APPENDIX D. DEVELOPMENT OF BACKGROUND CONCENTRATION LIMITS FOR SOIL

This appendix describes the statistical methodology used to develop background concentration limits (BCLs) for soil. ProUCL software (USEPA, 2007b) was selected to perform the statistical analysis because it includes methods for analyzing background data, including the Chebyshev method for upper prediction limits (UPLs), as discussed below. In addition, the current version of ProUCL includes methods for analyzing censored data such as the Kaplan-Meier (KM) method. ProUCL was developed for the U.S. Environmental Protection Agency (USEPA) and is widely used by environmental professionals to calculate exposure point concentrations for use in risk assessment.

UPLs have emerged as a preferred method for calculating BCLs. The Texas Risk Reduction Program is currently developing guidance for using UPLs (to be released as *TRRP-15, Determining Representative Concentrations*). UPLs are recommended by USEPA (1989 and 1992) for use at RCRA sites. The authors of ProUCL favor UPLs over other methods of determining BCLs (USEPA, 2007b, page 116).

Data that were used to develop BCLs are presented in Table D-1. Simple summary statistics for the soil concentration data are presented in Table D-2. The summary statistics were used to select appropriate methods for determining BCLs. Data and summary statistics are presented for pH and electrical conductivity, however, BCLs were not developed for those constituents.

D1.0 DEVELOPMENT OF BACKGROUND CONCENTRATION LIMITS

For constituents with at least two detected results, BCLs were calculated as the 95 percent Chebyshev UPL. Estimates of the mean and standard deviation, which are required for the Chebyshev UPL, were determined in two ways: 1) if the data do not contain nondetects, the mean and standard deviation were calculated using standard equations in Excel; and 2) if the data do contain nondetect measurements, the Kaplan-Meier method was used to estimate the mean and standard deviation. Because lead and molybdenum only have one nondetect value each, the nondetect was set equal to one-half the reporting limit and Microsoft Excel was used to estimate the mean and standard deviation. Details of the Kaplan-Meier and the Chebyshev UPL methods are described below. Development of the UPLs is presented in Table D-2, and the BCLs are summarized in Table D-2.

D1.1 Kaplan-Meier Estimation Method

The KM estimation method has been used extensively in the field of survival analysis where right censored data (i.e., “greater-thans”) are encountered. The

KM method has recently been adapted to environmental data sets, which often contain left censored data (i.e, “less-thans”). The KM method is particularly useful for environmental data because it can handle data sets with multiple detection limits. Helsel (2005) and USEPA (2007b) recommend the use of the KM estimation method for environmental data. Calculations were performed using ProUCL (USEPA, 2007a). Further details on the method are available in Kaplan and Meier (1958), Helsel (2005) and USEPA (2007b).

D1.2 Upper Prediction Limits by the Chebyshev Method

UPLs are one of several ways to develop BCLs. Examples of other methods are upper tolerance limits, upper percentiles, and the maximum concentration. An upper prediction limit gives a specified probability (e.g., 99%) that a single measurement from the site will produce a value higher than the UPL if the two distributions are the same. For a 99% UPL, there would be a one percent chance that the UPL could be exceeded by single site value even if there is no contamination (Gibbons 1994, page 11).

The Chebyshev method for calculating upper prediction limits was conducted for this analysis using the ProUCL software (EPA, 2007b). This method was selected because it produces realistic estimates of the UPL for a wide variety of data sets. Also, because this is a nonparametric method, it can be used on all data sets regardless of their distribution. The equation for calculating the Chebyshev UPL is given below (USEPA 2007b, eq. 5-2):

$$UPL = \bar{x} + [\sqrt{((1/\alpha)-1)*(1+1/n)}]s_x$$

Where $\bar{x}$ is the mean and s_x is the standard deviation. As stated previously, the mean and standard deviation were calculated using standard equations in Microsoft Excel for data sets with no nondetects. Otherwise, the KM method was used.

D2.0 GRAPHICAL REPRESENTATION

Individual value plots (IVPs) were constructed for the 18 constituents for which UPLs were calculated, and are provided in Figure D-1. Each concentration value was plotted individually, and a random horizontal offset was applied to decrease the overlap between data of the same magnitude. Minitab (2004) was used to construct the IVPs. BCLs are shown on the IVPs. These graphs were examined to evaluate the reasonableness of the BCLs relative to the background concentration data, and all of the BCLs appear to represent reasonable estimates of background conditions.

D3.0 REFERENCES

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Table D-1. Analyte Concentrations in Background Soils

Corporation Yard Landfill, Folsom, CA

Sample Location	Sample Date	Antimony (mg/kg)	Arsenic (mg/kg)	Barium (mg/kg)	Beryllium (mg/kg)	Cadmium (mg/kg)	Chromium (mg/kg)	Cobalt (mg/kg)	Copper (mg/kg)	Lead (mg/kg)
SS01	2/8/08	<2	2.8	97	0.29	0.60	60	14	28	18
SS02	2/8/08	<2	3.6	140	0.33	0.52	42	12	26	25
SS03	2/8/08	<2	2.1	48	0.13	0.28	76	18	69	<0.87
SS04	2/7/08	<2	5.2	71	0.33	0.34	46	11	35	36
SS05	2/7/08	<2	4.4	83	0.34	0.22	41	11	29	9.0
SS06	2/7/08	<2	6.9	75	0.36	<0.15	38	9.3	28	15
SS07	2/7/08	<2	4.2	85	0.50	0.40	54	10	25	53
SS08	2/7/08	<2	6.6	110	0.39	0.44	52	9.7	31	33
SS09	2/7/08	<2	3.9	110	0.38	0.18	45	11	31	29
SS10	2/7/08	<2	3.3	110	0.43	0.42	48	11	37	76
SS11	2/7/08	<2	3.8	92	0.39	<0.15	48	11	32	9.1
SS12	2/7/08	<2	4.6	93	0.37	<0.15	43	10	29	8.5
SS13	2/7/08	<2	3.9	110	0.45	0.32	47	12	32	9.9
SS14	2/7/08	<2	2.8	75	0.36	0.22	57	13	34	11
SS15	2/8/08	<2	4.0	150	0.40	0.52	38	15	22	22
SS16	2/8/08	<2	4.1	100	0.21	0.44	45	12	36	15
SS17	2/8/08	<2	2.5	120	0.18	<0.15	50	11	29	1.8
SS18	2/8/08	<2	2.4	130	0.22	0.16	55	11	24	2.4
SS19	2/8/08	<2	2.0	150	0.23	0.42	60	13	27	1.9
SS20	2/8/08	<2	2.3	42	0.11	0.50	130	20	64	1.0

Table D-1. Analyte Concentrations in Background Soils

Corporation Yard Landfill, Folsom, CA

Sample Location	Mercury (mg/kg)	Molybdenum (mg/kg)	Nickel (mg/kg)	Selenium (mg/kg)	Silver (mg/kg)	Thallium (mg/kg)	Vanadium (mg/kg)	Zinc (mg/kg)
SS01	<0.1	1.0	31	<0.38	0.24	0.44	72	46
SS02	0.10	1.0	28	<0.38	0.20	<0.4	60	45
SS03	<0.1	<0.24	36	<0.38	<0.18	0.44	61	30
SS04	<0.1	0.68	56	0.52	<0.18	<0.4	41	37
SS05	<0.1	0.59	35	0.39	<0.18	0.51	46	41
SS06	<0.1	0.86	35	<0.38	<0.18	0.45	42	37
SS07	<0.1	0.90	21	<0.38	<0.18	0.42	74	54
SS08	0.17	1.0	26	<0.38	<0.18	0.46	60	55
SS09	0.24	0.60	36	<0.38	<0.18	<0.4	52	44
SS10	0.19	1.1	33	<0.38	<0.18	0.43	60	79
SS11	<0.1	0.87	35	<0.38	<0.18	0.54	57	40
SS12	<0.1	0.60	35	<0.38	<0.18	0.57	51	33
SS13	<0.1	1.0	32	<0.38	<0.18	<0.4	61	39
SS14	<0.1	0.66	52	<0.38	<0.18	<0.4	50	38
SS15	<0.1	0.68	22	<0.38	<0.18	0.43	70	48
SS16	<0.1	0.88	33	<0.38	0.42	<0.4	54	54
SS17	<0.1	0.66	32	<0.38	<0.18	0.53	61	35
SS18	<0.1	0.49	32	<0.38	<0.18	<0.4	66	39
SS19	<0.1	0.69	34	<0.38	<0.18	<0.4	74	40
SS20	<0.1	0.43	56	<0.38	<0.18	0.43	50	34

Table D-1. Analyte Concentrations in Background Soils

Corporation Yard Landfill, Folsom, CA

Sample Location	Nitrate as NO3 (mg/kg)	Sulfate as SO4 (mg/kg)	pH (SU)	Elec. Conduc. (µmhos/cm)
SS01	10	8.2	6.52	7
SS02	10	22	7.39	14
SS03	5.4	8.9	6.52	7
SS04	5.2	4.7	6.24	7
SS05	7.4	6.0	6.36	11
SS06	7.2	9.4	7.00	11
SS07	25	42	6.74	23
SS08	4.6	6.1	6.89	7
SS09	3.9	5.2	6.01	4
SS10	4.4	7.2	6.70	6
SS11	4.0	5.0	6.66	4
SS12	4.5	6.0	6.59	5
SS13	4.7	5.5	6.34	6
SS14	3.3	3.3	5.96	2
SS15	11	6.3	6.54	8
SS16	4.6	3.6	6.57	6
SS17	4.5	3.2	6.61	5
SS18	4.3	3.3	6.70	4
SS19	4.4	4.5	6.82	5
SS20	6.5	3.8	6.76	4

Table D-2. Summary Statistics and Background Concentration Limits for Analytes in Soils

Corporation Yard Landfill, Folsom, CA

	Antimony (mg/kg)	Arsenic (mg/kg)	Barium (mg/kg)	Beryllium (mg/kg)	Cadmium (mg/kg)	Chromium (mg/kg)	Cobalt (mg/kg)	Copper (mg/kg)
Number of observations	20	20	20	20	20	20	20	20
Number of detects	0	20	20	20	16	20	20	20
Percent detects	0	100	100	100	80	100	100	100
Minimum detect	n/a	2.0	42	0.11	0.16	38	9.3	22
Maximum detect	n/a	6.9	150	0.50	0.60	130	20	69
Number of nondetects	20	0	0	0	4	0	0	0
Percent nondetects	100	0	0	0	20	0	0	0
Minimum nondetect	2	n/a	n/a	n/a	0.15	n/a	n/a	n/a
Maximum nondetect	2	n/a	n/a	n/a	0.15	n/a	n/a	n/a
Est. method for mean and standard deviation	n/a	arithmetic	arithmetic	arithmetic	KM	arithmetic	arithmetic	arithmetic
Mean	n/a	3.8	100	0.32	0.33	54	12	33
Standard deviation	n/a	1.4	30	0.11	0.14	20	2.7	12
Method for determining background concentration limit	reporting limit	95% Chebyshev UPL	95% Chebyshev UPL	95% Chebyshev UPL	95% Chebyshev UPL	95% Chebyshev UPL	95% Chebyshev UPL	95% Chebyshev UPL
Background conc. limit (BCL)	2	10	234	0.80	0.97	143	24	87

Notes

* The single nondetect was set equal to 1/2 the reporting limit

** BCL not established for specific conductivity and pH

KM - Kaplan-Meier

UPL - upper prediction limit

Table D-2. Summary Statistics and Background Concentration Limits for Analytes in Soils

Corporation Yard Landfill, Folsom, CA

	Lead (mg/kg)	Mercury (mg/kg)	Molybdenum (mg/kg)	Nickel (mg/kg)	Selenium (mg/kg)	Silver (mg/kg)	Thallium (mg/kg)	Vanadium (mg/kg)
Number of observations	20	20	20	20	20	20	20	20
Number of detects	19	4	19	20	2	3	12	20
Percent detects	95	20	95	100	10	15	60	100
Minimum detect	1.0	0.10	0.43	21	0.39	0.20	0.42	41
Maximum detect	76	0.24	1.1	56	0.52	0.42	0.57	74
Number of nondetects	1	16	1	0	18	17	8	0
Percent nondetects	5	80	5	0	90	85	40	0
Minimum nondetect	0.87	0.1	0.24	n/a	0.38	0.18	0.4	n/a
Maximum nondetect	0.87	0.1	0.24	n/a	0.38	0.18	0.4	n/a
Est. method for mean and standard deviation	arithmetic*	KM	arithmetic*	arithmetic	KM	KM	KM	arithmetic
Mean	19	0.12	0.74	35	0.40	0.21	0.45	58
Standard deviation	19	0.038	0.24	10	0.028	0.048	0.046	10
Method for determining background concentration limit	95% Chebyshev UPL	95% Chebyshev UPL	95% Chebyshev UPL	95% Chebyshev UPL	95% Chebyshev UPL	95% Chebyshev UPL	95% Chebyshev UPL	95% Chebyshev UPL
Background conc. limit (BCL)	105	0.28	1.8	78	0.52	0.43	0.66	103

Notes

* The single nondetect was set equal to 1/2 the reporting limit

** BCL not established for specific conductivity and pH

KM - Kaplan-Meier

UPL - upper prediction limit

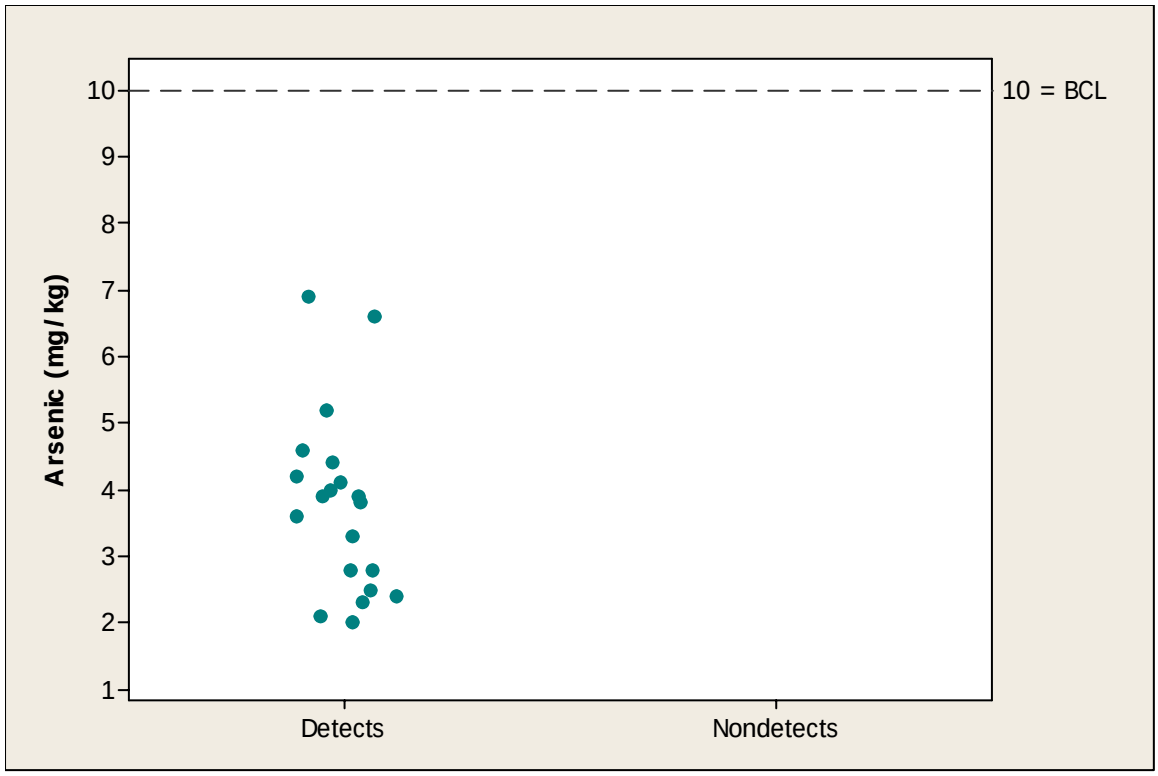
Table D-2. Summary Statistics and Background Concentration Limits for Analytes in Soils

Corporation Yard Landfill, Folsom, CA

	Zinc (mg/kg)	Nitrate as NO3 (mg/kg)	Sulfate as SO4 (mg/kg)	pH (SU)	Elec. Conduc. (µmhos/cm)
Number of observations	20	20	20	20	20
Number of detects	20	20	20	20	20
Percent detects	100	100	100	100	100
Minimum detect	30	3.3	3.2	5.96	2
Maximum detect	79	25	42	7.39	23
Number of nondetects	0	0	0	0	0
Percent nondetects	0	0	0	0	0
Minimum nondetect	n/a	n/a	n/a	n/a	n/a
Maximum nondetect	n/a	n/a	n/a	n/a	n/a
Est. method for mean and standard deviation	arithmetic	arithmetic	arithmetic	arithmetic	arithmetic
Mean	43	6.7	8.2	6.6	7.3
Standard deviation	11	4.8	8.9	0.33	4.7
Method for determining background concentration limit	95% Chebyshev UPL	95% Chebyshev UPL	95% Chebyshev UPL	n/a**	n/a**
Background conc. limit (BCL)	92	28	48		
Notes					
* The single nondetect was set equal to 1/2 the reporting limit					
** BCL not established for specific conductivity and pH					
KM - Kaplan-Meier					
UPL - upper prediction limit					

Figure D-1. Individual Value Plots with Background Concentration Limits for Soil

Corporation Yard Landfill, Folsom, CA



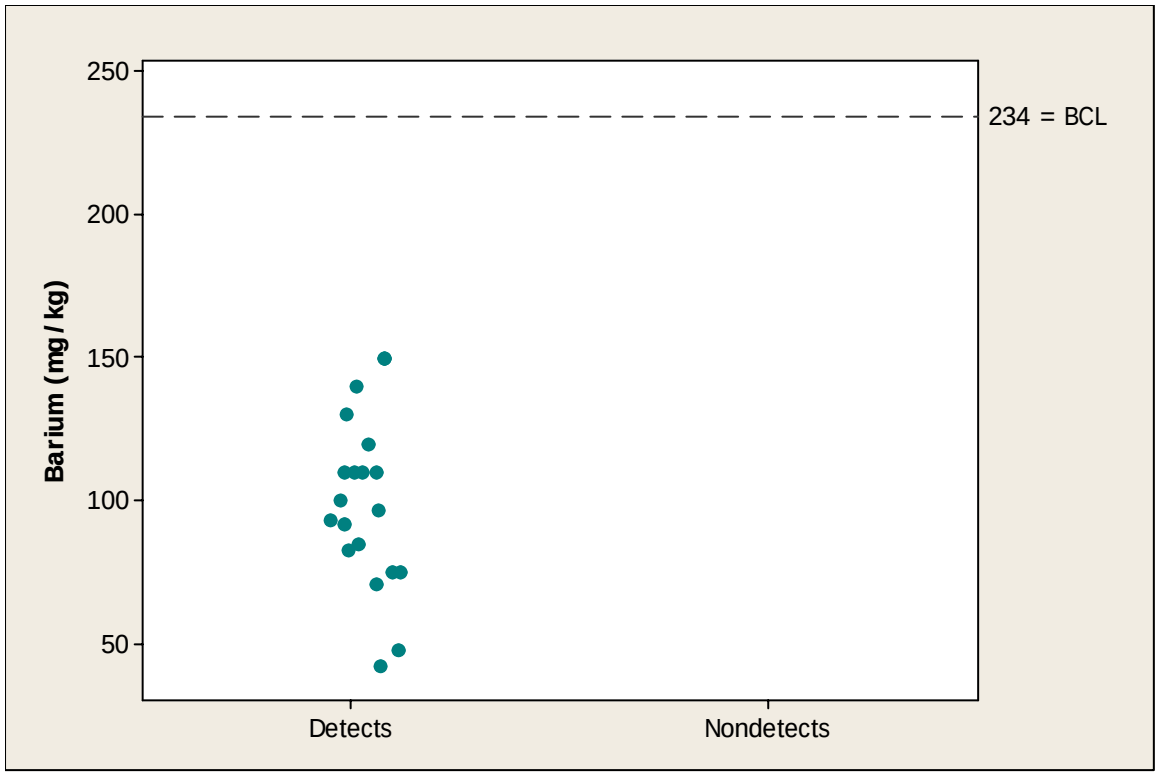
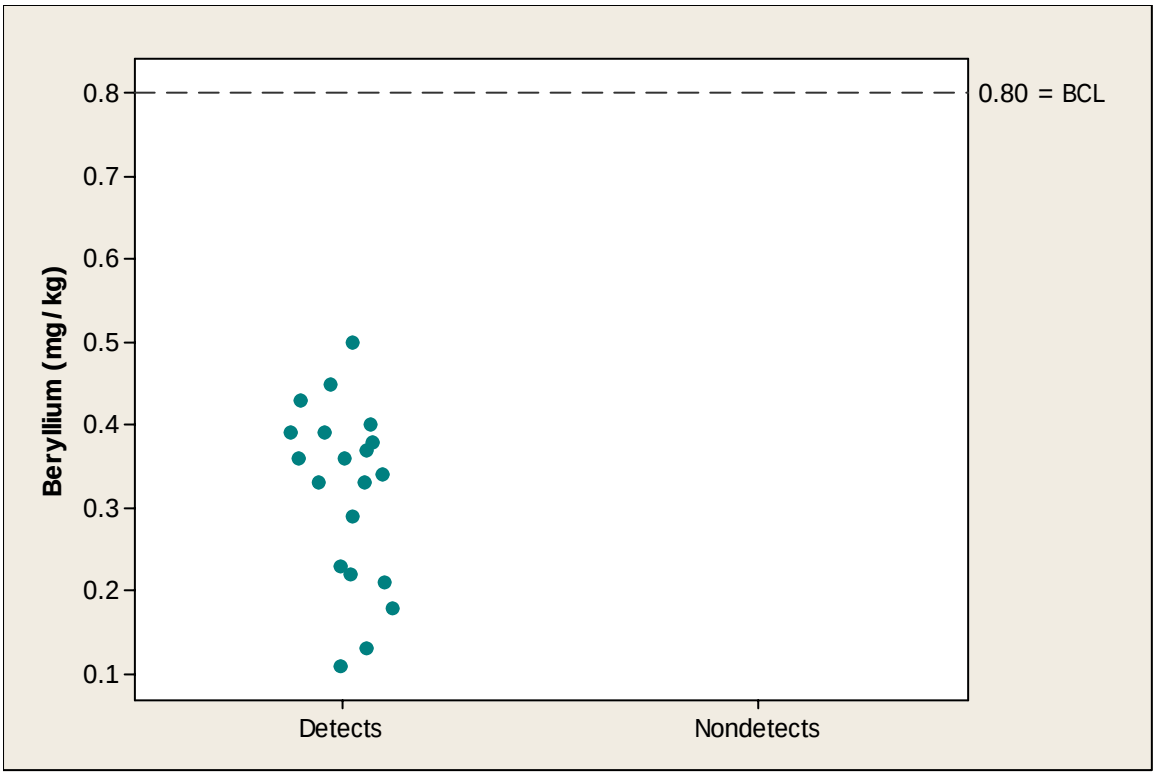


Figure D-1. Individual Value Plots with Background Concentration Limits for Soil

Corporation Yard Landfill, Folsom, CA



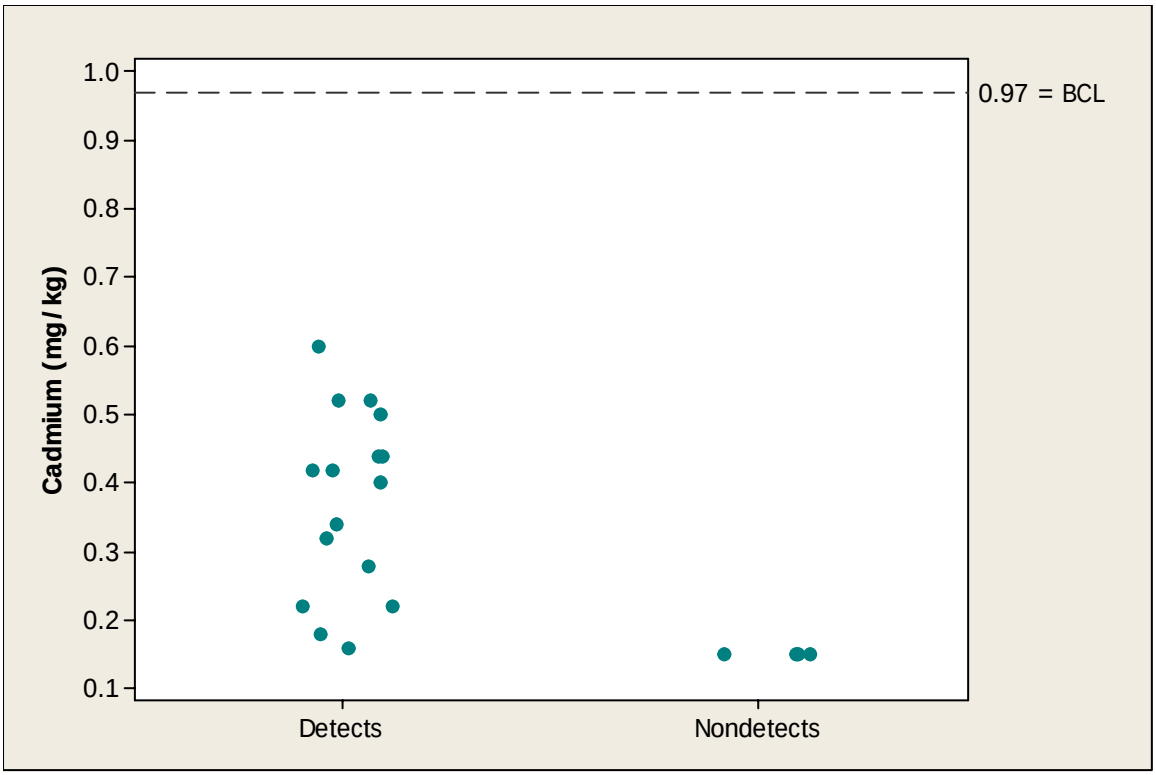
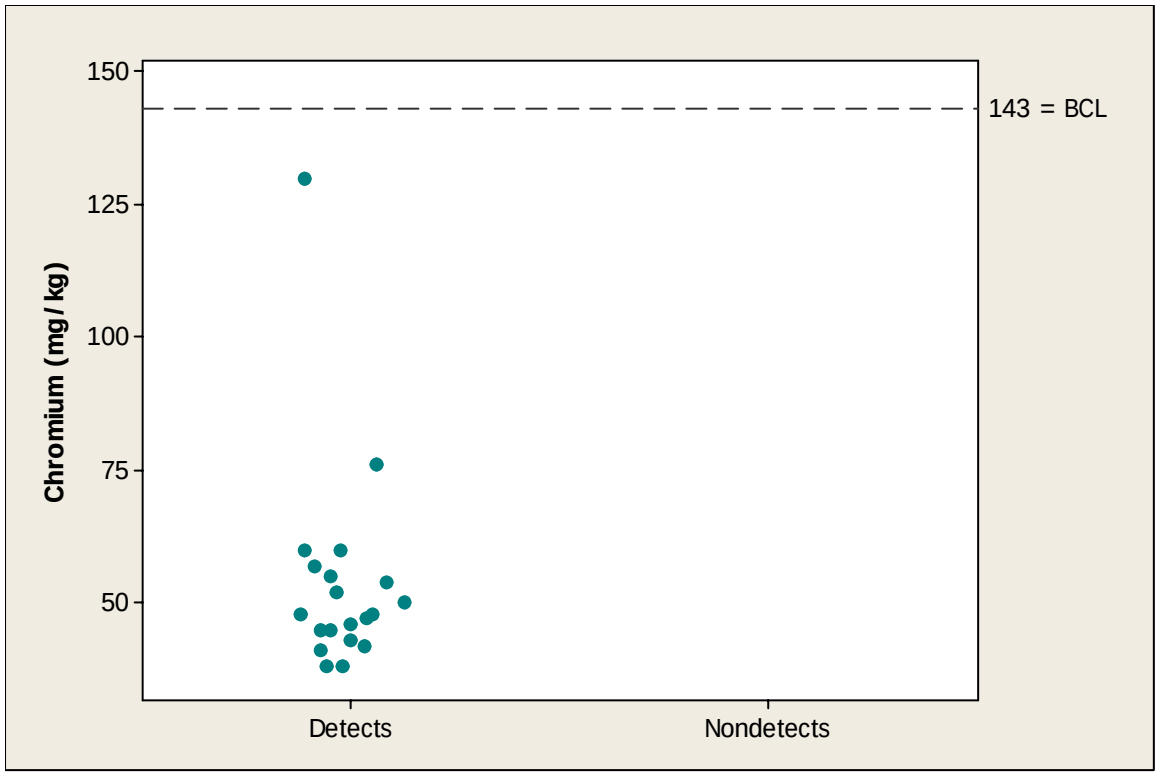


Figure D-1. Individual Value Plots with Background Concentration Limits for Soil

Corporation Yard Landfill, Folsom, CA



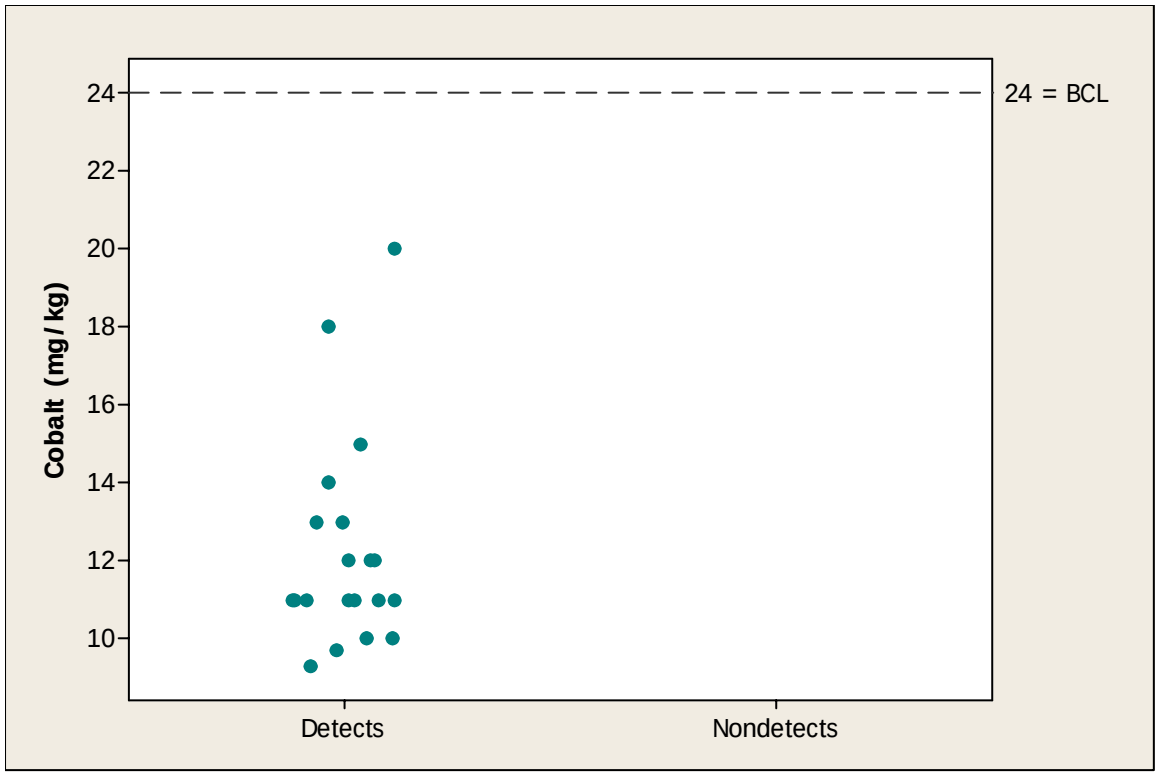
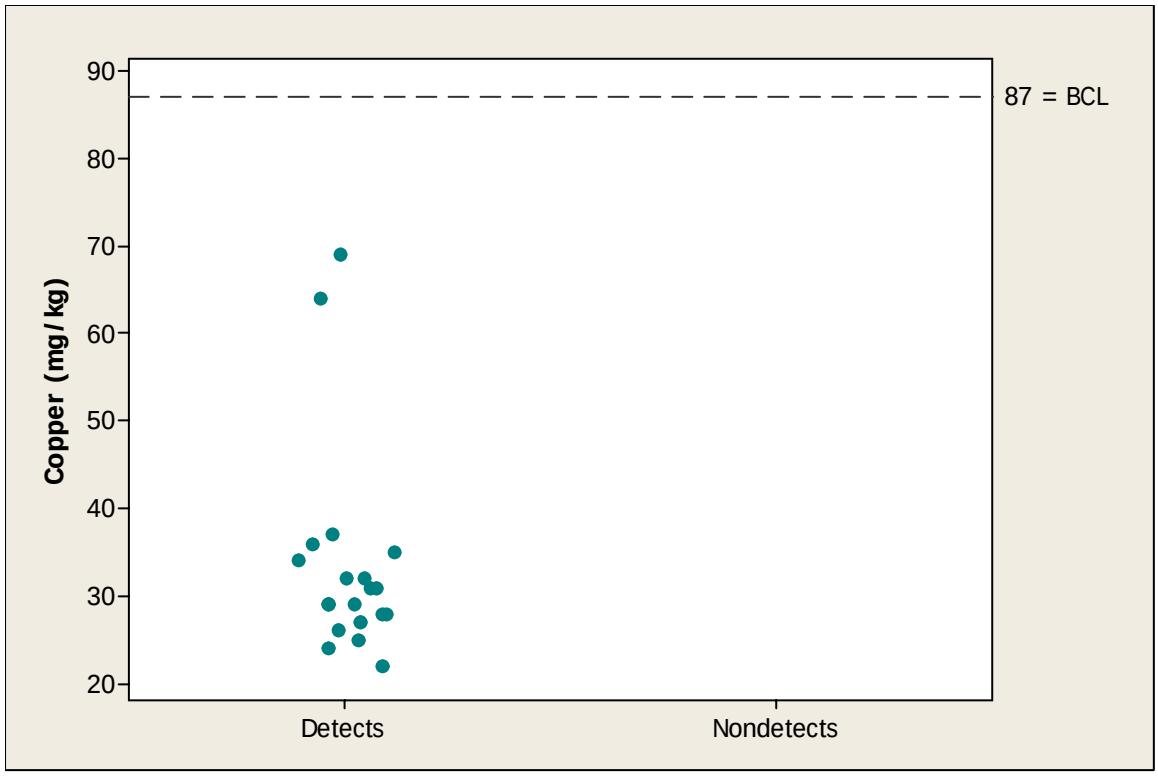


Figure D-1. Individual Value Plots with Background Concentration Limits for Soil

Corporation Yard Landfill, Folsom, CA



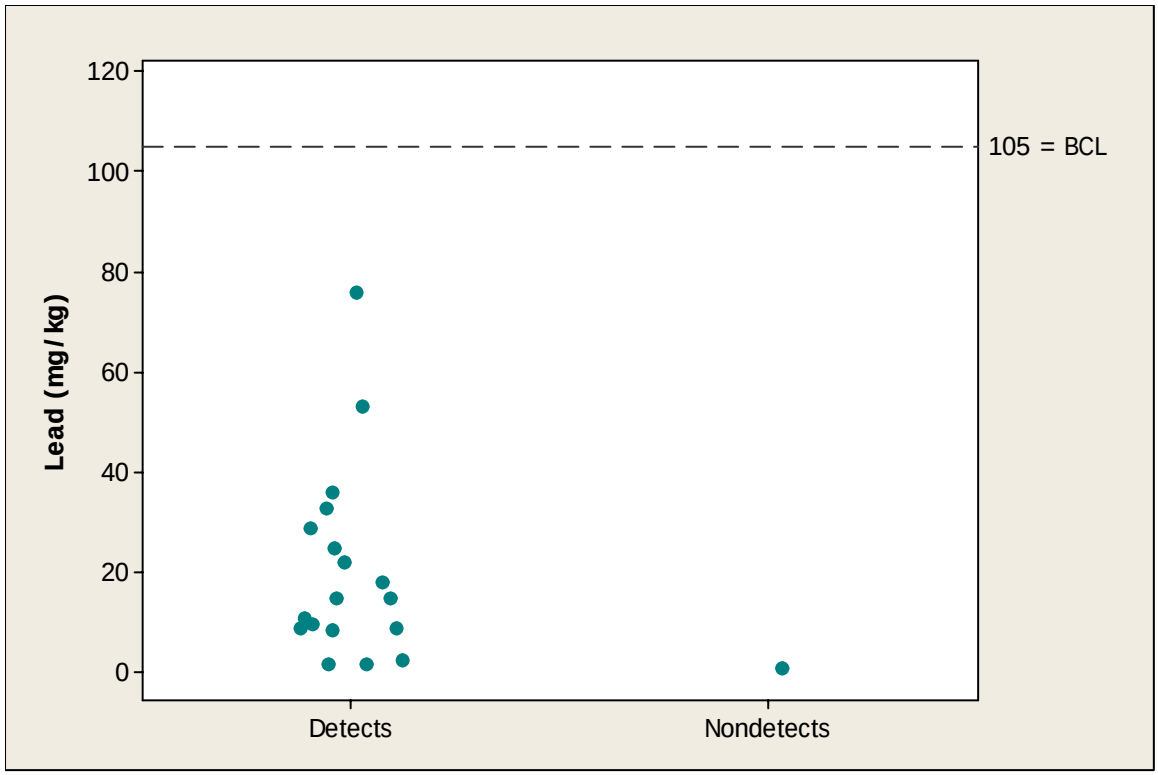
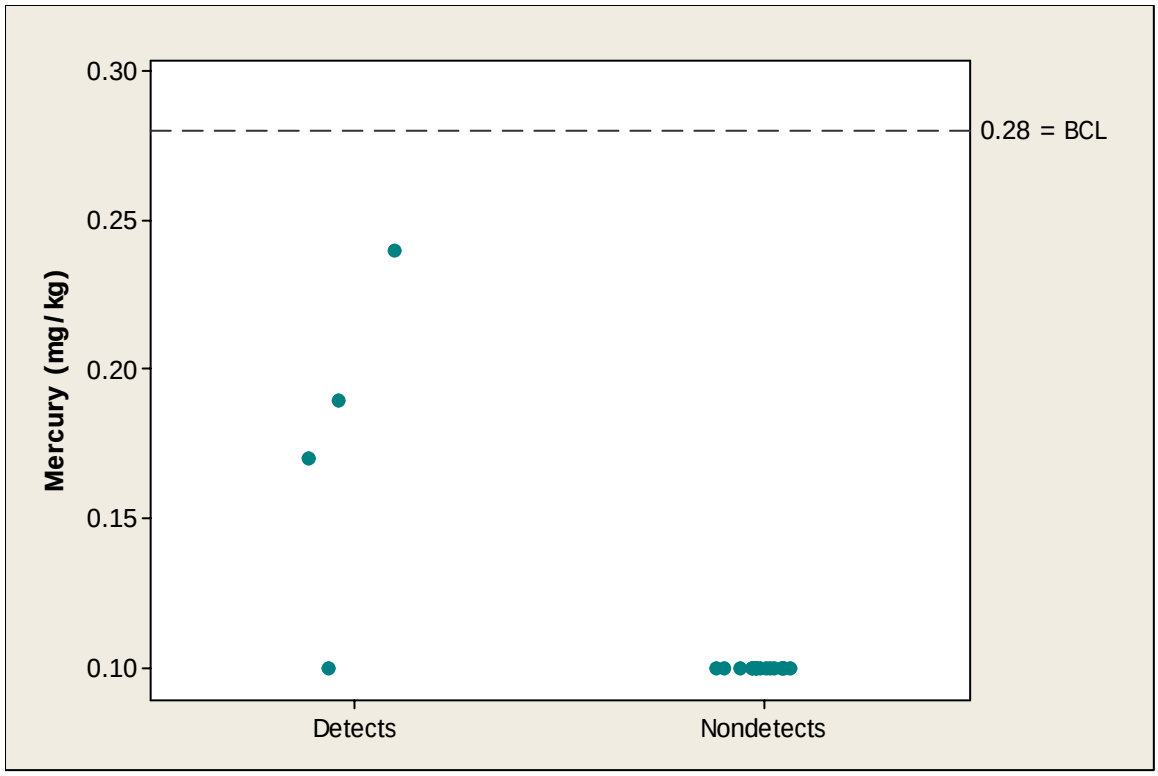


Figure D-1. Individual Value Plots with Background Concentration Limits for Soil

Corporation Yard Landfill, Folsom, CA



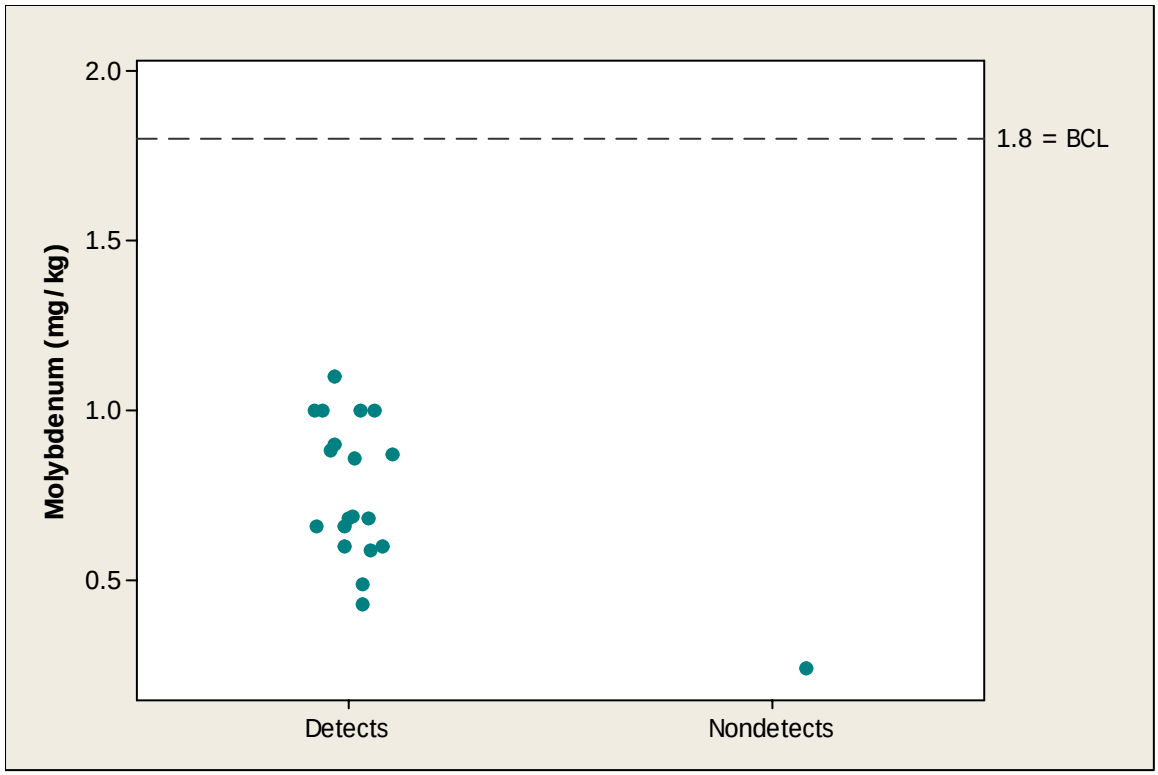
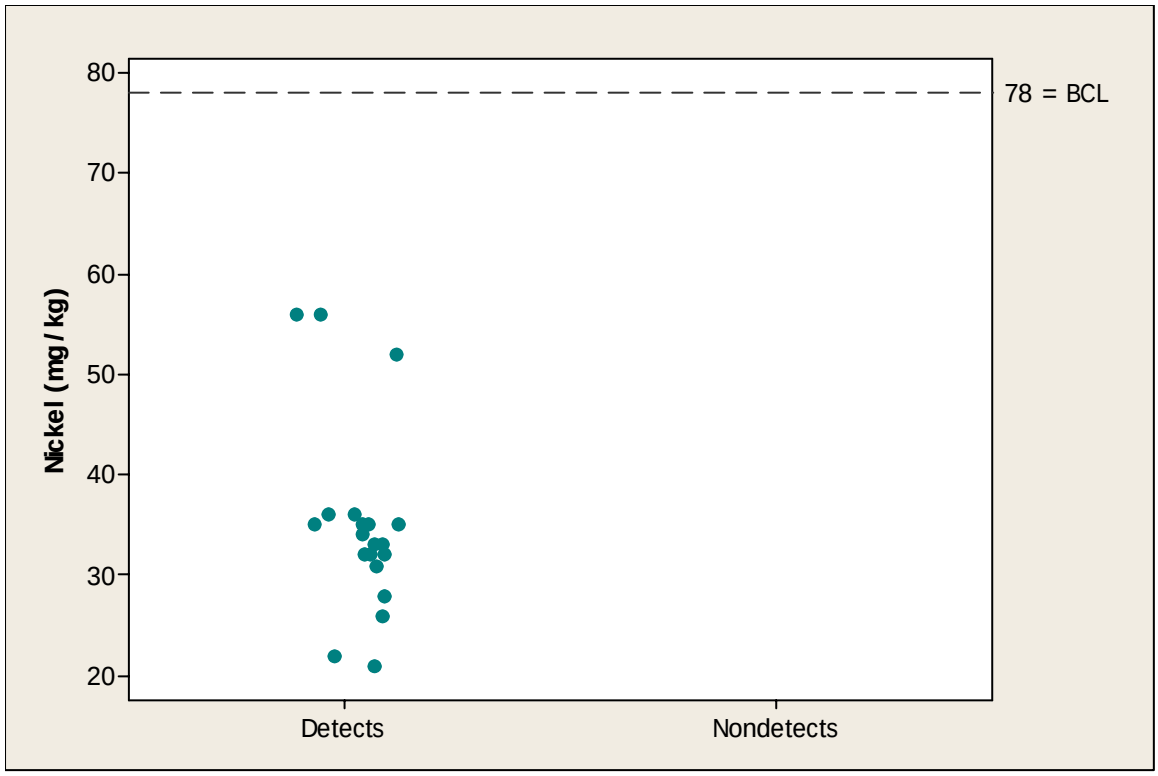


Figure D-1. Individual Value Plots with Background Concentration Limits for Soil

Corporation Yard Landfill, Folsom, CA



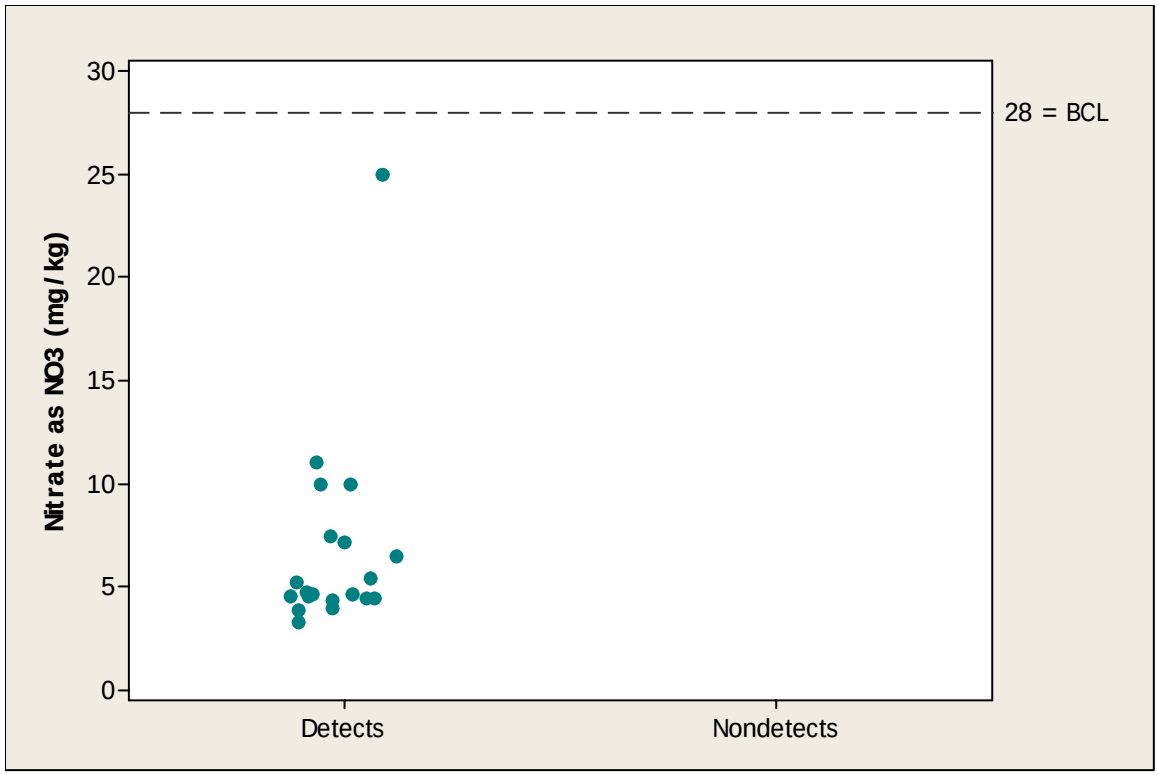
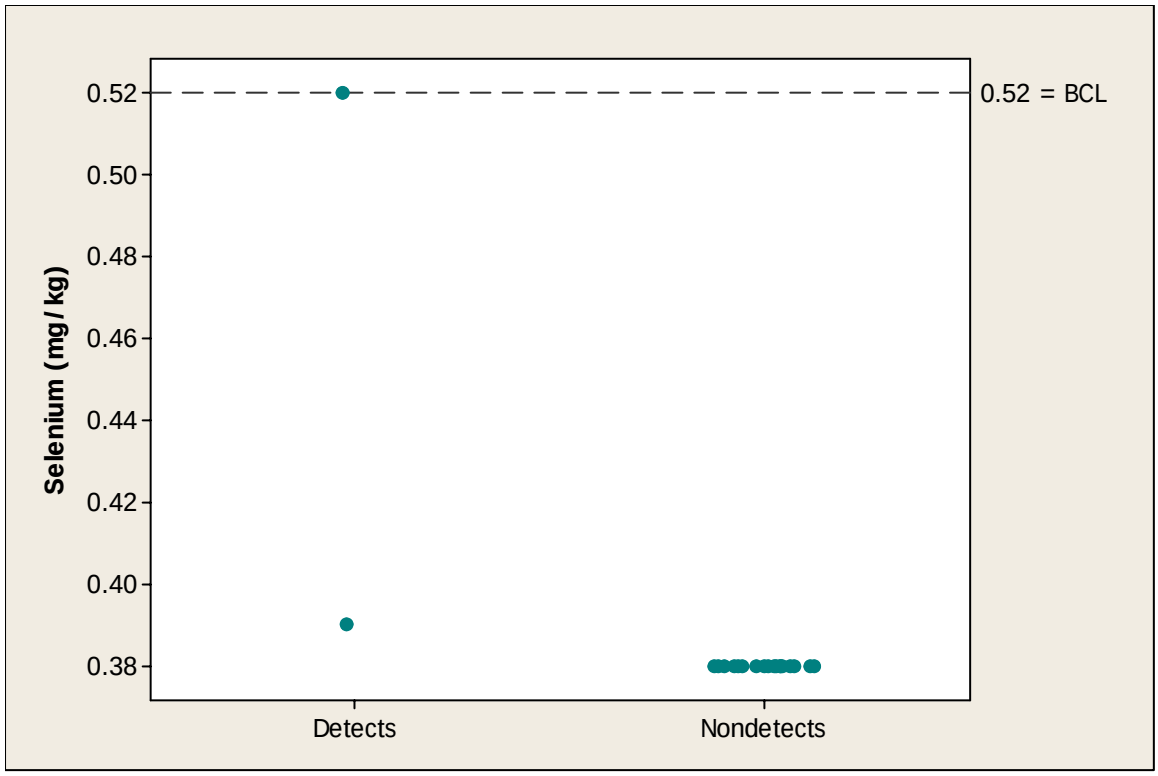


Figure D-1. Individual Value Plots with Background Concentration Limits for Soil

Corporation Yard Landfill, Folsom, CA



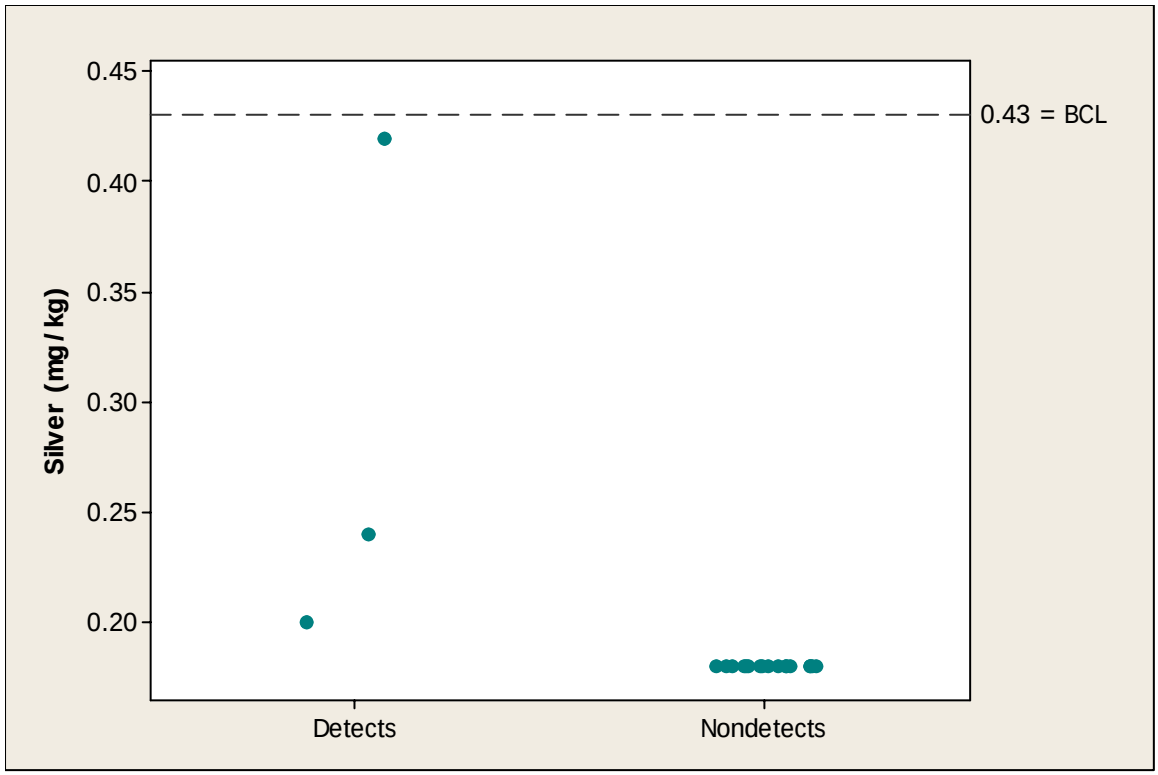
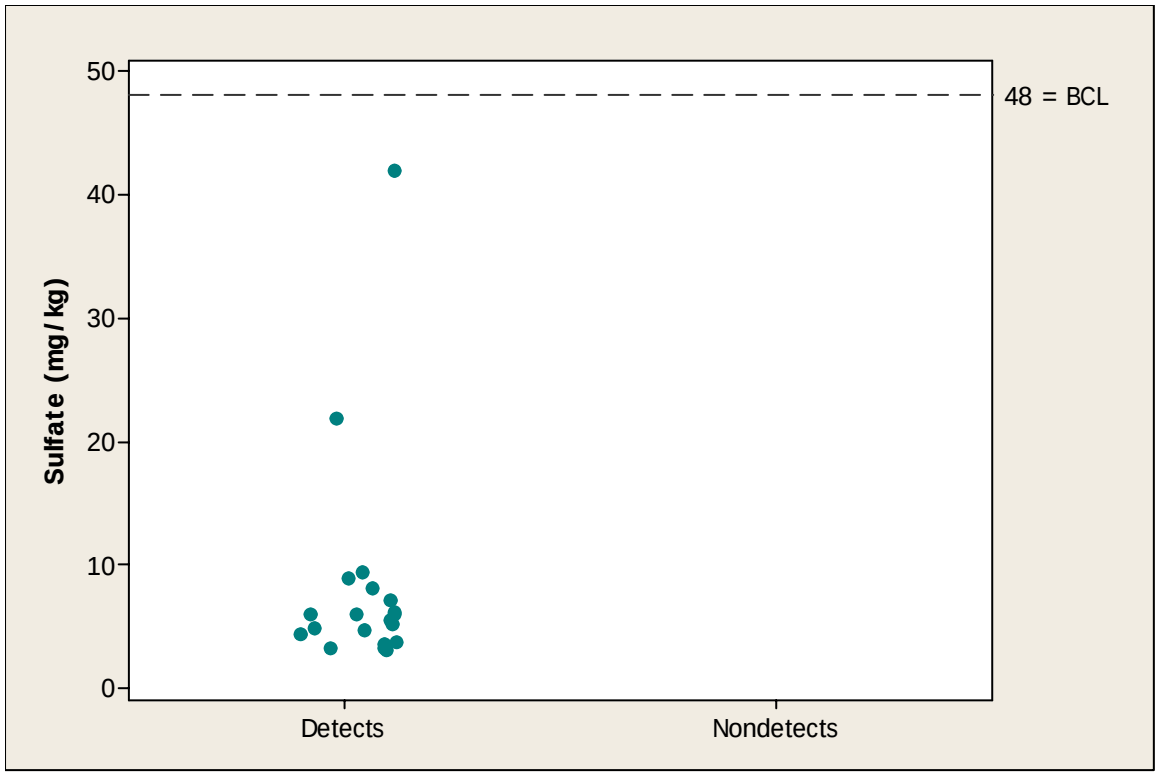


Figure D-1. Individual Value Plots with Background Concentration Limits for Soil

Corporation Yard Landfill, Folsom, CA



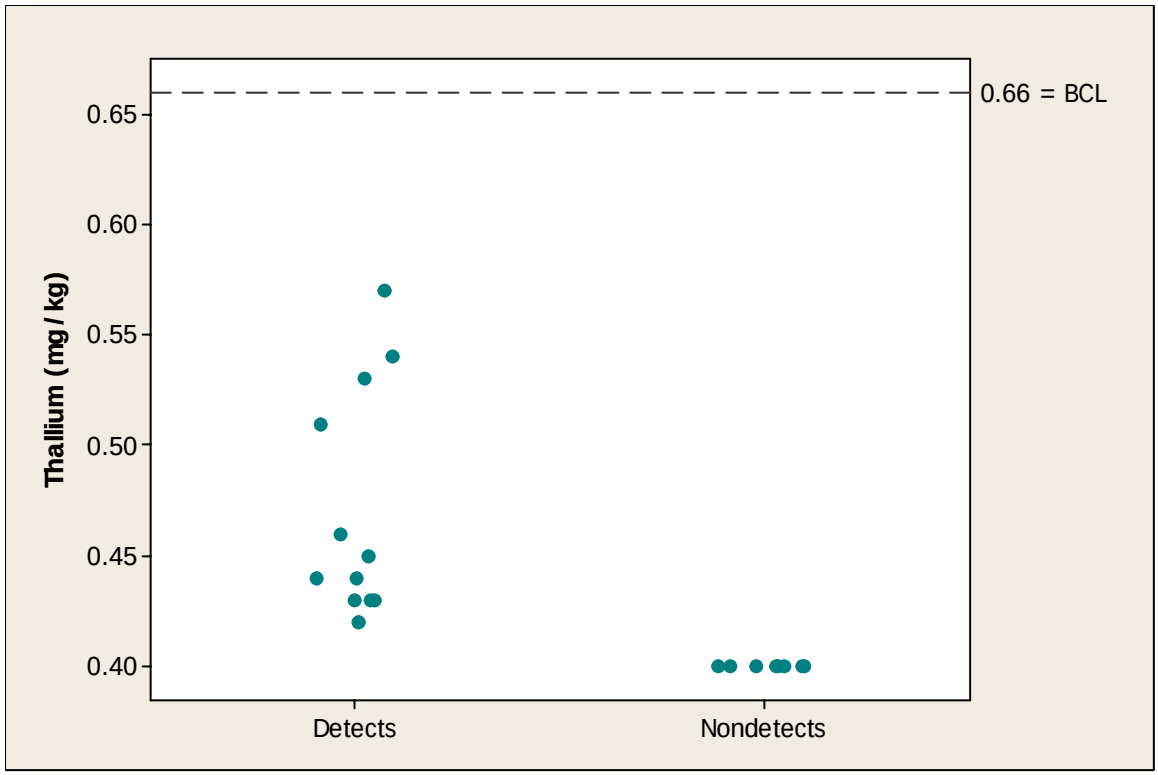


Figure D-1. Individual Value Plots with Background Concentration Limits for Soil

Corporation Yard Landfill, Folsom, CA