

4.0 BACKGROUND CONCENTRATIONS OF INORGANIC ANALYTES

This section discusses metal concentrations detected in background soil samples, and metal, anion, and radionuclide concentrations in groundwater across the site. The metal concentrations in background soil samples provide a measure of natural conditions against which to compare the results of soil sample analyses at SWMUs where metals are suspected contaminants. In the case of groundwater, a strong trend toward higher total dissolved solids (TDS) from northeast to southwest across the site requires a way of establishing a range of background concentrations of naturally occurring constituents in order to identify potential contamination. To establish these background levels of inorganic constituents in groundwater, statistical methods were applied. These methods, which are described below, demonstrated that background concentrations in groundwater cannot be confidently determined with the existing data. However, simple statistical summaries of the data are presented for use in subjective assessment of the values measured at any individual well. This section has not been altered, since new data generated as part of the Additional Sampling Program replace only a small portion of the RFI-Phase I data set.

4.1 BACKGROUND CONCENTRATIONS OF METALS IN SOIL

During the RFI-Phase I, ten background soil samples were collected to determine natural levels of metals near SWMUs 5, 8, 9, 14, 19, 22, 23, 26, 27, 29, and 36 where these metals were suspected contaminants in soil samples. The background soil samples, like the samples from the SWMUs, were composite samples from the 0 to 3 ft depth interval. The locations of these background samples are illustrated in appropriate figures in Section 5.0 of this report.

The background soil samples were analyzed for antimony, arsenic, beryllium, cadmium, chromium, copper, lead, mercury, nickel, selenium, silver, thallium, and zinc. Summary statistics were calculated to estimate the mean and upper bound of each background metal concentration. Table 4.1-1 summarizes these statistics.

Arsenic, beryllium, chromium, copper, silver, and zinc were among the metals detected in all ten background samples. The upper bounds of background concentrations of these metals were estimated by tolerance levels calculated according to procedures outlined in a RCRA guidance document on statistical methods (EPA 1989a). For each of these metals, the background concentration distribution was evaluated through a Kolmogorov-Smirnov test. Since each of these metals' concentration distributions was normal, the tolerance level was calculated by adding the mean concentration to one standard deviation times a tolerance factor related to the number of samples in the population. The greater the number of samples in the group, the smaller the tolerance factor. This process resulted in a background metal concentration upper bound with a confidence level of 95 percent. Therefore, a metal concentration within a SWMU that exceeds the tolerance level is considered to indicate contamination.

Sodium was detected in seven of ten background samples. For the derivation of the arithmetic mean and standard deviation, one-half of the CRL (detection limit) was substituted for the non-detections. The distribution was verified to meet the criteria of the Kolmogorov-Smirnov test for normality, and the tolerance level was calculated.

Table 4.1-1 • Background Metal Concentrations in Soil, Page 1 of 1

Metals	Frequency of Detections	Range (ug/g)	Arithmetic Mean (\bar{x}) (ug/g)	Geometric Mean (ug/g)	Standard Deviation (ug/g)	K-S Test Result	Tolerance Level (TL) (ug/g)
Antimony	0/10	<19.6	--	--	--	--	*** 20
Arsenic	10/10	12-39	18	17	7.9	0.22	41
Beryllium	10/10	0.23-0.38	0.30	0.29	0.05	0.98	0.45
Cadmium	1/10	<1.2-21	--	--	--	--	*** 21
Chromium	10/10	17-56	26	24	12	0.42	61
Copper	10/10	11-58	21	18	14	0.22	62
Lead	10/10	9.4-250	56	26	87	**0.03	250
Mercury	2/10	<0.03-0.32	--	--	--	--	***0.32
Nickel	0/10	<2.7	--	--	--	--	*** 2.7
Selenium	0/10	BCRL	--	--	--	--	*** 5.8
Silver	10/10	0.09-1.8	0.36	0.22	0.52	0.18	1.9
Sodium	7/10	* <19-2200	880	280	880	0.42	3400
Thallium	0/10	<34.3	--	--	--	--	*** 34
Zinc	10/10	46-230	81	71	56	0.27	240

* - Lower range values assigned at Certified Reporting Limit (CRL)/2

** - Does not meet criteria for normal distribution, TL = Maximum concentration detected

*** - TL = CRL or upper range of detections because of low frequency of detections

K-S - Kolmogorov-Smirnov test for normal distribution; result greater than 0.05 indicates normal distribution

TL - $\bar{x} + ks$, where \bar{x} = Arithmetic Mean, k = Tolerance Factor for one-sided tolerance intervals with probability (confidence factor) $Y = .95$ and coverage $P = 95\%$, s = Standard Deviation (EPA, 1989a).

-- - Not applicable

Lead concentrations in background samples did not satisfy the test for a normal distribution, but did meet the criteria for a log-normal distribution; therefore, the concentration data for lead were transformed by taking the natural log of each value and the natural log of the tolerance level was calculated. However, when the antilog of this calculated value was taken to find the actual tolerance level, this level was significantly higher than any lead concentration detected in background soil samples and was rejected. Because these samples were biased to be indicative of background conditions, the highest detected lead concentration in the background samples was, therefore, selected as a possible upper bound.

Mercury was detected in only two samples, and cadmium was detected in only one. For these two metals, the maximum detected background concentration was selected as a tentative upper bound, since statistical methods are inappropriate to use in cases of low frequency of detections.

Antimony, nickel, selenium, and thallium were not detected in any of the background soil samples. Therefore, any detection of these metals may indicate potential contamination.

These upper bound metal concentrations have been used in the evaluation of soil sample metal concentrations in the discussion of each sampled SWMU in Section 5.0 of this report.

4.2 BACKGROUND CONCENTRATIONS OF INORGANIC ANALYTES IN GROUNDWATER

During the RFI-Phase I field investigation, groundwater samples were collected from 73 monitoring wells across the site. Chemical analyses performed on each sample included measurement of metals, anions, and radionuclides that occur naturally in groundwater. The natural concentrations of these analytes are expected to follow trends across the site that are related to natural degradation of groundwater quality. The delineation of groundwater quality zones and the procedure used to establish background inorganic concentrations in each zone are discussed briefly below. In most cases, the assessment of background conditions was performed using RFI-Phase I data since previous sampling programs included fewer monitoring wells. However, where noted, certain RFI-Phase I results were confirmed using the previously collected data. All of the RFI-Phase I and previously collected data are considered in the discussion of each SWMU in Section 5.0 of this report.

4.2.1 Delineation of Water Quality Zones

The general water quality of Rush Valley has been studied previously by Hood, Price, and Waddell (1969). They reported a relatively abrupt change in TDS concentrations between the northeastern two-thirds and southwestern one-third of TEAD-S. This groundwater quality change occurs along a boundary which is generally consistent with the highest recognized Lake Bonneville shoreline in the TEAD-S area, suggesting that the change may correlate with a change in the underlying aquifer material.

Using groundwater data collected from numerous wells in Rush Valley, Hood, Price, and Waddell (1969) presented evidence that groundwater in the northeastern two thirds of TEAD-S flows

predominantly through alluvial sediments. This groundwater is hard and fresh, and is characterized by calcium and bicarbonate with relatively low concentrations of magnesium, sodium, sulfate, and chloride. Groundwater in the southwestern one-third of TEAD-S, which flows through lacustrine sediments, is brackish. The chemical composition of groundwater in this area is characterized by high concentrations of sodium, calcium, magnesium, bicarbonate, sulfate, and chloride.

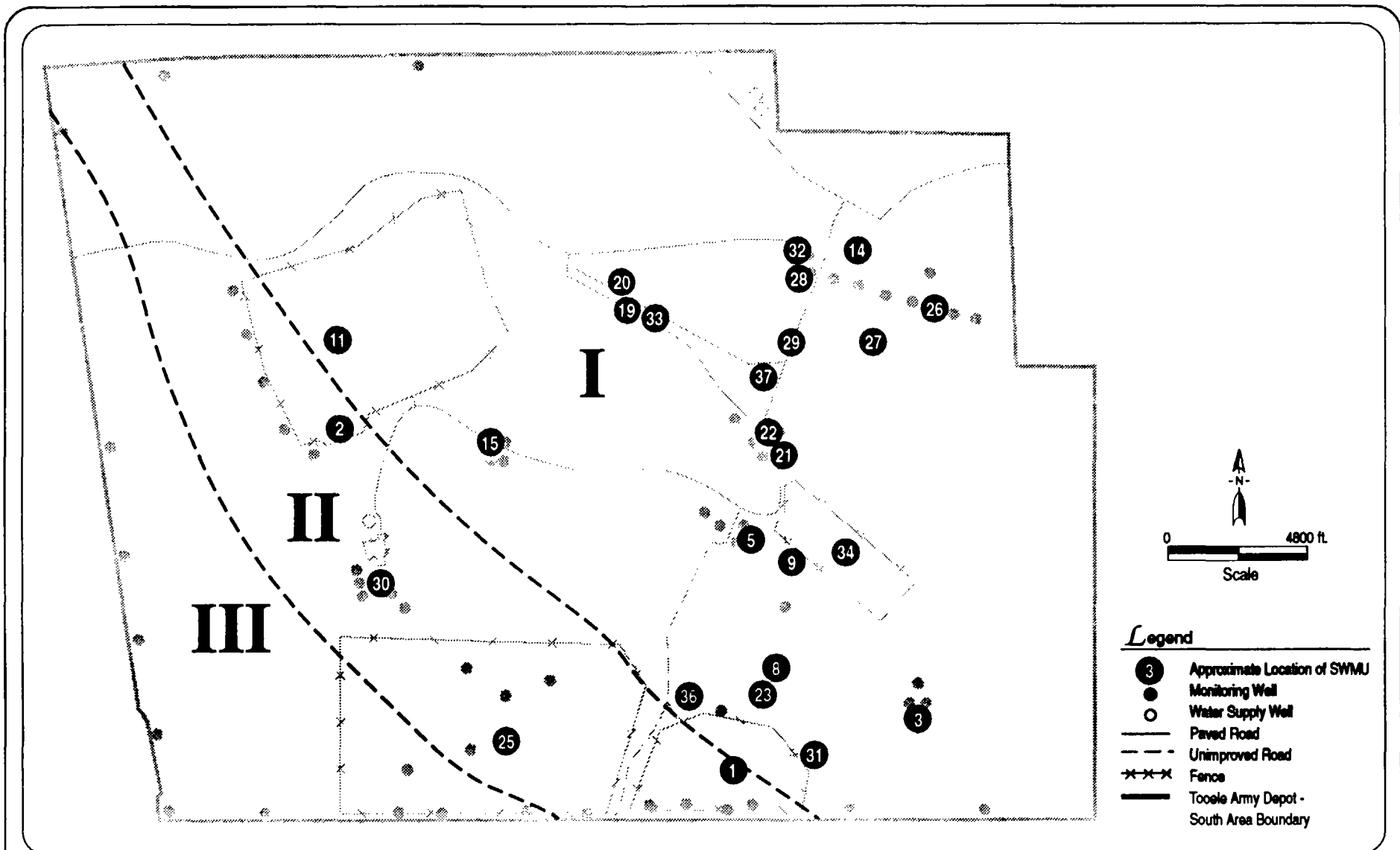
In the RI report (Weston 1991), total chloride plus sulfate concentrations were used to conservatively estimate TDS and delineate TDS-based water quality zones within TEAD-S. Since the RFI-Phase I analyses did not include sulfate, this process was repeated in the RFI-Phase I using chloride data, and three zones were distinguished (Figure 4.2-1). The trend of these zones is roughly consistent with the conclusions of Hood, Price, and Waddell (1969), and with the RI report.

The RFI-Phase I chloride data for all of the monitoring wells was compiled, and the arithmetic mean and standard deviation were calculated. The mean chloride concentration in all monitoring wells at the site was approximately 4,000 mg/l. This mean corresponds to brackish or more saline water quality based on TDS ranges (Driscoll 1986).

Using one-half of the standard deviation as a range about the mean yielded a range of chloride concentrations between 1,000 and 7,000 mg/l. Because chloride is only one component of TDS, this range is characterized by TDS concentrations of at least 1,000 mg/l to at least 7,000 mg/l and roughly corresponds with brackish water quality (Driscoll 1986). Wells with chloride concentrations greater than 7,000 mg/l were grouped as saline or corrosive saltwater, and wells with chloride concentrations less than 1,000 mg/l were grouped as fresh water.

The locations of the monitoring wells in each water quality group were plotted to assess whether the ranges corresponded to geographic zones. Except for a few wells, those with fresh water were located in the northeast part of the site, those with brackish water plotted in the central part of the site, and those with saltwater plotted in the southwest and west parts of the site. A few wells were shifted from one chemical group to another if their locations clearly contradicted the zone assignments made on the basis of chemistry alone. However, the reassignments were made only between adjacent zones.

Next, the zones were compared statistically to confirm that the zones were unique with respect to chloride concentration. A Scheffe one-way analysis of variance was conducted on chloride concentrations for all three zones and on each pair of zones. This analysis indicated that the chloride concentrations in each zone were significantly different and could be considered separate statistical populations. Therefore, all of the groundwater inorganic analyte data were divided into groups defined by the three zones, and subsequent statistical summaries are presented independently for each zone.



I - Fresh Zone
 II - Transition Zone
 III - Saline Zone

Figure 4.2-1
Water Quality Zones Based on Sodium Chloride Concentrations
 Tooele Army Depot - South Area
 Prepared by: Ebasco Services Incorporated

Table 4.2-1 lists the wells assigned to each water quality zone, and the location of each water quality zone is presented in Figure 4.2-1. Monitoring wells at SWMUs 1, 2, 11, 25, 30, 31, and 36, are in zones II and III. Monitoring wells at all other investigated SWMUs are in zone I.

4.2.2 Metals in Groundwater

RFI-Phase I metal data were evaluated statistically in an attempt to establish a background range for each metal in each water quality zone. Metals were analyzed in both filtered and unfiltered samples to measure dissolved and total concentrations, respectively. In general, the reported concentrations in filtered samples were as high or higher than those in unfiltered samples. The same relationship was noted in the RI results. Inaccuracy of the laboratory analytical method may account for this theoretically impossible relationship. For this reason and since the filtered samples best represent the groundwater medium, the analysis of background metal concentration ranges was attempted using only data from filtered samples.

The approach used to evaluate inorganics data followed RCRA guidance on statistical analysis of groundwater chemical data (EPA 1989a). The tolerance level procedure was followed to attempt to identify background concentrations for each metal within each water quality zone.

First the frequency of detection of each metal in each zone was tabulated. For analytes with a frequency of detection above 85 percent, the nondetects were replaced with a value equal to one-half of the CRL (detection limit), and the range, arithmetic mean, and standard deviation were calculated. Then the distribution was verified to be normal or log-normal using the Kolmogorov-Smirnov test. If the distribution was normal, a tolerance level was calculated using the arithmetic mean plus the standard deviation multiplied by the appropriate tolerance factor. The greater the number of samples in the group, the smaller the tolerance factor. This process resulted in a background metal concentration upper bound with a confidence level of 95 percent. Therefore, a metal concentration within a SWMU that exceeds the tolerance level determined for a water quality zone is considered to indicate contamination. If the distribution was log-normal only, then the data were transformed using the natural logarithm of the concentration and the value of the tolerance level was calculated before transforming the tolerance value by taking its antilog.

If the frequency of detections was less than 85 percent, only the range of reported concentrations was presented, and no further statistics were calculated. A summary of frequency of detections, arithmetic means, and standard deviations for each metal in each zone are presented in Table 4.2-2.

Sodium and arsenic were the only metals detected in water quality zones with frequencies of detections above 85 percent. Data were normally distributed for sodium in water quality zones II and III and arsenic in water quality zone III, and the tolerance level was calculated by adding the arithmetic mean concentration to one standard deviation times a tolerance factor related to the number of samples in the population.

Table 4.2-1 • Monitoring Wells Assigned to Water Quality Zones, Page 1 of 1

Zone 1 (Fresh)	Zone 2 (Transition)	Zone 3 (Saline)
2-S	S-1	S-14
S-10	S-12	S-18-88
S-16-88	S-22-88	S-19-88
S-17-88	S-25-88	S-21-88
S-2	S-26-88	S-23-88
S-20-88	S-27-88	S-24-88
S-32-90	S-28-88	S-31-88
S-33-90	S-29-88	S-6
S-34-90	S-3	S-67-90
S-35-90	S-30-88	
S-36-90	S-4	
S-37-90	S-45-90	
S-38-90	S-46-90	
S-39-90	S-5	
S-40-90	S-54-90	
S-41-90	S-55-90	
S-42-90	S-56-90	
S-43-90	S-57-90	
S-44-90	S-58-90	
S-47-90	S-59-90	
S-48-90	S-60-90	
S-49-90	S-64-90	
S-50-90	S-65-90	
S-51-90	S-66-90	
S-53-90	S-68-90	
S-61-90	S-7	
S-62-90	S-70-90	
S-63-90	S-71-90	
S-69-90	S-74-90	
S-8	S-75-90	
S-SBR-1	S-CAM-1	
	S-CAM-2	

Table 4.2-2 • Summary Statistics for Inorganics in Groundwater

Analyte	Zone I				Zone II				Zone III			
	Detection/ Number of Samples	Range (µg/l)	Arithmetic Mean (µg/l) *	Standard Deviation (µg/l) *	Detection/ Number of Samples	Range (µg/l)	Arithmetic Mean (µg/l) *	Standard Deviation (µg/l) *	Detection/ Number of Samples	Range (µg/l)	Arithmetic Mean (µg/l) *	Standard Deviation (µg/l) *
Metals												
Antimony	0/31	<38	--	--	3/32	<38-140	--	--	2/9	<38-120	--	--
Arsenic	13/31	<2.54-50	--	--	32/32	3.0-1,300	250	340	9/9	17-450	220	160
Beryllium	0/31	<5.0	--	--	0/32	<5.0	--	--	0/9	<5.0	--	--
Cadmium	0/31	<4.0	--	--	0/32	<4.0	--	--	0/9	<4.0	--	--
Chromium	9/31	<6.0-27	--	--	2/32	<6.0-31	--	--	0/9	<6.0	--	--
Copper	2/31	<8.1-31	--	--	4/32	<8.1-73	--	--	0/9	<8.1	--	--
Lead	14/31	<1.3-39	--	--	17/32	<1.3-25	--	--	3/9	<1.3-46	--	--
Mercury	1/31	<0.24-0.27	--	--	5/32	<0.24-0.93	--	--	0/9	<0.24	--	--
Nickel	0/31	<34	--	--	0/32	<34	--	--	0/9	<34	--	--
Selenium	4/31	<3.0-36	--	--	13/32	<3.0-200	--	--	5/9	<3.0-130	--	--
Silver	0/31	<4.6	--	--	0/32	<4.6	--	--	0/9	<4.6	--	--
Sodium	31/31	16,000-380,000	75,000	81,000	32/32	430,000-8,200,000	2,600,000	2,100,000	9/9	1,600,000-21,000,000	7,300,000	5,700,000
Thallium	0/31	<7.0	--	--	0/32	<7.0	--	--	0/9	<7.0	--	--
Zinc	8/31	<21-270	--	--	1/32	<21-26	--	--	0/9	<21	--	--
Anions												
Bromide	18/31	<5.0-1,500	--	--	29/32	<5.0-18,000	3,100	4,000	9/9	2,900-23,000	9,400	7,300
Chloride	29/31	<273-2,300,000	330,000	490,000	31/32	<273-18,000,000	5,400,000	900,000	9/9	40,000-36,000,000	12,000,000	1,000,000
Fluoride	13/31	<71-14,000	--	--	4/32	<71-8,300	--	--	2/9	<71-55,000	--	--

-- - Mean and Standard Deviations not presented for frequency of detections below 85%

* - For detection frequencies above 85%, for BCRL values, the CRL/2 was substituted for calculation of Mean and Standard Deviation.

For sodium in zone I and arsenic in zone II, the distribution of concentrations did not meet the criteria for a normal distribution; however, the distributions did meet the Kolmogorov-Smirnov criterion for a log-normal distribution. For these data, the tolerance level was calculated by taking the natural log of concentration values, calculating an arithmetic mean and standard deviation of the logs, calculating a transformed tolerance level and taking the antilog of that value. The tolerance levels calculated by this method greatly exceeded the highest detected value for arsenic and sodium and therefore were rejected. Results of the Kolmogorov-Smirnov test for distribution normality and tolerance levels for sodium and arsenic are presented in Table 4.2-3.

The frequency of detections was low for metals other than sodium and arsenic and ranges of detected concentrations for each metal generally overlap between zones. This may indicate that matrix interference due to high concentrations of sodium has affected the analytical results for other metals. The effects of the matrix interference were confirmed by the laboratory analysts. Therefore, metals other than sodium and arsenic were not analyzed statistically, and no background levels could be established. These other metal concentrations at each SWMU can only be compared subjectively to the simple summary statistics in Table 4.2-2.

4.2.3 Anions in Groundwater

Anion concentrations in samples collected previous to the RFI-Phase I were relatively high for chloride, fluoride, sulfate, and nitrate in the southwestern portions of TEAD-S. These results are consistent with the trend of deteriorating water quality that is thought to occur naturally across the site. Cyanide, which is not expected to occur naturally, was detected in 1982 (Ertec 1982) in one sample from a well in the area of SWMU 30, but no subsequent analyses have detected cyanide in any part of the site.

RFI-Phase I samples were analyzed for chloride, bromide, and fluoride. For anions in each zone that exhibited a frequency of detection above 85 percent, the nondetects were replaced with a value equal to one-half of the CRL (detection limit), and the range, arithmetic mean, and standard deviation were calculated. If the frequency of detections was less than 85 percent, only the range of reported concentrations was presented, and no further statistics were calculated.

The results of statistical analysis of these anion data are presented in Table 4.2-2. Chloride was detected in greater than 85 percent of the samples within each zone, and bromide was detected in more than 85 percent of the samples from zones II and III. The distributions of these anions were evaluated using the Kolmogorov-Smirnov test for normality or log-normality.

Chloride in water quality zones II and III and bromide in water quality zone III were normally distributed, and tolerance levels were calculated as for the metals. Chloride concentrations in zone I and bromide concentrations in zone II did not meet the criterion for normality but were log-normally distributed. Tolerance levels calculated using log transforms of the data were rejected because they greatly exceeded the highest detected levels of these anions. Therefore, except for chloride concentrations in water quality zones II and III and bromide concentrations

Table 4.2-3 • Tolerance Levels Compiled for Inorganics in Groundwater

Analyte	Zone I		Zone II		Zone III	
	K-S Test*	Tolerance Level (µg/l)	K-S Test*	Tolerance Level (µg/l)	K-S Test*	Tolerance Level (µg/l)
Metals						
Arsenic	--	--	0.018	3,100	0.54	700
Sodium	0.012	290,000	0.13	7,300,000	0.32	25,000,000
Anions						
Bromide	--	--	0.006	19,000	0.28	32,000
Chloride	0.037	4,100,000	0.07	7,400,000	0.79	15,000,000

* K-S Test - (Kolmogorov-Smirnov test for normal distributions) If result is less than 0.05, then the distribution may not be normal.

For results less than 0.05 on Table, distribution tested for log normal distribution.

All results of log normal distribution test were greater than 0.05.

-- - Detection frequencies below 85%

in water quality zone III, the anion concentrations at each SWMU can only be compared subjectively to the simple summary statistics in Table 4.2-2.

4.2.4 Radiological Parameters in Groundwater

Previous and RFI-Phase I analyses for radiological parameters included measurement of gross alpha, gross beta, and total uranium. These data were not evaluated statistically in this study because of the wide variability in the analytical results and the large uncertainties associated with the results.

Previous measurements of gross alpha, gross beta, and total uranium showed that, in general, the total uranium activity increased with increasing TDS and, therefore, appeared to be consistent with natural conditions. The only trend identified in the gross alpha and gross beta measurements was that gross alpha activity was greater than or equal to the gross beta activity in any one sample (Weston 1991).

The gross alpha, gross beta, and total uranium activities measured in RFI-Phase I samples collected in July and August 1990 were similar to previous measurements in varying widely from well to well and across the site. In addition, the high counting errors associated with each result cast doubt on the accuracy of these measurements (counting errors are statistically calculated measures of the method accuracy). Therefore, no statistical or other analyses of these data were successful in establishing background values of groundwater radioactivity.