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Hanford Operations

Review Report: Feasibility Study Strategies and Remedial System Performance Improvement for the 200-ZP-1/PW-1 Operable Units at Hanford

Prepared for

Office of Groundwater and Soil Remediation
Office of Environmental Management

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EXECUTIVE SUMMARY

At the request of the U.S. Department of Energy, Headquarters' Office of Environmental Management, the Office of Groundwater and Soil Remediation (EM-22), performed a Remediation System Evaluation (RSE) of the 200-ZP-1/PW-1 groundwater pump and treat (P&T) system, as well as the vadose zone Soil Vapor Extraction (SVE) system at the Hanford Site. These two systems are operated by Fluor Hanford (FH) to remove carbon tetrachloride (CT) from the vadose zone (i.e., SVE) and groundwater (i.e., P&T) under a Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) remedial action. DOE Richland (RL) is preparing a Feasibility Study (FS) for the Final Record of Decision (ROD) for the 200-ZP-1 OU. The RSE recommendations provide input to DOE to guide preparation, formulation, and optimization of the 200-ZP-1 and PW-1 draft FS submittals. The Review Team convened at Hanford from August 21-25, 2006, to conduct a site visit and inspection of the remedial systems under evaluation. Presentations were given by the 200-ZP-1/PW-1 FS and DOE Hanford teams on August 22-23, 2006,

The primary contaminant of concern (COC) for this review is CT, and to a lesser extent, technetium-99 (Tc-99). Investigations completed regarding CT releases in the 200-West area indicate three primary sources: the 216-Z-1A Tile Field, 216-Z-9 Trench, and 216-Z-18 Crib. The CT was reportedly disposed with several co-contaminants, including tributyl phosphate (TBP) and lard oil. The original conceptual site model (CSM) developed by the Hanford team regarding the release of the CT, includes residual CT in the vadose zone and dissolved CT in the saturated zone. This CSM was critically reviewed by the Review Team. Additional studies of the likely evaporation of CT from the Z-9 trench during discharge of waste during plant operations are proposed by the Hanford team to assess the mass likely released to the subsurface. The releases of Tc-99 to the subsurface are not clearly understood; source characterization efforts are in the early stages compared to the CT scope of work. Recent increases of Tc-99 have been noted in monitoring wells near the TX tanks, northeast of the CT sources.

The current interim groundwater extraction system consists of ten wells with capacities ranging from 7 to 60 gallons per minute and is located near and northeast of the source areas. There are concerns regarding deep aquifer contamination and an apparently growing plume of Tc-99. Current treatment for the water includes filtration followed by air stripping with vapor-phase carbon adsorption. Tc-99 and nitrate are not currently treated by the groundwater treatment system, and the treated water is injected into the aquifer at locations such that the injected water, including any Tc-99 and nitrate, is not recaptured by the extraction system. Though the ROD for the interim action acknowledges the lack of treatment for these other contaminants, it may not be clear to all stakeholders that the injected water may be moving outside the extraction system capture zone. Currently, a large and dedicated staff of operators manages the treatment systems across the facility, including the ZP-1 plant.

SVE has been conducted using one mobile extraction and treatment system, rotated among the three sites for a total of approximately 6 months per year. Currently, the extraction is almost exclusively conducted at the Z-1A and Z-9 locations. Despite the recovery of a large mass of contaminants out of the vadose zone, additional mass is believed to remain in the vadose zone, particularly in the fine-grained Cold Creek Unit. The Hanford team has considered thermally enhanced mass removal from this zone.

There are several vadose zone and groundwater modeling efforts ongoing, or completed, to support the 200-ZP-1 and 200-PW-1 FS preparation, as well as to refine the CSM and to design/evaluate the SVE and P&T systems. The models being used include STOMP for vadose zone transport, and MicroFEM for groundwater flow modeling. Additional facility-wide modeling is underway in support of the Site Wide Environmental Impact Analysis (EIS) using the MODFLOW/MT3D code.

Recommendations developed by the Review Team are summarized as follows. The FS should present and evaluate two conceptual models regarding potential for DNAPL below the water table to act as a continuing source of dissolved contamination, and should focus on expanded P&T as the primary remedial technology for groundwater. The remedial strategy discussed in the FS should emphasize hydraulic containment for most impacted portion of the groundwater plume, with compliance with standards achieved at locations beyond capture zone. These locations should be chosen based on modeling and monitoring such that the portions of the plume outside of the containment will attenuate to below the applied standards at the points of compliance (POC). The POCs should be established as soon as possible. Additional extraction wells should be placed primarily in areas of highest groundwater impact. The FS and proposed plan should establish a flexible framework for modifying pumping and monitoring configurations. The FS team should determine, as soon as possible, if treatment for co-contaminants (e.g., Tc-99, nitrate, etc.) will be required, and should continue to assess the vertical extent of the CT plume.

Commonly applied and publicly accessible modeling tools should be used whenever possible, and relatively simple modeling tools and approaches should be applied for the FS. The FS and EIS modeling teams should foster and adhere to open, two-way communication to maintain consistency regarding parameter values to the extent possible. Detailed modeling to improve the CSM and better interpret performance monitoring data should continue. Appropriate corporate-level quality assurance procedures are needed for consistent model development and application.

The Review Team recommends the Hanford team re-evaluate the value added of the proposed prompt evaporation study for CT release at the Z-9 trench. Rapid action is recommended instead to inhibit further migration of Tc-99 to the water table in the TX Tanks area. The Hanford team should also verify the acceptability of the incomplete capture of injected water with the stakeholders. Further study of current treatment plant staffing will likely identify potential cost efficiencies.

Though the team concurs with the strategy of periodic SVE operation, it recommends SVE be focused just above and below the Cold Creek Unit. Furthermore, the Hanford team should assess contaminant loading to groundwater due to vapor transport from residual vadose zone contamination. The need for in-situ thermal treatment to reduce CT sources in the vadose zone should be reconsidered; continued and improved SVE can be much more cost-effective.

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LIST OF ACRONYMS

ANL	Argonne National Lab
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFEST	Coupled Fluid, Energy, and Solute Transport computer modeling code
CIH	Certified Industrial Hygienist
CSM	Conceptual Site Model
CT	Carbon Tetrachloride
DBBP	Dibutyl-Butyl Phosphonate
DNAPL	Dense Non-Aqueous Phase Liquid
DoD	Department of Defense
DOE	Department of Energy
DWS	Drinking Water Standard
EIS	Environmental Impact Statement
EPA	Environmental Protection Agency
FH	Fluor Hanford
FID	Flame Ionization Detector
FS	Feasibility Study
ft	feet
GAC	Granular Activated Carbon
gal	gallons
gpm	gallons per minute
HDPE	High Density Polyethylene
HEPA	High-Efficiency Particulate Air filtering
HQ	Headquarters
ISTT	In-Situ Thermal Treatment
kg	kilograms
lb	pounds
liters per minute	liters per minute
NAPL	Non-Aqueous Phase Liquid
NEPA	National Environmental Policy Act
O&M	Operations and Maintenance
ORP	Office of River Protection
OU	Operable Unit
PFP	Plutonium Finishing Plant
PNNL	Pacific Northwest National Laboratory
POC	Point of Compliance
P&T	Pump and Treat
PVC	Polyvinyl Chloride
QA	Quality Assurance
RI	Remedial Investigation
RL	Department of Energy, Richland Office
ROD	Record of Decision
RSE	Remediation System Evaluation
STOMP	Subsurface Transport Over Multiple Phases computer modeling code
SVE	Soil Vapor Extraction
TBP	Tributyl Phosphate
Tc^{99}	Technetium 99

TCE	Trichloroethylene
TPA	Tri-Party Agreement
USACE	United States Army Corps of Engineers
VOC	Volatile Organic Compound

1.0 INTRODUCTION - PURPOSE AND PERSONNEL INVOLVED

1.1 Purpose

At the request of the U.S. Department of Energy (DOE), Headquarters' Office of Environmental Management, the Office of Groundwater and Soil Remediation (EM-22), performed a Remediation System Evaluation (RSE) of the 200-ZP-1/PW-1 groundwater pump and treat (P&T) system, as well as the vadose zone Soil Vapor Extraction (SVE) system at the Hanford Site. These two systems are operated by Fluor Hanford (FH) to remove carbon tetrachloride (CT) from the vadose zone (i.e., SVE) and groundwater (i.e., P&T) under a Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) remedial action. The RSE process, developed by the U.S. Army Corps of Engineers (USACE), is an independent and holistic evaluation of the system intended to meet the following primary objectives:

- Assess the performance and effectiveness of the system to achieve remediation objectives.
- Identify opportunities for reductions in operational costs, and remedy improvement.
- Verify that a clear and realistic exit strategy exists for the Operable Unit (OU), or designated site being remediated.
- Confirm adequate maintenance of government-owned equipment.

DOE Richland (RL) is preparing a draft Feasibility Study (FS) for the Final Record of Decision (ROD) for the 200-ZP-1 OU. The draft FS is due to be delivered to the regulator, the U.S. Environmental Protection Agency (EPA) Region 10, for a Tri-Party Agreement (TPA) milestone of May 31, 2007. A potential extension to the milestone, September 29, 2007, is under consideration by DOE and EPA. The RSE recommendations will provide input to DOE to guide preparation, formulation, and optimization of the 200-ZP-1 and PW-1 draft FS submittals. The subject FS will lead to preferred remedy selections, and a final ROD for ZP-1, thereby influencing the groundwater exit strategy for the Central Plateau at Hanford.

The RSE process results in recommendations that are not prescriptive, but should be considered by the project team and stakeholders for possible implementation as deemed appropriate. The RSE process has been used successfully at a large number of Department of Defense (DOD) and EPA sites.

1.2 RSE Team Composition

The team conducting the RSE consisted of the following individuals:

- Beth Moore, US DOE Headquarters (HQ); Hydrogeologist and Review Project Manager

- Dave Becker, USACE; Geologist and Review Team Leader
- Lindsey Lien, USACE; Environmental Engineer and Team Member
- Rob Greenwald, GeoTrans, Inc; Hydrogeologist and Team Member

1.3 Site Visit, Presentations, and Persons Contacted

The Review Team convened at Hanford from August 21-25, 2006, to conduct a site visit and inspection of the remedial systems under evaluation. Presentations were given by the 200-ZP-1/PW-1 FS team on August 22-23, 2006, as detailed below. The P&T and SVE systems were inspected by the Review Team on August 23, 2006. An outbriefing of initial RSE observations and recommendations from the site visit was presented to DOE and FS Team staff on August 25, 2006, by the Review Team Lead, Dave Becker.

- Mike Thompson, DOE RL; "200-ZP-1 Remedial System Evaluation & FS Process, Including Vadose Zone SVE"
- George Last, PNNL, "Hydrogeologic Data for the Hanford Site".
- Mitzi Miller and Tom DiFebbo, EQM, Inc/FH Team; "History of Sources and Activities Related to 200-ZP-1 Groundwater OU"
- Wes Bratton, Vista/FH Team; "Integrated Approach for Carbon Tetrachloride Source Term Location: Carbon Tetrachloride DNAPL Interim Report Conceptual Model Presentation"
- Ken Moser, Vista/FH Team; "Tc-99 Conceptual Models and Plume at T Area"
- Mark Byrnes, FH Team; "200-ZP-1 P&T System Design, Performance, and Cost"
- Virginia Rohay, FH Team; "200-PW-1 SVE System Design, Performance, and Cost"
- Mart Oostrom, Pacific Northwest National Laboratory (PNNL); "Carbon Tetrachloride Flow and Transport in the Subsurface of the 216-Z-9 Trench at the Hanford Site: Heterogeneous Model Development and Soil Vapor Extraction Modeling"
- David Miller, Argonne National Laboratory/FH Team; "Challenges and Opportunities for the CERCLA Decision Process for ZP-1"

- Mary Beth Burandt, DOE Office of River Protection (ORP) and Charles Hostetler, CESI; "MODFLOW-Based Groundwater Model Flow for DOE's Hanford Site/ NEPA Application"

The following individuals were contacted during the RSE to obtain their observations and input on the conduct of groundwater P&T and SVE operations, as well as conceptual and mathematical model development in support of the 200-ZP-1 FS.

- Dennis Faulk, EPA Region 10
- Arlene Tortoso, DOE RL
- Mike Thompson, DOE RL
- Briant Charboneau, DOE RL
- Matt McCormick, DOE RL
- Mary Beth Burandt, DOE ORP
- Charles Hostetler, CESI
- Mark Byrnes, FH
- David Miller, ANL/FH
- Mitzi Miller, EQM/FH
- Wes Bratton, Vista/FH
- Virginia Rohay, FH
- Mart Oostrom, PNNL
- Mark White, PNNL
- Bob Bryce, PNNL
- D.D. Blankenship, Operator, FH
- Carl Strode, Engineer, FH
- Steve Bickel, Operator, FH
- Pink Wilkerson, Operator, FH
- Ross Carrigan, Operator, FH

1.4 Structure of this Report

The report is structured as follows:

- Section 1.0 - Introduction - Purpose and Personnel Involved
- Section 2.0 - Site Conditions and the Conceptual Site Model Findings
- Section 3.0 - 200-ZP-1/PW-1 OUs Remediation Systems Findings
- Section 4.0 - Vadose Zone and Groundwater Modeling Findings
- Section 5.0 - Recommendations

For the benefit of the reader, some of the recommendations are stated in Sections 2 to 4 as part of the key findings. However, Section 5 contains a comprehensive presentation of the Review Team recommendations including a summary table.

2.0 SITE CONDITIONS AND THE CONCEPTUAL SITE MODEL FINDINGS

The conceptualization of the sources, migration, and fate of contaminants at the 200-ZP-1/PW-1 OU directly affects the assessment of the current interim actions and the screening of alternatives for future remedial actions. The ZP-1/PW-1 Project Team has made significant progress in assessing the conceptual site model (CSM). The key aspects of the CSM for the purposes of this report include the primary and secondary contaminant sources contributing to the groundwater plumes at the site (particularly the CT plume), the mass of volatile organic compounds (VOCs) remaining in the vadose zone near the sources, and the potential for non-aqueous-phase liquids in the saturated zone.

2.1 Contaminants Considered

The primary contaminant of concern (COC) for this review is CT, and to a lesser extent, Technetium-99 (Tc-99). Based on the CSM, CT is believed to have the largest source loading of the Group A COCs at the site, and is the focus of the interim actions, including the SVE and P&T systems. Other VOCs, including trichloroethene (TCE) and chloroform, are found at significantly lower levels within the CT plume. Tc-99 is observed at high levels in groundwater near the southwest corner of the TX Tank Farm.

2.2 Vadose Zone Contaminant Release Model

Investigations completed regarding CT releases in the 200-West area indicate three primary sources: the 216-Z-1A tile field, 216-Z-9 trench, and 216-Z-18 crib. The CT was reportedly disposed of along with several co-contaminants, including tributyl phosphate (TBP) and lard oil. Significant effort has been invested by the Project Team to estimate the mass of CT that infiltrated to the subsurface. Though other uncertainties exist, source estimates are highly sensitive to the amount of volatilization that occurred to the atmosphere from the crib vents. This finding led to a proposal for detailed study of prompt evaporation of CT at Z-9 crib. Specifically, the Project Team recommends a study to improve estimates of CT in the vadose zone by understanding and measuring crib evaporation rates, including soil diffusion length and crib ventilation. The Review Team concurs that a prompt evaporation study of CT released to Z-9 crib will likely improve source term estimates in the vadose and saturated zones, as well as the overall CSM. However, the proposed work is not currently considering the impact of the co-contaminants on the volatility and mobility of the CT. The phosphates and lard oil could significantly affect these rate value determinations. If the study is approved, the impact of the co-contaminants should be at least qualitatively evaluated.

At most contaminated sites, the mass of VOCs released to the environment is difficult to characterize, quantify, and validate. The presence of free or residual DNAPL, even limited volumes, can drastically skew mass estimates. Accurate source estimates are further complicated by the fact that DNAPL is difficult to detect and delineate. As such, the emphasis during most remediation projects is to focus on the cleanup results, such as achieving target concentrations in various media.

A key parameter for accurate CSM determination at the ZP-1 OU is the mass of CT in the vadose zone. The mass is significantly reduced relative to original levels due to the SVE interim action. The Review Team concurs with the determination by the FH Project Team that the remaining CT mass is largely contained within fine-grained sediments and caliche layers in the vadose zone, particularly the Cold Creek Unit.

The releases of Tc-99 to the subsurface are not clearly understood; source characterization efforts are in the early stages compared to the CT scope of work. Competing conceptual models exist for the sources, and multiple sources are likely based on the vertical distribution of Tc-99 in the groundwater in borings such as 299-W11-25B. It appears that groundwater is now being impacted and additional impacts are likely in the absence of actions to disrupt vadose zone migration (such as soil desiccation).

The Review Team is cognizant that as primary and secondary Tc-99 sources are characterized in the OU, the remedial systems designed to primarily capture and treat CT may require design and improvement modifications to treat Tc-99 as a co-contaminant in soil and groundwater. Therefore, the Review Team recommends that the draft FS evaluate technologies that are capable of co-contaminant treatment, and a methodology for establishing an optimization process to facilitate this remedial alternative. In addition, the Review Team recommends that DOE RL evaluate the existing systems' operation and maintenance contract to create incentives and insert performance measures to facilitate design modifications for the likely possibility of co-contaminant treatment.

2.3. Saturated Zone Conceptual Model

The hydrostratigraphy of the 200-ZP-1 OU includes saturated, coarse sediments of the Ringold Unit E which are underlain by the fine-grained Ringold "Mud" Unit. In the CSM, this later unit is considered a significant aquitard, and where present, potentially impedes downward migration of contaminants and recharge to the lower aquifer. However, the Ringold Mud Unit is not continuous under the 200-ZP-1 area. Where absent, direct hydraulic connection between the sandy portion of the Ringold Unit E and coarser sediments of the Ringold Unit A is evident. Further, recent investigations indicate that groundwater within the Ringold Unit A is contaminated by CT.

The volumes and phases of CT released to the cribs suggest that free-phase CT may be present in the subsurface. However, large amounts of water used to flush the CT releases may have introduced significant amounts of dissolved CT into the groundwater. Investigations completed to date do not directly indicate dense non-aqueous phase liquids (DNAPLs) in the saturated zone. However, data presented in the Remedial Investigation indicate that a sample from boring W15-46 had evidence of DNAPL at a depth of 65 feet in the unsaturated zone.

DNAPL is difficult to detect in environmental sampling, particularly when it is present as low saturations in heterogeneous materials. Maximum dissolved concentrations of CT in the saturated zone exceed 4,000 micrograms per liter (μg/L). The aqueous solubility of CT is approximately 800,000 μg/L (Verschueren1996). Observed CT concentrations in the saturated zone at 200-ZP-1 approach one percent of the solubility of the pure phase. Confirmation of the “one-percent solubility rule” for CT in the groundwater serves as a qualitative indicator for the presence of DNAPL. In addition, the co-disposal of TBP and lard oil with CT has likely influenced the solubility of CT.

The Review Team recommends that laboratory and/modeling studies be conducted to determine the effect that co-disposal of TBP and lard oil may have had on the solubility of CT in the subsurface. The benefit of determining a contaminant-specific solubility rate for the released mixture is to improve predictive analyses for fate and transport, as well as remedial system performance through design modifications.

During the site visit, the Project Team presented two opposing, but reasonable CSM scenarios regarding the potential presence of DNAPL in the saturated zone:

1) Little to no DNAPL is present in the saturated zone to act as a continuing source of dissolved contamination, attributed to layering in the unsaturated zone and/or prompt CT vaporization followed by CT dissolution with large volumes of process water released to the crib; or

2) DNAPL may exist within the heterogeneous aquifer matrix in the saturated zone whereby it acts as a persistent source of dissolved contamination.

The Project Team has selected the first CSM scenario as the preferred interpretation, based on recently-acquired characterization data, predictive modeling results, and published Remedial Investigation (RI) findings. However, as discussed in Section 4.4 and Section 5.2.1 of this report, predictive modeling scenarios previously performed by PNNL provide for a wide range of estimates regarding DNAPL mass below the water table, from 0 kg to more than 100,000 kg. DNAPL is difficult to detect in settings like that of 200-ZP-1, and cannot be ignored simply because it has not yet been detected. Regardless of characterization efforts performed to date, there is a real potential for DNAPL to be present below the water table which might cause dissolved CT concentrations to persist in groundwater for a long period of time. The FS approach should clearly account for that potential reality.

The Review Team believes both conceptual models should be presented in the FS as reasonable potential realities, and recommends that the uncertainty regarding these two CSM scenarios be acknowledged and considered throughout the FS analysis, because it is critical to assumptions for long-term remedy performance. The FS strategy should be one comprehensive strategy that considers and addresses both potential conceptual models (i.e., is appropriate whether or not DNAPL exists within the heterogeneous aquifer matrix within the saturated zone and acts as a persistent source of dissolved contamination). The uncertainty about DNAPL below the water table serving as a continuing source of dissolved contamination will not be resolved before the FS is completed. Performance of the remedy over time will ultimately provide the information required to discern whether or not there is enough DNAPL below the water table to serve as a persistent source of dissolved contamination.

The Review Team commends the Project Team for strategically improving the CSM, and supports continued scope and budgetary allocations toward validation and verification. CSM improvement is an iterative process of remedial system operation and improvement, and the Review Team recommends that the FS include objectives, and/or measures of system performance, to confirm aspects of the current CSM and/or allow competing CSM scenarios to be resolved.

3.0 200-ZP-1/PW-1 REMEDIATION SYSTEMS FINDINGS

CT was first detected in groundwater samples from several wells in 1986, and was recognized as a broad groundwater plume beneath the 200-West Area in 1987. CT was discharged to the ground between 1955 and 1973. Estimated quantities of CT discharged to the waste sites vary between 363,000 to 580,000 L [95,900 to 153,200 gallons (gal), or 577,000 to 922,000 kilograms (kg)] of liquid CT.

Over 2,700,000 kg of nitrate were also discharged at various locations in the ZP-1 area. A groundwater plume formed roughly coincident with the northern nitrate disposal locations.

Chloroform, a secondary COC for the interim remedial measure, is a degradation product of CT. Chloroform has a drinking water standard (DWS) of 80µg/L, and is also associated with septic waste disposal. The chloroform plume generally coincides with the high-concentration contour of the CT plume, but at much lower concentration levels.

The specific origin of TCE in waste streams is unknown, but it is attributed to the use of a degreaser. TCE has a DWS of 5 µg/L. Currently, the TCE plume has concentrations near or below the DWS and is centered around Wells 299-W15-34 and 299-W15-35, and extends north towards the 241-TY Tank Farm.

Interim actions at the 200-ZP-1/PW-1 OU to address these contaminants include installation and operation of both groundwater P&T and SVE systems.

3.1 Groundwater Remediation History at ZP-1

The 200-ZP-1 OU P&T system was implemented in a three-phased approach. Phase I operations consisted of the pilot-scale treatability test between August 1994 and July 1996, around the 216-Z-12 Crib. During this phase, contaminated groundwater was removed through a single extraction well (299-W18-1) at a rate of approximately 151 liters per minute [L/min or 40 gallons per minute (gpm)], treated using granular activated carbon (GAC), and returned to the aquifer through an injection well (299-W18-4). Concurrent with Phase I operations, the *Declaration of the Interim Record of Decision for the 200-ZP-1 Operable Unit* was issued by EPA in June 1995 (EPA 1995). The selected remedy was to use groundwater pump-and-treat technology to minimize further migration of CT, chloroform, and TCE in the groundwater and remove mass.

Phase II operations commenced August 5, 1996, in accordance with the interim action ROD (EPA 1995) and TPA Milestone M-16-04A, and were completed in August 1997. The 1996 groundwater plume was the basis for the interim action ROD. The well field configuration during Phase II operations consisted of three extraction wells (299-W15-33, 299-W15-34, and 299-W15-35), pumping at a combined rate of approximately 567.8 L/min (150 gpm), and a single injection well (299-W15-29).

Groundwater was treated using an air stripper to release CT as a vapor, and vapor phase GAC was used to collect it.

Phase III operations began on August 29, 1997, satisfying TPA Milestone M-16-04B. The well field for Phase III operations was expanded to include three additional extraction wells (i.e, existing wells plus 299-W15-32, 299-W15-36, and 299-W15-37) and four additional injection wells (existing wells plus 299-W18-36, 299-W18-37, 299-W18-38, and 299-W18-39). The total pumping rate was increased to more than 800 L/min (+200 gpm), versus a total treatment system capacity of 1,893 L/min (500 gpm). The treatment process for the Phase III system uses air-stripping, with a GAC off-gas system to remediate the contaminated groundwater.

3.2 Groundwater Extraction System

The current system consists of nine wells with capacities ranging from 7 to 60 gpm. With one exception, well 299-W15-36, the active wells are located at or north of the Z-9 crib and the PFP, in areas that have elevated (>1000 μg/L) concentrations of CT. The wells are generally completed to depths of approximately 76-79 meters [(m), or 250-260 feet (ft)] below grade. Well 299-W15-47 is screened to a depth of approximately 85 m (278 ft) below grade. As such, the extraction wells are partially penetrating, and likely do not withdraw groundwater from the entire saturated interval above the underlying aquitard, the Ringold Mud Unit. A tenth well, 299-W15-6, has recently been converted for extraction of groundwater from the Ringold Lower Mud at approximately 12 gpm. The Review Team believes that additional extraction wells open to deeper portions of the aquifer are warranted for contaminant extraction and plume capture in the future.

Currently, the treated water is injected back into the aquifer at three wells located west of the ZP-1 area. The treatment removes the VOCs, but is not adequate for removing non-volatile constituents, including Tc-99, nitrate, and chromium. The ROD for the current interim action specifically recognizes this fact. The location of the injection system is, however, not directly upgradient of the extraction wells, particularly now that several wells are operating north and east of the treatment plant. Given the presence of co-contaminants in the injected water, the Review Team recommends that the Project Team verify with the stakeholders that that the incomplete capture of injected water is still acceptable.

3.3 Groundwater Treatment System

The ZP-1 treatment system at Hanford is generally well run and maintained. The operators are knowledgeable and have a strong dedication to maintaining and improving the system. The ZP-1 treatment process flow diagram is included in Figure 3-1. Flow to the plant is through seven pipe headers with four above-ground headers constructed of 3-inch-diameter high density polyethylene (HDPE), and the three below-grade pipe lines constructed of poly vinyl chloride (PVC). Below-grade piping is double-walled. Current flow rate to the plant is approximately 290 gpm, well below the plant capacity of 500 gpm. The design influent concentration is 6000 μg/L CT.

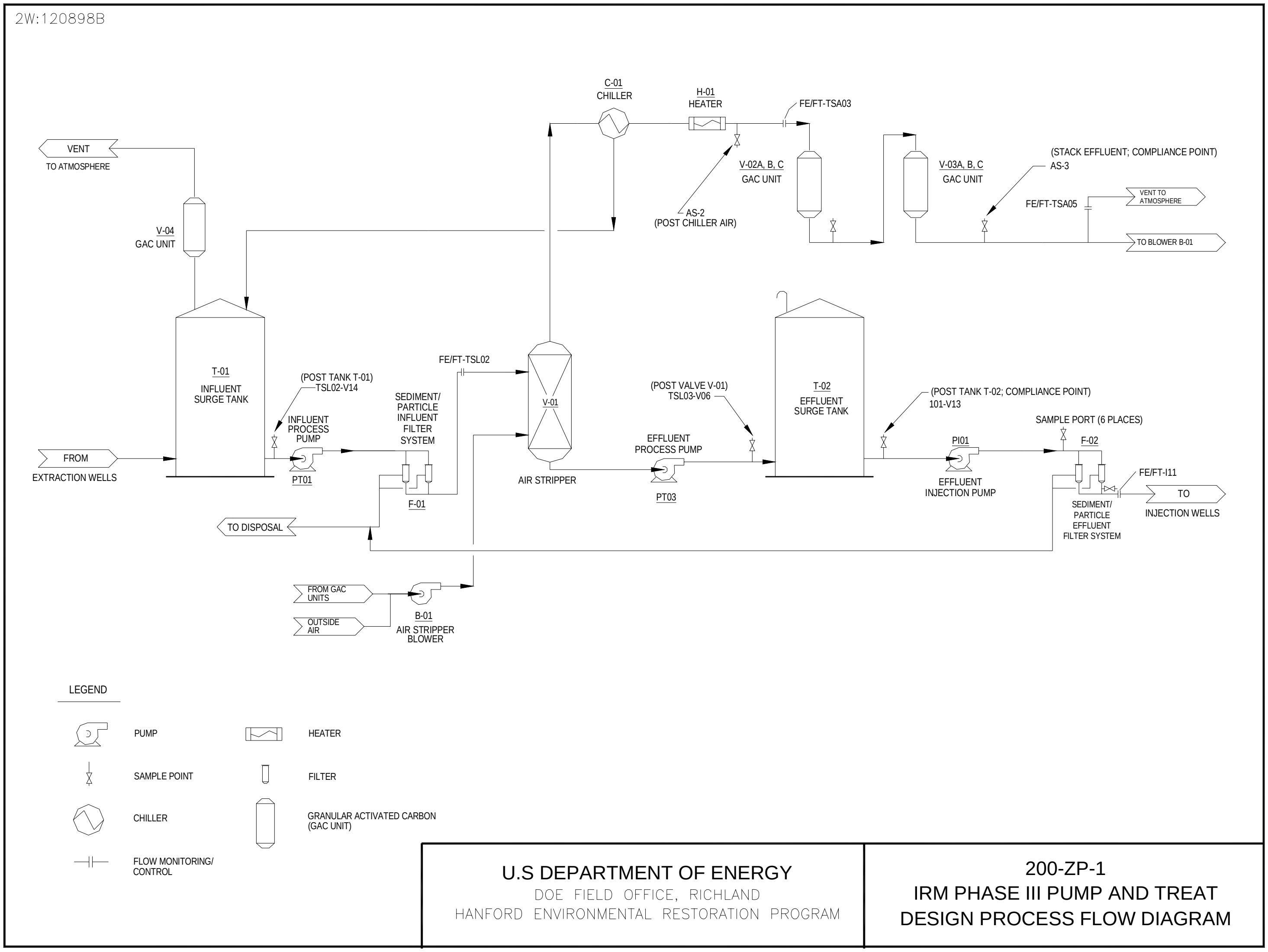

Figure 3 1. 200-ZP-1 Operable Unit Interim Remedial Operation Phase III Pump and Treat Design Process Flow Diagram.

Flow from the wells discharges to an influent surge tank (T-01), where it is pumped through 5 micron filters prior to passing through the 8-foot-diameter, 60-foot-tall packed-tower air stripping unit. Following treatment through the air stripper, the treated water is sent to an effluent surge tank (T-02). Water is pumped from T-02 to the injection well system following cartridge filtration. Off-gas from the air stripper is chilled to remove the moisture, and reheated to eliminate condensation as it is treated through vapor-phase GAC prior to discharge to the atmosphere. Monitoring of the individual GAC units and worker breathing space is done by an eight-channel continuous vapor sampler. A total of approximately 9,300 kg, or 20,460 pounds (lb) of CT has been removed.

3.4 Soil Vapor Extraction System

SVE has been conducted at the Z-1A tile field and Z-18 crib since 1992 and at the Z-9 crib since 1993. Initially, three separate systems were operated, one at each location. During 1998, the operation was switched to use of just one mobile system, rotated among the three sites for a total of approximately 6 months per year. Currently, the extraction is almost exclusively conducted at the Z-1A and Z-9 locations. Extraction is conducted from approximately 46 wells with varying screened intervals. A total of approximately 79,000 kg (174,000 lb) has been removed.

The existing extraction and treatment system consists of:

- A Sutorbilt rotary-lobe blower (30HP motor, rated at 500 cubic feet of air/minute with upstream and downstream silencers
- 1000-lb carbon vessels for vapor treatment downstream of the blower
- An air-to-air heat exchanger to pre-cool the blower discharge prior to carbon treatment
- Inlet air filtration through a high-efficiency particulate air (HEPA) filtration system
- Separation of condensate via a cyclone separators (one upstream of the blower and one downstream of the heat exchanger)
- Flexible hoses to connect to the extraction wells and various treatment components
- An autosampler for monitoring inlet and outlet air quality

The system is beginning to show its age, but has been well maintained. The 200-PW-1 Project Team will need to allocate budget for replacement (or rebuilding) of the blower at some point in the future. The longevity of the system is a credit to the Project Team's diligence in its maintenance. Costs for operation and maintenance of the system (including operations, performance monitoring, and project support) are approximately $370,000 per year. The carbon vessels need change-out approximately once every 6-7 weeks, with shorter times between changes in the winter months.

The Review Team concurs with the current strategy of periodic operation of the SVE system at the Z-9 crib and Z-1A tile field locations, and believes SVE provides an effective approach to mitigate the potential for further groundwater impacts that could otherwise occur due to vapor transport. The Review Team recommends that SVE performance be improved, as detailed in Section 5.5.

4.0 VADOSE ZONE AND GROUNDWATER MODELING FINDINGS

There are several vadose zone and groundwater modeling efforts ongoing, or completed, to support the 200-ZP-1 and 200-PW-1 draft FS submittals preparation, as well as to refine the CSM and to design/evaluate the SVE and P&T systems. The modeling platforms, including advantages and limitations, are briefly described below.

4.1 MicroFEM Simulations for Capture Zone Evaluation

This code is widely used at Hanford to simulate capture zones of existing P&T extraction wells in steady-state. MicroFEM (Hemker, C.J., *see* www.microfem.com) is a for-purchase (private domain), numerical, three-dimensional, finite-element code capable of simulating groundwater flow. Only water movement is modeled; contaminant transport cannot be studied or simulated via processes of dispersion, sorption, retardation, decay, and so on. Note there are no peer-reviewed publications regarding validation of this model, though it is widely used in Europe.

Appendix E of the Fiscal Year 2005 Annual Summary Report for 200-UP-1 and 200-ZP-1 Pump-and-Treat Operations (herein referred to as the "2005 Annual Report") provides details of MicroFEM application to evaluate capture zones of the P&T system at 200-ZP-1. The capture zone modeling uses a two-dimensional, finite-element grid for the horizontal dimensions, and three large layers in the vertical dimension. In other words, the model contains three, two-dimensional aquifer layers of variable thickness. Water is extracted from only the top aquifer layer, although water may enter this layer from the deeper layers. The capture zone plots included in the annual reports represent flow occurring only in the uppermost aquifer layer; the level of capture at greater depths is simulated in the model, but is not presented in the annual reports. The Review Team believes the current presentation of capture in the 2005 Annual Report provides an incomplete description, since the extent of capture in lower portions of the aquifer, which is not presented, is likely less than the extent of capture presented for the uppermost layer.

Based on the 2005 Annual Report, values for aquifer properties, such as hydraulic conductivity, were assigned consistent with previous site wide modeling performed with the Coupled Fluid, Energy, and Solute Transport (CFEST) code. Due to the relatively large grid spacing of 120 m (393.7 ft) in the CFEST model, results of local aquifer testing and drawdown analyses were reportedly used to refine the properties in the MicroFEM capture zone model. The Review Team found the documentation of the model input parameters for the capture zone modeling to be incomplete in the 2005 Annual Report, and recommends that such documentation be improved if similar evaluations are presented in the future.

4.2 CFEST Flow and Transport Simulations

Site wide groundwater modeling at Hanford, with the capability to incorporate local-scale simulations, was performed using the CFEST code (Gupta et al. 1987). CFEST modeling at Hanford included both steady-state and transient simulations of groundwater flow, plus contaminant transport. The environmental regulators and DOE recently agreed to transition the site wide modeling platform at Hanford to the public-domain MODFLOW family of codes in support of the ongoing Tank Closure and Waste Management Environmental Impact Statement analyses. Use of the MODLFOW codes at Hanford is expected to facilitate transparency and verification of model results and usage, as well as regulator and stakeholder understanding. The Review Team has not specifically reviewed details of the previous CFEST modeling, and therefore does not provide additional discussion of the CFEST modeling in this report.

4.3 STOMP Simulations Near the 216-Z-9 Crib

Numerical, three-dimensional, multi-fluid transport simulations of the vadose and saturated zones are performed near the 216-Z-9 trench, using the Subsurface Transport Over Multiple Phases (STOMP) code (White and Oostrom 2006). The Review Team was briefed by the Project Team regarding two STOMP modeling reports relevant to the ZP-1 OU: Oostrom et al. 2006 and Oostrom et al. 2004.

In both these studies, the numerical model was configured to represent: (1) the stratigraphy, hydrogeologic properties, and fluid properties for the likely mixtures of disposed organic liquid (e.g., mixtures of CT, lard oil, TBP, and dibutyl-butyl phosphonate [DBBP]); and (2) estimates of hydrologic boundary conditions, such as disposal rates. EarthVision software was used for geologic modeling, with results mapped to the numerical model grid. Fluid properties for relevant organic liquid mixtures were determined from laboratory studies. The 2004 study includes a base case simulation, plus additional simulations for 22 scenarios, where model input was varied to represent reasonable variation in key input parameters. It also includes simulations of the existing SVE system. The results address the following questions:

- Where is CT expected to accumulate?
- Where would continuing liquid CT sources to groundwater be suspected?
- Where would DNAPL contamination in groundwater be suspected?
- What is the estimated distribution and state of CT in the vadose zone?
- How does SVE affect the distribution of CT in the vadose zone?

The 2004 model study reports a wide range of potential estimates to these questions. Of interest to the Review Team is the range of DNAPL mass potentially migrating below the water table (0 kg to more than 100,000 kg). The 2006 study includes six additional conceptual model scenarios, particularly focusing on layering and small-scale heterogeneities. It also incorporates simulations of historical SVE operations in all of the scenarios from 1993 to 2005. The presence of small-scale heterogeneities reduces the amount of DNAPL reaching the water table in the STOMP simulations. The Review

Team notes that the STOMP modeling is extremely complex, and requires massive computing requirements. Although the STOMP model simulates both the saturated and unsaturated zones, it is important to note the simulations for the 216-Z-9 crib are for a small area, and focus primarily on transport of multiple phases through the unsaturated zone. A combined unsaturated/saturated zone model of this type for the entire 200-ZP-1 area is not computationally practical at the current time.

4.4 MODFLOW/MT3D Simulations for Site-Wide Environmental Impact Statement (EIS) Analyses

This modeling effort is the early stages of development to support EIS alternative analyses, primarily for the Tank Closure and Waste Management Projects. EIS modeling will be performed using MODFLOW-based codes (i.e., MODFLOW, MODPATH, MT3DMS), and will include linkages to STOMP results from local-scale simulations of the unsaturated zone to provide contaminant source terms for MT3DMS simulations.

Based on briefings to the Review Team by the EIS Project Team, this modeling will proceed in three steps:

- Step 1. Development of a steady-state, two-layer model with variable thickness that represents the basic features of the Hanford/Ringold suprabasalt aquifer. This step will evaluate gridding, model sensitivities to characterization uncertainties, alternate conceptualizations, and responses to forcing functions (using a transient implementation).

- Step 2. Development of a transient refined model with up to 60 physical layers of constant-elevation surfaces, superimposing an appropriate distribution of material types, with transient calibration to observed head and chemical concentration distributions

- Step 3. Evaluation of the sensitivities of the transient refined model to characterization uncertainties, and where they are significant, development and evaluation alternate conceptual models.

Horizontal grid spacing is expected to be no greater than 200 m (658 ft), and no less than 25 m (82 ft). The smaller spacing will be used in areas to accommodate dense data input, such as crib source areas and well locations. The model will be constructed with properly designed transitions to satisfy numeric convergence requirements, as well as the STOMP/MODFLOW interface.

The results of the EIS modeling are expected no earlier than January 2008. Therefore, the Review Team notes that the site wide EIS MODFLOW platform will not be available for draft FS use, nor for the initial phases of remedial design of the 200-ZP-1/PW-1 systems.

There are several studies related to the modeling efforts. Specifically, the Review Team was provided with a document describing laboratory studies performed to determine CT and chloroform partition coefficients derived from Hanford sediments (PNNL 1995). DOE and the Project Team should identify which ongoing model efforts will integrate these results, and assure consistent documentation, as well as cross-referencing consistent with quality assurance of model development and application at Hanford.

5.0 RECOMMENDATIONS

Review Team recommendations, and the basis for each, are presented in this section. Table 1 summarizes the recommendations.

5.1. Revisions to the Conceptual Site Model

5.1.1 Evaluate the Value Added of the Prompt Evaporation Study

The proposed work to evaluate the mass lost from the cribs through prompt evaporation, though helpful to estimate the mass released for modeling purposes, will not necessarily have a significant impact on technology selection, design, and optimization. In addition, the proposed work is not currently considering the impact of the co-contaminants on the volatility and mobility of the CT. The phosphates and lard oil could significantly influence these rate determinations. The value of the additional work will have to be carefully considered relative to the costs. If the work is done, the impact of the co-contaminants should be at least qualitatively considered.

5.1.2 Take Rapid Action to Inhibit Migration of Tc-99 to the Water Table

The Review Team concurs with the efforts to characterize the potential sources of Tc-99, and encourages expeditious actions to halt migration toward the water table to minimize groundwater impacts through the use of appropriate technologies, such as a soil desiccation barrier. Specifically, the Project Team proposes to demonstrate and evaluate the efficacy of a soil desiccation barrier at the Sisson and Lu site, for upscaling below the Cold Creek Unit in the vadose zone to impede the downward migration of contaminants to the water table. The Review Team believes that this proposal has merit over a traditional surface infiltration barrier, because the benefits are immediate in potentially reducing deep vadose zone loading to the water table. The performance and benefit of a surface barrier to reduce saturated zone infiltration can only be measured in timeframes of decades to hundreds of years in terms of effective travel time to the water table.

5.2 Feasibility Study Strategy Recommendations

5.2.1 Present and Evaluate Two Conceptual Models within the FS Regarding Potential for DNAPL Below the Water Table to Act as a Continuing Source of Dissolved Contamination

As discussed in Sections 2.0-4.0, there is significant uncertainty in the CSM regarding presence of DNAPL below the water table and the potential for such DNAPL to act as a persistent source of dissolved contamination. Based on the STOMP modeling performed in 2004 and 2006, ranges of parameters simulated suggest a potential range of DNAPL mass near the Z-9 crib, below the water table by 1993, ranging from 0 kg to nearly 135,000 kg (median and mean from the 29 simulations were approximately 22,000 kg and 33,000 kg, respectively). The Project Team favors a conceptual model that assumes the minor presence of pure DNAPL below the water table, which is consistent with simulations that assume more layered heterogeneity in the unsaturated zone and/or greater significance of prompt vaporization of materials released to the cribs. However, the PNNL modeling team concurred during the Review Team site visit that the current range of uncertainty regarding the amount of DNAPL below the water table, and its potential to act as a continuing source of dissolved groundwater contamination, cannot be resolved based on the current modeling. Given the contrasting interpretations of the two CSMs, it is apparent that uncertainties remain that will require iterative characterization and model refinement to resolve in the next 5-10 years.

Therefore, there are two competing but reasonable CSM scenarios regarding the potential presence of DNAZPL in the saturated zone:

1) Little to no DNAPL is present in the saturated zone to act as a continuing source of dissolved contamination, attributed to layering in the unsaturated zone and/or prompt CT vaporization followed by CT dissolution with large volumes of process water released to the crib; or

2) DNAPL may exist within the heterogeneous aquifer matrix in the saturated zone whereby it acts as a persistent source of dissolved contamination.

The Review Team recommends that these uncertainties be acknowledged and considered throughout the FS analysis, because it is critical with respect to assumptions regarding long-term remedy performance. Improvement of groundwater quality to levels approaching cleanup levels will be extremely unlikely if DNAPL below the water table acts as a persistent source of dissolved contamination. The FS strategy should be one comprehensive strategy that considers and addresses both potential conceptual models (i.e., is appropriate whether or not DNAPL exists within the heterogeneous aquifer matrix within the saturated zone and acts as a persistent source of dissolved contamination). The risk of assuming that DNAPL will not act as a continuing source when evaluating potential remedies is that unreasonable expectations for groundwater restoration will likely be established.

The uncertainty about DNAPL below the water table serving as a continuing source of dissolved contamination will not be resolved before the FS is completed. Performance of the remedy over time will ultimately provide the information required to discern whether or not there is enough DNAPL below the water table to serve as a continuing source of dissolved contamination. Monitoring and performance objectives should be considered in the FS to provide data that will resolve this uncertainty after a final remedy is implemented. Strongly declining concentration trends in areas of highest impact in response to expanded P&T will suggest that DNAPL is not present in sufficient quantity below the water table to act as a persistent source of dissolved contamination. However, flat or increasing concentration trends in highest concentration areas in response to expanded P&T will suggest. that DNAPL is present in sufficient quantity below the water table to act as a persistent source of dissolved contamination.

5.2.2 Focus on Expanded P&T as the Primary Remedial Technology for Groundwater

Consideration of the possibility for DNAPL below the water table to serve as a persistent source of dissolved contamination will likely result in a selected remedy with prominent hydraulic containment. Due to the size and depth of the groundwater plume, most or all of the alternatives to P&T will likely not pass the initial screening of technologies within the FS. The Review Team believes it is very likely that an expanded P&T system will ultimately be the primary component of the selected remedy. This will include additional and deeper extraction wells, beyond the capacity of the interim system.

5.2.3 Develop a Strategy with Hydraulic Containment for the Most Impacted Portion, with Compliance at Locations Beyond the Capture Zone Based on Modeling and Monitoring Results

The FS may include consideration of several P&T approaches. For instance, one approach might include hydraulic containment for the full extent of the CT plume above cleanup levels. An alternate approach that may require much less capital and life-cycle cost is hydraulic containment of the most impacted portion of the CT plume, with natural remediation for the portion of the plume beyond the zone of hydraulic containment. This latter approach is schematically illustrated in Figure 5-1. The Review Team believes this latter approach will be evaluated favorably within the FS, to the extent that a combination of modeling and monitoring is incorporated to demonstrate long-term protectiveness at point of compliance (POC) locations.

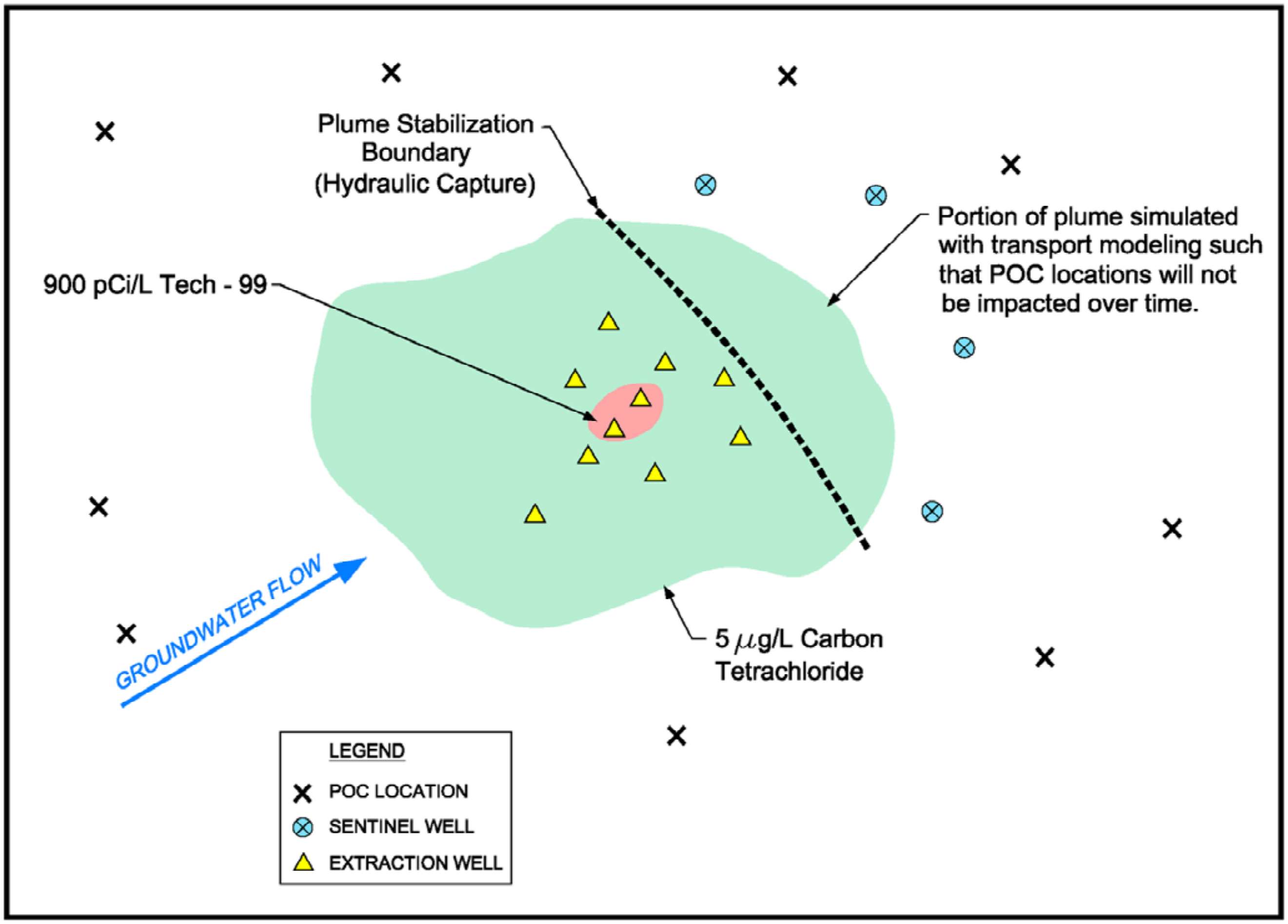

Figure 5.1. Schematic illustrating suggested remedial approach

Deciding on a specific boundary for the zone of hydraulic containment, the Target Capture Zone, will consider several factors:

- The Target Capture Zone should be located beyond any locations where potential DNAPL is suspected. In this manner, the groundwater downgradient from the zone of hydraulic containment should decrease in contaminant concentration over time by reducing source contribution through hydraulic containment.

- The Target Capture Zone should specify depths, or hydrostratigraphic units, where horizontal capture is required. Specifically, the Review Team noted that contamination within the Ringold Unit A, below the Ringold Lower Mud Unit, was not clearly indicated in some presentations regarding contaminant distribution. The Target Capture Zone should clearly indicate the extent to which horizontal capture in this unit is required.

- Contamination downgradient of the Target Capture Zone, CT and other contaminants, should attenuate to cleanup levels before reaching the POC locations (selection of POC locations is discussed below). For the FS, the Review Team recommends the use of simple transport models (see Section 5.3.3) to evaluate attenuation of contaminant concentrations between the Target Capture Zone and the POC locations. This exercise will help establish an appropriate location for the boundary of the Target Capture Zone, which combines an acceptable combination of distance to the POC locations and acceptable initial concentration outside the Target Capture Zone.

5.2.4 Establish POC Locations as Soon as Possible

Defining an appropriate Target Capture Zone for the P&T approach described above requires POC locations to be established. The distance to the POC locations must be known to perform simple transport modeling for the portion of the contaminant plume located downgradient of the Target Capture Zone. Based on the presentations made to Review Team, it is assumed that the POC locations will be located a substantial distance from the current downgradient extent of the CT plume. It is likely that these POCs will be located coincident with geographical or infrastructure features, such as roads, management area boundaries, etc. The Review Team recommends that the FS team establish the POCs with regulators and other stakeholders as soon as possible, so that the FS modeling can be performed.

5.2.5 Include Costs of Sentinel Well Drilling and Monitoring

The remedial approach described above should incorporate sentinel monitoring locations between the current plume extent and the POCs. The Review Team recommends that the FS include the scope and cost associated with drilling and long-term monitoring of sentinel wells, based on the estimated number of sentinel wells. The exact locations of the sentinel wells, and acceptable concentration limits for those sentinel wells, will be determined as part of the remedial design.

5.2.6 Locate Extraction Wells in Areas of Highest Groundwater Impact

For the FS, the Review Team suggests simple flow modeling (see Section 5.3) to determine the approximate number of extraction wells and associated extraction rates to satisfy the Target Capture Zone. Detailed modeling is expected during remedial design. Flow modeling for the FS and remedial design should assume that the extraction wells are located in the areas of highest concentration for one or more contaminants. In this manner, the remedial approach will demonstrate a commitment to restore the aquifer and to acquire performance data to resolve the uncertainty regarding the potential for DNAPL below the water table to act as a persistent source of dissolved contamination (and the related uncertainty regarding potential for aquifer restoration). Although some additional extraction wells in areas of lower concentrations may ultimately be required to establish adequate capture, the focus should be on pumping from areas of highest concentration.

5.2.7 Use the FS and Proposed Plan to Establish a Flexible Framework for Modifying Pumping Configuration and Monitoring Configuration

The Review Team recommends that FS and Proposed Plan establish a flexible framework for changing pumping configurations, modifying the locations or frequencies of groundwater monitoring, or implementing other potential contingent actions based on remedy performance. For instance, rigid requirements for pumping rates should be avoided. Potential modifications over time might include:

- Reducing or increasing pumping rates at individual locations
- Adding additional extraction wells, if there is evidence of loss of capture
- Adding additional extraction wells, if new areas of higher groundwater concentrations or new sources of groundwater contamination are discovered
- Modifying the location or extent of the Target Capture Zone based on changing plume configuration

The goal is to allow such actions to be implemented expediently, with regulator and stakeholder approval. These concepts can be introduced in the FS and Proposed Plan, with further details provided in the remedial design.

5.2.8 Determine as Soon as Possible if Treatment of Co-Contaminants will be Required

The need to actively treat for all potential co-contaminants (e.g., nitrate, uranium) has not been established. The presence of co-contaminants, especially nitrate, could require addition of a treatment process (i.e., ex-situ biological treatment) that is not readily compatible with other processes (i.e., air stripping or ion exchange) used to remove organics or metals. An effective nitrate removal process will require a large capital cost outlay, as well as increased operations costs. A biological nitrate removal process requires the addition of a large mass of substrate to produce anaerobic conditions for the nitrate-reducing bacteria to thrive, and the process to function properly. Potential problems with well, packing, and resin fouling may also result. In addition, a higher level of operator training and monitoring would increase operations and maintenance (O&M) costs.

The scope of the FS may not be acceptable to the regulators, if the evaluations are based on an assumption that co-contaminants will not require treatment. The Review Team recommends that priority be given to establishing these requirements as soon as possible, since it will impact evaluations within the FS.

5.3 Modeling

The Review Team makes the following general recommendations regarding modeling, and provides details of each in the subsections:

- Use commonly applied and publicly-accessible modeling tools whenever possible, ideally those in the public domain.
- Use simple modeling tools and approaches for the FS.
- Use simple modeling assumptions and approaches for the FS to conservatively determine the fate and transport of contaminants beyond a Target Capture Zone with respect to POC locations.
- Use simple flow modeling for the FS to estimate pumping locations and rates required for hydraulic containment.
- Foster and adhere to open, two-way communication with the EIS modeling team; maintain consistency regarding parameter values between the FS and EIS models to the extent possible.
- Continue with more detailed modeling (e.g., STOMP simulations) to improve the CSM and better interpret performance monitoring data.
- Institute appropriate, corporate-level quality assurance (QA) procedures for consistent model development and application between projects.

5.3.1 Use Commonly Applied and Publicly-Accessible Modeling Tools Whenever Possible, Ideally Those in the Public Domain

As a general rule, the Review Team has observed through many RSEs that the environmental regulators and stakeholders require well-accepted, documented, and open source codes/techniques to conduct analyses for compliance decisions. Hence, there is precedence and benefit for the use of public-domain codes.

MODFLOW/MODPATH/MT3DMS are public domain codes that the EIS Project is using as the model platform for saturated zone analyses . MicroFEM is a proprietary code that is available for purchase, and has been used at Hanford primarily for P&T design and optimization. CFEST is a proprietary, PNNL-developed code that has been used at Hanford historically for site wide and local-scale fate and transport simulations. STOMP is a PNNL-developed, open source code that state and federal regulators can obtain for free to use with limited-liability for PNNL. Further, STOMP is used for CSM development at ZP-1/PW-1, and the code will also be used for vadose zone modeling in support of the site wide EIS.

The Review Team recommends that public domain codes be favored for compliance decisions. In cases where public domain tools do not provide the best option from a technical, or an ease-of-use standpoint, the Review Team recommends that alternative codes/techniques be utilized that are easily available via purchase, widely used, well documented, and generally accepted by the regulator community. Open source codes that are not commercially available, that have been used on other projects, and are readily available for independent validation and testing should also be considered if such tools are made fully accessible for free to all site stakeholders and contractors working for those stakeholders. An example would be modeling or calculations performed in a spreadsheet. During the Review Team's site visit, an EPA Region 10 regulator noted that it is important for Hanford stakeholders to be able to independently run the models to visualize results, verify input files, and verify predictions.

5.3.2 Use Relatively Simple Modeling Tools and Approaches for the FS

The Review Team recommends the use of relatively simple modeling tools and approaches to support the FS effort, as compared to data-intensive and computational-intensive codes, such as STOMP. Reasons include the following:

- FS evaluations require comparisons of potential remedial alternatives, and relatively simple tools allow for iterative "what-if" comparisons to be performed.

- Simpler modeling is sufficient for the FS evaluation, can be completed by CY 2007, and this approach fits the overall FS schedule.

The Review Team recommends that the modeling evaluations for the FS be performed with simpler representations of the actual system, such as uniform background flow direction, uniform hydraulic conductivity distribution, etc. In some cases, analytical solutions may be utilized. Alternatively, numerical codes such as MODFLOW can be applied using very simple model construction and parameter assignment. In either case, uncertainties can be represented and bounded by performing multiple simulations using ranges for model input parameters (e.g., high hydraulic conductivity case and low hydraulic conductivity case), and/or conservative values. This should allow the feasibility of competing remedial alternatives to be evaluated within the FS, and for different alternatives to be compared to each other within the FS. The Review Team envisions that more sophisticated modeling would subsequently be employed during remedial design.

5.3.3 Use Simple Modeling Assumptions and Approaches for the FS to Conservatively Determine the Fate and Transport of Contaminants Beyond a Target Capture Zone With Respect to POC Locations

As discussed in Section 5.2.3, one remedial approach favored by the Review Team is to use groundwater extraction for hydraulic containment of the most impacted portion of the CT plume, with natural remediation for the portion of the plume beyond the zone of hydraulic containment (schematically illustrated previously in Figure 5.1).

The Review Team recommends the use of simple transport models to evaluate attenuation of contaminant concentrations between the Target Capture Zone and the POC locations. The transport modeling would include dispersion, adsorption, decay, and a declining source term over time, as a result of the hydraulic containment. To perform this modeling, a potential boundary for the Target Capture Zone would be specified for a specific scenario (e.g., 100 µg/L contour for CT), and POC location. The plume concentrations outside the zone of capture could then be represented as a vertical plane of highest concentration using an analytical approach, or as a matrix of initial concentrations using a numerical approach. The simulation would then predict the contaminant concentrations over time, with respect to distance towards the POC locations. If concentrations at POC locations remain acceptable for a reasonable range of parameter assignments (e.g., hydraulic conductivity, hydraulic gradient, decay rates), then the potential Target Capture Zone being evaluated (and the related concentration of contaminants beyond that Target Capture Zone) would be considered acceptable for the FS evaluation.

This simple transport modeling can be performed with analytical solutions, or numerical models. Analytical models for consideration include BIOCHLOR (Aziz et al. 2002) and AT123D:

- BIOCHLOR is a public domain code distributed by USEPA over the internet (http://www.epa.gov/ada/csmos/models/biochlor.html). BIOCHLOR is an easy-to-use screening model that simulates remediation by natural attenuation. Although specifically designed for dissolved solvents at chlorinated-solvent release sites, the software can be applied for other contaminants, including radionuclides. The software (programmed in the Microsoft Excel spreadsheet environment, and based on the Domenico analytical solute transport model) has the ability to simulate 1-D advection, 3-D dispersion, linear adsorption, and reductive dechlorination--the dominant biotransformation process at most chlorinated solvent sites. Reductive dechlorination is assumed to occur under anaerobic conditions, and dissolved solvent degradation is assumed to follow a sequential first-order decay process. BIOCHLOR includes three different model types:

1. Solute transport without decay

2. Solute transport with biotransformation modeled as a sequential first-order decay process

3. Solute transport with biotransformation modeled as a sequential first-order decay process with two different reaction zones (i.e., each zone has a different set of rate coefficient values)

Radionuclide decay can be represented as first-order, with no sequential decay (i.e., a rate constant is only applied for the parent compound). One excellent feature of BIOCHLOR is the option to use a separate first-order decay term to represent a declining source term. This approach may be applicable to the scenario at 200-ZP-1, since the source of dissolved contamination in the area being modeled (i.e., beyond the zone of hydraulic capture) will be eliminated by the hydraulic containment, and therefore will decline over time.

- AT123D is a widely used analytical code in the regulatory community. AT123D was originally developed by G. T. Yeh in 1981 at Oak Ridge National Laboratory. AT123D is a generalized, analytical three-dimensional groundwater transport and fate model. It simulates contaminant transport under one-dimensional groundwater flow. Transport and fate processes simulated include advection, dispersion, diffusion, adsorption and biological decay. Contaminant transport can be simulated without biological decay, or with biodegradation simulated as a first-order decay process.

  Results can be used to estimate how far a contaminant plume will migrate and can be compared to groundwater standards at specific locations and times. AT123D can handle the following: two kinds of source releases (instantaneous, continuous with a constant loading, or time-varying releases); three types of waste (radioactive, chemicals, or heat); four types of source configurations (point source, line source parallel to the x-, y-, z-axis, area source perpendicular to the z-axis, or a volume source); and four variations of the aquifer dimensions (finite depth and finite width, finite depth and infinite width, infinite depth and finite width, infinite depth and infinite width). There have been public domain versions of AT123D. For instance, it is part of a package of models to be included in the USEPA IGEMS package, currently in beta version (see http://www.epa.gov/opptintr/exposure/pubs/gems.htm). AT123D can also be purchased (less than $500) within the SeaView software package from Environmental Software Consultants, Inc., P.O. Box 2622, Madison, WI 53701-2622 (www.seaview.com).

This type of simple transport modeling can also be performed with numerical modeling, using simple parameter assignments to more closely approximate the ease of use of an analytical solution. If a numerical approach is utilized, the Review Team recommends MODFLOW/MT3DMS, which is public domain software that is widely utilized. The advantage of the numerical approach is that some complexity (e.g., heterogeneities, vertical layering, and an initial concentration matrix) can be incorporated. However, incorporating these types of complexities is not consistent with the simple modeling approach recommended.

The Review Team believes that the analytical transport modeling, or simple numerical transport modeling scopes described above can be completed within weeks to less than 2 months, consistent the schedule for modeling within the FS. More sophisticated numerical transport modeling, with more rigorous handing of site-specific heterogeneities, would be anticipated for the remedial design.

5.3.4 Use Simple Flow Modeling for the FS to Estimate Pumping Locations and Rates Required for Hydraulic Containment

Once a Target Capture Zone is identified, an estimate of the potential number of wells and pumping rates will be required to achieve the desired level of capture.

During the Review Team site visit, it was stated that the interim P&T system currently operates at a total extraction rate of approximately 290 gpm, predominantly from wells screened in the shallow portion of the aquifer. It is envisioned that the full-scale remedy will include more well locations, including pumping from deeper intervals. It was also stated that a potential future pumping rate of 1,000 gpm has been informally estimated.

As a first approximation, the Review Team performed a simple calculation of the amount of water flowing through the 100 μg/L CT plume, Q, using Darcy's Law:

$$Q = K*(w*b)*i$$

K = 50 ft/day (approximate hydraulic conductivity)
w = 6,000 ft (approximate width of 100 μg/L contour perpendicular to flow)
b = 200 ft (approximate saturated aquifer thickness)
i = 0.0016 (approximate hydraulic gradient)

Q = 96,000 ft^3/day = 500 gpm

This calculation provides a first estimate for the amount of pumping that might be required if the100 μg/L contour is selected as the Target Capture Zone. Ranges of parameter values could be utilized to develop a range of potential pumping rates. It is possible that 1,000 gpm is too high a pumping rate.

A next-level modeling analysis would incorporate similar parameter values, plus a background flow direction, to simulate capture zones at specific well locations with pumping rates assigned. As stated previously, the Review Team recommends that extraction wells be located in areas of highest concentrations for one or more contaminants. Thus, specific pumping strategies can be simulated using likely well locations for the full-scale system (based on high concentration areas), with the resulting simulated capture zones (composite) compared to the Target Capture Zone. Again, this could be done for a reasonable range of parameter values to assess uncertainties. In addition, each scenario could be simulated using end-member directions of background flow, since flow directions have been changing over time due to long-term operational changes at Hanford. In this manner, potential pumping strategies highlighted in the FS could be demonstrated to likely achieve successful capture over time as the background hydraulic gradient changes (i.e., increasing rates at some locations and decreasing rates at other locations over time to maintain successful capture).

For these types of evaluations to be performed within the FS, simple modeling with either analytical solutions or numerical models is recommended. If analytical techniques are employed there are many available code choices including:

- WhAEM2000 (public domain - http://www.epa.gov/ceampubl/gwater/whaem/)

- WINFLOW (for purchase – Environmental Simulations International, see website http://www.groundwatermodels.com/)

- TWODAN (for purchase – Fitts Geosolutions, see website http://www.fittsgeosolutions.com/twodan.htm)

Each of these codes is widely used. There are other codes that provide similar capabilities. The primary advantage of these analytical codes is they are easy to apply. Although these codes are used to represent simplified conditions, they do in some cases, allow for minor heterogeneities and/or layering. If these types of methods are utilized, the evaluation will need to address the handling of partially penetrating extraction wells For instance, the analysis might include the extent of vertical capture from a partially penetrating well as a function of distance from the well, to demonstrate whether or not partially penetrating wells effectively capture water from the full aquifer thickness.

If numerical modeling is employed, the Review Team recommends MODFLOW in conjunction with MODPATH. These are public domain codes. The advantage over the analytical codes is more flexibility regarding potential heterogeneities, layering, and partially penetrating wells. For instance, the aquifer can be divided into several layers, such as the three layers used for the capture zone modeling with MicroFEM. Particles could be released in each of the three layers and tracked forwards. The particle locations captured by each extraction well can then be plotted. This approach effectively illustrates the three-dimensional capture zone associated with partially penetrating wells.

The current MicroFEM numerical model, used for capture zone illustration, could also be used. However, this model as currently employed, goes beyond the simple type of modeling suggested. It incorporates site-specific layering and parameter variation associated with the site wide CFEST modeling. While this may offer some advantage, it may also compromise the intent of the Review Team recommendation of basing the FS evaluations on simple (i.e., uniform) geometries and parameter assignments.

The Review Team believes that the analytical transport modeling, or simple numerical transport modeling described above can be completed within weeks to less than 2 months, consistent the FS schedule.

5.3.5 Foster and Adhere to Open, Two-Way Communication with the EIS Modeling Team; Maintain Consistency Regarding Parameter Values to the Extent Possible

In the future, the MODFLOW/MT3D platform being developed for the site wide EIS will provide an excellent framework for simulating local-scale scenarios (based on the anticipated 25-meter spacing), or an excellent basis for developing "telescoped" local-scale models. However, this platform will not be available for use until January 2008, and therefore, will not be available for the FS modeling. Nevertheless, the Review Team recommends that the FS modeling group openly communicate with the EIS modeling group, and vice versa, so that consistency regarding parameter values (such as hydraulic conductivity) will be maintained to the extent possible. This will require effective two-way communication. The FS group will have to recognize that the EIS values may change after the FS is completed. The EIS group will need to recognize the FS group needs to proceed with an evaluation prior to the EIS model being complete, and should provide interim data/results from their work even though it is not final. Modeling efforts by the FS team and the EIS team may not use exactly the same parameter values based on the scale of the modeling efforts as well as tools used (i.e., analytical solutions versus numerical models). The Review Team recommends that a clear process be developed and clearly stated to allow for this type of open communication to occur, including a process for reconciling and resolving any inconsistencies that are identified between the two modeling efforts.

5.3.6 Continue with More Detailed Modeling (e.g., STOMP Simulations) to Improve the CSM and Better Interpret Performance Monitoring Data.

Although the Review Team is recommending simple modeling tools and approaches for the FS, efforts should continue in parallel for detailed modeling with STOMP to evaluate contaminant transport through the vadose zone. This modeling is critical for continued refinement of the CSM, and will facilitate interpretation of performance monitoring data. The Review Team also recommends that planning for more robust modeling in the design phase should begin now and be coordinated with the development of the remedy in the FS. In addition, as the EIS modeling nears completion, the EIS and FS teams should work together to transition the MODFLOW platform into the remedial design.

5.3.7 Institute Appropriate, Corporate-Level QA Procedures for Consistent Model Development and Application

Because of the public nature and high visibility of this work, it is essential that QA procedures for model development and application be funded and supported at the corporate level to assure consistency among projects. Two QA recommendations are made:

- For codes that are developed "in-house", such as STOMP, there should be a documented QA policy for the code development and distribution that pertains to code testing, code documentation, code update procedures, etc. If such a QA program does not exist for STOMP, or is not adequately documented, the Review Team recommends those items be addressed.

- For the application of any code, there should be a published QA policy for documenting assumptions and simulations (input and output) that are ultimately utilized for decision-making. If such a QA policy for documenting simulations does not exist for the FS and remedial design efforts, the Review Team recommends those items be addressed.

These actions will provide the regulators and stakeholders with assurance regarding the quality of simulations that are used as a basis for making decisions.

5.4 Groundwater Extraction and Treatment System

5.4.1 Continue Addition of New Deep Extraction Wells and Evaluate Capture Adequacy

The Review Team concurs with the addition of the new deep extraction well, and encourages the 200-ZP-1 team to further evaluate the adequacy of capture of the deeper contamination.

5.4.2 Continue Evaluation of the Vertical Extent of the CT Plume

The Review Team is particularly concerned about the fact that the CT plume's vertical extent now extends to the Ringold Unit A. It is assumed this issue will be further evaluated in developing remedial action objectives for the Feasibility Study.

5.4.3 Verify Acceptability of the Incomplete Capture of Injected Water

The ZP-1 project team should verify that incomplete capture of injected water is acceptable to all stakeholders. Adjustments, presumably to be made as part of the final remedy implementation, may be needed to address this. These adjustments, if necessary, may include locating additional injection points farther north than those existing injection wells coupled with balancing of the water distribution to improve control of injected water. Alternatively, the final remedy may include more treatment steps that would address other contaminants, if that is determined to be necessary.

5.4.4 Further Study Treatment Plant Staffing Commensurate with Duties and Cost

It is strongly recommended that DOE commission a study by an independent consultant to evaluate the duties performed by the Operations' staff at the100 and 200 areas. The study should closely evaluate the types and number of staff personnel required, commensurate with the actual duties performed.

The current plant is generally operated in a fully automated mode, but can operate in the full manual mode, if necessary. Operators spend approximately 4 hours per day at the plant. There are currently 9 operators, and a total of 14 Operations'personnel responsible for 7 plants in the 100 and 200 areas. A previous evaluation done in 2004 indicated the number of operations personnel could be reduced. Since that time, the number of Operations' personnel has increased from 11 to 14 persons, without adding any treatment facilities. Cost of operation less any new capital costs for the ZP-1 facility, and not including monitoring costs, is approximately $1,000,000 annually.

5.4.5 Retrofit the Extraction Wells with Variable Speed Controls

The Operations staff should consider outfitting the well pumps with variable speed controls to reduce heat buildup in the motors at wells that are throttled. Equipment similar to that used at other plants in the 100 Area could be used. Pumps without variable speed controls must be rebuilt more frequently at timescales ranging from 6 months to 6 years. The most prevalent causes of failure are bearings, and motor burn out. Biofouling in the injection and extraction wells has not occurred.

5.4.6 Discontinue Use of the Real Time Analyzer for Monitoring the GAC Units, and Ambient Air within the Plant

Discontinue the use of the real time analyzer for monitoring the GAC units, and ambient air within the plant. The existing analyzer equipment is old and requires significant resources to keep operating properly. GAC change-out has generally been very predictable. Fluor Hanford can develop a strategy to manually sample the GAC units which takes advantage of 10 years of operational data and allows the use of simple, low-tech methods. Continuous ambient air monitoring in a remediation equipment building such as this is very rare. One of the FH Certified Industrial Hygienists can evaluate the historical data, do a site inspection, and develop a method which meets standard industrial practices. If necessary, one or more of the operators assigned to facility maintenance can be trained in the use of a flame ionization detector to monitor CT in the building.

5.5 Soil Vapor Extraction System Recommendations

5.5.1. Continue Periodic Operation of the SVE

The Review Team concurs with periodic operation of the SVE system at the Z-9 crib and Z-1A tile field locations. The rebound periods allow for cost-effective operation, as well as assessment of the progress in removing mass from the low-permeability zones. Based on the observed rebound concentrations, the remaining CT mass is concentrated in fine-grained layers of the CCU. These units occur at depths of 35-45 m (115-148 ft), as well as units at about 20 m (66 ft) and 28 m (92 ft) below the surface, based on a plot of vertically discrete sampling results. Contaminant mass will continue to slowly diffuse out of these zones over time.

5.5.2 Focus SVE Above and Below the CCU

The Review Team recommends that vapor extraction from the vadose zone be focused just above, and more importantly, below the CCU. Extraction wells with screened intervals just above or below the Cold Creek Unit are preferred, provided the wells are located horizontally in the contaminated area. The Project Team should consider the use of the Pneulog tool (Praxis Environmental Technologies, undated) to assess the intervals yielding air and contaminant mass to the various extraction wells. Focused air flow will minimize the effort, and cost for electricity and carbon needed to remove the available diffusing mass. Praxis Environmental Technologies can provide estimates of the mass located in diffusion-limited zones based on the rebound vapor concentrations following cessation and restart of the SVE. A description of the recommended approach, extracted from the USACE SVE and Bioventing Engineer Manual (USACE, 2002), is attached as Appendix D.

5.5.3 Assess the Contaminant Loading to Groundwater from Vapor Transport

Based on the results of the Pneulog surveys and rebound analyses, an assessment of the impact to groundwater from CT in the vadose zone should be made at each potential release area. The STOMP model can be used to perform this assessment using a reasonable range of critical parameter values. The remaining CT mass subject to vapor transport and subsequent dissolution in groundwater may not pose a significant threat over the time frame needed for remediation. If that is determined with reasonable certainty, based on model results for reasonable ranges of parameter values, then SVE operations can cease. The Project Team may conduct an economic analysis, as the Air Force has done at the former McClellan AFB, that considers the cost of continued SVE relative to the non-discounted, incremental cost of groundwater treatment to determine if continued SVE treatment is warranted.

5.5.4 Reconsider the Use of In-Situ Thermal Treatment

Consideration of in-situ thermal treatment for CT removal within the CCU was discussed with the Review Team, with a potential cost in the tens of millions of dollars. The current cost of SVE is estimated to be less than $500 K/yr. The Review Team recommends that the Project Team not pursue thermal treatment for CT removal in the vadose zone at this time, until the recommendations provided herein are implemented and evaluated for efficacy. If the remaining CT mass in the vadose zone does not pose a significant long-term threat to groundwater, then there is little benefit to an aggressive and expensive approach such as thermal treatment. If the remaining CT mass in the vadose zone does pose a significant long-term threat to groundwater, then the relative protectiveness and cost of continued, or expanded SVE operations, should be compared to that for thermal treatment. The Review Team believes that continued SVE, and focusing SVE below the CCU, will cost-effectively remove mass diffusing from the fine-grained materials. This mass would be prevented from migrating to the water table. SVE operations are far less expensive than the implementation of thermal treatment, with equal protectiveness to groundwater.

5.5.5 Discontinue Use of the Real Time Analyzer for Monitoring the GAC Units

The Review Team recommends that the Project Team consider termination of the use of the autosampler and analysis system, if the system requires significant maintenance. Manual samples taken with simple instruments, such as a photo ionization detector, can be used and supplemented with TO-15 samples analyzed at a fixed lab.

5.6 Suggestions for Technical Improvement

The following suggestions are offered to improve data visualization and interpretation related to contaminant plumes.

5.6.1 Prepare Concentration Contour Maps (Plan View) For Multiple Layers Within The Ringold Unit E (Shallow, Medium, Deep)

The Review Team noted that contaminant plume distributions were presented as “cutaways” or “slices” of three-dimensional visualizations in many of the documents and presentations provided. Examples include Figures 3-6 to 3-12 of the Draft RI Report (Byrnes and Miller 2006). The presentation of data in this format has several key limitations:

- It is difficult, or impossible, for the reader to align the interpreted plumes with basemap features.

- Although dots representing monitor well locations are provided, they are not labeled. Therefore, the reader cannot discern specific data points used to develop the interpretations.

For the Ringold Unit E, which is the primary aquifer of concern, the Review Team suggests categorizing monitor wells into shallow, medium, and deep intervals for the purpose of contouring contaminant distributions. Separate contour maps should be prepared for each of these depth intervals, with data point locations clearly indicated. This will allow the reader to more easily understand the vertical distribution of concentrations, and the density of data points used to develop the interpretations. Plan view, depth-discrete contour maps can be supplemented with cross-sections or three-dimensional visualizations to improve presentation quality.

5.6.2 Post Measured Concentration Values on Concentration Contour Maps

The Review Team noted that many of the presentations of contaminant plume distributions did not include postings of the actual data values. For example, Figure 3-14 of the Draft RI Report (Byrnes and Miller 2006) is a plan view presentation and comparison of interpreted contours for CT distribution at the water table in 1990 versus 2004. However, these maps do not provide the locations, or values of data utilized for construction. The reader cannot evaluate the reasonableness of the interpretation, or determine alternate interpretations given the limitations of the data presented. Ideally, contour maps include both location labels and data values.

5.6.3 Prepare Contaminant Concentration Maps for the Aquifer Below the Ringold Mud (Ringold Unit A)

Contaminant distribution data presented to the Review Team did not clearly indicate the presence of contaminants in the Ringold Unit A, which is below the Ringold Lower Mud Unit. For instance, "cutaways" or "slices" of three-dimensional visualizations similar to Figures 3-6 to 3-12 of the Draft RI Report (Byrnes and Miller 2006) do not clearly indicate if they include the Ringold Unit A, or if they only extend to the top of the Ringold Lower Mud Unit. However, cross sections presented to the Review Team similar to Figures 4-37 to 4-38 of the same report do indicate contamination within the Ringold Unit A, as well as discontinuities where the Ringold Lower Mud Unit is not present.

The Review Team recommends that a plan view contour map of plume contamination in the Ringold Unit A be constructed for each contaminant. Posting the locations and data values used for the map will allow the reader to evaluate the density of data and alternate interpretations.

Table 1 Summary of Recommendations

Paragraph	Recommendation
5.1 Revisions to the Conceptual Site Model	
	1 Evaluate the value added of the prompt evaporation study.
	2 Take rapid action to inhibit migration of Tc-99 to the water table.
5.2 FS Strategy Recommendations	
	1 Present and evaluate two conceptual models within the FS regarding potential for DNAPL below the water table to act as a continuing source of dissolved contamination.
	2 Focus on expanded P&T as primary remedial technology for groundwater.
	3 Develop a strategy with hydraulic containment for most impacted portion, with compliance at POC locations beyond capture zone based on modeling & monitoring.
	4 Establish POC locations as soon as possible.
	5 Include costs of sentinel well drilling and monitoring.
	6 Locate extraction wells primarily in areas of highest groundwater impacts.
	7 Use the FS and proposed plan to establish a flexible framework for modifying pumping configuration and monitoring configuration.
	8 Determine as soon as possible if treatment for co-contaminants will be required.
5.3 Modeling	
	1 Use commonly applied and publicly-accessible modeling tools whenever possible, ideally those in the public domain.
	2 Use relatively simple modeling tools and approaches for the FS.
	3 Use simple modeling assumptions and approaches for the FS to conservatively determine the fate and transport of contaminants beyond a target capture zone with respect to POC locations.
	4 Use simple flow modeling for the FS to estimate pumping locations and rates required for hydraulic containment.
	5 Foster and adhere to open, two-way communication with the EIS modeling team and maintain consistency regarding parameter values to the extent possible.
	6 Continue with detailed modeling (e.g., STOMP simulations) to improve the CSM and better interpret performance monitoring data.
	7 Institute appropriate corporate-level QA procedures for consistent model development and application.
5.4 Groundwater Extraction and Treatment System	
	1 Continue addition of new deep extraction wells and evaluate capture adequacy.
	2 Continue evaluation of the vertical extent of the CT plume.
	3 Verify acceptability of the incomplete capture of injected water.
	4 Further study treatment plant staffing commensurate with duties and cost.
	5 Retrofit the extraction wells with variable speed controls.
	6 Discontinue using the real time analyzer for monitoring the GAC units, and ambient air within the plant.

Table 1 Summary of Recommendations, Continued

Paragraph	Recommendation
5.5 SVE System	
	1 Continue the current strategy of periodic operation of SVE.
	2 Focus SVE just above and below the Cold Creek Unit.
	3 Assess the contaminant loading to groundwater from vapor transport
	4 Reconsider use of in-situ thermal treatment.
	5 Discontinue use of the real time analyzer for monitoring the GAC units.
5.6 Suggestions for Technical Improvement	
	1 Prepare concentration contour maps (plan view) for multiple layers within the Ringold Unit E (shallow, medium, deep).
	2 Post measured concentration values on concentration contour maps.
	3 Prepare contaminant concentration maps for the aquifer below the Ringold Mud (Ringold Unit A).

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Appendix
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200-UP-1 and 200-ZP-1 Monitoring Network Figure, Central Mapping Services/Fluor Hanford, Inc., March 2006

200-ZP-1 Interim Remedial Measure Remedial Design Report, U.S. Department of Energy, Richland Operations Office, February 2006

Waste Management Plan for the Expedited Response Action for 200 West Area Carbon Tetrachloride Plume and the 200-ZP-1 and 200-PW-1 Operable Units, U.S. Department of Energy, Richland Operations Office, October 2005