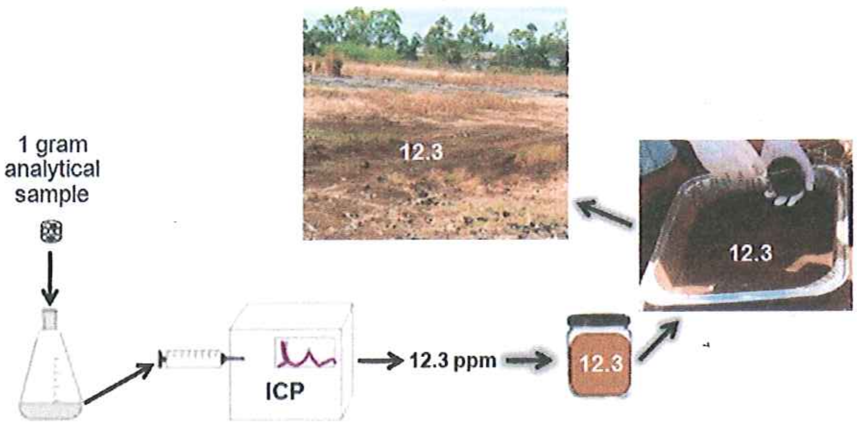
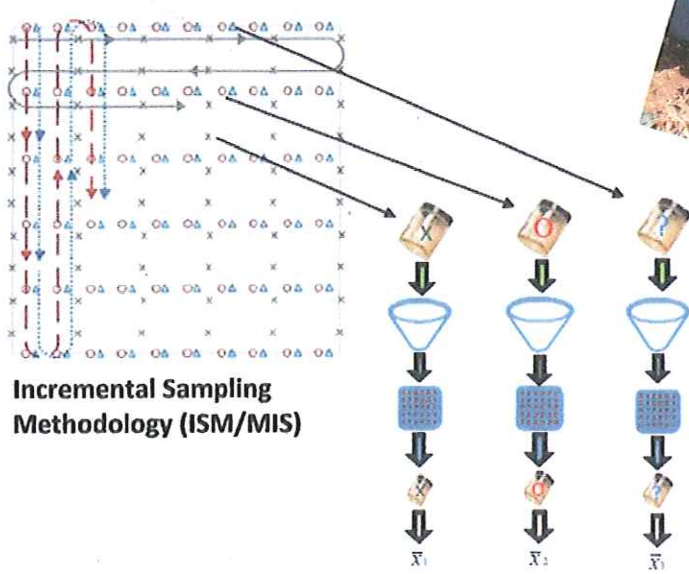
Lorena Perkins
MATH146, 6:50-7:50
4/16/11

Environmental Study
Soil Sampling Analysis



= extrapolation of analytical sample result back to the field



Incremental Sampling Methodology (ISM/MIS)

Environmental Study - Soil Sample Analysis

The purpose of this project is to compare for Hanford three different soil sampling methods which are: Incremental Sampling Method (MIS), Judgmental sampling, and Systematic sampling. At the end of this course a report will be delivered to The Department of Ecology at Hanford containing our findings. The areas being analyzed in this report are designated U1 and U2. These areas are considered contaminated. Samples were taken in May 2010, contaminated soil was removed, and samples were taken again in August of 2010.

At its most fundamental level, the purpose of most environmental investigations is to make decisions about the volumes of contaminants at concentrations above some level of concern. It is impractical to collect and analyze the entire volume of soil for which decisions must be made. Samples of that volume are collected for analyses to represent that entire volume of land. The costs of analyzing this type of data can be high and the number of samples collected is sometimes deficient because of budget constraints. Due to these limitations, Hanford is considering the use of MIS, but wants to make sure that the results are at least as accurate as the ones obtained from traditional systematic sampling.

Incremental Sampling Methodology (MIS) was developed to address some of the limitations mentioned above. MIS is a composite sampling approach where many (between 30 and 100) equal-mass increments are collected and combined in an unbiased manner from throughout the entire area of the soil/volume of interest. Once the combined increments are processed at the laboratory, a subsample is taken and analyzed.

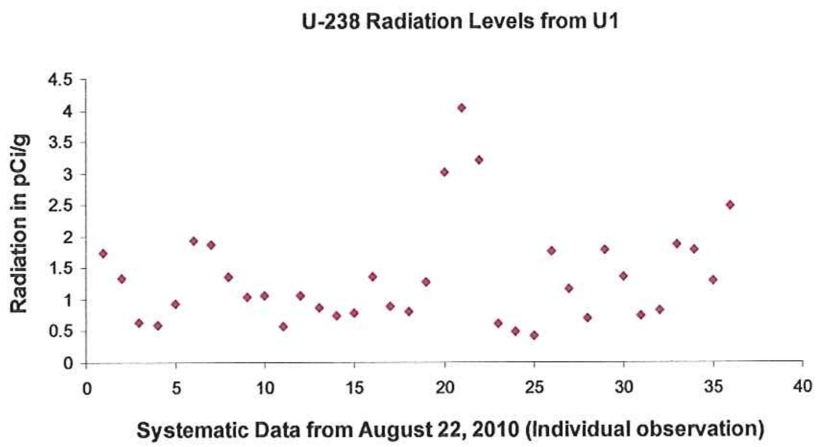
Judgmental Samplingis used when only a few discrete samples are collected. The number of samples collected is determined by negotiation, budget, professional judgment, or happenstance. The number of samples is often not based on statistical or other scientific rationale, and the location of the samples is often judgmental. Judgmental sampling plans are effective when source areas or migration pathways of high concentrations are being investigated.

Systematic Sampling requires that the area of interest be divided up into a number of grids and then a random sample(s) is taken from each and analyzed from within each of the grids. The combined results are used to represent the area of concern. The number of samples for this type of analysis may be quite large.

Graphing and Summarizing Data

1. Graphic Investigation of U-238

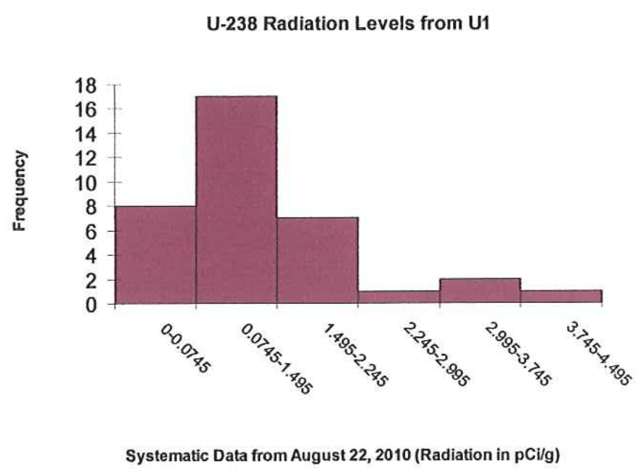
Initially the scatter plot below of the U-238 systematic data for area U1 collected August 22, 2010 was constructed to investigate the radiation levels of this element that were present at the time the sample was collected. This plot also demonstrates the heterogeneity of this radioactive element in area U1. The distribution of the unordered data appears somewhat inconsistent because there are points at which the radiation value is noticeably higher than the rest of the data. For example, there are three outliers on this graph that contain the highest levels of radiation which follow several points of relatively low levels of radiation. Also at the far left and right of the graph there are a few others points that contain higher radiation levels than the others.



Further analysis of the isotope U-238 was conducted using the same systematic data from August 22, 2010. This analysis is summarized in the Frequency Table and Histogram presented below.

U-238 Levels from U1

Radiation Level in pCi/g	Frequency
0-0.74	8
0.75-1.49	17
1.50-2.24	7
2.25-2.99	1
3.00-3.74	2
3.75-4.49	1



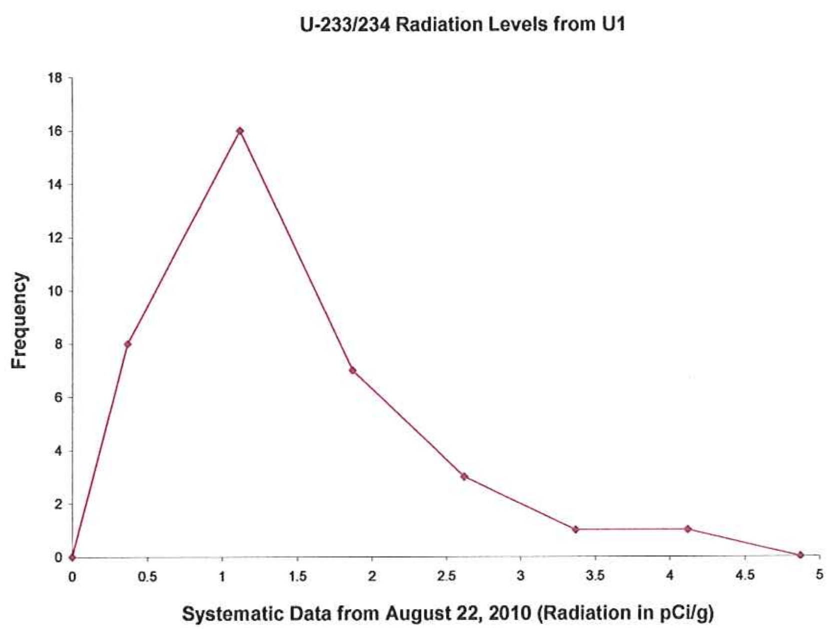
The frequency distribution and the accompanying histogram on the previous page also represent the heterogeneity of the samples taken in area U1. The frequency distribution shows that there is a substantially higher frequency in the lower levels of radiation and then a sharp decline in frequency as the levels of radiation get increasingly higher. The histogram, also on the previous page, provides visually the correspondence between the levels of radiation and their frequencies. From this it can be seen that the radiation levels of U-238 on August 22, 2010 appear to be fairly heterogeneous throughout the U1 area because the distribution of the data seems to be higher in some areas than others and is not uniform throughout. Additionally, the shape of this distribution appears to be skewed to the right, as shown in the histogram, because the lower radiation levels appear more frequently.

2. Graphic Investigation of U-233/234

The Frequency Polygon pictured below was used to illustrate the radiation levels of the isotope U-233/234 from the systematic data for area U1 collected August 22, 2010. The graph was constructed using the class midpoints for the frequency distribution below. This graph also shows the nature of the distribution of this element in area U1 at the time it was collected.

U-233/234 Values from U1

Radiation pCi/g	Frequency
0-0.74	8
0.75-1.49	16
1.50-2.24	7
2.25-2.99	3
3.00-3.74	1
3.75-4.49	1



The frequency polygon illustrates graphically that the majority of the radiation levels found in the samples were mostly at low values between 0 and 2.24 pCi/g. The frequency distribution also reflects that the distribution is skewed to the right, with a frequency of 8 for radiation levels below 0.74 pCi/g and then the frequency rapidly peaks at 16 for values between 0.75 and

1.49 pCi/g. It then gradually decreases until there are only 2 samples with radiation levels greater than 3.00 pCi/g.

3. Comparison of U-238 and U-233/234

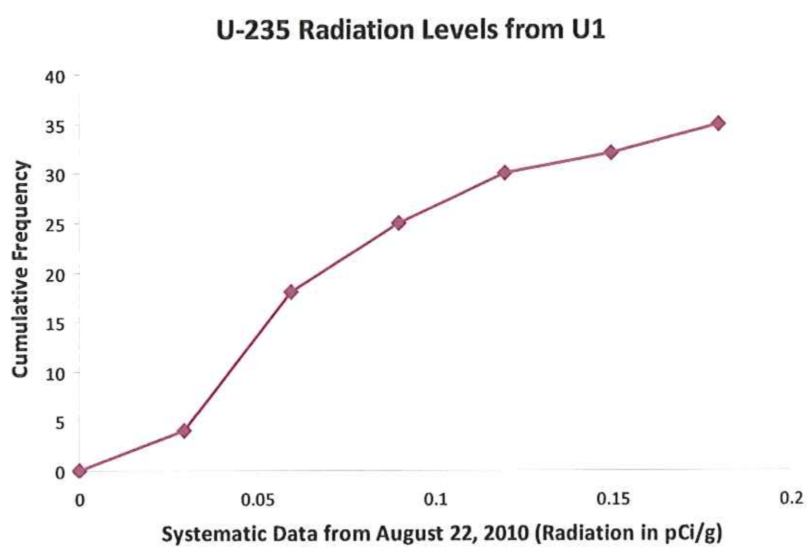
Comparing the histogram and the frequency polygon of the systematic data collected from the U1 and U2 areas on August 22, 2010 for the elements U-238 and U-233/234 it can be seen that the distribution of the data is skewed to the right in both graphs. A conclusion that can be drawn about the radiation levels in the U1 area is that there is a greater frequency of samples that correspond to the lower levels of radiation. The frequency distribution from section 1 and 2 also show this peak in frequency at lower levels of radiation. Another similarity between the two sets of data is that their frequencies and radiation levels start and end at similar levels. The starting frequencies for both sample sets are very close. They both begin with 8, peak at 16 or 17 then both decrease at an almost equal rate.

4. Graphic Investigation of U-235

The radioactive isotope U-235 was analyzed using a Cumulative Frequency Distribution in conjunction with an Ogive (cumulative frequency graph). The systematic data for this isotope was collected from area U1 on August 22, 2010. The single sample, B242080, had a level of 1.34 pCi/g and was left out of this analysis. This value is considered an outlier and is assumed to be unrepresentative of this area.

U-235 Levels from U1

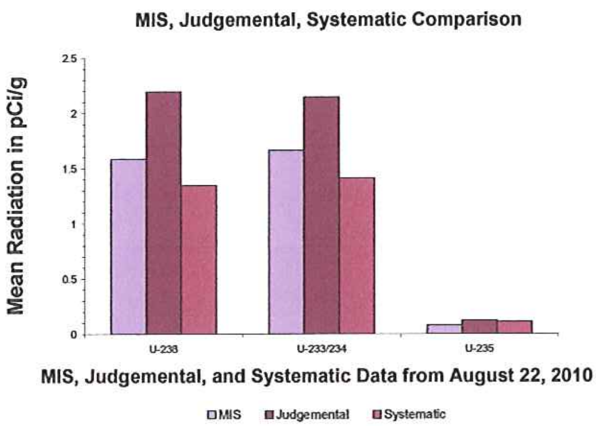
Radiation in pCi/g	Cumulative Frequency
Less than 0.03	4
Less than 0.06	18
Less than 0.09	25
Less than 0.12	30
Less than 0.15	32
Less than 0.18	35

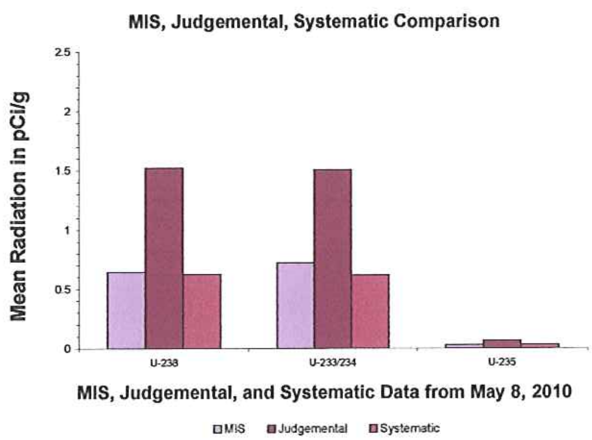


The previous cumulative frequency distribution and ogive can be used to see visually as well as numerically a composite of the radiation levels of U-235 in U1. This is helpful for analysis of the data because it shows the total frequency that corresponds below a certain radiation level.

5. Graphic Comparison of Sampling Methods for U-238, U-233/234, and U-235

A comparison analysis was conducted on the levels of radiation in the MIS, Judgmental, and systematic data collected from area U1 for U-238, U-233/234, and U-235 on August 22, 2010 and on May 8, 2010. The Multiple Bar graphs below were used to analyze this information.





When comparing the results of the MIS and systematic methods on the U-238 data from August 22 and May 8 it can be seen that both had similar results, but for both of the dates higher radiations were found through the MIS sampling method. Additionally, the judgemental sampling method obtained the highest amount of radiation in its samples, but this was the result of the data mostly being picked by their radiation amounts and not at random. The results for the U-233/234 data by using the MIS and systematic methods were similar to those of the U-238 samples because the MIS method detected higher levels of radiation than the systematic, but both were very close in their radiation amounts as was true in the U-238 results. The outcomes of the judgemental method in the U-233/234 samples were also similar to those of the U-238 samples. The radiation levels in August were higher than the ones in May. They were also higher than the other sampling methods. The MIS radiation levels for the U-235 samples were, on both dates, lower than the systematic results, but both were very similar in radiation levels. Again, the judgemental method's radiation levels were higher than the MIS and systematic results, and those same results were higher in August than in May.

6. Graphic Investigation of Chromium

A Stem and Leaf Plot was used to investigate the levels of Chromium contained in the systematic data for area U1 collected on August 22, 2010. The plot was constructed with the stems representing the ones digit of the original data values and the leaves representing the tenths digit of the original data values. This plot not only shows the nature of the Chromium distribution in the area U1 at the time of collection but allows for the preservation of the original data values.

Chromium Levels in mg/kg for Area U1, August 22, 2010

Stem (ones)	Leaf (tenths)
4	9
5	5 5 6 6 7 8 8
6	1 2 4 4 4 7 8 9
7	0 2 4 4 5 5 6 8
8	0 5 5 5 7 8
9	0 2 2 5 9
10	0

The stem and leaf plot above illustrates that the distribution of Chromium in the U1 area is fairly normal, or bell shaped, with the frequency of the radiation levels starting low, rapidly increasing, peaking, then dropping to the low frequency that it started with. It can also be seen from the stem plot above the exact value of the highest and lowest radiation levels, while still being able to see their frequencies at the same time.

Descriptive Statistics and Probability

1. Descriptive Statistics for U-238, U2344/234, and U-235

The first part of this report analyzed data collected primarily from area U1 on August 22, 2010. This section of the report will analyze data collected primarily from area U1 on May 8, 2010. Measures of central tendency and variation are extremely important when analyzing a data set. Thus, the following calculations were made and summarized in the table below for the isotopes U-238, U-233/234, and U-235 using the systematic data for U1 collected on May 8, 2010. Results were rounded to three decimal places.

U-238, U-233/234, U-235 Systematic Data from U1 May 8, 2010
(Radiation in pCi/g)

	U-238	U-233/234	U-235
Mean	0.624	0.617	0.0327
Median	0.56	0.555	0.032
Range	1.18	1.02	0.08
Standard Deviation	0.239	0.206	0.0164

The above information was used to calculate the minimum and maximum "usual" values for each isotope. Two techniques were used for these calculations, the Empirical Rule for 95% of data values and Chebyshev's Theorem for at least 93.75% of data values.

The Empirical Rule assumes that the population is normally distributed. It states that 95% of data values fall within 2 standard deviations of the mean. These calculations are presented below.

U-238 Levels

$Minimum"Usual"Value = \overline{x} - 2(s)$
$= 0.624 - 2(0.239)$
$= 0.146 pCi/g$
$Maximum"Usual"Value = \overline{x} + 2(s)$
$= 0624 + 2(0.239)$
$= 1.102 pCi/g$

U-233/234 Levels

$Minimum"Usual"Value = \overline{x} - 2(s)$
$= 0.617 - 2(0.206)$
$= 0.205 pCi/g$
$Maximum"Usual"Value = \overline{x} + 2(s)$
$= 0.617 + 2(0.206)$
$= 1.029 pCi/g$

U-235 Levels

$Minimum"Usual"Value = \overline{x} - 2(s)$
$= 0.0327 - 2(0.0164)$
$= -0.0001 pCi/g$
$Maximum"Usual"Value = \overline{x} + 2(s)$
$= 0.0327 + 2(0.0164)$
$= 0.0655 pCi/g$

Chebyshev's Theorem makes no assumptions about the distribution of the population from which the data was sampled. As a result, it provides a conservative estimate of the minimum and maximum "usual" values of a data set. This theorem states that at least 93.75% of data values fall within 4 standard deviations of the mean. These calculations are presented below.

U-238 Levels

$$Minimum"Usual"Value = \overline{x} - 4(s)$$
$$= 0.624 - 4(0.239)$$
$$= -0.332 pCi/g$$
$$Maximum"Usual"Value = \overline{x} + 4(s)$$
$$= 0.624 + 4(0.239)$$
$$= 1.58 pCi/g$$

U-233/234 Levels

$$Minimum"Usual"Value = \overline{x} - 4(s)$$
$$= 0.617 - 4(0.206)$$
$$= -0.207 pCi/g$$
$$Maximum"Usual"Value = \overline{x} + 4(s)$$
$$= 0.617 + 4(0.206)$$
$$= 1.441 pCi/g$$

U-235 Levels

$$Minimum"Usual"Value = \overline{x} - 4(s)$$
$$= 0.0327 - 4(0.0164)$$
$$= -0.0329 pCi/g$$
$$Maximum"Usual"Value = \overline{x} + 4(s)$$
$$= 0.0327 + 4(0.0164)$$
$$= 0.0983 pCi/g$$

Summaries of the "unusual" radiation levels of U-238, U-233/234, and U-235 collected using the systematic method from area U1, May 8, 2010 using both the Empirical Rule and Chebyshev's Theorem are presented in the table below.

"Unusual" Radiation Levels for Systematic Data from U1 May 8, 2010
(Radiation in pCi/g)

Element	Empirical Rule	Chebyshev's Theorem
U-238	1.13, 1.33, 1.62	1.62
U-233/234	1.03, 1.04, 1.19, 1.43	None
U-235	0.066, 0.086	None

This table shows that when using the Empirical Rule there are more "unusual" values than when using Chebyshev's Theorem. By using Chebyshev's Theorem more of the data points were included as "usual" levels of radiation because it included all data points within 4 standard deviations of the mean instead of only 2 standard deviations from the mean, which the Empirical Rule uses. Since the data is not normally distributed the use of Chebyshev's Theorem would be most appropriate in this case because the Empirical Rule cannot be used when a data set is not normally distributed or it is unknown whether it is normally distributed. Using the information from the table above it can also be concluded as to which values are the most "unusual" or extreme. Of the U-238 values, the only "unusual" value was the radiation level of 1.62 pCi/g. Any other data values should be considered "usual."

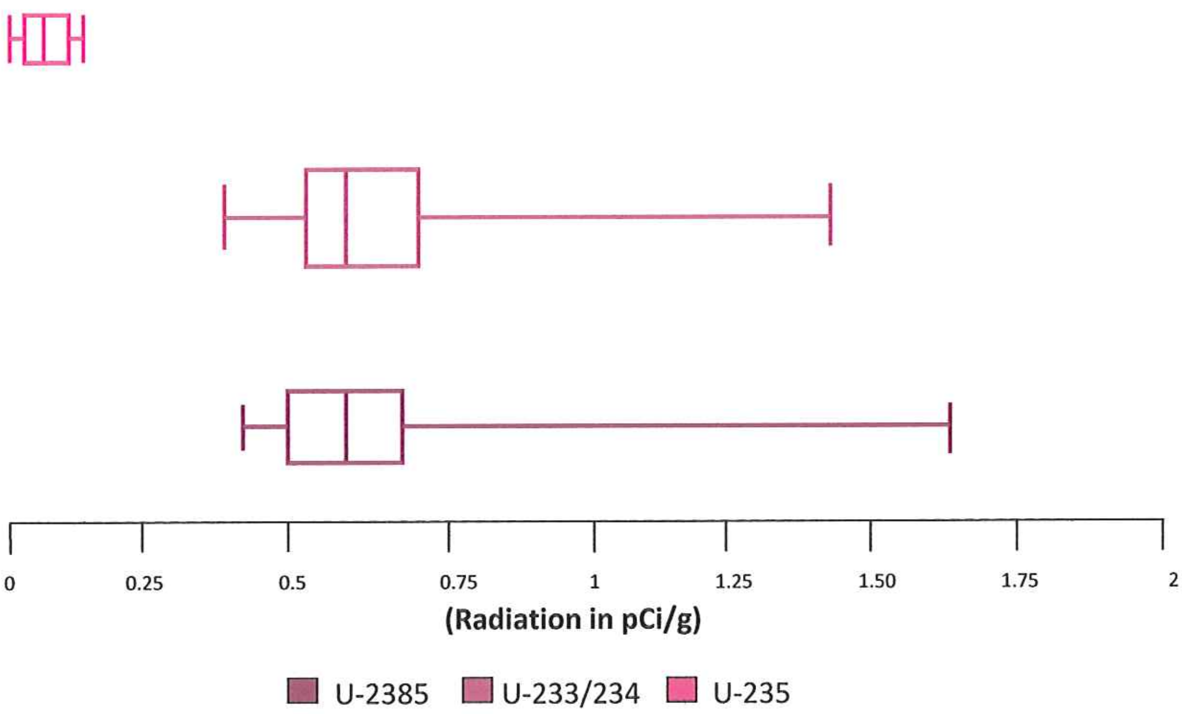
Descriptive statistical analysis also includes a 5-number summary consisting of the minimum value, the 25th percentile, the median, the 75th percentile, and the maximum value. These values are used to construct a boxplot representing the data set of interest. In this analysis 5-number summaries and stacked boxplots were calculated for the systematic data collected on

May 8, 2010 from area U1 for U-238, U-233/234, and U-235. This information is presented below.

U-238, U-233/234, U-235 Systematic Data from U1 May 8, 2010
(Radiation in pCi/g)

	U-238	U-233/234	U-235
Minimum	0.44	0.41	0.006
25th Percentile	0.5	0.53	0.021
Median	0.56	0.555	0.032
75th Percentile	0.625	0.64	0.0415
Maximum	1.62	1.43	0.086

U-238, U-233/234, U-235 Systematic Data from U1 May 8, 2010



The distribution of the U-238 radiation levels collected using the systematic method from area U1 on May 8, 2010 is skewed to the right. Similarly, the U-233/234 radiation levels collected using the systematic method from area U1 on May 8, 2010 are skewed to the right as well. The two vary by only a few points in their five number summaries. The minimum, 25th, and 75th percentiles are only different from each other by 0.03 pCi/g, 0.03 pCi/g, and 0.01 pCi/g, respectively. Both median values are about the same. This shows that the data sets have very similar values. However, the U-235 systematic data collected from U1 on May 8, 2010 was very different from the radiation levels of the other two elements. There is, however, a similarity between the U-235, U-238, and U-233/234 radiation levels because the distribution of the U-235 radiation is also skewed to the right.

2. Selecting Subsamples of U-238

Researchers observed several anomalies in the U-238 systematic data collect from area U1 on May 8, 2010. As a result of these observations, they were tasked with performing a more in depth analysis of this data. Due to budget constraints only 10 of the original samples will be selected for this extended analysis. The number of different subsamples of size 10 was determined using the following calculation:

$$_{n}C_{r} = \frac{n!}{(n-r)!r!}$$

$$_{40}C_{10} = \frac{40!}{(40-10)!10!}$$

$$= 847{,}660{,}528$$

The number 847,660,528 represents the total number of different subsamples of size ten that can be selected from the original 40 samples.

Once the researchers selected their 10 subsamples for extended analysis they were instructed to initially test only 4 of these subsamples. The order in which these 4 subsamples are tested is critical to their in-depth analysis. The number of different orders that 4 of the 10 subsamples can be selected and tested was determined using the following calculation:

$$_{n}P_{r} = \frac{n!}{(n-r)!}$$

$$_{10}P_{4} = \frac{10!}{(10-4)!}$$

$$= 5{,}040$$

This number represents the total number of different orders that 4 subsamples can be selected out of 10 subsamples.

3. Sample Probabilities for U-238, U-233/234, and U-235

Part of this soil sample research involves calculating different probabilities. The table below presents 120 different measurements taken of the radiation levels for U-238, U-233/234, and U-235 for the systematic data from U1 collected on May 8, 2010. The information in this table was used to calculate these probabilities.

Radiation Levels for the Systematic Data Collect on May 8, 2010 in Area U1

pCi/g	U-238	U-233/234	U-235	Total
0.00-0.50	10	8	40	58
0.51-1.00	26	28	0	54
1.01-1.51	3	4	0	7
1.51-2.00	1	0	0	1
Total	**40**	**40**	**40**	**120**

A single measurement was selected at random for analysis. The probability that the measurement had a radiation level of 0.50 pCi/g or less where the source of the radiation was unknown was calculated as follows:

$$P(0.50\ pCi/g\ or\ less) = \frac{\#\ of\ radiation\ levels\ less\ than\ 0.50\ pCi/g}{Total\ \#\ of\ radiation\ levels}$$

$$P(0.50\ pCi/g\ or\ less) = \frac{58}{120}$$

$$= 0.483$$

Two samples of size 4 each were selected at random and only their U-238 radiation level was analyzed. The probability that all 4 samples would have a radiation level of 0.50 pCi/g or less was evaluated. The first sample was selected with replacement. The second sample was selected without replacement. The detailed calculations of each of these probabilities are presented below and on the following page.

With Replacement:

$$P(4\ samples\ 0.50\ pCi/g\ or\ less) = \left(\frac{\#\ of\ radiation\ levels\ less\ than\ 0.50\ pCi/g}{Total\ \#\ of\ U\text{-}238\ radiation\ levels}\right)^4$$

$$P(\text{4 samples 0.50 pCi/g or less}) = \left(\frac{10}{40}\right)^4$$

$$= 0.00391$$

Without Replacement:

$$P(\text{4 samples 0.50 pCi/g or less}) = \frac{10}{40} \cdot \frac{9}{39} \cdot \frac{8}{38} \cdot \frac{7}{37}$$

$$= \frac{5{,}040}{2{,}193{,}360}$$

$$= 0.00230$$

A sample of size 4 was selected at random with replacement in which only the U-233/234 radiation levels were evaluated. To determine the probability that at least 1 out of these 4 samples has a radiation level that is greater than 0.50 pCi/g the following calculations were done.

With Replacement:

$$P(\text{Out of 4 samples at least } 1 > 0.50 \text{ pCi/g}) = 1 - P(\text{All } 4 < 0.50 \text{ pCi/g})$$

$$P(\text{All 4 less than 0.50 pCi/g}) = \left(\frac{8}{40}\right)^4$$

$$= 0.0016$$

$$P(\text{Out of 4 samples at least 1 greater than 0.50 pCi/g}) = 1 - 0.0016$$
$$= 0.998$$

Two measurements were to be randomly selected, without replacement, from the 120 radiation level measurements. The probability that the first would have a radiation level greater than 1.00 pCi/g source unknown and second would have a radiation level of 0.50 pCi/g or less source unknown was calculated as shown below.

$$P(1^{st} > 1.00 \text{ pCi/g}, 2^{nd} < 0.50 \text{ pCi/g}) = \frac{1^{st} > 1.00 \text{ pCi/g}}{\text{Total \# radiation levels}} \cdot \frac{2^{nd} < 0.50 \text{ pCi/g}}{\text{Total \# radiation levels} - 1}$$

Minimum "Usual" V
$= 0.617 - 4(0.206)$
$= -0.207\, pCi/g$
Maximum "Usual" V
$= (\quad + 4(0.206)$

$$P(1^{st} > 1.00\ pCi/g,\ 2^{nd} < 0.50\ pCi/g) = \frac{8}{120} \cdot \frac{58}{119}$$

$$= \frac{464}{14280}$$

$$= 0.0325$$

A sample was found in the lab after all the other samples had been properly stored. This sample had a radiation level between 0.00 and 0.50 pCi/g. The researchers decided to use probability to help them find the source of this radiation. The following probabilities were calculated to assist them in this determination.

$$P(U\text{-}238 \mid \text{less than } 0.50\ pCi/g) = \frac{\text{number of U-238 values less than } 0.50\ pCi/g}{\text{Total number of values less than } 0.50\ pCi/g} =$$

$$= \frac{10}{58}$$

$$= 0.172$$

$$P(U\text{-}233/234 \mid \text{less than } 0.50) = \frac{\text{number of U-233/235 values less than } 0.50\ pCi/g}{\text{Total number of values less than } 0.50\ pCi/g}$$

$$= \frac{8}{58}$$

$$= 0.138$$

$$P(U\text{-}235 \mid \text{less than } 0.50) = \frac{\text{number of U-235 Values less than } 0.50\ pCi/g}{\text{Total number of values less than } 0.50\ pCi/g} =$$

$$= \frac{40}{58}$$

$$= 0.690$$

Based on the above probabilities, the most likely source of radiation is from the U-235 samples collected using the systematic method from area U1 on May 8th, 2010, because a probability of 0.690 is substantially higher than the probability of the other two types of radiation: 0.172 and 0.138.

Analysis Samples and Probability Distributions

1. Ensuring Enough Samples for Analysis

The Hanford test planning team determined that the minimum number of samples required for analysis of their soil data would be 35. The test engineer is aware that samples can be excluded from the analysis for a variety of legitimate reasons. To ensure that at least 35 of the samples are fit for analysis, the test engineer proposes that they collect 40 samples. He uses the following Probability Distribution of usable data samples from a sample of size 40 to support his proposal.

Probability Distribution of Usable Samples from a Sample of Size 40

X	P(x)	xP(x)	$X^2P(x)$
40	0.021	0.84	33.6
39	0.153	5.967	232.713
38	0.281	10.678	405.764
37	0.253	9.361	346.357
36	0.139	5.004	180.144
35	0.104	3.64	127.4
34	0.023	0.782	26.588
33	0.015	0.495	16.335
32	0.011	0.352	11.264
Totals	**1**	**37.119**	**1380.165**

According to this Probability Distribution of Usable Samples, the expected number (mean) of usable samples out of 40 samples, would be $\mu = \sum X_i P(X_i)$ which is 37.1 samples. In addition the standard deviation for this distribution was calculated using the following formula, $\sigma = \sqrt{\sum X_i^2 P(X_i) - [\sum X_i P(X_i)]^2}$. This calculation resulted in a standard deviation of 1.5 samples. The standard deviation and the mean were both used to determine the minimum and maximum usual number of samples that are usable when 40 samples are collected. These calculations and values are presented below.

$$Minimum\text{"}Usual\text{"}Value = \mu - 2(\sigma)$$
$$= 37.1 - 2(1.5)$$
$$= 34.1\ Samples$$

$$Maximum\text{"}Usual\text{"}Value = \mu + 2(\sigma)$$
$$= 37.1 + 2(1.5)$$
$$= 40.1\ Samples$$

From the calculations above, it can be seen that the minimum usual number of samples that are usable out of 40 is 34.1 samples, and the maximum usual number of samples that can be used out of 40 is 40.1 samples. The test engineer should feel very comfortable with his decision to collect 40 samples. By following this approach, he will have the correct number of data samples that can be used, which is at least 35 samples, approximately 95% of the time.

2. Results Validation and Quality Control

Critical decisions about whether or not to cleanup areas U1 and U2 are to be made as a result of this analysis. To ensure the validity and quality of these results the test analysts require data from at least at 13 duplicate tests. The test engineer is aware of the fact that any given test may fail to meet the minimum usable sample requirement of at least 35 usable samples. To ensure that 13 usable duplicate tests are collected, he proposes that they conduct 15 duplicate tests. To support his proposal, initially the test engineer calculated the probability of a given sample having at least 35 usable samples out of 40 collected samples.

$$\begin{aligned} P(\text{at least 35 usable samples in 40}) &= P(35)+P(36)+P(37)+P(38)+P(39)+P(40) \\ &= 0.104+0.139+0.253+0.281+0.153+0.021 \\ &= 0.951 \end{aligned}$$

He then proceeded to calculate the probability of at least 13 usable tests out of 15 tests conducted using two different techniques. The first technique that he used involved the Binomial Probability Formula and the second technique that he used was the Normal Approximation to the Binomial Formula. These calculations are presented below.

Binomial Probability Formula

$$\begin{aligned} P(\text{at least 13}) &= {}_{15}C_{13}\,p^{13}q^{15\text{-}13} + {}_{15}C_{14}\,p^{14}q^{15\text{-}14} + {}_{15}C_{15}\,p^{15}q^{15\text{-}15} \\ &= {}_{15}C_{13}(0.951)^{13}(0.049)^{2} + {}_{15}C_{14}(0.951)^{14}(0.049)^{1} + {}_{15}C_{15}(0.951)^{15}(0.049)^{0} \\ &= 0.131+0.364+0.471 \\ &= 0.966 \end{aligned}$$

Normal Approximation to the Binomial Formula

$\mu=14.3\ \sigma=0.8$

$P(\text{at least } 13) = P(x \geq 13)$

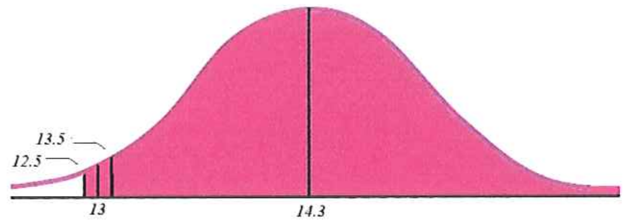
$= 1 - P(x<12.5)$

$= 1 - P\left(z<\dfrac{12.5 - 14.265}{0.836053228}\right)$

$= 1 - P(z<-2.11)$

$= 1 - 0.0174$

$= 0.983$



Normal Distribution for Duplicate Samples

The results of the previous two calculations did not yield the same probabilities. The probability found using the Binomial Formula was 0.966 which is lower than the results of the Normal Approximation to the Binomial Formula which was 0.983. There is not a significant difference between these two calculations, but the Binomial Formula results were the most accurate because all of the assumptions were true, whereas the data set did not meet the requirements for the Normal Approximation to the Binomial Formula because nq was not greater than 5 since $nq = 15(0.049)$ which equals 0.735. So, in this case, it would be inappropriate to use the Normal Approximation to the Binomial Formula calculations. According to the Binomial Formula calculations the test engineer should feel quite comfortable with his choice of conducting 15 duplicate tests since he will have the correct number of duplicate tests approximately 96.6% of the time.

3. Probabilities Involving Uranium Radiation Levels

The Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) requires the cleanup of surface soil having a radiation level of 5 pCi/g or more. The table below lists the samples that exceed that level.

Samples with Uranium Radiation Level Greater Than 5.0 pCi/g

Uranium from U1 8/22/2010

ID	Radiation Level
B24208	7.16
B24209	8.441
B24210	6.375
B24226	5.267

Uranium from U2 8/22/2010

ID	Radiation Level
B24260	5.694
B24268	5.389

Uranium U1 5/8/2010

ID	Radiation Level
None	None

Uranium U2 5/8/2010

ID	Radiation Level
None	None

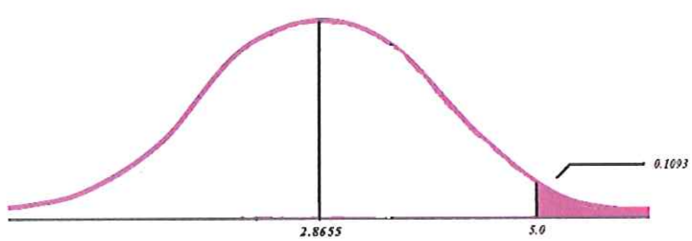
From the information presented on the previous page it can be seen that 4 out of the 36 samples of the uranium from U1 August 8, 2010, collected using the systematic method, from this data set exceed the CERCLA requirement for the cleanup of surface soils. Also, 2 out of a total of 40 uranium samples from U2 August 8, 2010, also collected using the systematic method, exceeded the requirement for cleanup. Finally, both data sets of systematic data from U1 taken on May 8, 2010 had no samples that exceeded the requirement for cleanup of surface soils. Since the most recent data came from the August collections, and due to the number of those samples that exceeded 5 pCi/g it might be worthwhile to conduct further analysis before declaring the area clean.

As a follow up to the reporting of sample radiation it has been determined that the August 22, 2010 sample data needs to be analyzed in greater detail. Due to budget constraints not all these samples can be analyzed again. Therefore the following probabilities were calculated to determine the probability of selecting one sample with a radiation level that may result in cleanup of the area U1. The probability was also calculated of selecting four samples with a mean radiation level that may result in the cleanup of area U1.

Single Sample

$$\mu = 2.8655$$
$$\sigma = 1.7336$$

$$P(x>5.0) = 1 - P(x<5.0)$$
$$= 1 - P\left(z < \frac{5.0 - 2.8655}{1.7336}\right)$$
$$= 1 - P(z<1.23)$$
$$= 1 - 0.8907$$
$$= 0.1093$$

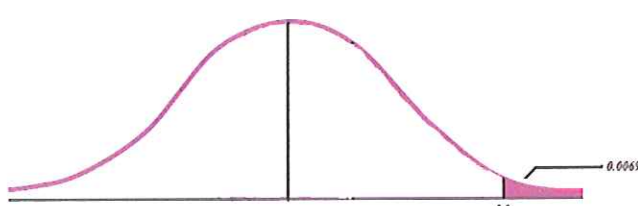


U1 Radiation Level for Single Sample 8/22/2010

Four Samples

$$\mu = 2.8655$$
$$\sigma = \frac{\sigma}{\sqrt{n}} = \frac{1.7336}{\sqrt{4}} = 0.8668$$

$$P(\bar{x}>5.0) = 1 - P(\bar{x}<5.0)$$
$$= 1 - P\left(z < \frac{5.0 - 2.8655}{0.8668}\right)$$
$$= 1 - P(z<2.46)$$
$$= 1 - 0.9931$$
$$= 0.0069$$



U1 Radiation Level for Four Samples 8/22/2010

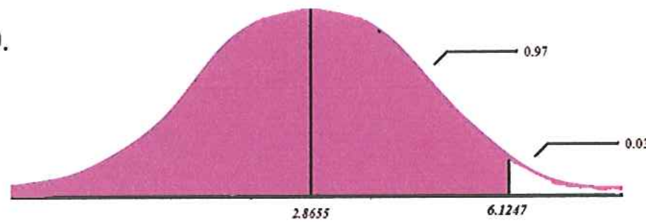
4. Percentiles Involving Uranium Radiation Levels

The assumption of normality was made with respect to the radiation levels of Uranium in areas U1 and U2 collected on August 22, 2010 in order to calculate the ninety-seventh percentile. This value represents the radiation level that separates the bottom 97% of radiation levels from the top 3%. A decision to declare an area clean will be made if at least 97% of the data values fall below 5 pCi/g. Otherwise, further testing will be conducted to determine if cleanup is required.

U1 97th Percentile for August 22, 2010

$Z_{0.03}$=1.88 $\bar{x} = 2.8655$ $s = 1.7336$ $\alpha = 0.$

$$x = \bar{x} + (z)(s)$$
$$= 2.8655 + 1.88(1.7336)$$
$$= 6.1247\ pCi/g$$

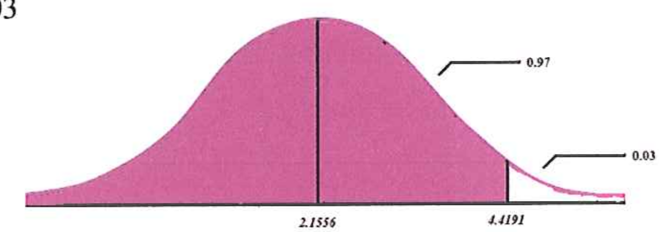


U1 97th Percentile August 22, 2010

U2 97th Percentile for August 22, 2010

$Z_{0.03}$=1.88 $\bar{x} = 2.1556$ $s = 1.204$ $\alpha = 0.03$

$$x = \bar{x} + (z)(s)$$
$$= 2.1556 + 1.88(1.204)$$
$$= 4.4191\ pCi/g$$



U2 97th Percentile August 22, 2010

According to the calculations on the previous page, it can be seen from the August, 2010 values from U1 that 6.1257 pCi/g is greater than the minimum requirement of 5 pCi/g that determines if there should be a cleanup of the area. This means that 97% of the data values do not fall below 5.0 pCi/g, and therefore the area passes the requirement for cleanup. For the data values of U2 collected in August, 2010, 97% of the data values were below 4.4191 pCi/g which is below the minimum requirement of 5.0 pCi/g, meaning that the area U2 does not meet the requirements for cleanup.

Confidence Intervals and Hypothesis Tests

In 2008, the Washington State Department of Ecology in cooperation with the Department of Energy (DOE) and the CH2M HILL Plateau Remediation Company (CHPRC) collected two samples from a single location immediately adjacent to the pipe discharge point for the pond designated 216-S-19. These samples were designated as "screening" samples in order to determine if the site would be a suitable location to conduct a comparison of three sampling designs (Judgmental, MIS, and Systematic). Based on the results of this screening effort, contaminants of potential concern (COPCs) were identified. The contaminants were Nitrate, Copper, Chromium, Zinc, Uranium-233/234, Uranium-238, Uranium-235, Plutonium-239/240, Plutonium-238, and Americium-241. This section of the report will be looking at the total radiation levels of Uranium and Nitrate.

1. Proportion of the Pond with High Radiation Levels of Uranium

DOE is concerned about the proportion of this pond that contains Uranium radiation levels above the CERCLA standard of 5 pCi/g. The Systematic sample data collected on August 22, 2010 from both areas U1 and U2 was used to address this concern. For the proportion of the contaminant in each area, a 90% confidence interval was constructed. It was assumed that all requirements for constructing this type of confidence interval were satisfied.

Area U1: The best point estimate for the proportion of the 216-S-19 pond with a uranium radiation level greater than 5 pCi/g from area U1 was calculated below:

$$\hat{p} = \frac{\text{Number of samples with radiation Levels} > 5 \text{ pCi/g in area U1}}{\text{Total number of samples from U1}} \qquad \hat{q} = 1 - \hat{p}$$

$$\hat{p} = \frac{4}{36} \qquad \hat{q} = 1 - \frac{1}{9}$$

$$\hat{p} = \frac{1}{9} \ (\hat{p} \approx 0.111) \qquad \hat{q} = \frac{8}{9} \ (\hat{q} \approx 0.889)$$

Before constructing this 90% confidence interval, the margin of error E was calculated using a $\alpha = 0.10$ significance level.

$$E = Z_{\alpha/2}\sqrt{\frac{\hat{p}\cdot\hat{q}}{n}} \quad \text{Where } Z_{\alpha/2} = Z_{0.10/2} = 1.645$$

$$E = 1.645 \bullet \sqrt{\frac{(\frac{1}{9})(\frac{8}{9})}{36}}$$

$$E = 0.086162271$$

$$E = 0.086$$

The 90% confidence interval for this data set is as follows:

$$\hat{p} - E < p < \hat{p} + E$$

$$\frac{1}{9} - 0.086 < p < \frac{1}{9} + 0.086$$

$$0.025 < p < 0.197$$

Area U2: The best point estimate for the proportion of the 216-S-19 pond with a uranium radiation level greater than 5 pCi/g in area U2 was calculated below:

$$\hat{p} = \frac{\text{Number of samples with radiation levels} > 5 \text{ pCi/g in area U2}}{\text{Total number of samples from U1}}$$

$$\hat{p} = \frac{2}{39} \quad (\hat{p} \approx 0.0513)$$

$$\hat{q} = 1 - \hat{p}$$

$$\hat{q} = 1 - \frac{2}{39}$$

$$\hat{q} = \frac{37}{39} \quad (\hat{q} \approx 0.949)$$

Before constructing this 90% confidence interval, the margin of error E was calculated using a $\alpha = 0.10$ significance level.

$$E = Z_{\alpha/2}\sqrt{\frac{\hat{p}\cdot\hat{q}}{n}} \quad \text{Where } Z_{\alpha/2} = Z_{0.10/2} = 1.645$$

$$E = 1.645 \bullet \sqrt{\frac{(\frac{2}{39})(\frac{37}{39})}{39}}$$

$$E = 0.058101166$$

$$E = 0.0581$$

The 90% confidence interval for this data set is calculated on the next page.

$$\hat{p}-E<p<\hat{p}+E$$

$$\frac{2}{39}-0.0581<p<\frac{2}{39}+0.0581$$

$$-0.0068<p<0.109$$

EPA guidance states that "because of the uncertainty associated with estimating the true proportion of a contaminant at a site, the 95% upper confidence limit (UCL) of the proportion should be used". Analysis of the data from August 22, 2010 yielded the subsequent results. For area U1, we are 95% confident that the proportion of this area that contains uranium radiation levels greater than 5 pCi/g is less than 0.197. For area U2, we are 95% confident that the proportion of this area that contains uranium levels greater than 5 pCi/g is less than 0.109.

2. Confidence Intervals for the Nitrate Level in the 216-S-19 Pond

During the "screening" process of the 216-S-19 pond, Nitrate was identified as one of the COPCs. Prior to the excavation of this pond, data was collected in both areas U1 and U2 on May 8, 2010. Three different sampling techniques were used; Systematic, MIS, and Judgmental. Separate 90% confidence intervals for the mean Nitrate levels contained in each area were calculated for the Systematic data and again for the MIS data. These confidence intervals were used to address the different sampling techniques as well as the mean levels of Nitrate in the soil in areas U1 and U2. All confidence intervals were constructed using a Student's-t distribution. The key underlying assumptions necessary to use this distribution were validated. The calculations are presented below.

Area U1 Systematic The best point estimate for the mean Nitrate level in area U1 is:

$$\bar{x}=\frac{\sum x}{n}$$

$$\bar{x}=21.255 \text{ mg/kg}$$

Before constructing the 90% confidence interval, the margin of error E was calculated using a $\alpha = 0.10$ significance level.

$$E=t_{\alpha/2}{}^{(n-1)}\cdot\left(\frac{s}{\sqrt{n}}\right) \text{ Where } t_{\alpha/2}{}^{(n-1)}=t_{0.10/2}{}^{(39)}=1.685$$

$$E = 1.685\left(\frac{17.399}{\sqrt{40}}\right)$$
$$E = 4.63547514$$
$$E = 4.635 \text{ mg/kg}$$

The 90% confidence interval for this set of data was calculated to be:

$$\bar{x} - E < \mu < \bar{x} + E$$
$$21.255 - 4.635 < \mu < 21.255 + 4.635$$
$$16.62 \text{ mg/kg} < \mu < 25.89 \text{ mg/kg}$$

Area U1 MIS: The best point estimate for the mean nitrate level in area U1 is:

$$\bar{x} = \frac{\sum x}{n}$$
$$\bar{x} = 10.1 \text{ mg/kg}$$

Before constructing this 90% confidence interval, the margin of error E was calculated using a $\alpha = 0.10$ significance level.

$$E = t_{\alpha/2}{}^{(n-1)} \cdot \left(\frac{s}{\sqrt{n}}\right) \quad \text{Where } t_{\alpha/2}{}^{(n-1)} = t_{0.10/2}{}^{(4)} = 2.132$$
$$E = 2.132\left(\frac{0.857321}{\sqrt{5}}\right)$$
$$E = 0.817420754$$
$$E = 0.817 \text{ mg/kg}$$

The 90% confidence interval for this set of data:

$$\bar{x} - E < \mu < \bar{x} + E$$
$$10.1 - 0.817 < \mu < 10.1 + 0.817$$
$$9.283 \text{ mg/kg} < \mu < 10.917 \text{ mg/kg}$$

Area U2 Systematic: The best point estimate for the mean nitrate level in area U2 is:

$$\bar{x} = \frac{\sum x}{n}$$
$$\bar{x} = 13.315 \text{ mg/kg}$$

Before constructing the 90% confidence interval, the margin of error E was calculated using a $\alpha = 0.10$ significance level.

$$E = t_{\alpha/2}^{(n-1)} \cdot \left(\frac{s}{\sqrt{n}}\right) \quad \text{Where } t_{\alpha/2}^{(n-1)} = t_{0.10/2}^{(39)} = 1.685$$

$$E = 1.685\left(\frac{13.17287}{\sqrt{40}}\right)$$
$$E = 3.50954096$$
$$E = 3.51 \text{ mg/kg}$$

The 90% confidence interval for this set of data is:

$$\bar{x} - E < \mu < \bar{x} + E$$
$$13.315 - 3.51 < \mu < 13.315 + 3.51$$
$$9.805 \text{ mg/kg} < \mu < 16.825 \text{ mg/kg}$$

Area U2 MIS: The best point estimate for the mean nitrate level in area U2 is:

$$\bar{x} = \frac{\sum x}{n}$$
$$\bar{x} = 11.82 \text{ mg/kg}$$

Before constructing the 90% confidence interval, the margin of error E was calculated using a $\alpha = 0.10$ significance level.

$$E = t_{\alpha/2}^{(n-1)} \cdot \left(\frac{s}{\sqrt{n}}\right) \quad \text{Where } t_{\alpha/2}^{(n-1)} = t_{0.10/2}^{(4)} = 2.132$$

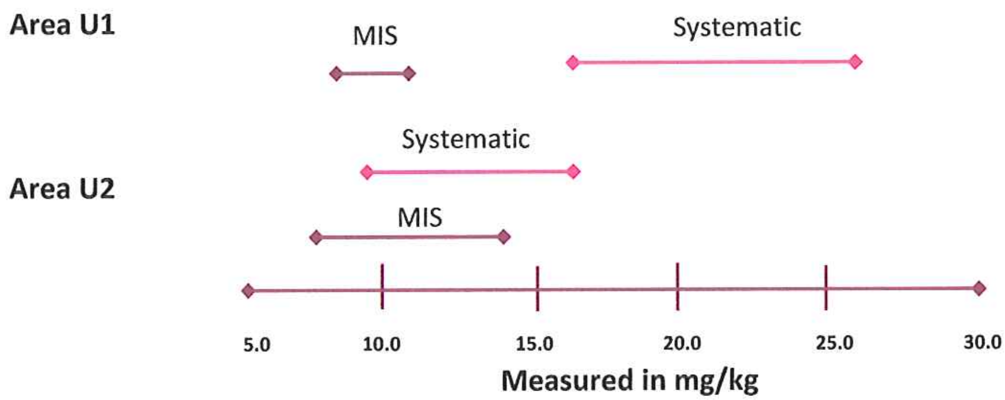
$$E = 2.132\left(\frac{3.076036}{\sqrt{5}}\right)$$
$$E = 2.932875395$$
$$E = 2.933 \text{ mg/kg}$$

The 90% confidence interval for this data set is:

$$\bar{x} - E < \mu < \bar{x} + E$$
$$11.82 - 2.933 < \mu < 11.82 + 2.933$$
$$8.887 \text{ mg/kg} < \mu < 14.753 \text{ mg/kg}$$

The following graph represents the four confidence intervals from areas U1 and U2 and the systematic and MIS sampling methods.

Confidence Intervals for Mean Nitrate Levels from May of 2010



The graph of the nitrate levels was used to informally compare the differences between the mean nitrate levels calculated using the MIS data and the systematic data from May of 2010. For area U1, the confidence intervals do not overlap. Therefore, there appears to be a significant difference in the mean nitrate level reported depending on the sampling technique. In contrast, the confidence intervals for the mean nitrate level in area U2 for MIS and systematic data do have an overlap. For this case, there does not appear to be a significant difference between the two sampling techniques.

Again, EPA guidance states that "because of the uncertainty associated with estimating the true average concentration of a contaminant at a site, the 95% upper confidence limit (UCL) of the arithmetic mean should be used". For the May 8, 2010 data collected in area U1 using the systematic sampling, we are 95% confident that the mean nitrate level is less than 25.89 mg/kg. For the MIS data collected at the same time in area U1, we are 95% confident that the mean nitrate level is less than 10.917 mg/kg. For the May 21, 2010 data collected in area U2 using systematic sampling, we are 95% confident that the mean nitrate level is less than 16.825 mg/kg. For the MIS data collected during the same time period in area U2, we are 95% confident that the mean nitrate level is less than 14.753 mg/kg.

3. Hypothesis Tests for Nitrate Levels in the 216-S-19 Pond

According to Hanford Contamination Levels, Nitrate levels of 40 mg/kg or more are a cause for concern that could lead to area cleanup. There were no MIS samples collected on May 8, 2010 in either area U1 or U2 that exceeded this level. However, during the same time period there were 7 Systematic samples out of 40 in area U1 and 3 Systematic samples out of 40 in area U2 that exceeded this contamination level. These samples are identified in the chart below.

Nitrate Levels above 40 mg/kg from May 8, 2010

U1 Systematic Data		U2 Systematic Data	
ID	**Nitrate Level Measured in mg/kg**	**ID**	**Nitrate Level Measured in mg/kg**
B241K4	44	B241R3	49
B241K8	42	B241R4	61
B241L0	47	B241W1	43
B241L9	71		
B241M0	60		
B241P0	48		
B241P2	48		

Hypothesis tests were conducted to formally test the claim that the mean Nitrate levels for the May 8, 2010 Systematic data in areas U1 and U2 are below the Hanford Contamination Level. These two tests are presented below.

U1 May 8, 2010 Systematic Data

$H_0: \mu = 40$

$H_1: \mu < 40$ (Claim)

$n = 40$

$\bar{x} = 21.255$

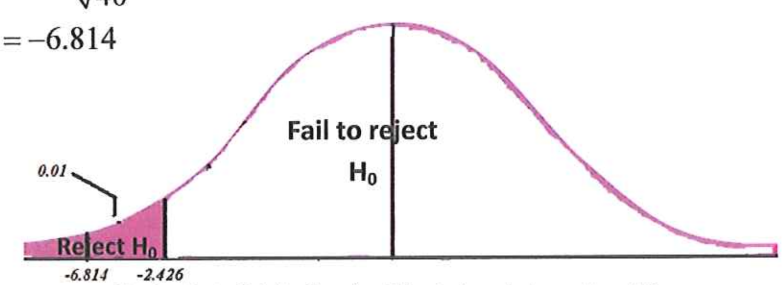
$s = 17.39901$

$\alpha = 0.01$

degrees of freedom (df) $= 39$

$$t^* = \frac{\bar{x} - \mu}{\frac{s}{\sqrt{n}}} = \frac{21.255 - 40}{\frac{17.39901}{\sqrt{40}}} = -6.814$$

$$t_\alpha(\text{df}) = t_{0.01}(39) = -2.426$$



Student's t-distribution for Nitrate Levels from Area U1

Since the test statistic $t^*=-6.814$ is less than the critical value $t_{0.01}=-2.426$, reject H_0. There is sufficient evidence to support the claim that the mean Nitrate levels for the May 8, 2010 Systematic data in area U1 are below the Hanford Contamination Level.

U2 May 8, 2010 Systematic Data

$H_0: \mu = 40$

$H_1: \mu < 40$ (Claim)

$n = 40$

$\bar{x} = 13.315$

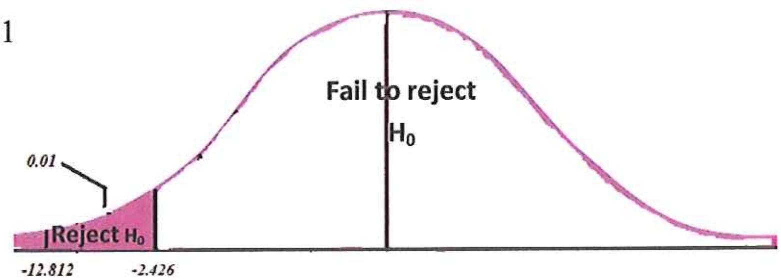
$s = 13.17287$

$\alpha = 0.01$

degrees of freedom (df) $= 39$

$$t^* = \frac{\bar{x} - \mu}{\frac{s}{\sqrt{n}}} = \frac{13.315 - 40}{\frac{13.17287}{\sqrt{40}}} = -12.81$$

$$t_\alpha (\text{df}) = t_{0.01}(39) = -2.426$$



Student's t-distribution for Nitrate Levels from Area U2

Since the test statistic t*=-12.812 is less than the critical value $t_{0.01}$=-2.426, reject H_0. There is sufficient evidence to support the claim that the mean Nitrate levels for the May 8, 2010 Systematic data in area U1 are below the Hanford Contamination Level of 40 mg/kg.

4. Calculating Sample Size

In order to meet EPA standards, the Hanford test designers determined that they want the estimates of the mean Nitrate level in areas U1 and U2 to be within 5 mg/kg of the true population mean Nitrate level. The number of usable systematic samples that need to be randomly collected from each of the areas U1 and U2 were calculated using a 95% confidence level. The population standard deviation is assumed to be 15.0 mg/kg.

Given: α=0.05, E=5.0 mg/kg, σ =15.0 mg/kg

$$Z_{\alpha/2} = Z_{0.05/2} = Z_{0.025} = 1.96$$

$$n = \left[\frac{Z_{\alpha/2} \cdot \sigma}{E}\right]^2 = \left[\frac{Z_{0.025} \cdot 15}{5}\right]^2 = \left[\frac{1.96 \cdot 15}{5}\right]^2 = 34.5744$$

$= 35$ systematic samples

As a result of these calculations, the test planners requested 35 usable systematic samples from each of the areas U1 and U2 for both May and August of 2010 for analysis.

Hypothesis Tests Comparing MIS, Systematic, and Judgmental Sampling

In 2008, Washington Department of Ecology in cooperation with DOE (Department of Energy) and CHPRC (CH2M Hill Plateau Remediation Company) collected two soil samples from a single location immediately adjacent to the Point of Discharge of the 216-S-19 Pond, a waste site of the 200-MG-1 Operable Unit. These samples were designed as "screening" in order to determine if the site would be a suitable location to conduct a comparison of three (Judgmental, Systematic Random, and Multi-Incremental) sampling designs. Based on the results of the Washington State Department of Ecology screening effort, COPCs (Chemical of Potential Concern) were selected and are the following: Chromium, Copper, Zinc, Mercury, Uranium-238, Uranium-233/234, Uranium-235, Plutonium-238, Plutonium-239/240, Americium-241, and Nitrate.

MIS sample points were selected by dividing each Decision Unit into grids with 100 units. One sample increment was collected from each grid unit for a total of 100 increments to comprise a single, multi-incremental "parent" sample. Four field replicate samples were also collected from each of the 100 grid-units in each Decision Unit.

Systematic Random sample points were selected using the 100-grid locations established in the MIS scheme above. Discrete sampling locations were proportioned out evenly within each Decision Unit using a random start point. In order to achieve a uniform distribution over each Decision Unit, 42 sample locations were identified rather than 40 as specified in the SAP.

Judgmental sample points were selected primarily based on field observations, professional judgment, and radiological field screening measurements. One location of highest expected (encountered) concentration will be selected, with the remaining four locations fanning out from that position. A total of five locations within each of the two Decision Units were identified and sampled.

Comparison testing of the mean concentration level of each of the elements listed above was done for these three different sampling techniques. Due to the nature of MIS sampling, the Central Limit Theorem applies, and this data can be assumed to be normally distributed as can the Systematic sampling data. The same assumption was made for the Judgmental sample data. However, any results involving Judgmental sampling should be viewed with caution as the assumption of normality is questionable. Due to time constraints, only the data collected on August 22, 2010 from area U1 were used in this analysis.

All comparison tests were conducted using a Student's t Distribution. The results for each test are summarized by element in various tables presented on the following pages. All 33 hypothesis tests used the following general format, test statistic, significance level, and critical value.

General Approach: Testing a Claim about Two Independent Population Means

Claim: There is no difference, when sampling the same area, between the mean element levels obtained from MIS sampling, Systematic sampling, and Judgmental sampling.

Hypothesis Test:

$H_o : \mu_1 - \mu_2 = 0 \quad (Claim)$

$H_1 : \mu_1 - \mu_2 \neq 0$

Test Statistic:

$$t^* = \frac{(\bar{x}_1 - \bar{x}_2) - (\mu_1 - \mu_2)}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}}$$

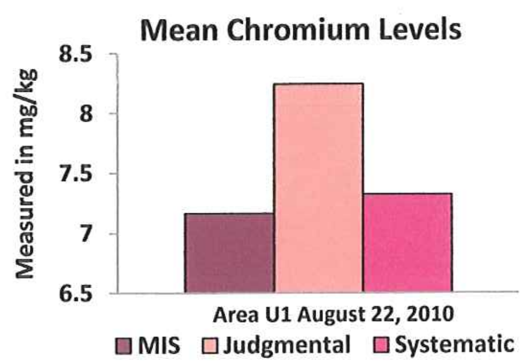
Significance Level: $\alpha = 0.05$ Critical Value: $t_{0.05/2} = \pm 2.776$ Degrees of Freedom: 4

Each element section is also accompanied by a bar graph which provides a visual comparison of the three sampling techniques and a table displaying the sample statistics used each hypothesis test. The results of these hypothesis tests are presented in a table along with the outcomes and written conclusions for each set of comparisons.

1. Comparison Tests Involving Chromium

Chromium Summary Statistics in mg/kg

Sampling Method	Mean	Standard Deviation
MIS	7.16	0.384707
Judgmental	8.24	0.559464
Systematic	7.3194444	1.4089144



Chromium Hypothesis Test Results

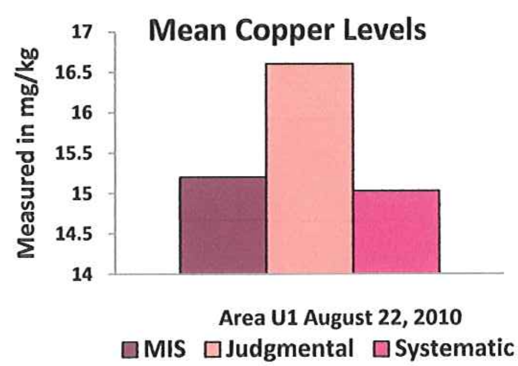
Hypothesis Test	Test Statistic	Outcome
MIS vs Systematic	-0.548	Fail to Reject H_0
MIS vs Judgmental	-3.557	Reject H_0
Systematic vs Judgmental	-2.683	Fail to Reject H_0

Conclusion: Since the test statistics for both the comparison of MIS and Systematic sampling as well as Systematic and Judgmental sampling (-0.548 and -2.683 respectively) are greater than the critical value of -2.776 and less than the critical value of 2.776, fail to reject H_0. There is insufficient evidence to reject the claim that there is no difference between mean Chromium levels obtained from MIS and Systematic sampling as well as Systematic and Judgmental sampling. However, the test statistic for the comparison of MIS and Judgmental sampling (-3.557) is less than the critical value of -2.766, reject H_0. There is sufficient evidence to reject the claim that there is no difference between Chromium levels obtained from MIS and Judgmental sampling.

2. Comparison Tests Involving Copper

Copper Summary Statistics in mg/kg

Sampling Method	Mean	Standard Deviation
MIS	15.2	1.643168
Judgmental	16.6	2.607681
Systematic	15.02778	1.796602



Copper Hypothesis Test Results

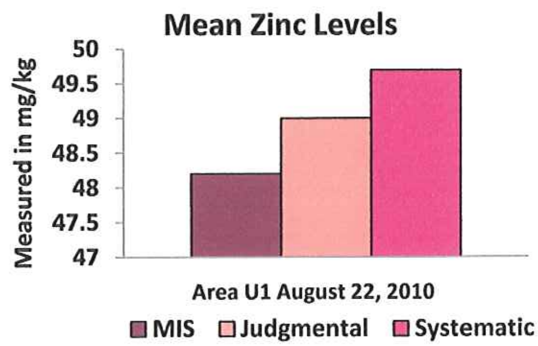
Hypothesis Test	Test Statistic	Outcome
MIS vs Systematic	0.217	Fail to Reject H_0
MIS vs Judgmental	-1.016	Fail to Reject H_0
Systematic vs Judgmental	-1.306	Fail to Reject H_0

Conclusion: Since the test statistics for all three comparisons (0.217,-1.016, and -1.306 respectively) were greater than the critical value of -2.776 and less than the critical value of 2.776, fail to reject H_0. There is insufficient evidence to reject the claim that there is no difference between mean Copper levels collected from MIS, Systematic, and Judgmental sampling techniques.

3. Comparison Tests Involving Zinc

Zinc Summary Statistics in mg/kg

Sampling Method	Mean	Standard Deviation
MIS	48.2	1.095445
Judgmental	49	2.345208
Systematic	49.69444	2.955087



Zinc Hypothesis Test Results

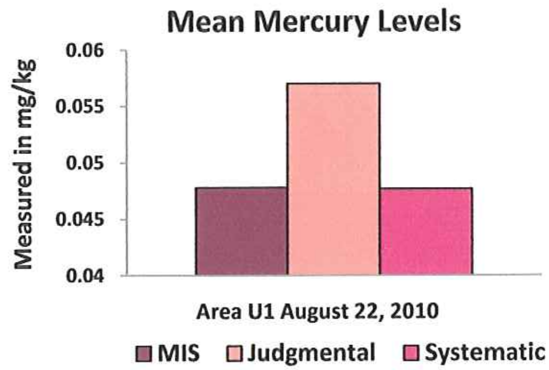
Hypothesis Test	Test Statistic	Outcome
MIS vs Systematic	-2.145	Fail to Reject H_0
MIS vs Judgmental	-0.691	Fail to Reject H_0
Systematic vs Judgmental	0.596	Fail to Reject H_0

Conclusion: Since the test statistics for all three comparisons (-2.145, -0.691, and 0.596 respectively) were greater than the critical value of -2.776 and less than the critical value of 2.776, fail to reject H_0. There is insufficient evidence to reject the claim that there is no difference between mean Zinc levels collected from MIS, Systematic, Judgmental sampling techniques.

4. Comparison Tests Involving Mercury

Mercury Summary Statistics in mg/kg

Sampling Method	Mean	Standard Deviation
MIS	0.0478	0.006017
Judgmental	0.057	0.017393
Systematic	0.047667	0.030792



Mercury Hypothesis Test Results

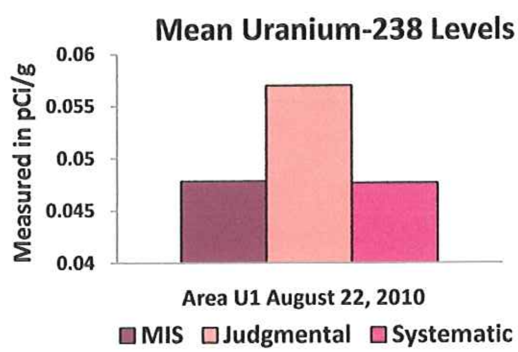
Hypothesis Test	Test Statistic	Outcome
MIS vs Systematic	0.022	Fail to Reject H_0
MIS vs Judgmental	-1.118	Fail to Reject H_0
Systematic vs Judgmental	-1.001	Fail to Reject H_0

Conclusion: Since the test statistics for all three comparisons (0.022, -1.118, and -1.001 respectively) were greater than the critical value of -2.776 and less than the critical value of 2.776, fail to reject H_0. There is insufficient evidence to reject the claim that there is no difference between mean Mercury levels collected from MIS, Systematic, and Judgmental sampling techniques.

5. Comparison Tests Involving Uranium-238

U-238 Summary Statistics in pCi/g

Sampling Method	Mean	Standard Deviation
MIS	1.584	0.085323
Judgmental	2.196	1.526771
Systematic	1.346389	0.810996



Uranium-238 Hypothesis Test Results

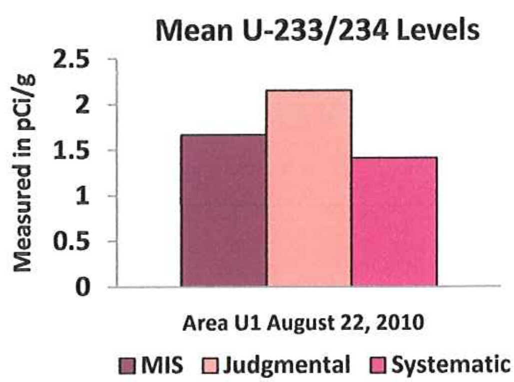
Hypothesis Test	Test Statistic	Outcome
MIS vs Systematic	1.692	Fail to Reject H_0
MIS vs Judgmental	-0.895	Fail to Reject H_0
Systematic vs Judgmental	-1.221	Fail to Reject H_0

Conclusion: Since the test statistics for all three comparisons (1.692, -0.895, and -1.221 respectively) were greater than the critical value of -2.776 and less than the critical value of 2.776, fail to reject H_0. There is insufficient evidence to reject the claim that there is no difference between mean Uranium-238 levels collected from MIS, Systematic, and Judgmental sampling techniques.

6. Comparison Tests Involving Uranium-233/234

U-233/234 Summary Statistics in pCi/g

Sampling Method	Mean	Standard Deviation
MIS	1.662	0.094710084
Judgmental	2.154	1.320219679
Systematic	1.410555556	0.815534687



Uranium-233/234 Hypothesis Test Results

Hypothesis Test	Test Statistic	Outcome
MIS vs Systematic	1.766	Fail to Reject H_0
MIS vs Judgmental	-0.831	Fail to Reject H_0
Systematic vs Judgmental	-1.227	Fail to Reject H_0

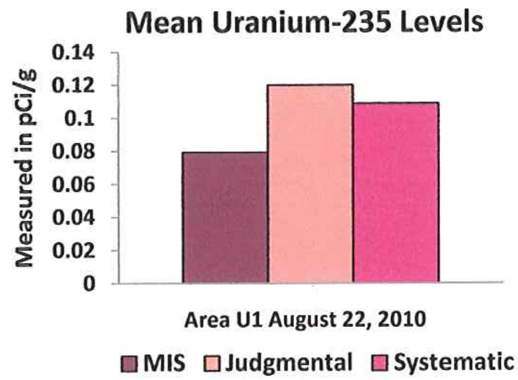
Conclusion: Since the test statistics for all three comparisons (1.766, -0.831, and -1.227 respectively) were greater than the critical value of -2.776 and less than the critical value of

2.776, fail to reject H_0. There is insufficient evidence to reject the claim that there is no difference between mean Uranium-233/234 levels collected from MIS, Systematic, and Judgmental sampling techniques.

7. Comparison Tests Involving Uranium-235

Uranium-235 Summary Statistics in pCi/g

Sampling Method	Mean	Standard Deviation
MIS	0.079	0.015700318
Judgmental	0.1198	0.06422772
Systematic	0.108555556	0.215240257



Uranium-235 Hypothesis Test Results

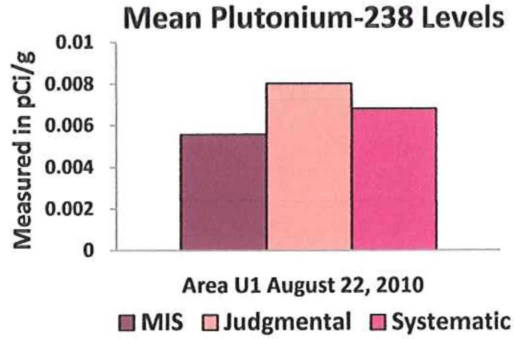
Hypothesis Test	Test Statistic	Outcome
MIS vs Systematic	-0.809	Fail to Reject H_0
MIS vs Judgmental	-1.380	Fail to Reject H_0
Systematic vs Judgmental	-0.245	Fail to Reject H_0

Conclusion: Since the test statistics for all three comparisons (-0.809, -1.380, and -0.245 respectively) were greater than the critical value of -2.776 and less than the critical value of 2.776, fail to reject H_0. There is insufficient evidence to reject the claim that there is no difference between mean Uranium-235 levels collected from MIS, Systematic, and Judgmental sampling techniques.

8. Comparison Tests Involving Plutonium-238

Plutonium-238 Summary Statistics in pCi/g

Sampling Method	Mean	Standard Deviation
MIS	0.00556	0.004326
Judgmental	0.008	0.005099
Systematic	0.006794	0.004738



Plutonium-238 Hypothesis Test Results

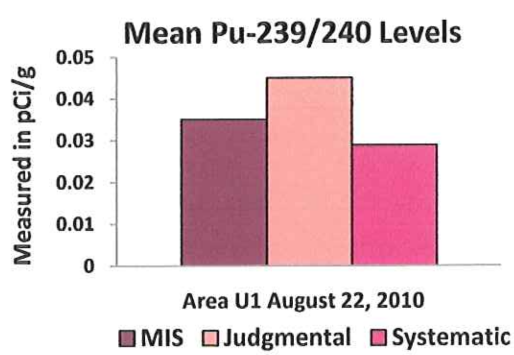
Hypothesis Test	Test Statistic	Outcome
MIS vs Systematic	-0.588	Fail to Reject H_0
MIS vs Judgmental	-0.816	Fail to Reject H_0
Systematic vs Judgmental	-0.501	Fail to Reject H_0

Conclusion: Since the test statistics for all three comparisons (-0.588, -0.816, and -0.501 respectively) were greater than the critical value of -2.776 and less than the critical value of 2.776, fail to reject H_0. There is insufficient evidence to reject the claim that there is no difference between mean Plutonium-238 levels collected from MIS, Systematic, and Judgmental sampling techniques.

9. Comparison Tests Involving Plutonium-239/240

Pu-239/240 Summary Statistics in pCi/g

Sampling Method	Mean	Standard Deviation
MIS	0.035	0.008155
Judgmental	0.045	0.031024
Systematic	0.028889	0.033041



Plutonium-239/240 Hypothesis Test Results

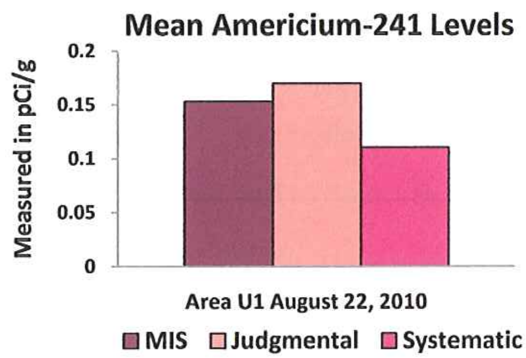
Hypothesis Test	Test Statistic	Outcome
MIS vs Systematic	0.925	Fail to Reject H_0
MIS vs Judgmental	-0.697	Fail to Reject H_0
Systematic vs Judgmental	-1.079	Fail to Reject H_0

Conclusion: Since the test statistics for all three comparisons (0.925, -0.697, and -1.079 respectively) were greater than the critical value of -2.776 and less than the critical value of 2.776, fail to reject H_0. There is insufficient evidence to reject the claim that there is no difference between mean Plutonium-239/240 levels collected from MIS, Systematic, and Judgmental sampling techniques.

10. Comparison Tests Involving Americium-241

Am-241 Summary Statistics in pCi/g

Sampling Method	Mean	Standard Deviation
MIS	0.1528	0.023805
Judgmental	0.1696	0.111215
Systematic	0.110389	0.18687



Americium-241 Hypothesis Test Results

Hypothesis Test	Test Statistic	Outcome
MIS vs Systematic	1.288	Fail to Reject H_0
MIS vs Judgmental	-0.330	Fail to Reject H_0
Systematic vs Judgmental	-1.009	Fail to Reject H_0

Conclusion: Since the test statistics for all three comparisons (1.288, -0.330, and -1.009 respectively) were greater than the critical value of -2.776 and less than the critical value of 2.776, fail to reject H_0. There is insufficient evidence to reject the claim that there is no

Location	Date	ID	Chromium	Copper	Zinc	Mercury	U 238	U233/234	U235	Pu238	Pu239/240	Am 241	Nitrate	
U1	8/22/2010	B23NF3	7	14	48	0.047	1.62	1.73	0.085	0.0007	0.036	0.149	18	
		B23NH6	7	15	47	0.058	1.71	1.68	0.07	0.01	0.027	0.152	17	
		B23NH7	7.2	14	48	0.046	1.57	1.55	0.093	0.009	0.039	0.188	15	MIS closeout
	MIS closeout	B23NH8	7.8	15	50	0.042	1.49	1.58	0.091	0.0068	0.027	0.154	20	
		B23NH9	6.8	18	48	0.046	1.53	1.77	0.056	0.0013	0.046	0.121	17	
	colmn means		7.16	15.2	48.2	0.0478	1.584	1.662	0.079	0.00556	0.035	0.1528	17.4	
	clmn StDev		0.3847077	1.6432	1.095	0.00602	0.08532	0.09471	0.0157	0.00433	0.0081548	0.02381	1.81659	
U1		B23NP4	8.4	20	51	0.059	1.92	2.06	0.112	0.004	0.036	0.281	9.3	
		B23NP5	8.2	17	50	0.055	4.6	4.18	0.194	0.002	0.023	0.094	0.8	Judgemental
	Judgemental	B23NP6	7.3	14	46	0.056	1.29	1.42	0.118	0.014	0.094	0.147	5.5	closeout
		B23NP7	8.6	18	51	0.082	2.56	2.45	0.154	0.008	0.055	0.287	30	
		B23NP8	8.7	14	47	0.033	0.61	0.66	0.021	0.012	0.017	0.039	5.8	
	column mean		8.24	16.6	49	0.057	2.196	2.154	0.1198	0.008	0.045	0.1696	10.28	
	Clmn StDev		0.559464	2.6077	2.345	0.01739	1.52677	1.32022	0.06423	0.0051	0.0310242	0.11122	11.4305	
U1	Systematic	B241X6	7	15	46	0.051	1.74	2.05	0.089	0.003	0.018	0.072	6.1	Systematic
		B241X7	9.9	20	55	0.044	1.33	1.5	0.11	0.003	0.035	0.047	16	closeout
		B241X8	7.4	14	47	0.036	0.64	0.74	0.06	0.008	0.034	0.113	2.5	
		B241X9	7.6	13	49	0.05	0.59	0.55	0.038	0.01	0.15	1.09	2.7	
		B241Y0	6.4	13	47	0.034	0.94	1.15	0.069	0.0072	0.028	0.111	15	
		B241Y1	8.8	16	52	0.035	1.94	2.04	0.098	0.013	0.0008	0.009	34	
		B241Y2	8.5	15	52	0.041	1.87	1.73	0.086	0.0053	0.019	0.063	35	
		B241Y3	6.4	14	48	0.033	1.36	1.31	0.092	0	0.027	0.059	18	
		B241Y4	9.5	19	54	0.036	1.05	1.15	0.049	0.015	0.024	0.035	34	
		B241Y5	7.5	15	51	0.048	1.07	1.13	0.043	0.0028	0.068	0.164	16	
		B241Y6	9.2	17	52	0.034	0.57	0.68	0.02	0.0051	0.0053	0.003	2.8	
		B241Y7	6.9	14	50	0.034	1.07	1.22	0.032	0.009	0.021	0.143	14	
		B241Y8	8	16	52	0.034	0.88	0.96	0.058	0.012	0.029	0.085	12	
		B24200	10	17	56	0.035	0.75	0.71	0.025	0.009	0.012	0.066	19	
		B24201	7.4	16	52	0.034	0.79	0.8	0.032	0	0.007	0.037	18	
		B24202	6.4	13	48	0.033	1.35	1.42	0.143	0.017	0	0.042	7.2	
		B24203	8.7	17	55	0.035	0.9	0.92	0.057	0.0007	0.0061	0.053	15	
		B24204	8.5	16	52	0.092	0.8	0.8	0.037	0.011	0.084	0.307	12	
		B24207	8.5	16	49	0.041	1.28	1.34	0.093	0.0067	0.03	0.09	4.4	

		B24208	9.2	17	52	0.2	3.02	2.8	1.34	0.009	0.059	0.241	5.5	
		B24209	9	18	52	0.035	4.03	4.24	0.171	0.003	0.009	0.032	4.3	
		B24210	7.5	15	50	0.034	3.2	3.01	0.165	0.0024	0.013	0.015	7.4	
		B24211	5.6	14	50	0.033	0.62	0.69	0.026	0.0007	0.027	0.024	6.8	
		B24212	6.8	14	48	0.034	0.49	0.6	0.053	0.0045	0.0068	0.006	7.9	
		B24213	5.8	13	48	0.033	0.43	0.43	0.014	0.004	0.012	0.029	3.8	
		B24215	6.7	13	48	0.047	1.76	1.78	0.114	0.015	0.039	0.121	7.5	
		B24216	5.6	13	47	0.038	1.17	1.32	0.076	0.011	0.027	0.107	4.6	
		B24217	5.8	13	47	0.033	0.69	0.66	0.052	0.005	0.003	0.021	13	
		B24218	5.5	16	49	0.042	1.79	1.69	0.076	0.016	0.131	0.38	2.2	
		B24219	6.2	13	50	0.033	1.36	1.28	0.049	0.0066	0.011	0.127	2	
		B24220	7.8	15	50	0.098	0.74	0.77	0.052	0.001	0.011	0.035	10	
		B24221	5.5	14	47	0.084	0.82	1	0.049	0.0061	0.01	0.071	3.2	
		B24222	5.7	15	49	0.059	1.87	2.41	0.146	0.004	0.033	0.074	2.2	
		B24224	6.1	14	46	0.055	1.79	1.85	0.078	0.0098	0.025	0.063	4.3	
		B24225	4.9	14	42	0.033	1.29	1.42	0.059	0.0027	0.008	0.016	13	
		B24226	7.2	14	47	0.045	2.48	2.63	0.157	0.006	0.017	0.023	3.5	
	column mean		7.3194444	15.028	49.69	0.04767	1.34639	1.410556	0.10856	0.00679	0.0288889	0.11039	10.6917	
	clmn StDev		1.4089144	1.7966	2.955	0.03079	0.811	0.815535	0.21524	0.00474	0.0330414	0.18687	8.94943	
Location	Date	ID	Chromium	Copper	Zinc	Mercury	U 238	U233/234	U235	Pu238	Pu239/240	Am 241	Nitrate	
U2	8/22/2010	B23NJ0	3.6	15	29	0.073	1.66	1.63	0.121	0.023	0.111	0.189	26	
		B23NJ1	6.8	14	47	0.042	1.06	1.07	0.077	0.0076	0.07	0.159	26	MIS Closeout
		B23NJ2	6.4	14	46	0.052	1.05	1.14	0.061	0.0076	0.127	0.127	24	
	MIS Closeout	B23NJ3	6.3	14	47	0.049	1.25	1.13	0.082	0.0065	0.096	0.186	20	
		B23NJ4	6.1	23	42	0.043	1.2	1.13	0.044	0.0034	0.064	0.132	24	
	column mean		5.84	16	42.2	0.0518	1.244	1.22	0.077	0.00962	0.0936	0.1586	24	
	clmn StDev		1.2778889	3.937	7.662	0.01256	0.24825	0.230868	0.02875	0.00767	0.0267264	0.02907	2.44949	
U2		B23NP9	6.3	14	47	0.047	0.86	0.93	0.045	0.029	0.264	0.54	9.9	
		B23NR1	7.9	15	49	0.034	1.13	1.16	0.089	0.01	0.042	0.155	45	Judgmental
	Judgmental	B23NR2	7.2	15	49	0.033	1.3	1.38	0.088	0.012	0.088	0.183	11	closeout
		B23NR3	6.8	15	46	0.034	0.8	0.91	0.071	0.01	0.024	0.037	9.7	
		B23NR4	7.9	15	50	0.035	1.66	1.59	0.039	0	0.021	0.117	27	
	colmn mean		7.22	14.8	48.2	0.0366	1.15	1.194	0.0664	0.0122	0.0878	0.2064	20.52	
	clmn StDev		0.6978539	0.4472	1.643	0.00586	0.34986	0.292797	0.02349	0.0105	0.1020745	0.1944	15.506	

U2	Systematic	B24227	6.3	10	42	0.034	0.51	0.5	0.02	0	0.015	0.014	16	
		B24228	6.3	16	47	0.035	0.52	0.55	0.023	0.014	0.018	0.045	15	Systematic
		B24229	5.5	14	47	0.035	0.45	0.46	0.016	0.0026	0.0079	0.009	13	closeout
		B24230	6.5	17	49	0.034	0.45	0.46	0.008	0.0014	0.01	0.002	5.9	
		B24232	6	13	47	0.034	0.432	0.47	0.041	0.005	0.008	0.011	5.8	
		B24233	4.6	13	46	0.034	0.53	0.54	0.035	0.007	-0.0012	0.006	2.1	
		B24234	6.9	14	47	0.035	0.58	0.72	0.044	0.012	0.035	0.044	6.8	
		B24235	6.1	14	46	0.034	1.21	1.08	0.066	0.02	0.029	0.096	5.5	
		B24236	7.9	14	48	0.035	1.09	1.08	0.05	0.01	0.008	0.053	5.6	
		B24237	5.3	14	46	0.033	0.86	0.9	0.047	0.003	0.038	0.038	5.6	
		B24238	6.8	13	45	0.034	0.86	0.92	0.052	0.011	0.012	0.022	5.9	
		B24239	7.1	14	47	0.047	1.15	1.07	0.072	-0.0002	0.033	0.116	4.3	
		B24240	6.2	14	46	0.034	0.88	0.92	0.076	0.019	0.013	0.057	5.4	
		B24241	6.6	14	46	0.035	0.55	0.52	0.044	0.01	0.041	0.047	12	
		B24243	6.8	14	46	0.034	1.08	1.02	0.068	0.011	0.019	0.151	18	
		B24244	7	14	47	0.035	1.34	1.38	0.07	0.0067	0.012	0.138	12	
		B24245	6.8	14	49	0.035	1	1.02	0.054	0.0052	0.035	0.119	15	
		B24246	7.4	14	50	0.035	1.38	1.31	0.05	0.008	0.026	0.121	8.7	
		B24247	7.5	14	50	0.035	1.42	1.59	0.071	-0.001	0.028	0.08	24	
		B24248	5.9	12	43	0.034	0.55	0.56	0.014	0.017	0.007	0.002	2	
		B24249	5.8	15	49	0.034	0.56	0.67	0.042	0.009	0.063	0.059	6.1	
		B24250	7.2	15	49	0.048	1.14	1.18	0.143	0.012	0.09	0.197	12	
		B24252	7.4	13	50	0.035	0.66	0.62	0.029	0.012	0.031	0.053	15	
		B24253	8.6	16	49	0.036	0.84	0.88	0.055	0.01	0.026	0.103	6.6	
		B24254	7.7	15	49	0.035	0.79	0.75	0.037	0.0007	0.018	0.038	9.9	
		B24255	9	16	53	0.041	1.62	1.7	0.023	0.0042	0.055	0.249	14	
		B24256	9.6	14	49	0.035	0.79	0.78	0.027	0.0017	0.008	0.021	5.5	
		B24257	5	18	49	0.033	0.46	0.412	0.015	-0.0009	0.004	0.009	4.2	
		B24258	7.6	16	50	0.083	1.66	1.83	0.115	0.006	0.159	0.252	15	
		B24259	6.9	14	48	0.072	1.99	1.9	0.097	0.0074	0.108	0.191	17	
		B24260	8.3	16	49	0.14	2.82	2.72	0.154	0.008	0.179	0.403	6.6	
		B24261	6.2	13	48	0.034	0.8	0.73	0.043	0.008	0.048	0.031	4.3	
		B24262	7.3	14	47	0.046	1.01	0.89	0.074	0.013	0.032	0.132	7.1	
		B24263	6.5	14	47	0.034	0.72	0.62	0.045	0.011	0.039	0.114	11	
		B24264	5.9	13	47	0.034	0.65	0.71	0.05	0.019	0.096	0.089	2.7	
		B24265	7	16	48	0.051	0.96	0.96	0.059	0.008	0.225	0.303	10	
		B24267	5.7	13	49	0.038	1.79	1.92	0.152	0.002	0.013	0.014	12	

		B24268	7.2	16	50	0.16	2.6	2.66	0.129	0.005	0.064	0.118	15	
		B24269	9.3	16	50	0.1	1.97	2.04	0.143	0.007	0.028	0.041	3	
	column mean		6.8641026	14.333	47.79	0.0459	1.04287	1.052359	0.06033	0.00782	0.0430692	0.092	9.37436	
	clmn StDev		1.1157927	1.4749	2.054	0.02841	0.58296	0.590636	0.03966	0.00558	0.0497862	0.09079	5.21732	
Location	Date	ID	Chromium	Copper	Zinc	Mercury	U 238	U233/234	U235	Pu238	Pu239/240	Am 241	Nitrate	
U1	5/8/2010	B23NF2	11	13	45	0.056	0.55	0.71	0.031	0	0.081	0.119	11	
		B23NF7	6	7.2	27	0.08	0.77	0.98	0.03	0.028	1.19	0.331	9.7	
	MIS	B23NF8	15	15	52	0.15	0.62	0.67	0.055	0.004	0.305	0.46	9.7	MIS
		B23NF9	17	21	51	0.23	0.73	0.72	0.021	0.023	0.297	0.36	9.1	
		B23NH0	9.9	14	49	0.053	0.55	0.53	0.012	-0.011	0.083	0.099	11	
	column mean		11.78	14.04	44.8	0.1138	0.644	0.722	0.0298	0.0088	0.3912	0.2738	10.1	
	clmn StDev		4.334974	4.9303	10.31	0.07582	0.10188	0.163003	0.01605	0.0163	0.4597817	0.15803	0.85732	
U1		B23NN2	11	19	39	0.15	0.85	0.64	0.037	0.026	1.04	0.5	6	
		B23NN3	7.7	12	36	0.086	0.64	0.63	0.027	0.017	0.74	0.319	5.3	
	Judgmental	B23NN4	77	150	60	37	6.3	6.3	0.246	2.41	57.1	123	23	Judgmental
		B23NN5	6.3	12	37	0.035	0.55	0.54	0.017	-0.006	0.007	0.007	38	
		B23NN6	6.3	12	36	0.035	0.4	0.45	0.036	-0.002	0.016	0.042	30	
		B23NN7	6.4	11	35	0.037	0.4	0.47	0.026	-0.003	0.052	0.052	12	
	column mean		19.116667	36	40.5	6.22383	1.52333	1.505	0.06483	0.407	9.8258333	20.6533	19.05	
	clmn StDev		28.414603	55.925	9.649	15.0772	2.34612	2.350377	0.08906	0.98135	23.163593	50.1398	13.4438	
	Systematic	B241J9	7.7	11	49	0.043	0.56	0.64	0.032	-0.0013	0.018	0.01	15	
		B241K1	7.6	10	46	0.036	0.62	0.55	0.024	-0.0011	0.0019	0.018	14	
		B241K2	7.6	9.6	46	0.035	0.59	0.55	0.017	0.0023	0.015	0.018	22	
		B241K3	7.5	8.9	45	0.039	0.47	0.54	0.011	0	0.01	0.021	19	
		B241K4	23	14	50	0.14	0.6	0.65	0.017	0.0082	0.208	0.063	44	Systematic
		B241K5	7.4	12	47	0.035	0.57	0.53	0.036	0.0006	0.0102	0.007	11	
		B241K6	7.5	11	47	0.037	0.6	0.48	0.032	0.001	0.0121	0.01	26	
		B241K7	7	9.9	47	0.036	0.56	0.46	0.027	-0.0022	0.016	0.003	3.3	
		B241K8	7.7	10	46	0.044	0.63	0.64	0.042	0.008	0.198	0.125	42	
		B241K9	7	8.3	45	0.036	0.53	0.57	0.048	0	0.0058	0.019	3.5	
		B241L0	8.6	8.9	47	0.035	0.44	0.53	0.017	0	0.01	0.042	47	
		B241L1	16	12	48	0.053	0.55	0.63	0.022	-0.0004	0.037	0.047	8.6	
		B241L3	16	13	52	0.072	0.64	0.65	0.043	-0.0013	0.103	0.015	3.1	
		B241L4	7.8	9.4	49	0.043	0.49	0.56	0.035	0.0062	0.014	0.008	11	

		B241L5	19	19	50	0.073	0.63	0.53	0.031	0.045	0.394	0.407	11	
		B241L6	7.7	8.9	47	0.034	0.47	0.47	0.007	-0.002	0.053	0.064	32	
		B241L7	9	10	47	0.037	0.61	0.56	0.034	-0.0004	0.026	0.04	34	
		B241L8	7.9	8.2	46	0.035	0.51	0.58	0.041	-0.002	0.0034	0.002	23	
		B241L9	13	12	49	0.084	0.52	0.53	0.006	-0.003	0.12	0.036	71	
		B241M0	17	12	48	0.076	0.57	0.55	0.024	0.01	0.159	0.054	60	
		B241M1	14	18	55	2.3	1.62	1.43	0.086	0.029	0.91	0.18	7.7	
		B241M2	7.7	10	48	0.037	0.64	0.67	0.058	-0.0013	0.069	0.026	5.1	
		B241M3	8.4	9.1	47	0.036	0.56	0.51	0.025	0.003	0.034	0.038	5	
		B241M4	8.1	9.7	49	0.044	0.61	0.53	0.031	-0.0023	0.029	0.014	36	
		B241M5	8	8.3	47	0.035	0.56	0.65	0.036	-0.0021	0.017	0.011	4	
		B241M6	7.6	8.6	48	0.034	0.49	0.57	0.015	-0.0036	0.03	0.013	29	
		B241M7	25	56	63	4.8	1.01	1.04	0.058	0.57	4.75	15.9	9.6	
		B241M9	7.8	9.9	47	0.037	0.55	0.5	0.03	0.0007	0.038	0.031	4.2	
		B241N0	7.8	11	52	0.036	0.44	0.43	0.035	0.009	0.049	0.044	4.2	
		B241N1	8.1	9.2	47	0.037	0.68	0.6	0.043	-0.005	0.078	0.098	8.1	
		B241N2	9.7	36	51	0.1	1.13	1.19	0.043	0.225	2.53	5.27	15	
		B241N3	7.3	7.6	45	0.035	0.52	0.53	0.032	0.0009	0.0091	0.002	14	
		B241N4	6.9	8.7	46	0.035	0.49	0.5	0.036	-0.0023	0.041	0.24	6.8	
		B241N5	76	16	57	0.29	0.65	0.73	0.02	0.0111	0.428	0.062	39	
		B241N6	8	9.9	48	0.036	0.52	0.6	0.011	-0.0011	0.057	0.045	11	
		B241N8	8	9.8	48	0.037	0.49	0.58	0.052	0.004	0.039	0.044	18	
		B241N9	12	21	51	0.51	1.33	1.03	0.066	0.14	4.17	5.6	22	
		B241P0	8.3	13	51	0.036	0.44	0.45	0.026	0.008	0.035	0.098	48	
		B241P1	8.2	12	51	0.042	0.48	0.41	0.019	0	0.007	0.009	15	
		B241P2	8.3	12	50	0.036	0.58	0.53	0.038	0.01	0.021	0.018	48	
	column mean		11.68	12.848	48.8	0.2394	0.62375	0.617	0.03265	0.02652	0.3688875	0.7188	21.255	
	clmn StDev		11.338028	8.5558	3.473	0.82396	0.23931	0.206002	0.01642	0.09748	1.0407214	2.7344	17.399	
Location	Date	ID	Chromium	Copper	Zinc	Mercury	U 238	U233/234	U235	Pu238	Pu239/240	Am 241	Nitrate	
U2	5/21/2011	B23NH1	6.4	12	44	0.031	0.63	0.58	0.027	0.0096	0.115	0.068	7.1	
		B23NH2	7.7	13	47	0.046	0.56	0.58	0.023	0.0063	0.22	0.171	12	MIS
	MIS	B23NH3	7.2	13	49	0.027	0.54	0.64	0.025	0.0035	0.105	0.062	14	
		B23NH4	11	20	57	0.25	1.22	1.21	0.057	0.028	1.58	0.384	15	
		B23NH5	7.9	16	51	0.047	0.69	0.67	0.033	0.012	0.239	0.096	11	
	column mean		8.04	14.8	49.6	0.0802	0.728	0.736	0.033	0.01188	0.4518	0.1562	11.82	
	clmn StDev		1.7529974	3.2711	4.879	0.09533	0.28137	0.267825	0.01393	0.00957	0.6335524	0.13453	3.07604	

U2		B23NN8	7.5	13	50	0.036	0.49	0.59	0.004	0	0.004	0.019	3.7	
		B23NP0	23	72	73	1.1	2.78	2.9	0.132	0.157	6.7	1.48	2.3	Judgmental
	Judgmental	B23NP1	71	360	190	5.6	5.71	5.92	0.31	1.36	22.3	12.3	4.5	
		B23NP2	7.1	9.9	50	0.037	0.41	0.58	0.028	0	0.045	0.015	7.5	
		B23NP3	7.3	12	50	0.037	0.53	0.56	0.024	0.009	0.096	0.046	2.7	
	column mean		23.18	93.38	82.6	1.362	1.984	2.11	0.0996	0.3052	5.829	2.772	4.14	
	Clmn StDev		27.583455	151.32	60.86	2.41344	2.30978	2.355525	0.12777	0.59342	9.647604	5.36338	2.06591	

U2	Systematic	B241P3	7.9	12	51	0.037	0.45	0.47	0.033	0.0018	0.038	0.036	4.8	
		B241P4	7.5	9.4	51	0.036	0.53	0.46	0.075	0	0.012	0.013	4.3	
		B241P5	7.5	13	51	0.037	0.54	0.53	0.016	0.0019	0.022	0.028	4.1	
		B241P6	7	9.6	51	0.035	0.5	0.44	0.05	-0.002	0.037	0.12	14	Systematic
		B241P7	7.2	11	50	0.036	0.49	0.49	0.028	0.002	0.024	0.03	29	
		B241P8	7.2	14	51	0.041	0.58	0.6	0.045	0.002	-0.004	0.018	23	
		B241P9	7.4	18	50	0.042	0.48	0.48	0.01	-0.002	0.04	0.035	17	
		B241R1	7.2	9.7	51	0.039	0.5	0.57	0.017	0.004	0.002	0.02	4.3	
		B241R2	8.4	11	54	0.037	0.68	0.6	0.033	0.0058	0.042	0.048	8.2	
		B241R3	7.7	12	52	0.037	0.52	0.56	0.076	0.003	0.02	0.026	49	
		B241R4	7	13	57	0.039	0.49	0.58	0.016	0.0057	0.027	0.085	61	
		B241R5	7.2	13	52	0.037	0.38	0.49	0.025	0.0038	0	0.019	4.9	
		B241R6	7.3	14	52	0.04	0.57	0.6	0.03	-0.0055	0.013	0.015	16	
		B241R7	7.3	11	53	0.038	0.57	0.56	0.021	0	0.011	0.028	2.2	
		B241R8	7.3	9.9	51	0.039	0.5	0.67	0.051	0.006	0.082	0.051	3.5	
		B241R9	10	20	55	0.45	1.42	1.31	0.091	0.055	1.95	0.77	4.9	
		B241T0	7	13	51	0.04	0.52	0.6	0.002	-0.0057	0.081	0.035	21	
		B241T1	8.2	13	52	0.036	0.58	0.71	0.042	0.0018	-0.0018	0.0132	17	
		B241T3	15	30	57	0.77	1.72	1.72	0.105	0.058	1.57	0.76	5.9	
		B241T4	7.2	14	51	0.16	0.85	0.96	0.1	0.028	2.45	0.486	6.9	
		B241T5	7.4	11	51	0.038	0.62	0.51	0.016	0.0089	0.126	0.066	4	
		B241T6	7.4	14	55	0.093	0.63	0.61	0.03	0.005	0.074	0.133	2.4	
		B241T7	7.5	11	53	0.037	0.48	0.55	0.043	0	0.019	0.021	2.5	
		B241T8	7.7	11	52	0.036	0.54	0.62	0.028	0.0039	0.062	0.06	7.3	
		B241T9	8.6	14	52	0.037	0.64	0.59	0.032	0.0058	0.075	0.075	7.6	
		B241V0	7.6	11	51	0.037	0.56	0.5	0.031	-0.0018	0.0035	0.013	16	
		B241V1	8.4	13	53	0.045	1.6	1.7	0.089	0.024	1.46	0.299	13	
		B241V2	7.8	11	53	0.037	0.45	0.56	0.056	0.002	0.011	0.024	2.2	