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FINAL TECHNICAL MEMORANDUM CALCULATION OF UPPER TOLERANCE LIMIT BACKGROUND VALUES CHEATHAM ANNEX FISC WILLIAMSBURG VA

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CH2M HILL

Final Technical Memorandum

Calculation of UTL Background Values

Naval Weapons Station Yorktown
Yorktown, Virginia
and
Cheatham Annex
Williamsburg, Virginia

NAVFAC MID-ATLANTIC

Prepared for

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CH2MHILL

Calculation of UTL Background Values at Naval Weapons Station Yorktown and Cheatham Annex

PREPARED FOR: Naval Weapons Station (WPNSTA) Yorktown and Cheatham Annex (CAX) Partnering Teams

PREPARED BY: CH2M HILL

DATE: December 30, 2010

Introduction

This Technical Memorandum (TM) describes the approach for calculating upper tolerance limit (UTL) background values in soil and groundwater at Naval Weapons Station (WPNSTA) Yorktown, Yorktown, Virginia and WPNSTA Yorktown Cheatham Annex (CAX), Williamsburg, Virginia. The calculated UTLs establish representative background concentrations for soil and groundwater inorganics, which can be compared to site-specific data at a particular environmental site to determine if concentrations are attributable to releases from these sites or consistent with background levels.

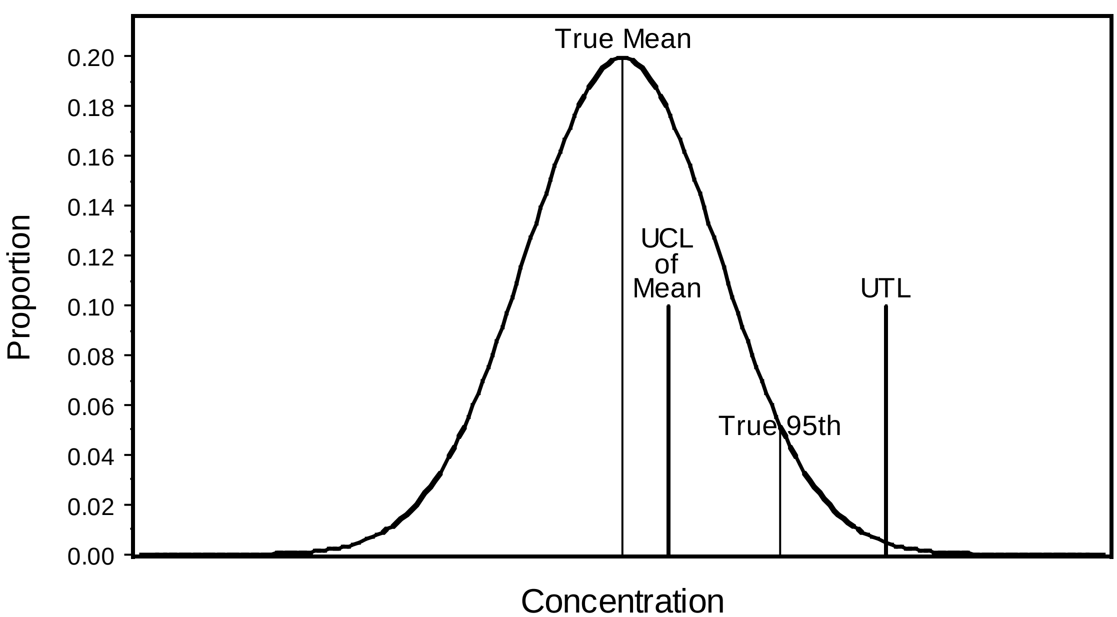
This TM was prepared under the United States Navy Comprehensive Long-term Environmental Action (CLEAN) Contract N62470-02-D-3052, for submittal to the Naval Facilities Engineering Command (NAVFAC) Mid-Atlantic Division, United States Environmental Protection Agency (USEPA) Region 3, and the Virginia Department of Environmental Quality (VDEQ). The Navy, USEPA, and VDEQ work jointly as the WPNSTA Yorktown and CAX Tier I Partnering Teams.

Existing soil and groundwater background data for WPNSTA Yorktown are documented in the *Final Summary of Background Constituent Concentrations and Characterization of Biotic Community from the York River Drainage Basin, Naval Weapons Station Yorktown, Yorktown Virginia* (Baker, 1995) and for CAX in the *Final Background Investigation Naval Weapons Station Yorktown, Yorktown, Virginia, Cheatham Annex Site, Williamsburg, Virginia* (Baker, 2003). These reports document calculation of a 95 percent upper confidence limit (UCL) of the mean using the individual WPNSTA Yorktown and CAX data sets. These UCLs have been conservatively used for previous Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) release/risk management assessments and remedial actions.

In July 2009, USEPA and VDEQ approved the *Final Background Study Work Plan, Naval Weapons Station Yorktown, Yorktown, Virginia and Cheatham Annex, Williamsburg, Virginia* (CH2M HILL, 2009) to revise the representative background values in soil and groundwater. The objective of the background study was not to re-evaluate or re-visit past use of background data but rather to supplement existing data and establish a more comprehensive and representative background data set for future application to CERCLA investigations and remedial actions based on the following:

- The 95 percent UCL of the mean provides a conservative estimate of the mean and is used in determining whether the mean of a population exceeds a constant threshold. As such, it provides a statistic about the the center tendency of a given population and does not address individual concentrations or provide an estimate of the upper tail of the distribution.
- A UTL is a more appropriate background threshold value because it represents a UCL of an upper percentile, specifically for this evaluation, the 95 percent UCL of the 95th percentile. Individual values consistent with the site population will only rarely exceed the UTL. The relationship between the UTL and the UCL of the mean is visually displayed in **Insert 1** for a hypothetical normal distribution. The exact relationship of these statistics will depend on the distribution and variability of the data, how well the background sample data represents the true parent population, and the number of background samples, but the UCL of the mean always provides a central tendency estimate whereas the UTL always provides an upper tail estimate.
- The greatest possible sample size, and therefore more comprehensive background data set, can be realized by combining existing background data from WPNSTA Yorktown and CAX facilities that share a common geographic boundary and the same physiographic, hydrogeologic, and soil association characteristics, which is further demonstrated by the fact that much of the background data collected as part of the CAX study are from samples collected on WPNSTA Yorktown.
- Insufficient background groundwater data existed for the Yorktown-Eastover aquifer relevant to future CERCLA groundwater investigations. More current background data from existing and new monitoring wells for this transient media were preferred.

INSERT 1
Example Positions of UCL of the Mean and 95/95 UTL (For a Normal Distribution)



The Background Study Work Plan (CH2M HILL, 2009) included a proposed approach for calculating the soil and groundwater UTL background values. However, since statistical approaches are dependent upon the distribution of the data and does not account for other natural variations, the Navy and USEPA agreed to review the data and come to an agreement on the best statistical approach. This TM describes the agreed upon approach.

Soil Background Evaluation

Summary of Data

A summary of surface and subsurface soil background data and the applicable soil association is provided in **Table 1**. Figures from the background investigations showing these sample locations are provided in **Appendix A**. As part of the previous WPNSTA Yorktown background investigation, a total of 40 surface soil and 14 subsurface soil samples were collected from the five soil associations. The surface soil samples were collected from 0 to 6 inches below ground surface (bgs) and the subsurface soil samples were collected at varying depths (1 to 33 feet bgs). As part of the previous CAX background investigation, a total of 40 surface soil and 40 subsurface soil samples were collected from Soil Associations 1 through 4 (Soil Association 5 does not exist at CAX). The surface soil samples were collected from 0 to 6 inches bgs and the subsurface soil samples were collected from 6 to 24 inches bgs.

The data from Soil Association 5 at WPNSTA Yorktown was excluded from the combined background data set because this soil association comprises a relatively small portion of the Base. Because subsurface soils were collected at varying depths (down to 33 feet bgs) during the previous WPNSTA Yorktown background investigation, only two subsurface samples collected from WPNSTA Yorktown at the 1–3 foot bgs interval were retained for inclusion in the combined background data set to be consistent with the 40 subsurface samples collected from 6 to 24 inches bgs as part of the previous CAX background investigation. In addition, samples collected as part of the WPNSTA Yorktown background investigation along former railroad tracks were also excluded from the combined data set as they are considered overly biased of potential non-point anthropogenic sources.

The WPNSTA Yorktown and CAX background data were combined for this evaluation. Duplicate results were reconciled to a single value in the same manner that site data is to be treated, that is, choosing the maximum detect or the lower of two detection limits (when both duplicates were nondetect). To determine which soil association groups should be combined when calculating background summary statistics, analysis of variance (ANOVA) and box and whisker plots were used to establish whether significant differences exist among soil associations. The conclusions from this evaluation were to calculate separate inorganic statistics for Soil Association 1 and Soil Association 2 and combined inorganic statistics for Soil Associations 3 and 4. However, because concentrations in the four soil associations are comparable, the WPNSTA Yorktown and CAX Partnering Teams agreed to combine all soil associations when calculating the UTL background values. Subsequent ANOVA for soil depth (surface and subsurface) was performed to determine whether to combine the depths or treat them separately for each constituent and soil association partition. Initially, when less than 50 percent detects existed for a given constituent, the soil associations and depths were combined since there was insufficient data to indicate that separate partitions were necessary. However, due to significant differences in inorganic contaminant concentrations of surface and subsurface soils, the WPNSTA Yorktown and CAX Partnering Teams agreed to compute separate inorganic surface and subsurface soil UTLs.

The WPNSTA Yorktown and CAX Partnering Teams agreed to not calculate background UTL values for organic constituents since a high degree of variability may exist with the large number of detects.

Statistical Analysis of Inorganic Compunds

Evaluation of Outliers

Soil outliers were evaluated with Dixon's and Rosner's outlier tests. Dixon's test was used when the number of samples was less than 25 and Rosner's test was used when the number of samples was 25 or more. Outlier evaluations were performed on the partitions determined to serve as separate populations via the ANOVA and graphical evaluation. Thus, each partition identified for separate calculation of summary statistics was provided a separate outlier evaluation (CH2M HILL, 2009). A list of soil mathematical outliers is provided in **Table 2**. The data included in the evaluation of outliers are plotted as normal probability plots in **Figure 1**. An "X" symbol is used for the mathematical outliers. Normal probability plots graph actual concentrations against theoretical quantiles if the true distribution of the data were normal. Thus, if the data set has strong adherence to a normal distribution, the plot resembles a straight line (with limited curvature).

An inspection of the plots in **Figure 1** reveals that many of the constituents contain data that are positively skewed as indicated by upward curvature. This is true even for the portion of the curve below suspected outliers. Both Dixon's and Rosner's test assume that the data values (aside from those being tested as potential outliers) are normally distributed. When upward curvature is present, as is the case for many constituents, the data are positively skewed which leads to more elevated results being identified as mathematical outliers than if an appropriate transformation of the data could be determined (USEPA, 2006) to render the data more normally distributed. This project chose to ignore this effect and exclude all the calculated mathematical outliers from the recommended background data set. Since the samples were believed to be obtained in appropriate background locations, this is considered an additional conservative step inthe calculation of background statistics.

Note that a higher percentage of nondetects creates increasing problems with the application of both Dixon's and Rosner's test. Due to this, constituents with a percentage of detects less than 10 percent were not evaluated by the mathematical outlier tests (but are included in **Figure 1**). A visual review of cases where less than 10 percent of results were detected did not reveal elevated results requiring exclusion from the background data set.

Background Threshold Value Calculations

The background threshold values were calculated as 95 percent/95 percent background UTLs; that is, upper bounds (with 95 percent confidence) of the background 95th percentiles. The UTL background values were calculated from the recommended background data set (values excluding mathematical outliers) following the algorithms and recommendations from ProUCL (USEPA, 2009). This included determining the distributional assumption that appeared most appropriate, or using a nonparametric (distribution free) approach when evidence for a particular distribution was not available.

The distribution possibilities included the normal, lognormal, and gamma distributions. The gamma distribution UTL algorithms were added to ProUCL in 2009. The normal approximation to the gamma distribution (proposed by Hawkins-Wixley) was used to calculate UTLs when the gamma distribution was determined to be an appropriate assumption.

As long as at least 60 percent of the results were detected, the distributions appearing most appropriate via ProUCL's distributional checks were used to calculate the UTL. For such cases, when data included some nondetects the ProUCL algorithms sought to apply maximum-likelihood-estimate (MLE) or regression on order statistics (ROS) techniques to estimate the mean and standard deviation parameters used in the calculation of the UTLs. When a UTL estimated using MLE or ROS techniques was possible within ProUCL's algorithms, that approach was preferred over one using alternate proxy values (e.g., detection limit divided by 2).

When all results were detected, but no discernable distribution was available, a nonparametric UTL, based on ranks of the data, was chosen. Another nonparametric approach provided in ProUCL is the Kaplan-Meier (KM) method. As applied in ProUCL, this approach estimates the mean and standard deviation for left-censored data sets (those with nondetects). When at least four detects were available the KM method was applied both to cases when fewer than 60 percent of the results were detected and when the percent detects was greater than 60 percent (but less than 100 percent) and no discernable distribution was available. When fewer than four detects were available (i.e., antimony, cadmium, and silver in surface soil and beryllium, cyanide, mercury, selenium, and silver in subsurface soil), no UTL background value was calculated.

Calculated UTL Background Values for Inorganics

Upon agreement of the statistical analysis approach outlined above, final surface and subsurface soil background concentrations (as well as final groundwater background concentrations) will be presented in a Background Study Report, to be submitted under separate cover from this TM. However the preliminary soil UTL background vaules are presented in **Table 3** for constituents detected in background samples. For cases with fewer than four detects, no calculated UTL background value is provided. Other summary statistics are also included in **Table 3** including the mean and standard deviation of detected results, minimums and maximums of detected values, and frequency of detection.

Groundwater Background Evaluation

Summary of Data

Existing background groundwater data for the Cornwallis Cave and Yorktown-Eastover aquifers were available from both WPNSTA Yorktown and CAX previous background studies. However, this data set provided only six samples from the Yorktown-Eastover aquifer, which was insufficient to calculate UTL background values. In addition, the chemical concentrations in groundwater are dynamic with fluctuations in concentrations that may result from attenuation of constituents, changes in water level evelvations, and/or groundwater parameters (e.g., pH). Therefore, as approved by the USEPA and VDEQ, a more current data set for evaluation of background groundwater quality was collected in 2009.

A summary of groundwater background data is provided in **Table 4**. Figures depicting the monitoring well sampling locations are provided in **Appendix B**. A total of 15 groundwater samples were collected from the Cornwallis Cave aquifer and a total of 13 groundwater samples were collected from the Yorktown-Eastover aquifer.

Groundwater samples were analyzed for organics [volatile organic compounds (VOCs), semi-volatile organic compounds (SVOCs), pesticides, polychlorinated biphenyls (PCBs), and explosives], and inorganics. The WPNSTA Yorktown and CAX Partnering Teams agreed to calculate background UTL values for the inorganic constituents, but not the organic concentrations since a high degree of variability may exist with the large number of detects.

Statistical Analysis of Inorganic Compounds

Evaluation of Outliers

Groundwater outliers were evaluated with Rosner’s outlier test. This test can be used when the number of samples is 25 or more, which was the case for each of the groundwater constituents. A list of groundwater mathematical outliers is provided in **Table 5**. The data included in the evaluation of outliers are plotted as normal probability plots in **Figure 2**. An “X” symbol is used for the mathematical outliers. Normal probability plots graph actual concentrations against theoretical quantiles if the true distribution of the data were normal. Thus, if the data set has strong adherence to a normal distribution, the plot resembles a straight line (with limited curvature).

An inspection of the plots in **Figure 2** reveals that many of the constituents contain data that is positively skewed as indicated by upward curvature. This is true even for the portion of the curve below suspected outliers. Rosner’s test assumes that the data values (aside from those being tested as potential outliers) are normally distributed. When upward curvature is present, as is the case for many constituents, the data are positively skewed which leads to more elevated results being identified as mathematical outliers than if an appropriate transformation of the data could be determined (USEPA, 2006) to render the data more normally distributed. This project chose to ignore this effect and exclude all the calculated mathematical outliers from the recommended background data set. Since the samples were obtained in appropriate background locations, this is considered an additional conservative step in the calculations of background statistics.

Note that a higher percentage of nondetects creates increasing problems with the application of Rosner’s test. Due to this, constituents with a percentage of detects less than 10 percent were not evaluated by Rosner’s test (but are included in **Figure 2**). A visual review of cases where less than 10 percent of results were detected did not reveal elevated results requiring exclusion from the background data set.

Background Threshold Value Calculations

The background threshold values were calculated as 95 percent/95 percent background UTLs; that is, upper bounds (with 95 percent confidence) of the background 95th percentiles. The UTL background values were calculated from the recommended background data set (values excluding mathematical outliers) following the algorithms and recommendations from ProUCL (USEPA, 2009). This included determining the distributional assumption that appeared most appropriate, or using a nonparametric (distribution free) approach when evidence for a particular distribution was not available.

The distribution possibilities included the normal, lognormal, and gamma distributions. The gamma distribution UTL algorithms were added to ProUCL in 2009. The normal approximation to the gamma distribution (proposed by Hawkins-Wixley) was used to calculate UTLs when the gamma distribution was determined to be an appropriate assumption.

As long as at least 60 percent of the results were detected, the distributions appearing most appropriate via ProUCL's distributional checks were used to calculate the UTL. For such cases, when data included some nondetects, the ProUCL algorithms sought to apply MLE or ROS techniques to estimate the mean and standard deviation parameters used in the calculation of the UTLs. When a UTL estimated using MLE or ROS techniques was possible within ProUCL's algorithms, that approach was preferred over one using alternate proxy values (e.g., detection limit divided by 2).

When all results were detected, but no discernable distribution was available, a nonparametric UTL, based on ranks of the data, was chosen. Another nonparametric approach provided in ProUCL is the KM method. As applied in ProUCL, this approach estimates the mean and standard deviation for left-censored data sets (those with nondetects). When at least four detects were available the KM method was applied both to cases when fewer than 60 percent of the results were detected and when the percent detects was greater than 60 percent (but less than 100 percent) and no discernable distribution was available. When fewer than four detects were available (i.e., dissolved aluminum, antimony, cobalt, copper, lead, mercury, nickel, selenium, and vanadium and total antimony, copper, lead, and mercury in the combined data sets from the Corwallis Cave and Yorktown-Eastover aquifers), no UTL was calculated.

Calculated UTL Background Values for Inorganics

Upon agreement of the statistical analysis approach outlined above, final groundwater background concentrations (as well as final surface and subsurface soil background concentrations) will be presented in a Background Study Report, to be submitted under separate cover from this TM. However the preliminary groundwater UTL background values are presented in **Table 6** for constituents detected in background samples. For cases with fewer than four detects, no calculated UTL background value is provided. Other summary statistics are also included in **Table 6** including the mean and standard deviation of detected results, minimums and maximums of detected values, and frequency of detection.

References

Baker Environmental, Inc. (Baker). 1995. *Final Summary of Background Constituent Concentrations and Characterization of Biotic Community from the York River Drainage Basin, Naval Weapons Station Yorktown, Yorktown Virginia.* July.

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Brockman et al. 1997. Geohydrology of the Shallow Aquifer System, Naval Weapons Station Yorktown, Yorktown, Virginia. U.S. Geological Survey Water-Resources Investigations Report 97-4188.

United States Environmental Protection Agency (USEPA). 2006. *Data Quality Assessment: Statistical Methods for Practitioners.* Office of Environmental Information, Washington, D.C.

USEPA. 2009. *ProUCL Version 4.00.04 Technical Guide (Draft),* Office of Research and Development.

Tables

Table 1
Summary of Background Soil Data Set

Summary of Samples Included in the Soil Background Data Set			
WPNSTA Yorktown			
Soil Association		Number of Samples	Analysis
	Surface Soils (0-6")		
#1	Bohicket, Johnston, Axis	5	inorganics
#2	Dogue, Pamunkey, Uchee	10	
#3	Emporia, Kempsville, Craven-Uchee Complex	10	
#4	Slagle, Emporia, Emporia Complex	11	
	Subsurface Soil Samples (1-3')		
#2	Dogue, Pamunkey, Uchee	1	Inorganics
#3	Emporia, Kempsville, Craven-Uchee Complex	1	
CAX			
Soil Association		Number of Samples	Analysis
	CAX Surface Soils (0-6")		
#1	Bohicket, Johnston, Axis	10	SVOCs, pesticides/PCBs, inorganics
#2	Dogue, Pamunkey, Uchee	10	
#3	Emporia, Slagle, Craven-Uchee	10	
#4	Kempsville, Emporia, Craven-Unchee Complex, Emporia Complex	10	
	CAX Subsurface Soil Samples (6-24")		
#1	Bohicket, Johnston, Axis	10	SVOCs, pesticides/PCBs, inorganics, TOC
#2	Dogue, Pamunkey, Uchee	10	
#3	Emporia, Slagle, Craven-Uchee	10	
#4	Kempsville, Emporia, Craven-Unchee Complex, Emporia Complex	10	
Summary of Samples Excluded from the Soil Background Data Set			
WPNSTA Yorktown			
		Number of Samples	Analysis
	Railroad Background Samples (0-6", Collected proximal to Main Road)	12	VOCs, SVOCs, pest/PCBs, explosives, inorganics
Soil Assocation			
	Surface Soils		
#5	Slagle, Bethera, Craven-Uchee	4	Inorganics
	Subsurface Soil Samples (collected at varying depths 3-33')		
#1	Bohicket, Johnston, Axis	3	inorganics
#2	Dogue, Pamunkey, Uchee	2	
#3	Emporia, Kempsville, Craven-Uchee Complex	1	
#4	Slagle, Emporia, Emporia Complex	3	
#5	Slagle, Bethera, Craven-Uchee	3	

Table 2: Calculated Soil Outliers (Assuming Normal Distribution)

Sample ID	Depth	Parameter	Units	Qualifier	Result
BG1-SB03-01	SB	Aluminum	mg/kg		18400
BG1-SB03-01	SB	Arsenic	mg/kg		10.4
BG1-SB09-01	SB	Arsenic	mg/kg		12.5
BG2-SB01-01D	SB	Arsenic	mg/kg		15.9
BG4-SB01-01	SB	Arsenic	mg/kg		18.6
BG4-SB10-01	SB	Arsenic	mg/kg		13.8
BG1-SB06-01	SB	Calcium	mg/kg		32200
BG2-SB06-01	SB	Calcium	mg/kg		162000
BG1-SB03-01	SB	Chromium	mg/kg		37.5
BG2-SB05-01	SB	Cobalt	mg/kg	J	7.3
BG3-SB09-01	SB	Cobalt	mg/kg	J	8.1
BG4-SB09-01	SB	Cobalt	mg/kg	J	7
BG1-SB03-01	SB	Copper	mg/kg	J	9.6
BG1-SB09-01	SB	Copper	mg/kg	J	9
BG2-SB06-01	SB	Copper	mg/kg	J	5
BG1-SB03-01	SB	Lead	mg/kg		23.3
BG1-SB08-01	SB	Lead	mg/kg		83.7
BG1-SB09-01	SB	Lead	mg/kg		35.3
BGSB05-01	SB	Lead	mg/kg	J	13.7
BG1-SB03-01	SB	Magnesium	mg/kg		4630
BG1-SB04-01	SB	Magnesium	mg/kg		1810
BG1-SB09-01	SB	Magnesium	mg/kg		3340
BG2-SB02-01	SB	Magnesium	mg/kg		1420
BG2-SB06-01	SB	Magnesium	mg/kg		3340
BG3-SB09-01	SB	Manganese	mg/kg		208
BG4-SB01-01D	SB	Manganese	mg/kg		195
BGSB04-01D	SB	Manganese	mg/kg	J	254
BG1-SB03-01	SB	Potassium	mg/kg		4240
BG1-SB04-01	SB	Potassium	mg/kg	J	2370
BG1-SB06-01	SB	Potassium	mg/kg	J	1970
BG1-SB09-01	SB	Potassium	mg/kg		2790
BG2-SB06-01	SB	Potassium	mg/kg		2100
BG1-SB01-01	SB	Selenium	mg/kg	B	0.8
BG1-SB04-01	SB	Selenium	mg/kg	B	0.9
BG1-SB05-01	SB	Selenium	mg/kg	L	1.9
BG2-SB01-01D	SB	Selenium	mg/kg	J	1.2
BG2-SB08-01	SB	Selenium	mg/kg	J	0.87
BG1-SB03-01	SB	Sodium	mg/kg		9810
BG1-SB06-01	SB	Sodium	mg/kg		2560
BG1-SB08-01	SB	Sodium	mg/kg		1700
BG1-SB09-01	SB	Sodium	mg/kg		10400
BG1-SB10-01	SB	Sodium	mg/kg		2360
BG1-SB03-01	SB	Vanadium	mg/kg		53.8
BG1-SB03-01	SB	Zinc	mg/kg		52.9
BG1-SB09-01	SB	Zinc	mg/kg		34.3
BG2-SB01-01D	SB	Zinc	mg/kg		29.5
BG2-SB06-01	SB	Zinc	mg/kg		30.8
BG4-SB01-01	SB	Zinc	mg/kg		32

Table 2: Calculated Soil Outliers (Assuming Normal Distribution)

Sample ID	Depth	Parameter	Units	Qualifier	Result
BG1-SS03-00	SS	Aluminum	mg/kg		16500
BGS21	SS	Aluminum	mg/kg		15600
BGS28	SS	Aluminum	mg/kg		19200
BG1-SS03-00	SS	Arsenic	mg/kg		9.9
BG1-SS06-00	SS	Arsenic	mg/kg		8.3
BG4-SS01-00D	SS	Arsenic	mg/kg		11.7
BGS21	SS	Arsenic	mg/kg		63.9
BGS20D	SS	Barium	mg/kg		75.7
BGS28	SS	Barium	mg/kg		80.2
BGS38	SS	Barium	mg/kg		76.3
BG1-SS03-00	SS	Beryllium	mg/kg	J	1.1
BGS38	SS	Beryllium	mg/kg	J	0.93
BG1-SS04-00	SS	Calcium	mg/kg		2950
BG1-SS05-00D	SS	Calcium	mg/kg		3500
BG1-SS06-00	SS	Calcium	mg/kg		33500
BG2-SS06-00	SS	Calcium	mg/kg		3320
BGS04	SS	Calcium	mg/kg		7820
BG1-SS03-00	SS	Chromium	mg/kg		43.2
BG1-SS09-00	SS	Chromium	mg/kg		26.8
BG1-SS03-00	SS	Copper	mg/kg		22.1
BG1-SS06-00	SS	Copper	mg/kg	J	8.8
BG1-SS09-00	SS	Copper	mg/kg	J	9.8
BGS04	SS	Copper	mg/kg		24.4
BG1-SS03-00	SS	Lead	mg/kg		136
BG1-SS09-00	SS	Lead	mg/kg		34.7
BGS07	SS	Lead	mg/kg		43.1
BGS22	SS	Lead	mg/kg	L	25.3
BGS28	SS	Lead	mg/kg	L	38.7
BG1-SS03-00	SS	Magnesium	mg/kg		6770
BG1-SS04-00	SS	Magnesium	mg/kg		2050
BG1-SS09-00	SS	Magnesium	mg/kg		5290
BGS34D	SS	Magnesium	mg/kg		1610
BG4-SS10-00	SS	Manganese	mg/kg		435
BGS03	SS	Manganese	mg/kg		491
BGS38	SS	Manganese	mg/kg		413
BG1-SS03-00	SS	Nickel	mg/kg	J	14.2
BG1-SS03-00	SS	Potassium	mg/kg		4560
BG1-SS04-00	SS	Potassium	mg/kg	J	1420
BG1-SS09-00	SS	Potassium	mg/kg		3510
BG2-SS06-00	SS	Potassium	mg/kg	L	1210
BGS34D	SS	Potassium	mg/kg	J	1640
BG1-SS04-00	SS	Selenium	mg/kg	J	1.5
BG1-SS05-00D	SS	Selenium	mg/kg	J	1.2
BG1-SS06-00	SS	Selenium	mg/kg	J	2.7
BG4-SS01-00D	SS	Selenium	mg/kg	L	1.4
BG4-SS10-00	SS	Selenium	mg/kg	K	1.2
BG1-SS03-00	SS	Sodium	mg/kg		21300
BG1-SS04-00	SS	Sodium	mg/kg		2610

Table 2: Calculated Soil Outliers (Assuming Normal Distribution)

Sample ID	Depth	Parameter	Units	Qualifier	Result
BG1-SS06-00	SS	Sodium	mg/kg		2970
BG1-SS09-00	SS	Sodium	mg/kg		20500
BG1-SS10-00	SS	Sodium	mg/kg		4140
BG1-SS03-00	SS	Vanadium	mg/kg		50.3
BG1-SS09-00	SS	Vanadium	mg/kg		41.2
BGS28	SS	Vanadium	mg/kg		34.7
BG1-SS03-00	SS	Zinc	mg/kg		113
BG1-SS08-00	SS	Zinc	mg/kg		41.2
BG1-SS09-00	SS	Zinc	mg/kg		47.8
BGS04	SS	Zinc	mg/kg		37.5
BGS28	SS	Zinc	mg/kg		48.4

Table 3: Summary Statistics for Soil Background Data

Soil Association	Depth	Chemical Group	Parameter	Calculated 95/95 UTL	UTL Basis	Number of Detects	Number of Analyses	Frequency of Detects	Percent Detects	Units	Minimum Detected Value	Maximum Detected Value	Minimum DL for Non-detects	Maximum DL for Non-detects	Location of Maximum Detected Concentration	Mean Value Detects	Standard Deviation Detects
Soil Associations 1, 2, and 3/4	SB	Total Metals	Aluminum	13000	Normal UTL	41	41	41/41	100	mg/kg	238	12600	NA	NA	BG2-SB04-01	6140	3230
Soil Associations 1, 2, and 3/4	SB	Total Metals	Arsenic	5.54	Kaplan Meier UTL	17	37	17/37	46	mg/kg	0.7	6.8	0.28	2.5	BG2-SB06-01	3.38	1.57
Soil Associations 1, 2, and 3/4	SB	Total Metals	Barium	84.5	Gamma UTL	42	42	42/42	100	mg/kg	0.9	58	NA	NA	BG4-SB04-01	27.1	14.6
Soil Associations 1, 2, and 3/4	SB	Total Metals	Beryllium	NA	Fewer than Four Detects	2	42	2/42	5	mg/kg	0.49	0.52	0.1	1.2	BGSB05-01	0.505	0.0212
Soil Associations 1, 2, and 3/4	SB	Total Metals	Calcium	2380	Lognormal UTL	40	40	40/40	100	mg/kg	56.4	1810	NA	NA	BG2-SB01-01	502	487
Soil Associations 1, 2, and 3/4	SB	Total Metals	Chromium	33.7	Gamma UTL	40	41	40/41	98	mg/kg	2.4	26.4	3.5	3.5	BG2-SB02-01	10.4	6.55
Soil Associations 1, 2, and 3/4	SB	Total Metals	Cobalt	5.18	Normal UTL MLE	33	39	33/39	85	mg/kg	0.2	6	0.16	1.4	BG4-SB10-01	2.27	1.28
Soil Associations 1, 2, and 3/4	SB	Total Metals	Copper	3.17	Kaplan Meier UTL	21	39	21/39	54	mg/kg	0.71	3.2	0.43	3.9	BG4-SB01-01	1.85	0.86
Soil Associations 1, 2, and 3/4	SB	Total Metals	Cyanide	NA	Fewer than Four Detects	1	42	1/42	2	mg/kg	2.7	2.7	0.04	0.59	BG1-SB03-01	2.7	NA
Soil Associations 1, 2, and 3/4	SB	Total Metals	Iron	32000	Gamma UTL	42	42	42/42	100	mg/kg	1280	30000	NA	NA	BG2-SB01-01	10200	7050
Soil Associations 1, 2, and 3/4	SB	Total Metals	Lead	8.79	Normal UTL	38	38	38/38	100	mg/kg	2.6	8.3	NA	NA	BG2-SB10-01	5.67	1.46
Soil Associations 1, 2, and 3/4	SB	Total Metals	Magnesium	1120	Gamma UTL	37	37	37/37	100	mg/kg	115	1350	NA	NA	BG1-SB06-01	433	264
Soil Associations 1, 2, and 3/4	SB	Total Metals	Manganese	176	Gamma UTL	39	39	39/39	100	mg/kg	2.9	154	NA	NA	BG4-SB09-01	47.2	39.4
Soil Associations 1, 2, and 3/4	SB	Total Metals	Mercury	NA	Fewer than Four Detects	2	42	2/42	5	mg/kg	0.067	0.14	0.036	0.12	BG4-SB03-01	0.104	0.0516
Soil Associations 1, 2, and 3/4	SB	Total Metals	Nickel	17.6	Gamma UTL	39	42	39/42	93	mg/kg	0.51	11	0.99	3.8	BG1-SB03-01	3.9	2.41
Soil Associations 1, 2, and 3/4	SB	Total Metals	Potassium	901	Kaplan Meier UTL	20	37	20/37	54	mg/kg	276	1190	78.8	259	BG1-SB05-01	519	274
Soil Associations 1, 2, and 3/4	SB	Total Metals	Selenium	NA	Fewer than Four Detects	3	39	3/39	8	mg/kg	0.26	0.64	0.57	1.8	BG4-SB10-01	0.427	0.194
Soil Associations 1, 2, and 3/4	SB	Total Metals	Silver	NA	Fewer than Four Detects	1	42	1/42	2	mg/kg	1.1	1.1	0.1	0.88	BGSB05-01	1.1	NA
Soil Associations 1, 2, and 3/4	SB	Total Metals	Sodium	811	Kaplan Meier UTL	4	37	4/37	11	mg/kg	58.5	1560	135	973	BG1-SB04-01	754	778
Soil Associations 1, 2, and 3/4	SB	Total Metals	Vanadium	48.3	Gamma UTL	41	41	41/41	100	mg/kg	2.1	37.8	NA	NA	BG1-SB09-01	16.2	9.84
Soil Associations 1, 2, and 3/4	SB	Total Metals	Zinc	28	Gamma UTL	34	37	34/37	92	mg/kg	4.5	20.9	2.5	4	BG1-SB02-01	10.7	4.84
Soil Associations 1, 2, and 3/4	SS	Total Metals	Aluminum	12200	Gamma UTL	72	72	72/72	100	mg/kg	235	12900	NA	NA	BGS20	4780	2660
Soil Associations 1, 2, and 3/4	SS	Total Metals	Antimony	NA	Fewer than Four Detects	3	73	3/73	4	mg/kg	1	11	0.33	10.6	BGS35	7.07	5.33
Soil Associations 1, 2, and 3/4	SS	Total Metals	Arsenic	6.36	Lognormal UTL	54	71	54/71	76	mg/kg	0.094	6	0.23	3.1	BG1-SS09-00	1.99	1.41
Soil Associations 1, 2, and 3/4	SS	Total Metals	Barium	52.9	Normal UTL MLE	69	72	69/72	96	mg/kg	0.75	62	16.1	32.7	BGS04	23.9	12.1
Soil Associations 1, 2, and 3/4	SS	Total Metals	Beryllium	0.587	Kaplan Meier UTL	30	73	30/73	41	mg/kg	0.23	0.79	0.079	0.74	BG4-SS10-00	0.433	0.146
Soil Associations 1, 2, and 3/4	SS	Total Metals	Cadmium	NA	Fewer than Four Detects	3	75	3/75	4	mg/kg	1.2	1.5	0.077	1.4	BGS30	1.33	0.153
Soil Associations 1, 2, and 3/4	SS	Total Metals	Calcium	2290	Gamma UTL	68	70	68/70	97	mg/kg	45.8	2940	258	319	BGS20	643	651
Soil Associations 1, 2, and 3/4	SS	Total Metals	Chromium	18.2	Lognormal UTL	72	73	72/73	99	mg/kg	1.8	18.3	2.8	2.8	BGS34	6.96	4.02
Soil Associations 1, 2, and 3/4	SS	Total Metals	Cobalt	9.93	Gamma UTL	66	75	66/75	88	mg/kg	0.2	6.7	0.13	2.3	BG4-SS10-00	2.4	1.5
Soil Associations 1, 2, and 3/4	SS	Total Metals	Copper	4.25	Kaplan Meier UTL	50	71	50/71	70	mg/kg	0.41	5.3	0.83	3.5	BGS28	2.27	1.19
Soil Associations 1, 2, and 3/4	SS	Total Metals	Iron	19900	Nonparametric UTL	75	75	75/75	100	mg/kg	1470	20300	NA	NA	BG4-SS01-00	6430	4650
Soil Associations 1, 2, and 3/4	SS	Total Metals	Lead	17.4	Normal UTL	70	70	70/70	100	mg/kg	1.1	22.7	NA	NA	BGS04	10.2	3.61
Soil Associations 1, 2, and 3/4	SS	Total Metals	Magnesium	1070	Lognormal UTL	67	71	67/71	94	mg/kg	112	1200	92.1	292	BG1-SS05-00	394	278
Soil Associations 1, 2, and 3/4	SS	Total Metals	Manganese	324	Gamma UTL	72	72	72/72	100	mg/kg	6.9	340	NA	NA	BGS20	96.1	81.6
Soil Associations 1, 2, and 3/4	SS	Total Metals	Mercury	0.111	Kaplan Meier UTL	7	75	7/75	9	mg/kg	0.051	0.24	0.037	0.16	BG1-SS03-00	0.119	0.0658
Soil Associations 1, 2, and 3/4	SS	Total Metals	Nickel	9.52	Normal UTL MLE	63	74	63/74	85	mg/kg	0.37	11.9	1	4.1	BGS20	4.6	2.45
Soil Associations 1, 2, and 3/4	SS	Total Metals	Potassium	708	Kaplan Meier UTL	22	70	22/70	31	mg/kg	245	911	86.8	449	BG1-SS06-00	560	201
Soil Associations 1, 2, and 3/4	SS	Total Metals	Selenium	0.51	Kaplan Meier UTL	22	70	22/70	31	mg/kg	0.27	0.69	0.22	2.2	BG2-SS02-00	0.384	0.117
Soil Associations 1, 2, and 3/4	SS	Total Metals	Silver	NA	Fewer than Four Detects	3	75	3/75	4	mg/kg	0.16	2.1	0.096	1.1	BGS21	1.09	0.973
Soil Associations 1, 2, and 3/4	SS	Total Metals	Sodium	521	Kaplan Meier UTL	36	70	36/70	51	mg/kg	17.4	1960	73.6	568	BG1-SS05-00	93.3	321
Soil Associations 1, 2, and 3/4	SS	Total Metals	Vanadium	27.9	Gamma UTL	72	72	72/72	100	mg/kg	2.4	29.8	NA	NA	BGS27	12	6.35
Soil Associations 1, 2, and 3/4	SS	Total Metals	Zinc	26.5	Gamma UTL	70	70	70/70	100	mg/kg	3.6	30	NA	NA	BG1-SS06-00	12.1	5.98

Table 4
Summary of Background Study Wells Sampled
(corresponds to maps in Appendix B)

Aquifer	Well ID
Cornwallis Cave	YBKL-GW02[1]
	YBKL-GW01[1]
	YBKG-GW15-3[2]
	YBKG-GW08A[3]
	YBKG-GW14-3[2]
	YBKG-GW07A[4]
	YBKG-GW07[4]
	YBKG-GW01[4]
	YBKG-GW06A[4]
	YBKG-GW12-3[2]
	YBKG-GW13-3[2]
	YBKG-GW03A[4]
	YBKG-GW05A[4]
	YBKG-GW11-3[2]
	YBKG-GW10[5]
Yorktown-Eastover	YBKG-GW15-1[2]
	YBKG-GW15-2[2]
	YBKG-GW14-1[2]
	YBKG-GW14-2[2]
	YBKG-GW01A[4]
	YBKG-GW12-1[2]
	YBKG-GW12-2[2]
	YBKG-GW13-1[2]
	YBKG-GW13-2[2]
	YBKG-GW11-1[2]
	YBKG-GW11-2[2]
	YBKG-GW09A[5]
	YBKG-GW10A[5]

[1]Installed as part of the previous CAX Background Study (Baker, 2003).

[2]Installed as part of the USGS Shallow Aquifer Study of Naval Weapons Station Yorktown (Brockman et. al, 1997).

[3]Installed as part of the previous Yorktown Background Study (Baker, 1995). Note: This well replaces USGS well 58G58 (N4) - the intended sampling location; however, the field crew discovered that USGS well had been destroyed by past vehicular activity.

[4]Installed as part of the previous Yorktown Background Study (Baker, 1995).

[5]New well installed as part of groundwater sample collection (CH2M HILL, 2009).

Table 5: Calculated Groundwater Outliers (Assuming Normal Distribution)

Sample ID	Parameter	Units	Qualifier	Result
YBKG-GW01A-YE-0809	Aluminum	ug/L	K	30700
YBKG-GW05A-CC-0809	Aluminum	ug/L	K	2080
YBKG-GW07-CC-0809	Aluminum	ug/L		8140
YBKG-GW10-CC-0809	Aluminum	ug/L	K	2650
YBKG-GW15P-3-CC-0809	Aluminum	ug/L		1720
YBKG-GW01A-YE-0809	Aluminum, Dissolved	ug/L	K	869
YBKG-GW01A-YE-0809	Arsenic	ug/L		15.4
YBKG-GW05A-CC-0809	Arsenic	ug/L		2.5
YBKG-GW07-CC-0809	Arsenic	ug/L		8.9
YBKG-GW08A-CC-0809	Arsenic	ug/L		4.3
YBKG-GW09A-YE-0809	Arsenic	ug/L		7.8
YBKG-GW08A-CC-0809	Arsenic, Dissolved	ug/L		2.5
YBKG-GW09A-YE-0809	Arsenic, Dissolved	ug/L		6.2
YBKG-GW15-1-YE-0809	Arsenic, Dissolved	ug/L	J	1.6
YBKG-GW01A-YE-0809	Barium	ug/L	J	178
YBKG-GW07A-CC-0809	Barium	ug/L		231
YBKG-GW01A-YE-0809	Chloroform	ug/L		3.8
YBKG-GW01A-YE-0809	Chromium	ug/L		96.8
YBKG-GW01P-CC-0809	Chromium	ug/L		103
YBKG-GW06A-CC-0809	Chromium	ug/L		22.3
YBKG-GW07-CC-0809	Chromium	ug/L		35.1
YBKG-GW09A-YE-0809	Chromium	ug/L		23.5
YBKG-GW09A-YE-0809	Chromium, Dissolved	ug/L		27.8
YBKG-GW14-1-YE-0809	Copper	ug/L		117
YBKG-GW01A-YE-0809	Iron	ug/L	K	62100
YBKG-GW05A-CC-0809	Iron	ug/L	K	4950
YBKG-GW07-CC-0809	Iron	ug/L		20100
YBKG-GW10-CC-0809	Iron	ug/L	K	5870
YBKG-GW01A-YE-0809	Iron, Dissolved	ug/L	K	1670
YBKG-GW03A-CC-0809	Iron, Dissolved	ug/L	K	1510
YBKG-GW13-3-CC-0809	Iron, Dissolved	ug/L	K	899
YBKG-GW14-3-CC-0809	Iron, Dissolved	ug/L		468
YBKG-GW11-1-YE-0809	Magnesium, Dissolved	ug/L		8380
YBKG-GW12-1-YE-0809	Magnesium, Dissolved	ug/L		6700
YBKG-GW14P-1-YE-0809	Magnesium, Dissolved	ug/L		6900
YBKG-GW15-1-YE-0809	Magnesium, Dissolved	ug/L		7870
YBKG-GW01A-YE-0809	Manganese	ug/L		279
YBKG-GW07-CC-0809	Manganese	ug/L		104
YBKG-GW10-CC-0809	Manganese	ug/L		126
YBKG-GW15-2-YE-0809	Manganese	ug/L		77.2
YBKG-GW10-CC-0809	Manganese, Dissolved	ug/L		77.2
YBKG-GW15-2-YE-0809	Manganese, Dissolved	ug/L		79.7
YBKG-GW13-2-YE-0809	Mercury, Dissolved	ug/L	L	0.14
YBKG-GW01A-YE-0809	Nickel	ug/L		43.9
YBKG-GW01P-CC-0809	Nickel	ug/L		45.6
YBKG-GW07A-CC-0809	Potassium	ug/L		19000
YBKG-GW10A-YE-0809	Potassium	ug/L		18200
YBKG-GW07A-CC-0809	Potassium, Dissolved	ug/L		17800

Table 5: Calculated Groundwater Outliers (Assuming Normal Distribution)

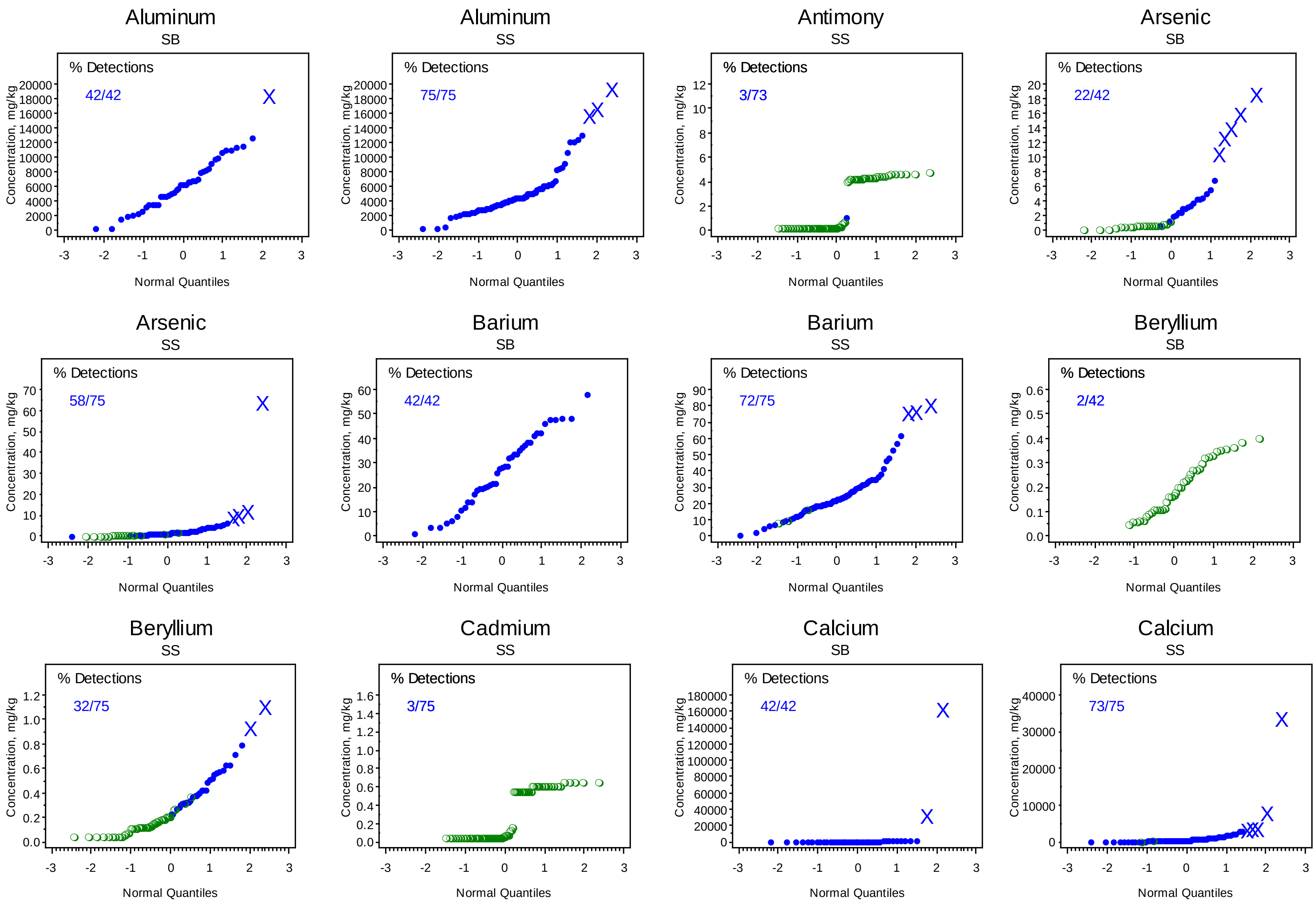
Sample ID	Parameter	Units	Qualifier	Result
YBKG-GW10A-YE-0809	Potassium, Dissolved	ug/L		19100
YBKG-GW15-1-YE-0809	Sodium	ug/L		84200
YBKG-GW15-1-YE-0809	Sodium, Dissolved	ug/L		85100
YBKG-GW01A-YE-0809	Vanadium	ug/L		83.9
YBKG-GW01A-YE-0809	Zinc	ug/L		146
YBKG-GW07-CC-0809	Zinc	ug/L		37.2
YBKG-GW07A-CC-0809	Zinc	ug/L		34

Table 6: Summary Statistics for Groundwater Background Data

Chemical Group	Aquifer	Parameter	Calculated 95/95 UTL	UTL Basis	Number of Detects	Number of Analyses	Frequency of Detects	Percent Detects	Units	Minimum Detected Value	Maximum Detected Value	Minimum DL for Non-detects	Maximum DL for Non-detects	Location of Maximum Detected Concentration	Mean Value Detects	Standard Deviation Detects
Dissolved Metals	CC-YE	Aluminum, Dissolved	NA	Fewer than Four Detects	3	25	3/25	12	ug/L	82.4	100	200	200	YBKG-GW15-3-CC	98.8	4.31
Dissolved Metals	CC-YE	Antimony, Dissolved	NA	Fewer than Four Detects	1	26	1/26	4	ug/L	9.7	9.7	0.25	20	YBKG-GW07A-CC	1.95	3.49
Dissolved Metals	CC-YE	Arsenic, Dissolved	1.37	HW Approx. Gamma UTL	23	23	23/23	100	ug/L	0.27	1.3	NA	NA	YBKG-GW06A-CC	0.588	0.268
Dissolved Metals	CC-YE	Barium, Dissolved	127	HW Approx. Gamma UTL	26	26	26/26	100	ug/L	16.3	101	NA	NA	YBKG-GW07A-CC	49.4	26.1
Dissolved Metals	CC-YE	Cadmium, Dissolved	0.177	Kaplan Meier UTL	6	26	6/26	23	ug/L	0.15	0.17	2	2	YBKG-GW15-1-YE	0.807	0.36
Dissolved Metals	CC-YE	Chromium, Dissolved	6.04	Kaplan Meier UTL	8	25	8/25	32	ug/L	0.9	5.8	10	10	YBKG-GW05A-CC	4.17	1.54
Dissolved Metals	CC-YE	Cobalt, Dissolved	NA	Fewer than Four Detects	1	26	1/26	4	ug/L	0.7	0.7	50	50	YBKG-GW11-3-CC	24.1	4.77
Dissolved Metals	CC-YE	Copper, Dissolved	NA	Fewer than Four Detects	1	26	1/26	4	ug/L	3	3	25	25	YBKG-GW14-1-YE	12.1	1.86
Dissolved Metals	CC-YE	Lead, Dissolved	NA	Fewer than Four Detects	1	26	1/26	4	ug/L	1.7	1.7	1.6	10	YBKG-GW10A-YE	3.97	1.73
Dissolved Metals	CC-YE	Manganese, Dissolved	49.5	Normal UTL MLE	21	24	21/24	88	ug/L	1.7	44.8	1.4	15	YBKG-GW13-3-CC	17.5	12.7
Dissolved Metals	CC-YE	Mercury, Dissolved	NA	Fewer than Four Detects	2	25	2/25	8	ug/L	0.072	0.1	0.2	0.2	YBKG-GW13-1-YE	0.0989	0.0056
Dissolved Metals	CC-YE	Nickel, Dissolved	NA	Fewer than Four Detects	1	26	1/26	4	ug/L	12.2	12.2	40	40	YBKG-GW01-CC	19.7	1.53
Dissolved Metals	CC-YE	Selenium, Dissolved	NA	Fewer than Four Detects	2	26	2/26	8	ug/L	7.7	9.1	35	35	YBKG-GW14-1-YE	16.8	2.48
Dissolved Metals	CC-YE	Vanadium, Dissolved	NA	Fewer than Four Detects	2	26	2/26	8	ug/L	2.5	4.3	50	50	YBKG-GW09A-YE	23.3	5.88
Dissolved Metals	CC	Calcium, Dissolved	148000	Normal UTL	13	13	13/13	100	ug/L	36500	123000	NA	NA	YBKG-GW07-CC	86800	23000
Dissolved Metals	YE	Calcium, Dissolved	113000	Normal UTL	13	13	13/13	100	ug/L	26100	93800	NA	NA	YBKG-GW14-2-YE	58500	20400
Dissolved Metals	CC	Iron, Dissolved	631	Normal UTL	7	11	7/11	64	ug/L	118	468	200	200	YBKG-GW14-3-CC	248	120
Dissolved Metals	YE	Iron, Dissolved	275	Kaplan Meier UTL	6	12	6/12	50	ug/L	31.6	234	200	200	YBKG-GW15-2-YE	110	80.3
Dissolved Metals	CC	Magnesium, Dissolved	3880	Normal UTL	13	13	13/13	100	ug/L	729	3460	NA	NA	YBKG-GW10-CC	1790	781
Dissolved Metals	YE	Magnesium, Dissolved	11200	Normal UTL	12	13	12/13	92	ug/L	1280	8380	438	438	YBKG-GW11-1-YE	4400	2510
Dissolved Metals	CC	Potassium, Dissolved	1710	Normal UTL	11	11	11/11	100	ug/L	775	1450	NA	NA	YBKG-GW03A-CC	1090	219
Dissolved Metals	YE	Potassium, Dissolved	12600	Normal UTL	12	12	12/12	100	ug/L	1140	9360	NA	NA	YBKG-GW15-1-YE	4430	2970
Dissolved Metals	CC	Sodium, Dissolved	10000	Normal UTL	10	10	10/10	100	ug/L	4610	8350	NA	NA	YBKG-GW13-3-CC	6160	1330
Dissolved Metals	YE	Sodium, Dissolved	62800	Normal UTL	12	12	12/12	100	ug/L	5240	51100	NA	NA	YBKG-GW12-1-YE	20800	15400
Total Metals	CC-YE	Aluminum	2230	HW Approx. Gamma UTL 1/2 DL	15	21	15/21	71	ug/L	94	1640	200	200	YBKG-GW09A-YE	314	381
Total Metals	CC-YE	Antimony	NA	Fewer than Four Detects	1	26	1/26	4	ug/L	18.8	18.8	0.28	20	YBKG-GW07A-CC	2.05	4.28
Total Metals	CC-YE	Arsenic	2.28	HW Approx. Gamma UTL	21	21	21/21	100	ug/L	0.31	1.9	NA	NA	YBKG-GW10-CC	0.817	0.467
Total Metals	CC-YE	Barium	118	HW Approx. Gamma UTL	24	24	24/24	100	ug/L	21.5	104	NA	NA	YBKG-GW11-1-YE	50.9	23.8
Total Metals	CC-YE	Beryllium	2.45	Kaplan Meier UTL	6	26	6/26	23	ug/L	0.23	2.4	5	5	YBKG-GW01A-YE	2.08	0.878
Total Metals	CC-YE	Cadmium	0.605	Kaplan Meier UTL	11	26	11/26	42	ug/L	0.15	0.72	2	2	YBKG-GW01A-YE	0.683	0.392
Total Metals	CC-YE	Chromium	15.1	Kaplan Meier UTL	11	21	11/21	52	ug/L	0.9	14	1.2	10	YBKG-GW05A-CC	5.22	4.01
Total Metals	CC-YE	Cobalt	20.6	Kaplan Meier UTL	4	26	4/26	15	ug/L	0.73	16.9	50	50	YBKG-GW01A-YE	22	7.69
Total Metals	CC-YE	Copper	NA	Fewer than Four Detects	3	25	3/25	12	ug/L	1.9	12.2	1.9	40.2	YBKG-GW12-3-CC	10.3	4.76
Total Metals	CC-YE	Lead	NA	Fewer than Four Detects	2	26	2/26	8	ug/L	0.51	21.3	1.6	10	YBKG-GW01A-YE	3.24	4.05
Total Metals	CC-YE	Manganese	57.9	Normal UTL MLE	19	22	19/22	86	ug/L	13.4	57	2.4	15.5	YBKG-GW08A-CC	26.5	13.9
Total Metals	CC-YE	Mercury	NA	Fewer than Four Detects	2	26	2/26	8	ug/L	0.078	0.081	0.2	0.2	YBKG-GW11-1-YE	0.0984	0.00559
Total Metals	CC-YE	Nickel	11.4	Kaplan Meier UTL	8	24	8/24	33	ug/L	2.2	9.9	40	40	YBKG-GW06A-CC	14.9	7.58
Total Metals	CC-YE	Vanadium	26.2	Kaplan Meier UTL	11	25	11/25	44	ug/L	1.2	32.4	50	50	YBKG-GW07-CC	16.9	11
Total Metals	CC-YE	Zinc	4.52	Kaplan Meier UTL	7	23	7/23	30	ug/L	2.4	4.3	2.8	19.3	YBKG-GW11-2-YE	3.86	2.32
Total Metals	CC	Calcium	158000	Normal UTL	12	12	12/12	100	ug/L	34400	124000	NA	NA	YBKG-GW15-3-CC	92200	24000
Total Metals	YE	Calcium	169000	Gamma UTL	13	13	13/13	100	ug/L	35400	146000	NA	NA	YBKG-GW01A-YE	66600	30700
Total Metals	CC	Iron	3590	Normal UTL	10	10	10/10	100	ug/L	198	2880	NA	NA	YBKG-GW08A-CC	1230	809
Total Metals	YE	Iron	894	Normal UTL	10	10	10/10	100	ug/L	114	753	NA	NA	YBKG-GW13-1-YE	340	190
Total Metals	CC	Magnesium	3600	Normal UTL	11	11	11/11	100	ug/L	709	3240	NA	NA	YBKG-GW07A-CC	1750	655
Total Metals	YE	Magnesium	11500	Normal UTL	13	13	13/13	100	ug/L	963	8770	NA	NA	YBKG-GW11-1-YE	4620	2560
Total Metals	CC	Potassium	3490	Gamma UTL	12	12	12/12	100	ug/L	880	3100	NA	NA	YBKG-GW07-CC	1510	607
Total Metals	YE	Potassium	12700	Normal UTL	12	12	12/12	100	ug/L	1570	9260	NA	NA	YBKG-GW15-1-YE	4820	2870
Total Metals	CC	Sodium	9920	Normal UTL	10	10	10/10	100	ug/L	4630	8290	NA	NA	YBKG-GW13-3-CC	6200	1280
Total Metals	YE	Sodium	64500	Normal UTL	12	12	12/12	100	ug/L	5740	52600	NA	NA	YBKG-GW12-1-YE	21000	15900

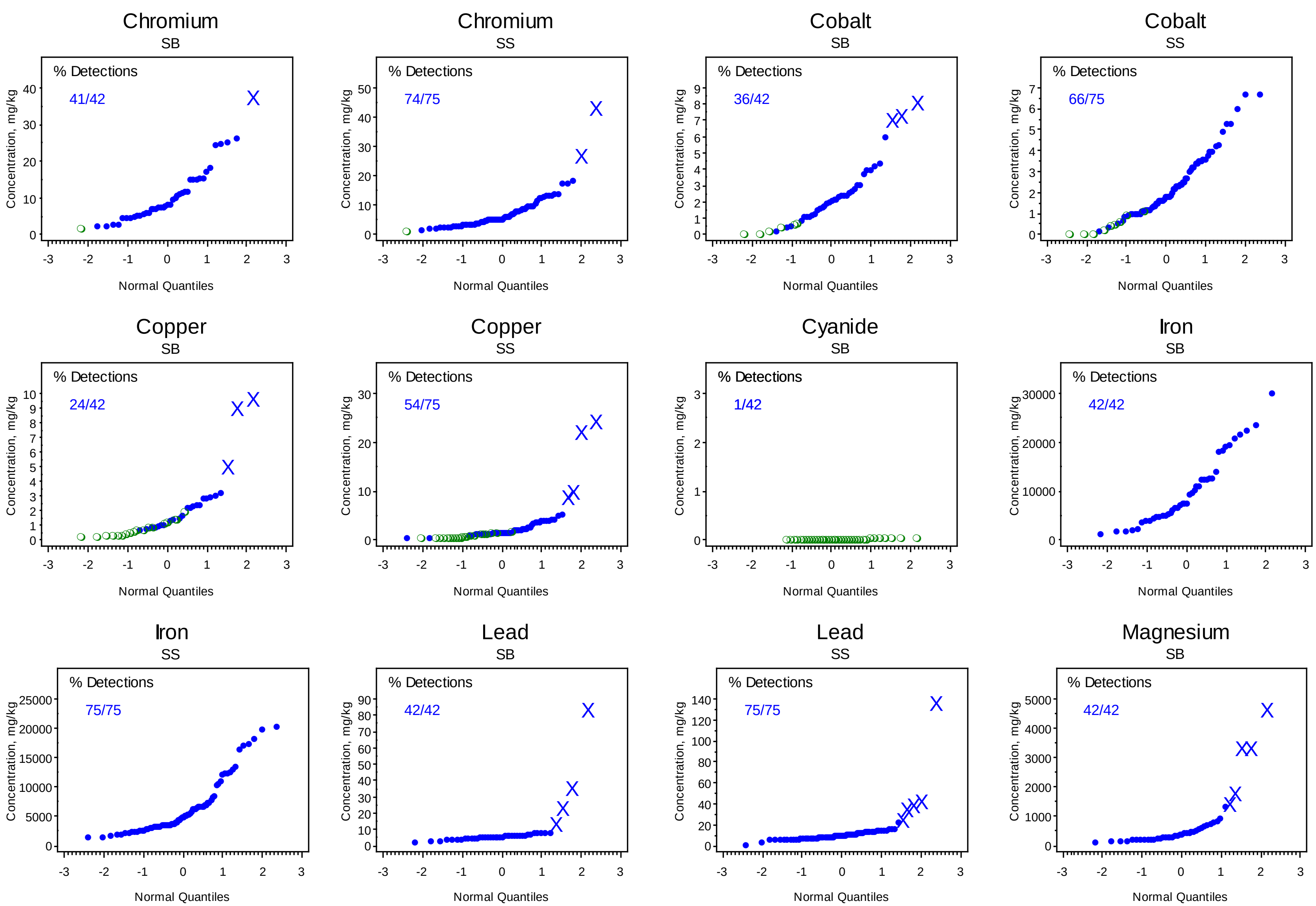
Figures

Figure 1: Probability Plots Using 1/2 the RL as Proxy for NDs



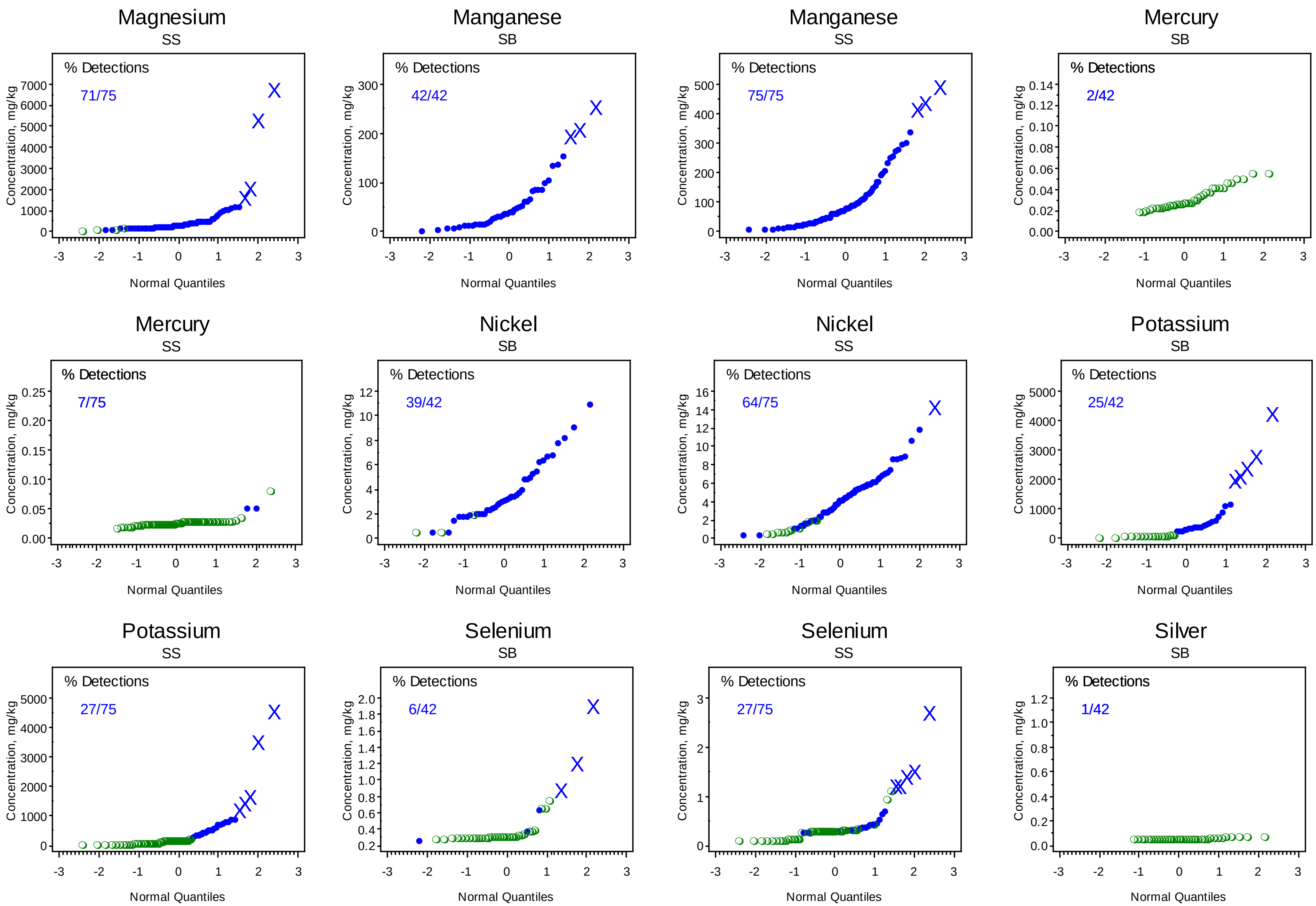
Green Open Symbol Represents 1/2 DL Proxy for Nondetect Value; Blue Symbol Represents Detected Values

Figure 1: Probability Plots Using 1/2 the RL as Proxy for NDs



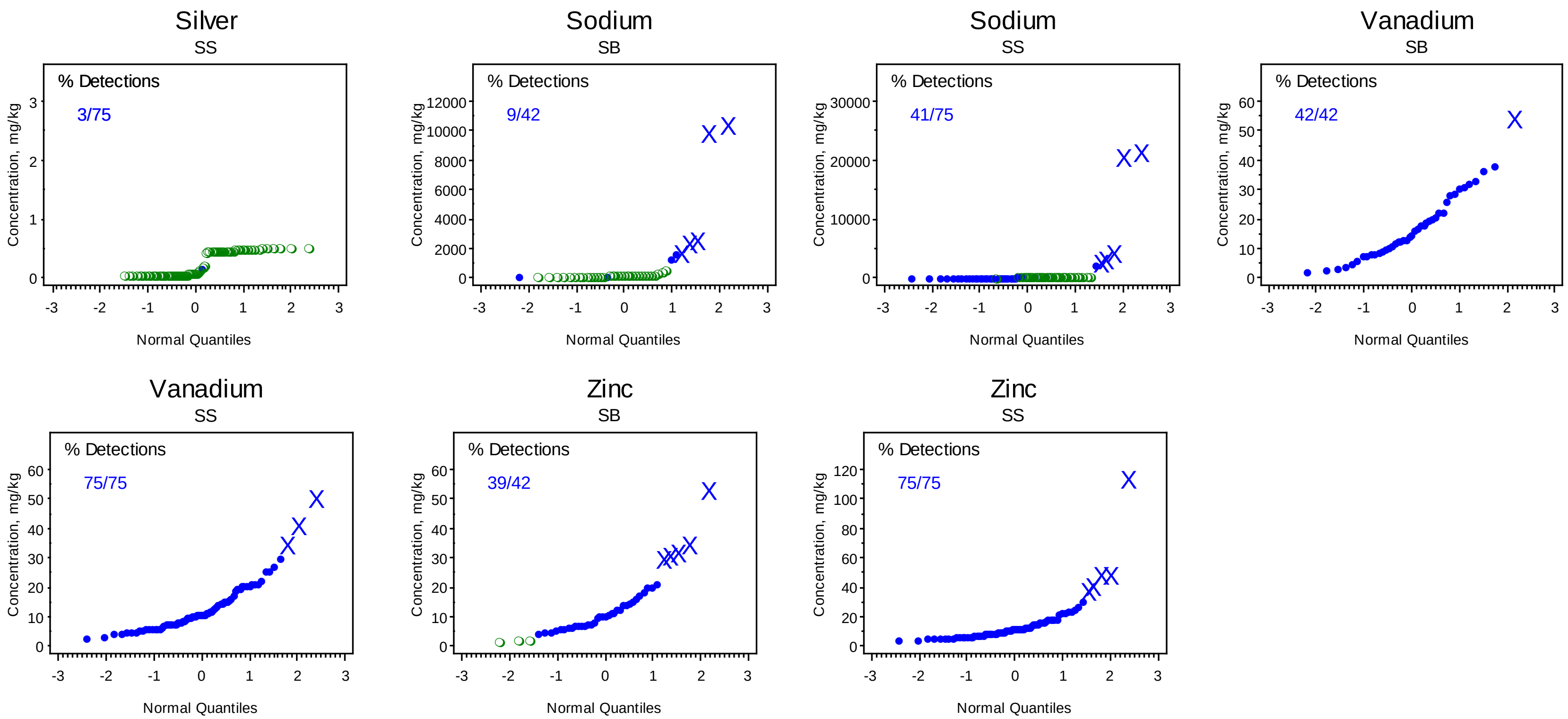
Green Open Symbol Represents 1/2 DL Proxy for Nondetect Value; Blue Symbol Represents Detected Values

Figure 1: Probability Plots Using 1/2 the RL as Proxy for NDs



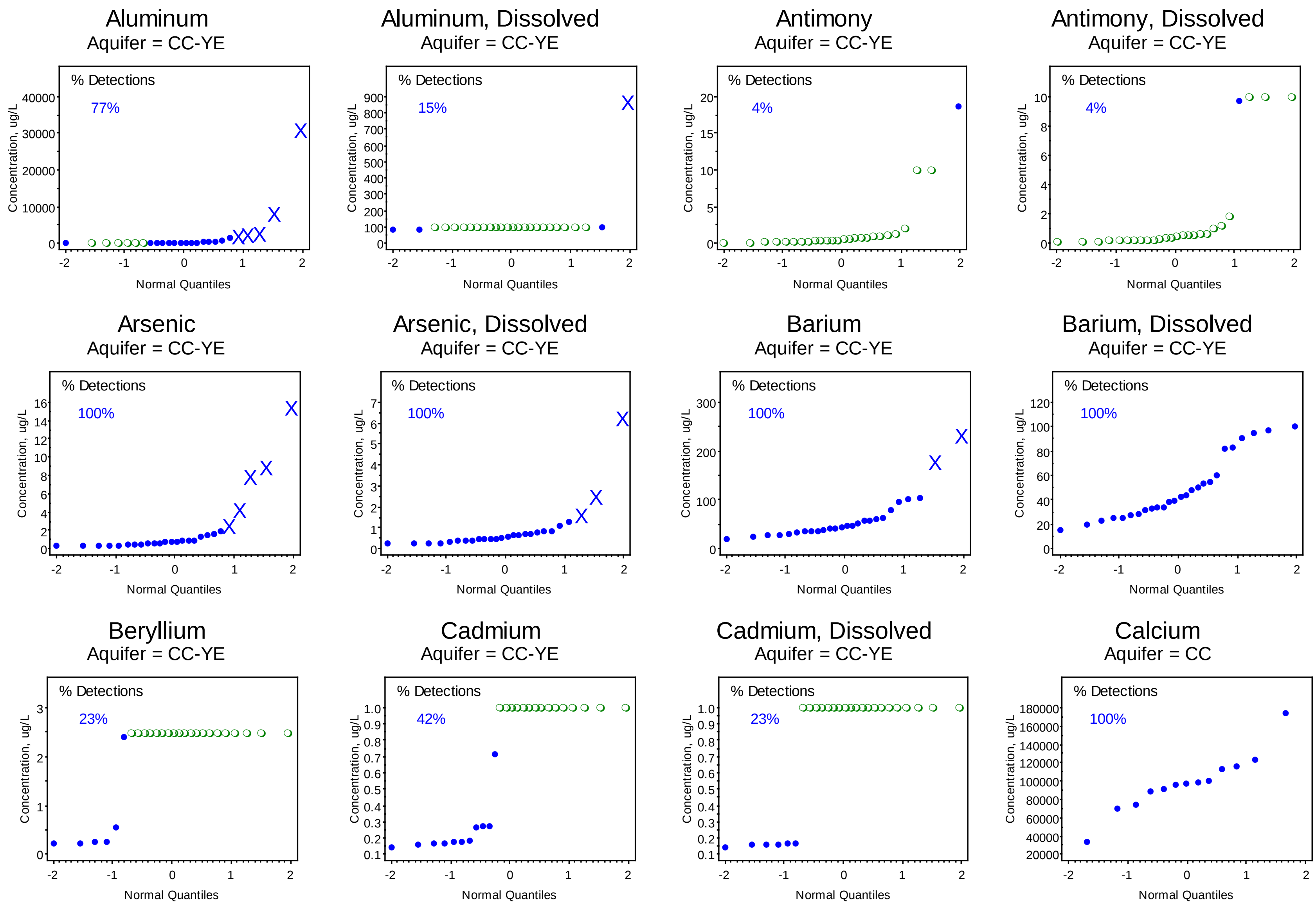
Green Open Symbol Represents 1/2 DL Proxy for Nondetect Value; Blue Symbol Represents Detected Values

Figure 1: Probability Plots Using 1/2 the RL as Proxy for NDs



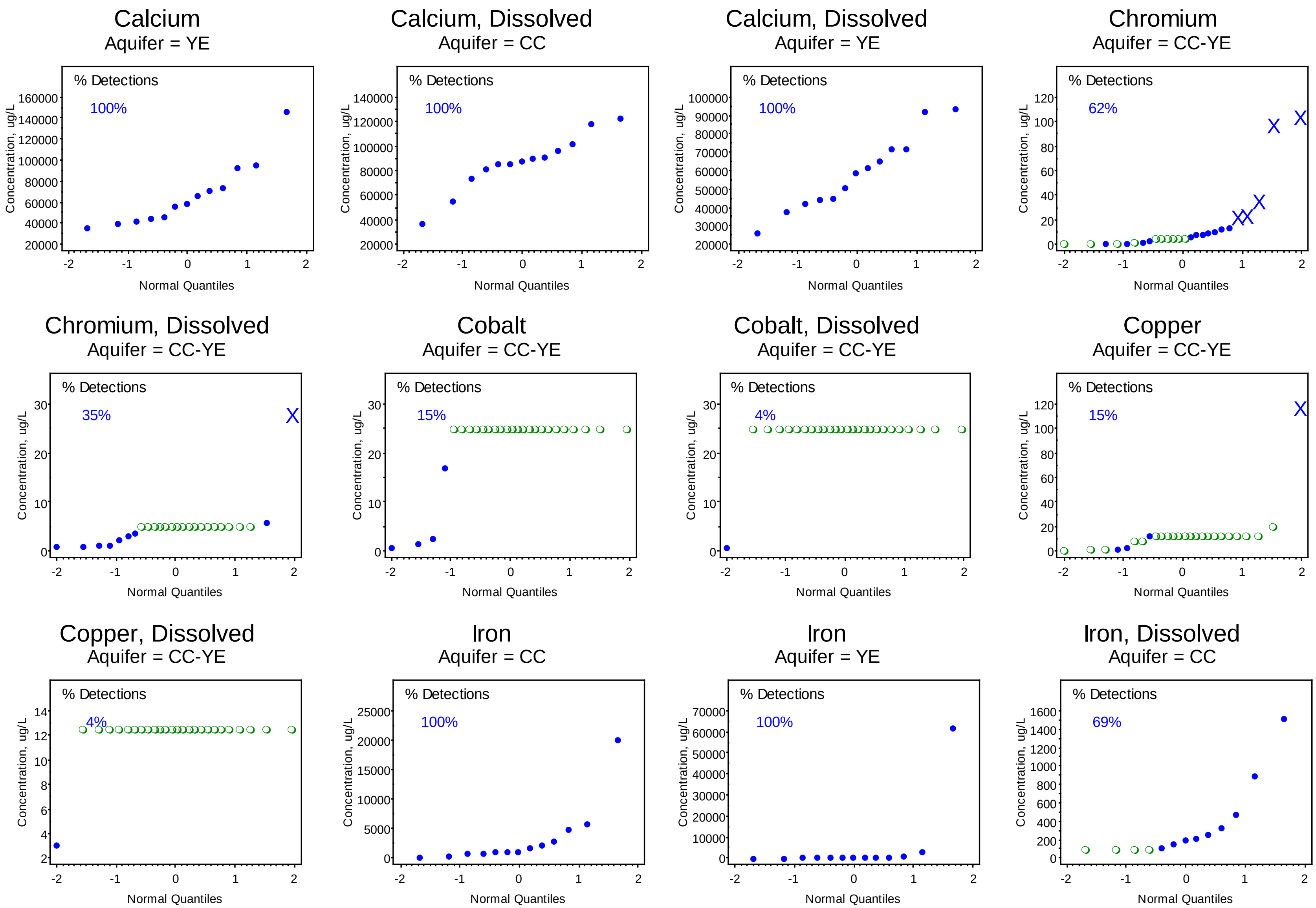
Green Open Symbol Represents 1/2 DL Proxy for Nondetect Value; Blue Symbol Represents Detected Values

Figure 2: Probability Plots for Groundwater Data



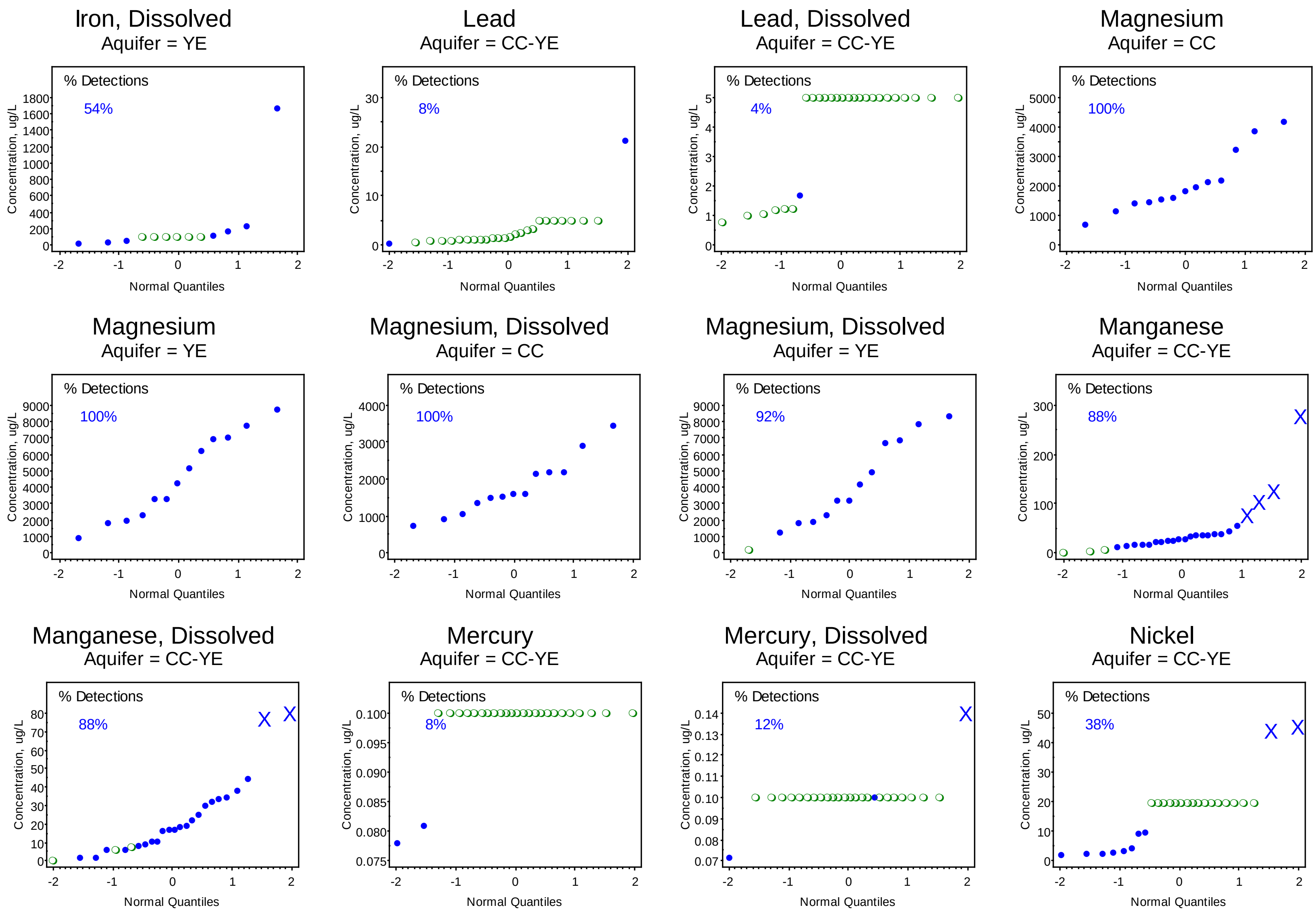
Green Open Symbol Represents 1/2 DL Proxy for Nondetects; Blue Symbol Represents Detects; X Represents Mathematical Outlier

Figure 2: Probability Plots for Groundwater Data



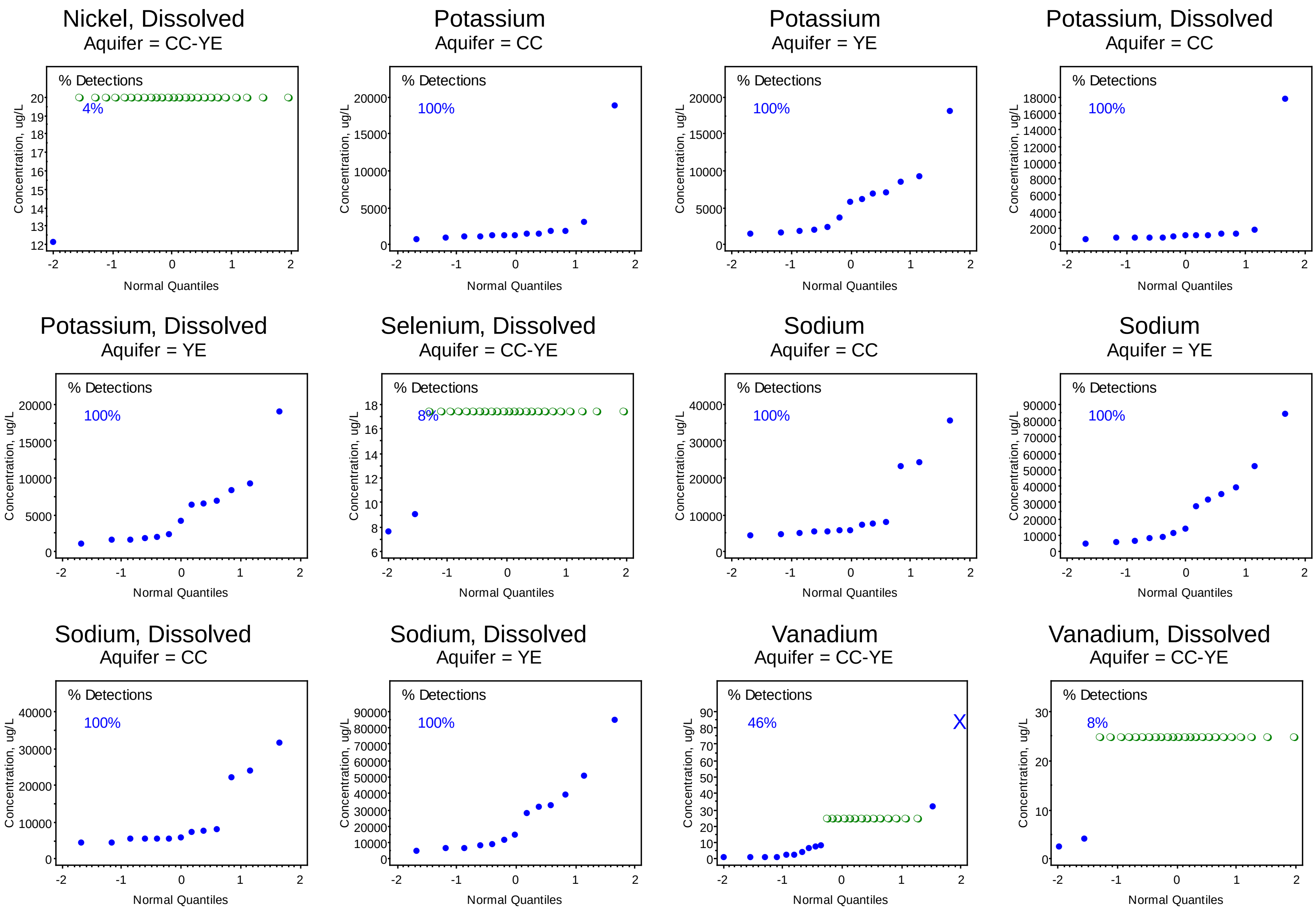
Green Open Symbol Represents 1/2 DL Proxy for Nondetects; Blue Symbol Represents Detects; X Represents Mathematical Outlier

Figure 2: Probability Plots for Groundwater Data



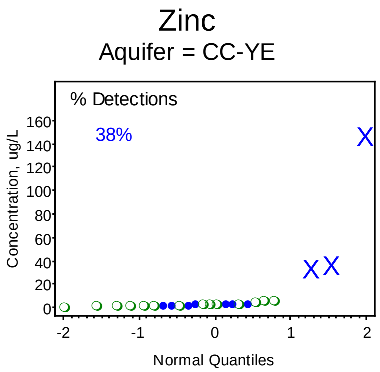
Green Open Symbol Represents 1/2 DL Proxy for Nondetects; Blue Symbol Represents Detects; X Represents Mathematical Outlier

Figure 2: Probability Plots for Groundwater Data



Green Open Symbol Represents 1/2 DL Proxy for Nondetects; Blue Symbol Represents Detects; X Represents Mathematical Outlier

Figure 2: Probability Plots for Groundwater Data

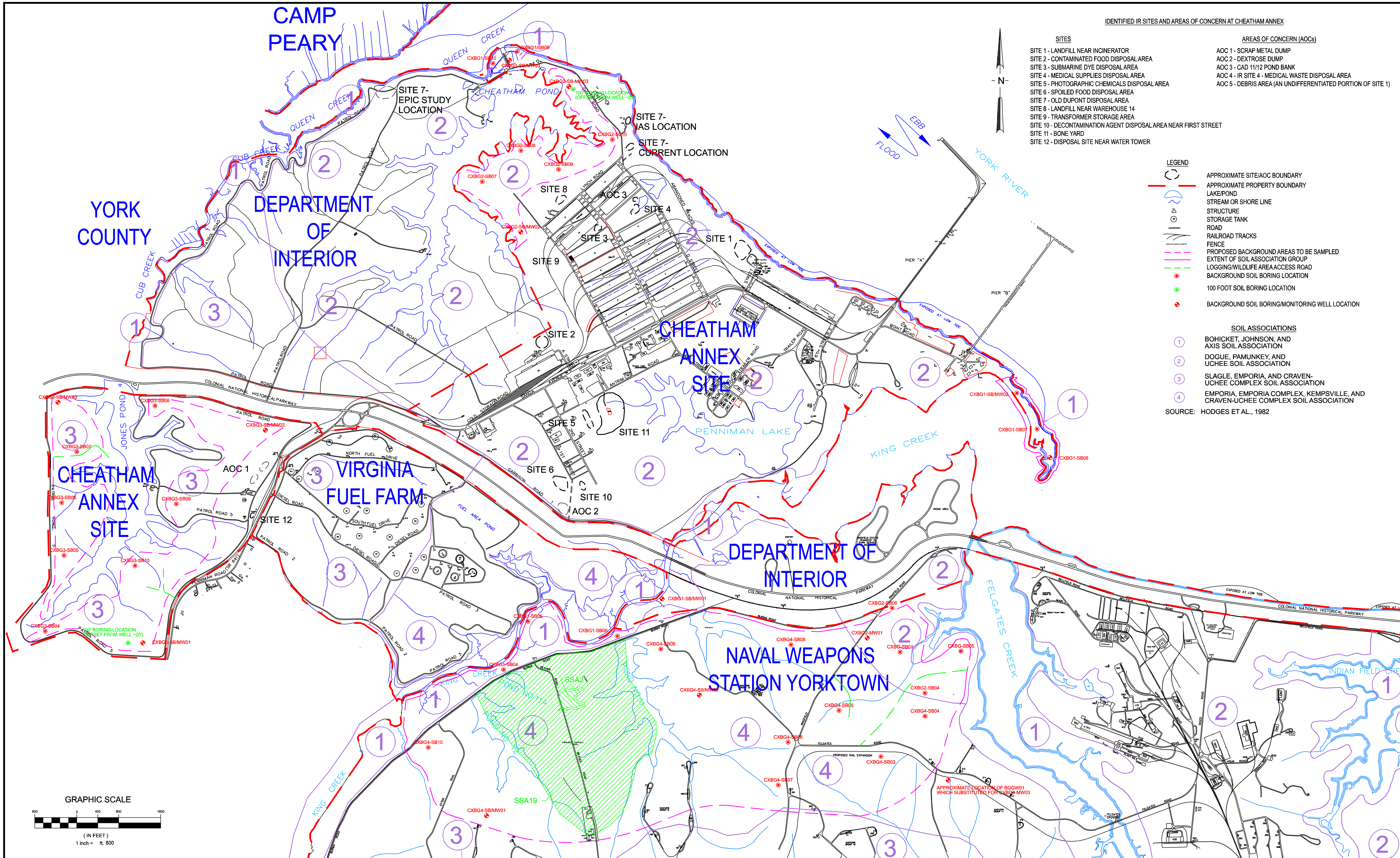


Green Open Symbol Represents 1/2 DL Proxy for Nondetects; Blue Symbol Represents Detects; X Represents Mathematical Outlier

Appendix A
Previous WPNSTA Yorktown and CAX Background Investigations Sample Locations

ATTACHMENT A
BACKGROUND SAMPLE LOCATIONS
YORK RIVER DRAINAGE BASIN

NAVAL WEAPONS STATION YORKTOWN — YORKTOWN, VIRGINIA



REVISIONS
1
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DSN/DWN: HGW/WJH
CHK: HGW
S.O. NO.: 26007-196
FILE: 2196705W

NORTH

N

NAVAL WEAPONS STATION YORKTOWN
YORKTOWN, VIRGINIA
CHEATHAM ANNEX SITE

Baker Environmental, Inc.
Coraopolis, Pennsylvania

Baker

SURFACE SOIL, SUBSURFACE SOIL, AND
GROUNDWATER SAMPLE LOCATION MAP
CTO - 0196

SCALE: 1" = 800'

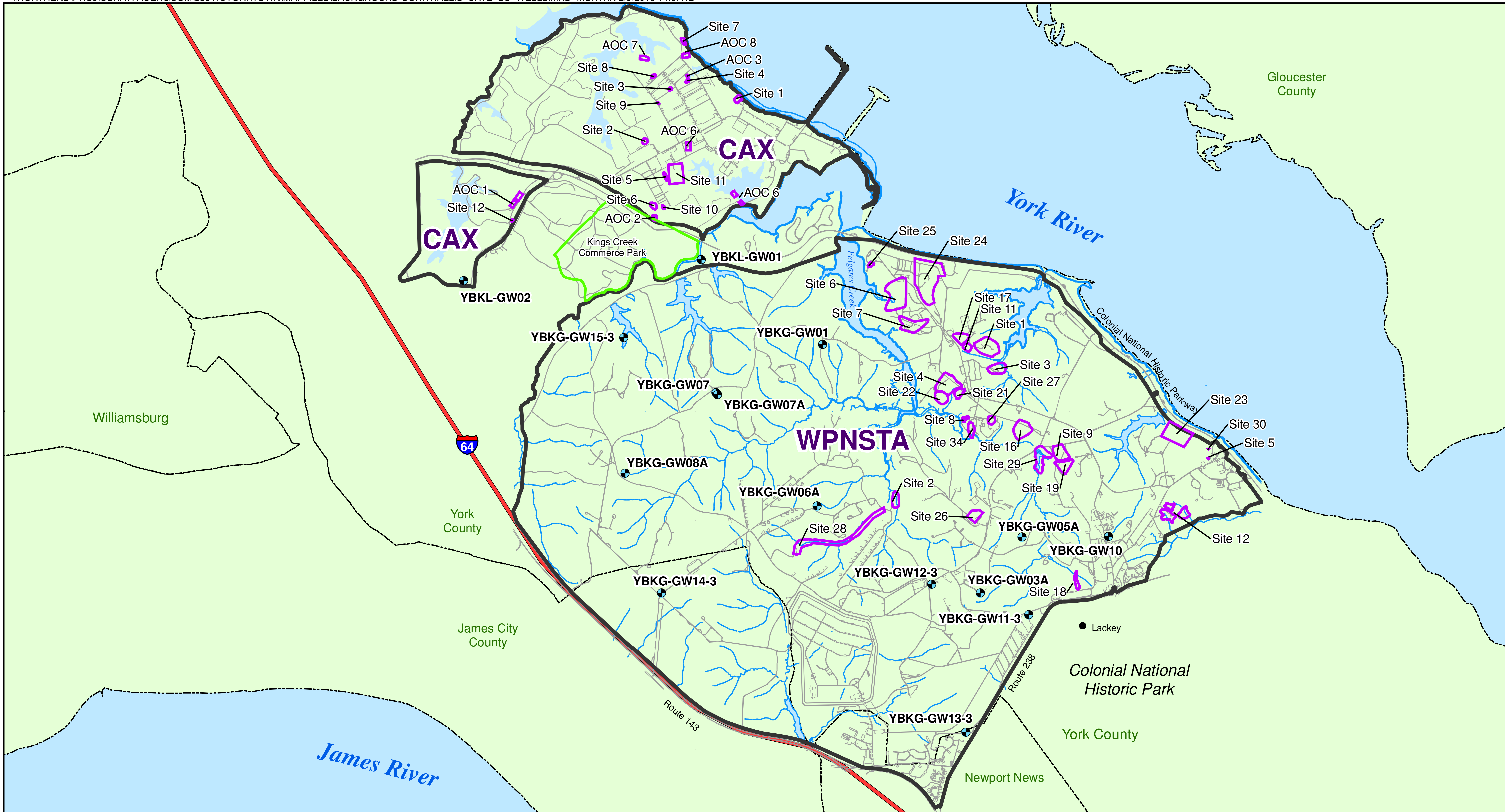
DATE: JULY 2002

FIGURE NO.
5-1

...\2196705W_Fig 5-1.dwg 3/3/2008 4:28:10 PM

Appendix B
2009 Groundwater Sample Locations

\\NORTHEND\PROJ\USNAVFACENGCOM\386475YORKTOWN\MAPFILES\BACKGROUND\CORNWALLIS_CAVE_BG_WELLS.MXD MUNWIN 2/9/2010 14:07:12



Legend

- Sampled Monitoring Well
- Roads
- Shoreline and Water Bodies
- Interstate 64
- Kings Creek Commerce Park
- City / County Boundaries
- Site Boundaries
- Activity Boundaries

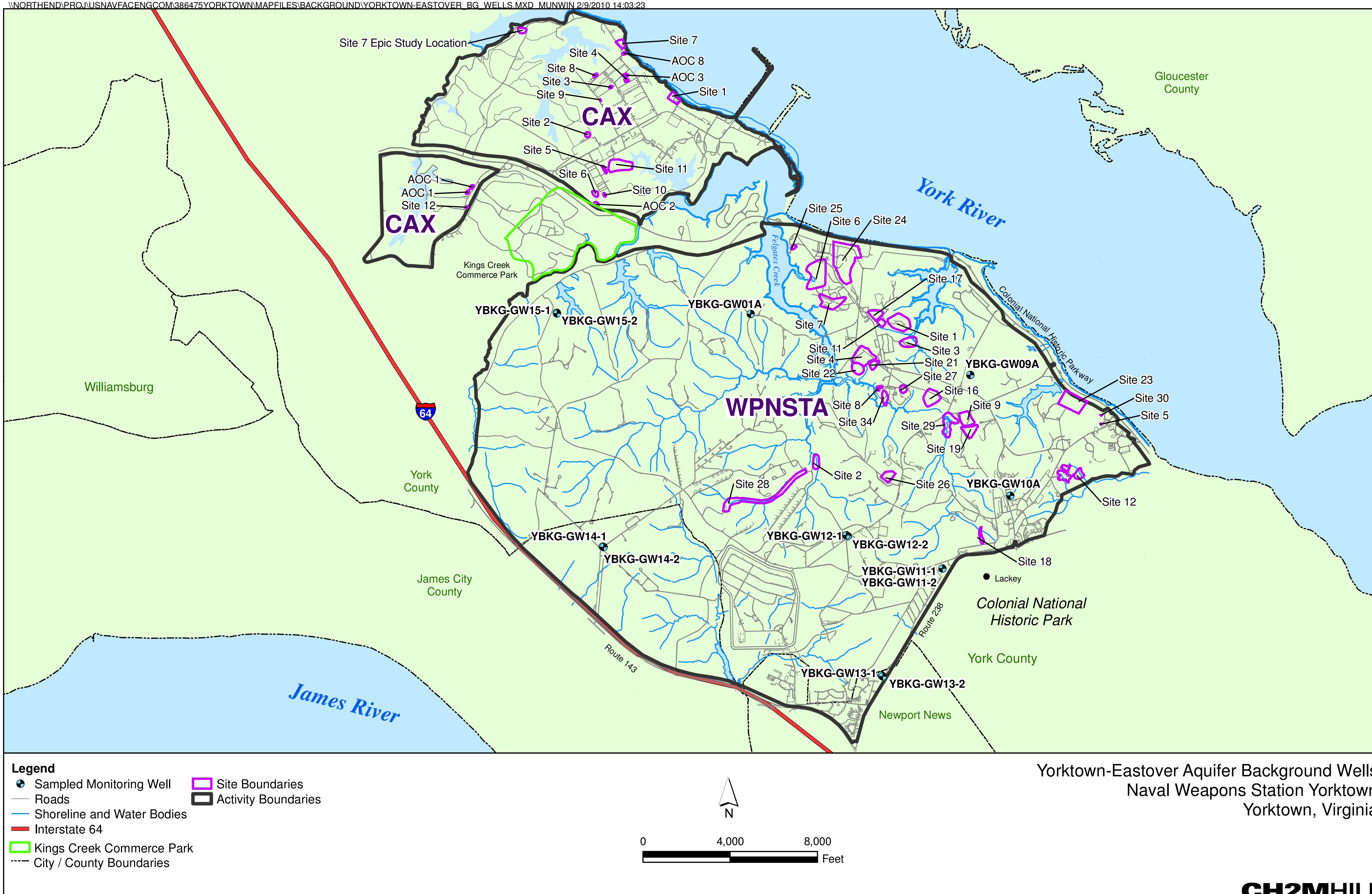
N

0 4,000 8,000 Feet

Cornwallis Cave Aquifer Background Wells
Naval Weapons Station Yorktown
Yorktown, Virginia

CH2MHILL

\\NORTHEND\PROJ\USNAVFACENGCOM\386475YORKTOWN\MAPFILES\BACKGROUND\YORKTOWN-EASTOVER_BG_WELLS.MXD MUNWIN 2/9/2010 14:03:23



Yorktown-Eastover Aquifer Background Wells
Naval Weapons Station Yorktown
Yorktown, Virginia

CH2MHILL

Responses to Comments

EPA's Comments on Draft TM

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION III
1650 Arch Street
Philadelphia, Pennsylvania 19103-2029

Robert Thomson, P.E., R.E.M.
Office of Federal Facility Remediation

Direct Dial (215) 814-3357
Mail Code: 3HS11

Date: May 5, 2010

Mr. Thomas Kowalski
NAVFAC MIDLANT, Code EV3
9742 Maryland Avenue
Building N-26, Room 3208
Norfolk, VA 23511-3095

Re: Naval Weapons Station–Yorktown NPL site, Yorktown, Va.
Naval Supply Center – Cheatham Annex NPL site, Williamsburg, Va
Review of draft *Calculation of Background Concentrations Technical Memorandum*

Dear Mr. Kowalski:

Enclosed, please find the U.S. Environmental Protection Agency's (EPA's) comments pertaining to the review of the U.S. Navy's (Navy's) February, 2010 draft *Calculation of Background Concentrations Technical Memorandum* (TM) for the Naval Weapons Station-Yorktown (NWSY) NPL site, and the Naval Supply Center – Cheatham Annex (CAX) NPL site:

EPA Region 3 has evaluated the appropriateness of statistical methods used by CH2M HILL to evaluate background concentrations at the NWSY NPL site and the CAX NPL site. In order to address the objective of this evaluation, in addition to reviewing the CH2M HILL draft TM, an independent analysis of the background data was performed for selected contaminants at the NWSY and CAX. This review letter therefore summarizes: 1) results of the independent analysis performed by EPA for selected COCs; 2) presents review comments on the statistical background study performed by CH2MHILL; and 3) makes recommendations based upon the statistical analyses performed by EPA.

Establishing Background/Reference Data

Whenever possible, background data sets are collected from pristine unimpacted locations. When using onsite background data to establish site-specific background level concentrations, it is necessary to assure that the selected background/ reference locations are not impacted by onsite activities and/or contamination originating from other industrial activities potentially impacting the site background.

Outliers in Background Data Sets

Elevated outlying observations in a background data set potentially may represent locations impacted by the site activities, especially when background data are collected from locations (e.g., onsite reference area locations chosen at large federal facilities) potentially impacted by the site and/or other industrial activities. In such scenarios (as is the case for CAX and NWSY onsite reference areas), all potential outliers are removed from background data sets (EPA 2000, 2002) before computing decision statistics (e.g., UTLs, UPLs) to estimate site-specific background level concentrations.

Tests for Outliers

Dixon and Rosner tests (EPA 2006) are often used to identify outliers. However the use more effective robust outlier identification procedures (e.g., Tukey's Biweight function – Hoaglin, Mosteller, and Tukey,1983; PROP influence function - Singh, 1993, LMS and MCD methods - Rosseeuuw and Leroy, 1987) is desirable to identify multiple outliers and multiple populations (e.g., several soil associations). In the present case, in order to keep things simple and verify computations performed by CH2M HILL, only classical Dixon and Rosner tests were used.

1.0 Data

Groundwater, surface, and subsurface soil background data were collected from CAX and NWSY sites. These sites consist of four soil assocaition types. For some locations, duplicate samples were collected. In such cases, higher value was retained and used in the statistical analyses perfromed by CH2MHILL to establish background level concentrations. For comaprison sake, the reviewers also used the higher duplicate value, even though the use of the average of duplicates is a preferred method and is commonly used in practice.

However, for background evaluation studies, the use of the lower value of the duplicate results perhaps will be more appropriate resulting in a conservative estimate (95/95UTL) of the background level concentration.

2.0 Constituents studied in this report

The reviewers used EPA software packages, ProUCL 4.00.05 and Scout to perform statistical analyses for selected COCs described below. The notations used in the statistical computation tables are described in ProUCL technical guide. For an example, KM represents Kaplan Meier method used to compute a decision making statistic such as an upper tolerance limit (UTL) based upon data sets with nondetects (NDs). The following constituents have been used to verify the computations described in the Draft CH2M HILL Report (February, 2010).

2.1 Inorganics – surface and subsurface soils

1. Arsenic (data consist of nondetects with multiple detection limits)
2. Lead
3. Manganese
4. Vanadium

2.2 Organics – surface and subsurface soils

1. Benzaldehyde
2. Benzo(a)pyrene
3. Dieldrin
4. Endosulfan sulphate
5. Total Organics

2.3 Groundwater

1. Arsenic, dissolved
2. Mercury, dissolved (data with nondetects at multiple detection limits)
3. Chromium, dissolved (data with nondetects at multiple detection limits)
4. Nitrobenzene (data with nondetects at multiple detection limits)
5. Arsenic
6. Manganese (data with nondetects with multiple detection limits)

3.0 General Procedure to Compute UTLs

In order to compute defensible upper tolerance limits (UTLs) to estimate background level concentrations, outlier analysis was performed for each selected COC. Since outying observation may potentially represent impacted locations, identified outliers are not inlcuded in the computation of UTLs. Outlier analysis was performed using Rosner's test when the number of observations was greater than 25 and Dixon's outlier test when the number was less than 25. For data sets with nondetects (NDs), the outlier tests were performed on data sets obtained using half of the detection limit (DL/2) values for NDs.

In order to demonstrate the influence of outliers on the computations of various statistics, 95/95UTLs were computed in two ways - with and without outliers. Also in order to compute manaeable statistics and estimates, oneway analysis of variance (ANOVA) was performed to determine if concentrations for the COCs in the 4 soil associations differ significantly. If the concentration distributions of a contaminant are comparable for the four soil types, then it is desirable to compute a single UTL to estimate background concentration for all soil associations combined.Statistical tests are also performed to determine: 1) if concentrations of COCs differ significantly in surface and subsurface soils; and 2) if concentrations of COCs found in CAX and NWSY background areas differ significantly.

Background Analysis for Selected Organics and Inorganics in Soils

There are 4 soil associations present in CAX and NWSY sites. The first step is to compare concentrations of the 4 soil associations to see if they can be combined to compute 95/95UTLs. This was performed using One-way ANOVA (Scout software) for surface and usbsurface soils. The next step is to search for high outliers since those outliers may represent impacted locations resulting in inflated UTL values. Once the outliers were removed, the UTLs were computed for the selected constituents. Depending upon the data distribution (parameteric, nonparametric) and NDs, appropriate 95/95 UTLs were calculated to estimate background level concentrations.

3.1 Background Statistics for CAX Area

3.1.1 CAX surface soils

Classical One-Way ANOVA was per formed to determine if the concentrations of COCs in the 4 soil associations in CAX area are comparable. The results of the ANOVA test are summarized in the Appendix, Table A-1. Based upon ANOVA test statistics, it is concluded that data for the four soil associations can be combined for arsenic, manganese and vanadium. Results of outlier tests performed on the combined data (4 soil associations) are summarized as follows. The outlier test on arsenic data was performed using ½ DL values for NDs.

Table 3.1: Outliers in CAX surface soils

Metals	N	# Outliers	Outlying Value (ID)
Arsenic	40	3	12.6 (BG4-SS01-00) 9.9 (BG1-SS03-00) 8.3 (BG1-SS06-00)
Lead	40	2	136 (BG1-SS03-00) 34.7 (BG1-SS09-00)
Manganese	40	1	435 (BG4-SS10-00)
Vanadium	40	2	50.3 (BG1-SS03-00) 41.2 (BG1-SS09-00)

ANOVA was performed again on lead data after removing the 2 outlying locations shown in the above table. Once the outliers were removed, ANOVA test results (Appendix, Table A-2) suggest that lead concentrations from the four soil associations can also be considered as coming from a single statistical population.

Table 3.2: 95/95UTLs based upon datasets with and without outliers for CAX - surface soil

Metals	N	Max	Raw Statistics		95/95 UTL	
			Mean	SD	No Outliers	With Outliers
Arsenic	37 (17 NDs)	6	1.178 (KM)	1.552 (KM)	4.501 KM	7.921 KM
Lead	38	16	8.963	3.195	15.78 Normal	136 Nonparametric
Manganese	39	304	95.52	74.52	332 HW Gamma	373.4 HW Gamma
Vanadium	38	26.1	9.626	5.848	27.38 Lognormal	36.8 Lognormal

3.1.2 CAX subsurface soils

A similar process was used for subsurface soil data collected from the CAX area. The ANOVA test statistics are given in Appendix, Table A-3. Based upon ANOVA test results, it is concluded that data for the four soil associations can be considered as coming from a single population. The following table summarizes outlier tests results. The outlier test on arsenic data was performed using ½ DL values for NDs.

Table 3.3: Outliers in CAX subsurface soils

Metals	N	# Outliers	Outliers Value (ID)
Arsenic	40	5	18.6 (BG4-SB01-01) 15.9 (BG2-SB01-01) 13.8 (BG4-SB10-01) 12.5 (BG1-SB09-01) 10.4 (BG1-SB03-01)
Lead	40	3	83.7 (BG1-SB08-01) 35.3 (BG1-SB09-01) 35.3 (BG1-SB03-01)

Manganese	40	2	208 (BG3-SB09-01) 195 (BG43-SB01-01)
Vanadium	40	1	53.8 (BG3-SB03-01)

Table 3.4: 95/95UTLs based upon datasets with and without outliers for CAX - subsurface soil

Metals	N	Max	Raw Statistics		95/95 UTL	
			Mean	SD	No Outliers	With Outliers
Arsenic	35 (20 NDs)	6.8	2.73 (KM)	1.202	5.323 KM	12.83 KM
Lead	37	8.3	5.889	1.375	8.831 Normal	83.7 Nonparametric
Manganese	38	154	46.29	39.32	172.5 HW Gamma	210.6 Gamma
Vanadium	39	37.8	17.37	10.15	38.94 Normal	54.98 Gamma

Conclusion: The concentrations of the selected metals found in four soil associations of CAX (for both surface and subsurface) are comparable. The four surface (and subsurface) soil associations can be considered to represent a single population. Therefore, background level concentrations (95/95 UTLs) can be computed using the combined surface (and combined subsurface) soil associations data sets.

3.1.3 CAX surface soil and subsurface soils combined

It is always desirable to evaluate if there are significant differences in contaminants concentrations of surface and subsurface soils. Two sample hypotheses tests were performed to determine if surface and subsurface concentrations for the selected COCs are comparable.

Null Hypothesis H_0: Data from surface and subsurface soils are comparable and can be combined.
Alternate Hypothesis H_A: Surface and subsurface soils data are different and cannot be combined

Table 3.5: Two Sample Test Results – CAX surface soil versus CAX subsurface soil

Metals	Test	Conclusion	P value (α = 0.05)
Arsenic	Gehan	Combine surface and subsurface soils	0.198
Lead	t-Test	Do not combine surface and subsurface soils	0
Manganese	t-Test	Do not combine surface and subsurface soils	0.001
Vanadium	t-Test	Do not combine surface and subsurface soils	0

Arsenic was the only metal where the surface and subsurface soil concentrations are comparable, and the two data sets may be merged to compute a UTL based upon the combined data set. The 95/95UTL for arsenic based upon the combined surface and subsurface soil data sets is given in the following table.

Table 3.6: 95/95UTLs based upon CAX surface and subsurface data combined

Metals	N	Max	Raw Statistics		95/95 UTL
			Mean	SD	
Arsenic	72 (37 NDs)	6.8	1.457 (KM)	1.763	4.947 KM

Conclusion: For most of the CAX COCs evaluated in this report, there are significant differences in contaminant concentrations of surface and subsurface soils, therefore, it is suggested to compute 95/95 UTLs separately for surface and subsurface soils.

3.2 Background Statistics for NWSY Site

The background analysis was performed for NWSY area following the similar procedure as used for CAX area.

3.2.1 NWSY surface soils

Classical ANOVA was performed to determine if the concentrations of the COC in four (4) soil associations are comparable. ANOVA test results are given in Appendix, Table A-4. Based upon the ANOVA test statistics, it is concluded that concentrations of selected

COCs in the 4 soil associations are comparable, and therefore just like the CAX area, 4 soil types can be considered to represent a single statistical populations. Site-wide background level concentrations for surface soils can be computed based upon the combined data set of the 4 soil types. Outlier tests were performed to identify any potentially impacted locations. As before, outlier test on arsenic data set was performed using ½ DL values. The following table summarizes the outlier test results.

Table 3.7: Outliers in NWSY surface soils

Metals	N	# Outliers	Outliers Value (ID)
Arsenic	35	2	63.9 (BGS21) 5.8 (BGS07)
Lead	35	4	43.1 (BGS07) 38.7 (BGS28) 25.3 (BGS22) 22.7 (BGS04)
Manganese	35	2	491 (BGS03) 413 (BGS38)
Vanadium	35	0	-

Table 3.8: 95/95UTLs based upon datasets with and without outliers for NWSY surface soil

Metals	N	Max	Raw Statistics		95/95 UTL	
			Mean	**SD**	**Without Outliers**	**With Outliers**
Arsenic	33	4.2	1.897	0.967	4.528 HW Gamma	63.9 Nonparametric
Lead	31	16.7	11.57	3.08	18.34 Normal	43.1 Nonparametric
Manganese	33	340	99.02	89.83	403.6 HW Gamma	508.1 HW Gamma
Vanadium	35	34.7	15.25	6.808	32.66 HW Gamma	32.66 HW Gamma

From the above table, it is easy to see how outliers inflate the decision statistics (e.g., arsenic) used to estimate background level concentrations.

3.2.2 NWSY subsurface soils

ANOVA test was performed to determine if concentration distributions of COCs in the 4 soil associations are comparable. The ANOVA test results are given in Appendix, Table A-5. Based upon ANOVA test results, it is concluded that concentrations of COCs found in 4 soil associations are comparable, and therefore data of the 4 soil associations can be combined to compute 95/95 UTLs. This means, a single background value can be computed for each of the selected COCs. In order to identify potentially impacted locations present in the site-specific data set, outlier tests were performed. The outlier test on arsenic data was performed using ½ DL values for NDs. The following table summarizes outlier test results.

Table 3.9: Outliers in NWSY subsurface soils

Metals	N	# Outliers	Outliers Value (ID)
Arsenic	13	2	42.7 (BGSB07-11) 26.2 (BGSB04-09)
Lead	13	0	
Manganese	13	3	2940 (BGSB07-11) 353(BGSB04-01) 284(BGSB04-09)
Vanadium	13	0	0

Table 3.10: 95/95UTLs based upon datasets with and without outliers for NWSY subsurface soil

Metals	N	Max	Raw Statistics		95/95 UTL	
			Mean	SD	No Outliers	With Outliers
Arsenic	11	13.8	5.615	4.983	19.64	78.54 Gamma
Lead	13	4.2	11.78	6.778	29.89	29.89 Normal
Manganese	10	94.5	39.88	37.11	325 Gamma	8011 Lognormal*
Vanadium	13	70.3	28.94	21.74	87.01 Normal	87.01 Normal

* It is easy to see how outliers inflate the decision statistics (arsenic, manganese) used to estimate background level concentrations.

Conclusion: The concentrations of the selected metals found in four soil associations of NWSY are (for both surface and subsurface) are comparable. The four surface (and subsurface) soil associations can be considered to represent a single population. Background concentrations (95/95 UTLs) can be computed based upon the combined surface (and subsurface) soil data set.

3.2.3 NWSY surface soil and subsurface soils combined

Just like the CAX site, hypothesis tests were conducted to determine if the concentrations of the COCs in surface and subsurface soils are comparable. The results are summarized in the following table.

Null Hypothesis H_0: Data from surface and subsurface soils are comparable and can be combined.
Alternate Hypothesis H_A: Surface and subsurface soils data are different and cannot be combined.

Table 3.11: Two Sample Test Results – NWSY surface soil versus NWSY subsurface soil

Metals	Test	Conclusion	P value (α = 0.05)
Arsenic	WMW	Combine surface and subsurface soils	0.104
Lead	t-Test	Combine surface and subsurface soils	0.885
Manganese	WMW	Do not combine surface and subsurface soils	0.018
Vanadium	WMW	Combine surface and subsurface soils	0.074

Test results for arsenic, lead, and vanadium suggest that surface and subsurface soil data may be combined to compute 95/95UTLs. The following table summarizes UTLs computed using the combined data sets.

Table 3.12: 95/95UTLs based upon NWSY surface and subsurface data combined

Metals	N	Max	Raw Statistics		95/95 UTL
			Mean	SD	
Arsenic	44	13.8	2.826	3.02	13.8 Nonparametric
Lead	44	25.5	11.63	4.41	20.86 Normal
Vanadium	48	70.3	18.96	13.86	64.95

Conclusion: For CAX area, it is concluded that there are significant differences in concentrations of selected COCs found surface and surface soils. Since only four metals were evaluated for NWSY area, and manganese concentrations are found to be significantly different in surface and subsurface soils. In order to keep things simple and comparable for the two background areas, it is suggested that 95/95 UTLs be computed separately for surface and subsurface soils. Often in practice, separate background values are computed for surface and subsurface soils.

3.3 Background Statistics for CAX and NWSY Background Areas all soils combined

Next, hypothesis tests were conducted to determine if concentrations of COCs in surface and subsurface from CAX are comparable to corresponding surface and subsurface concentrations found in NWSY. The detailed test results for each of the metals are given in Appendix, Tables A-6 to A-9. The main results are summarized in the following table.

Null Hypothesis H_0: Data from CAX and NWSY can be considered coming from a single population
Alternate Hypothesis H_A: Data from CAX and NWSY represent different populations

Table 3.13: Two Sample Test Results – CAX soils versus NWSY soils – (surface and subsurface combined)

Metals	Test	Result	P value (α = 0.05)
Arsenic	WMW	Do not combine CAX and NWSY soils	0.000
Lead	WMW	Do not combine CAX and NWSY soils	0.000
Manganese	WMW	Combine CAX and NWSY soils	0.504
Vanadium	WMW	Do not combine CAX and NWSY soils	0.0074

Table 3.14: NWSY/CAX Statistics – Using all background data

Metals	N	Max	Raw Statistics		95/95 UTL
			Mean	SD	
Manganese	121	340	76.26	72.05	259.5

For most of the COCs considered in this report, it is noted that concentrations of those COCs found in CAX and NWSY are not comaprable. Therefore, it is suggested that estimates (95/95UTLs) of background concentrations should be computed separately for the two background sites: CAX and NWSY.

Conclusion: Concentrtaions for the selected COCs in the two background areas: CAX and NWSY are significantlly different. Therefore, separate background level concentrations should be computed (95/95 UTLs) for the two background areas.

Error in Computation: While reviewing the CH2M HILL Report, some discrepancies were idenified. For an example, location BGSB04-09 (353) represents an outlier for manganese (also found in the CH2M report) for soil association 3 and not from soil association 1 (incorrectly included in calcluations for soil asscoiation type 1). It appears that this outlier has been incorrectly included in the calculation of manganese UTL of 244.8 for soil association 1.

It is suggested that CH2M HILL double check its calculations to assure that all statistics are correctly computed.

4.0 Background Analysis for Organics in Soils

CAX background data sets consist mostly of NDs for the four soil associations. Hence the data from the four soil associations for both surface and subsurface were combined to compute UTLs after testing for outliers. No organics background data are available for the NWSYsite. Due to lack of detected results, 95/95 UTLs are computed based upon the combined surface and subsurface data collected from the CAX site. Several (6) outliers were identified for total organics as summarized in Table 4.1.

Table 4.1: Outliers for Total Organics - Surface and Subsurface Data Combined

Chemical	N	# Outliers	Outliers Value (ID)
Total Organics	40	6	133000 (BG1-SB03-01) 55100 (BG1-SB09-01) 52360(BG1-SB06-01) 40740 (BG1-SB05-01) 34600 (BG1-SB04-01) 28660 (BG1-SB01-01)

The 95/95UTLs for selected COCs are summarized in Table 4.2.

Table 4.2: Statistics for Organic Compounds - Surface and Subsurface Data Combined

Organics	# Detects	# NDs	Max (detected)	Raw Statistics (using detects)		95/95 UTL	
				Mean	SD	EPA*	CH2M HILL
Benzaldehyde	4	75	100	76	27.72	123.1 KM UTL*	123 KM UTL
Benzo(a)pyrene	1	78	4.2	-	-	-	-

Dieldrin	7	72	4.5	3	0.927	3.282 KM UTL	3.54 KM UTL
Endosulfan Sulphate	7	72	3.4	2.6	0.735	3.516 KM UTL	3.54 KM UTL
Total Organics	34	0	10600	5315	2240	11314 HW Gamma	14900 Gamma

***EPA = EPA Las Vegas**

For Benzaldehyde, using the procedure used by CH2M HILL, the reviewers also get the same value for 95/95UTL. This gives us confidence in the computations made by CH2M HILL. However, based upon the sample size requirements summarized in ProUCL Tech Guide (Chapter 1), 95/95 UTL of 123.1 for Benzaldehyde (4detects and 75 NDs) deemed as an unreliable estimate of the background concentration.

For total organics, EPA identified 6 statistical outliers, and CH2M reported only 5 outliers (first 5 in Table 4.1 above). Inclusion of the last outlier, 28660 is the cause of a higher value, 14900 for 95/95UTL.

Dealing with nondetects: It is not easy to compute reliable decision statistics based upon data sets consisting of only a few detected values (e.g., 1 or 2). In a data set consisting mostly of NDs (e.g., >95%), a 95/95 UTL may also be considered a ND value. One can use nonparametric KM method to compute a 95/95UTL when number of detected observations is at least 4-5 (more are preferred for higher confidence) and percentage of NDs is less than 95%. However, the uncertainty associated with such a decision statistic (95/95 UTL) remains high. In such situations, one may want to use the largest or next largest detected value (provided they are not outliers) as an estimate of the background level concentration. However, it is the recommendation of EPA that organic background concentrations be eliminated given the high uncertainty surrounding the calculations involving a large number of nondetects.

5.0 Background Analysis for Groundwater

Following, a similar procedure as used for metals in soils, background evaluations were performed for groundwater data for the selected COCs identified by EPA. Results of outlier analysis performed on groundwater data are summarized in the following table.

Table 5.1: Outliers in groundwater

Chemical	N	# Outliers	Outliers Value (ID)
Arsenic, dissolved	32	3	6.5 (YBKG-GW09A-YE-0809) 2.5 (YBKG-GW08A-CC-0809) 2 (YBKL-GW01P-CC-0809)
Chromium, dissolved	32	1	27.8(YBKG-GW09A-YE-0809)
Arsenic	32	6	17.8 (YBKL-GW01P-CC-0809) 17.2 (YBKL-GW01-CC-0809) 15.4 (YBKG-GW01A-YE-0809) 8.9 (YBKG-GW07-CC-0809) 7.8 (YBKG-GW09A-YE-0809) 4.3 (YBKG-GW08A-CC-0809)
Manganese	32	4	279 (YBKG-GW01A-YE-0809) 126 (YBKG-GW10-CC-0809) 104 (YBKG-GW07-CC-0809)

Table 5.2: 95/95 UTLs with and without Outliers

Chemical	N (no outliers)	Max	Raw Statistics		UTLs		
			Mean	SD	EPA (no outliers)	EPA (with outliers)	CH2M
Arsenic, dissolved	29	1.6	0.614	0.329	1.552 HW Gamma	3.18 Lognormal	1.37 Gamma
Mercury, dissolved	32 (29 NDs)	0.14	0.104	0.0279	0.165 KM		0.118 KM
Chromium, dissolved	31 (19 NDs)	5.8	2.05	1.399	5.123 KM	13.1 Lognormal	6.04 KM
Nitrobenzene	32 (30 NDs)	9.4	2.613	1.183	5.199 KM		5.64 KM
Arsenic	26	2.5	0.903	0.552	2.518 HW Gamma	17.8 Nonparametric	2.21 Gamma
Manganese	28 (4 NDs)	13.4	29.54	12.97	58.66 KM	151.6 KM	57.9 Normal

Conclusion

For mercury, dissolved in groundwater, there are only 3 detects and they are all lower than the 29 nondetects with detection limit of 0.2. Three detected values for mercury are: 0.072, 0.1 and 0.14. The rest of the observations were nondetects with a detection limit of 0.2. As mentioned before, it is not possible to compute a reliable decision statistic (e.g., 95/95UTL) based upon such data sets with a few detects. In such situations, one may use the maximum or the next to the maximum detected value (provided that value is not an outlier) as an estimate of the background threshold concentration. As mentioned previously, EPA recommends that background concentrations calculated with a large number of nondetects be eliminated given the high uncertainty. For mercury, the below maybe acceptable to EPA, given that mercury is not identified as a COC for the Operable Unit. This should be discussed with the project team, as the statistics are highly suspect.

In the present case, for mercury one may use 0.1 (second largest detected value) as an estimate of the background level concentration.

For Nitrobenzene, there were only 2 detected values: 2.4 and 9.4, and rest of the 30 results are nondetects with detection limit of 0.25. It appears the detected value 9.4 may represent an outlier. Its cause should be determined as it may be a release. In such situation, the background concentration may be estimated by the next largest value which is = 2.613 or just a nondetect value. Alternatively, since most of the values for nitrobenzene are NDs, it can be determined that nitrobenzene is not present in background groundwater.

6.0 Summary and Conclusions

- For most of the COCs evaluated in this report, significant differences were found in contaminant concentrations of surface and subsurface soils (for both CAX and NWSY), therefore, it is suggested to compute 95/95 UTLs separately for surface and subsurface soils.

- The concentrations of the selected metals found in the four soil associations of CAX area (for both surface and subsurface individually) are comparable. Therefore, four surface (and subsurface) soil associations can be considered to represent a single surface (and subsurface) population for CAX area. Background concentrations (95/95 UTLs) can be computed based upon the combined surface soil data set, and combined subsurface soil data set. A similar conclusion is derived for the four soil associations of NWSY area.

  This is contrary to the CH2M Report which states that only soil associations 3 and 4 could be combined.

- Concentrations for the selected COCs in the two background areas: CAX and NWSY are significantlly different. Therefore, separate background level concentrations should be computed for the two background areas.

- As mentioned before, it is not possible to compute a reliable decision statistic (e.g., 95/95UTL) based upon data sets consisting mostly of nondetect results (e.g., mercury and nitrobenzene in groundwater). EPA recommends that background concentrations calculated with a large number of nondetects be eliminated given the high uncertainty. Mercury maybe an exception as discussed above, based upon input from the project team.

- Overall, 95/95 UTL computations made by CH2M HILL appear to be correct except in cases when the majority of data are nondetects.

- Since some errors were identified in the calculations performed, it is suggested that CH2M HILL double check its calculations to assure that all statistics are correctly computed.

- In some cases as identified in this report, it is noted that CH2M HILL included outliers in their compuations resulting in inflating values of UTLs. These outlier concentrations may have come from areas that have potentially been impacted by site operations. Elevated observations (outliers) from these areas may represent releases. Therefore, outliers should not be included in the computation of 95/95UTLs.

7.0 References

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Appendix

Table A-1 Classical One-Way ANOVA for the 4 metals in surface soil of the CAX Background Area

Arsenic

Group	Obs	Mean	SD	Variance
ssi-bk1	10	3.953	3.382	11.44
ssi-bk2	10	1.286	1.06	1.124
ssi-bk3	10	0.908	0.447	0.2
ssi-bk4	10	2.423	3.853	14.84
Grand Statistics (All data)	40	2.143	2.794	7.809

Classical One-Way Analysis of Variance Table

Source	SS	DOF	MS	V.R.(F Stat)	P-Value
Between Groups	56.13	3	18.71	2.712	0.0593
Within Groups	248.4	36	6.9		
Total	304.5	39			

Pooled Standard Deviation	2.627
R-Sq	0.184
Adj (R-Sq)	0.116

Lead

Group	Obs	Mean	SD	Variance
ssi-bk1	10	23.98	40.46	1637
ssi-bk2	10	8.5	1.57	2.464
ssi-bk3	10	9.07	2.161	4.669
ssi-bk4	10	9.58	3.631	13.18
Grand Statistics (All data)	40	12.78	20.63	425.5

Classical One-Way Analysis of Variance Table

Source	SS	DOF	MS	V.R.(F Stat)	P-Value
Between Groups	1678	3	559.2	1.35	0.274
Within Groups	14917	36	414.4		
Total	16595	39			

Pooled Standard Deviation	20.36
R-Sq	0.101
Adj (R-Sq)	0.0262

Manganese

Group	Obs	Mean	SD	Variance
ssi-bk1	10	42.94	35.02	1227
ssi-bk2	10	128.2	62.29	3880
ssi-bk3	10	112.7	86.69	7515
ssi-bk4	10	132.2	132.5	17548
Grand Statistics (All data)	40	104	91.06	8292

Classical One-Way Analysis of Variance Table

Source	SS	DOF	MS	V.R.(F Stat)	P-Value
Between Groups	51850	3	17283	2.291	0.0947
Within Groups	271533	36	7543		
Total	323383	39			

Pooled Standard Deviation	86.85
R-Sq	0.16
Adj (R-Sq)	0.0904

Vanadium

Group	Obs	Mean	SD	Variance
ssi-bk1	10	18.78	16	256
ssi-bk2	10	8.49	2.938	8.634
ssi-bk3	10	9.21	5.532	30.6
ssi-bk4	10	9.25	6.711	45.04
Grand Statistics (All data)	40	11.43	9.853	97.08

Classical One-Way Analysis of Variance Table

Source	SS	DOF	MS	V.R.(F Stat)	P-Value
Between Groups	723.5	3	241.2	2.835	0.0518
Within Groups	3063	36	85.08		
Total	3786	39			

Pooled Standard Deviation	9.224
R-Sq	0.191
Adj (R-Sq)	0.124

Table A-2 Classical One-Way ANOVA for Lead in surface soil of the CAX Background Area after removing the 2 outliers

Lead

Group	Obs	Mean	SD	Variance
ssi-bk1	8	8.638	5.183	26.87
ssi-bk2	10	8.5	1.57	2.464
ssi-bk3	10	9.07	2.161	4.669
ssi-bk4	10	9.58	3.631	13.18
Grand Statistics (All data)	38	8.963	3.195	10.21

Classical One-Way Analysis of Variance Table

Source	SS	DOF	MS	V.R.(F Stat)	P-Value
Between Groups	6.913	3	2.304	0.211	0.888
Within Groups	370.9	34	10.91		
Total	377.8	37			

Pooled Standard Deviation	3.303
R-Sq	0.0183
Adj (R-Sq)	-0.0683

Table A-3 Classical One-Way ANOVA for the 4 metals in subsurface soil of the CAX Background Area

Arsenic

Group	Obs	Mean	SD	Variance
sbi-bk1	10	4.427	4.083	16.67
sbi-bk2	10	4.82	4.222	17.83
sbi-bk3	10	1.173	0.444	0.197
sbi-bk4	10	4.526	6.297	39.65
Grand Statistics (All data)	40	3.737	4.407	19.42

Classical One-Way Analysis of Variance Table

Source	SS	DOF	MS	V.R.(F Stat)	P-Value
Between Groups	88.46	3	29.49	1.586	0.21
Within Groups	669.1	36	18.59		
Total	757.5	39			

Pooled Standard Deviation	4.311
R-Sq	0.117
Adj (R-Sq)	0.0432

Lead

Group	Obs	Mean	SD	Variance
sbi-bk1	10	17.9	25.37	643.6
sbi-bk2	10	6.86	1.251	1.565
sbi-bk3	10	5.2	1.169	1.367
sbi-bk4	10	6.06	1.274	1.623
Grand Statistics (All data)	40	9.005	13.3	177

Classical One-Way Analysis of Variance Table

Source	SS	DOF	MS	V.R.(F Stat)	P-Value
Between Groups	1069	3	356.2	2.198	0.105
Within Groups	5834	36	162		
Total	6902	39			

Pooled Standard Deviation	12.73
R-Sq	0.155
Adj (R-Sq)	0.0844

Manganese

Group	Obs	Mean	SD	Variance
sbi-bk1	10	24	25.8	665.5
sbi-bk2	10	65.76	37.65	1418
sbi-bk3	10	46.68	58.87	3466
sbi-bk4	10	79.78	62.85	3950
Grand Statistics (All data)	40	54.06	51.41	2642

Classical One-Way Analysis of Variance Table

Source	SS	DOF	MS	V.R.(F Stat)	P-Value
Between Groups	17565	3	5855	2.465	0.0779
Within Groups	85492	36	2375		
Total	103057	39			

Pooled Standard Deviation	48.73
R-Sq	0.17
Adj (R-Sq)	0.101

Vanadium

Group	Obs	Mean	SD	Variance
sbi-bk1	10	18.09	16.09	258.8
sbi-bk2	10	22.44	8.491	72.1
sbi-bk3	10	13.42	9.647	93.07
sbi-bk4	10	19.16	10.43	108.7
Grand Statistics (All data)	40	18.28	11.56	133.6

Classical One-Way Analysis of Variance Table

Source	SS	DOF	MS	V.R.(F Stat)	P-Value
Between Groups	417.4	3	139.1	1.045	0.385
Within Groups	4794	36	133.2		
Total	5211	39			

Pooled Standard Deviation	11.54
R-Sq	0.0801
Adj (R-Sq)	0.00343

Table A-4 Classical One-Way ANOVA for the 4 metals in surface soil of the NWSY Background Area

Arsenic

Group	Obs	Mean	SD	Variance
1	3	2.233	1.106	1.223
2	12	2.101	1.227	1.505
3	13	2.054	1.296	1.679
4	7	10.53	23.55	554.6
Grand Statistics (All data)	35	3.78	10.52	110.7

Classical One-Way Analysis of Variance Table

Source	SS	DOF	MS	V.R.(F Stat)	P-Value
Between Groups	398.4	3	132.8	1.223	0.318
Within Groups	3367	31	108.6		
Total	3765	34			

Pooled Standard Deviation	10.42
R-Sq	0.106
Adj (R-Sq)	0.0193

Lead

Group	Obs	Mean	SD	Variance
1	3	15.63	7.537	56.81
2	12	10.42	3.325	11.05
3	13	16.88	11.6	134.5
4	7	13.87	1.161	1.349
Grand Statistics (All data)	35	13.96	7.911	62.58

Classical One-Way Analysis of Variance Table

Source	SS	DOF	MS	V.R.(F Stat)	P-Value
Between Groups	270.3	3	90.1	1.504	0.233
Within Groups	1857	31	59.91		
Total	2128	34			

Pooled Standard Deviation	7.74
R-Sq	0.127
Adj (R-Sq)	0.0426

Manganese

Group	Obs	Mean	SD	Variance
1	3	184	126.4	15988
2	12	162	158.6	25146
3	13	82.67	89.5	8011
4	7	85.91	72.86	5309
Grand Statistics (All data)	35	119.2	120.8	14595

Classical One-Way Analysis of Variance Table

Source	SS	DOF	MS	V.R.(F Stat)	P-Value
Between Groups	59658	3	19886	1.412	0.258
Within Groups	436571	31	14083		
Total	496229	34			

Pooled Standard Deviation	118.7
R-Sq	0.12
Adj (R-Sq)	0.0351

Vanadium

Group	Obs	Mean	SD	Variance
1	3	16.43	6.679	44.6
2	12	13.28	4.607	21.22
3	13	15.79	8.378	70.19
4	7	17.13	7.43	55.21
Grand Statistics (All data)	35	15.25	6.808	46.34

Classical One-Way Analysis of Variance Table

Source	SS	DOF	MS	V.R.(F Stat)	P-Value
Between Groups	79.53	3	26.51	0.549	0.652
Within Groups	1496	31	48.26		
Total	1576	34			

Pooled Standard Deviation	6.947
R-Sq	0.0505
Adj (R-Sq)	-0.0414

Table A-5 Classical One-Way ANOVA for the 4 metals in subsurface soil of the NWSY Background Area

Arsenic

Group	Obs	Mean	SD	Variance
3	3	12.83	12.63	159.5
2	5	6.14	4.37	19.09
4	5	12.29	17.83	317.8
Grand Statistics (All data)	13	10.05	12.22	149.3

Classical One-Way Analysis of Variance Table

Source	SS	DOF	MS	V.R.(F Stat)	P-Value
Between Groups	124.8	2	62.41	0.374	0.697
Within Groups	1667	10	166.7		
Total	1792	12			

Pooled Standard Deviation	12.91
R-Sq	0.0697
Adj (R-Sq)	-0.116

Lead

Group	Obs	Mean	SD	Variance
3	3	8.767	4.486	20.12
2	5	15.74	7.963	63.4
4	5	9.64	5.678	32.24
Grand Statistics (All data)	13	11.78	6.778	45.95

Classical One-Way Analysis of Variance Table

Source	SS	DOF	MS	V.R.(F Stat)	P-Value
Between Groups	128.5	2	64.27	1.52	0.265
Within Groups	422.8	10	42.28		
Total	551.4	12			

Pooled Standard Deviation	6.502
R-Sq	0.233
Adj (R-Sq)	0.0798

Manganese

Group	Obs	Mean	SD	Variance
3	3	243.8	133.8	17916
2	5	40.5	38.2	1459
4	5	608.4	1304	1699605
Grand Statistics (All data)	13	305.8	799	638437

Classical One-Way Analysis of Variance Table

Source	SS	DOF	MS	V.R.(F Stat)	P-Value
Between Groups	821153	2	410576	0.6	0.567
Within Groups	6840087	10	684009		
Total	7661240	12			

Pooled Standard Deviation	827
R-Sq	0.107
Adj (R-Sq)	-0.0714

Vanadium

Group	Obs	Mean	SD	Variance
3	3	32.83	23.02	529.7
2	5	33.06	17.85	318.5
4	5	22.48	27.39	750
Grand Statistics (All data)	13	28.94	21.74	472.7

Classical One-Way Analysis of Variance Table

Source	SS	DOF	MS	V.R.(F Stat)	P-Value
Between Groups	339	2	169.5	0.318	0.735
Within Groups	5334	10	533.4		
Total	5673	12			

Pooled Standard Deviation	23.09
R-Sq	0.0598
Adj (R-Sq)	-0.128

Table A-6 Gehan's Test for Arsenic in CAX and NWSY Background Areas

Sample 1 Data: Arsenic(cax)

Sample 2 Data: Arsenic(nwsy)

Raw Statistics

	Sample 1	Sample 2
Number of Valid Samples	72	44
Number of Non-Detect Data	37	0
Number of Detect Data	35	44
Minimum Non-Detect	0.23	N/A
Maximum Non-Detect	3.1	N/A
Percent Non detects	51.39%	0.00%
Minimum Detected	0.094	0.36
Maximum Detected	6.8	13.8
Mean of Detected Data	2.709	2.826
Median of Detected Data	2.4	1.65
SD of Detected Data	1.816	3.02

Sample 1 vs Sample 2 Gehan Test

H0: Mu of Sample 2 = Mu of Sample 1

Gehan z Test Value	3.453
Lower Critical z (0.025)	-1.96
Upper Critical z (0.975)	1.96
P-Value	5.5409E-4

Conclusion with Alpha = 0.05

Reject H0, Conclude Sample 2 <> Sample 1

P-Value < alpha (0.05)

Table A-7 WMW Test for Lead in CAX and NWSY Background Areas

Sample 2 Data: Lead(nwsy)

Sample 1 Data: Lead(cax)

Raw Statistics

	Sample 1	Sample 2
Number of Valid Samples	75	44
Number of Distinct Samples	47	38
Minimum	1.1	4.2
Maximum	16	25.5
Mean	7.447	11.63
Median	6.8	11.4
SD	2.901	4.41
SE of Mean	0.335	0.665
W-Stat Rank Scores	3515	3626
Expected W Scores (H0)	4500	2640
SD of W Scores (H0)	181.7	181.7

Wilcoxon-Mann-Whitney (WMW) Test

H0: Mean/Median of Sample 2 = Mean/Median of Sample 1

Sample 2 Rank Sum W-Stat	3626
WMW U-Stat	2636
WMW Expected U	1650
WMW SD of U	181.7
Standardized WMW U-Stat	5.422
Lower Critical Value (0.025)	-1.96
Upper Critical Value (0.975)	1.96
Approximate P-Value	5.8855E-8

Approximate P-Value < alpha (0.05)

Conclusion with Alpha = 0.05

Reject H0, Conclude Sample 2 <> Sample 1

Table A-8 WMW Test for Manganese in CAX and NWSY Background Areas

Sample 2 Data: Manganese(nwsy)

Sample 1 Data: Manganese(cax)

Raw Statistics

	Sample 1	Sample 2
Number of Valid Samples	77	43
Number of Distinct Samples	74	43
Minimum	2.9	3.5
Maximum	304	340
Mean	71.23	85.27
Median	51.1	68.9
SD	64.37	84.16
SE of Mean	7.335	12.83
W-Stat Rank Scores	4573	2688
Expected W Scores (H0)	4659	2602
SD of W Scores (H0)	182.7	182.7

Wilcoxon-Mann-Whitney (WMW) Test

H0: Mean/Median of Sample 2 = Mean/Median of Sample 1

Sample 2 Rank Sum W-Stat	2688
WMW U-Stat	1742
WMW Expected U	1656
WMW SD of U	182.7
Standardized WMW U-Stat	0.468
Lower Critical Value (0.025)	-1.96
Upper Critical Value (0.975)	1.96
Approximate P-Value	0.64

Approximate P-Value >= alpha (0.05)

Conclusion with Alpha = 0.05

Do Not Reject H0, Conclude Sample 2 = Sample 1

Table A-9 WMW Test for Vanadium in CAX and NWSY Background Areas

Sample 2 Data: Vanadium(nwsy)

Sample 1 Data: Vanadium(cax)

Raw Statistics

	Sample 1	Sample 2
Number of Valid Samples	77	48
Number of Distinct Samples	71	44
Minimum	2.1	1.2
Maximum	37.8	70.3
Mean	13.55	18.96
Median	10.9	14.9
SD	9.13	13.86
SE of Mean	1.041	2
W-Stat Rank Scores	4324	3552
Expected W Scores (H0)	4851	3024
SD of W Scores (H0)	197	197

Wilcoxon-Mann-Whitney (WMW) Test

H0: Mean/Median of Sample 2 = Mean/Median of Sample 1

Sample 2 Rank Sum W-Stat	3552
WMW U-Stat	2376
WMW Expected U	1848
WMW SD of U	197
Standardized WMW U-Stat	2.675
Lower Critical Value (0.025)	-1.96
Upper Critical Value (0.975)	1.96
Approximate P-Value	0.00747

Approximate P-Value < alpha (0.05)

Conclusion with Alpha = 0.05

Reject H0, Conclude Sample 2 <> Sample 1

This concludes EPA's review of the Navy's February, 2010 draft *Calculation of Background Concentrations TM* for the NWSY NPL site, and the CAX NPL site. If you have any questions, please feel free to call me at (215) 814-3357,

Sincerely,

Robert Thomson, P.E., R.E.M.
Federal Facility Remediation (3HS11)

Cc: Wade Smith (VaDEQ, Richmond)
Dawn Ioven (USEPA, 3HS41)

Navy’s Response to EPA’s Comments on Draft TM

CH2M HILL
5700 Cleveland Street, Suite 101
Virginia Beach, VA 23462
Tel 757.518.9666

June 30, 2010

358549.RP.FR

Mr. Robert Thomson, P.E., R.E.M.
Office of Federal Facility Remediation
United States Environmental Protection Agency (EPA), Region 3
1650 Arch Street
Philadelphia, PA 19103-2029

Subject: Response to USEPA Comments: Draft Technical Memorandum, *Calculation of Background Concentrations Technical Memorandum at Naval Weapons Station Yorktown and Cheatham Annex,* Naval Weapons Station Yorktown (WPNSTA), Yorktown, VA and Cheatham Annex (CAX), Williamsburg, VA

Dear Mr. Thomson:

This letter is in response to comments received on May 5, 2010 regarding the referenced draft document. Each comment is presented in *italics*, followed by the Navy's response. The order of the comments and responses, as provided by USEPA, has been modified slightly to allow for the most broad-reaching issues to be addressed first.

Comments and Responses:

- *Concentrations for the selected COCs in the two background areas: CAX and NWSY are significantly different. Therefore, separate background level concentrations should be computed for the two background areas.*

Response: Although USEPA's analysis indicates a statistical difference between the soils at Yorktown and CAX, it should be noted that these facilities are immediately adjacent to each other, are part of the same watershed and have undergone the same environmental genesis (i.e., hydrology, erosion, deposition). The bases consist of identical soil types as presented in the Soil Conservation Survey for York County. Some of the statistical differences may, in part, be a result of slightly different depths at which the samples were collected at each base. However, the Navy believes that in order to best support the decision making process, a wider range of data should be considered in the data set. The data set should not be determined solely on the statistical fit of the data. USEPA agreed to the approach presented in the work plan to combine the data sets based on the physical setting of the bases. The amount of data, particularly for the groundwater dataset at Cheatham Annex, is insufficient to separate the sets. Additional data collection would unnecessarily delay site decisions and is currently not funded. Therefore, the Navy believes that the sample data should be combined.

Further information on the soils, geology, and hydrology of the two bases may be found in the following publications:

Thomas, P. and Harper, D., *Soil Survey of Tidewater Cities Area, Virginia.* U.S. Department of Agriculture, Natural Resources Conservation Service. 2008.

Brockman, A., Nelms, D. and others. *Geohydrology of the Shallow Aquifer System, Naval Weapons Station Yorktown, Yorktown, Virginia.* U.S. Geological Survey Water-Resources Investigations Report 97-4188. 1997.

- *For most of the COCs evaluated in this report, significant differences were found in contaminant concentrations of surface and subsurface soils (for both CAX and NWSY), therefore, it is suggested to compute 95/95 UTLs separately for surface and subsurface soils.*

Response: Calculating separate UTLs for surface and subsurface soils is acceptable to the Navy. The background UTLs in the draft final document will be updated accordingly.

- *The concentrations of the selected metals found in the four soil associations of CAX area (for both surface and subsurface individually) are comparable. Therefore, four surface (and subsurface) soil associations can be considered to represent a single surface (and subsurface) population for CAX area. Background concentrations (95/95 UTLs) can be computed based upon the combined surface soil data set, and combined subsurface soil data set. A similar conclusion is derived for the four soil associations of NWSY area.*

  This is contrary to the CH2M Report which states that only soil associations 3 and 4 could be combined.

Response: The Navy agrees to combine all soil associations for the purpose of UTL calculation.

- *As mentioned before, it is not possible to compute a reliable decision statistic (e.g., 95/95UTL) based upon data sets consisting mostly of non-detect results (e.g., mercury and nitrobenzene in groundwater). EPA recommends that background concentrations calculated with a large number of non-detects be eliminated given the high uncertainty. Mercury maybe an exception as discussed above, based upon input from the project team.*

Response: It is agreed that UTL calculations will not be completed for constituents for which data sets consist of a large number of non-detects.

- *Overall, 95/95 UTL computations made by CH2M HILL appear to be correct except in cases when the majority of data are non-detects.*

Response: Comment noted. Please see the previous response of proposed use of data with a majority of non-detects.

- *Since some errors were identified in the calculations performed, it is suggested that CH2M HILL double check its calculations to assure that all statistics are correctly computed.*

Response: The Navy is aware that one soil sample (BGSB04-09) may have been grouped within the wrong soil type. Following final resolution of sample groups, the statistics will be recalculated, but the incorrect grouping based on soils types will not have an impact on the final statistics. If there were any additional errors which were identified which would impact the new calculations, the Navy would appreciate the USEPA's help in identifying these.

- *In some cases as identified in this report, it is noted that CH2M HILL included outliers in their computations resulting in inflating values of UTLs. These outlier concentrations may have come from areas that have potentially been impacted by site operations. Elevated observations (outliers) from these areas may represent releases. Therefore, outliers should not be included in the computation of 95/95UTLs.*

Response: The intended approach during development of UTLs was to complete calculations without using outliers. There were probably some discrepancies in the outliers identified based on the grouping of soil associations in the USEPA calculations compared to the original Navy calculations. Any outliers will be excluded during the recalculations.

- *Groundwater, surface, and subsurface soil background data were collected from CAX and NWSY sites. These sites consist of four soil association types. For some locations, duplicate samples were collected. In such cases, higher value was retained and used in the statistical analyses performed by CH2M HILL to establish background level concentrations. For comparison sake, the reviewers also used the higher duplicate value, even though the use of the average of duplicates is a preferred method and is commonly used in practice.*

  However, for background evaluation studies, the use of the lower value of the duplicate results perhaps will be more appropriate resulting in a conservative estimate (95/95UTL) of the background level concentration.

Response: The Navy does not agree that use of the lower value of a pair of background duplicate samples is appropriate. During the comparison of site data to screening levels (e.g., RSLs, MCLs and background UTLs), the higher of the two site values is required in the comparison which reflects a more conservative measure. However, selecting the lower (and more conservative) duplicate value in the background data set will result in comparison of a conservatively high site value with a conservatively low background value. This may lead to unnecessary concerns of a release or clean up values below levels actually representative of background. The Navy requests the inclusion of the maximum duplicate number into the background data set for the purpose of UTL calculation.

- *When reviewing the CH2M HILL report, some discrepancies were identified. For an example location BGSB04-09 (353) represents an outlier for manganese (also found in the CH2M HILL report) for soil association 3 and not from soil association 1 (incorrectly included in calculations for soil association type 1. It appears this outlier has been incorrectly included in the calculation of manganese UTL of 244.8 for soil association 1.*

Response: Background calculations will be reevaluated and checked following agreement on the grouping of the data sets. After data partitioning decisions are completed, it will be determined if this result remains an outlier and the data may be excluded from the UTL calculation, as appropriate.

- "*However, it is the recommendation of EPA that organic background concentrations be eliminated given the high uncertainty surrounding the calculations involving a large number of nondetects.*"

Response: The Navy agrees that a high degree of variability may exist with organic background concentrations and UTLs for these compounds will not be included in the revised calculations.

If you have any questions or comments regarding the above response to comments, please feel free to contact me at 757-873-1442, x41634.

Sincerely,

CH2M HILL

Marlene Ivester
Project Manager

cc: Mr. Chris Murray/NAVFAC Mid-Atlantic
Mr. Tom Kowalski/NAVFAC Mid-Atlantic
Ms. Sue Haug/USEPA
Mr. Wade Smith/VDEQ
Mr. Bill Friedmann/CH2M HILL
Ms. Laura Cook/CH2M HILL
Ms. Stephanie Sawyer/CH2M HILL
Mr. Adam Forshey/CH2M HILL

EPA's Review of Navy's Response

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION III
1650 Arch Street
Philadelphia, Pennsylvania 19103-2029

Robert Thomson, P.E., R.E.M.
Office of Federal Facility Remediation

Direct Dial (215) 814-3357
Mail Code: 3HS11

Date: August 5, 2010

Mr. Thomas Kowalski
NAVFAC MIDLANT, Code EV3
9742 Maryland Avenue
Building N-26, Room 3208
Norfolk, VA 23511-3095

Re: Naval Weapons Station–Yorktown NPL site, Yorktown, Va.
Naval Supply Center – Cheatham Annex NPL site, Williamsburg, Va
Calculation of Background Concentrations Technical Memorandum
Review of the Navy's 6/30/10 response to EPA's 5/5/10 letter

Dear Mr. Kowalski:

The U.S. Environmental Protection Agency (EPA) has reviewed the U.S. Navy's (Navy's) June 30, 2010 response to EPA's May 5, 2010 letter pertaining to the Navy's February, 2010 draft *Calculation of Background Concentrations Technical Memorandum* (TM) for the Naval Weapons Station-Yorktown (NWSY) NPL site, and the Naval Supply Center – Cheatham Annex (CAX) NPL site. Based upon that review, we offer the following:

1. Based upon rigorous statistical evaluations, it was concluded that concentrations of the COCs in CAX and NWSY base areas are significantly different. The EPA did not, as the Navy's response contends, agree to ultimately combine the data sets without first evaluating the appropriateness of doing so. Statistically, the data sets are different. Thus, any rationale for combining the data sets has not been clearly presented by the Navy. For evaluating the appropriateness of combining said data sets outside the realm of statistics, it is recommended that a sensitivity analysis be performed to determine the degree of variation between data sets. For such a comparison, EPA recommends using the old Yorktown inorganic background data set, the new Yorktown inorganic background data set, and the new/existing Cheatham Annex inorganic background data set (even though it is small). Comparison of inorganic background concentrations between the three data sets should be illustrated for discussion with the EPA. We are looking for the range of variability between the data sets.

2. For site versus background comparisons, typically the higher duplicate site value is compared with background statistics or some other screening level. For the

computation of background statistics, the use of the higher duplicate value may yield inflated values of background statistcis (e.g., 95/95UTLs). This is especially true when the difference between the duplicate values is large.

It is suggested again that the Navy use an appropriate duplicate value (e.g., average or lower) to compute background statistics. If the use of the lower duplicate value is not acceptable, the Navy may just use the commonly used average value.

This concludes EPA's review of the Navy's 6/30/10 response to EPA's 5/5/10 letter pertaining to the Navy's February, 2010 draft *Calculation of Background Concentrations TM* for the NWSY NPL site, and the CAX NPL site. Please note that the remaining Navy responses not directly addressed above are considered acceptable. Additionally, based upon the Navy's responses, recalculation of the background data is necessary given the responses by the Navy. It is noted that such recalculations may also be affected by the outcome of the two remaining issues outlined above.

If you have any questions, please feel free to call me at (215) 814-3357.

Sincerely,

Robert Thomson, P.E., R.E.M.
Federal Facility Remediation (3HS11)

Cc: Wade Smith (VaDEQ, Richmond)
Dawn Ioven (USEPA, 3HS41)

Navy’s Response to EPA’s Review

WPNSTA and CAX Background Study

Review of Latest EPA Comments and Team Consensus on Path Forward

August 2010

Presentation Purpose

- Review EPA's 8/5/10 response to the Navy's 6/30/10 RTC letter

- Discuss the appropriateness of combining the CAX and Yorktown data sets

- Team consensus on path forward for CAX background (BG) values

Review of EPA's 8/05/10 Response

EPA Comment 1:

"Based upon rigorous statistical evaluations, it was concluded that concentrations of the COCs in CAX and NWSY base areas are significantly different. The EPA did not, as the Navy's response contends, agree to ultimately combine the data sets without first evaluating the appropriateness of doing so. Statistically, the data sets are different. Thus, any rationale for combining the data sets has not been clearly presented by the Navy. For evaluating the appropriateness of combining said data sets outside the realm of statistics, it is recommended that a sensitivity analysis be performed to determine the degree of variation between data sets. For such a comparison, EPA recommends using the old Yorktown inorganic background data set, the new Yorktown inorganic background data set, and the new/existing Cheatham Annex inorganic background data set (even though it is small). Comparison of inorganic background concentrations between the three data sets should be illustrated for discussion with the EPA. We are looking for the range of variability between the data sets."

Review of EPA's 8/05/10 Response continued

- Navy Response:

The EPA's 5/5/10 comments on the BG Study calculations technical memorandum provided examples of how the variability differed between the Yorktown and Cheatham Annex data sets. CH2M HILL's analysis of variance (ANOVA) indicated there were statistical differences. Therefore, performing a sensitivity analysis would simply reiterate this statistical finding and would not advance the discussion. The Navy contends that the statistical difference between the data sets should not preclude them from being combined. To view the combination of these data from strictly a statistical standpoint is academic and not practical for real world application, as non-statistical conditions, such as the environmental genesis (deposition, erosion, etc.) of both bases, are important and should be considered as well.

The next several slides that follow discuss why it is appropriate to combine the data sets.

Appropriateness to Combine the Data Sets

- Provides CAX with a more robust, useful BG set

- Example 1 - Inorganics in Surface Soil:

Constituent*	CAX UCLs / MAX BG (mg/kg)				WPNSTA UCLs / MAX BG (mg/kg)				EPA Vegas 95/95 UTL** (mg/kg)	
	Soil Assoc 1	Soil Assoc 2	Soil Assoc 3	Soil Assoc 4	Soil Assoc 1	Soil Assoc 2	Soil Assoc 3	Soil Assoc 4	CAX	WPNSTA
Arsenic	1.75/9.9	1.75/4.1	1.17/1.7J	4.48/12.6	2.82/3.4	2.92/4.2	2.71/5.8	17.66/63.9	4.501	4.528
Lead	9.41/136	9.41/11	10.32/12.2	12/16	18.98/22.7	11.81/16.5	20.40/43.1	20.08/38.7L	15.78	18.34
Manganese	164/257	164/257	163/278	209/435	242.17/298	208.38/413	262.89/340	190.53/491	332	403.6
Vanadium	10.19/50.3	10.19/15.2	12.42/22.1	13.14/26.1	19.38/21.2	16.35/20.8	19.39/27.8	22.69/34.7	27.38	32.66

Inorganic Data Qualifier Definition:
J = The associated value is an estimated quantity.
L= The analyte is present. The reported values may be biased low. The actual value is expected to be higher than reported.

*USEPA Vegas studied these constituents in their report on the draft *Background Calculation of Background Concentrations Technical Memorandum*, as provided in USEPA's May 5, 2010 comment letter.
**Without Outliers

Appropriateness to Combine the Data Sets, continued

- Example 2 - Inorganics in Subsurface Soil:

Constituent*	CAX UCLs/MAX BG (mg/kg)				WPNSTA UCLs/MAX BG (mg/kg)	EPA Vegas 95/95 UTL** (mg/kg)	
	Soil Assoc 1	Soil Assoc 2	Soil Assoc 3	Soil Assoc 4	Combined (no per Soil Assoc values)	CAX	WPNSTA
Arsenic	6.66/12.5	7.20/15.9	0.99/2.1	8.00/18.6	13.41/42.7	5.323	19.64
Lead	33/83.7	7.59/8.3	5.89/6.7	6.80/8.1	15.66/25.5L	8.831	29.89
Manganese	39/86.2	99/135	81/208	116/195	582.51/2940	172.5	325
Vanadium	27/53.8	27.36/33.2	2.39/36	25.2/35.1	36.59/70.3L	38.94	87.01

Inorganic Data Qualifier Definition:
J = The associated value is an estimated quantity.
L= The analyte is present. The reported values may be biased low. The actual value is expected to be higher than reported.

*USEPA Vegas studied these constituents in their report on the draft *Background Calculation of Background Concentrations Technical Memorandum*, as provided in USEPA's May 5, 2010 comment letter.
**Without Outliers

Appropriateness to Combine the Data Sets, continued

- From a geologic, hydrologic, and geomorphologic perspective, the soils of Yorktown and CAX are the same, and it is appropriate to combine the data.

  - The bases are adjacent.
  - Both bases derived from the same geomorphologic and geologic processes and are part of the same physiographic province.
  - Both have the same soil associations and underlying aquifers.

WPNSTA and CAX are Adjacent to Each Other

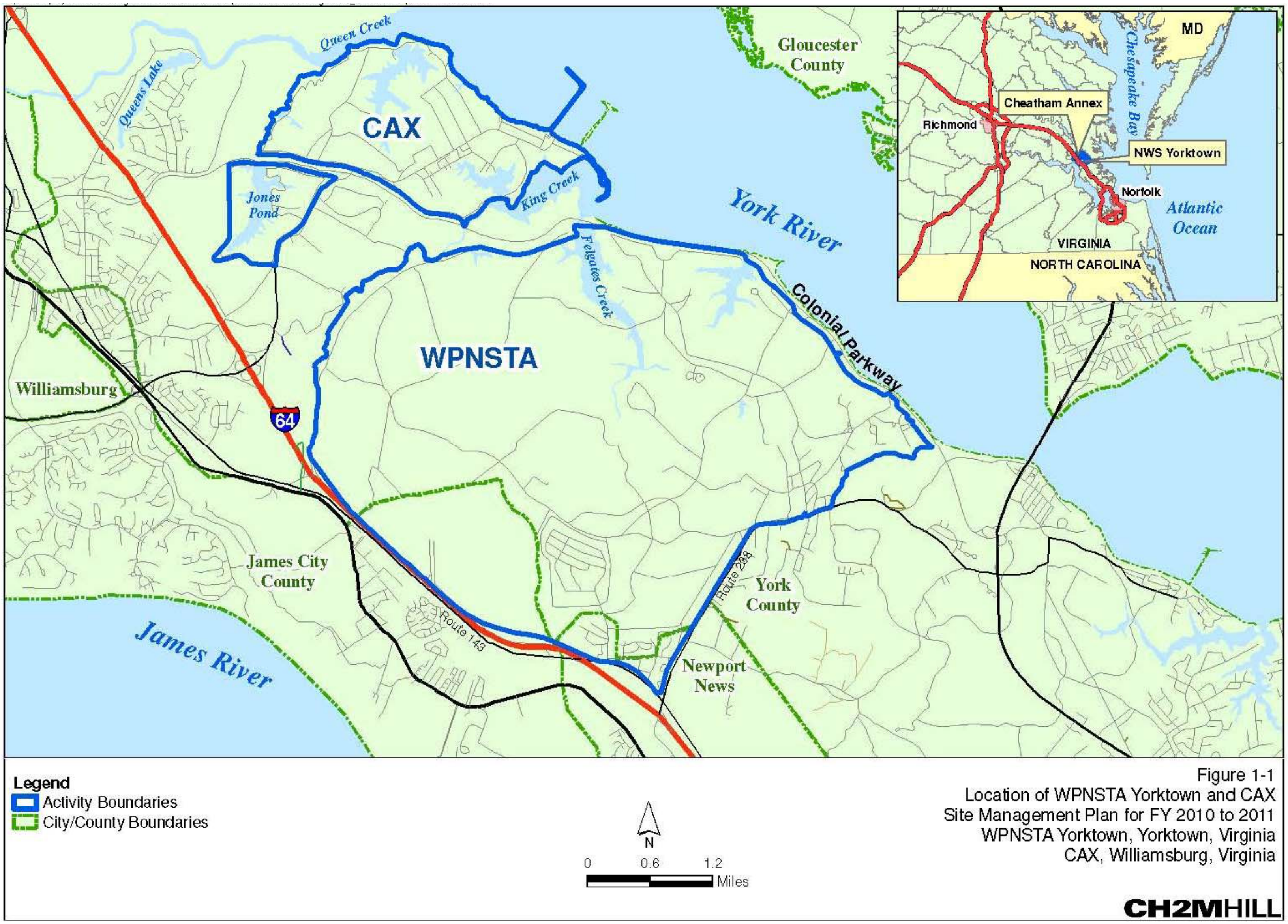
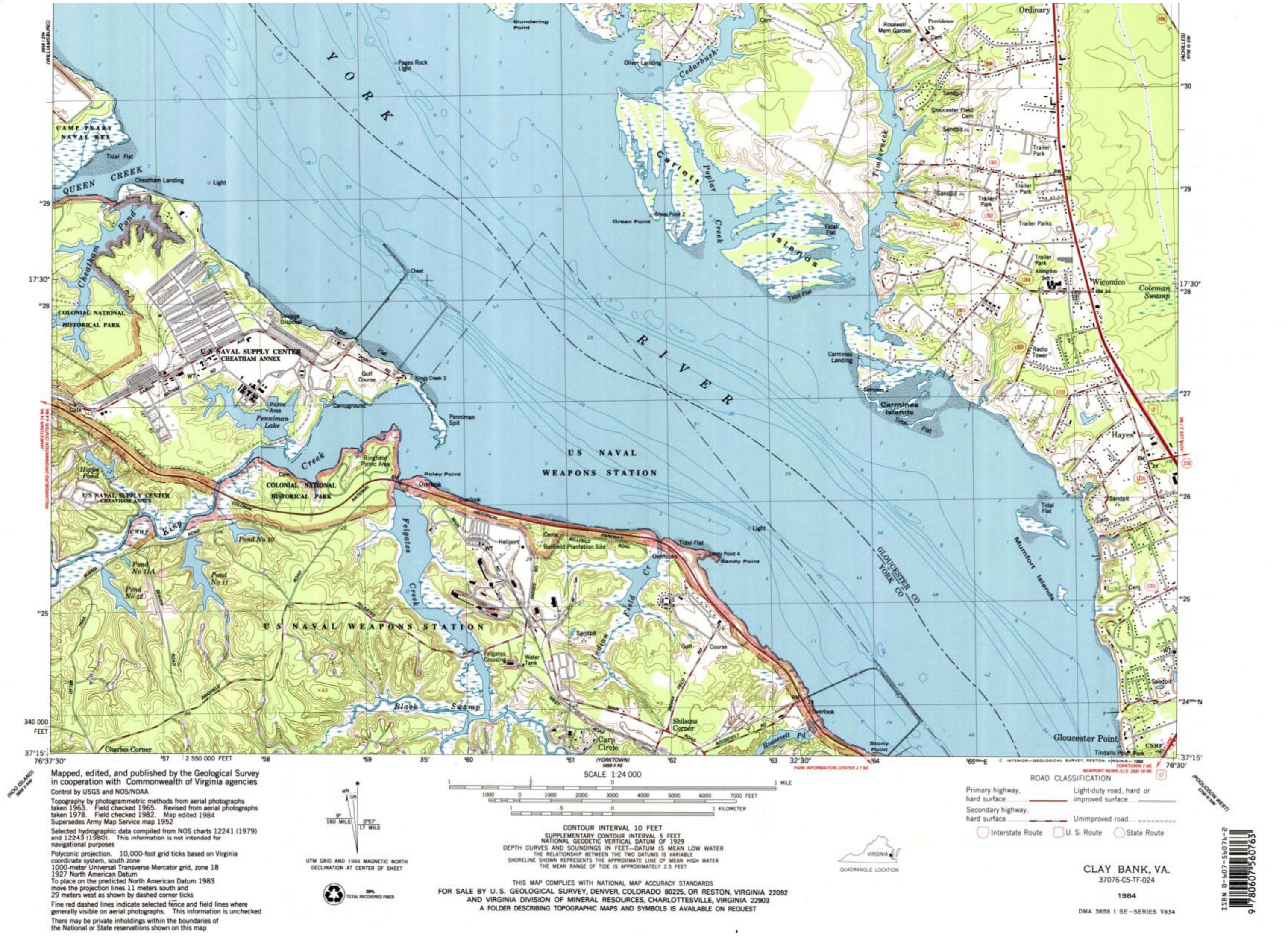


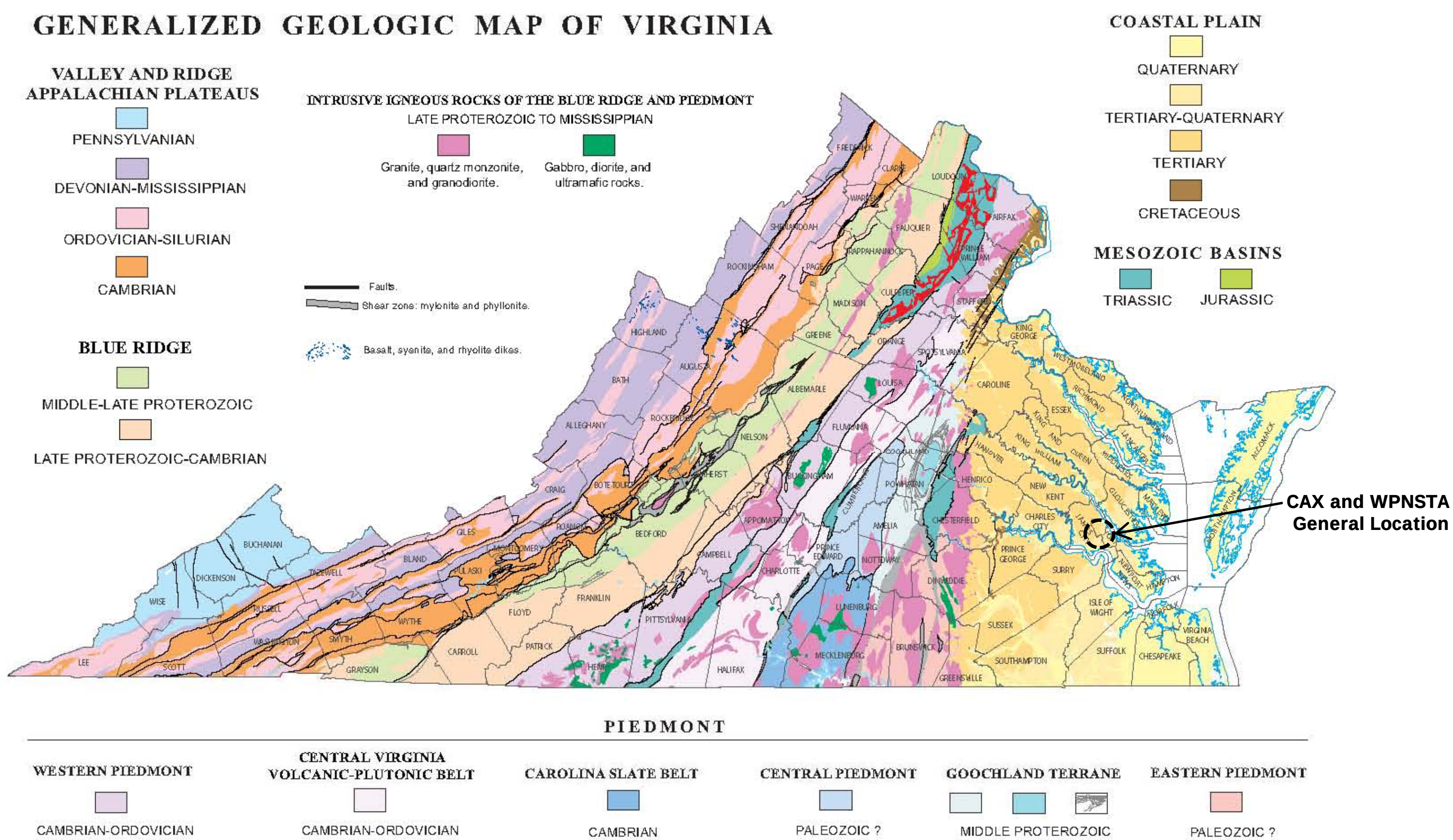
Figure 1-1
Location of WPNSTA Yorktown and CAX
Site Management Plan for FY 2010 to 2011
WPNSTA Yorktown, Yorktown, Virginia
CAX, Williamsburg, Virginia

WPNSTA and CAX have the same Geomorphology



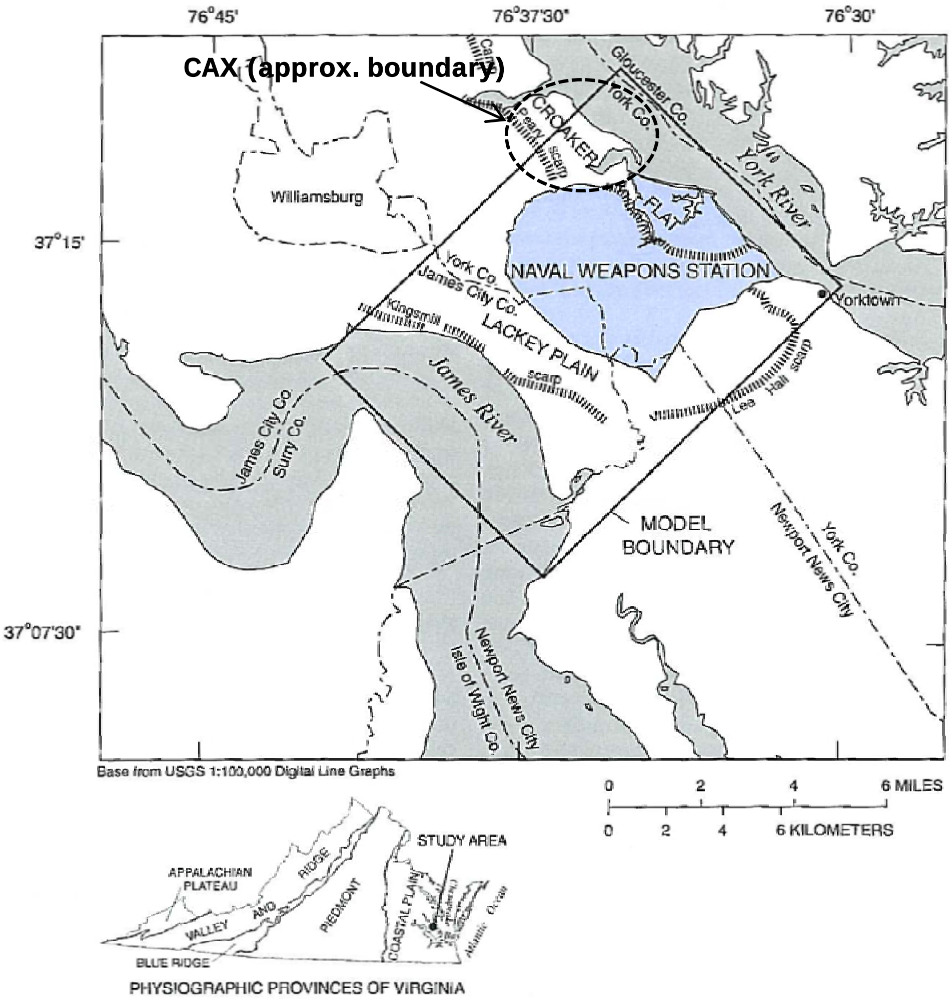
(Excerpt from: U.S. Geological Survey, Clay Bank Quadrangle, VA)

WPNSTA and CAX have the same Geology



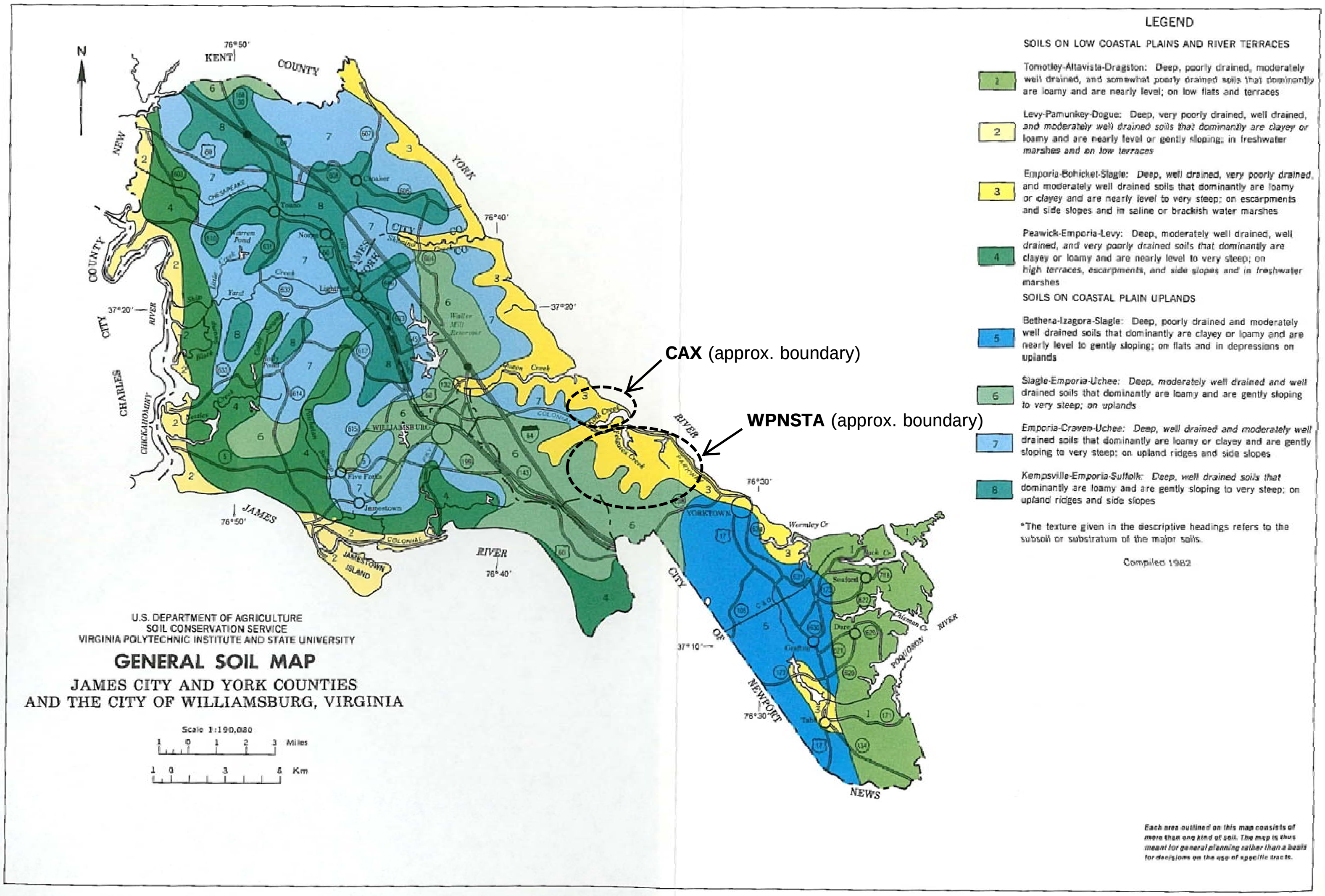
[Source: Virginia Department of Mines, Minerals, and Energy website. (http://www.dmme.virginia.gov)
Available 8/17/10: http://*www.dmme.**virginia**.gov/DMR3/dmrpdfs/VA%20geol%20**map**.pdf*]

WPNSTA and CAX are within the same Physiographic Province



(Source: Smith, Barry S. 2001. *Groundwater Flow in the Shallow Aquifer System at the Naval Weapons Station Yorktown, Virginia*. U.S. Geological Survey, Water-Resources Investigations Report 00-4077.)

WPNSTA and CAX have the same General Soils



(Source: U.S. Department of Agriculture, Soil Conservation Service. 1985. *Soil Survey of James City and York Counties and the City of Williamsburg Virginia.* April.)

Appropriateness to Combine the Data Sets, continued

- The approved background study work plan detailed the combination of the two data sets. The Navy was aware the EPA wanted to evaluate the data before agreeing on the calculation method (i.e., ProUCL vs. another method), however, was unaware that combining the data sets was in question.

- Separating the sets would require additional sample collection at CAX in order to calculate 95/95 UTLs. This would be a significant delay in the CAX Team schedule and goals and impacts the Draft SIs for 8 CAX sites. The current background study has been over 3 years in duration.

- Overall, background is one tool used to evaluate site data. Using the combined 95/95 UTLs does not mean a site that should be evaluated further will be eliminated. However, using CAX's current BG set does mean that a site or specific compounds could unnecessarily be elevated to an RI.

Review of EPA's 8/05/10 Response continued

- EPA Comment #2:

"For site versus background comparisons, typically the higher duplicate site value is compared with background statistics or some other screening level. For the computation of background statistics, the use of the higher duplicate value may yield inflated values of background statistics (e.g., 95/95UTLs). This is especially true when the difference between the duplicate values is large. It is suggested again that the Navy use an appropriate duplicate value (e.g., average or lower) to compute background statistics. If the use of the lower duplicate value is not acceptable, the Navy may just use the commonly used average value."

Review of EPA's 8/05/10 Response continued

Navy Response:

The Navy disagrees that using the lower or average value is an appropriate comparison, and that maximum BG concentrations should be used.

- BG sample locations were selected based on a review of past activities at the base and represent areas not impacted by CERCLA releases.
- By not including all of the duplicate values is statistical bias and not representative of the background conditions. Lower duplicate values are being requested for BG, and higher duplicate values for the site.
- Duplicate values represent the natural variability of that constituent over a short distance.
- Mathematical outliers were excluded from the BG data set.
- Lower or average values for duplicate samples may require further investigation and remediation of non-CERCLA related releases.

Team Consensus on Path Forward

- Does each Team member agree it is appropriate to combine the CAX and WPNSTA data sets?

- Does each Team member agree with using the higher (or maximum) duplicate value for computing the 95/95 UTLs?

- Following Team consensus on the CAX BG values to use, they will be presented in a BG study report.

Questions or Comments?

Please contact:

Chris Murray
christopher.r.murray@navy.mil
(757) 341-0485

Team Agreement for Final TM

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION III
1650 Arch Street
Philadelphia, Pennsylvania 19103-2029

Susanne Haug, P.E.
NPL/BRAC Federal Facilities Branch

Direct Dial (215) 814-3394
Mail Code: 3HS11

Date: October 5, 2010

Mr. Christopher Murray
NAVFAC MIDLANT, Code OPHREV4
9742 Maryland Avenue, Bldg N-26
Norfolk, VA 23511-3095

Re: Calculation of Background Concentrations, Naval Weapons station Yorktown, Yorktown, Virginia and Cheatham Annex Williamsburg, Virginia, February 2010

Dear Mr. Murray:

The U.S. Environmental Protection Agency (EPA) has reviewed the responses to comments sent via an e-mail attachment on 9/21/2010 regarding the U.S. Navy's above referenced report. Although we disagree with the responses to the two remaining comments presented in that e-mail attachment we accept the report. This acceptance should not be construed as an acceptance to use the same methodology at other Facilities. We will accept the report in this case because the computed background numbers are within an acceptable range for that part of the country and are not expected to affect the outcomes of any studies since the computed background numbers are below risk numbers.

If you have any questions, please feel free to call me at (215) 814-3394.

Sincerely,

Susanne Haug, P.E.
Federal Facility Remediation (3HS11)

Cc: Wade Smith (VaDEQ, Richmond)

COMMONWEALTH of VIRGINIA

DEPARTMENT OF ENVIRONMENTAL QUALITY
Street address: 629 East Main Street, Richmond, Virginia 23219
Mailing address: P.O. Box 1105, Richmond, Virginia 23218
TDD (804) 698-4021
www.deq.virginia.gov

L. Preston Bryant, Jr.
Secretary of Natural Resources

David K. Paylor
Director

(804) 698-4000
1-800-592-5482

January 6, 2011

Mr. Thomas Kowalski
Mr. Chris Murray
NAVFAC MIDLANT, Building N-26
Hampton Roads Restoration Product Line, Code OPHREV4
9742 Maryland Avenue
Norfolk, VA 23511-3095

RE: Final Calculation of UTL Background Values
Technical Memorandum
Naval Weapons Station Yorktown
Yorktown, Virginia and
Cheatham Annex
Williamsburg, Virginia

Dear Mr. Kowalski and Mr. Murray:

The Virginia Department of Environmental Quality (DEQ) has received the *Calculation of UTL Background Values at Naval Weapons Station Yorktown and Cheatham Annex* (Tech Memo). The December 30, 2010 Tech Memo, prepared by CH2M HILL, was received by the DEQ (electronically) on January 4, 2011.

Thank you for providing the DEQ's Office of Remediation Programs the opportunity to review the above-referenced Tech Memo. Subsequent to DEQ's internal review, this office is in agreement with the approach for calculating upper tolerance limit (UTL) background values in soil and groundwater at Naval Weapons Station Yorktown, Yorktown, VA and Cheatham Annex, Williamsburg, VA.

Please contact me at (804) 698-4125 or wade.smith@deq.virginia.gov with any additional questions.

Sincerely,

Wade M. Smith
Remediation Project Manager
Office of Remediation Programs

cc: Robert Thomson, EPA
Susanne Haug, EPA