

RCC Note 91-006  
July 22, 1991

**STATISTICAL EVALUATION OF CEBAF GROUND WATER ANALYSES OF SAMPLES  
COLLECTED SEPTEMBER 1989 - MARCH 1991**

*R. May and C. Wells*

**STATISTICAL EVALUATION OF CEBAF GROUND WATER ANALYSIS OF SAMPLES  
COLLECTED SEPTEMBER 1989 - MARCH 1991**

**Table of Contents**

	Page
Introduction	1
Trend Analysis	1
Statistical Analysis	2
Summary and Future Statistics	4
Acknowledgements	5
References	21
Appendix A	22

**List of Figures**

Figure 1: Graph of Gross Alpha Concentration	6
Figure 2: Graph of Gross Beta Concentration	7
Figure 3: Graph of Ground Water pH	8
Figure 4: Graph of Ground Water Conductivity	9
Figure 5: Graph of Total Metals Concentration	10

**List of Tables**

Table 1: Test of Proportions Data	3
Table 2: Data for Gross Alpha Concentration Graph	11
Table 3: Data for Gross Beta Concentration Graph	11
Table 4: Data for Ground Water Conductivity Graph	12
Table 5: Data for Ground Water pH Graph	12
Table 6: Data for Total Metals Concentration Graph	13
Table 7: Analysis Data for Well GW2	14
Table 8: Analysis Data for Well GW3	15
Table 9: Analysis Data for Well GW7	16
Table 10: Analysis Data for Well GW8	17
Table 11: Analysis Data for Well GW15	18
Table 12: Analysis Data for the West Arc Well [ARC(W)]	19
Table 13: Analysis Data for Construction Dewater Samples	20

RCG Note 91-006  
July 22, 1991

**STATISTICAL EVALUATION OF CEBAF GROUND WATER ANALYSES OF SAMPLES COLLECTED  
SEPTEMBER 1989 - MARCH 1991**

*R. May and C. Wells*

**Introduction**

On March 6, 1989 CEBAF submitted the revised pollution abatement permit application. The State of Virginia Water Control Board (SWCB) issued pollution abatement permit No. VPA01001 on June 16, 1989 with requirements for pre-operational and operational sample collection and analysis (Vpa89). As a result, CEBAF's ground water monitoring program was begun in September of 1989. Initially six wells and a construction site dewatering location were monitored on a monthly basis, but starting in October 1990 the monitoring frequency was changed to quarterly. The results of the analyses have been compiled and examined for trends and the addition of contaminants to the ground water system and also to document pre-operational ground water quality for compliance with SWCB's antidegradation policy (Wqs88). Plots of the values of several parameters versus time were made and inspected visually for observable trends. A statistical analysis was done comparing the detection ratios of several radionuclides in the up and down gradient wells. Both of these examinations indicated that there is no evidence that any contaminants are being added to the ground water system at the CEBAF location.

Operationally, no significant levels of activating radiation were present during the period, thus there has been no opportunity for CEBAF to add radionuclides to the ground water system. Many of the radionuclides listed for analysis are those not commonly found naturally in the environment at levels greater than the minimum detection level. Therefore, much of the radiochemical data is given as less than the minimum detection level (<MDL) and as a consequence is not discussed further in this note. There has been, and continues to be, considerable ground water disturbance due to construction activities. These construction activities could conceivably add non-radioactive constituents to the ground water, but there is no evidence to suggest that this has occurred.

**Trend Analysis**

The ground water analysis data were examined to identify anomalies and to determine possible trends. Most of the parameters showed little variation, so trend analysis was performed on those parameters which exhibited the most variability or could be expected to provide indication of major changes in the ground water system. The parameters chosen were: pH, conductivity, total

metals, gross alpha, and gross beta. It was decided to compare the values of these parameters across the ground water gradient identified in the site hydrogeological survey (Law85). The values for the west arc well were compared separately as this is the only well within the linac "race track".

For comparison with the up gradient well (GW15), analytical results for the four down gradient wells (GW2, GW3, GW7, and GW8) were averaged and the standard deviations computed. The down gradient well average, the west arc well (ARC(W)), and the up gradient well values for each parameter so treated are shown in tables 2 to 6; the values are shown graphically in figures 1 to 5.

Examination of the plots of gross alpha and gross beta show that the concentrations of the up and down gradient wells follow closely together. The concentration of gross alpha and gross beta in the water from the west arc well generally is greater than both the up and down gradient wells. An examination of the complete radionuclide results for the west arc well revealed that there are also higher levels of total radium and thorium isotopes. A possible explanation of these high results is that the well was drilled through or near a fossilized deposit of organic materials having a high natural uranium/radium concentration (Ehl82, Dav66). These radionuclides leach into the ground water over time, and raise the concentration of these radionuclides in the water. Since the deposit is quite localized and ground water flow quite slow, the other wells do not see the increased radionuclide levels.

The plot of pH shows that the up gradient well has pH values that are lower than the other wells. This well is located just off of Jefferson Avenue - a major thoroughfare in Newport News. It is possible that rain water run off and dissolved automobile emission gases enter the ground water system near this area resulting in a lower than average pH (Dav66).

Since the pH of the up gradient well exhibits a notable difference from the rest of the site, additional up gradient wells should be sampled to determine water quality entering the accelerator site. Wells installed during the planning phase of the project have been located near the Test Lab. As the construction data is available, these wells may be used to provide additional data.

#### Statistical Analysis

A statistical analysis of the radionuclide data was done to determine if there was evidence of contamination (ie., higher than "background" levels) in the down gradient wells as compared to the up gradient well. The method used was a test of proportions as found in section 8.1.2 of Epa89. Included in the test of proportions is a check to ensure that the data approximate a normal distribution.

The test of proportions may be used when the proportion of quantified values is small to moderate, and determines whether the proportion of analytical results greater than the detection limit in the up gradient well differs significantly from the proportion of analytical results greater than the

detection limit in the down gradient well(s). A statistic (Z) is computed as the ratio of the difference between the up and down gradient detection ratios to the calculated standard error of the difference in the proportions. The absolute value of Z is compared to the 97.5<sup>th</sup> percentile from the standard normal distribution, 1.96. If the absolute value of Z does not exceed 1.96, then statistical evidence at the 5% significance level that there is no contamination of the ground water as it flows across the site.

As mentioned earlier, prior to performing statistical calculations, the data was visually checked for anomalies. Several results were noted as being significantly different from other values. These results were tested to determine if they were outliers. The test used is detailed in section 8.2 of Epa89. The test identified two points as being outliers. Both points were from the August 1990 sample of the west arc well, and comprise the gross alpha and gross beta results. As there is no conclusive evidence of either a recording or laboratory error, or that the values are true, they were not rejected from inclusion in the calculations. Use of these data do not introduce an appreciable error into the calculated statistic, however one should be aware that these results are questionable.

The test was performed on data for gross alpha, gross beta, calcium 45, total radium, strontium 90, thorium 230, and thorium 232. (The other monitored radionuclides did not have any analysis results greater than the detection limit, and are not therefore amenable to this statistical test.) The test indicated that the data did conform to an approximation of a normal distribution. The computed statistic Z was  $\leq 1.96$  for each of above parameters; thus it can be inferred that no difference exists between the up gradient and down gradient wells. Table 1 lists the parameters and the values for the calculation variables as well as the value of Z. (A sample calculation is shown in Appendix A.)

Table 1: Test of Proportions Data

Parameter	Number of Detections in the Background Well	Number of Detections in the Down Grad. Wells	Number of Samples from the Background Well	Number of Samples from the Down Grad. Wells	Computed Statistic Z
Gross Alpha	8	58	15	88	1.96
Gross Beta	8	51	15	88	0.69
Ca <sup>45</sup>	2	8	15	88	1.75
Total Ra	7	43	15	88	0.31
Sr <sup>90</sup>	2	13	14	83	0.37
Th <sup>230</sup>	3	26	14	82	1.69
Th <sup>232</sup>	2	18	15	88	1.61

A Spearmans rank correlation coefficient test (Men75) was performed on data from the west arc well to determine the correlation (if any) between the values for gross alpha and gross beta, and Th<sup>230</sup> and Th<sup>232</sup>. Data previously identified as outliers were not used in this test. (For the purposes of this

test, results of <MDL were assigned the MDL value.) The test showed that the gross alpha and gross beta values had good correlation over the entire sampling history. This indicates that the alpha and beta results are in an equilibrium condition and suggests the presence of a naturally occurring decay chain.

The values for Th<sup>230</sup> and Th<sup>232</sup> isotopes correlate well over the sampling history. Thorium 232 is the parent of the thorium decay chain and thorium 230 is a member of the U<sup>238</sup> decay chain. This, in conjunction with the above test results, suggests the strong probability of a localized concentration of thorium and uranium in fossilized organic matter. This, as previously suggested, would be responsible for the higher concentrations of alpha and beta emitters in the west arc well water, and could also contribute to higher concentrations of other analytes (ie. hardness, conductivity, and metals).

#### Summary and Future Statistics

Several of the parameters monitored in some of the wells have been found to be in excess of state water quality standards (Wqs88). (Analytes having the majority of results above the standards are: iron, manganese, pH, hardness, gross alpha. Analytes having occasional results above the standards are: lead, zinc, TOC, total radium, and gross beta.) In light of this a detailed statistical analysis was indicated. The statistical examination of the ground water data accumulated since commencement of sampling (September 1989) show that, on the basis of the variability in their values, there is no significant difference between the ground water in the up gradient well and the down gradient wells. The trend analysis revealed that the samples drawn from the well within the accelerator ring have consistently higher concentrations of alpha and beta emitting radionuclides than the other wells, and that the up gradient well has a much lower pH than the other wells. Both of these trends could be a result of the particular placement of the respective wells, and not as a result of ground water contamination due to CEBAF's operations.

During the sampling period insufficient time elapsed to move any contaminants more than 10 metres (Law83 estimates the ground water average velocity at 2.5 metres per year). We know, therefore, that contamination added to the up gradient well would not have reached any down gradient well within the time of the sampling period. We also know that, as no significant levels of radiation have been produced, no activity has been induced in the ground water system by CEBAF operations.

The test of proportions infers that there is no difference between the up gradient and down gradient wells, and thus indicates that our pre-operational conditions are ideal for detecting future contamination problems. The addition of at least one other up gradient well would narrow the permissible difference between the probabilities of analyte detection in the up and down gradient wells. This would provide a more sensitive and positive indication of possible added contamination in the future. This is based upon the fact that the probability of accepting a false positive indication of non-contamination is reduced as the number of samples is increased, thereby

increasing the probability that any contamination will be detected. Additionally, the addition of at least one up gradient well will provide a check on the trends of such parameters as pH, conductivity, and TOC.

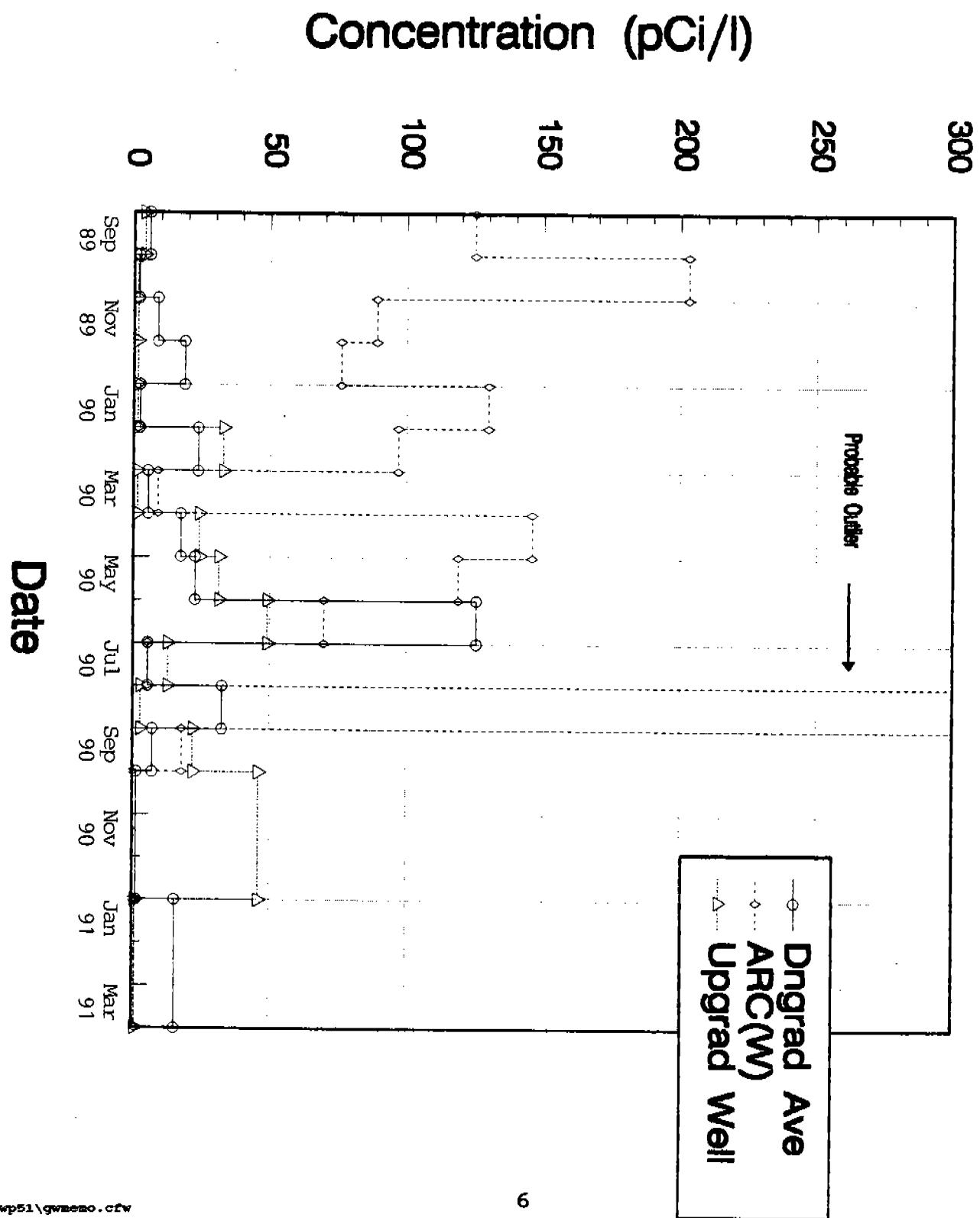
Further study should be undertaken to determine the source of the high readings in the west arc well. Such studies could include soil sampling and radioanalysis and detailed radiochemical analysis of well water for naturally occurring decay chain constituents.

As more data becomes available, it would be useful and appropriate to normalize the data to account for any seasonal variations, and construct a combined Shewart-Cumulative sum control chart. The seasonal correction helps to minimize the chance of a false positive or false negative indication of well contamination. The control chart can be used to monitor the inherent statistical variation of the data and to flag anomalous values. A sufficiently large data set will have been accumulated prior to the accelerator becoming operational so that these methods can be used. Descriptions of these methods and procedures for accomplishing them can be found in section 7 of Epa89.

#### Acknowledgments

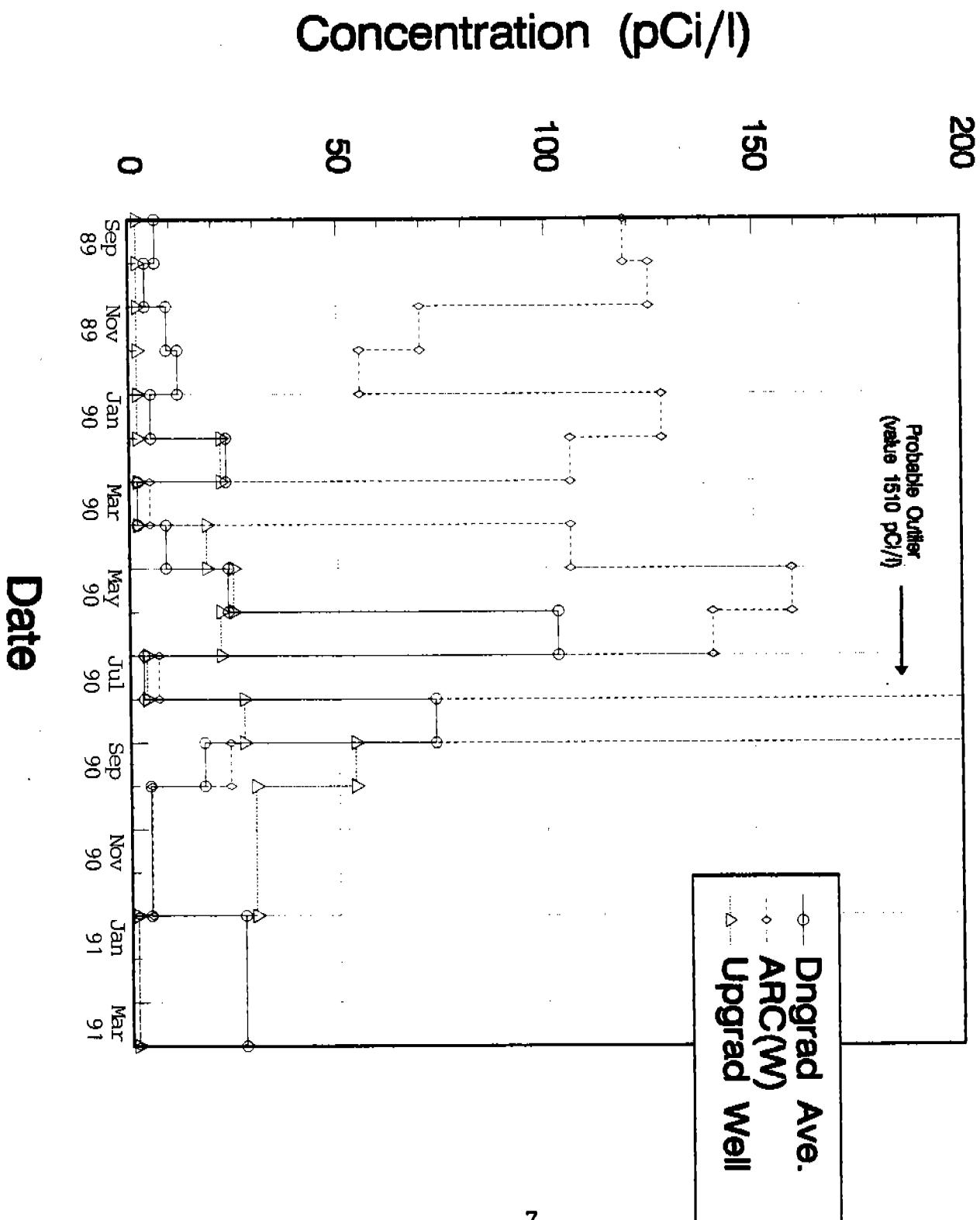
The authors would like to thank Geoffrey Stapleton for lending his editorial expertise to this project, and Evan J. Deemer, Jr. for making available his knowledge of geology and hydrology.

# GROSS ALPHA CONCENTRATION (Sept. 89 to Mar. 91)



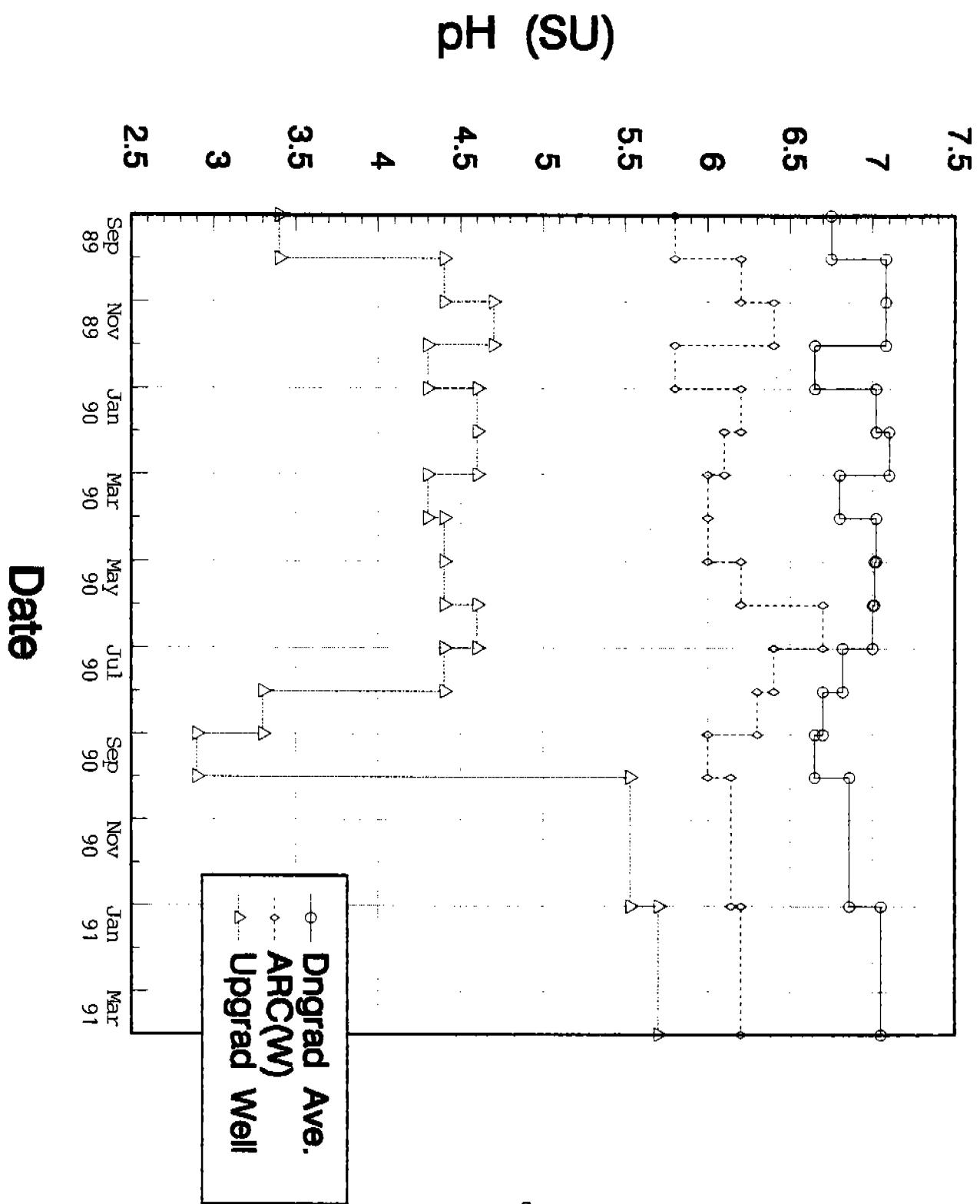
# GROSS BETA CONCENTRATION (Sept. 89 to Mar. 91)

Figure 2: Graph of Gross Beta Concentration



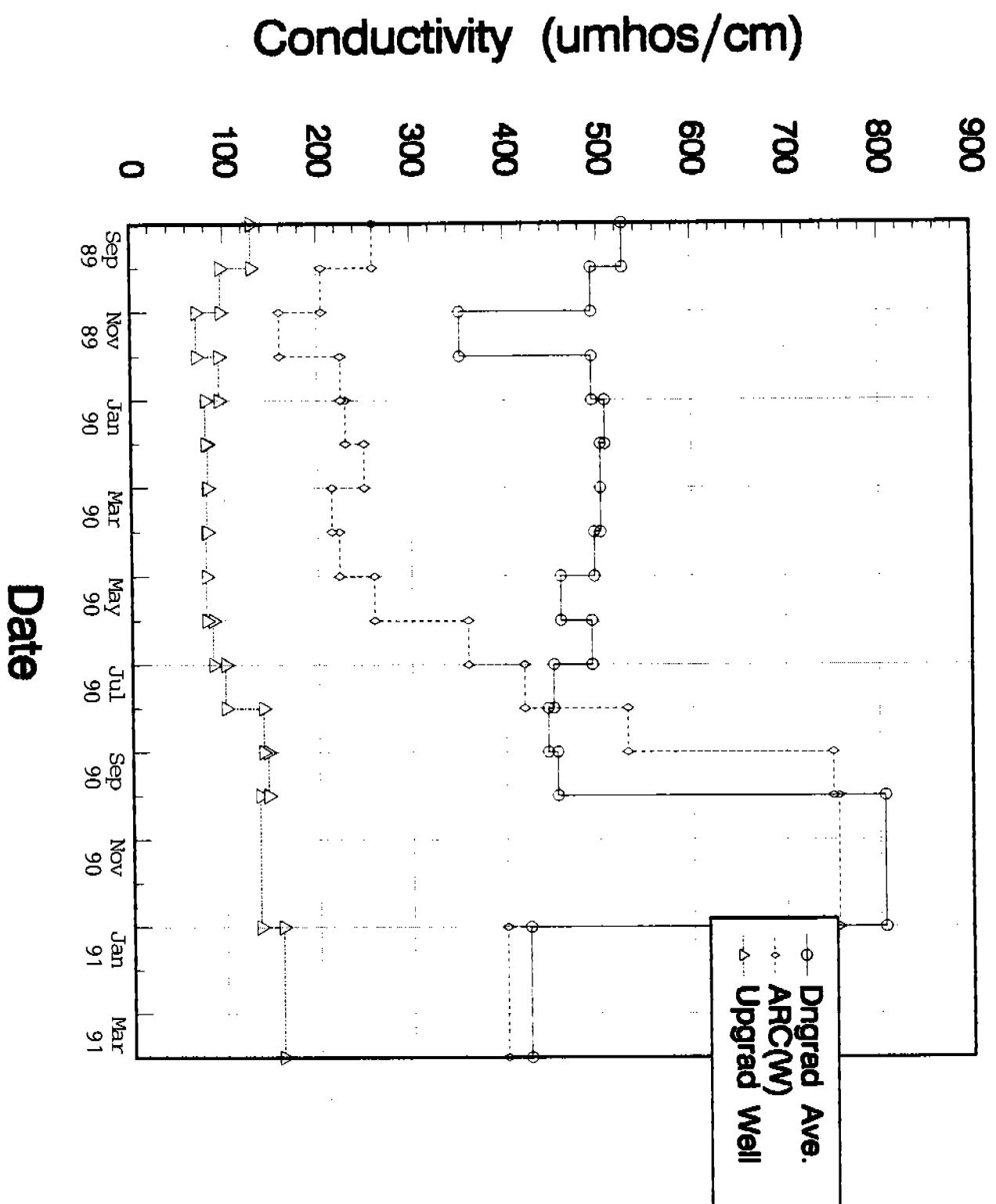
# GROUND WATER pH (Sept. 89 to Mar. 91)

Figure 3: Graph of Ground Water pH



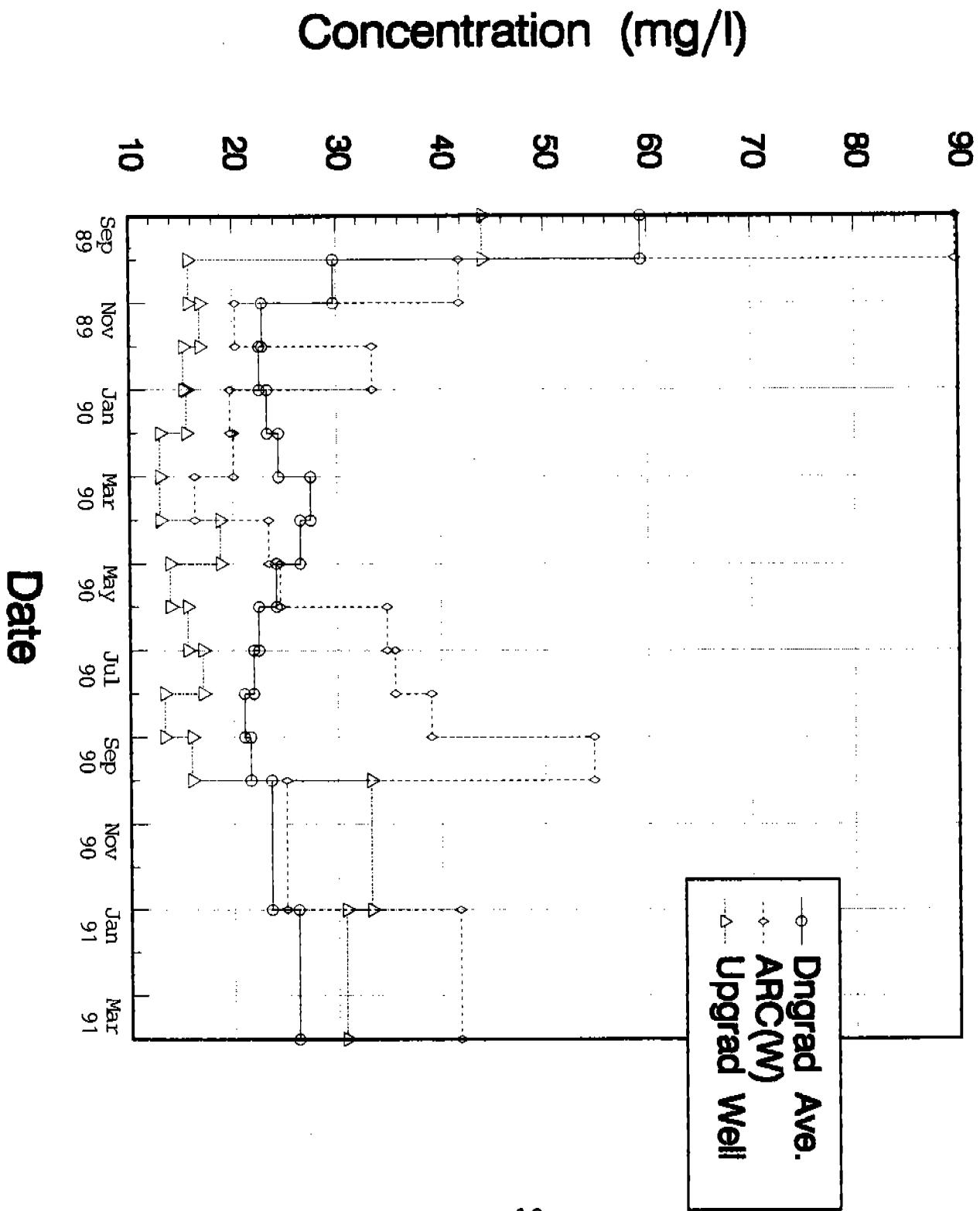
# GROUND WATER CONDUCTIVITY (Sept. 89 to Mar. 91)

Figure 4: Graph of Ground Water Conductivity



# TOTAL METALS CONCENTRATION (Sept. 89 to Mar. 91)

Figure 5: Graph of Total Metals Concentration



**Table 2: Data for Gross Alpha Concentration Graph**

Month		Down Grade Ave. ( $\pm 1s$ )	Up Grade Well	Arc West Well
Sep	89	5.88 (3.84)	4.00	125.0
Oct	89	2.00 (0.71)	1.50	203.0
Nov	89	8.88 (6.86)	1.50	89.0
Dec	89	18.75 (17.76)	1.50	76.0
Jan	90	2.38 (1.75)	1.50	130.0
Feb	90	23.75 (16.70)	33.00	97.0
Mar	90	5.43 (3.61)	1.50	9.04
Apr	90	17.48 (19.32)	24.20	146.0
May	90	22.66 (28.55)	31.40	119.0
Jun	90	125.59 (209.03)	49.10	69.8
Jul	90	5.49 (2.94)	12.80	5.28
Aug	90	32.68 (25.11)	2.90	364.0
Sep	90	7.25 (6.13)	22.00	18.0
Dec	90	1.45 (2.90)	46.00	0.0
Mar	91	15.50 (29.00)	1.00	1.0

Note: Units are pCi/l.

**Table 3: Data for Gross Beta Concentration Graph**

Month		Down Grade Ave. ( $\pm 1s$ )	Up Grade Well	Arc West Well
Sep	89	6.50 (3.41)	2.00	119.0
Oct	89	4.00 (1.41)	2.00	125.0
Nov	89	9.12 (6.54)	2.00	70.0
Dec	89	11.75 (8.91)	2.00	55.5
Jan	90	5.25 (4.27)	2.00	128.0
Feb	90	23.25 (12.74)	22.00	106.0
Mar	90	2.00 (0.00)	2.00	4.96
Apr	90	8.78 (9.91)	18.50	106.0
May	90	23.69 (22.24)	24.90	159.0
Jun	90	102.92 (151.33)	21.90	140.0
Jul	90	3.34 (2.16)	4.05	6.91
Aug	90	73.38 (55.85)	27.30	1510.0
Sep	90	17.75 (23.51)	54.00	24.0
Dec	90	4.72 (3.17)	30.00	5.0
Mar	91	27.38 (51.75)	1.50	1.5

Note: Units are pCi/l.

Table 4: Data for Ground Water Conductivity Graph

Month		Down Grade Ave. ( $\pm 1s$ )	Up Grade Well	Arc West Well
Sep	89	527.5 (265.6)	130.0	260.0
Oct	89	493.8 (142.7)	97.0	205.0
Nov	89	352.5 (130.5)	71.0	160.0
Dec	89	493.8 (157.4)	95.0	225.0
Jan	90	507.5 (132.2)	80.0	230.0
Feb	90	502.5 (133.3)	82.0	250.0
Mar	90	502.5 (99.8)	81.0	215.0
Apr	90	495.5 (124.8)	80.0	223.0
May	90	459.2 (97.8)	80.0	260.0
Jun	90	492.5 (150.8)	87.0	360.0
Jul	90	451.2 (91.7)	100.0	420.0
Aug	90	445.0 (108.5)	140.0	530.0
Sep	90	455.0 (112.5)	145.0	750.0
Dec	90	805.8 (620.5)	136.0	756.0
Mar	91	425.0 (104.1)	160.0	400.0

Note: Units are  $\mu\text{mho}/\text{cm}$ .

Table 5: Data for Ground Water pH Graph

Month		Down Grade Ave. ( $\pm 1s$ )	Up Grade Well	Arc West Well
Sep	89	6.75 (0.26)	3.40	5.80
Oct	89	7.08 (0.36)	4.40	6.20
Nov	89	7.08 (0.33)	4.70	6.40
Dec	89	6.65 (0.41)	4.30	5.80
Jan	90	7.02 (0.24)	4.60	6.20
Feb	90	7.10 (0.22)	4.60	6.10
Mar	90	6.80 (0.58)	4.30	6.00
Apr	90	7.02 (0.19)	4.40	6.00
May	90	7.01 (0.19)	4.40	6.20
Jun	90	7.00 (0.26)	4.60	6.70
Jul	90	6.82 (0.33)	4.40	6.40
Aug	90	6.70 (0.22)	3.30	6.30
Sep	90	6.65 (0.34)	2.90	6.00
Dec	90	6.86 (0.30)	5.53	6.14
Mar	91	7.05 (0.38)	5.70	6.20

Note: Units are standard pH units (SU).

Table 6: Data for Total Metals Concentration Graph

Month		Down Grade Ave. ( $\pm$ 1s)	Up Grade Well	Arc West Well
Sep	89	59.39 (1.93)	44.13	89.71
Oct	89	29.73 (1.36)	15.75	41.87
Nov	89	22.84 (1.20)	16.83	20.26
Dec	89	22.55 (1.19)	15.25	33.46
Jan	90	23.30 (1.21)	15.52	19.76
Feb	90	24.40 (1.24)	12.97	20.07
Mar	90	27.49 (1.31)	12.95	16.32
Apr	90	26.47 (1.29)	18.76	23.43
May	90	24.15 (1.23)	13.90	24.50
Jun	90	22.44 (1.18)	15.57	34.81
Jul	90	21.93 (1.17)	17.01	35.58
Aug	90	21.02 (1.15)	13.31	39.05
Sep	90	21.61 (1.16)	15.94	54.74
Dec	90	23.59 (1.21)	33.24	25.04
Mar	91	26.17 (1.28)	30.79	41.76

Note: Units are mg/l.

Table 7: Analysis Data for Well GW2

MONTH	YEAR	pH	COND	TOC	GR ALPHA	(±)	GR BETA	(±)	TRITIUM	(±)	Na-22	Na-24	Be-7	Ca-45	(±)
SEP	89	6.70	470.00	27.40	10.00	(4.00)	10.00	(5.00)	< 1000.00		< 40.00	note 1	< 600.00	< 6.00	
OCT	89	6.90	460.00	6.30	2.00	(1.00)	4.00	(2.00)	< 1000.00		< 40.00	< 60.00	< 600.00	< 6.00	
NOV	89	7.00	300.00	3.20	18.00	(8.00)	18.00	(6.00)	< 1000.00		< 40.00	< 60.00	< 600.00	< 6.00	
DEC	89	6.60	445.00	3.10	< 59.00		< 41.00		< 1000.00		< 40.00	< 66.00	< 600.00	< 6.00	
JAN	90	6.90	455.00	2.10	5.00	(2.00)	11.00	(2.00)	< 1000.00		< 40.00	< 60.00	< 600.00	< 6.00	
FEB	90	6.90	410.00	4.46	42.00	(18.00)	32.00	(17.00)	< 1000.00		< 40.00	< 619.00	< 600.00	< 6.00	
MAR	90	6.90	430.00	2.94	< 3.00		< 4.00		< 1000.00		< 40.00	< 58.00	< 600.00	< 6.00	
APR	90	6.90	430.00	4.07	44.90	(19.60)	23.50	(15.40)	< 1000.00		< 40.00	< 60.00	< 600.00	< 11.00	
MAY	90	6.90	432.00	3.84	65.50	(27.50)	56.20	(29.40)	< 1000.00		< 40.00	< 60.00	< 600.00	< 12.00	
JUN	90	7.10	480.00	14.60	437.00	(175.00)	325.00	(155.00)	< 1000.00		< 40.00	< 112.00	< 600.00	< 6.00	
JUL	90	6.90	510.00	3.98	< 19.00		< 13.00		< 1000.00		< 40.00	< 60.00	< 600.00	9.16 (3.95)	
AUG	90	6.80	500.00	7.24	19.10	(12.40)	16.20	(6.00)	< 1000.00		< 40.00	note 1	< 600.00	< 6.00	
SEP	90	6.60	520.00	3.84	16.00	(6.00)	53.00	(14.00)	< 500.00		< 15.00	< 50.00	< 40.00	< 5.00	
DEC	90	6.94	798.00	2.00	0.00	(5.20)	6.80	(2.90)	0.00 (340.00)		< 9.00	< 36.00	< 65.00	0.00 (1.30)	
MAR	91	7.00	450.00	3.04	< 2.00		< 3.00		< 1000.00		< 15.00	< 20.00	< 127.00	< 1.00	

MONTH	YEAR	TOTAL Ra (±)	Sr-90 (±)	Mn-54	Co-60	Cs-134	Th-230 (±)	Th-232 (±)	CaCO <sub>3</sub>	COD	Cu	Fe	
SEP	89	3.50 (0.70)	< 2.00		< 30.00	< 10.00	< 10.00	< 1.00	< 1.00	216.00	50.00	0.009	17.20
OCT	89	< 1.00	< 2.00		< 30.00	< 10.00	< 10.00	< 1.00	< 1.00	216.00	< 25.00	< 0.002	8.00
NOV	89	2.00 (0.30)	< 2.00		< 30.00	< 10.00	< 10.00	< 1.02	< 1.00	1200.00	39.00	0.004	1.83
DEC	89	2.27 (0.43)	< 2.00		< 30.00	< 10.00	< 10.00	47.40 (8.00)	4.62 (1.23)	224.00	93.00	0.005	0.53
JAN	90	< 1.00	< 2.00		< 30.00	< 10.00	< 10.00	< 1.00	< 1.00	208.00	25.00	0.005	1.74
FEB	90	3.68 (0.63)	< 2.00		< 30.00	< 10.00	< 10.00	2.46 (0.68)	1.38 (0.49)	236.00	100.00	0.002	1.69
MAR	90	< 1.00	3.84 (0.68)	< 30.00	< 10.00	< 10.00	< 1.00	< 1.00	< 1.00	188.00	35.00	0.002	6.00
APR	90	4.94 (0.81)	4.00 (0.79)	< 30.00	< 10.00	< 10.00	3.14 (0.86)	1.82 (0.62)	1020.00	74.00	0.004	1.48	
MAY	90	5.10 (0.85)	< 2.00		< 30.00	< 10.00	< 10.00	4.31 (1.07)	2.68 (0.79)	220.00	120.00	0.010	1.07
JUN	90	9.37 (1.37)	< 2.00		< 30.00	< 10.00	< 10.00	2.02 (1.10)	3.78 (1.51)	252.00	190.00	0.002	< 0.10
JUL	90	5.91 (0.96)	< 2.00		< 30.00	< 10.00	< 10.00	2.22 (0.83)	1.36 (0.66)	260.00	100.00	< 0.001	0.05
AUG	90	1.13 (0.35)	< 2.00		< 30.00	< 10.00	< 10.00	< 1.00	1.16 (0.46)	280.00	160.00	< 0.010	0.04
SEP	90	11.00 (1.00)	< 0.50		< 2.00	< 5.00	< 10.00	1.20 (0.80)	1.20 (0.80)	5400.00	120.00	< 0.010	0.75
DEC	90	0.00 (0.20)	0.00 (1.00)	< 8.00	< 9.00	< 8.00	< 8.00	< 8.00	< 8.00	269.00	< 20.00	0.002	7.20
MAR	91	< 1.00	< 0.70	< 15.00	< 10.00	< 10.00	note 2	< 1.00		230.00	< 25.00	0.002	4.33

MONTH	YEAR	Pb	Mn	Ni	Zn	Na	GWELEV
SEP	89	< 0.050	0.480	< 0.04	0.22	34.80	13.00
OCT	89	< 0.050	0.170	< 0.04	0.02	32.20	11.00
NOV	89	< 0.050	0.130	< 0.04	0.02	30.50	11.00
DEC	90	< 0.050	0.140	< 0.04	< 0.01	30.00	11.10
JAN	90	< 0.050	0.120	< 0.04	0.01	27.70	12.00
FEB	90	< 0.050	0.100	< 0.04	< 0.01	26.60	15.00
MAR	90	< 0.020	0.140	< 0.01	0.01	30.90	12.00
APR	90	< 0.020	0.130	< 0.01	< 0.01	31.70	10.00
MAY	90	< 0.050	0.120	< 0.04	0.01	29.80	9.00
JUN	90	0.020	0.090	< 0.01	< 0.01	29.60	4.00
JUL	90	< 0.010	0.107	< 0.01	0.01	28.60	10.00
AUG	90	< 0.010	0.095	< 0.01	0.01	27.80	5.00
SEP	90	< 0.010	0.145	< 0.01	0.02	27.50	6.00
DEC	90	0.003	0.120	< 0.10	0.04	28.00	20.80
MAR	91	< 0.010	0.134	< 0.01	< 0.01	31.60	6.00

NOTES

Note 1: Analysis not performed due to half life restrictions.  
Note 2: Analysis not performed, reason unknown.

Units:

pH	Standard pH units (SU)
Conductivity	µho/cm
TOC, CaCO <sub>3</sub> , COD,	mg/l
metals (Cu, Fe, Pb, Mn, Ni, Zn, Na)	
radio-isotopes	pCi/l
GW elevation	feet above sea level

Table 8: Analysis Data for Well GW3

MONTH	YEAR	pH	COND	TOC	GR ALPHA	(±)	GR BETA	(±)	TRITIUM	(±)	Na-22	SOD_24	Be-7	Ca-45	(±)
SEP	89	7.00	470.00	18.80	< 3.00		6.00 (2.00)		< 1000.00		< 40.00	note 1	< 600.00	< 6.00	
OCT	89	7.60	443.00	3.10	< 3.00		5.00 (1.00)		< 1000.00		< 40.00	< 60.00	< 600.00	< 6.00	
NOV	89	7.50	410.00	2.60	< 3.00		< 7.00		< 1000.00		< 40.00	< 60.00	< 600.00	< 6.00	
DEC	89	7.20	455.00	3.20	< 3.00		< 4.00		< 1000.00		< 40.00	< 60.00	< 600.00	< 6.00	
JAN	90	7.30	475.00	2.00	< 3.00		6.00 (1.00)		< 1000.00		< 40.00	< 60.00	< 600.00	< 6.00	
FEB	90	7.40	460.00	3.94	< 8.00		< 10.00		< 1000.00		< 40.00	< 932.00	< 600.00	< 6.00	
MAR	90	7.40	460.00	9.00	5.79 (2.87)		< 4.00		< 1000.00		< 40.00	< 66.00	< 600.00	< 6.00	
APR	90	7.30	462.00	3.06	< 3.00		< 4.00		< 1000.00		< 40.00	< 60.00	< 600.00	< 6.00	
MAY	90	7.30	460.00	2.29	10.70 (4.60)		9.66 (5.54)		< 1000.00		< 40.00	< 60.00	< 600.00	< 6.00	
JUN	90	7.30	450.00	12.50	< 10.00		< 12.00		< 1000.00		< 40.00	< 103.00	< 600.00	< 6.00	
JUL	90	7.20	480.00	2.97	< 7.20		< 5.00		< 1000.00		< 40.00	< 86.00	< 600.00	< 6.00	
AUG	90	6.90	430.00	4.74	16.80 (6.10)		37.40 (5.00)		< 1000.00		< 40.00	note 1	< 600.00	< 6.00	
SEP	90	7.00	450.00	4.72	3.00 (2.00)		6.00 (3.00)		< 500.00		< 15.00	< 50.00	< 40.00	< 5.00	
DEC	90	7.08	1680.00	2.00	0.00 (3.20)		6.20 (2.20)		0.00 (350.00)		< 13.00	< 24.00	< 82.00	0.00 (1.30)	
MAR	91	7.60	400.00	3.69	< 2.00		< 3.00		< 1000.00		< 10.00	< 20.00	< 82.00	< 1.00	

MONTH	YEAR	TOTAL Ra (±)	Sr-90 (±)	Mn-54	Co-60	Cs-134	Th-230 (±)	Th-232 (±)	CaCO3	COD	Cu	Fe
SEP	89	< 1.00	< 2.00	< 30.00	< 10.00	< 10.00	< 1.00	< 1.00	238.00	45.00	0.048	2.90
OCT	89	< 1.00	< 2.00	< 30.00	< 10.00	< 10.00	< 1.00	< 1.00	248.00	55.00	0.006	1.90
NOV	89	< 2.20	< 2.00	< 30.00	< 10.00	< 10.00	< 1.00	< 1.00	260.00	33.00	0.005	0.05
DEC	89	0.33 (0.14)	< 2.00	< 30.00	< 10.00	< 10.00	< 1.00	< 1.00	264.00	31.00	0.003	< 0.03
JAN	90	< 1.00	< 2.00	< 30.00	< 10.00	< 10.00	1.69 (0.37)	< 1.00	248.00	< 25.00	0.003	0.03
FEB	90	< 1.00	< 2.00	< 30.00	< 10.00	< 10.00	< 1.00	< 1.00	256.00	43.00	0.002	< 0.03
MAR	90	< 1.00	3.52 (0.68)	< 30.00	< 10.00	< 10.00	< 1.00	< 1.00	256.00	35.00	0.002	0.08
APR	90	< 1.00	3.32 (0.38)	< 30.00	< 10.00	< 10.00	< 1.00	< 1.00	360.00	40.00	0.005	0.03
MAY	90	< 1.00	< 2.00	< 30.00	< 10.00	< 10.00	< 1.00	< 1.00	240.00	25.00	0.004	0.03
JUN	90	1.29 (0.30)	< 2.00	< 30.00	< 10.00	< 10.00	< 1.00	< 1.00	232.00	77.00	0.007	< 0.10
JUL	90	< 1.00	< 2.00	< 30.00	< 10.00	< 10.00	< 1.00	< 1.00	252.00	60.00	0.002	0.02
AUG	90	< 1.00	< 2.00	< 30.00	< 10.00	< 10.00	< 1.00	< 1.00	212.00	67.00	< 0.010	0.03
SEP	90	< 1.00	< 0.50	< 2.00	< 5.00	< 10.00	< 0.60	< 1.00	2800.00	47.00	< 0.010	0.02
DEC	90	0.00 (0.10)	0.00 (1.00)	< 11.00	< 14.00	< 11.00	0.30 (0.20)	0.00 (0.10)	262.00	< 20.00	0.004	1.90
MAR	91	< 1.00	< 0.60	< 9.00	< 10.00	< 10.00	note 2	< 1.00	220.00	38.00	< 0.001	1.03

MONTH	YEAR	Pb	Mn	Ni	Zn	Na	GWELEV
SEP	89	< 0.050	0.110	< 0.04	0.08	32.00	32.00
OCT	89	0.060	0.070	< 0.04	0.21	30.10	34.00
NOV	89	< 0.050	0.050	< 0.04	0.02	30.00	33.00
DEC	89	< 0.050	0.070	< 0.04	0.01	29.80	33.00
JAN	90	< 0.050	0.070	< 0.04	< 0.01	28.40	33.00
FEB	90	< 0.050	0.040	< 0.04	< 0.01	23.50	35.00
MAR	90	< 0.020	0.060	< 0.01	0.01	26.60	35.00
APR	90	< 0.020	0.030	< 0.01	< 0.01	30.70	35.00
MAY	90	< 0.050	0.050	< 0.04	0.01	30.10	30.00
JUN	90	< 0.020	0.050	0.01	0.02	26.30	25.00
JUL	90	< 0.010	0.033	0.01	0.04	30.20	24.00
AUG	90	< 0.010	0.047	< 0.01	0.02	26.10	21.00
SEP	90	< 0.010	0.060	< 0.01	0.01	29.30	19.00
DEC	90	< 0.001	0.060	< 0.10	0.02	28.00	10.70
MAR	91	0.020	0.053	< 0.01	0.01	29.90	19.00

NOTES

Note 1: Analysis not performed due to half life restrictions.  
Note 2: Analysis not performed, reason unknown.

Units:

pH	Standard pH units (SU)
Conductivity	µho/cm
TOC, CaCO3, COD,	mg/l
metals (Cu, Fe, Pb, Mn, Ni, Zn, Na)	
radio-isotopes	pCi/l
GW elevation	feet above sea level

Table 9: Analysis Data for Well GW7

MONTH	YEAR	pH	COND	TOC	GR ALPHA (±)	GR BETA (±)	TRITIUM (±)	Na-22	Na-24	Be-7	Ca-45 (±)
SEP	89	6.40	270.00	34.60	4.00 (2.00)	< 4.00	< 1000.00	< 40.00	note 1	< 600.00	< 6.00
OCT	89	6.80	372.00	3.50	< 3.00	< 4.00	< 1000.00	< 40.00	< 60.00	< 600.00	< 6.00
NOV	89	6.70	200.00	2.80	9.00 (4.00)	5.00 (4.00)	< 1000.00	< 40.00	< 60.00	< 600.00	< 6.00
DEC	89	6.20	355.00	3.40	< 76.00	< 36.00	< 1000.00	< 40.00	< 60.00	< 600.00	< 6.00
JAN	90	6.80	400.00	2.50	< 3.00	< 4.00	< 1000.00	< 40.00	< 60.00	< 600.00	< 6.00
FEB	90	7.10	440.00	3.98	32.00 (13.00)	26.00 (13.00)	< 1000.00	< 40.00	< 1353.00	< 600.00	< 6.00
MAR	90	6.00	470.00	4.12	3.29 (2.11)	< 4.00	< 1000.00	< 40.00	< 89.00	< 600.00	< 6.00
APR	90	7.00	410.00	3.89	16.60 (6.70)	< 9.90	< 1000.00	< 40.00	< 60.00	< 600.00	< 6.00
MAY	90	6.80	355.00	4.08	< 14.00	< 18.00	< 1000.00	< 40.00	< 60.00	< 600.00	< 6.00
JUN	90	6.70	340.00	4.65	56.30 (29.30)	73.20 (29.20)	< 1000.00	< 40.00	< 92.80	< 600.00	100.00 (85.00)
JUL	90	6.40	315.00	5.94	5.87 (4.44)	< 4.50	< 1000.00	< 40.00	< 60.00	< 600.00	< 6.00
AUG	90	6.40	300.00	7.18	24.80 (8.70)	59.90 (7.80)	< 1000.00	< 40.00	note 1	< 600.00	< 6.00
SEP	90	6.20	300.00	5.08	4.00 (3.00)	7.00 (6.00)	< 500.00	< 15.00	< 50.00	< 40.00	< 5.00
DEC	90	6.41	285.00	2.00	5.80 (4.90)	5.90 (2.10)	0.00 (350.00)	< 13.00	< 38.00	< 79.00	0.00 (1.30)
MAR	91	6.80	300.00	3.42	59.00 (6.00)	105.00 (7.00)	< 1000.00	< 20.00	< 20.00	< 164.00	< 1.00

MONTH	YEAR	TOTAL Ra (±)	Sr-90 (±)	Mn-54	Co-60	Cs-134	Th-230 (±)	Th-232 (±)	CaCO <sub>3</sub>	COD	Cu	Fe
SEP	89	1.50 (0.40)	< 2.00	< 30.00	< 10.00	< 10.00	< 1.00	< 1.00	142.00	50.00	0.007	20.00
OCT	89	< 1.00	< 2.00	< 30.00	< 10.00	< 10.00	< 1.00	< 1.00	212.00	27.00	0.013	4.80
NOV	89	< 2.00	< 2.00	< 30.00	< 10.00	< 10.00	< 1.00	< 1.00	168.00	42.00	0.003	1.48
DEC	89	1.67 (0.33)	< 2.00	< 30.00	< 10.00	< 10.00	1.31 (0.34)	< 1.00	200.00	120.00	0.003	< 0.03
JAN	90	< 1.00	< 2.00	< 30.00	< 10.00	< 10.00	1.17 (0.32)	< 1.00	216.00	< 25.00	0.004	0.48
FEB	90	1.85 (0.37)	< 2.00	< 30.00	< 10.00	< 10.00	1.45 (0.39)	1.25 (0.36)	256.00	80.00	0.002	0.07
MAR	90	< 1.00	< 2.00	< 30.00	< 10.00	< 10.00	< 1.00	< 1.00	244.00	30.00	0.010	3.20
APR	90	< 1.00	< 2.00	< 30.00	< 10.00	< 10.00	< 1.00	< 1.00	784.00	51.00	0.004	0.04
MAY	90	< 1.00	< 2.00	< 30.00	< 10.00	< 10.00	1.84 (0.46)	< 1.00	184.00	67.00	0.007	0.75
JUN	90	2.96 (0.47)	< 2.00	< 30.00	< 10.00	< 10.00	< 1.00	< 1.00	192.00	110.00	0.002	0.20
JUL	90	< 1.00	< 2.00	< 30.00	< 10.00	< 10.00	< 1.00	< 1.00	196.00	77.00	0.003	1.09
AUG	90	< 1.00	< 2.00	< 30.00	16.30	< 10.00	< 1.00	< 1.00	152.00	49.00	< 0.010	2.28
SEP	90	2.00 (1.00)	< 0.50	< 2.00	< 5.00	< 10.00	< 0.60	< 0.60	450.00	120.00	0.010	1.71
DEC	90	0.00 (0.02)	0.00 (1.00)	< 11.00	< 12.00	< 11.00	0.00 (0.30)	0.00 (0.30)	148.00	< 20.00	< 0.001	3.60
MAR	91	3.00 (1.00)	< 0.60	< 18.00	< 10.00	< 10.00	note 2	< 1.00	210.00	< 25.00	0.001	2.52

MONTH	YEAR	Pb	Mn	Ni	Zn	Na	GWELEV
SEP	89	< 0.050	0.400	< 0.04	0.58	13.60	12.00
OCT	89	< 0.050	0.340	< 0.04	0.16	15.40	13.00
NOV	89	< 0.050	0.220	< 0.04	0.07	13.60	12.00
DEC	89	< 0.050	0.300	< 0.04	0.04	15.20	12.00
JAN	90	< 0.050	0.280	< 0.04	0.05	17.50	13.00
FEB	90	< 0.050	0.290	< 0.04	0.06	20.60	14.00
MAR	90	< 0.020	0.320	< 0.01	0.08	21.20	14.00
APR	90	< 0.020	0.240	< 0.01	0.06	21.60	15.00
MAY	90	< 0.050	0.230	< 0.04	0.09	18.20	13.00
JUN	90	< 0.020	0.220	0.01	0.07	16.10	13.00
JUL	90	< 0.010	0.215	< 0.01	0.10	14.60	12.00
AUG	90	< 0.010	0.191	< 0.01	0.08	14.30	12.00
SEP	90	< 0.010	0.190	0.01	0.07	14.60	11.00
DEC	90	0.003	0.100	< 0.10	0.06	10.00	25.40
MAR	91	0.010	0.231	< 0.01	0.04	13.00	12.00

NOTES

Note 1: Analysis not performed due to half life restrictions.  
 Note 2: Analysis not performed, reason unknown.

Units:

pH	Standard pH units (SU)
Conductivity	µho/cm
TOC, CaCO <sub>3</sub> , COD,	mg/l
metals (Cu, Fe, Pb, Mn, Ni, Zn, Na)	
radio-isotopes	pCi/l
GW elevation	feet above sea level

Table 10: Analysis Data for Well GW8

MONTH	YEAR	pH	COND	TOC	GR ALPHA	(±)	GRSBETA	(±)	TRITIUM	(±)	Na-22	Na-24	Be-7	Ca-45	(±)
SEP	89	6.90	900.00	30.20	8.00	(3.00)	8.00	(2.00)	< 1000.00		< 40.00	< 64.00	< 600.00	< 6.00	
OCT	89	7.00	700.00	5.30	3.00	(2.00)	5.00	(2.00)	< 1000.00		< 40.00	< 60.00	< 600.00	< 6.00	
NOV	89	7.10	500.00	2.90	7.00	(5.00)	10.00	(7.00)	< 1000.00		< 40.00	< 60.00	< 600.00	< 6.00	
DEC	89	6.60	720.00	3.90	< 12.00		< 13.00		< 1000.00		< 40.00	< 60.00	< 600.00	< 6.00	
JAN	90	6.80	700.00	2.40	< 3.00		< 4.00		< 1000.00		< 40.00	< 60.00	< 600.00	< 6.00	
FEB	90	7.00	700.00	3.59	17.00	(8.00)	24.00	(8.00)	< 1000.00		< 40.00	< 1109.00	< 600.00	< 6.00	
MAR	90	6.90	650.00	3.46	7.94	(4.05)	< 4.00		< 1000.00		< 40.00	< 69.00	< 600.00	< 6.00	
APR	90	6.90	680.00	7.73	6.90	(4.42)	< 9.30		< 1000.00		< 40.00	< 60.00	< 600.00	< 6.00	
MAY	90	7.00	590.00	2.97	7.42	(5.28)	19.90	(8.60)	< 1000.00		< 40.00	< 79.00	< 600.00	< 6.00	
JUN	90	6.90	700.00	4.83	4.07	(3.67)	< 15.00		< 1000.00		< 40.00	< 119.00	< 600.00	< 6.00	
JUL	90	6.80	500.00	3.83	< 6.00		< 3.20		< 1000.00		< 40.00	< 69.00	< 600.00	< 6.00	
AUG	90	6.70	550.00	4.07	70.00	(19.10)	150.00	(18.00)	< 1000.00		< 40.00	note 1	< 600.00	< 11.00	
SEP	90	6.80	550.00	9.65	3.00	(2.00)	5.00	(3.00)	< 500.00		< 15.00	< 50.00	< 40.00	< 5.00	
DEC	90	6.99	460.00	2.00	0.00	(3.10)	0.00	(2.60)	0.00	(350.00)	< 14.00	< 35.00	< 78.00	0.00 (1.20)	
MAR	91	6.80	550.00	3.42	< 2.00		< 3.00		< 1000.00		< 12.00	< 20.00	< 110.00	< 1.00	

MONTH	YEAR	TOTAL Ra (±)	Sr-90 (±)	Mn-54	Co-60	Cs-134	Th-230 (±)	Th-232 (±)	CaCO3	COD	Cu	Fe	
SEP	89	1.10 (0.30)	< 2.00		< 30.00	< 10.00	< 10.00	< 1.00	< 1.00	300.00	42.00	0.008	102.00
OCT	89	2.20 (0.50)	< 2.00		< 30.00	< 10.00	< 10.00	< 1.00	< 1.00	372.00	44.00	0.006	11.10
NOV	89	2.10 (0.30)	< 2.00		< 30.00	< 10.00	< 10.00	< 1.00	< 1.00	368.00	36.00	0.004	0.38
DEC	89	1.50 (0.33)	< 2.00		< 30.00	< 10.00	< 10.00	< 1.00	< 1.00	400.00	68.00	0.002	0.04
JAN	90	< 1.00	< 2.00		< 30.00	< 10.00	< 10.00	< 1.00	< 1.00	428.00	< 25.00	0.001	2.80
FEB	90	< 1.00	< 2.00		< 30.00	< 10.00	< 10.00	< 1.00	< 1.00	476.00	52.00	0.002	1.62
MAR	90	< 1.00	< 2.00		< 30.00	< 10.00	< 10.00	< 1.00	< 1.00	428.00	47.00	0.002	6.40
APR	90	1.44 (0.31)	2.52 (0.39)		< 30.00	< 10.00	< 10.00	< 1.00	< 1.00	840.00	40.00	0.003	1.72
MAY	90	< 1.00	< 2.00		< 30.00	< 10.00	< 10.00	< 1.00	< 1.00	376.00	48.00	0.004	3.20
JUN	90	< 1.00	< 2.00		< 30.00	< 10.00	< 10.00	1.55 (0.97)	< 1.00	424.00	50.00	0.001	2.30
JUL	90	< 1.00	< 2.00		< 30.00	< 10.00	< 10.00	< 1.00	< 1.00	356.00	40.00	0.002	0.73
AUG	90	< 1.00	14.00 (2.00)		< 30.00	< 10.00	< 10.00	< 1.00	< 1.00	340.00	46.00	< 0.010	1.76
SEP	90	< 1.00	< 0.50		< 2.00	< 5.00	< 10.00	< 0.60	0.60	875.00	75.00	< 0.010	0.32
DEC	90	0.00 (0.20)	0.00 (1.00)		< 11.00	< 13.00	< 12.00	0.00 (0.10)	0.00 (0.10)	274.00	< 20.00	0.002	7.00
MAR	91	< 1.00	< 0.70		< 12.00	< 10.00	< 10.00	note 2	< 1.00	380.00	< 25.00	0.002	8.97

MONTH	YEAR	Pb	Mn	Ni	Zn	Na	GWELEV
SEP	89	< 0.050	0.290	< 0.04	0.11	12.50	12.00
OCT	89	< 0.050	0.330	< 0.04	0.16	13.70	12.00
NOV	89	< 0.050	0.270	< 0.04	0.04	12.50	12.00
DEC	89	< 0.050	0.340	< 0.04	< 0.01	13.50	12.00
JAN	90	< 0.050	0.320	< 0.04	0.01	13.50	13.00
FEB	90	< 0.050	0.280	< 0.04	0.01	13.90	14.00
MAR	90	< 0.020	0.330	< 0.01	0.02	13.70	14.00
APR	90	< 0.020	0.330	0.02	0.03	17.70	14.00
MAY	90	< 0.050	0.310	< 0.04	0.02	12.40	13.00
JUN	90	< 0.020	0.290	0.01	0.01	14.30	12.00
JUL	90	< 0.010	0.246	< 0.01	0.02	11.60	11.00
AUG	90	< 0.010	0.253	< 0.01	0.02	11.00	11.00
SEP	90	< 0.010	0.241	< 0.01	0.02	11.40	11.00
DEC	90	0.003	0.160	< 0.10	0.04	8.00	24.50
MAR	91	< 0.010	0.266	< 0.01	0.01	12.50	12.00

NOTES

Note 1: Analysis not performed due to half life restrictions.  
 Note 2: Analysis not performed, reason unknown.

Units:

pH	Standard pH units (SU)
Conductivity	µho/cm
TOC, CaCO3, COD,	mg/l
metals (Cu, Fe, Pb, Mn, Ni, Zn, Na)	
radio-isotopes	pCi/l
GW elevation	feet above sea level

Table 11: Analysis Data for Well GW15

MONTH	YEAR	pH	COND	TOC	GR ALPHA	(±)	GR BETA	(±)	TRITIUM	(±)	Na-22	Na-24	Be-7	Ca-45	(±)
SEP	89	3.40	130.00	44.00	4.00	(1.00)	< 4.00		< 1000.00		< 40.00	note 1	< 600.00	< 6.00	
OCT	89	4.40	97.00	8.30	< 3.00		< 4.00		< 1000.00		< 40.00	< 60.00	< 600.00	< 6.00	
NOV	89	4.70	71.00	4.70	< 3.00		< 4.00		< 1000.00		< 40.00	< 60.00	< 600.00	< 6.00	
DEC	89	4.30	95.00	5.20	< 3.00		< 4.00		< 1000.00		< 40.00	< 60.00	< 600.00	< 6.00	
JAN	90	4.60	80.00	2.60	< 3.00		< 4.00		< 1000.00		< 40.00	< 60.00	< 600.00	< 6.00	
FEB	90	4.60	82.00	4.51	33.00	(12.00)	22.00	(12.00)	< 1000.00		< 40.00	< 881.00	< 600.00	< 6.00	
MAR	90	4.30	81.00	4.04	< 3.00		< 4.00		< 1000.00		< 40.00	< 100.00	< 600.00	< 3.00	
APR	90	4.40	80.00	8.24	24.20	(7.40)	18.50	(5.90)	< 1000.00		< 40.00	< 60.00	< 600.00	< 6.00	
MAY	90	4.40	80.00	5.24	31.40	(10.10)	24.90	(9.30)	< 1000.00		< 40.00	< 60.00	< 600.00	< 6.00	
JUN	90	4.60	87.00	6.94	49.10	(10.60)	21.90	(6.20)	< 1000.00		< 40.00	< 203.00	< 600.00	< 33.00	
JUL	90	4.40	100.00	3.82	12.80	(3.10)	4.05	(1.09)	< 1000.00		< 40.00	< 95.00	< 600.00	9.04 (2.54)	
AUG	90	3.30	140.00	8.29	< 5.80		27.30	(4.00)	< 1000.00		< 40.00	note 1	< 600.00	< 6.00	
SEP	90	2.90	145.00	8.43	22.00	(9.00)	54.00	(14.00)	< 500.00		< 15.00	< 50.00	< 40.00	< 5.00	
DEC	90	5.53	136.00	3.00	46.00	(11.00)	30.00	(5.00)	0.00 (330.00)	< 10.00	< 27.00	< 63.00	0.00 (2.20)		
MAR	91	5.70	160.00	3.21	< 2.00		< 3.00		< 1000.00		< 20.00	< 20.00	< 161.00	< 1.00	

MONTH	YEAR	TOTAL Ra (±)	Sr-90 (±)	Mn-54	CO-60	Cs-134	Th-230 (±)	THOR_232 (±)	CaCO3	COD	Cu	Fe	
SEP	89	< 1.00	< 2.00	< 30.00	< 10.00	< 10.00	< 1.00	< 1.00	120.00	42.00	0.014	33.00	
OCT	89	< 1.00	< 2.00	< 30.00	< 10.00	< 10.00	< 1.00	< 1.00	36.00	41.00	0.005	6.70	
NOV	89	< 2.00	< 2.00	< 30.00	< 10.00	< 10.00	< 1.00	< 1.00	104.00	42.00	0.008	7.00	
DEC	89	0.61 (0.15)	< 2.00	< 30.00	< 10.00	< 10.00	< 1.00	< 1.00	60.00	51.00	0.007	6.50	
JAN	90	< 1.00	< 2.00	< 30.00	< 10.00	< 10.00	< 1.00	< 1.00	36.00	< 25.00	0.006	7.00	
FEB	90	2.30 (0.42)	< 2.00	< 30.00	< 10.00	< 10.00	< 1.00	< 1.00	72.00	82.00	0.007	6.15	
MAR	90	< 1.00	< 2.00	< 30.00	< 10.00	< 10.00	< 1.00	< 1.00	20.00	47.00	0.008	6.10	
APR	90	3.30 (0.55)	< 2.00	< 30.00	< 10.00	< 10.00	1.01 (0.32)	< 1.00	156.00	68.00	0.005	10.60	
MAY	90	3.89 (0.67)	< 2.00	< 30.00	< 10.00	< 10.00	1.08 (0.31)	1.22 (0.34)	28.00	62.00	0.008	5.70	
JUN	90	3.00 (0.51)	< 2.00	< 30.00	< 10.00	< 10.00	< 1.00	< 1.00	28.00	83.00	0.002	7.40	
JUL	90	< 1.00	< 2.00	< 30.00	< 10.00	< 10.00	< 1.00	< 1.00	< 4.00	77.00	0.005	8.67	
AUG	90	< 1.00	2.31 (0.53)	< 30.00	< 10.00	< 10.00	< 1.00	< 1.00	36.00	55.00	< 0.010	2.95	
SEP	90	21.00 (2.00)	< 0.50		< 2.00	< 5.00	< 10.00	< 0.60	< 0.60	36.00	140.00	< 0.010	3.87
DEC	90	0.80 (0.30)	0.00 (1.00)	< 9.00	< 9.00	< 9.00	0.80 (0.20)	0.90 (0.20)	39.00	24.00	0.004	24.00	
MAR	91	< 1.00	< 0.70	< 18.00	< 10.00	< 10.00	note 2	< 1.00	44.00	41.00	0.001	17.30	

MONTH	YEAR	Pb	Mn	Ni	Zn	Na	GWELEV
SEP	89	< 0.050	0.140	< 0.04	0.13	10.80	15.00
OCT	89	< 0.050	0.060	< 0.04	0.04	8.90	17.00
NOV	89	< 0.050	0.050	< 0.04	0.03	9.70	16.00
DEC	89	< 0.050	0.060	< 0.04	0.04	8.60	16.00
JAN	90	< 0.050	0.050	< 0.04	0.02	8.40	13.00
FEB	90	< 0.050	0.050	< 0.04	0.02	6.70	18.00
MAR	90	0.020	0.070	< 0.01	0.05	6.70	18.00
APR	90	0.150	0.070	0.02	0.21	7.70	18.00
MAY	90	< 0.050	0.090	< 0.04	0.06	8.00	12.00
JUN	90	< 0.020	0.050	0.02	0.09	8.00	10.00
JUL	90	0.020	0.060	0.01	0.04	8.20	9.00
AUG	90	0.010	0.060	0.02	0.06	10.20	9.00
SEP	90	0.010	0.070	0.03	0.15	11.80	9.00
DEC	90	< 0.001	0.090	< 0.10	0.10	9.00	18.00
MAR	91	< 0.010	0.183	0.05	0.05	13.20	6.00

NOTES

Note 1: Analysis not performed due to half life restrictions.  
Note 2: Analysis not performed, reason unknown.

Units:

pH	Standard pH units (SU)
Conductivity	µmho/cm
TOC, CaCO <sub>3</sub> , COD,	mg/l
metals (Cu, Fe, Pb, Mn, Ni, Zn, Na)	
radio-isotopes	pCi/l
GWELEV	feet above sea level

Table 12: Analysis Data for the West Arc Well [ARC(W)]

MONTH	YEAR	pH	COND	TOC	GR ALPHA	(±)	GR BETA	(±)	TRITIUM	(±)	Na-22	Na-24	Be-7	Ca-45	(±)
SEP	89	5.80	260.00	59.40	125.00	(27.00)	119.00	(29.00)	< 1000.00		< 40.00	note 1	< 600.00	< 6.00	
OCT	89	6.20	205.00	6.40	203.00	(60.00)	125.00	(42.00)	< 1000.00		< 40.00	< 60.00	< 600.00	< 6.00	
NOV	89	6.40	160.00	3.90	89.00	(30.00)	70.00	(25.00)	< 1000.00		< 40.00	< 60.00	< 600.00	< 6.00	
DEC	89	5.80	225.00	4.40	< 152.00		< 111.00		< 1000.00		< 40.00	< 60.00	< 600.00	< 6.00	
JAN	90	6.20	230.00	2.10	130.00	(26.00)	128.00	(17.00)	< 1000.00		< 40.00	< 60.00	< 600.00	< 6.00	
FEB	90	6.10	250.00	520.00	97.00	(36.00)	106.00	(30.00)	< 1000.00		< 40.00	< 975.00	< 600.00	< 6.00	
MAR	90	6.00	215.00	9.82	9.04	(4.84)	4.96	(2.53)	< 1000.00		< 40.00	< 60.00	< 600.00	< 6.00	
APR	90	6.00	223.00	6.08	146.00	(44.00)	106.00	(33.00)	< 1000.00		< 40.00	< 60.00	< 600.00	< 6.00	
MAY	90	6.20	260.00	5.79	119.00	(48.00)	159.00	(50.00)	< 1000.00		< 40.00	< 60.00	< 600.00	< 6.00	
JUN	90	6.70	360.00	8.78	69.80	(34.40)	140.00	(50.00)	note 2		< 40.00	< 144.00	< 600.00	< 6.00	
JUL	90	6.40	420.00	2.84	5.28	(5.01)	6.91	(3.54)	< 1000.00		< 40.00	< 60.00	< 600.00	< 6.00	
AUG	90	6.30	530.00	5.94	364.00	(115.00)	1510.00	(170.00)	< 1000.00		< 40.00	note 1	< 600.00	< 26.00	
SEP	90	6.00	750.00	28.60	18.00	(11.00)	24.00	(7.00)	< 500.00		< 15.00	< 50.00	< 40.00	< 5.00	
DEC	90	6.14	756.00	3.00	0.00	(3.70)	5.00	(2.10)	0.00 (340.00)		< 14.00	< 46.00	< 80.00	0.00 (1.30)	
MAR	91	6.20	400.00	4.05	< 2.00		< 3.00		< 1000.00		< 16.00	< 20.00	< 137.00	< 1.00	

MONTH	YEAR	TOTAL Ra (±)	Sr-90 (±)	Mn-54	Co-60	Cs-134	Th-230 (±)	Th-232 (±)	CaCO3	COD	Cu	Fe	
SEP	89	< 1.00	57.50 (5.90)	< 60.00	< 10.00	< 10.00	8.80 (1.30)	6.27 (1.00)	130.00	53.00	0.210	65.00	
OCT	89	10.90 (1.70)	< 2.00		< 30.00	< 10.00	< 1.00	< 1.00	88.00	120.00	0.022	23.00	
NOV	89	11.10 (2.00)	< 2.00		< 30.00	< 10.00	< 1.00	< 1.00	140.00	92.00	0.007	2.30	
DEC	89	8.55 (1.31)	< 2.00		< 30.00	< 10.00	< 1.00	4.85 (0.79)	3.55 (0.63)	108.00	81.00	0.026	14.00
JAN	90	4.58 (0.75)	< 2.00		< 30.00	< 10.00	< 10.00	3.51 (0.63)	1.72 (0.40)	104.00	73.00	0.001	1.41
FEB	90	7.92 (1.22)	< 2.00		< 30.00	< 11.00	< 10.00	4.22 (0.79)	2.53 (0.55)	116.00	96.00	0.006	2.72
MAR	90	1.69 (0.34)	< 2.00		< 30.00	< 10.00	< 10.00	< 1.00	< 1.00	100.00	290.00	0.004	0.32
APR	90	9.31 (1.43)	< 2.00		< 30.00	< 10.00	< 10.00	3.71 (0.86)	3.43 (0.82)	680.00	71.00	0.004	2.40
MAY	90	7.35 (1.18)	< 2.00		< 30.00	< 10.00	< 10.00	5.32 (0.93)	5.63 (0.97)	108.00	100.00	0.005	< 0.03
JUN	90	5.23 (0.84)	< 2.00		< 30.00	< 10.00	< 10.00	2.67 (0.70)	< 1.00	164.00	80.00	0.003	1.20
JUL	90	2.38 (0.39)	< 2.00		< 30.00	< 10.00	< 10.00	< 1.00	< 1.00	212.00	85.00	0.001	3.68
AUG	90	3.31 (0.50)	< 2.00		< 30.00	< 10.00	< 10.00	< 1.20	< 1.20	260.00	49.00	< 0.010	8.66
SEP	90	4.00 (1.00)	< 0.50		< 2.00	< 5.00	< 10.00	< 0.60	< 0.60	1000.00	52.00	< 0.010	21.60
DEC	90	0.20 (0.20)	0.00 (1.00)	< 11.00	< 11.00	< 12.00	< 11.00	< 11.00	< 11.00	325.00	< 20.00	< 0.001	< 0.05
MAR	91	< 1.00	< 0.70		< 16.00	< 10.00	< 10.00	note 2	< 1.00	190.00	< 25.00	0.004	16.90

MONTH	YEAR	Pb	Mn	Ni	Zn	Na	GWELEV
SEP	89	0.210	0.230	< 0.04	0.64	23.40	6.00
OCT	89	0.070	0.160	< 0.04	0.10	18.50	19.00
NOV	89	< 0.050	0.090	< 0.04	0.02	17.80	6.00
DEC	89	0.060	0.130	< 0.04	0.12	19.10	6.00
JAN	90	< 0.050	0.090	< 0.04	0.01	18.20	7.00
FEB	90	< 0.050	0.090	< 0.04	< 0.01	17.20	12.00
MAR	90	< 0.020	0.070	< 0.01	0.01	15.90	10.00
APR	90	< 0.020	0.110	< 0.01	< 0.01	20.90	13.00
MAY	90	< 0.050	0.110	< 0.04	0.02	24.30	5.00
JUN	90	< 0.020	0.090	< 0.01	< 0.01	33.50	4.00
JUL	90	< 0.010	0.087	< 0.01	< 0.01	31.80	11.00
AUG	90	0.010	0.148	0.01	0.02	30.20	5.00
SEP	90	< 0.010	0.270	< 0.01	0.05	32.80	10.00
DEC	90	0.003	< 0.010	< 0.01	< 0.01	25.00	10.00
MAR	91	< 0.010	0.146	< 0.01	< 0.01	24.60	8.00

NOTES

Note 1: Analysis not performed due to half life restrictions.  
 Note 2: Analysis not performed, reason unknown.

Units:

pH	Standard pH units (SU)
Conductivity	µho/cm
TOC, CaCO <sub>3</sub> , COD,	mg/l
metals (Cu, Fe, Pb, Mn, Ni, Zn, Na)	
radio-isotopes	pCi/l
GW elevation	feet above sea level

Table 13: Analysis Data for Construction Dewater Samples

MONTH	YEAR	pH	COND	TOC	GR ALPHA (±)	GR BETA (±)	TRITIUM	Na-22	Na-24	Be-7	Ca-45 (±)
SEP	89	7.60	710.00	15.20	3.00 (1.00)	< 4.00	< 1000.00	< 40.00	< 74.00	< 600.00	< 6.00
OCT	89	8.20	700.00	4.20	4.00 (2.00)	< 3.00	< 1000.00	< 40.00	< 60.00	< 600.00	< 6.00
NOV	89	8.30	590.00	3.20	< 4.00	< 7.00	< 1000.00	< 40.00	< 60.00	< 600.00	< 6.00
DEC	89	7.50	480.00	4.20	< 24.00	< 4.00	< 1000.00	< 40.00	< 60.00	< 600.00	< 6.00
JAN	90	7.60	470.00	3.10	5.00 (2.00)	7.00 (1.00)	< 1000.00	< 40.00	< 60.00	< 600.00	< 6.00
FEB	90	7.50	540.00	5.26	4.00 (3.00)	< 9.00	< 1000.00	< 40.00	< 1329.00	< 600.00	< 6.00
MAR	90	6.90	380.00	2.56	6.56 (3.07)	< 4.00	< 1000.00	< 40.00	< 114.00	< 600.00	< 6.00
APR	90	7.70	415.00	2.62	< 3.80	< 5.20	< 1000.00	< 40.00	< 60.00	< 600.00	< 6.00
MAY	90	8.10	450.00	2.38	< 3.00	6.21 (3.79)	< 1000.00	< 40.00	< 60.00	< 600.00	< 6.00
JUN	90	note 2									
JUL	90	7.80	500.00	2.43	< 23.00	< 16.00	< 1000.00	< 40.00	< 110.00	< 600.00	22.50 (6.90)
AUG	90	7.80	520.00	5.03	69.3 (18.70)	42.90 (7.60)	< 1000.00	< 40.00	note 1	< 600.00	< 6.00
SEP	90	7.40	450.00	12.80	< 2.00	5.00 (3.00)	< 500.00	< 15.00	< 50.00	< 40.00	< 5.00
DEC	90	note 2									
MAR	91	7.50	350.00	3.06	8.00 (3.00)	194.00 (9.00)	< 1000.00	< 21.00	< 20.00	< 170.00	< 1.00

MONTH	YEAR	TOTAL Ra (±)	Sr-90 (±)	Mn-54	Co-60 (±)	Cs-134	Th-230 (±)	Th-232 (±)	CaCO <sub>3</sub>	COD	Cu	Fe
SEP	89	< 1.00	< 2.00	< 30.00	< 10.00	< 10.00	< 1.00	< 1.00	300.00	42.00	0.010	9.80
OCT	89	< 1.00	< 2.00	< 30.00	< 10.00	< 10.00	< 1.00	< 1.00	336.00	29.00	0.004	7.70
NOV	89	< 2.00	< 2.00	< 30.00	< 10.00	< 10.00	< 1.00	< 1.00	340.00	58.00	< 0.002	4.40
DEC	89	0.28 (0.13)	< 2.00	< 30.00	< 10.00	< 10.00	< 1.00	< 1.00	316.00	42.00	0.002	2.50
JAN	90	< 1.00	< 2.00	< 30.00	< 10.00	< 10.00	1.05 (0.31)	< 1.00	396.00	31.00	0.003	4.90
FEB	90	< 1.00	< 2.00	< 30.00	< 10.00	< 10.00	< 1.00	< 1.00	316.00	43.00	0.002	1.22
MAR	90	< 1.00	< 2.00	< 30.00	< 10.00	< 10.00	< 1.00	< 1.00	188.00	44.00	0.002	8.60
APR	90	< 1.00	2.45 (0.32)	< 30.00	< 10.00	< 10.00	< 1.00	< 1.00	580.00	32.00	0.004	< 0.03
MAY	90	< 1.00	< 2.00	< 30.00	< 10.00	< 10.00	1.25 (0.26)	< 1.00	192.00	< 25.00	0.002	6.30
JUN	90											
JUL	90	5.53 (0.93)	< 2.00	< 30.00	< 10.00	< 10.00	< 1.00	< 1.00	252.00	13.00	< 0.001	< 0.02
AUG	90	1.02 (0.18)	< 2.00	< 30.00	15.90 (5.30)	< 10.00	1.75 (0.59)	< 1.00	236.00	38.00	< 0.010	1.03
SEP	90	< 1.00	< 0.50	< 2.00	92.50 (3.90)	< 10.00	< 0.60	< 0.60	650.00	73.00	< 0.010	1.08
DEC	90											
MAR	91	< 1.00	< 0.60	< 19.00	< 10.00	< 10.00	note 2	< 1.00	220.00	26.00	0.003	1.76

MONTH	YEAR	Pb	Mn	Ni	Zn	Na	GWELEV
SEP	89	0.09	0.270	0.04	0.18	22.30	0.00
OCT	89	< 0.05	0.230	0.13	0.37	22.40	0.00
NOV	89	< 0.05	0.200	< 0.04	0.15	23.30	0.00
DEC	89	< 0.05	0.280	< 0.04	0.01	20.90	0.00
JAN	90	< 0.05	0.030	< 0.04	0.02	54.70	0.00
FEB	90	< 0.05	0.290	0.08	0.07	18.00	0.00
MAR	90	< 0.02	0.320	< 0.01	0.02	15.80	0.00
APR	90	< 0.02	0.080	< 0.01	0.02	28.90	0.00
MAY	90	< 0.05	0.080	< 0.04	0.15	30.40	0.00
JUN	90						
JUL	90	< 0.01	0.010	< 0.01	< 0.01	21.10	0.00
AUG	90	0.02	0.030	< 0.01	0.02	18.10	0.00
SEP	90	< 0.01	0.060	< 0.01	0.02	18.70	0.00
DEC	90						
MAR	91	0.01	0.094	< 0.01	0.03	17.70	0.00

#### NOTES

Note 1: Analysis not performed due to half life restrictions.  
 Note 2: No sample taken due to no surface water available.

#### Units:

pH	Standard pH units (SU)
Conductivity	µho/cm
TOC, CaCO <sub>3</sub> , COD,	mg/l
metals (Cu, Fe, Pb, Mn, Ni, Zn, Na)	
radio-isotopes	pCi/l
GWELEV	feet above sea level

## References

- Dav66      Hydrogeology; Stanley N. Davis and Roger J. M. DeWiest; John Wiley & Sons; 1966
- Ehl82      Petrology: Igneous, Sedimentary, and Metamorphic; Ernest G. Ehlers and Harvey Blatt; WH Freeman & Co.; 1982
- Epa89      Statistical Analysis of Ground-water Monitoring at RCRA Facilities; USEPA Publication; 1989
- Law85      Report of the Preliminary Geotechnical Exploration Continuous Electron Beam Accelerator Facility; Law Engineering Testing Company; Oct. 3, 1985
- Men75      Introduction to Probability and Statistics; William Mendenhall; Duxbury Press; 1975
- Vpa89      Application for Virginia Pollution Abatement Permit Number VPA01001; March 1989
- Wqs88      Commonwealth of Virginia State Water Control Board Regulations, Water Quality Standards; July 1988

## Appendix A Sample Calculation for Test of Proportions

The sample calculation will be done with the values for Ca<sup>45</sup>. The variables and their values are:

X - number of up gradient well samples with detectable concentrations of Ca<sup>45</sup>. Value for this calculation: 2

Y - number of down gradient well samples with detectable concentrations of Ca<sup>45</sup>. Value for this calculation: 8

n<sub>b</sub> - number of up gradient well samples analyzed. Value for this calculation: 15

n<sub>c</sub> - number of down gradient well samples analyzed. Value for this calculation: 88

$$\hat{P} = \frac{(X+Y)}{(n_b+n_c)} = \frac{(2+8)}{(15+88)} = \frac{10}{103} = 0.155$$

$$n\hat{P} = 103(0.155) = 15.96$$

$$n(1-\hat{P}) = 103(1-0.155) = 87.04$$

Since P<sub>b</sub> and P<sub>c</sub> are greater than 5, the normal approximation may be used. The next step is to compute the proportion of detects in the up and down gradient wells.

$$\hat{P}_b = \frac{X}{n_b} = \frac{2}{15} = 0.133$$

$$\hat{P}_c = \frac{Y}{n_c} = \frac{8}{88} = 0.091$$

The standard error of the difference of the proportions is calculated:

$$\begin{aligned} SD &= \sqrt{\frac{(X+Y)}{(n_b+n_c)} \left(1 - \frac{(X+Y)}{(n_b+n_c)}\right) \left(\frac{1}{n_b} + \frac{1}{n_c}\right)^{0.5}} \\ &= \sqrt{\frac{(2+8)}{(15+88)} \left(1 - \frac{(2+8)}{(15+88)}\right) \left(\frac{1}{15} + \frac{1}{88}\right)^{0.5}} \\ &= 0.024 \end{aligned}$$

Then the statistic Z is formed:

$$Z = \frac{(\hat{P}_b - \hat{P}_c)}{SD} = \frac{(0.133 - 0.091)}{0.024} = 1.75$$

Since this value is less than 1.96 we can say that there is no statistical evidence of contamination.