**Water Quality: Historic Values
and Impact of Drilling Activities
During FY 1988 at the Reference
Repository Location in
Southeastern Washington**

**P. A. Eddy
S. S. Teel**

**J. R. Raymond
W. H. Bierschenk**

March 1988

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

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PACIFIC NORTHWEST LABORATORY
operated by
BATTELLE MEMORIAL INSTITUTE
for the
UNITED STATES DEPARTMENT OF ENERGY
under Contract DE-AC06-76RLO 1830

Printed in the United States of America
Available from
National Technical Information Service
United States Department of Commerce
5285 Port Royal Road
Springfield, Virginia 22161

NTIS Price Codes
Microfiche A01

Printed Copy

Pages	Price Codes
001-025	A02
026-050	A03
051-075	A04
076-100	A05
101-125	A06
126-150	A07
151-175	A08
176-200	A09
201-225	A010
226-250	A011
251-275	A012
276-300	A013

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IN SOUTHEASTERN WASHINGTON

P. A. Eddy
S. S. Teel
J. R. Raymond
W. H. Bierschenk(a)

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Pacific Northwest Laboratory
Richland, Washington 99352

(a) Geological Engineer/Hydrogeologist
Eugene, Oregon 97401-9444

PREFACE

In 1986, the U.S. Department of Energy (DOE) selected the Hanford Site, Washington, for further study as a potential repository for commercial spent nuclear fuel and high-level radioactive waste. The DOE then initiated a site characterization program to obtain the information necessary for evaluating the suitability of locating a repository at the Hanford Site. These characterization activities were part of the Basalt Waste Isolation Project (BWIP). Pacific Northwest Laboratory (PNL) was contracted by the DOE to do the environmental studies. The DOE was required by Section 113(A) of the Nuclear Waste Policy Act (NWPA) to "conduct site characterization activities in a manner that minimizes any significant adverse environmental impacts identified..."

This document is part of the Environmental Topical Report series. Each report presents the results of the environmental monitoring studies at the BWIP site, up until BWIP was closed in response to the enactment of the Nuclear Waste Amendments Act of 1987. Some of the reports are preliminary because not all task objectives were completed at project close-out. However, they can serve as a reference source for other BWIP environmental reports related to site closure and reclamation. These Environmental Topical Reports are listed below:

1. Cold-Blooded Vertebrates at the Proposed Reference Repository Location in Southeastern Washington, by R. E. Fitzner, January 1988, PNL-6440.
2. Natural Vegetation at the Proposed Reference Repository Location in Southeastern Washington, by W. H. Rickard, February 1988, PNL-6402.
3. Bird Associations with Shrubsteppe Plant Communities at the Proposed Reference Repository Location in Southeastern Washington, by C. A. Schuler, March 1988, PNL-6493.
4. Descriptions of Plant Communities at the Proposed Reference Repository Location and Implications for Reclamation of Disturbed Ground, by W. H. Rickard and C. A. Schuler, March 1988, PNL-6494.
5. Habitat Associations of Vertebrate Prey Within the Controlled Area Study Zone, by N. V. Marr, C. A. Brandt, and R. E. Fitzner, and S. M. McCorquodale, March 1988, PNL-6495.

6. Productivity, Mortality, and Response to Disturbance of Nesting Swainson's Hawks on the Hanford Site, by L. D. Poole, N. V. Marr, R. E. Fitzner, and S. M. McCorquodale, March 1988, PNL-6496.
7. Water Quality: Historic Values and Impact of Drilling Activities During FY 1988 at the Reference Repository Location in Southeastern Washington, by P. A. Eddy, S. S. Teel, J. R. Raymond, and W. H. Bierschenk, March 1988, PNL-6497.

SUMMARY

The purpose of the Environmental Monitoring Program was to 1) monitor the characterization activities related to the Basalt Waste Isolation Project (BWIP) at boreholes DC-24CX and DC-25CX and 2) document any environmental impacts as a result of these activities including contamination and/or degradation of the aquifer water quality from the invasion of drilling fluids into the formation and surface contamination from the disposal of drilling fluid at the land surface. The first phase of this program involved describing the baseline water quality at the Reference Repository Location (RRL) including data for spring and surface waters, and both the unconfined and confined aquifers. This baseline data was compiled from Early et al. (1986) and PNL (1987). The second phase involved the collection and analysis of samples collected during drilling operations at wells DC-24CX and DC-25CX.

Five surface water and 25 spring sampling sites were designated for chemical and radiological background data collection for BWIP (Early et al. 1986). These springs generally emanate from the Saddle Mountains Basalt along the Umtanum Ridge, Yakima Ridge, and Rattlesnake Hills. The waters from the springs are calcium-sodium-bicarbonate in nature and low in total dissolved solids (TDS). Because these characteristics are similar to the unconfined aquifer water, we assumed that the springs are the result of natural recharge from precipitation that migrates along zones of high hydraulic conductivity until reaching geologic features that connect to the land surface.

Chemical and radiological background data from 61 wells that obtain water from the unconfined aquifers indicate that the chemistry of these aquifers is similar to the spring and surface water samples. However, some of the wells show contamination from existing operations and past operations of various facilities on the Hanford Site. These contaminants are both chemical and radiological in nature with nitrate as the primary chemical constituent and tritium as the major radiological constituent.

Background information from 22 wells in basalt on the confined aquifers indicate that the chemical characteristics of the confined aquifers beneath

the Reference Repository Location (RRL) and the surrounding areas are similar with the exception of chlorine and fluorine. The chlorine levels vary with location; wells west of the RRL show low levels of chlorine and wells to the east show significantly higher levels of chlorine. The fluorine concentration varies with depth in all the wells that were sampled.

Water levels in the unconfined aquifers in and around the RRL are influenced from past and present operations at the Hanford Site. As a result of the discharge of large amounts of plant effluent to the ground, the water table has risen considerably and has distorted the natural hydraulic gradients that existed before the start-up of the operations in 1944. Heads in wells that tap the basalt aquifers are variable due to irrigation practices to the west of the RRL site. At the RRL site there has been little change in heads. Measurements of heads in wells within and adjacent to the RRL site have shown changes of only 2 feet.

Ground water in the confined and unconfined aquifers is capable of being contaminated by drilling fluids and interaquifer communication caused by drilling. Once the aquifer is contaminated, it is very difficult to return it to its natural state. Therefore, extreme care must be taken to prevent contamination of the aquifers during drilling. Additionally, some of the ground water contains chemicals that exceed drinking water standards. The disposal of these waters must be controlled in such a way as to prevent contamination of surface areas and plants in the vicinity of the drilling operations. Analyses of the drilling fluid used when drilling boreholes DC-24CX and DC-25CX suggest that no significant environmental effects occurred as a result of these activities. These fluids meet none of the characteristics of a hazardous waste (ignitability, corrosivity, reactivity, EP Toxicity) under 40 CFR 261 Subpart C.

CONTENTS

PREFACE	iii
SUMMARY	v
INTRODUCTION	1
HYDROLOGY	3
SURFACE WATER	3
GROUND WATER	3
PREVIOUS STUDIES	4
WATER QUALITY	7
SPRING AND SURFACE WATER	7
UNCONFINED AQUIFER	12
CONFINED AQUIFER	13
HYDRAULIC HEAD DATA	19
UNCONFINED AQUIFER	19
CONFINED AQUIFER	19
ENVIRONMENTAL MONITORING PROGRAM SAMPLE COLLECTION	23
DRILLING METHODS	23
DRILLING FLUID	26
SAMPLE COLLECTION	27
LABORATORY ANALYSES AND RESULTS	29
TOP OF BASALT/BOTTOM OF UNCONFINED AQUIFER	29
MABTON INTERBED	33
UMTANUM FLOW	33
DISCUSSION OF RESULTS	33
CONCLUSIONS	35
REFERENCES	37
APPENDIX A - SURFACE WATER BASELINE DATA	A.1
APPENDIX B - WELL COORDINATES AT HANFORD	B.1

FIGURES

1. Reference Repository Location	2
2. Unconfined Aquifer Water Table Elevations for June 1986	5
3. Location of Surface Water Sampling Sites	8
4. Location of Spring Sampling Sites	9
5. Tritium Concentrations in Ground Water for 1986	11
6. Location of Sampling Wells for the Unconfined Aquifer	14
7. Nitrate Concentrations in Ground Water for 1986	15
8. Location of Sampling Wells for the Confined Aquifer	16
9. Locations of Wells DC-24CX and DC-25CX	24
10. Generalized Stratigraphic Column	25

TABLES

1. Summary of Surface Water and Spring Data	10
2. Summary of Unconfined Aquifer Water Quality Data	13
3. Summary of Groundwater Chemistry Data from the Confined Aquifer East of the Cold Creek Barrier	17
4. Summary of Groundwater Chemistry Data from the Confined Aquifer West of the Cold Creek Barrier	18
5. Vertical Hydraulic Head Gradients Calculated from Observed Water Levels in Piezometer Cluster DC-22 for March 1985	20
6. Comparison of Observed Hydraulic Head Gradients for Selected Basalt Flows in the Wanapum and Grande Ronde Basalts	21
7. Estimates of Fluid Loss During Drilling	26
8. Drilling Fluid Analyses for Wells DC-24CX and DC-25CX	30

INTRODUCTION

Extensive work has been completed by the Basalt Waste Isolation Project (BWIP) staff on characterizing the hydrology and geology of the Columbia Plateau, the Pasco Basin, and the Reference Repository Location (RRL). The purpose of the Environmental Monitoring Program is to 1) monitor the characterization activities related to the Basalt Waste Isolation Project (BWIP) and 2) document any environmental impacts as a result of these activities including contamination and /or degradation of the aquifer water quality from the invasion of drilling fluids into the formation and surface contamination from the disposal of drilling fluid at the land surface. The first phase of this program involved describing the baseline water quality in the area of the RRL including data for spring and surface waters, and both the unconfined and confined aquifers. This baseline data was summarized from Early et al. (1986) and PNL (1987). The second phase involved the analysis of samples collected during drilling operations at wells DC-24CX and DC-25CX.

The RRL, where most of the site characterization activities have been conducted, is situated near the center of the U.S. Department of Energy's Hanford Site, (Figure 1), which occupies approximately 1,500 km² of southcentral Washington State. The site has a semiarid climate, receiving approximately 16 cm of precipitation annually. The terrain is relatively flat, although bedrock ridges rise above the plains in places along the boundaries and in the center of the site. The elevation of the RRL and the exploratory shaft facilities is approximately 195 m above mean sea level.

FIGURE 1. Reference Repository Location

HYDROLOGY

SURFACE WATER

The primary surface-water features associated with the Hanford Site are the Columbia and Yakima rivers. The Columbia River flows through the northern part of the site and forms part of its eastern boundary while the Yakima River flows along a portion of the site's southern boundary. Several surface ponds and ditches also present on site are associated with or formed as a result of discharges from fuel and waste processing activities. Drainage is from two discontinuous, ephemeral streams, Dry Creek and Cold Creek. These streams have relatively short reaches and small discharges, and cross the southwestern part of the site.

Flow along the Hanford Reach of the Columbia River is controlled by the Priest Rapids Dam, located 16 km upstream of the northeastern Hanford Site boundary. Large Columbia River floods occurred in the past, but the likelihood of large-scale floods recurring was reduced by the construction of Priest Rapids and other upstream dams. The central part of the site, where the RRL is located, would not be affected by the probable maximum flood of the Columbia River considered previously (DOE 1986). A remote possibility does exist for flash flooding of the Cold Creek drainage (Skaggs and Walters 1981). Conservative calculations have indicated that the maximum flood of Cold Creek could potentially affect the portion of the RRL intended for repository support facilities.

GROUND WATER

The ground water beneath the site occurs under both confined and unconfined conditions. The unconfined aquifer is the uppermost aquifer and is contained within the sediments overlying the Columbia River Basalt Group. The depth to the water table, which is the top of the saturated zone, ranges from less than 0.3 m near the Columbia River to over 100 m near the center of the Hanford Site. The saturated portion of the unconfined aquifer reaches a thickness of over 70 m along the eastern edge of the RRL, where disposal of process waste water over the past 40 years has raised the water table by as

much as 25 m (ERDA 1975). Figure 2 illustrates the water levels in the unconfined aquifer in 1986.

Ground water in the unconfined aquifer generally flows eastward beneath the site and discharges into the Columbia River. The ground water is a calcium-bicarbonate chemical type containing a moderate amount of total dissolved solids (TDS), less than 350 mg/L, and of a good overall quality (Gephart et al. 1979). It has, however, been affected by the disposal of radioactive and chemical wastes on site, and the distribution and concentrations of various waste constituents are therefore monitored and reported (PNL 1987, Law and Schatz 1986).

The deeper, confined aquifers are contained in the sedimentary interbeds and interflow zones within the Columbia River Basalt. The main water-bearing portions of the interflow zones occur within a network of interconnecting vesicles and fractures of the flow tops and or flow bottoms (DOE 1986). Ground water in the shallow basalt aquifers probably discharges into the overlying confined aquifer and to the Columbia River. The discharge area for the deeper basalt aquifers has not been established, but may be the Columbia River south of the Hanford Site (LaSala and Doty 1971). The basalt aquifers are generally unaffected by the Hanford waste disposal activities, although some downward flow from the unconfined aquifer to the uppermost basalt aquifer has apparently occurred in the region east of the 200 East Area, as evidenced by trace concentrations of selected waste constituents (i.e., tritium and nitrate) in samples collected from that basalt unit (Graham et al. 1981).

PREVIOUS STUDIES

Water resources and other environmental media at the Hanford Site are routinely and extensively monitored under the ongoing Hanford Environmental Monitoring Project conducted by the Pacific Northwest Laboratory (PNL). This project was designed to determine the impacts of Hanford Site operations in the onsite and offsite environments. In the water resources portion of the project, samples are regularly collected from both surface and ground waters, and are then analyzed for a variety of chemical and radiological constituents.

FIGURE 2. Unconfined Aquifer Water Table Elevations for June 1986 (Schatz and Jensen 1986)

The analytical results are summarized and interpreted in reports produced on an annual basis (PNL 1987). Additional sampling of the unconfined ground water is conducted by the Westinghouse Hanford Company in the vicinity of the 200 Areas, as part of their waste management program (Law and Schatz 1986). Westinghouse staff members also collect and analyze ground-water samples as part of the BWIP drilling and testing effort.

Figure 2. Unconfined Aquifer Water Table Elevation for June 1980 (Schatz and Bennett 1986)

WATER QUALITY

Surface water and ground-water hydrochemical data from Early et al. (1986) and PNL (1987) was reviewed with reference to the area near the RRL. The purpose of this effort was to summarize and describe the background water quality at this location as a basis for evaluating potential interactions between the existing groundwater environment and activities related to the Basalt Waste Isolation Project. These background values are presented in table form in Appendix A and are summarized in the following sections. Details on the sampling and analysis procedures for these data can be found in Early et al. (1986) and PNL (1987).

SPRING AND SURFACE WATERS

Five surface-water sites and 25 springs near the RRL were sampled and analyzed for water quality information (Early et al. 1986). The location of these sampling sites are shown in Figures 3 and 4. Sampled surface-water bodies included the Columbia and Yakima rivers and Cold Creek. Cold Creek is an ephemeral stream that for the most part, only flows during periods of heavy rainfall or snowmelt. The springs are generally found associated with areas of exposed bedrock (i.e., Umtanum Ridge, Yakima Ridge, and the Rattlesnake Hills) and generally flow from the Saddle Mountains Basalts. Springs generally form where a local decrease in hydraulic conductivity directs ground water to discharge at the land surface.

Results indicate that the spring and surface waters are of a calcium-sodium-bicarbonate chemical type with low TDS. These results are listed in Appendix A and are summarized in Table 1. Spring samples generally show slightly higher values than the surface water samples. These data are generally consistent with previous data reported by Gephart et al. (1979). Conductivity data ranged from a low of 115 $\mu\text{mho/cm}$ to a high of 431 $\mu\text{mho/cm}$ and averaged 253 $\mu\text{mho/cm}$. Concentrations of chloride and fluoride are useful for comparing ground waters from different depths or flow systems. Deeper, more stagnant ground waters generally show higher chloride and fluoride values than more shallow, active flow systems. The spring and surface water

FIGURE 3. Location of Surface Water Sampling Sites

FIGURE 4. Location of Spring Sampling Sites

TABLE 1. Summary of Surface Water and Spring Data

Constituent	Surface Water (Range)	Springs (Range)
Na, mg/L	1.25-13.80	6.09-24.50
K, mg/L	0.30-2.67	1.41-6.20
Ca, mg/L	15.00-28.10	14.50-53.98
Mg, mg/L	4.59-12.00	4.30-19.50
Alkalinity, mg/L	55-122	55-203
Si, mg/L	0.93-21.10	15.40-28.30
Cl, mg/L	0.96-7.20	3.12-23.00
F, mg/L	0.12-0.57	0.10-3.70
SO ₄ , mg/L	7.00-13.3	6.40-31.80
pH	6.8-8.7	6.6-8.20
Conductivity, μmho/cm	115-278	158-431
TOC(a), mg/L	1.15-1.97	0.38-13.04
Tritium, pCi/L	18.93±0.58 - 252.9±0.129	0.387±0.258 - 23.16±0.61

(a) Total organic carbon.

samples had generally low values of both of these elements. Fluoride ranged from 0.10 to 0.70 mg/L in the spring samples (with the exception of the Railroad Springs' value of 3.70 mg/L) and from 0.12 to 0.57 mg/L for the surface waters. Chloride ranged from 3.12 to 23.00 mg/L for the springs and from 0.96 to 7.20 mg/L for the surface water samples.

Available tritium values range from a trace to about 23 pCi/L (about 7 tritium units) for the springs. The presence of tritium suggests that these spring waters have been recharged recently. Tritium values are significantly higher for the surface water samples, which range from 18.93 to 252.9 pCi/L. The highest two values of 135.01 pCi/L and 252.9 pCi/L were both found on the Columbia River at the DC-14 and Hanford Townsite (CR-HTS) sampling locations, respectively. Figure 5 is an isoconcentration map for tritium at the Hanford Site.

FIGURE 5. Tritium Concentrations in Ground Water for 1986 (PNL 1987)

UNCONFINED AQUIFER

Water quality data for 61 wells completed in the unconfined aquifer are shown in Appendix A and are summarized in Table 2. The locations of these wells are shown in Figure 6. The primary constituents found in the unconfined aquifer included calcium, bicarbonate, sulfate, silica, sodium, and magnesium. This ground water can be classed as a calcium bicarbonate type and is similar in composition to the spring samples. All of these wells are downgradient from the RRL except for wells 699-36-93, 699-37-82A, and 699-43-89. No significant chemical changes were seen between the upgradient and downgradient wells.

Because nitrate is mobile in the ground water and is present in many waste streams, it can be used to help define the extent of contamination. The Interim Primary Drinking Water Standards (DWS) for nitrate are 45 mg/L (as NO_3), and 10 mg/L (as N) according to 40 CFR 265, Appendix III. Concentrations of nitrate (as NO_3) higher than the standard were seen in only four wells: 699-20-20 (53 mg/L), 699-33-42 (49 mg/L), 699-38-70 (256 mg/L), and 699-49-57 (270 mg/L). Eleven wells have nitrate concentrations ranging from 20 to 44 mg/L, and 27 wells have concentrations averaging only 4.7 mg/L.

Nitrate is associated with process condensate liquid wastes although other liquids discharged to ground also contain nitrate. Waste management practices in the 200 West Area contribute to nitrate contamination in that region and to wells downgradient from 200 West and the RRL. Well 699-38-70 is located near the southeast corner of the 200 West Area (within the RRL), approximately 10 miles northwest and upgradient from 699-20-20. Well 699-49-57 is located just north of the northwest corner of the 200 East Area. An isoconcentration map for the Hanford Site for nitrate is shown in Figure 7.

Tritium is also an indicator of ground-water contamination from plant operations. Fourteen of the wells in Appendix A have tritium concentrations exceeding the DWS of 20,000 pCi/L; however, none of these wells exceeded the DOE draft derived concentration guides (DCG) of 2,000,000 pCi/L. Values of 1,200,000 and 1,600,000 for wells 699-35-66 and 699-35-70, respectively are the highest shown. Process condensate liquid wastes from the PUREX Plant in the 200 East Area and past operations at the REDOX Plant in the 200 West Area are the major sources of tritium in the ground water. All of the above-

TABLE 2. Summary of Unconfined Aquifer Water Quality Data

Constituent	Range	Average
Na, mg/L	<10-35	18
K, mg/L	3.2-10.3	5.5
Ca, mg/L	21-92	40
Mg, mg/L	<1-29	12
Alkalinity, mg/L	46-148	117
Si, mg/L	4-21	18
Cl, mg/L	<2-32	10
F, mg/L	0.11-1.30	0.47
SO ₄ , mg/L	2-99	37.5
pH, mg/L	7.6-10.7	7.9
Conductivity μmho/cm	219-927	383
TOC(a)	0.32-0.390	--
Tritium pCi/L	36±290 - 1.6x10 ⁶ ±5.3x10 ⁴	1x10 ⁵ ±5.76x10 ³

(a) Total organic carbon.

mentioned wells are located within the tritium plumes from these facilities. An isoconcentration map for the Hanford Site for tritium is shown in Figure 5.

CONFINED AQUIFER

Chemical and radiological data for 22 wells in the confined aquifers are shown in Appendix A. The locations of these wells are shown in Figure 8.

A summary of samples collected in the Saddle Mountains, Wanapum, and Grande Ronde Basalts east of the Cold Creek barrier is shown in Table 3. The Cold Creek "barrier" (Figure 8) is a northward trending structure (the nature of which is undefined) that acts as a hydrologic boundary (Gephart et al. 1979). The ground water in the Saddle Mountains Basalts is of a sodium-bicarbonate chemical type compared to the samples of the deeper basalts, which are of a sodium-chloride chemical type. Samples from the Saddle Mountains Basalts are higher in calcium, magnesium, and sulfate, and are

FIGURE 6. Location of Sampling Wells for the Unconfined Aquifer

FIGURE 7. Nitrate Concentrations in Ground Water for 1986 (PNL 1987)

FIGURE 8. Location of Sampling Wells for the Confined Aquifer

TABLE 3. Summary of Groundwater Chemistry Data from the Confined Aquifer East of the Cold Creek Barrier

Constituent	Saddle Mountains Basalts	Wanapum Basalts		Grande Ronde Basalts
		PR/Roza Member	FS Member	
Na, mg/L	2.30-68.7	123-176	120-177	126-355
K, mg/L	6.4-11.6	13.8-20.9	6.34-20.3	6.2-24.7
Ca, mg/L	4.8-25	1.09-4.07	1.12-3.83	1.28-13
Mg, mg/L	1.46-11.6	<0.1-0.55	<0.1-0.31	<0.1-0.76
Alkalinity, mg/L	17-184	124-190	110-167	113-210.6
Si, mg/L	9.87-70	27.3-62.5	28.3-50.3	34.8-63.2
Cl, mg/L	3.58-12.9	96.5-146	64.6-180	103-451
F, mg/L	0.47-0.74	6.99-19.1	6.28-16.9	7.63-26.6
SO ₄ , mg/L	0.14-20	<0.5-10.2	1.42-21.9	<0.5-16.8
NO ₃ , mg/L	--	<0.50	--	--
pH	7.2-8.86	9.14-9.67	8.6-9.92	8.8-10.18
Conductivity μ mho/cm	286-350	653.2-810	602-941	639-1700
TOC, mg/L	0.64-9.74	1.16-8.44	0.95-4.91	1.08-12.32

(a) Total organic carbon.

lower in sodium, potassium, chloride, fluoride, and conductivity than samples collected from the Wanapum and Grande Ronde Basalts. Sodium, chloride, and fluoride concentrations and conductivity values continue to increase with depth through the Wanapum into the Grande Ronde Basalts. Gephart et al. (1979) and DOE (1986) have suggested that stratigraphic changes in groundwater chemistry may delineate flow system boundaries. They have suggested that the unconfined aquifer and the upper basalts (Saddle Mountains and possibly the upper Wanapum) may be part of an active, local ground-water flow system and the deeper basalts (Wanapum and Grande Ronde) are part of a slower moving, intermediate to regional ground-water flow system. This would help explain the higher Cl and Na concentrations, and conductivity values with depth. Differences in hydrochemistry are also seen across the Cold Creek barrier.

Data from wells west of the barrier are shown in Appendix A and summarized in Table 4. Ground-water chemistry data are not available for aquifers in the Saddle Mountains Basalt west of the barrier. As with the wells on the east side of the barrier, Na, F, Cl, and conductivity increases with depth; however, the concentrations of these constituents are noticeably higher in the wells on the east side of the barrier. This supports the concept of limited interchange between the flow systems on each side of the "barrier." Hydraulic head data also support this conclusion.

TABLE 4. Summary of Ground-water Chemistry Data from the Confined Aquifer West of the Cold Creek Barrier

<u>Constituent</u>	<u>Wanapum Basalts</u>		<u>Grande Ronde Basalts</u>
	<u>Priest Rapids</u>	<u>Frenchman Springs</u>	
Na, mg/L	24.8-32.3	28.7-31.8	87.1-130
K, mg/L	6.22-9.45	7.80-9.20	8.06-10.17
Ca, mg/L	14.9-19.80	18.00-17.80	0.82-1.17
Mg, mg/L	7.18-11.70	5.80-9.30	<0.1()
Alkalinity, mg/L	140.00-170.00	150.00-151.00	176.00-208.00
Si, mg/L	26.10-31.30	30.00-31.00	43.50-56.60
Cl, mg/L	4.18-5.30	4.90-5.00	7.06-48.40
F, mg/L	0.60-0.77	0.63-0.64	3.41-11.00
SO ₄ , mg/L	0.81	0.05	0.26-6.23
NO ₃ , mg/L	--	--	--
pH	7.65-8.46	8.00-8.16	9.05-9.50
Conductivity, μ mho/cm	277.0-301.0	282.0-288.0	380.0-582.0
TOC(a), mg/L	0.28-0.86	0.43-0.50	1.94-8.77

(a) Total organic carbon.

Note: Groundwater Chemistry data not available for Saddle Mountains aquifers west of the Cold Creek barrier.

HYDRAULIC HEAD DATA

UNCONFINED AQUIFER

The elevation of the unconfined aquifer under the RRL ranges from 450 to 470 ft above mean sea level. The elevation of the water table is higher in the western portion of the RRL and the direction of ground-water flow is to the Columbia River along a hydraulic gradient of approximately 0.01 m/m (0.01 ft/ft) (Schatz 1984). A water table map of the unconfined aquifer is shown in Figure 2.

CONFINED AQUIFER

Hydraulic head data for the confined aquifer in the vicinity of the RRL has been reported by several authors including Yeatman and Bryce (1984a, b) Spane (1986), Early et al. (1986), and Swanson and Leventhal (1984). DOE (1986) reached several conclusions based upon the existing preliminary data:

- In the western area of the Hanford Site, hydraulic heads decrease with depth in the shallow basalts. The measured gradient was 0.04 (Table 5). This suggests that the Rattlesnake Hills and the Yakima and Umtanum Ridges are recharge areas for these basalts.
- Eastward across the Hanford Site, head values become more uniform with depth in the Cold Creek Syncline. This suggests lateral ground-water movement. The measured gradient from DC-22 to DC-15 was 1×10^{-4} (Table 6).
- Near the Columbia River, heads in the shallow basalts increase with depth or have a variable pattern. This suggests potential discharge.
- The deep basalt flows (Wanapum and Grande Ronde) appear to have an upward hydraulic gradient ranging from 2×10^{-3} to 8×10^{-4} (Table 5).
- Hydraulic heads measured in DC-19, DC-20, and DC-22 suggest that the direction of ground-water flow under the RRL is south to southwest.
- Head changes across the east and west sides of the Cold Creek barrier support the concept of this feature acting as a hydrologic boundary minimizing interaction between confined aquifers in this area.

TABLE 5. Vertical Hydraulic Head Gradients Calculated from Observed Water Levels in Piezometer Cluster DC-22 for March 1985(a)

Stratigraphic Interval Monitored	Observed Hydraulic Head (m above mean sea level) (b)	Vertical Interval Separating Designated Monitored Zones (m) (c)	Apparent Vertical Head Gradient Across Basalt Formation
Saddle Mountains Basalt Rattlesnake Ridge interbed Mabton interbed	134.8 125.1	231	4×10^{-2} (down)
Wanapum Basalt Priest Rapids Member Sentinel Gap flow Ginkgo flows	122.1 122.2 122.3	61 257	8×10^{-4} (up)
Grande Ronde Basalt Rocky Coulee flow Cohasset flow Umtanum flow	122.9 123.1 123.2	91 261	1×10^{-3} (up)
Wanapum and Grande Ronde Basalts			2×10^{-3} (up)

(a) Taken from DOE 1986.

(b) Data taken from Bryce and Yeatman (1985)

(c) Data taken from Jackson et al. (1984)

- Based on the preliminary vertical head distributions, it is suggested that the more permeable flow tops of the upper Wanapum Basalt may act as a conduit for deeper ground-water discharge. Therefore, discharge points may be similar for Wanapum and Grande Ronde ground waters.

TABLE 6. Comparison of Observed Hydraulic Head Gradients for Selected Basalt Flows in the Wanapum and Grande Ronde Basalts(a)(b)

<u>Stratigraphic Interval</u>	<u>Observed Hydraulic Heads (m above mean Sea level) (c)</u>		<u>Average Areal Distance Between Boreholes (m/m) (d)</u>
	<u>Head in DC-22</u>	<u>Head in DC-15</u>	
	<u>Wanapum Basalt</u>		
Priest Rapids Member	122.1	117.5	1 x 10 ⁻⁴
Sentinel Gap flow	122.2		
Ginkgo Flows	122.3	118.0	1 x 10 ⁻⁴
	<u>Grand Ronde Basalt</u>		
Rocky Coulee flow	122.9	119.0	1 x 10 ⁻⁴
Cohasset flow	123.1	119.0	1 x 10 ⁻⁴
Umtanum flow	123.2	121.5	4 x 10 ⁻⁵

(a) Note: 1 meter = 3.28 ft.

(b) Taken from DOE 1986.

(c) Observed hydraulic heads in borehole cluster DC-22 are monitored values recorded during March 1985. Values are reported to nearest 0.1 meter (Bryce and Yeatman 1985). Observed hydraulic heads in borehole DC-15 were collected in 1980 on a drill-and-test basis. Values are reported to nearest 0.5 m (Swanson and Wilcox 1985).

(d) Boreholes (DC-22 and DC-15 are separated by 37 km (approximately 23 m).

Based on the piezometric (vertical) head distribution, it is suggested that the water penetrable flow zone of the upper granitic bed is a conduit for deeper ground water discharge. Therefore, discharge points may be similar for granitic and gneissic ground waters.

TABLE 1. Comparison of Observed Hydraulic Head Gradients for Selected Areas in the Granitic and Gneissic Zones

Station Number	Observed Hydraulic Head in Granitic Zone (m)	Observed Hydraulic Head in Gneissic Zone (m)	Distance Between Stations (m)
1-10-4	122.5	122.5	100
1-10-4	122.5	122.5	100
1-10-4	122.5	122.5	100
1-10-4	122.5	122.5	100
1-10-4	122.5	122.5	100
1-10-4	122.5	122.5	100
1-10-4	122.5	122.5	100
1-10-4	122.5	122.5	100
1-10-4	122.5	122.5	100
1-10-4	122.5	122.5	100

The hydraulic head in the granitic zone is higher than in the gneissic zone. This is due to the fact that the granitic zone is more permeable than the gneissic zone. The hydraulic head in the granitic zone is higher than in the gneissic zone. This is due to the fact that the granitic zone is more permeable than the gneissic zone. The hydraulic head in the granitic zone is higher than in the gneissic zone. This is due to the fact that the granitic zone is more permeable than the gneissic zone.

ENVIRONMENTAL MONITORING PROGRAM SAMPLE COLLECTION

Samples of the drilling fluid used in the drilling of boreholes DC-24CX and DC-25CX were independently collected and analyzed by both PNL and Westinghouse Hanford Co. in order to document any impacts on the water quality as a result of drilling. The location of these wells is shown in Figure 9. These wells were drilled as part of the BWIP for the purpose of hydrologic characterization. Once the aquifer is contaminated, it is very difficult to return it to its natural state, therefore, extreme care must be taken to prevent contamination of the aquifers during drilling. The drilling procedures used for these wells (Jackson and Swanson 1987) were developed to assure that contamination to the aquifer would be kept to a minimum. Additionally, some of the ground water contains chemicals that exceed drinking water standards. The disposal of these waters must be controlled in such a way as to prevent contamination of surface areas and plants in the vicinity of the drilling operations. The collection and analysis of these samples are discussed in the following section.

DRILLING METHODS

Wells DC-24CX and DC-25CX were drilled using the cable-tool, mud-rotary and air-rotary drilling methods. The cable-tool method was used for drilling approximately the first 60 ft into the suprabasalt sediments and for setting the starter casing. The conventional mud-rotary method was used after the cable-tool method and through the Mabton interbed in the Saddle Mountains Basalts. A generalized stratigraphic column for the RRL is shown in Figure 10. The-mud rotary method was used in these units because of the stability that the mud adds in keeping the borehole open. A disadvantage to this method is that there is a potential for the bentonite mud to infiltrate into the formation during drilling, possibly having a detrimental effect on the aquifer. Because of this, the amount of fluid lost to the formation was closely monitored by Westinghouse Hanford Co. personnel. An estimate of the fluid loss in each interval is shown in Table 7. In DC-24CX, the maximum fluid loss was approximately 40,000 gallons in the Selah Interbed/Esquatzel

FIGURE 9. Locations of Wells DC-24CX and DC-25CX

Period	Epoch	Group	Subgroup	Formation	K-Ar Age Years x 10 ⁶	Member or Sequence	Geologic Mapping Symbol	Sediment Stratigraphy or Basalt Flows		
QUATERNARY	Pleistocene/ Holocene					Surficial Units	Ql	Loess		
	Qd						Sand Dunes			
	Pleistocene						Qa, Qaf	Alluvium and Alluvial Fans		
							Qld	Landslides		
							Qt	Talus		
							Qco	Colluvium		
			Hanford			Touchet Beds/ Pasco Gravels	Qht/Qhp			
								Plio-Pleistocene Unit		
	Pliocene		Ringold				Trs	Upper Ringold		
							Trc	Middle Ringold		
							Trls	Lower Ringold		
							Trg	Basal Ringold		
								Fanglomerate		
TERTIARY	Miocene	Columbia River Basalt Group	Yakima Basalt Subgroup	Saddle Mountains Basalt	8.5	Ice Harbor Member	Ti	Tig	Goose Island Flow	
								Tim	Martindale Flow	
								Tib	Basin City Flow	
						10.5	Elephant Mountain Member	Tem	Tem ₂	Ward Gap Flow
									Tem ₁	Elephant Mountain Flow
										Rattlesnake Ridge Interbed
					12.0	Pomona Member	Tp	Tp ₂	Upper Pomona Flow	
								Tp ₁	Lower Pomona Flow	
									Selah Interbed	
					13.6	Esquatzel Member	Te	Te ₂	Upper Gable Mountain Flow	
								Te ₁	Gable Mountain Interbed	
									Lower Gable Mountain Flow	
						Asotin Member		Ta	Cold Creek Interbed	
						Huntzinger Flow				
						Wilbur Creek Member		Tw	Wahluka Flow	
						Umatilla Member	Tu	Tu _s	Sillusi Flow	
								Tu _u	Umatilla Flow	
									Mabton Interbed	
						15.6	Priest Rapids Member	Tpr	Tpr ₁	Lolo Flow
					Tpr _r				Rosalia Flows	
									Quincy Interbed	
					Grande Ronde Basalt	Roza Member	Tr	Tr ₂	Upper Roza Flow	
				Tr ₁				Lower Roza Flow		
								Squaw Creek Interbed		
				Frenchman Springs Member		Tf	Tf _s	Sentinel Gap Flow		
							Tf _p	Wallula Gap Flow		
								Sand Hollow Flows		
								Silver Falls Flows		
								Ginkgo Flows		
								Palouse Falls Flow		
								Vantage Interbed		
								Undifferentiated Flows		
								Rocky Coulee Flow		
								Levering Flow		
								Cohasset Flow		
				Schwana Sequence	Tsb	Unnamed Flow				
						Birkett Flow				
						Undifferentiated Flows				
						McCoy Canyon Flow				
						Intermediate-Mg Flow				
						Low-Mg Flow Above Umtanum				
						Umtanum Flow				
						High-Mg Flows Below Umtanum				
						Very High-Mg Flow				
						At Least 30 Low-Mg Flows				

Ellensburg Formation Te1

Ellensburg Formation Tel

FIGURE 10. Generalized Stratigraphic Column (modified from Jackson and Swanson 1987)

TABLE 7. Estimates of Fluid Loss During Drilling (gallons)(a)

<u>Interval</u>	<u>DC-24CX</u>	<u>DC-25CX</u>
Hanford-Ringold Formation	6,800	3,200
Elephant Mountain Member	4,100	6,800
Rattlesnake Ridge Interbed	1,000	2,700
Pomona Member	4,300	29,600
Selah Interbed	40,000	900
Esquatzel Member		1,000
Cold Creek Interbed	---	3,500
Umatilla Member	6,900	7,000
Mabton Interbed	10,000	800

(a) Preliminary data from personal communication with Paul Thorne, Westinghouse Hanford Company, Richland, Washington, February 29, 1988

Member. In DC-25CX, the maximum fluid loss was approximately 29,600 gallons in the Pomona Member. Fluid losses were negligible below the Mabton Interbed.

In the Wanapum and Grande Ronde Basalts, the air-assisted, reverse-circulation rotary method was used. This is the preferred method because it contains no additives (such as bentonite) that could have any detrimental effects on the aquifer. Casing was grouted in place from the ground surface through the Saddle Mountains Basalt and Mabton Interbed. A complete description of the specifications for these wells can be found in Jackson and Swanson (1987).

DRILLING FLUID

The cable-tool method uses water as a drilling fluid. Drilling fluid for the mud-rotary method consists of a mixture of water, bentonite (Hydrogel), and varying amounts of lime or soda ash to balance pH. The air-rotary method uses air and water as the drilling fluid with fluorescein and lithium-bromide added as a tracer to track fluid losses and gains. The fluorescein and lithium-bromide concentrations in the drilling fluid may

range from 0.5 to 1.5 mg/L, and 5 to 15 mg/L, respectively (Jackson and Swanson 1987). The water used in all three methods consists of Hanford Site system water. Hanford Site system water is water pumped from the Columbia River and treated for site use. All of the drilling methods discussed above discharge excess drilling fluids to a "mud pit." The mud pit consists of a large clay-lined excavation.

SAMPLE COLLECTION

A total of six drilling fluid samples were collected during the drilling of boreholes DC-24CX and DC-25CX by PNL. Four of these samples were analyzed: samples from the Mabton Interbed and the Umtanum flow at DC-24CX; and, samples from the bottom of the unconfined aquifer/top of basalt and the Mabton Interbed at DC-25CX. Larger 50-l samples were taken at the Ginkgo flow at both DC-24CX and DC-25CX and from the Umtanum flow at DC-24CX and archived for later analyses if required.

Samples of the drilling fluid were collected at the boreholes during drilling operations. The samples were collected in 40 ml (for volatile organic constituents) and 1-l bottles. The bottles were filled at a point where fluids coming up from the bottom of the borehole enter a reservoir before passing over the "shale shaker." The "shale shaker" is a vibrating table that screens out sand-size particles. Fifty-liter carboy samples were collected from the drilling fluid supply tanks. Sample collection and chain of custody procedures were followed according to BWIP Environmental Monitoring Procedure EMP-23. The time, drilled depth, sample number, and other documentation for each sampling event was recorded in a logbook. The sample depth recorded was the borehole depth at the time the sample was collected and was not corrected for lag time. "Lag time" is the amount of time it takes cuttings generated at the bottom of the borehole to travel to the shale shaker. Lag time ranged from about 10 min for samples from the Mabton interbed to about 45 min for samples from the Umtanum flow.

LABORATORY ANALYSES AND RESULTS

The samples were analyzed for conductivity, alkalinity, pH, anions, Hg, As, Se, Pb, Cd, halogenated hydrocarbons (specifically carbon tetrachloride), total organic carbon (TOC), total organic halides (TOX), gross alpha and beta, gamma scan, tritium, and ^{129}I . All of these samples were analyzed at separate labs from the duplicate environmental samples collected by Westinghouse Hanford Company personnel except for the ^{129}I samples. Due to the high viscosity of the samples from the top of basalt and the Mabton interbed (due to the presence of bentonite), these samples were centrifuged prior to analysis.

The results of the laboratory analyses are shown in Table 8. The following sections discuss these results and their significance. At the time of the preparation of this report (mid-February 1988), the ^{129}I results were not yet available to include in Table 8.

TOP OF BASALT/BOTTOM OF UNCONFINED AQUIFER

A sample from the drilling fluid at the top of the Saddle Mountains Basalt was analyzed from well DC-25CX. All of the constituents analyzed were within the range of background concentrations (reported in Section IV for the unconfined aquifer) or were below the Interim Primary Drinking Water Standards (DWS) except conductivity, Cl, SO_4 , and arsenic. The conductivity value found at DC-25CX, 1360 $\mu\text{mho/cm}$, was somewhat higher than the highest background value of 927 $\mu\text{mho/cm}$. Chlorine was also slightly higher than the highest background value (41.3 mg/L compared to 32 mg/L). Sulfate was substantially higher than the highest background value (269 mg/L compared to 99 mg/L). Chloroform and methylene chloride were also found (2.0 $\mu\text{g/g}$ and 11.0 $\mu\text{g/g}$, respectively). This chloroform value is above the National Primary Drinking Water Standard of 0.10 $\mu\text{g/g}$ (0.10 mg/L) {40 CFR 141}. Arsenic was slightly above the DWS (0.110 mg/L compared to 0.05 mg/L). Although the value for arsenic is above the DWS, it is well below the EPA Toxicity limit of 5 mg/L {40 CFR 261.24 Subpart C}.

TABLE 8. Drilling Fluid Analyses for Wells DC-24CX and DC-25CX

Constituent	Units	DC-24CX		DC-25CX	
		Mabton Interbed 11/28/87	Umtanum Flow 12/27/87	Top of Basalt 11/18/87	Mabton Interbed 12/08/87
Depth (feet)		1187	3589	661.5	1547.8
pH	---	9.82	11.84	9.45	9.89
Conductivity	μmho	4848	2778	1368	1998
F^-	ppm	1.3	6.8	1.2	2.3
Cl^-	ppm	18.3	183	41.3	48.8
NO_2^-	ppm	---	---	3.7	---
PO_4^{3-}	ppm	---	1.2	---	---
Br^-	ppm	---	8.8	---	---
NO_3^-	ppm	1.1	---	13.8	8.8
SO_4^{2-}	ppm	258	5.8	289	388
$\text{C}_2\text{O}_4^{2-}$	ppm	---	1.8	2.7	---
CO_3^{2-}	ppm	597	422	78.3	78.3
HCO_3^-	ppm	1438	138	255	698
As	ppb	43.7	<18	118	<28
Cd	ppb	<8.1	<8.1	<8.3	<8.1
Hg	ppb	<1	<1.8	<1	<1
Pb	ppb	21.8	<18	31.1	58.2

TABLE 8. Drilling Fluid Analyses for Wells DC-24CX and DC-25CX (cont.)

Constituent	Units	DC-24CX		DC-25CX	
		Mabton Interbed	Utmanu Flow	Top of Basalt	Mabton Interbed
		11/20/87	12/27/87	11/16/87	12/08/87
Depth (feet)	1167	3589	661.5	1547.6	
Se	pbb	<25	<10	<25	<25
Xylene-m	µg/g	5.00E - 03 ^(a)	---	5.00E - 03	5.00E - 03 ^(a)
Hexane	µg/g	1.00E - 02 ^(a)	---	1.00E - 02	1.00E - 02 ^(a)
Total organic halogen	ppb	2.22E + 01	5.55E + 01 ^(a)	---	---
Total organic halogen	µg/g	---	---	---	1.45E + 00
Total organic carbon	ppb	3.81E + 02	7.73E + 02 ^(a)	---	---
Total organic carbon	µg/g	---	---	---	1.95E + 02
Tetrachloroethane	µg/g	5.00E - 03 ^(a)	---	5.00E - 03 ^(a)	5.00E - 03 ^(a)
Methyl ethyl ketone	µg/g	1.00E - 02 ^(a)	---	1.00E - 02 ^(a)	1.00E - 02 ^(a)
1, 1, 1-Trichloroethane	µg/g	5.00E - 03 ^(a)	---	5.00E - 03 ^(a)	5.00E - 03 ^(a)
1, 1, 2-Trichloroethane	µg/g	5.00E - 03 ^(a)	---	5.00E - 03 ^(a)	5.00E - 03 ^(a)
Trichloroethylene	µg/g	5.00E - 03 ^(a)	---	5.00E - 03 ^(a)	5.00E - 03 ^(a)
Perchloroethylene	µg/g	5.00E - 03 ^(a)	---	5.00E - 03 ^(a)	5.00E - 03 ^(a)
Xylene-o,p	µg/g	5.00E - 03 ^(a)	---	5.00E - 03 ^(a)	5.00E - 03 ^(a)
Chloroform	µg/g	5.00E - 03 ^(a)	---	2.00E + 00	5.00E - 03 ^(a)
Methylene chloride	µg/g	7.00E - 02	---	1.10E + 01	1.00E - 02 ^(a)
Tritium	pCi/g	3.59E + 02 ± 1.97E + 02	---	3.63E + 02 ± 1.98E + 02	---
Tritium	pCi/L	---	1.61E + 01 ± 1.88E + 02 ^(a)	---	1.07E + 02 ± 2.00E + 02 ^(a)

(a) Denotes a result less than the detection limit or overall error

TABLE 8. Drilling Fluid Analyses for Wells DC-24CX and DC-25CX (cont.)

Constituent	Units	DC-24CX		DC-25CX	
		Wabton Interbed 11/28/87	Umtanum Flow 12/27/87	Top of Basalt 11/18/87	Wabton Interbed 12/08/87
Depth (feet)		1167	3589	881.5	11547.8
Gross Beta	pCi/g	$1.94E + 01 \pm 3.00E + 00$	---	$5.11E + 02 \pm 7.20E + 01$	$1.04E + 01 \pm 2.90E + 00$
Gross Beta	pCi/L	---	$1.17E + 01 \pm 1.02E + 00^{(a)}$	---	---
Cobalt-60	pCi/L	---	$2.27E + 00 \pm 5.20E + 00^{(a)}$	---	---
Cesium-137	pCi/g	$1.07E - 01 \pm 2.50E - 01^{(a)}$	---	$3.77E - 03 \pm 1.49E - 02^{(a)}$	$1.58E - 02 \pm 1.50E - 02^{(a)}$
Cesium-137	pCi/L	---	$2.40E + 00 \pm 5.22E + 00^{(a)}$	---	---
Ruthenium-106	pCi/g	$1.24E - 01 \pm 2.50E - 01^{(a)}$	---	$0.90E - 02 \pm 1.29E - 01^{(a)}$	$1.08E - 01 \pm 1.30E - 01^{(a)}$
Ruthenium-106	pCi/L	---	$1.19E + 01 \pm 0.20E + 01^{(a)}$	---	---
K-40	pCi/g	---	---	---	$7.85E + 00 \pm 4.44E - 01$
MN-54	pCi/g	---	---	---	$2.00E - 02 \pm 1.30E - 02$
ZrNb-96	pCi/g	---	---	---	$4.71E - 02 \pm 3.00E - 02$
CS-134	pCi/g	---	---	---	$7.85E - 02 \pm 1.40E - 02^{(a)}$
ELJ-155	pCi/g	---	---	---	$7.38E - 02 \pm 0.75E - 02$
ELJ-154	pCi/g	---	---	---	$4.70E - 02 \pm 4.49E - 02^{(a)}$
RA-228DA	pCi/g	---	---	---	$0.04E - 01 \pm 5.00E - 02$
TH-232DA	pCi/g	---	---	---	$1.57E + 00 \pm 1.02E - 01$
Gross Alpha	pCi/g	$0.40E + 00 \pm 2.02E + 00$	---	$0.15E + 00 \pm 2.53E + 00$	$1.21E + 01 \pm 3.33E + 00$
Gross Alpha	pCi/L	---	$9.00E - 01 \pm 3.33E + 00^{(a)}$	---	---
Cobalt-60	pCi/g	$2.32E - 02 \pm 3.02E - 02^{(a)}$	---	$1.44E + 02 \pm 1.40E - 02^{(a)}$	$6.09E - 03 \pm 1.30E - 02^{(a)}$

(a) Denotes a result less than the detection limit or overall error

MABTON INTERBED

Similar results were found with samples from DC-24CX and DC-25CX from the Mabton interbed as with samples from the top of basalt. Conductivity, fluoride, and sulfate in both of these wells were higher than background values for the Saddle Mountains Basalt. However, values for conductivity, chloride, and total organic carbon differed somewhat between DC-24CX and DC-25CX at the Mabton interbed. Conductivity was noticeably higher at DC-24CX (4040 $\mu\text{mho/cm}$ compared to 1990 $\mu\text{mho/cm}$). Total organic carbon was also higher at DC-24CX (381 $\mu\text{g/g}$ compared to 195 $\mu\text{g/g}$). Chloride was lower at DC-24CX, 10.3 mg/L compared to 40.0 mg/L. This 40 mg/L value is slightly higher than the highest background value of 12.9 mg/L. None of the constituents were above the DWS.

UMTANUM FLOW

A sample from the Umtanum flow was analyzed from borehole DC-24CX. All of the values except for pH were within the range of the background values. The pH value recorded was 11.84 compared to the highest background value of 10.18. This is below the limit of 12.5 {40 CFR 261.22 Subpart C}. The presence of bromide in the sample analyzed is probably due to the addition of lithium-bromide tracer to the drilling fluid. None of the constituents analyzed were above the DWS.

DISCUSSION OF RESULTS

The results of the analyses from boreholes DC-24CX and DC-25CX do not seem to indicate any significant impacts to the ground-water quality. All of the constituents analyzed were below the standards except for arsenic and chloroform at DC-25CX (top of basalt). However, arsenic was below the EP Toxicity limit. Although higher than background values for conductivity, chlorine, sulfate, fluoride, and pH were found in some of the samples, these values are not high enough to have a significant impact on the water quality. The drilling fluid samples analyzed meet none of the characteristics of a hazardous waste (ignitability, corrosivity, reactivity, EP Toxicity) under 40 CFR 261 Subpart C. Therefore, these materials appear to pose no threat to the surface or subsurface environment.

However, no samples were collected or analyzed from the mud pits by PNL. This should be included in future environmental studies as well as the total volume discharged to the pits to more completely evaluate any potential effects of the drilling fluid on the surface environment.

CONCLUSIONS

Existing hydrochemical data were reviewed and summarized to define background water quality values in the area of the RRL. These background values were then compared to analyses results from samples collected during the drilling of boreholes DC-24CX and DC-25CX. This comparison indicated that:

- None of the constituents analyzed from the boreholes were above the DWS except for arsenic and chloroform from the top of basalt at DC-25CX. The arsenic value was only slightly above the limit and was below the EP Toxicity limit.
- The drilling fluid samples analyzed meet none of the characteristics of a hazardous waste (ignitability, corrosivity, reactivity, EP Toxicity) under 40 CFR 261 Subpart C.
- Several constituents were slightly above the background values including: conductivity, Cl, SO₄, F, and pH. However, none of these were high enough to significantly impact water quality.
- Although there was some drilling fluid loss to the formation during drilling, the analytical results of the samples of the drilling fluids, and the volume of fluid loss, do not appear to be high enough to have a significant effect on the subsurface environment.

Therefore, based on the analyses of the samples from boreholes DC-24CX and DC-25CX, it appears that there was no significant impact to the surface or subsurface environment as a result of the drilling activities. However, future studies should include data on the composition and volume of materials in the mud pits to completely evaluate potential impact to the surface environment.

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APPENDIX A

SURFACE WATER BASELINE DATA

TABLE A.1. Surface Water Baseline Data

Sampling Location	Date	Na (mg/L)	K (mg/L)	Ca (mg/L)	Mg (mg/L)	Alkalinity (mg/L as CaCO ₃)	Si (mg/L)	Cl (mg/L)	F (mg/L)	SO ₄ (mg/L)	NO ₃ (mg/L)	pH	Conductivity (micro/cm)	DOC (mg/L)	Turbidity (NTU)
Gold Creek	5/1/89	13.80	2.63	24.10	12.00	122	21.10	7.20	0.57	13.3	--	8.8	278	1.44	18.95 ± 1.58
CR-10-14	3/16/93	2.47	0.96	20.70	4.96	65	3.2	0.90	0.12	11.3	--	6.8	150	1.51	135.01 ± 3.55
CR-40	11/25/94	1.25	0.30	15.00	2.30	55	0.93	6.60	0.46	7.00	--	3.7	115	--	252.9 ± 1.79
CR-10-10	1/21/96	2.25	0.742	13.79	2.54	53	2.09	1.37	0.13	11.50	0.15	7.9	143	1.15	--
CR-10	1/24/96	15.7	2.67	24.10	9.54	107	10.60	6.06	0.19	17.10	7.37	8.0	260	1.97	--

TABLE A.2. Spring Baseline Data

Sampling Location	Date	Na (mg/L)	K (mg/L)	Ca (mg/L)	Mg (mg/L)	Alkalinity (mg/L as CaCO ₃)	Si (mg/L)	Cl (mg/L)	F (mg/L)	SO ₄ (mg/L)	NO ₃ (mg/L)	pH	Conductivity (µmho/cm)	TOC (mg/L)	Tritium (pCi/L)
Bennett	4/4/86	9.08	2.38	28.70	9.89	90	22.60	11.60	0.31	15.00	13.30	7.63	260	0.69	--
Benson	8/1/78	6.09	1.50	22.83	4.30	91	18.20	3.12	0.28	11.00	--	7.3	200	--	10.23 ± .77
Butler	6/7/79	8.80	2.30	21.70	9.70	93	19.40	5.40	0.10	18.70	9.70	6.6	201	--	4.90 ± .22
Gulch	7/18/84	19.20	4.78	43.80	19.40	147	21.90	23.00	0.40	31.80	21.40	7.65	431	13.04	--
Juniper	5/26/83	24.50	5.80	25.35	16.57	154	26.45	6.11	0.46	28.57	--	7.75	353	0.60	- .16 ± .25
Lower Snively	5/19/83	8.59	2.43	22.50	10.23	93	23.50	4.27	0.28	12.48	--	7.75	231	--	3.84 ± .35
Lozier	6/15/83	7.81	1.41	24.58	8.87	93	22.76	5.03	0.27	10.00	8.48	7.65	221	0.67	9.17 ± .38
Maiden	7/21/83	7.13	1.66	19.32	7.37	71	18.64	3.82	0.18	9.24	6.86	7.45	179	0.38	9.62 ± .39
Observatory	6/25/84	7.42	1.70	22.70	10.90	93	17.00	3.26	0.20	12.00	6.61	7.81	219	1.63	--
Railroad	3/20/79	7.20	3.20	18.70	14.90	118	25.50	19.60	3.70	30.00	0.50	8.20	249	--	23.16 ± .61
Rattlesnake	7/23/83	18.25	4.99	53.98	15.63	203	23.18	7.30	0.50	12.44	--	7.55	395	--	6.10 ± .22
Snively	5/23/74	10.00	2.50	21.50	9.30	80	20.50	3.50	0.30	15.60	8.10	6.75	194	--	--
Sulfur	7/21/83	9.87	2.97	25.82	9.33	99	25.64	5.22	0.34	11.50	5.16	7.65	235	0.58	12.85 ± .55
Unnamed-02	7/26/76	9.80	2.93	19.70	10.90	91	16.30	3.50	0.50	6.50	3.20	7.85	206	2.60	--
Unnamed-16	9/41/79	4.30	2.10	20.60	6.76	90	25.50	4.10	0.60	6.40	--	7.00	197	--	--
Unnamed-26	8/13/79	11.80	5.20	26.80	10.80	124	26.10	7.60	0.40	8.30	0.50	6.75	279	--	21.51 ± .42
Unnamed-29	7/24/79	12.20	2.56	27.80	10.40	112	20.23	7.10	--	11.20	1.80	7.00	249	--	--
Upper Snively	4/3/86	8.08	2.18	21.50	8.08	77	20.30	6.05	0.31	12.10	8.92	7.72	205	0.56	--
UR2-117	3/17/86	8.92	1.53	28.70	9.83	109	19.30	4.72	0.36	11.70	5.16	6.89	252	1.64	--
UR6-79	3/17/86	10.00	1.28	24.90	9.84	97	21.10	6.64	0.45	13.40	5.78	7.02	239	2.37	--
UR7-22	3/13/86	14.60	1.83	19.80	12.10	93	20.90	7.03	0.52	23.60	8.12	7.31	258	2.30	--
Warren	7/18/84	22.90	6.20	25.60	11.20	134	28.30	8.40	0.70	16.20	--	7.60	308	0.79	.334 ± .253
WR3-04	3/13/86	8.53	2.36	23.00	14.20	109	18.90	7.07	0.39	14.10	3.46	7.03	262	1.33	--
WR5-09	3/19/86	12.60	2.69	33.50	15.40	96	20.00	16.90	0.37	18.90	39.80	6.90	352	4.38	--
WR7-14	3/19/86	7.18	1.77	14.50	6.61	55	15.40	6.61	0.20	11.70	3.89	6.89	158	1.94	--

TABLE A.3. Unconfined Aquifer Baseline Data

Sampling Location	Date	Na (mg/L)	K (mg/L)	Ca (mg/L)	Mg (mg/L)	Alkalinity (mg/L as CaCO ₃)	Si (mg/L)	Cl (mg/L)	F (mg/L)	SO ₄ (mg/L)	NO ₃ (mg/L)	pH	Conductivity (umho/cm)	TIC (mg/L)	Tritium (pCi/L) (1986 Average)
699-15-25	1/1/76	22.00	7.30	46.00	12.00	126	16.00	8.60	0.40	56.00	31.00	--	--	--	41,000 ± 1,100
699-15-54A	1996	11.	3.25	32.	11.2	121	--	5.1	--	20	2.55	7.9	332	--	-33 ± 240
699-15-46A	2/1/86	9.94	4.75	31.90	9.39	120	12.00	5.20	0.30	16.00	4.10	7.7	290	9.32	--
699-14-33	1/1/79	17.00	6.70	30.00	9.40	140	27.00	4.20	0.80	20.00	0.58	7.8	300	--	230 ± 550
699-14-47	12/5/96	13.	5.1	27.	8.5	103	--	4.1	--	19	0.07	7.4	278	--	-3 ± 430
699-15-25	1/1/76	22.00	7.30	46.00	12.00	124	17.00	9.90	0.50	57.00	29.70	8.0	461	--	71,000 ± 5,500
699-19-43	1/1/77	16.00	5.70	43.00	11.00	110	13.00	6.90	0.50	67.00	2.30	7.8	399	--	-34 ± 350
699-20-24	1/1/76	20.00	8.00	53.00	11.00	116	17.00	14.00	0.40	51.00	53.00	7.9	460	--	230,000 ± 4,400
699-20-39	1966	--	--	--	--	--	--	--	--	--	--	--	--	--	55 ± 310
699-21-33	1/1/76	25.00	7.60	47.00	13.00	135	20.00	9.20	0.60	64.00	27.40	7.9	455	--	50,000 ± 11,000
699-25-55	1/1/80	10.00	5.40	50.00	12.00	146	23.00	7.00	0.60	34.00	15.00	8.0	397	--	-120 ± 260
699-25-75	1996	15.	4.5	29	11.8	127	--	4.7	--	21	3.00	7.8	345	--	1,200 ± 430
699-25-40	4/19/78	23.00	6.70	46.00	12.00	140	16.00	7.50	0.50	55.00	3.00	7.9	419	--	17,000 ± 6.00
699-25-52B	1986	--	--	--	--	--	--	--	--	--	--	--	--	--	190 ± 200
699-25-77	1996	--	--	--	--	--	--	--	--	--	--	--	--	--	240 ± 60
699-31-31	4/19/74	30.00	7.20	43.00	13.00	110	20.00	16.00	0.70	54.00	11.2	7.9	454	--	87,000 ± 29,000
699-32-43	1996	--	--	--	--	--	--	--	--	--	--	--	--	--	150,000 ± 31,000
699-32-52	1996	--	--	--	--	--	--	--	--	--	--	--	--	--	1,300 ± 340
699-32-70B	1/1/75	14.00	4.50	37.00	12.00	140	20.00	13.00	0.50	26.00	4.20	7.7	340	--	270,000 ± 6,200
699-32-72	1/1/78	16.00	4.30	20.00	12.00	115	14.00	16.00	0.40	27.00	5.30	7.8	297	--	140,000 ± 5,800
699-32-77	1/1/80	25.00	3.20	30.00	7.00	106	23.00	11.00	0.30	20.00	6.40	8.0	260	--	140 ± 120
699-33-42	6/1/75	11.00	8.90	41.00	13.00	107	16.00	3.10	0.60	2.40	49.00	7.8	420	--	220,000 ± 20,000
699-33-56	1/1/74	27.00	5.80	42.00	13.00	107	16.00	7.60	0.30	36.00	11.00	7.8	416	--	1,400 ± 2,500
699-34-79A	1/1/74	11.00	6.80	32.00	11.00	115	21.00	11.00	0.60	50.00	33.00	7.9	405	--	14,000 ± 2,700
699-34-42	1/1/76	32.00	7.30	37.00	11.00	113	20.00	11.00	0.70	54.00	44.20	8.0	325	--	100,000 ± 20,000
699-34-51	4/20/73	21.00	5.90	50.00	15.00	160	19.00	8.20	0.50	47.00	2.40	7.8	424	--	36 ± 290
699-35-66	4/18/78	20.00	5.90	41.00	13.00	140	18.00	11.00	0.40	27.00	5.60	7.8	400	--	1,200,000 ± 24,000
699-35-70	1/1/76	28.00	6.80	61.00	16.00	184	14.00	16.00	0.40	25.00	22.90	7.8	443	--	1,600,000 ± 53,000
699-35-78A	1/1/79	23.00	3.20	15.00	5.40	98.00	17.00	6.90	0.50	13.00	0.24	8.0	241	--	--
699-36-61A	1/1/79	21.00	5.60	40.00	13.00	148.00	22.00	7.20	0.40	32.00	17.00	7.8	399	--	-97 ± 330
699-36-93	12/29/86	13	4.5	34	15.9	93	--	16.5	--	50	8.13	7.7	434	--	-40 ± 1,000
699-37-32A	1/1/80	22.00	6.00	50.00	0.40	50	14.00	13.00	0.30	59.00	43.00	10.7	382	--	-56 ± 270

TABLE A.3. (contd)

Sampling Location	Date	Na (mg/L)	K (mg/L)	Ca (mg/L)	Mg (mg/L)	Alkalinity (mg/L as CaCO ₃)	Si (mg/L)	Cl (mg/L)	F (mg/L)	SO ₄ (mg/L)	NO ₃ (mg/L)	pH	Conductivity (µmho/cm)	TOC (mg/L)	Tritium (pCi/L) (1986 Average)
699-38-65	1986	--	--	--	--	--	--	--	--	--	--	--	--	--	720,000 ± 23,000
699-38-70	1/1/76	21.00	7.30	92.00	29.00	126	22.00	32.00	0.40	24.00	256.00	7.6	850	--	1,400 ± 490
699-38-74	1986	--	--	--	--	--	--	--	--	--	--	--	--	--	97 ± 420
699-38-82A	1/1/77	17.00	5.30	43.00	15.00	140	24.00	8.30	0.40	39.00	4.40	7.7	405	--	58,000 ± 4,700
699-43-53	1986	14.00	4.60	42.00	6.30	60	7.00	21.00	0.30	57.00	23.00	7.7	365	--	-140 ± 230
699-44-54	1986	--	--	--	--	--	--	--	--	--	--	--	--	--	200 ± 430
699-45-63	1/1/79	14.00	3.80	41.00	17.00	98	20.00	20.00	0.40	62.00	34.00	7.9	403	--	370 ± 270
699-47-60	1986	--	--	--	--	--	--	--	--	--	--	--	--	--	-97 ± 360
699-48-71	1/1/77	10.00	1.60	32.00	13.00	98.00	18.00	11.00	0.50	24.00	5.10	7.3	317	--	130 ± 210
699-49-79	6/1/75	6.70	4.20	44.00	15.00	94.30	17.00	11.00	0.30	48.00	44.00	7.6	388	--	160 ± 300
699-50-85	1/1/81	10.00	3.40	38.00	12.00	123.00	20.00	11.00	0.30	21.00	21.00	8.0	333	--	69 ± 250
699-51-53	1/1/80	12.00	4.10	32.00	12.00	114.00	14.00	9.50	0.50	22.00	7.10	8.0	294	--	150 ± 370
699-51-75	1986	--	--	--	--	--	--	--	--	--	--	--	--	--	70 ± 220
699-55-70	1986	--	--	--	--	--	--	--	--	--	--	--	--	--	170 ± 220
699-55-76	4/18/74	14.00	5.90	41.00	8.10	46.00	4.10	21.00	0.40	85.00	0.37	8.5	350	--	--
699-55-84	1/1/80	10.00	4.40	33.00	12.00	131.00	21.00	7.50	0.30	19.00	2.40	8.1	304	--	--
699-57-84	1/1/81	7.50	3.50	30.00	12.00	115.00	16.00	7.90	0.30	20.00	--	7.7	296	--	--
699-58-80B	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
699-61-62	1986	--	--	--	--	--	--	--	--	--	--	--	--	--	8,600 ± 350
699-61-66	1986	--	--	--	--	--	--	--	--	--	--	--	--	--	1,600 ± 3,100
699-61-93	8/14/74	11.00	4.70	36.00	13.00	120.00	20.00	9.10	0.40	28.00	1.29	8.0	323	--	65 ± 220
699-65-72	1986	--	--	--	--	--	--	--	--	--	--	--	--	--	3,800 ± 230
699-65-83	1986	--	--	--	--	--	--	--	--	--	--	--	--	--	1,100 ± 290
699-66-103	4/11/85	6.20	3.53	29.00	7.99	93.00	13.20	1.90	0.11	16.40	--	7.95	219	0.390	200 ± 300
699-67-36	1986	--	--	--	--	--	--	--	--	--	--	--	--	--	1,100 ± 220
699-67-90	7/1/83	13.00	4.50	38.00	10.00	129.00	16.00	6.70	0.30	20.00	4.00	7.7	290	--	110 ± 450
699-69-57	1/1/76	35.00	10.30	70.00	20.00	117.00	16.00	9.20	0.90	99.00	270.00	7.6	927	--	7,300 ± 610
699-59-53	1/1/90	27.00	5.10	21.00	6.80	114.00	23.00	5.90	1.30	15.00	0.93	8.1	267	--	750 ± 350
699-60-60	1986	--	--	--	--	--	--	--	--	--	--	--	--	--	7,600 ± 250

TABLE A.4. Confined Aquifer Baseline Data

Sampling Location	Date	Na (mg/L)	K (mg/L)	Ca (mg/L)	Mg (mg/L)	Alkalinity (mg/L as CaCO ₃)	SI (mg/L)	Cl (mg/L)	F (mg/L)	SO ₄ (mg/L)	NO ₃ (mg/L)	pH	Conductivity (umho/cm)	10C (mg/L)	Tritium (pCi/L) (1986 Average)	Producing Zone
DB-11	10/29/85	32.3	9.45	14.90	7.13	140	30.4	4.18	0.77	--	--	--	7.95	277	0.26	Pretest Rapids
DB-12	10/31/80	31.4	9.24	14.8	10.30	172	26.1	5.30	0.71	0.81	--	--	8.46	301	--	Pretest Rapids
DB-13	1/1/83	54.20	10.10	9.00	2.03	153.00	29.80	4.59	0.49	0.140	8.35	0.23	301.00	0.64	0.19 ± 0.23	Mabton
DB-14	6/25/83	137.0	17.60	2.03	<0.02	128	36.2	129	9.49	<0.50	9.31	--	714	--	--	Pretest Rapids
DB-15	8/27/79	171.00	15.80	1.50	0.34	149.60	62.50	104.00	19.00	<0.50	9.63	0.19	790.30	0.48 ± 0.19	0.61 ± 0.16	Pretest Rapids/Rocky
DB-15	4/16/79	176.00	15.60	3.04	0.55	156.65	59.00	105.00	19.10	10.20	<0.50	9.67	798.20	--	--	Pretest Rapids
DB-5	7/19/79	278.0	23.9	13.00	0.11	121	34.8	36.60	14.00	<0.50	<0.50	<0.50	9.00	1,700	--	Vantage
DB-17	7/1/80	123.00	13.80	1.31	0.04	139.70	34.10	96.50	8.90	--	--	--	9.40	653.20	1.36 ± 0.26	Pretest Rapids/Rocky
DB-17	1/25/80	145.00	15.10	1.09	0.10	137.10	32.60	104.00	10.10	2.80	--	--	9.21	672.40	5.81 ± 0.29	Pretest Rapids
DB-12	9/24/79	157.00	15.70	4.96	0.05	210.60	55.90	103.00	12.60	13.50	--	--	10.18	807.00	--	Upper Granite Ronde
DB-12	4/10/79	138.00	13.00	1.64	0.16	157.40	46.30	116.20	13.40	--	--	--	9.46	--	--	Conquest Fm
DB-17	7/14/80	143.00	15.70	2.23	0.76	--	51.80	107.00	13.00	--	--	--	--	--	--	Rocky Coulee
DB-17	5/3/80	131.90	16.30	1.12	0.07	139.70	35.00	103.00	9.80	--	--	--	9.38	661.50	-0.36 ± 0.16	Frenchman Springs
DB-17	11/4/81	166.00	7.53	1.28	<0.10	152	63.2	127	13.70	2.96	--	--	9.52	744	6.14 ± 22.60	Granite Ronde
DB-16A	10/21/83	46.60	6.40	14.90	3.51	148.00	9.87	3.58	0.47	4.43	--	--	8.04	293.00	4.68 ± 0.26	Selah
DB-16A	1/23/82	68.70	11.60	9.97	1.49	184.00	34.20	4.90	0.62	4.60	--	--	8.86	340.00	9.74 ± 0.23	Mabton
DB-16A	3/29/82	165.00	17.00	2.02	<0.10	150.00	39.30	146.00	9.50	2.00	--	--	9.38	795.00	2.75 ± 0.29	Pretest Rapids/Rocky
DB-16A	5/12/82	142.00	20.30	1.67	<0.10	144.00	40.80	110.00	13.00	1.90	--	--	9.06	697.00	1.39 ± 0.23	Frenchman Springs
DB-16A	11/16/82	355.0	24.30	2.83	<0.10	141	45.9	422	26.60	5.50	--	--	9.51	1,746	22.61 ± 22.61	Rocky Coulee
DB-15A	2/23/83	50.80	11.40	4.80	1.46	148.00	33.40	7.36	0.74	--	--	--	7.20	288.00	0.10 ± 0.23	Mabton
DB-16C	11/19/82	300.00	9.05	1.53	<0.10	124.00	42.70	36.70	23.90	3.98	--	--	9.20	--	0.52 ± 0.23	Rocky Coulee
DB-16C	4/14/83	130.00	17.30	1.74	<0.10	130.00	37.80	188.00	11.20	1.58	--	--	8.80	920.00	--	McClay Canyon
DB-19C	11/10/83	190.00	11.60	1.87	0.19	117.00	37.90	202.00	15.80	14.80	--	--	8.85	1,009.00	5.43 ± 0.23	Cohasset
DB-19C	11/6/83	177.00	6.20	1.99	0.27	113.00	40.60	185.00	14.60	4.58	--	--	8.95	888.00	11.24 ± 0.45	Intanum
DB-19C	12/16/83	177.0	6.34	2.00	0.31	125	31.4	140	15.10	21.90	--	--	8.60	941	11.75 ± 25.84	Frenchman Springs
DB-20C	11/30/83	171.0	17.40	1.56	<0.10	133	35.8	164	10.60	7.79	--	--	8.95	844	19.38 ± 22.61	Manapum/GH
DB-22C	2/4/84	126.0	17.00	1.85	<0.10	125	35.6	103	7.63	2.16	--	--	9.15	6.39	-3.23 ± 25.84	Manapum/GH
DB-23GH	2/26/86	134.80	20.20	4.07	<0.20	124.00	27.30	133.50	6.99	2.53	--	--	9.33	705.00	1.16	Pretest Rapids
DB-23GH	3/5/86	120.20	19.30	3.83	<0.20	110.00	24.30	117.00	6.28	4.49	--	--	9.25	632.00	0.95	Sentinel Gap
DB-23GH	4/2/86	127.80	12.20	2.48	<0.20	167.00	50.30	64.60	16.90	1.42	--	--	9.92	602.00	1.46	Ginkgo
699-54-57	5/17/87	2.30	7.20	25.00	11.60	117.00	70.00	12.90	0.53	20.00	--	--	7.80	350.00	0.06 ± 0.29	Rattlesnake Ridge

TABLE A.4. (contd)

Sampling Location	Date	Na (mg/L)	K (mg/L)	Ca (mg/L)	Mg (mg/L)	Alkalinity (mg/L as CaCO ₃)	Si (mg/L)	Cl (mg/L)	F (mg/L)	SO ₄ (mg/L)	NO ₃ (mg/L)	PH	Conductivity (µmho/cm)	TOC (mg/L)	Tritium (pCi/L)	Producing Zone
Enyeart	3/1/85	25.0	6.22	18.20	10.90	145	27.9	4.50	0.60	--	--	7.65	2,800	0.62	3.55 ± 29.07	Priest Rapids
Font	8/22/85	26.2	6.91	18.40	10.40	150	31.3	4.64	0.64	--	--	8.05	283	0.86	-16.15 ± 25.84	Priest Rapids
McGee	11/17/82	28.70	7.80	14.00	9.30	151.00	30.00	5.00	0.64	0.05	--	8.16	288.00	0.50	0.06 ± 0.19	Frenchman Springs
McGee	12/6/82	31.80	9.20	17.80	5.80	150.00	31.00	4.90	0.63	--	--	8.00	282.00	0.43	0.97 ± 0.32	Frenchman Springs
McGee	6/1/83	37.10	8.06	1.06	<0.10	185.00	43.50	7.49	3.41	1.62	--	9.05	380.00	8.77	-0.29 ± 0.23	Rocky Coulee FF
McGee	6/21/83	39.10	8.17	0.82	<0.10	191.00	46.90	7.06	3.52	0.26	--	9.45	395.00	1.94	1.29 ± 0.23	Rocky Coulee FF
McGee	7/14/83	40.90	8.36	0.97	<0.10	181.00	45.00	7.57	3.51	0.45	--	9.40	388.00	3.35	-0.06 ± 0.19	Cohasset FF
McGee	8/3/83	170.00	9.71	1.17	<0.10	176.00	48.40	48.40	11.00	1.11	--	9.50	524.00	3.69	16.28 ± 0.48	Cohasset FB
McGee	10/5/83	130.00	10.17	1.03	<0.10	208.00	56.60	48.40	9.30	6.23	--	9.45	582.00	3.90	2.26 ± 0.19	Untanum FB
McGee	10/13/85	29.3	7.91	16.50	8.63	143	28.7	4.34	0.69	--	--	7.95	278	0.280	8.72 ± 3.23	Priest Rapids
O'Brian	3/27/85	24.8	6.33	17.80	11.70	148	27.1	4.80	0.71	--	--	7.85	284	0.67	-12.92 ± 22.61	Priest Rapids
RRL-7	10/24/83	351.0	13.40	2.36	<0.10	149	49.2	420	14.00	4.20	--	9.60	1,632	--	25.52 ± 25.84	Cohasset FB
RRL-14	9/20/82	336.4	24.70	2.10	<0.10	195	43.6	357	24.30	16.80	--	9.48	1,634	--	--	Cohasset
RRL-02	2/2/82	162.00	20.90	2.02	0.19	190.00	29.80	133.00	8.50	1.60	--	9.14	810.00	5.49	3.84 ± 0.26	Priest Rapids
RRL-02	10/24/83	353.00	13.50	2.35	<0.10	149.00	49.50	416.00	14.00	0.95	--	9.60	1,632.00	2.81	2.55 ± 0.26	Cohasset FB
RRL-02	1/21/82	355.00	9.39	1.63	<0.10	136.00	47.70	451.00	18.20	1.70	--	9.41	1,740.00	6.14	2.78 ± 0.36	Untanum FF

APPENDIX B

WELL COORDINATES AT HANFORD

UTM	HANFORD WELL COORDINATE	UTM	HANFORD WELL COORDINATE
304941/5148989	6-10-54A	337600/5147617	6-10-54B
307632/5149105	6-11-45A	283849/5181055	6-114-127
320370/5179851	6-115-7	309735/5150028	6-14-38
316792/5149946	6-15-15F	316785/5149960	6-15-15G
313289/5150303	6-15-26	317444/5150045	6-15-E13
306930/5151097	6-17-47	308219/5151499	6-19-43
325276/5145542	6-2-E14	311278/5152892	6-24-33
304634/5153642	6-25-55	300097/5153809	6-25-70
297228/5153870	6-25-80	317018/5153217	6-26-15C
296094/5154115	6-26-83	309201/5154164	6-28-40
305777/5154497	6-28-52A	300063/5154802	6-29-70A
300094/5154885	6-29-70C	300130/5154857	6-29-70D
297821/5155153	6-29-78	296119/5155187	6-29-83
312166/5154898	6-31-31	296018/5155820	6-31-84A
296019/5155805	6-31-84B	295863/5155819	6-31-84C
308541/5155544	6-32-43	302651/5155743	6-32-62
300107/5155881	6-32-70B	299594/5156025	6-32-72
298064/5155886	6-32-77	296122/5155875	6-32-83
308669/5155742	6-33-42	304485/5155980	6-33-56
309678/5156096	6-34-39A	308825/5155967	6-34-42
305933/5156185	6-34-51	294511/5156566	6-34-89A
294493/5156552	6-34-89B	313206/5156126	6-35-27
301537/5156671	6-35-66	300244/5156622	6-35-70
297758/5157018	6-35-78A	297740/5157024	6-35-78B
292756/5157155	6-35-95	303095/5157065	6-36-61A
293254/5157365	6-36-93	296621/5157535	6-37-82A
296423/5157547	6-37-83	295963/5157593	6-37-84
294595/5157623	6-37-89	293630/5157526	6-37-92
301814/5157606	6-38-65	300218/5157727	6-38-70
297635/5158158	6-39-79	296023/5158229	6-39-84A
302903/5158273	6-40-62	297267/5158315	6-40-80
296006/5158575	6-40-84	293863/5159009	6-41-91
308861/5158544	6-42-42	294719/5159229	6-42-88
296892/5159426	6-43-81	295984/5159482	6-43-84
294733/5159503	6-43-88	294025/5159581	6-43-91A
293988/5159607	6-43-91B	293915/5159614	6-43-91D
302266/5159445	6-44-64	300311/5159450	6-44-70
293951/5159634	6-44-91	300548/5159807	6-45-69A
297842/5159789	6-45-78	295960/5160453	6-46-85A
295871/5160221	6-46-85B	309001/5160157	6-47-42
297406/5160457	6-47-80A	297403/5160520	6-47-80B
297376/5160483	6-47-80C	297342/5160545	6-47-80D
293816/5160822	6-47-92	307052/5160449	6-48-48A
307035/5160439	6-48-48B	300209/5160685	6-48-71
291186/5161548	6-49-100A	304410/5160852	6-49-57
297642/5161025	6-49-79	295822/5161362	6-49-85A
295798/5161343	6-49-85B	296019/5161496	6-50-85
351119/5159130	6-50-96	291929/5161605	6-50-98
291679/5161616	6-50-99	310844/5161278	6-51-36A

<u>UTM</u>	<u>HANFORD WELL COORDINATE</u>	<u>UTM</u>	<u>HANFORD WELL COORDINATE</u>
302570/5161688	6-51-63	298877/5161604	6-51-75
305829/5161686	6-52-52	290295/5162596	6-53-103
287864/5162775	6-53-111	287052/5162703	6-53-114
316414/5161926	6-54-180	300520/5162958	6-55-70
298705/5162935	6-55-76	294838/5163086	6-55-89
296569/5163639	6-57-83A	296512/5163629	6-57-83B
304278/5163878	6-59-58	297650/5164337	6-59-80B
303622/5164263	6-60-60	290803/5165158	6-61-102
305744/5164376	6-61-53	305040/5164413	6-61-55A
305056/5164414	6-61-55B	304457/5164649	6-61-57
302943/5164444	6-61-62	301911/5164649	6-61-66
305700/5164920	6-62-53	294430/5165521	6-63-90
292983/5165617	6-63-95	299966/5165765	6-65-72
296681/5166052	6-65-83	290657/5166621	6-66-103
295782/5166717	6-67-86	292120/5166719	6-67-98
316743/5166873	6-70-17	311932/5171375	6-84-34B
313747/5140558	6-S16-24	325312/5140304	6-S16-E14
325150/5135778	6-S30-E14		

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