

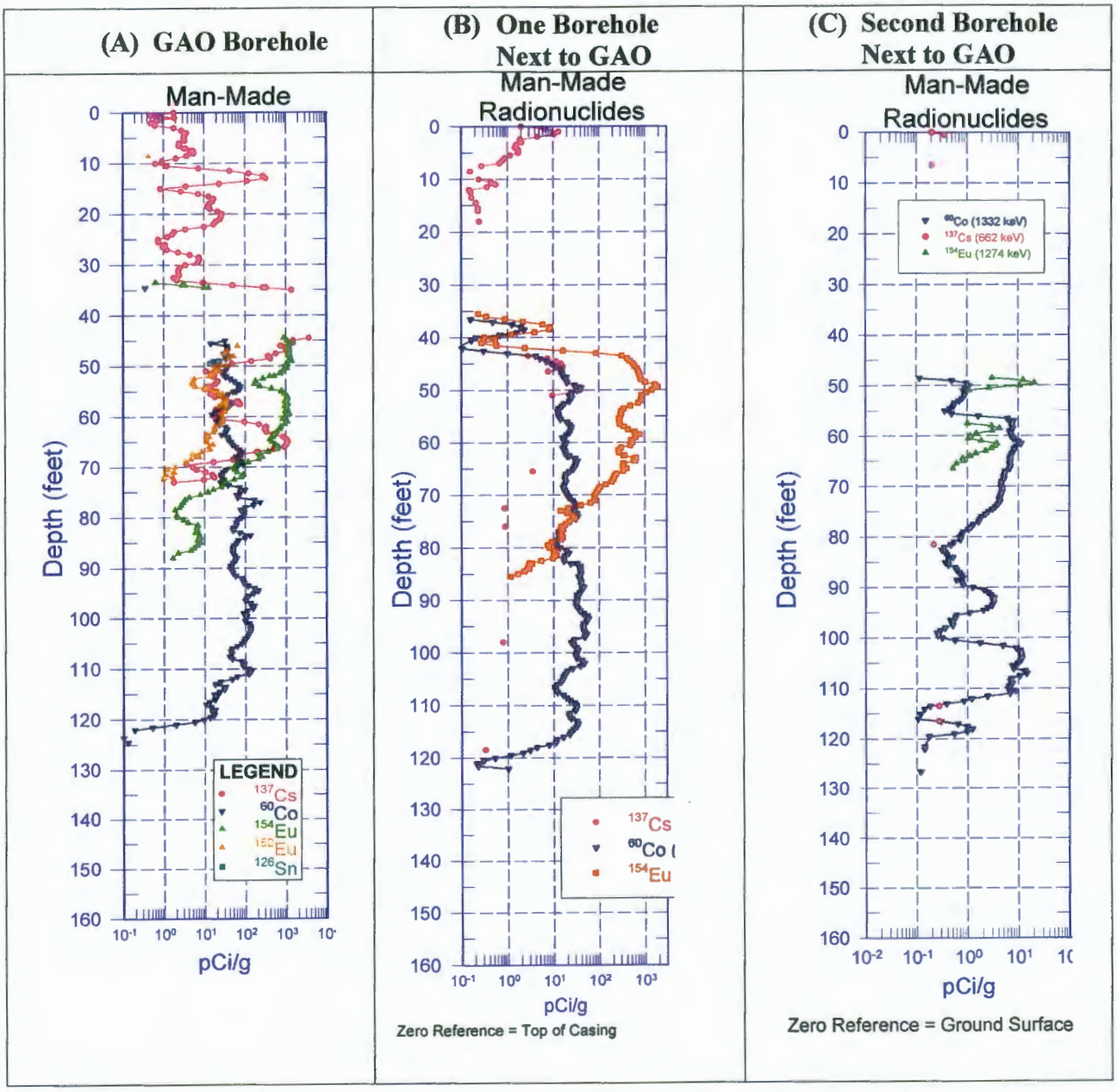
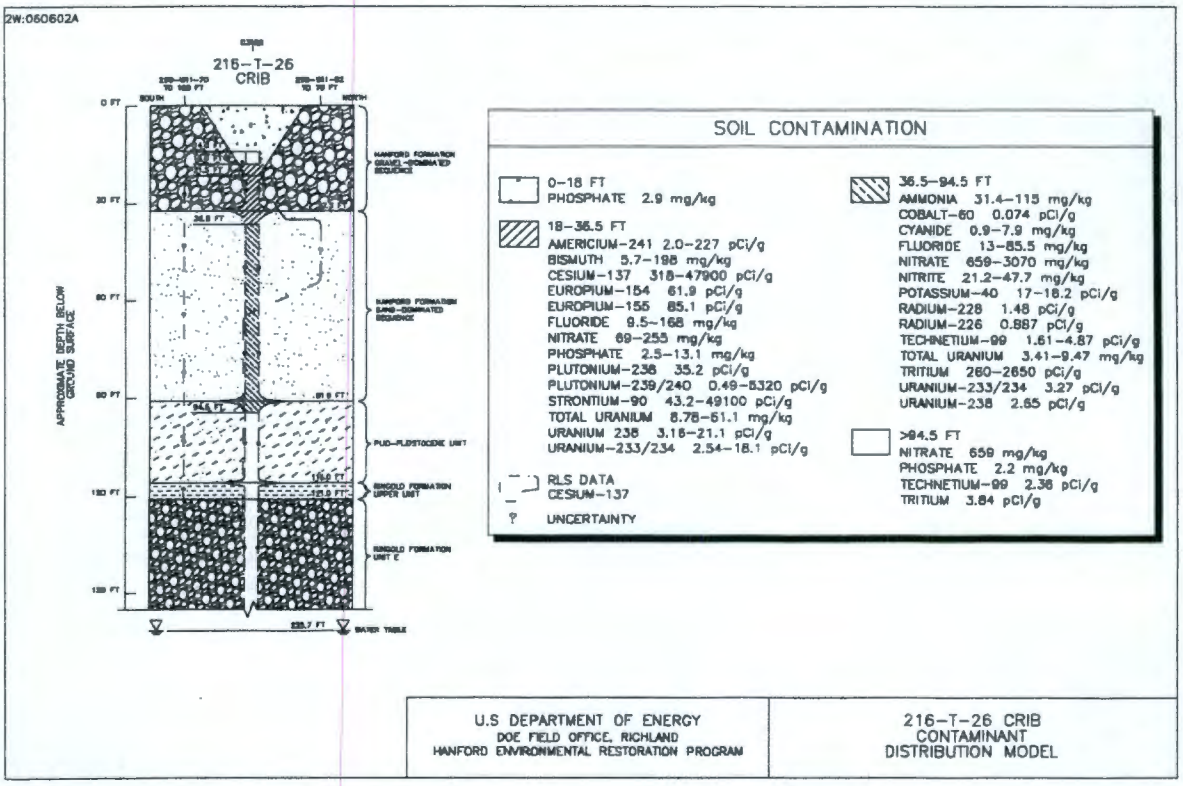


Figure 1-34. 216-T-26 Crib Contaminant Distribution Model.[a]



[a] From *Remedial Investigation Report for the 200-TW-1 and 200-TW-2 Operable Units (Includes the 200-PW-5 Operable Unit)*, DOE/RL-2002-42, Rev. 0 (DOE-RL 2003).

Table 1-1. References Reviewed for the Data Quality Objective Scoping Process. (2 sheets)

Reference	Summary
Historical Vadose Zone Contamination from T, TX, and TY Tank Farm Operations, RPP-5957, Rev. 0 (Williams 2002a)	Provides a description and timeline of events relative to the bismuth-phosphate process (T Plant and B Plant operations), uranium recovery operations, and tank stabilization, and discusses how those processes affected the T, TX, and TY Tank Farms and surrounding areas.
Tank Wastes Discharged Directly to the Soil at the Hanford Site, WHC-MR-0227 (WHC 1991)	Provides quantity of material purposely discharged to the Hanford soils. The text provides volumes discharged and a brief identification of the sources, but limited information is provided on radioactive isotopes and chemicals.
Historical Vadose Zone Contamination from S and SX Tank Farm Operations, HNF-SD-WM-ER-560, Rev. 1 (Williams 2001b)	Similar to RPP-5957 (Williams 2002a), except focused on S and SX Tank Farms and the REDOX Plant operations. Provides some process chemistry information to aid in tracking Tc-99 from the processing plants.
Historical Vadose Zone Contamination from U Farm Operations, RPP-7580, Rev. 0 (Williams 2002b)	Similar to RPP-5957 (Williams 2002a), except focused upon U Tank Farm and how it interfaced with the bismuth-phosphate, uranium recovery, and REDOX Plant operations, as well as in-tank solidification and interim stabilization and isolation.
A History and Discussion of Specific Retention Disposal of Radioactive Liquid Wastes in the 200 Areas, HW-54599 (GE 1958)	Provides a discussion of the background and thought process/criteria used in implementing the specific retention trenches.
Historical Vadose Zone Contamination From A, AX, and C Tank Farm Operations, RPP-7494, Rev. 0 (Williams 2001a)	Similar to RPP-5957 (Williams 2002a), except provides information on PUREX operations and isotope separations (i.e., Cs-137 and Sr-90) in B Plant and other smaller facilities. It also provided some process information to aid in tracking Tc-99 from the various operations.
Radioactive Contamination in Liquid Wastes Discharged to Ground at the Separations Facilities Through December 1963, HW-80877 (GE 1964)	Similar to WHC-MR-0227 (WHC 1991), except it provides more definitive timeline information for included cribs, trenches, etc., and additional information on quantities/volumes released.
Radioactive Contamination in Liquid Waste Discharged to Ground at the Separations Facilities through December, 1964, BNWC-91 (BNW 1965)	Similar to WHC-MR-0227 (WHC 1991), except it provides more definitive timeline information for included cribs, trenches, etc., and additional information on quantities/volumes released.
Historical Vadose Zone Contamination From B, BX, and BY Tank Farm Operations, HNF-5231, Rev. 0 (Williams 1999)	Similar to RPP-5957 (Williams 2002a), except provides information on B Plant operations, isotope separations (i.e., Cs-137 and Sr-90), and other smaller facilities. It also provides some process information to aid in tracking Tc-99 from the various operations.
Appendix B, "Hanford Process Chemistry History," DOE/ORP-2005-01, Rev. 0 (DOE-ORP 2006)	Provides additional details on the various Hanford separations processes that ultimately affected WMA-T.
RCRA Assessment Plan for Single-Shell Tank Waste Management Area T, PNNL-15301 (Horton 2006)	Provides concise background (history) of processes affecting WMA-T and figures showing the various wells, tanks, cribs, etc., as well as unplanned release information.
Inventory of Rhodium, Palladium, and Technetium Stored Hanford Wastes, ARH-1979 (ARH 1971)	Provides Tc-99 information in regard to waste streams and the storage tanks and compares the calculated Tc-99 inventories based upon reactor production and chemical processing, and actual (estimated) inventories based upon samples from various tanks.

Table 1-1. References Reviewed for the Data Quality Objective Scoping Process. (2 sheets)

Reference	Summary
Field Investigation Report for Waste Management Areas T and TX-TY, RPP-23752, Rev. 0 (Myers 2005)	Provides information on the 2005 assessment of the nature and extent of past major releases from the single-shell tanks.
Subsurface Conditions Description of the T and TX-TY Waste Management Areas, RPP-7123, Rev. 0 (CHG 2001)	Provides a description of the subsurface conditions relevant to the occurrence and migration of contaminants in the groundwater.
Characterization of Vadose Zone Sediments Below the TX Tank Farm: Boreholes C3830, C3831, C3832 and RCRA Borehole 299-W10-27, PNNL-14594 (Serne 2004)	Contains data for contaminated vadose zone sediments from three boreholes at TX Tank Farm and one uncontaminated borehole outside the TX Tank Farm fence line. Includes discussion on chemical species ratios in vadose zone porewater and nearby groundwater to evaluate source of contamination.
Characterization of Vadose Zone Sediments Below the T Tank Farm: Boreholes C4104, C4105, 299-W10-196 and RCRA Borehole 299-W11-39, PNNL-14849 (Serne et al. 2004)	Includes data for contaminated vadose zone sediments from three boreholes at T Tank Farm and one uncontaminated borehole outside the T Tank Farm fence line. Includes discussion on chemical species ratios in vadose zone porewater and nearby groundwater to evaluate source of contamination.
Waste Site Grouping for 200 Areas Soil Investigations, DOE/RL-96-81 (DOE-RL 1997)	Provides pore volume estimates for liquid waste disposal sites.
Remedial Investigation Report for the 200-TW-1 and 200-TW-2 Operable Units (Includes the 200-PW-5 Operable Unit), DOE/RL-2002-42 (DOE-RL 2003)	Includes vadose zone characterization data and contaminant conceptual model for selected liquid waste sites in the vicinity of the T Area.

PUREX = Plutonium-Uranium Extraction (Plant)
REDOX = Reduction-Oxidation (Plant)
WMA = waste management area

Table 1-2. Tank Contents for the T Farm Single-Shell Tank as of December 31, 2000. (2 sheets)

Tank	Source Designation/ Waste Type[a]	Waste Volume (L)[b]	Water (wt%)	Tc-99 (Ci/L)	Tc-99 (Total Ci)
241-T-101	Bismuth-phosphate metal waste, tributyl phosphate, supernatant containing coating waste, REDOX ion-exchange waste, REDOX HLW, PNNL laboratory waste, decontamination waste, evaporator bottoms, and 224-U waste	387,600	71.3	2.13E-05	8.24E+00
241-T-102	Bismuth-phosphate metal waste, REDOX coating, supernatant containing REDOX HLW, evaporator bottoms, B Plant ion-exchange waste, and B Plant LLW from tank farms	121,600	66.0	4.40E-07	5.44E-02
241-T-103	Bismuth-phosphate metal waste, coating waste, supernatant containing B Plant LLW, REDOX ion-exchange waste, REDOX HLW, and evaporator bottoms	102,600	60.5	2.05E-05	2.09E+00

Table 1-2. Tank Contents for the T Farm Single-Shell Tank as of December 31, 2000. (2 sheets)

Tank	Source Designation/ Waste Type[a]	Waste Volume (L)[b]	Water (wt%)	Tc-99 (Ci/L)	Tc-99 (Total Ci)
241-T-104	Bismuth-phosphate first-cycle waste	1,691,000	64.8	1.92E-06	3.23E+00
241-T-105	Bismuth-phosphate first-cycle and second-cycle waste, REDOX coating, decontamination waste, Hanford laboratory operations waste, supernatant containing LLW, and ion-exchange waste from tanks	372,400	69.7	3.16E-07	1.17E-01
241-T-106	Bismuth-phosphate first-cycle waste and supernatant containing coating waste, B Plant LLW, and ion-exchange waste from tanks	79,800	49.7	8.43E-07	6.70E-02
241-T-107	Bismuth-phosphate first-cycle waste, tributyl phosphate, supernatant containing bismuth-phosphate first-cycle waste, ion-exchange waste, and coating waste from tank farms	684,000	65.3	5.69E-07	3.88E-01
241-T-108	Tributyl phosphate, bismuth-phosphate first-cycle waste, Hanford laboratory operations waste, supernatant tributyl phosphate, B Plant LLW, ion-exchange waste, and evaporator bottoms from tanks	167,200	48.8	1.93E-06	3.22E-01
241-T-109	Bismuth-phosphate first-cycle waste, tributyl phosphate, supernatant containing tributyl phosphate, ion-exchange waste, evaporator bottoms, and PNNL laboratory waste from tank farms	220,400	37.7	3.15E-06	6.92E-01
241-T-110	Bismuth-phosphate second-cycle waste and 224-U Building waste	1,440,200	75.0	8.19E-08	1.17E-01
241-T-111	Bismuth-phosphate second-cycle waste and 224-U Building waste	1,740,400	77.1	7.92E-08	1.37E-01
241-T-112	Bismuth-phosphate second-cycle waste, PNNL laboratory waste, and supernatant containing B Plant LLW, ion-exchange waste from 241-T tank, and decontamination waste	254,600	83.1	7.75E-08	1.97E-02
241-T-201	224-U Building waste	110,200	69.5	1.10E-08	1.21E-03
241-T-202	224-U Building waste	79,800	68.6	1.14E-08	9.09E-04
241-T-203	224-U Building waste	133,000	68.6	1.14E-08	1.51E-03
241-T-204	224-U Building waste	144,400	68.6	1.14E-08	1.64E-03

[a] Data from *T Plant Source Aggregate Area Management Study Report*, DOE/RL-91-61, Rev. 0 (DOE-RL 1992b).
[b] Data from Hanford Defined Waste Model, Version 4.1 (2000), Los Alamos National Laboratory, Los Alamos, New Mexico (Agnew 1997). Volume, wt% water, and Tc-99 concentrations are given for total waste in tank (all phases combined).

HLW = high-level waste
LLW = low-level waste
PNNL = Pacific Northwest National Laboratory
REDOX = Reduction-Oxidation (Plant)

Table 1-3. Intentional Liquid Waste Release Quantities in the Vicinity of T Area. (2 sheets)

Site	Operable Unit	Location	Source	Waste Type[c]	Date	Quantity (L) (Standard Deviation)[b]	Comments	Pore Volume (m^3)[a]
216-T-3	200-TW-2	East of T Tank Farm	221-T/ 224-T	"5-6 waste"; "224 waste"	06/45 to 08/46	1.13E+07 (0.646)	Reverse well, replaced by 216-T-6	None listed
216-T-4A	200-CW-4	North of T Tank Farm	Multiple	Cooling water and steam condensate	1944-57, 1960-95	4.28E+10	T Pond and ditches	None listed
216-T-5	200-TW-2	West of T Tank Farm	221-T	Second-cycle (2C) waste	5/55	3.15 E+06	Backfilled	None listed
216-T-6	200-TW-2	East of T Tank Farm	221-T/ 224-T	"5-6 waste"	08/46 to 05/51	4.5E+07 (3.329)		1,306
216-T-7	200-TW-2	Southwest of T Tank Farm	221-T/ 224-T	Second-cycle (2C) waste; 224-T effluent; "5-6 waste"	1948 to 1955	1.10E+08 (0.485)	Capacity reached	8,908
216-T-12	200-CW-4	Pit northeast comer of 207-T	207-T	Contaminated sludge	11/54	5.0E+06 (0.041)	Backfilled	214
216-T-14	200-TW-2	Trench west of T Plant	221-T	First-cycle (1C) waste	01/54	1E+06 (0.042)	Capacity reached	4,943
216-T-15	200-TW-2	Trench west of T Plant	221-T	First-cycle (1C) waste	02/54	1E+06 (0.043)	Capacity reached	4,943
216-T-16	200-TW-2	Trench west of T Plant	221-T	First-cycle (1C) waste	02/54	1E+06 (0.042)	Capacity reached	4,943
216-T-17	200-TW-2	Trench west of T Plant	221-T	First-cycle (1C) waste	02/54 to 06/54	7.85E+05 (0.032)	Capacity reached	4,943
216-T-18	200-TW-1	Crib east of TY Tank Farm	221-T	Scavenged tributyl phosphate waste	12/53	1E+06 (0.040)	Test crib	599

Table 1-3. Intentional Liquid Waste Release Quantities in the Vicinity of T Area. (2 sheets)

Site	Operable Unit	Location	Source	Waste Type[c]	Date	Quantity (L) (Standard Deviation)[b]	Comments	Pore Volume (m^3)[a]
216-T-19	200-PW-1	South of TX Tank Farm	242-T	Process condensate from 242-T evaporator; "5-6 waste"; second-cycle (2C) waste, 224-T effluent	11/54	4.31E+08 (6.135)	Backfilled	12,506
216-T-26	200-TW-1	Crib east of TY Tank Farm	221-T	Scavenged first-cycle (1C) waste; scavenged tributyl phosphate waste	08/55 to 11/56	1.2E+07 (0.342)		680
216-T-32	200-TW-2	West side of WMA-T	224-T	224-T effluent	11/46 to 05/52	2.9E+07 (1.258)	Stabilized with gravel	2,644
216-T-36	200-SC-1	Southwest of WMA-T	221-T; 221-U; 2706-T	Steam condensate; decontamination waste; miscellaneous waste	05/67 to 01/69	5.2E+05 (0.015)	Backfilled	5,190

NOTES:

First-cycle (1C) waste: Byproduct from the first plutonium decontamination cycle of the bismuth-phosphate process.
Second-cycle (2C) waste: Byproduct from the second and last plutonium decontamination cycle of the bismuth-phosphate process.
224 waste: Low-level liquid waste from the 224-T Plutonium Concentrator Building.
5-6 waste: Low level liquid waste from floor drains in individual process cells in T Plant.

[a] Information obtained from *Waste Site Grouping for 200 Areas Soil Investigations*, DOE/RL-96-81, Rev. 0 (DOE-RL 1997).

[b] The quantity listed is the mean value. The standard deviation about the mean value is provided in parentheses below the mean value. The mean value plus or minus two times the standard deviation provides a 95% confidence interval of the volume about the mean. The information regarding the mean value and standard deviation was obtained from the SIM (*Hanford Site Inventory Model, Rev. 1* [Corbin et al. 2005]). The SIM also provides data indicating the percentage of results at or below a given volume, illustrating the distribution of the volume within the data set.

[c] Many of the waste types discharged to these sites were byproducts of the bismuth-phosphate process and are described in Section 1.5.1.1.

SIM = Soil Inventory Model
WMA = waste management area

Table 1-4. Unplanned Releases in the T Area.

Site Number	Location	Date	Leak Type	Waste Type	Quantity (ML) (Standard Deviation)[b]	Comments
UPR-200-W-14	Between 242-T and 207-T	10/52	Underground piping leak	Contaminated cooling water	--[a]	Stabilized with clean dirt
UPR-200-W-29	Camden and 23rd Avenue	11/15/54	Underground piping leak	First-cycle waste	0.003785 (1,000 gal) (0.00)	Stabilized with sand
UPR-200-W-62 (aka UPR-200-W-97)	Camden and 23rd Avenue	05/04/66	Underground piping leak	Second-cycle/ bismuth-phosphate waste	0.001996 (0.001)	Stabilized with gravel

[a] The SIM database (*Hanford Soil Inventory Model, Rev. 1*, RPP-26744, Rev. 0 [Corbin et al. 2005]) indicated zero volume and inventory for UPR-200-W-14.

[b] The quantity listed is the mean value. The standard deviation about the mean value is provided in parentheses below the mean value. The mean value plus or minus two times the standard deviation provides a 95% confidence interval of the volume about the mean. The information regarding the mean value and standard deviation was obtained from the SIM (Corbin et al. 2005). The SIM also provides data indicating the percentage of results at or below a given volume, illustrating the distribution of the volume within the data set.

aka = also known as
ML = million liters
SIM = Soil Inventory Model
UPR = unplanned release

Table 1-5. T Tank Farm Tank Leak Summary.

Tank Number	Liquid Level or Waste Transfer Record Indicate Leak?	Gamma-Logging Data Indicate Leak?	Estimated Leak Volume (gal)[a,b]	Leak/ Assumed Leak Date
241-T-101	Yes	Yes	7,500	1969
241-T-103	Yes	Yes	< 1,000	1973
241-T-106	Yes	Yes	115,000	1973
241-T-107	Yes	No	6	Unlikely or negligible (before 1976)
241-T-108	Yes	No	< 1,000	Unlikely or negligible (around 1974)
241-T-109	Yes	No	< 1,000	Unlikely or negligible (around 1974)
241-T-111	Yes	No	< 1,000	Unlikely or negligible (around 1974)

[a] Source: *Waste Tank Summary Report for Month Ending September 30, 2004*, HNF-EP-0182, Rev. 198 (Hanlon 2004).

[b] Appendix A provides estimated supernate inventories for each of these tanks at the time of the leaks, as well as estimated current entrained liquid radioisotope inventories.

Table 1-6. Results from Tracer-Dilution and Tracer Pump-Back Tests in Wells in Waste Management Area T.[a]

Well	Effective Porosity[b]	Horizontal Groundwater[b] Flow Velocity (m/day)	Average in Well Horizontal Flow Velocity[c]
299-W10-24	0.072	0.029	0.012
299-W11-39[d]	0.022	0.045	0.014
299-W11-40[e]	0.002	1.1	0.176

[a] Source: *RCRA Assessment Plan for Single-Shell Tank Waste Management Area T*, PNNL-15301, Rev. 0 (Horton 2005).
[b] Data from tracer pump-back tests.
[c] Data from tracer dilution tests.
[d] Slight downward vertical flow, data uncertain.
[e] Strong downward vertical flow, data highly uncertain.

Table 1-7. Hydraulic Properties from Slug and Constant Rate Pumping Tests and Calculated Horizontal Flow Velocities at New Wells at Waste Management Area T.[a]

Well	Hydraulic[b,c] Conductivity (m/day)	Hydraulic[b,d] Conductivity (m/day)	Transmissivity[b,d] (m^2/day)	Specific[b,d] Yield	Calculated Flow Velocity (m/day)
299-W10-23	1.62 to 2.35	ND	ND	ND	0.024[d]
299-W10-24	1.04 to 1.68	1.22	66	0.11	0.023[g]
299-W10-28	27.9[h]	ND	ND	ND	0.23[f]
299-W11-39	1.31 to 1.69	0.85	44	0.1	0.017[e]
299-W11-40	3.56 to 4.58	2.02	103	0.1	0.046[e]
299-W11-41	7.57 to 7.78	ND	ND	ND	0.078[f]
299-W11-42	28.1[h]	ND	ND	ND	0.28[f]

[a] Source: *RCRA Assessment Plan for Single-Shell Tank Waste Management Area T*, PNNL15301, Rev. 0 (Horton 2005).
[b] Data from *Results of Detailed Hydrologic Characterization Tests – Fiscal Year 1999*, PNNL-13378, Rev. 0 (Spane et al. 2001); *Results of Detailed Hydrologic Characterization Tests – Fiscal Year 2001*, PNNL-14113, Rev. 0, (Spane et al. 2002); and *Results of Detailed Hydrologic Characterization Tests – Fiscal Year 2002*, PNNL-14186, Rev. 0 (Spane et al. 2003).
[c] Slug test data.
[d] Constant pumping test data.
[e] Estimated using maximum hydraulic conductivity value, a gradient of 0.001, and specific yield from this table. Specific yield was used because downward flow in the well resulted in uncertain effective porosity.
[f] Estimated using maximum hydraulic conductivity value, a gradient of 0.001, and effective porosity values of 0.1.
[g] Estimated using maximum hydraulic conductivity value, a gradient of 0.001, and effective porosity value from Table 2.6 in *RCRA Assessment Plan for Single-Shell Tank Waste Area T*, PNNL-15301, Rev. 0 (Horton 2006).
[h] Indicates average hydraulic conductivity obtained from high-permeability, non-linear type-curve analysis method.
ND = not determined

Table 1-8. Comparison of Technetium-99 and Nitrate Representative Inventory Distribution with Depth at Boreholes 299-W10-196, C4104, and C4105 Based on Soil Water-Extraction Data.[a]

Depth Interval ft bgs/ (Stratigraphy)	Borehole 299-W10-196		Borehole C4104		Borehole C4105	
	pCi	% of Total	pCi	% of Total	pCi	% of Total
Tc-99 Inventory and Distribution						
~40 to ~85/(H2)	3.32E+05	5.29	7.78E+03	0.45	0.00E+00	0
~85 to 100/ (H2/CCU_u)	5.37E+05	8.58	6.44E+04	3.72	7.28E+05	51.9
~100 to 110/ (H2/CCU_2)	1.77E+06	28.3	6.63E+04	3.83	3.00E+05	21.4
~110 to 145 (R_{tf})	3.63E+06	57.9	1.59E+06	92.0	3.75E+05	26.7
Totals	**6.27E+06**	**100**	**1.73E+06**	**100**	**1.40E+06**	**100**
Nitrate Plus Nitrite Inventory and Distribution						
~40 to ~85/(H2)	6.84E+05	13.5	5.26E+04	3.32	2.05E+04	1.16
~85 to 100/ (H2/CCU_u)	2.28E+05	4.84	2.47E+05	15.61	8.36E+05	47.4
~100 to 110/ (H2/CCU_2)	1.10E+06	23.3	1.42E+05	8.96	3.49E+05	19.8
~110 to 145 (R_{tf})	2.80E+06	58.3	1.15E+06	72.1	5.57E+05	31.6
Totals	**4.81E+06**	**100**	**1.59E+06**	**100**	**1.76E+06**	**100**

[a] Source: *Field Investigation Report for Waste Management Areas T and TX-TY*, RPP-23752, Rev. 0-A (Myers 2005).

CCU = Cold Creek unit
H2 = Hanford formation sand sequence
R_{tf} = Taylor Flats member of the Ringold Formation

Table 1-9. T Area Best Estimate or Mean Radionuclide Soils Inventory. (3 sheets)

Waste Site - Groupings		Radionuclide			Volume (ML)[a]
		Tc-99 (Ci)	I-129 (Ci)	U-234/238 (Ci)	
207-T Retention Basin and 216-T-4 Pond					
216-T-4A	Mean[b]	0.067116	0.000443	0.40306	4.28E+04
	Standard deviation[b]	0.023	0.0[e]	0.125	1,025.08
216-T-12	Mean[b]	0.008516	8.90E-06	0.14467	5.005012
	Standard deviation[b]	0.004	0.0[e]	0.082	0.485
Subtotal		0.075632	0.000452	0.54773	42,831.72
		0.18%	0.00%	36.06%	99.47%
Cribs, Trenches, or Tile Fields Inside WMA-T					
200-W-52	Mean[b]	0.013812	0	0.014601	7.78
	Standard deviation[b]	0.035	0.0[e]	0.041	6.183
216-T-7	Mean[b]	0.1901	1.49E-05	0.2241	107.1242
	Standard deviation[b]	0.035	0.0[e]	0.041	6.183
216-T-32	Mean[b]	0.001334	2.28E-07	0.0003841	29
	Standard deviation[b]	0.001	0.0[e]	0.0[e]	1.26
Subtotal		0.205246	1.52E-05	0.2390851	143.9042
		0.49%	0.00%	15.74%	0.33%
Gravel Trench West of WMA-T					
216-T-5	Mean[b]	0.014985	0	0.015984	3.150005
	Standard deviation[b]	0.007	--	0.009	0.32
Subtotal		0.014985	0	0.015984	3.150005
		0.04%	0.00%	1.05%	0.01%
Trenches East of WMA-T					
216-T-3	Mean[b]	0.000957	4.24E+07	0.001327	17.3
	Standard deviation[b]	0.0[e]	0.0[e]	0.0[e]	0.646
216-T-6	Mean[b]	0.007872	3.49E+06	0.013776	45.0
	Standard deviation[b]	0.003	0.0[e]	0.003	3.329
216-T-14	Mean[b]	0.20339	0.001775	0.022739	1.006001
	Standard deviation[b]	0.094	0.001	0.011	0.041
216-T-15	Mean[b]	0.21071	0.001839	0.023546	1.042
	Standard deviation[b]	0.098	0.001	0.012	0.043
216-T-16	Mean[b]	0.20627	0.0018	0.023056	1.020001
	Standard deviation[b]	0.095	0.001	0.011	0.042
216-T-17	Mean[b]	0.15872	0.001385	0.017749	0.785001
	Standard deviation[b]	0.073	0.001	0.009	0.032
Subtotal		0.787919	4.589E+07	0.102193	66.153003
		1.88%	100.00%	6.73%	0.15%

Table 1-9. T Area Best Estimate or Mean Radionuclide Soils Inventory. (3 sheets)

Waste Site - Groupings		Radionuclide			Volume (ML)[a]
		Tc-99 (Ci)	I-129 (Ci)	U-234/238 (Ci)	
UPRs and Cribs South of WMA-T					
216-T-18	Mean[b]	0.153947	0.001484	0.036589	0.969
	Standard deviation[b]	0.071	0.001	0.017	0.040
216-T-19	Mean[b]	0.007906	0	0.008505	6.65
	Standard deviation[b]	0.002	--	0.002	6.14
216-T-26	Mean[b]	1.759978	0.016972	0.418257	7.64
	Standard deviation[b]	0.613	0.006	0.151	0.342
UPR-200-W-14[c]	Mean[b]	--	--	--	--
	Standard deviation[b]	--	--	--	--
UPR-200-W-29	Mean[b]	0.000766	6.69E-06	7.75E-05	0.003785
	Standard deviation[b]	0.0[e]	0.0[e]	0.0[e]	0.0[e]
UPR-200-W-97[d]	Mean[b]	9.51E-06	0	1.02E-05	0.001996
	Standard deviation[b]	0.0[e]	0.0[e]	0.0[e]	0.001
216-T-36	Mean[b]	0.000213	0.000298	0.14133	0.5094
	Standard deviation[b]	0.001	0.001	0.164	0.016
Subtotal		1.9228195	0.0187607	0.6047687	15.774181
		4.58%	0.00%	39.81%	0.04%
WMA-T -- Tanks Only					
241-T-101	Mean[b]	0.30394	0.000468	0.0007002	0.037854
	Standard deviation[b]	0.266	0.001	0.0[e]	0.0[e]
241-T-103	Mean[b]	0.93869	0.000709	0.0002074	0.011356
	Standard deviation[b]	0.996	0.001	0.0[e]	0.0[e]
241-T-106	Mean[b]	37.403	0.024617	0.0082862	0.435321
	Standard deviation[b]	40.064	0.023	0.005	0.0[e]
241-T-108	Mean[b]	0.012336	1.71E-05	7.77E-05	0.003785
	Standard deviation[b]	0.005	0.0[e]	0.0[e]	0.0[e]
241-T-109	Mean[b]	0.30607	0.000237	6.71E-05	0.003785
	Standard deviation[b]	0.296	0.001	0.0[e]	0.0[e]
241-T-111	Mean[b]	7.40E-06	1.23E-10	7.97E-06	0.003785
	Standard deviation[b]	0.0[e]	0.0[e]	0.0[e]	0.0[e]
Subtotal		38.96404	0.026047	0.0093465	0.495886
		92.84%	0.00%	0.62%	0.00%
Total inventory		**41.97064**	**4.589E+07**	**1.519107**	**43,061.2**

Table 1-9. T Area Best Estimate or Mean Radionuclide Soils Inventory. (3 sheets)

Waste Site - Groupings	Radionuclide			Volume (ML)[a]
	Tc-99 (Ci)	I-129 (Ci)	U-234/238 (Ci)	

[a] Volume is expressed as millions of liters (ML).
[b] The quantity listed is the mean value. The standard deviation about the mean value is provided in parentheses below the mean value. The mean value plus or minus two times the standard deviation provides a 95% confidence interval of the volume about the mean. The information regarding the mean value and standard deviation was obtained from the SIM (Corbin et al. 2005). The SIM also provides data indicating the percentage of results at or below a given volume, illustrating the distribution of the volume within the data set.
[c] The SIM database (Corbin et al. 2005) indicated zero volume and inventory for UPR-200-W-14.
[d] UPR 200-W-97 is the same site as UPR-200-W-62.
[e] The value for the standard deviation at these locations is so small that, when rounded to three significant figures, it becomes zero.
Data source: *Hanford Soil Inventory Model, Rev. 1*, RPP-26744, Rev. 0 (Corbin et al. 2005).
SIM = Soil Inventory Model
UPR = unplanned release
WMA = waste management area

Table 1-10. Data Quality Objective Team Members. (2 sheets)

Name	Organization	Role and Responsibility
Duane Horton	PNNL	Hydrology, groundwater expert
Mark Byrnes	FH	200-ZP-1 OU Remedial Investigation Task Lead
Michael Hickey	FH	Waste Site Remedial Investigation Task Lead
Mark Benecke	FH	Waste Site Remedial Investigation Task Lead
Dave Myers	CHG	Vadose Zone Investigations for Tank Farms
Frank Anderson	CHG	Manager, Vadose Zone Investigations for Tank Farms
Tom Jones	CHG	Environmental Engineering, specialist tank chemistry
Al Robinson	EQM	Radiochemist, risk modeler, fate and transport expertise, technical support to DQO process
Mitzi Miller	EQM	Facilitator
Duane Bogen	EQM	Process expert, technical support
Ken Moser	Vista Engineering	Geologist, technical support
P. Evan Dresel	PNNL	Isotope and element ratios
Charley Kincaid	PNNL	Soil Inventory Model – inventory
Rick McCain	Stoller	Geophysical logging
R. Jeff Serne	PNNL	Geochemist, vadose sediment and porewater characterization
Doug Sherwood	Rivers Edge Environmental	Hanford waste sites and groundwater expertise
John Morse	RL	RL Project Manager for Central Plateau
Mike Thompson	RL	RL Project Manager for Central Plateau
Bob Lober	ORP	ORP Project Manager for Tank Farms Programs and Projects

Table 1-10. Data Quality Objective Team Members. (2 sheets)

Name	Organization	Role and Responsibility
Joe Caggiano	Ecology	Regulatory and technical review
Dib Goswami	Ecology	Regulatory and technical review
Jeff Lyon	Ecology	Regulatory and technical review
Bryan Foley	RL	RL Project Manager for Central Plateau Waste Sites
Marcel Bergeron	PNNL	Groundwater flow, fate and transport expertise
Virginia Rohay	FH	200-ZP-1 OU Remedial Investigation Technical Lead

CHG = CH2M Hill Hanford Group, Inc.
DQO = data quality objective
Ecology = Washington State Department of Ecology
EQM = Environmental Quality Management, Inc.
FH = Fluor Hanford, Inc.
ORP = U.S. Department of Energy, Office of River Protection
OU = operable unit
PNNL = Pacific Northwest National Laboratory
RL = U.S. Department of Energy, Richland Operations Office

Table 1-11. Data Quality Objective Key Decision Makers.

Name	Organization	Role and Responsibility
Arlene Tortoso	RL	Project Manager for 200-ZP-1 OU
Dennis Faulk	EPA	Project Manager for 200 ZP-1 OU

EPA = U.S. Environmental Protection Agency
OU = operable unit
RL = U.S. Department of Energy, Richland Operations Office

Table 1-12. Project Dates.

Task Activities	Date
Phase I DQO summary report	March 2007
Phase I sampling and analysis plan	September 2006
Phase I field implementation	November 2006
Phase I laboratory analyses	TBD
Phase I data quality assessment	TBD
Phase I documentation of investigation results	TBD

DQO = data quality objective
TBD = to be determined (post-plan)

Table 1-13. Contaminants of Potential Concern Addressed by Concurrent Characterization Activities.

Media	COPCs	Characterization Activity
Groundwater and soil	Carbon tetrachloride, trichloroethene, chromium, nitrate, fluoride, Tc-99, and tritium	Boreholes next to tanks 241-T-106, C4104, and C4105; 299-W10-196; and RCRA borehole 299-W11-39 (Serne et al. 2004)
Groundwater	Tc-99, chromium, nitrate, total chromium, gross alpha/beta, gamma, tritium, and I-129	Wells 299-W11-45 and 299-W11-47 (DOE-RL 2005)
Groundwater	See Appendix A, Table A1-7 of 200-ZP-1 RI/FS work plan (DOE-RL 2004), which contains a list of COPCs for the OU	200-ZP-1 RI/FS work plan (DOE-RL 2004)

COPC = contaminant of potential concern
OU = operable unit
RCRA = *Resource Conservation and Recovery Act of 1976*
RI/FS = remedial investigation/feasibility study

Table 1-14. Rationale for Contaminant of Potential Concern Exclusions.

Media	COPCs	Rationale for Exclusion
Groundwater	See Appendix D	COPCs that were never detected in the groundwater wells previously listed. See frequency of detect = 0.
Groundwater	Bis(2-ethylhexyl) phthalate	Common laboratory contaminant, spurious detection, detected over the preliminary remedial action goals one time each in wells 299-W11-18, 299-W11-14; two times in well 299-W10-4. No consistent detection.
Groundwater	Aldrin	Pesticide, detected over the preliminary remedial action goals one time in one well, 299-W11-28, which is currently dry.
Groundwater	Cs-137	Results from all the wells listed in Appendix B were trended. The well with the highest Cs-137 concentration was 299-W10-4, and plots of Cs-137 data at well 299-W10-4 over time show that these results were anomalies with nondetects since the early 1990s. No other wells exhibited consistent detects over time.
Groundwater	Sr-90	Results from all the wells listed in Appendix B were trended. The well with the highest Sr-90 concentration was 299-W10-4, and plots of Sr-90 data at well 299-W10-4 over time show that these results were anomalies with nondetects since the early 1990s. No other wells exhibited consistent detects over time. In addition, PNNL evaluated the wells in the vicinity and indicated that no wells exhibited detects over time.

COPC = contaminant of potential concern
PNNL = Pacific Northwest National Laboratory

Table 1-15. Final List of Contaminants of Concern in Groundwater.

Antimony, arsenic, nitrate, nitrite, cadmium, chromium, iron, manganese, nickel, uranium, lead, vanadium, hexavalent chromium, tritium, carbon tetrachloride, chloroform, trichloroethylene (TCE), fluoride,Tc-99, and I-129.

Table 1-16. Preliminary Target Action Levels and Basis for Groundwater Contaminants of Concern. (4 sheets)

COC	Primary MCL	Secondary MCL[a]	CLARC Groundwater Method B[c]	Background[b]	Reporting Limit	Selected Limit[d]	Source[d]	Comments
Volatile Organics – Units for Nonradiological COCs (µg/L)								
Carbon tetrachloride	5	—	0.337	—	3	3	CRDL	CRDL > CLARC. CERCLA COC in current groundwater well monitoring network.[f]
Chloroform	80	—	7.17	—	5	7.17	CLARC	CLARC < MCL and CLARC > CRDL. CERCLA COC in current groundwater well monitoring network.[f]
Trichloroethylene (TCE)	5	—	3.98	—	5	5	CRDL	CLARC < MCL and CLARC < CRDL. CERCLA COC in current groundwater well monitoring network.[f]
Metals – Units for Nonradiological COCs (µg/L)								
Antimony	6	—	6.4	—	10	10	CRDL	MCL < CLARC, but CRDL > MCL.
Arsenic	10[e]	—	0.0583	10	6	10	CRDL	CLARC < MCL, CRDL= Hanford background > CLARC. CERCLA COC in current groundwater well monitoring network.[f]
Cadmium	5	—	8	<10	2	5	Primary MCL[e]	MCL < CLARC, and MCL = CRDL. CERCLA COC in current groundwater well monitoring network.[f]
Calcium[k]	—	—	—	—	—	N/A	—	
Chromium (total)	100[i]	—	24,000	<30	10	100	Primary MCL[e]	MCL < CLARC, and MCL > CRDL. CERCLA COC in current groundwater well monitoring network.[f]
Chromium (hexavalent)	—	—	48[c]	—	10	48	CLARC	CLARC > CRDL. There is no drinking water MCL for hexavalent chromium.

Table 1-16. Preliminary Target Action Levels and Basis for Groundwater Contaminants of Concern. (4 sheets)

COC	Primary MCL	Secondary MCL[a]	CLARC Groundwater Method B[c]	Background[b]	Reporting Limit	Selected Limit[d]	Source[d]	Comments
Iron	—	300	—	86	50	300	Secondary MCL	MCL > CRDL. Secondary DWS = 300 µg/L (www.epa.gov/ safewater/mcl.html)[i]
Lead	15	—	—	<5	5	15	Primary MCL[e]	MCL > CRDL. Drinking water treatment levels = 15 µg/L (www.epa.gov/ safewater/mcl.html).
Magnesium[k]	—	—	—	—	—	—	—	
Manganese	—	50	2,240	24.5	5	50	Secondary MCL	CLARC > CRDL. Secondary DWS = 50 µg/L (www.epa.gov/ safewater/mcl.html)[i].
Nickel	—	—	320	—	40	320	CLARC	CLARC > CRDL.
Potassium[k]	—	—	—	—	—	N/A	—	
Sodium[k]	—	—	—	—	—	N/A	—	
Uranium (total)	30	—	48	3.43	0.1	30	Primary MCL[e]	MCL < CLARC, and MCL > CRDL. CERCLA COC in current groundwater well monitoring network.[f]
Vanadium	—	—	112	15	50	112	CLARC	Noncarcinogen CLARC > CRDL.
Non-Metals – Units for Nonradiological COCs (µg/L)								
Alkalinity[k]	—	—	—	—	—	—	Background	
Chloride[k]	—	—	—	—	—	—	Background	Alkalinity[k]
Fluoride	4,000	2,000	—	775	500	4,000	Primary MCL[e]	Primary MCL > background and CRDL. Secondary DWS is unenforceable and other standards are available.
Nitrate	44,285	—	7,086	12,400	75	12,400	Background	Background > CLARC and CRDL.
Nitrate as nitrogen	10,000	—	25,600	2,800	17	10,000	CLARC	MCL<CLARC, background, CLARC and CRDL.

Table 1-16. Preliminary Target Action Levels and Basis for Groundwater Contaminants of Concern. (4 sheets)

COC	Primary MCL	Secondary MCL[a]	CLARC Groundwater Method B[c]	Background[b]	Reporting Limit	Selected Limit[d]	Source[d]	Comments
Nitrite	3,286	—	5,257	—	75	3,268	Primary MCL[e]	MCL < CLARC, and MCL > CRDL.
Nitrite as nitrogen	1,000	—	1,600	—	17	1,000	Primary MCL[e]	MCL < CLARC, and MCL > CRDL.
Sulfate[k]	—	250,000	—	—		250,000	Secondary MCL	
Radiological COCs – Beta Emitters – Units for Radiological COCs (pCi/L, unless otherwise noted)								
I-129	1[g]	—	—	—	0.5[j]	1[g]	Primary MCL[g]	MCL > CRDL. MCL based on 4 mrem/yr. CERCLA COC in current groundwater well monitoring network.[f] From www.epa.gov/safewater/mcl.html (EPA et al. 1997).
Tc-99	900[g,h]	—	—	—	20	900[g]	Primary MCL[g]	MCL > CRDL. MCL based on 4 mrem/yr. CERCLA COC in current groundwater well monitoring network.[f] From www.epa.gov/safewater/mcl.html (EPA et al. 1997).
H-3	20,000[g]	—	—	—	400	20,000[g]	Primary MCL[g]	MCL > CRDL. MCL based on 4 mrem/yr. From www.epa.gov/safewater/mcl.html (EPA et al. 1997).

Table 1-16. Preliminary Target Action Levels and Basis for Groundwater Contaminants of Concern. (4 sheets)

COC	Primary MCL	Secondary MCL[a]	CLARC Groundwater Method B[c]	Background[b]	Reporting Limit	Selected Limit[d]	Source[d]	Comments

[a] Primary MCLs were used where available and are assumed unless noted; secondary MCLs are noted in the comments column.
[b] *Hanford Site Groundwater Background*, DOE/RL-92-23, Rev. 0 (DOE-RL 1992a).
[c] WAC 173-340-740(4) groundwater Method B values from Ecology's *Cleanup Levels and Risk Calculations Under the Model Toxics Control Act Cleanup Regulation (CLARC III)* (Ecology 2005), with additional information from the Integrated Risk Information System database.
[d] The selected limit is the lower of the MCL or CLARC values with the following exception: if the background or CRDL is higher, the higher of these is selected. If the CLARC tables allowed a choice between carcinogenic and noncarcinogenic values for groundwater, the lower was chosen. In some cases, no regulatory limit is available.
[e] Target action level represents primary MCL (from web site www.epa.gov/safewater/mcl.html).
[f] From *Data Quality Objectives Summary Report for Establishing a RCRA/CERCLA/AEA Integrated 200 West and 200 East Groundwater Monitoring Network*, CP-15239, Rev. 0 (FH 2003a).
[g] Target action level based on the estimated groundwater concentration that would result 4 mrem/year (MCL) to the whole body or an organ if the groundwater water were used as drinking water (*Remedial Design Report/Remedial Action Work Plan for the 100 Area*, DOE/RL-96-17, Rev. 4 [DOE-RL 2002, Table 2-3]).
[h] Technetium-99 remedial target action levels defined in *Record of Decision for the 200-UP-1 Interim Remedial Measure* (EPA et al. 1997).
[i] Total chromium based on chromium III and VI values.
[j] For iodine-129, 0.5 pCi/L cannot be routinely attained, thus 1 pCi/L will be the same as the selected limit.
[k] Requested for general cation/anion balance, not used for regulatory action level.

AEA = *Atomic Energy Act of 1954*
CERCLA = *Comprehensive Environmental Response, Compensation, and Liability Act of 1980*
CLARC = *Cleanup Levels and Risk Calculations Under the Model Toxics Control Act Cleanup Regulation (CLARC III)*
COC = contaminant of concern
CRDL = contract-required detection limit
DWS = drinking water standard
Ecology = Washington State Department of Ecology
EPA = U.S. Environmental Protection Agency
MCL = maximum contaminant level
N/A = not applicable
RCRA = *Resource Conservation and Recovery Act of 1976*
WAC = *Washington Administrative Code*

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2.0 STEP 2 – IDENTIFY THE DECISION

The purpose of DQO Step 2 is to define the principal study questions (PSQs) that need to be resolved to address the problem identified in DQO Step 1 and the alternative actions (AAs) that would result from the resolution of the PSQs. The PSQs and AAs are then combined into decision statements (DSs) that express a choice among the AAs. Table 2-1 presents the PSQs, alternative actions, and resulting DSs. This table also provides a qualitative assessment of the severity of the consequences of taking an alternative action if it is incorrect.

Table 2-1. Summary of Data Quality Objective Step 2 Information. (2 sheets)

PSQ-AA #	AA	Consequences of Implementing the Wrong AA
PSQ #1 – Are the RCRA/CERCLA compliance well network and sampling frequency adequate to determine horizontal and vertical Tc-99 (and associated contaminant) groundwater plume movement, considering the rate and direction of groundwater flow at the T Area?		
AA-1-1	No; well network and/or sampling frequency needs to be modified.	Unnecessary cost in obtaining redundant data.
AA-1-2	Yes; no changes of the well network or sampling frequency are required.	Continued groundwater quality assessment requirements of 40 CFR 265.93 (d)(7) may not be fulfilled.
DS #1 – Determine whether the RCRA/CERCLA compliance well network and sampling frequency are adequate to determine horizontal and vertical Tc-99 groundwater plume movement and the rate and direction of groundwater flow at the T Area.		
PSQ #2 – Are the source(s) and driving forces through the vadose zone to groundwater identified for the contaminants exceeding drinking water standards in the wells located on the east boundary of WMA-T sufficiently to evaluate alternative actions to remediate sources?		
AA-2-1	No; additional data are needed.	Unnecessary cost in obtaining redundant data.
AA-2-2	Yes; additional data are not needed.	Source(s) and driving forces of contaminants may not be adequately identified; the data set may not be adequate for future decisions.
DS #2 – Determine if the source(s) and driving forces through the vadose zone to groundwater are identified and characterized for the contaminants exceeding drinking water standards in the wells located on the east boundary of WMA-T sufficiently to evaluate alternative actions to remediate sources.		
PSQ #3 – Are adequate data available to delineate the vertical and horizontal extent of theTc-99, chromium, nitrate, fluoride, tritium, and associated groundwater plumes at the T Area?		
AA-3-1	No; additional data are needed to delineate the groundwater plumes.	Unnecessary cost in obtaining redundant data.
AA-3-2	Yes; additional data are not needed to delineate the groundwater plumes.	Groundwater plume extents may not be adequately delineated; data set for future decisions may not be adequate.
DS #3 – Determine if adequate data are available to delineate the vertical and horizontal extent of the Tc-99, chromium, nitrate, fluoride, tritium, and associated groundwater plumes at the T Area.		

Table 2-1. Summary of Data Quality Objective Step 2 Information. (2 sheets)

PSQ-AA #	AA	Consequences of Implementing the Wrong AA
PSQ #4 – Are adequate data available to assess, using modeling, the potential for the groundwater plumes at the T Area to migrate from the 200 Area Central Plateau in the next 1,000 years?		
AA 4-1	No; additional data are needed to assess groundwater plume migration.	Unnecessary cost in obtaining redundant data.
AA 4-2	Yes; additional data are not needed to assess groundwater plume migration.	Groundwater plume migration from the 200 Area Central Plateau may not be adequately assessed; data set may not be adequate for future decisions.
DS #4 – Determine, using modeling, if adequate data are available to assess the potential for the groundwater plumes at the T Area to migrate from the 200 Area Central Plateau in the next 1,000 years.		
PSQ #5 – Are adequate data (e.g., contaminant concentration, chemical form, aquifer properties, and groundwater flow rate and direction) available to plan, implement, and assess the effectiveness of groundwater remediation technologies?		
AA 5-1	No; additional data are needed to plan, implement or assess the effectiveness of groundwater remediation technologies.	Unnecessary cost in obtaining redundant data.
AA 5-2	Yes; additional data are not needed to plan, implement or assess the effectiveness of groundwater remediation technologies.	If data are inadequate, the planning, implementation, or assessment of effectiveness of groundwater remediation technologies may be incorrect or compromised.
DS #5 – Determine if adequate data (e.g., contaminant concentration, chemical form, aquifer properties, and groundwater flow rate and direction) are available to plan, implement, and assess the effectiveness of groundwater remediation technologies.		

AA = alternative action
CERCLA = *Comprehensive Environmental Response, Compensation, and Liability Act of 1980*
CFR = *Code of Federal Regulations*
DS = decision statement
PSQ = principal study question
RCRA = *Resource Conservation and Recovery Act of 1976*
WMA = waste management area

3.0 STEP 3 – IDENTIFY INPUTS TO THE DECISION

The purpose of DQO Step 3 is to identify the type of data needed to resolve the DSs identified in DQO Step 2. The data may already exist or may be derived from computational or surveying/ sampling and analysis methods. Analytical performance requirements are also provided in this step for any new data that need to be collected.

3.1 CONCEPTUAL MODEL DATA INPUT NEEDS

3.1.1 Physical, Geological, Hydraulic, and Geochemical Properties

The actual technology and specifics of the various remediation options for the technetium-99 plume under the T Area will not be fully established until OU-specific information is collected during the RI to support selection of remedial alternative(s). It was determined that there was a need for fundamental studies related to the aquifer sediments in the 200-ZP-1 OU and the additional COCs identified in the 200-ZP-1 OU DQO summary report (FH 2003b). These studies were determined to be necessary to assist in decisions related to selection of OU-wide remedial alternatives and to increase confidence in the results of OU-wide modeling studies. This current DQO summary report will focus on the data to support the conceptual model for the specific technetium-99 plume detected adjacent to (and potentially under) the T Area but will also consider the data needs identified in the 200-ZP-1 DQO summary report to maximize the integration of data.

Specific parameters for the vadose zone and the unconfined aquifer in the T Area need to be measured or calculated. Enhanced understanding of these parameters will allow refinement of model predictions with regard to horizontal and vertical migration of the contaminants in the saturated zone. In addition, the saturated zone parameters listed in the 200-ZP-1 RI/FS work plan and SAP (DOE-RL 2004) are also needed for the T Area technetium-99 study.

To ensure that all required data are collected without redundant efforts, the data required for the T Area technetium-99 study are listed in two tables. Table 3-1 lists the parameters that need to be measured or calculated for the sediments and groundwater in the unconfined aquifer, and Table 3-2 lists the parameters needed for the vadose zone specific to the T Area technetium-99 investigation. Most of the parameters in Table 3-2 have yet to be measured. On the other hand, most of the parameters in Table 3-1 were identified in the 200-ZP-1 RI/FS work plan and SAP (DOE-RL 2004), and data for these parameters have already been collected. Pertinent information obtained from the 200-ZP-1 OU investigation will be used for this T Area investigation.

In Tables 3-1 and 3-2, the parameters to be collected are grouped by the phase to which they apply (i.e., sediment or water) and further categorized into the following major property types:

- Physical/geologic properties (e.g., particle size and calcium carbonate content)
- Hydraulic and transport properties (e.g., bulk density, total porosity, hydraulic conductivity, and effective porosity)
- Geochemical properties (e.g., cation exchange capacity [CEC] and K_d for each key COC).

Numerous measurements within each of the categories help to define representative parameters for the saturated zone. Sampling needed to support measurement of these parameters is discussed in Section 7.0.

3.1.2 Research Support

The potential for using technetium–99 data from other research projects exists, thus the research support is discussed in this section.

Research support comes from the Remediation and Closure Science Project funded by RL; scientific research funded at PNNL directly from CH2M Hill Hanford Group, Inc. (CHG); and the DOE's Office of Science – Environmental Management Science Program (EMSP). The Remediation and Closure Science Project (previously the Groundwater/Vadose Zone Integration Science and Technology Project) initially included studies of vadose zone issues associated with tank farms. In 2003, responsibility for tank farm vadose zone scientific investigations was transferred to CHG, where it currently resides.

The Office of Science sponsors the EMSP to fulfill DOE's continuing commitment to cleanup of DOE's environmental legacy. The EMSP was previously supported through DOE Office of Environmental Management (DOE-EM) Office of Science and Technology, in partnership with the Office of Energy Research. The program sponsors basic research to address long-term technical issues crucial to DOE-EM's mission, as well as near-term fundamental data that may be critical to resolve scientific issues or advance technologies that are under development but not yet at full scale or are not yet implemented. This basic research effort contributes to environmental management activities that decrease risk for the public and workers, to provide opportunities for major cost reductions, to reduce time required to achieve DOE-EM's mission, goals, and, in general, to address problems that are considered intractable without new knowledge. This program is designed to develop "breakthroughs" in areas critical to DOE-EM's mission through basic research. The research is conducted by DOE's national laboratories, universities, and/or private industry and is directed by DOE-Headquarters.

The Hanford Site responded to an EMSP call for proposals for subsurface science in FY99. The call was focused on the vadose zone, and several EMSP research projects were funded with potential benefit to remediation of the 200-UP-1 OU uranium and technetium-99 plume. These projects have been completed, and the final reports and publications are being evaluated for information that can be useful to the Hanford Site. Much of the information from the EMSP's projects relevant to the Remediation and Closure Science Project was summarized in the field investigation report for WMA-T and WMA-TX/TY (Myers 2005). During FY02, another call for subsurface science was issued and the following projects of potential benefit to uranium and technetium-99 remediation at Hanford were awarded:

- Project 86911, "Coupled Geochemical and Hydrological Processes Governing the Fate and Transport of Radionuclides and Toxic Metals Beneath the Hanford Tank Farms"
- Project 86898, "Reactivity of Primary Soil Minerals and Secondary Precipitates Beneath Leaking Hanford Waste Tanks."

The DOE Office of Science also funds the Natural and Accelerated Bioremediation Research (NABIR) Program. The goal of the NABIR Program is to provide the fundamental science to serve as the basis for the development of cost-effective bioremediation of radionuclides and metals in the subsurface at DOE sites. The focus of the program is on strategies leading to

long-term immobilization of these contaminants in place, including both intrinsic bioremediation and accelerated bioremediation through biostimulation, to reduce the risk to humans and the environment. Project 16259, "In-Situ Immobilization of Technetium-99 at the Hanford Site by Stimulation of Subsurface Microbiota," is focused on technetium-99 remediation.

Note that in 2006, EMSP and NABIR were combined into the Environmental and Remediation Sciences Program within the DOE Office of Science. Future calls for proposals related to subsurface science within this new office will be monitored for funding relevant to Hanford soil and groundwater remediation.

3.2 INFORMATION REQUIRED TO RESOLVE DECISION STATEMENTS

Tables 3-1 and 3-2 specify the information required to resolve the DSs identified in Table 2-1. Table 3-3 summarizes the data needs, assigns them to the relevant DSs, and identifies whether the data already exist. For the data identified as existing, the source references for the data have been provided with a qualitative assessment as to whether or not the data are of sufficient quality and quantity to resolve the corresponding DS.

3.3 BASIS FOR SETTING THE TARGET ACTION LEVELS

The target action levels are threshold values specified for each COC that provide criteria for determining whether enough data have been collected (i.e., for choosing among the AAs defined by the DSs). However, not all of the DSs are resolved by comparing specific data to specific target action levels. Several of the programmatic DSs rely on professional judgment to select a path forward.

Table 1-17 and Appendix C identify the basis for establishing the target action level for each of the COCs. The target action levels (selected limits) shown in Table 1-17 are primarily based on drinking water limits, CLARC limits, and in some cases background or laboratory detection limits. The levels identified in this table are the same as those identified for the 200-ZP-1 OU. By using the same action levels, consistency in decision making is promoted across the entire OU.

The final regulatory action levels will be established in the FS and the final ROD and may be different from the target action levels. It may be determined that one action limit will apply inside the core zone and another limit will apply outside.

3.4 COMPUTATIONAL METHODS

3.4.1 Background

Analyses to support the evaluation of alternate remedial actions for technetium-99 and co-contaminants originating in WMA-T will be a part of the computational framework used to support the baseline risk assessment and FS of the 200-ZP-1 RI/FS process. The objective of the baseline risk assessment analysis for the 200-ZP-1 RI/FS process is to examine predicted concentration levels and overall risks associated with existing technetium-99 and other COC plumes and their future potential sources within the 200-ZP-1 OU in 200 West Area. All sources within the northern portion of the 200 West Area that would be relevant to this baseline risk

assessment and the remedial alternative analysis in the timeframe of interest will be included in the analysis.

The assumed baseline risk assessment scenario will analyze the long-term effect of discontinuing the groundwater pump-and-treat system on existing plumes of key COCs in the northern portion of the 200 West Area. The analysis will consider the time period from an initial condition that reflects current interpretations of existing plumes and will continue through the period of 1,000 years to the present day. As applicable, inventory estimates and release and vadose zone transport for potential future sources of key COCs from waste sites and facilities within the northern portion of the 200 West Area will be evaluated.

The interpretation of the initial conditions and assumptions of potential continuing sources in the proposed modeling effort will need to consider current field observations in the T Area that reveal a complex environment that has been impacted by a series of planned discharges and UPR events over the 50-year period of Hanford operations. To predict with any confidence the future migration and fate of existing contamination in the vadose zone and groundwater, some understanding is required of the discharges and releases that occurred and their migration to observed positions in the environment today. To support an analysis of present location and future migration, some understanding will be required of (1) the hydrogeologic and man-made structures that define the domain of interest, (2) the events including purposeful discharges and accidental UPRs that occurred during Hanford operations in the vicinity, and (3) the thermal/ physical/geochemical processes that were and are primarily responsible for contaminant migration and fate in the vadose zone and saturated environment.

Field data show substantial concentrations of technetium-99 at considerable depth in the aquifer. It is believed that all of the discharges and releases potentially related to this technetium-99 contamination occurred at or near the land surface. Approximately 100 m (328 ft) of vadose zone vertically separate the discharge and release events from the observed technetium-99 groundwater contamination. The geologic strata that comprise the vadose zone include deposits of the Hanford formation, a Plio-Pleistocene unit, and the Ringold Formation. Interfaces between strata are not strictly horizontal giving rise to three-dimensional vadose zone flow and transport. Hydrogeologic structure data sufficient to develop a fully three-dimensional portrait of the T Area from land surface to top of basalt is needed.

The present-day setting of contaminant distribution in the vadose zone and aquifer underlying the T Area is a function of a complex suite of natural processes and operational events occurring over a 50-year period. The aquifer underlying the T Area is in the Ringold Formation, and this formation has a relatively low hydraulic conductivity which resulted in contaminant plumes from 50 years ago being resident in the aquifer today. Thus, the entire operational history is needed regarding cooling water discharges to ponds that caused groundwater mounding and of planned discharges and UPRs that carried contaminants into the environment to develop an understanding of past migration and to identify the source of the present-day contamination. Groundwater flow has undergone substantial change. Historical data reveal that groundwater flow direction was southward from 1954 through 1955, northward from 1983 through 1995, and eastward from 1997 through 2004. While technetium-99 is the contaminant of greatest interest, it will be important to develop information on the chromium and nitrate-nitrite-ammonia content of waste released to the environment in order to evaluate the technetium-to-chromium and the technetium-to-nitrate ratios for comparison to field data. Other mobile or substantially mobile contaminants (including tritium, iodine-129, and uranium) may also be of value in developing an

understanding of vadose zone and groundwater flow and contaminant transport in the T Area. The history of all operational events influencing or potentially influencing the groundwater underlying the T Area need to be cataloged to develop as complete of an understanding as possible of changes to the aquifer and potential sources of contamination seen today.

Once in the environment, contaminant migration and fate are a function of the processes acting on the contaminant and the contaminant's reaction with the host materials. Many waste releases, whether purposeful or unplanned, at the Hanford Site involved heated liquids. Clean water used to cool specific processes within the canyons created large volumes of heated water that were discharged to the environment. Water at temperatures in excess of natural groundwater temperature is buoyant and floats at the top of the aquifer. Tank wastes are generally warmer than the surrounding vadose zone, neutralized to a pH of nearly 14 to minimize corrosive impacts on steel tanks, have high salt contents, and may contain organics that cause analytes within the waste to be more mobile than when organics are absent. Because past tank leaks have involved relatively smaller volumes of waste in comparison to cribs and specific retention trenches, tank wastes leaked to the vadose zone have been neutralized within the vadose zone. While contaminant migration and fate in the near field to a release can be quite complex to simulate, the resulting far-field and longer term characteristics of waste migration involve isothermal, neutral pH, neutral oxidation potential (Eh), low-salt, low-organic concentration processes. However, any waste exhibiting the levels of technetium-99 observed in the aquifer underlying the T Area is clearly an exception that may require some analysis beyond that available from simplified models. Thus, it will be necessary to measure or develop from the literature data sufficient to evaluate and identify the thermal-physical-geochemical processes primarily responsible for the migration of the contaminant(s). In addition to the processes that resulted in the migration of technetium-99 to its position in the environment today, it will be necessary to include those data necessary to support analyses of alternate remedial actions in the data requirements.

3.4.2 Models and Calculations

Models and calculations will be used to assess specific portions of COC movement from waste site, to the vadose zone, to the groundwater. For example, vadose zone transport of COCs to the groundwater is modeled using the Subsurface Transport Over Multiple Phases (STOMP) code (White and Oostrom 2000).

The uppermost saturated zone on the Hanford Site, commonly referred to as the "unconfined aquifer," offers a pathway for contaminants released through the vadose zone from past, present, and future site activities to reach the environment. Radioactive and hazardous chemicals have been released on the Hanford Site from a variety of sources, including ponds, cribs, ditches, injection wells (referred to as "reverse wells"), surface spills, and tank leaks. Many of these sources have already affected the groundwater and some may affect groundwater in the future. Once in the groundwater, contaminants move along the pathways of least resistance, from higher to lower water potentials, where some contaminants may ultimately discharge into the Columbia River.

The transport of contaminants released from the vadose zone to points of regional discharge of groundwater along the Columbia River within the 1,000-year assessment period will be evaluated. Contaminants released to the groundwater form plumes, some of which extend from their source areas to the Columbia River. Using modeling, calculations, and existing data,

concentrations of contaminants in the groundwater will be estimated and these concentrations will be used in subsequent risk calculations and risk impact evaluations.

3.4.3 Human Health Risk Assessment

Models and calculations will be used to generate estimates of media- and time-specific concentrations to estimate potential impacts on the ecology of the Hanford Site, including the Columbia River Corridor, the health of persons who might live in or use the Corridor or the upland Hanford environment, the local economy, and cultural resources. The modules that provide estimate impacts on the local economy and cultural resources are not used as a part of the RI or the planned FS.

Estimates of cancer and non-cancer risks to humans from chronic exposures to contaminants in the study region will be generated. The routes of exposure will vary based on the scenarios for the assessment. The scenarios are focused on the use of potentially contaminated water and exposure to potentially contaminated soil and sediment. Ecological risk assessment from all the tank farms and all the waste sites will provide the ecological risk information for the entire Central Plateau area, and WMA-T is included in this area. No surface water exists in the WMA-T area for use by ecological receptors; an evaluation of potential risk based on the groundwater is presented in the forthcoming 200-ZP-1 RI.

Human exposure/risk scenarios have been defined the in the *Hanford Site Risk Assessment Methodology* (DOE-RL 1995), in *Screening Assessment and Requirements for a Comprehensive Assessment: Columbia River Comprehensive Impact Assessment* (CRCIA) (DOE-RL 1998), and in a September 1999 letter report (BHI 1999). Other more recent studies have described variants of these scenarios or new scenarios. In essence, a scenario definition must describe the exposure from all pathways (i.e., ingestion, inhalation, and external or dermal) to environmental contaminants in the groundwater, surface water, air, soil, and sediment, as well as ingestion of contaminated food products (i.e., vegetables, fish, meat, and other produce). Dose and/or risks from scenario definitions will be evaluated with the following general considerations:

- Exposure can occur at upland locations, along the Columbia River bank, or from river uses such as swimming or boating.
- Exposure pathways can include ingestion, inhalation, external (radioactive), or dermal (hazardous or carcinogenic chemicals).
- Contaminant concentrations can be developed for food crops based on dry-land assumptions or irrigated scenarios using groundwater or river water, as well as for aquatic foods.
- Environmental media concentrations include groundwater, soil (dry land, irrigated, or located along the riverbank), air, river water, river bottom porewater, and river sediment.

Thus, this framework can be used to evaluate risks or impacts for drinking water use, residential farming, ranger activities, avid or casual recreation either upland or on the river, and Native American lifestyle activities.

Two categories of impacts, carcinogenic and systemic effects, will be estimated in the human health risk assessment to evaluate adverse impacts from contaminants to humans. Impacts to human receptors will be assessed, and the metrics include the following:

- Carcinogenic effects will be evaluated for the radionuclides and carcinogenic chemicals. The incremental lifetime cancer risk will be calculated using available slope factors and dose conversion factors. In addition, the results of the human health impact assessment will be presented as an annual dose for the radionuclides considered, which is specified under DOE Order 5400.5 and DOE O 435.1.
- Systemic effects will be evaluated for noncarcinogenic radionuclides (e.g., the nephrotoxic effects of uranium) and chemicals. The hazard quotient will be calculated using available reference doses.

Contaminants in the environment may adversely affect human health and the environment when two conditions are met: (1) the key components of a system are exposed to the contaminant, and (2) the exposure exceeds a threshold above which effects are probable. Impact is defined as an adverse change in the system being examined. The transport models and calculations provide estimates of time-dependent contaminant concentrations from Hanford Site sources in a time-dependent manner in the vadose zone, groundwater, and the Columbia River and its associated river sediments.

Preliminary risk information has been developed from a selected set of existing plume concentration levels that exceed DWSs in the upcoming 200-ZP-1 RI report (in publication). During the period of institutional control, land use in the Central Plateau is assumed to be an exclusive industrial use that will preclude the use of groundwater. For purposes of the risk discussion presented in the RI, risks estimated consider a drinking water only and residential farmer scenarios. The baseline risk analysis, which is being deferred as part of the FS, may consider a broader set of exposure scenarios.

3.5 ANALYTICAL PERFORMANCE REQUIREMENTS

Table 3-4 specifies the analytical performance criteria for COCs in groundwater samples resulting from implementation of the final sampling design specified in Section 7.0. Information is consistent with the 200-ZP-1 RI/FS work plan and SAP (DOE-RL 2004) for the COCs specific to the T Area. Table 3-5 specifies the analytical performance criteria for COCs in sediment samples resulting from implementation of the final sampling design specified in Section 7.0.

Tables 3-1 and 3-2 provide the performance criteria for analyses of modeling input parameters. The data will be obtained during installation of new wells and vadose zone boreholes, as specified in Section 7.0.

Table 3-1. Saturated Zone Parameters of Aquifer Sediments and Groundwater Needed for Modeling Inputs, Remedial Action Alternative Evaluation. (10 sheets)

Property	Parameter	Reason for Measuring	Method	CRDL	Precision Required	Accuracy Required
Aquifer Sediments						
Physical/ geological	Particle-size distribution (by dry sieve and wet sieve for gravel and sand, and hydrometer method for silt and clay)	Particle size influences hydraulic properties (e.g., hydraulic conductivity, effective porosity, and bulk density) and geochemical properties (e.g., CEC and K_d). The fact that particle size is measured relatively inexpensively and can be correlated with so many other needed parameters makes it a valuable measurement with high usability.	ASTM 421 and/or ASTM D422, or ASTM 6913, or ASA Method 15-5.	N/A	N/A	N/A
	Calcium carbonate content (more correctly includes total carbon, inorganic carbon, and organic carbon by difference)	This parameter influences the pH-buffering capacity of the sediment, which is an important for many remediation technologies resin based ion-exchange systems. Calcium carbonate also is a cementing material in porous sediments that influences the hydraulic conductivity and porosity. Organic carbon content influences bioremediation technologies.	ASTM E1915, or EPA 9060A[d] or 415.1.[c]	N/A	N/A	N/A
	Borehole geophysics (neutron probe, natural gamma, spectral gamma, and gamma-gamma density[b])	Neutron probe yields information on sediment moisture content, natural gamma information helps determine geologic lithology and gamma-gamma density yields information on formation bulk density. All of these parameters help to establish the hydrogeologic conceptual model needed for the flow and transport modeling.	Hanford-specific versions of the following methods are available from the field loggers: ASTM D5753 (general logging guidelines), D6274 (gamma logging) and D6727 (neutron logging).[a]	N/A	N/A	N/A

Table 3-1. Saturated Zone Parameters of Aquifer Sediments and Groundwater Needed for Modeling Inputs, Remedial Action Alternative Evaluation. (10 sheets)

Property	Parameter	Reason for Measuring	Method	CRDL	Precision Required	Accuracy Required
	Mineralogy – bulk and clay size fraction separates	Relatively inexpensive measurement to aid in picking lithology, understanding CEC and K_d values.	XRD (see Drever 1973, Brindley and Brown 1980, and Moore and Reynolds 1997).	N/A	N/A	N/A
	Bulk density	Needed to calculate the retardation factor of contaminants in the transport model.	ASTM D2937 (see precautions on sampling handling in ASTM D6640); also acceptable ASTM D4564.	N/A	N/A	N/A
	Lithology	Needed to develop the geologic layers used in flow and transport models.	Geologist description using ASTM D2488 (see Folk 1968 and Wentworth 1922).	N/A	N/A	N/A
Hydraulic and transport	Effective porosity	Needed to calculate the retardation factor of contaminants in the transport model and aquifer groundwater-flow velocity calculations.	Determined quantitatively from laboratory core analyses, hydrologic field tracer tests or semi-quantitatively from numerical model calibration runs.			
	Particle density	Needed to establish the density-volume relationship of soils/rocks. Typically used to calculate porosity and to estimate optimum moisture in compaction tests.	Typically measured on the < 2-mm fraction on three replicate samples using the pychnometer method ASA 1986, Method 14-3 or ASTM D854.	N/A	NA	NA

Table 3-1. Saturated Zone Parameters of Aquifer Sediments and Groundwater Needed for Modeling Inputs, Remedial Action Alternative Evaluation. (10 sheets)

Property	Parameter	Reason for Measuring	Method	CRDL	Precision Required	Accuracy Required
	Total porosity	Needed to calculate the retardation factor of contaminants in the transport model.	Porosity is generally calculated by measuring bulk density of sediment in intact core and using the specific density of individual grains (generally ranges from 2.4 g/cm^3 for clays, 2.65 g/cm^3 for quartz, and 2.78 g/cm^3 for coarse sand and gravels. Porosity can be measured directly (ASA 1986, Method 18-2). Use ASTM D2937 for measuring bulk density and ASA Method 14-3 for particle density.	N/A	N/A	N/A
	Saturated hydraulic conductivity	A measure of the ability for a soil/rock to transmit fluids when fully saturated. Needed to calculate water flow rates in each lithology.	Determined using laboratory core tests based either on constant head ASTM D2434 or falling head method ASA 28-4.2 or EPA Method 9100[4]; also acceptable ASTM D5856, or determined using field hydrologic characterization tests conducted in wells (e.g., slug and constant-rate pumping tests; Spane 1993 and Spane and Wurstner 1993).	N/A	N/A	N/A
	Permeability anisotropy ratio	The ratio of the vertical hydraulic conductivity to the horizontal conductivity. Needed to calculate/model the spread of contaminants with depth within an aquifer	Calculated as the ratio of Kv/Kh, derived quantitatively from multi-well field characterization tests (see Spane 1993, 1996; Spane et al.1996; and Spane and Larssen 1995) or semi-quantitatively from field-scale experiments using inverse numerical modeling.	N/A	N/A	N/A

Table 3-1. Saturated Zone Parameters of Aquifer Sediments and Groundwater Needed for Modeling Inputs, Remedial Action Alternative Evaluation. (10 sheets)

Property	Parameter	Reason for Measuring	Method	CRDL	Precision Required	Accuracy Required
	Dispersivity	A measure of the amount of spreading about the center of mass. Dispersivity influences movement of COCs through porous media.	Laboratory column tests or field multi-well tracer tests. See ASA 1986, Chapter 44, or Parker and van Genuchten 1984, Gelhar 1992, or Gelhar et al. 1992.	N/A	N/A	N/A
	Thermal conductivity	A measure of the ability for a soil/rock to transmit heat. Needed for modeling evapotranspiration, recharge, and soil heat flux, both critical components of the energy balance and soil moisture due to thermal gradients	ASTM D 5334 or ASA 1986 Method 39-3.	N/A	N/A	N/A
	Heat capacity	The amount of heat required to change its temperature by one degree. Needed for modeling evapotranspiration, recharge, and soil heat flux, both critical components of the energy balance and soil moisture due to thermal gradients.	ASA 1986, Chapter 38, Method 38-3.	N/A	N/A	N/A
Geochemical	K_d (e.g., Tc-99, uranium [VI], and carbon tetrachloride)	Parameter needed to calculate retardation factor for each COC expected to dominate long-term risk.	ASTM 4319 or Relyea et al. 1980 for inorganics and ASTM 5285 for volatile organics.	N/A	±25%	±25%
	Specific surface area	Surface area of sediments correlates with adsorption of many contaminants and is often used to help explain or to predict from empirical relationships adsorption properties of sediments	Brunauer et al. 1938 and ASTM C1069 or ASTM D1993; or Gregg and Sing 1982.	N/A	±15%	±25%
	CEC or extractable cations	Often helps explain K_d values for cationic contaminants and useful for understanding sediments capacity to release competing common cations to water when performing ion-exchange remediations. If COCs are not dominated by cations, the extractable cation measurement using ammonium acetate extraction is sufficient.	Routson et al. 1973 for CEC or summation of cations in ASA 1996 (p. 1221 for NH_4OAc).	N/A	±25%	±25%

Table 3-1. Saturated Zone Parameters of Aquifer Sediments and Groundwater Needed for Modeling Inputs, Remedial Action Alternative Evaluation. (10 sheets)

Property	Parameter	Reason for Measuring	Method	CRDL	Precision Required	Accuracy Required
	Amorphous hydrous oxide content	Hydrous oxides especially of iron are the most influential adsorbers of inorganic COCs in many types of sediment that have low clay content, such as Hanford Site sediments. Knowledge of their content helps predict/explain K_d values. Amorphous hydrous oxides have very large specific surface areas and are the key adsorbent in weathering coatings on sediment grains.	ASA 1996 (see Loeppert and Inskeep and Gambrell sections or Chao and Zhou 1983).	N/A	±25%	±25%
	Crystalline hydrous oxide content	Hydrous oxides especially of iron are the most influential adsorbers of inorganic COCs in many sediments that have low clay content, such as Hanford Site sediments. Knowledge of their content helps predict/explain K_d values. Crystalline hydrous oxides have large specific surface areas and are the key adsorbent in weathering coatings on sediment grains. Differentiation between amorphous and crystalline oxides provides clues to age of coatings and whether some COCs might have been incorporated into recalcitrant precipitates.	ASA 1996 (see Loeppert and Inskeep).	N/A	±25%	±25%
Water						
Hydraulic and transport	Aquifer hydraulic head: determined from monitor well water-level elevation measurements	Used to calculate groundwater-flow direction and hydraulic gradient conditions. Can be used to calculate groundwater-flow velocity and as input for calibrating numerical groundwater-flow models.	Field measurements using steel or electrical tapes used to measure water-level depths/elevations within monitoring wells. Effects of barometric pressure must be accounted for in the well water-level measurements for quantitative determination of hydraulic head conditions (see Spane 1999, 2002).	N/A	0.001 m for water level	0.01 m for water level

Table 3-1. Saturated Zone Parameters of Aquifer Sediments and Groundwater Needed for Modeling Inputs, Remedial Action Alternative Evaluation. (10 sheets)

Property	Parameter	Reason for Measuring	Method	CRDL	Precision Required	Accuracy Required
	Field hydrologic characterization tests: slug test, slug interference test, constant rate discharge test, or tracer test	Used to determine hydraulic conductivity. Critical input parameter for modeling groundwater flow and contaminant transport.	Single- and multi-well field characterization tests (as discussed in Gelhar 1992; Gelhar et al. 1992; Spane 1993, 1996; and Spane and Wurstner 1993).	N/A	N/A	N/A
	Groundwater production/pumping flow rate performance	Helps determine efficacy and optimum design for pump-and-treat remediation.	Step-drawdown tests used to determine well loss and well efficiency (see Driscoll 1986).	N/A	N/A	N/A
Geochemical	Major cations (e.g., sodium, potassium, magnesium, and calcium)	Influences remediation techniques that rely on cation-exchange resins (Sr-90 and Cs-137) and is useful for understanding overall geochemical conditions that control contaminant/sediment interactions.	ASTM C1111 or EPA SW-846 Method 6010B.[d]	N/A	N/A	N/A
	Specific electrical conductivity	An inexpensive indicator of the total dissolved ion concentration of groundwater.	Field screening. Version of ASTM 1125 or EPA Method 9050A.[d]	N/A	N/A	N/A
	TOC (total dissolved organic carbon content)	Dissolved organic carbon can act as a food source during bioremediation and some forms of dissolved organic carbon can complex cation contaminants and alter their sorption properties. Thus, knowledge of the COC helps interpret mobility [K_d] information and guide bioremediation design.	EPA SW-846 Method 9060A[d] or ASTM D4129-88 or ASTM E1915-01 or 415.1.[c]	1,000 µg/L	25%	25%
	Alkalinity (can also be estimated from TIC measurement)	Is the key water parameter that controls pH-buffering capacity and is a key complexer of uranium (VI) and can control uranium (VI) sorption tendencies. Also competes with the anionic COCs for sorption onto anion-exchange resins.	ASTM D1067 or 310.1[c] or 310.2.[c]	10 mg/L as CO_3	20%	25%

Table 3-1. Saturated Zone Parameters of Aquifer Sediments and Groundwater Needed for Modeling Inputs, Remedial Action Alternative Evaluation. (10 sheets)

Property	Parameter	Reason for Measuring	Method	CRDL	Precision Required	Accuracy Required
	pH	Key parameter for controlling acid-base-buffering capacity or aquifer-sediment system. Generally influences most remediation technologies.	ASTM D1293 or EPA SW-846 Method 9040C.[d]	0.1 pH unit	±0.1 pH unit	±0.1 pH unit
	Temperature	Inexpensive to measure and may help in overall interpretation of source of plumes, identification of boundaries between different plumes and is a key parameter for chemical reactions that are kinetically controlled.	Field screening.	N/A	±1°C	1°C
	Major anions in sediment porewater (e.g., sulfate, chloride, fluoride, nitrate, phosphate, and bicarbonate/ carbonate)	Influences remediation techniques that rely on anion-exchange resins (uranium [VI] and Tc-99) and is useful for understanding overall geochemical conditions that control contaminant/sediment interactions.	Use IC; following two methods are equivalent ASTM 4327 or EPA SW-846 Method 9056.[d]	N/A	25%	25%
	DO or Eh measurement	Indicators for the REDOX state of the aquifer. Many COCs are REDOX sensitive (e.g., Tc-99, uranium, chromium, selenium, plutonium, and neptunium). Knowing the REDOX state aids in determining COC speciation and helps select appropriate remediation techniques.	DO: field screening Eh: laboratory measurement [ASTM D1498]; ASA 1986, Methods 49-2 and 49-3.	N/A N/A	0.1 mg/L ±20 mv	1% ±30 mv
	Ferrous iron content	Indicator for the REDOX state of the aquifer. Many COCs are REDOX sensitive (e.g., Tc-99, uranium, chromium, selenium, plutonium, and neptunium). Knowing the REDOX state aids in determining COC speciation and helps select appropriate remediation techniques.	Gibbs 1976.	N/A	25%	25%

Table 3-1. Saturated Zone Parameters of Aquifer Sediments and Groundwater Needed for Modeling Inputs, Remedial Action Alternative Evaluation. (10 sheets)

Property	Parameter	Reason for Measuring	Method	CRDL	Precision Required	Accuracy Required
	Methane content in Ringold Lower Mud Unit (if drilled into)	Redox state indicator of the aquifer and helps determine carbon tetrachloride mass balance. Knowing methane concentration aids in determining carbon tetrachloride speciation and mass balance and helps select appropriate remediation techniques.	GC on carefully preserved airtight water sample and prompt analysis at portable laboratory or quick-turnaround analytical laboratory method (Kampbell and Vandegrift 1998).	N/A	N/A	N/A
	Turbidity	Qualitative indication of well completion success and flag to watch for high probability of suspended solids bleed into water samples.	Field screening similar to ASTM D1889 or ASTM D6855.	<5 NTU	N/A[e]	N/A[e]
	COC concentrations	Need to know dissolved concentrations of each COC at each depth at each well sampled to develop plume maps	Various techniques dependent on COC; today most RCRA metals and long-lived radionuclides (e.g., uranium, Tc-99, I-129, Np-237, and Pu-239) are measured using ICP/MS using ASTM D5673 or EPA SW-846 Method 6020[d], carbon tetrachloride and its primary degradation products by EPA Methods 8260B (GC/MS) or 8021B (GC/PID), or Riley et al. 2005.	See Tables 1-20 and 3-4 for list of COCs and QC requirements	See Table 3-4	See Table 3-4
	Degradation products of carbon tetrachloride (especially chlorinated methanes)	Measurement of carbon tetrachloride degradation products allows mass balance calculations to be performed on the COC and allows degradation processes and their kinetic rates to be assessed.	EPA Methods 5021, 5030B, or 8021B, or Riley et al. 2005 may be applicable. The chlorinated methanes are likely very volatile (gases at temperature of groundwater). Will require special sample preservation and special analytical methods; likely GC or GC/MS.	N/A	25%	25%

Table 3-1. Saturated Zone Parameters of Aquifer Sediments and Groundwater Needed for Modeling Inputs, Remedial Action Alternative Evaluation. (10 sheets)

Property	Parameter	Reason for Measuring	Method	CRDL	Precision Required	Accuracy Required
	Isotope signature testing	Knowledge of isotope distribution of elements such as ruthenium, nitrate (i.e., nitrogen in nitrate, nitrite, and ammonium), uranium, and perhaps other mobile fission products such as molybdenum, rhodium, palladium allows one to estimate the source (from which disposal facility) of the contamination	Various techniques dependent on element. Most rely upon some pre-treatment of water to isolate the desired analyte from others and to concentrate it and then use of various mass spectroscopic techniques to accurately quantify the desired (generally stable) isotopes. See, for example, Dresel et al. 2002, Christensen et al. 2002, Singleton et al. 2005, and Brown et al. 2005.	For fission products and uranium, need to be capable of measuring concentrations in the parts per trillion to low parts per billion; sensitivity not as critical for nitrogen.	Precision must be stringent for good isotope signature measurements. Typically one strives for ±1 to 5%	Accuracy is not as important because one is comparing relative ratios of isotopes of the same element to each other. Absolute concentrations are less important.

Table 3-1. Saturated Zone Parameters of Aquifer Sediments and Groundwater Needed for Modeling Inputs, Remedial Action Alternative Evaluation. (10 sheets)

Property	Parameter	Reason for Measuring	Method	CRDL	Precision Required	Accuracy Required

NOTE: The reference information for the methods referenced in this table is provided in the attachment to the "References" section of this DQO summary report.

[a] Method will be defined by technical support prior to implementation.

[b] If gamma-gamma density probe is not available at the time of logging, proceed running only natural and neutron-induced capture gamma-ray spectroscopy.

[c] Method from *Standard Methods for Examination of Water and Wastewater* (Eaton et al. 1995).

[d] Method from EPA's SW-846 (available online www.epa.gov/epaoswer/hazwaste/test/sw846.htm) (*Test Methods for Evaluating Solid Waste: Physical/Chemical Methods* [EPA 1999]).

[e] Requirements are "yes/no" above or below 5 NTU; precision and accuracy do not apply.

ASA = American Society of Agronomy
ASTM = American Society for Testing and Materials
CEC = cation exchange capacity
COC = contaminant of concern
CRDL = contract-required detection limit
DO = dissolved oxygen
Eh = oxidation potential
EPA = U.S. Environmental Protection Agency
GC = gas chromatography
IC = ion chromatography
ICP = inductively coupled plasma
K_d = partition coefficient
MS = mass spectrometry
N/A = not applicable
NTU = nephelometric turbidity unit
PID = photoionization detector
QC = quality control
RCRA = *Resource Conservation and Recovery Act of 1976*
REDOX = reduction-oxidation
TIC = total inorganic carbon
TOC = total organic carbon
XRD = x-ray diffraction

Table 3-2. Vadose Zone Parameters of Porewater and Partially Saturated Sediments Needed for Modeling Inputs, Source and Remedial Action Alternative Evaluation. (8 sheets)

Property	Parameter	Reason for Measuring	Method	CRDL	Precision Required	Accuracy Required
Vadose Sediments						
Physical/ geological	Lithology	Needed to develop the "geologic layers" used in flow and transport models.	Geologist description using ASTM D2488, Folk 1968, and Wentworth (1922).	N/A	N/A	N/A
	Moisture content	Moisture content is a key parameter of unsaturated sediments that give clues as to the grain size of the sediments and whether the sediments are draining or desiccated. Key parameter for determining moisture flow attributes (vertical versus horizontal) through vadose zone.	ASTM D2216.	N/A	±5%	±1%
	Matrix potential	Matrix potential is a direct measurement of whether the sediments are draining or desiccated by natural evapotranspiration or complications of sampling and storage.	ASTM D5298.	N/A	N/A	N/A
	Particle-size distribution (by dry sieve and wet sieve for gravel and sand, and hydrometer method for silt and clay)	Particle size influences the hydraulic properties (e.g., hydraulic conductivity, effective porosity, and bulk density) and geochemical properties (e.g., CEC and K_d). The fact that particle size is measured relatively inexpensively and can be correlated with so many other needed parameters makes it a valuable measurement with high usability.	ASTM 421 and/or ASTM D422; or ASTM 6913 or ASA Method 15-5.	N/A	N/A	N/A
	Specific surface area	Surface area of sediments correlates with adsorption of many contaminants and is often used to help explain or to predict from empirical relationships adsorption properties of sediments.	Brunauer et al. 1938 and ASTM C1069 or ASTM D1993; or Gregg and Sing 1982.	N/A	±15%	±25%

Table 3-2. Vadose Zone Parameters of Porewater and Partially Saturated Sediments Needed for Modeling Inputs, Source and Remedial Action Alternative Evaluation. (8 sheets)

Property	Parameter	Reason for Measuring	Method	CRDL	Precision Required	Accuracy Required
	Calcium carbonate content (more correctly includes total carbon, inorganic carbon, and organic carbon by difference)	This parameter influences the pH-buffering capacity of the sediment, which is an important for many remediation technologies resin based ion-exchange systems. Calcium carbonate also is a cementing material in porous sediments that influences the hydraulic conductivity and porosity. Organic carbon content influences bioremediation technologies.	ASTM E1915, EPA 9060A[d] or 415.1.[c]	N/A	N/A	N/A
	Borehole geophysics (neutron probe, natural gamma, spectral gamma, and gamma-gamma density[b])	Neutron probe yields information on sediment moisture content, natural gamma information helps determine geologic lithology, and gamma-gamma density yields information on formation bulk density. All of these parameters help establish the hydrogeologic conceptual model needed for the flow and transport modeling.	Hanford specific versions of the following methods are available from the field loggers: ASTM D5753 (general logging guidelines), D6274 (gamma logging), and D6727 (neutron logging).[a]	N/A	N/A	N/A
	Mineralogy – bulk and clay size fraction separates	Relatively inexpensive measurement to aid in picking lithology, understanding CEC and K_d values.	XRD (see Drever 1973, Brindley and Brown 1980, and Moore and Reynolds 1997).	N/A	N/A	N/A
	Bulk density	Needed to calculate the retardation factor of contaminants in the transport model.	ASTM D2937; see precautions on sampling handling in ASTM D6640; also acceptable ASTM D4564.	N/A	N/A	N/A
Hydraulic and transport	Total porosity	Needed to calculate the retardation factor of contaminants in the transport model.	Porosity can be measured directly (Danielson and Sutherland 1986). Use ASTM D2937 for measuring bulk density and ASA Method 14-3 for particle density.	N/A	N/A	N/A

Table 3-2. Vadose Zone Parameters of Porewater and Partially Saturated Sediments Needed for Modeling Inputs, Source and Remedial Action Alternative Evaluation. (8 sheets)

Property	Parameter	Reason for Measuring	Method	CRDL	Precision Required	Accuracy Required
	Saturated hydraulic conductivity	Needed to calculate water flow rates in each lithology at water saturation if using empirical relationships to determine true hydraulic conductivity as a function of moisture content.	Generally use constant head ASTM D2434 sometimes use falling head method ASA 28-4.2 or EPA Method 9100[d]; also acceptable ASTM D5856.	N/A	N/A	N/A
	Unsaturated hydraulic conductivity	Needed to calculate water flow rates in each lithology as a function of moisture content if using direct measurement approach.	ASA 1986, Method 28-5 in Chapter 28.	N/A	N/A	N/A
	Moisture retention curve	The retention of water by porous materials at various matrix potentials. Needed to model flow and transport in variably saturated rocks and sediments.	Hanging water column for pressures between 0 and 100 mbar according to ASTM D6836 and D2325; pressure-plate extraction method for pressures over 100 mbar according to ASTM D2325.			
	Permeability anisotropy ratio	The ratio of vertical hydraulic conductivity to the horizontal conductivity and is a function of saturation. Needed to calculate the relative contributions of horizontal flux to the vertical flux in flow and transport simulations.	Calculated as the ratio of Kv/Kh. Derived from measurements according ASTM D2434 for vertically and horizontally sub-sampled cores; or from field scale experiments using inverse modeling.	N/A	N/A	N/A
	Thermal conductivity	A measure of the ability for a soil/rock to transmit heat. Needed for modeling evapotranspiration, recharge, and soil heat flux, both critical components of the energy balance and soil moisture due to thermal gradients.	ASTM D 5334 or ASA 1986, Method 39-3.	N/A	N/A	N/A

Table 3-2. Vadose Zone Parameters of Porewater and Partially Saturated Sediments Needed for Modeling Inputs, Source and Remedial Action Alternative Evaluation. (8 sheets)

Property	Parameter	Reason for Measuring	Method	CRDL	Precision Required	Accuracy Required
	Heat capacity	The amount of heat required to change its temperature by one degree. Needed for modeling evapotranspiration, recharge, and soil heat flux, both critical components of the energy balance and soil moisture due to thermal gradients.	ASA 1986, Method 38.3.	N/A	N/A	N/A
Geochemical	K_d (e.g., Tc-99 or uranium [VI]), carbon tetrachloride)	Parameter needed to calculate retardation factor for each COC expected to dominate long-term risk.	ASTM 4319 or Relyea et al. 1980 for inorganics and ASTM 5285 for volatile organics.	N/A	±25%	±25%
	Cation exchange capacity or extractable cations	Often helps explain K_d values for cationic contaminants and useful for understanding sediments capacity to release competing common cations to water when performing ion-exchange remediation. If COCs are not dominated by cations the extractable cation measurement using ammonium acetate extraction is sufficient.	Routson et al. 1973 for CEC or summation of cations in ASA 1996 (p. 1221 for NH_4OAc).	N/A	±25%	±25%
	Amorphous hydrous oxide content	Hydrous oxides especially of iron are the most influential adsorbers of inorganic COCs in many sediments that have low clay content, such as Hanford Site sediments. Knowledge of their content helps predict/explain K_d values. Amorphous hydrous oxides have very large specific surface areas and are the key adsorbent in weathering coatings on sediment grains.	ASA 1996 (see Loeppert and Inskeep, and Gambrell sections, or Chao and Zhou 1983).	N/A	±25%	±25%

Table 3-2. Vadose Zone Parameters of Porewater and Partially Saturated Sediments Needed for Modeling Inputs, Source and Remedial Action Alternative Evaluation. (8 sheets)

Property	Parameter	Reason for Measuring	Method	CRDL	Precision Required	Accuracy Required
	Crystalline hydrous oxide content	Hydrous oxides especially of iron are the most influential adsorbers of inorganic COCs in many sediments that have low clay content, such as Hanford Site sediments. Knowledge of their content helps predict/explain K_d values. Crystalline hydrous oxides have large specific surface areas and are the key adsorbent in weathering coatings on sediment grains. Differentiation between amorphous and crystalline oxides provides clues to age of coatings and whether some COCs might have been incorporated into recalcitrant precipitates.	ASA 1996 (see Loeppert and Inskeep).	N/A	±25%	±25%
	Porewater or 1:1 water extract	Vadose sediments do not in general have drainable water, which can be readily obtained for analysis. Thus, one must either "squeeze" existing water by overcoming the capillary forces holding the water in the partially saturated pores or add de-ionized water to "flush" the porewater out. Dependent on the size of vadose zone sample available, its field moisture content, and particle size, one must determine if ultracentrifugation will yield an adequate volume of fluid or if the 1:1 water extraction technique should be used. The water is needed to measure all the parameters listed below.	Ultracentrifuge (ideal equipment is UFA) or 1:1 water extract ASA 1996 (see Rhoades chapter).	N/A	N/A	N/A
Vadose Sediment Porewater						
Geochemical	Major cations (e.g., sodium, potassium, magnesium, and calcium)	Influences remediation techniques that rely on cation-exchange resins (Sr-90, Cs-137) and is useful for understanding overall geochemical conditions that control contaminant/sediment interactions.	ASTM C1111 or EPA SW-846, Method 6010B.[d]	N/A	N/A	N/A

Table 3-2. Vadose Zone Parameters of Porewater and Partially Saturated Sediments Needed for Modeling Inputs, Source and Remedial Action Alternative Evaluation. (8 sheets)

Property	Parameter	Reason for Measuring	Method	CRDL	Precision Required	Accuracy Required
	Specific electrical conductivity	An inexpensive indicator of the total dissolved ion concentration of groundwater.	ASTM 1125 or EPA Method 9050A.[d]	N/A	N/A	N/A
	TOC (total dissolved organic carbon content)	Dissolved organic carbon can act as a food source during bioremediation and some forms of dissolved organic carbon can complex cation contaminants and alter their sorption properties. Thus, knowledge of the TOC helps interpret mobility [K_d] information and guide bioremediation design.	EPA SW-846 Method 9060A[d] or ASTM D4129 or ASTM E1915 or 415.1.[e]	1,000 µg/L	25%	25%
	Alkalinity (can also be estimated from TIC measurement)	Is the key water parameter that controls pH-buffering capacity and is a key complexer of uranium (VI) and can control uranium (VI) sorption tendencies. Also competes with the anionic COCs for sorption onto anion-exchange resins.	ASTM D1067 or 310.1[e] or 310.2.[e]	10 mg/L as CO_3	20%	25%
	pH	Key parameter for controlling acid-base-buffering capacity or aquifer-sediment system. Generally influences most remediation technologies.	ASTM D1293 or EPA SW-846, Method 9045D.[d]	0.1 pH unit	±0.1 pH unit	±0.1 pH unit
	Major anions in sediment porewater (e.g., sulfate, chloride, fluoride, nitrate, phosphate, and bicarbonate/carbonate)	Influences remediation techniques that rely on anion-exchange resins (uranium [VI] and Tc-99) and is useful for understanding overall geochemical conditions that control contaminant/sediment interactions.	Use IC; the following two methods are equivalent: ASTM 4327 or EPA SW-846, Method 9056.[d]		25%	25%

Table 3-2. Vadose Zone Parameters of Porewater and Partially Saturated Sediments Needed for Modeling Inputs, Source and Remedial Action Alternative Evaluation. (8 sheets)

Property	Parameter	Reason for Measuring	Method	CRDL	Precision Required	Accuracy Required
	COC concentrations	Need to know dissolved concentrations of each COC at each depth at each well sampled to develop plume maps.	Various techniques dependent on COC; today most RCRA metals and long-lived radionuclides (e.g., uranium, Tc-99, I-129, Np-237, and Pu-239) are measured using ICP/MS using ASTM D5673 or EPA SW-846, Method 6020. For carbon tetrachloride and its degradation products, use EPA Methods 5021 or 5030B to extract sediments and 8260B (GC/MS) or 8021B (GC/PID) or Riley et al. 2005 for analysis.	See Tables 1-20 and 3-4 for list of COCs and QC requirements.	See Table 3-4	See Table 3-4
	Isotope signature testing	Knowledge of isotope distribution of elements such as ruthenium, nitrate (i.e., nitrogen in nitrate, nitrite, and ammonium), uranium, and perhaps other mobile fission products such as molybdenum, rhodium, and palladium allows one to estimate the source (from which disposal facility) of the contamination.	Various techniques dependent on element. Most rely upon some pre-treatment of water to isolate the desired analyte from others and to concentrate it and then use of various mass spectroscopic techniques to accurately quantify the desired (generally stable) isotopes. (See, for example, Dresel et al. 2002, Christensen et al. 2004, Singleton et al. 2005, and Brown et al. 2005.)	For fission products and uranium need to be capable of measuring concentrations in the parts per trillion to low parts per billion; sensitivity not as critical for nitrogen.	Precision must be stringent for good isotope signature measurements. Typically one strives for ± 1 to 5%	Accuracy is not as important because one is comparing relative ratios of isotopes of the same element to each other. Absolute concentrations are less important.

Table 3-2. Vadose Zone Parameters of Porewater and Partially Saturated Sediments Needed for Modeling Inputs, Source and Remedial Action Alternative Evaluation. (8 sheets)

Property	Parameter	Reason for Measuring	Method	CRDL	Precision Required	Accuracy Required

[a] Method will be defined by technical support prior to implementation.
[b] If gamma-gamma density probe is not available at the time of logging, proceed running only natural and neutron-induced capture gamma-ray spectroscopy.
[c] Method from *Standard Methods for Examination of Water and Wastewater* (Eaton et al. 1995).
[d] Method from EPA's SW-846 (available online at www.epa.gov/epaoswer/hazwaste/test/sw846.htm) (*Test Methods for Evaluating Solid Waste: Physical/Chemical Methods* [EPA 1999]).

ASA = American Society of Agronomy
ASTM = American Society for Testing and Materials
CEC = cation exchange capacity
COC = contaminant of concern
CRDL = contract-required detection limit
Eh = oxidation potential
EPA = U.S. Environmental Protection Agency
GC = gas chromatography
IC = ion chromatography
ICP = inductively coupled plasma
K_d = partition coefficient
MS = mass spectrometry
N/A = not applicable
NTU = nephelometric turbidity unit
PID = photoionization detector
QC = quality control
RCRA = *Resource Conservation and Recovery Act of 1976*
TIC = total inorganic carbon
TOC = total organic carbon
XRD = x-ray diffraction

NOTE: The reference information for the methods referenced in this table is provided in the attachment to the "References" section of this DQO summary report.

Table 3-3. Required Information and Reference Sources. (3 sheets)

DS #	Variable	Required Data	Do Data Exist?	Source Reference	Sufficient Quantity?	Additional Information Required?
1 through 5	COCs identified in Section 1-9	Identification of COCs and their concentrations currently or potentially in the vadose zone and unconfined aquifer.	Y	HEIS database Annual Hanford Site groundwater reports *Remedial Investigation/Feasibility Study Work Plan for the 200-ZP-1 Groundwater Operable Unit*, DOE/RL-2003-55, Rev. 0 (DOE-RL 2004)	N	Y
1	Groundwater flow rate	The current calculated groundwater flow rates do not adequately predict current plume locations, based on assumed sources. Additional evaluation of flow rate and/or collection of additional flow rate data related to plumes under the T Area are needed.	Y	Annual Hanford Site groundwater reports Current flow rates are for localized areas not for the entire plume (*RCRA Assessment Plan for Single-Shell Tank Waste Management Area T*, PNNL-15301, Rev. 0 [Horton 2006])	N	Y
4	Modeling input parameters	Geotechnical properties of unconfined aquifer (e.g., hydraulic conductivity, porosity, and transmissivity), K_d values, groundwater gradient, and mixing depth.	Y	*Data Quality Objectives Summary Report for Establishing a RCRA/CERCLA/AEA Integrated 200 West and 200 East Groundwater Monitoring Network*, CP-15329, Rev. 0 (FH 2003a) *Assessment of Carbon Tetrachloride Groundwater Transport in Support of the Hanford Carbon Tetrachloride Innovative Technology Demonstration Program*, PNNL-13560, Rev. 0 (Truex et al. 2001)	N	Y
2	Contaminant sources	Concentration estimates of the sources of Tc-99, times and locations of release to the soil column, and times and locations of release to the groundwater.	Y	Soil Inventory Model *T Plant Source Aggregate Area Management Study Report*, DOE/RL-91-61, Rev. 0 (DOE-RL 1992b) T Area leaking tanks (focusing on 241-T-101 and 241-T-106) Geophysical logging Section 1.5 of this DQO summary report	N	Y

Table 3-3. Required Information and Reference Sources. (3 sheets)

DS #	Variable	Required Data	Do Data Exist?	Source Reference	Sufficient Quantity?	Additional Information Required?
2	Driving forces in vadose zone	Times and locations of release of other sources of liquids to the vadose zone, and times and locations of release to the groundwater	Y	Soil Inventory Model *T Plant Source Aggregate Area Management Study Report*, DOE/RL-91-61, Rev. 0 (DOE-RL 1992b) Geophysical logging Section 1.5 of this DQO summary report	N	Y
2	Ratios to relate groundwater and vadose contamination to sources	Isotopes/chemical ratios to differentiate between sources; need to determine which ratios most logical to use.	Y	*RCRA Assessment Plan for Single-Shell Tank Waste Management Area T*, PNNL-15301, Rev. 0 (Horton 2006) *Fiscal Year 2005 Letter Report – Measurement of Stable Ruthenium Isotopes from Groundwater and Vadose Zone Samples Collected in the Vicinity of T Area* (Brown et al. 2005)	N	Y
3	Vertical and lateral extent in vadose zone and unconfined aquifer of COCs identified in Section 1.9	Concentration of COCs as a function of vertical and lateral location in the vadose zone and groundwater plume. Current data (based on two wells) do not define three-dimensional distribution of groundwater plume; more depth-discrete data from more wells are needed.	Y	Data from well 299-W11-45 and 299-W11-25B	N	Y
4	Need data from DS #1 and DS #3		Y	See above DSs	N	Y

Table 3-3. Required Information and Reference Sources. (3 sheets)

DS #	Variable	Required Data	Do Data Exist?	Source Reference	Sufficient Quantity?	Additional Information Required?
5	Variables for remedial alternatives	Concentration of COCs as a function of time, location. Three-dimensional distribution of any COCs that reach or may reach the groundwater. Geotechnical properties of unconfined aquifer (e.g., general groundwater quality indicators [total carbon, alkalinity, major cations and anions, etc.], hydraulic conductivity, porosity, and transmissivity), K_d values, groundwater gradient, and mixing depth.	N	Potential remedial alternatives for groundwater: • Pump-and-treat with ion exchange to remove Tc-99 and carbon column for organics • Other alternatives, based on data collected per the 200-ZP-1 RI/FS work plan (DOE-RL 2004) and the results of the 200-ZP-1 FS (in progress)	N	Y

COC = contaminant of concern
DQO = data quality objective
DS = decision statement
K_d = distribution coefficient
HEIS = Hanford Environmental Information System
RI/FS = remedial investigation/feasibility study

Table 3-4. Analytical Performance Requirements for Contaminant of Concern in Groundwater. (3 sheets)

Type of COC	COCs	Survey or Analytical Method[a]	Reporting Limit[b,k] (µg/L)	Precision Required	Accuracy Required
Nonradiological COCs					
Volatile organics	Carbon tetrachloride	SW-846, Method 8260	3[e]	±20%	80-120%
	Chloroform	SW-846, Method 8260	5[e]	±20%	80-120%
	Trichloroethylene (TCE)	SW-846, Method 8260	5[e]	±20%	80-120%
Metals	Antimony	SW-846 Methods 6010-B or 6020 or EPA Method 200.8	10	±25%	75-125%
	Arsenic	SW-846 Method 7060A	6[e]	±25%	75-125%
	Cadmium	SW-846 Methods 6010-B (trace) or 6020 or EPA Method 200.8	5/2[e,j]	±25%	75-125%
	Chromium (total)	SW-846 Methods 6010-B or 6020 or EPA Method 200.8	10	±25%	75-125%
	Chromium (hexavalent)	SW-846 Method 7196A	10	±25%	75-125%
	Common cations (Ca, K, Mg, and Na)	SW-846 Methods 6010-B or 6020 or EPA Method 200.8	c	±25%	75-125%
	Iron	SW-846 Methods 6010-B or 6020 or EPA Method 200.8	50[f]	±25%	75-125%
	Lead	SW-846 Methods 6010-B (trace) or 6020 or EPA Method 200.8	10/5[e,j]	±25%	75-125%
	Manganese	SW-846 Methods 6010-B or 6020 or EPA Method 200.8	5[f]	±25%	75-125%
	Nickel	SW-846 Methods 6010-B or 6020 or EPA Method 200.8	40	±25%	75-125%
	Vanadium	SW-846 Methods 6010-B or 6020 or EPA Method 200.8	50	±25%	75-125%

Table 3-4. Analytical Performance Requirements for Contaminant of Concern in Groundwater. (3 sheets)

Type of COC	COCs	Survey or Analytical Method[a]	Reporting Limit[b,k] (µg/L)	Precision Required	Accuracy Required
Non-metals	Fluoride	EPA Method 300.0[d]	500	±25%	75-125%
	Nitrite	EPA Method 300.0[d]	250	±25%	75-125%
	Nitrate	EPA Method 300.0[d]	250	±25%	75-125%
	Nitrogen in nitrite	EPA Method 300.0[d]	75	±25%	75-125%
	Nitrogen in nitrate	EPA Method 300.0[d]	75	±25%	75-125%
	Chloride	EPA Method 300.0[d]	200	±25%	75-125%
	Alkalinity	310.1/310.2[l]	5,000	±25%	N/A
	Sulfate	EPA Method 300.0	2,500	±25%	75-125%
Radiological COCs					
Beta emitters	I-129	Low-energy photon spectroscopy or ICP/MS by SW-846 Method 6020 or EPA Method 200.8	0.5g	±30%	70-130%
	Tc-99	ICP/MS by SW-846 Method 6020	20	±30%	70-130%
	H-3	Liquid scintillation	400	±30%	70-130%
Alpha emitters	Uranium (total)	Kinetic phosphorescence or ICP/MS by SW-846 Method 6020 or EPA Method 200.8	1 µg/L[h]	±25%[i]	50-125%[i]
Field Measurements					
Volatile organics	Carbon tetrachloride	Field gas chromatography	3	±25%	75-125%
	Chloroform	Field gas chromatography	5	±25%	75-125%
Field parameters	Specific conductance	Field screening	N/A	N/A	N/A
	pH	SW-846 Method 9040 or EPA Method 150.1	0.1 pH unit	N/A	N/A

Table 3-4. Analytical Performance Requirements for Contaminant of Concern in Groundwater. (3 sheets)

Type of COC	COCs	Survey or Analytical Method[a]	Reporting Limit[b,k] (µg/L)	Precision Required	Accuracy Required

[a] Analytical method selection is based on available methods by laboratories currently contracted to the Hanford Site. Equivalent methods may be substituted in future sampling and analysis plans or other documents. Four-digit methods are from EPA's SW-846 (*Test Methods for Evaluating Solid Waste: Physical/Chemical Methods* [EPA 1999]); other methods referenced to source.

[b] Typical reporting limit or MDC based on current Hanford laboratory contracts or are adjusted based on the project requirements. Detection limits in subsequent documents may differ depending on method selection and the contract laboratory. Units are "µg/L" for nonradiological COCs and "pCi/L" for radiological COCs (unless otherwise noted).

[c] CA = 1,000 µg/L; K = 4,000 µg/L; Mg = 750 µg/L; and Na = 500 µg/L.

[d] Method from *Methods for the Determination of Inorganic Substances in Environmental Samples*, EPA/600/R-93-100 (EPA 1993).

[e] If the reporting limit is very near (within 1 to 2 parts per billion) or above the preliminary target action levels, an attempt will be made to use larger sample volumes to allow decreased reporting limits.

[f] These are not reporting limits and are project-specific.

[g] The laboratory cannot routinely achieve 0.5 pCi/L; thus, the project is using 1 pCi/L as the reporting limit and the selected limit.

[h] The laboratory has routinely been achieving a 0.1 µg/L detection limit for uranium (total).

[i] Precision and accuracy are based on ICP/MS methods.

[j] First value shown is based on ICP/MS method, second value shown is based on trace ICP method. Trace ICP method will be used for analysis of arsenic, cadmium, and lead.

[k] WAC 173-340-707 allows use of the practical quantitation limit which is the reporting limit when the best available technology will not detect below the selected limit, in this case the MCL. The requirements of WAC 173-340-707 are applicable here for arsenic, cadmium, and lead.

[l] From *Methods of Chemical Analysis of Water and Waste*, EPA/600/4-79/020 (EPA 1983).

COC = contaminant of concern
EPA = U.S. Environmental Protection Agency
ICP = inductively coupled plasma
MCL = maximum contaminant level
MDC = minimum detectable concentration
MS = mass spectrometry
N/A = not applicable
WAC = *Washington Administrative Code*

Table 3-5. Analytical Performance Requirements for Contaminants of Concern in Sediment. (2 sheets)

Type of COC	COCs	Survey or Analytical Method[a]	Reporting Limit[b] (mg/kg)	Precision Required	Accuracy Required
Nonradiological COCs					
Metals	Antimony	SW-846 Methods 6010B or 6020 or EPA Method 200.8	6	±30%	70-130
	Arsenic	SW-846 Methods 6010-B or 6020 or EPA Method 200.8	10	±30%	70-130
	Cadmium	SW-846 Methods 6010-B or 6020 or EPA Method 200.8	0.5	±30%	70-130
	Chromium (total)	SW-846 Methods 6010-B or 6020 or EPA Method 200.8	1	±30%	70-130
	Chromium (hexavalent)	SW-846 Method 7196A	0.5	±30%	70-130
	Common cations (Ca, K, Mg, and Na)	SW-846 Methods 6010-B or 6020 or EPA Method 200.8	c	±30%	70-130
	Iron	SW-846 Methods 6010-B or 6020 or EPA Method 200.8	5	±30%	70-130
	Lead	SW-846 Methods 6010-B (trace) or 6020 or EPA Method 200.8	10	±30%	70-130
	Manganese	SW-846 Methods 6010-B or 6020 or EPA Method 200.8	5	±30%	70-130
	Nickel	SW-846 Methods 6010-B or 6020 or EPA Method 200.8	4	±30%	70-130
	Vanadium	SW-846 Methods 6010-B or 6020 or EPA Method 200.8	2.5	±30%	70-130
Non-metals	Fluoride	EPA Method 300.0[d]	5	±30%	70-130
	Nitrite	EPA Method 300.0[d]	2.5	±30%	70-130
	Nitrate	EPA Method 300.0[d]	2.5	±30%	70-130
	Nitrogen in nitrite	EPA Method 300.0[d]	0.75	±30%	70-130
	Nitrogen in nitrate	EPA Method 300.0[d]	0.75	±30%	70-130
	Chloride	EPA Method 300.0[d]	2.0	±30%	70-130
	Sulfate	EPA Method 300.0[d]	5	±30%	70-130

Table 3-5. Analytical Performance Requirements for Contaminants of Concern in Sediment. (2 sheets)

Type of COC	COCs	Survey or Analytical Method[a]	Reporting Limit[b] (mg/kg)	Precision Required	Accuracy Required
Radiological COCs					
Beta emitters	I-129	Low-energy photon spectroscopy or ICP/MS by SW-846 Method 6020 or EPA Method 200.8	2	±30%	70-130
	Tc-99	ICP/MS by SW-846 Method 6020	15	±30%	70-130
	H-3	Liquid scintillation	400	±30%	70-130
Alpha emitters	Uranium (total)	Kinetic phosphorescence or ICP/MS by SW-846 Method 6020 or EPA Method 200.8	1	±30%	70-130
Field Measurements					
Field parameters	Specific conductance	Field screening	N/A	N/A	N/A
	pH	SW-846 Method 9040 or EPA Method 150.1	0.1 pH unit	N/A	N/A

[a] Analytical method selection is based on available methods by laboratories currently contracted to the Hanford Site. Equivalent methods may be substituted in future sampling and analysis plans or other documents. Four-digit methods are from EPA SW-846 (*Test Methods for Evaluating Solid Waste: Physical/Chemical Methods* [EPA 1999]); other methods referenced to source.

[b] Typical reporting limit or MDC based on current Hanford laboratory contracts or are adjusted based on the project requirements. Detection limits in subsequent documents may differ depending on method selection and the contract laboratory. Units are "µg/L" for nonradiological COCs and "pCi/L" for radiological COCs (unless otherwise noted).

[c] Ca = 100 mg/kg, K = 400 mg/kg, Mg = 75 mg/kg, and Na = 50 mg/kg.

[d] Method from *Methods for the Determination of Inorganic Substances in Environmental Samples*, EPA/600/R-93-100 (EPA 1993).

COC = contaminant of concern
EPA = U.S. Environmental Protection Agency
ICP = inductively coupled plasma
MDC = minimum detectable concentration
MS = mass spectrometry
N/A = not applicable

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4.0 STEP 4 – DEFINE THE BOUNDARIES OF THE STUDY

The primary objective of DQO Step 4 is to identify the population of interest, define the spatial and temporal boundaries that apply to each DS, define the scale of decision making, and identify any practical constraints (i.e., hindrances or obstacles) that must be taken into consideration.

4.1 POPULATION OF INTEREST

Before defining the spatial and temporal boundaries of the site under investigation, it is first necessary to clearly define the populations of interest that apply for each DS (Table 4-1). The intent of Table 4-1 is to define the attributes that make up each population of interest by stating them in a way that makes the focus of the study unambiguous.

4.2 GEOGRAPHIC BOUNDARIES

Table 4-2 identifies the geographic boundaries that apply to each DS. Limiting the geographic boundaries of the study area ensures that the investigation does not expand beyond the original scope of the task. (Note that each groundwater OU is responsible for the remediation of contamination within its boundaries, regardless of the contaminant source.)

4.3 STRATA WITH HOMOGENEOUS CHARACTERISTICS

Existing information for the unconfined aquifer is insufficient to support subdivision of the strata into subsets with relatively homogeneous characteristics. Groundwater wells along the perimeter of WMA-T indicate that at a given depth below the water table, the technetium-99 concentrations vary (e.g., not detectable on the west side compared to a maximum reported concentration exceeding 180,000 pCi/L on the northeast side). The higher technetium-99 and nitrate concentrations on the northeast side of WMA-T are approximately 10 m (32.8 ft) below the water table. The lateral heterogeneity may be due to insufficient data below the water table and/or differences in the aquifer sediments. Additional data are required to better define the shallow unconfined aquifer conditions. The focus of this DQO summary report is to obtain data to better assess this anomaly.

4.4 TEMPORAL BOUNDARIES

Table 4-3 identifies the temporal boundaries that apply to each DS. The temporal boundary refers to the timeframe over which the data collected will apply to the DSs and to the optimum timeframe to collect the samples. The concentrations of the COCs may change as the water flows, thus changing over time. Using the appropriate fate and transport modeling or using simple calculations (after data discussed in Sections 3.0 and 7.0 are obtained and consolidated), the concentrations can be modeled over time. In addition, groundwater samples are typically collected quarterly or annually to allow assessment of concentrations over time from the same well.

The temporal boundaries shown in Table 4-3 are based on project goals and not on technical requirements. Note that the times are related to the CERCLA project; different times may be needed for RCRA compliance. The data collected may support both CERCLA and RCRA decisions; however, CERCLA is the major focus of this study. Integration between CERCLA

and RCRA was the primary global issue identified by the decision makers and is discussed in Section 1.3.1. The SAP will describe the proper sample preservation, including temperature storage conditions and holding time requirements to ensure sample integrity.

4.5 SCALE OF DECISION MAKING

In Table 4-4, the scale of decision making has been defined for each DS. The scale of decision making is defined by joining the population of interest and the geographic and temporal boundaries of the area under investigation. For this DQO summary report, the scale of decision making is described in fairly global terms. As discussed in recent EPA DQO guidance (EPA 2000), the scale of decision making may be based on widely different project needs. It is expected that as the cleanup of the site progresses, more specific and different decision-making scales will be developed. The paragraph below summarizes recent EPA guidance:

> *The scale of decision making is the smallest area or volume of the media, or the shortest timeframe associated with the contamination problem of the site for which the planning team wishes to control decision errors. The goal of this activity is to define subsets of media about which the planning team will be able to make independent decisions that satisfy the decision error constraints specified in Step 6. The scale may range from the entire geographic boundaries of the site to the smallest area that can be remediated with a given technology. The scale of decision making is sometimes called a decision unit. The scale of decision making may be based on the following:*
>
> *(1) Risk*
> *(2) Permits and regulatory conditions*
> *(3) Technology considerations*
> *(4) Financial*
> *(5) Other considerations.*
>
> *A temporal scale of decision making might be necessary for studies where contamination varies significantly over time. For example, at a site with contaminated groundwater, investigators may be concerned that quarterly sampling of perimeter monitoring wells might inadvertently allow migrating contamination to go undetected for too long and possibly endanger human health or the environment. Therefore, the investigators may choose a shortened period, such as a month, between sampling events* (EPA 2000).

4.6 PRACTICAL CONSTRAINTS

Potential practical constraints that could interfere with the implementation of the sampling program outlined in Section 7.0 are as follows:

- Access to planned locations for one or more groundwater monitoring wells or disposal facility vadose zone boreholes could be temporarily impeded due to security issues, radiological controls, or other health and safety or worker protection issues.
- Access to the T Tank Farm fenced area to sample below suspected leaking tanks, the 216-T-7 and 216-T-32 Cribs, and various diversion boxes and catch tanks may be restricted based on radiological controls and/or other health and safety issues.

- Sampling schedule may be constrained by availability of resources, weather, or other practical factors.
- Air rotary drilling techniques must not be used to collect samples in the aquifer because these techniques will remove volatile constituents.
- Sediment sampling techniques may not collect a sufficient volume of material to complete all identified analyses.
- Well maintenance or pump problems could impede collection of some groundwater samples.
- Budgetary issues could limit the installation and sampling of new wells and vadose zone boreholes.
- Sample shipping or laboratory problems can affect holding times and completeness of sample analysis.
- Well(s) could go dry.

If sampling is incomplete due to any of the above issues, it will not be considered as a noncompliance with this DQO summary report.

Table 4-1. Characteristics that Define the Population of Interest.

DS #	Population of Interest
1 through 5	Identity and concentration of COCs in vadose zone and unconfined groundwater underlying the T Area within the 200-ZP-1 OU. This data, along with other well data within the OU, will be used to model COC concentration in groundwater for the next 1,000 years.
1	Groundwater flow and direction in the Tc-99 and other plume areas
2	Concentration of contaminants and applicable physical modeling parameters in the vadose zone, vadose zone sediments, and vadose zone porewater in the T Area.
3	Horizontal and vertical distribution of COCs in groundwater in the T Area within the 200-ZP-1 OU.
4	Data required to evaluate initial candidate remedial action alternatives.
5	Data required to evaluate remedial action alternatives for specific plumes.

COC = contaminant of concern
DS = decision statement
OU = operable unit

Table 4-2. Geographic Boundaries of the Investigation.

DS #	Geographic Boundaries of the Investigation
1 through 5	The major lateral area is the groundwater under the T Area and the groundwater east and northeast of the T Area within the 200-ZP-1 OU. The T Area study boundary is shown in Figure 7-1. The basis for the T Area study boundary is the 900 pCi/L estimated isopleth at the water table[a], which is also the drinking water limit for Tc-99, which extends to the east-northeast. The western boundary includes 216-T-5 and 216-T-7. The southwest corner is 216-T-36 and the northwest boundary is the lobe of T Pond that received effluent from a pipeline from the 207-T retention basin. The primary focus is the highest concentration zone of Tc-99 to provide better information for future remedial actions. The groundwater depth is defined from the groundwater surface to the top of the Ringold Lower Mud Unit.
2	The vadose zone from the ground surface to the top of the groundwater in the T Area.
4	Groundwater[b] outside the T Area but inside the 200 Area Central Plateau, as shown in Figure 7-1, which lies within the 200-ZP-1 OU, as well as the groundwater affected by the SALDS discharges and any plumes that originate in the 200-ZP-1 Groundwater OU.

[a] The 900 pCi/L isopleth depicted at the water table in Figure 1-1 and Figure 7-1 was based on the map of technetium-99 concentrations documented in *Hanford Site Groundwater Monitoring for Fiscal Year 2004*, PNNL-15070, Rev. 0 (PNNL 2005). The study area shown in Figures 1-1 and 7-1 encompasses the area defined by the 900 pCi/L isopleth at the water table and was selected as a reasonable focus for initial investigations of groundwater contamination and potential sources. During the DQO process to support Phase II activities, new data acquired after completion of the Phase I DQO process will used to refine the conceptual model of the technetium-99 contamination and to revise the study area boundary, as appropriate.

[b] For this data quality objective process, the groundwater of interest is from the top of the saturated zone to the top of the Ringold Lower Mud Unit.

DS = decision statement
OU = operable unit
SALDS = State-Approved Land Disposal Site

Table 4-3. Temporal Boundaries of the Investigation.

DS #	Timeframe (Years)	When to Collect Data
1 through 5	0 to 0.5	Historical data collected and evaluated in this DQO summary report.
2	0 to 2	Calculations can be performed with current data and performed with new data as additional deep wells are drilled.
3	0 to 2	During the drilling of new groundwater monitoring wells, collect depth-discrete samples of both sediment (vadose and aquifer) and groundwater. Additional boreholes that sample only the vadose zone are also contemplated to better investigate the COC source and COC inventory.
4	0-3	Data will be collected to allow modeling before the ROD.
5	1 to 4	Prior to choosing remedial action alternative and completion of the ROD revision.

COC = contaminant of concern
DQO = data quality objective
DS = decision statement
ROD = Record of Decision

Table 4-4. Scale of Decision Making. (2 sheets)

DS #	Population of Interest	Geographic Boundaries	Temporal Boundary		Scale of Decision
			Time-frame	When to Collect Data	
1 through 5	Identity and concentration of COCs in groundwater below the east side of the T Area in the northeastern corner of the 200-ZP-1 OU.	Core zone and groundwater outside of the core zone within the 200-ZP-1 OU, as shown in Figure 7-2. The groundwater depth is defined from the groundwater surface to the top of the Ringold Lower Mud Unit.	See Table 4-3	See Table 4-3	Groundwater within the geographic boundaries over the next 0.5 years.
1 through 5	Identity and concentration of COCs in the vadose zone below and downgradient of facilities that may have been the source of the current groundwater plume below the east side of the T Area in the northeastern corner of the 200-ZP-1 OU.	The vadose zone from the ground surface to the top of the groundwater in the T Area.	See Table 4-3	See Table 4-3	Vadose zone sediments/porewater within the geographic boundaries and below key disposal facilities over the next 0.5 years.

Table 4-4. Scale of Decision Making. (2 sheets)

DS #	Population of Interest	Geographic Boundaries	Temporal Boundary		Scale of Decision
			Time-frame	When to Collect Data	
2	Groundwater flow rate and direction for groundwater in the saturated zone within in the east side of the T Area in the northeastern corner of the 200-ZP-1 OU.	Core zone and groundwater outside of the core zone within the 200-ZP-1 OU, as shown in Figure 7-2. The groundwater depth is defined from the groundwater surface to the top of the Ringold Lower Mud Unit.	See Table 4-3	See Table 4-3	Groundwater within the geographic boundaries over the next 2 years.
3	Horizontal and vertical distribution of COCs in groundwater in the east side of the T Area in the northeastern corner of the 200-ZP-1 OU.	Core zone and groundwater outside of the core zone within the 200-ZP-1 OU, as shown in Figure 7-2. The groundwater depth is defined from the groundwater surface to the top of the Ringold Lower Mud Unit.	See Table 4-3	See Table 4-3	Groundwater within the geographic boundaries over the next 2 years.
4	Data required to evaluate candidate remedial action alternatives.	Core zone and groundwater outside of the core zone within the 200-ZP-1 OU, as shown in Figure 7-2. The groundwater depth is defined from the groundwater surface to the top of the Ringold Lower Mud Unit.	See Table 4-3	See Table 4-3	A specific groundwater contaminant plume within the geographic boundaries over the next 3 years.
5	Data required to evaluate specific chosen remedial action alternatives.	Core zone and groundwater outside of the core zone within the 200-ZP-1 OU, as shown in Figure 7-2. The groundwater depth is defined from the groundwater surface to the top of the Ringold Lower Mud Unit.	See Table 4-3	See Table 4-3	Groundwater within the geographic boundaries over the next 4 years.

COC = contaminant of concern
DS = decision statement
OU = operable unit

5.0 STEP 5 – DEVELOP A DECISION RULE

Typically, in DQO Step 5, the statistical parameters of interest are defined, the final action levels are identified, and decision rules (DRs) are developed. However, the objective of this study is not to perform a statistical analysis between wells or within a well, but to better understand the horizontal and vertical distribution of technetium-99 and other COCs within the unconfined aquifer so remedial actions can be assessed. Therefore, the establishment of statistical parameters (i.e., mean or 95th upper confidence level of COC concentrations to be compared against the action levels) is not applicable. The action levels are the selected levels PRGs from the 200-ZP-1 RI/FS work plan (DOE-RL 2004), as previously noted. Even with a judgmental design, DRs can be developed and are useful for guiding data collection efforts.

In this section, a DR is developed for each of the DSs identified in DQO Step 2. Each DR is in the form of an "IF…THEN…" statement that incorporates the parameter of interest (from Section 3.0), the scale of decision making (from Section 4.0), the action level (from Section 3.0), and the AA(s) (from Section 2.0) that would result from resolution of the decision.

5.1 ADEQUACY OF MONITORING NETWORK FOR PLUME TRACKING

- *DS #1 – Determine whether the RCRA/CERCLA compliance well network and sampling frequency are adequate to determine horizontal and vertical technetium-99 groundwater plume movement and the rate and direction of groundwater flow at the T Area.*

  In order to determine if the compliance well network and sampling frequency are adequate, it is necessary to estimate the movement of the groundwater plume. The groundwater flow rate and flow direction are fundamental inputs to evaluating the lateral (and to some extent, the vertical) distribution of contamination. The flow rate and flow direction are also valuable inputs to determine contamination sources. Therefore, the flow rate and flow direction need to be known where contaminants are encountered in the groundwater.

  The existing flow-rate data need to be reviewed to reconcile apparent plume extents with potential sources and to guide future interpretation and use of this data set. For several of the various conceptual models discussed in Section 1.12, the arrival of contamination at specific wells does not match the estimated timeframe based on existing groundwater flow rates and assumed sources. A DR regarding the review of existing flow rate data is as follows:

  - *DR #1a – Review the existing estimates of groundwater flow rate and direction. If the existing groundwater flow rate and direction can be reconciled with the current technetium-99 groundwater plume boundaries and potential source areas, then the data are adequate for assessing the RCRA/CERCLA compliance well network; otherwise, additional data to evaluate groundwater flow rate and direction will be collected during drilling of new wells and will be considered using existing wells that have appropriately configured locations and screened intervals.*

  The existing groundwater flow rates calculated from aquifer tests conducted by Spane et al. (2001, 2002, 2003) within single wells and summarized by Horton (2006) vary by more than a factor of 10 in the general area of interest, ranging from 6.2 to

102 m/yr (20.3 to 334.6 ft/yr). The groundwater flow rate for the current easterly flow was estimated by Horton (2006) from breakthrough of contaminants to be approximately 4.6 m/yr (15.1 ft/yr) over the period of 1997 to 2004. The average groundwater flow rate over a larger aquifer area (ideally, the plume area) is needed to assess the compliance well network. A DR regarding the collection of additional groundwater flow data is as follows:

- *DR#1b – If the RCRA/CERCLA compliance well network (well location and depth) and sampling frequency are adequate to determine the horizontal and vertical movement of the technetium-99 groundwater plume given the groundwater flow rate and direction in the T Area, then no new wells are needed; otherwise, new wells need to be installed.*

With the existing or additional groundwater flow rate and direction data in the T Area, the RCRA/CERCLA compliance well network can be assessed for location, depth, and sampling frequency for tracking the technetium-99 plume movement. The DR regarding the compliance well network assessment is as follows:

- *DR #1c – If new wells are needed, the locations and depths will follow DR #3a and DR #3b for delineating the vertical and horizontal groundwater plume extents.*

5.2 CONTAMINANT SOURCES AND DRIVING FORCES

- *DS #2 – Determine if the source(s) and driving forces through the vadose zone to groundwater are identified and characterized for the contaminants exceeding DWSs in the wells located on the east boundary of WMA-T sufficiently to evaluate alternative actions to remediate sources.*

Determinations of vadose zone contaminant source(s), driving forces, mass of the contaminants, and migration pathways will result from syntheses of historical data, data gathered as part of this DQO process, and data gathered as part of other programs, such as the Tank Farm Vadose Zone Project and the 200-ZP-1 OU RI/FS process. If source remedial action alternatives cannot be evaluated from the synthesis of this information, then additional boreholes or wells will be needed to differentiate between two or more contaminant sources. The DRs addressing these issues are as follows:

- *DR #2a– If more data are needed in a specific area to distinguish among two or more potential sources of contamination or to better define the existing vadose zone inventory of key COCs, then new boreholes appropriately placed at these potential sources will be sampled and analyzed for COCs, and selected isotopes to evaluate the contaminant source(s); otherwise, no new boreholes are needed.*
- *DR #2b– If more data are needed to define source(s) and driving forces for moving contamination through the vadose zone, then records of existing borehole geophysical logging will be examined. If geophysical logging has not been performed, it will be performed or a reason for not performing the logging will be recorded. Geophysical logging (i.e., gamma or spectral gamma, and neutron moisture, if feasible) will be performed on all new boreholes. The gamma geophysical logs will be used to determine the depth distribution of any gamma-emitting contaminants around the boreholes, to develop (if possible) vadose zone*

plume geometries for gamma-emitting contaminants that might indicate a source(s), to support interpretation of subsurface lithology, and to provide baseline information. The neutron-moisture geophysical logs will be used to determine the moisture profile with depth, potentially indicating zones more likely to be associated with lateral migration in the vadose zone.

5.3 EXTENT OF GROUNDWATER CONTAMINATION

- *DS #3 – Determine if adequate data are available to delineate the vertical and horizontal extent of the technetium-99, chromium, nitrate, fluoride, tritium, and associated groundwater plumes at the T Area.*

The vertical and horizontal extent of the various groundwater contamination plumes are required by CERCLA/RCRA and are necessary to determine the total mass of technetium-99 and other contaminants in the groundwater. The lateral and vertical extent of vadose zone and groundwater contamination are also necessary to assess future migration and to plan remedial actions. Thus, it is important to know the spatial distribution of contaminants in the unconfined aquifer in the T Area. It is not only important to know the spatial distribution of contaminants in the aquifer at the time that a new well is drilled, but it is important to know how the contaminant profile changes with time.

Depth-discrete sampling will be performed. After the vertical extent of groundwater contamination at a well location is known (based on rapid turnaround analyses for technetium-99 and other COCs and application of DR #3b or DR #3c), the well will be screened across a vertical interval that includes as many COC maxima as possible, with priority being the technetium-99 maximum and considering the following well-screen length limits: in the top of the aquifer, screen lengths up to 10.7 m (35 ft) can be used, whereas deeper in the aquifer, shorter screens may be required. The DRs regarding the lateral extent of contamination are outlined below:

- *DR #3a – If a given contaminant groundwater plume is enclosed laterally and downgradient, at the water table and at depth, by monitoring wells or additional OU wells with concentrations less than the DWS for the given contaminant, then the lateral extent of the given contaminant groundwater plume is sufficiently understood; otherwise, additional wells are needed.*

For cases where the vertical extent of a given contaminant groundwater plume is not known, additional wells will be necessary to define the extent of the plume. An additional DR regarding the vertical extent of contamination is as follows:

- *DR #3b – If depth-discrete groundwater sampling at a well location (during or after drilling) shows that, at some depth, the concentration for a given COC is less than the DWS for the given contaminant, and that concentrations above that depth passed through a maximum value, then the vertical extent of contamination for the given contaminant at that well location is defined; otherwise, additional, deeper wells are needed.* (The COCs for this project are provided in Section 1.0.)

For cases where the concentration for the given contaminant remains high at the total depth of the well, the vertical extent of contamination in the area is not well known. Additional DRs regarding the vertical extent of contamination are as follows:

- *DR #3c – If a well in the process of being drilled has reached a depth at least approximately 36.6 m (120 ft) below the water table, and the estimated concentration of a COC (that can be analyzed using a rapid turnaround) is greater than the DWS for the given contaminant, then a decision can be made to extend the depth of the well within the unconfined aquifer until contaminant concentrations in two successive groundwater samples spaced at least approximately 3 m (10 ft) apart are less than the DWS for the given contaminant; otherwise, stop drilling. The minimum depth of 36.6 m (120 ft) below the water table was selected to be consistent with the minimum depth for drilling other 200-ZP-1 OU RI wells.* (The COCs for this project are provided in Section 1.0.)
- *DR #3d – If the subject well is not a new well, and the estimated concentration of a COC is greater than the DWS for the given contaminant, then decisions can be made to prioritize a new, deeper well at that location; otherwise, no new, deeper well is needed at that location.* (The COCs for this project are provided in Section 1.0.)
- *DR #3e – If the estimated concentration of a COC is greater than the DWS for the given contaminant and is found deeper than the Ringold Lower Mud Unit (or its equivalent position if the Lower Mud Unit is not present), the lower boundary of the study area will be re-evaluated.* (The COCs for this project are provided in Section 1.0.)

It is also important to plan on obtaining depth-discrete samples as a function of time in wells that extend over the entire vertical extent of the contaminant plumes. For wells that have been screened over the entire contaminated zone, a DR is as follows:

- *DR #3f – If additional information is needed regarding temporal changes in the vertical distribution of a COC in the aquifer, then either deepen, reconfigure, and sample existing wells, or drill and sample new wells; otherwise, no additional vertical contamination data are needed.*

5.4 GROUNDWATER PLUME MIGRATION

- *DS #4 – Determine, using modeling, if adequate data are available to assess the potential for the groundwater plumes at the T Area to migrate from the 200 Area Central Plateau in the next 1,000 years.*

The potential for groundwater contamination plumes in the T Area to migrate from the 200 Area Central Plateau in the next 1,000 years is needed to assess long-term risk and the appropriate remedial action. The adequacy of data available or obtained to answer the DRs discussed above for groundwater flow rate and direction and the extent of groundwater contamination will also be required to evaluate the potential for groundwater plume migration.

In order to determine if the groundwater contamination will migrate from the 200 Area Central Plateau, the current and future groundwater flow rate and direction between the current plumes and the plateau boundary are needed as inputs to the selected model, in addition to information regarding contaminant concentrations and chemical states. The DRs regarding future groundwater plume migration are as follows (note that DR #4a and DR #4b are interdependent [i.e., both types of data must be adequate in order to assess the potential for migration of groundwater plumes]):

- *DR #4a – If knowledge of the current and future aquifer properties, and groundwater flow rate and direction is adequate to populate the selected model between the farthest extent of the groundwater plumes and the 200 Area Central Plateau boundary, then sufficient data are available to determine if the groundwater contamination plumes will migrate from the 200 Area Central Plateau in the next 1,000 years; otherwise, additional data are needed.*
- *DR #4b – If knowledge of the contaminant concentrations and chemical form in the vadose zone and groundwater are adequate to populate the selected model, then sufficient data are available to determine if the groundwater contamination plumes will migrate from the 200 Area Central Plateau in the next 1,000 years; otherwise, additional data are needed.*

5.5 POTENTIAL GROUNDWATER REMEDIATION TECHNOLOGIES

- *DS #5 – Determine if adequate data (e.g., contaminant concentration, chemical form, aquifer properties, and groundwater flow rate and direction) are available to plan, implement, and assess the effectiveness of groundwater remediation technologies.*

The groundwater contaminant concentrations and chemical form (as well as the aquifer properties, groundwater flow rate and direction, and the extent of groundwater contamination) are needed to plan, implement, and assess the effectiveness of any necessary groundwater remediation. Although there are a wide variety of in situ and ex situ groundwater remediation technologies (e.g., permeable barriers, monitored natural attenuation, air sparging, pump-and-treat, etc.), to a large extent, a common data set is needed to plan and implement them. A DR regarding the data available to plan, implement, and assess groundwater remediation technologies is as follows:

- *DR #5 – If the contaminant concentrations and chemical form, aquifer properties, groundwater flow rate and direction, and data related to the location and mass of contaminants in the vadose zone and potential for movement from the vadose zone to the groundwater are technically defensible as related to the vertical and horizontal extent of the groundwater plumes in the T Area, then sufficient data are available to plan, implement, and assess the effectiveness of necessary groundwater remediation technologies; otherwise, additional data are needed.*

5.6 DECISION RULE SUMMARY

The DRs and DSs developed above are summarized in Table 5-1.

Table 5-1. Summary of Decision Rules. (3 sheets)

Decision Statement	Decision Rule
DS #1 – Determine whether the RCRA/CERCLA compliance well network and sampling frequency are adequate to determine horizontal and vertical Tc-99 groundwater plume movement and the rate and direction of groundwater flow at the T Area.	DR #1a – Review the existing estimates of groundwater flow rate and direction. If the existing groundwater flow rate and direction can be reconciled with the current Tc-99 groundwater plume boundaries and potential source areas, then the data are adequate for assessing the RCRA/CERCLA compliance well network; otherwise, additional data to evaluate groundwater flow rate and direction will be collected during drilling of new wells and will be considered using existing wells that have appropriately configured locations and screened intervals.
	DR #1b – If the RCRA/CERCLA compliance well network (well location and depth) and sampling frequency are adequate to determine the horizontal and vertical movement of the Tc-99 groundwater plume, given the groundwater flow rate and direction in the T Area, then no new wells are needed; otherwise, new wells need to be installed.
	DR #1c – If new wells are needed, the locations and depths will follow DR #3a and DR #3b for delineating the vertical and horizontal groundwater plume extents.
DS #2 – Determine if the source(s) and driving forces through the vadose zone to groundwater are identified and characterized for the contaminants exceeding DWSs in the wells located on the east boundary of WMA-T sufficiently to evaluate alternative actions to remediate sources.	DR #2a – If more data are needed in a specific area to distinguish among two or more potential sources of contamination or to better define the existing vadose zone inventory of key COCs, then new boreholes appropriately placed at these potential sources will be sampled and analyzed for COCs, and selected isotopes to evaluate the contaminant source(s); otherwise, no new boreholes are needed.
	DR #2b – If more data are needed to define source(s) and driving forces for moving contamination through the vadose zone, then records of existing borehole geophysical logging will be examined. If geophysical logging has not been performed, it will be performed or a reason for not performing the logging will be recorded. Geophysical logging (i.e., gamma or spectral gamma, and neutron moisture, if feasible) will be performed on all new boreholes. The gamma geophysical logs will be used to determine the depth distribution of any gamma-emitting contaminants around the boreholes, to develop (if possible) vadose zone plume geometries for gamma-emitting contaminants that might indicate a source(s), to support interpretation of subsurface lithology, and to provide baseline information. The neutron-moisture geophysical logs will be used to determine the moisture profile with depth, potentially indicating zones more likely to be associated with lateral migration in the vadose zone.

Table 5-1. Summary of Decision Rules. (3 sheets)

Decision Statement	Decision Rule
DS #3 – Determine if adequate data are available to delineate the vertical and horizontal extent of the Tc-99, chromium, nitrate, fluoride, tritium, and associated groundwater plumes at the T Area.	DR #3a – If a given contaminant groundwater plume is enclosed laterally and downgradient, at the water table and at depth, by monitoring wells or additional OU wells with concentrations less than the DWS for the given contaminant, then the lateral extent of the given contaminant groundwater plume is sufficiently understood; otherwise, additional wells are needed.
	DR #3b – If depth-discrete groundwater sampling at a well location (during or after drilling) shows that, at some depth, the concentration for a given COC[a] is less than the DWS for the given contaminant, and that concentrations above that depth passed through a maximum value, then the vertical extent of contamination for the given contaminant at that well location is defined; otherwise, additional, deeper wells are needed.
	DR #3c – If a well in the process of being drilled has reached a depth at least approximately 36.6 m (120 ft) below the water table, and the estimated concentration of a COC[a] (that can be analyzed using a rapid turnaround) is greater than the DWS for the given contaminant, then a decision can be made to extend the depth of the well within the unconfined aquifer until contaminant concentrations in two successive groundwater samples spaced at least approximately 3 m (10 ft) apart are less than the DWS for the given contaminant; otherwise, stop drilling. The minimum depth of 36.6 m (120 ft) below the water table was selected to be consistent with the minimum depth for drilling other 200-ZP-1 OU remedial investigation wells.
	DR #3d – If the subject well is not a new well, and the estimated concentration of a COC[a] is greater than the DWS for the given contaminant, then decisions can be made to prioritize a new, deeper well at that location; otherwise, no new, deeper well is needed at that location.
	DR #3e – If the estimated concentration of a COC[a] is greater than the DWS for the given contaminant and is found deeper than the Ringold Lower Mud Unit (or its equivalent position if the Lower Mud Unit is not present), the lower boundary of the study area will be re-evaluated.
	DR #3f – If additional information is needed regarding temporal changes in the vertical distribution of a COC[a] in the aquifer, then either deepen, reconfigure, and sample existing wells, or drill and sample new wells; otherwise, no additional vertical contamination data are needed.
DS #4 – Determine, using modeling, if adequate data are available to assess the potential for the groundwater plumes at the T Area to migrate from the 200 Area Central Plateau in the next 1,000 years.	DR #4a – If knowledge of the current and future aquifer properties, and groundwater flow rate and direction, is adequate to populate the selected model between the farthest extent of the groundwater plumes and the 200 Area Central Plateau boundary, then sufficient data are available to determine if the groundwater contamination plumes will migrate from the 200 Area Central Plateau in the next 1,000 years; otherwise, additional data are needed.

Table 5-1. Summary of Decision Rules. (3 sheets)

Decision Statement	Decision Rule
	DR #4b – If knowledge of the contaminant concentrations and chemical form in the vadose zone and groundwater are adequate to populate the selected model, then sufficient data are available to determine if the groundwater contamination plumes will migrate from the 200 Area Central Plateau in the next 1,000 years; otherwise, additional data are needed.
DS #5 – Determine if adequate data (e.g., contaminant concentration, chemical form, aquifer properties, and groundwater flow rate and direction) are available to plan, implement, and assess the effectiveness of groundwater remediation technologies.	DR #5 - If the contaminant concentrations and chemical form, aquifer properties, groundwater flow rate and direction, and data related to the location and mass of contaminants in the vadose zone and potential for movement from the vadose zone to the groundwater are technically defensible as related to the vertical and horizontal extent of the groundwater plumes in the T Area, then sufficient data are available to plan, implement, and assess the effectiveness of necessary groundwater remediation technologies; otherwise, additional data are needed.

[a] The COCs for this project are provided in Section 1.0.

CERCLA = *Comprehensive Environmental Response, Compensation, and Liability Act of 1980*
COC = contaminant of concern
DR = decision rule
DS = decision statement
DWS = drinking water standard
OU = operable unit
RCRA = *Resource Conservation and Recovery Act of 1976*
WMA = waste management area

6.0 STEP 6 – SPECIFY TOLERABLE LIMITS ON DECISION ERRORS

The subsurface is typically characterized through the collection and analysis of discrete samples. The goal of this project is to assess the reason for the elevated technetium-99 concentrations approximately 10 m (30 ft) below the groundwater surface. Due to the demonstrated heterogeneity of the subsurface WMA-T and constraints on sampling in certain areas, a judgmental design was used to select the well locations; therefore, a statistical design is not appropriate. The well locations are based on the groundwater-flow information; historical and new data and historical information related to pipeline leaks or breaks; location and content of waste disposal sites and historical T Tank Farm borehole data.

This process minimizes, but does not eliminate, the potential for error. Decisions based on these data must consider that potential (i.e., decision error). For this reason, the primary objective of DQO Step 6 is to determine if any DSs require a statistically based sample design. For this DQO summary report, a number of programmatic DSs have been formulated. These DSs result in several DRs that require professional judgment to assess the adequacy of the available data and to determine whether data are missing or should be augmented with additional data.

Because the DSs for this DQO summary report do not require traditional statistical calculations, tables defining the null hypothesis, alpha and beta error, and width of the gray region have been excluded. Table 6-1 provides the proposed non-statistical sampling design for each DS. Statistical sampling applies to verification of cleanup and compliance monitoring rather than to the process of defining the extent of contamination.

Table 6-1 . Statistical Versus Non-Statistical Sampling Design.

DS #	Time-Frame (Years)	Resampling Access (Accessible/ Inaccessible)	Proposed Sampling Design (Statistical/Non-Statistical)
1 through 4	0 to 3	Accessible	Non-statistical; decisions will be based on the application of professional judgment to analytical data obtained for the concentrations of COCs in the plumes over a period of time.
5	1 to 4	Accessible	Non-statistical; data will be collected to facilitate feasibility studies. Required data are typically one-time measurements of geological, geochemical, and physical parameters. The groundwater and vadose zone concentrations will be determined as part of DS #1 through DS #4.

COC = contaminant of concern
DS = decision statement

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7.0 STEP 7 – OPTIMIZE THE DESIGN

The purpose of this section is to define the sampling and analysis design to address the data gaps identified in the previous sections.

The RCRA facility investigation/corrective measures study investigation of WMA-T will be ongoing during implementation of this sampling and analysis design. An effort will be made to coordinate the activities of the two projects to avoid duplication of effort and to support collection of all needed data.

All well construction will be in accordance with specifications in *Washington Administrative Code* (WAC) 173-160, "Minimum Standards for Construction and Maintenance of Wells."

7.1 MONITORING NETWORK ADEQUATE FOR PLUME TRACKING

7.1.1 Decision Rule #1a – Groundwater Flow Rate and Direction

The existing groundwater flow rate and direction data will be reviewed by an integrated Site contractor team to attempt to reconcile the potential sources and apparent plume extents with this data and to guide future interpretation and use of this data set. For several of the various conceptual models discussed in Section 1.12.3, the arrival of contamination at specific wells does not match the timeframe based on estimated groundwater flow rates over the period of interest (if one assumes certain and specific contaminant sources). Part of this discrepancy may be related to the date of the source release, the timeframe of the impact to groundwater, and the location that the contaminant entered the groundwater, which will also be reviewed.

The specific issues to be reviewed and addressed by the integrated Site contractor team will include the following:

1. Identify dates that contamination may have impacted groundwater.
2. Review existing aquifer tests and groundwater velocity estimates in the T Area to identify the horizontal and vertical velocity data ranges to be used in this DQO process or to identify new data that need to be collected.
3. Review the basis for defining the groundwater plumes in the T Area, especially considering the available macro-constituent chemistry data.
4. Assess the usefulness of conducting particle-tracking analyses to predict plume movement forward and backward in time.
5. Determine if a local-scale groundwater model is available to assist in predicting plume movement.
6. Refine the locations for new vadose zone boreholes and monitoring wells (as described in Sections 7.2 and 7.3) as new data are collected.
7. Refine the list of potential sources of the current technetium-99 and other key COCs in the groundwater at the northeastern and eastern boundaries of WMA-T.
8. Evaluate the effects of standing water and precipitation on the movement of contaminants to groundwater.

9. Further evaluate the use of ratios to assess the source of the technetium-99.
10. Determine if added inventory information can be obtained from the breach of the distribution pipe from the 207-T retention basin to T Pond

The existing data review is considered to be low to moderate cost.

The estimates of groundwater flow rate and flow direction are dependent on estimations of hydraulic conductivity and effective porosity, the accuracy of water-level measurements, and heterogeneities in the hydrogeologic system. Flow rates and direction might also be estimated through evaluation of breakthrough curves (data documenting the arrival of contaminants from a well-quantified release or an upgradient well). The available data show that the unconfined aquifer is quite heterogeneous, with some hydraulic properties varying by an order of magnitude. The fundamental aquifer hydraulic property information must be obtained from field measurements in groundwater wells. New wells drilled as part of this investigation will be hydraulically tested using single-well slug tests, pumping tests, and tracer dilution tests (as noted in Table 3-1). Where well locations and screened intervals can be appropriately configured, multiple-well tests will also be conducted.

7.1.1.1 Flow Rate. Flow rate is a fundamental parameter for predicting plume movement and distribution. Because the existing monitoring network surrounding WMA-T is not conducive to measurement of flow rate using multi-well methods (e.g., tracer tests), the more classic method to estimate flow rate (using the Darcy equation) has typically been used. This approach is based on hydraulic conductivity of the aquifer in combination with the water-table gradient and effective porosity. The effective porosity and hydraulic conductivity have been estimated from the results of aquifer tests (e.g., slug tests, tracer tests, and pumping tests) in several wells surrounding WMA-T (summarized in Horton 2006). The water-table gradient is determined from water-level measurements. Water-level measurements are collected quarterly during RCRA sampling events and annually in March in the wells surrounding WMA-T. Water levels will be measured in all new wells.

Multiple-well pumping/tracer tests are needed between appropriately configured wells to obtain aquifer hydraulic properties that are representative of a larger portion of the aquifer than single-well aquifer tests. Pumping tests can obtain hydraulic conductivity, storativity, and specific yield of the unconfined aquifer, and tracer tests can be used to measure the groundwater flow rate.

7.1.1.2 Flow Direction. Groundwater flow direction will be inferred from water-table elevations in available or newly installed wells within the groundwater plume areas. This approach depends on accurate depth-to-water measurements. Barometric corrections will be conducted if needed. Reliable well locations and casing elevations will be obtained for new wells or assessed for existing wells based on available information. Gyroscopic surveys will be conducted to determine the amount and direction of deviation from vertical for new wells and for all existing wells that are used to determine Darcy velocities. The water-level measurements will be used to map the groundwater flow direction in the plume areas after depth-to-water corrections are made. A second method to estimate flow direction will be applied to the corrected depth-to-water measurements. A series of three-point problems will be applied to several series of water-level measurements across the groundwater plume areas. The three-point problem is a typical analysis used in earth science to determine the orientation of a plane in space.

Collection and analysis of these new measurements is considered to be low to moderate cost compared to the costs of drilling and completing new monitoring wells.

7.1.2 Decision Rules #1b and #1c – Compliance Well Location, Depth, and Sampling Frequency

The locations, depths, and sampling frequencies of new wells will be based on the following:

- Groundwater flow rate and direction data
- DR #3a and DR #3b (discussed in Sections 5.3 and 7.3) for delineating the vertical and horizontal plume extents
- Data review by the integrated Site contractor team (as discussed previously)
- Any RCRA and/or CERCLA requirements for sampling frequency.

Given the identified lateral extent of technetium-99 in the shallow portion of the unconfined aquifer and the existing well locations (all are shown in Figure 7-1), at least seven new downgradient wells may be needed to investigate the high-concentration portion of the plume and the plume extent. At least three wells also may be needed to determine if technetium-99 contamination is currently present deeper in the unconfined aquifer to the west and south of WMA-T. The rationale and logic for selecting these new well locations is discussed in Section 7.3.

The new wells will be drilled and sampled for groundwater through the entire thickness of the unconfined aquifer, to the top of the Ringold Lower Mud Unit. The groundwater samples will be analyzed for the constituents and parameters identified in Table 3-4. The wells also will be sampled for sediments throughout the vadose zone and unconfined aquifer. The sediment samples will be analyzed for the constituents and parameters identified in Table 3-5. Wells will be completed with 15.24–cm (6-in.)-diameter casing; screened intervals will be determined using the protocol discussed in Section 5.3. Following completion, a groundwater sample will be collected.

The two highest priority wells (identified in Section 7.3) will be drilled and sampled at part of the Phase I sampling design, based on this Phase I DQO process. The rationale and logic for selecting additional wells will be reconsidered during the Phase II DQO process.

Drilling, sampling, and completing new wells are considered to be high costs.

7.2 CONTAMINANT SOURCES AND DRIVING FORCES

7.2.1 Decision Rule #2a – New Boreholes at Potential Sources

New vadose zone boreholes are needed to help characterize and distinguish the potential sources in the T Area that have contributed to groundwater contamination. New vadose zone boreholes will be considered for each of the following potential source areas: 216-T-7 tile field, 216-T-36 Crib, one of the 216-T-14 through 216-T-17 Trenches, 216-T-32 Crib, 216-T-5 Trench, and in the northeastern corner of the T Tank Farm area. The need for a borehole at a given waste site will be based on the results of the HRR studies, other vadose zone characterization results, the groundwater characterization results, and any new information on potential sources. The borehole location(s) in each waste site will be based on review of the results of the HRR studies

and other surface-based geophysical surveys conducted in the T Area, accessibility to the waste site, and existing knowledge of the waste site configuration. It is anticipated that the vadose zone boreholes will be located near the discharge line into each waste site. In large waste sites (e.g., 216-T-7, 216-T-36, one of the 216-T-14 through 216-T-17 Trenches, and in the northeastern corner of the T Tank Farm area), the borehole location will also be selected based on the results of spectral-gamma borehole logging conducted in four to five cone penetrometer or hydraulic-hammer rig push holes advanced to refusal in each of these sites. Each of the new vadose zone boreholes will be advanced and sampled to the base of contamination (based on rapid turnaround analyses for technetium-99) or to the top of groundwater, whichever comes first. If the entire vadose zone is contaminated, a groundwater sample from the top of the aquifer will also be collected and analyzed for key COCs. Vadose zone sediment samples will be collected at minimum of 1.5–m (5-ft) spacing with a bias to collecting samples at fine-grained layers. Selected sediment samples will be analyzed for the key COCs and parameters listed in Table 3-5.

The drilling and sampling of new vadose zone boreholes and sample characterization are considered to be very high cost due to expected high levels of contamination.

7.2.2 Decision Rule #2b – Sources and Driving Forces

To help determine the driving forces in the vadose zone, borehole geophysical logging will be conducted in existing dry wells, in monitoring wells, in the new (proposed) push holes, in boreholes, and in wells to identify vertical contaminant distribution and to track contaminant movement. The borehole geophysical logging will include spectral-gamma and neutron-moisture probes, if feasible. For the spectral-gamma logging, depending on the source, longer count times may allow more mobile radionuclides (e.g., cobalt-60) to be detected. The natural gamma spectra of potassium, uranium, and thorium are also useful for defining geologic contacts.

The purpose of the logging is to determine the depth distribution of any gamma-emitting contaminants around the boreholes, to develop (if possible) vadose zone plume geometries for gamma-emitting contaminants that might indicate a source(s), to interpret subsurface lithology, and to provide baseline information. The boreholes are to be logged throughout the entire drilled depth.

If feasible, neutron-moisture geophysical logging will also be conducted in the new boreholes through the vadose zone. The purpose of neutron-moisture logging is to determine the moisture profile with depth. The moisture profile can potentially indicate zones more likely to be associated with lateral migration in the vadose zone. If the neutron-moisture logging tool is not calibrated for the diameter of the borehole at the time logging would be conducted, this logging may not be conducted. However, if the logging tool is not calibrated for the borehole diameter, consideration will be given to whether the resulting profile still could be used to assess the selection of grab sample locations relative to fine-grained units that are likely to be holding the moisture.

Borehole geophysical logging is considered to be a low cost.

If the HRR investigation results correlate with the presence of mobile contaminants (e.g., nitrate and technetium-99) in the vadose zone, then further HRR investigations at specific waste sites may be considered because the borehole geophysical logging cannot track these mobile contaminants.

The location of the potential pipeline leak in the vicinity of well 299-W11-27 will be investigated by a camera survey, if feasible. Cone penetrometer or hydraulic-hammer rig push holes will then be used to investigate the vadose zone in the potential leak area. Selected vadose zone sediment samples collected from these push holes, and the porewater from those samples will be analyzed for selected COCs and parameters listed in Table 3-5 based on sample volume/ mass availability to help characterize the nature and impact of this leak. If the data were recorded and remain available, it may be possible to assess pipeline losses by comparing 207-T discharge volumes to 216-T-4 receipts.

7.3 EXTENT OF GROUNDWATER CONTAMINATION

7.3.1 Decision Rules #3a, #3b, #3c, #3d, and #3e – Lateral and Vertical Extent of Groundwater Plumes

If a given groundwater contaminant plume is sufficiently delineated vertically and is enclosed laterally by monitoring wells with sample concentrations less than the DWS for that contaminant, then the lateral extent of the given contaminant is well understood. If not, new wells are needed.

As discussed in Section 7.1, given the current understanding of the lateral extent of the technetium-99 plume in the shallow aquifer and the existing well locations, at least seven new downgradient wells may be needed to investigate the high-concentration portion of the plume and the plume extent. At least three wells also may be needed to determine if technetium-99 contamination is currently present within the unconfined aquifer to the west and south of WMA-T. Although this area is upgradient, based on the current groundwater flow conditions, it was downgradient from the T Tank Farm and the adjacent waste sites early in the period of operation of the 216-T-4 Pond (see Section 1.5.12 and the timeline in Figure 1-3). As the T Pond mound declined and the groundwater gradient reduced, the groundwater flow direction gradually has returned to a more easterly direction.

The integrated Site contractor team made an initial assessment of the available data to identify the locations and prioritize the drilling of proposed new groundwater monitoring wells. The proposed new well locations are shown in Figure 7-1, and the rationale for these locations is summarized in Table 7-1. The CSMs discussed in Section 1.12 are related to the purpose and rationale; therefore, Table 7-1 associates the number of the CSM with the rationale and the well letters. As the data from newly installed wells 299-W11-45 ("T-2") and 299-W11-47 ("T-3") (see Figure 7-1) are evaluated, the reviews of groundwater flow rate and direction and other issues are completed by the integrated Site contractor team (as discussed in Section 7.1), and the data from the proposed new wells becomes available, the integrated Site contractor team will use the logic diagram in Figure 7-2 to review and refine the proposed well locations.

During the DQO process, concern was expressed that the current understanding of the technetium-99 plume (shown in Figures 1-20 and 7-1) only reflects data from the top of the aquifer. For deeper zones within the unconfined aquifer, it is likely that the contamination could

be displaced to the south of the plume (as shown in those figures) because most of the potential sources received discharges relatively early when the water-table elevations were lower and the groundwater flow direction in this area was radially away from T Pond. This rationale and a focus on contamination that may be present within deeper zones within the unconfined aquifer have influenced the proposed well locations shown in Figure 7-1.

The priority for well and borehole drilling for Phase I of this DQO process will be as follows:

1. Proposed new wells "G" and "C," based on the priority in Table 7-1 and as shown in Figure 7-1, to investigate the lateral and vertical extent of the technetium-99 plume in areas where there is a lack of data.

The priority for well and borehole drilling for Phase II of this DQO process will be as follows:

1. Remaining proposed new wells (as shown in Figure 7-1), as necessary, to define the lateral and vertical extent of the technetium-99 plume. The logic diagram in Figure 7-2 will be used to review and refine the proposed well locations.
2. Vadose zone boreholes, as necessary, to investigate potential source areas (Section 7.2).

The new wells will be drilled and sampled through the entire thickness of the unconfined aquifer, to the top of the Ringold Lower Mud Unit. Each will be completed as a 15.24-m (6-in.)-diameter well with a screened interval that will be determined using the protocol discussed in Section 5.3 If contamination is found on top of the Ringold Lower Mud Unit, then the lower boundary of the study area will be re-evaluated.

The best opportunity to collect depth-discrete groundwater samples for use in determining the vertical extent of the groundwater contaminant plumes is during well drilling. Depth-discrete groundwater samples will be collected at minimum 3–m (10-ft) intervals from the water table to total well depth. During drilling, groundwater samples can be collected using a depth-discrete sampler (e.g., Kabis® bailer), sampling pump, or other suitable method. Air-lift sampling cannot be used for volatile organic compounds. Chromium and potentially technetium-99 are constituents that are sensitive to reduction-oxidation, and collection of representative samples may require sampling by pump after purging has removed the groundwater affected by drilling. However, differences in concentrations for constituents such as uranium, technetium-99, chromium, and manganese, both the "drilling-affected" and "well-pumped/purged" samples have proved valuable in interpreting whether the samples were in fact affected by drilling. As a result, key constituents will be measured in all types of samples to determine the representative sample results. Samples will be analyzed for all primary COCs and selected parameters as noted in Table 3-4.

After the vertical extent of groundwater contamination at a well location is known (based on rapid turnaround analyses for technetium-99 and other COCs) by following DR #3b or DR #3c, the well will be screened across a vertical interval that includes as many COC maxima as possible, with priority being the technetium-99 maximum and considering the following well screen length limits: in the top of the aquifer, screen lengths up to 10.7 m (35 ft) can be used, whereas deeper in the aquifer, shorter screens may be required.

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Representative sediment grab samples, primarily from drill cuttings, will be collected every 1.5 m (5 ft) from the ground surface to total depth. Additional samples are to be collected at significant changes in lithology or at depths where unusual conditions or sediments are encountered (e.g., zones displaying unusual color changes, visual mineralogy changes/anomalies, particle size changes, and/or radiological activity changes). Samples are to be collected in quart-size, plastic or glass jars capable of sealing existing moisture in the sample for a reasonable time period. If representative samples cannot be collected (e.g., if large particles do not fit in the container), notes describing the condition of the sample will be put in the geologist's logbook. The samples should be contained in the airtight containers and kept under refrigeration. This process is used to maintain sediment moisture in as close to field condition as possible.

Initial analytical efforts will focus on selected samples for the primary COCs and selected parameters as noted in Table 3-5. The initial results will be evaluated, along with the borehole log and spectral-gamma and neutron-moisture geophysical logging, to determine if additional sediment samples should be analyzed (CHG 2002).

Drilling, sampling, and completing new wells are considered to be high-cost activities.

7.3.2 Decision Rule #3f – Temporal Changes in Vertical Contaminant Distributions

If information regarding the temporal changes in the vertical contamination within the aquifer is needed, then options such as deepening or reconfiguring wells, or installing new wells, should be considered as opposed to installing wells with long screens across most of the aquifer.

Concerns with installing long screens in the aquifer include the following:

- The variable hydraulic conductivity of the aquifer throughout the screened interval might compromise the representativeness of the samples (e.g., the water from a contaminated zone may be diluted by water from a noncontaminated zone).
- The well might provide a pathway for the contamination to migrate to a deeper or shallower part of the aquifer due to the vertical mixing and variable hydraulic conductivity of the strata.

The consensus among the DQO team members was that long screens posed too great of a risk and that if, at a later date, sampling was needed at a depth different from the depth of the existing screen, options could be considered to deepen/reconstruct a well or to drill new wells.

Deepening and reconfiguring existing wells or installing new wells are considered to be high-cost activities.

7.4 GROUNDWATER PLUME MIGRATION

7.4.1 Decision Rules #4a and #4b – Groundwater Plume Migration Potential

The potential for groundwater contamination plumes in the T Area to migrate from the 200 Area Central Plateau in the next 1,000 years is needed to assess long-term risk and the need to implement an appropriate remedial action. The adequacy of data available or obtained to answer DR #1a (discussed previously for groundwater flow rate and direction) and DR #3a through DR #3e (discussed previously for the extent of groundwater contamination) (see Sections 7.1 and 7.3) will also be required to evaluate the potential for groundwater plume migration. In addition, previous calculations regarding the long-term migration of the uranium plume in the

200-UP-1 OU, and the tritium plume from the SALDS facility will be reviewed as potential analogs for the far-field (e.g., beyond the current plume extent) migration potential of the T Area groundwater plumes. Recent work that is relevant, such as the groundwater modeling for the T Area documented in *Initial Single-Shell Tank System Performance Assessment for the Hanford Site* (DOE-ORP 2006), will also be reviewed.

Because technetium-99, in the chemical form pertechnetate (TcO_4), has a K_d of 0, an initial qualitative groundwater plume migration assessment will use the shortest horizontal downgradient distance between the leading edge of the 900 pCi/L technetium-99 groundwater concentration contour and the edge of the 200 Area Central Plateau, along with the current groundwater flow rate, to calculate the number of years for the plume to migrate this distance. If the calculated number of years is significantly less than 1,000 years, then specific groundwater modeling for this project may not be needed.

The groundwater plume migration evaluation is considered to range from low to moderate cost.

7.5 POTENTIAL GROUNDWATER REMEDIATION TECHNOLOGIES (DECISION RULE #5)

The groundwater contaminant concentrations (as well as the aquifer properties, groundwater flow rate and direction, and the extent of groundwater contamination plumes) are needed to plan, implement, and assess the effectiveness of any necessary groundwater remediation. Although there are a wide variety of in situ and ex situ groundwater remediation technologies (e.g., permeable barriers, monitored natural attenuation, air sparging, pump-and-treat, etc.), to a large extent, this common data set is needed to plan and implement all of the remediation technologies. Both existing and new data collected as part of this DQO process will be used to plan necessary groundwater remediation studies. The primary purpose of the new downgradient wells (discussed in Sections 7.1 and 7.3) is to define the horizontal and vertical extent of the groundwater plumes and to improve the monitoring well network. Although the new wells installed in the high-concentration portion of the plume will be completed as 15.24–cm (6-in.)-diameter wells so they can be converted to extraction wells if necessary, additional extraction wells may be needed because the hydraulic capture zone from these wells will not be known in advance.

Each of the potential groundwater remediation technologies has pros and cons in its ability to effectively treat the potential primary COCs in the T Area (e.g., carbon tetrachloride, TCE, tritium, nitrate, fluoride, and technetium-99). For some contaminants (e.g., tritium), there is no economical treatment method. Groundwater pump-and-treat is currently being used just south of the T Area to treat carbon tetrachloride, TCE, and chloroform as an interim remedy at the 200-ZP-1 OU. The current treatment system is not designed to remove technetium-99, but technetium-99 could be treated by adding IX to the treatment process.

The IX process for removing dissolved metals and radionuclides, including technetium-99, is a well-established and effective technology. Pre-treatment of groundwater may be necessary. Factors that may negatively affecting the design and performance of an IX system include the presence of oil and grease, contaminant concentration, exchange capacity of the resin, suspended solids, metals, oxidant content, concentration of competing inorganic ions in groundwater, and pH of the groundwater. Typically, the cost for an IX system ranges from $0.08 to $0.21 per

1,000 L treated ($0.30 to $0.80 per 1,000 gal treated). Key cost factors include pre-treatment requirements, discharge requirements and resin use, and the regenerant used and its efficiency.

The chemical, geological, and physical data that are obtained from the vadose zone and groundwater as a result of the boreholes and wells proposed in this DQO process will provide adequate baseline information to make initial remediation decisions. At such time as a final remediation action is proposed, it is likely that additional information specific to the remediation action will be necessary.

The final planning, implementation, and assessment of groundwater remediation technologies are considered to be high-cost activities.

Figure 7-1. Proposed New Well Locations.

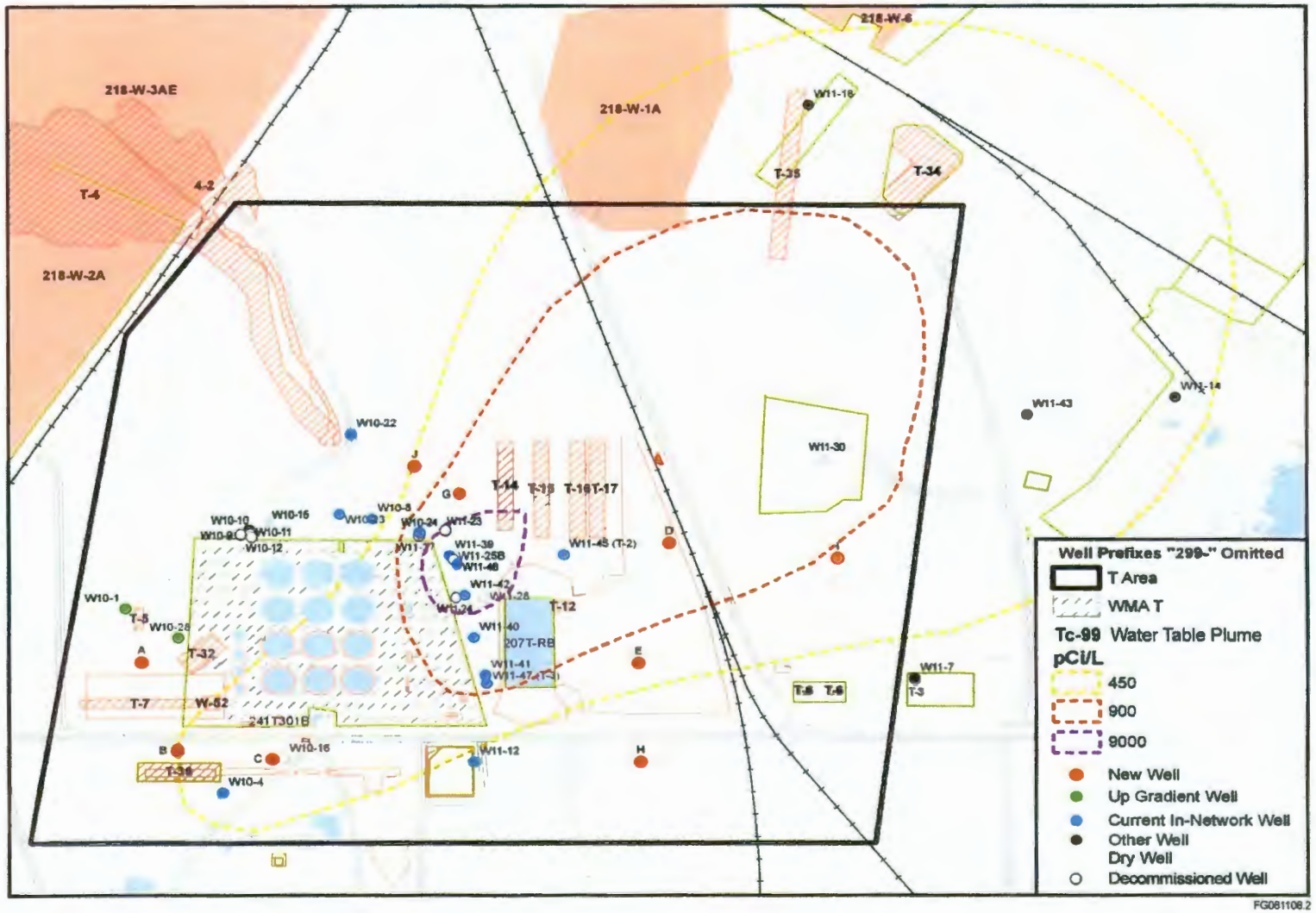

Figure 7-2. Logic Chart for Locating New Monitoring Wells.

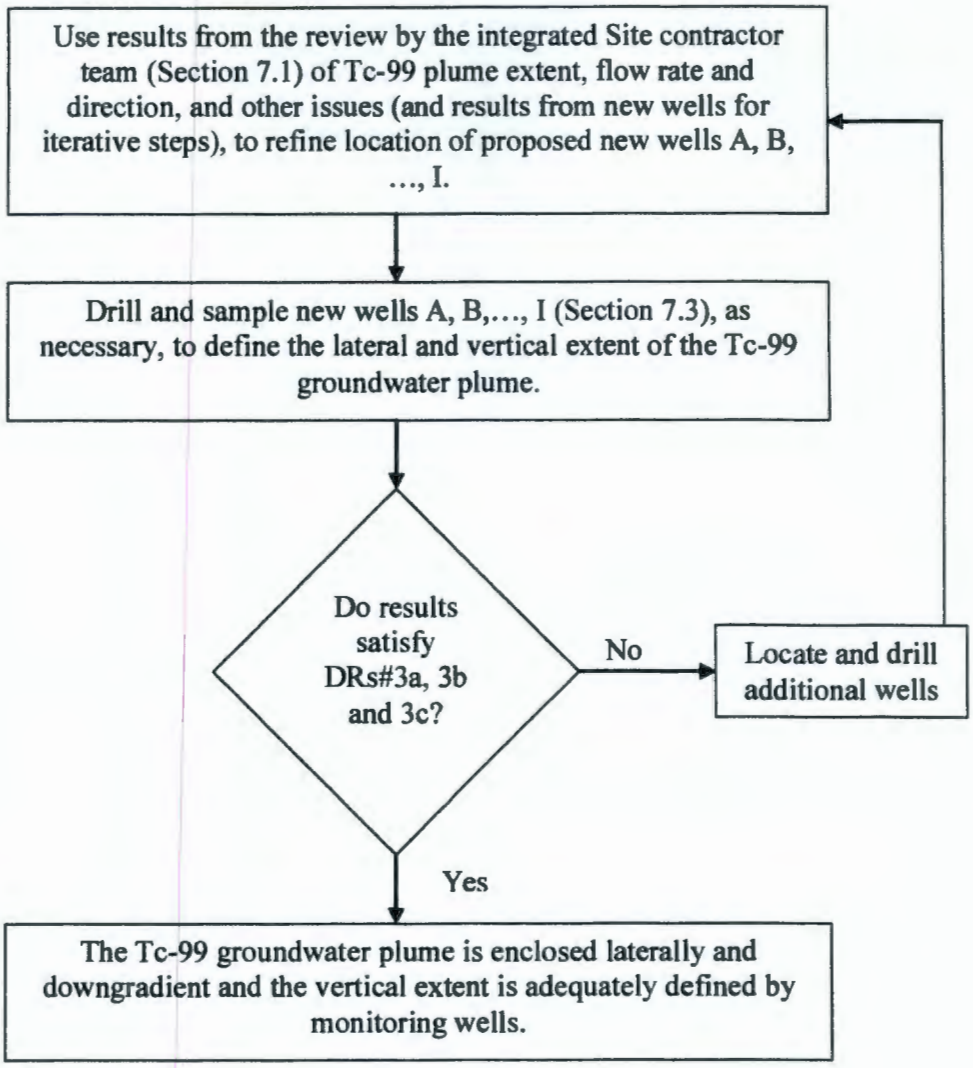

Table 7-1. Rationale for Proposed New Well Locations.

Well Location[a]	Primary Purpose or Rationale	Priority[b]	Associated CSM #
A	Characterization of 216-T-7 and 216-T-32 impacts to groundwater; new upgradient RCRA well, plume extent (vertical and horizontal).	4	2, 3, 7
B	Characterization of 216-T-7 and 216-T-36 impacts to groundwater; upgradient plume extent (vertical and horizontal), determine if deep contamination comes from sources to the south.	4	2, 3, 6, 7, 8
C	Characterization of 216-T-5, 216-T-7, and 216-T-36 impacts to groundwater, upgradient from T Tank Farm, plume extent.	2	2, 3, 8
D	Characterization of WMA-T impacts to groundwater. Define downgradient limit and vertical extent of Tc-99 found in 299-W11-45 (T-2).	3	1, 4, 5
E	Define lateral and vertical extent of the Tc-99 plume from potential tank farm leaks, define southern boundary of high-concentration plume. Results of T-3 will affect this well.	4	1, 3, 4, 5, 7
F	Define lateral and vertical extent of the Tc-99 plume; 216-T-14 through 216-T-17 impacts to groundwater.	4	1, 2, 4, 5, 7
G	Define lateral and vertical extent of the Tc-99 plume; help determine if tank farm leak is the source of Tc-99.	1	1, 2, 4, 5, 7
H	Help define the southern boundary of the plume; determine if deep contamination comes from sources to the south, but contingent based on results of other wells.	4	3, 6, 7
I and J	Define lateral and vertical Tc-99 plume limits; help determine source, but contingent on results of other wells.	4	3, 6, 7

[a] See Figure 7-1 for well locations.
[b] Priorities #1 and #2 are proposed for FY06; priorities #3 and #4 are proposed after FY06 and will be completed after DR #1(re-evaluation of data) and after the first two wells are installed. Source investigation is priority #5. These are recommended after the groundwater plumes are better delineated.

CSM = conceptual site model (model numbers are described in detail in Section 1.12)
DR = decision rule
FY = fiscal year
RCRA = *Resource Conservation and Recovery Act of 1976*
WMA = waste management area

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APPENDIX A

LIQUID INVENTORY ESTIMATES FOR 241-T TANKS

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APPENDIX A
LIQUID INVENTORY ESTIMATES FOR 241-T TANKS

Estimated current inventories for entrained liquids in Waste Management Area T (WMA-T) tanks are provided in this appendix. In addition, historical estimates are provided for liquids in three tanks (241-T-101, 241-T-103, and 241-T-106) that have leaked or overflowed. The estimates are given for the end of the calendar quarter nearest to the time of the leak.

Estimates in this appendix are based upon computer modeling performed in *HDW Rev. 4.1, User Interface* (Agnew 1998), as described in *Hanford Tank Chemical and Radionuclide Inventories: HDW Model, Rev. 4* (Agnew 1997). Although a more recent version (Revision 5) of the HDW model is available (Higley 2004), tank waste inventories in the newer version are calculated by waste type and not on a tank-by-tank basis, as was the case with Revision 4 and older versions. No user computer interface is available for Revision 5, making inventory calculations for individual tanks difficult. Revision 4 has a user interface that facilitates calculation of current and historical tank inventories. Historical inventories may be modeled on a per-calendar-quarter basis over the entire fill history of the tank of interest.

The technetium-99 inventories across the tank farms overall have decreased approximately 23% between HDW model Revision 4 and Revision 5 due to modeling of process losses. However, newer technetium-99 inventory estimates for tanks in WMA-T overall are substantially higher. The best-basis inventory (BBI) (which uses the HDW model Revision 5 as a basis for much of its technetium-99 inventory estimates in WMA-T) indicates the total estimated inventory of WMA-T as 150 Ci as opposed to 15 Ci in HDW model Revision 4.

The BBI is not as useful to determine concentrations of technetium-99 during a potential leak because BBI is a bulk inventory (i.e., it is in terms of total tank inventory in the combined waste phases, not analyte concentration in each waste phase). The BBI also cannot easily be used to determine historical inventories. For these reasons, Revision 4 was used to produce estimates of tank waste inventories in this appendix.

Table A-1. Single-Shell Tank 241-T-101 Entrained Liquid Inventory Estimate Currently in Tank.[a] (3 sheets)

Physical Properties			
Total entrained liquid waste	2.57E+05 (kg)	(65.0 kgal)	----
Heat load	2.96E-02 (kW)	(101 BTU/hr)	----
Bulk density[b]	1.04 (g/cc)	----	----
Water wt%[c]	92.5	----	----
TOC wt% (wet)	9.14E-02	----	----
Chemical Constituents	**mole/L**	**ppm**	**kg**
Na^{+}	1.06	2.33E+04	5.99E+03
Al^{3+}	9.11E-02	2.36E+03	605
Fe^{3+} (total Fe)	1.03E-03	55.1	14.1
Cr^{3+}	9.53E-03	475	122
Bi^{3+}	2.79E-04	56.0	14.4
La^{3+}	1.55E-04	20.6	5.28
Hg^{2+}	3.82E-07	7.34E-02	1.88E-02
Zr (as $ZrO(OH)_2$)	8.87E-06	0.776	0.199
Pb^{2+}	3.50E-05	6.96	1.78
Ni^{2+}	4.69E-04	26.4	6.78
Sr^{2+}	0	0	0
Mn^{4+}	7.55E-04	39.8	10.2
Ca^{2+}	2.41E-03	92.7	23.8
K^{+}	1.39E-02	521	134
OH^{-}	0.628	1.02E+04	2.63E+03
NO_3^{-}	0.354	2.11E+04	5.40E+03
NO_2^{-}	0.181	7.98E+03	2.05E+03
CO_3^{2-}	4.54E-02	2.61E+03	670
PO_4^{3-}	7.17E-03	653	167
SO_4^{2-}	2.27E-02	2.10E+03	537
Si (as SiO_3^{2-})	7.26E-03	196	50.2
F^{-}	1.43E-02	261	67.0
Cl^{-}	1.81E-02	615	158
$C_6H_5O_7^{3-}$	4.62E-03	838	215
$EDTA^{4-}$	7.32E-05	20.2	5.19
$HEDTA^{3-}$	1.45E-04	38.0	9.75
$Glycolate^{-}$	9.32E-03	670	172
$Acetate^{-}$	1.13E-05	0.641	0.164
$Oxalate^{2-}$	2.02E-04	17.1	4.38
DBP	2.54E-03	512	131
Butanol	2.54E-03	180	46.3
NH_3	6.07E-03	99.0	25.4
$Fe(CN)_6^{4-}$	0	0	0

Table A-1. Single-Shell Tank 241-T-101 Entrained Liquid Inventory Estimate Currently in Tank.[a] (3 sheets)

Radiological Constituents	Ci/L	µCi/g	Ci
H-3	2.44E-05	2.34E-02	6.01
C-14	4.64E-06	4.45E-03	1.14
Ni-59	2.32E-07	2.23E-04	5.71E-02
Ni-63	2.29E-05	2.20E-02	5.64
Co-60	5.36E-06	5.14E-03	1.32
Se-79	3.50E-07	3.36E-04	8.62E-02
Sr-90	1.19E-02	11.4	2.93E+03
Y-90	1.19E-02	11.4	2.93E+03
Zr-93	1.73E-06	1.66E-03	0.425
Nb-93m	1.23E-06	1.18E-03	0.303
Tc-99	3.27E-05	3.14E-02	8.05
Ru-106	8.94E-10	8.57E-07	2.20E-04
Cd-113m	9.71E-06	9.31E-03	2.39
Sb-125	2.34E-05	2.24E-02	5.76
Sn-126	5.29E-07	5.08E-04	0.130
I-129	6.32E-08	6.06E-05	1.56E-02
Cs-134	6.20E-08	5.94E-05	1.52E-02
Cs-137	8.63E-03	8.27	2.12E+03
Ba-137m	8.16E-03	7.83	2.01E+03
Sm-151	1.23E-03	1.18	303
Eu-152	4.09E-07	3.92E-04	0.101
Eu-154	7.82E-05	7.50E-02	19.2
Eu-155	2.41E-05	2.31E-02	5.94
Ra-226	1.24E-11	1.19E-08	3.05E-06
Ra-228	2.64E-10	2.53E-07	6.48E-05
Ac-227	7.32E-11	7.02E-08	1.80E-05
Pa-231	3.57E-10	3.42E-07	8.78E-05
Th-229	1.23E-11	1.18E-08	3.03E-06
Th-232	8.73E-11	8.37E-08	2.15E-05
U-232	1.01E-08	9.65E-06	2.48E-03
U-233	3.90E-08	3.74E-05	9.59E-03
U-234	6.10E-08	5.85E-05	1.50E-02
U-235	2.53E-09	2.43E-06	6.23E-04
U-236	1.82E-09	1.75E-06	4.48E-04
U-238	5.86E-08	5.62E-05	1.44E-02
Np-237	1.12E-07	1.07E-04	2.75E-02
Pu-238	1.69E-07	1.62E-04	4.16E-02
Pu-239	5.30E-06	5.08E-03	1.30
Pu-240	9.22E-07	8.84E-04	0.227
Pu-241	1.17E-05	1.12E-02	2.88
Pu-242	6.60E-11	6.33E-08	1.62E-05
Am-241	5.80E-06	5.56E-03	1.43
Am-243	2.37E-10	2.27E-07	5.82E-05

Table A-1. Single-Shell Tank 241-T-101 Entrained Liquid Inventory Estimate Currently in Tank.[a] (3 sheets)

Radiological Constituents	Ci/L	µCi/g	Ci
Cm-242	1.72E-08	1.65E-05	4.23E-03
Cm-243	1.67E-09	1.60E-06	4.10E-04
Cm-244	1.88E-08	1.81E-05	4.64E-03
Totals	**M**	**µg/g**	**kg**
Pu	5.64E-05 (g/L)	----	1.39E-02
U	7.23E-04	165	42.3

[a] Source: *Hanford Tank Chemical and Radionuclide Inventories: HDW Model, Rev. 4*, LA-UR-96-3860, Rev. 4 (Agnew 1997).
[b] Density is calculated based on Na, OH-, and AlO_2^-.
[c] Water weight-percent (wt%) derived from the difference of density and total dissolved species.
BTU = British thermal units
ppm = parts per million
TOC = total organic carbon

Table A-2. Single-Shell Tank 241-T-101 Liquid Inventory Estimated in Tank on June 30, 1969.[a] (3 sheets)

Physical Properties			
Total liquid waste	2.44E+05 (kg)	(55.0 kgal)	----
Heat load	4.03E-02 (kW)	(138 BTU/hr)	----
Bulk density[b]	1.17 (g/cc)	----	----
Water wt%[c]	77.5	----	----
TOC wt% (wet)	7.73E-04	----	----
Chemical Constituents	**mole/L**	**ppm**	**kg**
Na^+	3.06	6.00E+04	1.46E+04
Al^{3+}	0.872	2.01E+04	4.90E+03
Fe^{3+} (total Fe)	1.76E-03	83.8	20.5
Cr^{3+}	1.22E-02	540	132
Bi^{3+}	6.92E-07	0.123	3.01E-02
La^{3+}	1.71E-12	2.02E-07	4.93E-08
Hg^{2+}	8.10E-06	1.39	0.338
Zr (as $ZrO(OH)_2$)	6.91E-08	5.38E-03	1.31E-03
Pb^{2+}	1.30E-03	229	55.9
Ni^{2+}	1.38E-03	69.2	16.9
Sr^{2+}	0	0	0
Mn^{4+}	5.04E-06	0.236	5.76E-02
Ca^{2+}	7.92E-03	271	66.1
K^+	5.57E-03	186	45.4
OH^-	3.80	5.51E+04	1.34E+04
NO_3^-	0.929	4.91E+04	1.20E+04

Table A-2. Single-Shell Tank 241-T-101 Liquid Inventory Estimated in Tank on June 30, 1969.[a] (3 sheets)

Chemical Constituents	mole/L	ppm	kg
NO_2^-	0.931	3.65E+04	8.92E+03
CO_3^{2-}	8.42E-03	431	105
PO_4^{3-}	4.48E-05	3.63	0.886
SO_4^{2-}	1.43E-02	1.17E+03	286
Si (as SiO_3^{2-})	1.60E-02	384	93.8
F^-	3.57E-05	0.579	0.141
Cl^-	2.42E-02	733	179
$C_6H_5O_7^{3-}$	3.69E-05	5.95	1.45
$EDTA^{4-}$	1.44E-06	0.353	8.62E-02
$HEDTA^{3-}$	1.19E-06	0.279	6.81E-02
Glycolate$^-$	5.21E-05	3.33	0.813
Acetate$^-$	5.41E-06	0.272	6.64E-02
Oxalate^{2-}	2.23E-12	1.68E-07	4.09E-08
DBP	3.27E-05	5.87	1.43
Butanol	3.27E-05	2.07	0.505
NH_3	4.06E-03	58.8	14.4
$Fe(CN)_6^{4-}$	0	0	0
Radiological Constituents	**Ci/L**	**µCi/g**	**Ci**
H-3	2.38E-05	2.03E-02	4.96
C-14	1.30E-06	1.11E-03	0.271
Ni-59	1.06E-07	9.02E-05	2.20E-02
Ni-63	1.02E-05	8.74E-03	2.13
Co-60	1.15E-06	9.83E-04	0.240
Se-79	1.94E-07	1.66E-04	4.04E-02
Sr-90	6.06E-03	5.17	1.26E+03
Y-90	6.06E-03	5.17	1.26E+03
Zr-93	9.62E-07	8.21E-04	0.200
Nb-93m	6.87E-07	5.86E-04	0.143
Tc-99	1.01E-05	8.66E-03	2.11
Ru-106	2.63E-10	2.24E-07	5.47E-05
Cd-113m	5.27E-06	4.50E-03	1.10
Sb-125	4.11E-06	3.51E-03	0.856
Sn-126	2.90E-07	2.47E-04	6.04E-02
I-129	1.93E-08	1.64E-05	4.01E-03
Cs-134	2.23E-07	1.90E-04	4.64E-02
Cs-137	3.26E-02	27.8	6.80E+03
Ba-137m	3.09E-02	26.3	6.43E+03
Sm-151	6.82E-04	0.582	142
Eu-152	1.10E-07	9.40E-05	2.29E-02
Eu-154	2.75E-05	2.34E-02	5.72
Eu-155	5.69E-06	4.85E-03	1.18
Ra-226	8.30E-12	7.08E-09	1.73E-06

Table A-2. Single-Shell Tank 241-T-101 Liquid Inventory Estimated in Tank on June 30, 1969.[a] (3 sheets)

Radiological Constituents	Ci/L	µCi/g	Ci
Ra-228	1.60E-10	1.36E-07	3.32E-05
Ac-227	4.56E-11	3.89E-08	9.49E-06
Pa-231	2.02E-10	1.72E-07	4.21E-05
Th-229	3.83E-12	3.27E-09	7.97E-07
Th-232	2.13E-11	1.81E-08	4.43E-06
U-232	1.63E-09	1.39E-06	3.40E-04
U-233	6.19E-09	5.28E-06	1.29E-03
U-234	3.38E-07	2.89E-04	7.04E-02
U-235	1.35E-08	1.16E-05	2.82E-03
U-236	1.53E-08	1.31E-05	3.19E-03
U-238	2.79E-07	2.38E-04	5.81E-02
Np-237	4.95E-08	4.23E-05	1.03E-02
Pu-238	1.98E-07	1.69E-04	4.12E-02
Pu-239	7.76E-06	6.62E-03	1.62
Pu-240	1.19E-06	1.02E-03	0.248
Pu-241	9.16E-06	7.81E-03	1.91
Pu-242	3.24E-11	2.77E-08	6.75E-06
Am-241	3.04E-06	2.59E-03	0.633
Am-243	8.14E-11	6.94E-08	1.70E-05
Cm-242	2.92E-10	2.49E-07	6.08E-05
Cm-243	6.65E-12	5.67E-09	1.38E-06
Cm-244	2.07E-10	1.77E-07	4.31E-05
Totals	**M**	**µg/g**	**kg**
Pu	1.30E-04 (g/L)	---	2.71E-02
U	3.52E-03	714	174

[a] Source: *Hanford Tank Chemical and Radionuclide Inventories: HDW Model, Rev. 4*, LA-UR-96-3860, Rev. 4 (Agnew 1997).
[b] Density is calculated based on Na, OH-, and AlO_2-.
[c] Water weight-percent (wt%) derived from the difference of density and total dissolved species.
BTU = British thermal units
ppm = parts per million
TOC = total organic carbon

Table A-3. Single-Shell Tank 241-T-102 Entrained Liquid Inventory Estimate Currently in Tank.[a]

Physical Properties		
Total entrained liquid waste	4.92E+04 (kg)	(13.0 kgal)
Heat load	0 (kW)	(0 BTU/hr)
Bulk density[b]	1.00 (g/cc)	----
Water wt%[c]	100	----
TOC wt% (wet)	0	----

NOTE: All current chemical and radionuclide inventories for liquids are modeled as zero.

[a] Source: *Hanford Tank Chemical and Radionuclide Inventories: HDW Model, Rev. 4*, LA-UR-96-3860, Rev. 4 (Agnew 1997).

[b] Density is calculated based on Na, OH-, and AlO_2^-.

[c] Water weight-percent (wt%) derived from the difference of density and total dissolved species.

BTU = British thermal units

TOC = total organic carbon

Table A-4. Single-Shell Tank 241-T-103 Entrained Liquid Inventory Estimate Currently in Tank.[a] (3 sheets)

Physical Properties			
Total entrained liquid waste	3.68E+04 (kg)	(9.00 kgal)	----
Heat load	8.37E-03 (kW)	(28.6 BTU/hr)	----
Bulk density[b]	1.08 (g/cc)	----	----
Water wt%[c]	87.2	----	----
TOC wt% (wet)	0.155	----	----
Chemical Constituents	**mole/L**	**ppm**	**kg**
Na^+	1.89	4.04E+04	1.48E+03
Al^{3+}	0.213	5.31E+03	195
Fe^{3+} (total Fe)	1.68E-03	87.2	3.21
Cr^{3+}	1.85E-02	893	32.8
Bi^{3+}	3.11E-05	6.02	0.221
La^{3+}	3.67E-10	4.72E-05	1.74E-06
Hg^{2+}	7.66E-07	0.142	5.24E-03
Zr (as $ZrO(OH)_2$)	4.10E-06	0.347	1.27E-02
Pb^{2+}	1.14E-04	21.9	0.806
Ni^{2+}	7.19E-04	39.1	1.44
Sr^{2+}	0	0	0
Mn^{4+}	9.73E-04	49.5	1.82
Ca^{2+}	3.65E-03	136	4.98
K^+	8.25E-03	299	11.0

Table A-4. Single-Shell Tank 241-T-103 Entrained Liquid Inventory Estimate Currently in Tank.[a] (3 sheets)

Chemical Constituents	mole/L	ppm	kg
OH^-	1.37	2.16E+04	794
NO_3^-	0.534	3.07E+04	1.13E+03
NO_2^-	0.373	1.59E+04	585
CO_3^{2-}	7.78E-02	4.33E+03	159
PO_4^{3-}	4.22E-03	371	13.7
SO_4^{2-}	3.78E-02	3.36E+03	124
Si (as SiO_3^{2-})	1.25E-02	326	12.0
F^-	1.37E-03	24.2	0.889
Cl^-	3.11E-02	1.02E+03	37.5
$C_6H_5O_7^{3-}$	8.16E-03	1.43E+03	52.6
$EDTA^{4-}$	1.43E-04	38.1	1.40
$HEDTA^{3-}$	2.57E-04	65.2	2.40
$Glycolate^-$	1.60E-02	1.11E+03	40.8
$Acetate^-$	1.02E-04	5.59	0.205
$Oxalate^{2-}$	4.80E-10	3.92E-05	1.44E-06
DBP	4.53E-03	882	32.4
Butanol	4.53E-03	311	11.4
NH_3	9.60E-03	151	5.56
$Fe(CN)_6^{4-}$	0	0	0
Radiological Constituents	**Ci/L**	**µCi/g**	**Ci**
H-3	4.87E-05	4.51E-02	1.66
C-14	8.48E-06	7.86E-03	0.289
Ni-59	4.30E-07	3.98E-04	1.46E-02
Ni-63	4.25E-05	3.94E-02	1.45
Co-60	9.76E-06	9.04E-03	0.332
Se-79	6.57E-07	6.09E-04	2.24E-02
Sr-90	2.13E-02	19.7	725
Y-90	2.13E-02	19.7	725
Zr-93	3.24E-06	3.01E-03	0.111
Nb-93m	2.31E-06	2.14E-03	7.87E-02
Tc-99	6.01E-05	5.57E-02	2.05
Ru-106	1.64E-09	1.52E-06	5.58E-05
Cd-113m	1.83E-05	1.70E-02	0.623
Sb-125	4.25E-05	3.93E-02	1.45
Sn-126	9.92E-07	9.20E-04	3.38E-02
I-129	1.16E-07	1.07E-04	3.95E-03
Cs-134	1.65E-07	1.53E-04	5.63E-03
Cs-137	2.19E-02	20.3	745
Ba-137m	2.07E-02	19.2	705
Sm-151	2.31E-03	2.14	78.7
Eu-152	7.54E-07	6.99E-04	2.57E-02

Table A-4. Single-Shell Tank 241-T-103 Entrained Liquid Inventory Estimate Currently in Tank.[a] (3 sheets)

Radiological Constituents	Ci/L	µCi/g	Ci
Eu-154	1.45E-04	0.134	4.93
Eu-155	4.42E-05	4.10E-02	1.51
Ra-226	2.25E-11	2.09E-08	7.68E-07
Ra-228	5.10E-10	4.73E-07	1.74E-05
Ac-227	1.38E-10	1.28E-07	4.71E-06
Th-229	3.16E-11	2.93E-08	1.08E-06
Th-232	1.96E-10	1.82E-07	6.69E-06
U-232	2.14E-08	1.99E-05	7.30E-04
U-233	8.28E-08	7.68E-05	2.82E-03
U-234	1.13E-07	1.05E-04	3.86E-03
U-236	3.89E-09	3.60E-06	1.33E-04
U-238	1.04E-07	9.64E-05	3.54E-03
Np-237	2.07E-07	1.92E-04	7.05E-03
Pu-238	2.29E-07	2.13E-04	7.81E-03
Pu-239	6.01E-06	5.57E-03	0.205
Pu-240	1.11E-06	1.03E-03	3.78E-02
Pu-241	1.55E-05	1.43E-02	0.528
Pu-242	9.07E-11	8.40E-08	3.09E-06
Am-241	1.08E-05	1.00E-02	0.368
Am-243	4.35E-10	4.03E-07	1.48E-05
Cm-242	3.11E-08	2.88E-05	1.06E-03
Cm-243	3.02E-09	2.80E-06	1.03E-04
Cm-244	3.38E-08	3.13E-05	1.15E-03
Totals	**M**	**µg/g**	**kg**
Pu	1.02E-04 (g/L)	----	3.47E-03
U	1.31E-03	289	10.6

[a] Source: *Hanford Tank Chemical and Radionuclide Inventories: HDW Model, Rev. 4*, LA-UR-96-3860, Rev. 4 (Agnew 1997).
[b] Density is calculated based on Na, OH-, and AlO_2-.
[c] Water weight-percent (wt%) derived from the difference of density and total dissolved species.
BTU = British thermal units
ppm = parts per million
TOC = total organic carbon

Table A-5. Single-Shell Tank 241-T-103 Liquid Inventory Estimated in Tank on June 30, 1973.[a] (3 sheets)

Physical Properties			
Total liquid waste	2.38E+06 (kg)	(538 kgal)	----
Heat load	1.07 (kW)	(3.65E+03 BTU/hr)	----
Bulk density[b]	1.17 (g/cc)	----	----
Water wt%[c]	74.7	----	----
TOC wt% (wet)	0.306	----	----
Chemical Constituents	**mole/L**	**ppm**	**kg**
Na^{+}	4.04	7.95E+04	1.89E+05
Al^{3+}	0.454	1.05E+04	2.49E+04
Fe^{3+} (total Fe)	3.60E-03	172	409
Cr^{3+}	3.96E-02	1.76E+03	4.19E+03
Bi^{3+}	6.64E-05	11.9	28.2
La^{3+}	7.83E-10	9.30E-05	2.21E-04
Hg^{2+}	1.64E-06	0.281	0.668
Zr (as $ZrO(OH)_2$)	8.76E-06	0.683	1.63
Pb^{2+}	2.44E-04	43.2	103
Ni^{2+}	1.54E-03	77.1	184
Sr^{2+}	0	0	0
Mn^{4+}	2.08E-03	97.6	232
Ca^{2+}	7.79E-03	267	636
K^{+}	1.76E-02	589	1.40E+03
OH^{-}	2.93	4.26E+04	1.01E+05
NO_3^{-}	1.14	6.04E+04	1.44E+05
NO_2^{-}	0.797	3.14E+04	7.46E+04
CO_3^{2-}	0.166	8.53E+03	2.03E+04
PO_4^{3-}	9.01E-03	732	1.74E+03
SO_4^{2-}	8.06E-02	6.63E+03	1.58E+04
Si (as SiO_3^{2-})	2.68E-02	643	1.53E+03
F^{-}	2.93E-03	47.6	113
Cl^{-}	6.63E-02	2.01E+03	4.79E+03
$C_6H_5O_7^{3-}$	1.74E-02	2.82E+03	6.71E+03
$EDTA^{4-}$	3.05E-04	75.1	179
$HEDTA^{3-}$	5.48E-04	128	306
$Glycolate^{-}$	3.41E-02	2.19E+03	5.20E+03
$Acetate^{-}$	2.18E-04	11.0	26.2
$Oxalate^{2-}$	1.03E-09	7.72E-05	1.84E-04
DBP	9.67E-03	1.74E+03	4.14E+03
Butanol	9.67E-03	613	1.46E+03
NH_3	2.05E-02	298	710
$Fe(CN)_6^{4-}$	0	0	0

Table A-5. Single-Shell Tank 241-T-103 Liquid Inventory Estimated in Tank on June 30, 1973.[a] (3 sheets)

Radiological Constituents	Ci/L	µCi/g	Ci
H-3	1.04E-04	8.89E-02	212
C-14	1.81E-05	1.55E-02	36.9
Ni-59	9.18E-07	7.85E-04	1.87
Ni-63	9.07E-05	7.76E-02	185
Co-60	2.08E-05	1.78E-02	42.4
Se-79	1.40E-06	1.20E-03	2.86
Sr-90	4.54E-02	38.9	9.25E+04
Y-90	4.54E-02	38.9	9.25E+04
Zr-93	6.93E-06	5.93E-03	14.1
Nb-93m	4.93E-06	4.22E-03	10.0
Tc-99	1.28E-04	0.110	261
Ru-106	3.50E-09	2.99E-06	7.12E-03
Cd-113m	3.91E-05	3.34E-02	79.5
Sb-125	9.06E-05	7.75E-02	185
Sn-126	2.12E-06	1.81E-03	4.31
I-129	2.48E-07	2.12E-04	0.504
Cs-134	3.53E-07	3.02E-04	0.718
Cs-137	4.67E-02	39.9	9.51E+04
Ba-137m	4.42E-02	37.8	8.99E+04
Sm-151	4.93E-03	4.22	1.00E+04
Eu-152	1.61E-06	1.38E-03	3.28
Eu-154	3.09E-04	0.264	629
Eu-155	9.44E-05	8.08E-02	192
Ra-226	4.81E-11	4.12E-08	9.80E-05
Ra-228	1.09E-09	9.32E-07	2.22E-03
Ac-227	2.95E-10	2.52E-07	6.01E-04
Pa-231	1.48E-09	1.26E-06	3.01E-03
Th-229	6.75E-11	5.77E-08	1.37E-04
Th-232	4.19E-10	3.59E-07	8.53E-04
U-232	4.57E-08	3.91E-05	9.31E-02
U-233	1.77E-07	1.51E-04	0.360
U-234	2.42E-07	2.07E-04	0.493
U-235	9.91E-09	8.48E-06	2.02E-02
U-236	8.30E-09	7.10E-06	1.69E-02
U-238	2.22E-07	1.90E-04	0.452
Np-237	4.42E-07	3.78E-04	0.900
Pu-238	4.90E-07	4.19E-04	0.997
Pu-239	1.28E-05	1.10E-02	26.1
Pu-240	2.37E-06	2.03E-03	4.83
Pu-241	3.31E-05	2.83E-02	67.3
Pu-242	1.94E-10	1.66E-07	3.94E-04

Table A-5. Single-Shell Tank 241-T-103 Liquid Inventory Estimated in Tank on June 30, 1973.[a] (3 sheets)

Radiological Constituents	Ci/L	µCi/g	Ci
Am-241	2.31E-05	1.97E-02	47.0
Am-243	9.28E-10	7.94E-07	1.89E-03
Cm-242	6.64E-08	5.68E-05	0.135
Cm-243	6.45E-09	5.51E-06	1.31E-02
Cm-244	7.22E-08	6.18E-05	0.147
Totals	**M**	**µg/g**	**kg**
Pu	2.17E-04 (g/L)	----	0.442
U	2.80E-03	569	1.35E+03

[a] Source: *Hanford Tank Chemical and Radionuclide Inventories: HDW Model, Rev. 4*, LA-UR-96-3860, Rev. 4 (Agnew 1997).
[b] Density is calculated based on Na, OH-, and AlO_2-.
[c] Water weight-percent (wt%) derived from the difference of density and total dissolved species.
BTU = British thermal units
ppm = parts per million
TOC = total organic carbon

Table A-6. Single-Shell Tank 241-T-104 Entrained Liquid Inventory Estimate Currently in Tank.[a] (3 sheets)

Physical Properties			
Total entrained liquid waste	1.59E+04 (kg)	(3.01 kgal)	----
Heat load	1.57E-02 (kW)	(53.7 BTU/hr)	----
Bulk density[b]	1.40 (g/cc)	----	----
Water wt%[c]	49.0	----	----
TOC wt% (wet)	0.720	----	----
Chemical Constituents	**mole/L**	**ppm**	**kg**
Na^+	9.44	1.55E+05	2.47E+03
Al^{3+}	0.978	1.89E+04	301
Fe^{3+} (total Fe)	7.61E-03	304	4.85
Cr^{3+}	8.90E-02	3.32E+03	52.8
Bi^{3+}	2.02E-03	302	4.80
La^{3+}	1.76E-05	1.75	2.78E-02
Hg^{2+}	8.33E-06	1.20	1.91E-02
Zr (as $ZrO(OH)_2$)	2.35E-04	15.3	0.244
Pb^{2+}	5.71E-04	84.8	1.35
Ni^{2+}	4.42E-03	186	2.96
Sr^{2+}	0	0	0
Mn^{4+}	2.35E-03	92.5	1.47
Ca^{2+}	2.35E-02	676	10.8

Table A-6. Single-Shell Tank 241-T-104 Entrained Liquid Inventory Estimate Currently in Tank.[a] (3 sheets)

Chemical Constituents	mole/L	ppm	kg
K^+	4.22E-02	1.18E+03	18.8
OH^-	6.01	7.32E+04	1.17E+03
NO_3^-	3.38	1.50E+05	2.39E+03
NO_2^-	1.53	5.05E+04	803
CO_3^{2-}	0.288	1.24E+04	197
PO_4^{3-}	0.102	6.96E+03	111
SO_4^{2-}	0.174	1.20E+04	190
Si (as SiO_3^{2-})	6.08E-02	1.22E+03	19.5
F^-	9.78E-02	1.33E+03	21.2
Cl^-	0.162	4.12E+03	65.6
$C_6H_5O_7^{3-}$	1.90E-02	2.58E+03	41.0
$EDTA^{4-}$	1.43E-02	2.96E+03	47.1
$HEDTA^{3-}$	2.72E-02	5.34E+03	85.0
$Glycolate^-$	7.81E-02	4.20E+03	66.8
$Acetate^-$	4.80E-03	203	3.23
$Oxalate^{2-}$	2.30E-05	1.45	2.31E-02
DBP	1.18E-02	1.77E+03	28.2
Butanol	1.18E-02	626	9.96
NH_3	7.64E-02	930	14.8
$Fe(CN)_6^{4-}$	0	0	0
Radiological Constituents	**Ci/L**	**µCi/g**	**Ci**
H-3	1.57E-04	0.113	1.79
C-14	2.31E-05	1.66E-02	0.264
Ni-59	1.46E-06	1.05E-03	1.66E-02
Ni-63	1.43E-04	0.102	1.63
Co-60	2.61E-05	1.87E-02	0.297
Se-79	2.35E-06	1.68E-03	2.67E-02
Sr-90	8.63E-02	61.9	985
Y-90	8.64E-02	61.9	985
Zr-93	1.15E-05	8.23E-03	0.131
Nb-93m	8.35E-06	5.98E-03	9.52E-02
Tc-99	1.64E-04	0.118	1.87
Ru-106	4.97E-09	3.56E-06	5.66E-05
Cd-113m	6.02E-05	4.31E-02	0.687
Sb-125	1.14E-04	8.15E-02	1.30
Sn-126	3.55E-06	2.54E-03	4.05E-02
I-129	3.17E-07	2.27E-04	3.61E-03
Cs-134	1.95E-06	1.40E-03	2.23E-02
Cs-137	0.170	122	1.94E+03
Ba-137m	0.161	115	1.84E+03
Sm-151	8.26E-03	5.92	94.3

Table A-6. Single-Shell Tank 241-T-104 Entrained Liquid Inventory Estimate Currently in Tank.[a] (3 sheets)

Radiological Constituents	Ci/L	µCi/g	Ci
Eu-152	2.91E-06	2.08E-03	3.32E-02
Eu-154	4.31E-04	0.309	4.91
Eu-155	1.73E-04	0.124	1.97
Ra-226	1.00E-10	7.17E-08	1.14E-06
Ra-228	8.00E-08	5.73E-05	9.12E-04
Ac-227	6.27E-10	4.50E-07	7.15E-06
Pa-231	2.85E-09	2.04E-06	3.25E-05
Th-229	1.89E-09	1.35E-06	2.15E-05
Th-232	5.26E-09	3.77E-06	6.00E-05
U-232	4.26E-07	3.05E-04	4.86E-03
U-233	1.63E-06	1.17E-03	1.86E-02
U-234	6.07E-07	4.35E-04	6.93E-03
U-235	2.50E-08	1.79E-05	2.85E-04
U-236	1.68E-08	1.21E-05	1.92E-04
U-238	5.65E-07	4.05E-04	6.44E-03
Np-237	5.95E-07	4.27E-04	6.79E-03
Pu-238	8.21E-07	5.88E-04	9.36E-03
Pu-239	2.74E-05	1.97E-02	0.313
Pu-240	4.56E-06	3.27E-03	5.20E-02
Pu-241	5.47E-05	3.92E-02	0.623
Pu-242	3.12E-10	2.23E-07	3.55E-06
Am-241	4.01E-05	2.87E-02	0.457
Am-243	1.50E-09	1.08E-06	1.71E-05
Cm-242	1.12E-07	8.04E-05	1.28E-03
Cm-243	1.04E-08	7.48E-06	1.19E-04
Cm-244	1.01E-07	7.22E-05	1.15E-03
Totals	**M**	**µg/g**	**kg**
Pu	4.62E-04 (g/L)	---	5.27E-03
U	7.11E-03	1.21E+03	19.3

[a] Source: *Hanford Tank Chemical and Radionuclide Inventories: HDW Model, Rev. 4*, LA-UR-96-3860, Rev. 4 (Agnew 1997).

[b] Density is calculated based on Na, OH-, and AlO_2-.

[c] Water weight-percent (wt%) derived from the difference of density and total dissolved species.

BTU = British thermal units
ppm = parts per million
TOC = total organic carbon

Table A-7. Single-Shell Tank 241-T-105 Entrained Liquid Inventory Estimate Currently in Tank.[a]

Physical Properties		
Total entrained liquid waste	0 (kg)	(1.70E-02 kgal)
Heat load	0 (kW)	(0 BTU/hr)
Bulk density[b]	0 (g/cc)	----
Water wt%[c]	0	----
TOC wt% (wet)	0	----

NOTE: All current chemical and radionuclide inventories for liquids are modeled as zero.

[a] Source: *Hanford Tank Chemical and Radionuclide Inventories: HDW Model, Rev. 4*, LA-UR-96-3860, Rev. 4 (Agnew 1997).

[b] Density is calculated based on Na, OH-, and AlO_2^-.

[c] Water weight-percent (wt%) derived from the difference of density and total dissolved species.

BTU = British thermal units

TOC = total organic carbon

Table A-8. Single-Shell Tank 241-T-106 Entrained Liquid Inventory Estimate Currently in Tank.[a]

Physical Properties		
Total entrained liquid waste	7.59E+03 (kg)	(2.01 kgal)
Heat load	0 (kW)	(0 BTU/hr)
Bulk density[b]	1.00 (g/cc)	----
Water wt%[c]	100	----
TOC wt% (wet)	0	----

NOTE: All current chemical and radionuclide inventories for liquids are modeled as zero.

[a] Source: *Hanford Tank Chemical and Radionuclide Inventories: HDW Model, Rev. 4*, LA-UR-96-3860, Rev. 4 (Agnew 1997).

[b] Density is calculated based on Na, OH-, and AlO_2^-.

[c] Water weight-percent (wt%) derived from the difference of density and total dissolved species.

BTU = British thermal units

TOC = Total Organic Carbon

Table A-9. Single-Shell Tank 241-T-106 Liquid Inventory Estimated in Tank on June 30, 1973.[a] (3 sheets)

Physical Properties			
Total liquid waste	2.01E+05 (kg)	(45.0 kgal)	----
Heat load	9.62E-02 (kW)	(329 BTU/hr)	----
Bulk density[b]	1.18 (g/cc)	----	----
Water wt%[c]	73.0	----	----
TOC wt% (wet)	0.334	----	----
Chemical Constituents	**mole/L**	**ppm**	**kg**
Na^{+}	4.37	8.50E+04	1.71E+04
Al^{3+}	0.472	1.08E+04	2.17E+03
Fe^{3+} (total Fe)	4.07E-03	192	38.7
Cr^{3+}	4.29E-02	1.89E+03	380
Bi^{3+}	9.45E-05	16.7	3.36
La^{3+}	8.61E-10	1.01E-04	2.04E-05
Hg^{2+}	1.74E-06	0.295	5.93E-02
Zr (as $ZrO(OH)_2$)	2.89E-05	2.23	0.449
Pb^{2+}	2.42E-04	42.4	8.53
Ni^{2+}	1.81E-03	90.0	18.1
Sr^{2+}	0	0	0
Mn^{4+}	2.28E-03	106	21.4
Ca^{2+}	9.17E-03	311	62.6
K^{+}	2.03E-02	671	135
OH^{-}	3.08	4.44E+04	8.93E+03
NO_3^{-}	1.25	6.58E+04	1.32E+04
NO_2^{-}	0.842	3.28E+04	6.59E+03
CO_3^{2-}	0.185	9.38E+03	1.89E+03
PO_4^{3-}	1.09E-02	873	176
SO_4^{2-}	8.93E-02	7.26E+03	1.46E+03
Si (as SiO_3^{2-})	2.95E-02	701	141
F^{-}	5.44E-03	87.6	17.6
Cl^{-}	7.21E-02	2.16E+03	435
$C_6H_5O_7^{3-}$	1.91E-02	3.05E+03	614
$EDTA^{4-}$	2.96E-04	72.2	14.5
$HEDTA^{3-}$	5.96E-04	138	27.8
$Glycolate^{-}$	3.90E-02	2.48E+03	498
$Acetate^{-}$	1.26E-05	0.630	0.127
$Oxalate^{2-}$	1.13E-09	8.41E-05	1.69E-05
DBP	1.06E-02	1.88E+03	379
Butanol	1.06E-02	664	134
NH_3	2.62E-02	377	75.9
$Fe(CN)_6^{4-}$	0	0	0

Table A-9. Single-Shell Tank 241-T-106 Liquid Inventory Estimated in Tank on June 30, 1973.[a] (3 sheets)

Radiological Constituents	Ci/L	µCi/g	Ci
H-3	1.08E-04	9.17E-02	18.4
C-14	1.96E-05	1.66E-02	3.35
Ni-59	1.01E-06	8.54E-04	0.172
Ni-63	9.97E-05	8.44E-02	17.0
Co-60	2.26E-05	1.91E-02	3.85
Se-79	1.52E-06	1.29E-03	0.260
Sr-90	5.00E-02	42.4	8.52E+03
Y-90	5.01E-02	42.4	8.53E+03
Zr-93	7.51E-06	6.36E-03	1.28
Nb-93m	5.36E-06	4.54E-03	0.914
Tc-99	1.39E-04	0.118	23.7
Ru-106	3.80E-09	3.22E-06	6.48E-04
Cd-113m	4.20E-05	3.56E-02	7.16
Sb-125	9.83E-05	8.32E-02	16.7
Sn-126	2.30E-06	1.95E-03	0.392
I-129	2.68E-07	2.27E-04	4.57E-02
Cs-134	3.57E-07	3.02E-04	6.08E-02
Cs-137	4.86E-02	41.2	8.29E+03
Ba-137m	4.60E-02	39.0	7.84E+03
Sm-151	5.36E-03	4.54	913
Eu-152	1.75E-06	1.48E-03	0.298
Eu-154	3.33E-04	0.282	56.8
Eu-155	1.03E-04	8.73E-02	17.6
Ra-226	5.34E-11	4.52E-08	9.10E-06
Ra-228	8.12E-10	6.87E-07	1.38E-04
Ac-227	3.12E-10	2.64E-07	5.31E-05
Pa-231	1.53E-09	1.29E-06	2.60E-04
Th-229	3.64E-11	3.08E-08	6.20E-06
Th-232	2.99E-10	2.53E-07	5.09E-05
U-232	3.93E-08	3.33E-05	6.70E-03
U-233	1.52E-07	1.29E-04	2.60E-02
U-234	2.63E-07	2.23E-04	4.49E-02
U-235	1.08E-08	9.13E-06	1.84E-03
U-236	9.33E-09	7.90E-06	1.59E-03
U-238	2.40E-07	2.03E-04	4.09E-02
Np-237	4.79E-07	4.05E-04	8.16E-02
Pu-238	5.41E-07	4.58E-04	9.22E-02
Pu-239	1.41E-05	1.19E-02	2.40
Pu-240	2.59E-06	2.20E-03	0.442
Pu-241	3.63E-05	3.08E-02	6.19
Pu-242	2.15E-10	1.82E-07	3.66E-05

Table A-9. Single-Shell Tank 241-T-106 Liquid Inventory Estimated in Tank on June 30, 1973.[a] (3 sheets)

Radiological Constituents	Ci/L	µCi/g	Ci
Am-241	2.53E-05	2.14E-02	4.31
Am-243	1.03E-09	8.71E-07	1.75E-04
Cm-242	7.24E-08	6.13E-05	1.23E-02
Cm-243	6.99E-09	5.92E-06	1.19E-03
Cm-244	7.95E-08	6.73E-05	1.35E-02
Totals	**M**	**µg/g**	**kg**
Pu	2.38E-04 (g/L)	--	4.06E-02
U	3.02E-03	609	122

[a] Source: *Hanford Tank Chemical and Radionuclide Inventories: HDW Model, Rev. 4*, LA-UR-96-3860, Rev. 4 (Agnew 1997).
[b] Density is calculated based on Na, OH-, and AlO_2^-.
[c] Water weight-percent (wt%) derived from the difference of density and total dissolved species.
BTU = British thermal units
ppm = parts per million
TOC = total organic carbon

Table A-10. Single-Shell Tank 241-T-107 Entrained Liquid Inventory Estimate Currently in Tank.[a]

Physical Properties		
Total entrained liquid waste	3.41E+04 (kg)	(9.01 kgal)
Heat load	0 (kW)	(0 BTU/hr)
Bulk density[b]	1.00 (g/cc)	----
Water wt%[c]	100	----
TOC wt% (wet)	0	----

NOTE: All current chemical and radionuclide inventories for liquids are modeled as zero.
[a] Source: *Hanford Tank Chemical and Radionuclide Inventories: HDW Model, Rev. 4*, LA-UR-96-3860, Rev. 4 (Agnew 1997).
[b] Density is calculated based on Na, OH-, and AlO_2^-.
[c] Water weight-percent (wt%) derived from the difference of density and total dissolved species.
BTU = British thermal units
TOC = total organic carbon

Table A-11. Single-Shell Tank 241-T-108 Entrained Liquid Inventory Estimate Currently in Tank.[a]

Physical Properties		
Total entrained liquid waste	0 (kg)	(3.00E-03 kgal)
Heat load	0 (kW)	(0 BTU/hr)
Bulk density[b]	0 (g/cc)	----
Water wt%[c]	0	----
TOC wt% (wet)	0	----

NOTE: All current chemical and radionuclide inventories for liquids are modeled as zero.

[a] Source: *Hanford Tank Chemical and Radionuclide Inventories: HDW Model, Rev. 4*, LA-UR-96-3860, Rev. 4 (Agnew 1997).

[b] Density is calculated based on Na, OH-, and AlO_2-.

[c] Water weight-percent (wt%) derived from the difference of density and total dissolved species.

BTU = British thermal units

TOC = total organic carbon

Table A-12. Single-Shell Tank 241-T-109 Entrained Liquid Inventory Estimate Currently in Tank.[a]

Physical Properties		
Total entrained liquid waste	0 (kg)	(0 kgal)
Heat load	0 (kW)	(0 BTU/hr)
Bulk density[b]	0 (g/cc)	----
Water wt%[c]	0	----
TOC wt% (wet)	0	----

NOTE: All current chemical and radionuclide inventories for liquids are modeled as zero.

[a] Source: *Hanford Tank Chemical and Radionuclide Inventories: HDW Model, Rev. 4*, LA-UR-96-3860, Rev. 4 (Agnew 1997).

[b] Density is calculated based on Na, OH-, and AlO_2-.

[c] Water weight-percent (wt%) derived from the difference of density and total dissolved species.

BTU = British thermal units

TOC = total organic carbon

Table A-13. Single-Shell Tank 241-T-110 Entrained Liquid Inventory Estimate Currently in Tank.[a] (3 sheets)

Physical Properties			
Total entrained liquid waste	1.20E+04 (kg)	(3.07 kgal)	----
Heat load	1.18E-04 (kW)	(0.401 BTU/hr)	----
Bulk density[b]	1.03 (g/cc)	----	----
Water wt%[c]	94.4	----	----
TOC wt% (wet)	3.71E-12	----	----
Chemical Constituents	**mole/L**	**ppm**	**kg**
Na^{+}	0.799	1.78E+04	214
Al^{3+}	0	0	0
Fe^{3+} (total Fe)	1.26E-03	68.3	0.817
Cr^{3+}	3.41E-03	172	2.06
Bi^{3+}	2.52E-03	511	6.11
La^{3+}	1.21E-12	1.64E-07	1.96E-09
Hg^{2+}	0	0	0
Zr (as $ZrO(OH)_2$)	0	0	0
Pb^{2+}	0	0	0
Ni^{2+}	1.01E-03	57.5	0.688
Sr^{2+}	0	0	0
Mn^{4+}	1.63E-12	8.70E-08	1.04E-09
Ca^{2+}	5.67E-03	221	2.64
K^{+}	2.33E-03	88.4	1.06
OH^{-}	4.77E-02	788	9.42
NO_3^{-}	0.433	2.61E+04	312
NO_2^{-}	4.30E-03	192	2.30
CO_3^{2-}	5.67E-03	330	3.95
PO_4^{3-}	6.89E-02	6.35E+03	76.0
SO_4^{2-}	1.69E-02	1.58E+03	18.9
Si (as SiO_3^{2-})	1.23E-02	335	4.01
F^{-}	7.30E-02	1.35E+03	16.1
Cl^{-}	1.07E-02	369	4.41
$C_6H_5O_7^{3-}$	0	0	0
$EDTA^{4-}$	0	0	0
$HEDTA^{3-}$	0	0	0
$Glycolate^{-}$	0	0	0
$Acetate^{-}$	0	0	0
$Oxalate^{2-}$	1.59E-12	1.36E-07	1.63E-09
DBP	0	0	0
Butanol	0	0	0
NH_3	2.03E-06	3.36E-02	4.02E-04
$Fe(CN)_6^{4-}$	0	0	0

Table A-13. Single-Shell Tank 241-T-110 Entrained Liquid Inventory Estimate Currently in Tank.[a] (3 sheets)

Radiological Constituents	Ci/L	µCi/g	Ci
H-3	2.12E-08	2.06E-05	2.46E-04
C-14	8.31E-09	8.07E-06	9.65E-05
Ni-59	2.36E-09	2.29E-06	2.74E-05
Ni-63	2.15E-07	2.09E-04	2.50E-03
Co-60	2.24E-09	2.18E-06	2.60E-05
Se-79	1.75E-09	1.70E-06	2.04E-05
Sr-90	8.38E-04	0.814	9.74
Y-90	8.38E-04	0.814	9.74
Zr-93	8.32E-09	8.08E-06	9.67E-05
Nb-93m	6.95E-09	6.75E-06	8.08E-05
Tc-99	5.78E-08	5.61E-05	6.71E-04
Ru-106	1.14E-15	1.11E-12	1.32E-11
Cd-113m	2.19E-08	2.13E-05	2.54E-04
Sb-125	2.28E-09	2.21E-06	2.65E-05
Sn-126	2.65E-09	2.58E-06	3.08E-05
I-129	1.09E-10	1.06E-07	1.27E-06
Cs-134	1.05E-10	1.02E-07	1.22E-06
Cs-137	9.54E-04	0.927	11.1
Ba-137m	9.03E-04	0.877	10.5
Sm-151	6.48E-06	6.30E-03	7.54E-02
Eu-152	3.17E-10	3.08E-07	3.69E-06
Eu-154	4.28E-08	4.15E-05	4.97E-04
Eu-155	2.13E-08	2.07E-05	2.47E-04
Ra-226	3.56E-13	3.46E-10	4.14E-09
Ra-228	8.76E-19	8.51E-16	1.02E-14
Ac-227	1.84E-12	1.79E-09	2.14E-08
Pa-231	4.15E-12	4.03E-09	4.83E-08
Th-229	1.71E-16	1.66E-13	1.98E-12
Th-232	2.27E-18	2.21E-15	2.64E-14
U-232	2.60E-12	2.52E-09	3.02E-08
U-233	1.19E-13	1.16E-10	1.38E-09
U-234	1.08E-07	1.05E-04	1.25E-03
U-235	4.77E-09	4.63E-06	5.54E-05
U-236	1.11E-09	1.07E-06	1.29E-05
U-238	1.10E-07	1.07E-04	1.28E-03
Np-237	3.61E-10	3.50E-07	4.19E-06
Pu-238	4.54E-08	4.41E-05	5.28E-04
Pu-239	5.64E-06	5.48E-03	6.55E-02
Pu-240	5.51E-07	5.35E-04	6.40E-03
Pu-241	1.99E-06	1.94E-03	2.32E-02
Pu-242	9.11E-12	8.85E-09	1.06E-07

Table A-13. Single-Shell Tank 241-T-110 Entrained Liquid Inventory Estimate Currently in Tank.[a] (3 sheets)

Radiological Constituents	Ci/L	µCi/g	Ci
Am-241	2.19E-08	2.13E-05	2.55E-04
Am-243	1.59E-13	1.54E-10	1.84E-09
Cm-242	6.30E-12	6.12E-09	7.32E-08
Cm-243	1.30E-13	1.26E-10	1.51E-09
Cm-244	3.78E-12	3.67E-09	4.39E-08
Totals	**M**	**µg/g**	**kg**
Pu	9.32E-05 (g/L)	----	1.08E-03
U	1.38E-03	319	3.82

[a] Source: *Hanford Tank Chemical and Radionuclide Inventories: HDW Model, Rev. 4*, LA-UR-96-3860, Rev. 4 (Agnew 1997).
[b] Density is calculated based on Na, OH-, and AlO_2^-.
[c] Water weight-percent (wt%) derived from the difference of density and total dissolved species.
BTU = British thermal units
ppm = parts per million
TOC = total organic carbon

Table A-14. Single-Shell Tank 241-T-111 Entrained Liquid Inventory Estimate Currently in Tank.[a] (3 sheets)

Physical Properties			
Total entrained liquid waste	7.95E+03 (kg)	(2.06 kgal)	----
Heat load	4.83E-05 (kW)	(0.165 BTU/hr)	----
Bulk density[b]	1.02 (g/cc)	----	----
Water wt%[c]	96.5	----	----
TOC wt% (wet)	5.10E-12	----	----
Chemical Constituents	**mole/L**	**ppm**	**kg**
Na^+	0.489	1.10E+04	87.8
Al^{3+}	0	0	0
Fe^{3+} (total Fe)	7.70E-04	42.2	0.336
Cr^{3+}	2.09E-03	107	0.848
Bi^{3+}	1.54E-03	316	2.51
La^{3+}	1.65E-12	2.25E-07	1.79E-09
Hg^{2+}	0	0	0
Zr (as $ZrO(OH)_2$)	0	0	0
Pb^{2+}	0	0	0
Ni^{2+}	6.17E-04	35.6	0.283
Sr^{2+}	0	0	0
Mn^{4+}	2.22E-12	1.20E-07	9.51E-10

Table A-14. Single-Shell Tank 241-T-111 Entrained Liquid Inventory Estimate Currently in Tank.[a] (3 sheets)

Chemical Constituents	mole/L	ppm	kg
Ca^{2+}	3.47E-03	136	1.09
K^{+}	1.42E-03	54.7	0.435
OH^{-}	2.92E-02	487	3.87
NO_3^{-}	0.265	1.61E+04	128
NO_2^{-}	2.63E-03	119	0.945
CO_3^{2-}	3.47E-03	204	1.63
PO_4^{3-}	4.21E-02	3.93E+03	31.3
SO_4^{2-}	1.04E-02	977	7.77
Si (as SiO_3^{2-})	7.51E-03	207	1.65
F^{-}	4.46E-02	833	6.63
Cl^{-}	6.55E-03	228	1.81
$C_6H_5O_7^{3-}$	0	0	0
$EDTA^{4-}$	0	0	0
$HEDTA^{3-}$	0	0	0
Glycolate^{-}	0	0	0
Acetate^{-}	0	0	0
Oxalate^{2-}	2.16E-12	1.87E-07	1.49E-09
DBP	0	0	0
Butanol	0	0	0
NH_3	1.24E-06	2.08E-02	1.65E-04
$Fe(CN)_6^{4-}$	0	0	0
Radiological Constituents	**Ci/L**	**µCi/g**	**Ci**
H-3	1.29E-08	1.27E-05	1.01E-04
C-14	5.08E-09	4.99E-06	3.97E-05
Ni-59	1.44E-09	1.42E-06	1.13E-05
Ni-63	1.32E-07	1.29E-04	1.03E-03
Co-60	1.37E-09	1.35E-06	1.07E-05
Se-79	1.07E-09	1.05E-06	8.38E-06
Sr-90	5.12E-04	0.503	4.00
Y-90	5.13E-04	0.504	4.00
Zr-93	5.09E-09	5.00E-06	3.97E-05
Nb-93m	4.25E-09	4.18E-06	3.32E-05
Tc-99	3.53E-08	3.47E-05	2.76E-04
Ru-106	6.97E-16	6.84E-13	5.44E-12
Cd-113m	1.34E-08	1.32E-05	1.05E-04
Sb-125	1.39E-09	1.37E-06	1.09E-05
Sn-126	1.62E-09	1.59E-06	1.27E-05
I-129	6.69E-11	6.57E-08	5.23E-07
Cs-134	6.40E-11	6.29E-08	5.00E-07
Cs-137	5.84E-04	0.573	4.56
Ba-137m	5.52E-04	0.542	4.31

Table A-14. Single-Shell Tank 241-T-111 Entrained Liquid Inventory Estimate Currently in Tank.[a] (3 sheets)

Radiological Constituents	Ci/L	µCi/g	Ci
Sm-151	3.97E-06	3.90E-03	3.10E-02
Eu-152	1.94E-10	1.91E-07	1.52E-06
Eu-154	2.61E-08	2.57E-05	2.04E-04
Eu-155	1.30E-08	1.28E-05	1.02E-04
Ra-226	2.18E-13	2.14E-10	1.70E-09
Ra-228	5.36E-19	5.26E-16	4.18E-15
Ac-227	1.13E-12	1.11E-09	8.80E-09
Pa-231	2.54E-12	2.50E-09	1.98E-08
Th-229	1.04E-16	1.02E-13	8.15E-13
Th-232	1.39E-18	1.36E-15	1.09E-14
U-232	1.59E-12	1.56E-09	1.24E-08
U-233	7.28E-14	7.15E-11	5.68E-10
U-234	6.60E-08	6.49E-05	5.16E-04
U-235	2.92E-09	2.86E-06	2.28E-05
U-236	6.77E-10	6.65E-07	5.29E-06
U-238	6.71E-08	6.59E-05	5.25E-04
Np-237	2.21E-10	2.17E-07	1.72E-06
Pu-238	2.78E-08	2.73E-05	2.17E-04
Pu-239	3.45E-06	3.39E-03	2.69E-02
Pu-240	3.37E-07	3.31E-04	2.63E-03
Pu-241	1.22E-06	1.20E-03	9.52E-03
Pu-242	5.57E-12	5.47E-09	4.35E-08
Am-241	1.34E-08	1.32E-05	1.05E-04
Am-243	9.70E-14	9.53E-11	7.58E-10
Cm-242	3.85E-12	3.78E-09	3.01E-08
Cm-243	7.94E-14	7.79E-11	6.20E-10
Cm-244	2.31E-12	2.27E-09	1.81E-08
Totals	**M**	**µg/g**	**kg**
Pu	5.70E-05 (g/L)	----	4.45E-04
U	8.45E-04	198	1.57

[a] Source: *Hanford Tank Chemical and Radionuclide Inventories: HDW Model, Rev. 4*, LA-UR-96-3860, Rev. 4 (Agnew 1997).
[b] Density is calculated based on Na, OH-, and AlO_2-.
[c] Water weight-percent (wt%) derived from the difference of density and total dissolved species.
BTU = British thermal units
ppm = parts per million
TOC = total organic carbon

Table A-15. Single-Shell Tank 241-T-112 Entrained Liquid Inventory Estimate Currently in Tank.[a]

Physical Properties		
Total entrained liquid waste	2.66E+04 (kg)	(7.03 kgal)
Heat load	0 (kW)	(0 BTU/hr)
Bulk density[b]	1.00 (g/cc)	----
Water wt%[c]	100	----
TOC wt% (wet)	0	----

NOTE: All current chemical and radionuclide inventories for liquids are modeled as zero.

[a] Source: *Hanford Tank Chemical and Radionuclide Inventories: HDW Model, Rev. 4*, LA-UR-96-3860, Rev. 4 (Agnew 1997).

[b] Density is calculated based on Na, OH-, and AlO_2-.

[c] Water weight-percent (wt%) derived from the difference of density and total dissolved species.

BTU = British thermal units

TOC = total organic carbon

Table A-16. Single-Shell Tank 241-T-201 Entrained Liquid Inventory Estimate Currently in Tank.[a]

Physical Properties		
Total entrained liquid waste	3.79E+03 (kg)	(1.00 kgal)
Heat load	0 (kW)	(0 BTU/hr)
Bulk density[b]	1.00 (g/cc)	----
Water wt%[c]	100	----
TOC wt% (wet)	0	----

NOTE: All current chemical and radionuclide inventories for liquids are modeled as zero.

[a] Source: *Hanford Tank Chemical and Radionuclide Inventories: HDW Model, Rev. 4*, LA-UR-96-3860, Rev. 4 (Agnew 1997).

[b] Density is calculated based on Na, OH-, and AlO_2-.

[c] Water weight-percent (wt%) derived from the difference of density and total dissolved species.

BTU = British thermal units

TOC = total organic carbon

Table A-17. Single-Shell Tank 241-T-202 Entrained Liquid Inventory Estimate Currently in Tank.[a]

Physical Properties		
Total entrained liquid waste	0 (kg)	(0 kgal)
Heat load	0 (kW)	(0 BTU/hr)
Bulk density[b]	0 (g/cc)	----
Water wt%[c]	0	----
TOC wt% (wet)	0	----

NOTE: All current chemical and radionuclide inventories for liquids are modeled as zero.

[a] Source: *Hanford Tank Chemical and Radionuclide Inventories: HDW Model, Rev. 4*, LA-UR-96-3860, Rev. 4 (Agnew 1997).

[b] Density is calculated based on Na, OH-, and AlO_2-.

[c] Water weight-percent (wt%) derived from the difference of density and total dissolved species.

BTU = British thermal units

TOC = total organic carbon

Table A-18. Single-Shell Tank 241-T-203 Entrained Liquid Inventory Estimate Currently in Tank.[a]

Physical Properties		
Total entrained liquid waste	0 (kg)	(1.00E-03 kgal)
Heat load	0 (kW)	(0 BTU/hr)
Bulk density[b]	0 (g/cc)	----
Water wt%[c]	0	----
TOC wt% (wet)	0	----

NOTE: All current chemical and radionuclide inventories for liquids are modeled as zero.

[a] Source: *Hanford Tank Chemical and Radionuclide Inventories: HDW Model, Rev. 4*, LA-UR-96-3860, Rev. 4 (Agnew 1997).

[b] Density is calculated based on Na, OH-, and AlO_2-.

[c] Water weight-percent (wt%) derived from the difference of density and total dissolved species.

BTU = British thermal units

TOC = total organic carbon

Table A-19. Single-Shell Tank 241-T-204
Entrained Liquid Inventory Estimate Currently in Tank.[a]

Physical Properties		
Total entrained liquid waste	0 (kg)	(1.00E-03 kgal)
Heat load	0 (kW)	(0 BTU/hr)
Bulk density[b]	0 (g/cc)	----
Water wt%[c]	0	----
TOC wt% (wet)	0	----

NOTE: All current chemical and radionuclide inventories for liquids are modeled as zero.

[a] Source: *Hanford Tank Chemical and Radionuclide Inventories: HDW Model, Rev. 4*, LA-UR-96-3860, Rev. 4 (Agnew 1997).

[b] Density is calculated based on Na, OH-, and AlO_2-.

[c] Water weight-percent (wt%) derived from the difference of density and total dissolved species.

BTU = British thermal units

TOC = total organic carbon

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APPENDIX B

CONTAMINANT OF POTENTIAL CONCERN EVALUATION SUMMARY

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APPENDIX B
CONTAMINANT OF POTENTIAL CONCERN EVALUATION SUMMARY

Well: 299-W10-1
Status: Upgradient **Drilled: 1947** **Screen Depth: 190 to 270 ft**

Analyte	No. of Exceedences	Max.	Min.	Standard Deviation	Screening Value[1]	Units
Antimony	1	51.6	51.6		10	µg/L
Carbon tetrachloride	14	1,700	38	488.61	3	µg/L
Chloroform	9	17	7.4	3.36	7.17	µg/L
Chromium	4	264	190	35.93	100	µg/L
Iron	1	752	752		300	µg/L
Methylene chloride	1	54	54		5	µg/L
Nitrate	35	1,050,000	16,000	197,910.87	12,400	µg/L
Nitrate-N	4	1,100,000	940,000	80,000.00	2,800	µg/L
Strontium-90	3	200	28	99.30	8	pCi/L
Trichloroethylene (TCE)	10	13	5	2.97	5	µg/L
Tritium	14	1,200,000	24,645	310,619.72	20,000	pCi/L

Well: 299-W10-12
Status: Dry **Drilled: 1974** **Screen Depth: 196 to 248 ft**

Analyte	No. of Exceedences	Max.	Min.	Standard Deviation	Screening Value[1]	Units
Antimony	1	38.6	38.6		10	µg/L
Carbon tetrachloride	3	1,400	520	484.18	3	µg/L
Chloroform	1	15	15		7.17	µg/L
Chromium	1	104	104		100	µg/L
Fluoride	5	5,000	4,290	280.93	4,000	µg/L
Nitrate	9	380,000	156,000	98,526.79	12,400	µg/L
Strontium-90	1	70	70		8	pCi/L
Trichloroethylene (TCE)	1	10	10		5	µg/L
Tritium	5	27,000	21,700	2,207.49	20,000	pCi/L

Well: 299-W10-15
Status: Dry **Drilled: 1989** **Screen Depth: 201 to 222 ft**

Analyte	No. of Exceedences	Max.	Min.	Standard Deviation	Screening Value[1]	Units
Antimony	1	33	33		10	µg/L
Arsenic	1	10	10		10	µg/L
Carbon tetrachloride	9	1,600	430	361.86	3	µg/L
Chloroform	8	16	8	2.76	7.17	µg/L
Chromium	36	930	100	174.93	100	µg/L
Fluoride	24	5,100	4,100	295.49	4,000	µg/L
Iodine-129	1	49.4	49.4		1	pCi/L
Iron	12	3,100	309	897.20	300	µg/L
Manganese	2	117	50	47.38	50	µg/L
Nickel	1	500	500		320	µg/L
Nitrate	8	426,000	290,000	62,814.92	12,400	µg/L
Nitrate-N	19	510,000	230,000	69,526.38	2,800	µg/L
Technetium-99	1	10,100	10,100		900	pCi/L
Trichloroethylene (TCE)	7	14	7.3	2.48	5	µg/L
Tritium	27	379,000	30,300	66,101.03	20,000	pCi/L

Well: 299-W10-16
Status: Dry **Drilled: 1989** **Screen Depth: 198 to 219 ft**

Analyte	No. of Exceedances	Max.	Min.	Standard Deviation	Screening Value[1]	Units
Antimony	1	50	50		10	µg/L
Carbon tetrachloride	7	1,200	690	174.48	3	µg/L
Chloroform	5	11	7.2	1.62	7.17	µg/L
Chromium	12	390	100	102.69	100	µg/L
Iodine-129	1	1.26	1.26		1	pCi/L
Iron	13	11,000	440	2,759.01	300	µg/L
Manganese	1	100	100		50	µg/L
Nitrate	12	234,000	144,000	24,220.58	12,400	µg/L
Nitrate-N	19	170,000	120,000	15,,408.66	2,800	µg/L
Trichloroethylene (TCE)	7	13	8.2	1.57	5	µg/L
Tritium	29	53,200	34,500	5,001.07	20,000	pCi/L

Well: 299-W10-22
Status: Cross-gradient, assessment Drilled: 1994 Screen Depth: 216 to 246 ft

Analyte	No. of Exceedances	Max.	Min.	Standard Deviation	Screening Value[1]	Units
Carbon tetrachloride	8	1,000	380	221.68	3	µg/L
Chloroform	3	7.8	7.3	0.26	7.17	µg/L
Nitrate	23	292,000	20,000	65,194.72	12,400	µg/L
Trichloroethylene (TCE)	8	7.4	5.2	0.66	5	µg/L

Well: 299-W10-23
Status: Assessment Drilled: 1998 Screen Depth: 226 to 261 ft

Analyte	No. of Exceedances	Max.	Min.	Standard Deviation	Screening Value[1]	Units
Carbon tetrachloride	6	1,600	1,500	51.64	3	µg/L
Chloroform	6	14	11	1.21	7.17	µg/L
Chromium	11	153	106	16.66	100	µg/L
Fluoride	8	4,600	4,000	212.13	4,000	µg/L
Hexavalent chromium	2	75.9	75.9	0.00	48	µg/L
Nitrate	28	584,000	233,000	89,265.49	12,400	µg/L
Trichloroethylene (TCE)	6	12	9	1.26	5	µg/L
Tritium	7	25,500	20,400	2,231.16	20,000	pCi/L

Well: 299-W10-24
Status: Downgradient Drilled: 1998 Screen Depth: 233 to 268 ft

Analyte	No. of Exceedances	Max.	Min.	Standard Deviation	Screening Value[1]	Units
Carbon tetrachloride	6	1,600	220	491.39	3	µg/L
Chloroform	4	25	10	6.65	7.17	µg/L
Chromium	4	115	110	2.45	100	µg/L
Fluoride	15	4,960	4,000	296.07	4,000	µg/L
Manganese	5	71.4	55.2	7.68	50	µg/L
Methylene chloride	1	8	8		5	µg/L
Nitrate	34	531,000	60,600	80,830.00	12,400	µg/L
Technetium-99	24	3,660	922	574.24	900	pCi/L
Trichloroethylene (TCE)	4	11	6	2.50	5	µg/L
Tritium	8	29,600	20,500	4,117.91	20,000	pCi/L

Well: 299-W10-28
Status: Upgradient **Drilled: 2001** **Screen Depth: 225 to 260 ft**

Analyte	No. of Exceedances	Max.	Min.	Standard Deviation	Screening Value[1]	Units
Chromium	10	316	109	72.91	100	µg/L
Hexavalent chromium	2	323	323	0.00	48	µg/L
Manganese	2	97.2	69.2	19.80	50	µg/L
Nitrate	15	2,000,000	1,120,000	275,452.87	12,400	µg/L

Well: 299-W10-4
Status: Assessment **Drilled: 1952** **Screen Depth: 190 to 245 ft**

Analyte	No. of Exceedances	Max.	Min.	Standard Deviation	Screening Value[1]	Units
Antimony	1	45.7	45.7		10	µg/L
Arsenic	4	14	10	1.92	10	µg/L
Bis(2-ethylhexyl) phthalate (see footnote 2)	2	20	11	6.36	6	µg/L
Carbon tetrachloride	25	2800	570	581.88	3	µg/L
Cesium-137	55	740	120	167.12	60	pCi/L
Chloroform	25	21	11	3.10	7.17	µg/L
Chromium	32	722	119	173.91	100	µg/L
Fluoride	9	10,100	4,100	1,942.09	4000	µg/L
Nitrate	56	7,610,000	18,000	1,401,797.84	1,2400	µg/L
Nitrate-N	3	180,000	150,000	15,275.25	2800	µg/L
Strontium-90	81	700	11	114.06	8	pCi/L
Technetium-99	2	972	906	46.67	900	\pCi/L
Trichloroethylene (TCE)	25	32	6.7	7.87	5	µg/L
Tritium	18	111,000	21,900	26,508.60	20,000	pCi/L
Uranium, total (see footnote 3)	1	47	47		20	pCi/L

Well: 299-W10-8
Status: Downgradient **Drilled: 1973** **Screen Depth: 211 to 251 ft**

Analyte	No. of Exceedances	Max.	Min.	Standard Deviation	Screening Value[1]	Units
Antimony	1	64	64		10	µg/L
Arsenic	1	101	101		10	µg/L
Cadmium	1	93	93		5	µg/L
Carbon tetrachloride	5	1,100	12	482.46	3	µg/L
Chloroform	1	9	9		7.17	µg/L
Chromium	11	6,180	100	1,825.86	100	µg/L
Fluoride	3	10,500	4,500	3,435.60	4,000	µg/L
Iron	1	328,000	328,000		300	µg/L
Lead	1	340	340		15	µg/L
Manganese	1	2,320	2,320		50	µg/L
Nitrate	63	478,000	29,000	133,298.85	12,400	µg/L
Trichloroethylene (TCE)	1	6.9	6.9		5	µg/L
Tritium	10	28,800	20,600	2,697.24	20,000	pCi/L
Vanadium	1	1,140	1,140		112	µg/L

Well: 299-W11-12
Status: Downgradient **Drilled: 1953** **Screen Depth: 200 to 250 ft**

Analyte	No. of Exceedances	Max.	Min.	Standard Deviation	Screening Value[1]	Units
Carbon tetrachloride	2	65	45	14.14	3	µg/L
Nitrate	47	1,200,000	66,000	170,482.20	12,400	µg/L
Tritium	34	160,000	41,600	24,034.88	20,000	pCi/L

Well: 299-W11-15
Status: Outside **Drilled: 1965** **Screen Depth: 240 to 263 ft**

Analyte	No. of Exceedances	Max.	Min.	Standard Deviation	Screening Value[1]	Units
Bis(2-ethylhexyl) phthalate (see footnote 2)	1	9	9		6	µg/L
Carbon tetrachloride	16	17,00	440	378.06	3	µg/L
Chloroform	6	12	9	1.21	7.17	µg/L
Iodine-129	8	4.247	1.98	0.76	1	pCi/L
Iron	2	26,300	1,430	17,585.75	300	µg/L
Manganese	1	766	766		50	µg/L
Methylene chloride	2	40	11	20.51	5	µg/L
Nitrate	10	248,000	63,700	62,056.07	12,400	µg/L
Nitrate-N	6	310,000	110,000	75,210.81	2,800	µg/L
Trichloroethylene (TCE)	7	14	8.3	2.15	5	µg/L
Tritium	7	210,000	45,000	58,307.51	20,000	pCi/L
Uranium	12	106	39.9	19.65	30	µg/L
Uranium, total (see footnote 3)	1	207	207		20	pCi/L

Well: 299-W11-18
Status: Outside **Drilled: 1967** **Screen Depth: 227 to 295 ft**

Analyte	No. of Exceedances	Max.	Min.	Standard Deviation	Screening Value[1]	Units
Bis(2-ethylhexyl) phthalate (see footnote 2)	1	20	20		6	µg/L
Carbon tetrachloride	14	540	340	58.40	3	µg/L
Cesium-137	9	640	210	119.77	60	pCi/L
Chloroform	1	10	10		7.17	µg/L
Methylene chloride	3	55	41	7.37	5	µg/L
Nitrate	9	171,000	89,400	25,756.25	12,400	µg/L
Nitrate-N	6	80,000	73,000	2,804.76	2,800	µg/L
Strontium-90	50	62	8.1	6.71	8	pCi/L
Trichloroethylene (TCE)	9	6.6	5.1	0.51	5	µg/L
Tritium	5	41,500	28,748	5,720.77	20,000	pCi/L

Well: 299-W11-23
Status: Dry **Drilled: 1973** **Screen Depth: 200 to 240 ft**

Analyte	No. of Exceedances	Max.	Min.	Standard Deviation	Screening Value[1]	Units
Carbon tetrachloride	3	10	5.2	2.69	3	µg/L
Chromium	2	129	127	1.41	100	µg/L
Iron	1	402	402		300	µg/L
Manganese	2	172	80	65.05	50	µg/L
Nitrate	27	757,000	20,000	188,233.70	12,400	µg/L
Nitrate-N	5	14,000	3,400	3,821.39	2,800	µg/L
Technetium-99	13	8,540	1,120	2,256.32	900	pCi/L

Well: 299-W11-24
Status: Dry **Drilled: 1973** **Screen Depth: 210 to 250 ft**

Analyte	No. of Exceedances	Max.	Min.	Standard Deviation	Screening Value[1]	Units
Chromium	1	209	209		100	µg/L
Iron	5	9,500	344	3,909.01	300	µg/L
Manganese	14	1,380	52.9	344.63	50	µg/L
Nitrate	28	540,000	64,200	10,0082.71	12,400	µg/L
Nitrite	9	36,100	3,710	11,619.71	3,268	µg/L
Tritium	9	28,200	21,000	2,286.25	20,000	pCi/L

Well: 299-W11-25B
Status: Downgradient; decommissioned **Drilled: 2005** **Drilled Depth: 410 ft**

Analyte	No. of Exceedances	Max.	Min.	Standard Deviation	Screening Value[1]	Units
Carbon tetrachloride	21	1,483	520	236.96	3	µg/L
Chloroform	21	110	7.9	25.05	7.17	µg/L
Methylene chloride	12	8	5	1.07	5	µg/L
Technetium-99	2	20,000	17,400	1,838.48	900	pCi/L
Trichloroethylene (TCE)	20	9.1	5	1.33	5	µg/L

Well: 299-W11-27
Status: Dry **Drilled: 1991** **Screen Depth: 213 to 234 ft**

Analyte	No. of Exceedances	Max.	Min.	Standard Deviation	Screening Value[1]	Units
Antimony	2	28	24	2.83	10	µg/L
Cadmium	2	127	11.6	81.60	5	µg/L
Carbon tetrachloride	7	360	4.1	144.12	3	µg/L
Chromium	12	590	100	152.07	100	µg/L
Iron	12	4,000	330	12,29.77	300	µg/L
Manganese	5	97	53	18.04	50	µg/L
Nitrate	11	231,000	72,200	52,976.32	12,400	µg/L
Nitrate-N	18	190,000	4,300	45,643.94	2,800	µg/L
Sulfate (see footnote 4)	9	326,000	256,000	23,069.34	250,000	µg/L
Technetium-99	15	21,700	3,481.8	5,648.16	900	pCi/L

Well: 299-W11-28
Status: Dry **Drilled: 1991** **Screen Depth: 224 to 245 ft**

Analyte	No. of Exceedances	Max.	Min.	Standard Deviation	Screening Value[1]	Units
Aldrin (see footnote 5)	1	0.05	0.05		0.00515	µg/L
Cadmium	1	6.5	6.5		5	µg/L
Carbon tetrachloride	9	1900	150	535.49	3	µg/L
Chloroform	8	47	10	15.78	7.17	µg/L
Chromium	8	930	115	270.15	100	µg/L
Iron	16	34,000	304	9,825.08	300	µg/L
Manganese	28	494	51	110.61	50	µg/L
Nickel	1	420	420		320	µg/L
Nitrate	20	266,000	140,000	34,174.28	12,400	µg/L
Nitrate-N	14	220,000	120,000	36,374.12	2,800	µg/L
Nitrite	1	14,800	14,800		3,268	µg/L
Nitrite-N	4	4,300	1,000	1,436.14	1,000	µg/L
Trichloroethylene (TCE)	8	19	10	3.07	5	µg/L
Tritium	33	67,966	21,700	13,430.06	20,000	pCi/L

Well: 299-W11-39
Status: Downgradient **Drilled: 2000** **Screen Depth: 239 to 274 ft**

Analyte	No. of Exceedances	Max.	Min.	Standard Deviation	Screening Value[1]	Units
Chromium	4	122	101	9.39	100	µg/L
Fluoride	1	4,100	4,100		4,000	µg/L
Hexavalent chromium	2	88.5	88.5	0.00	48	µg/L
Manganese	1	124	124		50	µg/L
Nitrate	19	593,000	50,000	118,621.08	12,400	µg/L
Technetium-99	19	27,400	1,490	7,249.62	900	pCi/L

Well: 299-W11-40
Status: Downgradient **Drilled: 2000** **Screen Depth: 238 to 273 ft**

Analyte	No. of Exceedances	Max.	Min.	Standard Deviation	Screening Value[1]	Units
Nitrate	21	1,560,000	148,000	299,144.55	12,400	µg/L
Technetium-99	7	2,050	1,040	334.86	900	pCi/L
Tritium	7	26,600	20,600	2,329.83	20,000	pCi/L

Well: 299-W11-41
Status: Downgradient **Drilled: 2000** **Screen Depth: 237 to 272 ft**

Analyte	No. of Exceedances	Max.	Min.	Standard Deviation	Screening Value[1]	Units
Chromium	20	162	128	10.49	100	µg/L
Hexavalent chromium	2	166	166	0.00	48	µg/L
Nitrate	20	850,000	358,000	133,109.37	12,400	µg/L
Technetium-99	13	3,940	1,200	951.19	900	pCi/L
Tritium	12	32,500	21,200	3,692.33	20,000	pCi/L

Well: 299-W11-42
Status: Downgradient **Drilled: 2000** **Screen Depth: 237 to 272 ft**

Analyte	No. of Exceedances	Max.	Min.	Standard Deviation	Screening Value[1]	Units
Carbon tetrachloride	3	1,800	1,600	100.00	3	µg/L
Chloroform	3	12	10	1.15	7.17	µg/L
Chromium	20	184	119	19.44	100	µg/L
Fluoride	10	4,900	4,000	343.35	4,000	µg/L
Hexavalent chromium	2	181	181	0.00	48	µg/L
Nitrate	20	1,120,000	239,000	200,555.65	12,400	µg/L
Technetium-99	11	2,390	986	470.94	900	pCi/L
Trichloroethylene (TCE)	3	11	11	0.00	5	µg/L

Well: 299-W11-7
Status: Farfield **Drilled: 1951** **Screen Depth: 245 to 290 ft**

Analyte	No. of Exceedances	Max.	Min.	Standard Deviation	Screening Value[1]	Units
Carbon tetrachloride	13	2,500	230	588.07	3	µg/L
Chloroform	6	37	7.6	11.57	7.17	µg/L
Fluoride	1	9,700	9,700		4,000	µg/L
Iodine-129	3	2.13	1.06	0.54	1	pCi/L
Iron	1	2,680	2,680		300	µg/L
Manganese	1	91	91		50	µg/L
Nitrate	37	830,000	22,000	217,882.42	12,400	µg/L
Nitrate-N	3	190,000	180,000	5,773.50	2,800	µg/L
Trichloroethylene (TCE)	9	7.8	5	0.88	5	µg/L
Tritium	9	510,000	20,500	218,974.99	20,000	pCi/L

Footnote 1: Screening values were obtained from Table A1-7 of the *Remedial Investigation/Feasibility Study Work Plan for the 200-ZP-1 Groundwater Operable Unit*, DOE/RL-2003-55, Rev. 0 (DOE-RL 2004).

Footnote 2: Bis(2-ethylhexyl) phthalate is a common laboratory/sampling contaminant from plastics based on U.S. Environmental Protection Agency (EPA) functional guidelines. The EPA risk assessment guidance indicates that common laboratory contaminants with few positive detections (i.e., one or two in this case) and which are not risk drivers, maybe excluded as contaminants of concern. Refer to the following references:

Bleyler, R., 1988b, *Laboratory Data Validation Functional Guidelines for Evaluating Organics Analyses*, U.S. Environmental Protection Agency, Hazardous Site Evaluation Division, Washington, D.C.

EPA, 1989, *Risk Assessment Guidance for Superfund (RAGS), Volume I, Human Health Evaluation Manual (Part A), Interim Final*, OSWER Directive 9285.7-01A, EPA/540/1-89/002, Office of Solid Waste and Emergency Response, U.S. Environmental Protection Agency, Washington, D.C

Footnote 3: The EPA has promulgated a drinking water maximum contaminant level (MCL) of 30 μg/L for total uranium (40 *Code of Federal Regulations* [CFR] 141.66, "National Primary Drinking Water Regulations"). Based on the isotopic distribution of uranium on the Hanford Site, the 30 μg/L MCL corresponds to 21.2 pCi/L (value rounded down for table). Mass concentration to activity calculation are documented in *Calculation of Total Uranium Activity Corresponding to a Maximum Contaminant Level for Uranium of 30 Micrograms per Liter in Groundwater*, Calculation Brief 0100X-CA-V0038, Rev. 0 (dated 2001).

Footnote 4: Well 299-W11-27 is dry and was not part of the monitoring network examined in the *Remedial Investigation/ Feasibility Study Work Plan for the 200-ZP-1 Operable Unit*, DOE/RL-2003-55, Rev. 0 (dated 2004). No other wells in this area exceed the sulfate limits. Unless this contaminant of concern persists in other wells, it is not thought to be a contaminant of concern.

Footnote 5: Well 299-W11-28 is dry and was not part of the monitoring network examined in the *Remedial Investigation/ Feasibility Study Work Plan for the 200-ZP-1 Operable Unit*, DOE/RL-2003-55, Rev. 0 (dated 2004). No other wells in this area exceed the aldrin limit. Unless this contaminant of concern persists in other wells, it is not thought to be a contaminant of concern.

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APPENDIX C

PRELIMINARY TARGET ACTION LEVELS AND BASIS FOR GROUNDWATER CONTAMINANTS OF CONCERN IN THE 200-ZP-1 GROUNDWATER OPERABLE UNIT

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Table C-1. Preliminary Target Action Levels and Basis for Groundwater Contaminants of Concern in 200-ZP-1 Groundwater Operable Unit. (6 sheets)

COC	Primary MCL	Secondary MCL[a]	CLARC Groundwater Method B[c]	Back ground[b]	CRDL	Selected Limit[d]	Source[d]	Comments
Volatile Organics – Units for Nonradiological COCs (µg/L)								
Acetone	—	—	7,200[o]	—	20	7200	CLARC[o]	CLARC > CRDL. CERCLA COC in current groundwater well monitoring network.[f]
Benzene	5	—	0.795	—	5	5	CRDL	CLARC < MCL and CRDL > CLARC.
Carbon disulfide	—	—	800	—	5	800	CLARC	CLARC > CRDL. CERCLA COC in current groundwater well monitoring network.[f]
Carbon tetrachloride	5	—	0.337	—	3	3	CRDL	CRDL > CLARC. CERCLA COC in current groundwater well monitoring network.[f]
Chloroform	80	—	7.17	—	5	7.17	CLARC	CLARC < MCL and CLARC > CRDL. CERCLA COC in current groundwater well monitoring network.[f]
Chlorobenzene	100	—	160	—	5	100	Primary MCL[e]	MCL < CLARC, and MCL > CRDL
Ethyl benzene	700	—	800	—	5	700	Primary MCL[e]	MCL < CLARC, and MCL > CRDL
Methylene chloride	5	—	5.83	—	1	5	Primary MCL[e]	MCL < CLARC, and MCL > CRDL.
Methyl ethyl ketone	—	—	4,800	—	10	4,800	CLARC	CLARC > CRDL.
4-methyl-2-pentanone (hexone, MIBK)	—	—	640	—	10	640	CLARC	CLARC > CRDL.
N-butyl benzene	—	—	320	—	5	320	CLARC	CLARC > CRDL.
Cis 1,2-dichloroethylene	70	—	80	—	10	70	Primary MCL[e]	MCL < CLARC, and MCL > CRDL.
Trans 1,2-dichloroethylene	100	—	160	—	10	100	Primary MCL[e]	MCL < CLARC, and MCL > CRDL.
1,2-dichloroethane (DCA)	5	—	0.481	—	5	5	CRDL	CLARC < MCL and CRDL > CLARC.
Toluene	1,000	—	1,600	—	5	1,000	Primary MCL[e]	MCL < CLARC, and MCL > CRDL.
1,1,1-trichloroethane (TCA)	200	—	7,200	—	5	200	Primary MCL[e]	MCL < CLARC, and MCL > CRDL.

Table C-1. Preliminary Target Action Levels and Basis for Groundwater Contaminants of Concern in 200-ZP-1 Groundwater Operable Unit. (6 sheets)

COC	Primary MCL	Secondary MCL[a]	CLARC Groundwater Method B[c]	Back ground[b]	CRDL	Selected Limit[d]	Source[d]	Comments
Trichloroethylene (TCE)	5	—	3.98	—	5	5	CRDL	CLARC < MCL and CLARC < CRDL. CERCLA COC in current groundwater well monitoring network.[f]
Tetrachloroethylene (PCE)	5	—	0.858	—	5	5	CRDL	CLARC < MCL and CLARC > CRDL.
Xylene (total)	10,000	—	1,600[o]	—	10	10,000	CLARC[o]	CLARC< MCL, and MCL > CRDL.
Semi-Volatile Organics – Units for Nonradiological COCs (µg/L)								
Cresols	—	—	80[g]	—	10	80	CLARC	CLARC > CRDL. CLARC based on p-cresol.
Kerosene	—	—	—	—	500	TBD[h]		No regulatory limits available.
Phenols (total)	—	—	4,800	—	10	4800	CLARC[o]	CLARC > CRDL.
Metals – Units for Nonradiological COCs (µg/L)								
Antimony	6	—	6.4	—	10	10	CRDL	MCL < CLARC, but CRDL > MCL.
Arsenic	10[e]	—	0.0583	10	10	10	CRDL	CLARC < MCL, CRDL= Hanford background > CLARC. CERCLA COC in current groundwater well monitoring network.[f]
Cadmium	5	—	8	<10	5	5	Primary MCL[e]	MCL < CLARC, and MCL = CRDL. CERCLA COC in current groundwater well monitoring network.[f]
Chromium (total)	100[n]	—	24,000	<30	10	100	Primary MCL[e]	MCL < CLARC, and MCL > CRDL. CERCLA COC in current groundwater well monitoring network.[f]
Chromium (hexavalent)	—	—	48[c]	—	10	48	CLARC	CLARC > CRDL. There is no drinking water MCL for hexavalent chromium.
Iron	—	300	—	86	50	300	Secondary MCL	MCL > CRDL. Secondary drinking water standard = 300 µg/L (www.epa.gov/safewater/mcl.html). See footnote m.
Lead	15	—	—	<5	10	15	Primary MCL[e]	MCL > CRDL. Drinking water treatment levels = 15 µg/L (www.epa.gov/safewater/mcl.html).
Lithium	—	—	320	—	25	320	CLARC[o]	CLARC > CRDL.

Table C-1. Preliminary Target Action Levels and Basis for Groundwater Contaminants of Concern in 200-ZP-1 Groundwater Operable Unit. (6 sheets)

COC	Primary MCL	Secondary MCL[a]	CLARC Groundwater Method B[c]	Back ground[b]	CRDL	Selected Limit[d]	Source[d]	Comments
Magnesium	—	—	—	16,480	750	TBD[h]		No regulatory limits available.
Manganese	—	50	2,240	24.5	5	50	Secondary MCL	CLARC > CRDL. Secondary drinking water standard = 50 µg/L (www.epa.gov/safewater/mcl.html). See footnote m.
Mercury	2	—	4.8	<0.1	0.5	2	Primary MCL[e]	MCL < CLARC, and MCL > CRDL.
Nickel	--	—	320	—	40	320	CLARC	CLARC > CRDL.
Selenium	50	—	80	—	10	50	Primary MCL[e]	MCL < CLARC, and MCL > CRDL.
Silver	—	100	80	—	10	80	CLARC	CLARC > CRDL.
Uranium (total)	30	—	48	3.43	0.1	30	Primary MCL[e]	MCL < CLARC, and MCL > CRDL. CERCLA COC in current groundwater well monitoring network.[f]
Vanadium	—	—	112	15	50	112	CLARC	Noncarcinogen CLARC > CRDL.
Non-Metals – Units for Nonradiological COCs (µg/L)								
Ammonium	—	—	—	120	50	TBD[h]		No regulatory limits available.
Cyanide	200	—	320	—	5	200	Primary MCL[e]	MCL < CLARC, and MCL > CRDL.
Fluoride	4,000	2,000	—	775	500	4,000	Primary MCL[e]	Primary MCL > background and CRDL. Secondary drinking water standard is unenforceable and other standards are available.
Nitrate	44,285	—	7,086	12,400	75	12,400	Background	Background > CLARC and CRDL.
Nitrate as nitrogen	10,000	—	25,600	2,800	17	2,800	MCL[o]	MCL > CLARC and CRDL.
Nitrite	3,286	—	5,257	—	75	3,268	Primary MCL[e]	MCL < CLARC, and MCL > CRDL.
Nitrite as nitrogen	1,000	—	1,600	—	17	1,000	Primary MCL[e]	MCL < CLARC, and MCL > CRDL.
Phosphate	—	—	—	<1,000	500	TBD[h]		No regulatory limits available.
Radiological COCs – Beta Emitters – Units for Radiological COCs (pCi/L, unless otherwise noted)								
C-14	2,000[j]	—	—	—	200	2,000[j]	Primary MCL[j]	MCL > CRDL. MCL based on 4 mrem/yr. From www.epa.gov/safewater/mcl.html (EPA et al. 1997).

Table C-1. Preliminary Target Action Levels and Basis for Groundwater Contaminants of Concern in 200-ZP-1 Groundwater Operable Unit. (6 sheets)

COC	Primary MCL	Secondary MCL[a]	CLARC Groundwater Method B[c]	Back ground[b]	CRDL	Selected Limit[d]	Source[d]	Comments
I-129	1[j]	—	—	—	0.5	1[j]	Primary MCL[j]	MCL > CRDL. MCL based on 4 mrem/yr. CERCLA COC in current groundwater well monitoring network.[f] From www.epa.gov/safewater/mcl.html (EPA et al. 1997).
Se-79	4 mrem/yr[i]	—	—	—	30	4 mrem/yr[j]	Primary MCL[i]	MCL > CRDL. MCL based on 4 mrem/yr. From www.epa.gov/safewater/mcl.html (EPA et al. 1997).
Sr-90	8[j]	—	—	—	2	8[j]	Primary MCL[j]	MCL > CRDL. MCL based on 4 mrem/yr. CERCLA COC in current groundwater well monitoring network.[f] From www.epa.gov/safewater/mcl.html (EPA et al. 1997).
Tc-99	900[j,k]	—	—	—	20	900[j]	Primary MCL[j]	MCL > CRDL. MCL based on 4 mrem/yr. CERCLA COC in current groundwater well monitoring network.[f] From www.epa.gov/safewater/mcl.html (EPA et al. 1997).
H-3	20,000[j]	—	—	—	400	20,000[j]	Primary MCL[j]	MCL > CRDL. MCL based on 4 mrem/yr. From www.epa.gov/safewater/mcl.html (EPA et al. 1997).
Radiological COCs – Alpha Emitters – Units for Radiological COCs (pCi/L)								
Np-237	15	—	—	—	1	15	Primary MCL	MCL > CRDL.
Pa-231	15	—	—	—	1	15	Primary MCL	MCL > CRDL.
Radiological COCs – Gamma Emitters – Units for Radiological COCs (pCi/L)								
Cs-137	60[j]	—	—	—	15	60[j]	MCL[j]	CERCLA COC in current groundwater well monitoring network.[f]

Table C-1. Preliminary Target Action Levels and Basis for Groundwater Contaminants of Concern in 200-ZP-1 Groundwater Operable Unit. (6 sheets)

COC	Primary MCL	Secondary MCL[a]	CLARC Groundwater Method B[c]	Back ground[b]	CRDL	Selected Limit[d]	Source[d]	Comments

[a] Primary MCLs were used where available and are assumed unless noted; secondary MCLs are noted in the comments column.
[b] *Hanford Site Groundwater Background*, DOE/RL-92-23 (DOE-RL 1992).
[c] WAC 173-340-740(4) groundwater Method B values from Ecology's *Cleanup Levels and Risk Calculations Under the Model Toxics Control Act Cleanup Regulation (CLARC III)*, Section 3.1 tables (Ecology 2005).
[d] The selected limit is the lower of the MCL or CLARC values with the following exception: if the background or CRDL is higher, the higher of these is selected. If the CLARC tables allowed a choice between carcinogenic and noncarcinogenic values for groundwater, the lower was chosen. In some cases, no regulatory limit is available.
[e] Target action level represents primary MCL (from web site www.epa.gov/safewater/mcl.html).
[f] From *Data Quality Objectives Summary Report for Establishing a RCRA/CERCLA/AEA Integrated 200 West and 200 East Groundwater Monitoring Network* (FH 2003).
[g] It is not known which of the cresols might be found; therefore, target action levels were based on p-cresol and are a factor of 10 lower than the other cresols.

Table C-1. Preliminary Target Action Levels and Basis for Groundwater Contaminants of Concern in 200-ZP-1 Groundwater Operable Unit. (6 sheets)

COC	Primary MCL	Secondary MCL[a]	CLARC Groundwater Method B[c]	Back ground[h]	CRDL	Selected Limit[d]	Source[d]	Comments

[h] These nonradiological COCs will be sampled and analyzed in FY04 and FY06 for wells identified in Section A3.2.1 of the 200-ZP-1 RI/FS work plan (DOE-RL 2004). If these COCs are not found during these sampling events, they will not be considered again in this CERCLA process. If these COCs are detected at levels deemed significant (greater than the CRDLs in Table A2-1 of the 200-ZP-1 RI/FS work plan), then a target action level may be established with RL and EPA concurrence.

[i] This radiological COC will be sampled and analyzed in FY04 and FY06 for wells identified in Section A3.2.1 of the 200-ZP-1 RI/FS work plan (DOE-RL 2004). If these COCs are not found during these sampling events, they will not be considered again in this CERCLA process. A calculation has not been performed to establish a target action level (pCi/L) from the drinking water regulatory requirement of 4 mrem/yr for these COCs. If these COCs are detected at levels deemed significant (greater than the CRDLs in Table A2-1 of the 200-ZP-1 RI/FS work plan [DOE-RL 2004]), then a target action level may be established with RL and EPA concurrence to ensure that the hypothetical dose from these radionuclides is less than 4 mrem/yr outside the core zone.

[j] Target action level based on the estimated groundwater concentration that would result 4 mrem/year (MCL) to the whole body or an organ if the groundwater water were used as drinking water (DOE-RL 2002, Table 2-3).

[k] Technetium-99 remedial target action levels defined in *Record of Decision for the 200-UP-1 Interim Remedial Measure* (EPA et al. 1997).

[m] In some instances, drilling through basalt for the well may contribute to contamination of the well water with iron and manganese.

[n] Total chromium based on chromium III and VI values.

[o] CLARC 3.1 updated to CLARC database with additional Integrated Risk Information System database limits, generated by CH2M Hill Hanford Group, Inc. for the River Corridor, August 26, 2005. Limits updated since 2003 are footnoted.

AEA = *Atomic Energy Act of 1954*
CERCLA = *Comprehensive Environmental Response, Compensation, and Liability Act of 1980*
CLARC = *Cleanup Levels and Risk Calculations Under the Model Toxics Control Act Cleanup Regulation*
COC = contaminant of concern
CRDL = contract-required detection limit
Ecology = Washington State Department of Ecology
EPA = U.S. Environmental Protection Agency
FY = fiscal year
MCL = maximum contaminant level
RCRA = *Resource Conservation and Recovery Act of 1976*
RI/FS = remedial investigation/feasibility study
RL = U.S. Department of Energy, Richland Operations Office
TBD = to be determined
WAC = *Washington Administrative Code*

REFERENCES

Atomic Energy Act of 1954, 42 U.S.C. 2011, et seq.

Comprehensive Environmental Response, Compensation, and Liability Act of 1980, 42 U.S.C. 9601, et seq.

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DOE-RL, 2002, *Sampling and Analysis Plan for the 200-ZP-1 Groundwater Monitoring Well Network*, DOE/RL-2002-17, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE-RL, 2004, *Remedial Investigation/Feasibility Study Work Plan for the 200-ZP-1 Groundwater Operable Unit*, DOE/RL-2003-55, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

Ecology, 2005, *Cleanup Levels and Risk Calculations Under the Model Toxics Control Act Cleanup Regulation (CLARC III)*, Publication No. 94-145 (updated August 2005), Washington State Department of Ecology, Olympia, Washington.

EPA, Ecology, and DOE, 1997, *Record of Decision for the 200-UP-1 Interim Remedial Measure*, U.S. Environmental Protection Agency, Washington State Department of Ecology, and U.S. Department of Energy, Olympia, Washington.

FH, 2003, *Data Quality Objectives Summary Report for Establishing a RCRA/CERCLA/AEA Integrated 200 West and 200 East Area Groundwater Monitoring Network*, CP-15239, Rev. 0, Fluor Hanford, Inc., Richland, Washington.

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

WAC 173-340, "Model Toxics Control Act – Cleanup," *Washington Administrative Code*.

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APPENDIX D

MINIMUM AND MAXIMUM NONDETECTIONS AND DETECTIONS AND ASSOCIATED ANALYTICAL METHODS FOR WASTE MANAGEMENT AREA T

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Constituent Name	Analytical Units	Frequency of Detect	Total Number of Samples	Minimum Result	Maximum Result	Count of Detects	Minimum Detect	Maximum Detect	Count of Nondetects	Minimum Nondetect	Maximum Nondetect	Target Action Level	Target Action Level Analytical Units	Minimum Method	Maximum Method
1 1 1 2-tetrachloroethane	µg/L		8	10	10		10	10	8	10	10			8240_VOA_GCMS	8240_VOA_GCMS
1 1 1-trichloroethane	µg/L	0.006024	166	0.036	100	1	0.036	100	165	0.036	100	200	µg/L	8010_VOA_GC	8240_VOA_GCMS
1 1 2 2-tetrachloroethane	µg/L		40	0.3	100		0.3	100	40	0.3	100			8260_VOA_GCMS	8240_VOA_GCMS
1 1 2-trichloroethane	µg/L	0.006135	163	0.043	100	1	0.043	100	162	0.043	100			8010_VOA_GC	8240_VOA_GCMS
1 1-dichloroethane	µg/L	0.006289	159	0.047	100	1	0.047	100	158	0.047	100			8010_VOA_GC	8240_VOA_GCMS
1 1-dichloroethylene	µg/L	0.022727	44	0.04	100	1	0.04	100	43	0.04	100	7	µg/L	8260_VOA_GCMS	8240_VOA_GCMS
1 2 3 4-tetrachlorobenzene	µg/L		7	10	10		10	10	7	10	10			8270_SVOA_GCMS	8270_SVOA_GCMS
1 2 3 5-tetrachlorobenzene	µg/L		7	10	10		10	10	7	10	10			8270_SVOA_GCMS	8270_SVOA_GCMS
1 2 3-trichlorobenzene	µg/L		7	10	10		10	10	7	10	10			8270_SVOA_GCMS	8270_SVOA_GCMS
1 2 3-trichloropropane	µg/L		8	10	10		10	10	8	10	10			8240_VOA_GCMS	8240_VOA_GCMS
1 2 4 5-tetrachlorobenzene	µg/L		7	10	10		10	10	7	10	10			8270_SVOA_GCMS	8270_SVOA_GCMS
1 2 4-trichlorobenzene	µg/L		13	10	10		10	10	13	10	10			8270_SVOA_GCMS	8270_SVOA_GCMS
1 2 4-trichlorobenzene	µg/L		13	10	10		10	10	13	10	10			8270_SVOA_GCMS	CLP_SVOA_GCMS
1 2 4-trichlorobenzene	µg/L		13	10	10		10	10	13	10	10			CLP_SVOA_GCMS	8270_SVOA_GCMS
1 2 4-trichlorobenzene	µg/L		13	10	10		10	10	13	10	10			CLP_SVOA_GCMS	CLP_SVOA_GCMS
1 2-dibromo-3-chloropropane	µg/L		8	10	10		10	10	8	10	10			8240_VOA_GCMS	8240_VOA_GCMS
1 2-dibromoethane	µg/L		8	10	10		10	10	8	10	10			8240_VOA_GCMS	8240_VOA_GCMS
1 2-dichlorobenzene	µg/L		14	0.14	10		0.14	10	14	0.14	10			8260_VOA_GCMS	8270_SVOA_GCMS
1 2-dichlorobenzene	µg/L		14	0.14	10		0.14	10	14	0.14	10			8260_VOA_GCMS	CLP_SVOA_GCMS
1 2-dichloroethane	µg/L	0.006289	159	0.029	100	1	0.029	100	158	0.029	100	5	µg/L	8010_VOA_GC	8240_VOA_GCMS
1 2-dichloroethylene (total)	µg/L	0.028571	35	0.18	100	1	0.18	100	34	0.18	100	70	µg/L	8260_VOA_GCMS	8240_VOA_GCMS
1 2-dichloropropane	µg/L		40	0.17	100		0.17	100	40	0.17	100			8260_VOA_GCMS	8240_VOA_GCMS
1 2-diphenylhydrazine	µg/L		3	10	10		10	10	3	10	10			8270_SVOA_GCMS	8270_SVOA_GCMS
1 3 5-trichlorobenzene	µg/L		7	10	10		10	10	7	10	10			8270_SVOA_GCMS	8270_SVOA_GCMS
1 3-dichlorobenzene	µg/L		14	0.13	10		0.13	10	14	0.13	10			8260_VOA_GCMS	8270_SVOA_GCMS
1 3-dichlorobenzene	µg/L		14	0.13	10		0.13	10	14	0.13	10			8260_VOA_GCMS	CLP_SVOA_GCMS
1 3-dichloropropene	µg/L		8	10	10		10	10	8	10	10			8240_VOA_GCMS	8240_VOA_GCMS
1 4-dichlorobenzene	µg/L	0.02963	135	0.055	20	4	0.055	20	131	0.055	20			8010_VOA_GC	8010_VOA_GC
1 4-dichlorobenzene	µg/L	0.02963	135	0.055	20	4	0.055	20	131	0.055	20			8010_VOA_GC	8020_VOA_GC
1 4-dioxane	µg/L		20	2.6	500		2.6	500	20	2.6	500			8260_VOA_GCMS	8240_VOA_GCMS
1 4-naphthoquinone	µg/L		3	10	10		10	10	3	10	10			8270_SVOA_GCMS	8270_SVOA_GCMS
1-butanol	µg/L	0.012821	78	1	1,000	1	1	1,000	77	1	1,000	1,600	µg/L	8240_VOA_GCMS	8240_VOA_GCMS
1-chloro-2 3-epoxypropane	µg/L		3	10	10		10	10	3	10	10			8270_SVOA_GCMS	8270_SVOA_GCMS
1-naphthylamine	µg/L		3	10	10		10	10	3	10	10			8270_SVOA_GCMS	8270_SVOA_GCMS
2 3 4 6-tetrachlorophenol	µg/L		3	10	10		10	10	3	10	10			8270_SVOA_GCMS	8270_SVOA_GCMS
2 4 5-trichlorophenol	µg/L		9	25	50		25	50	9	25	50			CLP_SVOA_GCMS	8270_SVOA_GCMS
2 4 5-trichlorophenol	µg/L		9	25	50		25	50	9	25	50			CLP_SVOA_GCMS	CLP_SVOA_GCMS
2 4 5-trichlorophenoxyacetic acid	µg/L		34	0.018	2		0.018	2	34	0.018	2			8150_HERBICIDE_GC	8150_HERBICIDE_GC
2 4 6-trichlorophenol	µg/L		32	1.3	10		1.3	10	32	1.3	10	7.95	µg/L	8040_PHENOLIC_GC	8270_SVOA_GCMS
2 4 6-trichlorophenol	µg/L		32	1.3	10		1.3	10	32	1.3	10	7.95	µg/L	8040_PHENOLIC_GC	CLP_SVOA_GCMS
2 4-dichlorophenol	µg/L	0.028571	35	0.27	10	1	0.27	10	34	0.27	10			8270_SVOA_GCMS	8270_SVOA_GCMS

Constituent Name	Analytical Units	Frequency of Detect	Total Number of Samples	Minimum Result	Maximum Result	Count of Detects	Minimum Detect	Maximum Detect	Count of Nondetects	Minimum Nondetect	Maximum Nondetect	Target Action Level	Target Action Level Analytical Units	Minimum Method	Maximum Method
2 4-dichlorophenol	µg/L	0.028571	35	0.27	10	1	0.27	10	34	0.27	10			8270_SVOA_GCMS	CLP_SVOA_GCMS
2 4-dichlorophenoxyacetic acid	µg/L		34	0.052	10		0.052	10	34	0.052	10			8150_HERBICIDE_GC	8150_HERBICIDE_GC
2 4-dimethylphenol	µg/L		32	1.01	10		1.01	10	32	1.01	10			8040_PHENOLIC_GC	8270_SVOA_GCMS
2 4-dimethylphenol	µg/L		32	1.01	10		1.01	10	32	1.01	10			8040_PHENOLIC_GC	CLP_SVOA_GCMS
2 4-dinitrophenol	µg/L		32	0.96	150		0.96	150	32	0.96	150			8040_PHENOLIC_GC	8040_PHENOLIC_GC
2 4-dinitrotoluene	µg/L		9	10	10		10	10	9	10	10			8270_SVOA_GCMS	8270_SVOA_GCMS
2 4-dinitrotoluene	µg/L		9	10	10		10	10	9	10	10			8270_SVOA_GCMS	CLP_SVOA_GCMS
2 4-dinitrotoluene	µg/L		9	10	10		10	10	9	10	10			CLP_SVOA_GCMS	8270_SVOA_GCMS
2 4-dinitrotoluene	µg/L		9	10	10		10	10	9	10	10			CLP_SVOA_GCMS	CLP_SVOA_GCMS
2 6-dichlorophenol	µg/L		26	1.4	10		1.4	10	26	1.4	10		µg/L	8040_PHENOLIC_GC	8270_SVOA_GCMS
2 6-dinitrotoluene	µg/L		9	10	10		10	10	9	10	10			8270_SVOA_GCMS	8270_SVOA_GCMS
2 6-dinitrotoluene	µg/L		9	10	10		10	10	9	10	10			8270_SVOA_GCMS	CLP_SVOA_GCMS
2 6-dinitrotoluene	µg/L		9	10	10		10	10	9	10	10			CLP_SVOA_GCMS	8270_SVOA_GCMS
2 6-dinitrotoluene	µg/L		9	10	10		10	10	9	10	10			CLP_SVOA_GCMS	CLP_SVOA_GCMS
2-(2 4 5-trichlorophenoxy)propionic acid	µg/L	0.029412	34	0.015	2	1	0.015	2	33	0.015	2			8150_HERBICIDE_GC	8150_HERBICIDE_GC
2-acetylaminofluorene	µg/L		3	10	10		10	10	3	10	10			8270_SVOA_GCMS	8270_SVOA_GCMS
2-butanone	µg/L	0.03876	129	0.1	2,000	5	0.1	2,000	124	0.1	2,000	4,800	µg/L	8260_VOA_GCMS	8240_VOA_GCMS
2-chloroethyl vinyl ether	µg/L		10	10	10		10	10	10	10	10			8240_VOA_GCMS	8240_VOA_GCMS
2-chloronaphthalene	µg/L		9	10	10		10	10	9	10	10			8270_SVOA_GCMS	8270_SVOA_GCMS
2-chloronaphthalene	µg/L		9	10	10		10	10	9	10	10			8270_SVOA_GCMS	CLP_SVOA_GCMS
2-chloronaphthalene	µg/L		9	10	10		10	10	9	10	10			CLP_SVOA_GCMS	8270_SVOA_GCMS
2-chloronaphthalene	µg/L		9	10	10		10	10	9	10	10			CLP_SVOA_GCMS	CLP_SVOA_GCMS
2-chlorophenol	µg/L		32	1.42	10		1.42	10	32	1.42	10			8040_PHENOLIC_GC	8270_SVOA_GCMS
2-chlorophenol	µg/L		32	1.42	10		1.42	10	32	1.42	10			8040_PHENOLIC_GC	CLP_SVOA_GCMS
2-cyclohexyl-4 6-dinitrophenol	µg/L		3	10	10		10	10	3	10	10			8270_SVOA_GCMS	8270_SVOA_GCMS
2-hexanone	µg/L		32	0.11	1,000		0.11	1,000	32	0.11	1,000			8260_VOA_GCMS	8240_VOA_GCMS
2-methyl-2-(methylthio)propionaldehyde-o-(methylcarbonyl) ox	µg/L		3	10	10		10	10	3	10	10			8270_SVOA_GCMS	8270_SVOA_GCMS
2-methylaziridine	µg/L		3	10	10		10	10	3	10	10			8270_SVOA_GCMS	8270_SVOA_GCMS
2-methyllactonitrile	µg/L		3	10	10		10	10	3	10	10			8270_SVOA_GCMS	8270_SVOA_GCMS
2-methylnaphthalene	µg/L		6	10	10		10	10	6	10	10			CLP_SVOA_GCMS	CLP_SVOA_GCMS
2-methylphenol (cresol o-)	µg/L		11	0.24	10		0.24	10	11	0.24	10			8270_SVOA_GCMS	8270_SVOA_GCMS
2-methylphenol (cresol o-)	µg/L		11	0.24	10		0.24	10	11	0.24	10			8270_SVOA_GCMS	CLP_SVOA_GCMS
2-naphthylamine	µg/L		3	10	10		10	10	3	10	10			8270_SVOA_GCMS	8270_SVOA_GCMS
2-nitroaniline	µg/L		6	25	50		25	50	6	25	50			CLP_SVOA_GCMS	CLP_SVOA_GCMS
2-nitrophenol	µg/L		32	0.64	10		0.64	10	32	0.64	10			8270_SVOA_GCMS	CLP_SVOA_GCMS
2-picoline	µg/L		5	1.2	10		1.2	10	5	1.2	10			8270_SVOA_GCMS	8270_SVOA_GCMS
2-propanol	µg/L		1	500	500		500	500	1	500	500			502.2_VOA_GC	502.2_VOA_GC
2-secbutyl-4 6-dinitrophenol (dinoseb)	µg/L		56	0.24	10		0.24	10	56	0.24	10			8150_HERBICIDE_GC	8270_SVOA_GCMS
3 3'-dichlorobenzidine	µg/L		9	10	20		10	20	9	10	20			CLP_SVOA_GCMS	8270_SVOA_GCMS
3 3'-dichlorobenzidine	µg/L		9	10	20		10	20	9	10	20			CLP_SVOA_GCMS	CLP_SVOA_GCMS
3 3'-dimethoxybenzidine	µg/L		3	10	10		10	10	3	10	10			8270_SVOA_GCMS	8270_SVOA_GCMS

Constituent Name	Analytical Units	Frequency of Detect	Total Number of Samples	Minimum Result	Maximum Result	Count of Detects	Minimum Detect	Maximum Detect	Count of Nondetects	Minimum Nondetect	Maximum Nondetect	Target Action Level	Target Action Level Analytical Units	Minimum Method	Maximum Method
3 3'-dimethylbenzidine	µg/L		3	10	10		10	10	3	10	10			8270_SVOA_GCMS	8270_SVOA_GCMS
3+4 methylphenol (cresol m+p)	µg/L		2	0.31	1.7		0.31	1.7	2	0.31	1.7			8270_SVOA_GCMS	8270_SVOA_GCMS
3-methylcholanthrene	µg/L		3	10	10		10	10	3	10	10			8270_SVOA_GCMS	8270_SVOA_GCMS
3-methylphenol (cresol m-)	µg/L		2	10	10		10	10	2	10	10			8270_SVOA_GCMS	8270_SVOA_GCMS
3-nitroaniline	µg/L		6	25	50		25	50	6	25	50			CLP_SVOA_GCMS	CLP_SVOA_GCMS
4 4'-ddd (dichlorodiphenyldichloroethane)	µg/L		34	0.001	0.2		0.001	0.2	34	0.001	0.2			8080_PESTPCB_GC	CLP_PESTPCB_GCMS
4 4'-dde (dichlorodiphenyldichloroethylene)	µg/L		34	0.001	0.2		0.001	0.2	34	0.001	0.2			8080_PESTPCB_GC	CLP_PESTPCB_GCMS
4 4'-ddt (dichlorodiphenyltrichloroethane)	µg/L	0.029412	34	0.001	0.2	1	0.001	0.2	33	0.001	0.2			8080_PESTPCB_GC	CLP_PESTPCB_GCMS
4 4'-methylenebis(2-chloroaniline)	µg/L		3	10	10		10	10	3	10	10			8270_SVOA_GCMS	8270_SVOA_GCMS
4 6-dinitro-2-methylphenol	µg/L		32	1.18	200		1.18	200	32	1.18	200			8040_PHENOLIC_GC	8040_PHENOLIC_GC
4-aminobiphenyl	µg/L		3	10	10		10	10	3	10	10			8270_SVOA_GCMS	8270_SVOA_GCMS
4-bromophenylphenyl ether	µg/L		9	10	10		10	10	9	10	10			8270_SVOA_GCMS	8270_SVOA_GCMS
4-bromophenylphenyl ether	µg/L		9	10	10		10	10	9	10	10			8270_SVOA_GCMS	CLP_SVOA_GCMS
4-bromophenylphenyl ether	µg/L		9	10	10		10	10	9	10	10			CLP_SVOA_GCMS	8270_SVOA_GCMS
4-bromophenylphenyl ether	µg/L		9	10	10		10	10	9	10	10			CLP_SVOA_GCMS	CLP_SVOA_GCMS
4-chloro-3-methylphenol	µg/L		32	1.12	10		1.12	10	32	1.12	10			8040_PHENOLIC_GC	8270_SVOA_GCMS
4-chloro-3-methylphenol	µg/L		32	1.12	10		1.12	10	32	1.12	10			8040_PHENOLIC_GC	CLP_SVOA_GCMS
4-chloroaniline	µg/L		9	10	10		10	10	9	10	10			8270_SVOA_GCMS	8270_SVOA_GCMS
4-chloroaniline	µg/L		9	10	10		10	10	9	10	10			8270_SVOA_GCMS	CLP_SVOA_GCMS
4-chloroaniline	µg/L		9	10	10		10	10	9	10	10			CLP_SVOA_GCMS	8270_SVOA_GCMS
4-chloroaniline	µg/L		9	10	10		10	10	9	10	10			CLP_SVOA_GCMS	CLP_SVOA_GCMS
4-chlorophenylphenyl ether	µg/L		6	10	10		10	10	6	10	10			CLP_SVOA_GCMS	CLP_SVOA_GCMS
4-methyl-2-pentanone	µg/L	0.024194	124	0.1	1,000	3	0.1	1,000	121	0.1	1,000	640	µg/L	8260_VOA_GCMS	8240_VOA_GCMS
4-methylphenol (cresol p-)	µg/L		11	0.69	10		0.69	10	11	0.69	10			8270_SVOA_GCMS	8270_SVOA_GCMS
4-methylphenol (cresol p-)	µg/L		11	0.69	10		0.69	10	11	0.69	10			8270_SVOA_GCMS	CLP_SVOA_GCMS
4-nitroaniline	µg/L		9	25	50		25	50	9	25	50			CLP_SVOA_GCMS	8270_SVOA_GCMS
4-nitroaniline	µg/L		9	25	50		25	50	9	25	50			CLP_SVOA_GCMS	CLP_SVOA_GCMS
4-nitrophenol	µg/L		32	0.65	50		0.65	50	32	0.65	50			8040_PHENOLIC_GC	8270_SVOA_GCMS
4-nitrophenol	µg/L		32	0.65	50		0.65	50	32	0.65	50			8040_PHENOLIC_GC	CLP_SVOA_GCMS
5-(aminomethyl)-3-isoxazolol	µg/L		3	10	10		10	10	3	10	10			8270_SVOA_GCMS	8270_SVOA_GCMS
5-nitro-o-toluidine	µg/L		3	10	10		10	10	3	10	10			8270_SVOA_GCMS	8270_SVOA_GCMS
7 12-dimethylbenz[a]anthracene	µg/L		3	10	10		10	10	3	10	10			8270_SVOA_GCMS	8270_SVOA_GCMS
7h-dibenzo[c g]carbazole	µg/L		3	10	10		10	10	3	10	10			8270_SVOA_GCMS	8270_SVOA_GCMS
acenaphthene	µg/L		6	10	10		10	10	6	10	10			CLP_SVOA_GCMS	CLP_SVOA_GCMS
Acenaphthylene	µg/L		6	10	10		10	10	6	10	10			CLP_SVOA_GCMS	CLP_SVOA_GCMS
Acetone	µg/L	0.421053	114	0.21	2,000	48	0.21	2,000	66	0.21	2,000	7,200	µg/L	8260_VOA_GCMS	8240_VOA_GCMS
Acetonitrile	µg/L		6	3,000	3,000		3,000	3,000	6	3,000	3,000			8240_VOA_GCMS	8240_VOA_GCMS
Acetophenone	µg/L		3	10	10		10	10	3	10	10			8270_SVOA_GCMS	8270_SVOA_GCMS
Acrolein	µg/L		8	10	10		10	10	8	10	10			8240_VOA_GCMS	8240_VOA_GCMS
Acrylonitrile	µg/L		8	10	10		10	10	8	10	10			8240_VOA_GCMS	8240_VOA_GCMS
Aldrin	µg/L	0.029412	34	0.002	0.1	1	0.002	0.1	33	0.002	0.1	0.00515	µg/L	8080_PESTPCB_GC	CLP_PESTPCB_GCMS

Constituent Name	Analytical Units	Frequency of Detect	Total Number of Samples	Minimum Result	Maximum Result	Count of Detects	Minimum Detect	Maximum Detect	Count of Nondetects	Minimum Nondetect	Maximum Nondetect	Target Action Level	Target Action Level Analytical Units	Minimum Method	Maximum Method
Alkalinity	µg/L	1	474	48,200	201,000	474	48,200	201,000					µg/L	310.1_ALKALINITY	310.1_ALKALINITY
Alpha	pCi/L	0.986577	149	-0.1	220	147	-0.1	220	2	-0.1	0.757			UST_RAD_CNT_LSC	UST_RAD_CNT_LSC
Alpha alpha-dimethylphenethylamine	µg/L		3	10	10		10	10	3	10	10			8270_SVOA_GCMS	8270_SVOA_GCMS
Alpha-BHC	µg/L		38	0.001	0.1		0.001	0.1	38	0.001	0.1			8080_PESTPCB_GC	8080_PESTPCB_GC
Alpha-BHC	µg/L		38	0.001	0.1		0.001	0.1	38	0.001	0.1			8080_PESTPCB_GC	CLP_PESTPCB_GCMS
Alpha-chlordane	µg/L		4	0.05	1		0.05	1	4	0.05	1			CLP_PESTPCB_GCMS	CLP_PESTPCB_GCMS
Aluminum	µg/L	0.275142	527	7	3,600	145	7	3,600	382	7	150			6010_METALS_ICP	6010_METALS_ICP
Amitrole	µg/L		3	10	10		10	10	3	10	10			8270_SVOA_GCMS	8270_SVOA_GCMS
Ammonia	µg/L		2	26.3	26.3		26.3	26.3	2	26.3	26.3			350.1_AMMONIA	350.1_AMMONIA
Ammonium ion	µg/L	0.190476	42	38.5	300	8	38.5	300	34	38.5	100		µg/L	D1426D_AMMONIUM	D1426D_AMMONIUM
Aniline	µg/L		3	10	10		10	10	3	10	10			8270_SVOA_GCMS	8270_SVOA_GCMS
Anthracene	µg/L		6	10	10		10	10	6	10	10			CLP_SVOA_GCMS	CLP_SVOA_GCMS
Antimony	µg/L	0.049911	561	2.2	200	28	2.2	200	533	2.2	200	10	µg/L	6010_METALS_ICP	6010_METALS_ICP
Antimony-125	pCi/L	0.057508	313	-21.8	24.6	18	-21.8	24.6	295	-18.9	24.6			GAMMA_GS	GAMMA_GS
Aramite	µg/L		3	10	10		10	10	3	10	10			8270_SVOA_GCMS	8270_SVOA_GCMS
Aroclor-1016	µg/L		4	0.5	1		0.5	1	4	0.5	1	0.5	µg/L	CLP_PESTPCB_GCMS	CLP_PESTPCB_GCMS
Aroclor-1221	µg/L		4	0.5	2		0.5	2	4	0.5	2	0.5	µg/L	CLP_PESTPCB_GCMS	CLP_PESTPCB_GCMS
Aroclor-1232	µg/L		4	0.5	1		0.5	1	4	0.5	1	0.5	µg/L	CLP_PESTPCB_GCMS	CLP_PESTPCB_GCMS
Aroclor-1242	µg/L		4	0.5	1		0.5	1	4	0.5	1	0.5	µg/L	CLP_PESTPCB_GCMS	CLP_PESTPCB_GCMS
Aroclor-1248	µg/L		4	0.5	1		0.5	1	4	0.5	1	0.5	µg/L	CLP_PESTPCB_GCMS	CLP_PESTPCB_GCMS
Aroclor-1254	µg/L		4	1	2		1	2	4	1	2	0.16	µg/L	CLP_PESTPCB_GCMS	CLP_PESTPCB_GCMS
Aroclor-1260	µg/L		4	1	2		1	2	4	1	2	0.5	µg/L	CLP_PESTPCB_GCMS	CLP_PESTPCB_GCMS
Arsenic	µg/L	0.622951	122	0.64	101	76	0.64	101	46	0.64	5	10	µg/L	7060_AS_GFAA	7060_AS_GFAA
Arsenic filtered	µg/L	0.7	10	5	8	7	5	8	3	5	5			UNKNOWN_METALS	UNKNOWN_METALS
Auramine	µg/L		3	10	10		10	10	3	10	10			8270_SVOA_GCMS	8270_SVOA_GCMS
Barium	µg/L	1	572	18.2	732	572	18.2	732						6010_METALS_ICP	6010_METALS_ICP
Benz[c]acridine	µg/L		3	10	10		10	10	3	10	10			8270_SVOA_GCMS	8270_SVOA_GCMS
Benzene	µg/L	0.037736	159	0.013	100	6	0.013	100	153	0.013	100	5	µg/L	8010_VOA_GC	8240_VOA_GCMS
Benzenethiol	µg/L		3	10	10		10	10	3	10	10			8270_SVOA_GCMS	8270_SVOA_GCMS
Benzidine	µg/L		3	10	10		10	10	3	10	10			8270_SVOA_GCMS	8270_SVOA_GCMS
Benzo(a)anthracene	µg/L		9	10	10		10	10	9	10	10			8270_SVOA_GCMS	8270_SVOA_GCMS
Benzo(a)anthracene	µg/L		9	10	10		10	10	9	10	10			8270_SVOA_GCMS	CLP_SVOA_GCMS
Benzo(a)anthracene	µg/L		9	10	10		10	10	9	10	10			CLP_SVOA_GCMS	8270_SVOA_GCMS
Benzo(a)anthracene	µg/L		9	10	10		10	10	9	10	10			CLP_SVOA_GCMS	CLP_SVOA_GCMS
Benzo(a)pyrene	µg/L		10	2.2	10		2.2	10	10	2.2	10			8270_SVOA_GCMS	8270_SVOA_GCMS
Benzo(a)pyrene	µg/L		10	2.2	10		2.2	10	10	2.2	10			8270_SVOA_GCMS	CLP_SVOA_GCMS
Benzo(b)fluoranthene	µg/L		9	10	10		10	10	9	10	10			8270_SVOA_GCMS	8270_SVOA_GCMS
Benzo(b)fluoranthene	µg/L		9	10	10		10	10	9	10	10			8270_SVOA_GCMS	CLP_SVOA_GCMS
Benzo(b)fluoranthene	µg/L		9	10	10		10	10	9	10	10			CLP_SVOA_GCMS	8270_SVOA_GCMS
Benzo(b)fluoranthene	µg/L		9	10	10		10	10	9	10	10			CLP_SVOA_GCMS	CLP_SVOA_GCMS
Benzo(ghi)perylene	µg/L		6	10	10		10	10	6	10	10			CLP_SVOA_GCMS	CLP_SVOA_GCMS

Constituent Name	Analytical Units	Frequency of Detect	Total Number of Samples	Minimum Result	Maximum Result	Count of Detects	Minimum Detect	Maximum Detect	Count of Nondetects	Minimum Nondetect	Maximum Nondetect	Target Action Level	Target Action Level Analytical Units	Minimum Method	Maximum Method
Benzo(k)fluoranthene	µg/L		6	10	10		10	10	6	10	10			CLP_SVOA_GCMS	CLP_SVOA_GCMS
Benzo[j]fluoranthene	µg/L		3	10	10		10	10	3	10	10			8270_SVOA_GCMS	8270_SVOA_GCMS
Benzoic acid	µg/L		4	50	50		50	50	4	50	50			CLP_SVOA_GCMS	CLP_SVOA_GCMS
Benzothiazole	µg/L		3	0.4	10		0.4	10	3	0.4	10			8270_SVOA_GCMS	8270_SVOA_GCMS
Benzyl alcohol	µg/L		4	10	10		10	10	4	10	10			CLP_SVOA_GCMS	CLP_SVOA_GCMS
Benzyl chloride	µg/L		3	10	10		10	10	3	10	10			8270_SVOA_GCMS	8270_SVOA_GCMS
Beryllium	µg/L	0.197509	562	0.05	5	111	0.05	5	451	0.05	5			6010_METALS_ICP	6010_METALS_ICP
Beryllium-7	pCi/L	0.018182	275	-703	48.5	5	-703	48.5	270	-51.5	32.7			GAMMA_GS	GAMMA_GS
Beta-1 2 3 4 5 6-hexachlorocyclohexane (beta-BHC)	µg/L		38	0.001	0.1		0.001	0.1	38	0.001	0.1			8080_PESTPCB_GC	8080_PESTPCB_GC
Beta-1 2 3 4 5 6-hexachlorocyclohexane (beta-BHC)	µg/L		38	0.001	0.1		0.001	0.1	38	0.001	0.1			8080_PESTPCB_GC	CLP_PESTPCB_GCMS
Bis(2-chloro-1-methylethyl)ether	µg/L		9	10	10		10	10	9	10	10			8270_SVOA_GCMS	8270_SVOA_GCMS
Bis(2-chloro-1-methylethyl)ether	µg/L		9	10	10		10	10	9	10	10			8270_SVOA_GCMS	CLP_SVOA_GCMS
Bis(2-chloro-1-methylethyl)ether	µg/L		9	10	10		10	10	9	10	10			CLP_SVOA_GCMS	8270_SVOA_GCMS
Bis(2-chloro-1-methylethyl)ether	µg/L		9	10	10		10	10	9	10	10			CLP_SVOA_GCMS	CLP_SVOA_GCMS
Bis(2-Chloroethoxy)methane	µg/L		9	10	10		10	10	9	10	10			8270_SVOA_GCMS	8270_SVOA_GCMS
Bis(2-Chloroethoxy)methane	µg/L		9	10	10		10	10	9	10	10			8270_SVOA_GCMS	CLP_SVOA_GCMS
Bis(2-Chloroethoxy)methane	µg/L		9	10	10		10	10	9	10	10			CLP_SVOA_GCMS	8270_SVOA_GCMS
Bis(2-Chloroethoxy)methane	µg/L		9	10	10		10	10	9	10	10			CLP_SVOA_GCMS	CLP_SVOA_GCMS
Bis(2-chloroethyl) ether	µg/L		9	10	10		10	10	9	10	10			8270_SVOA_GCMS	8270_SVOA_GCMS
Bis(2-chloroethyl) ether	µg/L		9	10	10		10	10	9	10	10			8270_SVOA_GCMS	CLP_SVOA_GCMS
Bis(2-chloroethyl) ether	µg/L		9	10	10		10	10	9	10	10			CLP_SVOA_GCMS	8270_SVOA_GCMS
Bis(2-chloroethyl) ether	µg/L		9	10	10		10	10	9	10	10			CLP_SVOA_GCMS	CLP_SVOA_GCMS
Bis(2-ethylhexyl) phthalate	µg/L	0.416667	12	2	20	5	2	20	7	2.7	10	6	µg/L	CLP_SVOA_GCMS	CLP_SVOA_GCMS
Bis(chloromethyl) ether	µg/L		8	10	10		10	10	8	10	10			8240_VOA_GCMS	8240_VOA_GCMS
Bismuth	µg/L		2	5	5		5	5	2	5	5			UNKNOWN_METALS	UNKNOWN_METALS
Boron	µg/L	1	9	21	86	9	21	86						6010_METALS_ICP	6010_METALS_ICP
Bromide	µg/L	0.390625	128	11	10,000	50	11	10,000	78	11	10,000			D4327_ANIONS_IC	300.0_ANIONS_IC
Bromoacetone	µg/L		8	10	10		10	10	8	10	10			8240_VOA_GCMS	8240_VOA_GCMS
Bromodichloromethane	µg/L		33	0.1	100		0.1	100	33	0.1	100			8260_VOA_GCMS	8240_VOA_GCMS
Bromoform	µg/L		41	0.3	100		0.3	100	41	0.3	100			8260_VOA_GCMS	8240_VOA_GCMS
Bromomethane	µg/L		40	0.1	200		0.1	200	40	0.1	200			8260_VOA_GCMS	8240_VOA_GCMS
Butylbenzylphthalate	µg/L		9	10	10		10	10	9	10	10			8270_SVOA_GCMS	8270_SVOA_GCMS
Butylbenzylphthalate	µg/L		9	10	10		10	10	9	10	10			8270_SVOA_GCMS	CLP_SVOA_GCMS
Butylbenzylphthalate	µg/L		9	10	10		10	10	9	10	10			CLP_SVOA_GCMS	8270_SVOA_GCMS
Butylbenzylphthalate	µg/L		9	10	10		10	10	9	10	10			CLP_SVOA_GCMS	CLP_SVOA_GCMS
Cadmium	µg/L	0.02139	561	0.15	127	12	0.15	127	549	0.15	10	5	µg/L	6010_METALS_ICP	6010_METALS_ICP
Calcium	µg/L	1	572	10,400	377,000	572	10,400	377,000						6010_METALS_ICP	6010_METALS_ICP
Carbazole	µg/L		2	10	10		10	10	2	10	10			CLP_SVOA_GCMS	CLP_SVOA_GCMS
Carbon disulfide	µg/L	0.128205	117	0.06	100	15	0.06	100	102	0.06	100	800	µg/L	8260_VOA_GCMS	8240_VOA_GCMS
Carbon tetrachloride	µg/L	0.924419	172	0.075	2,800	159	0.075	2,800	13	0.075	5	3	µg/L	8010_VOA_GC	8240_VOA_GCMS

Constituent Name	Analytical Units	Frequency of Detect	Total Number of Samples	Minimum Result	Maximum Result	Count of Detects	Minimum Detect	Maximum Detect	Count of Nondetects	Minimum Nondetect	Maximum Nondetect	Target Action Level	Target Action Level Analytical Units	Minimum Method	Maximum Method
Carbon-14	pCi/L	0.5	2	2.79	8.66	1	2.79	8.66	1	2.79	2.79	2,000	pCi/L	C14_LSC	C14_LSC
Cerium/praseodymium-144	pCi/L	0.166667	24	-175	7.36	4	-175	7.36	20	-10.5	7.36			GAMMA_GS	GAMMA_GS
Cesium-134	pCi/L	0.023729	295	-12.4	5.37	7	-12.4	5.37	288	-11.9	5.37			GAMMA_GS	GAMMA_GS
Cesium-137	pCi/L	0.441538	650	-22.8	740	287	-22.8	740	363	-17.7	5.89	60	pCi/L	UST_RAD_CNT_LSC	UST_RAD_CNT_LSC
Chlordane	µg/L		30	0.006	0.1		0.006	0.1	30	0.006	0.1			8080_PESTPCB_GC	8080_PESTPCB_GC
Chloride	µg/L	1	547	1,900	99,500	547	1,900	99,500				250,000	µg/L	D4327_ANIONS_IC	300.0_ANIONS_IC
Chlornaphazine	µg/L		3	10	10		10	10	3	10	10			8270_SVOA_GCMS	8270_SVOA_GCMS
Chloroalkyl ethers	µg/L		3	10	10		10	10	3	10	10			8270_SVOA_GCMS	8270_SVOA_GCMS
Chlorobenzene	µg/L		41	0.16	100		0.16	100	41	0.16	100	100	µg/L	8260_VOA_GCMS	8240_VOA_GCMS
Chloroethane	µg/L		32	0.1	200		0.1	200	32	0.1	200			8260_VOA_GCMS	8240_VOA_GCMS
Chloroform	µg/L	0.844828	174	0.041	110	147	0.041	110	27	0.041	100	7.17	µg/L	8010_VOA_GC	8260_VOA_GCMS
Chloromethane	µg/L		40	0.09	200		0.09	200	40	0.09	200			8260_VOA_GCMS	8240_VOA_GCMS
Chloromethyl methyl ether	µg/L		8	10	10		10	10	8	10	10			8240_VOA_GCMS	8240_VOA_GCMS
Chromium	µg/L	0.950963	571	2.7	6,180	543	2.7	6,180	28	2.7	20	100	µg/L	6010_METALS_ICP	6010_METALS_ICP
Chrysene	µg/L		10	2.1	10		2.1	10	10	2.1	10			8270_SVOA_GCMS	8270_SVOA_GCMS
Chrysene	µg/L		10	2.1	10		2.1	10	10	2.1	10			8270_SVOA_GCMS	CLP_SVOA_GCMS
cis-1 2-Dichloroethylene	µg/L	0.025862	116	0.045	20	3	0.045	20	113	0.045	20	70	µg/L	8010_VOA_GC	8010_VOA_GC
cis-1 3-Dichloropropene	µg/L		32	0.13	100		0.13	100	32	0.13	100			8260_VOA_GCMS	8240_VOA_GCMS
Cobalt	µg/L	0.043796	548	0.87	20	24	0.87	20	524	0.87	20			6010_METALS_ICP	6010_METALS_ICP
Cobalt-58	pCi/L		5	-5.54	3.3		-5.54	3.3	5	-5.54	3.3			GAMMA_GS	GAMMA_GS
Cobalt-60	pCi/L	0.498447	644	-11.8	2,000	321	-11.8	2,000	323	-11.8	28.7			GAMMA_GS	UST_RAD_CNT_LSC
Coliform bacteria	Col/100mL	0.035714	28	1	2.2	1	1	2.2	28	1	2.2			9132_COLIFORM	9131_COLIFORM
Coliform bacteria	µg/L	1	1	6	6	1	6	6	28	1	2.2			9222B_COLIFORM	9222B_COLIFORM
Copper	µg/L	0.224199	562	0.86	130	126	0.86	130	436	0.86	20			6010_METALS_ICP	6010_METALS_ICP
Crotonaldehyde	µg/L		8	10	10		10	10	8	10	10			8240_VOA_GCMS	8240_VOA_GCMS
Cyanide	µg/L	0.02439	41	1.24	20	1	1.24	20	40	1.24	20	200	µg/L	9012_CYANIDE	9010_CYANIDE
Decane	µg/L		3	10	1,000		10	1,000	3	10	1,000			8270_SVOA_GCMS	8270_SVOA_GCMS
Delta-BHC	µg/L		38	0.001	0.1		0.001	0.1	38	0.001	0.1			8080_PESTPCB_GC	8080_PESTPCB_GC
Delta-BHC	µg/L		38	0.001	0.1		0.001	0.1	38	0.001	0.1			8080_PESTPCB_GC	CLP_PESTPCB_GCMS
Dibenz[a h]acridine	µg/L		3	10	10		10	10	3	10	10			8270_SVOA_GCMS	8270_SVOA_GCMS
Dibenz[a h]anthracene	µg/L		9	10	10		10	10	9	10	10			8270_SVOA_GCMS	8270_SVOA_GCMS
Dibenz[a h]anthracene	µg/L		9	10	10		10	10	9	10	10			8270_SVOA_GCMS	CLP_SVOA_GCMS
Dibenz[a h]anthracene	µg/L		9	10	10		10	10	9	10	10			CLP_SVOA_GCMS	8270_SVOA_GCMS
Dibenz[a h]anthracene	µg/L		9	10	10		10	10	9	10	10			CLP_SVOA_GCMS	CLP_SVOA_GCMS
Dibenz[a j]acridine	µg/L		3	10	10		10	10	3	10	10			8270_SVOA_GCMS	8270_SVOA_GCMS
Dibenzo[a e]pyrene	µg/L		3	10	10		10	10	3	10	10			8270_SVOA_GCMS	8270_SVOA_GCMS
Dibenzo[a h]pyrene	µg/L		3	10	10		10	10	3	10	10			8270_SVOA_GCMS	8270_SVOA_GCMS
Dibenzo[a i]pyrene	µg/L		3	10	10		10	10	3	10	10			8270_SVOA_GCMS	8270_SVOA_GCMS
Dibenzofuran	µg/L		6	10	10		10	10	6	10	10			CLP_SVOA_GCMS	CLP_SVOA_GCMS
Dibromochloromethane	µg/L		33	0.16	100		0.16	100	33	0.16	100			8260_VOA_GCMS	8240_VOA_GCMS
Dibromomethane	µg/L		8	10	10		10	10	8	10	10			8240_VOA_GCMS	8240_VOA_GCMS

Constituent Name	Analytical Units	Frequency of Detect	Total Number of Samples	Minimum Result	Maximum Result	Count of Detects	Minimum Detect	Maximum Detect	Count of Nondetects	Minimum Nondetect	Maximum Nondetect	Target Action Level	Target Action Level Analytical Units	Minimum Method	Maximum Method
Dichlorodifluoromethane	µg/L		8	10	10		10	10	8	10	10			8240_VOA_GCMS	8240_VOA_GCMS
Dichloromethyl-benzene	µg/L		3	10	10		10	10	3	10	10			8270_SVOA_GCMS	8270_SVOA_GCMS
Dieldrin	µg/L		34	0.001	0.2		0.001	0.2	34	0.001	0.2	0.00547	µg/L	8080_PESTPCB_GC	CLP_PESTPCB_GCMS
Diethyl arsine	µg/L		8	10	10		10	10	8	10	10			8240_VOA_GCMS	8240_VOA_GCMS
Diethylphthalate	µg/L	0.111111	9	2	10	1	2	10	8	10	10			CLP_SVOA_GCMS	8270_SVOA_GCMS
Diethylphthalate	µg/L	0.111111	9	2	10	1	2	10	8	10	10			CLP_SVOA_GCMS	CLP_SVOA_GCMS
Dihydrosafrole	µg/L		3	10	10		10	10	3	10	10			8270_SVOA_GCMS	8270_SVOA_GCMS
Dimethyl phthalate	µg/L		9	10	10		10	10	9	10	10			8270_SVOA_GCMS	8270_SVOA_GCMS
Dimethyl phthalate	µg/L		9	10	10		10	10	9	10	10			8270_SVOA_GCMS	CLP_SVOA_GCMS
Dimethyl phthalate	µg/L		9	10	10		10	10	9	10	10			CLP_SVOA_GCMS	8270_SVOA_GCMS
Dimethyl phthalate	µg/L		9	10	10		10	10	9	10	10			CLP_SVOA_GCMS	CLP_SVOA_GCMS
Di-n-butylphthalate	µg/L	0.444444	9	1	10	4	1	10	5	10	10			CLP_SVOA_GCMS	8270_SVOA_GCMS
Di-n-butylphthalate	µg/L	0.444444	9	1	10	4	1	10	5	10	10			CLP_SVOA_GCMS	CLP_SVOA_GCMS
Di-n-octylphthalate	µg/L		9	10	10		10	10	9	10	10			8270_SVOA_GCMS	8270_SVOA_GCMS
Di-n-octylphthalate	µg/L		9	10	10		10	10	9	10	10			8270_SVOA_GCMS	CLP_SVOA_GCMS
Di-n-octylphthalate	µg/L		9	10	10		10	10	9	10	10			CLP_SVOA_GCMS	8270_SVOA_GCMS
Di-n-octylphthalate	µg/L		9	10	10		10	10	9	10	10			CLP_SVOA_GCMS	CLP_SVOA_GCMS
Diphenylamine	µg/L		3	10	10		10	10	3	10	10			8270_SVOA_GCMS	8270_SVOA_GCMS
Dodecane	µg/L		3	10	1.000		10	1.000	3	10	1.000			8270_SVOA_GCMS	8270_SVOA_GCMS
Endosulfan I	µg/L		34	0.001	0.1		0.001	0.1	34	0.001	0.1			8080_PESTPCB_GC	8080_PESTPCB_GC
Endosulfan I	µg/L		34	0.001	0.1		0.001	0.1	34	0.001	0.1			8080_PESTPCB_GC	CLP_PESTPCB_GCMS
Endosulfan II	µg/L		34	0.001	0.2		0.001	0.2	34	0.001	0.2			8080_PESTPCB_GC	CLP_PESTPCB_GCMS
Endosulfan sulfate	µg/L		34	0.002	0.5		0.002	0.5	34	0.002	0.5			8080_PESTPCB_GC	8080_PESTPCB_GC
Endrin	µg/L		38	0.001	0.2		0.001	0.2	38	0.001	0.2	2	µg/L	8080_PESTPCB_GC	CLP_PESTPCB_GCMS
Endrin aldehyde	µg/L		31	0.002	0.2		0.002	0.2	31	0.002	0.2		µg/L	8080_PESTPCB_GC	8080_PESTPCB_GC
Endrin ketone	µg/L		4	0.1	0.2		0.1	0.2	4	0.1	0.2			CLP_PESTPCB_GCMS	CLP_PESTPCB_GCMS
Ethyl cyanide	µg/L	0.012821	78	0.68	130	1	0.68	130	77	0.68	130			8260_VOA_GCMS	8260_VOA_GCMS
Ethyl methacrylate	µg/L		8	10	10		10	10	8	10	10			8240_VOA_GCMS	8240_VOA_GCMS
Ethyl methanesulfonate	µg/L		3	10	10		10	10	3	10	10			8270_SVOA_GCMS	8270_SVOA_GCMS
Ethylbenzene	µg/L	0.03125	96	0.034	100	3	0.034	100	93	0.034	100	700	µg/L	8010_VOA_GC	8240_VOA_GCMS
Ethylene oxide	µg/L		6	3.000	3.000		3.000	3.000	6	3.000	3.000			8240_VOA_GCMS	8240_VOA_GCMS
Ethyleneimine	µg/L		3	10	10		10	10	3	10	10			8270_SVOA_GCMS	8270_SVOA_GCMS
Europium-152	pCi/L		182	-13	13.3		-13	13.3	182	-13	13.3	200	pCi/L	GAMMA_GS	GAMMA_GS
Europium-154	pCi/L	0.016949	295	-21	74	5	-21	74	290	-19.4	74	60	pCi/L	GAMMA_GS	GAMMA_GS
Europium-155	pCi/L	0.013559	295	-11.8	42.2	4	-11.8	42.2	291	-9.98	42.2	533	pCi/L	GAMMA_GS	GAMMA_GS
Fluoranthene	µg/L		9	10	10		10	10	9	10	10			8270_SVOA_GCMS	8270_SVOA_GCMS
Fluoranthene	µg/L		9	10	10		10	10	9	10	10			8270_SVOA_GCMS	CLP_SVOA_GCMS
Fluoranthene	µg/L		9	10	10		10	10	9	10	10			CLP_SVOA_GCMS	8270_SVOA_GCMS
Fluoranthene	µg/L		9	10	10		10	10	9	10	10			CLP_SVOA_GCMS	CLP_SVOA_GCMS
Fluorene	µg/L		6	10	10		10	10	6	10	10			CLP_SVOA_GCMS	CLP_SVOA_GCMS
Fluoride	µg/L	0.994565	552	100	10.500	549	100	10.500	3	500	500	960	µg/L	D4327_ANIONS_IC	300.0_ANIONS_IC

Constituent Name	Analytical Units	Frequency of Detect	Total Number of Samples	Minimum Result	Maximum Result	Count of Detects	Minimum Detect	Maximum Detect	Count of Nondetects	Minimum Nondetect	Maximum Nondetect	Target Action Level	Target Action Level Analytical Units	Minimum Method	Maximum Method
Formaldehyde	µg/L		8	500	500		500	500	8	500	500			8240_VOA_GCMS	8240_VOA_GCMS
Gamma-BHC (Lindane)	µg/L		38	0.001	0.1		0.001	0.1	38	0.001	0.1	0.0673	µg/L	8080_PESTPCB_GC	8080_PESTPCB_GC
Gamma-BHC (Lindane)	µg/L		38	0.001	0.1		0.001	0.1	38	0.001	0.1	0.0673	µg/L	8080_PESTPCB_GC	CLP_PESTPCB_GCMS
Gamma-chlordane	µg/L		4	0.05	1		0.05	1	4	0.05	1			CLP_PESTPCB_GCMS	CLP_PESTPCB_GCMS
Gross alpha	pCi/L	0.466411	521	-8.56	273	243	-8.56	273	278	-8.56	9.02	15	pCi/L	9310_ALPHABETA_GPC	UST_RAD_CNT_LSC
Gross beta	pCi/L	0.998031	1,016	0.533	160,000	1,014	0.533	160,000	2	0.533	1.25	50	pCi/L	9310_ALPHABETA_GPC	UST_RAD_CNT_LSC
Heptachlor	µg/L		34	0.002	0.1		0.002	0.1	34	0.002	0.1	0.0194	µg/L	8080_PESTPCB_GC	CLP_PESTPCB_GCMS
Heptachlor epoxide	µg/L		34	0.001	1		0.001	1	34	0.001	1			8080_PESTPCB_GC	8080_PESTPCB_GC
Hexachlorobenzene	µg/L		13	10	10		10	10	13	10	10			8270_SVOA_GCMS	8270_SVOA_GCMS
Hexachlorobenzene	µg/L		13	10	10		10	10	13	10	10			8270_SVOA_GCMS	CLP_SVOA_GCMS
Hexachlorobenzene	µg/L		13	10	10		10	10	13	10	10			CLP_SVOA_GCMS	8270_SVOA_GCMS
Hexachlorobenzene	µg/L		13	10	10		10	10	13	10	10			CLP_SVOA_GCMS	CLP_SVOA_GCMS
Hexachlorobutadiene	µg/L		9	10	10		10	10	9	10	10			8270_SVOA_GCMS	8270_SVOA_GCMS
Hexachlorobutadiene	µg/L		9	10	10		10	10	9	10	10			8270_SVOA_GCMS	CLP_SVOA_GCMS
Hexachlorobutadiene	µg/L		9	10	10		10	10	9	10	10			CLP_SVOA_GCMS	8270_SVOA_GCMS
Hexachlorobutadiene	µg/L		9	10	10		10	10	9	10	10			CLP_SVOA_GCMS	CLP_SVOA_GCMS
Hexachlorocyclopentadiene	µg/L		9	10	10		10	10	9	10	10			8270_SVOA_GCMS	8270_SVOA_GCMS
Hexachlorocyclopentadiene	µg/L		9	10	10		10	10	9	10	10			8270_SVOA_GCMS	CLP_SVOA_GCMS
Hexachlorocyclopentadiene	µg/L		9	10	10		10	10	9	10	10			CLP_SVOA_GCMS	8270_SVOA_GCMS
Hexachlorocyclopentadiene	µg/L		9	10	10		10	10	9	10	10			CLP_SVOA_GCMS	CLP_SVOA_GCMS
Hexachloroethane	µg/L		9	10	10		10	10	9	10	10			8270_SVOA_GCMS	8270_SVOA_GCMS
Hexachloroethane	µg/L		9	10	10		10	10	9	10	10			8270_SVOA_GCMS	CLP_SVOA_GCMS
Hexachloroethane	µg/L		9	10	10		10	10	9	10	10			CLP_SVOA_GCMS	8270_SVOA_GCMS
Hexachloroethane	µg/L		9	10	10		10	10	9	10	10			CLP_SVOA_GCMS	CLP_SVOA_GCMS
Hexachlorophene	µg/L		7	10	10		10	10	7	10	10			8270_SVOA_GCMS	8270_SVOA_GCMS
Hexachloropropene	µg/L		3	10	10		10	10	3	10	10			8270_SVOA_GCMS	8270_SVOA_GCMS
Hexavalent chromium	µg/L	1	6	37	323	6	37	323				48	µg/L	7196_CR6	7196_CR6
Hydrazine	µg/L		26	1.89	30		1.89	30	26	1.89	30			D1385_HYDRAZINE	D1385_HYDRAZINE
Hydrogen sulfide	µg/L		8	10	10		10	10	8	10	10			8240_VOA_GCMS	8240_VOA_GCMS
Indeno(1 2 3-cd)pyrene	µg/L		9	10	10		10	10	9	10	10			8270_SVOA_GCMS	8270_SVOA_GCMS
Indeno(1 2 3-cd)pyrene	µg/L		9	10	10		10	10	9	10	10			8270_SVOA_GCMS	CLP_SVOA_GCMS
Indeno(1 2 3-cd)pyrene	µg/L		9	10	10		10	10	9	10	10			CLP_SVOA_GCMS	8270_SVOA_GCMS
Indeno(1 2 3-cd)pyrene	µg/L		9	10	10		10	10	9	10	10			CLP_SVOA_GCMS	CLP_SVOA_GCMS
Iodine-129	pCi/L	0.153285	274	-1.7	49.4	42	-1.7	49.4	232	-1.7	13.7	1	pCi/L	I129_SEP_LEPS_GS	I129_SEP_LEPS_GS
Iodomethane	µg/L		8	10	10		10	10	8	10	10			8240_VOA_GCMS	8240_VOA_GCMS
Iron	µg/L	0.706503	569	5.24	328,000	402	5.24	328,000	167	5.24	56.6	300	µg/L	6010_METALS_ICP	6010_METALS_ICP
Iron-59	pCi/L		4	-2.11	2.46		-2.11	2.46	4	-2.11	2.46			GAMMA_GS	GAMMA_GS
Isophorone	µg/L		6	10	10		10	10	6	10	10			CLP_SVOA_GCMS	CLP_SVOA_GCMS
Isosafrole	µg/L		3	10	10		10	10	3	10	10			8270_SVOA_GCMS	8270_SVOA_GCMS
Lead	µg/L	0.470588	119	0.508	340	56	0.508	340	63	0.508	20	15	µg/L	7421_PB_GFAA	UNKNOWN_METALS

Constituent Name	Analytical Units	Frequency of Detect	Total Number of Samples	Minimum Result	Maximum Result	Count of Detects	Minimum Detect	Maximum Detect	Count of Nondetects	Minimum Nondetect	Maximum Nondetect	Target Action Level	Target Action Level Analytical Units	Minimum Method	Maximum Method
Lithium	µg/L	0.111111	9	7.5	12.7	1	7.5	12.7	8	7.5	10	320	µg/L	6010_METALS_ICP	6010_METALS_ICP
M+P-xylene	µg/L		1	0.23	0.23		0.23	0.23	1	0.23	0.23			8260_VOA_GCMS	8260_VOA_GCMS
Magnesium	µg/L	1	572	3,200	148,000	572	3,200	148,000					µg/L	6010_METALS_ICP	6010_METALS_ICP
Maleic hydrazide	µg/L		3	500	500		500	500	3	500	500			8270_SVOA_GCMS	8270_SVOA_GCMS
Malononitrile	µg/L		3	10	10		10	10	3	10	10			8270_SVOA_GCMS	8270_SVOA_GCMS
Manganese	µg/L	0.815603	564	0.072	2,320	460	0.072	2,320	104	0.072	10	50	µg/L	6010_METALS_ICP	6010_METALS_ICP
m-Dinitrobenzene	µg/L		3	10	10		10	10	3	10	10			8270_SVOA_GCMS	8270_SVOA_GCMS
Melphalan	µg/L		3	10	10		10	10	3	10	10			8270_SVOA_GCMS	8270_SVOA_GCMS
Mercury	µg/L	0.034188	117	0.05	0.54	4	0.05	0.54	113	0.05	0.2	2	µg/L	7470_HG_CVAA	UNKNOWN_METALS
Methacrylonitrile	µg/L		8	10	10		10	10	8	10	10			8240_VOA_GCMS	8240_VOA_GCMS
Methanethiol	µg/L		8	10	10		10	10	8	10	10			8240_VOA_GCMS	8240_VOA_GCMS
Methapyrilene	µg/L		3	10	10		10	10	3	10	10			8270_SVOA_GCMS	8270_SVOA_GCMS
Metholonyl	µg/L		3	10	10		10	10	3	10	10			8270_SVOA_GCMS	8270_SVOA_GCMS
Methoxychlor	µg/L		38	0.016	3		0.016	3	38	0.016	3			8080_PESTPCB_GC	8080_PESTPCB_GC
Methyl methacrylate	µg/L		8	10	10		10	10	8	10	10			8270_SVOA_GCMS	8270_SVOA_GCMS
Methyl methanesulfonate	µg/L		3	10	10		10	10	3	10	10			8270_SVOA_GCMS	8270_SVOA_GCMS
Methylene chloride	µg/L	0.331325	166	0.056	75	55	0.056	75	111	0.056	75	5	µg/L	8010_VOA_GC	8240_VOA_GCMS
Methylthiouracil	µg/L		3	10	10		10	10	3	10	10			8270_SVOA_GCMS	8270_SVOA_GCMS
Molybdenum	µg/L		7	40	40		40	40	7	40	40			6010_METALS_ICP	6010_METALS_ICP
N N-diethylhydrazine	µg/L		8	10	10		10	10	8	10	10			8240_VOA_GCMS	8240_VOA_GCMS
Naphthalene	µg/L		18	0.3	10		0.3	10	18	0.3	10			8270_SVOA_GCMS	8270_SVOA_GCMS
Naphthalene	µg/L		18	0.3	10		0.3	10	18	0.3	10			8270_SVOA_GCMS	CLP_SVOA_GCMS
n-Butyl benzene	µg/L		2	0.12	0.28		0.12	0.28	2	0.12	0.28	320	µg/L	8260_VOA_GCMS	8260_VOA_GCMS
Neptunium-237	pCi/L		2	0	0		0	0	2	0	0	15	pCi/L	NP237_LLE_PLATE_AEA	NP237_LLE_PLATE_AEA
Nickel	µg/L	0.236234	563	0.97	500	133	0.97	500	430	0.97	70	320	µg/L	6010_METALS_ICP	6010_METALS_ICP
Nicotinic acid	µg/L		3	100	100		100	100	3	100	100			8270_SVOA_GCMS	8270_SVOA_GCMS
Nitrate	µg/L	0.997118	694	280	7,610,000	692	280	7,610,000	2	2,500	2,500	44,285	µg/L	UNKNOWN_GENCHEM	300.0_ANIONS_IC
Nitrite	µg/L	0.104247	518	3.28	36,100	54	3.28	36,100	464	3.28	1,000	3,268	µg/L	300.0_ANIONS_IC	300.0_ANIONS_IC
Nitrobenzene	µg/L		9	10	10		10	10	9	10	10			8270_SVOA_GCMS	8270_SVOA_GCMS
Nitrobenzene	µg/L		9	10	10		10	10	9	10	10			8270_SVOA_GCMS	CLP_SVOA_GCMS
Nitrobenzene	µg/L		9	10	10		10	10	9	10	10			CLP_SVOA_GCMS	8270_SVOA_GCMS
Nitrobenzene	µg/L		9	10	10		10	10	9	10	10			CLP_SVOA_GCMS	CLP_SVOA_GCMS
Nitrosopyrrolidine	µg/L		3	10	10		10	10	3	10	10			8270_SVOA_GCMS	8270_SVOA_GCMS
N-nitrosodiethanolamine	µg/L		3	10	10		10	10	3	10	10			8270_SVOA_GCMS	8270_SVOA_GCMS
N-nitrosodiethylamine	µg/L		3	10	10		10	10	3	10	10			8270_SVOA_GCMS	8270_SVOA_GCMS
N-nitrosodimethylamine	µg/L		3	10	10		10	10	3	10	10	0.00172	µg/L	8270_SVOA_GCMS	8270_SVOA_GCMS
N-nitrosodi-n-butylamine	µg/L		3	10	10		10	10	3	10	10			8270_SVOA_GCMS	8270_SVOA_GCMS
N-nitrosodi-n-dipropylamine	µg/L		9	10	10		10	10	9	10	10			8270_SVOA_GCMS	8270_SVOA_GCMS
N-nitrosodi-n-dipropylamine	µg/L		9	10	10		10	10	9	10	10			8270_SVOA_GCMS	CLP_SVOA_GCMS
N-nitrosodi-n-dipropylamine	µg/L		9	10	10		10	10	9	10	10			CLP_SVOA_GCMS	8270_SVOA_GCMS

Constituent Name	Analytical Units	Frequency of Detect	Total Number of Samples	Minimum Result	Maximum Result	Count of Detects	Minimum Detect	Maximum Detect	Count of Nondetects	Minimum Nondetect	Maximum Nondetect	Target Action Level	Target Action Level Analytical Units	Minimum Method	Maximum Method
N-nitrosodi-n-dipropylamine	µg/L		9	10	10		10	10	9	10	10			CLP_SVOA_GCMS	CLP_SVOA_GCMS
N-nitrosodiphenylamine	µg/L		6	10	10		10	10	6	10	10			CLP_SVOA_GCMS	CLP_SVOA_GCMS
N-nitrosomethylethylamine	µg/L		3	10	10		10	10	3	10	10			8270_SVOA_GCMS	8270_SVOA_GCMS
N-nitrosomethylvinylamine	µg/L		3	10	10		10	10	3	10	10			8270_SVOA_GCMS	8270_SVOA_GCMS
N-nitrosomorpholine	µg/L		3	10	10		10	10	3	10	10			8270_SVOA_GCMS	8270_SVOA_GCMS
N-nitroso-N-methylurethane	µg/L		3	10	10		10	10	3	10	10			8270_SVOA_GCMS	8270_SVOA_GCMS
N-nitrosonornicotine	µg/L		3	10	10		10	10	3	10	10			8270_SVOA_GCMS	8270_SVOA_GCMS
N-nitrosopiperidine	µg/L		3	10	10		10	10	3	10	10			8270_SVOA_GCMS	8270_SVOA_GCMS
O O O-triethyl phosphorothioate	µg/L		3	10	10		10	10	3	10	10			8270_SVOA_GCMS	8270_SVOA_GCMS
o p-xylene	µg/L		16	5	10		5	10	16	5	10			8240_VOA_GCMS	8240_VOA_GCMS
Organic	µg/L	1	2	100	100	2	100	100						UNKNOWN_ORG	UNKNOWN_ORG
Osmium	µg/L		4	300	300		300	300	4	300	300			6010_METALS_ICP	6010_METALS_ICP
o-toluidine hydrochloride	µg/L		3	10	10		10	10	3	10	10			8270_SVOA_GCMS	8270_SVOA_GCMS
o-xylene	µg/L		1	0.12	0.12		0.12	0.12	1	0.12	0.12			8260_VOA_GCMS	8260_VOA_GCMS
p-benzoquinone	µg/L		3	10	10		10	10	3	10	10			8270_SVOA_GCMS	8270_SVOA_GCMS
p-dimethylaminoazobenzene	µg/L		3	10	10		10	10	3	10	10			8270_SVOA_GCMS	8270_SVOA_GCMS
Pentachlorobenzene	µg/L		7	10	10		10	10	7	10	10			8270_SVOA_GCMS	8270_SVOA_GCMS
Pentachloroethane	µg/L		8	10	10		10	10	8	10	10			8240_VOA_GCMS	8240_VOA_GCMS
Pentachloronitrobenzene (PCNB)	µg/L		3	10	10		10	10	3	10	10			8270_SVOA_GCMS	8270_SVOA_GCMS
Pentachlorophenol	µg/L		37	0.58	100		0.58	100	37	0.58	100	1	µg/L	8270_SVOA_GCMS	8040_PHENOLIC_GC
Perchlorate	µg/L	0.142857	21	300	500	3	300	500	18	500	500			PERCHLORATE_IC_HIST	PERCHLORATE_IC_HIST
Perchlorate anion	µg/L		2	5.000	5.000		5.000	5.000	2	5.000	5.000			300.0_ANIONS_IC	300.0_ANIONS_IC
pH	pH Units	1	749	5.7	10.25	749	5.7	10.25				6.5	pH Units	UNKNOWN_PHYSICAL	9040_PH
pH	pH Units	1	749	5.7	10.25	749	5.7	10.25				8.5	pH Units	UNKNOWN_PHYSICAL	9040_PH
Phenacetin	µg/L		3	10	10		10	10	3	10	10			8270_SVOA_GCMS	8270_SVOA_GCMS
Phenanthrene	µg/L		6	10	10		10	10	6	10	10			CLP_SVOA_GCMS	CLP_SVOA_GCMS
Phenylenediamine	µg/L		3	10	10		10	10	3	10	10			8270_SVOA_GCMS	8270_SVOA_GCMS
Phosphate	µg/L	0.013889	144	22	1.000	2	22	1.000	142	22	1.000		µg/L	300.0_ANIONS_IC	300.0_ANIONS_IC
Phosphorus	µg/L	1	3	38.5	40.9	3	38.5	40.9						365.2_PHOSPHATE	365.1_PHOSPHATE
Phosphorus	µg/L	1	3	38.5	40.9	3	38.5	40.9						365.2_PHOSPHATE	365.4_PHOSPHATE
Phthalic acid esters	µg/L		3	10	10		10	10	3	10	10			8270_SVOA_GCMS	8270_SVOA_GCMS
Plutonium	pCi/L	1	7	110	220	7	110	220						UST_RAD_CNT_LSC	UST_RAD_CNT_LSC
Plutonium-238	pCi/L	0.264151	53	-0.014	0.0264	14	-0.014	0.0264	39	-0.014	0.021	1.2	pCi/L	PUISO_IE_AEA	PUISO_IE_AEA
Plutonium-239/240	pCi/L	0.283019	53	-0.007	0.0953	15	-0.007	0.0953	38	-0.007	0.028	1.2	pCi/L	PUISO_IE_AEA	PUISO_IE_AEA
Potassium	µg/L	0.993007	572	1.420	15.200	568	1.420	15.200	4	1.420	2.640			6010_METALS_ICP	6010_METALS_ICP
Potassium-40	pCi/L	0.093863	277	-310	442	26	-310	442	251	-310	262	800	pCi/L	GAMMA_GS	GAMMA_GS
Pronamide	µg/L		3	10	10		10	10	3	10	10			8270_SVOA_GCMS	8270_SVOA_GCMS
Protactinium-231	pCi/L		2	-24.1	-14.5		-24.1	-14.5	2	-24.1	-14.5	15	pCi/L	GAMMA_GS	GAMMA_GS
Pyrene	µg/L		6	10	10		10	10	6	10	10			CLP_SVOA_GCMS	CLP_SVOA_GCMS
Pyridine	µg/L		8	500	500		500	500	8	500	500			8240_VOA_GCMS	8240_VOA_GCMS

Constituent Name	Analytical Units	Frequency of Detect	Total Number of Samples	Minimum Result	Maximum Result	Count of Detects	Minimum Detect	Maximum Detect	Count of Nondetects	Minimum Nondetect	Maximum Nondetect	Target Action Level	Target Action Level Analytical Units	Minimum Method	Maximum Method
Radium	pCi/L	0.789474	38	-0.061	6.42	30	-0.061	6.42	8	-0.061	0.118			9315_RADIUMISO_AEA	UST_RAD_CNT_LSC
Reserpine	µg/L		3	10	10		10	10	3	10	10			8270_SVOA_GCMS	8270_SVOA_GCMS
Resorcinol	µg/L		3	10	10		10	10	3	10	10			8270_SVOA_GCMS	8270_SVOA_GCMS
Ruthenium-106	pCi/L	0.319231	520	-76.8	1,100	166	-76.8	1,100	354	-73.2	145			UST_RAD_CNT_LSC	UST_RAD_CNT_LSC
Safrol	µg/L		3	10	10		10	10	3	10	10			8270_SVOA_GCMS	8270_SVOA_GCMS
Selenium	µg/L	0.408696	115	0.65	20	47	0.65	20	68	0.65	20	50	µg/L	7740_SE_GFAA	CLP_METALS_GFAA
Selenium-79	pCi/L		2	6.45	6.74		6.45	6.74	2	6.45	6.74	30	pCi/L	SE79_SEP_IE_LSC	SE79_SEP_IE_LSC
Silicon	µg/L	1	7	19,100	83,100	7	19,100	83,100						6010_METALS_ICP	6010_METALS_ICP
Silver	µg/L	0.053476	561	0.9	20	30	0.9	20	531	0.9	20	80	µg/L	6010_METALS_ICP	6010_METALS_ICP
Sodium	µg/L	0.998288	584	1,470	565,000	583	1,470	565,000	1	26,500	26,500			6010_METALS_ICP	6010_METALS_ICP
Specific conductance	uS/cm	1	798	148	5,240	798	148	5,240						9050_CONDUCT	9050_CONDUCT
Strontium	µg/L	0.991071	448	54.7	2,420	444	54.7	2,420	4	300	300			6010_METALS_ICP	6010_METALS_ICP
Strontium-90	pCi/L	0.60339	295	-1.66	700	178	-1.66	700	117	-0.85	1.44	8	pCi/L	SRTOT_SEP_PRECIP_GPC	UST_RAD_CNT_LSC
Strychnine	µg/L		3	50	50		50	50	3	50	50			8270_SVOA_GCMS	8270_SVOA_GCMS
Styrene	µg/L		32	0.13	100		0.13	100	32	0.13	100			8260_VOA_GCMS	8240_VOA_GCMS
Sulfate	µg/L	1	548	2,400	326,000	548	2,400	326,000				250,000	µg/L	D4327_ANIONS_IC	300.0_ANIONS_IC
Sulfide	µg/L	0.115385	26	300	10,000	3	300	10,000	23	300	10,000			9030_SULFIDE	9030_SULFIDE
sym-trinitrobenzene	µg/L		3	10	10		10	10	3	10	10			8270_SVOA_GCMS	8270_SVOA_GCMS
Technetium-99	pCi/L	0.969231	520	-1.02	36,000	504	-1.02	36,000	16	-1.02	10.3	900	pCi/L	TC99_SEP_LSC	TC99_ETVDSK_LSC
Tetrachloroethylene	µg/L	0.404624	173	0.049	100	70	0.049	100	103	0.049	100	5	µg/L	8010_VOA_GC	8240_VOA_GCMS
Tetrachlorophenol	µg/L		23	1.05	10		1.05	10	23	1.05	10			8040_PHENOLIC_GC	8040_PHENOLIC_GC
Tetradecane	µg/L		3	10	1,000		10	1,000	3	10	1,000			8270_SVOA_GCMS	8270_SVOA_GCMS
Tetrahydrofuran	µg/L	0.015625	64	1.2	74	1	1.2	74	63	1.2	74			8260_VOA_GCMS	8260_VOA_GCMS
Thallium	µg/L	0.010204	98	0.58	5	1	0.58	5	97	0.58	5			7841_TL_GFAA	7841_TL_GFAA
Thiofanox	µg/L		3	10	10		10	10	3	10	10			8270_SVOA_GCMS	8270_SVOA_GCMS
Thiuram	µg/L		3	10	10		10	10	3	10	10			8270_SVOA_GCMS	8270_SVOA_GCMS
Tin	µg/L	0.015267	131	17	100	2	17	100	129	17	100			6010_METALS_ICP	6010_METALS_ICP
Titanium	µg/L	0.142857	7	60	169	1	60	169	6	60	60			6010_METALS_ICP	6010_METALS_ICP
Toluene	µg/L	0.044025	159	0.016	100	7	0.016	100	152	0.016	100	1,000	µg/L	8010_VOA_GC	8240_VOA_GCMS
Toluenediamine	µg/L		3	10	10		10	10	3	10	10			8270_SVOA_GCMS	8270_SVOA_GCMS
Total beta radiostrontium	pCi/L		2	0.0691	0.125		0.0691	0.125	2	0.0691	0.125			SRTOT_SEP_PRECIP_GPC	SRTOT_SEP_PRECIP_GPC
Total carbon	µg/L	1	42	24,400	42,000	42	24,400	42,000						D2579A_CARBON	D2579A_CARBON
Total cresols	µg/L		26	4.66	10		4.66	10	26	4.66	10	80	µg/L	8040_PHENOLIC_GC	8040_PHENOLIC_GC
Total cresols	µg/L		26	4.66	10		4.66	10	26	4.66	10	80	µg/L	8040_PHENOLIC_GC	8270_SVOA_GCMS
Total dissolved solids	µg/L	1	241	183,000	1,680,000	241	183,000	1,680,000						160.1_TDS	160.1_TDS
Total halogens (all)	µg/L	1	5	238	720	5	238	720						9020_TOX	9020_TOX
Total organic carbon	µg/L	0.686016	379	200	1,900	260	200	1,900	119	200	1,000		µg/L	9060_TOC	9060_TOC
Total organic halides	µg/L	0.923077	260	2.65	3,330	240	2.65	3,330	20	2.65	3,330		µg/L	9020_TOX	9020_TOX

Constituent Name	Analytical Units	Frequency of Detect	Total Number of Samples	Minimum Result	Maximum Result	Count of Detects	Minimum Detect	Maximum Detect	Count of Nondetects	Minimum Nondetect	Maximum Nondetect	Target Action Level	Target Action Level Analytical Units	Minimum Method	Maximum Method
Total petroleum hydrocarbons - diesel range	µg/L		2	60	127		60	127	2	60	127			WTPH_DIESEL	CATPH_8015M_GC
Total petroleum hydrocarbons - gasoline range	µg/L		1	29	29		29	29	1	29	29			WTPH_GASOLINE	WTPH_GASOLINE
Total petroleum hydrocarbons - kerosene range	µg/L		8	500	10,000		500	10,000	8	500	10,000		µg/L	WTPH_DIESEL	8270_SVOA_GCMS
Total phenols	µg/L	0.018868	53	0.26	83	1	0.26	83	52	0.26	25	4,800	µg/L	8270_SVOA_GCMS	8240_VOA_GCMS
Toxaphene	µg/L		38	0.7	5		0.7	5	38	0.7	5			8080_PESTPCB_GC	CLP_PESTPCB_GCMS
trans-1 2-dichloroethylene	µg/L	0.016	125	0.045	20	2	0.045	20	123	0.045	20	100	µg/L	8010_VOA_GC	8010_VOA_GC
trans-1 3-dichloropropene	µg/L		32	0.12	100		0.12	100	32	0.12	100			8260_VOA_GCMS	8240_VOA_GCMS
trans-1 4-dichloro-2-butene	µg/L		8	10	10		10	10	8	10	10			8240_VOA_GCMS	8240_VOA_GCMS
Tributyl phosphate	µg/L		10	0.22	10		0.22	10	10	0.22	10		µg/L	8270_SVOA_GCMS	8270_SVOA_GCMS
Trichloroethylene	µg/L	0.80117	171	0.043	100	137	0.043	100	34	0.043	100	5	µg/L	8010_VOA_GC	8240_VOA_GCMS
Trichloromethanethiol	µg/L		8	10	10		10	10	8	10	10			8240_VOA_GCMS	8240_VOA_GCMS
Trichloromonofluoromethane	µg/L		8	10	10		10	10	8	10	10			8240_VOA_GCMS	8240_VOA_GCMS
Trichlorophenol	µg/L		23	1.11	5		1.11	5	23	1.11	5			8040_PHENOLIC_GC	8040_PHENOLIC_GC
Trichloropropane	µg/L		8	10	10		10	10	8	10	10			8240_VOA_GCMS	8240_VOA_GCMS
Tris(2 3-dibromopropyl) phosphate	µg/L		3	10	10		10	10	3	10	10			8270_SVOA_GCMS	8270_SVOA_GCMS
Tris-2-chloroethyl phosphate	µg/L		3	0.24	10		0.24	10	3	0.24	10			8270_SVOA_GCMS	8270_SVOA_GCMS
Tritium	pCi/L	0.973199	597	1.85	1,200,000	581	1.85	1,200,000	16	51.721	291	20,000	pCi/L	TRITIUM_DIST_LSC	UST_RAD_CNT_LSC
Turbidity	NTU	1	495	0.2	1,000	495	0.2	1,000						214A_TURBIDITY	214A_TURBIDITY
Uranium, by activity	pCi/L	1	32	0.646	207	32	0.646	207				20	pCi/L	UST_RAD_CNT_LSC	UST_RAD_CNT_LSC
Uranium, total	µg/L	0.98913	92	0.603	106	91	0.603	106	1	1.27	1.27	30	µg/L	UTOT_IE_FLUOR	UTOT_IE_FLUOR
Vanadium	µg/L	0.957746	568	2	1,140	544	2	1,140	24	2	30	112	µg/L	6010_METALS_ICP	6010_METALS_ICP
Vinyl acetate	µg/L		5	10	10		10	10	5	10	10			8240_VOA_GCMS	8240_VOA_GCMS
Vinyl acetate	µg/L		5	10	10		10	10	5	10	10			8240_VOA_GCMS	CLP_VOA_GCMS
Vinyl acetate	µg/L		5	10	10		10	10	5	10	10			CLP_VOA_GCMS	8240_VOA_GCMS
Vinyl acetate	µg/L		5	10	10		10	10	5	10	10			CLP_VOA_GCMS	CLP_VOA_GCMS
Vinyl chloride	µg/L	0.019231	156	0.07	200	3	0.07	200	153	0.07	200			8260_VOA_GCMS	8240_VOA_GCMS
Warfarin	µg/L		3	10	10		10	10	3	10	10			8270_SVOA_GCMS	8270_SVOA_GCMS
Xylenes, total	µg/L	0.018072	166	0.035	100	3	0.035	100	163	0.035	100	1,600	µg/L	8010_VOA_GC	8240_VOA_GCMS
Zinc	µg/L	0.632327	563	0.42	747	356	0.42	747	207	0.42	12.2	4,800	µg/L	6010_METALS_ICP	6010_METALS_ICP
Zinc-65	pCi/L	0.208333	24	-4.68	3.28	5	-4.68	3.28	19	-4.46	1.2			GAMMA_GS	GAMMA_GS
Zirconium	µg/L		7	50	50		50	50	7	50	50			6010_METALS_ICP	6010_METALS_ICP
Zirconium/niobium-95	pCi/L	0.208333	24	-276	11.6	5	-276	11.6	19	-3.05	2.35			GAMMA_GS	GAMMA_GS

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