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Response to the First Five-Year Review Report for the Test Reactor Area, Operable Unit 2-13, at the Idaho National Engineering and Environmental Laboratory

May 2005

Idaho Completion Project

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Prepared for the
U.S. Department of Energy
DOE Idaho Operations Office

ABSTRACT

The *First Five-Year Review Report for the Test Reactor Area, Operable Unit 2-13, at the Idaho National Engineering and Environmental Laboratory* concluded that the selected remedies implemented under the *Final Record of Decision Test Reactor Area Operable Unit 2-13* were protective of human health and the environment. The First Five-Year Review Report also identified several issues that warranted further investigation to ensure the continued effectiveness of the selected remedies. These issues included the recurrence of diesel in Well PW-13, increasing Co-60 in Well PW-12, increasing Sr-90 in several perched-water wells, continued usage of the Test Reactor Area facility beyond the 2007 closure assumed in the pre-Record of Decision model, and fluctuations in perched-water chemistry. Investigative activities included fieldwork, modeling, and conceptual model research. The activities concluded that the identified issues do not affect the selected remedies. Other activities, including a Track 2 investigation of a release site that is potentially related to the Sr-90 activities, are ongoing and will be completed in the next fiscal year. Findings from the Track 2 investigation will be detailed in a Track 2 summary report. Additionally, the advancement of weed control and establishment of better native vegetative cover is currently being pursued through the updating of planning and methods described in PLN-611, "Sitewide Noxious Weed Management." The revision of this plan is expected to be completed during the next fiscal year and is not discussed in this report.

SUMMARY

The *First Five-Year Review Report for the Test Reactor Area, Operable Unit 2-13, at the Idaho National Engineering and Environmental Laboratory* (DOE-ID 2003) concluded that the selected remedies implemented under the *Final Record of Decision Test Reactor Area Operable Unit 2-13* (DOE-ID 1997a) were protective of human health and the environment. The First Five-Year Review Report also identified several issues that warranted further investigation in order to ensure the continued effectiveness of the selected remedies. Those issues include the recurrence of diesel in Well PW-13, increasing Co-60 activities in Well PW-12, increasing Sr-90 activities in several perched-water wells, extended use of the Test Reactor Area (TRA) facility beyond the 2007 closure date that was assumed for the pre-Record of Decision (ROD) calculations, large fluctuations in perched-water chemistry, and the establishment and maintenance of desirable vegetation on native soil covers for the Sewage Leach Pond and Chemical Waste Pond. This report details the investigation and activities completed for each of the identified issues with the exception of the ongoing vegetative cover issue. The establishment and maintenance of desirable vegetation are addressed elsewhere. Additionally, a Track 2 investigation regarding a release site is ongoing and the summary report is scheduled to be completed during the next fiscal year.

The sporadic recurrence of diesel fuel at Well PW-13 was investigated through historical research and sampling. Two new wells also were drilled and installed to monitor the perched-water body proximal to PW-13. The investigation indicates that the diesel recurrence is due to subsurface cycling of diesel fuel from a historical leak. There is no evidence of a new diesel fuel leak. The diesel probably entered the subsurface from a historical leak in a fuel transfer line, identified in a Track 2 investigation of PW-13 and a Track 1 investigation of the fuel transfer line. The cycling of the diesel into and out of PW-13 is likely to occur for a period of years and passive collection of the diesel is recommended on a trial basis for 1 year.

A geochemical investigation was conducted to explore the observed large fluctuations in the perched-water chemistry. The investigation served several purposes, including the fingerprinting of the various zones in the perched-water body, identification of source water, characterization of subsurface geochemical conditions, and definition of hydrogen and oxygen isotope ratios of the perched water. Sampling of perched-water wells and selected aquifer wells was conducted in March 2004 to provide a completed data set for this effort. The investigation indicates that the perched-water body consists of several different water types. The major sources include the Cold Waste Ponds, the Chemical Waste Pond, and water similar to the Snake River Plain Aquifer (SRPA). The similarity between the SRPA water and water collected from perched-water wells at TRA seems to indicate that raw SRPA water might be leaking from utility pipes. Although the recharge sources to the perched water do not contain contaminants, the infiltrating water does provide a mechanism for contaminant migration.

Increasing Co-60 activities were identified in samples collected from Well PW-12. The March 2003 activity exceeded the maximum contaminant level (MCL) of 200 pCi/L. Subsequent samples collected from the well indicated decreasing activities and were below the MCL. This investigation indicated two potential causes for the unexpected increase in Co-60 activities; both potential causes are transient. The fluctuating activities could be the result of changing subsurface conditions. Transient changes in water chemistry could cause more residual Co-60 to be mobilized and transported in flow toward the well, thereby causing the higher activities observed in the well. When the water chemistry returns to baseline conditions, Co-60 levels will decrease. Alternatively, historically documented and investigated release sites near Well PW-12 have left some residual Co-60 contamination in the subsurface. Changes in the location and rate of water infiltrating through residual contamination could cause fluctuations observed in PW-12. The increase and subsequent decrease in Co-60 in PW-12 have

occurred at least once in the past and it seems that spikes in Co-60 in PW-12 may continue to occur until the residual contamination has decayed away or the perched-water body dissipates.

The spike in Co-60 measured in PW-12 is consistent with the conceptual model of the site and does not warrant further investigation. Continued monitoring is recommended. Six mechanisms were identified in the first five-year review as potentially controlling the fluctuations in contaminant concentrations in certain perched-water wells. The mechanisms include (1) adsorption/desorption occurring with changing perched-water levels, (2) changing flow pathways in response to remediation and fluctuations in discharge to the Cold Waste Pond (or between alternating cells), (3) seasonal variations of natural infiltration at a local scale, (4) variations in recharge from unidentified manmade sources, (5) lateral flux from the Big Lost River, or (6) new leaks of contamination from unidentified sources. Of the six mechanisms considered, it was concluded that the variable discharge to the Cold Waste Pond likely was the primary cause for the observed fluctuations. The variations in discharge to the ponds and the changes in discharge location as the pond use is rotated likely cause the perched-water system to change significantly. The investigation also indicated that new sources for the contaminants in question are highly unlikely.

A review of modeling efforts performed in support of the ROD also was conducted. Simulations were run using the original modeling code and assumptions in confirmation of the original predictions. The model was then run using updated assumptions, most importantly the extended operational life of TRA, which includes extended period of discharge to the Cold Waste Ponds. The updated assumptions also were used in a second set of simulations that employed a state-of-the-art, commercially available modeling code. The input from both modeling codes indicated that the remedy would remain protective of human health and the environment, even with the extended operational life of the TRA. New modeling, assuming an extended operational life of 2024, predicted that all contaminants of concern were projected to be well below their MCLs by 2115, the date used for the future-use risk assessment.

The investigations into the issues raised during the completion of the first five-year review did not reveal evidence or information that would negate the remedies selected in the ROD (DOE-ID 1997a). The selected remedies remain protective of human health and the environment. Although the investigations did not negate the remedy, they did provide recommendations for future actions.

Recommendations are made suggesting individuals supporting Comprehensive Environmental Response, Compensation, and Liability Act activities at TRA take the following actions: (1) stay abreast of ongoing research into the TRA facility during closure for issues that might affect groundwater quality, such as Voluntary Consent Order operations; (2) maintain a current knowledge of improvements in modeling software that may allow for more accurate modeling of the TRA subsurface; (3) conduct periodic reviews of new developments in hydrogeologic and geochemical research that may be relative to the TRA subsurface; and (4) perform installation and monthly maintenance of petroleum traps in three perched-water wells. The findings also support the recommended monitoring defined in the *Groundwater Monitoring Plan for the Test Reactor Area Operable Unit 2-13* (DOE-ID 2004a) in accordance with the ROD (DOE-ID 1997a).

CONTENTS

FIGURES

TABLES

ACRONYMS

amsl	above median sea level
bls	below land surface
BTEX	benzene, toluene, ethylbenzene, and xylene
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	*Code of Federal Regulations*
COC	contaminant of concern
CWP	Cold Waste Pond
DEQ	[Idaho] Department of Environmental Quality
DOE	U.S. Department of Energy
DOE-ID	U.S. Department of Energy Idaho Operations Office
DR	dual rotary
EPA	U.S. Environmental Protection Agency
ETR	Engineering Test Reactor
GMWL	global metoric water line
ICP	Idaho Completion Project
ID	identification
INEEL	Idaho National Engineering and Environmental Laboratory
INTEC	Idaho Nuclear Technology and Engineering Center
INWIMIS	INEEL Nonradiological Waste Management Information System
MCL	maximum contaminant level
MTR	Materials Test Reactor
ND	not detected
NM	not measured
OU	operable unit
PZNPC	point of zero net proton charge

RCT	radiological control technician
ROD	Record of Decision
SRPA	Snake River Plain Aquifer
TRA	Test Reactor Area
USC	*United States Code*
USGS	United States Geological Survey
VCO	Voluntary Consent Order
WWP	Warm Waste Pond

Response to the First Five-Year Review Report for the Test Reactor Area, Operable Unit 2-13, at the Idaho National Engineering and Environmental Laboratory

1. INTRODUCTION

The purpose of the *First Five-Year Review Report for the Test Reactor Area, Operable Unit 2-13, at the Idaho National Engineering and Environmental Laboratory* (DOE-ID 2003) was to evaluate and determine whether the remedies prescribed by the *Final Record of Decision Test Reactor Area Operable Unit 2-13* (DOE-ID 1997a) are expected to remain protective of human health and the environment. The selected remedy was found to be protective in the short term; however, the First Five-Year Review Report (DOE-ID 2003) identified several issues requiring more in-depth evaluation to ensure protectiveness over the long term. These issues do not currently negate the remedy's protectiveness of the aquifer, but they must be evaluated prior to the second five-year review to ensure continued protection of human health and safety and the environment.

The remedy for the Test Reactor Area (TRA),[a] Operable Unit (OU) 2-13 at the Idaho National Engineering and Environmental Laboratory (INEEL)[b] included consolidating and capping contaminated sediments, removing contaminated materials, maintaining institutional controls, and monitoring the decrease of contamination in groundwater caused by radioactive decay, dispersion, and natural attenuation. The selected remedies and institutional controls were implemented in accordance with the OU 2-13 Record of Decision (ROD) (DOE-ID 1997a), as modified by the *Explanation of Significant Differences to the Record of Decision for Test Reactor Area Operable Unit 2-13* (DOE-ID 2000). Institutional controls and monitoring are implemented through the *Groundwater Monitoring Plan for the Test Reactor Area Operable Unit 2-13* (DOE-ID 2004a) and the *INEEL Sitewide Institutional Controls Plan* (DOE-ID 2004b) and reported through monitoring reports and annual institutional controls reports.

The purpose of this report is to (1) document the response actions taken to the issues identified in the first TRA five-year review, (2) present the findings from the response actions, and (3) satisfy requirements for follow-on activities driven by the first TRA five-year review. The second five-year review for TRA is required by September 2008—5 years from the date of the U.S. Environmental Protection Agency (EPA) review (EPA 2003). This requirement will be met by including TRA in the next INEEL Sitewide five-year review that is proposed for 2005.

The U.S. Department of Energy (DOE) is preparing this report pursuant to Section 121 of the "Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA/Superfund)" (42 USC § 9601 et seq.) and 40 *Code of Federal Regulations* (CFR) 300, "National Oil and Hazardous Substances Pollution Contingency Plan."

1.1 Summary of Issues Identified in the First Five-Year Review

After reviewing the First Five-Year Review Report (DOE-ID 2003), the EPA, Region 10, determined that the remedy for OU 2-13 currently protects human health and the environment because institutional controls are in place and functioning and because trends for contaminants of concern (COCs) in the aquifer are either below maximum contaminants levels (MCLs) or are projected to be below MCLs

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[a] The Test Reactor Area is now called the Reactor Technology Complex.

[b] The Idaho National Engineering and Environmental Laboratory is now called the Idaho National Laboratory.

by 2012, based upon data trends presented in the first five-year review, 4 years earlier than the date predicted by pre-ROD modeling. However, in order for the remedy to be protective in the long term, the EPA specified that several tasks would need to be completed before the next five-year review (EPA 2003). These actions are listed in Table 1 along with the response taken by the INEEL to address each issue.

The following sections of this report begin with a summary of the physical and hydrogeologic setting of TRA (Section 2). It is followed by Section 3 that describes the activities undertaken to define and understand the continued presence (since 1990) of floating diesel fuel on perched water near Well PW-13 (Section 3). Section 4 presents the geochemical investigation of perched and aquifer water at TRA performed to characterize various sources of water for the perched-water body. During the five-year review, Co-60 was observed in Well PW-12 to have increased to levels exceeding the MCL (the levels have since dropped below the MCL). The historical Co-60 levels in PW-12 are presented in Section 5 along with a detailed discussion of potential sources. Section 6 considers mechanisms that might cause concentrations of Sr-90 and Co-60 to rise and fall over periods of months to years, contrary to the anticipated continuous decline expected from radioactive decay and attenuation. Section 7 describes the numerical modeling activities undertaken to update the assumption in the ROD (DOE-ID 1997a) that the TRA would be decommissioned in 2007 and, thus, terminate the sources of the perched water (primarily the Cold Waste Pond [CWP]). A summary of the investigation is provided in Section 8, and recommendations are provided in Section 9.

2. PHYSICAL AND HYDROGEOLOGIC SETTING

The TRA was established in the early 1950s for the purpose of studying radiation effects on materials, fuels, and equipment. A general map of TRA and the surrounding vicinity with monitoring wells and waste disposal ponds is shown in Figure 1. For reference, the area within the double security fence at TRA is about 1,700 × 1,900 ft (approximately 70 acres). The TRA is located on an alluvial plain consisting of surficial sediment with thickness ranging from 30 to 75 ft. A series of basalt flows interbedded with sedimentary deposits of eolian and fluvial origin underlie the surficial sediments. The sedimentary interbeds vary in both thickness and lateral extent. The basalt contacts, often rubbly and highly vesicular, are typically very permeable, water-bearing intervals in both the perched-water zones and the underlying Snake River Plain Aquifer (SRPA). The basalt/sediment interfaces and the unfractured, massive basalts in the centers of flows have much lower permeabilities and act as aquitards and perching layers. The combination of complicated geology, a semiarid climate (~8.7 in. annual precipitation), and infiltration from anthropogenic sources leads to a thick vadose zone (~450 ft thick) that contains perched-water bodies of varying size.

This section provides background regarding the hydrologic setting at TRA. Section 2.1 describes the physiographic setting. Lithology and stratigraphy are provided in Section 2.2. The main perched-water bodies are described in Section 2.3 and the underlying SRPA is described in Section 2.4.

2.1 Physiographic Setting

The TRA is situated within the INEEL at a location approximately 8 mi east of the Lost River Range promontory on the Snake River Plain of southeastern Idaho (Figure 2). The land surface at TRA is gently sloped to the southwest and is relatively flat with elevations ranging from 4,945 ft on top of a rubble pile in the CWP to 4,908 ft at the bottom of the Chemical Waste Pond. The TRA is located on thick deposits of alluvial gravels associated with the relatively flat floodplain of the Big Lost River. The

Table 1. Summary of five-year review issues and Idaho National Engineering and Environmental Laboratory responses.

Issue from Five-Year Review	Summary of INEEL Response	Reference
Perform a field characterization effort to identify the extent and source of diesel in the PW-13 perched-water well.	Investigated potential diesel sources, installed two new perched-water wells near Well PW-13, sampled new wells and selected existing wells for dissolved constituents of diesel fuel, evaluated natural attenuation of diesel, and performed analysis of natural mechanisms for “cycling” diesel in the subsurface.	Section 3 of this report
Perform a geochemical investigation to fingerprint various water sources at TRA to correlate sources of water to perched-water wells.	Performed additional sampling of perched and aquifer wells, examined the distribution of contaminants in the perched water to determine sources of contaminants, characterized water sources based on major ion chemistry and oxygen and hydrogen isotope data to determine water sources, evaluated flow paths using oxygen and hydrogen isotope data and major ion chemistry data, and combined information on contaminant sources and water sources to characterize perched-water bodies.	Section 4 of this report
Perform a systematic analysis to identify the source of increasing Sr-90 and Co-60 in the perched water.	Investigated potential sources for Co-60 near Well PW-12, evaluated historical contaminant trends in perched-water wells, assessed natural mechanisms that might create nonidealized behavior, and examined new research suggesting that nonideal behavior may be a characteristic common to fractured rock vadose zones.	Sections 5 and 6 of this report
Evaluate the impacts of continued TRA operations on the perched-water system and the assumptions used in the OU 2-13 ROD (DOE-ID 1997a).	Developed a water budget for water use at TRA, updated the pre-ROD model with new operational scenario, and developed a new vadose flow and transport model using a commercially available, modern numerical simulator.	Section 7 of this report
Revise the Groundwater Monitoring Plan (DOE-ID 2004a) based on monitoring data.	Modified the Groundwater Monitoring Plan (DOE-ID 2004a) and reduced the number of analytes to include only chromium, tritium, Sr-90, and Co-60 and to include one round of sampling for Tc-99 and I-129.	Groundwater Monitoring Plan (DOE-ID 2004a)
Address improved establishment of desirable native vegetation and control of intrusive species on the covers at the site.	Actions are planned to control intrusive weed species to enhance the covers’ structural integrity by providing greater resistance to erosion and animal intrusion.	Draft update in May 2004 of PLN-611, “Sitewide Noxious Weed Management,” December 2002. Revision to be PLN-1313, “Weed Control and Revegetation Status Report for Fiscal Years 2002 through 2004 and Schedule for Fiscal Years 2005 and 2006 (Draft).”

DOE-ID = U.S. Department of Energy Idaho Operations Office
INEEL = Idaho National Engineering and Environmental Laboratory
OU = operable unit
PLN = plan
ROD = Record of Decision
TRA = Test Reactor Area

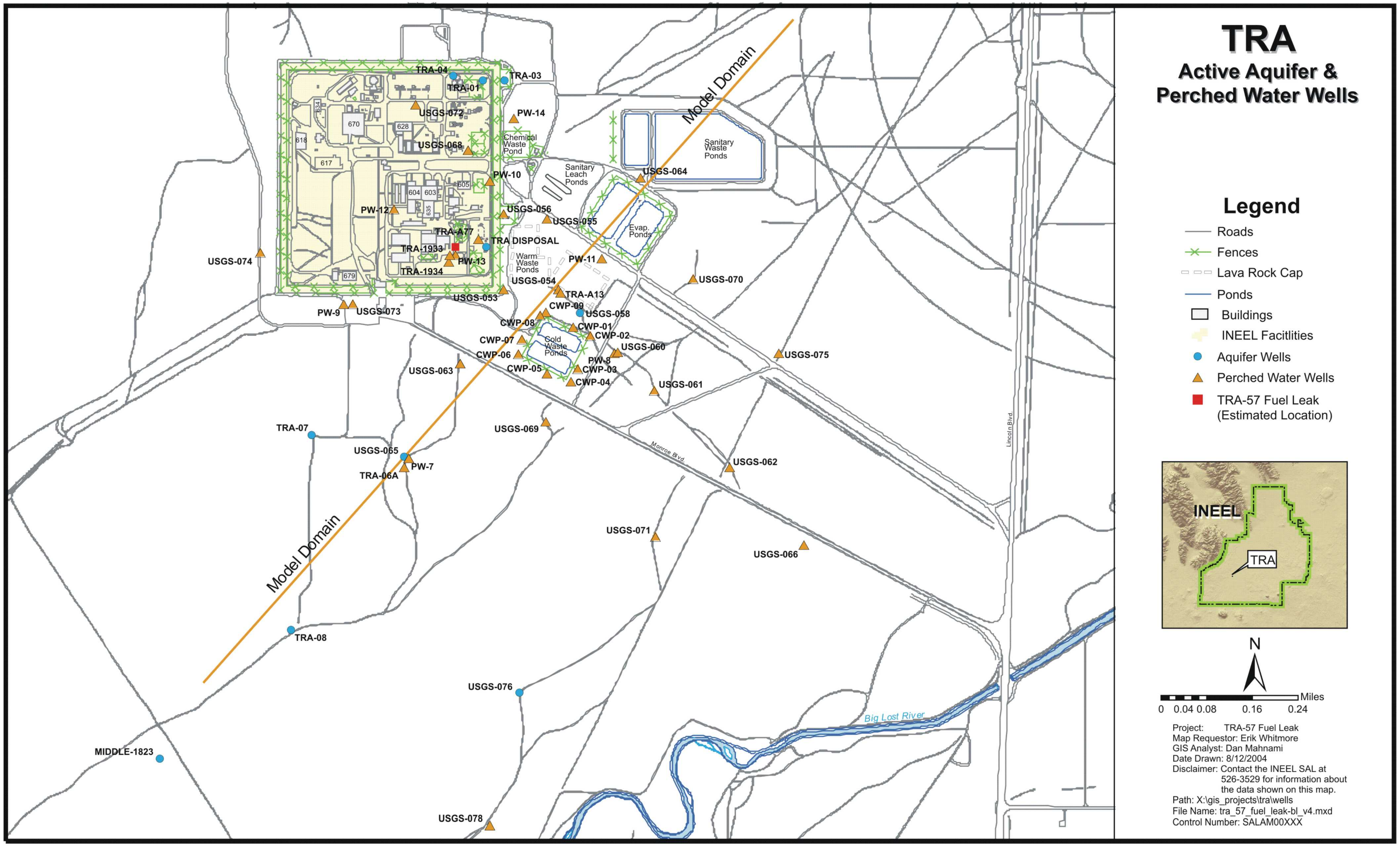

Figure 1. Map of the Test Reactor Area.

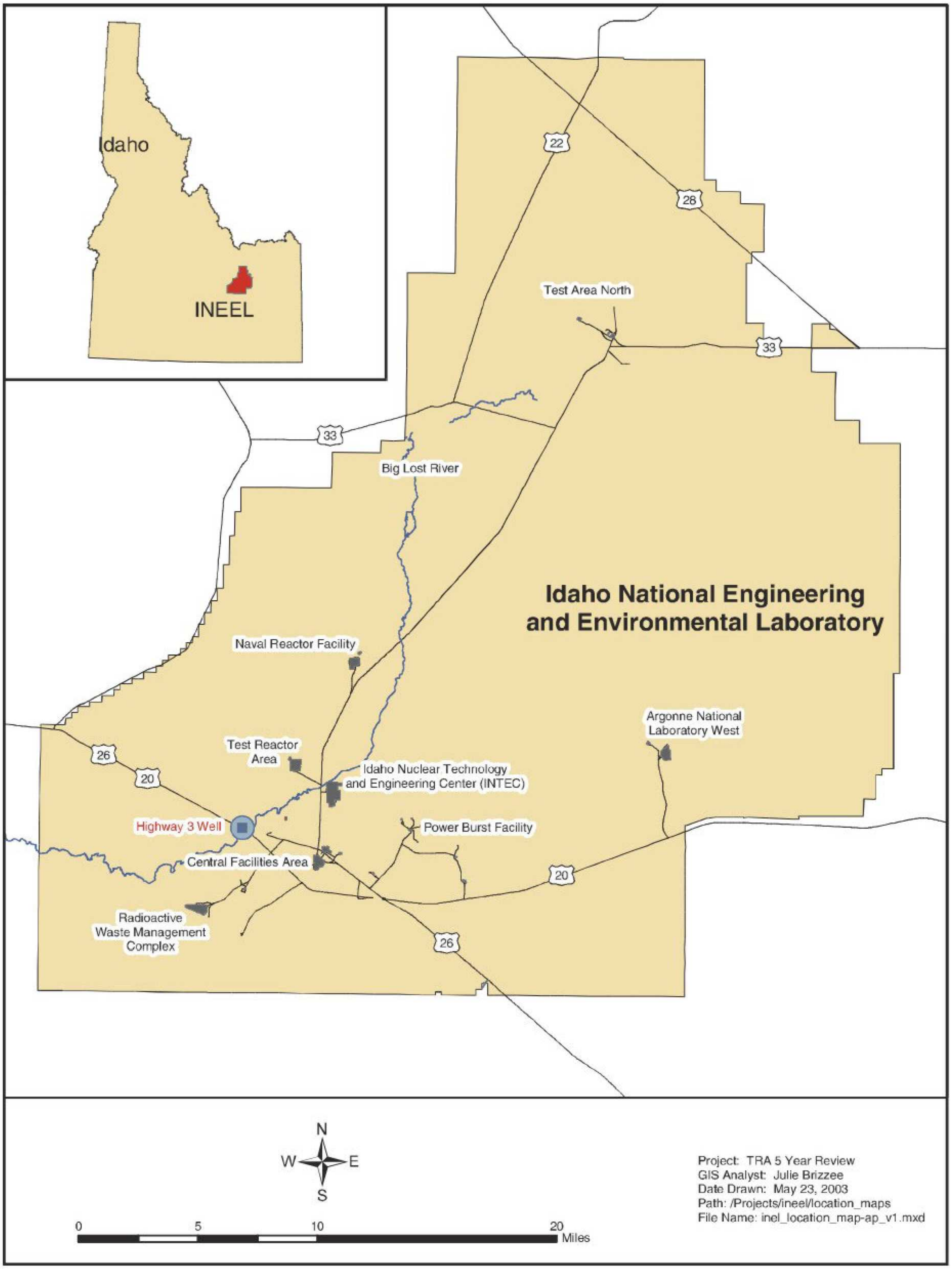

Figure 2. Map of Idaho showing the Idaho National Engineering and Environmental Laboratory and the Test Reactor Area.

channel of the Big Lost River is approximately 1 mi east-southeast of the TRA boundary, and the TRA lies outside of the 100-year floodplain. The Big Lost River flows on an intermittent basis, flowing during years with higher precipitation, mostly associated with snowmelt in mountainous drainages to the west.

The Big Lost River floodplain overlies the eastern Snake River basalt plain (Greeley 1982). This basalt plain was formed by eruption of basalts from low-shield volcanoes and vents. Overlapping flows and intercalated sedimentary deposits produced the complex stratigraphy underlying TRA (see Section 2.2). Geologic features adjacent to TRA include a series of volcanic rift zones, rhyolite domes, and other eruptive features (Anderson 1991). The Arco volcanic rift zone extends southeast across the southwestern part of the INEEL. The axial volcanic rift zone extends southwest across the southeastern part of the INEEL. The Lava Ridge volcanic rift zone extends southeast across the northern part of the INEEL. A series of rhyolite domes occur to the south. The AEC Butte is an eruptive feature immediately northeast of TRA that was the source for an areally extensive, thick basalt unit. The flat-lying character of the basalts and associated sedimentary units indicate that no significant tectonic activity occurred in the immediate vicinity of TRA.

2.2 Stratigraphy/Lithology at the Test Reactor Area

The stratigraphy at TRA consists of a complex stack of basalt flows intercalated with sedimentary deposits above a rhyolitic basement. The upper portion of the basalt-sediment stack is capped with a thick section of surficial alluvial/fluvial deposits. The surficial alluvial deposits are unconsolidated sediments laid down by the fluvial action of the nearby Big Lost River. The alluvial deposits (chiefly sands and gravels) rest atop the undulating surface of a massive basalt flow group; hence, the thickness of the alluvium varies throughout the area. Finer-grained sediments accumulated in local depressions in the basalt surface. In general, thickness of the alluvium ranges from about 32 ft in the northwest section of TRA to about 55 ft in the southern portion with a mean thickness of 49 ft (Anderson 1991).

A thick sequence of basalt flows and sedimentary interbeds lies beneath the surficial alluvium at TRA, extending to depths of 2,000 to 3,000 ft below land surface (bls). The basalt stratigraphy at TRA has been determined by thorough evaluation of cores and cuttings and by correlation of geophysical logs from over 70 wells completed in the eastern SRPA. A total of 17 basalt flow groups were identified, along with at least eight sedimentary interbeds. The basalt flows increase in thickness and decrease in hydraulic conductivity with depth. This decrease can be partially attributed to decreased interflow rubble zones and to secondary mineralization within fractures and other porous regions of the flows. Two interbeds within the vadose zone are of hydrologic significance. The first is located above the DE-4 basalt flow group at an approximate depth of 140 to 200 ft. The thickness of this sedimentary interbed measures approximately 60 ft, and it has been encountered in 14 of 17 wells drilled in the area. A second significant sedimentary interbed is encountered in Well USGS-65 at about 500 ft bls (INEEL 2003).

2.3 Perched Water at the Test Reactor Area

Shallow and deep perched-water bodies have formed in the vadose zone at TRA in response to infiltration of wastewater disposed of to unlined ponds. These perched-water bodies developed as the rate of infiltrating water exceeded the capacity of a low-permeability layer to transmit water. Barriers to the vertical migration of water induced a local saturated condition and lateral spreading of the perched water along the top of the low-permeability layer. The size or "footprint" of the perched-water body expanded until sufficient area was wetted to transmit the flux of infiltrating water. Alternatively, water might have "spilled" over the edge of a perching layer that is not laterally extensive. Thus, widespread layers with very low permeability formed larger perched-water bodies. The footprint and depth of the perched-water body increased or decreased as the rate of infiltration increased or decreased. Figure 3 is a conceptual drawing illustrating the development of perched water at TRA.

Discharge of water to the TRA ponds (see pond locations on Figure 1) is recognized to have contributed to the formation of the perched-water zones. Historically, the CWP, in service since 1982, has been the largest source of water to the perched-water zones. The average discharge rate to the CWP between early 1982 and late 1991 was 460 gpm. Since late 1991, discharges to the CWP have averaged 380 gpm. Prior to implementation of the CWP, the Warm Waste Pond (WWP), first constructed in 1952, had been the principle source of infiltration to the perched-water zones. The WWP continued to contribute a significant amount of recharge to the perched-water zone until it was taken out of service in 1993. Water used for landscape irrigation within TRA also has contributed to the perched water. In the past, other surface sources of water (including the former WWP, Sewage Pond, and the Chemical Waste Pond) contributed a much smaller amount to the subsurface. A history of liquid effluent discharge to ponds for the period of 1982–2003 is shown in Figure 4 (DOE-ID 2003).

Water-level trends in several perched-water wells correspond directly to the disposal rates to the CWP. The thickness and size of the two perched-water zones have changed over time, depending on the amount of water discharged to the ponds. The relationship between pond discharge and the footprint of the perched-water bodies has been tracked and described in numerous reports (e.g., EG&G Idaho 1989; EG&G Idaho 1991a; Dames and Moore 1992a).

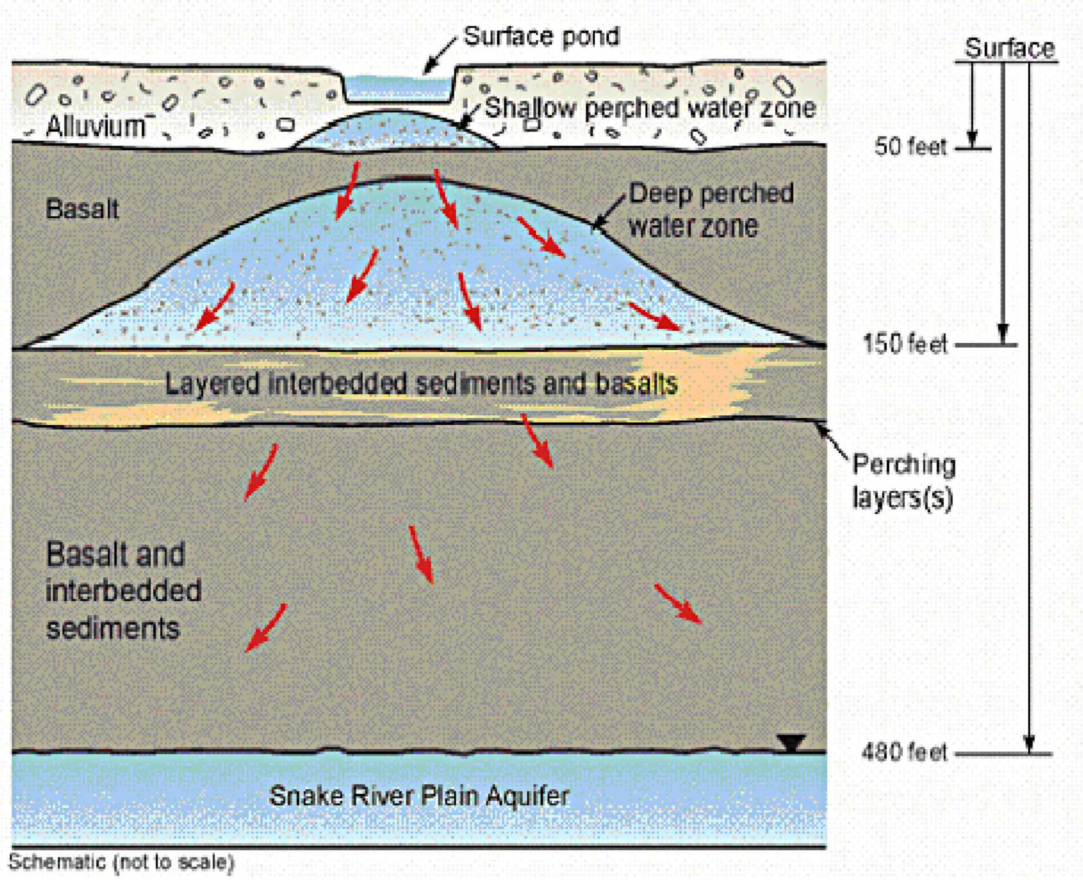

Figure 3. Conceptual diagram demonstrating perched-water formation.

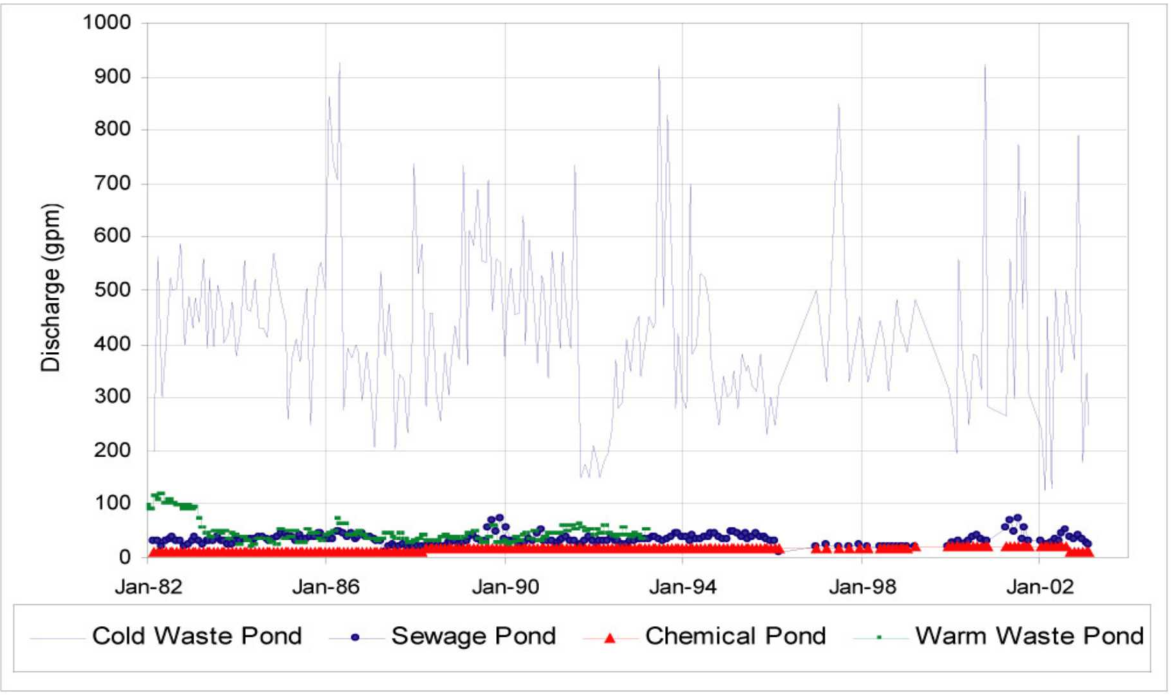

Figure 4. Graph of historic discharge to Test Reactor Area waste ponds.

A shallow perched-water zone formed on a layer of fine-grained sediments at the alluvial-basalt contact—about 50 ft bls. This zone is monitored routinely in 11 shallow wells (CWP-01 through CWP-09, TRA-A13, and TRA-A77) (see Figure 1). Because of variations in discharge to the pond(s), most of the shallow perched-water wells have shown episodic wetting and drying since 1990 (CWP-01 and CWP-09 have been continually wet over the period of record). When the WWP was removed from service in 1993 and replaced by a lined evaporation pond, the volume of infiltrating water was decreased slightly, as noted in Figure 4. The result of this decrease was small and made only a slight difference in the shallow perched-water zone's footprint.

The deep perched-water zone formed within a section between 140 and 200 ft bls consisting of low-permeability sediments, dense basalts, and basalt with sediment-filled fractures. Because the deep-perched zone has a larger footprint than the shallow perched zone, this layer's composite permeability is considered to be less than that of the perching layer for the shallow perched-water zone. Alternatively, the deep perching horizon may be of larger areal extent than that of the shallow horizon with vertical flow through the shallow horizon increasing at the edge of the perching layer perched-water zone. The deep perched-water zone is monitored by 17 wells that are sampled routinely for contaminants of concern.

A contour map was constructed showing the configuration of the deep perched-water zone in 1991. This map (Figure 5) was developed for the *Record of Decision Test Reactor Area Perched Water System Operable Unit 2-12, Idaho National Engineering and Environmental Laboratory* (DOE-ID 1992). The deep perched-water zone ranged in elevation from less than 4,750 ft above mean sea level (amsl) to greater than 4,860 ft amsl. The zone was elongated in a northwest to southeast direction and was

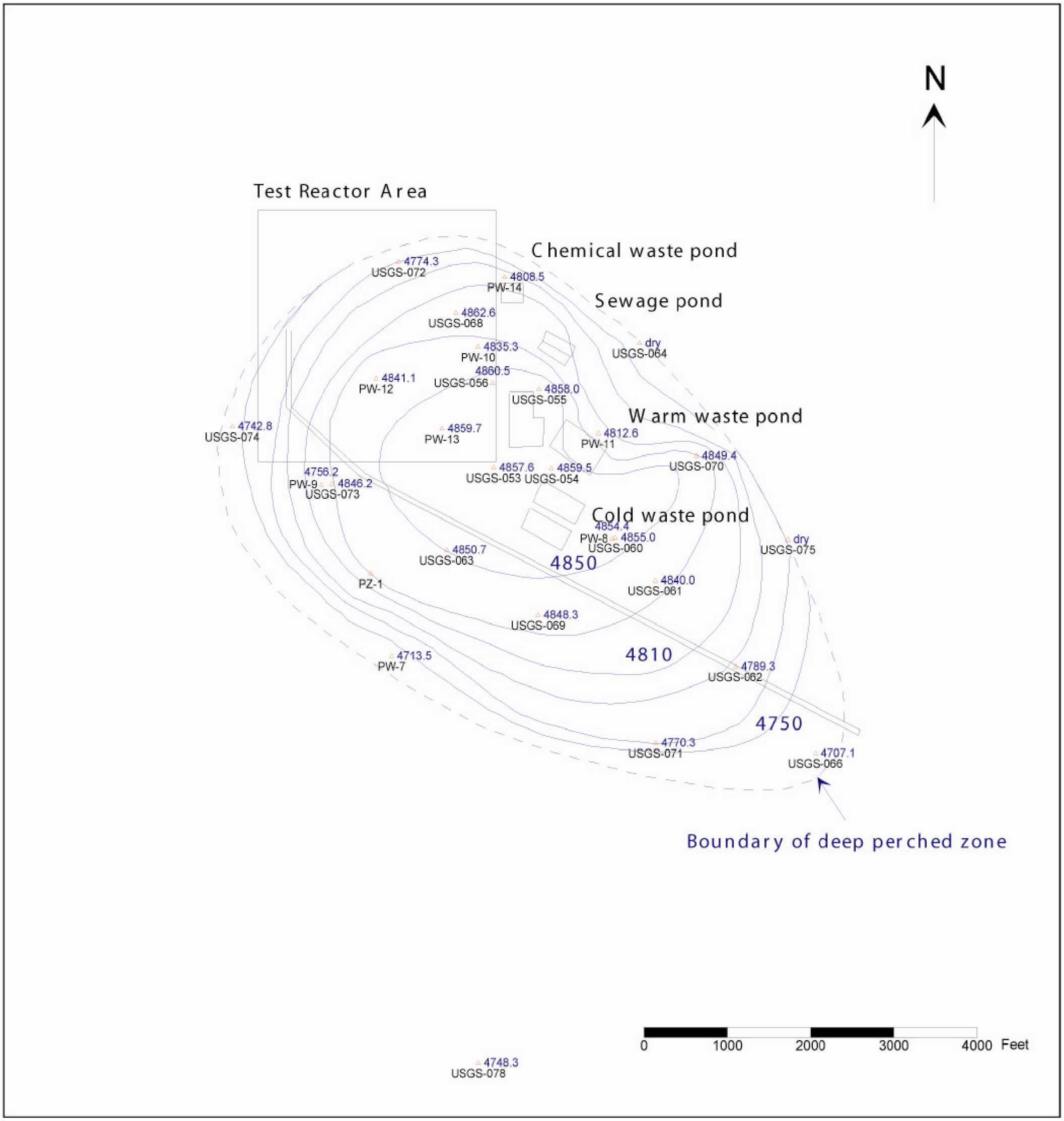

Figure 5. Configuration of the perched water at Test Reactor Area based upon 1991 water-level elevations.

characterized by a broad, flat top with steeply sloping flanks. The highest water levels were centered beneath the CWP and WWP. Figure 6 depicts the configuration of the deep perched-water zone 12 years later with contours on the surface of the deep-perched zone for November 2003. The deep perched-water zone was narrower and the elevations ranged from less than 4,730 ft amsl to greater than 4,850 ft amsl. Water levels had declined from the 1991 measurements and the highest water levels were centered beneath the CWP. Water-level declines are attributed to a slight decrease in discharge to the CWP between 1991 and 2003 and to discontinuation of disposal to the WWP in 1993.

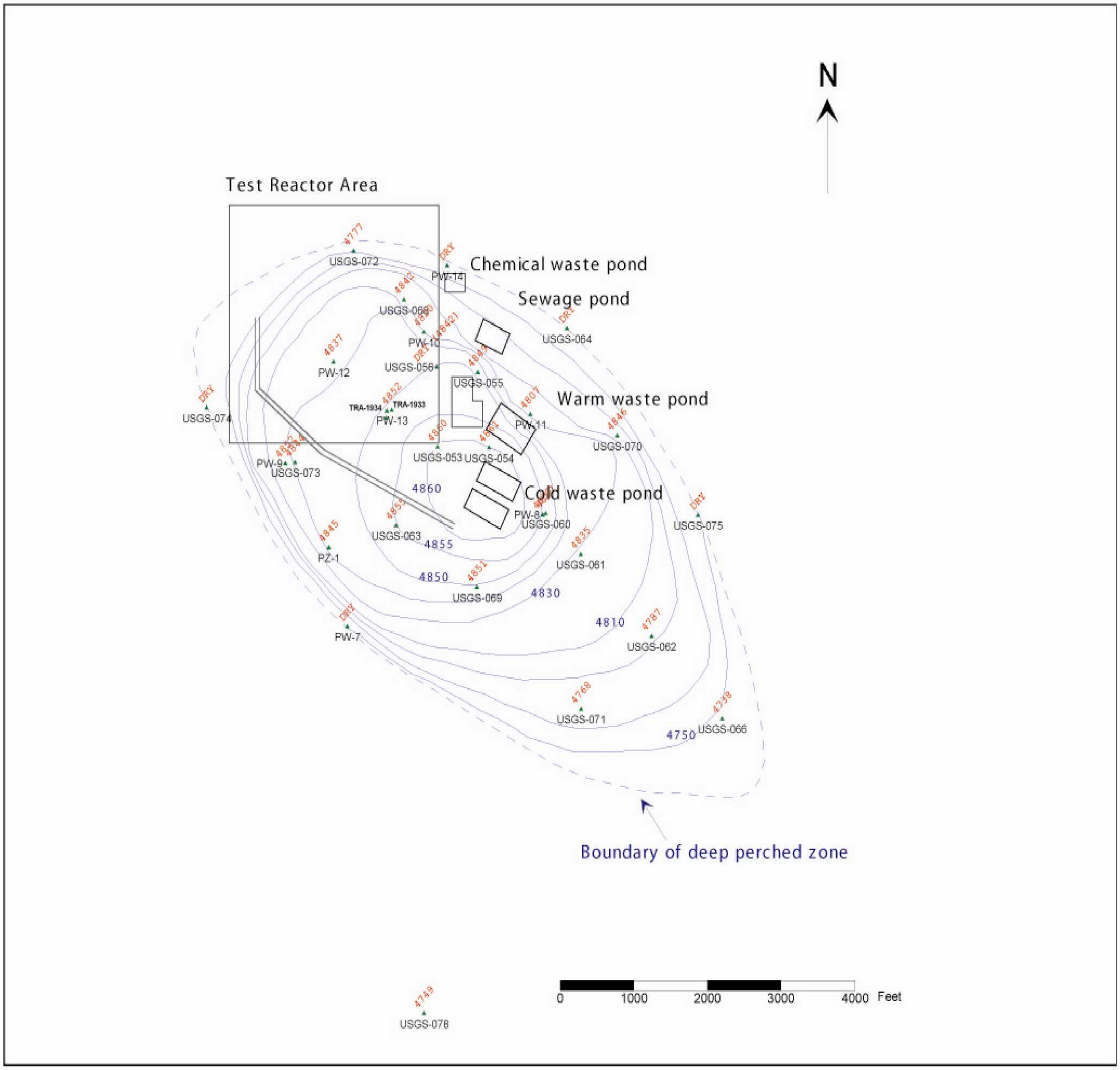

Figure 6. Configuration of the perched-water zone at Test Reactor Area, modified from November 2003 data.

2.4 Snake River Plain Aquifer at the Test Reactor Area

The SRPA is defined as the series of water-bearing basalt flows and the interlayered pyroclastic and sedimentary materials that underlie the eastern Snake River Plain east of Bliss, Idaho (EG&G Idaho 1989). The SRPA is approximately 200 mi long, 40 to 60 mi wide, and covers an area of 9,600 mi^2 (EG&G Idaho 1989). The aquifer is very permeable because of the presence of fractures, fissures, and rubble zones at contacts between individual basalt flows. On October 7, 1991, the EPA designated the SRPA as a sole-source aquifer under the “Safe Drinking Water Act” (42 USC § 300f to 300j-26). At TRA, the top of the SRPA occurs at a depth of approximately 480 ft bls.

Generally, groundwater in the SRPA flows to the southwest under the ambient hydraulic gradient (Figure 7). Figure 8 depicts the aquifer water table at TRA in October 2002. The inherent heterogeneity of the fractured basalt aquifer makes it very difficult to contour the water table, and local flow directions may vary significantly. Figure 8 also shows the inferred direction of groundwater flow at TRA. The direction of flow is inferred, because the aquifer’s highly heterogeneous nature creates anisotropy that can result in flow paths not perpendicular to the water-level contours. Fluctuating water levels caused by recharge and pumping further complicate determination of the local groundwater flow directions. Groundwater flow at TRA is generally to the southwest (Figure 8), but the local direction of flow and gradient of the water table varies in both time and space.

Infiltrating groundwater from the deep perched-water zone moves downward over a large diffuse area, probably under varying levels of saturation, until it intersects the upper surface of the SRPA. The perched-water recharge to the aquifer appears insufficient to cause local mounding, as this has not been observed in the TRA aquifer wells. Recharge is rapidly diluted in the SRPA because of the relatively fast (4.3 ft/day) rate of flow in the aquifer (EG&G Idaho 1991a). However, a thin, laterally extensive sedimentary layer located beneath the water table at a depth of 488 ft bls may restrict dilution locally beneath TRA. Wells USGS-065 and TRA-06A—although only approximately 100 ft apart—have different completion depths and, because of the sedimentary interbed, tap two different zones in the aquifer (see Figure 9). Well USGS-065 has an open-hole interval from 456–498 ft bls. Well TRA-06A is screened from 528–558 ft bls. As shown in Figure 9, the open interval of USGS-065 terminates in the interbed, tapping about 8 ft of the aquifer above the interbed. Conversely, the screened interval of TRA-06A is beneath the depth of this interbed with about 40 ft of filter pack exposed to the aquifer. It should be noted that the interbed was not noted during the drilling of TRA-06A. However, a rubble/cinder zone was encountered, possibly indicating an interflow zone that might contain a thin interbed. It may be possible that dilution of contaminants with aquifer water near USGS-65 may be restricted by sedimentary interbed. The presence of this sedimentary interbed, just beneath the water table, could explain the higher groundwater concentrations measured in wells completed above the interbed (DOE-ID 2003).

It is also possible that USGS-065 might have served as a vertical conduit for flow from the deep perched-water zone. In USGS-065, well casing (shown in Figure 9 as thick lines) extends to a depth of 456 ft bls with a grout seal extending from 456 to 355 ft bls. A string of outer casing extends from ground surface to 326.5 ft bls. A second grout seal extends from ground surface to 15 ft. The well completion is open hole. Under saturated or “perched-water” conditions, the open annulus behind the outer casing may provide a pathway for rapid vertical migration of water to the top of the seal at 355 ft. Sloughing and caving of the formation against the well casing would reduce this migration, but its presence is not documented. The perched water in the area of the wells has receded and PW-07 has been dry since October 1994. Unless the deep perched-water zone expands back into this area, future rapid vertical transport at this location will not threaten the aquifer’s water quality (DOE-ID 2003).

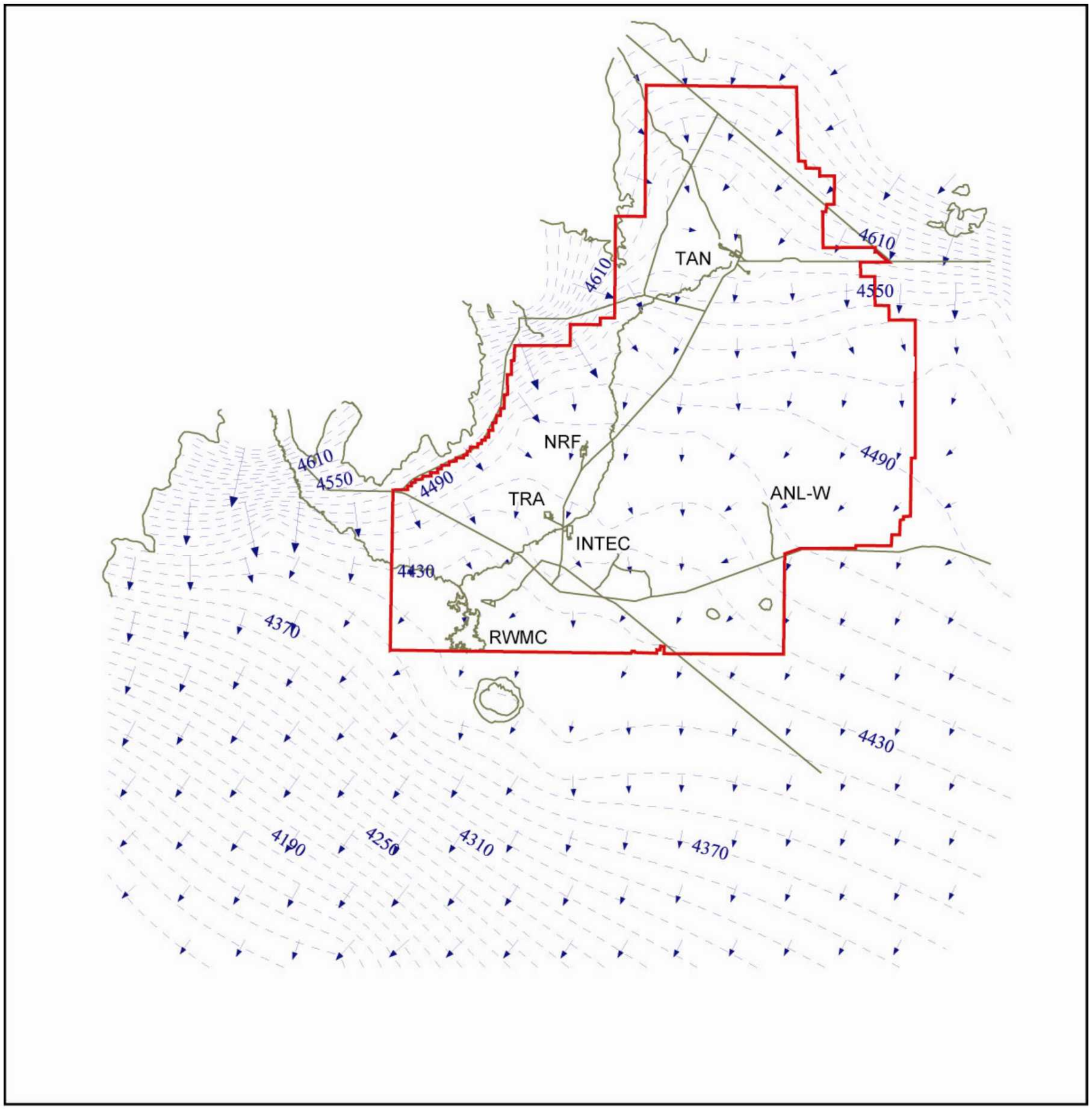

Figure 7. June 2004 water-table elevation contour map.

NOTE: *Water-table measurements are in feet above mean sea level for the Snake River Plain Aquifer in the vicinity of the INEEL with hydraulic gradient vectors (shown proportional to gradient magnitude).*

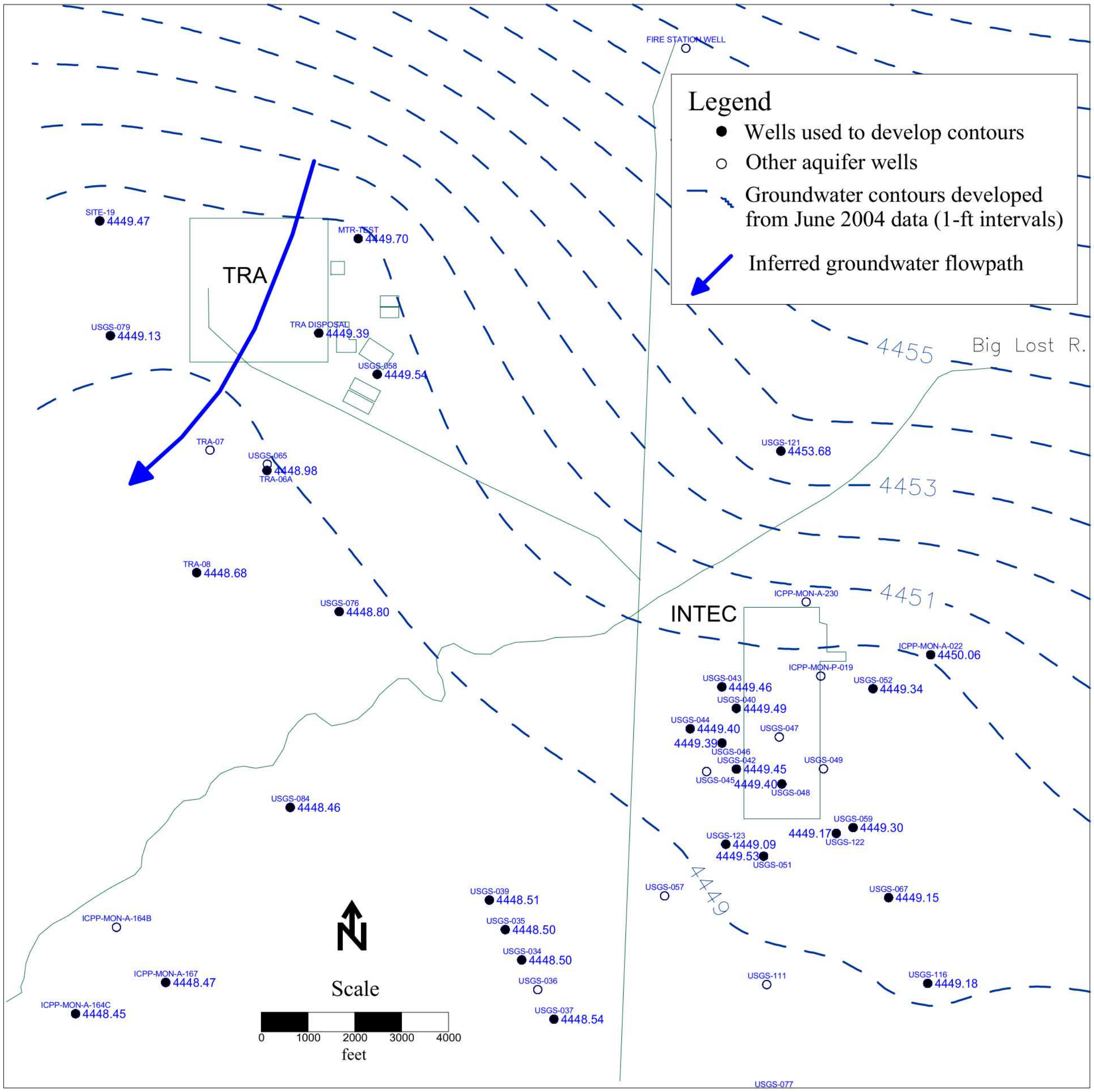

Figure 8. Snake River Plain Aquifer water-table configuration for June 2004.

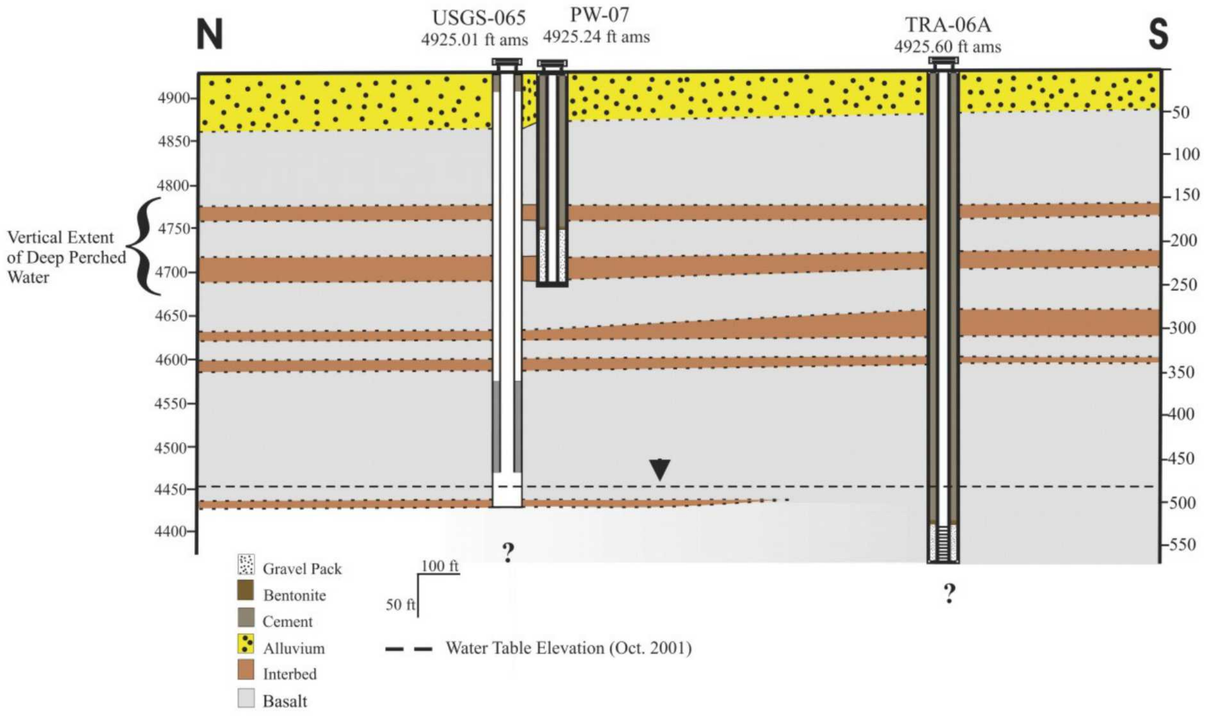

Figure 9. Generalized cross-section showing the stratigraphy at Wells USGS-065, TRA-06A, and PW-07.

3. WELL PW-13 DIESEL INVESTIGATION

3.1 Introduction

The First Five-Year Review Report (DOE-ID 2003) identified the recurrence of free-phase diesel fuel in the PW-13 TRA perched-water well as an issue. As a best management practice, the diesel contamination was further investigated to determine if the associated risk was greater than previously believed. This section documents that investigation. A short history of the diesel contamination at Well PW-13 is provided in Section 3.2. The drilling and installation of two new perched-water wells, TRA-1933 and TRA-1934, are detailed in Section 3.3. Analytical results from groundwater sampling in and around Well PW-13 are presented in Section 3.4. The extent of the diesel contamination is discussed in Section 3.5. Potential mechanisms for the recurrence of free-phase diesel in Well PW-13 are described in Section 3.6. The findings of this investigation are summarized in Section 3.7 and recommended actions are provided in Section 3.8.

3.2 Diesel Contamination at Well PW-13

Well PW-13 is located approximately 50 ft southeast of the Engineering Test Reactor (ETR) on the south end of Pike Street within TRA (see Figure 10). This well was installed in 1990 to monitor the deep perched-water zone. A layer of free-phase diesel fuel was discovered at the water surface of PW-13 during initial coring and was removed prior to well completion. The contamination at PW-13 was first investigated in 1994 as a Track 2 investigation (Sherwood et al. 1994). The PW-13 Track 2 investigation pointed to a diesel transfer line (TRA-57) as the source of contamination and a No Further Action determination was made. A subsequent Track 1 investigation of the TRA-57 transfer line recommended continued monitoring of PW-13 (INEEL 2002).

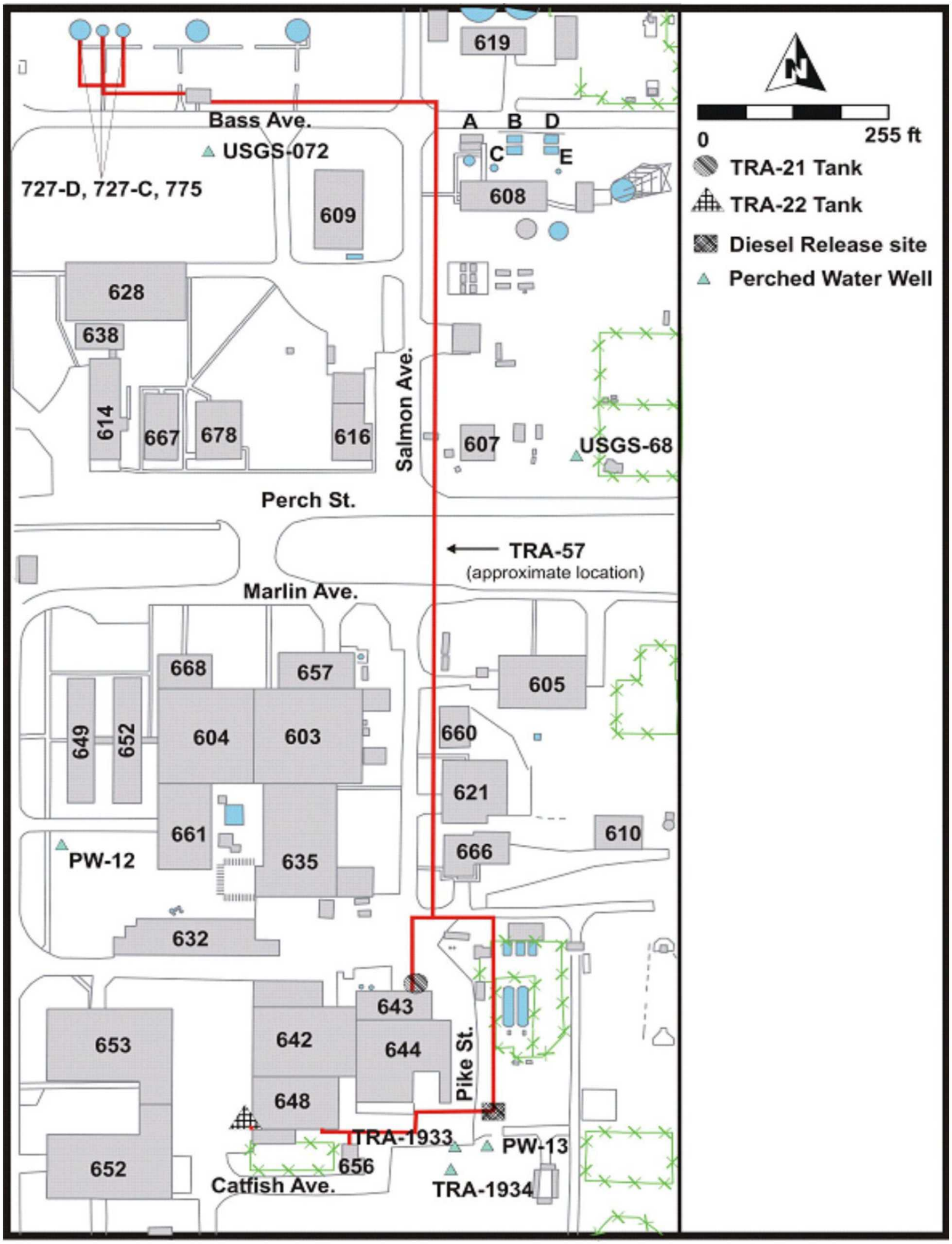

Figure 10. Map of the Test Reactor Area with well locations and the approximate location of the TRA-57 fuel transfer line and the diesel release.

Free-phase diesel fuel has been observed in PW-13 on several occasions since 1999. In each case, the floating diesel layer disappeared from the well without remediation. This section (Section 3.2) of the report details the installation of PW-13 and initial discovery of diesel (Section 3.2.1), history of the diesel contamination at PW-13 (Section 3.2.2), and the probable source as identified in the 1994 Track 2 investigation (Section 3.2.3).

3.2.1 Well PW-13 Construction and Completion

Information concerning the drilling and installation of Well PW-13 was compiled from the project logbooks, ERP-126-90 and ERP-60-90, unless otherwise noted.

Well PW-13 was drilled and cored in August–September of 1990. Surface casing was set to a depth of 42 ft bls with a tricone bit. The surface casing extends through the alluvium and penetrates approximately 3 ft into the underlying basalt. After the surface casing was grouted in place, the well was cored to total depth using an HQ barrel. Coring was halted at the end of the shift on September 5, 1990, at a depth of 145.2 ft bls. A diesel odor was noted on the first core pulled when operations resumed on September 6, 1990; operations were halted at this depth (148.5 ft bls). The onsite geologist did not note any diesel odor or staining on any of the core at the time of coring. The water level was recorded at 75.5 ft bls. The core hole was bailed intermittently over the next 2 months until recovery of free product ceased. A full history of the contamination at PW-13 is located in Section 3.2.2.

The core hole was grouted from 148.5 to 95 ft bls on November 8, 1990. The hole was then over reamed with a 9-7/8-in. drill bit from 42.0 to 97.0 ft bls on November 9, 1990. A bentonite seal was installed from 97.0 to 88.5 ft bls. Installation of the well began on November 14, 1990. A 0.020-in. slot, 4-in. stainless-steel well screen was installed from 87.5 to 57.5 ft bls; 4-in. wire-wrapped, stainless-steel well casing was installed from 57.5 ft bls to 2.5 ft above land surface; and a filter pack of 10 × 20 silica sand from 88.5 to 51.0 ft bls. A bentonite seal extends from 51.0 ft bls to the surface casing that was grouted in place at 42.0 ft bls. The well was developed on January 9, 1991. During development, 15 gal of water was bailed from the well, but no diesel contamination was noted. Figure 11 shows the well completion diagram and lithology for PW-13.

As part of the recent investigation, a review of the PW-13 core in December 2003 at the United States Geological Survey (USGS) Core Library also did not reveal any diesel odor or staining.

3.2.2 History of Diesel Contamination in Well PW-13

As stated above, diesel odor was noted during the coring of Well PW-13 on September 6, 1990. The core rods were removed, and samples of the floating product were collected for analysis. The initial samples indicated that the product was diesel fuel (EG&G Idaho 1990). Sampled free-product density was measured at 0.84 g/mL, which is near the diesel density of 0.827 g/mL. The increased density likely reflects the decay of gasoline-range aliphatic and cycloalkane hydrocarbons. A video log of the core hole completed after reaching total depth showed an approximately 8.5-ft-thick layer of free-phase diesel floating above the diesel-water interface at 75.5 ft bls (4,847.8 ft above mean sea level). The video log also showed what may have been diesel fuel entering the core hole from a fractured basalt zone at 47 ft bls, which is ~7 ft below the basalt-alluvium contact.[c] Over the next 6 weeks, the thickness of free-phase diesel in the core hole was measured. The free-phase diesel also was removed by bailing. Approximately 20 gal of diesel was removed between September 7 and November 9, 1990. The volume

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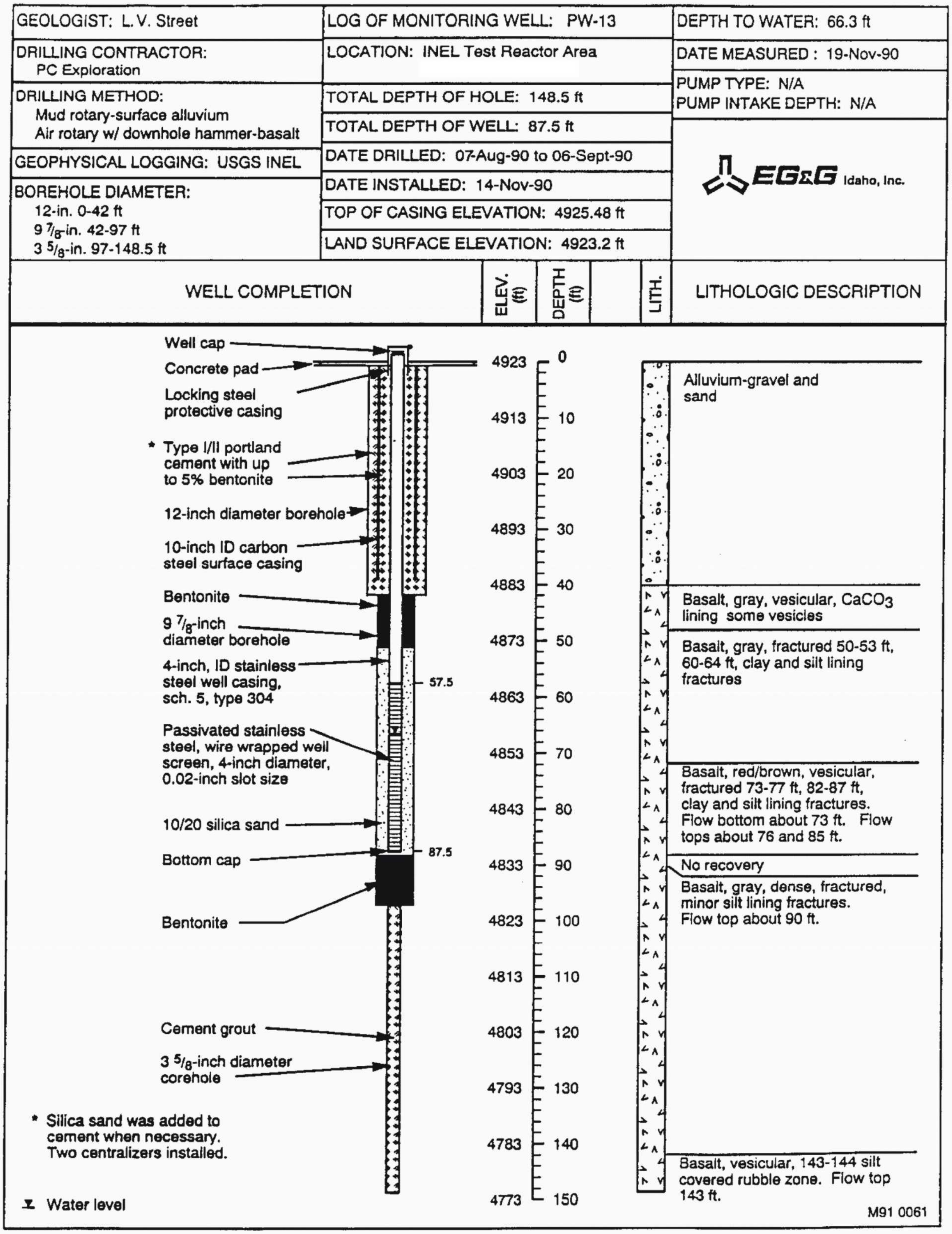
[c] INEEL Logbook ERP-126-90.



GEOLOGIST: L.V. Street

LOG OF MONITORING WELL: PW-13

DEPTH TO WATER: 66.3 ft

DRILLING CONTRACTOR:
PC Exploration

LOCATION: INEL Test Reactor Area

DATE MEASURED : 19-Nov-90

PUMP TYPE: N/A
PUMP INTAKE DEPTH: N/A

DRILLING METHOD:
Mud rotary-surface alluvium
Air rotary w/ downhole hammer-basalt

TOTAL DEPTH OF HOLE: 148.5 ft

TOTAL DEPTH OF WELL: 87.5 ft

GEOPHYSICAL LOGGING: USGS INEL

DATE DRILLED: 07-Aug-90 to 06-Sept-90

DATE INSTALLED: 14-Nov-90

BOREHOLE DIAMETER:
12-in. 0-42 ft
9 7/8-in. 42-97 ft
3 5/8-in. 97-148.5 ft

TOP OF CASING ELEVATION: 4925.48 ft

LAND SURFACE ELEVATION: 4923.2 ft

EG&G Idaho, Inc.

WELL COMPLETION | ELEV. (ft) | DEPTH (ft) | LITH. | LITHOLOGIC DESCRIPTION

Alluvium-gravel and sand

Basalt, gray, vesicular, $CaCO_3$ lining some vesicles

Basalt, gray, fractured 50-53 ft, 60-64 ft, clay and silt lining fractures

Basalt, red/brown, vesicular, fractured 73-77 ft, 82-87 ft, clay and silt lining fractures. Flow bottom about 73 ft. Flow tops about 76 and 85 ft.

No recovery

Basalt, gray, dense, fractured, minor silt lining fractures. Flow top about 90 ft.

Basalt, vesicular, 143-144 silt covered rubble zone. Flow top 143 ft.

* Silica sand was added to cement when necessary. Two centralizers installed.

⊻ Water level

M91 0061

Figure 11. Well completion diagram and lithology of the Test Reactor Area Perched-Water Well PW-13.

of diesel recovery in the core hole progressively decreased to a trace amount or thin film (van Deusen 1990; EG&G Idaho 1991a). When well construction was initiated on November 14, no diesel was noted in the core hole. Diesel was not noted during well development on January 9, 1991 (see footnote c).

Water level and diesel thickness in Well PW-13 were measured six times between December 1990 and April 1997, with no discovery of free product. The next measurement in November 1999 reported a 1.03-ft layer of floating diesel. Thickness of the floating diesel increased to 1.37 ft in February 2000, and then it began decreasing. No free product was measured in August 2000. A diesel thickness of 0.11 ft was measured in September 2000, but none was found in November 2000. Measurements made since June 2001 have indicated a continued presence of diesel until April 2004. Measurements made during this investigation have recorded diesel thicknesses of 3.3 ft and 1.2 ft in December 2003; in January 2004, 3.07 ft of diesel was measured. A measurement of the diesel thickness in April 2004 indicated that no measurable thickness was present in the well. However, Well PW-13 was sampled in March 2004 and the diesel may not have had sufficient time to accumulate in the well. A thickness of 2.98 ft was measured in the well in March prior to sampling; no further measurements were made until April 2004. Figure 12 shows the history of diesel thicknesses in PW-13.

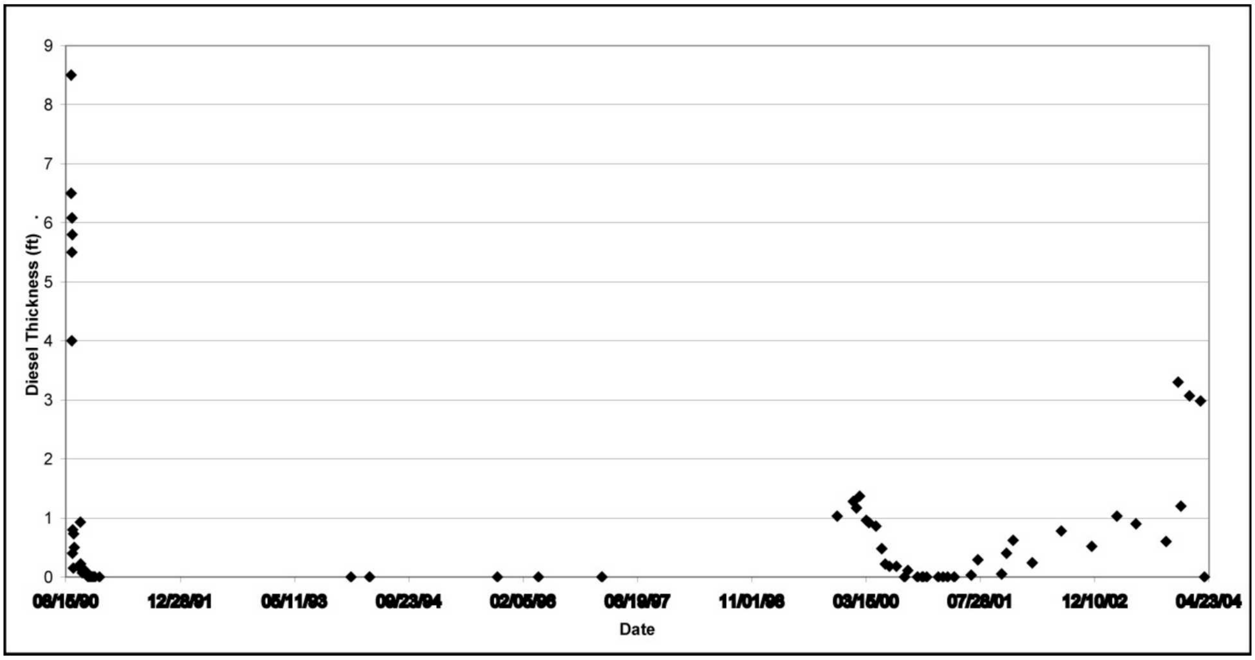


Figure 12. Measured free-phase diesel thickness in Well PW-13.

Well PW-13 is not a routinely sampled monitoring well and analytical data for the well are limited. Sampling of the water phase at PW-13 first occurred in 1990, shortly after the initial discovery of free-phase product. Initial samples collected from PW-13 in 1990 did not contain detectable concentrations of the aromatic hydrocarbon compounds benzene, ethylbenzene, or toluene, which are common constituents of diesel fuel. Ethylbenzene was found at a concentration of 5.41 µg/L in 1993, but had decreased to nondetectable concentrations by April 1994. Four samples collected in October 1995 contained ethylbenzene at concentrations ranging from 0 to 3.6 µg/L. The most recent previous samples, collected in June 2001, did not contain detectable concentrations of ethylbenzene. Benzene has only been detected once in Well PW-13. One of the four samples collected in June 2001 contained a concentration of 0.6 µg/L, while the remaining three samples did not contain detectable concentrations of benzene. The concentration of 0.6 µg/L (J flag) is near the reporting limit for the contaminant. Benzene has not been detected in previously collected samples or in subsequent samples.

Xylene (total), another common constituent of diesel fuel, was found at a concentration of 31,000 µg/L during the 1990 sampling (Johnson 1990). The relatively high xylene concentration seems to be anomalous when compared to the apparent absence of benzene, ethylbenzene, and toluene, also in 1990. This seemingly anomalous data point is unvalidated and unqualified. Subsequent samples collected in 1993 and 1995 did not contain detectable concentrations of xylene. Samples collected in November 2000 detected a concentration of 1 µg/L. The data were J flagged and are considered an estimate because of the uncertainty near the reporting limit. In June 2001, one of four samples measured 2 µg/L of xylene.

Sampling at Well PW-13 has shown the presence of diesel-range organics, also referred to as total petroleum hydrocarbons/diesel. Both sampling events since 1990 have indicated the presence of diesel-range organics. A May 2001 sample contained a concentration of 72,000 µg/L (J flagged for exceeding hold time). Samples collected in June 2001 contained concentrations of 7,300 µg/L and 83,000 µg/L. Gasoline-range organics, also referred to as total petroleum hydrocarbons/gasoline, were also collected during sampling. Analytical results from a May 2001 sample showed a concentration of 43,000 µg/L. The June 2001 sample indicated concentrations of 10,000 and 21,000 µg/L. With the limited number of samples collected, no clear conclusion can be determined as to an overall increase or decrease of the concentration of the contaminants.

3.2.3 Probable Diesel Source

A review of historical documents suggests that the source of the diesel in Well PW-13 is a 2-in. diesel transfer line (TRA-57). As shown in Figure 10, TRA-57 ran from the TRA-727 and TRA-775 storage tanks to the TRA-643, TRA-648, and TRA-656 ETR buildings (INEEL 2002). The fuel line was installed in the late 1950s and abandoned in the early 1980s. Two possible leaks may have occurred, one in 1980 and another in 1981. Both are documented in the *Preliminary Scoping Track 2 Summary Report for the Test Reactor Area Operable Unit 2-04: Fuel Spills* (Sherwood et al. 1994). The 1981 diesel spill also is documented in *Track 1 Sites: Guidance for Assessing Low Probability Hazard Sites at the INEEL, Site Description: Abandoned Buried Diesel Fuel Line from TRA-727 and TRA-775 to ETR, Site ID: TRA-57* (INEEL 2002). The latter report provides information that was not included in the abovementioned Preliminary Scoping Track 2 Summary Report (Sherwood et al. 1994). The information in the cited reports is not entirely consistent with respect to the dates and resolution of the leaks. The 1980 and 1981 leaks are discussed separately below.

3.2.3.1 1980 Leak. Information regarding a possible 1980 leak is conflicting. The *Environmental Characterization Report for the Test Reactor Area* (EG&G Idaho 1991a) stated that the line was replaced from TRA-605 to the turn between the Materials Test Reactor (MTR) (TRA-635 building) and ETR (TRA-643 building) because of leaks (Figure 10). No estimation of volume or information concerning removal or discovery of contaminated soil around the reported excavation was reported. Information located in the Preliminary Scoping Track 2 Summary Report (Sherwood et al. 1994) also indicated that the potential leak simply may have been a discrepancy between the utilities usage and the storage tank levels, indicating that there may not have actually been a leak. Discussion captured in meeting notes with one participant having direct knowledge of operations during the timeframe of the 1980 leak did not recall any excavations in 1980, but did remember activities associated with the leak documented in 1981 (Sherwood et al. 1994).

3.2.3.2 1981 Leak. The 1981 leak occurred at an elbow in the 2-in. fuel transfer line 60 ft northeast of Well PW-13 (see Figure 10). The leak was discovered when the day tank, located in the TRA-648 building, supplying the ETR generator would not fill with the transfer pumps operating at full capacity. The day tank was excavated and inspected, and it was found not to have leaked. The fuel line was then spliced into a nearby abandoned 1.5-in. carbon steel steam line (INEEL 2002). The abandoned line is located adjacent to the fuel transfer line. The cross-connection is visible on one end inside the TRA-648 building and is believed that the other cross-connection is underground approximately 328 ft east of TRA-648 (INEEL 2002). In December 1990, a tracer tight test was conducted on the reconfigured fuel line (INEEL 2002). The test did not reveal any leaks in the fuel line. Based upon pumping rates, the elapsed time, and the capacity of the transfer pipe, the volume of diesel fuel released prior to the repair was estimated at 2,000 gal (Sherwood et al. 1994). This volume included potential storage remaining within the old transfer line itself. It should be noted that the volume of the reconfigured line is slightly less than that used during the original calculation as a result of the 1/2-in. decrease in diameter of the pipeline. Further, it should be noted that approximately 328 ft of the 2-in. carbon steel fuel transfer line was abandoned in place (INEEL 2002). Based upon the proximity of the known 1981 release site to PW-13 and the lack of alternative sources, it is believed that the diesel in PW-13 is the result of the 1981 leak. Use of the fuel line was ceased in 1990; neither the original line nor the additional portions of the reconfigured line are in use. The lines are flanged on both ends.

3.2.3.3 Other Possible Sources. Five diesel tanks were associated with the TRA-57 diesel line, three source tanks (i.e., TRA-727C, TRA-727D, and TRA-775), and two destination tanks (INEEL 2002). The destination tanks, TRA-21 and TRA-22, were located on the north side of the TRA-643 building (Figure 10) and on the west side of TRA-648 (Figure 10), respectively. Both destination tanks were removed in the early 1990s (INEL 1993a, 1993b). The line also provided fuel to heaters located in the TRA-656 building. Neither tank showed signs of leakage, although the ETR tank did have some contaminated soil removed from the excavation (INEL 1993a, 1993b). Soil beneath the ETR tanks was field screened and any soil above 50 ppm was removed for disposal. Once field screening levels were below 50 ppm, samples were collected and the excavation was backfilled with clean soil. Approximately 5 yd^3 of soil was removed and disposed of at the Central Facilities Area landfill. Samples indicated low levels of total petroleum hydrocarbons in two of the six samples collected (10 ppm, 100 ppm). Four of the six samples collected contained low levels of toluene: 0.3 ppm in one sample and 0.2 ppm in the four other samples. It is unlikely that these tanks contributed to the source of diesel detected in Well PW-13. Both tanks were reviewed by the EPA and the Idaho Department of Environmental Quality (DEQ) and were determined to be no action sites. Despite the minor contamination found beneath the ETR tank, it is unlikely that it had any influence upon the free-phase diesel in PW-13. Despite the contamination present beneath the tank, the integrity of the tank was good and no leaks or damage were noted.

Further research did not reveal another possible point of origin for the diesel fuel found in PW-13. Utility maps do not show any other nearby transfer lines, and the only fuel tanks known to be in the immediate area have been removed. Fuel tanks currently in use are at the north end of the facility, over 1,800 ft away from PW-13. The tanks also are downgradient of PW-13 and the diesel release site, in terms of the overall geometry of the perched water (Figure 13). Note that the contour intervals in Figure 13 are irregular; intervals are irregular for the purpose of easier viewing. No spills of significant quantities have been reported in the area of PW-13. Based upon the proximity of the known 1981 release site to PW-13 and the lack of alternative sources, it is believed that the diesel in PW-13 is the result of the 1981 leak.

3.3 Well Installation

This section documents the drilling and installation of the TRA-1933 and TRA-1934 perched-water wells. These two wells were installed to provide additional information regarding diesel in the vicinity of Well PW-13. Information in this section was compiled from the *End of Well Report for TRA-1933 and TRA-1934* (ICP 2004a).

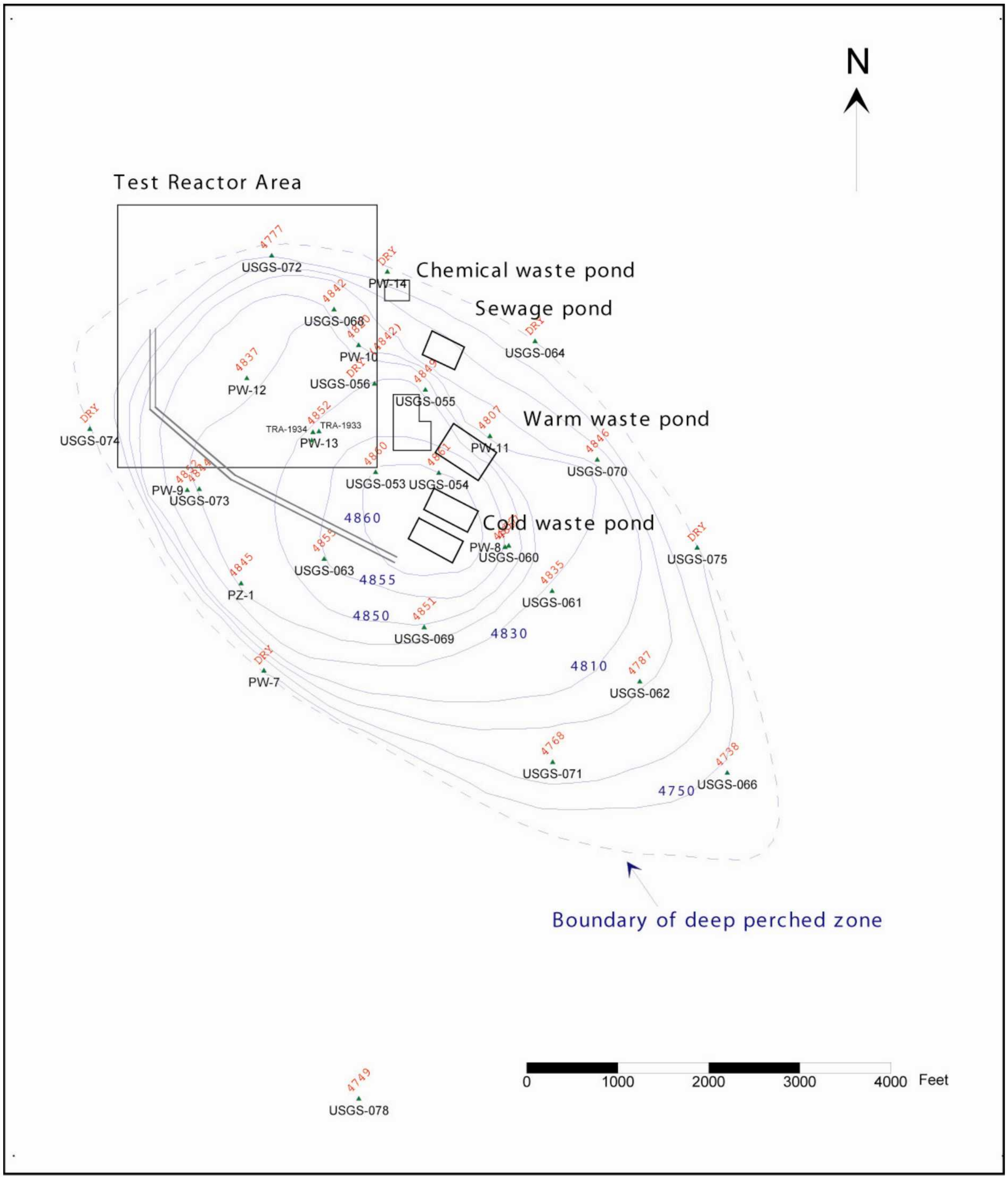


Figure 13. Contour map of the perched water at the Test Reactor Area (November 2003 data).

3.3.1 Drilling and Well Completions

A well site geologist recorded the drilling and well completion activities as well as the lithology. The geologist collected specimens every 5 ft and at each observed change in lithology. The specimens were returned to the corresponding waste box at the completion of drilling.

Initial planning recommended that the wells should be located such that one well was "upgradient and one downgradient" of Well PW-13 and the diesel release site, as shown in the *Characterization Plan for Diesel Contamination in TRA Perched Water Well PW-13* (ICP 2004b). It should be noted that discussions of the perched-water gradient refer to relative elevations of the potentiometric surface of the perched water and the overall geometry of the perched-water system (Figure 13). Thus, a well downgradient of PW-13 would be located at a nearby location inferred to have a lower water-level elevation. Subsurface surveys conducted prior to drilling indicated that utilities and a building foundation were located at or near the intended locations. Potential alternate sites were evaluated with respect to structures, tanks, subsurface, utilities, overhead utilities, roadways, and potential impact on normal daily operations at the TRA facility. Two sites were selected, both within 250 ft of the believed diesel source and as close to the originally chosen locations as possible. Well TRA-1933 is located approximately 50 ft due west of PW-13; Well TRA-1934 is approximately 120 ft southwest of PW-13 (Figure 10). Both of these final locations provide "downgradient" monitoring relative to PW-13 and the diesel source. Potential upgradient locations would have been in close proximity to an existing well, USGS-053, and it was decided that a second downgradient well would be of greater benefit.

It should also be noted that the Characterization Plan (ICP 2004b) called for the wells to be completed as 2-in. polyvinyl chloride screens with a sand pack of 10 × 20 silica sand. Technical comments from project staff recommended the use of 4-in. stainless-steel casing and screen and 8 × 12 sand. The 4-in. stainless-steel casing and screen were used to simplify maintenance, increase the life of the well, and provide for easier sampling. The sand pack change was recommended to provide better flow into the well. The change in the sand pack may also prevent possible capillary exclusion of free-phase diesel, allowing more accurate observations of subsurface conditions. Cost increases resulting from the changes in materials were negligible, as was the additional waste generated from the increase in borehole diameter.

3.3.1.1 Well TRA-1933. Drilling of TRA-1933 was initiated on April 3, 2004. A small excavation approximately 1–2 ft deep was made by hand. The radiological control technician (RCT) performed a radiological survey of the excavated area and soil. No radiological contamination was noted. The 8-5/8-in. dual rotary (DR) casing was advanced approximately 7 ft bls before initiating air rotary drilling. Water was allowed to flow around the exterior of the casing from a garden hose, discharging 2 to 3 gpm. Bentonite was added as needed. Water discharge varied with the rate of casing advance and borehole conditions. Approximately 100 gal of water was discharged while setting the DR casing. Water approved for use during drilling was obtained from the coal-fired power plant at the Idaho Nuclear Technology and Engineering Center (INTEC).

The DR casing was advanced from 7 ft bls to basalt, located at 42 ft bls, using air rotary drilling in conjunction with the casing drive. The casing was advanced 8 ft into the basalt (50 ft bls). Drilling continued to a depth of 100 ft bls without further advancement of the casing. The perched-water zone was encountered at approximately 70 ft bls. A faint diesel odor was noted at 83 ft bls. A strong diesel odor and sheen were present on the cuttings throughout the remaining interval (83–100 ft bls).

After completion of drilling to 100 ft bls, an obstruction was found at a depth of 86 ft. The obstruction was drilled out and the hole advanced another 3 ft (to 103 ft bls) in order to provide space for sloughing material (basalt rubble) to accumulate and not interfere with well completion. The water level in TRA-1933 was measured several times before installation of the well and was determined to be stable at 70.1 ft bls. An interface probe was unable to measure the thickness of the floating diesel in the well. However, a video log of the hole that was completed before constructing the well showed a scum or sheen of floating diesel. The video log also confirmed the water-level measurement.

Well installation commenced on April 3, 2004. The well was installed with a 30-ft section of 4-in. stainless-steel, wire-wrapped, 0.020-in. slot screen from 90 to 60 ft bls. A 4-in. stainless-steel well casing was installed from the top of the screen to 2.5 ft above ground surface. A filter pack of 8 × 12 sand was installed from total depth to 54.1 ft bls. A bentonite seal was then installed from 54.1 to 20 ft bls. A 6-in. permanent protective surface casing was then installed from 20 ft bls to 3 ft above ground surface. Installation of bentonite continued until the annular spaces were filled with bentonite (Figure 14). The DR casing was removed during installation of the bentonite. Bentonite was kept inside the DR casing as it was removed. As the casing was removed, the bentonite inside the DR casing filled the annular space around the permanent well casing and prevented alluvium from caving in around the well casing, ensuring a complete seal.

Upon completion of the well on April 4, 2004, the drilling site was cleaned and the equipment demobilized to the Dynatec (subcontracted drilling company) laydown area east of INTEC. The equipment was surveyed by the onsite RCT before removal from the radiological buffer area; no radiological contamination was found and the equipment was approved for release from TRA.

A surface completion (including three impingement posts, cement surface pad, brass survey cap, and locking well cap) was installed on April 5, 2004. The USGS performed geophysical logging on May 3, 2004, recording natural gamma, gamma-gamma, and neutron logs of the well. Official well completion diagrams with lithology and geophysical logs are provided as supplemental information in Attachment 1 on the included data CD.

3.3.1.2 Well TRA-1934. Drilling of TRA-1934 was initiated on April 2, 2004. A small excavation approximately 1–2 ft deep was made by hand. The RCT performed a radiological survey of the excavated area and soil. No radiological contamination was noted. The 8-5/8-in. DR casing was advanced approximately 7 ft bls before initiating air rotary drilling. Water was allowed to flow around the exterior of the casing from a garden hose, discharging 2 to 3 gpm. Bentonite was added as needed. Discharge of water varied with the rate of casing advance and borehole conditions. Approximately 100 gal of water was discharged while setting the DR casing. Water approved for use during drilling was obtained from the coal-fired power plant at INTEC.

The DR casing was advanced from 7 ft bls to basalt, located at 56 ft bls, using air rotary drilling in conjunction with the casing drive. The casing was advanced 4 ft into basalt (60 ft bls). Drilling continued to a total depth of 100 ft bls. The perched-water zone was encountered at approximately 75 ft. The only indication of diesel was a faint odor noted at 90 ft bls. No subsurface difficulties were encountered during drilling.

Upon completion of drilling, the depth of the well was measured at 98 ft bls. The water level was measured several times before installation of the well and was determined to be stable at 75.4 ft bls. A video log of the hole showed a fractured vesicular zone at approximately 75 ft bls. A scum or sheen of diesel floating on the perched water also was noted in the video log. The water level was monitored after completion of the video log. The initial water-level measurement was 75.4 ft and the final measurement of 75.08 ft after the well was allowed to stand for over 1.5 hours.

The well was installed with a 30-ft section of 4-in. stainless-steel, wire-wrapped, 0.020-in. slot screen from 95 to 65 ft bls. A 4-in. stainless-steel well casing was installed from the top of the screen to 2.5 ft above ground surface. A filter pack of 8 × 12 sand was installed from total depth to 60.3 ft bls. The short distance between the top of the screen and the alluvium limited the sand pack above the screen to 4.7 ft in order to allow for an adequate seal between the alluvium and the sand pack. A bentonite seal was then installed from 60.3 to 20 ft bls. A 6-in. permanent protective surface casing was then installed from 20 ft bls to 3 ft above ground surface (Figure 15). The DR casing was removed during installation of the

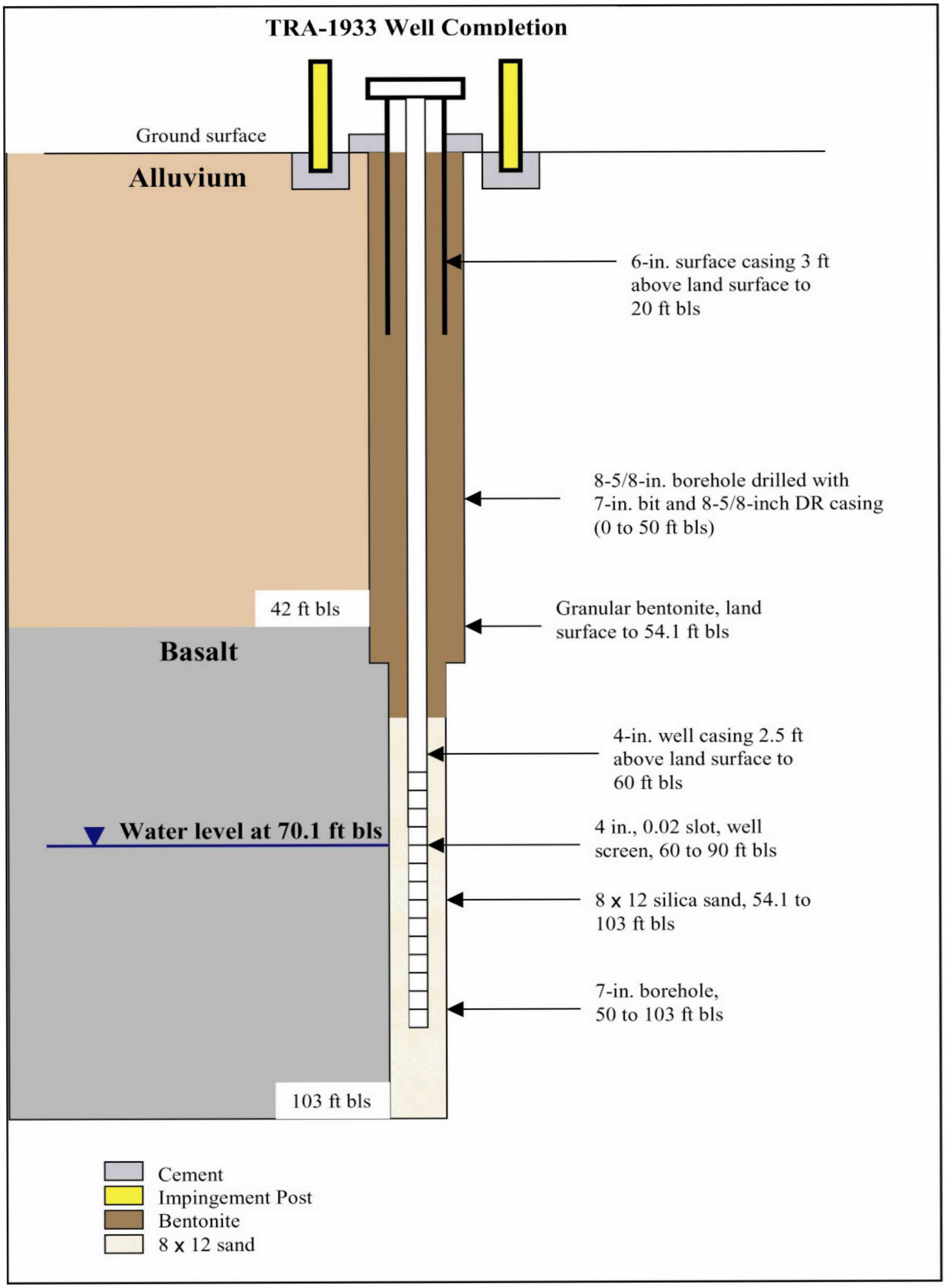


Figure 14. General completion diagram and lithology of TRA-1933 (not to scale).

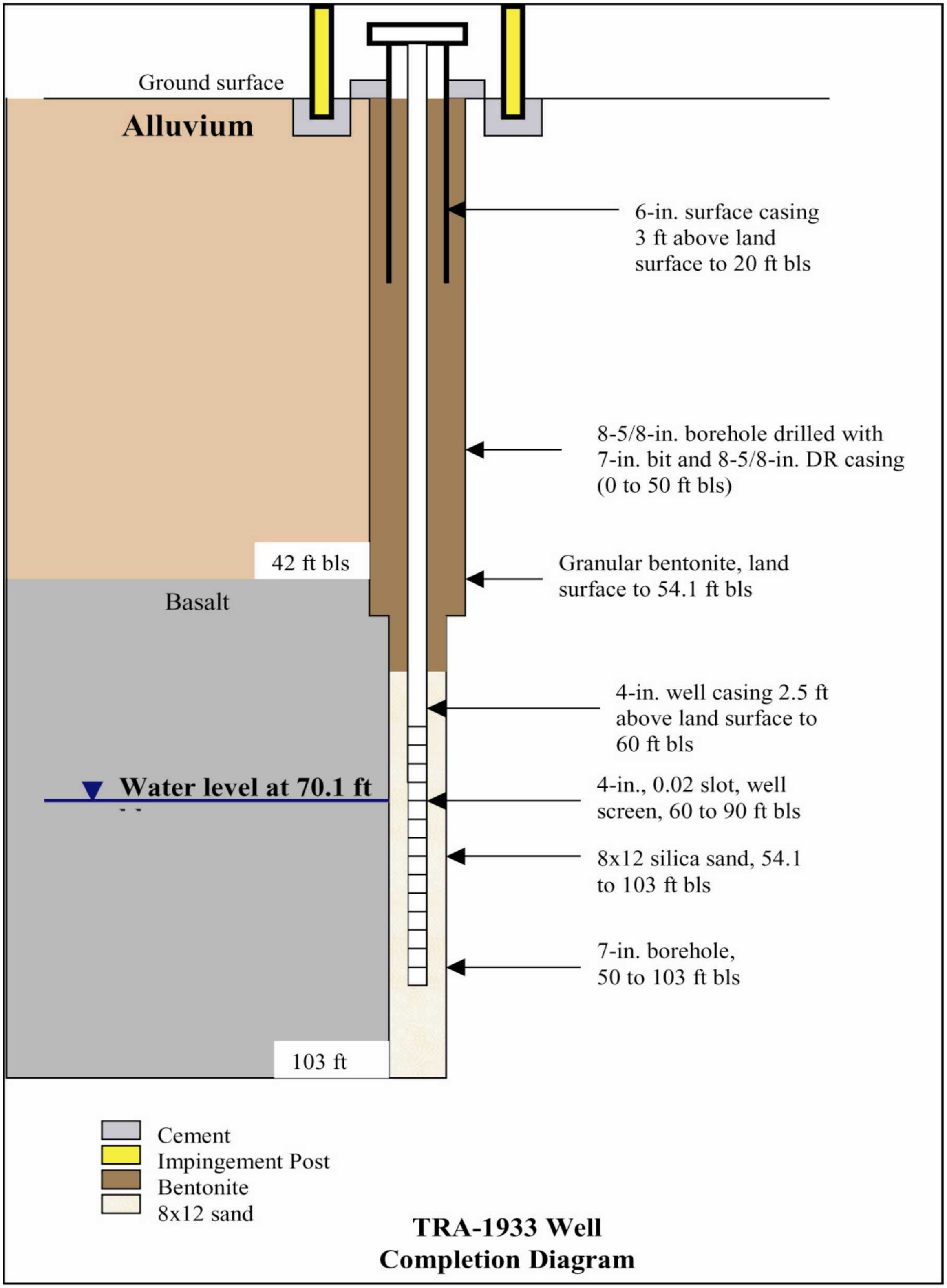


Figure 15. General completion diagram and lithology of TRA-1934 (not to scale).

bentonite. Bentonite was kept inside the DR casing as it was removed. As the casing was removed, the bentonite inside the DR casing filled the annular space around the permanent well casing and prevented alluvium from caving in around the well casing, thereby ensuring a complete seal.

Upon completion of the well on April 3, 2004, the drilling site was cleaned and the equipment was moved to the TRA-1933 site. The onsite RCT surveyed the equipment for contamination prior to moving to the new site and no radiological contamination was detected.

A surface completion (including three impingement posts, cement surface pad, brass survey cap, and locking well cap) was installed on April 5, 2004. The USGS performed geophysical logging on May 3, 2004, recording natural gamma, gamma-gamma, and neutron logs of the well. Official well completion diagrams with lithology and geophysical logs are provided as supplemental information in Attachment 1 on the included data CD.

3.4 Sampling and Analysis

Extent of the diesel contamination was investigated by sampling the two new wells (TRA-1933 and TRA-1934) and selected other wells for dissolved constituents of diesel fuel. Two downgradient aquifer wells (TRA-07 and USGS-076) were sampled to determine if diesel constituents had reached the aquifer. Four existing perched-water wells were selected to provide contaminant information up, down, and cross gradient with respect to the diesel release and PW-13 (Figure 13). Wells PW-10 (cross gradient), PW-12 (downgradient), USGS-053 (upgradient), and USGS-073 (cross gradient) were selected to constrain the lateral contamination, while Well PW-13 was selected for sampling to provide further analytical data regarding the diesel source and contaminant degradation.

Sampling of the existing perched water and aquifer wells was conducted in conjunction with the TRA quarterly groundwater-monitoring event in March 2004. Well PW-13 was sampled on March 17, 2004. Wells TRA-1933 and TRA-1934 were sampled on April 21, 2004. Existing wells were sampled in accordance with the G*roundwater Monitoring Plan for the Test Reactor Area Operable Unit 2-13* (DOE-ID 2004a). Wells TRA-1933 and TRA-1934 were sampled in accordance with the *Field Sampling Plan for the Characterization of the Diesel Contamination in the TRA Perched Water Well PW-13* (ICP 2004c). Wells TRA-1933, TRA-1934, and PW-13 were sampled for diesel-range organics (SW-846 8015A/B), gasoline-range organics (SW-846 8015B), and benzene, toluene, ethylbenzene, and xylene (BTEX) (SW-846 8021B) (EPA 2002). Well TRA-1934 also was selected for duplicate sampling for quality assurance purposes. Well PW-13 also was sampled for duplicate and replicate samples for gasoline-range organics and BTEX analysis. The remaining perched-water and aquifer wells were sampled for diesel-range organics (SW-846 8015A/B) (EPA 2002). Analytical results for the perched-water wells are compiled in Table 2. Note that the table included duplicates and replicate samples. More complete analytical data are provided in Attachment 2 on the included data CD.

3.4.1 Analytical Data from Selected Aquifer Wells

Diesel-range organic contaminants were not detected in either of the two sampled aquifer wells, TRA-07 and USGS-076. Both of these wells are located south of TRA and are downgradient of the source relative to the regional aquifer gradient (Figure 7). Well TRA-07 was selected for sampling because of its position relative to the diesel source and the regional aquifer flow. Based on the geometry of the perched-water system (Figure 13), the diesel contamination is believed to be migrating westward. The regional flow of the aquifer is south-southwest (DOE-ID 2003). Well TRA-07 is located downgradient to the southwest of the diesel source (Figure 10). Well USGS-076 is located almost directly south of the diesel release. This well was selected to provide a secondary data point and because of anecdotal reports of well-head odor. A visit to the well indicated that the odor likely was an environmentally friendly lubricant, possibly used during the installation of the pump riser and water access line, rather than diesel. As with the other aquifer well, TRA-07, diesel-range organics were not detected at USGS-076.

Table 2. Summary table of organics data from perched-water wells.

Well Name	Diesel-Range Organics	Gasoline-Range Organics	Benzene	Toluene	Ethylbenzene	Xylene (total)
PW-10	ND	—	—	—	—	—
PW-12	1 mg/L (J*)	—	—	—	—	—
PW-12	0.3 mg/L (J*)	—	—	—	—	—
PW-13	4.7 mg/L (J*)	309 µg/L	ND	ND	0.25 µg/L (J)	0.6 µg/L (J)
		87 µg/L	ND	ND	0.25 µg/L (J)	0.7 µg/L (J)
		86.3 µg/L	ND	ND	0.25 µg/L (J)	0.68 µg/L (J)
TRA-1933	0.83 mg/L	264 µg/L	ND	ND	2 µg/L	8.9 µg/L
TRA-1934[a]	1.2 mg/L	206 µg/L	ND	ND	2.4 µg/L	2.5 µg/L
TRA-1934[a]	1.3 mg/L	102 µg/L	ND	ND	3.6 µg/L	3.6 µg/L
USGS-053	ND	—	—	—	—	—
USGS-073	0.38 mg/L	—	—	—	—	—

a. A duplicate sample was collected from TRA-1934 for quality purposes.
— = not sampled
J = Considered an estimate because of the uncertainty near reporting limit.
J* = Hold time was exceeded. (NOTE: The PW-13 diesel-range organics sample also was flagged for high surrogate recovery.)
ND = not detected
TRA = Test Reactor Area
USGS = United States Geological Survey

3.4.2 Analytical Data from Selected Perched-Water Wells

Sampling was conducted at existing perched-water wells (PW-10, PW-12, PW-13, USGS-053, and USGS-073) as well as at the two recently drilled perched-water wells (TRA-1933 and TRA-1934). Wells PW-13, TRA-1933, and TRA-1934 were sampled for diesel-range organics, gasoline-range organics, and BTEX, while the remaining perched-water wells were only analyzed for diesel-range organics.

Results (Table 2) indicated the presence of diesel-range organics in Wells PW-12, PW-13, TRA-1933, TRA-1934, and USGS-073. Diesel-range organics were detected in USGS-073 at a concentration of 0.38 mg/L (380 µg/L). The well is located to the southwest of the diesel release (Figure 16). Diesel-range organics also were detected in the PW-12 perched-water well, located northwest of the diesel release. However, the reported values of 1 mg/L (1,000 µg/L) and 0.3 mg/L (300 µg/L) received J flags. Diesel-range organics were not detected in samples from Wells PW-10 (located north of the diesel release) and USGS-053 (located southeast of the diesel release) (Figure 16).

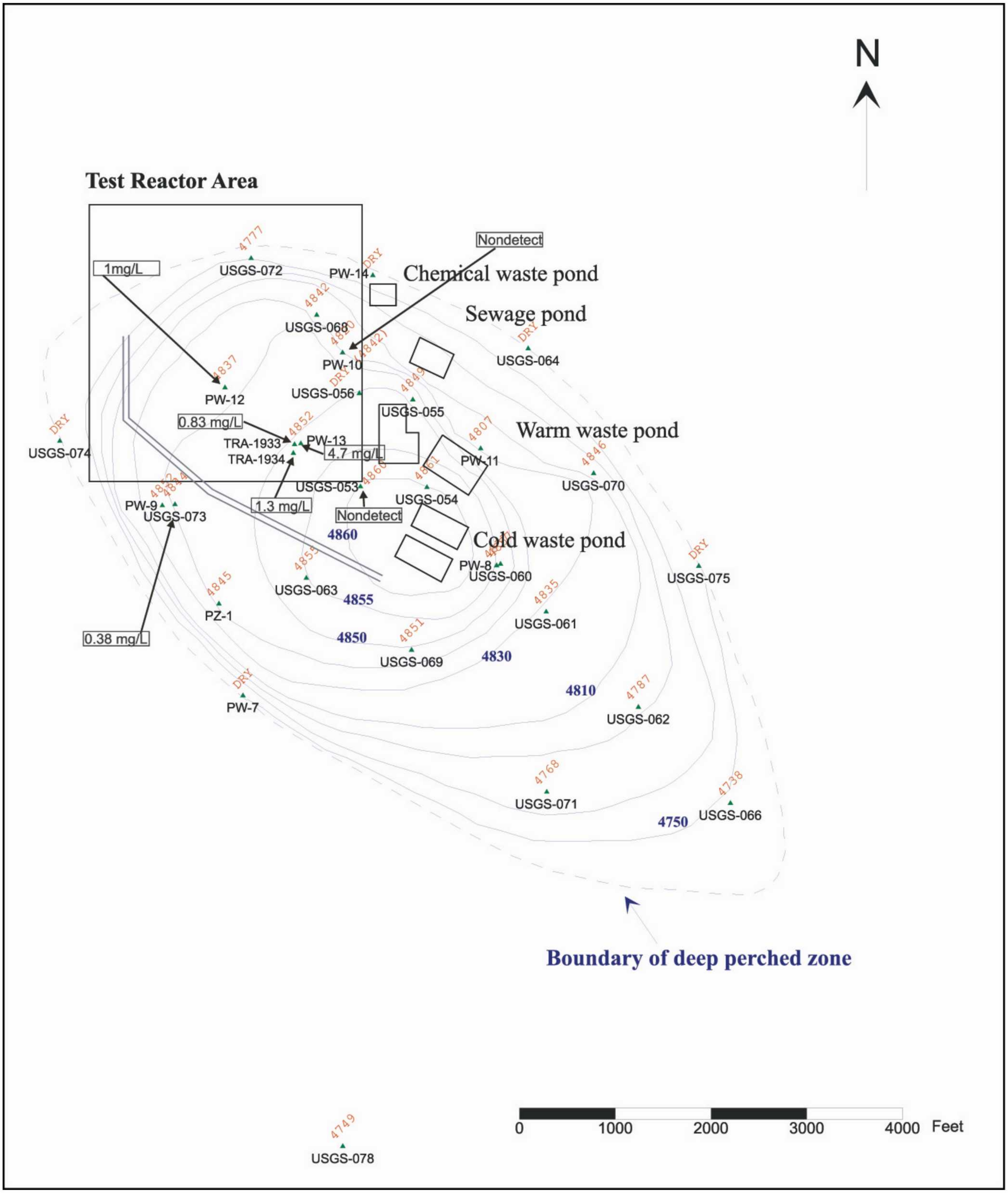


Figure 16. Map of the perched-water body at Test Reactor Area with diesel-range organics' concentrations.

The presence of diesel-range organics in Wells PW-12 and USGS-073 indicate that dissolved-phase diesel is migrating in the perched water. These two wells had not been previously sampled for diesel-range organics; therefore, it cannot be determined how long the contamination has been present or the rate of migration. Well PW-12 is downgradient of the diesel release site, based upon the overall geometry of the perched-water body. Well USGS-073 is cross- and slightly downgradient of the diesel release site. Analysis of perched-water data, discussed in Section 4, suggests that a previously unidentified source of water may be influencing the perched-water body beneath TRA. Data discussed in Section 4 identify several wells, including PW-13, as having geochemical signatures similar to aquifer water samples collected from the TRA-03 aquifer well, which is a TRA water supply well.

The similarity between the perched water at these locations and the water in the aquifer could indicate that water line(s) might be leaking. A leaking water line would not only influence the chemical signature of the water but the local hydrology as well. Thus, local flow paths may differ from those expected from the general shape of the perched-water body (Figure 16). (Note that the contour intervals in Figure 16 are irregular. Contour intervals are irregular for easier viewing.) Leaking water lines may account for the southwestward migration of the contaminants toward Well USGS-073 or the migration may simply be the result of the heterogeneous nature of the subsurface. It should also be noted that no free-phase diesel or diesel odor has been noted in either well, although Well PW-12 is not screened over the proper interval to allow free-phase diesel to enter the well. There is no direct evidence to indicate that the water lines may be leaking, but both potable and fire water lines pass within 20 ft of Well PW-13.

3.4.3 Analytical Data from Wells PW-13, TRA-1933, and TRA-1934

Samples collected from Wells PW-13, TRA-1933, and TRA-1934 were analyzed for diesel-range organics, gasoline-range organics, and BTEX (Table 2). Diesel-range organics were detected in all three wells. Well PW-13 contained a concentration of 4.7 mg/L, but the data were J flagged. Well TRA-1933 contained a diesel-range organic concentration of 0.83 mg/L. Although the odor and sheen of diesel were more noticeable in TRA-1933, a higher concentration of diesel-range organics, 1.2 and 1.3 mg/L, was measured in TRA-1934. Note that Well TRA-1934 was selected for duplicate sampling for quality assurance purposes and that two samples were collected from the well.

Gasoline-range organic constituents were detected in water from all three wells. Well PW-13 contained concentrations of 309, 87, and 86.3 µg/L. Comparing these three samples to the historical data presented in Section 3.2.2, the average gasoline-range organic concentrations within the well seem to be decreasing. Gasoline-range organic concentrations were reported at 264 µg/L in TRA-1933 and at 206 and 102 µg/L in TRA-1934.

Benzene and toluene were not detected in PW-13, TRA-1933, or TRA-1934. The lack of these common diesel-trace constituents support the hypothesis of an older, degraded diesel source. Ethylbenzene and xylene (total) were detected in all three wells. Three ethylbenzene samples were collected from PW-13 and the reported concentrations were 0.25 µg/L. The data were J flagged because of the uncertainty near the reporting limit. The previous sampling at PW-13 found no detectable concentration of ethylbenzene. An ethylbenzene concentration of 2 µg/L was reported for the sample collected from TRA-1933. Two samples were collected from TRA-1934 with reported values of 2.4 and 2.6 µg/L. Xylene (total) contamination also was detected in the three wells. Three samples collected from PW-13 contained concentrations of 0.6 to 0.7 µg/L, but the data were J flagged because of the uncertainty near the reporting limit. The reported values for Well PW-13 were lower than the single sample containing a detectable concentration of 2 µg/L, collected in June 2001. Wells TRA-1933 and TRA-1934 contained low concentrations of xylene with concentrations between 2.5 and 8.9 µg/L.

Concentrations of contaminants in PW-13 continue to decrease, possibly as a result of the degradation of the diesel. The single exception was a slight increase in the concentration of ethylbenzene in March 2004. The 0.25 µg/L of ethylbenzene was an increase from the nondetect recorded in June 2001. The previous detectable concentration was 0.2 µg/L, detected in November 2000. However, the increase in the reported value for March 2004 may be imprecise or inaccurate, as the reported value of 0.25 µg/L was J flagged, as was the previously detected concentration of 0.2 µg/L from November 2000. A geochemical analysis of the perched water (see Section 4) suggests that natural attenuation processes have removed the more soluble fraction of the diesel product, leaving behind the less soluble components as floating product.

3.5 Extent of Contamination

This section discusses the extent of the diesel contamination in the perched water. Diesel was not detected in the sampled aquifer wells. Diesel fuel can migrate laterally along the top of the perched-water body as a floating free phase, while dissolved constituents of the diesel fuel migrate within the water phase. The extent of contamination was defined in the Field Sampling Plan (ICP 2004c) as the lateral extent of contamination and the vertical thickness of the free-phase diesel. The lateral extent of contamination in the perched water and the vertical thickness of the free-phase diesel are discussed in Sections 3.5.1 and 3.5.2, respectively.

3.5.1 Lateral Extent of Diesel Contamination

Free-phase diesel was only discovered in the immediate vicinity of the 1981 release. As described in Section 3.5.2, the historical record shows the sporadic recurrence of free-phase diesel within Well PW-13. Small amounts of free-phase diesel also were noted during the drilling of TRA-1933 and TRA-1934. The minor amount of diesel encountered during the drilling of TRA-1934 may indicate that the well is near the outer extent of the free-phase diesel migration. Well TRA-1933 is closer to the source and showed a somewhat stronger presence of free-phase diesel during drilling activities. Neither free-phase diesel nor diesel odor was reported during the sampling of the other selected perched-water wells (PW-10, PW-12, USGS-053, and USGS-073). However, it should be noted that PW-12 is the only well not screened over the appropriate interval to allow free-phase diesel to enter the well at the current perched-water level. Based on these observances, it seems that the lateral extent of the free-phase diesel is limited to locations near the source (Figure 16). The lateral extent of the free-phase diesel is uncertain because of the limited data points available. However, continued monitoring of the wells exhibiting diesel contamination should provide information to constrain the lateral extent. Measurements of the diesel thickness were made using an interface probe at TRA-1933 and TRA-1934 during sampling, and no measurable thickness was present. Although the highly heterogeneous nature of this system precludes a complete understanding of the subsurface conditions, an adequate characterization of the subsurface can be completed.

Soluble constituents of the diesel enter the water phase through dissolution and degradation processes. These compounds, now in solution, will migrate with the water. The mobility of the dissolved-phase diesel in the subsurface is greater than that of the free-phase diesel and will result in wider migration of the dissolved-phase contaminants. As a result, the extent of the dissolved-phase constituents is considerably larger than the extent of the free-phase diesel. Consequently, it is not unusual to have detected diesel-range organics in a larger area than where free product is found. Diesel-range organics were detected in PW-12, PW-13, TRA-1933, TRA-1934, and USGS-073. Wells PW-10 and USGS-053 also were sampled for diesel-range organics, and results indicated no detectable concentrations. As shown in Figure 16, migration of the diesel has been westward toward Well PW-12 and USGS-073. Lack of detection at those wells could result from limited travel time, degradation, and dispersion of the soluble constituents within the perched-water body to below detectable levels; the influence of heterogeneity; and the vertical component of the flow. Downward flow of the water, and consequently the dissolved-phase contaminants, may reduce the lateral extent of the dissolved-phase diesel contamination as contaminants infiltrate to depths greater than that of the well before migrating laterally into the well. As with the free-phase diesel, the heterogeneous nature of the vadose zone precludes a complete understanding of the lateral extent of dissolved-phase contamination; however, adequate characterizations can be made based upon analytical and hydrogeologic data.

Based upon the fluid properties of diesel, it is reasonable to believe that the extent of the free-phase diesel is significantly less than that of the dissolved-phase contaminants. Movement of diesel in the saturated zone will be controlled vertically by the presence of water and laterally by the physical characteristics of the subsurface and the moisture content. Undersaturated conditions, the migration of diesel will be limited because of the presence of the water. Water will preferentially flow through pore spaces around trapped diesel, preventing lateral and vertical migration. Physical characteristics also will limit diesel migration; fractures and dense basalt may hinder the lateral movement of diesel.

3.5.2 Vertical Thickness of Free-Phase Diesel

The field evidence indicates that the free-phase diesel floating on the perched-water body is relatively thin and discontinuous and it is likely that its extent could not be accurately determined unless many wells were drilled at close spacing. Free-phase diesel was encountered in Well PW-13 and during the drilling of Wells TRA-1933 and TRA-1934. In the former case (PW-13), diesel thickness is sporadic and highly variable (Figure 12). For the new wells (TRA-1933 and TRA-1934), small amounts of free-phase diesel were encountered while drilling below the surface of the perched-water body. After completion of drilling, only a thin sheen of diesel was found on the water surface with a thickness below the detection limit of the interface probe (1/100 ft). These limited data suggest that the free-phase diesel does not exist in a laterally extensive, thick layer. It is more likely that it is thin and fragmented. It should be noted that no free-phase diesel was noted above or at the surface of the perched water during the drilling of either TRA-1933 or TRA-1934, indicating an absence of floating free-phase product, at least at the time of drilling.

The presence of free-phase diesel at depths below the surface of the perched-water body might indicate that the diesel migrated into the drill holes from above the perched-water body during drilling activities in a manner similar to that believed to have occurred at PW-13. As an alternative, the free-phase diesel may have migrated into the areas of TRA-1933 and TRA-1934 during a period of lower water levels in the perched-water body. A subsequent rapid rise in the water level could have trapped the diesel beneath the current surface of the perched water in cavities and/or dead-end fractures. The diesel fuel also could have been forced below the water surface through an isolated vertical fracture when the leak occurred.

3.6 Controlling Mechanisms for the Recurrence of Diesel

The First Five-Year Review Report (DOE-ID 2003) identified the recurrence of free-phase diesel fuel in TRA Perched-Water Well PW-13 as an issue. The sporadic nature of that recurrence is atypical and warrants further discussion. Typically, one would expect that a single release of diesel fuel would produce a regular thickness of floating free phase that would decrease gradually in thickness with distance away from the source and also dissipate steadily with time. This investigation has shown that the free-phase diesel is not laterally or vertically extensive in the vicinity of Well PW-13 and that the presence of diesel in PW-13 is sporadic. This situation could be explained by either an intermittent source of diesel or a mechanism that moves a nonuniform thickness of free-phase diesel around in the subsurface.

Historical research and analytical data indicate that there is currently no ongoing source of diesel influencing the diesel levels in PW-13. Analysis of the diesel indicates that the diesel is degraded. The only known potential source is the abandoned transfer line, TRA-57, and testing of the line in 1990 did not reveal any leaks. The maximum potential volume of diesel that may remain in the transfer line is 310.5 gal and represents less than 16% of the total released volume. With no or minimal continued flux of diesel, the alternative explanation is that the diesel in the subsurface is being recycled by changing conditions. Several hypothetical mechanisms were developed and are presented below to illustrate how changing floating product thicknesses could be the result of natural conditions and not an indication of continued leakage. The hypothetical mechanisms are not tied to specific subsurface characterization, but are thought to be possible based upon the known subsurface conditions (i.e., a fractured, heterogeneous basalt aquifer with intermingled sediments and fluctuating water levels and flow conditions). Potential mechanisms are discussed in Sections 3.6.1, 3.6.2, 3.6.3, and 3.6.4.

3.6.1 Changing Flow Paths

Changing flow paths may move a finite volume of free-phase diesel from one location to another, taking it away from or bringing it to a well. The overall shape of the deep perched water at TRA is that of an elongated mound and appears relatively smooth at the scale of Figure 16. However, the highly heterogeneous nature of the geology may cause that mound to have local undulations that vary in size/shape with changes in recharge. Local flow paths will then vary with the size/shape of those undulations. Note that changes in recharge arise not only from discharge to the CWP, but may also be affected by natural recharge and irrigation (see Section 4). Free-phase diesel may become trapped in local depressions in the perched-water table and then move as the shape of the perched-water table changes. Figure 17 illustrates how local changes in the perched-water body could move a small body of floating free-phase diesel away from or to a well. Because such undulations in the surface of the perched-water body would be local in scale (i.e., not detectable in the overall geometry of the perched water), it may not be possible to determine if this is the mechanism for the recurrence. Chemical analysis of the perched water and its relation to the various sources may, however, provide some indication of local flow paths.

3.6.2 Changing Water Levels

Diesel trapped in the subsurface may be mobilized or remobilized by changing water levels. The flow system at TRA includes high-permeability fractures, interflows, and rubble zones that are separated from one another by the relatively impermeable basalt. The high-permeability features tend to have considerable storage capability but may not be well connected. In Figure 18a, free-phase diesel is trapped in fractures and a rubble zone, but cannot flow to the well. An increase in elevation of the perched water table allows the free-phase diesel to enter the well through the rubble zone (Figure 18b). Repeated rises and declines in the water table would lead to sporadic appearances of free-phase diesel in the well. The total volume of free-phase diesel would decline with time, leading to eventual cessation of this occurrence. Diesel fuel also could be released by a declining water table, as shown in Figure 19a, b. Note that these two geometric configurations (Figures 18 and 19) were developed as illustrative examples for the purpose of demonstrating the conceptual theory, not as a pictoral or schematic representation of actual subsurface conditions at this location. A wide variety of different geometries involving fractures of all orientations (i.e., vertical to horizontal), rubble zones, and interflows could trap and release diesel fuel with changing conditions in the perched-water table. Although the water levels and recurrence of diesel may be related, the regular fluctuations within the water level may make it difficult to verify. Continued routine measurements in PW-13, as well as in TRA-1933 and TRA-1934, could provide the necessary information to make this determination.

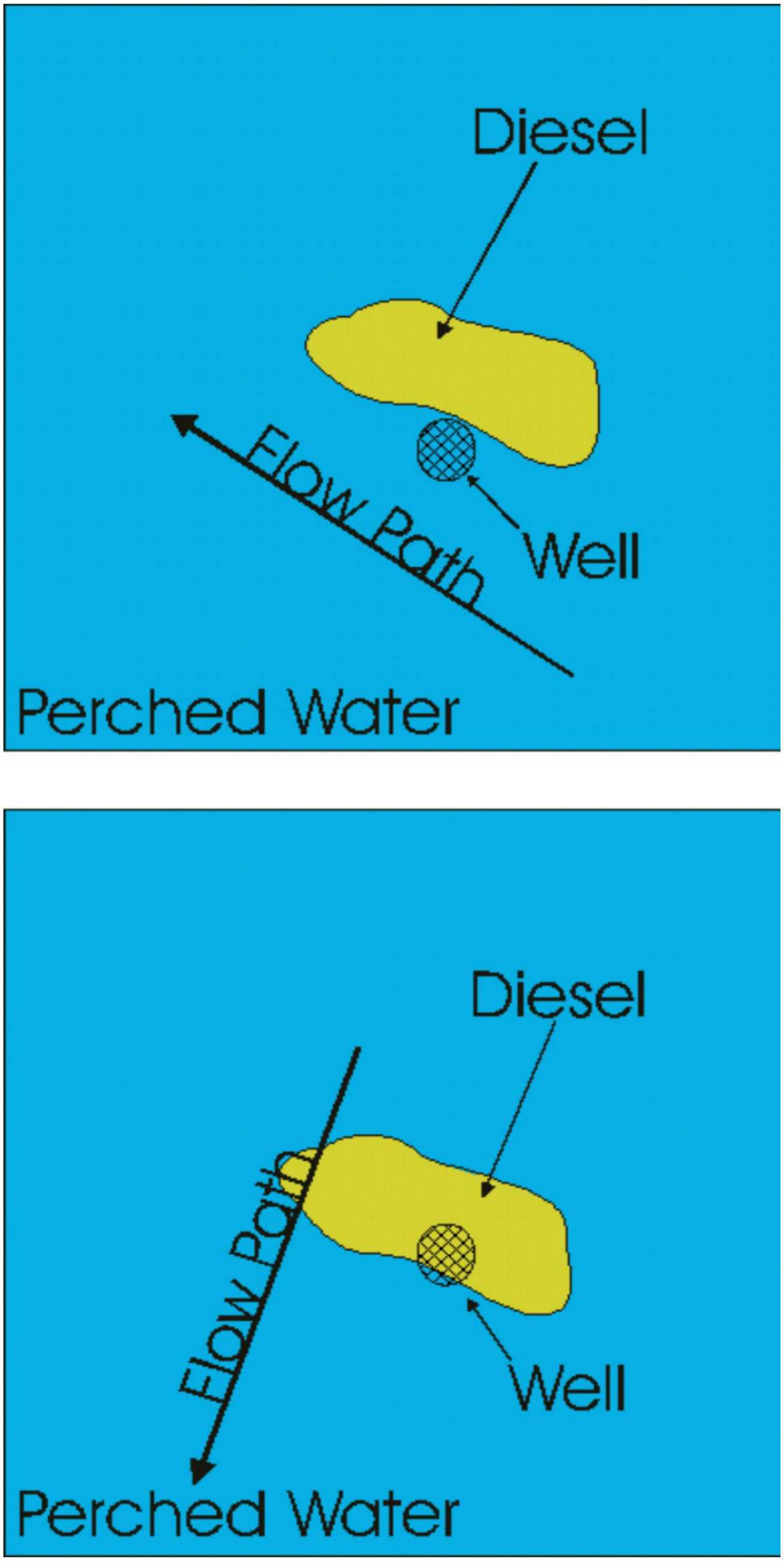


Figure 17. Diesel migration influenced by a changing flow path.

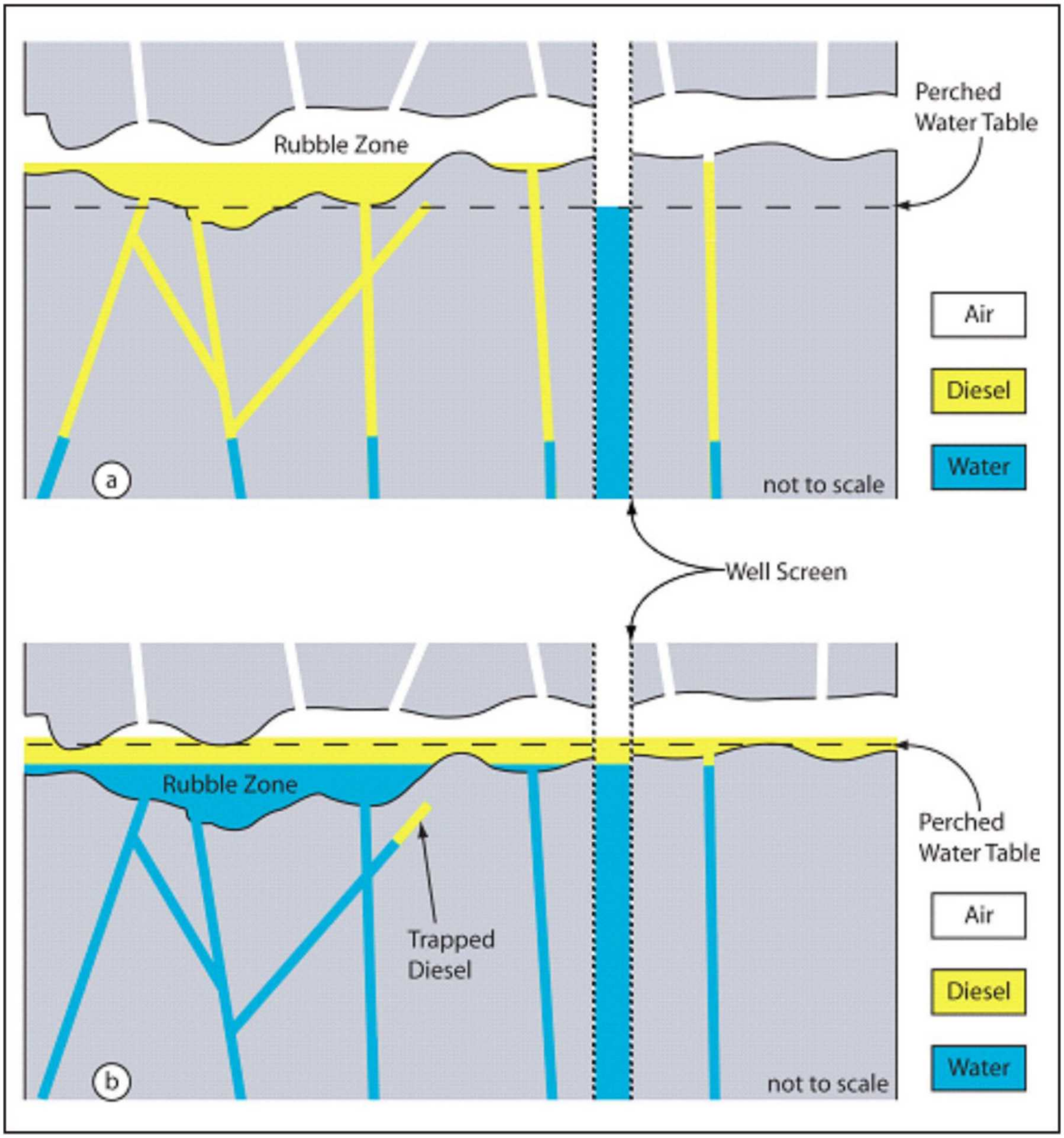


Figure 18. Remobilization of diesel resulting from an increase in water level.

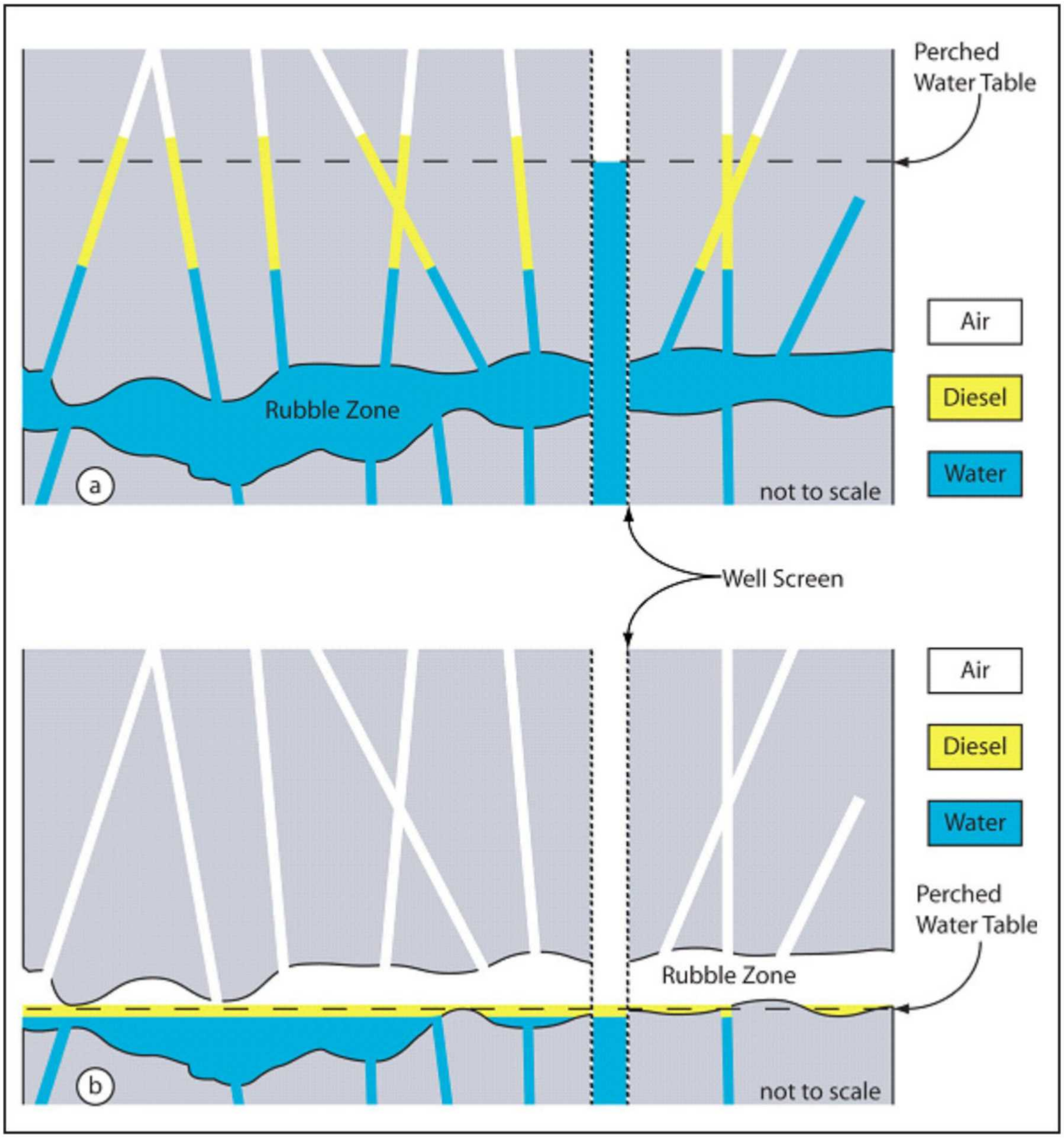


Figure 19. Remobilization of diesel resulting from a decrease in water level.

3.6.3 Pulsed Flux

Migration of diesel into the well could result from pulsed flux of diesel from above the perched-water body. Diesel fuel that leaked from TRA-57 may have pooled in various locations above the perched-water body. Potential locations for such pools include dead-end fractures, rubble zones, and at the alluvium-basalt interface. Few fractures extend vertically through the dense, massive interior of a basalt flow; hence, pools above the perched water may be poorly connected in the vertical direction. The pooled diesel may be periodically mobilized by transient conditions in the subsurface. Figure 20 provides an illustrative example of diesel fuel pooled on top of a small perched-water body located in sediments above the alluvium-basalt interface. Please note that Figure 20 is provided as an illustrative example for demonstrating a conceptual theory, not as a pictorial representation of actual subsurface conditions.

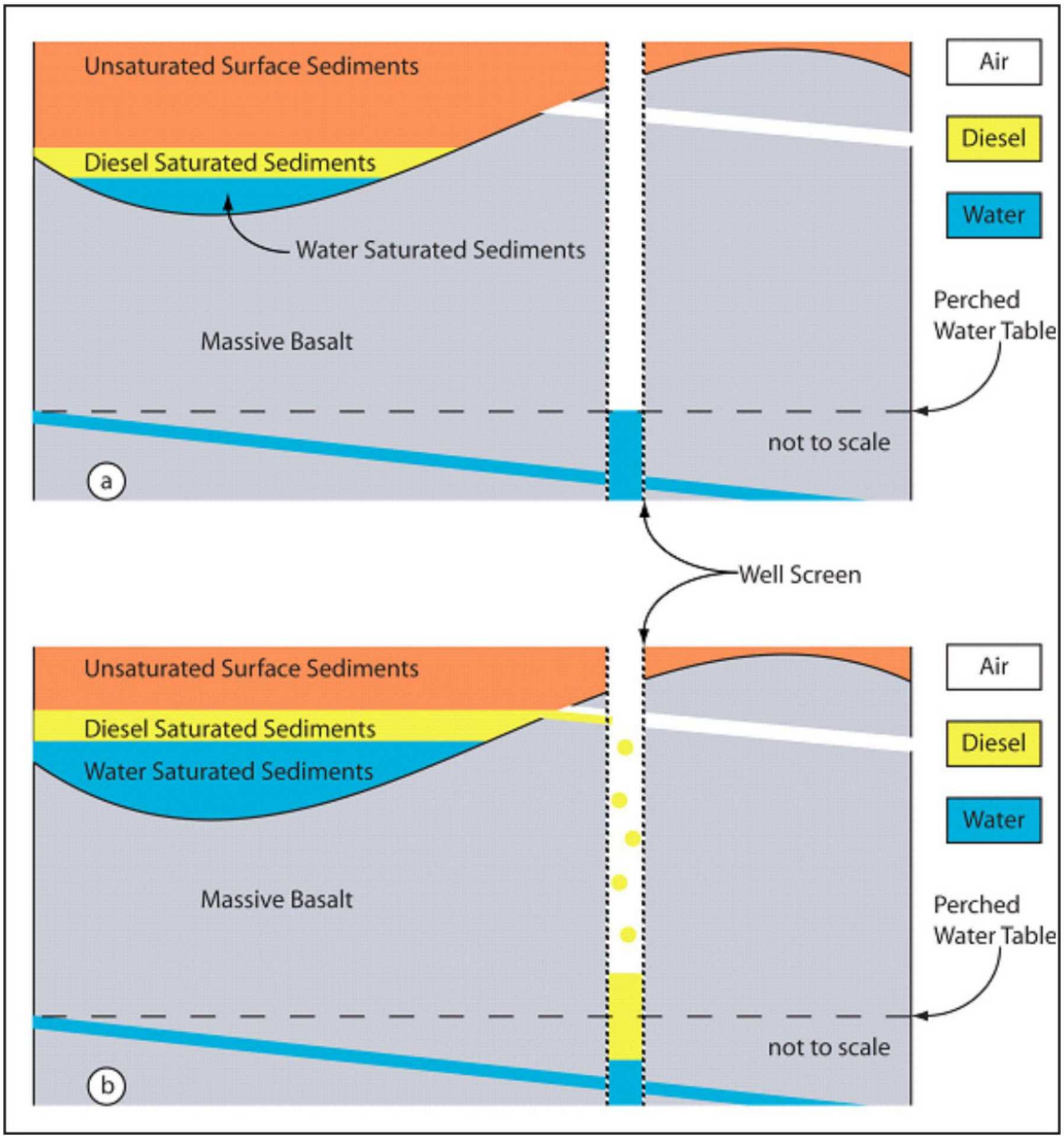


Figure 20. Pulsed flux of diesel from an overlying local perched-water body.

The low permeability of the basalt restricts downward migration, trapping the diesel above a shrinking water pool (Figure 20a). Subsequent addition of water (recharge) raises the diesel fuel to connect with a fracture that intersects the well (Figure 20b). The example shown in Figure 20 is just one of many geometric configurations that could lead to pulsed flow. Other configurations could carry diesel directly to the perched-water body, rather than to the well. However, note that the configuration shown in Figure 20 would produce a substantial thickness of diesel within the well alone. Free-phase diesel would not spread from the well; instead, it would dissipate through dissolution into the perched-water body. This scenario is consistent with observations at Well PW-13. In addition, there could be multiple pools of diesel above the perched-water body with individual pools pulsing at different times or possibly cascading vertically from one pool to the next. Changes in the subsurface distribution of diesel fuel could result from a leak in the nearby raw water line. Although there is no evidence that the line is leaking, the chemical signature of the water at PW-13 seems to indicate the possibility, as discussed in Section 3.6.4.

3.6.4 Continued Flux

Although it is highly unlikely that the diesel recurrence in PW-13 is from an ongoing leak, the recurrence could be attributed to continued flux from the original source. The original entry of diesel fuel into PW-13 during the 1990 coring operation is believed to have occurred at 47 ft bls, well above the perched-water body. The next reported occurrence of free-phase diesel in PW-13 was 9 years later in November 1999. This timeline would be consistent with an unusually slow migration through the unsaturated zone. In effect, the original diesel release may be moving slowly downwards to the perched-water body and having fragmented along the way is arriving at discrete intervals. Slow migration of the diesel could be the result of transient conditions (such as moisture content in the unsaturated zone or flow paths of different lengths). During wetter periods, the diesel migration could be slowed or even halted by an increased moisture content, as water moves into large pores that would normally be open to the flow of a non-wetting fluid (such as air or diesel fuel). This situation can occur during periods of infiltration because of spring melts or leaking water pipes. The transient conditions might have caused the continued flux of diesel from the original source to appear irregular and/or pulsed.

3.7 Summary of Findings

Although the diesel fuel found in Well PW-13 was apparently released to the subsurface over 20 years ago, no diesel contamination has been detected in aquifer wells, although only limited sampling (TRA-07 and USGS-076) has been conducted. Under saturated conditions, water will migrate preferentially through pore spaces, restricting and trapping free-phase diesel. Further, the less dense diesel will also float or pool on water, effectively prohibiting the downward migration of diesel in a free-phase state, if the perched water zone is laterally continuous. The physical properties and interation of water and diesel, coupled with the limited analytical data, suggest that the diesel fuel likely is trapped in the perched-water zone above the regional aquifer. The perched-water body currently serves to limit the downward migration of the free-phase diesel, while providing an opportunity for the diesel fuel to degrade and disperse. Although no contamination—free phase or dissolved—has been noted in the aquifer, it should be noted that there is only limited analytical data and a limited number of aquifer wells downgradient of TRA, and dependent upon the actual local conditions of the aquifer, the existing wells might not be sufficient to capture contamination resulting from the diesel release. Vertical migration of free-phase product also could occur along the margins of the perched-water body or even within the areal extent of perched-water body if the saturated zone is not laterally continuous.

Analytical data obtained during this investigation indicate an older source for the diesel contamination that has degraded while in contact with the perched-water body. These data support historical data collected after the discovery of diesel during the drilling of PW-13. The data cannot rule out a continued flux of degraded diesel from the original source (TRA-57). However, the line was tested in 1990 and the results indicated no leaks in the line. The No Further Action determination for the TRA-57 fuel line was based upon a release of 2,000 gal, which included the maximum volume (310.5 gal) that the fuel transfer line could contain. The risk assessment completed during the Track 1 showed that the 2,000 gal of diesel fuel entering the aquifer did not pose a risk. Consequently, any fuel that might have remained in the transfer line and has begun to leak since the 1990 test has been accounted for during the Track 1 risk assessment and accounts for less than 16% of the total volume released.

Information obtained from both drilling and sampling did not provide evidence to dispute the calculated volume of 2,000 gal. Although diesel was encountered during the drilling of both TRA-1933 and TRA-1934 and dissolved-phase diesel was detected in the PW-12 and USGS-073 perched-water wells, the heterogeneous nature of the TRA subsurface can allow for wide spreading along preferential flow paths (such as fractures or interflow zones).

With no sources of diesel within 1,800 ft of PW-13, and analytical data indicating a degraded diesel, the recurrence of diesel within PW-13 seems to be the result of periodic remobilization of diesel in the subsurface. The diesel contained with traps and fractures is periodically remobilized, entering the well during changes in subsurface conditions and likely being returned to the fractures and traps when the conditions change again. The diesel could be cycled repeatedly over time, but always decreasing in total volume.

The diesel encountered beneath the surface of the perched water might indicate that the diesel migrated into the areas of TRA-1933 and TRA-1934 during a period or periods of lower water levels. The absence of diesel floating on the perched water during drilling at these locations might indicate that the free-phase diesel that migrated into these areas is now trapped within the perched-water zone, restricting further migration of the free-phase diesel, but also potentially increasing the rate of dissolution because of the greater surface area in contact with the perched water. However, it is also possible that the diesel encountered beneath the surface of the perched water is the result of injection of diesel because of differences in pressure head or it could be the result of diesel draining into the borehole during drilling. An injection of diesel below the subsurface could occur if a significant difference in head existed. If free-phase diesel pooled in a fracture above and connected to the perched water, continued accumulation could create a difference in pressure heads, allowing the diesel to inject into the perched water (i.e., the pressure head of the diesel is greater than the pressure head of the water).

Natural attenuation processes likely are impacting the dissolved-phase hydrocarbons. As a result, the residual floating petroleum product might contain a high percentage of less easily degradable petroleum hydrocarbons that are more resistant to natural attenuation processes. The highly variable occurrence of floating product in PW-13 would favor passive recovery of the petroleum product.

Data and information collected during this investigation indicate that the No Further Action determination listed in the OU 2-13 ROD (DOE-ID 1997a) is currently protective of human health and the environment.

3.8 Recommendations

Because of the sporadic and inconsistent behavior of the diesel recurrence, further monitoring is recommended. Additional routine monitoring is recommended to document any further migration of diesel and ensure that the No Further Action determination remains valid. Suggested monitoring activities are listed below:

- Installation of petroleum traps in Wells PW-13, TRA-1933, and TRA-1934. The traps will allow the volume of diesel to be measured and will provide an inexpensive, passive means for the removal of old diesel and collection of samples for analyses to determine if new diesel is entering the subsurface. Petroleum traps (Figure 21) consist of a hydrophobic filter attached to a float. The float keeps the filter above the water level, allowing diesel to enter the filter. The diesel is collected in a collection canister, which can be drained during maintenance.

- Monthly water-level and diesel thickness measurements at Wells PW-13, TRA-1933, and TRA-1934.
- Monthly maintenance of the petroleum traps performed in conjunction with water-level and diesel thickness measurements (see note below).
- Periodic monitoring of selected perched-water wells or aquifer wells may be warranted, but it is recommended that they occur no more frequently than annually, unless monitoring results dictate otherwise. It is recommended that Well PW-12 have diesel-range organics added to the analyte list and that USGS-073, TRA-1933, and TRA-1934 be added to the Waste Area Group 2 groundwater monitoring plan for diesel-range organics analysis. It is also recommended that at least one sample of the free-phase product be collected and analyzed to determine the extent of degradation. The free-phase sample will be used to determine the degradation state of the diesel. The sample is recommended as a one-time event unless the sample indicates a nondegraded source.

NOTE: *The use of petroleum traps may complicate the measurement of diesel thicknesses. If petroleum traps are installed, it is recommended that they be removed during the monthly maintenance and the volume contained in the trap measured. The water level and remaining diesel thickness, if any, should be measured before reinstalling the trap. The volume of the diesel in the trap should then be converted to a thickness and added to the measured diesel thickness in order to obtain a complete diesel thickness measurement. Any diesel remaining in the borehole should then be removed by reinstalling and removing the trap or by bailing.*

4. GEOCHEMICAL EVALUATION OF PERCHED-WATER CONTAMINATION AND WATER SOURCES

The First Five-Year Review Report (DOE-ID 2003) recommended that a geochemical investigation be performed to “fingerprint” various water sources at TRA and correlate sources to water in the perched-water wells. This section presents sampling results from March 2004 and then discusses the sources of perched water and contaminants in the perched water. The flux of contaminants from the vadose zone into the aquifer also is examined. Identification of water sources responsible for the perched-water bodies is essential for modeling and remediating contamination because water sources provide the medium for transporting contaminants to the perched-water bodies and eventually to the aquifer. Historical data also are used to evaluate the sources of perched water and contamination. The goals of the geochemical evaluation are as follows:

- Examine the distribution of contaminants in the perched water to determine sources of contaminants
- Characterize water sources based on major-ion chemistry and oxygen- and hydrogen-isotope data to determine water sources
- Evaluate flow paths using oxygen- and hydrogen-isotope data and major-ion chemistry data
- Combine information on contaminant sources and water sources to characterize perched-water bodies.

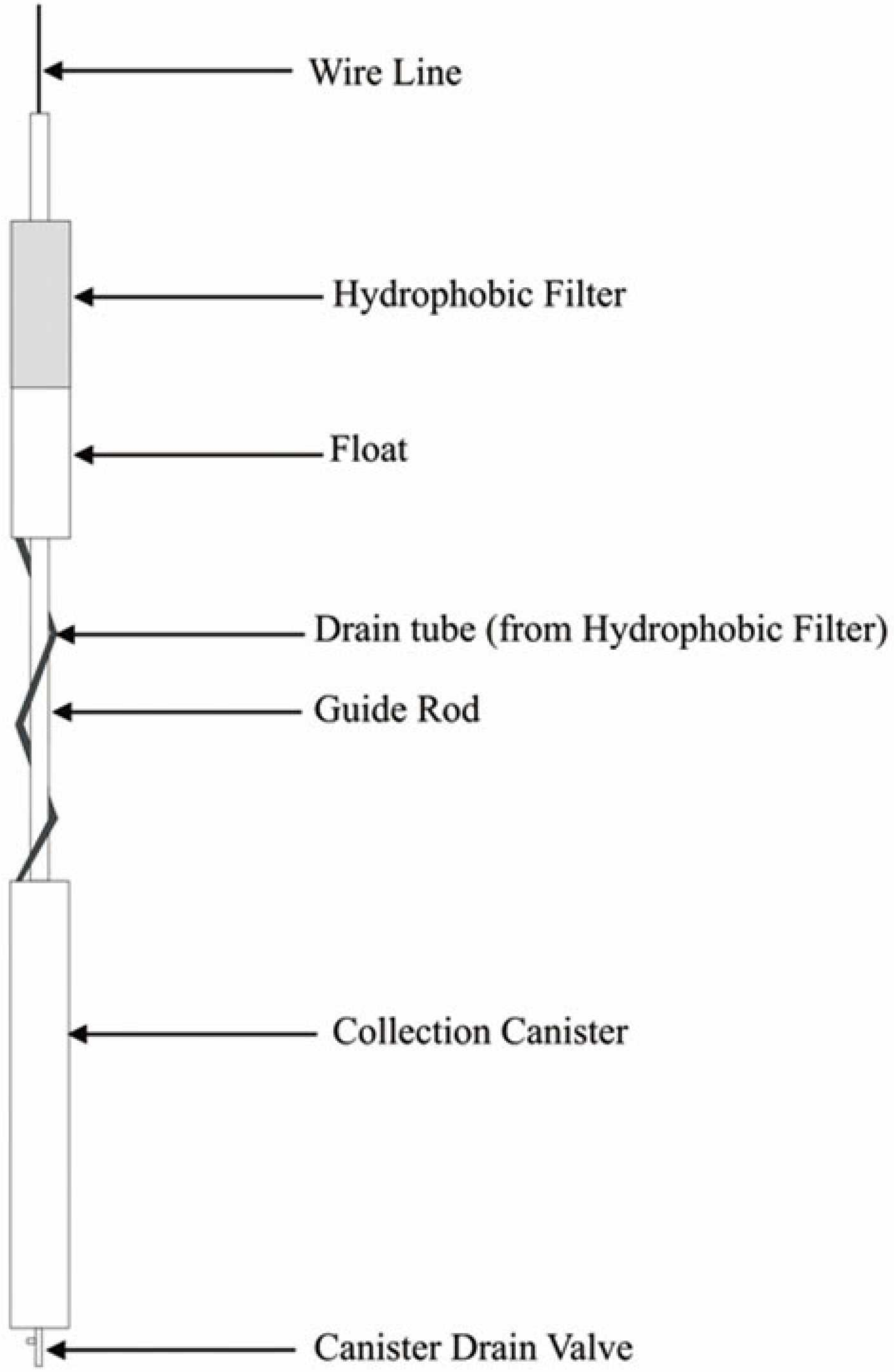


Figure 21. Simple illustration of a petroleum trap.

Groundwater samples were collected from the perched-water wells and aquifer wells that are listed in Table 3. Samples were not collected from the PW-14 and USGS-056 perched-water wells, because they were dry at the time of sampling. Perched-water samples were analyzed for metals, Sr-90, tritium, anions, and gamma-emitting isotopes. Seven wells also were sampled for organics to evaluate the extent of petroleum contamination near Well PW-13. When radiological results are reported in the text of this document, only the concentrations are given; the associated analytical uncertainties are listed in Table 3 and are provided in Attachment 2 on the supplemental data CD. The minimum detectable activity for each sample is included in Attachment 2, and complete data from the water sampling conducted in March 2004 also are provided in Attachment 2.

4.1 Perched-Water Contaminant Data

Extensive perched-water sampling and analysis were conducted on TRA wells during March 2004 as part of this investigation and in coordination with regular Waste Area Group 2 sampling activities. Table 3 summarizes the primary radiological (Co-60, Sr-90, and tritium), anion (sulfate), and metals (chromium) contaminant data. Sample concentrations are compared with MCLs. However, these comparisons are not intended to imply that the perched-water bodies represent an aquifer capable of long-term use or as a potable water source.

Metals samples were filtered to provide a representative and consistent data set for the geochemical analysis. Although, small colloidal particles can still get through the 0.45-μm filters, the filtered fraction more closely represents the fraction of metals that are dissolved and therefore more mobile and representative of geochemical processes. Unfiltered samples were not used for the geochemical analysis because the chemistry of perched-water samples can be greatly altered when the acid used to preserve the sample is added because perched-water samples contain varying amounts of suspended solids. In unfiltered samples, the dissolved metals fraction or naturally mobilized fraction cannot be separated from the metals fraction that is mobilized by the acid added to preserve the sample. In order to avoid the uncertainties associated with using unfiltered data, the filtered metals data were used to determine sources of water and to evaluate geochemical processes, because a representative and comparable data set was needed.

4.1.1 Chromium

Chromium analytical results from the perched-water wells were below the EPA-defined MCL of 100 μg/L during the March 2004 sampling event for filtered samples. Figure 22 shows filtered chromium concentrations in the perched-water wells from March 2004. The highest filtered concentration was in PW-10 at 76.9 μg/L. The highest chromium concentrations are northwest of the CWP near the former WWP and Warm Waste Retention Basins and the former Chemical Waste Pond. In addition to the main area of elevated chromium concentrations, chromium was present in Wells USGS-073 (33.1 μg/L) and USGS-066 (28.6 μg/L). The chromium results are for total chromium. The assumption is made that most of the chromium would be in hexavalent form under oxidizing conditions present in the perched water at locations other than PW-13, TRA-1933, and TRA-1934.

4.1.2 Cobalt-60

Cobalt-60 was detected in Well PW-12 at a concentration of 52.7 pCi/L in March 2004. Cobalt-60 was not present at detectable concentrations in any of the other wells. The concentration level found at PW-12 is below the EPA-defined MCL of 200 pCi/L for Co-60. The Co-60 concentration in PW-12 has declined considerably from the result in March 2003 of 330 pCi/L (ICP 2004d).

Table 3. Summary of select analytes for samples collected in March 2004.

		Cobalt-60			Strontium-90			Tritium			Sulfate		Chromium (filtered)			Chromium (unfiltered)		
Well	Depth	pCi/L	+/-	Flag	pCi/L	+/-	Flag	pCi/L	+/-	Flag	mg/L	Flag	ug/L	Flag		ug/L	Flag	
Perched-Water Wells																		
CWP-1	48.45–59.44	0.00552	1.96	U	0.0519	0.106	U	-29	78.4	U	283	—	4.27	B	U	8.26	B	—
CWP-2	45.95–52	—[a]	—	—	—	—	—	—	—	—	95.8	—	0.503	U	—	—	—	—
CWP-3	50.16–57	0.0744	1.58	U	5.9	0.876	—	0	82.3	U	58.4	—	2.21	B	U	7.55	B	—
CWP-9	34.3–64.45	0.362	1.33	U	**91.1**	12.8	—	293	91.7	—	0	U	0.503	U	—	2.46	B	—
PW-10	103.02	4.98	2.76	U	0.981	0.186	—	8,200	256	—	258	—	76.9	—	—	79.7	—	—
PW-11	109.75	4.61	2.87	U	0.975	0.214	—	37,700	643	—	162	—	30.8	—	—	32.7	—	—
PW-12	85.4	52.7	6.03	—	**67.7**	8.62	—	1,610	146	—	23.6	—	5.79	B	U	19.1	—	—
PW-13	71.52–89.97	1.7	3.11	U	**14**	1.88	—	-92.7	81.1	U	20.2	—	7.32	B	U	3.63	B	—
PW-8	69.55	0.314	1.42	U	5.65	0.831	—	167	82.9	UJ	127	—	4.98	B	U	6.2	B	—
USGS-053	70.03	0.14	4.35	U	**48**	6.2	—	3,620	191	—	98.4	—	16.6	—	—	18.5	—	—
USGS-054	66.01	0.651	1.83	U	**48.6**	7	—	247	88.5	UJ	101	—	5.12	B	U	6	B	—
USGS-054	66.01	-1.19	2.04	U	**48.6**	6.48	—	122	87	U	100	—	5.84	B	—	5.57	B	—
USGS-055	62.1	5.08	1.82	UJ	**42.5**	5.59	—	13,000	231	—	94.1	—	26.7	—	—	31.6	—	—
USGS-060	68.58	1.63	1.82	U	0.695	0.159	J	-91.6	80.1	U	98.4	—	4.31	B	U	4.27	B	—
USGS-060	68.58	-0.733	2.01	U	0.372	0.123	UJ	-57	76.1	U	102	—	5.09	B	U	4.37	B	—
USGS-061	90.27	2.82	1.36	UJ	0.179	0.129	U	2,580	152	—	140	—	10.1	—	—	12.7	—	—
USGS-062	136.57	3.05	1.42	UJ	1.44	0.257	—	147	86.7	U	142	—	7.76	B	—	6.53	B	—
USGS-063	76.05	3.09	2.26	U	1.26	0.228	—	30.9	86.2	U	133	—	8.82	B	—	9.97	B	—
USGS-066	183.9	-0.00969	2.02	U	-0.00371	0.101	U	1,230	126	—	155	—	28.6	—	—	539	—	—
USGS-068	83.74	-1.11	1.83	U	0.421	0.129	UJ	0	84.3	U	1,100	—	48	—	—	77.8	—	—
USGS-068	83.74	2.67	1.9	U	0.239	0.116	UJ	29.2	81.4	U	1,220	—	63.4	—	—	74.8	—	—
USGS-069	79.45	2.14	1.77	U	-0.0979	0.122	U	-30.3	82.1	U	87.5	—	1.46	B	U	11.1	—	—
USGS-070	72.86	3.75	2.31	U	**33.1**	4.18	—	2,850	157	—	106	—	13.7	—	—	13.2	—	—
USGS-073	87.48	10.4	5.95	U	0.518	0.151	U	10,500	291	—	89.5	—	33.1	—	—	150	—	—
Aquifer Wells																		
TRA-03	—	—	—	—	—	—	—	—	—	—	23.6	—	3.13	B	U	—	—	—
TRA-06	479.6	0.0416	3.89	U	0.272	0.185	U	2,400	171	—	—[b]	—	8.32	B	—	8.37	B	—
TRA-07	485.32	0.449	1.97	U	0.0748	0.154	U	18,800	447	—	99.8[c]	—	131	—	—	146	—	—
TRA-08	489.5	-0.56	1.65	U	0.272	0.15	U	4,450	218	—	51.9	—	33.1	—	—	40.2	—	—
USGS-058	503	-0.517	1.76	U	-0.177	0.179	U	1,910	151	—	32.8	—	15.5	—	—	15.6	—	—

Table 3. (continued).

		Cobalt-60			Strontium-90			Tritium			Sulfate		Chromium (filtered)			Chromium (unfiltered)		
Well	Depth	pCi/L	+/-	Flag	pCi/L	+/-	Flag	pCi/L	+/-	Flag	mg/L	Flag	ug/L	Flag		ug/L	Flag	
USGS-065	467.55	0.0304	1.81	U	0.127	0.144	U	8,610	298	—	—[b]	—	109	—	—	107	—	—
MIDDLE-1823	493.04	2.69	1.63	U	-0.0749	0.176	U	2,260	163	—	—	—	6.44	B	J	12.1	—	J
HWY-3	750	5.03	2.18	UJ	0.171	0.16	U	169	96.3	U	—[b]	—	1.43	U	—	1.43	U	—
USGS-076	489.29	—	—	—	—	—	—	—	—	—	30.6	—	11.3	—	U	—	—	—

CWP = Cold Waste Pond
TRA = Test Reactor Area
USGS = United States Geological Survey

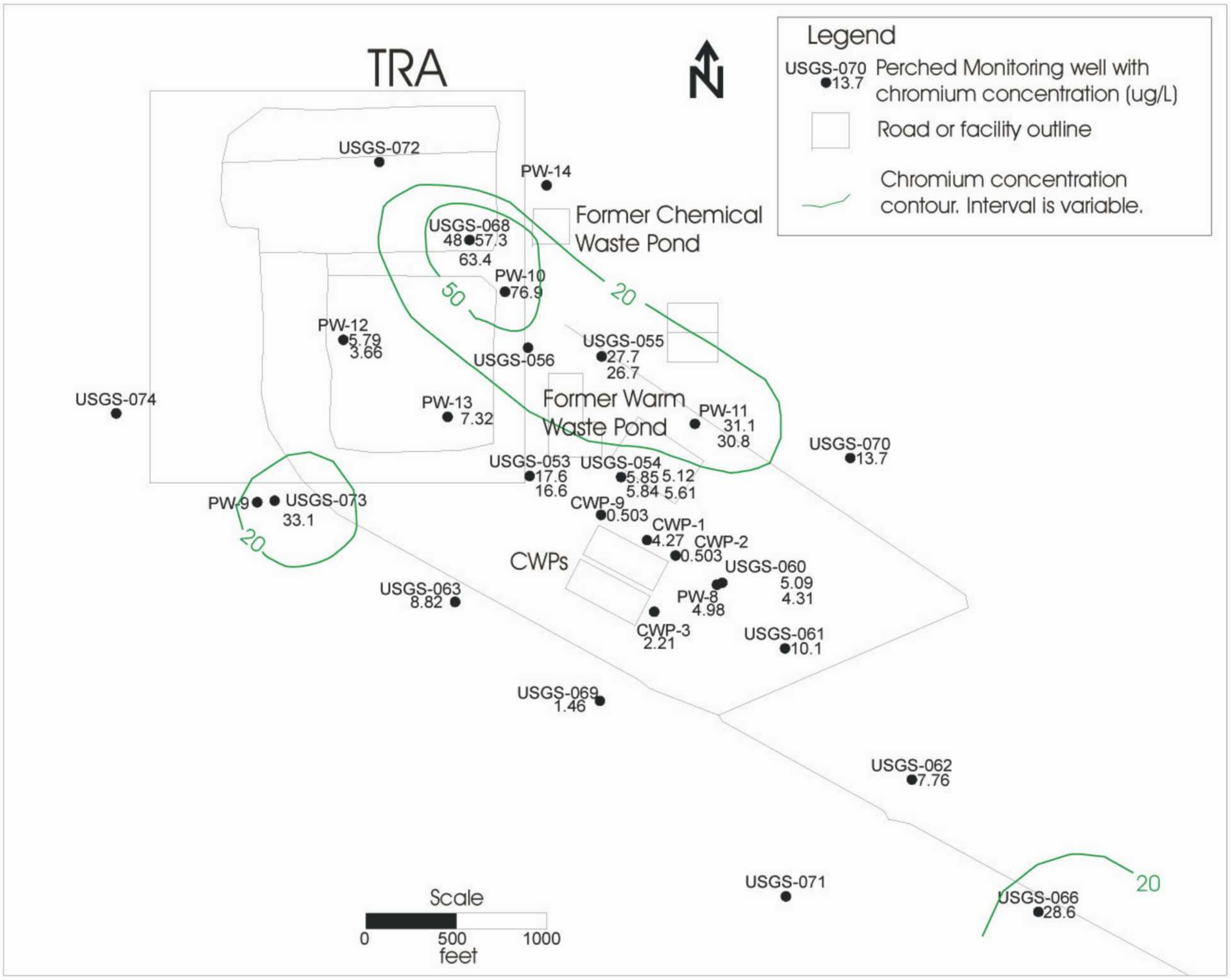


Figure 22. Distribution of chromium in perched water, March 2004.

4.1.3 Strontium-90

Strontium-90 results in the sampled perched-water wells ranged from nondetect to 91.1 pCi/L. Concentrations at seven wells (CWP-9, PW-12, PW-13, USGS-053, USGS-054, USGS-055, and USGS-070) exceeded the EPA-defined MCL of 8 pCi/L (Figure 23). The highest Sr-90 concentrations are northeast of the CWP near the former WWP (TRA-04).

4.1.4 Tritium

Tritium is present at detectable concentrations in 10 of the sampled perched-water wells, but only exceeds the 20,000-pCi/L MCL in Well PW-11 (Figure 24). The tritium concentration in Well PW-11 was 37,700 pCi/L in March 2004, which is the lowest concentration ever measured at that well. The distribution of tritium in the perched water in 2004 shows that the highest concentrations are north of the CWP near the former WWP. In comparison to past data, the tritium concentrations in some perched-water wells have declined by more than an order of magnitude from 1990 to 2004 (compare Figures 24 and 25). In 1990, the highest tritium concentration was around USGS-056, which is located to the northeast of the CWP near the former WWP. In 2004, USGS-056 was dry, likely a result of the discontinued use of the WWP and Warm Waste Retention Basins. In addition to the main area of tritium concentrations near the former WWP, tritium was present in Well USGS-073 (10,500 pCi/L) and USGS-066 (1,230 pCi/L).

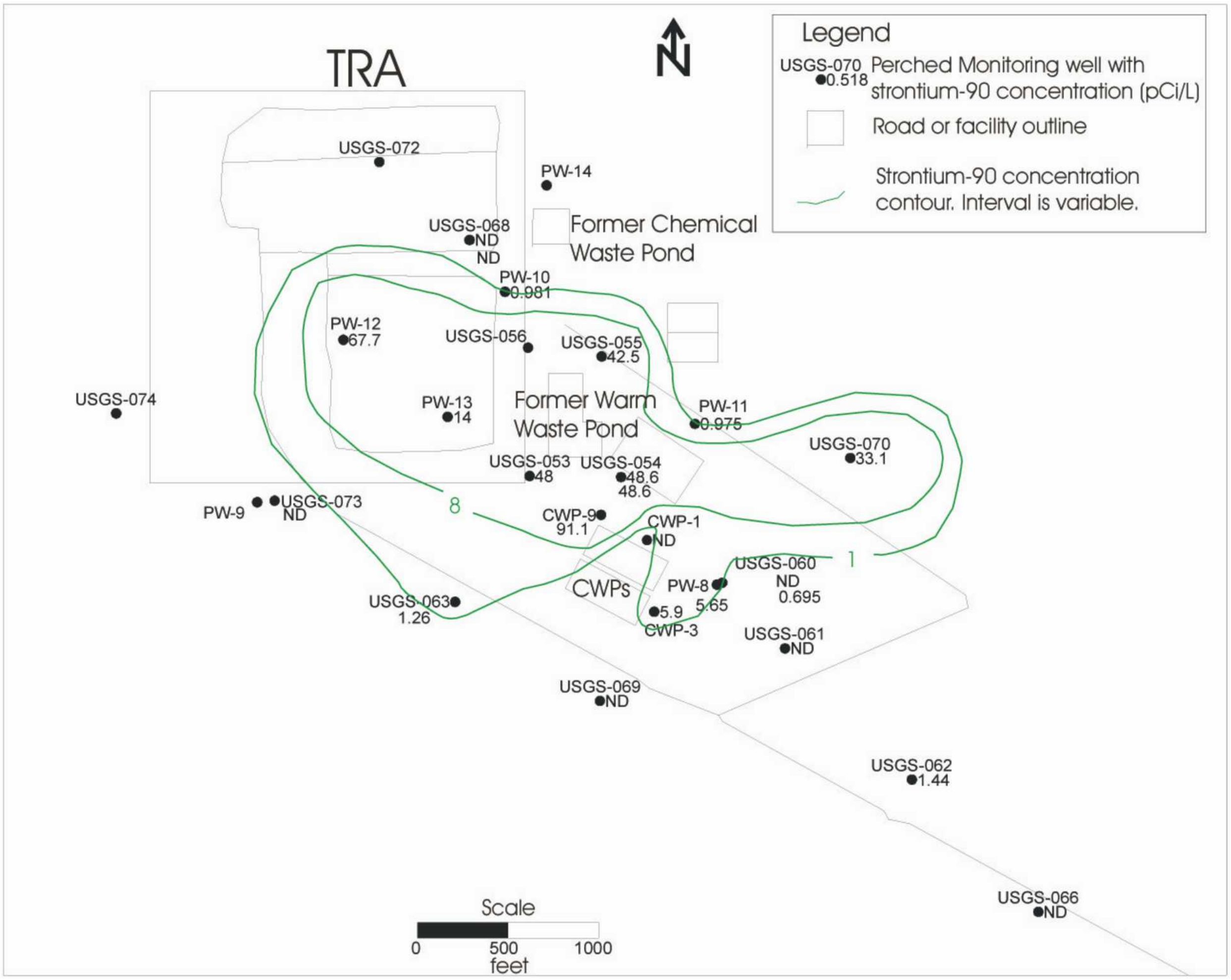


Figure 23. Distribution of strontium-90 in perched water in March 2004.

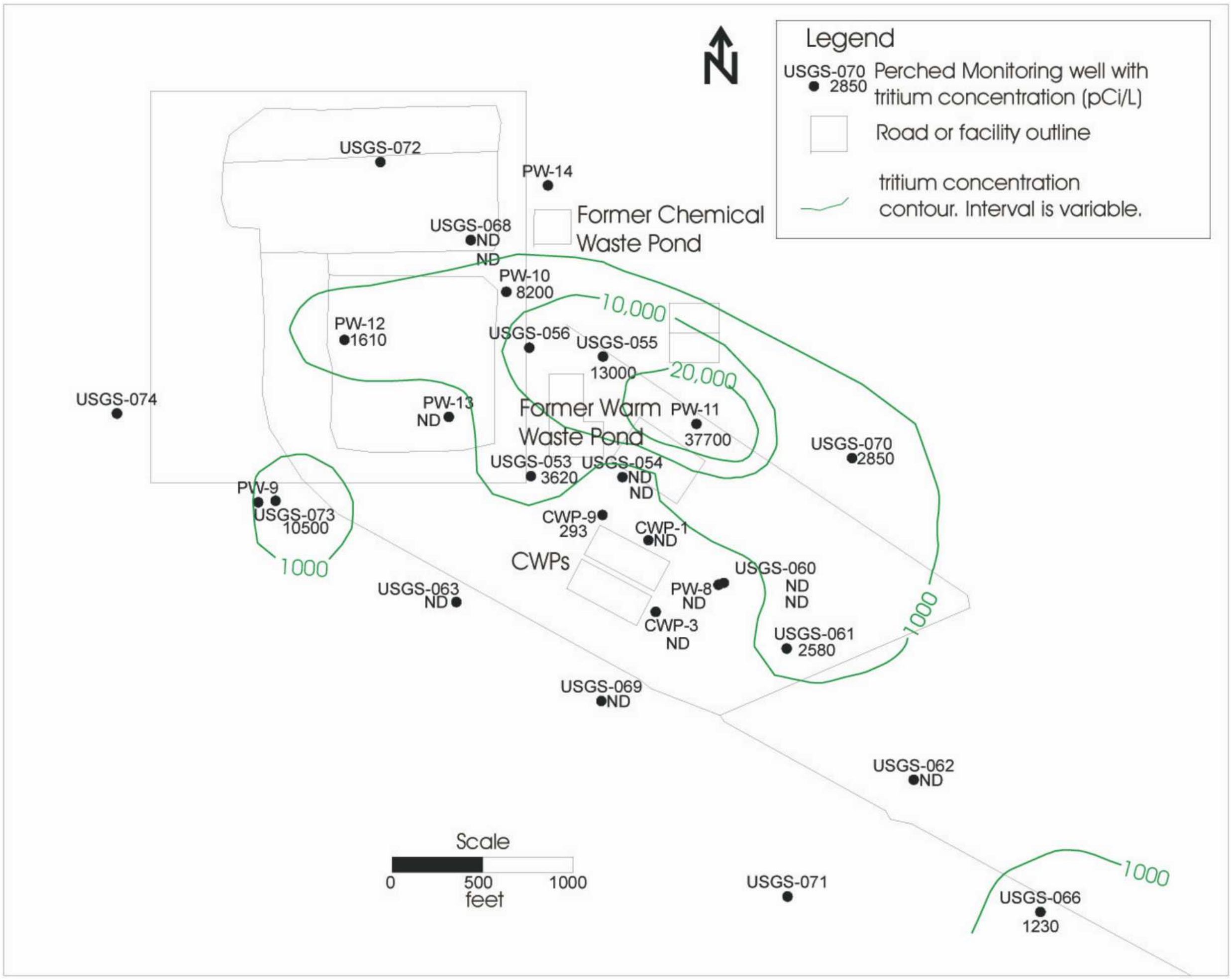


Figure 24. Distribution of tritium in perched water in March 2004.

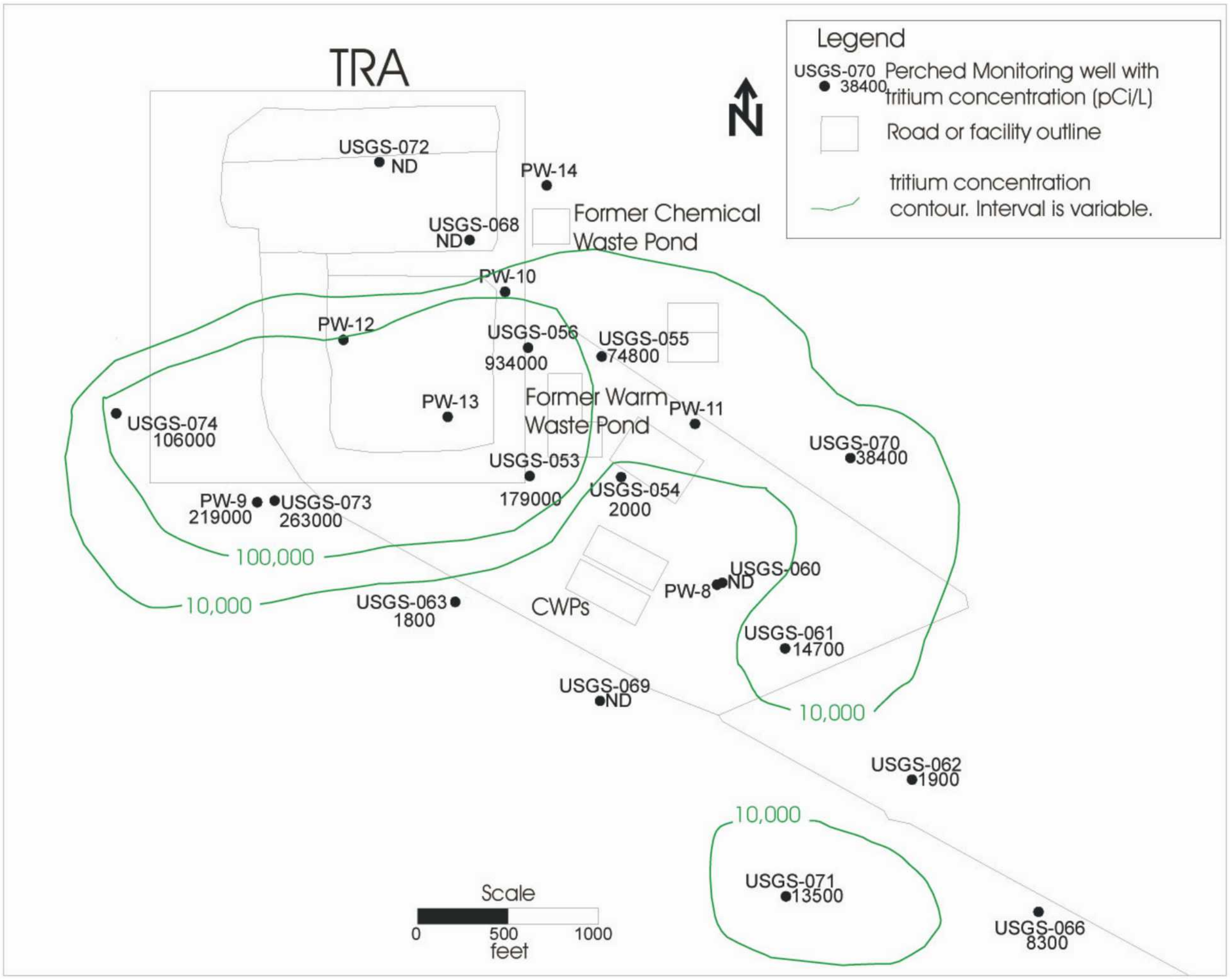


Figure 25. Distribution of tritium in perched water in 1990.

4.1.5 Organics

Seven wells (PW-10, PW-12, PW-13, USGS-053, USGS-073, TRA-1933, and TRA-1934) were sampled for diesel-range organics. The highest concentration for diesel-range organics was 4.7 mg/L in PW-13. The TRA-1933 and TRA-1934 wells had concentrations of diesel-range organics of 0.83 and 1.2 mg/L, respectively. Well PW-13 also was sampled for gasoline-range organics and had a concentration range of 87 to 309 μg/L with the gasoline-range organic results for TRA-1933 and TRA-1934 also falling within this range. Wells PW-13, TRA-1933, and TRA-1934 also were sampled for BTEX. Benzene and toluene were below detection limits in all samples. Xylenes were present at low concentrations (<10 μg/L) in all three wells. Ethylbenzene also was detected in all three at concentrations less than 3 μg/L.

4.2 Aquifer Contaminant Data

Groundwater samples were collected from the TRA-06A, TRA-07, TRA-08, USGS-065, MIDDLE-1823, and USGS-058 aquifer wells in March 2004 as part of this investigation and in coordination with the regular Waste Area Group 2 sampling. Aquifer wells were analyzed for chromium (filtered and unfiltered), Sr-90, gamma isotopes (includes Co-60), tritium, anions, and metals. In addition, Wells TRA-03, TRA-07, TRA-08, USGS-058, and USGS-076 also were analyzed for metals and anions.

The key constituents—chromium, tritium, Sr-90, Co-60, and organics—are summarized in the following subsections. The results for tritium, Sr-90, and chromium in aquifer wells are summarized in Table 3. In addition to the above analytes, TRA-07 and USGS-076 were sampled for diesel-range organics. Diesel-range organics were below detection limits in TRA-07 and USGS-076. The point of compliance in the aquifer, as stated in the OU 2-12 ROD (DOE-ID 1992), is the upper 12.5 ft of the SRPA.

4.2.1 Chromium

Chromium was present at detectable concentrations in all aquifer wells sampled for this investigation and the regular Waste Area Group 2 sampling. Both filtered and unfiltered samples were collected for chromium. With the exception of TRA-03, chromium concentrations were above background concentrations for all aquifer wells; however, the EPA-defined MCL of 100 μg/L was exceeded only in Wells TRA-07 and USGS-065 (Figure 26 and Table 3). The TRA-07 and USGS-065 wells show a decreasing trend in chromium concentrations (Figure 27).

4.2.2 Tritium

Tritium was present in all of the aquifer wells sampled as part of this study, except for TRA-03. Tritium concentrations were below the 20,000-pCi/L MCL in all wells (Table 3). The highest concentration (18,800 pCi/L) of the samples collected in March occurred in TRA-07 (Figure 26).

4.2.3 Strontium-90 and Cobalt-60

Strontium-90 and Co-60 were not detected in any of the aquifer wells sampled in March 2004.

4.3 Water Source/Characterization Data

Water-quality data and stable-isotope ratios (hydrogen, oxygen) were employed to characterize water sources. The relative and absolute concentrations of common cations and anions are water-quality parameters that can be used to distinguish sources of water. The common cations are sodium, potassium, calcium, and magnesium. The common anions are chloride, sulfate, and bicarbonate. A limited amount of complete water quality data sets have been collected for perched water and the water from the SRPA at TRA. This report addresses the two most complete geochemical data sets, which were collected in 1991 and March 2004. These data sets are indicative of the time of sampling and may not reflect conditions at different times of the year or when the Big Lost River flows.

The current sources of water that could cause perched zones at TRA and transport contaminants include the CWP, the sewage treatment lagoons, infiltrating precipitation, and lawn irrigation. There is also a possibility of leakage from current water lines used for fire-protection water, water supply, and steam. In the past, the WWP and the Warm Waste Retention Basins, along with associated piping, were known to leak (DOE-ID 2003). In addition, the Chemical Waste Pond was active until 2001. The sewage lagoons are lined and assumed not to leak. The chemical signature of the water from the remaining current sources can be used to determine the source(s) of water in the perched-water wells. The source of water for the water supply, lawn irrigation, fire-protection water, and steam lines is the SRPA. The TRA-03 water supply well was sampled to provide the chemical composition of these water sources. The composition of water from TRA-03 is nearly identical to that of USGS-121, which is hydraulically upgradient of INTEC and cross gradient to TRA.

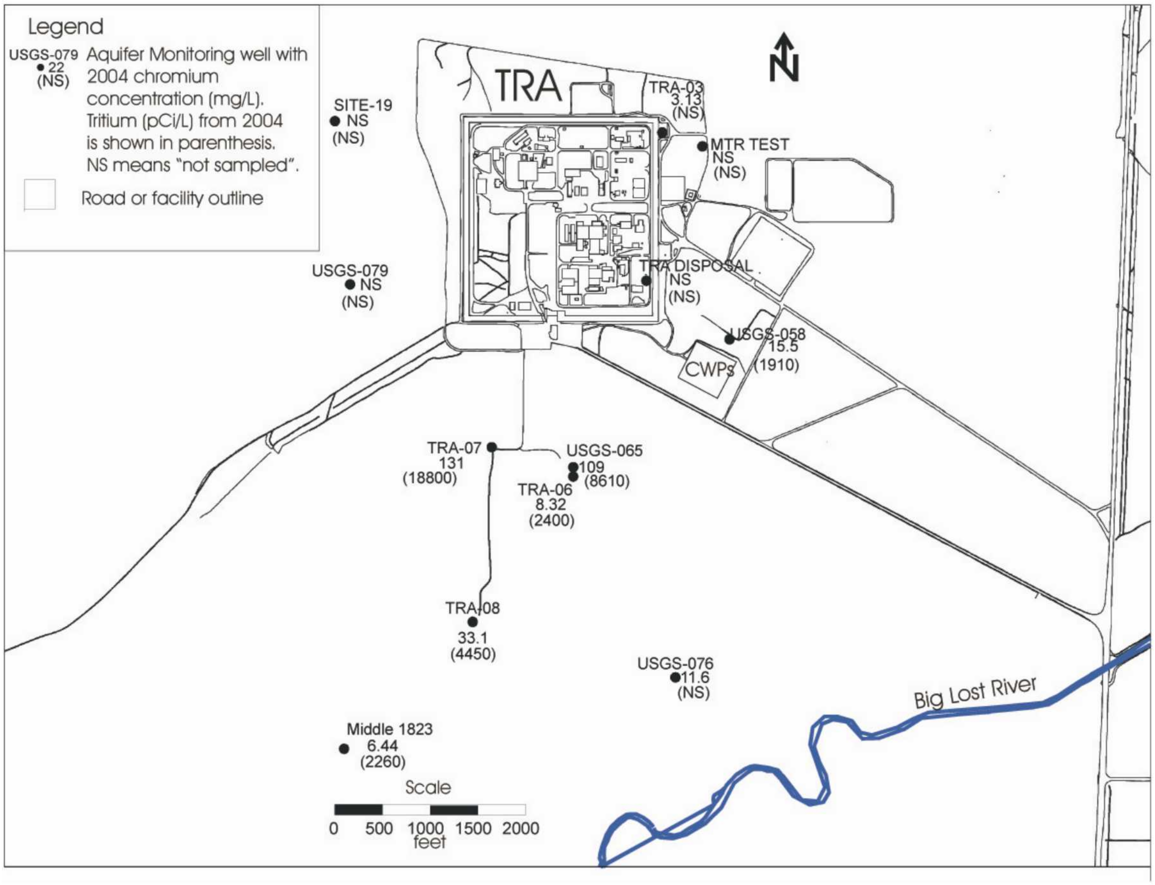


Figure 26. Chromium and tritium concentrations in the Snake River Plain Aquifer at Test Reactor Area in March 2004.

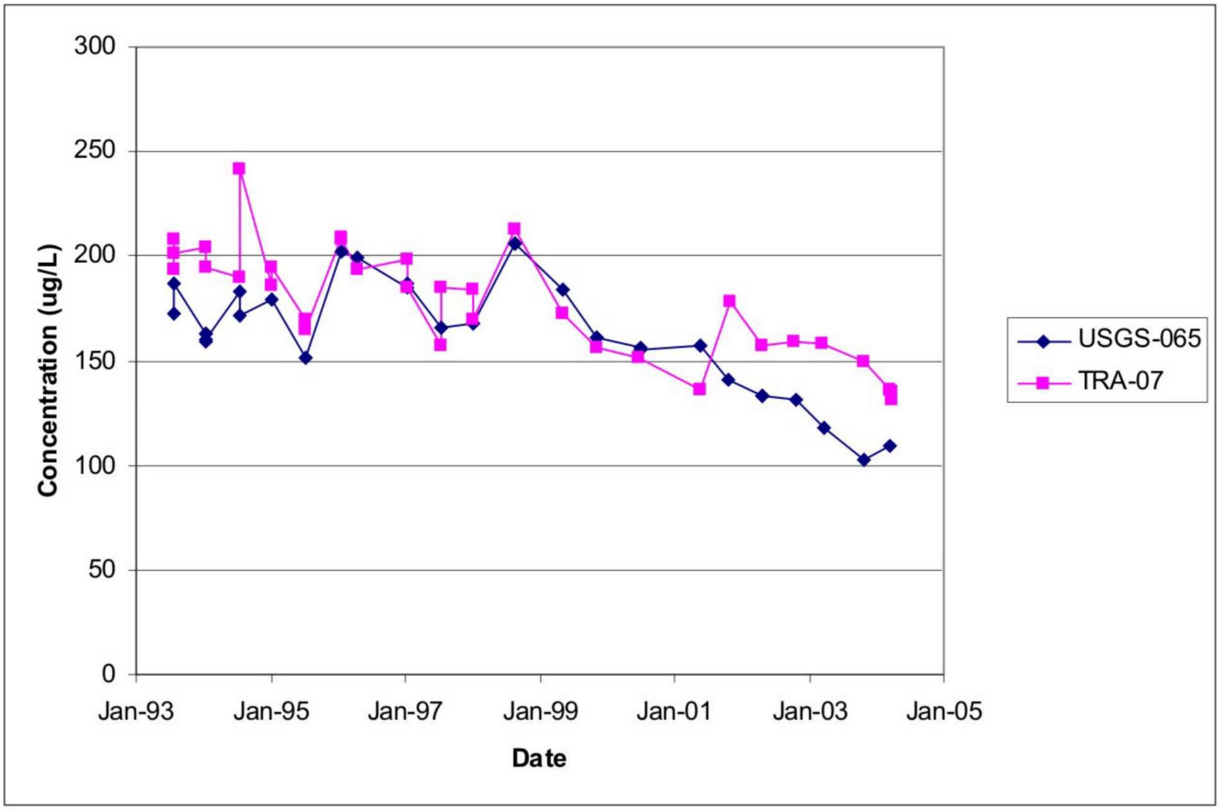


Figure 27. Chromium trends in USGS-065 and TRA-07.

4.3.1 Water-Quality Parameter Data

A Piper diagram was constructed from the 2004 sampling data for major cations and anions (Figure 28). The Piper plot shows that the water discharged into the CWP is enriched in calcium and sulfate while the SRPA water is enriched in calcium and bicarbonate. The effluent to the CWP is distinguished from the SRPA water by its high sulfate content. Because of a lack of complete anion and cation analyses, a value for the effluent to the CWP from 1998 is shown on the Piper diagram, but anion and cation concentrations have varied considerably over time. For instance, sulfate concentrations in effluent to the CWP have varied from 40 to over 400 mg/L. Most wells plot in a trend from the effluent to the CWP to the water-supply well. Unlike wells near the CWP, Wells PW-12 and PW-13 within TRA have anion concentrations that are similar to the water-supply well. Well USGS-068 may have some influence from the CWP, but appears to show influence mostly from the former Chemical Waste Pond. In 2004, Well PW-14 located near the Chemical Waste Pond was dry, probably because of the discontinued use of the pond since 1993. The spatial distribution of the sampled wells and their apparent source influences are shown on Figure 29. Wells that show influence from the CWP include USGS-054, USGS-053, USGS-055, USGS-069, USGS-060, USGS-061, USGS-062, USGS-063, USGS-066, USGS-069, USGS-070, USGS-073, PW-8, PW-11, CWP-1, and CWP-2. Well CWP-3 indicates a mix of water from the CWP and either precipitation or water from the SRPA (water supply/fire protection). Although a sample is not available, water infiltrating from the surface as a result of precipitation should be a relatively dilute calcium bicarbonate water that is probably similar in composition to the SRPA water, but more dilute.

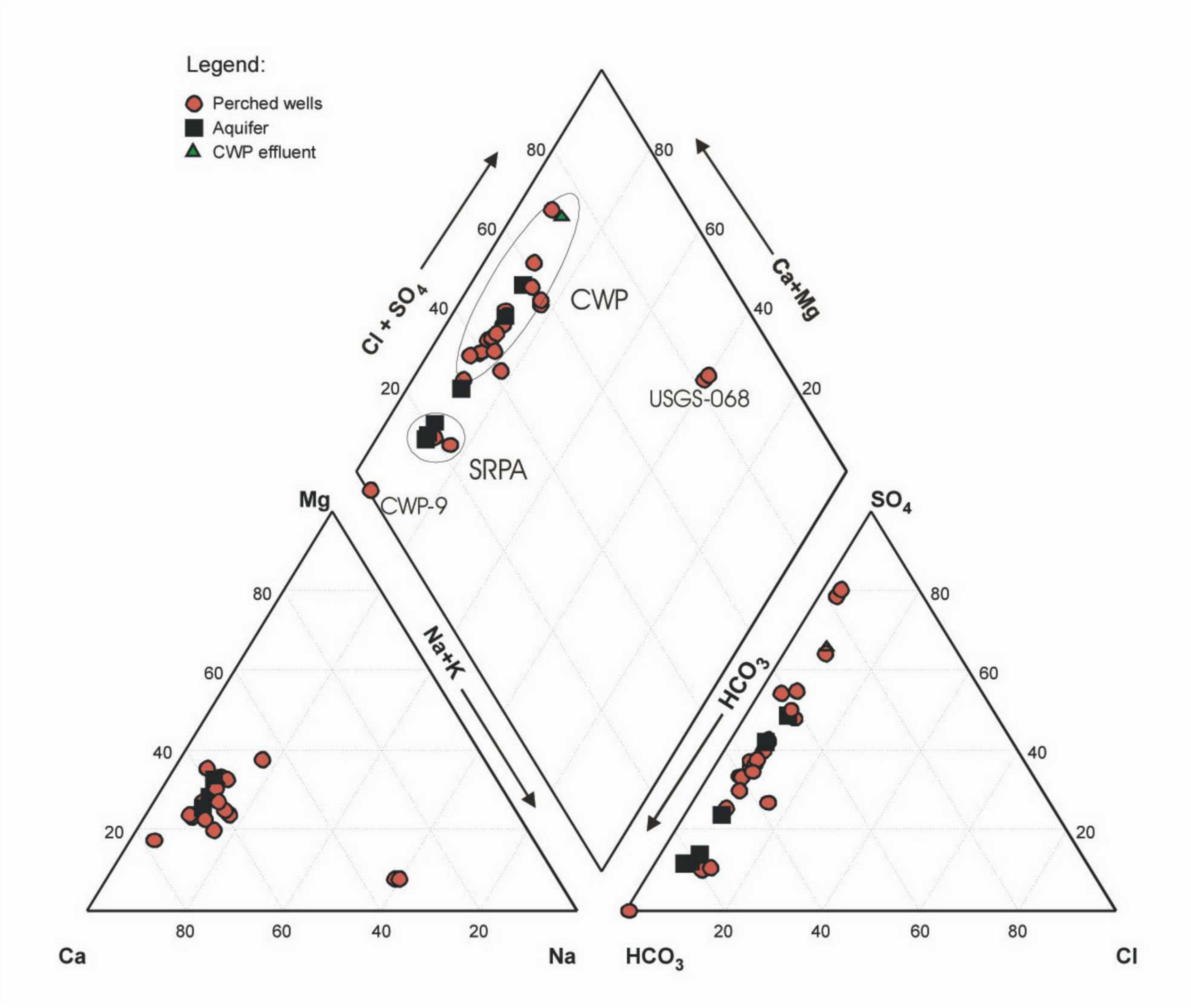


Figure 28. Piper diagram for March 2004 data.

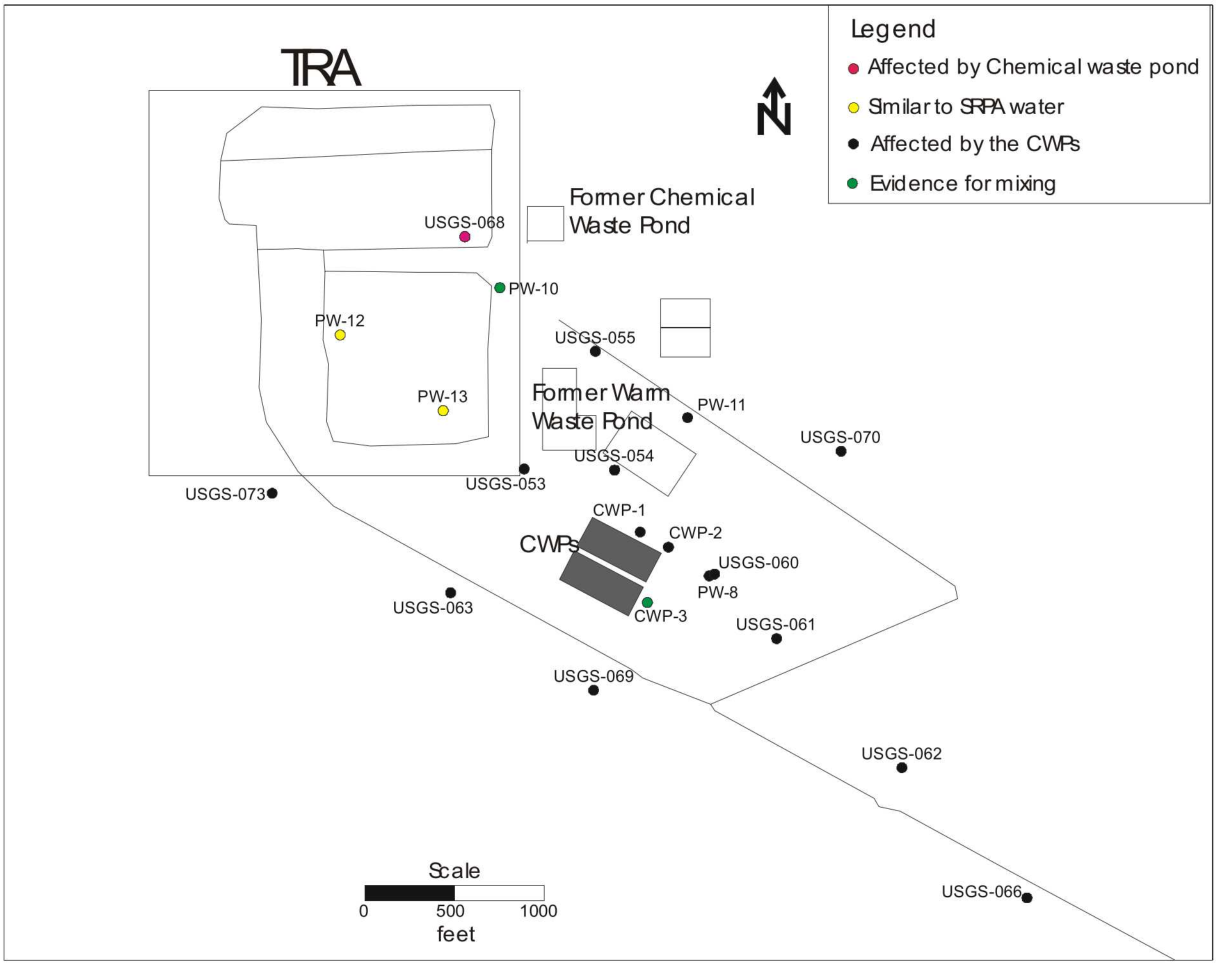


Figure 29. Characterization of perched-water sources for 2004.

(**NOTE:** *The former Chemical Waste Pond and former Warm Waste Pond are no longer in use.)*

As an additional note, the cation concentrations in PW-13 were elevated in the 2004 sample, in comparison to the 1991 results. The relative proportion of cations was the same in 2004 as in 1991, and the anion concentrations are similar. Consequently, the PW-13 sample from 2004 plots at the same position on the Piper diagram as the 1991 sample, but the large charge balance error for the 2004 sample would suggest a problem with the cation analysis. The cation results for TRA-1933 and TRA-1934 located near PW-13 are similar to earlier results for PW-13 rather the current data.

A Piper diagram for perched monitoring wells sampled in 1991 also shows that most of the perched-water wells contain water from the CWP (Figure 30). The full analytical results for the 1991 samples are reported in the *Environmental Characterization Report for the Test Reactor Area* (EG&G Idaho 1991a). Most wells plot in a similar position to the samples near the CWP collected in 2004 and the effluent to the CWP from 1998. As seen on Figure 30, the composition of perched water from USGS-68 and PW-14 is considerably different from the water discharged to the CWP. The anion and cation compositions of USGS-068 and PW-14 appear to be influenced by the former Chemical Waste Pond that was operating in 1991. Well USGS-068 may have some water from the CWP, because it plots between PW-14 and the wells near the CWP on Figure 30. Perched-water samples directly under TRA—like PW-12, PW-13, USGS-073, and USGS-072—are primarily calcium bicarbonate waters and

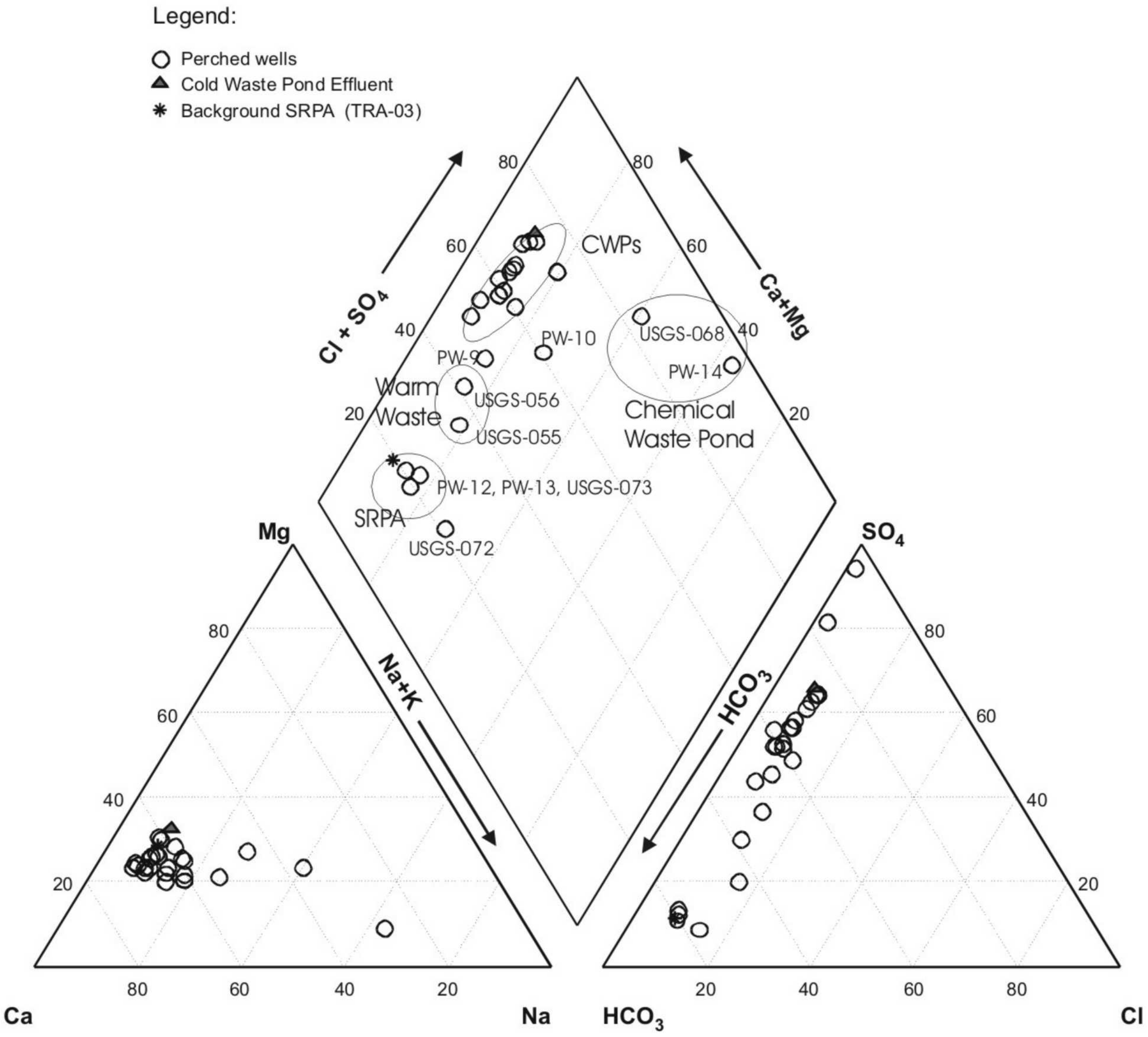


Figure 30. Piper diagram for 1991 perched-water wells.

are similar to water from the SRPA or infiltrating precipitation. Well PW-10 appears to show mixing between water from the Chemical Waste Pond and either the CWP or raw water line leaks. Wells USGS-055 and USGS-056 appear to show influence from the former WWP. Wells that show influence from the CWP include USGS-054, USGS-053, USGS-069, USGS-060, USGS-061, USGS-062, USGS-063, USGS-066, USGS-069, USGS-070, USGS-071, USGS-074, PW-8, CWP-1, and CWP-2 (Figure 31). Wells PW-9 and PW-11 appear to show mixing between water from the WWP and CWP. In addition to the chemical data, water-level fluctuations in USGS-68, USGS-072, and PW-12 do not respond to the change in flux to the Cold Waste Ponds like wells closer to the CWP, which implies that these wells have a source of water other than the CWP (INEL 1996).

A comparison of the perched-water source characterization plots for 1991 and 2004 suggest that the source of water for some wells has changed over time as water sources (Chemical Waste Pond and WWP/Warm Waste Retention Basins) have been removed (compare Figures 29 and 30). The removal of the sources has probably also led to PW-14 and USGS-056 drying up. The historical influence of the Chemical Waste Pond, WWP, and Warm Waste Retention Basins helps explain why contaminants are

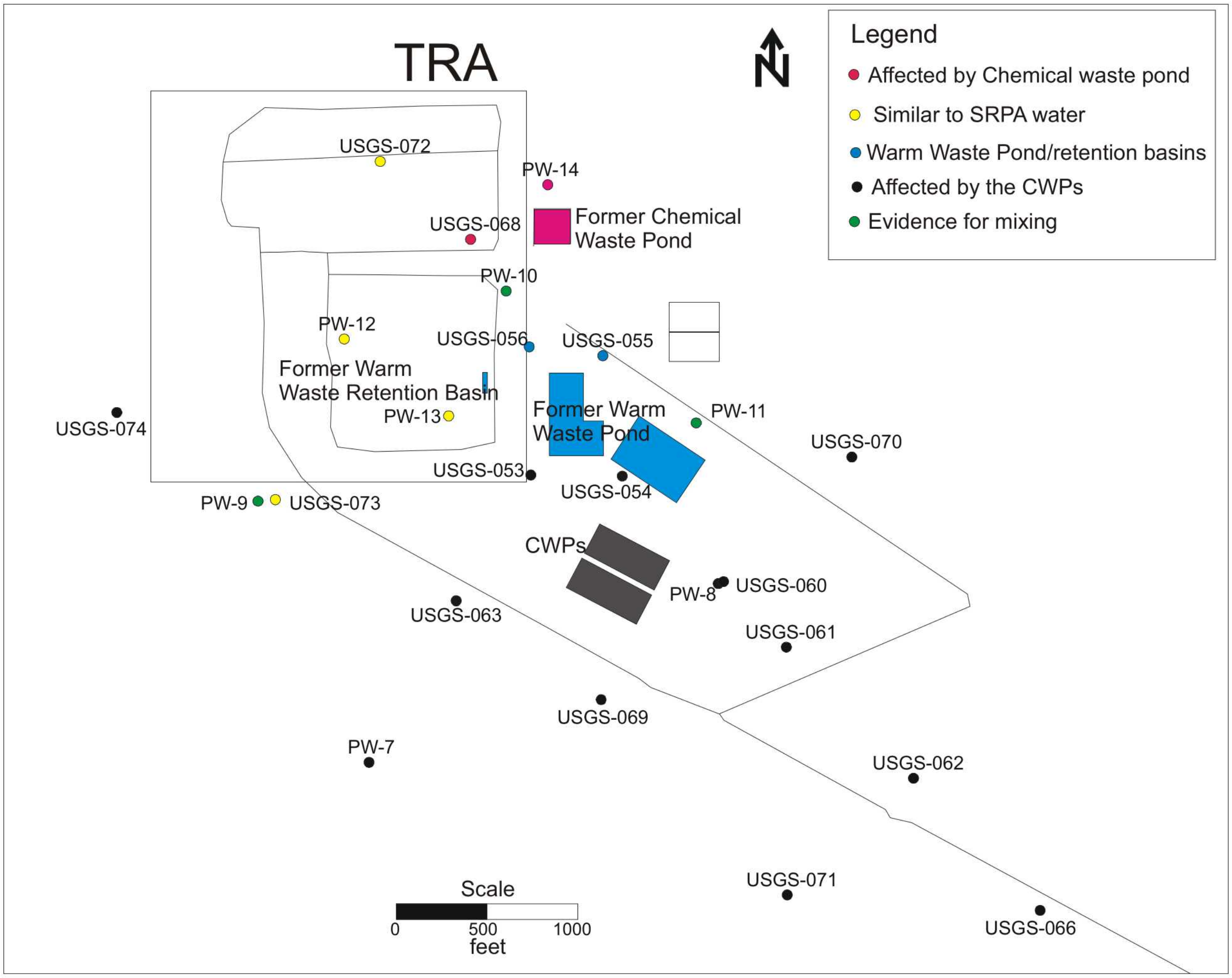


Figure 31. Characterization of perched-water sources for 1991.

still present in some wells today even though the original water source has been replaced in some cases by a different water source. The *Remedial Investigation Report for Test Reactor Area Perched Water System (Operable Unit 2-12)* (Dames and Moore 1992a) contains several figures showing historical contaminant concentrations in the perched water.

4.3.2 Physical Parameter Data

The data for field-measured parameters including temperature, pH, dissolved oxygen, and specific conductance are summarized in Table 4 for perched and aquifer wells. The data for field parameters can be used as indicators of contamination and water-source characteristics. The conductivity values for the aquifer wells in the immediate vicinity of TRA ranged from 0.407 to 0.625 millimhos per centimeter (mmhos/cm). The lowest values are for the upgradient well, TRA-03. The conductivity of most of the perched-water samples also was greater than that of TRA-03. The pH values for SRPA wells ranged from 7.57 to 8.02.

Table 4. Field-measured parameters for March 2004.

Well Name	Date Sampled	Temperature (ºC)	pH	Specific Conductivity (mmhos/cm)	Dissolved Oxygen (mg/L)
Perched Water					
CWP-1	3/7/2004	13.25	7.64	0.825	NM
CWP-2	3/7/2004	NM	NM	NM	NM
CWP-3	3/3/2004	14.67	8.06	0.466	5.7
CWP-4	3/3/2004	14.11	7.96	0.467	6.96
CWP-8	3/3/2004	17.44	7.91	0.462	5.74
CWP-9	3/2/2004	9.29	7.48	0.097	NM
PW-10	3/17/2004	14.84	7.25	0.847	5.86
PW-11	3/8/2004	16.35	7.79	0.657	6.89
PW-12	3/17/2004	15.61	7.48	0.483	5.13
PW-13	3/17/2004	NM	NM	NM	NM
PW-8	3/9/2004	16.35	7.62	0.606	6.45
USGS-53	3/9/2004	16.97	7.3	0.554	4.02
USGS-54	3/8/2004	16.9	7.54	0.546	6.06
USGS-55	3/8/2004	14.3	7.45	0.553	5.41
USGS-60	3/9/2004	15.15	7.59	0.554	6.64
USGS-61	3/9/2004	13.73	7.73	0.605	6.23
USGS-62	3/10/2004	16.89	7.29	0.626	6.29
USGS-63	3/10/2004	17.58	7.44	0.617	6.34
USGS-66	3/15/2004	12.93	7.57	0.734	6.03
USGS-68	3/17/2004	13.71	7.17	2.82	6.55
USGS-69	3/11/2004	15.41	7.68	0.493	4.63
USGS-70	3/15/2004	13.93	7.61	0.562	6.41
USGS-72	3/21/2004	16	7.29	0.47	2.53
USGS-73	3/10/2004	14.67	8.00	0.562	1.44
Aquifer Wells					
MIDDLE-1823	3/23/2004	15.4	7.57	0.499	5.98
TRA-03	3/15/2004	13.15	7.8	0.407	7.03
TRA-06	3/11/2004	13.29	7.74	0.438	7.1
TRA-07	3/16/2004	12.81	7.86	0.607	7.59
TRA-08	3/25/2004	14.88	8.02	0.439	7.55
TRA-08	3/16/2004	12.94	7.96	0.448	6.98
USGS-58	3/10/2004	13.12	7.79	0.434	7.46
USGS-65	3/11/2004	13.06	7.63	0.625	7.38
USGS-76	3/23/2004	12.61	7.75	0.434	6.97

CWP = Cold Waste Pond
NM = not measured
TRA = Test Reactor Area
USGS = United States Geological Survey

The specific conductance values for the perched-water wells showed a wide range from 0.097 to 2.82 mmhos/cm, but most perched wells were in the range of 0.45 to 0.85 mmhos/cm. The conductivity of the perched-water samples also was greater than that of TRA-03. The pH values for perched wells ranged from 7.17 to 8.00.

4.3.3 Environmental Isotope Data

The sampling activities for this investigation and the regular Waste Area Group 2 sampling activities for March 2004 included the analysis of hydrogen and oxygen isotope ratios from perched and aquifer wells. The stable isotope data were collected to determine source(s) of perched water and to evaluate the flux from the vadose zone into the aquifer. Potential sources of perched water in 2004 include discharge to the CWP, SRPA water leaking from raw water lines, local precipitation (principally snowmelt), and the Big Lost River. Water samples were collected from 29 perched and SRPA wells (Table 5). The conclusions and inferences drawn from the stable isotope study are indicative of the time of sampling in March 2004 and could be different during a different time of the year or when the Big Lost River flows. The analytical methods used to determine the hydrogen and isotope ratios are described in Attachment 2 on the included supplemental data CD.

The stable isotope data for oxygen and hydrogen used in the discussion below are expressed in conventional delta (δ) notation in per mil (‰, parts per thousand) difference in the ratio of the less abundant isotope to the most abundant isotope in a sample relative to the same ratio in a known reference standard (Clark and Fritz 1997). Equation (1) is used:

$$\delta X_{sample} = [(R_{sample} - R_{standard})/ R_{standard}] \times 1{,}000 \qquad (1)$$

where

δX = the isotope of interest (δ18O or δD)

R = the ratio of 18O/16O or D/H.

The δD results for the perched-water samples ranged from -126.9 to -136.9‰, while the $\delta^{18}O$ results ranged from -16.1 to -17.9‰. The δD results for the SRPA samples ranged from -131.4 to -137.7‰, while the $\delta^{18}O$ results ranged from -16.8 to -17.9‰. Most of the perched-water and SRPA samples had $\delta^{18}O$ values of -17 to -18‰ and δD values of -132 to -137‰.

A plot of $\delta^{18}O$ and δD values for the perched-water and SRPA samples is shown on Figure 31 along with the global meteoric water line (GMWL) (Craig 1961). The GMWL defines the relationship between $\delta^{18}O$ and δD values in worldwide fresh waters, but this line is actually a composite of many local or regional meteoric water lines. It is used as a reference, because a local meteoric water line has not yet been determined. The SRPA and perched-water samples plot below and to the right of the GMWL (Figure 32). A best-fit line ($\delta D = 5.04\delta^{18}O - 46.5$) through the perched-water and aquifer samples intersects the GMWL at approximate $\delta^{18}O$ and δD values of -19 and -142, respectively.

Table 5. Oxygen and hydrogen isotope results.

Sample ID	Well	Depth (ft)	δD	$\delta^{18}O$	Sample Date
Perched Water					
TRA 075 01 3A	CWP-1	48.45–59.44	-126.91	-16.1	3/7/2004
TRA 076 01 3A	CWP-2	45.95–52	-132.4	-17.08	3/7/2004
TRA 077 013A	CWP-3	50.16–57	-135.86	-17.72	3/3/2004
TRA 083 013A	CWP-9	34.3–64.45	-133.07	-16.66	3/3/2004
TRA 087 01 3A	PW-10	176.45	-135.82	-17.73	3/17/2004
TRA 178 01 3A	PW-11	109.75	-129.81	-16.68	3/8/2004
TRA 179 01 3A	PW-12	85.4	-135.02	-17.71	3/17/2004
TRA 088 01 3A	PW-13	71.52–89.97	-136.85	-17.94	3/17/2004
TRA 084 01 3A	PW-8	69.55	-132.62	-17.06	3/9/2004
TRA 181 01 3A	USGS-53	70.03	-134.08	-17.41	3/9/2004
TRA 182 01 3A	USGS-54	66.01	-134.81	-17.38	3/8/2004
TRA 183 01 3A	USGS-55	62.1	-134.39	-17.28	3/8/2004
TRA 089 01 3A	USGS-60	68.58	-134.06	-17.24	3/9/2004
TRA 090 01 3A	USGS-61	90.27	-131.35	-16.79	3/9/2004
TRA 091 01 3A	USGS-62	136.57	-133.06	-16.91	3/10/2004
TRA 092 01 3A	USGS-63	76.05	-133.19	-17.06	3/10/2004
TRA 094 01 3A	USGS-66	183.9	-128.33	-16.36	3/15/2004
TRA 095 01 3A	USGS-68	83.74	-130.81	-17.15	3/17/2004
TRA 195 01 3A	USGS-68	83.74	-131.99	-17.1	3/17/2004
TRA 096 01 3A	USGS-69	79.45	-133.35	-17.23	3/11/2004
TRA 097 01 3A	USGS-70	72.86	-133.44	-17.16	3/15/2004
TRA 100 01 3A	USGS-73	87.48	-130.08	-16.68	3/10/2004
Aquifer Wells					
TRA 19101 3A	MIDDLE-1823	720	-136.71	-17.94	3/23/2004
TRA 10801 3A	USGS-76	489.29	-136.77	-17.92	3/23/2004
TRA 190 01 3A	USGS-65		-131.52	-16.78	3/11/2004
TRA 104 01 3A	TRA-03		-137.71	-17.92	3/15/2004
TRA 10501 3A	TRA-07	485.32	-131.41	-16.83	3/25/2004
TRA 10601 3A	TRA-08	489.5	-137.56	-17.84	3/25/2004
TRA 18901 3A	USGS-58	470.14	-136.02	-17.89	3/25/2004

CWP = Cold Waste Pond
ID = identification
TRA = Test Reactor Area
USGS = United States Geological Survey

The use of SRPA water in industrial processes and irrigation should produce a shift in the $\delta^{18}O$ and δD values and cause samples to plot to the right of the GMWL. The majority of the perched-water samples show a limited evaporative effect with higher $\delta^{18}O$ and δD values than water from the SRPA based on the values for TRA-03 (Figure 32). Discharge to the CWP should show seasonal changes with an increase in the $\delta^{18}O$ and δD values of the effluent in the summer as a result of evaporative effects. In addition, irrigation that is applied to lawns in TRA should also show an increase in $\delta^{18}O$ and δD values as a result of evaporative effects, unless leaks occurred underground in the irrigation pipes.

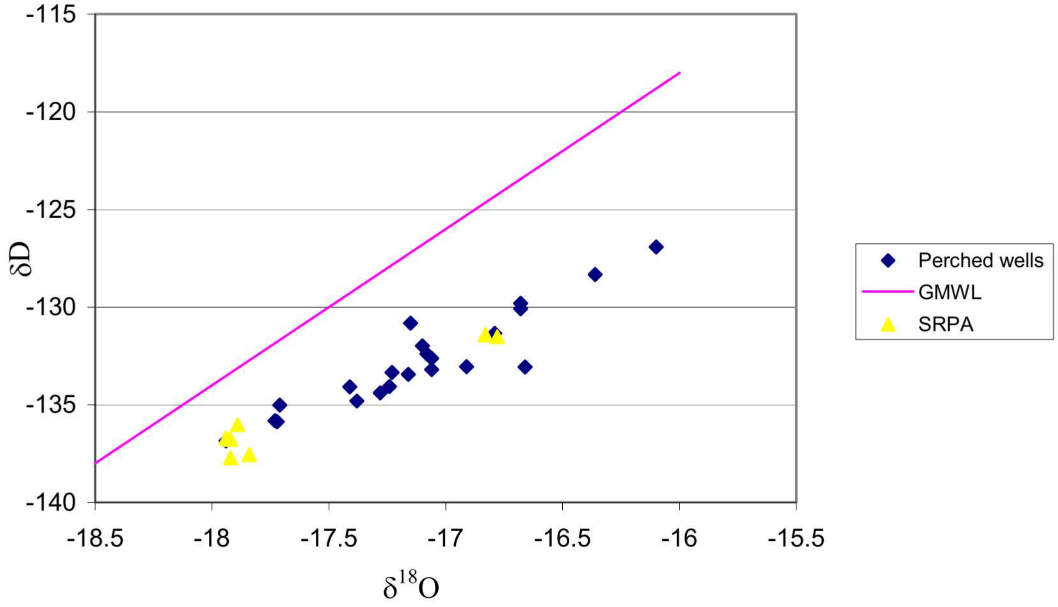


Figure 32. Plot of $\delta^{18}O$ versus D values for perched water and Snake River Plain Aquifer water.

NOTE: *The global meteoric water line is shown for reference.*

4.4 Discussion of Perched-Water Contamination and Water Sources

This subsection discusses sources of perched water and contamination. The perched-water sources are discussed using primarily data collected in 2004. The principal contaminants in the perched water are Sr-90, tritium, chromium, Co-60, and sulfate, while the principal contaminants in the SRPA are chromium, sulfate, and tritium. Historically, the WWPs and retention basins have been a primary source of contamination. The extent of perched-water contamination from the WWPs has depended on waste disposal practices and on the variation over time of the quantities of contaminants and discharge water (Dames and Moore 1992a). The extent of the perched zones also has changed as a result of sources of perched water coming online like the CWPs in 1982 and the elimination of perched-water sources like the Chemical Waste Ponds.

4.4.1 Discussion of Water Sources Responsible for Perched-Water Bodies

The stable isotope (δD, $\delta^{18}O$) results and sulfate data for March 2004 suggest that water from the CWP accounts for water in most of the perched-water wells. However, the water-quality and stable-isotope data suggest that the perched water consists of multiple perched-water bodies with different water sources. Sulfate is plotted versus the $\delta^{18}O$ of the water to integrate the identification of the water sources with contaminant sources because sulfate concentrations vary considerably for the water sources as seen on the Piper diagrams. The sulfate versus $\delta^{18}O$ plot shows several groupings of wells corresponding to different water sources (Figure 33). Most wells plot in a grouping that indicates an influence from the CWP. Well CWP-1 does not plot in the group for the CWP on Figure 33; however, CWP-1 does plot with the CWP group on the Piper diagram (Figure 27). This suggests that the source of water for CWP-1 is a more evaporated version of water that is currently discharged to the CWP. Well CWP-1 could be in a slower migration pathway and reflects an averaged yearly $\delta^{18}O$ and sulfate composition. Although sulfate concentrations in the effluent to the CWP are variable, mixing in the vadose zone should average sulfate concentrations along slower flow paths.

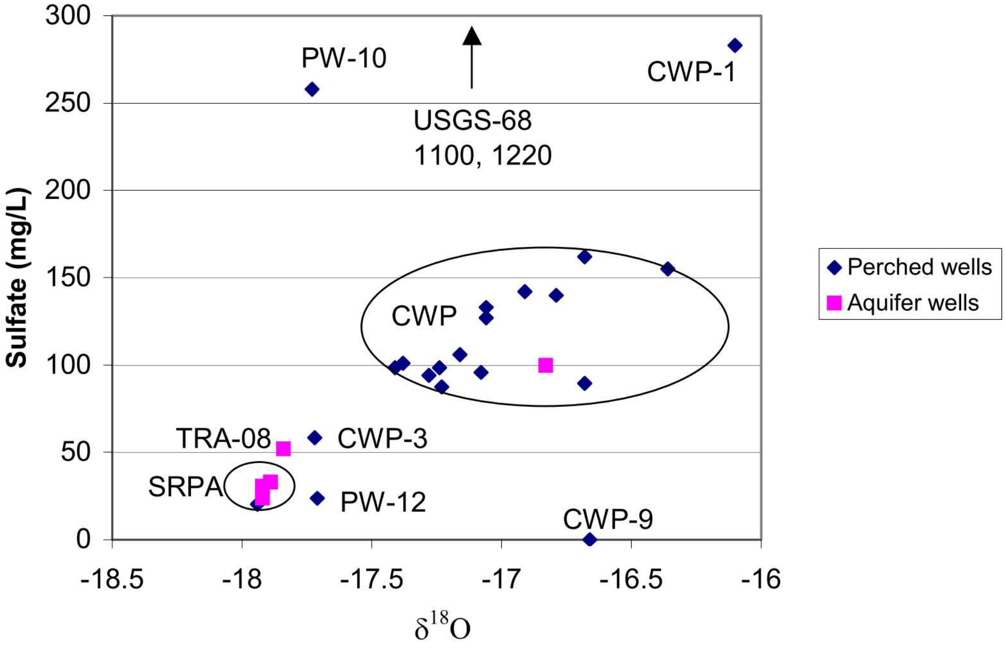


Figure 33. Plot of $\delta^{18}O$ versus sulfate.

The $\delta^{18}O$ and δD values in the perched-water wells near the CWP show a general pattern of lower $\delta^{18}O$ and δD values near the CWP (USGS-054, USGS-053, USGS-60, and USGS-069) and higher $\delta^{18}O$ and δD values farther away (USGS-066, USGS-062, USGS-061, and USGS-073). This pattern could indicate more rapid flushing of the perched-water wells near the CWP with the wells farther away from the CWP showing a lower flux rate. The higher $\delta^{18}O$ and δD values in wells farther from the CWP probably reflect an averaging of the water values for multiple seasons. The summer infiltration from the CWP could have higher $\delta^{18}O$ and δD values as a result of evaporation. In contrast, winter infiltration from the CWP should be shifted only slightly higher than the values for the water supply (i.e., the SRPA).

Three wells (including PW-10, PW-12, and PW-13) are similar in δD and $\delta^{18}O$ composition to the SRPA water, suggesting that the source of the perched water is from leaking raw water pipes. The water supply for TRA is drawn locally from the SRPA at TRA-03. The stable isotope data for PW-12 have been shifted slightly from SRPA water and this could indicate infiltration from precipitation. In addition, a drainage ditch is located near PW-12. Well PW-10 has a much different anion and cation signature than PW-13 or PW-12, and it plots near the CWP group on the Piper diagram. However, the lower $\delta^{18}O$ value (similar to the SRPA) for PW-10 suggests a different water source than the CWP. The composition of PW-10 could reflect the influence from the former Chemical Waste Pond. The CWP does not appear to be the source of water in PW-13, but the occurrence of Sr-90 in Well PW-13 could provide a clue as to the source of water migrating to this well and perhaps the source of diesel as well. The δD and $\delta^{18}O$ along with the sulfate concentration suggests that Wells PW-10, PW-12, and PW-13 intersect perched water bodies that are mostly isolated from the influence of the CWP.

Two wells that plot as isolated points on Figure 33 are CWP-9 and USGS-068. A possible source of water in CWP-9 could be infiltrating precipitation near the CWP, because the sulfate concentration is too low in this well to indicate that the water in this well is from the CWP or SRPA. The source of water in USGS-068 also could be precipitation or leaking facility raw water lines based on the $\delta^{18}O$ value, but the high sulfate concentration would indicate that the infiltration would have to pick up contaminants from the former Chemical Waste Pond along the migration pathway.

Well CWP-3 plots in between the δD and $\delta^{18}O$ range for the SRPA and the values for CWP (Figure 33). The water in CWP-3 could be a mix of CWP and SRPA water, because it lies between these two water sources on Figure 33. However, precipitation cannot be ruled out as a water source for CWP-3.

4.4.2 Discussion of Perched-Water Contamination and Sources

The very distinct geochemical signatures of the different water sources discussed above and the contaminant data in perched-water wells indicate that the deep perched water beneath TRA occurs in stratified or isolated zones with minimal mixing between some zones. This is a departure from the idealized conceptual model presented in Figure 3. Well coverage, both laterally and vertically, is insufficient to completely characterize these zones. Some water-level data indicate that the hydraulic head differences between zones are distinct over short distances. The heterogeneous fractured basalt and discontinuous sediment layers coupled with multiple water sources undoubtedly create these zones. This subsection presents and discusses the limited data that support the premise of multiple, distinct zones forming the deep perched water beneath TRA.

The distribution of tritium in the perched water in 2004 and in 1990 indicates a source of contamination to the northwest of the CWP (Figures 22 through 25). Although USGS-053 was used as an injection well in the early 1960s, the only identified sources of tritium since then are the former WWP and Warm Waste Retention Basins or piping and sumps associated with these facilities. Historically, USGS-056 has had some very high tritium concentrations (956,000 pCi/L), but that well has dried up after the former WWP and Warm Waste Retention Basins were removed from service. The influence of the WWP and Warm Waste Retention Basins extended below the current CWP and southeast to USGS-066 and west under TRA to USGS-074 prior to the initiation of discharge to the CWP in 1982 (Dames and Moore 1992a).

In 1990, tritium was detected in wells that occur in an arc pattern around the CWP (Figure 24). In 2004, the distribution of tritium was similar to that in 1990, but the tritium concentrations had decreased significantly (Figure 25). The decrease in tritium concentrations was greater than that expected from radioactive decay alone (half-life of 12.3 years). For example, the observed decrease in tritium concentration in USGS-055 from 74,800 to 13,000 pCi/L was considerably more than the decrease to approximately 34,000 pCi/L calculated for radioactive decay alone. This tritium pattern indicates that the flux of water in the immediate vicinity of the CWP flushes the perched system fairly rapidly near the CWP, but the flux is much lower further out from the CWP. This pattern of water flux also is suggested by oxygen and hydrogen isotope data, as discussed in the previous section.

The historical occurrence of high tritium concentrations in the USGS-074 and PW-9 perched-water wells, but not in PW-12 or PW-13 located between USGS-074 and PW-9 and the most likely source (WWP/Warm Waste Retention Basins), suggests that the deep perched water is not continuous. Separate deep perched-water zones also are inferred from the oxygen- and hydrogen-isotope data and general water-quality parameter data discussed in the previous section. The presence of high tritium concentrations in PW-9 and USGS-074 might indicate the occurrence of a deep perched-water zone below TRA at a depth of approximately 200 ft that is currently related to the CWP and shows the residual influence of the former WWP and Warm Waste Retention Basins. Evidence for a lower and upper deep-perched zone is found at Wells PW-9 and USGS-073, located next to each other, but screened at different depths. Well PW-9 is screened from 140 to 200 ft bls and the measured depth to water bls is 176.45 ft. Well USGS-073 is screened from 62 to 127 ft bls and the depth to water bls is 87.48 ft. The large difference (90 ft) in water levels between PW-9 and USGS-073 is an indication of stratification and limited hydraulic communication in the deep perched water beneath TRA (Figure 34). This difference in water levels also can be seen in the *Remedial Investigation Report for the Test Reactor Area Perched Water System (Operable Unit 2-12)* (Dames and Moore 1992a). Large differences in head across short distances indicate the presence of rock and/or sediment with very low permeability. Layers and/or fingers of low permeability in the subsurface also could serve to isolate the geochemical character of waters found in different water-bearing zones. The large difference in water level between PW-9 and USGS-073 contrasts sharply with the small difference in water levels for the PW-8 and USGS-060 paired wells (Figure 35).

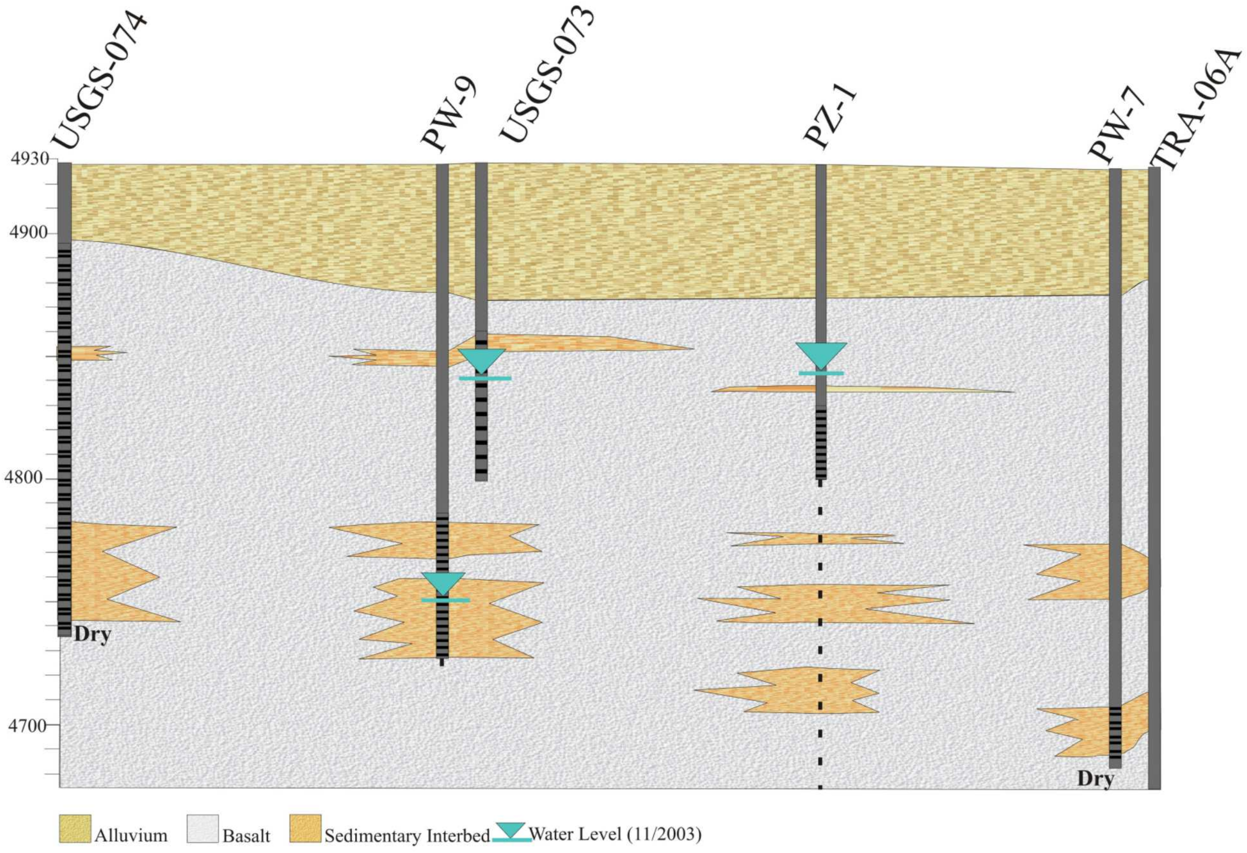


Figure 34. Cross-section from USGS-074 to TRA-06A.

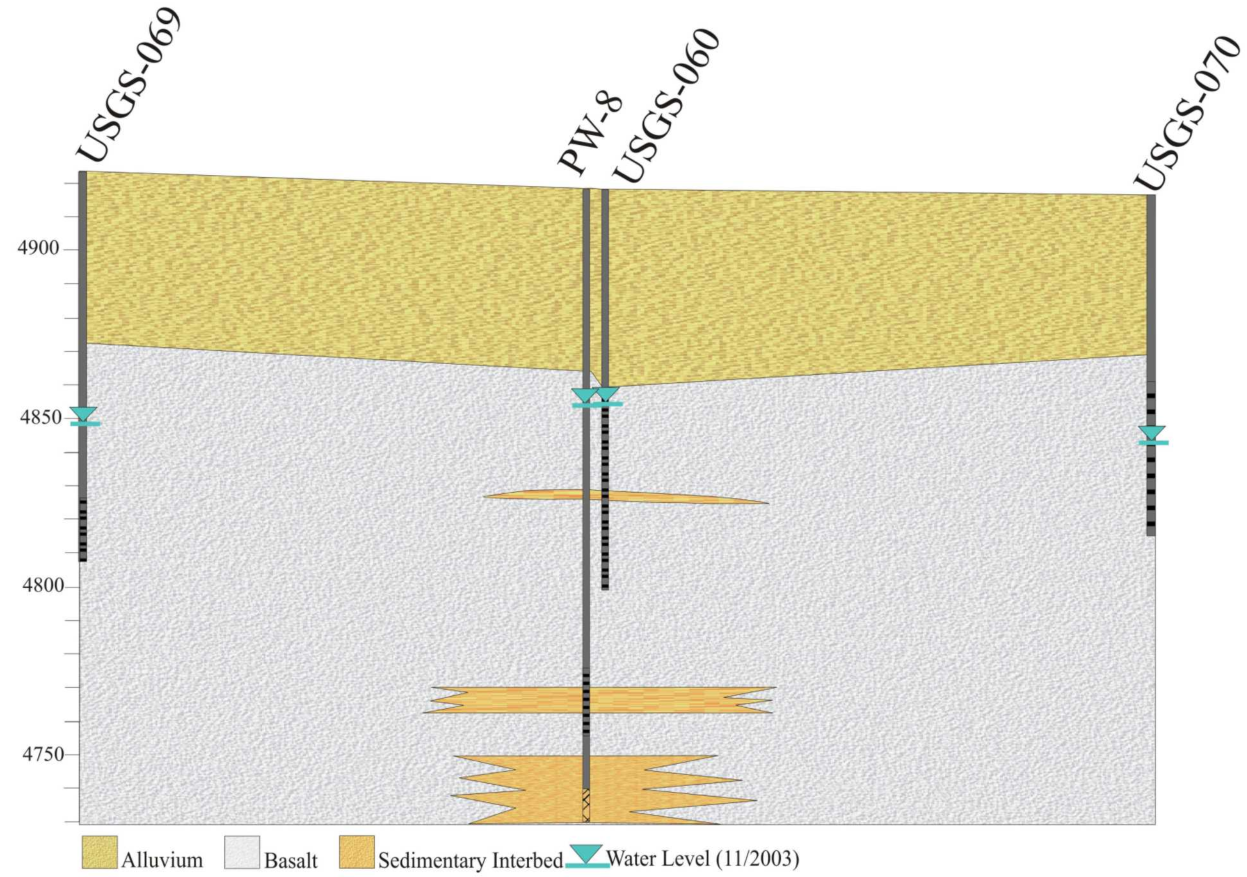


Figure 35. Cross-section from USGS-069 to USGS-070.

The distributions of chromium and Sr-90 in the perched water in 2004 indicate a source of contamination to the northwest of the CWP (Figures 22 through 25). The high Sr-90 and chromium concentrations associated with Wells USGS-055, USGS-054, USGS-070, and CWP-9 probably indicate leakage from the former WWP and Warm Waste Retention Basins (TRA-04) or piping and sumps associated with these facilities. However, the source of Sr-90 in PW-13 is uncertain, because Sr-90 is not associated with tritium in this well, suggesting that the WWP is not the source of contamination in this well.

Cobalt-60 has not been detected in any aquifer wells; in the perched water, Co-60 has only been detected in Well PW-12. The concentration of Co-60 in PW-12 recently spiked, but it is now declining (ICP 2004d). In addition to Co-60, Sr-90 exhibits an overall upward trend in concentration in PW-12 (ICP 2004d). The source of Co-60 likely is either the result of the migration of residual contamination from one of three nearby Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) sites with known contamination or the result of hydrologic mechanisms. The common ion and stable isotope data suggest that the water source moving the contaminant may be from leaking raw water lines near PW-12 with some influence from precipitation. In contrast to chromium and tritium, Co-60 transport does not appear to be aided by infiltrating water from the CWP.

4.4.3 Discussion of PW-13 Diesel Contamination

The potential for microorganisms to degrade hydrocarbon (natural attenuation) contamination (diesel) in Well PW-13 and the two new wells, TRA-1933 and TRA-1934, is evaluated by examining the water chemistry. Diesel fuel is typically composed of hydrocarbons that have a range of 5 to 20 carbon atoms (C_5 to C_{20} hydrocarbons) with the majority of the diesel product in the C_9 through C_{20} range. In general, the C_5 through C_8 hydrocarbons are more soluble in water and mobile in the environment than the C_9 through C_{20} hydrocarbons. The C_5 through C_8 hydrocarbons include the BTEX components.

Dissolved oxygen is an important parameter for evaluating natural attenuation of hydrocarbons. Although dissolved oxygen data were not collected in March 2004 for PW-13, TRA-1933, and TRA-1934, dissolved oxygen was measured in October 2004. The dissolved oxygen readings for PW-13, TRA-1933, and TRA-1934 in October 2004 were 0.17, 0.21, and 0.70 mg/L, respectively. The low dissolved oxygen readings in PW-13, TRA-1933, and TRA-1934 in comparison to other perched wells (average 5.5 mg/L) suggest that aerobic respiration has depleted the amount of dissolved oxygen. If the background or natural dissolved oxygen concentrations for PW-13, TRA-1933, and TRA-1934 are similar to the average for the other perched wells at TRA, then the perched water has a significant aerobic assimilative capacity or natural attenuation capacity.

The biologically mediated processes involved in the degradation of hydrocarbons typically produce a shift from oxidizing to anaerobic (reducing) conditions in the groundwater. The shift from oxidizing to anaerobic conditions produces changes in groundwater chemistry that are reflected in the concentrations of redox-dependant species. The primary processes involved in the degradation of dissolved hydrocarbons are (1) aerobic respiration (dissolved oxygen concentration decrease), (2) anaerobic-denitrification (nitrate concentration decreases), (3) anaerobic-iron (III) reduction iron (+3) (dissolved iron concentration increases), (4) anaerobic-sulfate reduction (sulfate concentration decreases), and (5) anaerobic-methanogenesis (methane concentration increases) (EPA 1994, 1998). The degradation processes and changes in groundwater chemistry are shown on Figure 36. In addition, the creation of anaerobic conditions can lead to significantly increased concentrations of manganese, barium, and arsenic along with the production of methane. The significance of anaerobic processes can be evaluated by looking at concentrations of dissolved oxygen, nitrate, dissolved iron, and sulfate.

The elevated manganese concentration in Wells PW-13, TRA-1933, and TRA-1934 indicate that dissolved oxygen is depleted and therefore utilized to degrade hydrocarbons. Nitrate is typically utilized after dissolved oxygen is depleted. Nitrate concentrations in PW-13 are lower than the possible water source (SRPA water from TRA-03), but concentrations in the source are also low (less than 1 mg/L). Because nitrate is lower in concentration in PW-13 than TRA-03, it appears that nitrate is being at least partially utilized. In TRA-1933 and TRA-1934, nitrate is below detection limits and appears to have been utilized, suggesting that anaerobic biodegradation processes are active. However, without a good background value for nitrate, it is not possible to fully evaluate the utilization of nitrate in PW-13, TRA-1933, or TRA-1934. Because manganese concentrations are elevated and iron concentrations are only slightly elevated in all three wells, this would indicate that the redox conditions are not favorable for the reduction of sulfate. This would imply that sulfate is not being utilized to a large extent by bacteria and that the sulfate concentration in PW-13 is only marginally affected. The sulfate concentrations in TRA-1933 and TRA-1934 are lower than in PW-13, suggesting that sulfate is utilized to a slightly greater extent in these wells than in PW-13. Barium concentrations are significantly elevated in PW-13, but not in TRA-1933 or TRA-1934. Arsenic concentrations are within the natural range for all three wells.

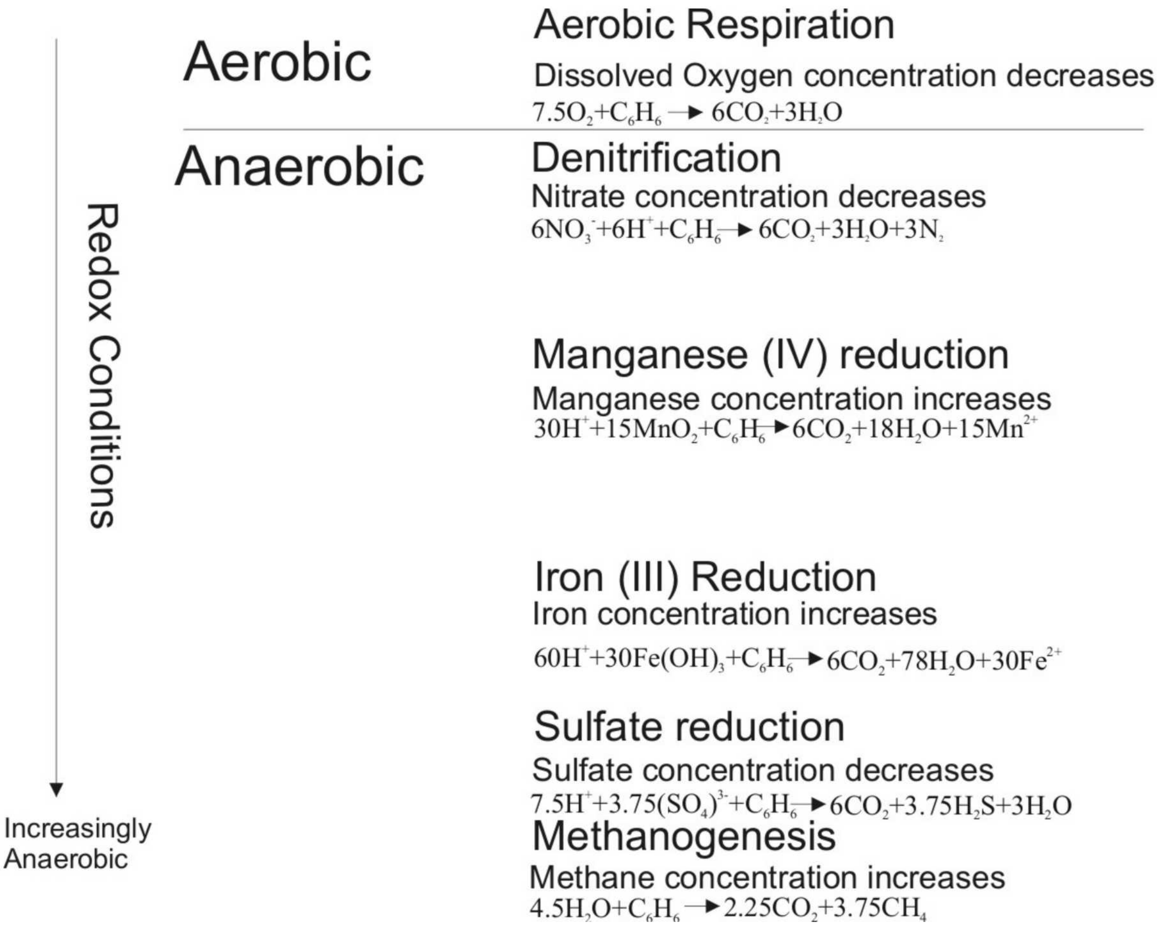


Figure 36. Schematic illustrating the natural attenuation processes involved in the degradation of hydrocarbons. (Note that the spacing between processes reflects the relative redox change and possible reactions [from (EPA 1998)] for benzene [C_6H_6] are given as examples.)

Anaerobic degradation may not have fully developed in Wells PW-13, TRA-1933, and TRA-1934—as evidenced by extensive sulfate depletion, high dissolved iron concentrations, and the presence of methane—because the aerobic assimilative capacity of the perched water is sufficient to prevent this zone from developing. If floating petroleum product is from a release in the early 1980s, then most of the mobile and soluble hydrocarbon fraction of the product would have had time to have partitioned from the residual product. The current low gasoline-range organics and relatively low diesel-range organic concentrations in the perched water indicate that the more mobile and easily degradable hydrocarbons have probably been removed from the residual floating product. In addition, the mobile and soluble hydrocarbons are the most biodegradable components of diesel. Thus, the remaining residual product in perched water is probably composed of low-solubility hydrocarbons that are resistant to natural attenuation processes.

The BTEX and gasoline-range organics data indicate that natural attenuation processes have removed the C_5 through C_8 hydrocarbons that are the more soluble and mobile hydrocarbons. Although no samples of the residual floating petroleum product have been analyzed, the product is probably composed mostly of greater than C_9 hydrocarbons that are not readily degradable. If recovery of the remaining petroleum fraction (floating product) is required, physically pumping (either actively or passively) may be the best alternative. Free-phase hydrocarbons in nonaqueous-phase liquid (floating product) are not readily degradable by microorganisms and are only slightly affected by natural attenuation processes. The highly variable occurrence of floating product in PW-13 would favor passive recovery of the petroleum product.

Alternatively, the hydrocarbons could have migrated away from the floating product, but several studies have demonstrated that dissolved hydrocarbon plumes are susceptible to biodegradation processes and the data collected from this investigation suggest that as well (EPA 1994). The biodegradation of dissolved hydrocarbons, principally BTEX, is mainly limited by the supply of electron acceptors (dissolved oxygen, nitrate, iron (III), sulfate, and carbon dioxide). The authors of the *Technical Protocol for Evaluating Natural Attenuation of Chlorinated Solvents in Ground Water* (EPA 1998) concluded that in most, if not all, hydrogeologic environments there appears to be an adequate supply of electron acceptors.

4.4.4 Evaluation of Flux from the Vadose Zone into the Aquifer

The extent of the CWP's influence on the SRPA can be qualitatively evaluated by looking at a map of the sulfate plume in the SRPA (Figure 37). The distribution of sulfate in the SRPA in 1991 points to the CWP as the primary source of the sulfate plume, because the highest sulfate concentrations are downgradient (see Figure 8) of the CWP (Figure 37). The sulfate plume could also in part originate from the former Chemical Waste Pond, since sulfate was elevated in the MTR test well in 1991, which is located near the former Chemical Waste Pond. However, it is uncertain if the high sulfate and cation concentrations in the MTR test well are from the CWP or from the former Chemical Waste Pond. The influence of the CWP and former Chemical Waste Pond can be seen on a plot of sulfate concentrations in the perched water in 1991 (Figure 38). The small increase in sulfate above background (Well TRA-03 is used for background based on the hydraulic gradient) in USGS-058 suggests that most of the water from the CWP impacts the SRPA south-southwest of USGS-58.

Two aquifer wells, USGS-065 and TRA-07, downgradient of the CWP show higher $\delta^{18}O$ and δD values than the other aquifer wells. The higher $\delta^{18}O$ and δD values along with elevated sulfate concentrations indicate influence from the CWP. The higher $\delta^{18}O$ and δD values probably reflect mixing of seasonal $\delta^{18}O$ and δD values at depth in the vadose zone. This would imply that the average travel time from the perched zone to the aquifer is greater than 6 months to allow for mixing over several seasons (at least spring to fall). However, not enough data exist to fully evaluate this travel-time estimate. The USGS data for USGS-065 collected on May 16, 1991, indicated similar $\delta^{18}O$ and δD values (-16.90 and -133.0 per mil), as determined in this investigation (USGS 1999). Well TRA-08 plots in between the δD and $\delta^{18}O$ range for the SRPA and the values for the CWP (Figure 33). This suggests that the water in Well TRA-08 probably reflects mixing of water from the CWP with water from the SRPA.

Elevated tritium and chromium concentrations also are associated with elevated sulfate concentrations in the TRA-07, USGS-065, and TRA-08 SRPA wells. This could indicate that while the CWP is not the source of these contaminants, water from the CWP is aiding the transport of these contaminants to the aquifer. In addition, USGS-076 shows sulfate and chromium above background in 2004 and has had tritium detections in the past, but tritium was not sampled for in USGS-076 in 2004.

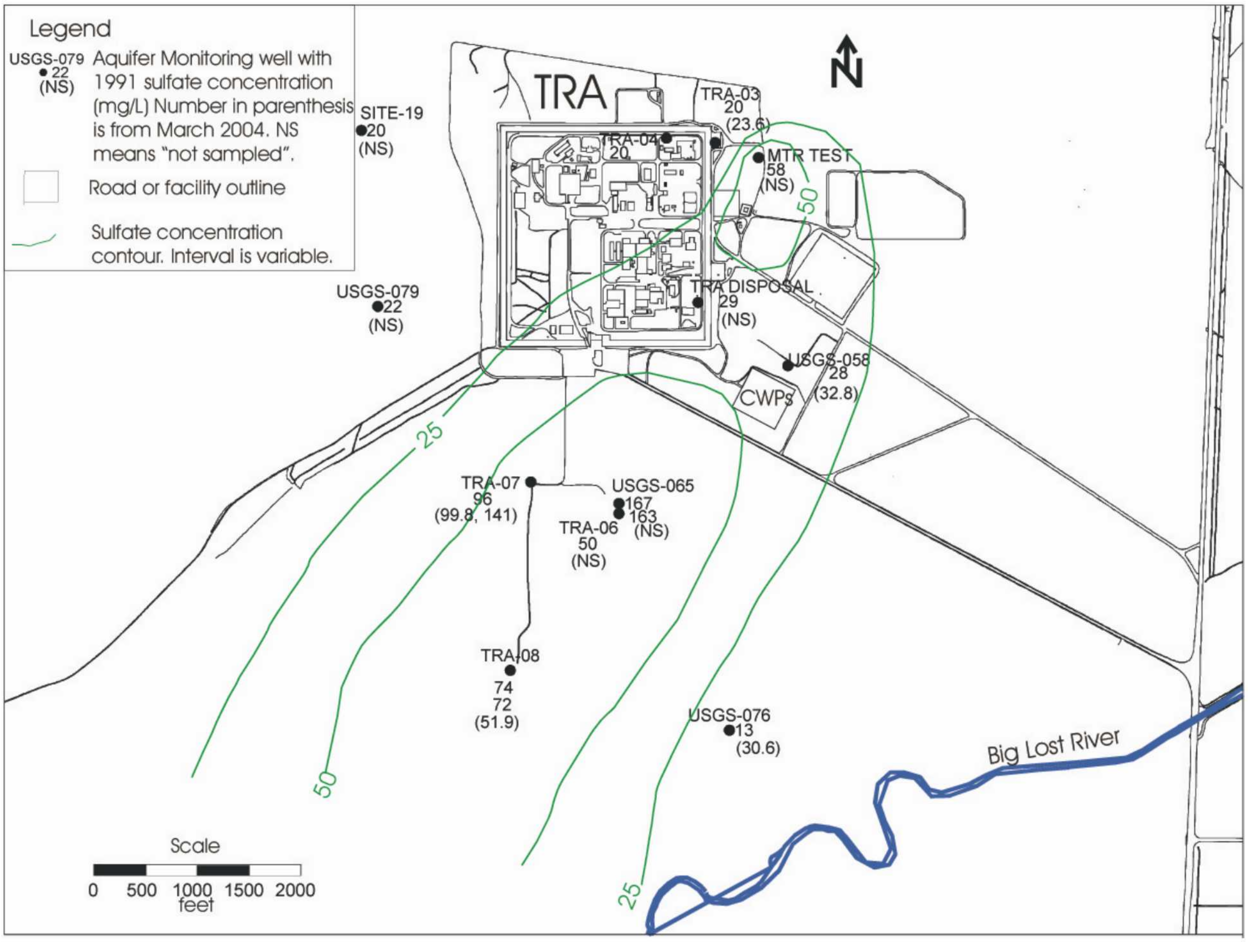


Figure 37. Distribution of sulfate in the Snake River Plain Aquifer in 1991 and 2004.

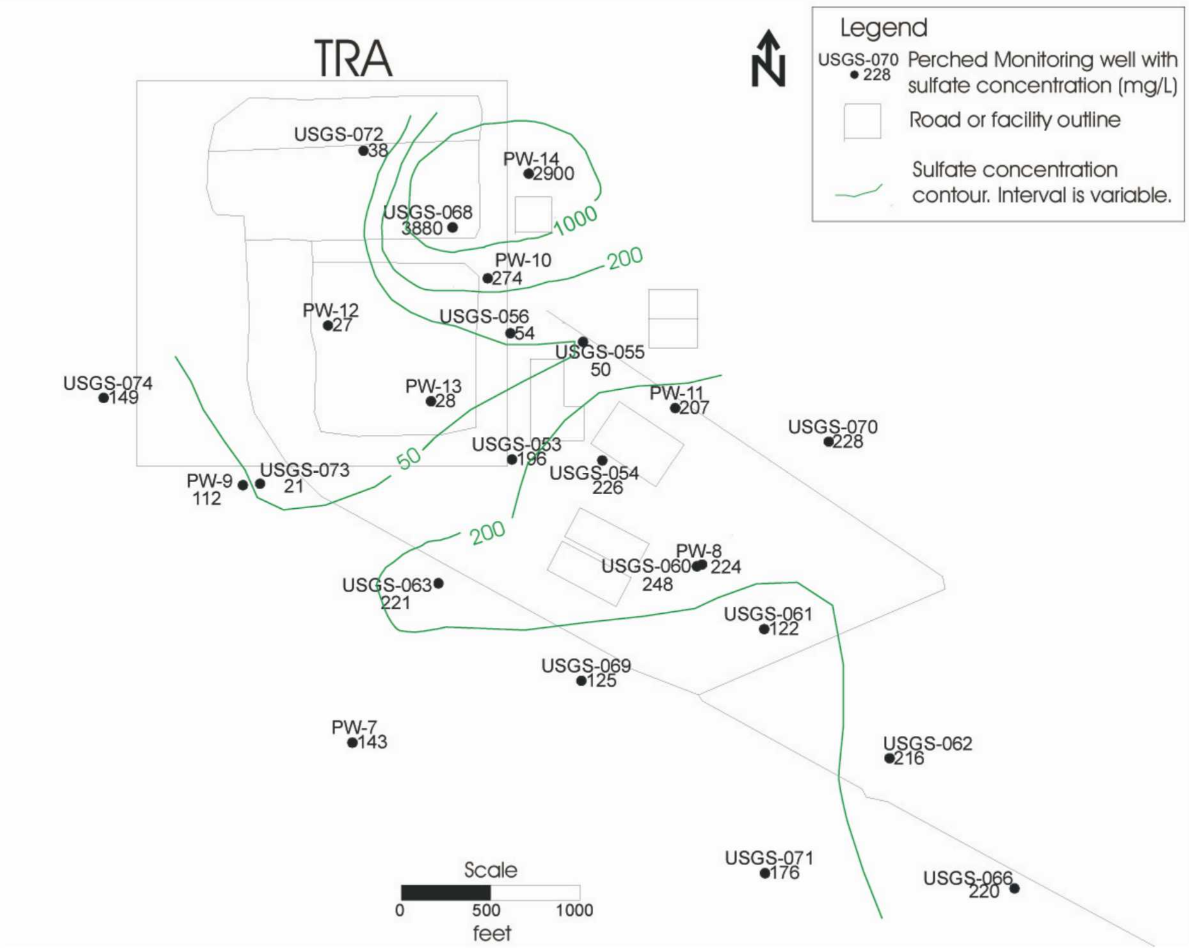


Figure 38. Distribution of sulfate in the perched water in 1991.

4.5 Summary and Conclusions

The contaminant, water-quality, and stable-isotope data indicate that the deep perched water beneath TRA consists of several types of water from multiple sources rather than a single, homogenous perched-water body. These sources include the obvious source of water from the CWP. In addition, water-chemistry data from Wells PW-12, PW-13, and USGS-072 indicate a source derived from leakage from underground (raw water) piping with some precipitation input. The perched water near these wells appears to have a separate geochemical signature from water derived from the CWP. The contaminant, geochemical, and hydraulic head data for PW-9, USGS-073, PW-12, and PW-13 suggest that the deep perched zone might actually consist of upper and lower perched-water zones rather than a single deep perched-water body.

Wells USGS-068 and PW-14 reflect contamination from the former Chemical Waste Pond with a local water source (precipitation and raw water lines). Well PW-14 has dried up since the Chemical Waste Pond was taken out of service, indicating that the primary water source for this area has been eliminated.

The source of Co-60 (see Section 5) appears to be a carbon-steel warm waste line. Transport of the Co-60 contamination observed in PW-12 might be caused by a leaking raw water pipeline aided by precipitation that carries the Co-60 from the soil around the warm waste line.

The water chemistry data indicate that natural attenuation processes have removed the less than C_8 components (the more soluble fraction) of the diesel product near Wells PW-13, TRA-1933, and TRA-1934 with the possible result that the floating product is composed of the less soluble, greater than C_8 hydrocarbons that are more resistant to natural degradation processes.

Although the CWP is not the source of contaminants, water infiltrating from the CWP could aid the migration of contaminants. This is indicated by the fact that the wells in the SRPA that have the highest contaminant concentrations (tritium and chromium) also show the strongest influence from the CWP.

4.6 Recommendations

The possibility of the deep perched water consisting of multiple perched-water bodies needs to be examined in terms of the site geology. The site geology should be evaluated with respect to the presence of perching layers and the influence of stratigraphy on perched water.

A sample of the floating product should be collected from Well PW-13 (if it reappears) and analyzed to verify that the less than C_8 fraction of the product is gone and that it is composed primarily of greater than C_8 hydrocarbons. This would also confirm that an additional source is not contributing to the floating product.

5. COBALT-60 IN WELL PW-12

5.1 Introduction

The First Five-Year Review Report (DOE-ID 2003) identified the unexplained increase of Co-60 in the PW-12 perched-water well as an issue. Cobalt-60 is a gamma-emitting isotope with a half-life of 5.2 years (EG&G Idaho 1991a). The PW-12 perched-water well is located near the center of the TRA facility, just west of the TRA-661 building. In March 2003, samples collected from PW-12 indicated that the Co-60 activities in the well had exceeded the MCL of 200 pCi/L. It should be noted that with regard to Co-60, the only well in question is PW-12. Cobalt-60 was not detected in samples collected from the aquifer during the period of evaluation for the five-year review (1990 to 2003) or during sampling events following the review. The investigation into the increase in activities at PW-12 indicates that the increase is most likely the result of remobilization of residual contamination in the subsurface by changing hydrogeologic conditions causing higher levels of contamination to move toward the well. Process knowledge indicates that the most recent use of a waste line in the vicinity of PW-12 was in 1996, coincident with the closure of the Hot Cells located in TRA-632. Recent fluctuations in Co-60 concentrations in Well PW-12 might be attributed to contaminant mobilization from three nearby CERCLA sites with known Co-60 contamination. The investigation concluded that the selected remedies listed in the OU 2-13 ROD (DOE-ID 1997a) remain protective of human health and the environment.

This section addresses the issue of Co-60 contamination in the PW-12 perched-water well. The history of PW-12 and Co-60 measurements is provided in Section 5.2. Potential sources for that contamination are discussed in Section 5.3. Conclusions are provided in Section 5.4 and recommendations are presented in Section 5.5.

5.2 History of PW-12

Well PW-12 was completed during the 1990 investigation of the perched water beneath TRA. The well was cored to a total depth of 141.5 ft bls. The well was completed with a screened interval from 108 to 128 ft bls using a 4-in. stainless-steel, wire-wrapped screen. A filter pack of 10 × 20 sand was installed from 102.5 to 131.8 ft bls. The associated well casing is 4-in. stainless steel. A bentonite seal extends from the top of the sand to 97.5 ft bls with cement grout from 97.5 ft bls to land surface. A 10-in. protective surface casing was installed during the grouting and extends from approximately 3 ft above ground surface to 39.6 ft bls. The alluvial/basalt interface is located at 39 ft bls. A 4-ft-thick zone of red sand and cinders was encountered at 138 ft bls. The remainder of the drilled interval consists of basalt.

As part of the Waste Area Group 2 groundwater monitoring plan, Well PW-12 has been sampled quarterly to semiannually since 1993 for gamma emitters, including Co-60. The history of Co-60 activities in water samples collected from PW-12 is displayed in Figure 39. Measured Co-60 activities show a decreasing trend from 1995 to late 2002; Co-60 activities were below detectable limits during some sampling events. Measured Co-60 activities began to increase in October 2002, culminating in an activity of 330 pCi/L measured during the spring of 2003. After peaking in March 2003, subsequent samples collected from Well PW-12 indicated decreasing activities. By October 2003, the Co-60 activities were at 62.2 pCi/L and the March 2004 sample was 52.7 pCi/L, continuing the decreasing trend.

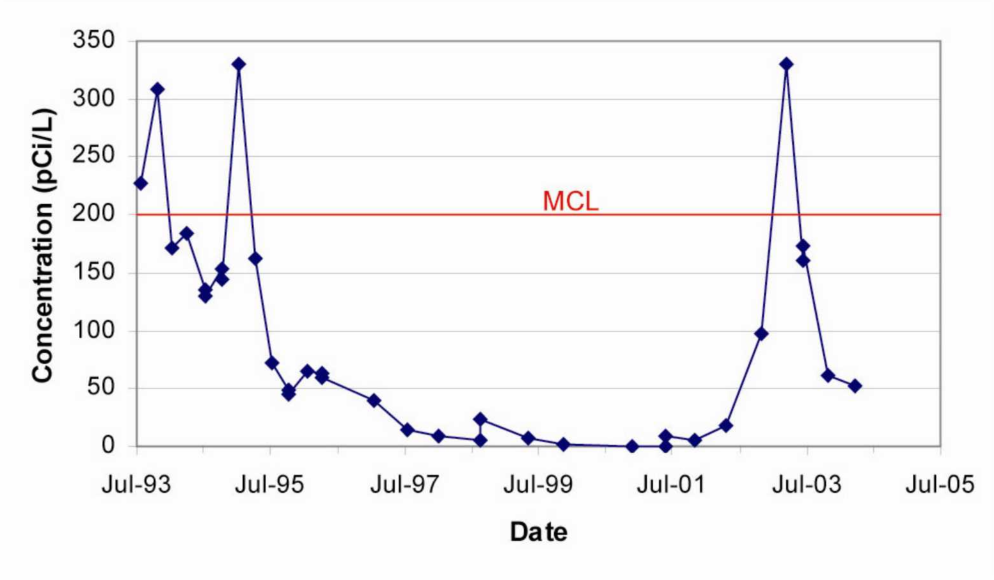


Figure 39. Activities of cobalt-60 in Well PW-12.

5.3 Proximal Cobalt-60 Contamination

Buildings and pipelines in the vicinity of Well PW-12 are known to have historically contained various radionuclides, including Co-60. This section discusses numerous buildings, pipelines, and CERCLA sites near PW-12 that could be sources for the Co-60 contamination observed at PW-12. The data are insufficient to identify the specific source, but the recent decline in Co-60 activity measured in water from PW-12 suggests that the Co-60 is from one of the historical releases described in this section. It should be noted that Co-60 contamination has not been detected in the aquifer during the evaluation period of the five-year review (1990–2003) or following the review. In addition, Well PW-12 was the only well identified during the five-year review period with a potential issue pertaining to Co-60. Although Co-60 has been detected in other perched-water wells, Well PW-12 is the only well to display an increase in the reported activity levels. The rest of Section 5.3 describes the history of CERCLA sites with known Co-60 contamination proximal to PW-12 and other potential sources for Co-60 contamination at TRA.

5.3.1 Brass Cap Area

The Brass Cap Area (see Figure 40) is identified as a CERCLA site under the OU 2-13 ROD (DOE-ID 1997a) and lists Co-60 as a COC. The Brass Cap Area is located in the center of TRA, near the TRA-630 building and southeast of Site TRA-19 between TRA-635 and TRA-632. The location of the brass cap is approximately 250 ft southeast of Well PW-12. The original source of contamination at the Brass Cap Area was identified as the 3” HDA-630 hot waste line. The release of contaminants was identified in 1985, but it was believed to be the result of damage to the pipeline that occurred during the installation of a new firewater line in 1978 (EG&G Idaho 1985a). The contaminants were later remobilized away from the site in the summer of 1985 when a pressurized firewater line separated (EG&G Idaho 1985b). A brass marker was placed in the concrete to designate the area of subsurface contamination. The contamination under the concrete was determined to extend to approximately 10 ft bls. After the contamination was discovered, the leaking waste line was repaired and contaminated soil in the immediate proximity of the repaired waste line was removed. The excavation was backfilled with clean soil and resurfaced with concrete (DOE-ID 2003).

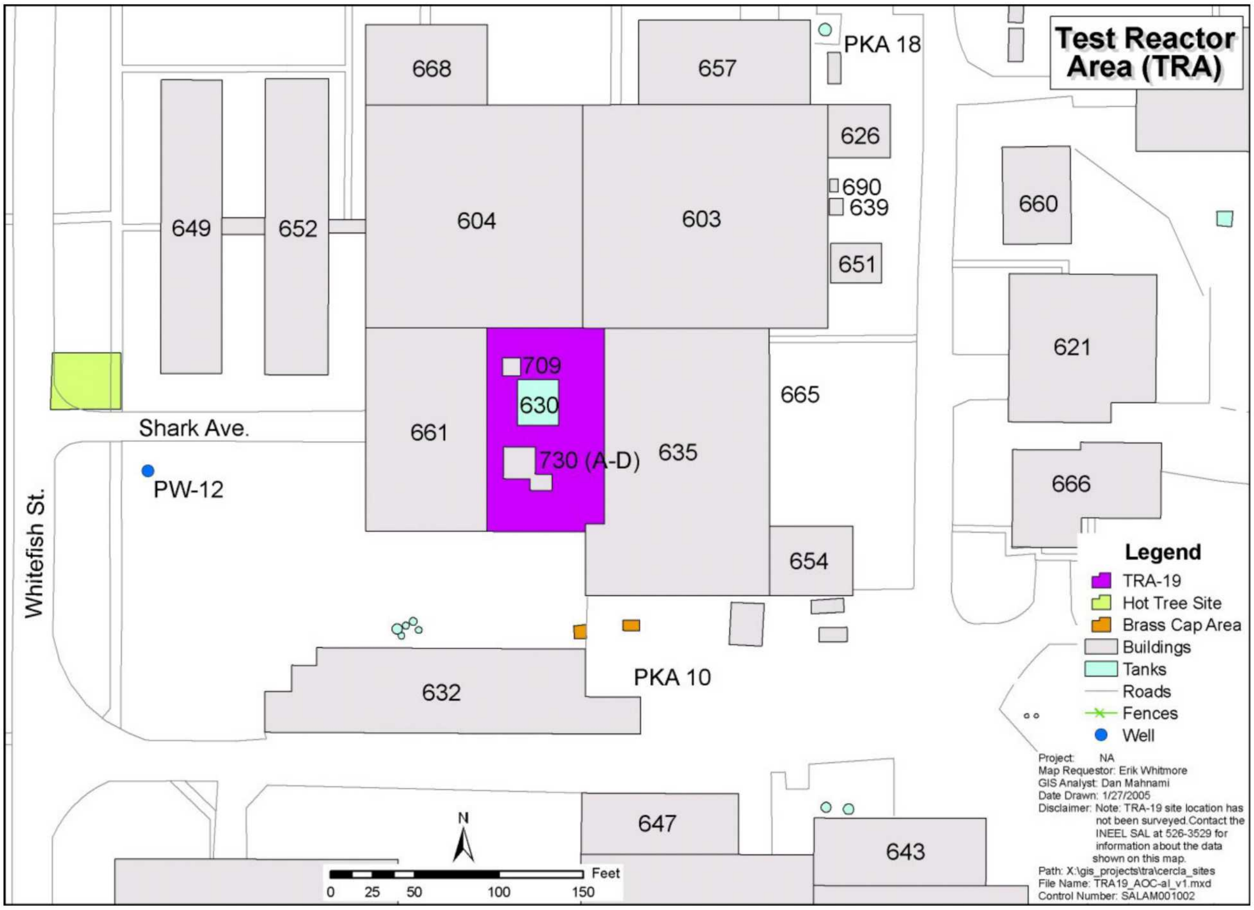


Figure 40. Map of Comprehensive Environmental Response, Compensation, and Liability Act sites in the area of PW-12.

5.3.2 Hot Tree Site

The TRA-43 CERCLA site, Hot Tree Site (Figure 40), is located in the center of TRA, west of the TRA-649 building and approximately 50 ft northwest of Well PW-12. Surface screening of the spruce tree's branches by RCTs indicated that it had been contaminated with gamma-emitting radionuclides. The tree was removed, boxed, and disposed of in May 1994. After removal of the tree, soil borings were collected for field screening approximately 2 ft bls in the area of the tree. In addition, the root system was surveyed. Three additional surface soil samples were collected and submitted to the Radiation Measurements Laboratory for analysis. The results of sampling were evaluated in the OU 2-13 baseline risk assessment. The risk assessment showed that an unacceptable risk does not exist at this site because of low contaminant concentrations in the soil. The site is restricted to industrial usage, because the calculated current residential excess cancer risk is greater than 1E-04 for 30 years because of potential exposure to Cs-137. The highest radiologically contaminated area was west of the tree, indicating that an abandoned warm waste line, 4" WDC-641, was the source of contamination. The warm waste line is a Duriron line that originated from the Gamma Facilities Building (TRA-641), approximately 10 ft west and 6 ft bls from the Hot Tree Site. Waste transferred through the line consisted of low-pressure, demineralized water. Since it was believed that the line was drained and there was no leak test performed, this line was submitted for evaluation and acceptance under the *Federal Facility Agreement and Consent Order for the Idaho National Engineering Laboratory* (DOE-ID 1991) as new CERCLA Site ID# TRA-61 on March 9, 2000 (DOE-ID 2003). It was recommended that this site did not meet the criteria for acceptance as a new site. The responsible project managers concurred with this recommendation between March 21 and April 2, 2001.

Data regarding the Hot Tree Site, listed in the OU 2-13 ROD (DOE-ID 1997a), indicate that although Co-60 is not a COC, Co-60 contamination was detected in samples collected at the site. The Hot Tree Site is located approximately 50 ft northwest of Well PW-12.

5.3.3 Soil Surrounding Tanks at TRA-630 (TRA-19)

The *Comprehensive Remedial Investigation/Feasibility Study for the Test Reactor Area Operable Unit 2-13 at the Idaho National Engineering and Environmental Laboratory* (DOE-ID 1997b) identified Co-60 as one of the possible COCs for the soil surrounding the tanks at TRA-630 (TRA-19) (Figure 40). The site, TRA-19, located near the Catch Tanks, is approximately 220 ft northeast of Well PW-12. According to the OU 2-13 ROD (DOE-ID 1997a), contamination of the soil surrounding the tanks was the result of a leak from a radiologically contaminated waste drain line (WDC-641) originating within the Gamma Facility Building (TRA-641) or a possible release from the Catch Tanks. The Catch Tanks were replaced in 1985–1986 and were found to be intact, and no leaks are suspected from either the new tanks or the old tanks. However, recent investigations have determined that there may have been releases from multiple sources in the courtyard.

The 4" HDC-604B warm waste line ran from the radiochemistry laboratories in the TRA-604 building to the TRA-630 Catch Tanks. The HDC-604B line also was used to transfer waste from TRA-661 to TRA-630. The HDC-604B line was removed from service in 1985. The HDC-604A line is documented as having leaked in Facility Change Form 8.9.2-4 (EG&G Idaho 1991b). The line was repaired after leaking in 1985 and was in service until it was cut and abandoned in 1991. The chemical composition and volume of the release were not recorded and are unknown. The HDC-604B line is located approximately 200 ft northeast of PW-12 at its nearest point.

A 4-in. Duriron line, 4" HDC-632 (located approximately 200 ft east of PW-12) was used to transfer hot waste from Building TRA-632 to TRA-630. Building TRA-632, also known as the Hot Cells, was used for irradiation experiments and processes, utilizing various materials, including Co-60. The line was used from the 1950s until 1996. There is no evidence to indicate that the 4” HDC-632 line has leaked. Investigations conducted by the Voluntary Consent Order (VCO) Program, including excavations near the pipeline, have not located any contamination outside the pipeline. The 2” HDA-661 pipeline is a 2-in. stainless-steel hot waste transfer line. At its nearest point, the line is approximately 175 ft due east of PW-12. The line was installed in 1959 or 1960 and was used until 1996. The line transferred hot waste from TRA-661 to the TRA-713 hot waste storage tanks. A release from this line was discovered in 1986. During excavation for the TRA-730 tank vault, the line was found to be leaking (Briscoe 1986). The line was repaired after the new vault was installed. A total of 1,024 ft^3 of contaminated soil was removed from the excavation. The soil was removed to 10 ft below grade. A Geiger Mueller detector indicated that contamination extended an additional 3 ft beneath the excavation.

5.3.4 Additional Known Cobalt-60 Contamination

Several other sites with known Co-60 contamination have been documented at TRA (DOE-ID 1997b). Although it is unlikely that these sources are currently contributing to the increase in the Co-60 activity noted in Well PW-12, they should still be identified as potential contributors because of the recorded presence of Co-60. Sites listed below are more distal from the source relative to those listed in the previous subsections. The CERCLA sites with recorded Co-60 contamination are listed below:

- TRA-03B (Warm Waste Pond sediments)
- TRA-04 (Warm Waste Retention Basin)
- TRA-08 (Cold Waste Pond)
- TRA-13 (Sewage Leach Pond and Soil Contamination Area)
- TRA-15 (Soil Surrounding Hot Waste Tanks at TRA-613).

5.4 Conclusions

Because of the recent increase and subsequent decrease in the Co-60 activities in PW-12, coupled with similar trends in historical activities, monitoring of this well will be continued to ensure that the remedy remains effective. Despite the recent increase and decrease in the activities at this location, the remedy still seems to be effective at this time. The decreasing activities reported in samples collected from PW-12, coupled with the short half-life of Co-60, suggest that the unexpected increase is not related to a new source from an ongoing release. The brief increase likely is due to the mobilization of a pulse of Co-60 from residual contamination to PW-12 or due to hydrogeologic mechanisms discussed in Section 6 of this document.

Mobilization may occur when recharge pathways to perched water change in response to variations in precipitation and irrigation or potentially from leaks in raw water lines within the area. Although the water lines are not currently documented as leaking, an analysis of geochemical data from samples from perched-water wells in March 2004 may indicate leakage from pipes containing raw water (see Section 4). Water samples collected from several wells, including PW-12, displayed chemical signatures closely resembling that of a sample collected from the TRA-03 supply well, an aquifer well located near the northeast corner of TRA. Further analysis also showed that the chemical signature of the water in these wells is consistently different than in wells near to the CWP and that this signature has been present since at least 1991. Currently, there are raw, potable, demineralized, and firewater lines near PW-12 and the three referenced CERCLA sites. If residual Co-60 exists in the geologic matrix (alluvium or basalt) around or near one or more of these water lines, and the water line is leaking, it is possible for the contamination to be mobilized. Analytical data seem to indicate that the source water is most likely raw water, ruling out demineralized water lines. Likewise, changes in the location and rate of infiltration from precipitation or irrigation might carry a pulse of Co-60 to PW-12 as the water moves through residual contamination. Alternatively, the increase in the activities of Co-60 in PW-12 could be the result of hydrogeologic mechanisms discussed in Section 6 of this report. Section 6 discusses the hydrogeologic mechanisms that may influence fluctuations of certain analytes in the perched water at TRA.

It should also be noted that the March 2003 sample result of 330 pCi/L does not seem to be anomalous or erroneous. The sample data received Level "A" validation and was not flagged by the laboratory or during validation. When viewed in relation to past and subsequent results for PW-12, the March 2003 data point does not seem atypical for this well. At least one other such spike in Co-60 activity has been observed in this well. A similar increase and decrease in the activities of Co-60 occurred in 1995 (Figure 39).

5.5 Recommendations

Continued monitoring in accordance with the Groundwater Monitoring Plan (DOE-ID 2004a) is recommended. The increase of Co-60 noted in the five-year review and the subsequent decrease seems to be in line with past monitoring data. However, continued monitoring is warranted in accordance with the accepted groundwater monitoring plan, but no additional activities are recommended at this time. The pipelines believed to be responsible for the three CERCLA sites near PW-12 are currently under investigation by the VCO (TRA-630 Area Catch Tanks Closure Project) Program (DOE-ID 1997b); however, it should be recognized that VCO is not performing their investigation as a response to the Co-60 levels. The VCO investigation is related to independent actions relating to the removal of piping and building material at these locations. Piping within these sites is subject to Resource Conservation and Recovery Act (42 USC § 6901 et seq.) closure under VCO-5.8.d, TRA-004, and TRA-11. Soil samples within existing CERCLA sites will be conducted under Resource Conservation and Recovery Act closure, and data collected will be used during CERCLA activities to determine if the contingent excavation remedy specified in the ROD is required. Consequently, the most plausible sources for Co-60 are currently under investigation. It is further recommended that that the VCO activities and findings for the aforementioned investigations be tracked by CERCLA personnel so that the new information can be used to assist in the interpretation of groundwater monitoring results. Although the VCO is conducting an independent investigation for a distinct purpose, their investigation may provide information useful in assessing groundwater contamination at TRA.

6. POTENTIAL MECHANISMS AFFECTING PERCHED CONTAMINANT CONCENTRATIONS

The First Five-Year Review Report (DOE-ID 2003) identified the occurrence of steady or increasing activities of Sr-90 in the PW-12, USGS-054, USGS-055, and USGS-070 perched-water wells as an issue. It was further recommended that several mechanisms be evaluated as being potential causes for these unexplained trends. Those mechanisms include (1) adsorption/desorption occurring with changing perched-water levels, (2) changing flow pathways in response to lining of the Warm Waste Pond and/or fluctuations in discharge to the CWP (or between alternating cells), (3) seasonal variations of natural infiltration at a local scale, (4) variations in recharge from unidentified manmade sources, (5) lateral flux from the Big Lost River, or (6) new leaks of contamination from unidentified sources. This section considers possible mechanisms that might explain the unexpected trends in Sr-90 measurements. The issue of unpredicted concentration trends is introduced in Section 6.2. The potential explanatory mechanisms identified in the First Five-Year Review Report are discussed in Section 6.3. Recent research findings suggest another possible mechanism that is introduced in Section 6.4. Conclusions are provided in Section 6.5.

6.1 Unpredicted Concentration Trends

Contaminant-concentration data from the TRA perched-water monitoring network were evaluated as part of the five-year review for the period 1997–2002. Measured chromium, tritium, Sr-90, and Co-60 concentrations decreased during this period at most of the deep perched-water wells. However, contaminant concentrations did not decrease in several of the wells. Contaminant concentrations were expected to decrease in response to changing disposal practices and natural processes, including radioactive decay and water/rock interactions. Strontium-90 concentrations in water from Wells PW-12, USGS-54, USGS-55, and USGS-70 (see Figure 1) increased or remained about the same during the five-year period (Figure 41). As discussed further in Section 5 of this report, the Co-60 concentration in water from Well PW-12 increased (Figure 39) in 2002. Additionally, chromium concentrations in water from several TRA perched-water wells rose during the early 1990s, coincident with perched-water-level increases (Figures 42 and 43).

6.2 Potential Mechanisms Identified for the First Five-Year Review

Mechanisms that could result in unanticipated contaminant-concentration trends include (1) adsorption/desorption occurring with changing perched-water levels, (2) changing flow pathways in response to remediation and fluctuations in discharge to the CWP, (3) seasonal variations of natural infiltration at a local scale, (4) variations in water recharge from unidentified manmade sources, (5) lateral flux from the Big Lost River, or (6) potential leaks of water from unidentified sources. The unanticipated contaminant-concentration trends also could result from a combination of these mechanisms. The remainder of this section discusses these potential mechanisms.

6.2.1 Adsorption/Desorption of Contaminants of Concern

Concentrations of the contaminants in groundwater may fluctuate as aqueous geochemical equilibria cause adsorption or desorption of the contaminants onto and off of the geologic media. This section discusses adsorption/desorption relationships and their potential effect on perched water beneath TRA. Mobility of a specific contaminant in perched groundwater at TRA is dependent on the chemical valence of the contaminant, geochemical processes within the subsurface, and fluctuations in perched-water levels.

6.2.1.1 Mobility of Selected Contaminants of Concern at the Test Reactor Area. The mobility of chromium is dependent on its valence state. Under natural conditions, chromium can occur in two valence states: Cr(III) and Cr(VI). The Cr(III) exists in the environment under reducing conditions and is highly immobile. Hexavalent chromium (Cr[VI]) exists under oxidizing conditions in the environment as chromate anion (CrO_4^{2-}), which is very mobile (Oliver et al. 2003). The Cr(VI) is estimated to account for 89% of the total chromium in groundwater beneath TRA (EG&G Idaho 1989). Because a large fraction of the total chromium in the subsurface beneath TRA occurs in the hexavalent state, chromium is one of the most mobile of the COCs at TRA, second only to tritium (Dames and Moore 1992a).

Both Co-60 and Sr-90 exist in solution as divalent cations. As a result, both are relatively immobile and retarded during transport (Dames and Moore 1992a).

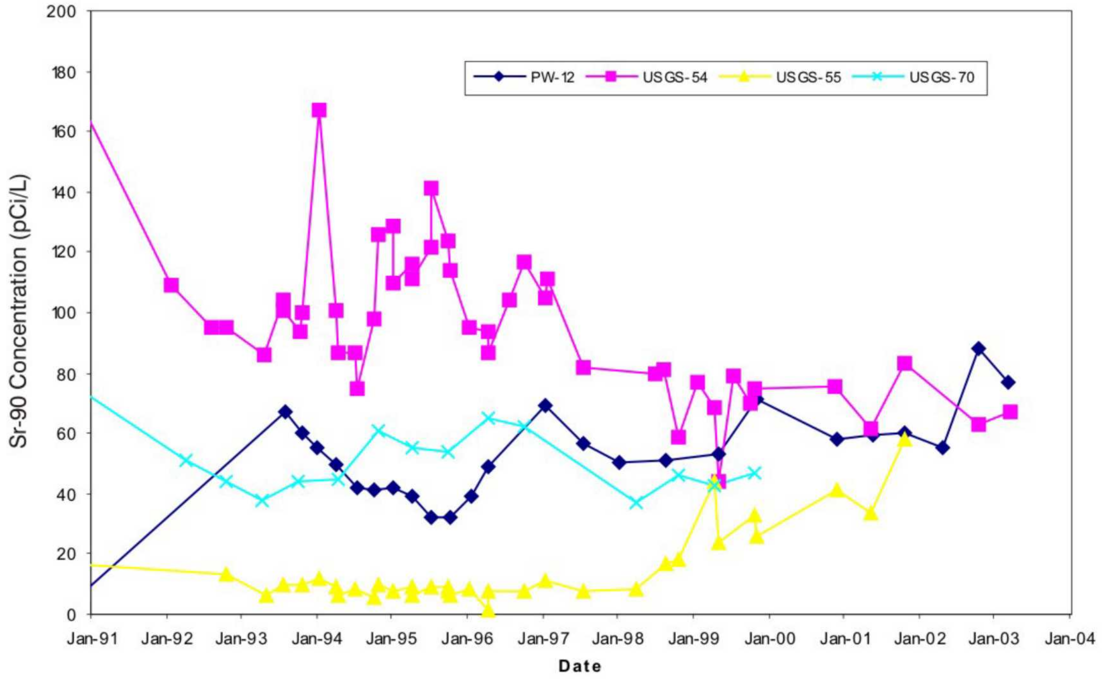


Figure 41. Strontium-90 concentrations in deep perched-water wells proximal to the Warm Waste Pond.

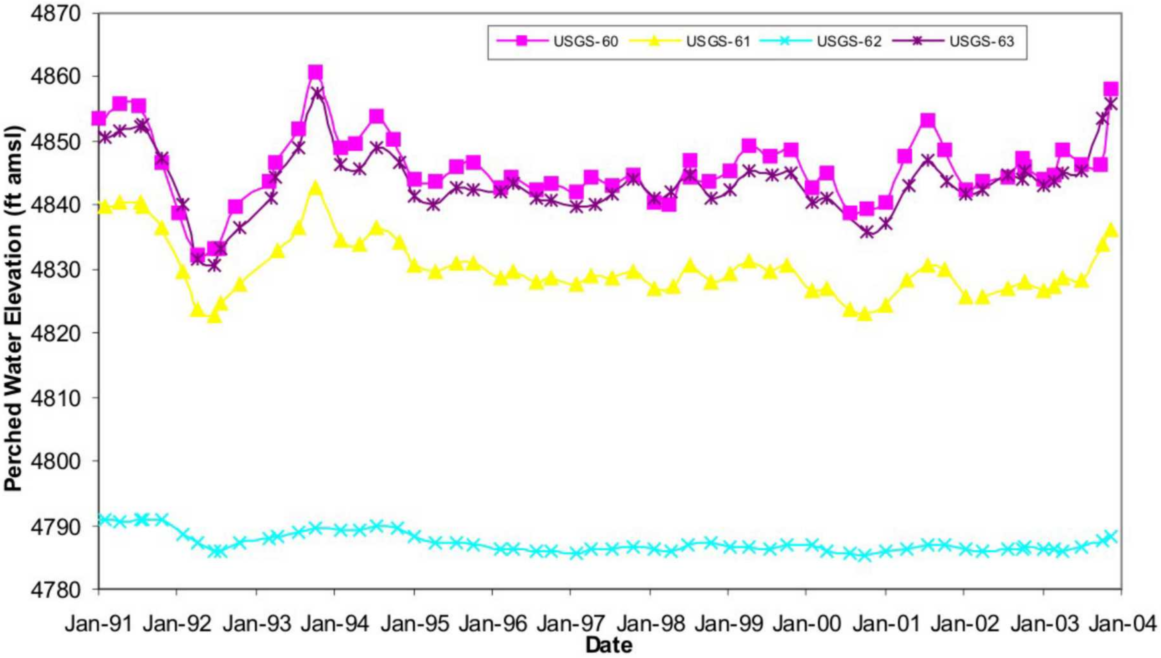


Figure 42. Hydrographs for the USGS-60, USGS-61, USGS-62, and USGS-63 perched-water wells.

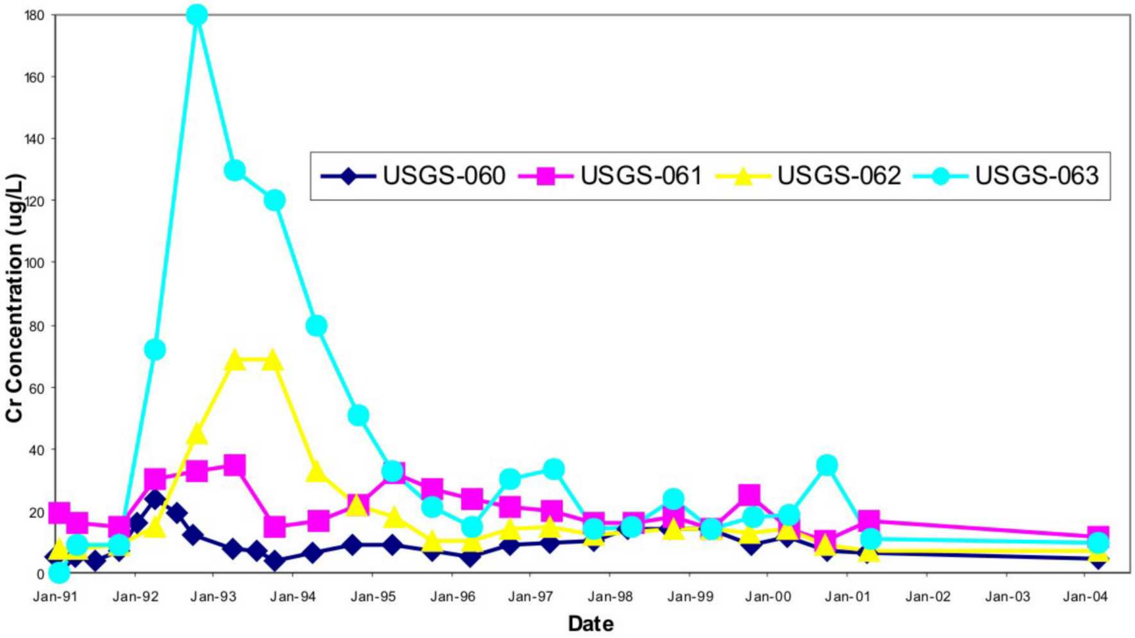


Figure 43. Chromium trending in Wells USGS-60, USGS-61, USGS-62, and USGS-63.

6.2.1.2 Geochemical Processes that Control Adsorption/Desorption. Adsorption occurs because of the presence of electrically charged sites on solid surfaces that attract oppositely charged dissolved species. The sorptive capacity of a solid is primarily controlled by the density of charged surface sites and the surface area of particles on which those surface sites occur. A sorbent phase with a net negative surface charge is said to have a cation exchange capacity (i.e., dissolved species with a positive charge are adsorbed), whereas a sorbent phase with a net positive surface charge is said to have an anion exchange capacity (i.e., anions are sorbed). Surface charge may be permanent and independent of a solution's composition or can vary with changes in solution composition. Surface charge is permanent in many clay minerals, while surface charges of metal oxyhydroxide minerals are highly dependent on the pH of the solution; they are net positive at low pH and net negative at higher pH (Langmuir 1997).

The pH inflection point at which neither cations nor anions are preferentially adsorbed is material dependent and is known as the point of zero net proton charge (PZNPC). Published PZNPCs for Na-feldspar fall near the pH of natural waters (5.2<PZNPC<6.8) (Langmuir 1997). The PZNPCs of several iron oxides and oxyhydroxides (including goethite and hematite) also fall near the pH of natural waters. Minor fractions of each of these minerals may occur in basalt at the INEEL. As a result, small fluctuations in the pH of soil and groundwater beneath TRA may lead to adsorption or desorption of a COC if the PZNPC is crossed.

In addition to the effects of pH on adsorption/desorption relationships, other components of solution chemistry could affect the degree to which sorbed species are desorbed. Adsorption of a dissolved ionic species is always part of an exchange reaction that involves a competing ionic species. Ion exchange models of adsorption are often employed to describe these as an equilibrium process (Langmuir 1997).

The ion exchange concept can be described in terms of exchange equilibrium between two similar ions, such as Ca^{2+} and Mg^{2+} (Langmuir 1997), as shown in Equation (2):

$$Ca^{2+} + MgX = Mg^{2+} + CaX \tag{2}$$

Where Mg^{2+} and Ca^{2+} are the dissolved ion concentrations and MgX and CaX are the fractions of each ion in the exchanger (solid) phase, the equilibrium or exchange constant for this reaction is shown in Equation (3) below:

$$K_{ex} = \frac{[Mg^{2+}][CaX]}{[Ca^{2+}][MgX]} \tag{3}$$

Equation (2) may be rearranged as follows in Equation (4):

$$[Mg^{2+}] = \frac{K_{ex}[Ca^{2+}][MgX]}{[CaX]} \tag{4}$$

Equation (3) demonstrates that the concentration of Mg^{2+} in solution is directly proportional to the concentration of Ca^{2+} in solution and the mass of Mg^{2+} sorbed to the solid phase. In other words, as the concentration of dissolved Ca^{2+} increases, the concentration of dissolved Mg^{2+} also increases as Ca^{2+} replaces Mg^{2+} on the solid phase and drives Mg^{2+} from the solid phase into solution.

In the context of perched water beneath TRA, increases in the dissolved concentration of cations such as Ca, Mg, Na, or heavy metals might be expected to drive sorbed cations such as Co-60 or Sr-90 from exchange sites and into solution. The result would be an increase in the concentration of Co-60 or Sr-90 in solution. Similar exchange-site competition can occur between anions such as chromate, sulfate, bicarbonate, and nitrate if a net positive surface charge existed on the solid phase.

6.2.1.3 Effect of Perched-Water-Level Fluctuations on Sorption.

Increases in perched-water levels may be a mechanism by which water of one chemical composition (i.e., the perched water) is mixed with water of another (e.g., the soil water in the unsaturated material that becomes inundated as perched-water levels rise). In the case of chromate, if the perched water contains higher levels of competing anions than the soil water, chromate may be released from the previously unsaturated material by ion exchange according to an equilibrium reaction similar to that presented in Equations (2) through (4).

In addition, if the pH of the perched water is lower than the PZNPC and the pH of the soil water immediately above the perched-water zone is higher than the PZNPC, an anion species might desorb from the previously unsaturated solid material and go into solution.

It is difficult to quantify the effects of this mechanism without extensive study on the sorptive capacity of minerals contained in the geologic materials beneath TRA and equilibrium relationships for the species competing for sorption and desorption. Much of this information may be available for clay minerals and nonradioactive dissolved species; however, the effects of basalt mineralogy and the presence of radionuclides on adsorption/desorption relationships are sufficiently unique that a large amount of original research would have to be conducted to quantify this mechanism.

Differences in water chemistry that may cause adsorption (or desorption) are difficult to define, because only samples of the perched-water body are currently collected. Water contained in the vadose zone immediately above the perched-water zone is not sampled and its chemistry is not known.

6.2.2 Changing Flow Paths in Response to Wastewater Disposal Changes

Variable discharge rates to TRA wastewater infiltration ponds might have impacted water chemistry in perched-water wells for several reasons. First, changing discharge rates to different infiltration ponds might have affected the wastewater flow pathways from the ponds to perched-water bodies. Second, the hydraulic character of the perched-water body itself might have been modified by variable surface discharges. Each of these scenarios is expected to affect mass transport in the vadose zone. These scenarios are discussed in Sections 6.3.2.1 and 6.3.2.2, respectively.

6.2.2.1 The Effect of Wastewater Disposal on Flow Paths from the Land Surface to Perched-Water Bodies. Wastewater disposal changes to the TRA infiltration ponds might have affected flow paths between the ponds and perched-water bodies. These changes might have been reflected in COC concentration trends. Figures 42 and 43 contain water-level elevation and Cr concentration data from perched-water wells in the southeastern portion of TRA during 1990–2002. The Cr concentrations presented in Figure 43 were taken from both USGS records and TRA CERCLA-mandated sampling records. The data presented are an example of concentration variability in response to perched water-level changes. Water discharge to the CWP (Figure 44) can be compared to the concentration and water-level data shown in Figures 42 and 43. Low discharges to the CWP were observed between 1991 and 1993. The WWP was still being used for disposal at that time, although no notable trend in discharge volumes was observed. During this period, water levels declined in the USGS-60, USGS-61, USGS-62, and USGS-63 perched-water wells. Increased Cr concentrations were observed during a low-discharge period (1991–1993) in water samples collected from the same wells (Figure 43).

Based on these data, reduced discharge to the CWP might have acted to increase the concentration of selected COCs at certain wells despite the fact that none of the COCs were present in wastewater disposed of at the CWP. This response suggests an interplay between the flow-path set from the CWP and the flow-path set from the WWP. The COCs were disposed of at the WWP. Therefore, flow paths between the WWP and the deep perched zone should contain most of the residual COC contamination. As the contribution of flow along the CWP flow paths was decreased, concentrations of the COCs increased as the relative contribution from the WWP was increased (i.e., decreased dilution).

6.2.2.2 Perched-Water Flow Paths. Variable discharge to surface recharge sources may have locally resulted in changes to the physical character of the deep perched-water body itself. In the scenario presented in the previous section, changes in discharge to the CWP were shown to have effects on both perched-water levels and chromium concentrations at several wells. It is also plausible that additions of water from the surface to the deep perched-water body might result in local water-level increases. For example, localized mounds in the perched-water surface could develop beneath fractures and flow paths along which recharge occurs only during specific surface-discharge conditions. Similarly, discontinued flow through a flow path between the surface and the deep perched zone could result in a localized depression in the perched-water surface. These localized mounds and depressions would not be observable because of the coarse spacing of wells.

Localized perturbations to the surface of the perched-water body might change local hydraulic gradients within the perched-water body. These gradient changes might result in movement of water and contaminants from one part of the perched-water body to another. These possible fluxes could explain erratic contaminant concentrations with time in water from a monitoring well. However, these changes to the local hydraulic gradient in the perched-water zone would not increase or decrease the total mass of a particular contaminant in the entire perched-water body; rather, contaminant mass would simply be shifted from one location to another. Concentration trends influenced by this mechanism would be further affected by dispersion, sorption, and diffusion as the perched water is shifted between locations.

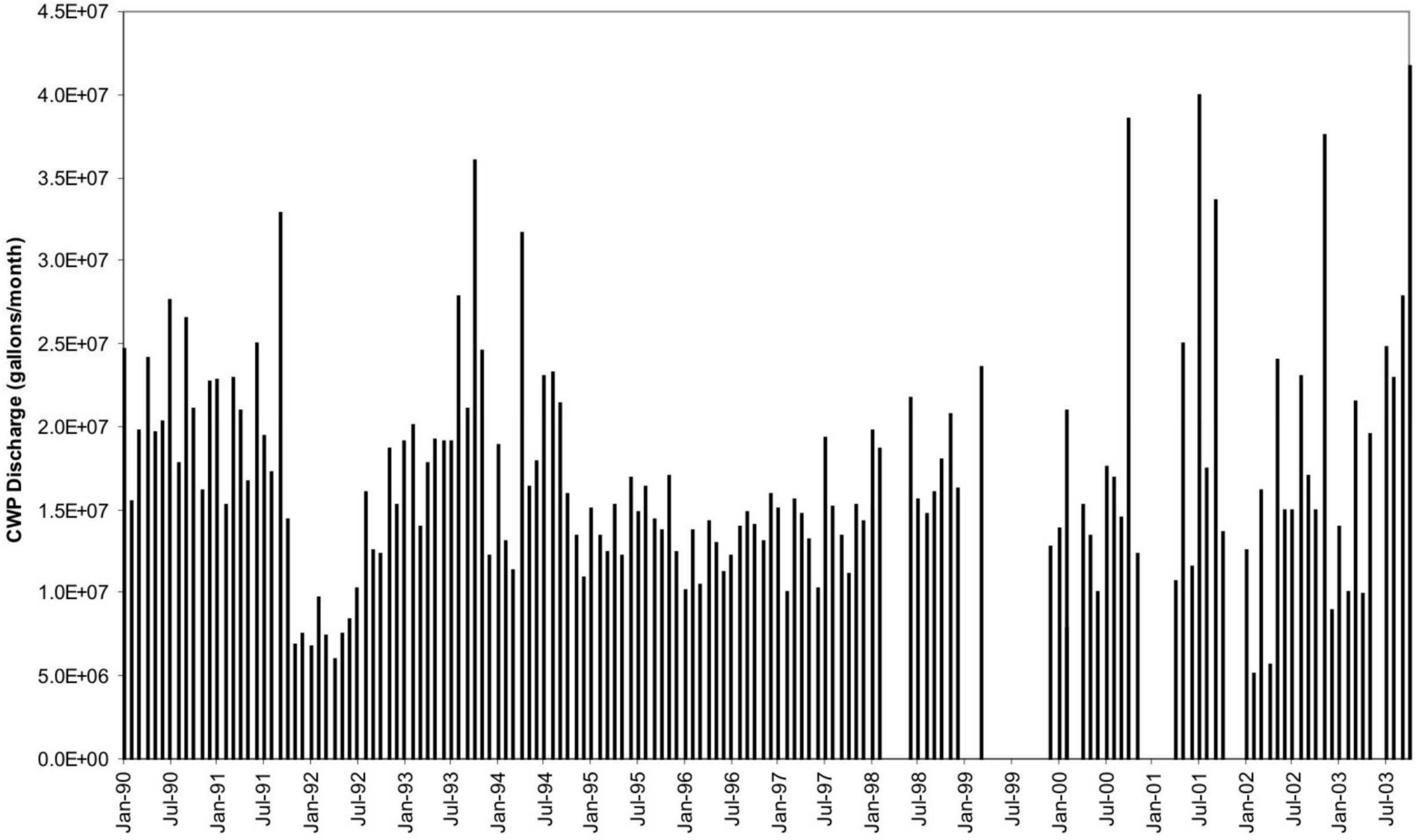


Figure 44. Monthly discharge to the Cold Waste Pond from 1990 through 2002.

6.2.3 Seasonal Variations of Natural Infiltration on a Local Scale

Seasonal variations in natural infiltration might result as run-off from spring snowmelt accumulates in surface depressions and ditches. If naturally derived water from a filled surface depression infiltrates into the perched groundwater body, this infiltration might modify flow paths and contribute to contaminant dilution. This mechanism is very similar to that presented in Section 6.3.2.2 with the exception that discharge variability will occur on a seasonal basis.

If this mechanism was an important factor in influencing concentration trends in the deep perched zone, notable concentration trends should have developed during the mid- to late-1990s. From 1996 through 2000, abnormally moist weather conditions persisted in the region. Figure 45 is a time series plot that contains cumulative precipitation and Sr-90 concentration data for four perched-water wells that have shown flat or increasing concentration trends in recent years. The three shaded intervals depicted in Figure 45 indicate notably moist periods. During the third shaded interval (April through June 1999), Sr-90 concentrations decreased in water collected from Wells USGS-54 and USGS-55. The lower Sr-90 concentration in those wells might be the result of dilution through localized infiltration of precipitation. Outside of that short-term fluctuation, no pronounced trends are apparent; however, the Sr-90 sampling frequency is generally insufficient to resolve seasonal trends resulting from the infiltration of precipitation.

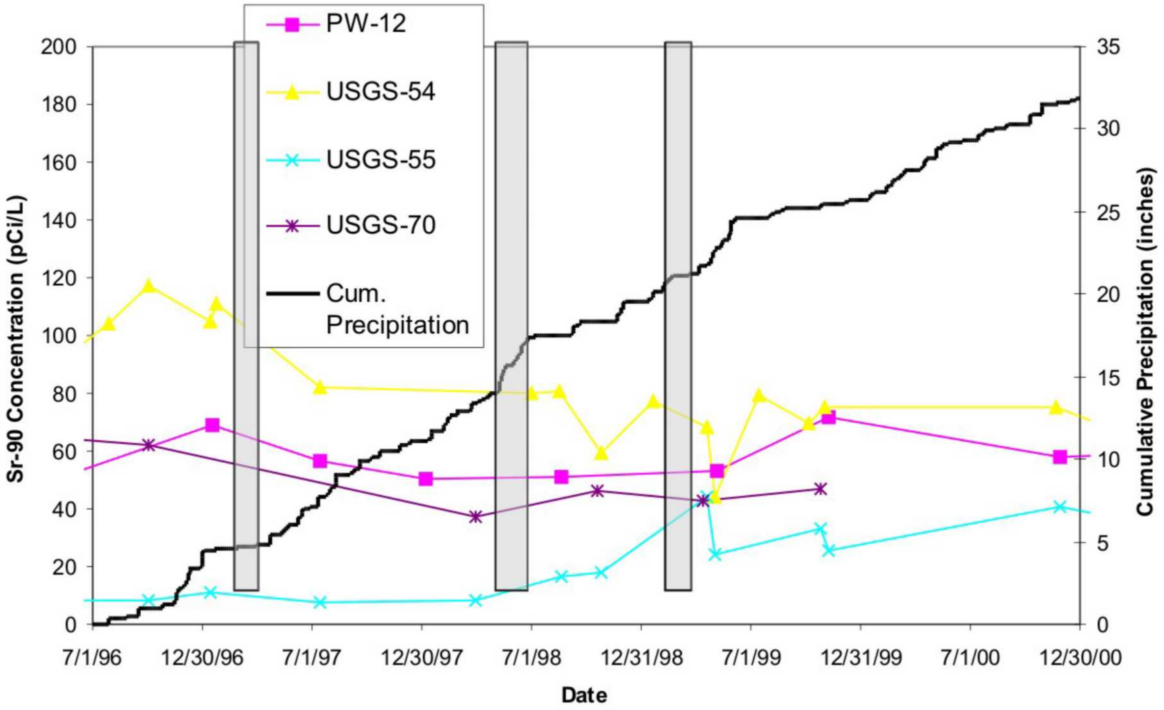


Figure 45. Cumulative precipitation at the Central Facilities Area and strontium-90 concentrations in four perched-water wells.

NOTE: *Shaded intervals indicate unusually moist periods.*

6.2.4 Variations in Recharge from Unidentified Manmade Sources

Leaks from TRA facility infrastructure piping might potentially provide a source of recharge to perched-water bodies at TRA. The water budget presented in Section 7 indicates that nearly all of the water pumped from SRPA production wells for facility use is accounted for in water discharges to the infiltration ponds. However, facility records for several years indicate that more water was discharged to the ponds than was pumped from the aquifer. Uncertainties in the water-budget method probably are derived from measurement errors. These uncertainties limit the capability to quantify leaks from unidentified sources.

Because the TRA water budget is nearly balanced and the resolution of the water balance method is limited by the accuracy of facility gauging and record keeping, it is not possible to adequately determine the presence of infrastructure leaks unless those leaks account for a significant fraction of annual water use. For instance, 1% of annual facility water use during the period of record presented in Section 7 represents 7.8 million gal of water. Most good flow meters are only accurate to +/- 5% of the measured flow rate. As a result, tens of millions of gallons of water would have to be lost before it was observable above the measurement noise of the system. It is conceivable that an undetected leak within the +/-5% error range of the system could have substantial impacts on flow pathways in the perched-water system.

Analysis of water chemistry data (Section 4) suggests that a substantial fraction of perched water is inconsistent with discharge to the CWP. That water exhibits major ion and isotope geochemical characteristics that are consistent with unprocessed, unevaporated SRPA water. Sources of water with these characteristics could include pressurized fire water lines, potable water lines, belowgrade irrigation lines, or other SRPA water lines that feed TRA industrial processes. Water returns from irrigation are expected to have a unique isotopic signature as a result of evaporation and are excluded as a major contributor of the apparent SRPA-derived perched water.

Because the location and quantity of water discharged along any unidentified manmade sources are unknown, the effects on the deep perched zone beneath the TRA are unclear. Depending on the quantity of water that leaked from the source, perched-water levels may or may not be affected by changes in discharge from the source. In cases where a small volume of water is leaked, only the local-scale hydraulics of the perched-water body could be affected. However, as pointed out in Section 5, the effects on concentrations could be significant if the leak occurs near a residual source. For small leaks away from residual sources, the resultant changes to perched-water chemistry will be similar to the changes observed for the mechanisms presented in Sections 6.3.2.2 and 6.3.3 and will be difficult to attribute to this mechanism.

For large leaks, the large-scale shape and hydraulics of the perched aquifer might change. In addition, the location and quantity of water leaked from the unidentified sources could influence flow paths from the contaminant sources to the deep perched zone. These large-scale changes might affect perched-water quality in much the same way as variability in CWP discharge affects water quality (see Section 6.3.2.1).

6.2.5 Lateral Flux from the Big Lost River

The Big Lost River has been considered a potential source of perched water near TRA. However, the river is approximately 4,000 ft from the southeast corner of the TRA fence line on years that it flows. Some evidence has been presented that water levels in two perched-water wells located southeast of TRA (USGS-71 and USGS-62) are affected by exceptionally high flows in the Big Lost River (EG&G Idaho 1991a). These two wells are situated near the southeastern edge of the deep perched-water body (Figure 6). Well USGS-62 was sampled in 1965 during water-level rises that occurred after high

Big Lost River flows and no chemical signature of recharge from the Big Lost River was observed. This lack of chemical response probably is indicative of a hydraulic response without significant mixing of recharged stream flow and existing perched water in the vicinity of the monitoring well.

The Big Lost River flowed frequently during the mid- to late-1990s because of unusually moist weather conditions. During that period, no evidence of water-level increases was observed in Wells USGS-62 or USGS-71. Well USGS-71 was sampled numerous times during that interval and no obvious concentration trends developed for the COCs. Because these wells are the most likely wells to be impacted by lateral flow from the Big Lost River (based on their close proximity to the river) and no obvious and consistent correlation exists with Big Lost River flow, it is not likely that this mechanism is responsible for the increasing and erratic concentration trends observed near the wastewater ponds.

6.2.6 New Leaks of Contamination from Unidentified Sources

Increasing concentration trends could result from new leaks of contamination from unidentified sources. This mechanism is similar to the mechanisms presented in Sections 6.3.2 and 6.3.4 in that the new leaks could affect the hydraulic character of the perched body and influence contaminant advection. However, this mechanism is different in that the other mechanisms do not necessarily provide a new source of contaminants to the perched zone, while this mechanism does.

Warm wastewater was found to leak from the Warm Waste Retention Basin in the early 1970s and continued leaking until 1993. It is estimated that as much as 15 million gal of wastewater per year could have leaked from the basin. That wastewater was part of the same radioactive wastewater stream that discharged the COCs to the WWP. Large leaks of contamination such as this can clearly affect perched-water chemistry. Figure 46 shows a large spike in Sr-90 concentrations in USGS-053 and USGS-054 during the early 1970s that may be explained by leaks from the Warm Waste Retention Basin or a similar unidentified source.

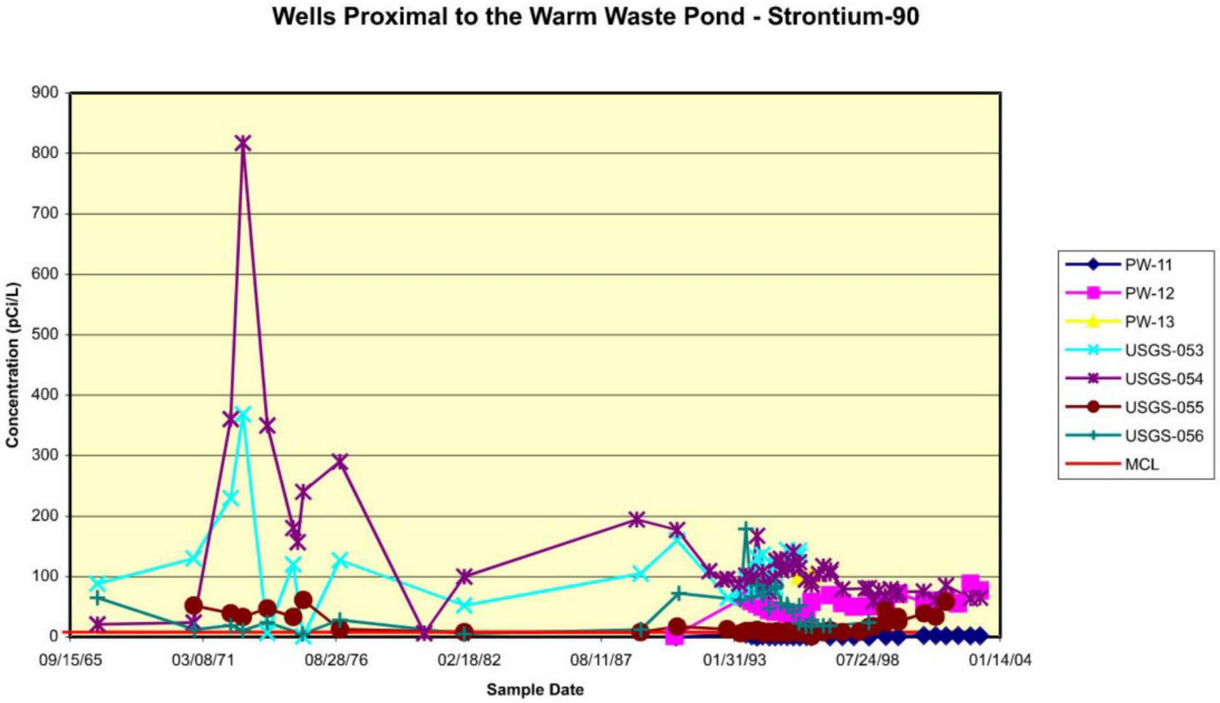


Figure 46. Strontium-90 concentrations in Wells USGS-053 and USGS-054.

The current increasing trend in Sr-90 concentrations and the spike in Co-60 concentrations in Well PW-12 are much lower in magnitude than the spike developed during the early 1970s. If a leak is responsible for the recent observations, then the flux of contaminants from that leak is much smaller than the flux from the source of the early 1970s spike. Section 5 identifies potential sources that could be responsible for the recent Co-60 concentration increase in water collected from PW-12. Strontium-90 concentrations have increased much more gradually than recent Co-60 trends (Figures 41 and 42). If a leak is responsible for the Sr-90 increases, then that leak must be persistent and provide only a small flux of Sr-90 to the perched body; otherwise, a more pronounced increase in Sr-90 concentrations would be expected.

6.3 Alternate Mechanism Identified by Recent Research

Recent large-scale laboratory and small-scale field experiments suggest that the current conceptual model of a slow, diffusive wetting front moving through a fractured rock vadose zone is not valid in many cases. These research investigations used idealized physical models of fracture networks to represent flow in natural systems. The models were easily characterized and monitored, which is a great advantage over the rudimentary understanding gained through many tens of wells on wide spacings at TRA. Through the use of time-lapse photography and sophisticated measuring techniques, several characteristic behaviors began to emerge as common to these systems (Glass et al. 2002a; Wood et al. 2004). These behaviors are not anticipated using conventional predictive, volume-averaged vadose zone numerical models (Fairley, Podgorney, and Wood 2004). Taken at face value, the new research findings suggest that the observed fluctuations in Co-60 and Sr-90 at TRA are to be expected instead of the slow decline predicted using the current conceptual model of idealized flow.

Fracture intersections have been shown to integrate slow, steady, unsaturated flow as water pools above the capillary barrier formed by the intersection (Wood, Nicholl, and Glass 2002; Ji et al. 2004). When the pool height increases sufficiently, the capillary barrier is broken and a large, less frequent discharge occurs below the intersection. Intersections also have been shown to divert flow from one vertical fracture to another (Glass et al. 2002a; Glass et al. 2003; LaViolette et al. 2003). Many fracture intersections interacting in a network commonly cause flow to converge with depth (LaViolette et al. 2003) or cause flow paths to switch between vertical pathways even under steady supply (Glass et al. 2002a). Another common behavior of unsaturated flow in fracture networks is the failure of most to evolve to a steady state; that is, pathways tend to change in discharge rate and/or location over time (Wood et al. 2004). The failure for these systems to converge to a steady state suggests that they are sensitive to small changes in environmental conditions (e.g., minute changes in temperature and barometric pressure).

Although the behavior observed in laboratory experiments has not yet been conclusively documented in a large-scale field problem like the TRA perched-water body, a handful of small-scale field tests suggest that it is likely that they do occur in natural systems (Nicholl and Glass 2002; Glass et al. 2002b; Podgorney et al. 2000; Nativ et al. 1995). The conclusive demonstration of these behaviors at field sites is limited by the difficulty in collecting sufficient monitoring data to track system behavior. Indeed, the fluctuations in Sr-90 and Co-90 observed in some TRA perched-water wells may be the first subtle indications that flow path switching and flow integration do occur in natural systems.

It is possible that changes in the discharge rate to the CWP, fluctuations in barometric pressure, and changes in natural recharge might cause flow path switching in the subsurface beneath TRA. This would expose water to different levels of residual contamination causing concentrations measured in wells to vary in time. Alternatively, slow diffusive flow from the CWP may accumulate above one or more capillary barriers, eventually breaching the barrier and releasing a pulse of water. The pulses of water could create a high level of variability in contaminant levels measured in monitoring wells.

The results are discussed here as one of several plausible explanations for the unexplained fluctuations in Co-60 and Sr-90. There is a strong theoretical basis suggesting that the behavior observed in laboratory experiments may be occurring in the subsurface beneath TRA. More experimental work is needed to clearly correlate field data sets to experimental results. The recent experimental investigations cited above were funded by the DOE Office of Basic Energy Science, Environmental Management Science Program, and Environmental Science Research Alliance.

6.4 Conclusions

Of the six mechanisms considered in Section 6.3, it seems most likely that changes in discharge to the CWP might be the main cause for unexplained increases and decreases of contaminants in perched-water wells. Variations in discharge to the ponds change in response to operational activities, and the location of the water input to the system changes significantly when discharge is cycled from one CWP cell to the other in order to prevent clogging of the pond bottoms by bio-films and sediment. This clearly would change subsurface pathways, exposing water to different levels of residual contamination. Recent research indicates that even if the discharge was constant and to a single pond, flow convergence with depth, flow path switching, and flow integration into pulses would occur. Variations in natural recharge and seasonal input from irrigation further complicate data analysis and probably trigger changes to flow pathways. Complex geochemical relationships between contaminant advection, adsorption, dispersion, and radioactive decay are impossible to sort out under these variable physical flow-field conditions, but undoubtedly affect concentrations in wells, possibly in a nonlinear manner.

It is unlikely that new sources of contamination or undiscovered old sources of contamination are present at TRA, based upon the historical record of concentrations measured during known releases decades ago. The recent unexplained increases and decreases of contamination do not have the same character as the older records. Past system leaks resulted in much larger contamination spikes than the relatively modest increasing trends observed in recent years. The analysis presented in Section 6.3.5 indicates that it is unlikely that lateral flux from the Big Lost River will cause significant changes to the flow field in the vicinity of the TRA fence.

Given the complexity of the subsurface environment and spatial/temporal variability in both the amount and chemistry of recharge sources, short-term variations in concentration levels are to be expected for the perched-water body. These short-term variations are not of concern as long as the trend is seen to decrease again over a maximum period of a few years. Given the current status of scientific understanding regarding flow and transport in unsaturated fractured rock, it is impossible to say what the long-term impacts to aquifer concentrations will be. Currently, there are no numerical simulators that can take advantage of new advances in the experimentally derived conceptual models. We must continue to use the commercially available, volume-averaged diffusive flow and transport models.

Recommendations are as follows:

1. *Continued monitoring of the perched water wells according to the existing groundwater monitoring plan with modifications as approved by DOE, DEQ, and the EPA. It should be realized that not all increasing trends or spikes in contamination pose an immediate or eventual threat to the effectiveness of the remedy and should be evaluated individually to determine the potential of their impact.* Keep current and support ongoing research that focuses on further development of improved conceptual models of unsaturated flow in fractured-rock environments and research that focuses on the development of numerical simulators that can take advantage of new advances in these conceptual models.

7. CONTINUED OPERATION OF THE COLD WASTE POND

7.1 Introduction

The First Five-Year Review Report (DOE-ID 2003) identified continued usage of the CWP beyond 2007 as an issue. At the time of the OU 2-13 ROD (DOE-ID 1997a), it was assumed that the TRA, including the CWP, would be decommissioned in 2007. Under a recent decision (2003) by DOE, the TRA will remain active for at least another 20 years. Continued discharge to the CWP from TRA operations will cause the perched-water systems to persist. This section evaluates contaminant transport to the aquifer under conditions of continued operation through 2027 and beyond. Potential sources of recharge to the perched-water system are evaluated through the development of a water budget for TRA in Section 7.2. A history of modeling efforts leading to the OU 2-13 ROD (DOE-ID 1997a) is presented in Section 7.3, along with an evaluation of the underlying assumptions in light of current understanding. The model is updated to consider continued operations through 2027 in Section 7.4. The findings of this investigation are summarized in Section 7.5, and recommended actions are provided in Section 7.6.

7.2 Water Budget for Sources of Perched Water

A system of perched-water bodies has formed in the vadose zone beneath TRA primarily because of artificial groundwater recharge induced by infiltration of wastewater from unlined ponds at the facility (Figure 1). The presence of perched water beneath TRA might facilitate the downward migration of COCs. The purpose of this section is to evaluate potential sources of recharge to the perched water at TRA. This begins with an accounting of all water used at TRA (Section 7.2.2) and concludes with a discussion of individual sources (Section 7.2.3). The data from this analysis are provided in electronic format in Attachment 3 on the supplemental data CD. A readme file (readme.txt), which describes the electronic data, also can be found on the CD.

7.2.1 Water Balance Accounting

All water used at TRA is currently derived from three aquifer production wells (TRA-01, TRA-03, and TRA-04). Water pumping and discharge data from the TRA facility are recorded in the INEEL Nonradiological Waste Management Information System (INWIMIS) database on a monthly basis. Aquifer pumping data are available for the intervals from January 1975 through December 1984 and from January 1998 through October 2003. A number of anomalously high discharge volumes are recorded in the INWIMIS database prior to January 1983, thus precluding water balance calculations before that date. As a result, only monthly data from January 1983 through December 1984 and January 1998 through October 2003 are used to check the completeness of the water budget at TRA.

In an analysis of the water budget at TRA, water losses are indicated if observed water use is found to be less than the total volume pumped from the SRPA. Such losses could then potentially serve as additional untracked sources of recharge to the perched-water system beneath TRA. During the 1983–1984 period, the average sum of all of the monthly fractional water uses is 101% of the total water pumped. During the 1998–2003 periods, the average sum of the monthly volumetric discharges is 99% of the water pumped. On a monthly basis, the volume pumped might differ from discharge by up to 25% to 30% (perhaps resulting from lag times between water pumpage and disposal). However, the average of the monthly readings indicates that approximately 100% of the pumped water is accounted for by the known discharge sources. If water is lost through system leaks, the fraction of the total pumped water represented by leakage is small compared to other sources (less than 5%).

Table 6 presents the annual fraction of aquifer pumping represented by each discharge source. The fractions were calculated for years in which a full pumping record and discharge record were available. During 4 years in which a full year's worth of pumping and discharge data were available (1975, 1977, 1983, and 2002), the sum of all fractional discharges suggests that nearly 100% of water pumped from the production wells at TRA is accounted for in the discharges. This result is consistent with the results discussed in the previous paragraph for the monthly data.

It is important to note that the average annual volume of water pumped from the SRPA is 780 million gal during the period of record. This means that a 1% water imbalance represents approximately 7.8 million gal of water. System losses are not likely to be noticed unless an imbalance of at least 5% is found; therefore, approximately 40 million gal of water could potentially be leaked to the perched-water system before the water balance accounting method detects the leaks.

7.2.2 Potential Recharge Sources to the Perched-Water System at the Test Reactor Area

As originally designed and installed, two separate wastewater streams were used at TRA: one for sanitary sewage and the second for all other wastewater. The sanitary sewage has always been separate from the other wastewater streams and has always been disposed of at the dedicated sewage lagoons. Over the years, additional segregation of the non-sewage wastewater streams has taken place.

Seven disposal systems in total have been used for long-term wastewater disposal at TRA. The systems include the unlined WWP, the lined Warm Waste Evaporation Pond, the unlined CWP, the unlined Chemical Waste Pond, the Disposal Well, the unlined Sewage Leach Pond, and the lined Sewage Lagoon. Four of these systems—the unlined WWP, unlined CWP, unlined Chemical Waste Pond, and unlined Sewage Leach Pond—have been considered to be sources of recharge water to the perched-water bodies beneath TRA. In addition, several miscellaneous sources might have contributed to recharge, either historically or in the present.

The remainder of this section discusses individual fluid sources that might have contributed to recharge of the perched-water system at TRA. Much of this discussion of historical wastewater streams at TRA in the following sections is excerpted from the *Conceptual Model and Description of Affected Environment for the TRA Warm Waste Pond (Waste Management Unit TRA-03)* (EG&G Idaho 1989). The discharge history for those sources is summarized in Table 7. A historical record of major wastewater discharges is provided in Table 8, and discharge to the four largest contributors is graphed as Figure 4.

7.2.2.1 Warm Waste Pond. The WWP and associated collection system were designed to dispose of radioactive wastewater. The WWP consisted of three unlined cells excavated into Big Lost River gravels. The first cell was excavated in 1952 and had bottom dimensions of 150 × 250 ft. Continued operations resulted in pond bottom plugging, reducing the infiltration capability. Because of the decreased infiltration capacity of the original cell, a second cell was excavated in 1957 with bottom dimensions of 125 × 230 ft. The third cell was excavated in 1964 and had bottom dimensions of 250 × 400 ft.

Originally, all non-sewage wastewater streams were collected in a sump at the southeast corner of TRA until that sump filled to a certain level. At that time, the wastewater was pumped from the sump into the WWP. Before reaching the sump, wastewater containing radionuclide contaminants passed through a Warm Waste Retention Basin intended to allow short-lived radionuclides to decay before final disposal at the WWP.

Table 6. Water balance summary of Test Reactor Area discharges relative to the volume of water pumped from the Snake River Plain Aquifer.

Year	Aquifer Pumpage (gal × 10^6)	CWP	Sewage	Irrigation	Chemical Waste Pond	Radioactive Stream	Desert	Cooling Tower Evaporation	Disposal Well	Sum
		Percentage of Water Pumped from Aquifer								
1975	1,083	—	0.7	1.9	2.4	20.3	22.4	29.0	31.6	108
1976	1,301	—	**	2.2	2.0	15.4	29.1	20.7	35.1	**
1977	981	—	0.9	2.7	2.2	15.0	39.4	‡‡	39.0	99
1978	694	—	1.4	1.9	3.0	18.0	**	‡‡	38.8	**
1979	753	—	1.2	3.3	2.3	9.8	**	‡‡	35.5	**
1980	650	—	1.3	3.5	1.8	8.8	**	‡‡	50.4	**
1981	607	—	1.0	1.6	1.6	9.1	**	‡‡	39.8	**
1982	632	31.3	0.8	2.5	1.4	8.1	**	‡‡	5.9	**
1983	664	37.1	0.9	1.8	1.0	3.9	0.1	55.2	—	99
1984	647	38.2	0.9	2.5	0.9	2.9	—	**	—	**
2002	576	33.8	3.1	9.0	—	1.3	—	52.8	—	100
Average =		35	1.2	3.0	1.9	10.2	22.7	39.4	34.5	

— = Source not in use
** = Incomplete data set for the year
‡‡ = Anomalous readings for CT evaporation during these years (monthly fractions greater than volume of water pumped)
CWP = Cold Waste Pond
WWP = Warm Waste Pond

NOTE: *Based on limited data from the 1970s and 1980s, steam loss and condensate loss are each expected to represent less than 1% of water pumped from the aquifer. The radioactive stream includes wastewater discharged to both the WWP and lined warm waste evaporation pond.*

Table 7. Historical summary of Test Reactor Area wastewater discharge.

Year	Event
1952	Discharge to the WWP and Sewage Leach Pond commences.
1960	The USGS-53 receives wastewater from an unknown source from November 1960 through January 1962.
1962	Chemical Waste Pond is brought online in November 1962.
1963	The USGS-53 receives wastewater from an unknown source between June and August of 1963.
	Discharge line leading to WWP breaks and discharges wastewater to surface 250 ft west of WWP. Leak is repaired.
1964	Aquifer Disposal Well begins receiving waste in November 1964.
	Only warm waste types are disposed of to the WWP. The cold fractions of the waste stream have been diverted to the Disposal Well and Chemical Waste Pond.
Early 1970s	Warm Waste Retention Basin is known to be leaking. The basin continued leaking at a minimum rate of 30 gpm until it was taken offline in 1993.
1982	The CWP is brought online.
	Discharge to the Disposal Well ceases.
1993	Discharge to the WWP ceases.
	Warm waste is diverted to the Lined Evaporation Pond.
1995	Discharge to the Sewage Leach Pond ceases.
	Sewage stream is diverted to lined sewage lagoons.
1999	Chemical Waste Pond is taken offline.

CWP = Cold Waste Pond
USGS = United States Geological Survey
WWP = Warm Waste Pond

Table 8. Annual discharge volumes of potentially important Test Reactor Area perched-water sources.

Year	Warm Waste Pond	Chemical Waste Pond	Irrigation	Cold Waste Pond	Sewage Leach Pond
(Discharge in millions of gal per year)					
1952	75	—	**	—	**
1953	75	—	**	—	**
1954	75	—	**	—	**
1955	97	—	**	—	**
1956	94	—	**	—	**
1957	107	—	**	—	**
1958	266	—	**	—	**

Table 8. (continued).

Year	Warm Waste Pond	Chemical Waste Pond	Irrigation	Cold Waste Pond	Sewage Leach Pond
1959	232	—	**	—	**
1960	221	—	**	—	**
1961	232	—	**	—	**
1962	283	—	**	—	**
1963	202	45	**	—	**
1964	172	45	**	—	**
1965	146	45	**	—	**
1966	130	37	**	—	**
1967	181	45	**	—	**
1968	188	47	**	—	**
1969	279	45	**	—	**
1970	281	45	**	—	**
1971	191	46	**	—	9.3
1972	217	73	**	—	10
1973	269	31	**	—	9.4
1974	246	31	**	—	8.2
1975	220	26	20	—	7.5
1976	200	26	28	—	8.7
1977	147	22	26	—	9.3
1978	125	20	13	—	9.4
1979	74	17	25	—	8.7
1980	57	12	23	—	8.2
1981	55	9.3	10	—	5.8
1982	51	8.9	16	203	5.1
1983	26	6.7	12	238	6.1
1984	19	5.8	16	248	6.0
1985	20	6.0	12	222	7.2
1986	25	6.3	13	272	8.5
1987	19	5.5	26	178	6.8
1988	18	4.2	54	224	7.4
1989	23	7.7	54	294	8.2

Table 8. (continued).

Year	Warm Waste Pond	Chemical Waste Pond	Irrigation	Cold Waste Pond	Sewage Leach Pond
1990	20	7.5	51	254	8.6
1991	29	8.6	75	206	13
1992	23	8.5	125	143	13
1993	17	6.4	72	250	14
1994	—	6.0	47	214	33
1995	—	6.4	**	169	22
1996	—	5.6	60	162	—
1997	—	5.9	**	172	—
1998	—	4.5	65	157	—
1999	—	0.96	—	36	—
2000	—	—	23	181	—
2001	—	—	34	152	—
2002	—	—	52	195	—

— = Source did not exist or was not included in recent utility reports.
** = Data were not recorded in INWIMIS database; volume either zero or unknown.
INWIMIS = INEEL Nonradiological Waste Management Information System

From 1952 through 1962, the WWP received all non-sewage wastewater. In 1962, the fraction of wastewater from the Demineralization Plant was diverted from the WWP to the newly constructed Chemical Waste Pond. By 1964, only wastewater containing radionuclides was disposed of in the WWP. All three cells were taken offline and remediated in late 1993. At that time, the warm wastewater stream was diverted to the newly constructed, lined Warm Waste Evaporation Pond.

As presented in Table 8, between 17 million and 283 million gal of wastewater was disposed of annually in the WWP from 1952 until the pond's closure in 1993. Before the addition of the CWP in 1982, discharges to the WWP represented the primary source of water to the TRA perched-water system.

7.2.2.2 Test Reactor Area Disposal Well. The TRA disposal well was constructed to dispose of nonradioactive wastewater from cooling tower blowdown directly to the SRPA. Wastewater containing chromate was discharged to the TRA disposal well beginning in November 1964 and ending with the construction of the CWP in 1982. The well presently is used as a monitoring well and is screened over several intervals between 512 and 1,267 ft bls.

7.2.2.3 Cold Waste Pond. The CWP was brought online in 1982 and has been used since that time as a replacement for the Disposal Well. The pond consists of two cells, each 150 × 400 ft. Water disposed of at the CWP primarily originates from cooling tower blow-down, air-conditioning units, secondary system drains, floor drains, and other nonradioactive drains throughout TRA (DOE-ID 2003). Historically, only one of the two cells has been used at a time with rotation on an annual basis.

Wastewater discharge to the CWP has been the largest contributor to the TRA perched-water system since it came online in 1982. As presented in Table 8, between 36 million and 294 million gal of wastewater has been disposed of each year in the CWP. The CWP is projected to receive approximately 300 million gal of wastewater per year through at least 2024.[d]

7.2.2.4 Sewage Leach Pond. The Sewage Leach Pond consisted of cells excavated in 1950 and 1965 that received discharge from sanitary sewer drains. Process knowledge indicates that effluent was limited to domestic sewage (DOE-ID 2003). Low-level radionuclides were detected in the 1950 cell, but have been attributed to airborne dust accumulation in the pond. Sewage discharge rates to the pond are available beginning in 1971.

Annual discharge to the unlined Sewage Leach Pond varied between 5.1 million and 33 million gal of wastewater from 1971 to its closure in 1995 (Table 8). The Lined Sewage Lagoon was brought online with the decommissioning of the Sewage Leach Pond.

7.2.2.5 Chemical Waste Pond. The Chemical Waste Pond was excavated in 1962 and was first used in November of that year to dispose of wastewater from ion exchange columns and water softeners. The pit was unlined and had bottom dimensions of 170 × 170 ft. Wastewater discharged to the Chemical Waste Pond contained sulfuric acid, sodium hydroxide, and sodium chloride. The pond was taken out of service in 1999 (DOE-ID 2003).

Table 8 presents wastewater volumes discharged to the Chemical Waste Pond from the time of its construction in 1964 to its final remediation in 1999. Annual volumes of disposed water ranged from approximately 1 million gal in 1999 to a maximum of 73 million gal in 1972.

7.2.2.6 Other Potential Perched-Water Sources and Sinks. Other potential sources and sinks exist that could affect the perched-water system. These sources are either poorly quantified, infrequent, or potentially minor contributors to the perched-water system based on the relative magnitude of their volumetric discharge compared to the major contributors identified in the previous sections.

7.2.2.6.1 Lawn Irrigation—Lawn irrigation presents a potential source of perched water. Most grassy areas inside the TRA fence that would require irrigation during the spring through fall months are located in the central, northern, and western portions of the facility. The annual volume of irrigation discharge ranged from 10 million gal in 1981 to 125 million gal in 1992 (Table 8).

7.2.2.6.2 Known Leaks— Several leaks and/or unplanned discharges are known to have occurred since the commencement of operations at TRA. They include the following:

- Since the early 1970s, it was known that the Warm Waste Retention Basin leaked, although it is not known when the leak started. The exact rate of leakage is unknown, although 30 gpm is a minimum estimate. At 30 gpm, leakage would have exceeded 15 million gal of wastewater each year. The leaking portion of the basin was taken offline in 1993, coincident with the construction of the new lined Warm Waste Evaporation Pond.

- In August of 1963, a wastewater line leading to the WWP broke and discharged liquids to the surface approximately 250 ft west of the pond. A small perched-water zone that formed in surficial alluvial deposits beneath this leak diminished after the leak was repaired.

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[d] Personal communication with TRA Facility Operations, April 2004.

7.2.2.6.3 Wastewater Discharge to USGS-53—Wastewater from an unknown source was disposed of in the USGS-53 perched-water well from November 1960 through January 1962 and June 1963 through August 1963. Well USGS-53 is completed to a depth of 90 ft bgs in the deep perched-water zone. While the source of wastewater disposed of in the well is unknown, injection rates have been estimated at about 148,000 gal/day. Over the period of operation presented above, it is estimated that a total of 220 million gal of wastewater was discharged directly to the deep perched-water zone through USGS-53 (Dames and Moore 1992a).

7.2.2.6.4 Desert—During the 1970s, discharge to locations designated as "Desert" and "Desert Depression" in the INWIMIS database are recorded. The location(s) of these discharge point(s) are unknown and may or may not have had a significant impact on the perched-water system at TRA. Over 200 million gal of water was discharged to this location (or locations) during the mid-1970s (see Attachment 3, provided on the supplemental data CD).

7.2.2.6.5 Steam and Condensate Loss—Steam and condensate loss are listed in the INWIMIS database during a portion of the 1970s and 1980s. During that time, monthly losses from these sources account for less than 1% each of the total water pumped from the aquifer. Based on available aquifer pumping data, 1% of the pumped volume represents less than 10 million gal of water per year. Some of this loss can potentially reach the perched-water system through direct discharge to the subsurface.

7.2.2.6.6 Big Lost River—The Big Lost River has been considered a potential source of perched water near TRA. However, the river channel is approximately 4,000 ft from the southeast corner of the TRA fence line. Some evidence has been presented that water levels in two perched-water wells located southeast of TRA (USGS-71 and USGS-62) are affected by exceptionally high flows in the Big Lost River (EG&G Idaho 1991a). No chemical signature of recharge from the Big Lost River was observed at USGS-62 during water-level rises that occurred after high Big Lost River flows in 1965.

Because it is difficult to determine when TRA water levels might be affected by Big Lost River flow, let alone how much water might be contributed to the perched-water system southeast of the facility, this source is an unknown. However, the river's lateral and vertical distance from the TRA fence line and the vicinity of the CWP make it unlikely that its effect on the perched-water system would be significant. However, the mounding height of the perched water can potentially be used for further analysis and provide a definitive determination.

7.2.2.6.7 Precipitation—Average annual precipitation in the southwestern portion of the INEEL is 8.7 in. (DOE-ID 2003). Most of this precipitation falls as snow during the winter and spring months and subsequently melts as warmer spring temperatures arrive. The pre-ROD perched-water system model implemented a single, natural (i.e., precipitation-induced) infiltration rate of 5.92 in./year over the entire simulation period, which equates to over 100 million gal/yr spread over the greater area of TRA. This infiltration rate was insufficient to sustain perched-water bodies after manmade discharges were shut off in the calibrated model.

7.2.2.6.8 Evaporation—The discharge volumes reflected in Tables 6 and 7 are gross discharge volumes and do not reflect the effects of evaporation. Evaporation from small lakes in southeast Idaho (a surrogate for the TRA wastewater impoundments) is on the order of 32 to 36 in./yr (Linsley, Kohler, and Paulhus 1982). For the periods during which at least two of the three WWP cells were filled, this evaporation rate (and the estimate area from which evaporation would occur) would have accounted for approximately 1 to 8% of the total warm waste discharge volume (EG&G Idaho 1989). Similar calculations could be conducted to determine the percentage of water lost to evaporation at other TRA water impoundments based on their submerged surface area and the evaporation rate presented previously. The pre-ROD perched-water system model assumes that the evaporation rate is 10% of pond discharge, regardless of pond surface area (Dames and Moore 1992a).

7.3 Modeling History and Evaluation of Perched-Water System Model Assumptions

Modeling of the perched-water system and underlying SRPA has been conducted to examine in a predictive manner the nature and extent of the contamination in the subsurface at TRA. Additional modeling is required, because the pre-ROD model assumed that TRA would cease operations in 2007; however, this assumption is no longer valid. The general approach for this modeling effort involves the use of two numerical codes: the original model updated to extend the period of operation to 2024 and the use of a modern, commercially available, state-of-the art numerical code. This approach was taken to (1) provide a higher level of assurance for predictions and (2) provide redundancy for the calculations made by the original code, which is now somewhat antiquated and out of date. This section describes the history and rationale of the modeling efforts (Section 7.3.1) as well as the simulation code used (Section 7.3.2). A presentation and discussion of the assumptions used in the modeling effort also are provided (Sections 7.3.3 and 7.3.4, respectively).

7.3.1 Modeling History and Rationale

The TRA perched-water system model was developed in 1991 to provide exposure-point concentrations for the TRA human health and ecological risk assessment and to predict both vadose zone moisture conditions and contaminant concentrations in the SRPA. The results of those simulations were used to evaluate remedial action alternatives under the CERCLA process.

The OU 2-12 ROD (DOE-ID 1992) identifies procedures that are being employed to ensure that contaminant concentrations are protective of human health and the environment. The OU 2-12 ROD called for no remedial action, because the human health and ecological risk assessments determined that conditions at the site pose no unacceptable risks to human health or the environment for expected current and future site users (i.e., users in the year 2115). The No Remedial Action decision was based on the requirement that groundwater monitoring be conducted to verify that aquifer contaminant concentration trends match the results predicted with the perched-water system model. In addition, the decision was based on the assumptions that operations at TRA will continue through at least 2007 and that the WWP, which was the major source of contamination to the aquifer, was to be replaced with a lined pond in 1993.

The OU 2-13 ROD (DOE-ID 1997a) reaffirms the OU 2-12 ROD (DOE-ID 1992) and describes activities that are necessary for protection of human health, as follows: “Groundwater monitoring will be conducted to verify that contaminant concentration trends follow those predicted by the groundwater model. Computer modeling shows that through natural radioactive decay, natural attenuation, and dispersion, contaminants in the groundwater will steadily decrease to acceptable levels within the next 20 years, which is consistent with the time of continued operations at the TRA.”

The First Five-Year Review Report (DOE-ID 2003) and the OU 2-12 ROD (DOE-ID 1992) state that the perched-water system model predicted that tritium and chromium concentrations were expected to fall below their MCLs by 2004 and 2016, respectively.

In order to evaluate the ability of the existing perched-water system model to accurately predict contaminant concentrations in the SRPA beneath TRA, it is necessary to evaluate the assumptions of that model in light of current understanding of the TRA conceptual model. Section 7.2.2 presents the assumptions inherent in the existing perched-water system model and discusses their potential impact on the prediction of contaminant concentrations in the SRPA.

7.3.2 Simulation Code Selection

The TARGET-2DU computer code, Version 4.3 (Dames and Moore 1985; Dames and Moore 1995) was used to simulate flow and transport beneath TRA in support of a human health risk assessment (Dames and Moore 1992b). The TARGET-2DU computer code is one component of the TARGET suite of modeling software, which also can be used to simulate other flow conditions such as three-dimensional, saturated flow- and density-coupled flow using a grid-centered, finite-difference approach. The rationale used to select TARGET is documented in Dames and Moore (1992a), who state that TARGET is peer-reviewed, commercially available, and technically capable of simulating the interaction of the perched-water system and SRPA at TRA.

7.3.3 Perched-Water System Model Assumptions

The existing perched-water system model is a two-dimensional, cross-sectional model oriented parallel to the local hydraulic gradient in the SRPA. While flow directions are variable both spatially and temporally, the average direction of groundwater flow in the SRPA below TRA is to the southwest (DOE-ID 2003). Because the primary sources of contaminants to the subsurface, the WWP, and CWP are aligned along a northeast-southwest oriented line and sufficient wells exist along that line to constrain the geologic framework, the two-dimensional model was oriented to include those features. The cross-section discretized into the model is approximately 2 mi long and 700 ft deep, approximately centered on the CWP (as shown on Figure 5-3 in Dames and Moore [1992b]).

The assumptions listed below were made by Dames and Moore (1992b) during the development of the perched-water system model:

1. The perched-water system can be represented by a two-dimensional slice model.
2. Flow is vertical except in the shallow and deep-perched zones.
3. The perched-water system is an equivalent porous medium.
4. Individual layers are homogeneous.
5. Basalt is anisotropic with vertical hydraulic conductivity (K_v) greater than horizontal hydraulic conductivity (K_h). For sediments, K_v is less than K_h.
6. Moisture-characteristic curves for fractured tuff are applicable to the unsaturated zone at TRA.
7. Active thickness of the SRPA is 250 ft.
8. Interaction of the perched-water system and the Big Lost River is negligible.
9. The WWP and CWP are the primary sources of perched water.
10. Chromium injected to USGS-53 can be modeled as going into the WWP.
11. Sources of water to the subsurface include known wastewater sources and precipitation. No other potential sources of groundwater recharge are included in the model.
12. Discharge to the CWP would end in 2007 with closure of the TRA facility.

13. Discharge to the CWP will continue from 1990 through 2007 at the rate observed in 1990 (approximately 250 million gal/yr).

7.3.4 Discussion of Model Assumptions

The modeling assumptions presented in the previous section were discussed and defended at the time of model development (Dames and Moore 1992b). This section presents a summary of the modeling assumption discussion presented by Dames and Moore (1992b) and provides some additional insight into the model assumptions gained during the model update process to be discussed in Section 7.4.

Assumption 1 implies that the geologic and hydraulic setting in the plane of the cross-section is representative of the setting outside this plane. If there is significant variation outside the plane of the model, this assumption may be violated. Factors that might influence the physical setting outside the plane of the model include the presence of recharge sources and different stratigraphy outside the model cross-section.

Assumption 2 implies gravity-driven flow conditions to exist in areas of the vadose zone outside of the perched-water bodies. Within the perched-water bodies, as well as in unsaturated areas above the perched water, the flow of infiltrating water includes a lateral component.

Assumption 3 was considered valid because the point of interest (the SRPA) is relatively far from the source and breakthrough curves for contaminants that resemble those that would be obtained for a porous medium.

Assumption 4 was necessary because, even though heterogeneity is know to exist, there is a lack of data available to define it within the individual model layers. Dames and Moore (1992b) stated that this assumption is valid if the model recreates observed conditions since heterogeneity in the layers is known to exist.

The relationship of K_v to K_h in basalt presented in Assumption 5 is contrary to the accepted conceptual model of flow in fractured basalt, which dictates that rubble zones allow rapid migration of fluids in the horizontal plane. However, the relationship used in the model is consistent with the concept of higher K in the direction of flow (i.e., the stratigraphic control on the flow is different depending on the direction of flow).

Assumption 6 was made because characteristic curves for fractured basalt were unavailable at the time of the 1992 modeling.

Assumption 7 was based upon the *Conceptual Model and Description of the Affected Environment for the TRA Warm Waste Pond (Waste Management Unit TRA-03)* (EG&G Idaho 1989), which discussed the thickness of the SRPA.

Assumption 8 was based upon several observations, specifically: (1) there is no consistent pattern of perched-water-level rises attributable to Big Lost River infiltration; (2) no perched-water-level rises west, northwest, or north of the CWP and WWP were observed as a result of Big Lost River infiltration; (3) the bulk of contaminated perched water is northwest of the ponds; and (4) the INEEL flood diversion system precludes the possibility of large amounts of infiltration from the Big Lost River as a result of flood inundation.

Assumption 9 implies that error associated with lumping contaminant sources into the two ponds should be minimal.

Assumption 10 essentially results in an underestimation of travel time to the aquifer and overestimation of sorption for the water injected at USGS-53. These elements were not considered important by Dames and Moore (1992b) because of the long simulation period and short travel time to the SRPA.

Assumption 11 was not explicitly stated in the original modeling report. It amounts to effectively neglecting the infiltration of irrigation water applied to lawns inside the TRA fence. The validity of this assumption can be questioned.

Assumptions 12 and 13 are no longer valid based on current knowledge of TRA facility operations. The facility will not be closed by 2007. Under a recent decision by DOE, TRA will remain active for at least another 20 years (DOE-ID 2003).

Dames and Moore (1992b) argued that the relatively good calibration of the model to chromium and tritium concentrations and observed heads validates Assumptions 1–10. Assumptions 11–13 were not expected to have had a significant impact on the calibration of the model. However, those assumptions might affect predicted future concentrations of contaminants in the SRPA.

During a qualitative assessment of model sensitivity to various input parameters, Dames and Moore (1992b) found that the model is not very sensitive to natural infiltration (precipitation) rate changes and that the natural infiltration rate used in the model is conservative (i.e., high). A similar sensitivity assessment could be conducted to determine the model sensitivity to infiltration of irrigation water. If the model is relatively insensitive to infiltration rates that approximate those resulting from lawn irrigation, then Assumption 11 could be considered valid. If the effects of simulated lawn irrigation are large, which would be indicated by significant perched-water body formation from irrigation water alone, then Assumption 11 would be invalid and Assumption 1 would need to be reevaluated. Because the irrigated portions of the facility do not lie on the model transect, the applicability of a two-dimensional model (as assumed in Assumption 1) would be questionable if infiltrating irrigation water has large effects on the perched-water system.

7.4 Update of the Pre-Record of Decision Perched-Water System Model

This section describes the activities involved with updating and revising the pre-ROD perched-water system numerical model as well as comparing the TARGET model with the commercially available code TOUGH2 (Section 7.4.1). The updated TARGET modeling results are compared with the pre-ROD predictions as well as the TOUGH2 results in Section 7.4.2.

7.4.1 Model Update

The pre-ROD perched-water system model implemented using TARGET assumed that the TRA facility would close in 2007 and discharge to the CWP would cease at that time. The mission at TRA has been extended since the original model was developed, and the CWP is expected to receive wastewater at current levels through at least 2024. The pre-ROD model was updated to consider the effects of this operational change. In addition, the model has been further extended to evaluate the impact of CWP discharge beyond 2024.

This section identifies the COCs for which updated simulations were conducted, describes the changes made to the original perched-water system model, and presents updated simulation results.

7.4.1.1 Extended Period for Existence of Perched-Water Sources. The original perched-water system model simulated discharge to the CWP through 2007. However, current TRA facility plans dictate that the CWP will continue to receive wastewater at an estimated rate of 25 million gal per month (300 million gal/yr) through at least 2024 (personal communication, see footnote d). This change was implemented in the updated TARGET model by adding CWP discharge at 270 million gal/yr (300 million gal/yr minus 10% for evaporation) to the model from 2003 through 2024. During the development of the original model, it was assumed that evaporation equaled 10% of the volume of water discharged to the wastewater ponds (Dames and Moore 1992a). In addition, the CWP discharge volumes used in the original model for the period from 1990 through 2002 were revised to reflect the annual discharges measured by TRA Facility Operations as presented in Table 8 (minus 10% for evaporation). Because the site COCs were not present in CWP wastewater, no changes to contaminant source terms were necessary.

7.4.1.2 Updated Contaminants of Concern. At the time the pre-ROD TARGET model was developed, limited concentration data were available for analytes other than tritium and Cr. As a result, the contaminant transport portion of the model was calibrated solely to these compounds (Dames and Moore 1992b). Simulations were originally carried out using the TARGET model for a number of potential COCs, including Am-241, As, Be, Cd, Cs-137, Cr, Co-60, F, Pb, Mn, Sr-90, tritium, and Hg.

During the data analysis for the First Five-Year Review Report (DOE-ID 2003), only Cr, tritium, Co-60, and Sr-90 were reported to have a significant impact on perched water and the aquifer. As a result, updated simulations were only carried out for these four COCs. The results of the updated simulations are presented in Section 7.4.2.

7.4.1.3 Revisions to the TARGET Model. Despite the lack of changes to contaminant source terms, two omissions that affect simulated contaminant concentrations were discovered during the model update process; radioactive decay of Co-60 and Sr-90 was not implemented in the original perched-water system model. The Co-60 and Sr-90 half-lives of 5.20 and 28.0 years, respectively, were implemented in the updated model. Because any previous risk calculations were conducted using simulated Co-60 and Sr-90 concentrations that were unaffected by radioactive decay, those concentrations can be considered conservative.

7.4.1.4 TOUGH2 Modeling. Simulations of vadose zone flow and transport also were carried out using the TOUGH2 numerical simulator (Pruess 1991). The setup and conditions of the TARGET simulations were duplicated (i.e., modeled domain, boundary conditions, grid size, and parameters) to the degree possible with the TOUGH2 code. These efforts were conducted in order to compare the results with a modern, well-documented, and widely accepted commercially available code. The objective of these simulations was to provide a basis of comparison with the results of the updated TARGET modeling (with the CWP operational until 2024). Development of an independent numerical model was beyond the scope of this task.

Several modifications to the simulated domain and parameters had to be made to implement the simulations with the TOUGH2 code. The TARGET code uses a unique formulation for calculating the relative permeability and capillary pressure functions for vadose zone flow that are not available in the TOUGH2 code. Therefore, the Leverett function (1941) was used to calculate the relative capillary pressure in the TOUGH2 simulations, while the van Genuchten model (1980) was used to determine the relative permeability. Data points were extracted from the plots of pressure head vs. moisture content presented by Dames and Moore (1992a, Figure 5-5) and used in the computer code RETC (van Genuchten, Leij, and Yates 1991) to determine parameters for the van Genuchten's relative permeability model.

As was performed in the TARGET modeling, the model results for chromium and tritium were first compared with the monitoring data in USGS-65. In order to better match the field observations, several minor modifications were made to the parameter values used in the TARGET simulations: (1) the vertical hydraulic conductivity in the SRPA was reduced by a factor of 8, (2) van Genuchten relative permeability model "m" parameter in the alluvium was increased from 0.15 to 0.25, and (3) K_d values for the lower interbed were increased by 30%.

7.4.1.5 Model Comparison. The numerical modeling codes used in this assessment vary significantly in their implementation for a particular problem. The TARGET code consists of four independent computer codes for (1) two-dimensional, vertically integrated, confined/unconfined, transient groundwater flow, and solute transport; (2) two-dimensional vertically oriented (cross-section), variably saturated, density-coupled, transient groundwater flow, and solute transport (used for the TRA simulations); (3) multilayer (variable layer thickness), confined/unconfined, transient groundwater flow, and solute transport; and (4) three-dimensional, saturated, density-coupled, transient groundwater flow, and solute transport. The TOUGH2 code consists of a single, primary executable routine that is linked to one of a number of Equation of State modules, depending on the problem at hand. The TOUGH2 code can accommodate all of the applications of the four TARGET executables as well as a significant suite of other, more complex applications.

The TARGET code is a proprietary code that is supplied as an executable program by the authors. This is in contrast to TOUGH2, which is a public domain code supplied as basic FORTRAN files that must be compiled and linked by the user. This difference makes application of the codes vary significantly. The TOUGH2 code, owing to the ability to modify the source code and flexibility built into the primary executable, has the capabilities to handle many more situations than the TARGET code, but owing to this ability, many more input variables might be required (that may or may not be available).

For the present application, the TOUGH2 code was made to mimic the TARGET code to the extent possible (i.e., using similar property sets and functions for the simulation of flow and transport). Differences that cannot be reconciled between the two codes, such as the numerical solution schemes (TOUGH2 uses a set of fairly advanced routines that are selectable by the user), grid cell connection averaging, and weighting can account for the differences in the simulation results.

7.4.2 Model Results

Predicted concentrations presented in the OU 2-12 ROD (DOE-ID 1992) and used during the human health and ecological risk assessment represent the maximum concentrations in the top 12.5 ft of the SRPA in the model domain (Dames and Moore 1992a). Maximum concentrations were assumed to occur in that interval, directly beneath the waste ponds, before mixing and dilution in the aquifer could occur. Dames and Moore (1992a) noted that risks calculated using the 12.5-ft screened interval at the top of the aquifer are likely to be conservative, because typical SRPA wells are completed over a larger saturated (40- to 100-ft) interval, which is expected to yield a more diluted sample than the predictions would indicate.

The TOUGH2 modeling results were comparable with those obtained with the TARGET modeling. The TOUGH2 simulation results in general showed lower maximum concentrations of the four COCs in the SRPA. With the exception of tritium, the TOUGH2 simulations showed concentrations returning to near baseline concentrations in the aquifer earlier than in the TARGET simulations.

Contaminant concentrations predicted in the upper 12.5 ft of the aquifer have been presented in previous documents and represent maximum concentrations in the aquifer; therefore, results presented in this section are also derived from that interval. The following sections present the results of the original

(CWP discharge until 2007) and updated (CWP discharge through 2024) model simulations for the four COCs as well as the TOUGH2 modeling results.

7.4.2.1 Chromium. The original TARGET perched-water system model predicted that Cr concentrations would fall below MCLs by 2016. The updated model predicts that Cr concentrations in the SRPA will remain above MCLs until 2034, assuming that discharge to the CWP ceases in 2024. As portrayed in Figure 47a, the TARGET model predicts a sharp decreasing trend in Cr concentrations that begins at the time CWP discharge is simulated to end in the updated model. This result can be explained by the expected reduction of Cr flux from the vadose zone to the aquifer after 2024, when the only source of groundwater recharge is precipitation.

The TOUGH2 model predicted lower concentrations of chromium in the SRPA under conditions of the CWP being operational until 2024 (Figure 47b) with concentrations falling below the MCLs in approximately 2022. The concentration of chromium is predicted to drop rapidly with cessation of flow into the CWP.

7.4.2.2 Tritium. The results of the pre-ROD and updated TARGET modeling (2024 CWP operations) of tritium show very little change in the predicted concentration in the SRPA. All the TARGET models predict that tritium concentrations are near MCLs at the present time (2004). Because of the radioactive decay of this relatively short-lived isotope, tritium concentrations are expected to continue to fall and remain below MCLs for the entire simulated period (Figure 48a). Tritium concentrations are not predicted to rise above MCLs in the updated perched-water system model. The TOUGH2 modeling predicted tritium concentrations to fall below MCLs in the year 2018 (see Figure 48b).

7.4.2.3 Cobalt-60. The effects of both the cessation of discharge to the CWP and radioactive decay are evident in the pre-ROD and updated TARGET simulation shown on Figure 49a. Cobalt-60 is more highly retarded in the vadose zone than more conservative species such as Cr or tritium. Therefore, it reaches peak concentrations after the wastewater discharge period simulated in the pre-ROD and updated TARGET models. Once the flux of Co-60 into the aquifer is reduced, radioactive decay plays a more significant role in defining the concentration trend. This COC is not predicted to exceed MCLs in the SRPA at any time under the extended TRA operational scenario. The results of the TOUGH2 modeling show similar trends as the TARGET model; however, the peak concentrations are approximately 25% of those predicted with the TARGET model, as shown on Figure 49b.

7.4.2.4 Strontium-90. The effects of both the cessation of discharge to the CWP and radioactive decay are also evident in the predicted concentration trends for Sr-90 (Figure 50a). As with Co-60, Sr-90 is more highly retarded in the vadose zone than Cr or H-3 and therefore does not reach peak concentrations until after the wastewater discharge period ends in the pre-ROD and updated TARGET models. In the extended model, Sr-90 concentrations reach a peak of ~7.6 pCi/L at approximately 2102 and begin declining trends until the end of the simulation period. This COC is not predicted to exceed MCLs in the SRPA at any time under any of the TRA operational scenarios. Comparison of the TOUGH2 and TARGET modeling (Figure 50b) is similar to the results for Co-60 with the TOUGH2 simulations predicting similar trends but with a maximum concentration of approximately 25% of that in the TARGET simulations.

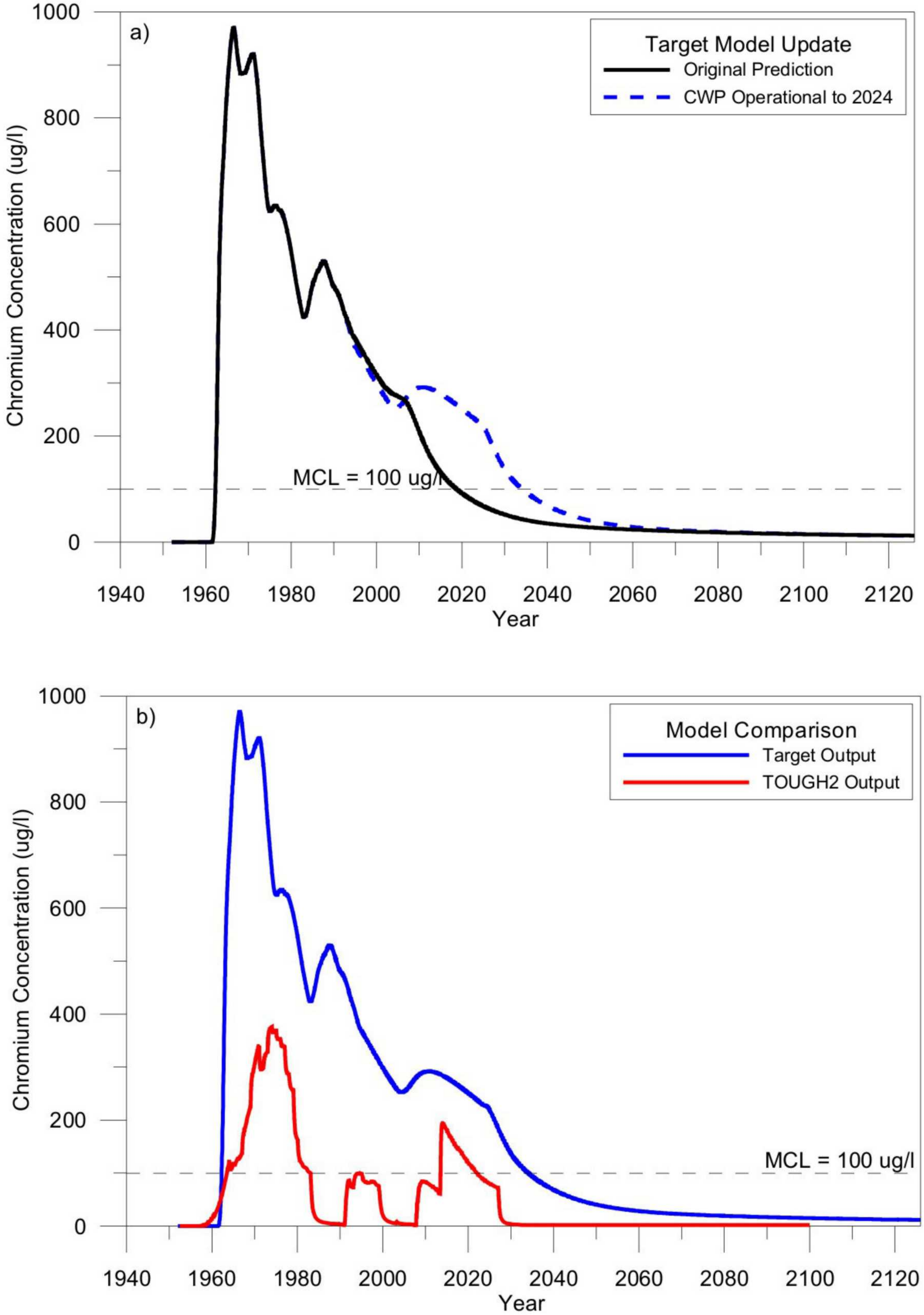

Figure 47. (a) Original and updated TARGET predicted maximum chromium concentration in the Snake River Plain Aquifer and (b) comparison of the TARGET and TOUGH2 results.

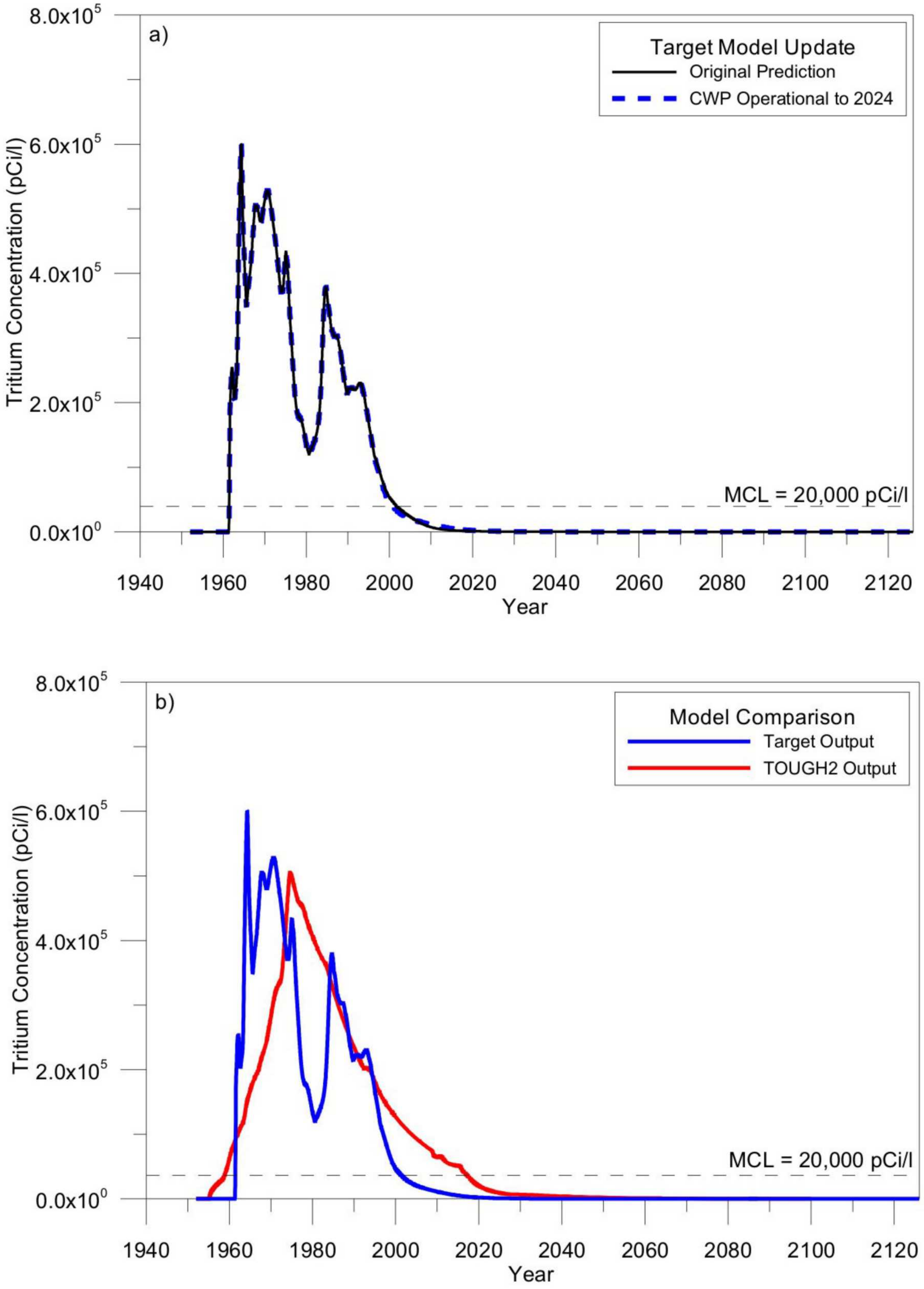

Figure 48. (a) Original and updated TARGET predicted maximum tritium concentration in the Snake River Plain Aquifer and (b) comparison of the TARGET and TOUGH2 results.

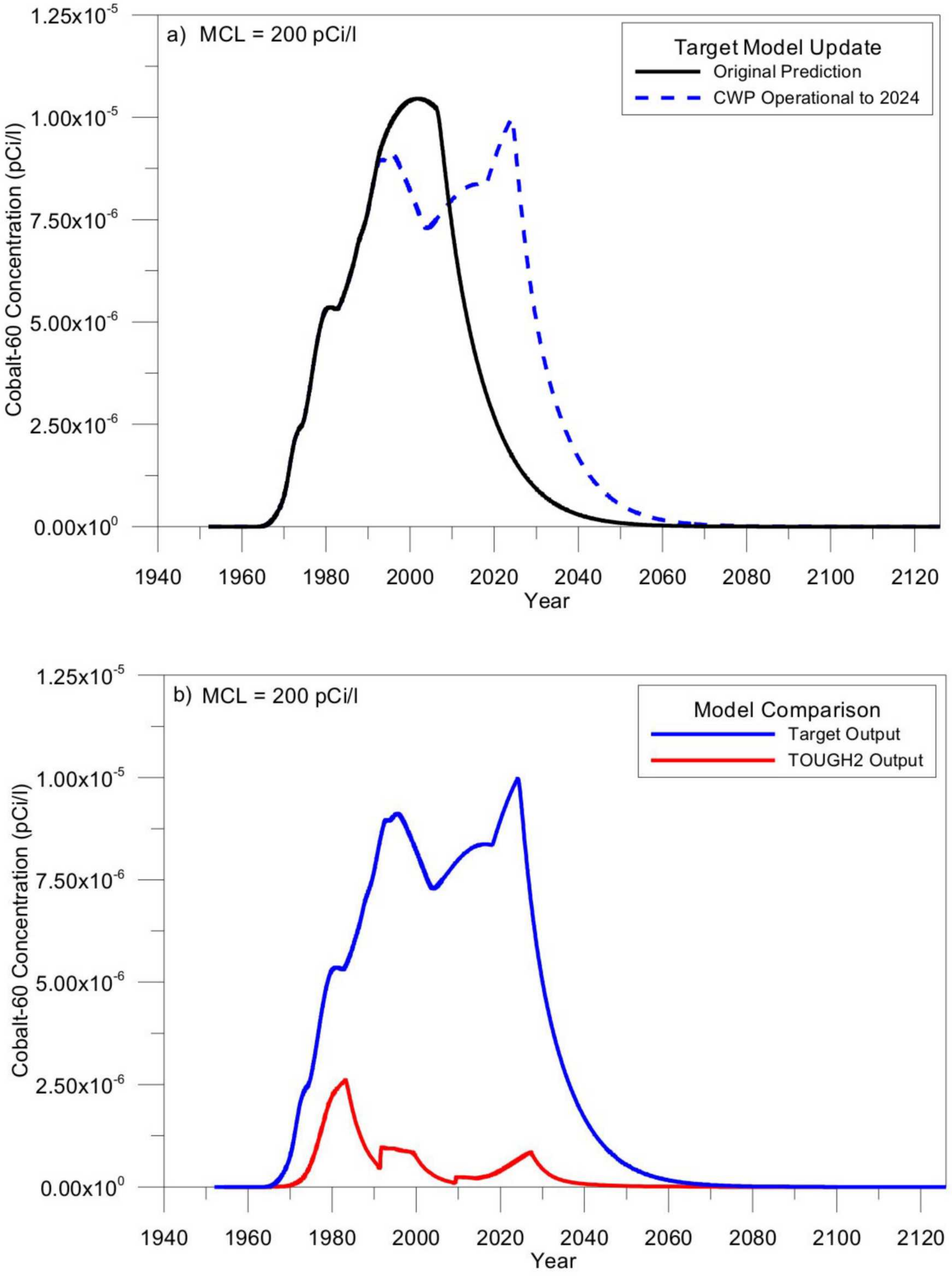

Figure 49. (a) Original and updated TARGET predicted maximum cobalt-60 concentration in the Snake River Plain Aquifer and (b) comparison of the TARGET and TOUGH2 results.

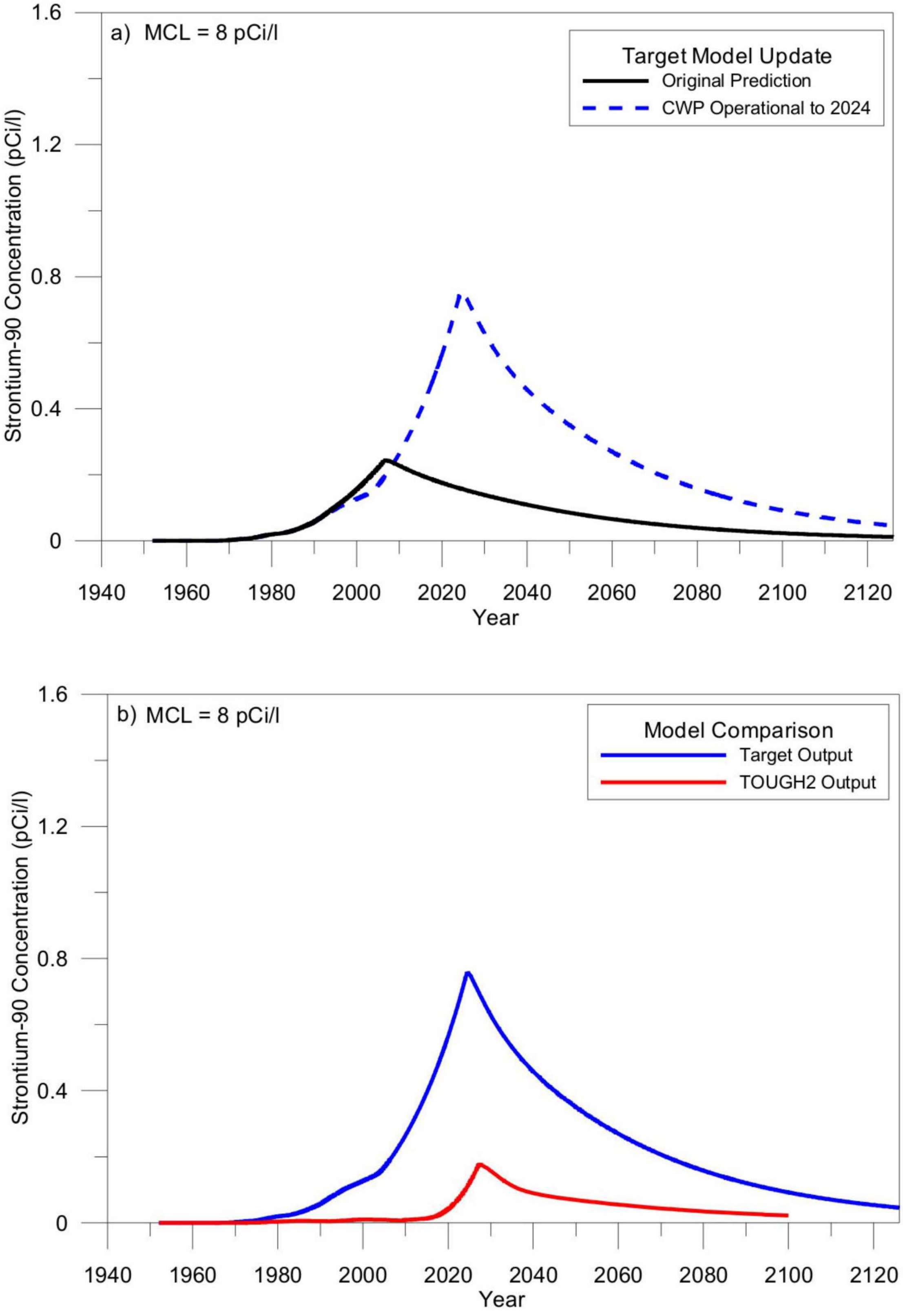

Figure 50. (a) Original and updated TARGET predicted maximum strontium-90 concentration in the Snake River Plain Aquifer and (b) comparison of the TARGET and TOUGH2 results.

7.5 Conclusions and Recommendations

The following recommendations/conclusions can be made following the evaluation of the TRA water budget, modeling assumptions, and updated modeling efforts.

7.5.1 Water Budget for Sources of Perched Water

Four unlined, manmade wastewater impoundment structures have contributed to the perched-water system at TRA at rates of at least 10 million gal each per year; they are: (1) the WWP, (2) the CWP, (3) the Chemical Waste Pond, and (4) the Sewage Leach Pond. Of these, the WWP and CWP have each received more than 200 million gal of wastewater during a single year and are (or were) the primary contributors to the perched-water system. Additional sources of water to the perched-water system are lawn irrigation, precipitation, discharge to Well USGS-53, discharge to an unknown desert location, and known infrastructure leaks.

A water balance consisting of all TRA water-use sources and sinks was conducted in an effort to identify previously unknown water losses. The water balance was nearly complete based on a limited number of years for which data from all sources and sinks were available. No obvious water losses were identified. However, water losses less than approximately 40 million gal/yr are unlikely to be detected based on the resolution of this water balance accounting method.

7.5.2 Perched-Water System Model Assumptions

At least three assumptions used during the development of the existing perched-water system model could affect predicted concentrations. First, the model does not include infiltration of water from irrigated portions of the TRA facility. The importance of this assumption should be evaluated by assessing the sensitivity of the model to infiltration rates that approximate infiltration from the irrigated area. The sensitivity of the model to irrigation water infiltration could affect the assumption that a two-dimensional slice model is appropriate for the TRA perched-water system. It is not expected that alternate sources of recharge have a large effect on simulated contaminant concentrations or it would have been difficult to calibrate the model to observed concentrations without accounting for those recharge sources.

Two assumptions relating to the period of CWP discharge and the rate of discharge are invalid based on current knowledge of TRA facility operations. The model assumed that discharge to the CWP would continue through 2007. It is now known that the TRA facility will operate at least 20 years longer, and CWP discharge at a rate of approximately 300 million gal/yr will continue during that interval.

7.5.3 Update of the Pre-Record of Decision Perched-Water System Model

The TRA perched-water system model was updated to include the discharge of wastewater to the CWP through 2024. In addition, radioactive decay half-lives for Co-60 and Sr-90 were implemented in each case, because they were apparently omitted during simulation with the original perched-water system model. Results from the updated model show the maximum concentrations of all COCs in the SRPA are expected to be well below MCLs by 2095. The Co-60 and Sr-90 concentrations are predicted to never exceed MCLs. Concentrations of the contaminants in the SRPA are predicted to fall and remain below MCLs by 2115—the date for which risk to future site users is defined in the OU 2-12 ROD (DOE-ID 1992)—and continued discharge of water to the CWP is expected to be protective of human health and the environment under the conditions presented in the ROD (i.e., groundwater monitoring with comparison to predicted concentration trends) and assumptions employed in the original, updated, and extended perched-water system models.

8. SUMMARY

The First Five-Year Review Report (DOE-ID 2003) concluded that implemented remedies from the OU 2-13 ROD (DOE-ID 1997a) are protective of human health and the environment. The review observed that COCs measured in the aquifer during this first five-year review period either are currently below the MCLs or are projected to be below the MCLs in 2012. The First Five-Year Review Report also identified a set of issues and recommendations. This document details actions taken in response to those issues and recommendations.

The First Five-Year Review Report (DOE-ID 2003) identified the sporadic recurrence of free-phase diesel fuel in the PW-13 TRA perched-water well as an issue. Two new downgradient wells (TRA-1933 and TRA-1934) were installed to investigate the extent of the diesel contamination. Samples also were collected from selected existing perched-water and aquifer wells to test for the presence of dissolved-phase diesel components. Diesel components were not detected in the selected aquifer wells. Relatively low concentrations of dissolved-phase diesel were measured in several of the perched-water wells. Small amounts of free-phase diesel were detected in the two new perched-water wells and in PW-13. The diesel fuel appears to have aged in contact with the perched-water body, and no new sources of diesel fuel were identified. The free-phase diesel fuel in the vicinity of PW-13 is apparently from a 1981 spill of 2,000 gal, as previously concluded in a Track 1 investigation of the responsible fuel transfer line. The sporadic recurrence of free-phase diesel fuel in Well PW-13 is most likely the result of a natural cycling or remobilization mechanism in the fractured basalt/sediment sequence that is driven by changing water levels. The remaining diesel fuel likely will continue to dissolve and disperse in the perched-water body. The continued presence of the perched-water body helps to isolate the diesel fuel from the aquifer. The rate of natural attenuation is expected to slow as the more soluble components of the free-phase diesel are preferentially removed, leaving behind the less easily degradable fraction.

The First Five-Year Review Report (DOE-ID 2003) recommended that a geochemical investigation be performed to “fingerprint” various water sources at TRA and correlate those sources to water samples collected from the perched-water wells. Data were collected from selected wells in both the perched water and the aquifer. The contaminant, water-quality, stable-isotope, and water-level data indicate that the deep perched water consists of multiple zones rather than a single, continuous deep perched-water body. Some of the perched-water wells within TRA appear to have a water source other than the CWP. Wells PW-12, PW-13, and USGS-072 appear to reflect leaking (raw water) piping in combination with some precipitation input. Well USGS-068 reflects contamination from the former Chemical Waste Pond in combination with a local water source (precipitation and raw water lines). Although the CWP is not the source of contaminants, water infiltrating from the CWP is the primary source of water for perched water beneath TRA. Infiltration from the CWP appears to aid in the migration of contaminants through the vadose zone to the aquifer since the wells in the SRPA that have the highest contaminant concentrations (tritium and chromium) also show the strongest influence from the CWP.

The First Five-Year Review Report (DOE-ID 2003) identified the unexplained increase of Co-60 in the PW-12 perched-water well that occurred between October 2001 and March 2003 as an issue. More recent samples from October 29, 2003, and March 17, 2004, show a continuing decline in the Co-60 concentration at Well PW-12. Potential sources were examined. A review of the area surrounding PW-12 indicated a history of contamination and presence of Co-60. Three OU 2-13 CERCLA sites are located within 100 ft of PW-12. The three sites were all known or believed to have Co-60 contamination present in varying levels. Several abandoned warm and hot waste pipelines, including two with a history of releases (responsible for the three CERCLA sites), are located within 100 ft of PW-12. The increase in Co-60 likely is the result of a pulse of residual contamination to PW-12 or the result of changing subsurface conditions. The contamination is probably transported down to the perched zone by water from a leaking raw water line with precipitation possibly aiding the transport of contaminants to PW-12.

The geochemical signature of the perched water at PW-12 supports the belief that a leaking utility line transports the contamination.

The First Five-Year Review Report (DOE-ID 2003) identified the unexplained steady or increasing activities of Sr-90 in the PW-12, USGS-054, USGS-055, and USGS-070 perched-water wells as an issue. It was further recommended that the following mechanisms be evaluated as being potential causes for these unexplained trends: (1) adsorption/desorption occurring with changing perched-water levels, (2) changing flow pathways in response to remediation and fluctuations in discharge to the CWP (or alternating cells), (3) seasonal variations of natural infiltration at a local scale, (4) variations in recharge from unidentified manmade sources, (5) lateral flux from the Big Lost River, or (6) new leaks of contamination from unidentified sources. In addition to these six mechanisms, recent research suggests that the fundamental physics of unsaturated flow in fracture networks can lead to pathway switching and temporal fluctuations in downwards flow. Alone, or in combination, the aforementioned mechanisms will induce localized temporal fluctuations in measured concentrations within a generally declining trend. Given the complexity of the subsurface environment and spatial/temporal variability in both the amount and chemistry of recharge sources, short-term variations in concentration levels are to be expected for the perched-water body. These short-term variations are not of concern as long as the trend is seen to decrease again over a maximum period of a few years. At the time of the five-year review, it was also believed that the TRA-605 Warm Waste Line, known to have released contamination, was contributing to the increasing Sr-90. A Track 2 investigation into the extent and nature of the contamination is currently being conducted. Findings from this investigation will be presented in a Waste Area Group 10 Track 2 Summary Report in Fiscal Year 2005.

The First Five-Year Review Report (DOE-ID 2003) identified continued usage of the CWP beyond 2007 as an issue. At the time of the OU 2-13 ROD (DOE-ID 1997a), it was assumed that the TRA, including the CWP, would be decommissioned in 2007. Under a recent decision (2003) by DOE, the TRA will remain active for at least another 20 years. The TRA perched-water system model was updated to include the discharge of wastewater to the CWP through 2024. In addition, radioactive decay half-lives for Co-60 and Sr-90 were implemented, because they were apparently omitted during simulation with the original perched-water system model. Results from the updated pre-ROD model for the 20-year case show that the maximum concentrations of all COCs in the SRPA are expected to be well below MCLs by 2035.

The Co-60 and Sr-90 concentrations are predicted to never exceed MCLs. Because concentrations of the contaminants in the SRPA are predicted to fall and remain below MCLs by 2115, the date for which risk to future site users is defined in the OU 2-12 ROD (DOE-ID 1992), continued discharge of water to the CWP is expected to be protective of human health and the environment under the conditions presented in the ROD (i.e., groundwater monitoring with comparison to predicted concentration trends) and assumptions employed in the original, updated, and extended perched-water system models.

9. RECOMMENDATIONS

This report recommends the following actions to ensure that the selected remedies are protective of human health and the environment and to ensure best management practices:

- Installation of petroleum traps in Wells PW-13, TRA-1933, and TRA-1934. The traps will allow the volume of floating diesel to be measured and provide an inexpensive, passive means for the removal of old diesel and collection of samples for analyses to determine if new diesel is entering the subsurface. The petroleum traps should be maintained monthly with concurrent measurements of water level and diesel thickness. A sample of the floating product should be collected (if sufficient quantity reappears) and analyzed to verify that the less than C_8 fraction of the product is gone and that it is composed primarily of greater than C_8 hydrocarbons.

- Periodic monitoring of selected perched-water wells and aquifer wells for dissolved components of diesel fuel may be warranted, but it is recommended that such measurements be made at least annually, unless monitoring results dictate otherwise.

- Continued monitoring of Well PW-12 for Co-60 in accordance with the approved Groundwater Monitoring Plan for TRA.

- Update the Groundwater Monitoring Plan (DOE-ID 2004a) to include the two new wells installed as part of this investigation, TRA-1933 and TRA-1934, and to add diesel-range organics to the analyte list for PW-12 and to add USGS-073 to the monitoring plan for diesel-range organics analysis.

- Monitor VCO investigations of the piping systems at TRA in relation to Co-60 activities at Well PW-12 and to aid in developing long-term understanding of the perched-water system beneath TRA.

- Correlate the stratigraphic and lithologic structure of the TRA subsurface with recent geochemical fingerprinting that indicates multiple and distinct sources for the perched water. Previous interpretations of the TRA perched-water system referred to only two distinct water bodies: the shallow and the deep perched. The significance of multiple deep perched-water bodies is unclear at this time. Developing an enhanced understanding of the perched-water bodies might provide additional insight into their influence on contaminant transport.

- Continued monitoring of the perched water wells according to the existing groundwater monitoring plan with modifications as approved by DOE, DEQ, and the EPA. It should be realized that not all increasing trends or spikes in contamination pose an immediate or eventual threat to the effectiveness of the remedy and should be evaluated individually to determine the potential of their impact.

- Keep abreast of and support ongoing research (e.g. Vadose Zone Research Park and old INTEC percolation ponds) that focuses on further development of improved conceptual models of unsaturated flow in fractured rock environments and research that focuses on the development of numerical simulators that can take advantage of new advances in these conceptual models.

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