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Summary of Analytical Results for Hydrologic Studies of Wells Open Through Large Intervals of the Snake River Plain Aquifer at the Idaho National Engineering Laboratory

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DOE Grant: DE-FG07-911D-13042

Administered By:
Idaho Department of Health and Welfare INEL Oversight Program

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by Michael McCurry
Professor of Geology
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I. INTRODUCTION

This report summarizes results of groundwater analyses for samples collected from wells USGS-44, -45, -46 and -59 in conjunction with the INEL Oversight Program straddle-packer project between 1992 and 1995.

The purpose of this project was to develop and deploy a high-quality straddle-packer system for characterization of the three-dimensional geometry of solute plumes and aquifer hydrology near the Idaho Chemical Processing Plant (ICPP). Principle objectives included (1) characterizing vertical variations in aquifer chemistry; (2) documenting deviations in aquifer chemistry from that monitored by the existing network, and (3) making recommendations for improving monitoring efforts.

The focus of this report is documentation of analyses of samples obtained with the straddle-packer system. Related open borehole sampling procedures and results are to be in theses by Morse (Idaho State University M.S. Thesis, in progress) and Olsen (University of Idaho M.S. Thesis, in progress). Related hydrologic data and borehole geophysics data are summarized and described by Johnson, et al. (1994), and Wood and Benecke (1994) and Frederick and Johnson (1996), respectively. Preliminary interpretations of the geochemical data are described by McCurry, et al. (1994), Estes and McCurry (1994), Fromm, et al. (1994), Fromm (1995) and Estes (in progress). Details regarding the design of the straddle-packer are described by Olsen (1994).

This report outlines the sampling and analyses procedures, quality control and chain of custody procedures, and presents a summary and brief discussion of pertinent analytical data. A complete record of all related analytical information is appended to the report (Appendix 1).

Sampling Sites and Intervals:

An array of four wells near the ICPP were identified and targeted for straddle-packer sampling (Figures 1a,b; 2). These wells, USGS-44, -45, -46 and -59, were selected on the basis of their suitable locations with respect to known contaminant plumes, large vertical intervals open to the aquifer, and favorable borehole size (6"). Each was first sampled by traditional methods (in this case by dedicated submersible pumps), then by thief sampler, and finally by the straddle-packer system. The stratigraphic framework for wells sampled west of the ICPP is illustrated in Figure 2.

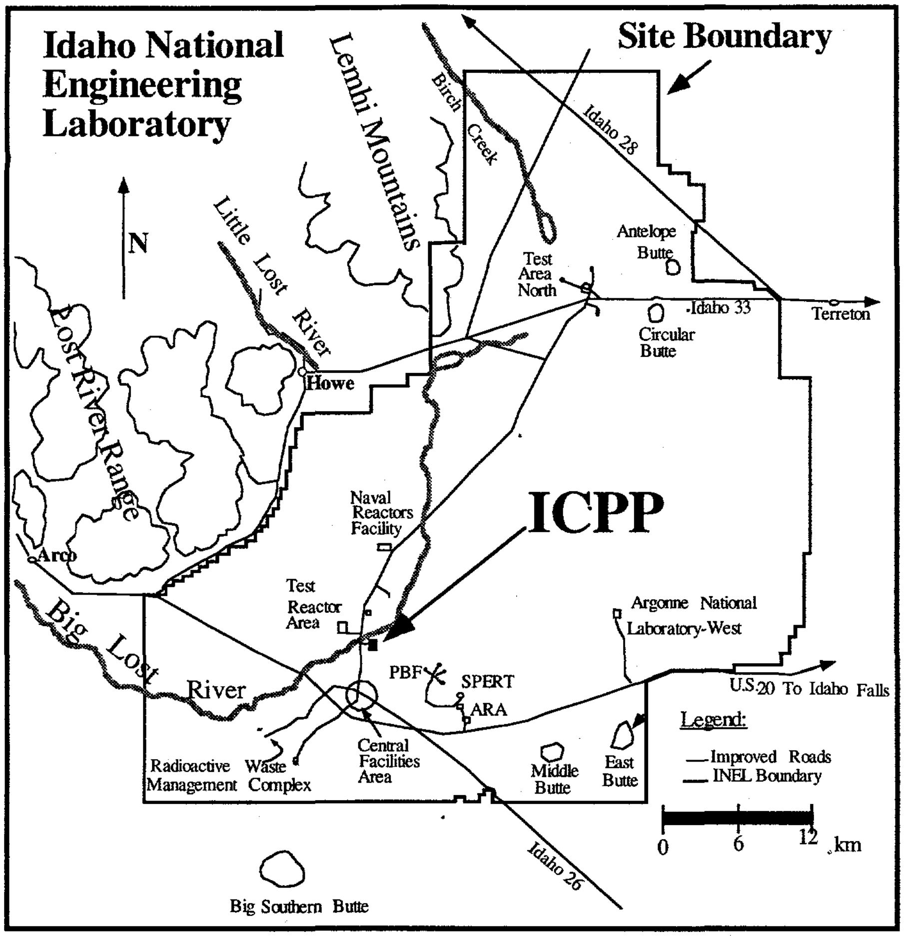
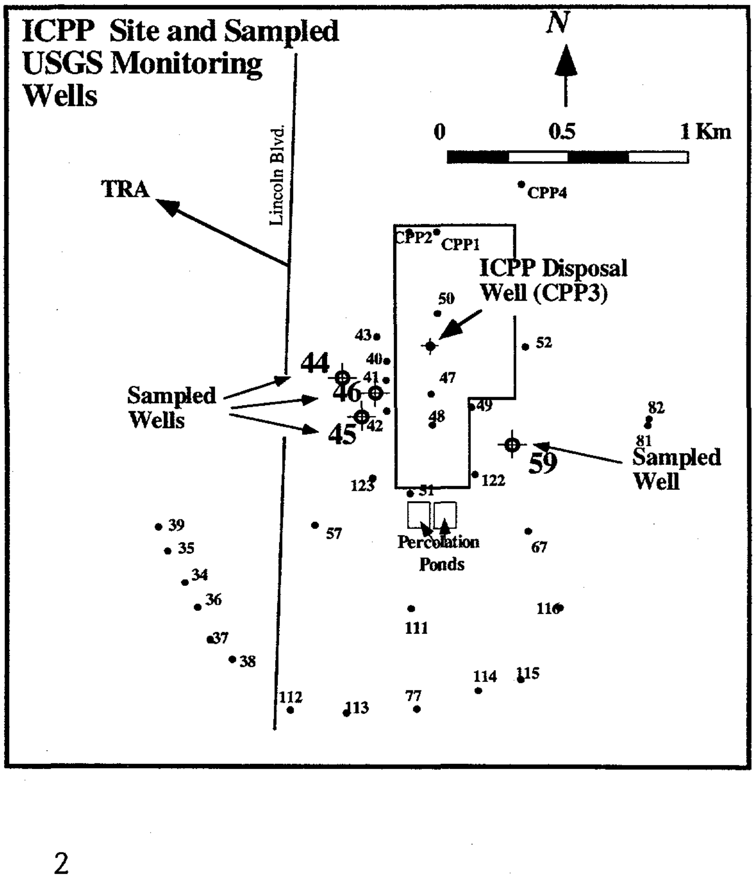
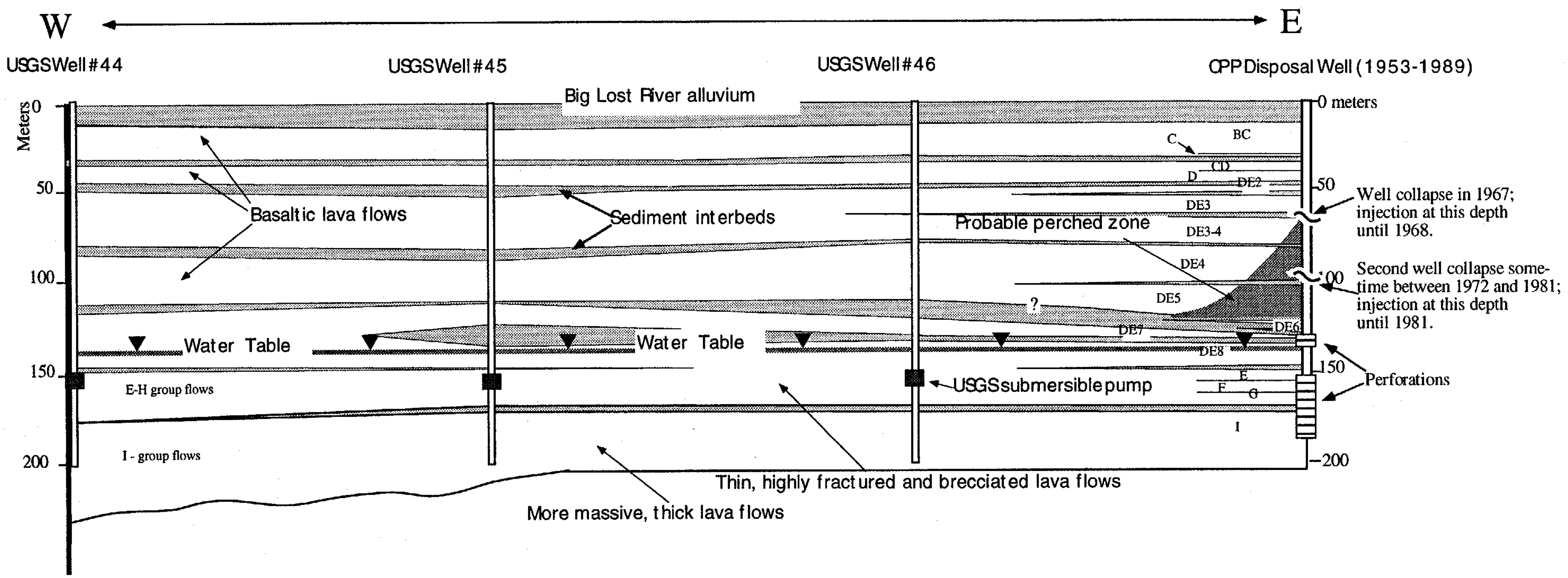


Figure 1(a). Location map for the INEL.

Figure 1(b). Location map for Idaho Chemical Processing Plant.





* Stratigraphic interpretation and basalt flow unit designations based on Anderson, 1991; injection well history from Fromm, 1995. Figure is not to scale.

Figure 2. Stratigraphic Setting*

Sampled intervals were selected to give maximum vertical resolution in variations in groundwater chemistry (note that the packers cannot be placed closer than 11 feet from each other; Olsen, 1994), to site the packers across zones of high permeability (as identified from borehole caliper and geophysical logs), and to seat the packers so that the bladders could adequately seal off the sampled intervals. The sampled intervals are listed in Table 1. The intervals listed in the table should be interpreted as approximately equal to the part of the well which has been isolated by the packer, assumed to be the interval from the center of the lower packer to the center of the upper packer. The exact spacing of the packers will vary slightly because the inner part of the packer moves in response to expansion of the packer bladder (Olsen, 1994).

Table 1. Straddle Packer-Sample Intervals* (in feet below land surface)

USGS 44	USGS 45	USGS 46	USGS 59
467-482'	462-477'	464-483'	462-480'
495-515'	480-495'	488-506'	484-502'
519-534'	500-515'	507-525'	517-535'
535-555'	519-534'	531-549'	538-556'
557-577'	538-553'	553-571'	538-561' (bottom)
580-600'		575-593'	
580-649' (bottom)		594-612'	
		612-629'	

* Intervals indicate the approximate distance between points at which the packers are seated against the wall of the borehole.

II. ANALYTES

Analytes are categorized and labeled in Table 2. Most metals analyses were conducted at "State Lab" (Table 2 footnote). However, in order to obtain more complete data, and in order to evaluate interlab errors, a subset of these samples were sent to one additional laboratory (UI Laboratory) which employs different analytical methodology. Comparisons of data from the two labs are consistently within 10% relative error. Beginning in the summer of 1995, subsets of selected samples were sent to State Lab and to the ISU-LEG laboratory. Comparisons of data from these two labs are also consistently within 10% relative error. Another subset of samples was sent to Activation Laboratories for metals analyses. This lab employs an ICP-MS, allowing for detection limits down to 10 parts per trillion. Specific EPA methods for analyte suites are listed in Appendix 2.

Analyses were also conducted in the field for parameters which change rapidly with time or exposure to air. Figure 3 diagrammatically illustrates the configuration of the field

Table 2. Analyses Suites*

Analyses Suite	Laboratory	Method	EPA Method	Analytes
Metals	Activation Lab[1]	ICP-MS	n/a	Ag, Al , As , Au, Ba , Be , Bi, Ca , Cd, Ce, Co, Cr, Cs, Cu , Dy, Er, Eu, Fe, Ga, Gd, Ge, Hf, Hg , Ho, I, In, Ir, K , La, Li , Lu, Mg , Mn, Mo , Na , Nb, Nd, Ni , Os, P, Pb , Pd, Pr, Pt, Rb, Re, Rh, Ru, Sb , Sc, Se, Si, Sm, Sn, Sr , Ta, Tb, Te, Th, Ti, Tl, Tm, U, V , W, Y, Yb, Zn , Zr
Metals	ISU-LEG[2]	ICP-AES	Modified EPA6010	Ag, Al , B, Ba , Be , Ca , Cd, Co, Cr, Cu , Fe, Hg , K , La, Mg , Mn, Na , Ni , P, Pb , Rb, Sc, Si, Sr , Ti, V , Y, Zn
Metals	UI Lab[3]	ICP-AES	Modified EPA6010	Ag, Al , As , Ba , Be , Ca , Cd, Co, Cr, Cu , Fe, Hg , K , Li , Mg , Mn, Mo , Na , Ni , P, Pb , Ru, Sb , Sc, Se, Si, Sr , V , Zn
Metals	SL[4]	See Appendix	See Appendix	Ag, As , Ba , Be , Ca , Cd, Cr, Cu , Fe, Hg , K , Mg , Mn, Na , Ni , Pb , Se, Sr , Zn
Anions	SL[4]	See Appendix	See Appendix	Boron, chloride, fluoride, bromide, sulfate, specific conductance, hardness, alkalinity
Nutrients	SL[4]	See Appendix	See Appendix	Total nitrate plus nitrite, Total P, Total Kjeldahl N
Stable Isotopes	U.S. Geological Survey[5]			87Sr/86Sr
Stable Isotopes	Waterloo Geochem Lab[6]; Krueger Lab[6]	Gas ratio mass spectrometry		$\delta^{18}O$, $\delta^{13}C$, δD
Radioactive Isotopes	ISU-EML[7]			Gross α, β, γ; Co-60; Cs-137; H-3; Pu-238,239,240; Sr-90
Radioactive Isotopes	U.S. Geological Survey			I-129; C-36
Regulated VOC's	State Lab	See Appendix	See Appendix	27 analytes; See Appendix
Unregulated VOC's	State Lab	See Appendix	See Appendix	36 analytes; See Appendix

* Contract Lab Work

Laboratory Contacts:

1. Activation Laboratories, 1336 Sandhill Drive, Ancaster, Ontario, Canada, L9G 4V5 (Bob Clark).
2. ISU-LEG: Department of Geology, Idaho State University, Pocatello, ID, 83209 (Michael McCurry).
3. Idaho Analytical Laboratory System, Holm Research Center, University of Idaho, Moscow, ID (Greg Moller).
4. State Lab: Bureau of Laboratories, 2220 Old Penetentiary Rd., Boise, ID, 83712 (Wally Baker - organic parameters; Jim Dodds - inorganic parameters).
5. U.S. Geological Survey, INEL, MS4148, PO Box 2230, Idaho Falls, ID, 83401 (Leroy Knobel).
6. Waterloo Geochem Lab - Environmental Isotope Laboratory, Dept. of Earth Sciences, University of Waterloo, Waterloo, Ontario N2L 3G1; Krueger Lab - Krueger Enterprises, Inc., Geochron Laboratories Division, 24 Blackstone St., Cambridge, MA 02139.
7. ISU-EML: Environmental Monitoring Lab, Dept. of Physics, Idaho State University, Pocatello, ID, 83209 (Tom Gesell).

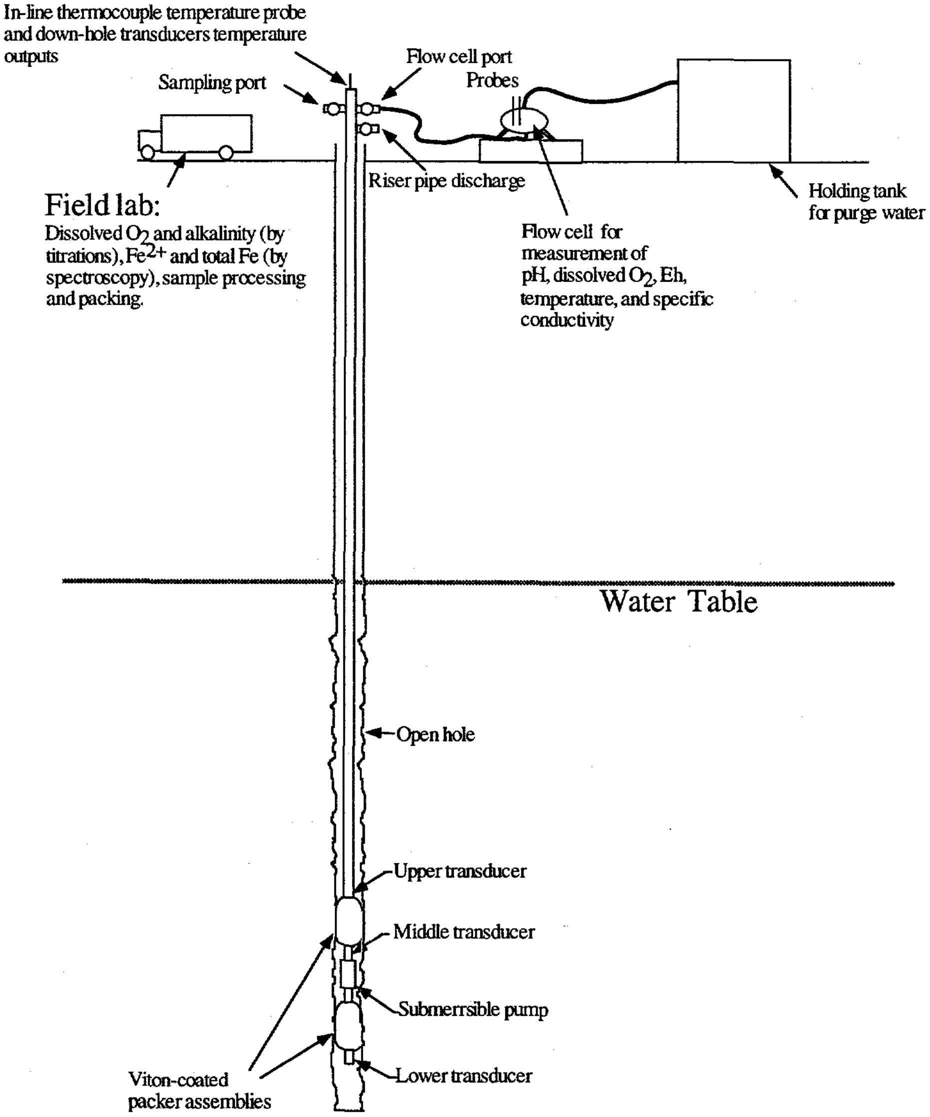


Figure 3. Schematic Diagram for Sample Collection and Field Measurements

lab and field measurements. Field analytical equipment and methods are described in Appendix 3.

III. SAMPLING AND ANALYSIS PROCEDURES

Sampling and Decontamination Procedures:

Sampling procedures are developed to insure that the collected samples, as near as possible, represent aquifer water from the isolated interval. Details of SOP's developed and utilized for sample collection as well as tracer testing are describe in the 1993 Packer Work Plan. To briefly summarize salient aspects of the procedures: 1. the packer assembly was thoroughly steam cleaned using deionized water prior to being deployed in the monitoring well; 2. packed intervals were pumped to remove at least 3 borehole volumes of water (where possible) prior to sampling; 3. all sample containers were precleaned by acid soaking and then rinsed with water from the sampled interval, prior to collecting the final sample; 4. samples were obtained directly at the well head through a Teflon valve system; 5. filtering of appropriate samples took place immediately after obtaining the bulk sample at the wellhead, using standard precleaned 0.45 micron filtering equipment; 6. samples were stored in ice chests containing blocks of ice to maintain a storage temperature of near 4°C.

Sampling Containers and Preservatives:

Sample containers and preservatives are listed in Table 3.

Calibration and Preventive Maintenance:

Sampling equipment and measuring devices were calibrated according to manufacturers' specifications, as well as to the type and sensitivity level of data to be collected.

Instruments which were used to collect field chemical measurements are listed in Appendix 3. Field instrument calibration and maintenance records are kept in record books specific to each instrument or group of instruments. Calibrations are performed with standard solutions in the field lab prior to and after sampling according to manufacturer's instructions.

TABLE 3 . Sample Handling and Storage

Type of analysis	Container type	Filtered[1]/ Unfiltered	Preservation	Storage temperature	Max. holding time
Dissolved Metals	1 L LDPE[2]	Filtered	1.5 mL HNO_3	Cool 4°C	6 mo.
Anions	1 L LDPE	Filtered	None	Cool 4°C	14 days
Nutrients	1 L LDPE	Unfiltered	2mL H_2SO_4	Cool 4°C	14 days
VOC's	2x40 mL	Unfiltered	0.5 gm ascorbic acid	Cool 4°C	14 days
O-18; H-2	1 oz. paraffin seal glass	Unfiltered	None	Cool 4°C	6 mo.
H-3	500 ml HDPE	Unfiltered	None	Cool 4°C	6 mo.
I-129; Cl-36	1L Amber glass	Unfiltered	None	Cool 4°C	6 mo.
Sr-90; U-234,235,238;Pu-239,240,238	1L HDPE	Unfiltered	None	Cool 4°C	6 mo.
C-13	1L Glass	Unfiltered	None	Cool 4°C	6 mo.
Gross α, β, γ	2L HDPE	Unfiltered	None	Cool 4°C	6 mo.
87Sr/86Sr	1L HDPE	Filtered	1.5 mL HNO3	Cool 4°C	6 mo.
Ferric/ Ferrous Iron	200 ml glass	Both	None	Cool 4°C	< 1 hour
Field Alkalinity; Dissolved oxygen	200 ml glass	Unfiltered	None	Cool 4°C	< 1 hour

1. 0.45 micron filter.
2. State Lab required 1L; ISU-LEG, UI and ActiLab required 500 ml.

Physical data pertaining to transducers, flow meters, barometric and environmental data, data logger and PC operation, data storage/backup records, data communication and data backup checks, etc. were kept in the project's bound record books.

Maintenance of equipment was as needed or according to manufacturers' recommendations or specifications.

IV. QUALITY ASSURANCE

Precision and Accuracy Objectives:

Precision: In the interests of field implementation and data comparability, we define a QA precision objective based on analyses of: 1) multiple samples collected at the wellhead and processed identically and 2) multiple, lab-prepared spikes carried through the same field handling and preservation protocols. In the case of (1), multiple samples were collected from the wellhead discharge point. In the case of (2), multiple spikes prepared by the analytical laboratory were treated in the field in the same manner as the samples. The acceptable coefficient of variation ($CV = 100 * \sigma/\mu$; p. 8 of Skoog, 1985) of measurements on the replicates and multiple lab spikes was established as $\leq 20\%$ for VOC's, and $\leq 10\%$ for anions, nutrients and metals. Quality control spikes provided by the State Lab are listed in Table 4. Analyses of spikes and blanks are listed in Tables 5 and 6. Most analytes meet or exceed the precision requirements. Those which did not include benzene and dichloroethane, which yielded CV's of 25% and 21%, respectively. In addition, sulfate and total-P also slightly exceeded the precision limits, yielding CV's of 17% and 14%, respectively.

Table 4 . Quality Control Samples for Samples Analyzed by the State Lab.

Method	Concentration	Analytes
Dissolved Metals	20 ug/L	Cr, Pb, Cd, Ni
	10 mg/L	Ca, Mg, Na, K
Nutrients	5 mg/L	Nitrate + nitrite
	1 mg/L	Total P
Anions	20 mg/L	Cl, SO4
	1 mg/L	F
Regulated VOCs	5 ug/L ea.	All regulated compounds

NOTE: Lab spikes for dissolved metals, nutrients and anions were prepared by the State Lab, taken to the field and submitted blind for analyses at the State Lab

Accuracy: Accuracy includes random and systematic errors in a measurement process (defined here as the chain of sampling, handling and analysis steps leading to production of measured values). Although a combined statistic, based on both random and systematic error estimates, can be computed as an estimate of total uncertainty or accuracy, this is difficult to specify a priori, particularly when field sampling and handling have the potential for introducing significant errors to the overall measurement error. Impacts of equipment, air-borne dust contamination, and deionized water blanks on water quality samples have been identified as significant problems during the 1992 test phase. In order to minimize dust contamination, sampling was typically done before noon when wind velocities are lowest.

We define a QA accuracy objective based on replicate analyses of a spiked solution of selected species which has been handled and processed identically with field samples and which is analyzed by a given laboratory and compared to expected parameter values. The mean difference or "bias" between a parameter value reported by a laboratory and the expected parameter value is defined as $100\ \Sigma(x-x_{true})/n/x_{true}$ (%) for spiked solutions. Analyses of the spikes samples are listed in Tables 5 and 6. Averages for most inorganic analytes are consistently within 10% of the known concentrations. Sulfate averages approximately 33% low, and exhibits a high CV of 17%. Total-P is approximately 44% high, and also exhibits a high CV of 14.4%. Although total-P concentrations at the ICPP are low, sulfate is a significant anion. Sulfate uncertainties are therefore the most significant potential problem in our analytical data.

In addition to the above definitions, the ionic charge equivalent balance error for a complete water analysis, defined as

$$\text{Charge balance error} = 100 * \frac{\Sigma\text{cation equivalents} - \Sigma\text{anion equivalents}}{\Sigma\text{cation equivalents} + \Sigma\text{anion equivalents}}, \%$$

is a standard check for consistency and quality of analytical data. Our QA objective was that complete major ion analyses shall yield a charge balance error of less than or equal to 10%. Calculated charge balances are listed in Table 7. All meet the 10% limit, and most are within 5% of charge balance. The good charge balances suggest that potential sulfate analytical errors described above are probably not significant in our water quality data.

Table 5. Spikes and blanks analyses for VOC's[1].

Sample Type	Sample Purpose	Sample Date	Analyzing Lab	Benzene µg/L	Carbon Tetra -chloride µg/L	1,1-Dichloro-ethylene µg/L	1,2-Dichloro-ethane µg/L	p-Dichloro-benzene µg/L	1,1,1-Trichloro-ethane µg/L	Trichloro-ethylene µg/L	Vinyl chloride µg/L
VOC'S	Spike	7/10/92	SL	5.7	4.9	4.6	5.7		5.4	5.8	4.0
VOC'S	Spike	7/23/92	SL	6.2	4.7	4.2	5.4		5.5	6.0	6.6
VOC'S	Spike	7/23/92	SL	6.1	4.7	4.4	5.5		5.5	6.0	6.7
VOC'S	Spike	7/30/92	SL	4.9	3.8	4.1	1.9		3.6	7.6	2.2
VOC'S	Spike	8/1/94	SL	4.2	4.7	4.2	5.1	4.5	4.8	4.7	3.3
VOC'S	Spike	9/29/93	SL	4.1	4.2	3.8	4.9	4.1	4.9	4.4	2.4
VOC'S	Spike	9/27/93	SL	7.8	3.9	5.6	5.8	4.4	5.6	5.5	2.8
VOC'S	Spike	9/13/93	SL	7.9	3.6	5.8	5.8	4.6	6.9	5.8	4.7
VOC'S	Spike	8/19/93	SL	3.6	4.4	3.7	4.5	3.7	4.9	4.8	1.3
VOC'S	Spike	8/6/93	SL	5.3	5.3	6.3	5.5	4.5	5.1	5.6	4.8
VOC'S	Spike	7/15/93	SL	4.7	4.4	<0.5	5.2	5.0	4.6	4.9	4.3
VOC'S	Spike	8/13/92	SL	[10.1]	[11.3]	[10.3]	[10.2]		[13.7]	[12.2]	5.5
VOC'S	Spike	8/17/93	SL	4.8	5.3	5.4	5.5	4.4	5.5	5.5	3.3
Average				5.4	4.5	4.7	5.1	4.4	5.2	5.6	4.0
CV (%)				25.2	12.2	18.7	21.1	8.6	15.0	15.1	41.6
VOC'S	Blank	7/10/92	SL	<0.5	<0.5	<0.5	<0.5		<0.5	<0.5	<0.5
VOC'S	Blank	8/1/94	SL	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
VOC'S	Blank	9/29/93	SL	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
VOC'S	Blank	9/27/93	SL	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
VOC'S	Blank	9/13/93	SL	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
VOC'S	Blank	8/19/93	SL	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
VOC'S	Blank	8/6/93	SL	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
VOC'S	Blank	7/15/93	SL	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
VOC'S	Blank	8/13/92	SL	<0.5	<0.5	<0.5	<0.5		<0.5	<0.5	<0.5
VOC'S	Blank	8/10/92	SL	<0.5	<0.5	<0.5	<0.5		<0.5	<0.5	<0.5
VOC'S	Blank	8/6/92	SL	<0.5	<0.5	<0.5	<0.5		<0.5	<0.5	<0.5
VOC'S	Blank	7/30/92	SL	<0.5	<0.5	<0.5	<0.5		<0.5	<0.5	<0.5
VOC'S	Blank	7/28/92	SL	<0.5	<0.5	<0.5	<0.5		<0.5	<0.5	<0.5
VOC'S	Blank	8/3/92	SL	<0.5	<0.5	<0.5	<0.5		<0.5	<0.5	<0.5
VOC'S	Blank	7/23/92	SL	<0.5	<0.5	<0.5	<0.5		<0.5	<0.5	<0.5
VOC'S	Blank	7/23/92	SL	<0.5	<0.5	<0.5	<0.5		<0.5	<0.5	<0.5
VOC'S	Spike	8/6/92	SL	<0.5	<0.5	<0.5	<0.5		<0.5	<0.5	<0.5
VOC'S	Spike	8/17/93	SL	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5

1. SL - State Lab (Table 2 explanation). Brackets indicate values which are anomalously low and are inferred to be errors by the SL in their preparation of the spike solutions (see "Note" in Table 4); these samples were not included in the calculations of averages and standard deviations. CV - coefficient of variation.

Table 6a. Analyses of spikes and blanks for metals suites[1].

Sample Purpose	Sample Date	Analyzing Lab	Ca µg/L	Cd µg/L	Cr µg/L	K µg/L	Mg µg/L	Na µg/L	Ni µg/L	Pb µg/L
Spike	7/10/92	SL	[100]	20	[<2]	9,900	9,700	9,400	24	20
Spike	7/23/92	SL	[100]	20	[<2]	10,000	9,700	9,800	27	21
Spike	8/3/92	SL	[<100]	20	[<2]	9,900	9,800	9,600	23	18
Spike	8/6/93	SL	9,200	22	20	9,600	9,600	10,400	23	22
Spike	7/23/92	SL	[200]	[<1]	[<2]	[<100]	[<100]	[900]	[<10]	[<5]
Spike	7/6/94	SL	9,600	17	21.6	10,000	10,000	10,000	21	21
Spike	10/1/93	SL	[<100]	[<1]	[<2]	9,600	10,000	10,200	23	21
Spike	10/1/93	SL	10,000	[<1]	22	[100]	[<100]	[200]	[<10]	[<5]
Spike	8/10/92	SL	[1500]	23	[<2]	9,800	9,700	9,600	25	22
Spike	8/1/94	ISU-LEG	10,200	18	16	10,000	10,000	10,500	14	<30
Average			9,750	20	20	9,850	9,813	9,938	23	21
CV (%)			3.9	10.0	10.0	1.6	1.6	3.8	17.4	4.8
Blank	7/10/92	SL	100	<1	<2	100	100	100	<10	<5
Blank	8/6/93	SL	<100	<1	<2	100	<100	<100	<10	<5
Blank	10/1/93	SL	<100	<1	<2	100	<100	100	<10	<5
Blank	8/10/92	SL	500	<1	<2	100	<100	<100	<10	<5
Blank	8/3/92	SL	100	<1	<2	<100	<100	100	<10	<5

1. SL - State Lab (Table 2 explanation). Brackets indicate values which are anomalously low and are inferred to be errors by the SL in their preparation of the spike solutions (see "Note" in Table 4); these samples were not included in the calculations of averages and standard deviations. CV - coefficient of variation.

Table 6b. Analyses of spikes and blanks for anions and nutrient suites[1].

Anions spikes and blanks Sample Purpose	Sample Date	Analyzing Lab	Cl^- µg/L	F^- µg/L	SO_4 µg/L	Nutrient spikes and blanks Sample Purpose	Sample Date	Analyzing Lab	Total N (NO_3-N & NO_2-N) µg/L	Total P µg/L
Spike	8/3/92	SL	20000	900	19000	Spike	7/10/92	SL	[27]	[5,410]
Spike	7/23/92	SL	[31000]	950	18000	Spike	7/23/92	SL	4,980	1,200
Spike	8/10/92	SL	20000	1,000	19000	Spike	8/3/92	SL	5,730	830
Spike	8/6/93	SL	20000	990	15400	Spike	7/23/92	SL	[22]	[120]
Spike	7/6/94	SL	19000	970	12,000	Spike	7/11/94	SL	[2,440]	[<50]
Spike	10/1/93	SL	20000	960	19000	Spike	7/6/94	SL	5,370	980
						Spike	10/1/93	SL	4,340	1,230
						Spike	8/6/93	SL	4,580	980
						Spike	8/10/92	SL	5,350	1,040
Average			19800	962	17067	Average			5058	1043
CV (%)			2.3	3.6	16.7	CV (%)			10.4	14.4
Blank	8/6/93	SL	<900	<100	<1,000	Blank	8/6/93	SL	<5	110
Blank	8/1/94	SL	<900	<100	<1,000	Blank	10/1/93	SL	<5	90
Blank	10/1/93	SL	<900	<100	<1,000	Blank	8/10/92	SL	173	<50
Blank	8/10/92	SL	<1,000	<100	<1,000	Blank	8/3/92	SL	16	<50
Blank	8/3/92	SL	<1,000	<100	<1,000					

1. SL - State Lab (Table 2 explanation). Brackets indicate values which are anomalously low or high and are inferred to be errors by the SL in their preparation of the spike solutions (see "Note" in Table 4); these samples were not included in the calculations of averages and standard deviations. CV - coefficient of variation.

Sample Custody and Documentation:

Documentation of Tests and Test Data.

1. All hydrochemical tests performed were documented on forms or in notebooks designated for that purpose. Each form may include information and data for one or more tests, depending on the type of test and the amount of data to be recorded for the test. Data captured on the field-computer/data-logging system were referenced in field notebooks and backed-up at least daily.

2. Sample handling and analysis follow chain of custody procedures and documentation to guarantee sample integrity. Chain of custody procedures produced a permanent record of sample custody and followed procedures outlined in EPA SW-846, Vol. II, sec. 9.2.2.7. Documentation included the use of a bound field logbook, sample identification and custody transfer sheets, sample labels, custody seals for bulk sample containers (e.g., coolers), and sample analysis request sheets. Examples of these forms are found in Appendicies 6 through 8.

3. Information on procedures and operations were recorded in bound notebooks or on forms specifically designated for that purpose.

4. All environmental samples taken by the Oversight Program have the following seven or nine digit format:

   first two digits = 91 (last two digits of year project plan was first submitted)

   third and fourth digits = 06 (sequential project number)

   fifth, sixth and seventh digits = sequential sample number starting with 001

Quality Control Checks:

Quality control samples represent approximately 10% of the total sample population analyzed at the state laboratory, for each of the analyte groups (dissolved metals, anions, nutrients and VOC's). These data were used to determine the accuracy and precision of analytical results and the influence of field activities on sample chemistry. These include:

A. Field QC Checks

Blind duplicates, Spiked samples, Blank samples

B. Laboratory QC Checks

1. State Laboratory Inorganics:

    a. One QC check of at least 5 times background equivalent concentration per test series or every twentieth sample.

    b. Standard analyzed each analytical run.

2. State Laboratory Organics for VOCs:

    a. Blanks, standards and laboratory fortified blanks spiked at 5 ug/L of regulated VOC's and analyzed initially and every tenth sample during the analytical run.

    b. The lab monitors QC samples fortified with 1,1-dichloroethene and trichloroethene on the ELCD detector and p-dichlorobenzene and benzene on the PID detector.

3. The external labs run QC checks at the start of each working day and the start of each analytical run or every 20 samples, which ever is less. An analytical run is any group of samples from a single customer. If there are more than 20 samples in a run the QC procedures are repeated every 20 samples. The procedure for each run is as follows; a standard solution, a blank, and a matrix spike at beginning of run. A duplicate matrix spike and a lab spike in middle of run. A duplicate standard at end of run.

V. SUMMARY OF ANALYTICAL RESULTS

Metals and Anions:

Major solute data are summarized in Table 7 and a representative group of solutes are illustrated in Figure 4a and 4b. Most analytes overlap with ranges of concentration measured in previous studies of these wells (e.g., Fromm, 1995; Fromm, et al., 1994; Table 8). However, several exhibit significant vertical variations which extend well beyond these ranges. Several patterns in these data are observed in wells bordering the west side of the ICPP (i.e. USGS-44 through 46), and are described below:

Two prominent, systematic patterns emerge from these data: 1. there is a distinctive three-layered pattern to the data for many solutes, in particular Na, Cl and NO3 (expressed in the Figure 4a and Table 7 as N). These layers are defined from top to bottom,

Table 7. Major Element Analyses for wells USGS-44, -45, -46 and -59.

Well Number	Sample Method[1]	Sampling Date	Depth (feet below land surface)	Ca, ppm	SiO2, ppm	Mg, ppm	Na, ppm	K, ppm	Cl, ppm	F, ppm	NO3 & NO2 as N), ppm	SO4, ppm	Total Alkalinity as CaCO3, ppm	Charge Balance (percent)[2]
USGS-44	DP	7/1/92	499'	58.8	22.2	15.1	10.7	2.5	18.0	0.2	1.2	24.5	170	-2.7
USGS-45	DP	7/1/92	503'	58.5	24.5	15.8	10.0	2.8	20.0	0.2	1.3	25.0	168	-2.6
USGS-45	DP	6/2/93	499'	58.0	22.1	14.5	11.0	2.6	19.8	0.2	1.2	23.0	164	-3.1
USGS-46	DP	7/1/92	502'	60.5	22.2	16.3	12.0	2.8	23.0	0.2	2.9	27.8	170	-1.8
USGS-44	TS	7/10/92	500'	60.0		15.0	10.0	2.4			1.3			
USGS-45	TS	7/10/92	500'	61.0	22.0	15.5	10.0	2.6	21.0	0.2	1.3	26.3	166	-3.4
USGS-45	TS	6/17/93	500'	54.0	22.7	14.0	12.0	2.6	19.0	0.1	1.2	31.0	157	-0.9
USGS-46	TS	7/10/92	500'	61.0	21.0	16.0	15.0	2.5	29.0	0.2	5.2	28.2	162	-1.3
USGS-44	UIP	8/13/92	499'	59.5	21.1	15.0	10.0	2.1	19.0	0.3	1.3	28.0	170	-1.3
USGS-45	UIP	7/8/93	500'	55.0	23.0	14.6	10.3	2.4	19.0	0.2	1.2	23.5	164	-1.2
USGS-44	PP	8/14/92	467-482'	62.0	21.1	15.0	9.9	2.3	20.0	0.2	1.2	28.0	171	-2.2
USGS-44	PP	7/20/92	495-515'	60.0	21.2	15.0	11.0	2.2	18.0	0.2	1.1	26.0	168	-3.4
USGS-44	PP	7/21/92	495-515'	60.0	21.2	15.0	10.0	2.3	18.0	0.2	1.1	27.0	168	-2.8
USGS-44	PP	8/18/92	519-534'	58.7	21.1	15.0	11.0	2.3	20.0	0.2	1.3	29.0	169	-1.2
USGS-44	PP	7/24/92	535-555'	60.6	21.2	15.0	10.4	2.3	20.0	0.2	1.1	24.0	170	-3.0
USGS-44	PP	7/29/92	557-577'	59.0	21.9	15.8	9.8	2.7	20.0	0.2	1.3	26.0	173	-1.4
USGS-44	PP	8/3/92	580-600'	49.3	25.2	16.0	15.3	3.2	27.5	0.3	2.1	24.5	153	-1.0
USGS-44	OPI	7/30/92	580-649'	52.0	24.9	16.0	15.0	3.3	25.0	0.3	2.0	25.0	159	-1.7
USGS-45	PP	8/19/93	462-477'	51.2	25.1	14.4	11.5	2.5	23.8	0.2	1.6	22.2	156	0.1
USGS-45	PP	8/17/93	480-495'	52.5	24.4	14.6	11.0	2.5	21.3	0.2	1.3	24.5	162	0.3
USGS-45	PP	8/10/93	500-515'	51.3	25.4	15.0	10.8	2.6	20.4	0.2	1.2	23.8	158	-0.7
USGS-45	PP	8/6/93	519-534'	52.5	25.6	14.8	11.2	2.6	20.6	0.2	1.3	25.0	162	-0.1
USGS-45	PP	7/16/93	538-553'	55.0	22.8	15.0	10.2	2.4	23.0	0.2	1.2	25.0	166	0.4
USGS-46	PP	9/13/93	464-483'	58.6	22.8	15.7	14.6	2.2	27.6	0.2	4.8	23.0	165	-0.8
USGS-46	PP	9/16/93	488-506'	59.0	22.3	15.6	12.6	2.2	23.7	0.1	3.3	29.0	167	-0.5
USGS-46	PP	9/27/93	507-525'	57.6	22.4	15.1	10.2	2.2	19.3	0.2	1.6	29.0	171	0.2
USGS-46	PP	9/29/93	531-549'	56.2	22.8	15.4	9.8	2.2	19.1	0.1	1.4		[204][3]	
USGS-46	PP	10/1/93	553-571'	57.5	22.9	16.0	9.6	2.2	19.6	0.1	1.5	25.5	175	-0.2
USGS-46	PP	9/20/93	575-593'	58.9	24.0	16.3	8.6	2.3	19.3	0.1	1.3	27.0	175	-0.7
USGS-46	PP	10/20/93	594-612'	56.7	24.3	15.7	8.6	2.0	19.1					
USGS-46	PP	11/30/93	595-613'	45.3	25.6	16.4	8.4	2.3	10.2	0.2	1.3	22.0	173	2.9
USGS-46	PP	11/17/93	612-629'	34.1	27.8	16.0	8.5	2.6	15.8	0.2	0.9	19.0	130	0.2
USGS-59	PP	6/29/94	462-480'	52.3	24.8	12.9	42.2	4.8	69.0	0.3	2.9	21.0	142	-3.4
USGS-59	PP	7/6/94	484-502'	42.8	23.3	13.4	21.7	5.7	35.5	0.6	3.4	17.0	163	5.1
USGS-59	PP	8/1/94	517-535'	63.9	18.9	16.2	48.1	4.6	83.0	0.3	2.0	32.0	161	-4.5
USGS-59	PP	8/4/94	538-556'	67.8	25.7	17.1	72.6	5.6	126.0	0.2	1.8	27.0	155	-7.2
USGS-59	PP	8/22/94	538-651'		22.8				26.0	0.2	1.5	23.0	168	

1. PP - Straddle-packer system; OPI - Straddle-packer, upper packer inflated; UIP - Uniflated packer system; TS - Thief sampler; DP - USGS dedicated pump.
2. Charge Balance = 100*(anions-cations)/(anions+cations).
3. Brackets indicate a measurement which is anomaolous and considered unreliable.

respectively, as Zone 1, Zone 2 and Zone 3. 2. The same solutes exhibit a systematic decline in concentration away from the ICPP within the upper zone, but exhibit no systematic variation in concentrations with respect to the ICPP in the lower two zones. Zone 2 has the greatest consistency among the wells and is described first.

Zone 2, from 158 to 175 mbls (meters below land surface), is characterized by essentially flat vertical gradients in solute components. Concentrations are near inferred background (BK) for some (e.g., SiO2 and NO3). ICPP background values (BK) represent averages of water analyses from wells CPP-1, 2, 3 and USGS-34 taken between 1950 and 1951. These values are listed in Table 8, and are generally comparable to site-wide aquifer chemistry values compiled by McLing (1994) and Orr, et al. (1991).

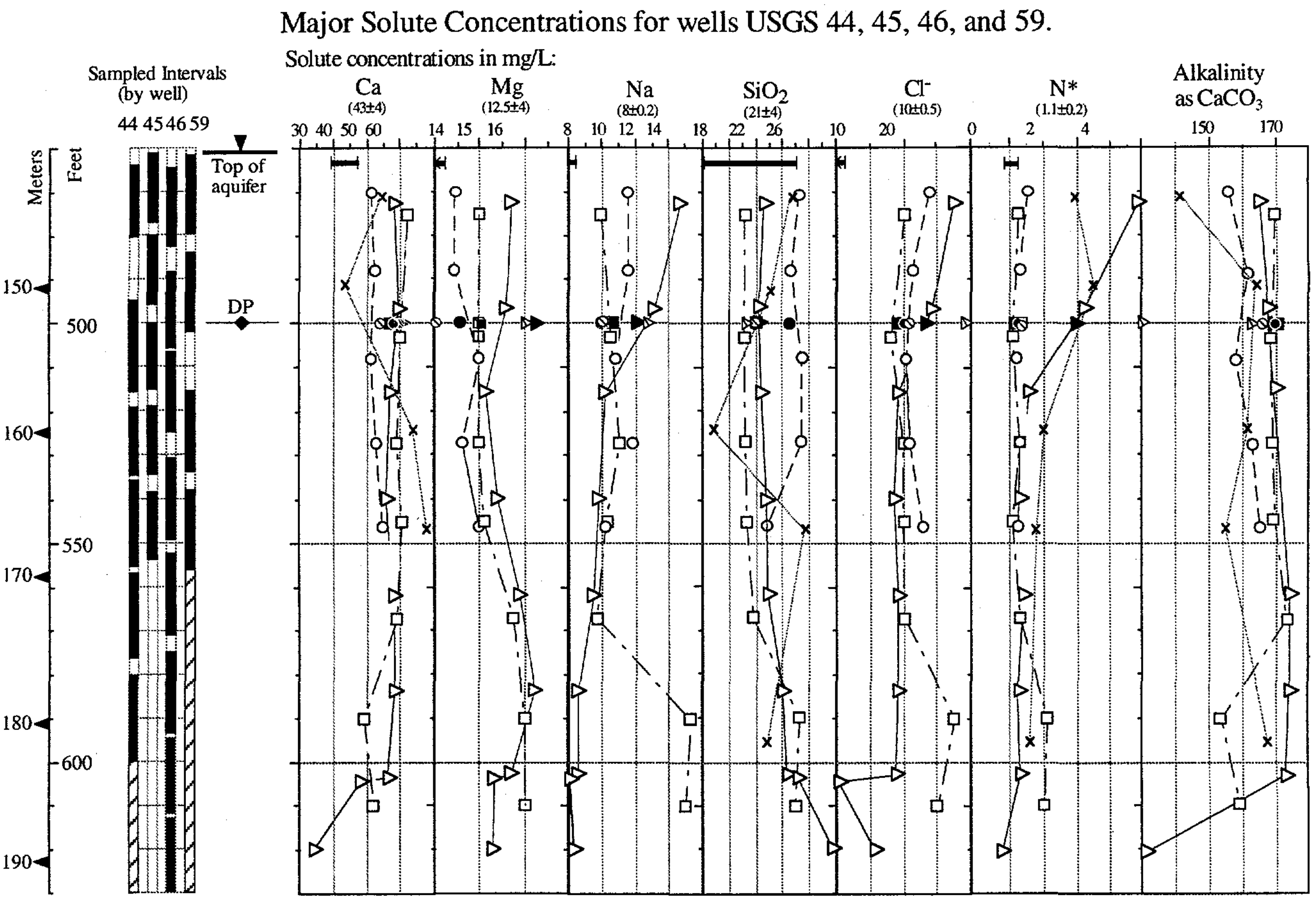
TABLE 8. Background conditions for aquifer system near the CPP*.

Parameter	CPP Background		
T in °C	12.5	±	0.6
pH	8.0	±	0.4
SiO2, mg/L	21.0	±	4
Fe-D**, mg/L	0.07	±	0.10
Ca, mg/L	43.50	±	4
Mg, mg/L	12.50	±	0.6
Na, mg/L	8.0	±	0.2
K, mg/L	2.9	±	1.4
HCO3, mg/L	74	±	11
SO4, mg/L	21.0	±	0.8
Cl, mg/L	9.7	±	0.5
F, mg/L	0.18	±	0.05
NO3, mg/L	1.1	±	0.2

* CPP background values represent averages and standard deviations of water analyses from wells CPP-1, 2, 3 and USGS-34 taken between 1950 and 1951, prior to CPP disposal operations (Nace, et al., 1951; Robertson, et al., 1974; and Bagby, et al., 1985).

** Fe-D = dissolved iron.

Significant deviations from background include Ca (10-50% above BK), Mg (20-30% above BK), Na (20% above BK) and Cl (100% above BK). Although uncertainties for our inferred background values have not been rigorously quantified, we believe these deviations are significant and assume therefore that direct or indirect anthropogenic processes have played a role in elevating their values.



Major Solute Concentrations for wells USGS 44, 45, 46, and 59.

Figure 4a. Selected major solutes are plotted against depth sampled by the straddle-packer system. Solute concentrations are in mg/L; total phosphorous is plotted as P; total nitrogen as N. Sampled intervals are shown with solid bars; diagonal lines indicate intervals sampled with the upper packer inflated and the lower packer uninflated. Estimates of natural (background) solute concentrations are shown in parentheses and with range bars at the top of each plot. Thief and USGS pump samples (500') are illustrated with lined and filled symbols, respectively, for the respective wells. Symbols for wells: □ - USGS-44; ○ - well 45; ▷ - well 46; x - USGS-59 . Solute concentrations for Mg, Na and Cl are not shown for well USGS-59 because they plot off the graphs (see Figure 4b).

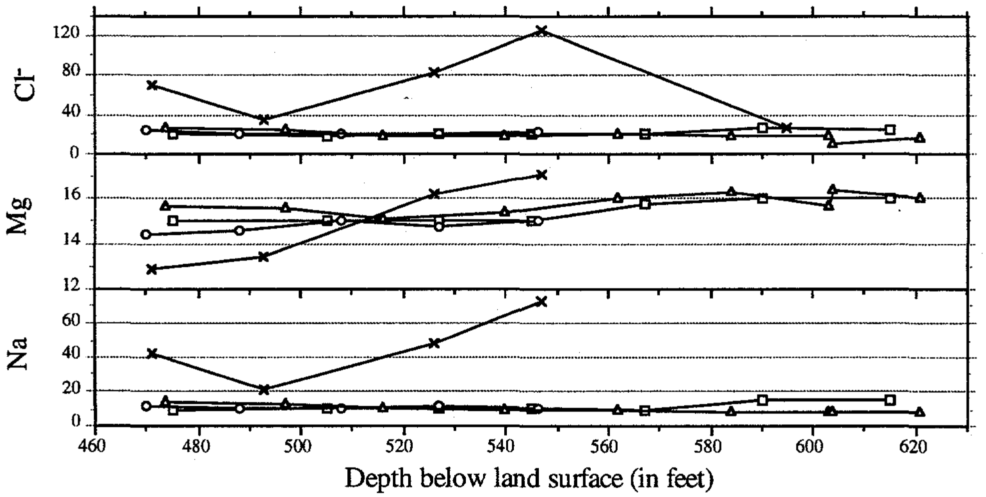


Figure 4b. Solute concentrations of Mg, Na, and Cl for well USGS-59 are contrasted with the same solutes from wells USGS-44, 45 and 46. Symbols are the same as in Figure 4a.

Several constituents (e.g., SiO_2 and Mg) exhibit vertical variations greater than would be expected from analytical uncertainties. Although trends are subtle, concentrations of both increase slightly with depth.

Zone 1, from 140 to 158 mbls, is distinguished by steep upward gradients in Na, Cl and NO_3. The upward gradients decrease systematically to the west (in projection) from the ICPP, from wells USGS-46 to -44. These variations are shown in Table 9 as concentration ratios. Nearest the ICPP (well 46) NO_3 increases by nearly a factor of 3.6, while Na and Cl increase upward by about 50%. These gradients decrease by about half at USGS-45, and are essentially flat at USGS-44. Little variation is exhibited by other constituents.

Zone1 concentration ratios

Component	USGS-44	USGS-45	USGS46
Na	0.90	1.1	1.5
Cl	1.00	1.2	1.5
N	0.96	1.3	3.6

Table 9. This table lists ratios of concentrations of Na, Cl and NO_2+ NO_3 as N between the top of Zone 1 and top of Zone 2 for INEL Wells 44-46.

Zone 3, from 175 meters to base in USGS-44 and from 180 meters to base in well USGS-46, is distinguished by step-wise increases and decreases in solution concentrations, and by a lack of positive correlations of nitrate, sodium, and chloride concentrations with distance to the ICPP. For example, Na decreases downward by about 20% in USGS-46 (to inferred background concentration), while it increases downward by 75% in USGS-44. Nitrate also increases downward in USGS-44, but decreases slightly with depth in USGS-46.

Several other constituents exhibit systematic patterns of variation, e.g., Ca decreases downward by 15% and 40% in USGS-44 and 46; SiO_2 increases downward by 20% in both wells.

Comparisons are made in Figure 4 between data gathered by the packer with analyses obtained sampling from the open-borehole with the U.S. Geological Survey dedicated submersible pump, and thief sampler. Thief, dedicated pump and uninflated packer samples yield analyses which are similar in some cases with analyses obtained from samples taken from the nearest packed-off intervals. The most significant exception occurs for well 46 in which a thief sample a yielded total-nitrogen concentration 70% higher than samples from either the USGS dedicated pump or nearest packed-off interval.

Thief samples were taken at widely separated time intervals (~1 year) from wells 44 and 45 to evaluate possible temporal variations in aquifer chemistry (Table 7). Although most data are similar within uncertainties associated with analytical and sampling errors, some significant differences were observed: 1. Na and Cl decrease by ~15% in USGS-44 (but not in USGS-45); 2. H-3 activity increases by ~200% in USGS-45. Interpretation of these data is complicated because we now have clear indications of vertical variations in aquifer chemistry which exceed these ranges. Variations in vertical flow rates (e.g., in response to production pumping cycles at the ICPP) could induce changes in borehole water chemistry at any particular depth by mixing from various levels, producing a possible artifact of the type observed. This is a serious limitation of open-borehole sampling methods near the ICPP.

Water quality analyses from USGS-59 overlap with those of USGS-44, 45 and 46 for most components (Fig 4a). Some trends also parallel those the of latter well. For example, Mg-concentration increases downhole by 33%. However, they are distinguished by higher concentrations of some analytes, in particular Na, Mg, and Cl (Figure 4b). In addition, in contrast to USGS-44, 45 and 46, Na and Cl-concentrations in USGS-59 do not increase systematically downhole. Both exhibit large, seemingly random fluctuations (over a factor of three) suggesting 1. that the well may be stratified vertically on a scale smaller than can be sampled with the straddle-packer, or 2. that the aquifer chemistry at USGS-59 fluctuates over time scales of less than a few months (i.e. the time it took to move the packer assembly between the 5 sampled intervals).

Trace Elements: Selected trace elements are listed in Table 10. Most appear to lack vertical gradients exhibited by some of the major elements. Sr and Ba are the dominant trace metals, having mean concentrations of ~310 and ~100 ppb, respectively. Cr concentrations average ~6 ppb. They exhibit little variation in wells USGS-44, 45, and 46, but are characterized by a strong systematic vertical decline in USGS-59, of from 8.3 to 4 ppb.

Radiological Activities:

Patterns among radiological constituents are similar to those of the major solutes, and even better define the proposed three-layer zonation in hydrochemistry. Only four radionuclides were consistently detected at concentrations above detection limits, in

Table 10. Selected Trace Element Analyses of Straddle Packer Samples for wells USGS-44, -45, -46 and -59[1]

Well Number	Sample Method	Sample Date	Sample Depth	Ba µg/L	Cr µg/L	Fe µg/L	Mn µg/L	Ni µg/L	Pb µg/L	Rb µg/L	Sc µg/L	Se µg/L	Sr µg/L	Zn µg/L
USGS-44	PP	8/14/92	467-482'	100	5.9	<10	<10	<10	<1			1.5	300	<2
USGS-44	PP	7/21/92	495-515'	100	5.7	10	<10	<10	<5			<5	305	<2
USGS-44	PP	8/18/92	519-534'	100	5.95	<10	<10	<10	<1			1.1	307	<2
USGS-44	PP	7/24/92	535-555'	102	6.2	<10	<10	<10	<1			<2	310	<2
USGS-44	PP	7/29/92	557-577'	105	5.8	<10	<10	<10	<1			1.4	315	<2
USGS-44	PP	8/3/92	580-600'	90	5.55	<10	<10	<10	<1			1.4	293	<2
USGS-44	OPI	7/30/92	580-649'	85	5.2	<10	<10	<10	<1			1.4	290	<2
USGS-45	PP	8/19/93	462-477'	94	6.9	<10	0.7	1.3	1.2	6.9	0.4	1.6	308	0.0
USGS-45	PP	8/17/93	480-495'	95	7.0	<10	0.8	1.1	1.8	6.9	0.5	1.8	304	0.5
USGS-45	PP	8/10/93	500-515'	92	6.9	<10	0.5	0.8	0.4	7.6	0.4	2.0	313	0.3
USGS-45	PP	8/6/93	519-534'	92	6.2	<10	1.2	1.5	0.6	7.1	0.4	1.9	328	0.3
USGS-45	PP	7/19/93	538-553'	95	6.0	<10	1.4	1.9	0.7	7.4	0.4	2.2	342	1.2
USGS-46	PP	9/13/93	464-483'	97	6.9	<10	0.3	0.6	0.6	5.3	0.4	2.0	292	<0.01
USGS-46	PP	9/16/93	488-506'	96	7.3	15	0.5	0.9	0.7	5.7	0.4	1.8	305	<0.01
USGS-46	PP	9/20/93	575-593'	94	8.5	<10	0.6	1.1	1.0	5.6	0.4	2.1	312	<0.01
USGS-46	PP	9/27/93	507-525'	96	8.4	10	0.8	1.3	1.3	5.9	0.4	1.9	322	0.06
USGS-46	PP	9/29/93	531-549'	92	8.6	10	0.6	0.7	0.8	5.8	0.4	1.7	305	<0.01
USGS-46	PP	10/1/93	553-571'	94	7.4	10	0.4	0.7	0.9	5.6	0.4	1.5	289	<0.01
USGS-46	PP	10/20/93	594-612'	87	9.8	<10	1.8	2.9	1.5	5.6	0.5	2.1	305	7.9
USGS-46	PP	11/30/93	595-613'	77	5.1	40	22	11.0	0.9	9.3	0.5	1.7	257	7.0
USGS-46	PP	11/17/93	612-629'	74	5.3	<10	2.3	6.0	0.6	10.3	0.5	1.5	208	6.5
USGS 59	PP	6/29/94	462-480'	127	8.3	65	5.6	6.0	<5	<40	<2	<5	318	29
USGS 59	PP	7/6/94	484-502'	103	6.0	13	<2	5.5	<30	<40	<2		260	<20
USGS 59	PP	8/1/94	517-535'	136	4.5	4	<2	<5	<30	44.5	<2		274	<20
USGS 59	PP	8/4/94	538-651'	177	4	11	<2	<5	<30	44	<2		305	<20

1. Symbols are the same as in Table 1.

Table 11. Sr-90, H-3, I-129 and Cl-36 Analyses[1]

Well Number	Sample Method	Sample Date	Sample Depth	Sr-90 pCi/L	H-3 pCi/L ±100*	I-129 pCi/L	Cl-36 pCi/L
USGS-44	DP	7/1/92	499'	3.6±0.5	500		
USGS-44	TS	7/10/92	500'		1,100		
USGS-44	TS	10/4/93	505'	5.2±0.7	900		
USGS-44	UIP	8/13/92	499'	7.9±0.9	950		
USGS-45	DP	7/1/92	503'	16.9±0.8	1,100		
USGS-45	DP	6/2/93	499'		1,600		
USGS-45	TS	7/10/92	500'	1±1	800		
USGS-45	TS	6/17/93	500'		2,700		0.16±0.01
USGS-45	UP	7/8/93	500'	3.7±0.3	1,700		0.085±0.008
USGS-46	DP	7/1/92	502'	17.8±0.8	3,100		
USGS-46	TS	7/10/92	500'	13.1±1.2	4,000		
USGS-44	PP	8/14/92	467-482'	9.8±1.0	1,300	0.23±0.01	0.041±0.002
USGS-44	PP	7/20/92	495-515'	8.8±1.0	500	0.212±0.01	0.026±0.002
USGS-44	PP	8/18/92	519-534'	8.5±1.1	750	0.257±0.01	0.06±0.003
USGS-44	PP	7/24/92	535-555'	5.5±0.6	350	0.132±0.004	0.019±0.001
USGS-44	PP	8/3/92	580-600'	4.3±0.8	7,250	0.97±0.02	0.45±0.01
USGS-44	OPI	7/30/92	580-649'	6.1±0.8	6,500	0.87±0.02	0.26±0.04
USGS-45	PP	8/19/93	462-477'	3.7±0.7	4,500	0.55±0.02	0.29±0.01
USGS-45	PP	8/17/93	480-495'	2.7±0.4	3,000		0.22±0.01
USGS-45	PP	8/10/93	500-515'	2.4±0.6	2,700	0.44±0.02	0.17±0.01
USGS-45	PP	8/6/93	519-534'	3.5±0.6	3,200	0.59±0.02	0.16±0.01
USGS-45	PP	7/15/93	538-553'	4.9±0.7	1,700	0.32±0.01	0.083±-.005
USGS-46	PP	9/13/93	464-483'	0.22±0.01	8000±200	0.528±0.01	0.65±0.02
USGS-46	PP	9/16/93	488-506'	0.17±0.01		0.430±0.01	0.30±0.01
USGS-46	PP	9/20/93	575-593'	4.9±0.7	1,300	0.088±0.003	0.053±0.002
USGS-46	PP	9/27/93	507-525'	8.6±0.9	2,500	0.40±0.01	0.12±0.003
USGS-46	PP	9/29/93	531-549'	6.5±0.7	3,200	0.315±0.01	0.115±0.005
USGS-46	PP	10/1/93	553-571'	8.9±0.8	2,000	0.161±0.004	0.093±0.003
USGS-46	PP	10/20/93	594-612'	7.5±0.7	1,400	0.139±0.004	
USGS-46	PP	11/30/93	595-613'	1.4±0.9	900	0.083±0.003	0.052±0.002
USGS-46	PP	10/29/93	612-629'	0.8±0.5	4,900	0.105±0.003	0.150±0.004
USGS-59	PP	6/23/94	462-480'	14±2	13000±300		
USGS-59	PP	7/6/94	484-502'	12±2	3600±300		
USGS-59	PP	7/11/94	517-535'	12±2	3900±300		
USGS-59	PP	8/4/94	538-556'	10±2	6200±240		
USGS-59	PP	8/22/94	538-651'	11±1	2700±290		
SITE 14	TS	10/15/93	707'		<400		
SITE 14	TS	10/15/93	707'	0.5±0.4			
SITE 14	TS	10/15/93	707'			<0.00001	
SITE 14	TS	10/6/93	375'		300		
SITE 14	TS	10/6/93	375'	0.4±0.4			
SITE 14	TS	10/6/93	375'				
SITE 14	TS	10/6/93	375'			0.00065±0.00001	
ANL #1	TS	1/24/95	1811'	0.2±0.8	3600±500		
ANL #1	TS	1/27/95	930'	1.1±0.9	3500±500		
ANL #1	TS	1/27/95	1020'	0.4±0.8	3500±500		
ANL #1	TS	3/3/95	720'	0.6±1	3600±500		

[1] Symbols and abbreviations are the same as for Table 1.

* The 2σ measurement uncertainties for H-3 are 100pCi/L unless otherwise noted.

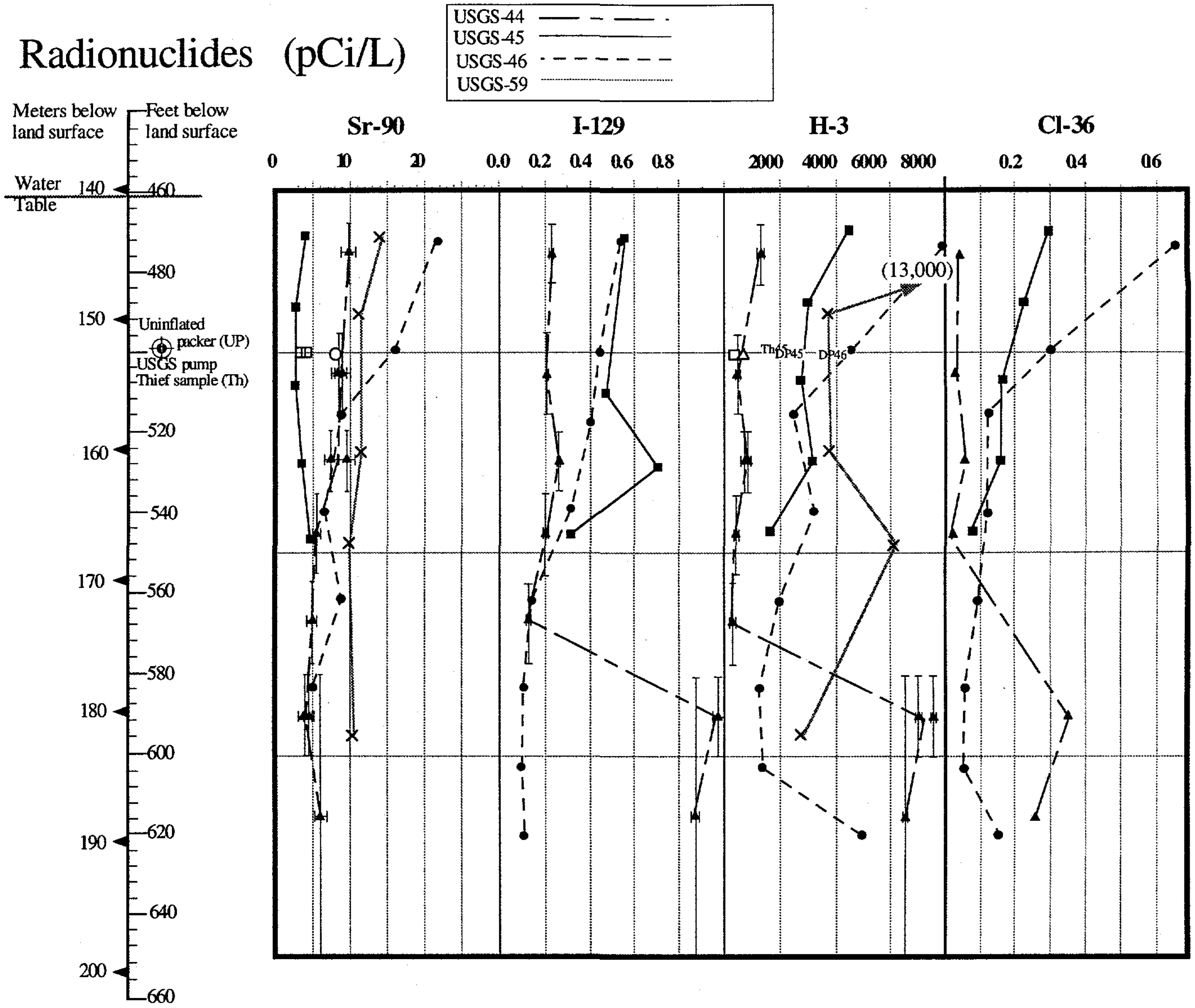


Figure 5. Plots of H-3, I-129 and Sr-90 vrs. depth for wells USGS-44 through 46 and 59. Units are in pCi/L. Thief (TS) and U.S. Geological Survey open-hole submersible pumps sample (DP) analyses also plotted for comparison as follows: Open square, circle and triangle - USGS pump, uninflated packer and thief sampler, respectively for Well #44; Th45 and DP45, DP46 - thief and dedicated pump analyses for wells 45 and 46 (analyses plot at center of symbols).

decreasing order of activity: H-3 >> Sr-90 > I-129 ≈ Cl-36. These data are listed in Table 11, and are plotted in Figure 5. Zone boundaries occur at the same depths as previously described for the major solutes.

Zone 2 is characterized by little vertical variation in radiological concentrations. However, in contrast to the major solutes, there is a systematic decline in activities of H-3, and possibly Sr-90, away from the ICPP. The pattern is best demonstrated by H-3; concentrations decline from about 2500 pCi/L in USGS-46 to approximately 500 pCi/L in USGS-44.

Strontium-90 may also decrease slightly away from the ICPP. The Sr-90 data are complicated by a cross-over of USGS-44 and 45 data near the top of Zone 2. However, we interpret this as a result of disturbance of the well rather than reflecting changes in formation chemistry. Note that thief and dedicated pump (U.S. Geological Survey) samples taken shortly before installing the packer into the well, are much lower than those obtained by the packer. We tentatively suggest that the "anomalously" high Sr-90 data from the packer samples is a result of detachment of particles from near the borehole (because of disturbance to the formation by pumping from the confined interval), which had adsorbed Sr-90 during peak periods of plume activity, effectively doubling the actual aquifer Sr-90 activity.

Zone 1 is characterized by steep upward increasing gradients in H-3, Sr-90, and Cl-36 activites. I-129 also increases upwards, but at a lower rate, and does not exhibit the rather sharp change in slope of activities characterizing the other isotopes. The breaks in activity occur at the same depth as described above for some major solutes. They also exhibit a decline in gradient in westward projection from the ICPP, to the flat "background" of Zone 2. Maximum H-3 concentrations decrease from 8000 pCi/L (USGS-46), to 4500 pCi/L (USGS-45), to 1300 pCi/L (USGS-44). Maximum Sr-90 concentrations decrease from 22 pCi/L (USGS-46) to ~4 pCi/L (USGS-45). Sr-90 concentrations in Zone 1 from USGS-44 are complicated for the same reasons stated above for Zone 2. However, thief and U.S. Geological Survey pump data suggest that it is approximately the same as for USGS-45.

In contrast to Zone 1, Zone 3 is distinguished by a prominent step-wise increase in both H-3 and I-129. The increases are by about a factor of 10 in H-3 activity for USGS-44, and are more modest (~5X) for USGS-46. I-129/H-3 activity ratios decrease downward from Zone 2 to Zone 3 from ~4 to $1.3x10^{-3}$—similar to the transition to Zone 1. Sr-90 exhibits no change from Zone 2.

Three salient aspects of these preliminary data are that: 1. the vertical patterns of nonconservative (Sr-90) and conservative (H-3, I-129) radionuclides activities are decoupled; 2. I-129 activites are partially decoupled from Cl-36 and H-3 activities (indicating a possible mixing process; McCurry, et. al., 1994); 3. activities of radionuclides exhibit a clear three-dimensional complexity - vertical variations are at least as great as horizontal variations at the scale examined.

Radiological activities of H-3 and Sr-90 were measured in USGS-59 (Figure 5). H-3, and to a lesser extent, Sr-90 exhibit vertical declines similar to that of USGS-45 and 46. H-3 also exhibits the 3-layered pattern exhibited by USGS-45 and 46. However, H-3 concentration is much higher in the upper part of the aquifer (13,000 pCi/L).

Other Radiological Analyses: Isotopes of Co-, Pu- and U, as well as gross α, β and γ, are listed in Table 12. Most of these measurements were near or below detection limits. As expected, β-activities correlate with H-3 and Sr-90 activites. One interval from near the base of USGS-46 (593-613') yielded significant activities of Pu-238, Pu-239/240, and U-235, of 1.23, 4.29 and 0.57 pCi/L, respectively (all approximately 5-10 times detection limits). However, these relatively high activites were not recorded in the sampling of an overlapping interval from the same well which was sampled one month earlier (Table 12).

Stable Isotope Ratios:

Ratios for $\delta^{18}0$, $\delta^{13}C$, and δD are listed in Table 13. Wells 44, 45, 46 and 59 exhibit little vertical or lateral variations, and are typical of the eastern Snake River Plain Aquifer. $\delta^{18}0$ averages about -17.9 per mil, $\delta^{13}C$ about -10 per mil, and δD about -137 per mil.

Field Measurements:

Field measurements are summarized in Table 14. As previously stated, significant scatter occurs in these data primarily owing to unfavorable laboratory conditions. In the following we summarize and present some interpretations of these data.

Flow cell temperatures are about 12.5°C for the upper sampled intervals, increasing step wise by about 1.5°C for the bottom two. These temperatures are well above previous measurements from this well (approximately 11°C), and are interpreted as being anomalously high relative to original aquifer temperature because of heating between the aquifer and flow cell due to the sampling pump. Although the change in temperature correlates in depth with changes in water chemistry, this change could be an artifact of greater surface heating rather than actual aquifer characteristics.

Table 12. Co-, Pu-, U- and α, β, γ radiological analyses[1]

Well Number	Sample Method	Sample Date	Sample Depth	gross α pCi/L $\pm 2\sigma$	gross β pCi/L $\pm 2\sigma$	gross γ pCi/L $\pm 2\sigma$	Co-60 pCi/L	Pu-238 pCi/L$\pm 2\sigma$	Pu-239/40 pCi/L$\pm 2\sigma$	U-235 pCi/L$\pm 2\sigma$
USGS-44	DP	7/1/92	499'	<1.20	16±2	<1.95		<0.03	<0.03	
USGS-44	TS	7/10/92	500'	<1.50	19±2	1.2±1.3		<0.05	<0.12	
USGS-44	TS	10/4/93	505'							
USGS-44	UIP	8/13/92	499'	<1.20	9±2	1.2±1.2		<0.14	<0.03	
USGS-45	DP	7/1/92	503'	<1.05	7±2	0.1±1.3		<0.05	<0.03	
USGS-45	DP	6/2/93	499'	<1.5	11±2	<1.95	1.2±1.2	0.005±0.024	0.005±0.02	
USGS-45	TS	7/10/92	500'	<1.35	11±2	<1.95		<0.08	<0.03	
USGS-45	TS	6/17/93	500'	1±1	10±2	<1.95	0.9±1.2	0.005±0.027	0.005±0.02	
USGS-45	UP	7/8/93	500'	<1.50	8±2	<1.80	<1.80	0.005±0.024	0.03±0.04	
USGS-46	DP	7/1/92	502'	<1.20	24±2	5.5±1.5		<0.05	<0.03	
USGS-46	TS	7/10/92	500'	<1.20	54±2	6.6±1.8		<0.18	<0.14	
USGS-44	PP	8/14/92	467-482'	<1.35	15±2	0.6±1.2		<0.05	0.2±0.8	
USGS-44	PP	7/20/92	495-515'	<1.20	15±2	<1.80		<0.05	<0.03	
USGS-44	PP	8/18/92	519-534'	1±1	6±2	1.0±1.1		<0.05	<0.05	
USGS-44	PP	7/24/92	535-555'	<0.90	9±2	0.5±1.2		<0.03	0.07±0.03	
USGS-44	PP	8/3/92	580-600'	<1.05	10±2	0.3±1.2		<0.17	0.5±0.3	
USGS-44	OPI	7/30/92	580-649'	1.0±0.9	7±2	1.7±1.2		<0.11	0.8±0.3	
USGS-45	PP	8/19/93	462-477'	1±1	6±2	0.5±1.3	2.1±1.2	0.007±0.034	0.007±0.03	0.02±0.04
USGS-45	PP	8/17/93	480-495'	1±1	8±2	<1.80	0.5±1.3	0.007±0.035	0.007±0.04	0.007±0.04
USGS-45	PP	8/10/93	500-515'	<1.50	4±2	<1.80	0.5±1.3	0.006±0.032	0.013±0.04	0.007±0.03
USGS-45	PP	8/6/93	519-534'	4±2	13±3	2±1.3	2±1.1	0.008±0.038	0.0080±04	0.007±0.03
USGS-45	PP	7/15/93	538-553'	<1.50	11±2	<1.95	0.8±1.1	0.006±0.032	0.0060±03	0.007±0.03
USGS-46	PP	9/13/93	464-483'	3±2	55±2	1.2±1.3	3.9±1.4	<0.12	<0.11	0.13±0.03
USGS-46	PP	9/16/93	488-506'	3±2	46±2	2.7±1.5		<0.06	<0.06	0.2±0.05
USGS-46	PP	9/20/93	575-593'	2±2	14±2	0.4±1.1	<1.6	<0.27	<0.20	2±0.5
USGS-46	PP	9/27/93	507-525'	1±1	21±1	3.5±1.4	0.6±1.3	<0.09	0.45±0.1	
USGS-46	PP	9/29/93	531-549'	1±2	3±3	1.9±1.4	0.4±1.3	<0.11	<0.21	1.6±0.3
USGS-46	PP	10/1/93	553-571'	3±2	24±3	<1.95	0.6±1.3	<0.08	<0.06	0.57±0.1
USGS-46	PP	10/20/93	594-612'	3±2	11±3	1±1.2	0.1±1.3	<0.45		0.34±0.05
USGS-46	PP	11/30/93	595-613'	1±1	8±3	0.5±1.3	1.7±1.3	1.23±0.54	4.29±0.74	0.57±0.05
USGS-46	PP	10/29/93	612-629'	3±1	5±3	3±1.5	1.5±1.3	<0.03	0.3±0.1	
USGS-59	PP	6/23/94	462-480'			1.8±3		0.008±0.081	0.000±08	0.03±0.1
USGS-59	PP	7/6/94	484-502'			<0.3		0.072±0.188	0.014±0.1	0.061±0.2
USGS-59	PP	7/11/94	517-535'	2±3	27±3	1.1±2.9		0.008±0.079	0.008±0.08	0.008±0.08
USGS-59	PP	8/4/94	538-556'	4±6	31±3	<4.20		0.008±0.075	0.008±0.08	0.008±0.08
USGS-59	PP	8/22/94	538-651'	2±3	28±3			0.008±0.075	0.008±0.08	0.008±0.08

1. Symbols and abbreviations are the same as for Table 1.

Table 13. Stable Isotope Ratios[1]

Well	Method Sampled[2]	Date Sampled	Depth Sampled	$\delta^{18}O$ ‰	$\delta^{13}C$ ‰	δD ‰
USGS-44	PP	7/20/92	495-515'	-17.99	-10.26	-135.5
USGS-44	PP	8/18/92	519-534'	-17.87	-9.80	-136.8
USGS-44	PP	7/24/92	535-555'	-18.07	-10.04	-136.7
USGS-44	PP	7/28/92	557-577'	-17.89	-10.18	-137.7
USGS-44	PP	8/14/92	467-482'	-17.86	-9.90	-135.3
USGS-44	PP	8/3/92	580-600'	-18.05	-10.49	-136.2
USGS-44	PP	8/3/92	580-600'	-18.06	-10.58	-135.9
USGS-44	OPI	7/30/92	580-641'	-18.04	-10.38	-136.7
USGS-45	PP	7/15/93	538-553'	-18.00	-10.30	-134.0
USGS-45	PP	8/6/93	519-534'	-17.80	-10.00	-136.0
USGS-45	PP	8/10/93	500-515'	-17.80	-9.40	-136.0
USGS-45	PP	8/17/93	480-495'	-17.90	-10.00	-137.0
USGS-45	PP	8/19/93	462-477'	-17.80	-9.90	-138.5
USGS-46	PP	9/13/93	464-483'	-17.70		-137.0
USGS-46	PP	9/16/93	488-506'	-17.45	-10.20	-138.0
USGS-46	PP	9/27/93	507-525'	-17.80	-10.00	-137.0
USGS-46	PP	9/29/93	531-549'	-17.70	-10.00	-138.0
USGS-46	PP	10/1/93	553-571'	-17.80	-9.30	-138.0
USGS-46	PP	9/20/93	575-593'	-17.70	-10.00	-138.0
USGS-46	PP	10/20/93	594-612'	-17.70	-9.90	-137.0
USGS-46	PP[3]	11/30/93	595-613'	-17.80	-10.30	-141.0
USGS-46	PP	10/29/93	612-629'	-18.05	-10.15	-140.5
USGS-46	PP[3]	11/17/93	612-629'	-17.90	-10.30	-141.0
SITE 14	TS	10/6/93	375'	-17.80	-8.20	-137.0
SITE 14	TS	10/15/93	707'	-17.70	-10.80	-138.0

1. Estimated uncertainties: $\delta^{18}O$ and $\delta^{13}C$ = 0.1‰ (absolute); δD = 1‰ (absolute).
2. Symbols are the same as in Table 1.
3. N_2 purge sampling method.

Table 14. Field Lab Measurements

Well Number	Sample Method	Sample Date	Sample Depth	Flow Cell[1] pH	Flow Cell Spec. Cond. µmhos/cm	Flow Cell DO[2] mg/L	Flow Cell Eh mV	Flow Cell Temp celsius	Flow Cell pH temp celsius	Flow Cell SC temp celsius	Alkalinity[3] as CaCO3 mg/L	Filtered Ferrous Iron[4] mg/L	Filtered Total Iron[4] mg/L	Nonfiltered Ferrous Iron[4] mg/L	Nonfiltered Total Iron[4] mg/L	DO[5] mg/L
USGS-44	UIP	8/13/92	499'	7.4	435	8.5	199	13.3			180	0.006	0.023		0.025	
USGS-45	DP	6/2/93	499'	8.0	451		314		12.8	11.9						
USGS-45	UIP	7/8/93	500'	7.9	429		306		12.8	12.5						8.0
USGS-44	PP	8/14/92	467-482'	7.6	[725][6]	9.7	261	14.4			205		0.014		0.025	
USGS-44	PP	7/21/92	495-515'	7.7	436.5	10.0	249.0	12.5			190	0.001			0.015	
USGS-44	PP	8/18/92	519-534'	7.6	[541]	9.0	293	13.8				0.004	0.025		0.025	
USGS-44	PP	7/24/92	535-555'	7.7	447	9.9	241	14.0			150	0.005	0.027		0.028	
USGS-44	PP	7/28/92	557-577'	7.8	506	9.2	294	13.5			215	0.001	0.017		0.019	
USGS-44	PP	8/3/92	580-600'	7.7	[737]	9.6	184	[18.3]			175	0.002	0.014		0.015	
USGS-44	OPI	7/30/92	580-649'	8.2	462	10.3	245	13.7			210	0.004	0.023		0.026	
USGS-45	PP	8/19/93	462-477'	7.7	446	9.4	158		14.4	14.1	147			0.022	0.122	7.5
USGS-45	PP	8/17/93	480-495'	7.7	430	8.6	165		14.2	13.5				0.012	0.029	
USGS-45	PP	8/10/93	500-515'	7.8	435	9.6			13.8	12.8			0.015	0.024	0.118	7.4
USGS-45	PP	8/6/93	519-534'	7.7	442		268		13.9	13.8						7.0
USGS-45	PP	7/16/93	538-553'	8.0	426		249		13.4	12.8				0.017	0.031	8.6
USGS-46	PP	9/13/93	464-483'	7.7	490		248		13.2	12.5	[164]					8.3
USGS-46	PP	9/16/93	488-506'	7.8	479		222		14.6	13.9	166		0.024	0.003	0.026	8.6
USGS-46	PP	9/27/93	507-525'	7.9	455		[180]		13.9	13.2	164		0.019	0.004	0.038	8.3
USGS-46	PP	9/29/93	531-549'	7.8	447		[213]		12.6	12.3	165			0.001	0.019	8.2
USGS-46	PP	10/1/93	553-571'	7.7	468		153		12.9	12.5	163			0.011	0.024	8.1
USGS-46	PP	9/20/93	575-593'	7.9	449	6.6	221		14.1				0.017	0.002	0.078	8.2
USGS-46	PP	10/20/93	594-612'	7.9	475				12.6	11.9	170		0.009	0.007	0.065	7.9
USGS-46	PP	10/29/93	612-629'	8.0	414				10.1	11.3	137.7					6.8
USGS-46	PP	6/23/94	462-480'	7.9	560	[6.74]	225		18.1	17.6	139		0.026	0.003	0.024	
USGS-59	PP	7/6/94	484-502'	7.8	540		134		16.4	16.3	152			[0.004]	0.004	
USGS-59	PP	7/11/94	517-535'			[8.30]							[0.035]	[0.013]	[0.023]	
USGS-59	PP	8/4/94	538-556'	7.8	[868]		240		14.8	14.3	[158]		[0.035]	[0.011]	0.024	7.3
USGS-59	PP	8/22/94	538-651'	8.0	[526]		70		14.2	13.7	156		0.03	[0.010]	0.022	[7.7]

1. Flow cell measurements were made by pumping water directly from the well head through an enclosed vessel into which were inserted a variety of probes (as listed).
2. Determined by potentiometric methods with probe inserted into flow cell.
3. Determined in the field lab by sulfuric acid titration.
4. Determined in the field lab which a Hach spectrophotometer.
5. Determined in the field by titration.
6. Brackets indicate values which are considered potentially unreliable or semiquantitative because of analytical problems such as excess drift during the respective analyses.

Specific conductivity exhibits no significant variability in wells 44, 45 and 46, averaging about 450 µmhos/cm. However, conductivities in USGS-59 are considerably higher, averaging about 550 µmhos/cm. These data correlate with significant increases in Na, K, Cl and SO4 in USGS-59 relative to the other wells.

Values for pH average about 7.9. No statistically significant variations were observed.

Measurements of alkalinity, Fe^{2+}, Fe_T and Eh exhibit significant scatter. Eh averages about 250 mV in USGS-44, yielding 80 to 98% of air saturation oxidation potential. Given the problems of bubbling within the flow cell, and electrode calibration problems, we interpret these data as indicating the aquifer is near or at oxygen saturation (consistent with measured dissolved oxygen concentration of 9 to 10 ppm). USGS-45, -46 and -59 are similar.

Alkalinity measurements vary from 150 to 200 ppm (alkalinity expressed as calcium carbonate). There is little systematic trend in the data with respect to depth, except for USGS-44 and -46, which exhibit strong decreases in alkalinity near the bottom of the wells. These decreases correlate with similar decreases in Ca contents at the same depths.

Finally, total iron concentrations on unfiltered samples vary from about 4 to 122 ppb. These concentrations are generally similar to slightly higher than those measured on filtered samples, 10 to 30 ppb. The difference is likely related to the presence of ≥ 0.45 micron iron-bearing particles in the ground water. Low ratios of ferrous to total iron indicate most of the iron is in the ferric oxidation state, consistent with the high Eh and DO contents of the waters.

VOC's and BNA's:

Few VOC's, and no BNA's, were detected in the sampled wells. A trace of toluene was detected at intervals between 495 and 555 feet in USGS-44. A maximum concentration of about 2 ppb occurs just below the location of the USGS submersible pump. However, the fact that the high concentration occurs near the location of the dedicated pump, that there are no appropriate confining layers, and that the toluene anomaly does not correlate with any other feature of water chemistry suggests it is probably an artifact of contamination. Secondly, there is a record of 3.7 ppb 1,2,3-trichlorobenzene from the 557-577 foot interval. This is an isolated occurrence, and without additional confirmation we do not conclude that it is an aquifer signature.

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APPENDIX 1. COMPREHENSIVE DATABASE

The comprehensive database includes all measured geochemical parameters gathered during this study. Because of its length, it is included on an enclosed DOS-fomatted disk, as an Microsoft© Excel 5 spreadsheet.

APPENDIX 2. EPA ANALYTICAL METHODS FOR STATE LAB

Inorganic Parameters (specific) - to be Analyzed by State Lab

Parameter	Analytical Method EPA # (unless noted)	MRVRequired * ug/L	MCL ug/L	
Metals				
Arsenic	206.2	10	12	
Barium	208.1	100	100	
Beryllium	210.1	2	5	
Cadmium	213.2	1	2	
Calcium	215.1	100	1000	
Chromium	218.2	2	2	
Copper	220.1	10	12	
Iron	236.1	10	20	
Lead	239.2	5	5	
Magnesium	242.1	100	1000	
Manganese	243.1	10	15	
Mercury	245.1	0.5	1	
Nickel	249.2	10	15	
Potassium	258.1	100	1000	
Selenium	270.2	5	10	
Silver	272.2	1	5	
Sodium	273.1	100	1000	
Strontium	***	1	2	
Zinc	289.1	2	2	
Anions, Other (mg/L)				
Sp. Conductance (µmhos/cm)	120.1	0.5	200	NA
Hardness as $CaCO_3$	130.2	4	100	NA
Total Alkalinity as $CaCO_3$	310.1	1	100	NA
Silica	370.1	10	3000	NA
Boron	212.3	5	10	NA
Chloride	325.3	0.9	5	250
Fluoride	340.2,340.3	0.01	0.1	2
Bromide	**			
Sulfate	375.4	5	10	250

* Minimum Reportable Values
** Ion Specific Electrode measurement
*** Proprietary method, Perkins-Elmer Co.

Parameter	Analytical Method EPA #	MRV * mg/L	Required Sensitivity mg/L	MCL mg/L
Nutrients				
Total Nitrate plus Nitrite as N	353.2	0.005	1	10
Total Kjeldahl N as N	351.1	0.05	1	NA
Total P as P	365.2,365.4	.005,.05	1	NA
Miscellaneous				
Total Dissolved Solids (TDS)	160.3	1.0	50	500

* Minimum Reportable Values

Base/Neutral and Acid Methylene Chloride Extractable Semi-Volatile Organic Compounds (BNA) - EPA Method 625

NOTE: MCLs do not exist for these parameters and Required Sensitivity is twice the MDL for a given species.

From FR / Vol.49, No.209 / Friday, October 26, 1984 / Rules and Regulations / pages 43390-43391.

Base/Neutral Extractables	Detection Limit (ug/L)	MethodCAS # CAS #
Acenaphthene	1.9	83-32-9
Acenaphthylene	3.5	208-96-8
Aldrin	1.9	309-00-2
Anthracene	1.9	120-12-7
Benzo(a)anthracene	7.8	56-55-3
Benzo(b)fluoranthene	4.8	205-99-2
Benzo(k)fluoranthene	2.5	207-08-9
Benzo(ghi)perylene	4.1	191-24-2
Benzo(a)pyrene	2.5	50-32-8
Benzyl butyl phthalate	2.5	85-68-7
_ BHC	4.2	319-85-
_ BHC	3.1	319-86-8
Bis(2-chloreothoxy)methane	5.3	111-91-1
Bis(2-chloreothyl)ether	5.7	111-44-4
Bis(2-chloroisopropyl)ether	5.7	108-60-1
Bis(2-ethylhexyl)phthalate	2.5	117-81-7
4-Bromophenyl phenyl ether	1.9	101-55-3
Chlordane	57-74-9	
2-Chloronaphthalene	1.9	91-58-7
4-Chlorophenyl phenyl ether	4.2	7005-72-3
Chrysene	2.5	218-01-9
4,4'-DDD	2.8	72-54-8
4,4'-DDE	5.6	72-55-9
4,4'-DDT	4.7	50-29-3
Dibenzo(a,h)anthracene	2.5	53-70-3
Dibutylphthalate	2.5	84-74-2
1,2-Dichlorobenzene	1.9	95-50-1
1,3-Dichlorobenzene	1.9	541-73-1
1,4-Dichlorobenzene	4.4	106-46-7
3,3'-Dichlorobenzidine	16.5	91-94-1
Dieldrin	2.5	60-57-1
Diethyl phthalate	1.6	84-66-2
Dimethyl phthalate	1.6	131-11-3
2,4-Dinitrotoluene	5.7	121-14-2
2,6-Dinitrotoluene	1.9	606-20-2
Di-n-octylphthalate	2.5	117-84-0
Endosulfan sulfate	5.6	1031-07-8
Endrin aldehyde		7421-93-4
Fluoranthene	2.2	206-44-0
Fluorene	1.9	86-73-7
Heptachlor	1.9	76-44-8
Heptachlor epoxide	2.2	1024-57-3
Hexachlorobenzene	1.9	118-74-1
Hexachlorobutadiene	0.9	87-68-3

Hexachloroethane	1.6	67-72-1
Indeno(1,2,3-c,d)pyrene	3.7	193-39-5
Isophorone	2.2	78-59-1
Naphthalene	1.6	91-20-3
Nitrobenzene	1.9	98-95-3
n-Nitrosodi-n-propylamine		621-64-7
PCB-1016		12674-11-2
PCB-1221	30	11104-28-2
PCB-1232		11141-16-5
PCB-1242		53469-21-9
PCB-1248		12672-29-6
PCB-1254	36	11097-69-1
PCB-1260		11096-82-5
Phenanthrene	5.4	85-01-8
Pyrene	1.9	129-00-0
Toxaphene		8001-35-2
1,2,4-Trichlorobenzene	1.9	120-82-1
4-Chloro-3-methylphenol	3.0	59-50-7
2-Chlorophenol	3.3	95-57-8
2,4-Dichlorophenol	2.7	120-83-2
2,4-Dimethylphenol	2.7	105-67-9
2,4-Dinitrophenol	42	51-28-5
2-Methyl-4,6-Dinitrophenol	24	534-52-1
2-Nitrophenol	3.6	88-75-5
4-Nitrophenol	2.4	100-02-7
Pentachlorophenol	3.6	87-86-5
Phenol	1.5	108-95-2
2,4,6-Trichlorophenol	2.7	88-06-2

Volatile Organic Compounds (VOCs), EPA Method 502.2

Species	MDL	Required Sensitivity	MCL
	ug/L	ug/L	ug/L
Trihalomethanes (THM) (total THMs) 100 100			
Bromodichloromethane	.16*	1	--
Bromoform	.20*	1	--
Dibromochloromethane	.11*	1	--
Chloroform	.10*	1	--
Regulated			
Vinal Chloride	.52*	1	2
1,1,1-Trichloroethane	.12*	1	200
Benzene	.10*	1	5
Trichloroethene	.16*	1	5
1,1-Dichloroethene	.26*	1	7
Carbon Tetrachloride	.17*	1	5
1,2-Dichloroethane	.12*	1	5
1,4-Dichlorbenzene	.21*	1	75
Unregulated			
Bromobenzene	.14*	1	--
Bromochloromethane	.01	1	--
Bromomethane	.19	1	--
n-Butylbenzene	.14*	1	--
sec-Butylbenzene	.16*	1	--
tert-Butylbenzene	.16*	1	--
Chlorobenzene	.09*	1	--
Chloroethane	.13	1	--
Chloromethane	.10	1	--
2-Chlorotoluene	.04	1	--
4-Chlorotoluene	.07	1	--
1,2-Dibromo-3-Chloropropane	.20	1	--
1,2-Dibromoethane	.17	1	--
Dibromoethane	.07	1	--
1,2-Dichlorobenzene	.17*	1	600
1,3-Dichlorobenzene	.19*	1	--
Dichlorodifluoromethane	.29	1	--
1,1-Dichloroethane	.12*	1	
cis-1,2-Dichloroethene	.05	1	70
trans-1,2-Dichloroethene	.17*	1	100
1,2-Dichloropropane	.12*	1	5
1,3-Dichloropropane	.02	1	--
2,2-Dichloropropane	ND	1	--
,1-Dichloropropene	.05	1	--
-1,3-dichloropropene	.05*	1	--
trans-1,3-dichloropropene	.20*	1	--
Benzene	.09*	1	700
Hexachlorobutadiene	.09	1	--
p-Isopropylbenzene	.14	1	--
p-Isopropyltoluene	.13	1	--
Methylene Chloride	.14*	1	--

Naphthalene	.05*	1	--
n-Propylbenzene	.15*	1	--
Styrene	.08*	1	00
,1,1,2-Tetrachloroethane	ND	1	--
1,1,2,2-Tetrachlorethane	.28	1	--
Toluene	.05*	1	1000
1,2,3-Trichlorobenzene	.06	1	--
1,2,4-Trichlorobenzene	.08	1	--
,1,2-Trichloroethane	.04	1	--
Trichlorofluoromethane	.34	1	--
1,2,3-Trichloropropane	.02	1	--
1,2,4-Trimethylbenzene	.10*	1	--
1,3,5-Trimethylbenzene	.11*	1	--
Xylenes (total xylene)			10,000
o-Xylene	.11*	1	--
m-Xylene	.11*	1	--
p-Xylene	.11*	1	--

* Determined by State Lab.

APPENDIX 3. FIELD ANALYTICAL EQUIPMENT AND METHODS

Wellhead Chemical Measurements and Field Analyses
(using wellhead flow cell, calibrated electrodes, and temperature- controlled buffers, except where noted)

Parameter	Analytical Method	MDL	Req.Sens.	MCL
Water				
Temperature	SM 2550	0.1°C	0.1°C	NA
pH	USGS (1976)	NA	NA	NA
Eh	USGS (1976)	NA	NA	NA
Specific conductance	EPA 120.1		10 mg/L	5 mg/L NA
Alkalinity	USGS (1976)	NA	NA	NA
Dissolved Oxygen*	USGS (1976), SM 4500-	0.05 mg/L O.G.	0.1 mg/L NA	
Ferrous iron**	SM 3500-Fe.D.	0.015mg/L	0.1 mg/L NA	

* membrane electrode in wellhead flow cell
** spectrophotometric method, field laboratory

FIELD EQUIPMENT:

Parameter Instrumentation
Method

pH, T Orion 290A Digital pH/mV/ORP Meter
Sensitivity --- +- 0.01 pH unit
Sensitivity --- +- 0.1°C

Eh Orion 290A Digital pH/mV/ORP Meter
Sensitivity --- +- 0.1 mv

DO Orion 290A Digital pH/mV/ORP Meter
Sensitivity --- +- 0.01 mg\L

Speific Conductance Cole-Parmer LED Digital
Conductivity/Temperature Meter
Sensitivity --- +- 0.1µMOHS

Br^- concentration Orion 290A Digital pH/mV/ORP Meter and
and Corning Ion-Specific Electrode
Sensitivity --- +- 1 mg\L

Ferrous iron Hach DR/3000 Spectrophotometer
Sensitivity --- +- 0.01 mg\L

Alkalinity Orion 290A Digital pH/mV/ORP Meter and
(titration) and Orion pH Electrode

Sensitivity --- +- 10 mg\L as CaCO3

APPENDIX 4. WELLHEAD MEASUREMENTS PROCEDURES

1. Perform Instrument Checks
   - conductivity meter ON, cell constant checked
   - Orion pH meter ON, battery check
   - disable auto-off, set to pH Mode
   - Orion D.O. meter ON, battery check
   - disable auto-off, set to pH Mode
   - Hach spectrophotometer ON, 15 minute warm-up
   - check instrument calibration

2. Calibration Preparations and Pre-calibrations
   - Conductivity and pH buffers equilibrated to at or near ground water temperature, and stored in cooler until needed
   - D.O. glass bottles thoroughly stirred with magnetic stirrer, to equilibrate with air at ambient temperature
   - pre-calibrate Br ISE electrode, linearity checked
   - if time permits, prepare 1 ppm iron standard solution and check spectrophotometer stored methods for ferrous and total iron, record readings

3. Tracer and Flow Cell Preparations
   - calculate required amount of LiBr for test interval
   - make up tracer solution and transfer to 1 liter injection flask
   - dilute 1 ml in 1000 ml and analyze Br concentration
   - connect 1 liter injection flask to MicroPump and prime inlet line
   - make preparations to connect MicroPump outlet line to reel of Tefzel injection line tubing in bus when injection line fills with water from below
   - make preparations to connect flow cell inlet to xmas tree at valved outlet
   - fill in pertinent data on flow cell test sheet

4. Calibrate Flow Cell Electrodes
   - Br ISE
   - conductivity
   - pH
   - dissolved oxygen
   - do these immediately prior to start of pumping

5. Connect Flow Cell, Fill and De-Air
   - remove and store caps from electrodes in flow cell <u>immediately</u> prior to filling of flow cell! (replace as soon as flow cell is emptied!)
   - divert flow to flow cell, fill flow cell in inverted position, and allow air bubbles to escape through exit port and/or through one of the electrode ports.

6. Inject LiBr Tracer Solution into Straddled Interval
   - APV valve set to divert part of pump discharge through Tracer Injection Line to surface
   - start submersible pump, fill Tracer Injection Line from bottom, displacing all air in reel, until entire line is air-free and flowing continuously
   - connect MicroPump outlet line to reel of Tracer Injection Line in bus
   - start MicroPump, force ca. 1 liter of concentrated LiBr tracer solution down Tracer Injection Line; stop pump when 95% of solution has been injected; flush with additional 500-1000 ml of D.I. water; pump an additional two reel volumes of D.I. water (10 gal) down injection line
   - reset APV valve position if necessary and proceed with pump test

7. Commence Flow Cell Measurements and Br Tracer Analyses
   - have someone record time, conductivity, pH, temperature and dissolved oxygen readings every minute or so, initially, decreasing to every 3-5 minutes as the test progresses
   - collect water samples at the main riser discharge every minute for the first 5 minutes, then at 2-3 minute intervals, starting as soon as the flow cell has been connected and de-aired, and analyze for Br (also, check standard drift)

8. Water Sampling
   - when $[Br]/[Br^o] < 0.05$, purging of interval volume is considered complete and water sampling can commence
   - continue flow cell measurements, if necessary, while water sampling
   - sample for iron, D.O. and alkalinity in 300 ml glass-stoppered bottles and ice samples immediately

9. Wellhead Chemical Measurements
   - within 1 hour of sampling for iron, analyze for ferrous and total iron as per SOP's
   - within 3 hours of sampling for alkalinity, titrate for alkalinity
   - titrate for D.O. before end of day or seal and ice samples and titrate first thing next morning

10. Shut-down, Storage and Data Archive
    - store equipment and electrodes as per SOP's
    - ensure that all electrodes are properly rinsed, capped with appropriate storage solutions and safely stowed
    - clean labware, rinse with D.I. water, air dry
    - check, collate all SOP/data sheets for flow cell and wellhead measurements, and staple into lab book

APPENDIX 5. FLOW CELL MEASUREMENTS - PROCEDURES

I. Specific Conductance
- use Cole Parmer meter and pencil probe
- calibrate probe for 25°C with 447 and 718 microS standards

II. pH and Temperature
- use triode pH probe and Orion meter
- maintain pH buffers within ca. 5 degrees of ground water temp.
- calibrate probe immediately prior to inserting probe in flowcell

III. Dissolved Oxygen
- use Orion oxygen probe and meter for real-time D.O. readings; collect samples for modified Winkler titration analysis of final, stabilized discharge
- calibrate in air at room temperature, and check water calibration against tabulated values by measuring air-saturated D.I. water, immediately prior to inserting in flow cell

IV. Redox Potential
- use Corning probe and Orion meter after D.O. measurements completed
- no calibration, but keep daily log of check readings of air-saturated D.I. water and temperature

APPENDIX 6. FIELD MEASUREMENTS FORMS

Analysis Date__________ Lab temp _____________ Well No/Interval___________
Sampling Time__________ Lab conditions________ Sampling conditions________

Wellhead Chemistry - Alkalinity

Power on meter ______

Disable auto-off feature _______
[press 2nd Setup, go to 1-4 (Yes), set to OFF (Scroll Up),press Measure]

Prepare 1.6 N H_2SO_4 cartridge pipettor, and fill in sample sheet (ie. sample ID, volume, acid concentration, initial pH)

Pipette 100 ml of sample into erlenmeyer flask, add stirring bar, and place on magnetic stirrer

Rinse, immerse pH electrode in sample, stabilize and record pH^o

Start magnetic stirrer, low-medium speed, with no splashing

Titrate sample with acid, initially at a rate of about $N_{clicks} = 20$ per acid increment, decreasing to 1 click per increment as pH drops below 5.0; use a smooth, repeatable, even increment of time between each acid addition, pH stabilization, reading and recording

Record for each acid increment: volume of acid added, in clicks (in ml = $N_{clicks}/800$), stabilized pH after acid addition

When pH < 3.8, stop titration, identify end-point near pH=4.3-4.6 by maximum dpH/dN_{clicks}, calculate total N_{clicks} added up to and end-point, and calculate alkalinity by:

$$\text{Alkalinity} = N_{clicks}/800 \times 16 \text{ (mequiv/l)}$$

where $N_{clicks}/800$ = total acid (ml) added, up to end-point

Comments:

Sample No.________________

Analyst _______________

Analysis Date__________ Lab temp _____________ Well No/Interval___________
Sampling Time__________ Lab conditions________ Sampling conditions________

ALKALINITY TITRATION

Sample Volume (ml) __________
Acid Normality _______________ Initial pH __________________

```
--------------------------------
 pH    Vacid    dpH/dVacid
--------------------------------
```

Total Vacid
to end-point _______,ml

Comments:

Sample No.________________

Analyst ______________

Analysis Date__________ Lab temp ____________ Well No/Interval___________
Sampling Time__________ Lab conditions________ Sampling conditions________

Wellhead Chemistry - Ferrous and Total Iron

Power on spectrophotometer, allow 15 minutes warm-up ________

Check instrument calibration daily (p. 1-8 of manual) _______

Follow stored-methods instructions for ferrous and total iron in manual; use one glass cell for blank; rinse sample cell with D.I. and sample water between each use

Measure ferrous iron in duplicate for sample: _________ ________
(check, reset zero concentration if necessary between each analysis)

Measure total iron in duplicate for sample: _________ _________
(check, reset zero concentration if necessary between each analysis)

Filter remaining sample and measure total iron in filtrate:______ ______
(check, reset zero concentration if necessary between each analysis)

After sample measurements completed, prepare 1 ppm Fe standard, by diluting 1 ml of Fe primary standard in 100 ml D.I. water

Measure ferrous iron for standard, using stored method: _________

Measure total iron for standard, using stored method: _________

If stored-method standard check differs from 1 ppm by more than 5%, repeat standard check

If still more than 5% difference, perform instrument calibration check (p. 1-8 in manual), record results in logbook

If calibration check normal, prepare new Fe standard, repeat stored-method calibration check

If 5% or more discrepancy remains, inform JW immediately so that a primary Fe standard check can be made up for next day.

Comments (calibration problems, dust, temperature problems, etc.):

Sample No.________________

Analyst _______________

Sampling Date__________ Lab temp ____________ Well No/Interval___________
Sampling Time__________ Lab conditions________ Sampling conditions________

Wellhead Chemistry - Dissolved Oxygen Titration

Time of sample collection __________ ; time of chemical fixation __________

Fixation: MnSO4 ___ Alk I-azide ___
Agitation x2 : ___

Titration data:

Date of sample titration: __________
Time of sample titration: __________

Acidification: ___

Sample No.________________

Analyst _______________

Lab temp _____________ Lab conditions________

Sample Volume (if different from 100 ml) _____

Set Beginning Titrator Reading to Zero ___

Indicator Solution added at yellow intermediate point: ___

Titrator Reading at End-Point ___________ ; estimated uncertainty __________

For 100 ml sample, D.O.(mg/l) = End-point digital reading x 0.02 = _________
For 200 ml sample, D.O.(mg/l) = End-point digital reading x 0.01 = _________

For Standardization Check:

Acidify 300 ml I-IO3 standard solution: ___
Agitation x2: ___
Measure 100 ml solution into titration flask:___
Add indicator solution: ___
Set Titrator reading to zero: ___
Indicator solution added at yellow-point: ___
Titrator reading at end-point: _________
D.O.(mg/l) = End-point digital reading x 0.02 = _________

Comments:

Sample No.________________

Analyst ______________

Analysis Date__________ Lab temp ____________ Well No/Interval___________
Sampling Time__________ Lab conditions________ Sampling conditions________

Flow Cell Measurements - Specific Conductance

Power on meter _______

Set to D range, 25°C, ca. 3% slope ______

Check cell constant and set if necessary

ATC on ________ D Range ______

Keep buffers at or within 5°C of ground water temperature

Unscrew flow cell cap and remove cap and probe assembly

Rinse probe, internally and externally, blot dry

Immerse in 718 uS standard, gently agitate, allow to stabilize

Set with slope control ________

Rinse probe, blot dry

Immerse in 447 uS standard, stabilize and record reading ______

Insert in flow cell, insert vent tube into probe's top end

Do not switch meter off until flow cell measurements are done

Store probe in flow cell until next use

If problematic readings, try backup electrode

Comments:

Sample No.________________

Analyst _______________

Analysis Date__________ Lab temp _____________ Well No/Interval___________
Sampling Time__________ Lab conditions________ Sampling conditions________

Flow Cell Measurements - pH and Temperature

Power on meter ______

Disable auto-off feature _______
[press 2nd Setup, go to 1-4 (Yes), set to OFF (Scroll Up),press Measure]

Meter in pH mode ______

Keep buffers at or within 5°C of ground water temperature; Buffer T =_______

Unscrew flow cell cap and remove cap and probe assembly

Rinse probe with D.I. water, shake off excess water, wipe outside of probe, immerse in pH=7 buffer

Press 2nd Cal, wait until Ready, press Yes

Rinse probe with D.I. water, shake off excess water, wipe outside of probe, immerse in pH=10 buffer

Press 2nd Cal, wait until Ready, press Yes

Press Measure, check pH=7 again to verify calibration _________

Insert in flow cell, probe tip capped with storage solution until flow cell filled

Do not switch meter off until flow cell measurements are completed

Store probe in flow cell, capped with storage solution, until next use

Comments:

Sample No.________________

Analyst _______________

Analysis Date__________ Lab temp _____________ Well No/Interval___________
Sampling Time__________ Lab conditions________ Sampling conditions________

Flow Cell Measurements - Dissolved Oxygen

Power on meter ______

Disable auto-off feature _______
[press 2nd Setup, go to 1-4 (Yes), set to OFF (Scroll Up),press Measure]

Meter in pH mode _____

Unscrew flow cell cap and remove cap and probe assembly

Check probe battery: switch to Batt (OK if > 13.4) ________

Switch to Zero, set readout to zero _______

Obtain barometric pressure (Pb), in mm Hg _______

Place probe into Air-calibration bottle; place bottle on magnetic stirrer, turn on, set speed to high rate

Switch probe setting to Air, wait for reading to stabilize, set reading to Pb/100 _________

Switch probe setting to H2O position, immerse probe membrane in air-saturated D.I. water bottle, stirrer on low-medium rate

Stabilize, record reading _________, temperature _________, and ppm O_2 expected for current temperature ________

Use O_2 solubility table in electrode manual x Pb/760 to estimate expected ppm O_2; if reading differs from estimated value by more than 5%, re-check Pb, T values, repeat calibration if necessary; if discrepancy still exists, replace electrode membrane module (see electrode manual)

Insert probe in flow cell, probe tip capped with a few drops of water until flow cell filled

Store probe in flow cell, with probe turned OFF and capped with water, until next use

Comments:

Sample No.________________

Analyst ______________

Analysis Date_________ Lab temp ____________ Well No/Interval___________
Sampling Time_________ Lab conditions_______ Sampling conditions_______

Flow Cell Measurements - Redox Potential

After D.O. measurements are completed (ie. stable values attained, water samples about to be collected), disconnect oxygen probe from Orion meter, connect Eh probe

Meter in mV mode

Record readings every 30 secs for 3 minutes, or until stable

Time	mV

Unscrew flow cell cap and remove cap and probe assembly

Rinse probe with D.I. water, blot excess water from tip, immerse in air-saturated D.I. water bottle

Stabilize reading, record mV ________, water temperature in bottle_______

Store probe in flow cell, capped with storage solution, until next use

Comments:

APPENDIX 7. EXAMPLE SAMPLE REQUEST FORM
DISSOLVED METALS ANALYSIS REQUEST FORM - STATE LAB

Sample Collection

Sample Number ___ Sample Location _____

Sample Date M____ D____ Y____ Time _am/pm (Mtn Time Zone)

Type of Sample: Grab___ Composite___ Sample Collector ____

Volume per Container ___ Number of Containers

Preservatives: Cooled 4C_____ HNO_3_____ H_2SO_4_____ Other_____

Analyses Requested From This Sample:

Parameter	Analytical Method EPA #	MRV Sensitivity ug/L	Required ug/L	MCL 1992 ug/L	MCL ug/L
Arsenic	206.2	10	12	50	50
Barium	208.1	100	100	1000	2000
Beryllium	210.1	2	5	NA	NA
Cadmium	213.2	1	2	10	5
Calcium	215.1	100	1000	NA	NA
Chromium	218.2	2	2	50	100
Copper	220.1	10	12	1000	1000
Iron	236.1	10	20	NA	NA
Lead	239.2	5	5	50	15
Magnesium	242.1	100	1000	NA	NA
Manganese	243.1	10	15	50	50
Mercury	245.1	0.5	1	2	2
Nickel	249.2	10	15	NA	NA
Potassium	258.1	100	1000	NA	NA
Selenium	270.2	5	10	10	50
Silver	272.2	1	5	50	50
Sodium	273.1	100	1000	20	20
Strontium	***	1	2	NA	NA
Zinc	289.1	2	2	5000	5000

Sample Receipt (To be filled out by Laboratory):

Damage Inspection _____ Label Inspection
Received by ____ Lab Number _____

Comments:

***** Report Results to <u>both</u>:

J.Welhan, M. McCurry
Dept. of Geology
Idaho State University
Pocatello, ID 83209

<u>AND</u> Warren Barrash, Steve R. Hill
INEL Oversight Program
1410 N. Hilton
Boise, Idaho 83706

APPENDIX 8. CHAIN OF CUSTODY FORM

CHAIN-OF-CUSTODY RECORDSheet No of

Project Name/Number ____________ Lab Destination ____________

Sample Team Members ____________

Sample Location and Description Collected	Date and Time Volume	Sample Containers	Number of (Name and Date)	Condition on Receipt

Special Instructions:

SIGNATURES: (Name, Date, and Time)

1. Relinquished by: ____________

   Received by: ____________

2. Relinquished by: ____________

   Received by: ____________

3. Relinquished by: ____________

   Received by: ____________