APPENDIX G

Phase I Environmental Site Assessment

LIMITED PHASE II SITE SCREENING

November 21, 2016

Vacant Land
Saratoga, Santa Clara County, California 95070
Assessor Parcel No. (APN): 389-06-20 & 389-06-21

Prepared for:
Mr. Mike Sneper
michaelsneper@gmail.com

Prepared by:
Phase-1 Environmental Services
5216 Harwood Rd
San Jose, CA 95124
(831) 422-2290

Phase-1
Environmental Services
5216 Harwood Road, San Jose, CA 95124

LIMITED PHASE II SOIL SAMPLING REPORT

SUBMITTED TO:

Mr. Mike Sneper
michaelsneper@gmail.com
3333 S. Bascom Ave., Campbell, CA
Ph: (650) 771-6167

SUBJECT PROPERTY:

APNs: 389-06-20 & 389-06-21
Saratoga, CA 95070

History Briefing

The Subject Property is being redeveloped for sensitive-receptor occupancy (retirement home facility). A Phase I ESA was performed at the Subject Property by Phase-1 ES in November 2015. This study identified that the site had a history of being part of a orchard from as early as 1944 through the mid-1970s. To clear the Property of environmental concerns, the Phase I recommended that the near surface soils be sampled and tested in accordance with the California DTSC guidelines for previous agricultural properties. Based on the size of the Property, a total of 4 discrete samples were recommended to be collected from 0-6" below grade surface, and at a minimum, analyzed for Organo-Chlorine Pesticides (OCPs) and Arsenic.

This document reports on the sampling and testing of soils from the Subject Property. All work was performed in accordance with the California DTSC and EPA Guidance for Sampling Agricultural Properties, Third Revision, dated; August 7, 2008 (copy in **Attachment B**).

Soil Collection

On November 07, 2016, a Phase-1 ES ASTM-Qualified Phase II Environmental Professional collected soil samples from 4 locations on the Property as shown on **Figure 2**. Soil samples were collected from between 0 and 6 inches Below Grade Surface (BGS) from each of the collection points using a spade shovel that was washed with TSP and water before, and between each sample collection. Samples were immediately placed in new 8-ounce glass sample jars, each of them discretely labeled, and placed on ice in an ice chest for transportation to a state certified analytical laboratory under documented Chain-of-Custody.

Analytical Laboratory Testing

The 4 samples were tested at BC Laboratories, Inc. of Bakersfield, CA (a state certified analytical laboratory) for Organochlorine Pesticides under EPA Method 8081A and for Arsenic and Copper metals under EPA Method 6010B. Laboratory analytical results and Chain-of-Custody documentation are contained in **Attachment A**.

Lab Analyses Results

Samples B-1, B-2, and B-3, contained no detectable quantities of Organochlorine Pesticides above laboratory detection limits. Sample B-4 was found to contain 0.0011 ppm of 4,4'-DDE and 0.0003 of 4,4'-DDT, which is well below residential Tier-1 ESLs. Arsenic was detected in B-1 @ 4.7 ppm, in B-2 @ 5.7 ppm, B-3 @ 4.6 ppm, and B-4 @ 3.4 ppm – all of which exceeded Tier-1 residential ESLs, however, all were within background range levels that are common for the San Francisco Bay Area region (see **Attachment C** 2011 study by Dylan Jacques Duvergé), and not actionable by regional standards. Copper was detected in all four samples at between 26 and 28 ppm, which are well below Tier-1 Residential ESLs.

Recommendations

No further environmental actions or studies regarding Organochlorine Pesticides or their respective Metals of concern are recommended for this Property. The shallow soils at this site do not appear to contain actionable levels of pesticides or metals under current regulatory agency residential and sensitive-receptor occupancy standards.

Limitations

This study was limited to the constituents that were analyzed for and is not representative of all materials that could exist on the site, such as fill or other import. Samples were collected from logical points in accordance with standard practices. Phase-1 ES is not responsible for conditions or materials at or on this site that were not made known or noted prior to the performance of this limited study.

Respectfully submitted this 21st day of November, 2016,
Phase-1 Environmental Services

Stuart G. Solomon – Principal Partner
Qualified Phase II Environmental Professional

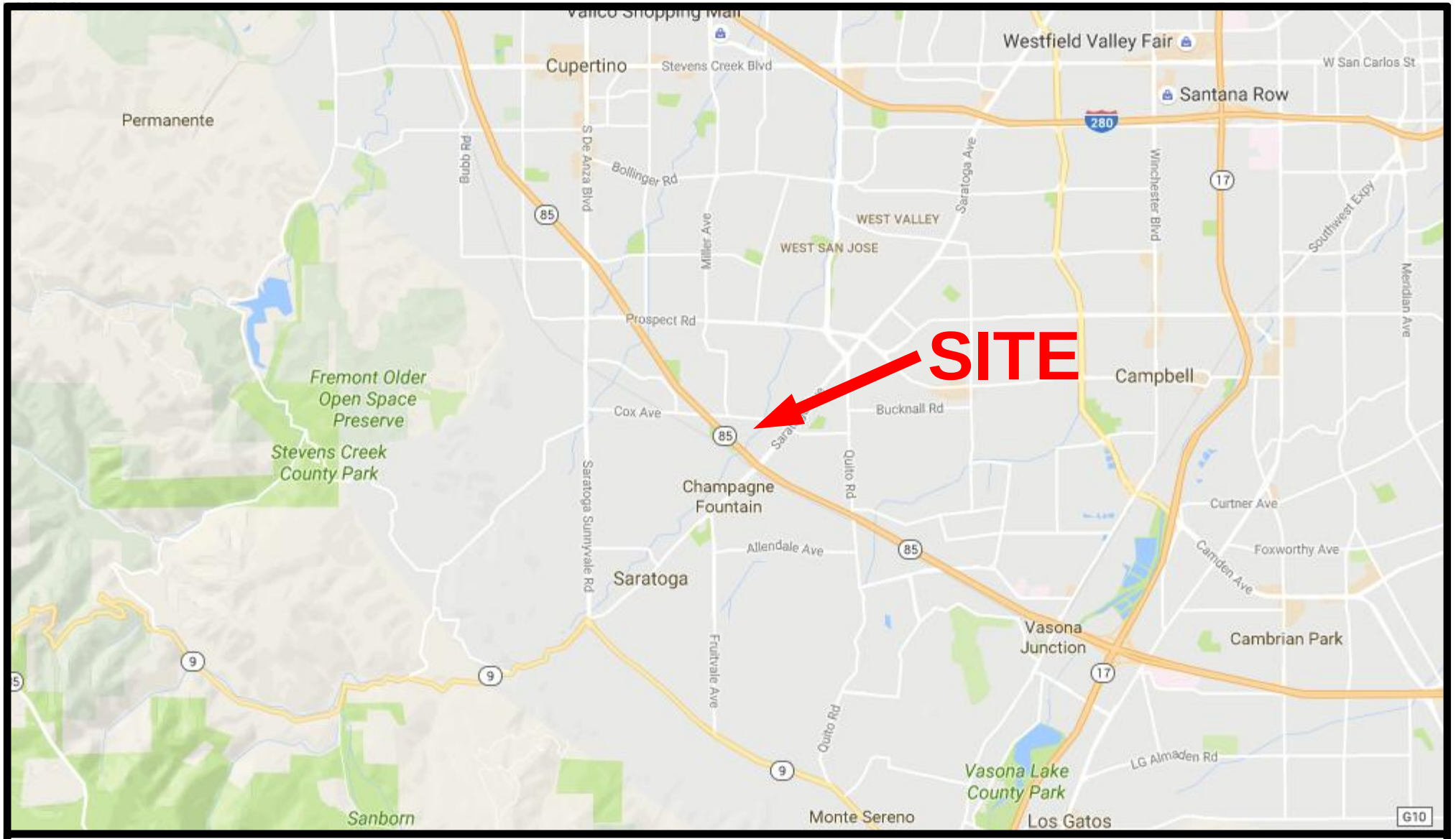
ASTM Phase I and II Environmental Professional
Stuart G. Solomon

Figures

1) Site Vicinity Map 2) Sample/Boring Locations 3) Parcel Map
4) Aerial Photograph 5) Topographical Map

Attachments

A) Boring Logs, Chain-of-Custody and Laboratory Analytical Report
B) California DTSC and EPA Guidance for Sampling Agricultural Properties
C) Bay Area Arsenic Background Study by Dylan Jacques Duvergé



Legend

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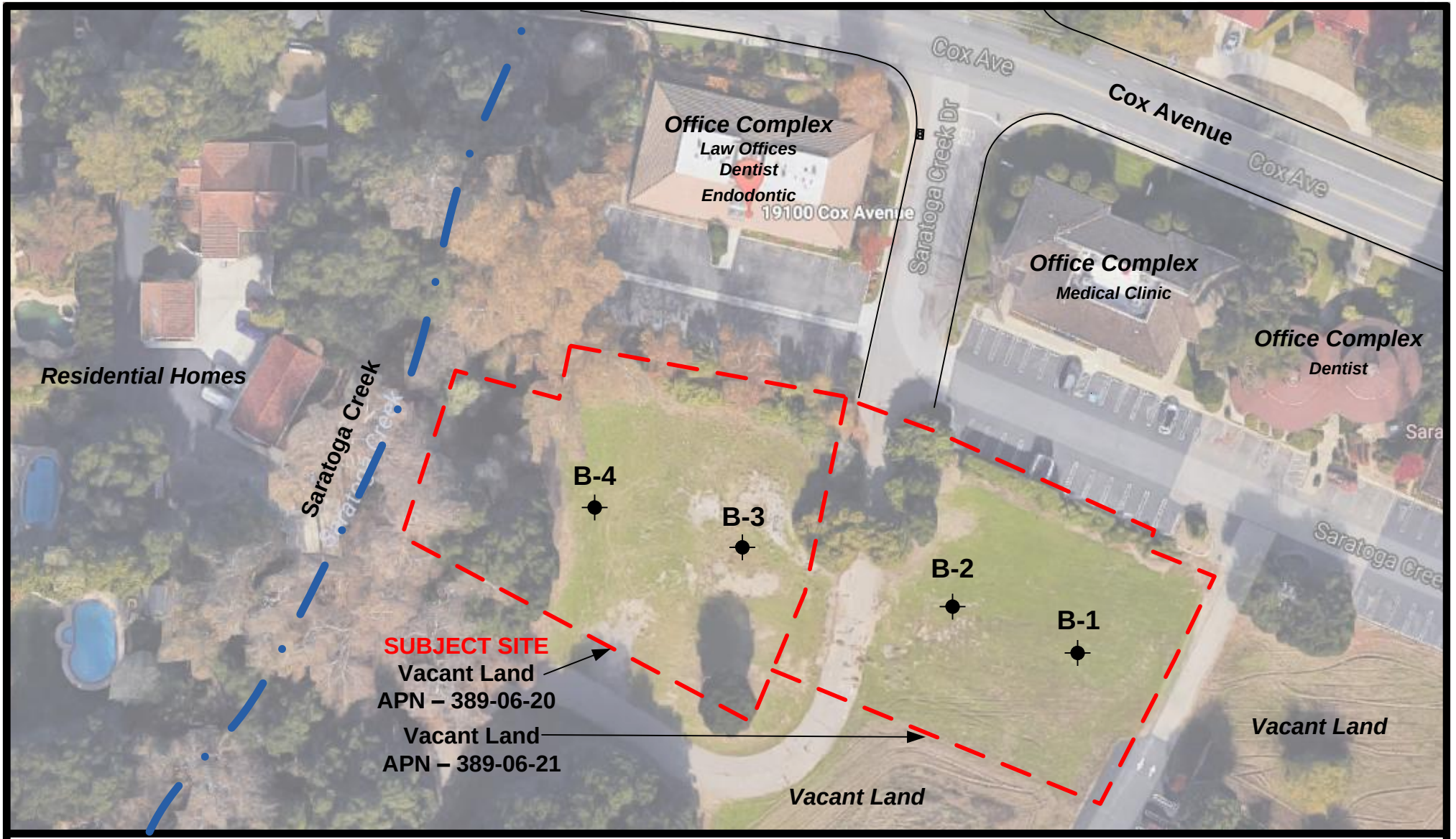
Environmental Services
Silicon Valley Environmental Group
www.phase-1environmental.com

Figure 1
SITE VICINITY MAP

COX Avenue Parcel #'s 389-06-20 & 389-06-21, Saratoga, CA 95070
Project Number: P5-10-19-16

N
W E
S



Legend

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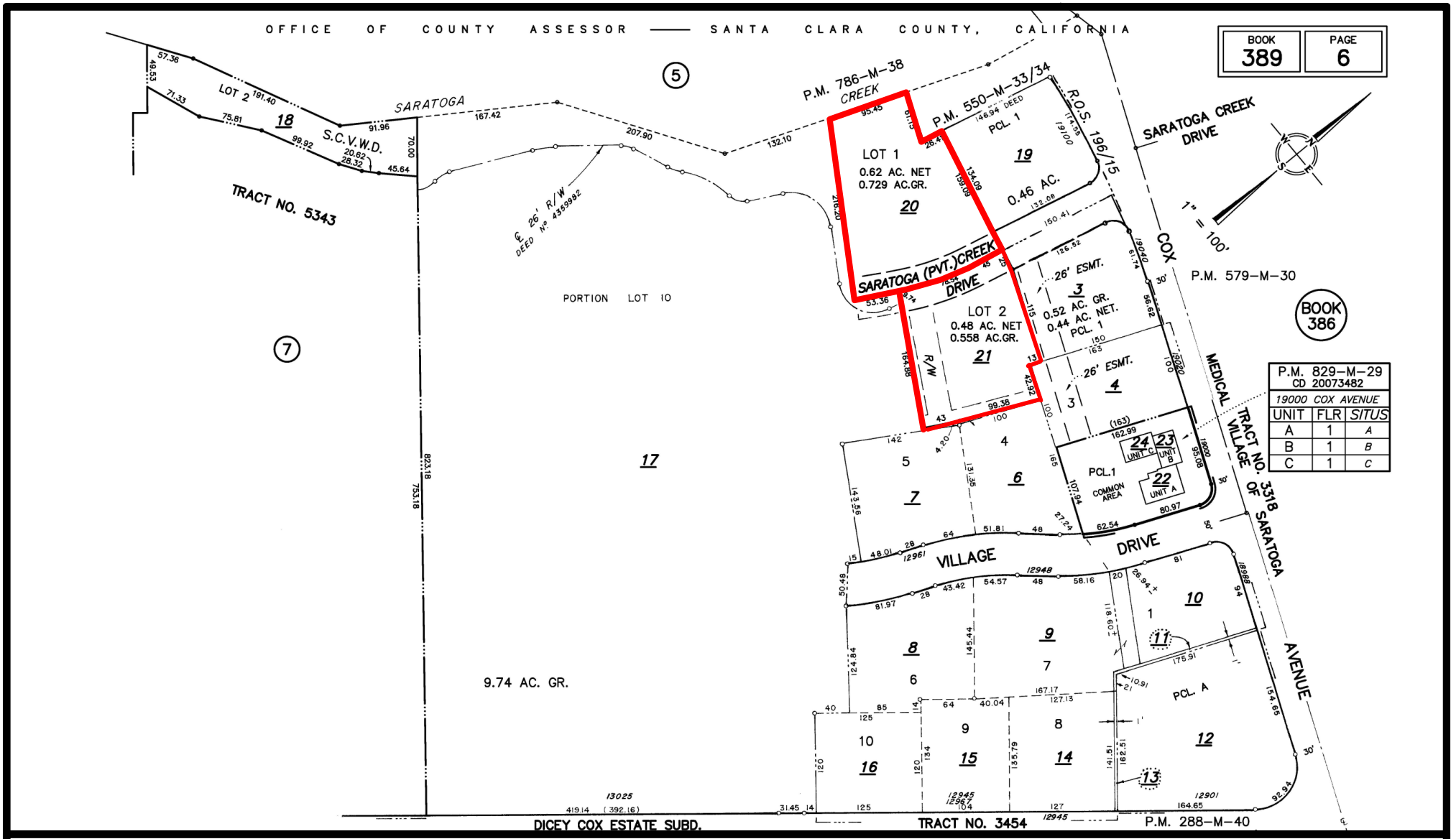
Figure 2
BORING LOCATIONS

COX Avenue Parcel #'s 389-06-20 & 389-06-21, Saratoga, CA 95070
Project Number: P5-10-19-16

N
W E
S



Legend

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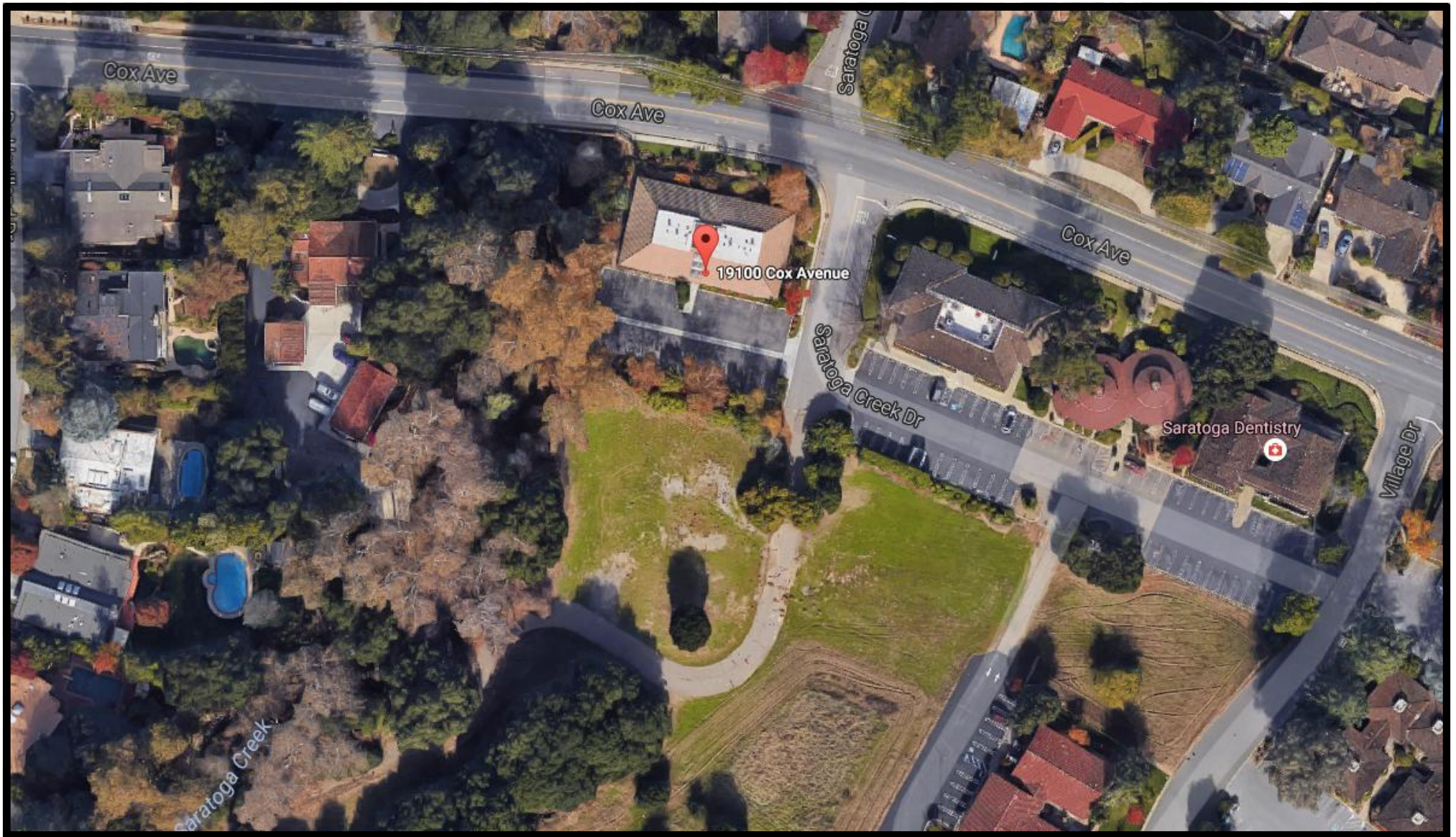
Figure 3
PARCEL OUTLINE

COX Avenue Parcel #'s 389-06-20 & 389-06-21, Saratoga, CA 95070
Project Number: P5-10-19-16



Legend

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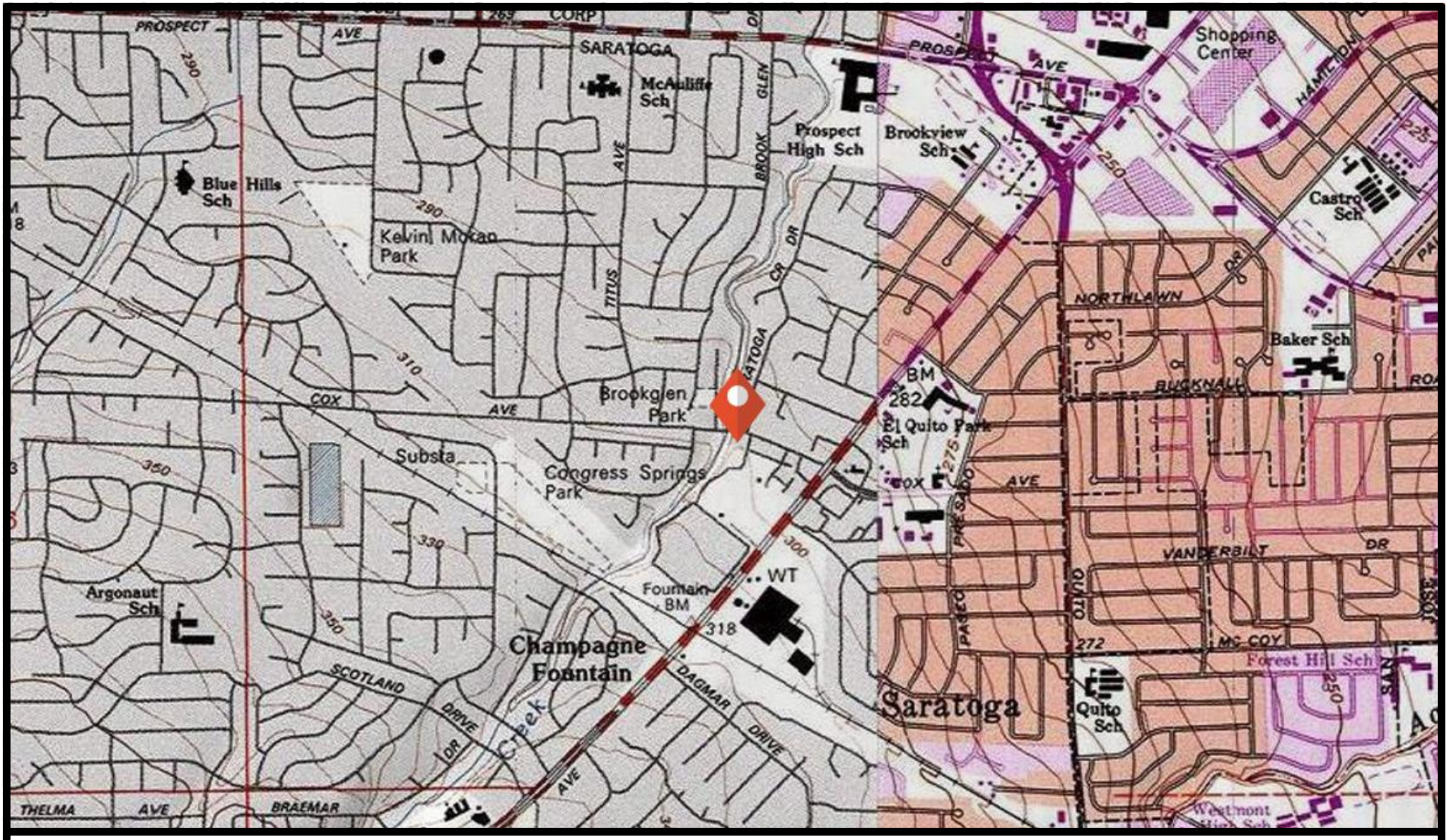
Figure 4
AERIAL PHOTOGRAPH

COX Avenue Parcel #'s 389-06-20 & 389-06-21, Saratoga, CA 95070
Project Number: P5-10-19-16

N
W E
S



Legend

Topographical Map: Cupertino, CA Map MRC: 37122C1

Site is approx. 300' Above MSL

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Figure 5

TOPOGRAPHICAL MAP

COX Avenue Parcel #'s 389-06-20 & 389-06-21, Saratoga, CA 95070

Project Number: P5-10-19-16

N

W E

S

Attachment A

Boring Logs, Chain-of-Custody & Laboratory Analytical Report

DATE 11/07/2016
PROJECT NAME Vacant Land – Saratoga CA
PROJECT NUMBER P5-10-19-16
PROJECT LOCATION San Jose, CA
GROUND ELEVATION
BORING DEPTH 6"
GROUND WATER LEVEL:
1ST ENCOUNTERED N/A

DRILLING CONTRACTOR Phase-1 Environmental
DRILLING METHOD 4" Hand Auger
LOGGED BY CGS
FIELD NOTES

Depth (ft)	Sample	Sample ID	Analyzed For	Odors or Discoloration	PID (ppm)	Lithology	SOIL DESCRIPTION
		B-1 (0'-6")	8081, 6010B (Arsenic), 6010 B (Copper)	None			Fill SILTY CLAY (CL): Light brown
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							
11							
12							
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14							
15							
16							
17							
18							
19							
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21							
22							
23							
24							
25							

WELL/BORING CONSTRUCTION DETAILS:
Backfilled with neat cement (Portland I/II)

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Environmental Services
Silicon Valley Environmental Group
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BORING LOG

Vacant Land – Saratoga, CA
APN's: 389-06-20 & 389-06-21

BORING
B-1

DATE 11/07/2016
PROJECT NAME Vacant Land – Saratoga CA
PROJECT NUMBER P5-10-19-16
PROJECT LOCATION San Jose, CA
GROUND ELEVATION
BORING DEPTH 6"
GROUND WATER LEVEL:
1ST ENCOUNTERED N/A

DRILLING CONTRACTOR Phase-1 Environmental
DRILLING METHOD 4" Hand Auger
LOGGED BY CGS
FIELD NOTES

Depth (ft)	Sample	Sample ID	Analyzed For	Odors or Discoloration	PID (ppm)	Lithology	SOIL DESCRIPTION
1	■	B-2 (0'-6")	8081, 6010B (Arsenic), 6010 B (Copper)	None			Fill SILTY CLAY (CL): Light brown
2							
3							
4							
5							
6							
7							
8							
9							
10							
11							
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20							
21							
22							
23							
24							
25							

WELL/BORING CONSTRUCTION DETAILS:
Backfilled with neat cement (Portland I/II)

Phase-1
Environmental Services
Silicon Valley Environmental Group
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BORING LOG

Vacant Land – Saratoga, CA
APN's: 389-06-20 & 389-06-21

BORING
B-2

DATE 11/07/2016
PROJECT NAME Vacant Land – Saratoga CA
PROJECT NUMBER P5-10-19-16
PROJECT LOCATION San Jose, CA
GROUND ELEVATION
BORING DEPTH 6"
GROUND WATER LEVEL:
1ST ENCOUNTERED N/A

DRILLING CONTRACTOR Phase-1 Environmental
DRILLING METHOD 4" Hand Auger
LOGGED BY CGS
FIELD NOTES

Depth (ft)	Sample	Sample ID	Analyzed For	Odors or Discoloration	PID (ppm)	Lithology	SOIL DESCRIPTION
1		B-3 (0'-6")	8081, 6010B (Arsenic), 6010 B (Copper)	None			Fill SILTY CLAY (CL): Light brown
2							
3							
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22							
23							
24							
25							

WELL/BORING CONSTRUCTION DETAILS:
Backfilled with neat cement (Portland I/II)

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Environmental Services
Silicon Valley Environmental Group
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BORING LOG

Vacant Land – Saratoga, CA
APN's: 389-06-20 & 389-06-21

BORING
B-3

DATE 11/07/2016
PROJECT NAME Vacant Land – Saratoga CA
PROJECT NUMBER P5-10-19-16
PROJECT LOCATION San Jose, CA
GROUND ELEVATION
BORING DEPTH 6"
GROUND WATER LEVEL:
1ST ENCOUNTERED N/A

DRILLING CONTRACTOR Phase-1 Environmental
DRILLING METHOD 4" Hand Auger
LOGGED BY CGS
FIELD NOTES

Depth (ft)	Sample	Sample ID	Analyzed For	Odors or Discoloration	PID (ppm)	Lithology	SOIL DESCRIPTION
1		B-4 (0'-6")	8081, 6010B (Arsenic), 6010 B (Copper)	None			Fill SILTY CLAY (CL): Light brown
2							
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25							

WELL/BORING CONSTRUCTION DETAILS:
Backfilled with neat cement (Portland I/II)

Phase-1
Environmental Services
Silicon Valley Environmental Group
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BORING LOG

Vacant Land – Saratoga, CA
APN's: 389-06-20 & 389-06-21

BORING
B-4

Date of Report: 11/21/2016

Stuart Solomon

Phase-1 Environmental Services
5216 Hardwood Road
Silicon Valley Environmental Group
San Jose, CA 95124

Client Project:	P5-10-19-16 Vacant Land APN 384-06-20 & 389-06-21
BCL Project:	Misc
BCL Work Order:	1631520
Invoice ID:	B252462

Enclosed are the results of analyses for samples received by the laboratory on 11/9/2016. If you have any questions concerning this report, please feel free to contact me.

Sincerely,

Contact Person: Felicia Johnson
Client Service Rep

Authorized Signature

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BC LABORATORIES, INC.

Chain of Custody Form

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Report To:
Client: PHASE-1 ENVIRONMENTAL
Attn: STUART SOLOMON
Street Address: 5216 HARWOOD RD
City, State, Zip: SAN JOSE, CA 95124
Phone: 831 422-2240 Fax:
Email: STUART@PHASE-1ENVIRONMENTAL.COM
Work Order #: 1610-31520

Project #: PS-10-19-16
Project Name: VACANT LAND
APN 384-06-20 + 384-06-21
Sampler(s): CHRIS
SOLOMON (CGS)

Analysis Requested

Please refer to the back of this page for completion instructions and method legend.

Comments:

Sample #	Description	Date Sampled	Time Sampled	8081 PESTICIDES	6010B - TOTAL ARSENIC	6010B - TOTAL COPPER	Sample Matrix: Soil	Sludge	Drinking Water	Ground Waater	Waste Water	Other	Notes
B-1	-1 0" - 6"	11/07/16	9:03Am	X	X	X	X						
B-2	-2 0" - 6"	11/07/16	9:15Am	X	X	X	X						
B-3	-3 0 - 6"	11/07/16	9:25Am	X	X	X	X						
B-4	-4 0 - 6"	11/07/16	9:55Am	X	X	X	X						

Result Request **Surcharge: ☐ STD (10 Days) ☐ 5 Day** ☐ 2 Day** ☐ 1 Day**

CHK BY ____ DISTRIBUTION ____ SUB-OUT ☐

Billing ☐ Same as above
Client:
Address:
City: State Zip
Attn:
P.O. #:

EDF Required? Geotracker ☐ Yes ☒ No
Send Copy to State of CA? (EDT) ☐ Yes ☒ No

Global ID (Needed for EDF)
System # (Needed for EDT)

		Date	Time			Date	Time
1. Relinquished By		11/7/16	2:00	1. Received By	BCL	11/07/16	1400
2. Relinquished By	BCL UPS 650	11/8/16	1601	2. Received By		11/9/16	915
3. Relinquished By				3. Received By			

BC Laboratories, Inc. – 4100 Atlas Ct. – Bakersfield, CA 93308 – 661.327.4911 – Fax: 661.327.1918 – www.bclabs.com

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Chain of Custody and Cooler Receipt Form for 1631520 Page 2 of 2

BC LABORATORIES INC. COOLER RECEIPT FORM Page 1 Of 1

Submission #: 16-31520

SHIPPING INFORMATION
Fed Ex ☐ UPS ☐ Ontrac ☐ Hand Delivery ☐
BC Lab Field Service ☐ Other ☐ (Specify) GSO

SHIPPING CONTAINER
Ice Chest ☑ None ☐ Box ☐
Other ☐ (Specify)

FREE LIQUID
YES ☐ NO ☐
W / S

Refrigerant: Ice ☑ Blue Ice ☐ None ☐ Other ☐ Comments:

Custody Seals Ice Chest ☐ Intact? Yes ☐ No ☐ Containers ☐ Intact? Yes ☐ No ☐ None ☑ Comments:

All samples received? Yes ☒ No ☐ All samples containers intact? Yes ☑ No ☐ Description(s) match COC? Yes ☒ No ☐

COC Received ☑ YES ☐ NO

Emissivity: 0.97 Container: PE Thermometer ID: 208 Date/Time 11/9/16

Temperature: (A) 5.0 °C / (C) 5.0 °C Analyst Init DSC 915

SAMPLE CONTAINERS	SAMPLE NUMBERS 1	2	3	4	5	6	7	8	9	10
QT PE UNPRES										
4oz / 8oz / 16oz PE UNPRES										
2oz Cr^{+6}										
QT INORGANIC CHEMICAL METALS										
INORGANIC CHEMICAL METALS 4oz / 8oz / 16oz										
PT CYANIDE										
PT NITROGEN FORMS										
PT TOTAL SULFIDE										
2oz. NITRATE / NITRITE										
PT TOTAL ORGANIC CARBON										
PT CHEMICAL OXYGEN DEMAND										
PtA PHENOLICS										
40ml VOA VIAL TRAVEL BLANK										
40ml VOA VIAL										
QT EPA 1664										
PT ODOR										
RADIOLOGICAL										
BACTERIOLOGICAL										
40 ml VOA VIAL- 504										
QT EPA 508/608/8080										
QT EPA 515.1/8150										
QT EPA 525										
QT EPA 525 TRAVEL BLANK										
40ml EPA 547										
40ml EPA 531.1										
8oz EPA 548										
QT EPA 549										
QT EPA 8015M										
QT EPA 8270										
8oz / 16oz / 32oz AMBER Jar	A	A	A	A						
8oz / 16oz / 32oz JAR										
SOIL SLEEVE										
PCB VIAL										
PLASTIC BAG										
TEDLAR BAG										
FERROUS IRON										
ENCORE										
SMART KIT										
SUMMA CANISTER										

Comments:
Sample Numbering Completed By: Date/Time: 11-9-16 1825
A = Actual / C = Corrected

Rev 21 05/23/2016
[S:\WPDoc\WordPerfect\LAB_DOCS\FORMS\SAMREC rev 20]

Phase-1 Environmental Services 5216 Hardwood Road Silicon Valley Environmental Group San Jose, CA 95124	**Reported:** 11/21/2016 14:38 Project: Misc Project Number: P5-10-19-16 Vacant Land APN 384-06-20 & 389-06- Project Manager: Stuart Solomon

Laboratory / Client Sample Cross Reference

Laboratory	Client Sample Information			
1631520-01	**COC Number:**	---	**Receive Date:**	11/09/2016 09:15
	Project Number:	---	**Sampling Date:**	11/07/2016 09:03
	Sampling Location:	---	**Sample Depth:**	---
	Sampling Point:	B-1 0"-6"	**Lab Matrix:**	Solids
	Sampled By:	Chris Solomon	**Sample Type:**	Soil
1631520-02	**COC Number:**	---	**Receive Date:**	11/09/2016 09:15
	Project Number:	---	**Sampling Date:**	11/07/2016 09:15
	Sampling Location:	---	**Sample Depth:**	---
	Sampling Point:	B-2 0"-6"	**Lab Matrix:**	Solids
	Sampled By:	Chris Solomon	**Sample Type:**	Soil
1631520-03	**COC Number:**	---	**Receive Date:**	11/09/2016 09:15
	Project Number:	---	**Sampling Date:**	11/07/2016 09:25
	Sampling Location:	---	**Sample Depth:**	---
	Sampling Point:	B-3 0"-6"	**Lab Matrix:**	Solids
	Sampled By:	Chris Solomon	**Sample Type:**	Soil
1631520-04	**COC Number:**	---	**Receive Date:**	11/09/2016 09:15
	Project Number:	---	**Sampling Date:**	11/07/2016 09:55
	Sampling Location:	---	**Sample Depth:**	---
	Sampling Point:	B-4 0"-6"	**Lab Matrix:**	Solids
	Sampled By:	Chris Solomon	**Sample Type:**	Soil

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Phase-1 Environmental Services 5216 Hardwood Road Silicon Valley Environmental Group San Jose, CA 95124	**Reported:** 11/21/2016 14:38 Project: Misc Project Number: P5-10-19-16 Vacant Land APN 384-06-20 & 389-06- Project Manager: Stuart Solomon

Organochlorine Pesticides (EPA Method 8081A)

BCL Sample ID: 1631520-01 | **Client Sample Name:** B-1 0"-6", 11/7/2016 9:03:00AM, Chris Solomon

Constituent	Result	Units	PQL	MDL	Method	TTLC Limits	Lab Quals	Run #
Aldrin	ND	mg/kg	0.00050	0.000055	EPA-8081A	1.4		1
alpha-BHC	ND	mg/kg	0.00050	0.000064	EPA-8081A			1
beta-BHC	ND	mg/kg	0.00050	0.000071	EPA-8081A			1
delta-BHC	ND	mg/kg	0.00050	0.000059	EPA-8081A			1
gamma-BHC (Lindane)	ND	mg/kg	0.00050	0.000034	EPA-8081A	4.0		1
Chlordane (Technical)	ND	mg/kg	0.050	0.0015	EPA-8081A	2.5		1
4,4'-DDD	ND	mg/kg	0.00050	0.000085	EPA-8081A	1.0		1
4,4'-DDE	ND	mg/kg	0.00050	0.000083	EPA-8081A	1.0		1
4,4'-DDT	ND	mg/kg	0.00050	0.000078	EPA-8081A	1.0		1
Dieldrin	ND	mg/kg	0.00050	0.000070	EPA-8081A	8.0		1
Endosulfan I	ND	mg/kg	0.00050	0.000087	EPA-8081A			1
Endosulfan II	ND	mg/kg	0.00050	0.00011	EPA-8081A			1
Endosulfan sulfate	ND	mg/kg	0.00050	0.000099	EPA-8081A			1
Endrin	ND	mg/kg	0.00050	0.000087	EPA-8081A	0.2		1
Endrin aldehyde	ND	mg/kg	0.00050	0.000097	EPA-8081A			1
Heptachlor	ND	mg/kg	0.00050	0.000057	EPA-8081A	4.7		1
Heptachlor epoxide	ND	mg/kg	0.00050	0.000078	EPA-8081A			1
Methoxychlor	ND	mg/kg	0.00050	0.00011	EPA-8081A	100		1
Toxaphene	ND	mg/kg	0.050	0.0013	EPA-8081A	5		1
TCMX (Surrogate)	68.1	%	20 - 130 (LCL - UCL)		EPA-8081A			1
Decachlorobiphenyl (Surrogate)	63.7	%	40 - 130 (LCL - UCL)		EPA-8081A			1

Run #	Method	Prep Date	Run Date/Time	Analyst	Instrument	Dilution	QC Batch ID
1	EPA-8081A	11/11/16	11/14/16 14:17	HKS	GC-17	1.017	BZK1333

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Phase-1 Environmental Services 5216 Hardwood Road Silicon Valley Environmental Group San Jose, CA 95124	**Reported:** 11/21/2016 14:38 Project: Misc Project Number: P5-10-19-16 Vacant Land APN 384-06-20 & 389-06- Project Manager: Stuart Solomon

Total Concentrations (TTLC)

BCL Sample ID: 1631520-01 | **Client Sample Name:** B-1 0"-6", 11/7/2016 9:03:00AM, Chris Solomon

Constituent	Result	Units	PQL	MDL	Method	TTLC Limits	Lab Quals	Run #
Arsenic	**4.7**	**mg/kg**	**1.0**	**0.40**	**EPA-6010B**	500		1
Copper	**28**	**mg/kg**	**1.0**	**0.050**	**EPA-6010B**	2500		1

Run #	Method	Prep Date	Run Date/Time	Analyst	Instrument	Dilution	QC Batch ID
1	EPA-6010B	11/18/16	11/18/16 15:24	JRG	PE-OP2	0.980	BZK1778

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Phase-1 Environmental Services 5216 Hardwood Road Silicon Valley Environmental Group San Jose, CA 95124	**Reported:** 11/21/2016 14:38 Project: Misc Project Number: P5-10-19-16 Vacant Land APN 384-06-20 & 389-06- Project Manager: Stuart Solomon

Organochlorine Pesticides (EPA Method 8081A)

BCL Sample ID: 1631520-02 | **Client Sample Name:** B-2 0"-6", 11/7/2016 9:15:00AM, Chris Solomon

Constituent	Result	Units	PQL	MDL	Method	TTLC Limits	Lab Quals	Run #
Aldrin	ND	mg/kg	0.00050	0.000055	EPA-8081A	1.4		1
alpha-BHC	ND	mg/kg	0.00050	0.000064	EPA-8081A			1
beta-BHC	ND	mg/kg	0.00050	0.000071	EPA-8081A			1
delta-BHC	ND	mg/kg	0.00050	0.000059	EPA-8081A			1
gamma-BHC (Lindane)	ND	mg/kg	0.00050	0.000034	EPA-8081A	4.0		1
Chlordane (Technical)	ND	mg/kg	0.050	0.0015	EPA-8081A	2.5		1
4,4'-DDD	ND	mg/kg	0.00050	0.000085	EPA-8081A	1.0		1
4,4'-DDE	ND	mg/kg	0.00050	0.000083	EPA-8081A	1.0		1
4,4'-DDT	ND	mg/kg	0.00050	0.000078	EPA-8081A	1.0		1
Dieldrin	ND	mg/kg	0.00050	0.000070	EPA-8081A	8.0		1
Endosulfan I	ND	mg/kg	0.00050	0.000087	EPA-8081A			1
Endosulfan II	ND	mg/kg	0.00050	0.00011	EPA-8081A			1
Endosulfan sulfate	ND	mg/kg	0.00050	0.000099	EPA-8081A			1
Endrin	ND	mg/kg	0.00050	0.000087	EPA-8081A	0.2		1
Endrin aldehyde	ND	mg/kg	0.00050	0.000097	EPA-8081A			1
Heptachlor	ND	mg/kg	0.00050	0.000057	EPA-8081A	4.7		1
Heptachlor epoxide	ND	mg/kg	0.00050	0.000078	EPA-8081A			1
Methoxychlor	ND	mg/kg	0.00050	0.00011	EPA-8081A	100		1
Toxaphene	ND	mg/kg	0.050	0.0013	EPA-8081A	5		1
TCMX (Surrogate)	65.2	%	20 - 130 (LCL - UCL)		EPA-8081A			1
Decachlorobiphenyl (Surrogate)	60.0	%	40 - 130 (LCL - UCL)		EPA-8081A			1

Run #	Method	Prep Date	Run Date/Time	Analyst	Instrument	Dilution	QC Batch ID
1	EPA-8081A	11/11/16	11/14/16 14:32	HKS	GC-17	0.993	BZK1333

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Phase-1 Environmental Services 5216 Hardwood Road Silicon Valley Environmental Group San Jose, CA 95124	**Reported:** 11/21/2016 14:38 Project: Misc Project Number: P5-10-19-16 Vacant Land APN 384-06-20 & 389-06- Project Manager: Stuart Solomon

Total Concentrations (TTLC)

BCL Sample ID: 1631520-02 | **Client Sample Name:** B-2 0"-6", 11/7/2016 9:15:00AM, Chris Solomon

Constituent	Result	Units	PQL	MDL	Method	TTLC Limits	Lab Quals	Run #
Arsenic	**5.7**	**mg/kg**	**1.0**	**0.40**	**EPA-6010B**	500		1
Copper	**28**	**mg/kg**	**1.0**	**0.050**	**EPA-6010B**	2500		1

Run #	Method	Prep Date	Run Date/Time	Analyst	Instrument	Dilution	QC Batch ID
1	EPA-6010B	11/18/16	11/18/16 15:26	JRG	PE-OP2	0.971	BZK1778

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Phase-1 Environmental Services 5216 Hardwood Road Silicon Valley Environmental Group San Jose, CA 95124	**Reported:** 11/21/2016 14:38 Project: Misc Project Number: P5-10-19-16 Vacant Land APN 384-06-20 & 389-06- Project Manager: Stuart Solomon

Organochlorine Pesticides (EPA Method 8081A)

BCL Sample ID: 1631520-03 | **Client Sample Name:** B-3 0"-6", 11/7/2016 9:25:00AM, Chris Solomon

Constituent	Result	Units	PQL	MDL	Method	TTLC Limits	Lab Quals	Run #
Aldrin	ND	mg/kg	0.00050	0.000055	EPA-8081A	1.4		1
alpha-BHC	ND	mg/kg	0.00050	0.000064	EPA-8081A			1
beta-BHC	ND	mg/kg	0.00050	0.000071	EPA-8081A			1
delta-BHC	ND	mg/kg	0.00050	0.000059	EPA-8081A			1
gamma-BHC (Lindane)	ND	mg/kg	0.00050	0.000034	EPA-8081A	4.0		1
Chlordane (Technical)	ND	mg/kg	0.050	0.0015	EPA-8081A	2.5		1
4,4'-DDD	ND	mg/kg	0.00050	0.000085	EPA-8081A	1.0		1
4,4'-DDE	ND	mg/kg	0.00050	0.000083	EPA-8081A	1.0		1
4,4'-DDT	ND	mg/kg	0.00050	0.000078	EPA-8081A	1.0		1
Dieldrin	ND	mg/kg	0.00050	0.000070	EPA-8081A	8.0		1
Endosulfan I	ND	mg/kg	0.00050	0.000087	EPA-8081A			1
Endosulfan II	ND	mg/kg	0.00050	0.00011	EPA-8081A			1
Endosulfan sulfate	ND	mg/kg	0.00050	0.000099	EPA-8081A			1
Endrin	ND	mg/kg	0.00050	0.000087	EPA-8081A	0.2		1
Endrin aldehyde	ND	mg/kg	0.00050	0.000097	EPA-8081A			1
Heptachlor	ND	mg/kg	0.00050	0.000057	EPA-8081A	4.7		1
Heptachlor epoxide	ND	mg/kg	0.00050	0.000078	EPA-8081A			1
Methoxychlor	ND	mg/kg	0.00050	0.00011	EPA-8081A	100		1
Toxaphene	ND	mg/kg	0.050	0.0013	EPA-8081A	5		1
TCMX (Surrogate)	51.1	%	20 - 130 (LCL - UCL)		EPA-8081A			1
Decachlorobiphenyl (Surrogate)	46.4	%	40 - 130 (LCL - UCL)		EPA-8081A			1

Run #	Method	Prep Date	Run Date/Time	Analyst	Instrument	Dilution	QC Batch ID
1	EPA-8081A	11/11/16	11/14/16 14:46	HKS	GC-17	1.017	BZK1333

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Phase-1 Environmental Services 5216 Hardwood Road Silicon Valley Environmental Group San Jose, CA 95124	**Reported:** 11/21/2016 14:38 Project: Misc Project Number: P5-10-19-16 Vacant Land APN 384-06-20 & 389-06- Project Manager: Stuart Solomon

Total Concentrations (TTLC)

BCL Sample ID: 1631520-03 | **Client Sample Name:** B-3 0"-6", 11/7/2016 9:25:00AM, Chris Solomon

Constituent	Result	Units	PQL	MDL	Method	TTLC Limits	Lab Quals	Run #
Arsenic	**4.6**	**mg/kg**	**1.0**	**0.40**	**EPA-6010B**	500		1
Copper	**27**	**mg/kg**	**1.0**	**0.050**	**EPA-6010B**	2500		1

Run #	Method	Prep Date	Run Date/Time	Analyst	Instrument	Dilution	QC Batch ID
1	EPA-6010B	11/18/16	11/18/16 15:27	JRG	PE-OP2	0.980	BZK1778

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Phase-1 Environmental Services
5216 Hardwood Road
Silicon Valley Environmental Group
San Jose, CA 95124

Reported: 11/21/2016 14:38
Project: Misc
Project Number: P5-10-19-16 Vacant Land APN 384-06-20 & 389-06-
Project Manager: Stuart Solomon

Organochlorine Pesticides (EPA Method 8081A)

BCL Sample ID: 1631520-04 | **Client Sample Name:** B-4 0"-6", 11/7/2016 9:55:00AM, Chris Solomon

Constituent	Result	Units	PQL	MDL	Method	TTLC Limits	Lab Quals	Run #
Aldrin	ND	mg/kg	0.00050	0.000055	EPA-8081A	1.4		1
alpha-BHC	ND	mg/kg	0.00050	0.000064	EPA-8081A			1
beta-BHC	ND	mg/kg	0.00050	0.000071	EPA-8081A			1
delta-BHC	ND	mg/kg	0.00050	0.000059	EPA-8081A			1
gamma-BHC (Lindane)	ND	mg/kg	0.00050	0.000034	EPA-8081A	4.0		1
Chlordane (Technical)	ND	mg/kg	0.050	0.0015	EPA-8081A	2.5		1
4,4'-DDD	ND	mg/kg	0.00050	0.000085	EPA-8081A	1.0		1
4,4'-DDE	**0.0011**	**mg/kg**	**0.00050**	**0.000083**	**EPA-8081A**	1.0		1
4,4'-DDT	**0.00031**	**mg/kg**	**0.00050**	**0.000078**	**EPA-8081A**	1.0	**J**	1
Dieldrin	ND	mg/kg	0.00050	0.000070	EPA-8081A	8.0		1
Endosulfan I	ND	mg/kg	0.00050	0.000087	EPA-8081A			1
Endosulfan II	ND	mg/kg	0.00050	0.00011	EPA-8081A			1
Endosulfan sulfate	ND	mg/kg	0.00050	0.000099	EPA-8081A			1
Endrin	ND	mg/kg	0.00050	0.000087	EPA-8081A	0.2		1
Endrin aldehyde	ND	mg/kg	0.00050	0.000097	EPA-8081A			1
Heptachlor	ND	mg/kg	0.00050	0.000057	EPA-8081A	4.7		1
Heptachlor epoxide	ND	mg/kg	0.00050	0.000078	EPA-8081A			1
Methoxychlor	ND	mg/kg	0.00050	0.00011	EPA-8081A	100		1
Toxaphene	ND	mg/kg	0.050	0.0013	EPA-8081A	5		1
TCMX (Surrogate)	86.8	%	20 - 130 (LCL - UCL)		EPA-8081A			1
Decachlorobiphenyl (Surrogate)	73.2	%	40 - 130 (LCL - UCL)		EPA-8081A			1

Run #	Method	Prep Date	Run Date/Time	Analyst	Instrument	Dilution	QC Batch ID
1	EPA-8081A	11/11/16	11/14/16 15:45	HKS	GC-17	0.984	BZK1333

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Phase-1 Environmental Services 5216 Hardwood Road Silicon Valley Environmental Group San Jose, CA 95124	**Reported:** 11/21/2016 14:38 Project: Misc Project Number: P5-10-19-16 Vacant Land APN 384-06-20 & 389-06- Project Manager: Stuart Solomon

Total Concentrations (TTLC)

BCL Sample ID: 1631520-04 | **Client Sample Name:** B-4 0"-6", 11/7/2016 9:55:00AM, Chris Solomon

Constituent	Result	Units	PQL	MDL	Method	TTLC Limits	Lab Quals	Run #
Arsenic	**3.4**	**mg/kg**	**1.0**	**0.40**	**EPA-6010B**	500		1
Copper	**26**	**mg/kg**	**1.0**	**0.050**	**EPA-6010B**	2500		1

Run #	Method	Prep Date	Run Date/Time	Analyst	Instrument	Dilution	QC Batch ID
1	EPA-6010B	11/18/16	11/18/16 15:28	JRG	PE-OP2	0.943	BZK1778

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Phase-1 Environmental Services 5216 Hardwood Road Silicon Valley Environmental Group San Jose, CA 95124	**Reported:** 11/21/2016 14:38 Project: Misc Project Number: P5-10-19-16 Vacant Land APN 384-06-20 & 389-06- Project Manager: Stuart Solomon

Organochlorine Pesticides (EPA Method 8081A)

Quality Control Report - Method Blank Analysis

Constituent	QC Sample ID	MB Result	Units	PQL	MDL	Lab Quals
QC Batch ID: BZK1333						
Aldrin	BZK1333-BLK1	ND	mg/kg	0.00050	0.000055	
alpha-BHC	BZK1333-BLK1	ND	mg/kg	0.00050	0.000064	
beta-BHC	BZK1333-BLK1	ND	mg/kg	0.00050	0.000071	
delta-BHC	BZK1333-BLK1	ND	mg/kg	0.00050	0.000059	
gamma-BHC (Lindane)	BZK1333-BLK1	ND	mg/kg	0.00050	0.000034	
Chlordane (Technical)	BZK1333-BLK1	ND	mg/kg	0.050	0.0015	
4,4'-DDD	BZK1333-BLK1	ND	mg/kg	0.00050	0.000085	
4,4'-DDE	BZK1333-BLK1	ND	mg/kg	0.00050	0.000083	
4,4'-DDT	BZK1333-BLK1	ND	mg/kg	0.00050	0.000078	
Dieldrin	BZK1333-BLK1	ND	mg/kg	0.00050	0.000070	
Endosulfan I	BZK1333-BLK1	ND	mg/kg	0.00050	0.000087	
Endosulfan II	BZK1333-BLK1	ND	mg/kg	0.00050	0.00011	
Endosulfan sulfate	BZK1333-BLK1	ND	mg/kg	0.00050	0.000099	
Endrin	BZK1333-BLK1	ND	mg/kg	0.00050	0.000087	
Endrin aldehyde	BZK1333-BLK1	ND	mg/kg	0.00050	0.000097	
Heptachlor	BZK1333-BLK1	ND	mg/kg	0.00050	0.000057	
Heptachlor epoxide	BZK1333-BLK1	ND	mg/kg	0.00050	0.000078	
Methoxychlor	BZK1333-BLK1	ND	mg/kg	0.00050	0.00011	
Toxaphene	BZK1333-BLK1	ND	mg/kg	0.050	0.0013	
TCMX (Surrogate)	**BZK1333-BLK1**	**104**	%	**20 - 130 (LCL - UCL)**		
Decachlorobiphenyl (Surrogate)	**BZK1333-BLK1**	**92.6**	%	**40 - 130 (LCL - UCL)**		

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Phase-1 Environmental Services 5216 Hardwood Road Silicon Valley Environmental Group San Jose, CA 95124	**Reported:** 11/21/2016 14:38 Project: Misc Project Number: P5-10-19-16 Vacant Land APN 384-06-20 & 389-06- Project Manager: Stuart Solomon

Organochlorine Pesticides (EPA Method 8081A)

Quality Control Report - Laboratory Control Sample

Constituent	QC Sample ID	Type	Result	Spike Level	Units	Percent Recovery	RPD	Control Limits Percent Recovery	Control Limits RPD	Lab Quals
QC Batch ID: BZK1333										
Aldrin	BZK1333-BS1	LCS	0.0049158	0.0049342	mg/kg	99.6		70 - 130		
gamma-BHC (Lindane)	BZK1333-BS1	LCS	0.0052895	0.0049342	mg/kg	107		60 - 140		
4,4'-DDT	BZK1333-BS1	LCS	0.0054977	0.0049342	mg/kg	111		60 - 140		
Dieldrin	BZK1333-BS1	LCS	0.0048740	0.0049342	mg/kg	98.8		70 - 130		
Endrin	BZK1333-BS1	LCS	0.0051974	0.0049342	mg/kg	105		60 - 140		
Heptachlor	BZK1333-BS1	LCS	0.0051803	0.0049342	mg/kg	105		60 - 140		
TCMX (Surrogate)	BZK1333-BS1	LCS	0.0095076	0.0098684	mg/kg	96.3		20 - 130		
Decachlorobiphenyl (Surrogate)	BZK1333-BS1	LCS	0.017909	0.019737	mg/kg	90.7		40 - 130		

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Phase-1 Environmental Services 5216 Hardwood Road Silicon Valley Environmental Group San Jose, CA 95124	**Reported:** 11/21/2016 14:38 Project: Misc Project Number: P5-10-19-16 Vacant Land APN 384-06-20 & 389-06- Project Manager: Stuart Solomon

Organochlorine Pesticides (EPA Method 8081A)

Quality Control Report - Precision & Accuracy

Constituent	Type	Source Sample ID	Source Result	Result	Spike Added	Units	RPD	Percent Recovery	Control Limits RPD	Control Limits Percent Recovery	Lab Quals
QC Batch ID: BZK1333	Used client sample: N										
Aldrin	MS	1625251-57	ND	0.0048660	0.0050505	mg/kg		96.3		50 - 140	
	MSD	1625251-57	ND	0.0047754	0.0050505	mg/kg	1.9	94.6	30	50 - 140	
gamma-BHC (Lindane)	MS	1625251-57	ND	0.0049949	0.0050505	mg/kg		98.9		50 - 140	
	MSD	1625251-57	ND	0.0049108	0.0050505	mg/kg	1.7	97.2	30	50 - 140	
4,4'-DDT	MS	1625251-57	ND	0.0056542	0.0050505	mg/kg		112		50 - 140	
	MSD	1625251-57	ND	0.0057303	0.0050505	mg/kg	1.3	113	30	50 - 140	
Dieldrin	MS	1625251-57	ND	0.0049609	0.0050505	mg/kg		98.2		40 - 140	
	MSD	1625251-57	ND	0.0049094	0.0050505	mg/kg	1.0	97.2	30	40 - 140	
Endrin	MS	1625251-57	ND	0.0053865	0.0050505	mg/kg		107		50 - 150	
	MSD	1625251-57	ND	0.0054084	0.0050505	mg/kg	0.4	107	30	50 - 150	
Heptachlor	MS	1625251-57	ND	0.0050128	0.0050505	mg/kg		99.3		60 - 140	
	MSD	1625251-57	ND	0.0049623	0.0050505	mg/kg	1.0	98.3	30	60 - 140	
TCMX (Surrogate)	MS	1625251-57	ND	0.0096606	0.010101	mg/kg		95.6		20 - 130	
	MSD	1625251-57	ND	0.0093939	0.010101	mg/kg	2.8	93.0		20 - 130	
Decachlorobiphenyl (Surrogate)	MS	1625251-57	ND	0.018832	0.020202	mg/kg		93.2		40 - 130	
	MSD	1625251-57	ND	0.019601	0.020202	mg/kg	4.0	97.0		40 - 130	

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Phase-1 Environmental Services 5216 Hardwood Road Silicon Valley Environmental Group San Jose, CA 95124	**Reported:** 11/21/2016 14:38 Project: Misc Project Number: P5-10-19-16 Vacant Land APN 384-06-20 & 389-06- Project Manager: Stuart Solomon

Total Concentrations (TTLC)

Quality Control Report - Method Blank Analysis

Constituent	QC Sample ID	MB Result	Units	PQL	MDL	Lab Quals
QC Batch ID: BZK1778						
Arsenic	BZK1778-BLK1	ND	mg/kg	1.0	0.40	
Copper	BZK1778-BLK1	ND	mg/kg	1.0	0.050	

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Phase-1 Environmental Services 5216 Hardwood Road Silicon Valley Environmental Group San Jose, CA 95124	**Reported:** 11/21/2016 14:38 Project: Misc Project Number: P5-10-19-16 Vacant Land APN 384-06-20 & 389-06- Project Manager: Stuart Solomon

Total Concentrations (TTLC)

Quality Control Report - Laboratory Control Sample

Constituent	QC Sample ID	Type	Result	Spike Level	Units	Percent Recovery	RPD	Control Limits Percent Recovery	Control Limits RPD	Lab Quals
QC Batch ID: BZK1778										
Arsenic	BZK1778-BS1	LCS	9.8020	10.000	mg/kg	98.0		75 - 125		
Copper	BZK1778-BS1	LCS	95.341	100.00	mg/kg	95.3		75 - 125		

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Phase-1 Environmental Services 5216 Hardwood Road Silicon Valley Environmental Group San Jose, CA 95124	**Reported:** 11/21/2016 14:38 Project: Misc Project Number: P5-10-19-16 Vacant Land APN 384-06-20 & 389-06- Project Manager: Stuart Solomon

Total Concentrations (TTLC)

Quality Control Report - Precision & Accuracy

Constituent	Type	Source Sample ID	Source Result	Result	Spike Added	Units	RPD	Percent Recovery	Control Limits RPD	Control Limits Percent Recovery	Lab Quals
QC Batch ID: BZK1778	Used client sample: N										
Arsenic	DUP	**1631836-01**	**3.3732**	**4.1833**		**mg/kg**	**21.4**		**20**		**A02**
	MS	**1631836-01**	**3.3732**	**12.457**	**10.000**	**mg/kg**		**90.8**		**75 - 125**	
	MSD	**1631836-01**	**3.3732**	**11.601**	**10.000**	**mg/kg**	**7.1**	**82.3**	**20**	**75 - 125**	
Copper	DUP	**1631836-01**	**19.391**	**24.158**		**mg/kg**	**21.9**		**20**		**Q01**
	MS	**1631836-01**	**19.391**	**107.77**	**100.00**	**mg/kg**		**88.4**		**75 - 125**	
	MSD	**1631836-01**	**19.391**	**109.41**	**100.00**	**mg/kg**	**1.5**	**90.0**	**20**	**75 - 125**	

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Phase-1 Environmental Services 5216 Hardwood Road Silicon Valley Environmental Group San Jose, CA 95124	**Reported:** 11/21/2016 14:38 Project: Misc Project Number: P5-10-19-16 Vacant Land APN 384-06-20 & 389-06- Project Manager: Stuart Solomon

Notes And Definitions

J	Estimated Value (CLP Flag)
MDL	Method Detection Limit
ND	Analyte Not Detected
PQL	Practical Quantitation Limit
A02	The difference between duplicate readings is less than the quantitation limit.
Q01	Sample precision is not within the control limits.

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Attachment B

California DTSC and EPA Guidance for Sampling Agricultural Properties

Linda S. Adams
Secretary for
Environmental Protection

Department of Toxic Substances Control

Maureen F. Gorsen, Director
8800 Cal Center Drive
Sacramento, California 95826-3200

Arnold Schwarzenegger
Governor

Interim Guidance for Sampling Agricultural Properties (Third Revision)

California Department of Toxic Substances Control
California Environmental Protection Agency

August 7, 2008

Preface

In June 2000, DTSC issued "Interim Guidance for Sampling Agricultural Soils" to provide a uniform approach for evaluating former agricultural properties where pesticides have been applied, and DTSC issued the revised Version 2 in August 2002. Over the last seven years, DTSC has reviewed several hundred former agricultural properties across California. DTSC has been committed to revising and updating the approach to these properties as new information and issues emerge. This revised guidance, Version 3, incorporates and refines the sampling and risk assessment approach to former agricultural properties.

This guidance is intended to supplement the DTSC Preliminary Endangerment Assessment (PEA) Guidance Manual, CalEPA 1994 (Second Printing, June 1999). Data obtained from the investigations should be evaluated for potential health risks according the PEA Manual. This guidance is not intended to diminish the need to take focused, authoritative samples at site locations commonly associated with hazardous substances releases nor replace guidance provided by the PEA Guidance Manual. This guidance is not applicable to areas where pesticides were mixed, stored, disposed, or areas where pesticides may have accumulated, such as ponds and drainage ditches.

The scope of this document is limited to evaluating only agricultural properties during a PEA or other initial sampling investigation. This applies to proposed new and/or expanded school sites or other project where new land use could result in increased human exposure, especially residential use. Agricultural properties are lands where pesticides were uniformly applied for agricultural purposes consistent with normal application practices, and where other non-agriculturally related activities have been absent. Data obtained from the sampling analyses will be incorporated into the PEA Report, including performing a risk analysis in accordance with the guidance in the PEA Manual.

This guidance <u>does not apply</u> to disturbed land, such as, land that has been graded in preparation for construction, areas where imported soil has been brought in, or any other activity

that would redistribute or impact the soil, other than normal agricultural practices, such as disking and plowing.

This guidance is an on-going effort to streamline the characterization of agricultural properties. As additional knowledge and experience is obtained, DTSC may modify this guidance, as appropriate.

1.0 PURPOSE

This guidance was initially prepared for use in evaluating soil at proposed new school sites and existing schools undergoing expansion projects where the property was currently or previously used for agricultural activities. This guidance is now expanded to include any project with DTSC oversight and is intended to supplement the DTSC PEA, and provide a uniform and streamlined approach for evaluating agricultural properties. This guidance can be used to assist environmental assessors in designing initial investigations or developing PEA Workplans for properties with agricultural uses. The analytical data obtained are to be incorporated into a risk analysis and PEA Report performed in accordance with the guidance in the PEA Manual.

2.0 AGRICULTURAL PROPERTIES

2.1 Eligible Agricultural Properties

This guidance is specific to agricultural properties where pesticides and/or fertilizers were presumably applied uniformly, for agricultural purposes consistent with normal application practices. It is applicable to agricultural properties that are currently under cultivation with row, fiber or food crops, orchards, or pasture. It is also applicable to fallow and former agricultural properties that are no longer in production and have not been disturbed beyond normal disking and plowing practices. Each field of the same crop is assumed to have been watered, fertilized and treated with agricultural chemicals to the same degree across the field. Because of this homogeneous application, contaminant levels are expected to be similar at any given location within the field. This is the underlying premise of the guidance, and one that must be verified at the scoping stage of the PEA process.

2.2 Properties not covered by this Guidance

This guidance does not apply to former agricultural property that has been graded for construction or other purposes, that has received fill, or has had parking lots or structures placed on it following active use as an agricultural field. An urban residential area that was agricultural property in the past does not qualify for this guidance since the construction of the residences would have resulted in the disturbance and redistribution of potential agricultural contaminants in the soil. These areas may require biased, discrete sampling as opposed to the sampling for agricultural properties discussed in this document.

2.3 Grazing Land and Dry-Land Farmed Agricultural Properties

2.3.1 Grazing Land and Pasture

Agricultural sampling is not required for property used exclusively as grazing lands or pasture, where the topography is not conducive to pesticide application, or the application of pesticides is not economically feasible. Aerial photographs, topographic maps, and a site visit should be used to evaluate the topography of the proposed school site and past land use. Sites that are suitable for animal grazing will often have irregular topography and often a cover of native trees,

brush and range grasses. In keeping with the definition of agricultural soils, the site must not have contained any structures, or been used for any commercial or manufacturing activities.

2.3.2 Dry-Land Farmed Agricultural Soils

Dry-land farming is the practice of growing a crop without irrigation. Many dry-land farming fields are not treated with pesticides or infrequently treated, since the lack of water does not provide a desirable habitat for most agricultural pests. Properties that clearly qualify as dry-land farming do not need further investigation for pesticides or metals. For properties where there is uncertainty regarding dry-land farming, limited sampling may be conducted at a rate of four discrete samples per site, with one sample collected in each quadrant.

Some production crops such as winter wheat and barley can be grown under dry-land farming conditions. If the site has been planted in a dry-land farming production crop, every assurance should be made to determine that the crop was not irrigated and pesticides were not applied. This information may be obtained from interviews with farmers in the area, records that the County Agricultural Commissioner may have, and information the Commissioner may have about the irrigation practices for that crop in the specific county. If it cannot be clearly shown that irrigation did not take place and pesticides were not applied, limited sampling for organochlorine pesticides (OCPs) and arsenic may be necessary. At a minimum, this should include four samples per site, one sample per quadrant.

2.4 Agricultural Properties Prior to 1950

A review of 35 proposed school sites along with the historical background of OCP use in California indicates that sites with agricultural usage ending prior to 1950 do not need to be evaluated for OCPs. Organochlorine pesticides were first introduced into California agriculture in 1944 and reached peak usage in the 1960's. In 1974 the use of the DDT was banned for agricultural purposes, and the elimination of remaining OCPs in California agriculture quickly followed. Data from 35 proposed school sites where agricultural use ended prior to 1950 indicates that OCPs were not identified as chemicals of potential concern. In those cases where OCPs were identified, the source appears to have been the application to structures on the property, and not the agricultural crops grown prior to 1950. It is recommended that former agricultural properties that terminated operation prior to 1950 not be evaluated for agriculturally related OCPs. Arsenic should still be evaluated as a chemical of potential concern (COPC) since its use as arsenical pesticides and herbicides predates 1950.

2.5 Continued Agricultural Use After PEA Sampling

Chemicals associated with agricultural activities may result in potential risks to human health or the environment. If agricultural activities continue on the subject site after DTSC issues a no further action determination on the PEA, DTSC cannot ensure the no further action determination will remain in effect.

This may have impacts for school projects where the school districts elect to postpone school construction and allow continued agricultural use of the property. The most recent chemical use documentation (e.g., local Agricultural Commissioner Pesticide Application Permits) regarding the quantity and types of agricultural chemicals used on the property should be provided in the PEA report. If the type of agricultural chemicals applied to the site change after DTSC's no further action determination, DTSC recommends submittal of the chemical use documentation to DTSC at least three months prior to commencement of grading or other construction activities at the school site. DTSC will review the information, and if necessary, may recommend additional sample collection and analyses to assess potential impacts and ensure school site safety.

2.6 Other Areas of Concern on Agricultural Properties

In many cases, agricultural properties may include other areas of concern such as operations yards, storage areas, fuel tanks, residences, irrigation systems, and animal facilities. Examples of areas of concern may include:

- Structures such as homes, garages, equipment sheds, barns, and other out-buildings
- Pesticide storage, mixing/loading, and wash-down areas
- Ecological habitats, or rare, threatened, or endangered species
- Irrigation ditches/canals, containment berms, and low-lying swales or drainage areas
- Irrigation water containment ponds and collection/recirculation sumps
- Production wells and pumps
- Pole- or pad-mounted transformers
- Waste oil areas
- Animal pens, barns, and manure and disposal piles
- Burn piles
- Underground and above ground storage tanks
- Properties in dibromochloropropane (DBCP) study areas

Although agricultural-related, these targeted areas should be considered during the PEA scoping meeting and investigated using standard PEA protocols. The following DTSC guidance documents may be considered in these investigations:

- Interim Guidance: Evaluating Total Petroleum Hydrocarbons (TPH) (DTSC 2008) (The draft TPH guidance document is being revised at this time and will not be available to the public until DTSC finalizes the document.)
- Interim Guidance: Evaluation of School Sites with Potential Contamination from Lead Based Paint, Termiticides, and Electrical Transformers (DTSC, June 9, 2006)
- Arsenic Strategies for Determination of Arsenic Remediation: Development of Arsenic Cleanup Goals for Proposed and Existing School Sites (DTSC 2007)
- Advisory: Methane Assessment and Common Remedies at School Sites (DTSC, June 2005)
- Advisory: Active Soil Gas Investigations (DTSC, January 2003)
- Guidance for the Evaluation and Mitigation of Subsurface Vapor Intrusion into Indoor Air (DTSC 2004)
- Fact Sheet: Information Advisory, Clean Imported Fill Material (DTSC, October 2001)
- Guidance Manual: Preliminary Endangerment Assessment (DTSC, January 1999)
- Data Validation Memorandum , Summary of Level II Data Validation (DTSC, May 2006)
- Guidance: Ecological Risk Assessment at Hazardous Waste Sites and Permitted Facilities (DTSC, July 4, 1996)

3.0 SAMPLING STRATEGIES

3.1 Chemicals of Concern

3.1.1 Pesticides

When the property is under active agricultural production, the operator should be interviewed to determine the types and amounts of pesticides historically used on the property. The County Agricultural Commissioner should also be consulted to verify pesticide usage on the property. The Agricultural Commissioner is required to maintain this information for three years, but often will have extensive knowledge of the farming practices over many years. A local or specialized farm advisor such as the University of California Cooperative Extension Agent is another source of information for farming practices in the area. These consultations should occur during the scoping phase of the investigation. For those properties that have not been actively farmed in the past three years, obtaining accurate information is more difficult. Information from surrounding or neighboring agricultural operations on the types of crops grown in the area during the time of active farming can provide clues on what chemicals may have been applied.

Based on data from former agricultural properties over the past seven years, the only pesticide class requiring analyses at agricultural properties are OCPs, such as DDT, toxaphene, dieldrin, etc. OCPs are biopersistent and bioaccumulate in the environment. Most other classes of pesticides have relatively short half-lives and have not been found in the agricultural fields. While paraquat does have a longer half-life in soil, it has either not been detected or detected rarely at trace levels at sites which DTSC has had oversight, therefore routine analyses for paraquat is not required for field areas. Analyses for paraquat may be required in storage and mixing/loading areas.

3.1.2 Metals

Based on data from former agricultural properties, the only heavy metal required for routine analyses for these properties is arsenic. Arsenic in the form of arsenical herbicides has been applied to many agricultural properties and elevated levels of arsenic have been reported in the evaluation of these properties.

Other heavy metals may be required on a case by case basis depending on history of the property and the surrounding environment. Certain counties, such as Kern and Merced in the Central Valley, allow the application of municipal sludge on agricultural properties with or without a permit. Municipal sludge has been often shown to have elevated levels of heavy metals. These metals concentrations can impact vadose soils and often may migrate to groundwater. If there is a history of sludge application, or if sludge application is suspected on an agricultural property, Title 22 metals (former CAM 17 metals) should be evaluated.

Copper compounds were generally applied directly to select crops (e.g. vineyards) to prevent or reduce mildew. Vineyards and grain storage areas may have elevated copper due to the use of copper compounds as fungicides. To date, DTSC has not found elevated copper in any agricultural property. However, analyzing soil or sediment samples for copper may be appropriate at agricultural properties with the potential to impact aquatic ecological habitats (e.g. a creek or stream which runs through site).

3.1.3 Additional Chemicals of Concern

3.1.3.1 Mixing/Loading/Storage Areas

Focused sampling in mixing/loading/storage areas, drainage ditches, farm houses, or outbuilding areas may require analyses for a number of other constituents besides OCPs and arsenic, including other classes of pesticides/herbicides, paraquat, metals, and petroleum related compounds (see Section 2.6).

3.1.3.2 Smudge Pots

If smudge pots have been routinely used on agricultural properties, for example in citrus groves, additional sampling for PAHs and TPH may be required.

3.2 Sampling Frequency

Sampling frequency may vary depending on the size of the site and conditions found. When the site has been used for agricultural crop, the presumption is that agricultural chemicals were applied uniformly across the site in any given year and that the variation across the site will be relatively small. An analysis of several hundred former agricultural properties by DTSC has supported the general use of the assumption of uniform application.

The assumption of uniform application may not apply to areas cultivated in different crops, adjoining or adjacent properties with different owners or operators. The uniform application assumption does not apply for non-cultivated areas (e.g. drainage ditches, farm houses and other structures, mixing/loading areas, storage sheds, etc.)

In general, the sampling pattern should be sufficient to characterize the site. Recommended numbers of borings or sampling locations and composite analyses are provided in Table 1 for both OCPs and arsenic analyses for sites up to 50 acres. DTSC should be consulted for sites greater than 50 acres. For these sites, the sampling frequency may be reduced based on documentation that verifies consistent owner, operator, and use. If different parcels of the property have different owners, operators or crops, the number of samples shown in Table 1 should be applied for each different parcel.

Table 1: Recommended Number of Sampling Locations

Site Acres	Number of Borings	OCP Analyses (Composites)	Arsenic Analyses (Discrete only)
1	4	4 (Discrete analyses)	4
2	4	4 (Discrete analyses)	4
3	4	4 (Discrete analyses)	4
4	8	4	4
5	10	4	4
6	12	4	4
7	14	4	4
8	16	4	4
9	18	5	5
10	20	5	5
11	21	6	6
12	22	6	6
13	23	6	6
14	24	6	6
15	25	7	7
16	26	7	7
17	27	7	7
18	28	7	7
19	29	8	8
20	30	8	8
21	31	8	8
22	32	8	8
23	33	9	9
24	34	9	9
25	35	9	9
26	36	9	9
27	37	10	10

Site Acres	Number of Borings	OCP Analyses (Composites)	Arsenic Analyses (Discrete only)
28	38	10	10
29	39	10	10
30	40	10	10
31	41	11	11
32	42	11	11
33	43	11	11
34	44	11	11
35	45	12	12
36	46	12	12
37	47	12	12
38	48	12	12
39	49	13	13
40	50	13	13
41	51	13	13
42	52	13	13
43	53	14	14
44	54	14	14
45	55	14	14
46	56	14	14
47	57	15	15
48	58	15	15
49	59	15	15
50	60	15	15
>50	Consult with DTSC		

3.3 Composite Samples

Since this guidance assumes a relatively even distribution of chemicals across the agricultural field portion of a site, compositing of discrete samples allows for increased sampling coverage for a site, while not significantly increasing the number of analytical samples. Composite surface samples may be made up of a maximum of four discrete surface samples from adjacent sampling locations. Compositing may occur in the field or at the laboratory. In cases where two crops were grown on the site, only discrete samples from within the same crop area may be composited.

Specify the method of selecting the discrete samples to be composited and the compositing factor (e.g. 3 to 1: three discrete samples composited to one) in the workplan. Compositing requires that each discrete sample be the same in terms of volume or weight, and that the discrete sample be thoroughly homogenized prior to compositing. The detection level does not need to be reduced since the composite sampling area is assumed to be homogeneous in concentration.

If compositing is not chosen, analyses will be performed on all the discrete samples and the number of analyses will correspond to the number of borings.

For more information on composite samples, see the references provided in Section 6.0.

3.4 Discrete Sampling for Arsenic

A minimum of four discrete on-site surface samples must be analyzed for arsenic. When samples are composited for OCP analysis, one discrete sample from each composite must be analyzed for arsenic. When more than four composite samples are analyzed for OCPs, the total number of discrete samples analyzed for arsenic does not need to be greater than the number of total composite samples used for OCP analysis (see Table 1).

3.5 Sampling Depth

Based on the extensive data DTSC has reviewed for agricultural properties, only surface samples will be required for the screening assessment. Each location should be sampled to include one surface sample (0 to 6 inches). [Note: 0 inches means first encountered soil. Thick mats of vegetable material, roots, and other extraneous material should not be sampled. The locations can be staked and surveyed using a sub-meter global positioning system. This will facilitate collection of supplemental site investigation samples, such as subsurface or step out sampling, if necessary.

3.6 Sample Collection

Sampling both the furrows and beds of existing rows will detect the greatest variability in the residuals. Some methods of pesticide application will favor residuals in the beds while others favor the furrows. In fields where rows remain, roughly half of the samples should be gathered from the furrows and half from the beds in an alternating pattern. Orchards should have the sampling locations placed at the current drip line for the trees, under the canopy, between the tree rows, and between the trees within a row. For sites with slopes, swales, or other uneven topography, sampling from centers should be modified to include samples from those areas where surface water would be expected to flow and accumulate.

3.7 Field Duplicates

Field duplicates should be collected at a rate of 10 percent (or a minimum of one). For arsenic, a discrete co-located sample should be collected and analyzed for every 10 arsenic samples collected. For OCPs where composite samples will be prepared and analyzed, every 10th

composite sample should be prepared (independently) in duplicate and analyzed. See Section 4.1 for a description on preparation of composite samples.

3.8 Requirements for Collection of Background Metal Samples

Consult with the DTSC project manager regarding the need for collecting background arsenic samples. In general, with the exception of arsenic, background samples for metals will not be necessary if all metals are below their respective California Human Health Screening Levels (CHHSLs). If all the arsenic results for the site are at or below 12 mg/kg, then collection of background samples will not be required. For sites where either arsenic or other metals are above their respective screening values, either collection of a background data set or use of an appropriate background data set may be required.

3.8.1 Sampling for Background Metals

If samples are needed to determine background levels of arsenic and/or other heavy metals (if additional metals are required for the PEA), a minimum of four onsite locations should be sampled at non-impacted areas, or samples may be collected at a depth of 5 to 5.5 feet bgs. In order to use background samples from 5 to 5.5 feet bgs, a licensed professional must make the determination that the background soils are similar enough geologically to the surface soils as to be representative.

Other background data sets may be substituted for on site sampling on a case by case basis in consultation with DTSC.

4.0 LABORATORY ANALYSES

4.1 Preparation of Composite Samples

Each discrete sample should be homogenized and uniformly split by trained field staff prior to compositing. A portion of each discrete sample should be frozen and archived in case additional analysis is warranted based on the composite results. Compositing requires that each discrete sample be the same in terms of volume or weight, and that the discrete sample be thoroughly homogenized prior to compositing. Excess sample from the homogenized composite sample shall be archived by the lab and/or used as a duplicate, as appropriate, for that composite set. The samples may be discarded when the PEA process has been completed and approved by the DTSC.

4.2 Methods

The analytes of primary concern are OCPs, arsenic, and, in some cases, Title 22 metals. Depending on the site history, analysis of other types of pesticides may be required. OCPs should be analyzed using U.S. EPA 8081A or equivalent. Metals must be analyzed using the U.S. EPA 6000/7000 series. If the site history indicates other classes of persistent pesticides should be evaluated, DTSC should be consulted for the acceptable method of analysis and appropriate detection limits. Highly organic topsoil may interfere with proper extraction of pesticides.

Sample holding times should be consistent with U.S. EPA SW-846. Variances to holding times and affects on data results must be discussed in the data validation section of the report.

Please note, for comparison of chlordane concentrations against the CHHSL, chlordane must be quantified against a ***technical chlordane*** standard. For purposes of the PEA, DTSC will not

allow quantitation of the individual alpha and gamma isomers, with a total concentration determined by addition of those concentrations.

4.3. Detection Limits

The actual detection limits obtained will vary depending on the particular analyte. For OCPs, the analytes typically causing detection limit concerns in agricultural fields are aldrin, dieldrin, and toxaphene. The detection limits should be 0.005 mg/kg for aldrin, dieldrin, and 0.05 mg/kg for toxaphene. Table 2 lists the detection limits for several OCPs.

In samples with elevated DDT, the detected concentration may be above the range of calibration. This can result in the analytical laboratory diluting the sample for reanalysis, and then reporting only the final result. In these cases, the reported detection limits for aldrin, dieldrin, and toxaphene may exceed the detection limits needed for determining potential health effects. Ideally the laboratory should be asked to report if those three analytes were detected in the first analysis prior to dilution. Multiple analyses of the same samples may be required to obtain the data necessary for risk assessment purposes.

Table 2. Analytical Methods and Detection Limits for Selected OCPs

Pesticide	Methods[2]	CAS No.[3]	DL[4] mg/kg
Aldrin	8081A	309-00-2	0.005
a-BHC	8081A	319-84-6	0.005
b-BHC	8081A	319-85-7	0.005
g-BHC (Lindane)	8081A	58-89-9	0.005
d-BHC	8081A	319-86-8	0.005
Total Chlordane[1]	8081A	57-74-9	0.05
DBCP[5]	8081A	96-12-8	0.01
DDD	8081A	72-54-8	0.05
DDE	8081A	72-55-9	0.05
DDT	8081A	50-29-3	0.05
Dieldrin	8081A	60-57-1	0.005
Endosulfan I	8081A	959-98-8	0.005
Endosulfan II	8081A	33213-65-9	0.005
Endosulfan sulfate	8081A	1031-07-8	0.005
Endrin	8081A	72-20-8	0.05
Endrin aldehyde	8081A	7421-93-4	0.05
Endrin ketone	8081A	53494-70-5	0.05
Heptachlor	8081A	76-44-8	0.05
Heptachlor epoxide	8081A	1024-57-3	0.005
Hexachlorobenzene (HCB)	8081A	118-74-1	0.3
Hexachlorocyclopentadiene	8081A	77-47-4	0.5
Methoxychlor	8081A	72-43-5	0.005
Toxaphene	8081A	8001-35-2	0.05

Notes:

1 = Report total Chlordane (based on a Technical Chlordane standard)
2 = Although other methods may be used to quantify OPCs, DTSC recommends the use of 8081A as the primary method of quantitation
3 = Chemical Abstract Service registry number
4 = Detection Limit recommended for risk assessment purposes
5 = If sampling for this compound is indicated, inclusion in the method must be requested in the workplan and/or QAPP

4.4 Pesticide Analyses

Surface samples, discrete or composite, must be analyzed for OCPs. Analysis for other classes of persistent pesticides may be required as indicated by the agricultural history of the site. If the composite sample result exceeds the health risk screening criteria (see Section 5.3), analyze each discrete sample that made up the composite sample.

4.5 Sub-surface sample analysis

In consultation with DTSC, analyses of sub-surface samples may be required if surface samples results exceed specified screening levels. This sampling may be a part of the PEA or included in a Supplemental Site Investigation. If subsurface samples were collected during the PEA sampling event, those samples may be taken off "hold" and analyzed by the laboratory. If subsurface samples were not collected during the PEA, a Supplemental Site Investigation Workplan or Technical Memorandum should be prepared identifying appropriate step-out (vertical and horizontal) sampling locations.

4.6 Quality Control

Quality control (QC) procedures specified in SW-846 must be followed. A matrix spike/matrix spike duplicate on one soil sample per batch of 20 samples must be performed to demonstrate that the targeted pesticide(s) can be recovered from the soil investigated. The laboratory data package must include a summary of the quality control sample results: blanks, matrix spike/ matrix spike duplicate, surrogate recoveries, laboratory control samples, etc., as specified by the method. The laboratory should provide a signed narrative stating whether the QC was met and listing any discrepancies. The consultant should perform a supplementary evaluation of the data, also referred to as data validation, and present the results of that evaluation in the PEA report. For an example of what to included in the data validation section, see the example data validation memorandum at the DTSC website:
http://www.dtsc.ca.gov/Schools/upload/Data_Validation.pdf

5.0 REPORTING

5.1 Format

The results of the sampling effort are to be reported in a PEA report as described in the DTSC PEA Guidance Manual.

5.1.1 Summary Tables

Include data tables in the PEA report to summarize the results of the investigation. Summary tables should include the analytes of interest, the reported concentrations or the reporting limit for non-detect results, and indicate whether a reported concentration exceeds its respective CHHSL screening level (if a CHHSL comparison is being conducted). In addition, for samples analyzed at multiple dilutions for purposes of reporting concentrations within calibration ranges (as described in Section 4.3), summary tables should either present the results for all of the dilution analyses indicating the appropriate result for each analyte, or a combined analysis indicating which results are being reported after a dilution. Sample results should also be flagged with appropriate qualifiers, where necessary, after data validation.

5.2 Evaluating Metals (Inorganic Elements) Data

Using a robust statistical procedure to determine if on-site metal concentrations are indicative of background conditions or the result of site-related activities can be problematic because of the limited number of background samples collected at any one site. Local site background may be used if the data is approved for use by the DTSC project manager and toxicologist. If DTSC

background levels are not available, then a defensible procedure for comparing on-site with background metals should be used. The DTSC project manager and DTSC toxicologist assigned to the project should be consulted on the most appropriate method of comparison.

5.2.1 Arsenic Evaluations

The DTSC Schools Program evaluated data from a large number of school sites across California. The data evaluation indicates that 12 mg/kg maybe a useful screening number for the Schools Program when evaluating arsenic as a COPC. If the proposed school property has been adequately characterized for arsenic and all the arsenic data are equal to or less than 12 mg/kg, then arsenic will be not be considered a COPC. This decision does not require collection and comparison to a background data set. If arsenic concentrations are greater than 12 mg/kg, then comparisons to background data will be required. In some cases additional sampling may also be required.

5.2.2 Strategy for Comparison of Background Metals

If background samples are necessary, follow the procedures provided in Section 3.8.
The following strategy may be used for comparing site data to background data:

1. Compare the highest site concentration with the highest background concentration. If the site concentration is equal to or less than the background, the metal may be eliminated as a COPC. If the onsite maximum is greater than the background maximum, go to 2).

2. Compare the site and background arithmetic mean concentrations. If the means are comparable, and if the highest site concentration is below the concentration associated with unacceptable risk or hazard, the metal may be eliminated as a COPC. If the site mean is greater than the maximum background, go to 3).

3. Two approaches may be used, depending on the size of the background data set.
   - If the background data set is of sufficient size, statistically evaluate the overlap of the background and onsite distributions to determine if they come from the same population. If they do, and if the highest site concentration is below the concentration associated with unacceptable risk or hazard, the metal may be eliminated as a COPC. If not, include the metal as a COPC in the risk evaluation.

   - If the background data set is limited (n=4), the onsite data can be evaluated statistically using probability plots to determine if one or more populations are present. If only one population is present, and if the highest site concentration is below the concentration associated with unacceptable risk or hazard, the metal may be eliminated as a COPC. If there are two or more populations present, then include the metal as a COPC.

4. Additional information on eliminating metals as COPCs can be found in "*Selecting Inorganic Constituents as Chemicals of Potential Concern at Risk Assessments at Hazardous Waste Sites and Permitted Facilities – Final Policy* (DTSC/HERD 1997),

5.3 Human Health Risk Assessment

All detected pesticides and any onsite metals above background should be evaluated as COPCs in a human health risk assessment as described in the DTSC PEA Guidance Manual or in comparison to CHHSLs. In the initial screening analysis, the highest

concentration of each detected pesticide and metal above background must be used as the exposure point concentration in the risk assessment.

Since agricultural properties are assumed to have uniform application of pesticides, DTSC has allowed compositing of samples for OCP analyses (Sections 3.3 and 4.1). The concentration from the composited sample can be used directly in the risk assessment without adjusting the toxicity screening numbers, such as the CHHSLs. The review of the former agricultural properties over the past seven years has supported the assumption of uniform application. This is in contrast to other DTSC guidance, such as the *Lead-Based Paint, Termiticide and PCB Guidance*, (DTSC, June, 2006), where adjustments to the CHHSLs are required for composite samples because applications were not necessarily uniform.

5.3.1 Application of PEA Risk Assessment Equations and CHHSLs

Chemicals of potential concern are evaluated either by comparison to the CHHSL, or by calculating the excess cancer risk and hazard index based on equations in the PEA Guidance.

Note: CHHSLs may not be used to "screen out" COPCs.

5.3.1.1 CHHSLs

CHHSLs are soil and/or soil gas concentrations for selected chemicals developed by Cal-EPA with a target threshold of a 1E-06 risk for carcinogens, and a hazard quotient of one for non-carcinogens. CHHSLs were developed using models and exposure assumptions similar to those used in the PEA Guidance Manual, with the exception of the concentrations for volatile organic compounds (VOCs), which were developed using the vapor intrusion model for addressing the inhalation of contaminated indoor air. CHHSLs may be used as a soil screening value at school sites if all of the chemicals detected at the site have a listed CHHSL, if it is agreed upon by all parties concerned, and if it is agreed that the screening document will be reviewed by a toxicologist from the Human and Ecological Risk Division. For school sites, only the residential-based CHHSLs may be used. The exposure pathways used in calculating the CHHSLs are incidental soil ingestion, dermal absorption, and inhalation of dusts in indoor air for non-volatile soil-bound chemicals, and the inhalation of indoor air pathway for VOCs. Direct exposures to VOCs are not included in the calculation of the CHHSLs and CHHSLs do not take into consideration the leaching of contaminants from soil to groundwater. CHHSLs are not appropriate if ecological receptors are the most sensitive species on the site. Lead should be evaluated using the most current DTSC LeadSpread Model or the school site lead screening level of 255 mg/kg.

5.3.1.2 Human Health Risk Assessment with CHHSLs

Independent of whether sites were analyzed with discrete samples or with composite samples, the evaluation is similar. Note that the CHHSL values are not adjusted for the number of discrete samples that comprise a composite. The rationale behind this comparison to un-adjusted CHHSL is that application of pesticides is assumed to be uniform throughout the field, and large variations in the pesticide concentrations are not expected. This rationale applies only to the agricultural portion, not to mixing areas, storage sites, structures, etc.

5.3.2 Procedure for Human Health Risk Assessment with CHHSL or PEA Guidance

- Determine that all of the chemicals detected at the site have the appropriate CHHSLs for soil and/or soil vapor. If they do not, then a PEA risk assessment must be conducted. A DTSC toxicologist will evaluate if the CHHSL screening is appropriate for the site

- The screening document, PEA or equivalent, will be reviewed by a toxicologist from the Human and Ecological Risk Division.

- The most recently published CHHSLs should be used. This may be found at: http://www.calepa.ca.gov/Brownfields/documents/2005/CHHSLsGuide.pdf.
- The exposure pathways at the site must match the exposure pathways used to develop the CHHSLs.
  Use the maximum concentration of each contaminant detected at the site and compare to unrestricted (residential) CHHSL or PEA risk calculations.
- Background metal concentrations can be used to screen metals as COPC. Construct a table listing the COPC (see Section 5.2.2 for discussion on background metals).
- The risk and hazard for each COPC should be calculated using the following equations:

$$\text{RISK} = \frac{[\text{maximum detected concentration}]}{\text{CHHSL}} \times 10^{-6}$$

$$\text{HQ} = \frac{[\text{maximum detected concentration}]}{\text{CHHSL}}$$

  - If there are multiple COPCs, calculate the cumulative risk and/or hazard. An Excel calculator is provided on the Cal/EPA website for CHHSLs: (http://www.calepa.ca.gov/Brownfields/documents/2005/Calculator.xls).
  - Complete a Risk Characterization Section where the total risk and hazard are presented and discussed along with the need for any further action.
  - If the maximum concentrations detected on site pose an unacceptable risk or hazard, a spatial analysis should be conducted to determine if the elevated levels represent a "hot spot", or are representative of concentrations across the site. In those cases where the elevated concentrations are determined to be one or more "hot spots", risk or concentration isopleths should be constructed to differentiate between those areas of the site in need of further action, and those where no further action is required. Any deviations from these analyses must be approved by the DTSC toxicologist assigned to the project.

Note: For evaluation of composite samples, the CHHSL values are not adjusted for the number of discrete samples that comprise a composite. The rationale behind this comparison to un-adjusted CHHSL is that application of pesticides is assumed to be uniform throughout the field, and large variations in the pesticide concentrations are not expected. Note that this rationale applies only to the agricultural portion, not to mixing areas, storage sites, structures, etc.

6.0 ADDITIONAL SOURCES OF INFORMATION

Pesticide Physical Properties and Half-Lives

http://ace.orst.edu/info/extoxnet/pips/ghindex.html
http://www.arsusda.gov/rsml/ppdb1.html

Active Pesticide Ingredient by Brand Name

http://www.cdpr.ca.gov/docs/label/prodnam.htm
http://www.cdpr.ca.gov/ - see databases
Farm Chemicals Handbook, current edition, Meister Publishing Company,

Willoughby, Ohio.

Maximum Application Rates

http://ace.orst.edu/info/extoxnet/
Agricultural Chemicals – Thomas Publications, Fresno, CA

Pesticide Usage by Year, County, and Crop

http://www.ipm.ucdavis.edu/PUSE/puse1.html
http://www.cdpr.ca.gov/ - see databases

Composite Sampling

http://www.clu-in.org/download/char/SF_Rep_Samp_Guid_soil.pdf
U.S.EPA. 1995a. *Superfund Program Representative Sampling Guidance, Volume 1: Soil, Interim Final,* OSWER Directive 9360.4-10, EPA 540/R-95/141, PB96-963207. Environmental Response Team, Office of Emergency and Remedial Response, Office of Solid Waste and Emergency Response. December 1995, Page 28.

http://clu-in.org/download/stats/composite.pdf
U.S.EPA. 1995b. *EPA Observational Economy Series, Volume 1: Composite Sampling*, EPA-230-R-95-005. Policy, Planning, and Evaluation (2163). August 1995.

Test Methods

http://www.epa.gov/epaoswer/hazwaste/test/
SW-846: U.S. EPA, *Test Methods for Evaluating Solid Waste, Physical/Chemical Methods, Third Edition, Current Revision*

Pesticide Toxicology Information

http://ace.orst.edu/info/extoxnet/ghindex.html
http://www.state.nj.us/health/eoh/rtkweb/rtkhsfs.htm

CHHSLs

http://www.calepa.ca.gov/Brownfields/documents/2005/CHHSLsGuide.pdf
http://www.calepa.ca.gov/Brownfields/documents/2005/Calculator.xls

Acronym List

bgs	Below Ground Surface
CalEPA	California Environmental Protection Agency
CHHSL	California Human Health Screening Levels
COPC(s)	Chemicals of Potential Concern
DBCP	Dibromochloropropane
DTSC	Department of Toxic Substances Control
NFA	No Further Action
OCP(s)	Organochlorine Pesticides
PAH	Polyaromatic Hydrocarbon
PEA	Preliminary Endangerment Assessment
QC	Quality Control
TPH	Total Petroleum Hydrocarbon
U.S. EPA	United States Environmental Protection Agency
VOCs	Volatile Organic Compounds

Attachment C

Bay Area Arsenic Background Study by Dylan Jacques Duvergé

ESTABLISHING BACKGROUND ARSENIC IN SOIL OF THE URBANIZED SAN FRANCISCO BAY REGION

A thesis submitted to the faculty of
San Francisco State University
In partial fulfillment of
The Requirements for
The Degree

Master of Science
In
Geosciences

By

Dylan Jacques Duvergé

San Francisco, California

December 2011

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CERTIFICATION OF APPROVAL

I certify that I have read *Establishing Background Arsenic in Soil of the Urbanized San Francisco Bay Region* by Dylan Jacques Duvergé, and that in my opinion this work meets the criteria for approving a thesis submitted in partial fulfillment of the requirements for the degree: Master of Science in Geosciences at San Francisco State University.

Dr. Jason Gurdak
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Professor of Geography and Environmental Studies

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Professional Geologist, San Francisco Bay
Regional Water Quality Control Board

ESTABLISHING BACKGROUND ARSENIC IN SOIL OF THE URBANIZED SAN FRANCISCO BAY REGION

Dylan Jacques Duvergé
San Francisco, California
2011

Soil analysis data within the nine-county San Francisco Bay Area was compiled from the State Water Quality Control Board's Geotracker online database to determine the background levels and variability of arsenic concentrations across four Quaternary geologic units. Arsenic analyses of 1,454 soil samples across 77 sites were screened from Geotracker for inclusion in a JMP 7.0 database. Mean arsenic concentrations within Holocene alluvium (5.10 mg/kg) were determined to be statistically greater than those within Pleistocene alluvium (3.65 mg/kg) and "other" Quaternary units (3.30 mg/kg); and no significant relationship was found between arsenic concentrations and sampling depth. The proposed upper estimate for background arsenic (99th percentile) within undifferentiated flatland soils of the study area—11.00 mg/kg—is markedly lower than commonly cited sources in the literature. These findings present the first regional estimates of background arsenic concentrations in the San Francisco Bay Area.

I certify that the Abstract is a correct representation of the content of this thesis.

12-5-2011

Chair, Thesis Committee

Date

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1.0 INTRODUCTION AND BACKGROUND

1.1 Introduction

The San Francisco Bay Area (Bay Area) has an enormous natural and cultural diversity where concern for environmental quality permeates regional and local land use planning decisions on a daily basis. Among the broad spectrum of environmental problems is the potential for contaminated soil and groundwater to adversely affect human health. Arsenic—recognized as a potential contaminant by local, state and federal environmental agencies—is a trace metal that is present in low levels in all environmental media (soil and rock, water, and air). Over our lifetimes, we ingest trace levels of arsenic that are naturally occurring in food, drinking water, and (to a lesser extent) air without suffering adverse health effects. However, long-term exposure to elevated levels of inorganic arsenic is known to decrease production of red and white blood cells, cause damage to blood vessels, and lead to characteristic effects such as changes in skin pigmentation, appearance of warts or bruises, skin irritation, and increased risk of skin and other cancers (ASTDR, 2009). In the Bay Area, arsenic is present both as a natural component of soil and rock, as well as a byproduct of human activities such as historical pesticide applications and the presence of copper chromated arsenate- (CCA) treated wood. In this context, environmental investigators face the difficult challenge of determining whether arsenic detections at a site reflect the local soil type or anthropogenic inputs, particularly when detected in the upper range of arsenic concentrations thought to occur naturally.

By screening from an extensive database of soil sampling results that have been submitted to regulatory agencies in the course of environmental cleanup activities, this thesis aims to estimate background arsenic concentrations in soil around the Bay Area, and investigate whether spatial variability in arsenic concentrations can be at least

partially explained by variations in soil type. Estimates of the mean and range for trace metals have been developed nationally (7.2, <0.1 – 97 mg/kg) (Shacklette and Boerngen, 1984), for California (3.5, <0.2 -11 mg/kg) (UCR, 1996), and for localized areas in the San Francisco Bay region (5.5, <DL – 42 mg/kg) (LBNL, 2002; Scott, 1991); but there has thus far been no effort to characterize background arsenic on a regional scale or investigate the effect of soil type on arsenic concentrations in the Bay Area. An improved understanding of background concentrations of trace metals and their variability across soil types could help regulators make informed decisions on whether trace metal detections on a property reflect site-related contamination.

1.2 Definitions

This thesis uses several terms and concepts that may have various meanings in other works depending on their topic, scope, and purpose. The meaning of commonly used terms in this thesis is clarified below:

Arsenic: Toxicological profile sheets distributed by the U.S. Department of Health and Human Services (ASTDR, 2009) define arsenic as a naturally occurring element that is widely distributed in the Earth's crust. Arsenic is a chemical element (As) classified as a metalloid, having both properties of a metal and a nonmetal; however, it is frequently referred to as a metal. Elemental arsenic (sometimes referred to as metallic arsenic) is a steel grey solid material. However, arsenic is usually found in the environment combined with other elements such as oxygen, chlorine, and sulfur. Arsenic combined with these elements is called inorganic arsenic. Arsenic combined with carbon and hydrogen is called organic arsenic.

Background: Both U.S. Environmental Protection Agency (EPA) and U.S. Navy describes "background" as substances or locations that are not influenced by existing site-

related sources of contamination and is often specified as either representing the naturally occurring background or the anthropogenic background (NAVFAC, 2002; EPA, 2002):

- The *natural background* refers to substances present as a result of geochemical processes that have not been influenced by human activity. Naturally occurring organic and inorganic background substances in soil are solely attributable to the natural geological characteristics of the area.
- The *anthropogenic background* (sometimes referred as the "ambient" levels of a substance) refers to substances present at concentrations that potentially exceed the natural background as a result of human activities, but that cannot be attributed to a specific land-use activity or contaminated area.

Soil: The term "soil" as used in this thesis is broadly defined as loose, unconsolidated clay, silt, sand, and gravel found from the ground surface down to the depth of bedrock. This meaning is consistent with the usage in the field of engineering and environmental geology, and is broader than the definition used by soil scientists and agronomists.

Soil Type: Soils are classified in this thesis based on mapping of quaternary geology, which distinguishes soils by age (e.g., Holocene or Pleistocene) and depositional process (e.g., fluvial, marine, estuarine, or lacustrine). References to soil type contained herein are not synonymous with U.S. Department of Agriculture soil series or surveys, which are more specific and focused on the upper 200 cm of soil for agricultural and other resource management purposes.

Source Rock/Parent Material: The source rock or parent material of a soil refers to the bedrock upon which the soil formed (for residual soils), or from which the soil material was originally derived (for transported soils).

Censored Data: Censored data refers to analytical values that are determined by the laboratory, but that are lower than limits deemed reliable enough to report as numerical values. These observations are reported as seminumerical values that contain qualifiers indicating that the analyte is below the limits of reliability for accurate quantification. Typically, these values are expressed as ‘‘nondetects’’ or ‘‘less thans’’ such as <0.5.

Environmental Screening Levels (ESLs): ESLs are a compilation of screening levels specific for use at sites overseen by San Francisco Bay Regional Water Quality Control Board for a number of different environmental concerns. ESLs for chemicals in soil are developed for protection against direct exposure (ingestion, dermal absorption, inhalation of vapors and dust in outdoor air), protection of groundwater quality (leaching of chemicals from soil), protection of terrestrial (nonhuman) biota; and protection against nuisance concerns (odors, etc.).

1.3 Arsenic Variability in Soil and Rock

Arsenic (atomic number 33 and relative atomic mass 74.92) belongs to a group of elements often referred to as “trace” elements because its concentration does not normally exceed 1,000 mg/kg (0.1%) while a small group of ten “major” elements make up over 99% of the earth’s crust (Alloway, 1990). Trace elements are initially introduced into igneous rocks by substituting for the more common cations that form the crystal matrix of minerals. Typically, substitution occurs when arsenic has similar elemental properties and atomic radii of the more common heavy element. Numerous arsenic containing minerals have been identified, the most common of which are arsenopyrite (FeAsS), realgar (AsS), orpiment (As_2S_3), and enargite (Cu_3AsS_4). Arsenic in sedimentary rocks is related to the source and absorptive properties of the sedimentary material that was lithified, the properties of secondary minerals and clays, and the arsenic content of the water that deposited the sedimentary material (Alloway, 1999).

Alloway (1990) reported global mean concentrations of arsenic in different types of rock (Table 1). Mean arsenic content is generally consistent among the major rock types—about 1–1.5 mg/kg—except for some argillaceous sedimentary rocks (shales, mudstones, slates) and phosphorites, which have mean arsenic concentrations from 10–15 mg/kg and have locally been reported to have natural concentrations as high as 900 mg/kg. Separating by rock type, the typical range of concentrations is <1–15 mg/kg for various igneous rocks, <1–20 mg/kg for sandstones and limestones, and <1–200 mg/kg for phosphate rocks. The arsenic content of metamorphic rocks usually reflects the arsenic content of the original, unmetamorphosed rock type.

The typical range of concentrations for arsenic in soils is 1–40 mg/kg with most soils being on the lower end. Kabata-Pendias (1985) reported the mean and range of arsenic background concentrations for several different types of soil, including alluvial soils (8.2, 1.2 to 22 mg/kg), clay and clay loamy soils (7.7, 1.7 to 27 mg/kg), light loamy soils (7.3, 0.4 to 31 mg/kg), and granitic soils (3.6, 0.7 to 15 mg/kg). The type of parent rock is only one of the factors that control metal concentrations in soils. Weathering, biological chemical reactions, and other natural geochemical processes can significantly enrich or deplete the concentrations of certain metals. Due to the high capacity of clay and organic matter to adsorb metallic ions, arsenic concentrations tend to be highest in

Table 1 – Worldwide mean and range of arsenic for major rock types (mg/kg)

	Earth's Crust	Igneous Rocks			Sedimentary Rocks			Alluvial Soils
		Ultra Mafic	Mafic	Granitic	Limestone	Sandstone	Shale	
Mean	1.5	1.5	1	1	1.5	1	9	8.2
Range	--	1-15			1-20		1-900	1.2-22

Sources: Alloway, 1999; Kabata-Pendias, 1985

soils that contain high percentages of clay and organic material (e.g., clay and clay loamy soils, organic light [or rich] soils) (NAVFAC, 2002; Alloway, 1990). Therefore, it is expected that finer-grained depositional environments within the Bay Area would likely have higher natural concentrations of arsenic relative to sandy or gravelly soils.

1.4 Geologic Sources of Elevated Arsenic

As discussed above, soil and rock rich in clay and organic material have been reported to contain elevated concentrations of arsenic relative to other rock types and sandy soils. In addition, unusually high arsenic concentrations have been attributed to highly mineralized geologic environments and zones of hydrothermal alteration. For this reason, arsenic concentrations are commonly used as a pathfinding tool in mineral resource prospecting because high concentrations can indicate the presence of mineralized areas containing valuable commodities such as silver and gold (Alloway, 1990). Further, a national study by Welch et al. (2000) associated thermal waters (e.g. Yellowstone and the Mono Basin), presence of sulfide minerals (e.g. pyrite and marcasite), and areas of high evapotranspiration to high levels of arsenic in groundwater. Welch et al. (2000) did not identify the Bay Area as a region with high arsenic concentrations associated with these processes; however, due to the coarse scale of their study, the possibility that the Bay Area contains localized “hot spots” of naturally-occurring arsenic cannot be ruled out.

Hydrothermally altered mineral zones and coal deposits are relatively rare in the Bay Area, but such environments are locally present in the hills of the region. For example, abundant sulfide bearing rocks are present in the Mt. Diablo district in Contra Costa County, where mercury sulfides and copper were mined in scattered locations on and off throughout the latter half of the 18th century until about the mid-1950s (USGS, 1940; USGS, 2005). Sulfide minerals, including pyrite, marcasite, cinnabar and

metacinnibar were formed via hydrothermal deposits within Franciscan Complex rocks bounded on the east by the Great Valley Sequence (USGS, 1940). In addition, locations on either side of the central and southern Santa Clara Valley (including the historic New Almaden Quicksilver District) have also been reported to contain mercury and other precious metals, although associated sulfide minerals are less abundant than in the Mt. Diablo District (USGS, 2005: Bailey and Everhart, 1964). Aside from the mineral districts around Mt. Diablo and New Almaden, the USGS mineral resources data system indicates widely scattered locations within the hills and mountains of the region that contain occurrences of mercury, copper, gold, silver and other mineral commodities that are possible indicators of hydrothermally altered zones and sulfide minerals (USGS, 2005). The only extensive deposits of coal in Northern California are located in the Black Diamond Mines area, north of the Mt. Diablo district. The coal originates from lignite coal beds in the Domengine Formation, and was extensively mined from the 1860's to the beginning of this century (Mount Diablo Interpretive Association, 2009).

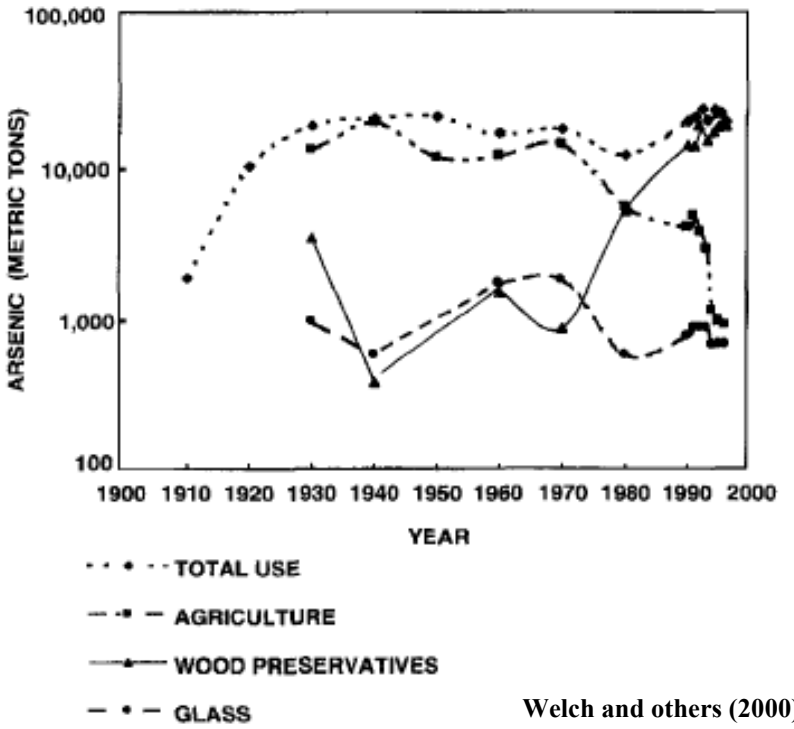
There are no studies specifically aimed at confirming or quantifying the presence of arsenic “hot spots” within the aforementioned locales; but similar geologic environments have been reported in the literature to contain naturally high concentrations of arsenic (USGS, 1940; Alloway, 1990; NAVFAC, 2002; Welch et al., 2000). Such mineralized areas and coal-bearing deposits are confined to a few localized areas in the hills and mountains of the region. Moreover, mercury deposits and associated sulfide minerals in these areas are concentrated in narrow fracture zones within the host rock (Bailey and Everhart, 1964; USGS, 1940). The predominant bedrock and the Quaternary-age deposits of the region are likely to have arsenic concentrations that reflect the more typical concentration ranges discussed in Section 1.3.

1.5 Anthropogenic Sources of Arsenic

Arsenic has a long history of use as a poison dating back to ancient times, but there are several modern uses of arsenic that has made primary production of arsenic compounds, primarily arsenic trioxide, commercially viable. Arsenic trioxide or elemental arsenic is no longer produced in the United States, but it continues to be imported in large quantities, primarily for use as a wood preservative using copper chromated arsenate (CCA). CCA-treated wood, also referred to a "pressure" treated wood, currently accounts for over 50% of domestic consumption of arsenic trioxide; though prior to 2004, it accounted for over 90% of consumption (USGS, 2010). CCA is a water-based product that protects several commercially available species of western lumber from decay and insect attack and is widely used in treating utility poles, building lumber, and wood foundations. The use of CCAs in the wood industry has experienced more recent declines, owing to voluntary elimination of CCA in residential wood products in 2004 (USGS, 2010). However, CCA continues to be used in commercial and industrial applications, and is present in residential structures built prior to 2004 (e.g., in wood needing all-weather proofing). None of the major manufacturers of CCA-treated wood are located in the Bay Area.

Arsenic has also been used in the agricultural industry for pest and weed control. As shown in Figure 1, the use of arsenic in the agricultural industry has experienced a significant decline since the early 1900s. Prior to the introduction of organic pesticides (such as DDT) in the 1940s, inorganic arsenic was the primary pesticide used by orchard growers and farmers. Inorganic arsenic compounds continued to be used as an herbicide, fungicide, growth regulator, desiccant, and/or as a weed control agent along railroad right-of-ways, in potato fields, on grape vines, on lawns, cotton crops, in industrial areas, as well as in baits and to debark trees (ASTDR, 2009). As a result of voluntary industry

Figure 1 – Arsenic consumption in the United States by industrial sector (1900-2000)



Welch and others (2000)

phase-outs and regulatory decisions by the EPA, the use of inorganic arsenic in agriculture has virtually disappeared since the 1980's and 1990's (ASTDR, 2009). The only remaining allowable uses are as ant baits and wood preservatives. Arsenic is also used in the manufacture of glass products, as an alloying element in ammunition and solders, and in semiconductors that are broadly used in computer, biomedical, communications, solar cells, space research and electronics applications (USGS, 2010). Certain industrial processes and mining activities release arsenic as a byproduct, such as stack emissions from copper smelting, coal combustion, and waste incineration; and from mine tailings (Alloway, 1990).

Of particular relevance to the Bay Area is that many of the flatlands surrounding the San Francisco Bay (in particular the Santa Clara Valley) have historically supported

irrigated agriculture, such as orchards and other crops that are likely to have utilized arsenic-based agricultural chemicals (Anderson, 1998). As urbanization has encroached on formerly agricultural land, the underlying soils may continue to have elevated arsenic levels representative of its past agricultural use. However, the extent to which former land owners actually applied arsenic-based pesticides, and whether or how much of the arsenic has since leeched out of soils is usually unknown. Generally, anthropogenic sources of arsenic which cannot be attributed to a specific waste discharge, disposal activity, or emission source can be considered "non-point" sources. As defined in Section 1.2, the natural background combined with the anthropogenic background (i.e., non-point anthropogenic sources) makes up the regional or "ambient" levels of background arsenic.

Arsenic may also have been released to the environment from current or former smelters, coal-fired power plants, and municipal incinerators; but very little is known about arsenic atmospheric deposition rates to Bay Area soils. Coal combustion is commonly cited as a source of atmospheric emissions of arsenic, although review of the USGS mineral resources data system shows no current or former coal mines or natural geological occurrence of coal in the Bay Area aside from the Black Diamond Mine area discussed in Section 1.3 (USGS, 2005). Alloway (1999) reports that the annual rate of increase in arsenic concentrations in soil due to atmospheric deposition is minor—about 0.05% for the northern hemisphere. Further, energy production facilities in the Bay Area use natural gas, solar, wind, geothermal, and landfill gas as energy sources rather than coal (EIA, 2009). Prior to the availability of natural gas, manufactured gas plants, primarily concentrated in San Francisco and Oakland, used coal and oil to produce gas for lighting, heating and cooking., these gas plants have all been closed and operated for a short time in the early 1900s (PG&E, 2011). Today, air pollution control technologies used in the Bay Area for stationary sources are advanced and tightly regulated by the EPA and the California Air Resources Board (BAAQMD, 2011). Given the lack of coal

combustion or copper smelting facilities in the Bay Area, atmospheric deposition is not likely to be a significant contributor to arsenic concentrations in soil. However, current and former stack emissions cannot be entirely ignored as a possible contributor to the anthropogenic background level of arsenic in the Bay Area.

Disposal of arsenic-containing products, including CCA-treated wood and electronic-wastes (for arsenic-containing products such as semiconductors), can cause locally concentrated levels of arsenic in regulated landfills; or if improperly disposed of, in undocumented areas on private or public property. Numerous former military bases located around the margins of the San Francisco Bay have been closed and identified as hazardous waste or superfund sites (EPA, 2011). Since arsenic was used for munitions and other military applications (USGS, 2010), areas on these bases that formerly stored munitions may also have elevated arsenic concentrations. Numerous state and federal laws—such as the Resource Conservation and Recovery Act and Title 22, Division 4.5 of the California Code of Regulations—regulate the generation, treatment, and disposal of solid and potentially hazardous wastes such that most arsenic-containing products are likely to end up in a landfill. However, such regulations originated in the 1970s and thus improper disposal of arsenic-containing wastes could have occurred prior to that time, and may still occur as a result of negligent or unlawful activities. Generally, anthropogenic sources of arsenic such as these, which can be traced back to an identifiable source, can be considered “point” sources.

1.6 Arsenic Background Studies

Many environmental scholars, managers, and regulators have recognized the need to characterize the source and distribution of trace metals in the soil environment. Previous work has focused on a) the association between groups of trace metals and their potential to predict other geochemical properties, b) the effect of rock type and land use

on metal concentrations at the scale of cities, and c) the advantages and disadvantages of various methods for characterizing geochemical background environments (Facchinelli et al, 2001; Yesilonis et al., 2008; Zhang and Selenius, 1998; Li et al., in press). Traditionally, classical statistics and multivariate analysis have been used to characterize trace metal populations in soils; however, researchers have increasingly recognized the value of using Geographic Information Systems (GIS) and geostatistics to map the spatial pattern and variability of trace metals in soil and visualizing relations with geology and land use (Zhang and Selenius, 1998). While researchers often carry out their own sampling and laboratory analyses for local studies, regional studies have increasingly utilized publically available geochemical databases for the study of trace metals (Rawlins et al., 2003; Zhao et al., 2007; and Lado et al., 2008). Existing studies of background concentrations of arsenic that are relevant to the Bay Area are listed in Table 2 and described below.

Table 2 – Scope and findings for existing background studies of arsenic

Author(s)	Geographic Scope	Number of Samples / Depth	Average, Range (mg/kg)
Shacklette and Boerngen (1984)	National, along major roads, average of 1 sample / 6000 km^2	1,318 / 20 cm (7.9 inches)	7.2, <0.1 – 97
UCR (1996)	Statewide, agricultural soils, primarily Central Valley	50 / 50 cm (1.6 feet)	3.5, <0.2 -11
Lawrence Berkeley National Laboratory (2002)	Local, Berkeley Hills, large cleanup site	1,397 / up to 60 meters (197 feet)	5.5, <DL - 42
Scott (1991)	Local, northern Santa Clara Valley, urbanized light industrial and research land uses	108 / up to 10 meters (33 feet)	2.86, <DL – 20

On a national level, the most comprehensive study of naturally-occurring trace metals in the environment has been performed by Shacklette and Boerngen (1984). The study collected 1,318 soil samples from around the country at depths of 20 cm below the ground surface (bgs) from locations about 80 km apart that, insofar as possible, had surficial materials that were very little altered from their natural condition and that supported native plants. The mean concentration of arsenic for the western conterminous United States was 7.2 mg/kg, with a maximum concentration of 97 mg/km. Three Bay Area samples that were collected near Stanford University, in the City of San Francisco, and near Mill Valley were all within the upper 40% of the frequency distribution plot (Shacklette and Boerngen, 1984). Gustavvson et al., (2001) later re-interpolated the results and produced a colored surface map of arsenic distribution in the United States, which indicated broad regional variability in arsenic concentrations. For example, high arsenic concentrations in northern Idaho and the Appalachian Basin were at least in part coincident with base- and precious-metal mining, coal-bearing deposits and coal-fired power plants (Gustavvson et al., 2001). An area in north-central Nebraska with low concentrations of arsenic corresponds to the Nebraska Sand Hills, the largest dune field in the Western Hemisphere. The authors observe that many of the geochemical abundance patterns reflect regional geological characteristics. However, they acknowledge that the low spatial density of the dataset means that some of the observed patterns may be due to random chance rather than geologic source controls.

On the state level, an important source of information on background trace metals is from the Kearny Foundation Special Report on Background Concentrations of Trace and Major Elements in California Soils (UCR, 1996). The study selected 50 samples from 22 benchmark soils from a collection of soil profiles held at the University of California, Berkeley (the soil profiles were collected in 1967). The profiles were taken from sites distant from known point sources of contamination throughout the state at 50

cm bgs, primarily within agricultural fields. Arsenic concentrations across the 22 “benchmark” soils had an average of 3.5 mg/kg, a standard deviation of 2.5 mg/kg, and values ranging from 0.6-11 mg/kg. The report authors used the W test for normality, finding arsenic to be neither normally nor lognormally distributed.

In the Bay Area, private consulting firms, local governments, and academic researchers have used a variety of methods to characterize background concentration of trace metals. A study by researchers at the Lawrence Berkeley National Laboratory (LBNL) (2002) characterized the natural background metal concentrations on the LBNL property in the Berkeley Hills by compiling the results of previous environmental investigations, eliminating outliers, evaluating the probability distributions of metal samples, and deriving summary statistics. The LBNL (2002) study determined that the 1,257 soil samples at various depths less than 60 meters (179 feet) bgs had a mean arsenic concentration of 5.5 mg/kg and standard deviation of 5.4 mg/kg. The authors also observed that naturally occurring concentrations of arsenic in samples taken from the Great Valley Sequence were elevated relative to those within Tertiary-age sedimentary rocks. Similar to the Kearny Foundation Special Report, the authors found that arsenic concentrations did not appear to be either normally or lognormally distributed, even after separating the dataset by rock type. The LBNL study determined the upper limit of background concentrations for arsenic to be 42 mg/kg for the Great Valley Sequence, and 24 mg/kg for other geologic units.

Anderson’s (1998) literature review of natural concentrations of selenium, nickel, and arsenic in soil and groundwater of the South Bay identified that that certain geologic environments are naturally enriched in nickel (from serpentinite) and selenium (from marine shales and sulfides), but found no evidence or areas with naturally enriched with arsenic. A master's thesis by Scott (1991) characterized background soil metals in an area

within a two mile (3.2 kilometer) radius in Mountain View and Sunnyvale in northern Santa Clara County. An analysis of 108 samples up to 10 meters (33 feet) bgs revealed mean arsenic concentration to be 2.86 mg/kg with a standard deviation of 2.61 mg/kg. Neither of the studies proposed upper limits for background concentrations of arsenic.

The existing studies of background arsenic vary greatly in scale, geographic scope and data source. While all the studies described above took measures to avoid obvious sources of anthropogenic arsenic contamination, the studies at the local and state scale (UCR, 1996; LBNL, 2002; Scott, 1991) were located in agricultural fields or heavily urbanized settings previously disturbed by humans, whereas the study by Shacklette and Boerngen (1984) targeted natural areas supporting native plants (although many were located close to roads, and not necessarily outside of urban areas). While all of the studies reported high variability and ranges, even in relatively localized study areas; interestingly, arsenic concentrations detected in the national study were generally higher than those reported in the local and state studies which have high degree of anthropogenic disturbance relative to the undisturbed areas sampled in the Shacklette and Boerngen study. Due to differences in study design, such as variability in number and depth of samples, land-use setting, and geographic scope, the available background studies report inconsistent arsenic concentrations and thus may provide misleading benchmarks of background arsenic for use by environmental managers and regulators in the Bay Area or any other specific location.

1.7 Problem Statement and Purpose

Arsenic found in soil—either naturally occurring or from anthropogenic releases—forms insoluble complexes with iron, aluminum, and magnesium oxides found in soil surfaces, and in this form, arsenic is relatively immobile. However, under certain reducing conditions, arsenic can be released from the solid phase, resulting in soluble

mobile forms of arsenic, which may potentially leach into groundwater or result in runoff of arsenic into surface waters (Alloway, 1990). Thus, in addition, to arsenic in soil representing a direct exposure hazard (i.e., via inhalation of dust during construction activities; children eating soil in open-space areas; or consumption of food crops grown on contaminated soils), elevated arsenic levels in soil could also lead to elevated levels of arsenic in surface and groundwater used as sources of drinking water—leading to the potential for more dispersed and widespread exposure to the public. It is in this context that regulators seek to control and minimize potentially hazardous levels of arsenic in soil.

To protect the human health and/or the environment, state environmental regulators have established environmental screening levels (ESLs) for arsenic, above which trace metal concentrations are considered potentially hazardous (San Francisco Bay RWQCB, 2008). Generally, locations with arsenic concentrations below ESLs are assumed to not pose a significant, long-term (chronic) threat to human health and the environment. Locations with arsenic concentrations above ESLs usually require some form of action which may range from additional sampling and analysis to contaminant removal. The ELSs used in the San Francisco Bay Region are risk based screening values, which are derived from equations combining exposure assumptions with toxicity data, and are not related to background levels of a substance in the environment. The risk-based screening level for arsenic in soil varies based on exposures assumptions. For example, the ESL for arsenic in shallow residential soil is 0.39 mg/kg (San Francisco Bay RWQCB, 2008). Due to regional background concentrations of arsenic, ESLs are nearly always exceeded, even in locations where no anthropogenic arsenic contamination has occurred (UCR, 1996; San Francisco Bay RWQCB, 2008). Therefore, as a practical matter, regulators have generally accepted the background levels of arsenic found in the environment as an appropriate screening criteria, because property owners are not

considered liable for arsenic concentrations that are representative of background (ITRC, 2005).

When environmental contamination is reported or suspected on a site, or in the course of non-residential real estate transactions, environmental site assessments (ESAs) are typically performed to identify potential sources of contamination and guide further cleanup efforts. When laboratory analyses of soil are performed as part of an ESA, detections of arsenic above ESLs may require no further action (with respect to arsenic) if there is a reasonable basis to conclude that arsenic concentrations are representative of background (San Francisco Bay RWQCB, 2008). In the absence of site-specific background control samples, it is my experience that ESAs in the Bay Area frequently use data from Shacklette and Boerngen (1984), LBNL (2002) or other studies of uncertain applicability to conclude trace metal concentrations found on a property are non-anthropogenic in origin. Most Bay Area properties that require ESAs are located on the urbanized bay plain whereas the LBNL site is located in the east bay hills where the rock type, geomorphology and soil forming processes differ. As such, use of LBNL background concentrations, or nationwide estimates, may not be appropriate given that geology may be a significant control on background arsenic concentrations.

Despite the abundance of soil analytical data publically available through environmental agencies, in particular the State Water Resources Control Board (SWRCB), there has been little attempt to discern whether there are geochemical patterns of arsenic that correlate with soil types or source rocks. Sites undergoing environmental investigations and cleanups often submit soils for laboratory analysis of a standard suite of trace metals (referred to as CAM 17 metals) that are incidental to the primary contaminants of concern on the site, such as motor fuels or organic solvents. As such, the data represents a potentially valuable source of background information that has thus far

been underutilized. By incorporating regional information on soil type to these analytical results, this thesis will assess whether there are statistically significant differences in arsenic concentrations across the different soil environments in the Bay Area.

The purpose of this thesis is to provide regulators and environmental investigators with a locally relevant study of background arsenic in the Bay Area. The findings herein can be used as a tool to make informed decisions about whether arsenic detections on a property are indicative of background in cases where site-specific background reference samples are infeasible or cost-prohibitive. Rather than the current reliance on background arsenic data of low-resolution and questionable applicability, this thesis provides a regional and geologic context to the question of "what is background arsenic in soil?"

2.0 STUDY AREA

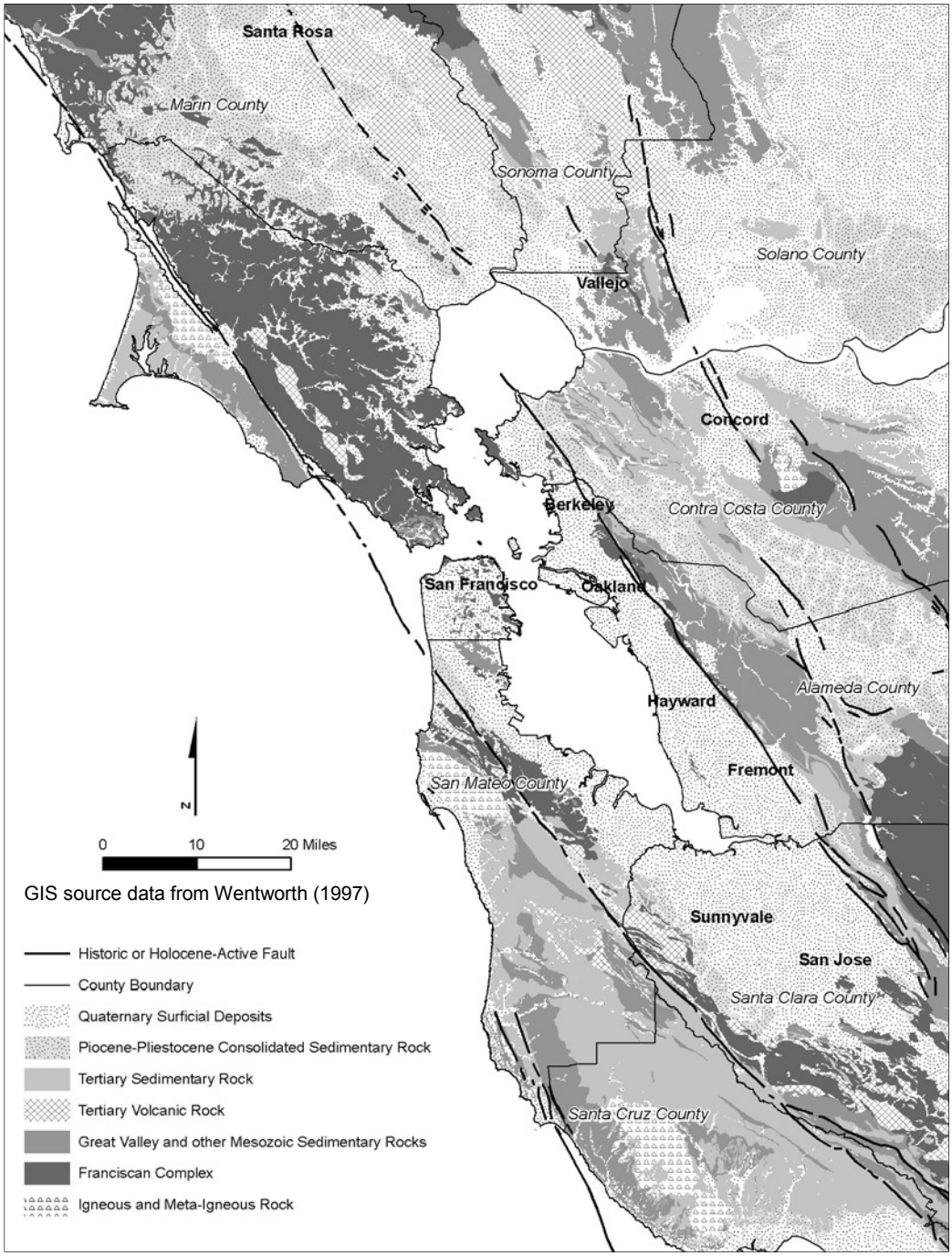
2.1 Study Area

The geographic scope of this study encompasses the nine-county Bay Area (Figure 2), including Alameda, Contra Costa, Marin, Napa, San Mateo, San Francisco, Santa Clara, Solano, and Sonoma Counties. Because environmental investigations are most often done in urban land use settings where the potential for contamination is greatest, the study area is restricted to the urbanized flatlands of the bay region underlain by Quaternary-age geologic units. By restricting the geographic scope of analysis in this way, the resulting background estimates are more likely to be directly applicable to future ESAs.

2.2 Regional Geologic Setting

The Bay Area is part of the Coast Range geomorphic province characterized by northwest-trending mountain ranges and valleys that are subparallel to the general structural trend of the San Andreas Fault System (CGS, 2008). The Coast Range is predominantly composed of thick Mesozoic and Cenozoic sedimentary strata. In the northern Bay Area, the Coast Ranges are dominated by the irregular, knobby, landslide topography of the Franciscan Complex, which is overlain in several regions by volcanic cones and flows of the Quien Sabe, Sonoma and Clear Lake volcanic fields. In the eastern Bay Area, the Coast Ranges are characterized by strike-ridges and valleys in Tertiary and Upper Mesozoic sedimentary strata. The southern Bay Area is characterized by a mix of Franciscan Complex rocks on the east side of the Santa Clara Valley, and both Tertiary sedimentary rocks as well as granitic rocks of the Salinian Block west of the valley in the Santa Cruz Mountains.

Figure 2 – Geologic map of the San Francisco Bay Area

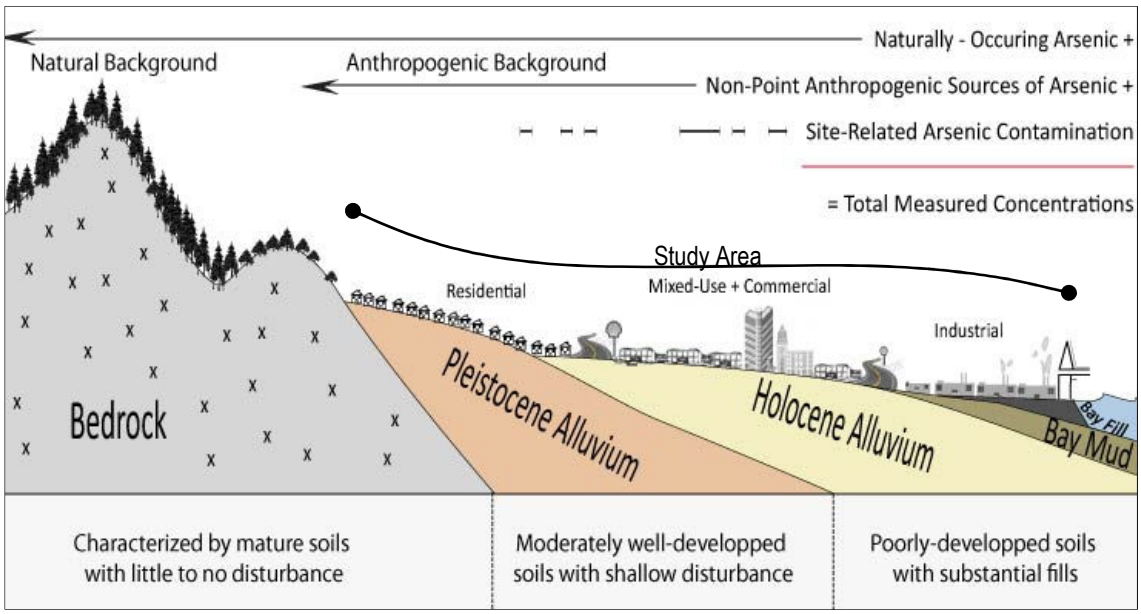


The core of the urbanized Bay Area is located on Quaternary-age surficial deposits that have formed the flatlands around the margins of the bay. These flatland deposits include Pleistocene and Holocene alluvial fans emanating out from the hills and mountains, as well as floodplain, basin and bay mud deposits located closer to the bay margins (Helley et al., 1979).

2.3 Land Use Setting

With 7.1 million residents, the Bay Area is the fifth most populous metropolitan area in the United States (ABAG and MTC, 2011). In 2000, approximately 16 percent (or about 700,000 acres) of the region's total acreage was developed for urban use (ABAG and MTC, 2011). The majority of the land areas developed for urban use consists of flatlands that surround the San Francisco Bay and which create several large inland valleys in the east bay. Generally the most intensely developed areas, including ports, airports, former military bases, and major industrial areas, are located close to the bay margins, whereas the urban fringes and foothills of major mountain ranges generally support low-density residential development. Mixed use, high-density residential areas, and commercial districts are concentrated in urban centers and along major highway corridors. Figure 3 presents a conceptual cross section of the east bay, showing the general relationship between geology, land use, and the components of total measured arsenic concentrations. Because this study is regional in scope, a rough understanding of the interplay between geology, land use and their possible effects on measured arsenic concentrations can help frame the discussion of results.

Figure 3 – Representative cross section of land use and geology and the relation to total measured arsenic concentrations



Geologic cross section based on Helley et al., 1979, not to scale.

3.0 METHODS

Results of soil chemical analyses from previous environmental investigations in the Bay Area were used to derive summary statistics and investigate the variability of arsenic concentrations across different Quaternary soil types. The source data, site selection criteria, database compilation, analysis and treatment of data, and statistical tests are described below.

3.1 Source Data

The data used in this study was retrieved from the State Water Resources Control Board (SWRCB) "Geotracker" database. Geotracker is a data system for managing sites that impact groundwater, especially those that require groundwater cleanup. In September 2004, the SWRCB formally adopted regulations that require Electronic Submittal of Information (ESI) for all groundwater cleanup programs, although parties responsible for cleanup of underground storage tanks had already been required to submit groundwater analytical data, surveyed locations of monitor wells, and other data to the Geotracker database for several years (since about 2001). As of January 1, 2005, ESI has been required by all groundwater cleanup programs including underground storage tanks, non-tank site cleanups, military sites, and land disposal sites. ESIs include site location information, soil and groundwater analytical data, monitoring well and boring log information, and electronic (pdf) copies of site investigation reports prepared by responsible parties and/or their consultants. GeoTracker's ESI module is the largest receiving system nationally for analytical and field data for cleanup sites (SWRCB, 2010). Geotracker has about 4,500 sites from the Bay Area.

Other sources of publically accessible soil analytical data exist—namely from the Department of Toxics Substances Control (DTSC), which regulates sites that handle,

treat, store, or dispose of hazardous wastes, and some limited data from the U.S. Geological Survey (USGS) geochemical database. Geotracker has advantages over other data sources because of the large volume of data and the common reporting protocol required for Geotracker, which includes specific guidelines for preparing datasets and a defined set of valid values for each database field. This protocol helps ensure that the various laboratories that analyze soil samples report data in a consistent manner. Direct electronic reporting also avoids the need for manual re-entry of hard-copy laboratory data, minimizing data entry errors and inconsistencies. Data in Geotracker is generally less than five years old, which means that the laboratory methods used are consistent and reflect the current industry standard. This is important because analysis procedures and method detection limits have frequently changed over the past decades, which can present problems in obtaining reliable or comparable statistics.

Finally, the majority of the sites regulated by the SWRCB are those that have underground storage tanks that have leaked or are potentially leaking their contents, or that for other reasons have groundwater contaminated with motor fuels or organic solvents. For most sites, there will be little or no correlation between the metal and organic compound distributions (NAVFAC, 2010). Chemical releases that contain both types of contaminants are relatively uncommon and, more importantly, organic compounds and metals have very different fate and transport properties. It also is important to note that the presence of organic co-contaminants has no effect on metal concentration background ranges (NAVFAC, 2002). In most cases, the soils analyzed for arsenic are done so as a precautionary measure to demonstrate the absence of arsenic contamination, and are generally incidental to the primary contaminants of concern. In this context, such analyses have value as a potential source of background data.

3.2 Site Selection Criteria and Database Compilation

The user interface on the Geotracker website allows for site or location queries, allowing users to search by address, site name, or other identifying information. In order to perform a custom query of the database, raw ESI data was downloaded as a tab-delimited file for each of the nine counties in the Bay Area (called an electronic data file, or EDF). Geotracker is always being updated as additional sampling and analytical data is generated at regulated sites. As such, the arsenic-related data presented in this thesis should be considered as representative of the database as of March 2010, which is the date the EDFs were downloaded. The EDF contains raw laboratory analytical data for the numerous cleanup sites in the Bay Area that are associated with the specific locations using a Global ID field. Concurrently with the download of ESI data, an excel file of regulated site information was downloaded, which contains site names, addresses, coordinates, cleanup/regulatory status, potential contaminants of concern, and other site information fields that are also associated to a Global ID field. Additional information on the database structure is available on the Geotracker website (geotracker.waterboards.ca.gov).

Using JMP 7.0, a statistical software package, the ESI data and regulated site information were linked by Global ID and queried to return all sites that have analytical data for arsenic from soil samples. The criteria for including sites in the database were as follows:

- Arsenic is not identified as a contaminant of potential concern
- ESI data includes arsenic analyses on soil samples (analyte=AS and Matrix=Soil).
- At least 5 samples per site (N>=5)
- At least 25% of the data is above the reporting limit.

These criteria were applied in order to eliminate sites that were identified in Geotracker as being potentially contaminated with arsenic, or that contained insufficient data to reliably estimate a central tendency or derive other simple statistics. Sites that otherwise would have satisfied the criteria were excluded from the database due to one or more of the following reasons: 1) laboratory notes indicated excessive interference or other problems with the analysis, 2) arsenic contamination was suspected based on detected data, and 3) duplicate ESI entries (i.e. the same laboratory report was submitted to Geotracker more than once). The level of effort and approach taken to avoid sites with metals contamination used in this study is consistent with other works that have utilized existing data (LBNL, 2002; Scott, 1994; Yesilonis et al., 2008; Lado et al., 2008).

Following ESI data download and site selection, the JMP 7.0 database was expanded to include fields that were not a part of the original ESI, including sample depth and geologic unit. Using ArcMap 9.2, the site locations were overlain onto a regional geologic map of the Bay Area to assign geologic units to each site. The geologic map is a digital database containing a GIS shapefile for the general distribution of geologic materials in the San Francisco Bay Region released by the USGS (Wentworth 1997). Geologic materials are categorized in the database by general age and lithology. The cleanup sites used in this study were predominantly underlain by Pleistocene alluvium, Holocene alluvium, and Holocene bay mud deposits. Other geologic units included undifferentiated Quaternary units such as terrace deposits, colluvium, and dune sands. The fields included in the database, their definitions and source are provided in Table 3. All the samples in the database were analyzed by either inductively coupled plasma (ICP) atomic emission spectroscopy or ICP mass spectrometry.

Table 3 - Explanation of database fields by name, type and source

Field Name	Type	Source / Description
Global ID	text / nominal	Geotracker
Site name	text / nominal	Geotracker cleanup site database
City	text / nominal	Geotracker cleanup site database
County	text / nominal	Geotracker cleanup site database
Site N	numeric / ordinal	Number of samples per site; derived in JMP
Sample ID	text / nominal	Geotracker EDF download
Field point class	text / nominal	Identifies sample collection method. Geotracker EDF download
Depth	numeric / continuous	Site investigation reports
Depth class	text / nominal	Shallow or subsurface, based on Navy guidance. See section 3.3
Value (mg/kg)	numeric / continuous	Geotracker EDF download
RL	numeric / continuous	Reporting Limit, Geotracker website, site by site search
MDL	numeric / continuous	Method Detection Limit, Geotracker website, site by site search
D_Arsenic	numeric / ordinal	Censored data identifier
Arsenic	numeric / continuous	Arsenic value field with censored data estimates. See Section 3.4
Substitution method	text / nominal	See Section 3.4
Comments	text / nominal	Optional field for comments
Age-Lith	text / nominal	Age / lithology ID from USGS
Geologic Unit	text / nominal	Geologic unit name from USGS
Geology Class	text / nominal	Geologic units grouped into four categories for this analysis

In order to gather information on sample depths, pdf or scanned hard copies of the site investigation report(s) for each site were reviewed and pertinent information was then transferred to the database. Site investigation reports were not available for approximately 17 sites in the Geotracker database, in which case information on sample depth was either left blank, or assumed based on the sample ID (i.e., if the sample ID was "B-2@2'" the depth was recorded as 2 feet in the database). Sample depths and field collection method were reviewed to classify samples as being either surface or subsurface samples. Boring equipment used to collect soil samples may not be capable of collecting samples over discrete intervals less than 2 feet long. In addition, the boring action may mix soil from near the surface with deeper soils. Therefore, as recommended in a Navy guidance document for environmental background analysis (NAVFAC, 2002), each of the following were considered as surface soil samples:

- soil samples collected with hand tools ("grab samples") between the surface and 0.5 foot bgs
- soil samples collected from borings between the surface and 2 feet bgs
- soil samples explicitly identified as surface samples

All other samples were considered subsurface soil samples. Composites or samples without depth information were not assigned depths or depth classes.

As discussed in Chapter 2, the study area is within urban areas whose soils have likely been disturbed and reworked within several feet of the ground surface due to grading, soil moving, construction activity and utility work. It is possible that anthropogenic inputs of arsenic, if present, have been mixed down to the historical depth of disturbance. To account for this possibility, soil depths were also classified as shallow (≤ 6 feet bgs) or deep (> 6 feet bgs). Six feet (1.8 meters), while somewhat arbitrary, was

considered a reasonable depth based on common depths of excavation needed for utilities, roads, building foundations and site leveling within flatland soils.

3.3 Assessment of Site Data, Treatment of Censored Data, and Identification of Outliers

Due to the broad geographical area, geological diversity, and land-use setting of the study area, before conducting an assessment of background arsenic concentrations within the Bay Area as a whole, outliers and censored data for each individual site were evaluated. For sites that contain censored data (i.e., nondetects, or values that are less than the laboratory reporting limit), normal quantile plots of site data were generated in JMP to characterize the distribution of arsenic concentrations. Where neither a normal nor lognormal model fit the data, non-parametric statistical methods were used to conduct further analyses. For several sites, especially those with a low number of samples, the graphical methods were insufficient to determine the type of population distribution. In such cases, goodness-of-fit tests available in ProUCL were used to best estimate the distribution type of the data. ProUCL is a statistical application released by the U.S. EPA that is designed specifically for environmental datasets with nondetects. Most of the statistical methods described and recommended in EPA's guidance on assessing background concentrations at contaminated sites (EPA, 2002) are incorporated into ProUCL. Either the Shapiro-Wilk test or the Lilliefors test, depending on sample size was used to determine the distribution type. Information on the distribution type was used to estimate the values of censored data, as described below.

The predominant method in the environmental field to incorporate nondetects data into statistical analysis is to replace censored data with artificial values, such as the reporting limit or half of the reporting limit (i.e., simple substitution). However, Helsel

and Hirsch (2002) found that summary statistics obtained using the simple substitution method do not perform well even when the percentage of nondetect observations is low, such as 5%-10%. Therefore, rather than handling non-detect values in the conventional way, the regression on order statistics (ROS) method recommended by Helsel and Hirsch (2002) was used to estimate the values of censored data. An ROS estimation function in ProUCL was used to generate estimated values for the censored data based on the most likely distribution type at each site. For censored data at sites where no discernable distribution was apparent, simple substitution using half the reporting limit was used to substitute for nondetects.

Outliers—defined as sample values that are unusually large (or small), and that are obvious deviations from the background distribution—may result from analytical errors, transcriptions errors, or the presence of contaminated samples in the background dataset. To identify outliers, box plots were generated for each site in JMP. Any values beyond the upper (or lower) quantile +/- 1.5x the inter-quartile range (IQR) were identified as outliers and eliminated from the database. The purpose of this evaluation was to minimize the effect of outliers on the background statistical analysis.

3.4 Summary Statistics and Statistical Tests

Using JMP, summary statistics were derived for each site in the database, including the number of observations (N), percent of observations that were nondetects, mean, median, standard deviation, and IQR. A frequency distribution and a normal probability plot were also generated to graphically display the site medians. The spatial autocorrelation tool in ArcMap 9.2 was used to assess the degree to which site medians were spatially clustered. The sites were then grouped based on the mapped geology, and summary statistics were derived for each soil type. Using analysis of variance (ANOVA) and the Tukey Kramer HSD test (Tukey test) available in JMP, each geological grouping

was used to test for significant differences among their means. The sites were also grouped by depth class, and Wilcoxon test was used to determine if the group medians are significantly different. A 95% confidence level was used for all statistical tests to determine statistically significant differences among group means. ProUCL provides a number of statistical options for calculating background threshold values (BTVs). Because of the large, well distributed nature of the dataset, and consistent with federal guidance (EPA, 2002; NAVFAC, 2002), the 99th percentile was selected as the appropriate measure of the upper range of background concentrations within the study area.

3.5 Limitations and Assumptions

Because this research is based on existing data and does not involve field sampling or field verification of geologic mapping, the statistical analyses and associated findings presented herein must be viewed in the context of several assumptions and associated limitations:

- It is assumed that the geology of a Geotracker site is representative of the lithology mapped by Wentworth (1997), and that Geotracker has recorded accurate locations for each of the sites. Locations close to the bay or in dense urban settings are likely to be underlain by a variable thickness of artificial fill soils used to prepare sites for development. Due to the relatively flat topography of Quaternary geologic units, it is standard practice to balance cuts and fills onsite during construction-related grading. Therefore, for sites mapped as being within Pleistocene or Holocene alluvium, it is assumed that fill soils are representative of the same geologic unit. For sites within bay mud, which are highly compressible and (from a geotechnical standpoint) not suitable for most urban development projects, fills from offsite sources have commonly been placed over the surface of

the bay mud (Helley at al., 1979). For sites in Geotracker mapped as being on bay mud, boring logs of the site were reviewed, if available, to verify the accuracy of the mapped geology. Samples identified as being within artificial fills were removed from the database because their origin and lithology is unknown.

- It is assumed that the Geotracker database fields identifying potential contaminants of concern are accurate and represent the full range of contaminants thought to be the result of site-related activities. If arsenic or metals were not identified as a contaminant of concern in the database, it is assumed that arsenic detections are generally representative of the anthropogenic background. This assumption was verified to the extent possible through review of the site investigation reports available in Geotracker.
- A generic method (see Section 3.2) was used to identify outliers for each site in the database that may not effectively identify outliers that are part of a second distribution. EPA guidance (NAVFAC, 2002) generally recommends identifying outliers through observation of log-transformed data on a probability plot. Data points that are not near the line or do not fit a continuous distribution are generally considered as outliers or belonging to a second, contaminated population. However, due to the high number of sites in the database, any values exceeding the upper quartile + 1.5*IQR were considered outliers for the purpose of efficiency.

This study does not attempt to characterize the geochemical behavior of arsenic in soil or explain the influence of small-scale geochemical processes on total arsenic concentrations. Rather, sufficient data is being collected to reasonably characterize arsenic concentrations representative of background at a regional scale, and to determine whether differences in flatland geology represents a statistically significant variable. The

results of this study are most relevant to areas underlain by quaternary geologic units within the Bay Area, and should not be used outside of the relevant geographical area.

4.0 RESULTS

4.1 Summary of the Database

Based on the site selection criteria (Section 3.2), 77 sites were selected from the Geotracker database for inclusion in this study. The 77 sites represent 2 percent of the total number of Geotracker sites within the 9-county Bay Area. The number of arsenic samples at each site ranges from 5 to a maximum of 139, totaling 1,454 samples across the 77 sites. All 1,454 records, including the fields described in Table 3 are included in a Microsoft Excel file on CD attached to this thesis. Approximately 65 percent of the data selected from Geotracker comes from soil borings, which were made for the purpose of collecting soil samples or as part of the installation of groundwater monitoring or remediation wells. The remaining 35 percent of the data consists of 1) soil samples collected from the walls or pits of excavated areas that formerly contained underground storage tanks or soils impacted by petroleum hydrocarbons or organic solvents, 2) surface samples collected by hand or hand-auger as part of an environmental investigation, or 3) soil stockpile samples for the purpose determining an appropriate off-site disposal method. Reporting limits in the database were generally below 1 mg/kg, although approximately 16 samples (less than 0.5 percent of the database) had high reporting limits over 5 mg/kg.

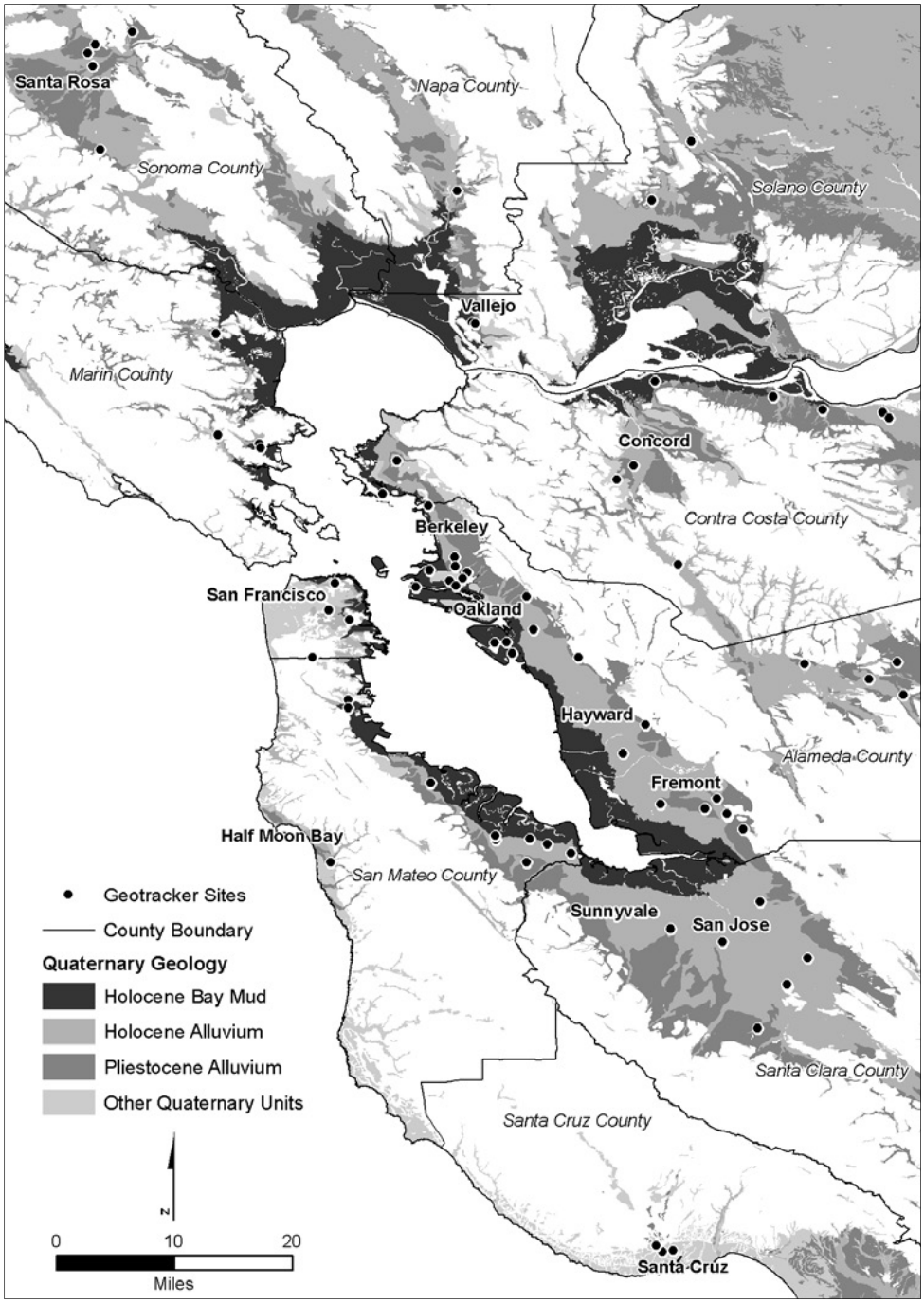
A summary of the 77 sites by county and soil type is provided in Table 4 and illustrated in Figure 4. All of the sites are located within urbanized portions of the Bay Area and consist primarily of industrial, military, transportation, and service commercial facilities, including numerous gas stations. A handful of sites consist of housing developments proposed on formerly industrial sites or residential properties. The sites are located across relatively flat Quaternary surficial deposits (Figure 4).

Table 4 – Summary of the 77 sites from the Geotracker database, sorted by county and soil type

	No. of Sites	No. of Samples
By County		
Alameda	30	745
Contra Costa	11	145
Marin	4	48
Napa	1	9
San Francisco	4	30
San Mateo	10	140
Santa Clara	5	154
Santa Cruz	3	81
Solano	4	48
Sonoma	5	54
By Soil Type		
Holocene Bay Mud	14	192
Holocene Alluvium	27	694
Pleistocene Alluvium	24	369
Other Quaternary Unit	11	190
Residual Soil, Franciscan Complex	1	9
TOTAL	**77**	**1,454**

Sites located within Pleistocene alluvium tend to be located on large alluvial fans extending out from the base of hills, whereas sites underlain by Holocene bay mud are located along the margins of the bay (Figure 4). Sites underlain by Holocene alluvium are generally found on large flat plains between the Pleistocene alluvial fans and bay muds (see Figures 3 & 4).

Figure 4 – Location of the 77 selected sites selected from the Geotracker database

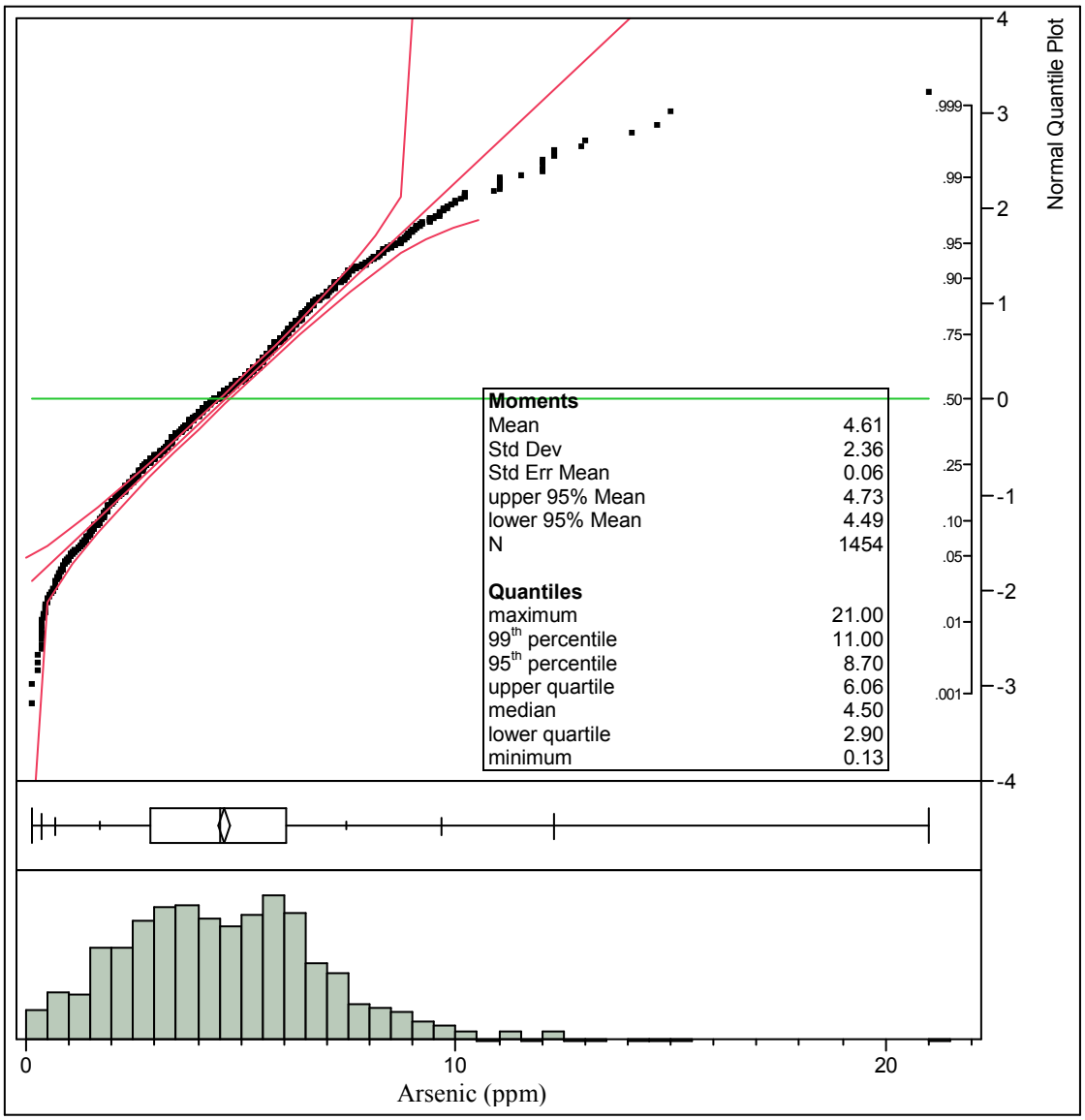


Adapted from Wentworth (1997)

The geographic distribution of the 77 sites is not uniform; rather, they are more concentrated within the more heavily urbanized portions of the Bay Area, particularly in Alameda County and other parts of the east bay (Figure 4). The relatively high density of sites in certain areas may indicate the general intensity of industrial and commercial development and the efficiency with which local enforcement agencies impose electronic reporting to Geotracker. Over 50 percent of the data in the database comes from Alameda County. Further, a relatively small number of sites make up a large fraction of the database—50 percent of the data comes from about 16 of the 77 sites. For the above reasons, the background dataset is biased both in terms of the number of samples per site and due to geographic clustering. Given the Bay Area has a developed land area of about 2,800 square kilometers (ABAG and MTC, 2011); the average density of sites is approximately one site per 36 square kilometers.

The database contains all arsenic data that is considered representative of background. Using the methods described in Section 3.3, the ROS method was used to replace 77 nondetects with estimated values, and 60 outliers were identified and eliminated. Figure 5 presents a histogram, quantile box plot, normal quantile plot, and summary statistics for the arsenic concentrations within the database. The data includes all samples from the 77 sites, thereby skewing the distribution pattern and overall summary statistics in favor of sites with a high number of samples, and combining multiple background populations into one distribution. As such, the visual analysis of the histogram and probability plot are unlikely to point to regional-scale influences on arsenic concentrations such as geography or geologic unit. In addition, the right tail of the probability plot shows several data points that might be interpreted as outliers; however, these did not meet the criteria for excluding outliers discussed in Section 3.3.

Figure 5 – Distribution of arsenic concentrations, including a histogram, a quantile box plot, and a normal quantile plot



Summary statistics of arsenic concentration in the database include a mean of 4.61 ppm, median of 4.50 ppm mg/kg, standard deviation of 2.36 mg/kg; and an IQR of 3.16 mg/kg (Figure 5). The concave shape of the normal quantile plot indicates that arsenic concentrations are not normally distributed. Based on the Lilliefors tests in ProUCL, the arsenic concentration data do not follow a discernable distribution and thus non-parametric methods are used when comparing groups (i.e., sample depth) within the database. Based on this data, the upper estimate of arsenic concentrations (99th percentile) considered as background is **11 mg/kg**.

4.2 Summary of Background Arsenic Concentrations by Site

Appendix A lists the 77 sites selected from Geotracker, their location, the soil type and basic summary statistics, including quantiles. Figure 6 and Figure 7 include a normal quantile plot, a quantile box plot, and a histogram of median values from the 77 sites first in original values (Figure 6), and as log-transformed data (Figure 7). The Lilliefors test was used on both distributions to test the null hypothesis that the data come from a normally (or log-normally) distributed population. The test, which used untransformed data to test both the normal and lognormal model, failed to reject the null hypothesis in either case, indicating the data can be characterized as being normally or log-normally distributed. The correlation coefficients (R) for both tests were nearly identical—R values were 0.981 and 0.983 for the normal and the log-normal data, respectively; however, the lognormal distribution has a better visual fit to the data. Site medians range from 0.61 mg/kg to 11 mg/kg, and the data display a positively skewed distribution. The mean of the dataset is 4.23 mg/kg, the median is 3.9 mg/kg, and additional summary statistics are shown in the box in Figure 6.

Figure 6 – Normal quantile plot, box plot, and histogram of site medians

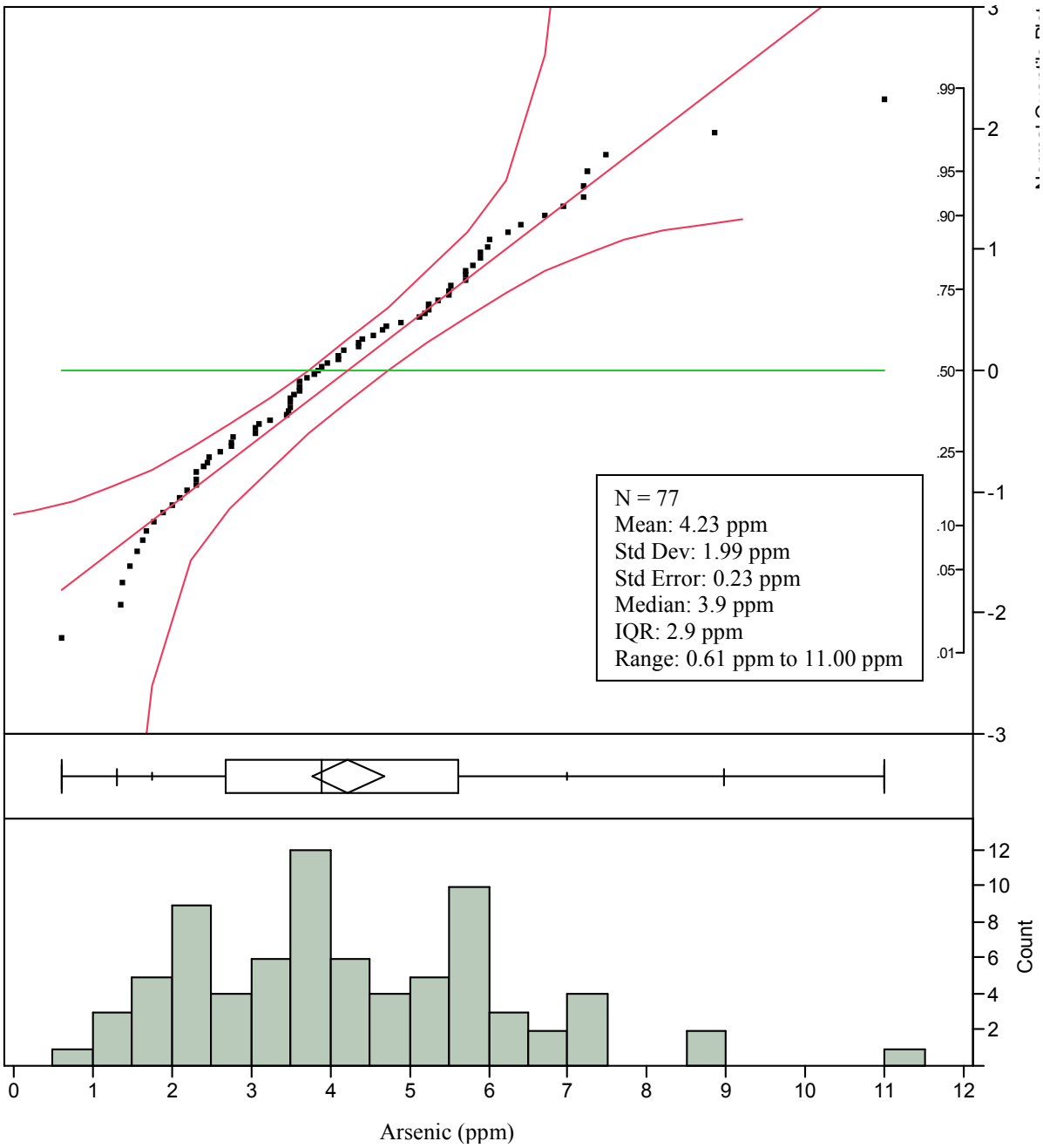
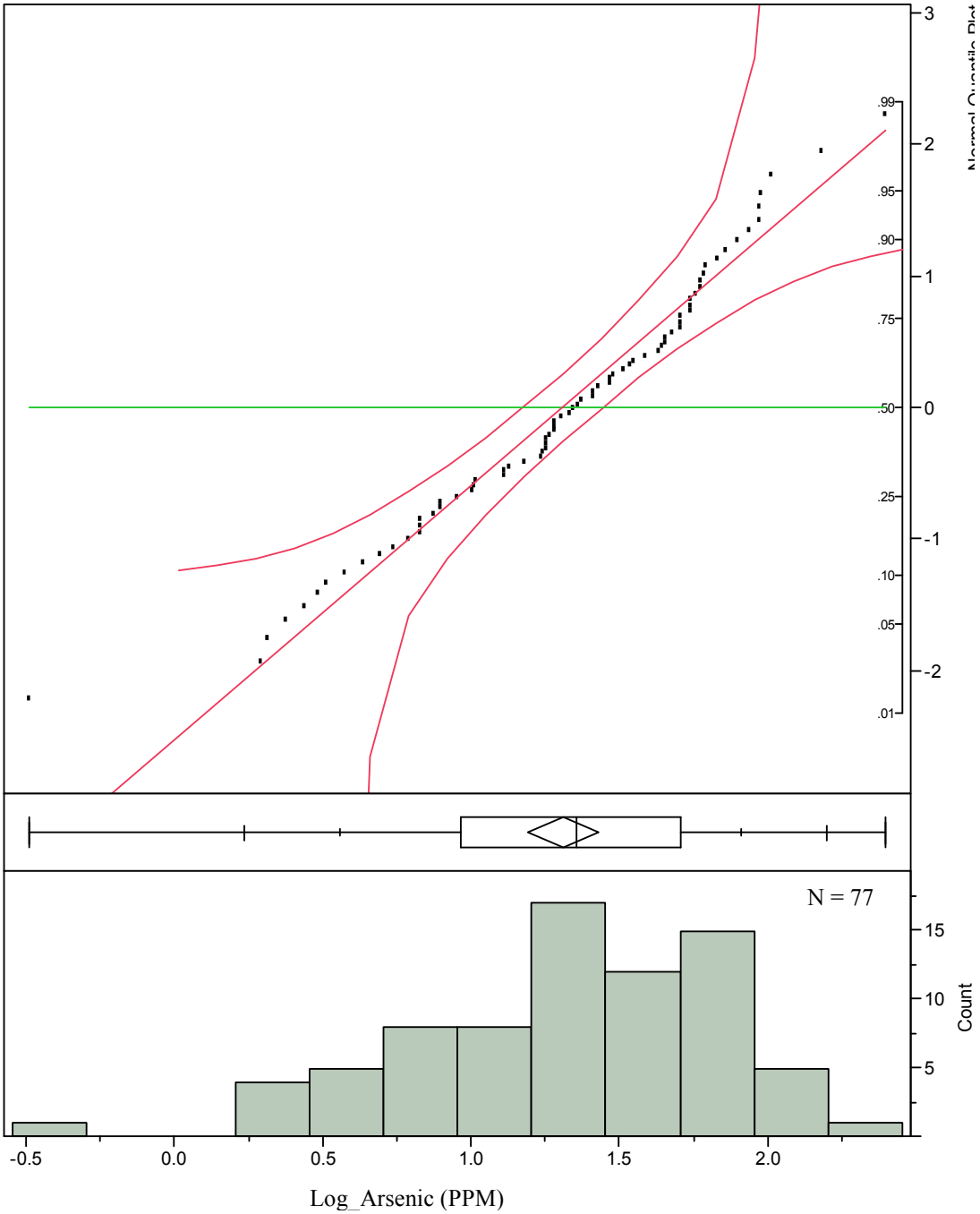


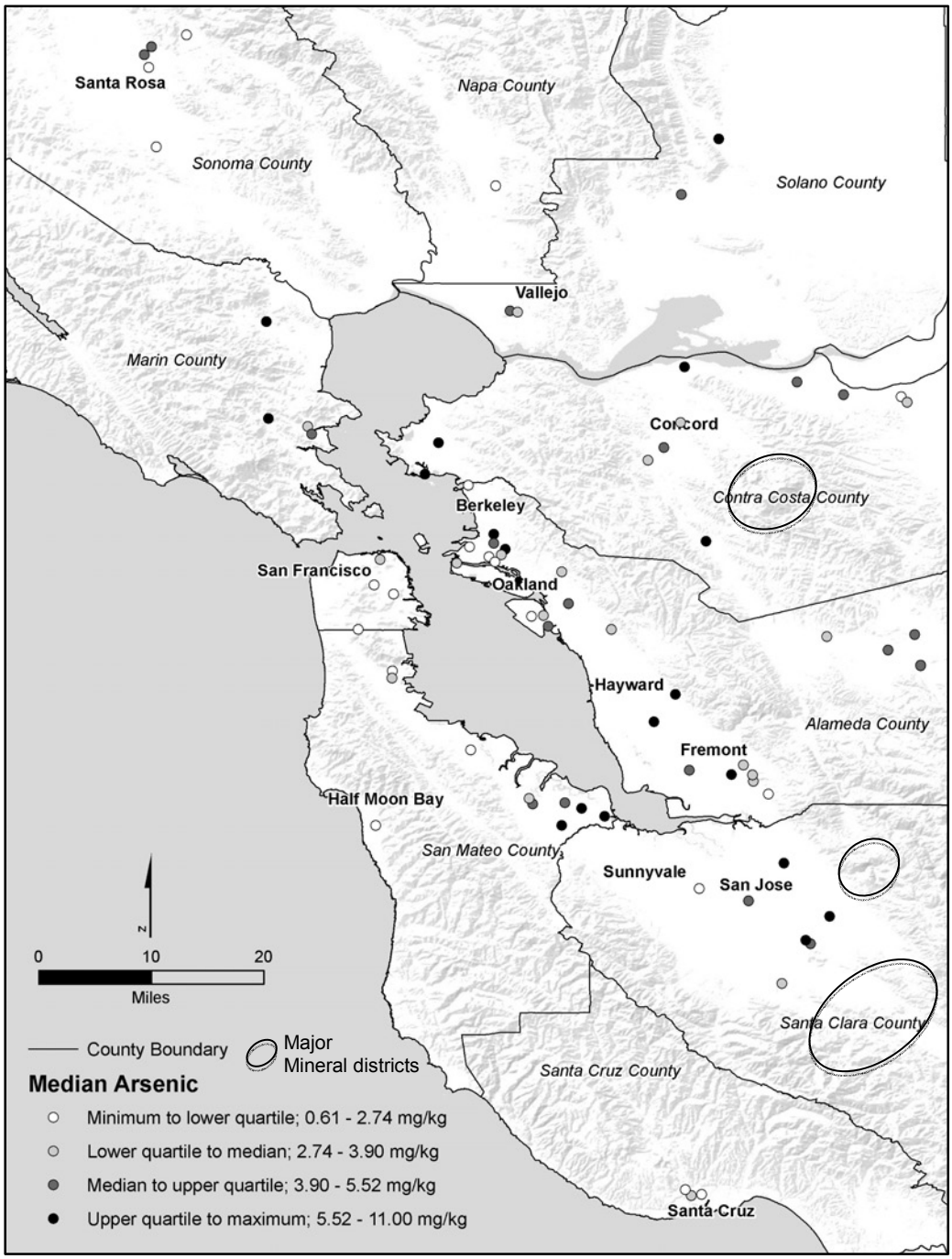
Figure 7 – Normal quantile plot, box plot, and histogram of the natural log of site medians



Three sites contributed to a large portion of the spread in the data. On the low end, site no. 22 has a mean of 0.8 mg/kg and 75 percent of the data, including the median is below the reporting limit (Appendix A). The detected data for site no. 22 ranged from 1.0 mg/kg to 2.0 mg/kg. Review of the site investigation report for the property did not indicate a reason (such as laboratory analysis problems or site-related sources of arsenic contamination) that the site should be excluded from the dataset. On the high end, site nos. 18 and 25 have median arsenic concentrations of 11.0 mg/kg and 8.9 mg/kg, respectively. The samples collected from both sites were deep (>1.8 meters bgs) and the site investigation reports contained no evidence to indicate site related arsenic contamination has occurred. As such, the sites were not eliminated from the dataset as outliers.

Figure 8 illustrates the spatial pattern of median arsenic concentrations by site across the study area. The 77 sites are colored by value, with white and black dots representing the lowest fourth and highest fourth of median values, respectively. Median values for sites in the northern San Francisco Peninsula and along the Pacific coastline appear to be consistently on the low end of the range, whereas sites on the high end of the range do not appear to dominate a single geographic region. Certain areas, such as central Marin County, the City of Hayward, the east side of San Jose, and the west end of Contra Costa County, have sites with high median arsenic concentrations. However, a clear geographic pattern cannot be discerned due to the low spatial density of the data in those places. Areas where the spatial density of sampling sites is high, such as the Berkeley, Oakland, Fremont, and north of Sunnyvale areas, have median arsenic concentrations that vary from the low to the high end of the range within relatively short distances. Figure 8 also shows general regions where rocks have been historically mined for Mercury.

Figure 8 – Map of median arsenic by site



To evaluate whether the spatial pattern expressed is clustered, dispersed, or random, the spatial autocorrelation tool in ArcMap 9.2 was used to calculate the Moran's I Index value and a Z score. A Moran's I value near +1.0 indicates clustering while a value near –1.0 indicates dispersion. The Z score value indicates whether or not the null hypothsis that there is no spatial clustering can be rejected. The Moran's I Index for the site medians is 0.18 and the Z score is 1.2 standard deviations. These scores confirm the visual observation that while somewhat clustered, the observed pattern of median arsenic concentrations may be due to random chance.

4.3 Arsenic Concentrations by Sample Depth

Because releases of arsenic are most likely to occur above ground (NAVFAC, 2002), sample depths (bgs) were classified as surface or subsurface as described in Section 3.2 to evaluate whether arsenic contamination within surface soils should be suspected. Soil samples were excluded from this analysis if the sample depth was not reported or if a composite depth was reported, which represents a range of depth rather than discrete depth. To compare depth classes, a univariate plot of arsenic concentrations for surface samples vs. subsurface samples was examined (Figure 9). Arsenic concentrations in the database plotted on a normal quantile plot indicate the distribution pattern is non-parametric in nature (Figure 5). As such, the non-parametric Wilcoxon test was used to determine if the group medians are significantly different. The test resulted in a significance probability (probability > |z|) of 0.40. Because the observed significance probability is not less than 0.05, there is no significant difference between surface and subsurface soil concentrations at the 95% confidence level. A univariate plot of arsenic concentrations for shallow (≤ 1.8 meters) vs. deep (> 1.8 meters) samples was created (Figure 10), and the non-parametric Wilcoxon test resulted in a significance probability

Figure 9 – Univariate plot of arsenic concentrations vs. sampling depth (surface and subsurface)

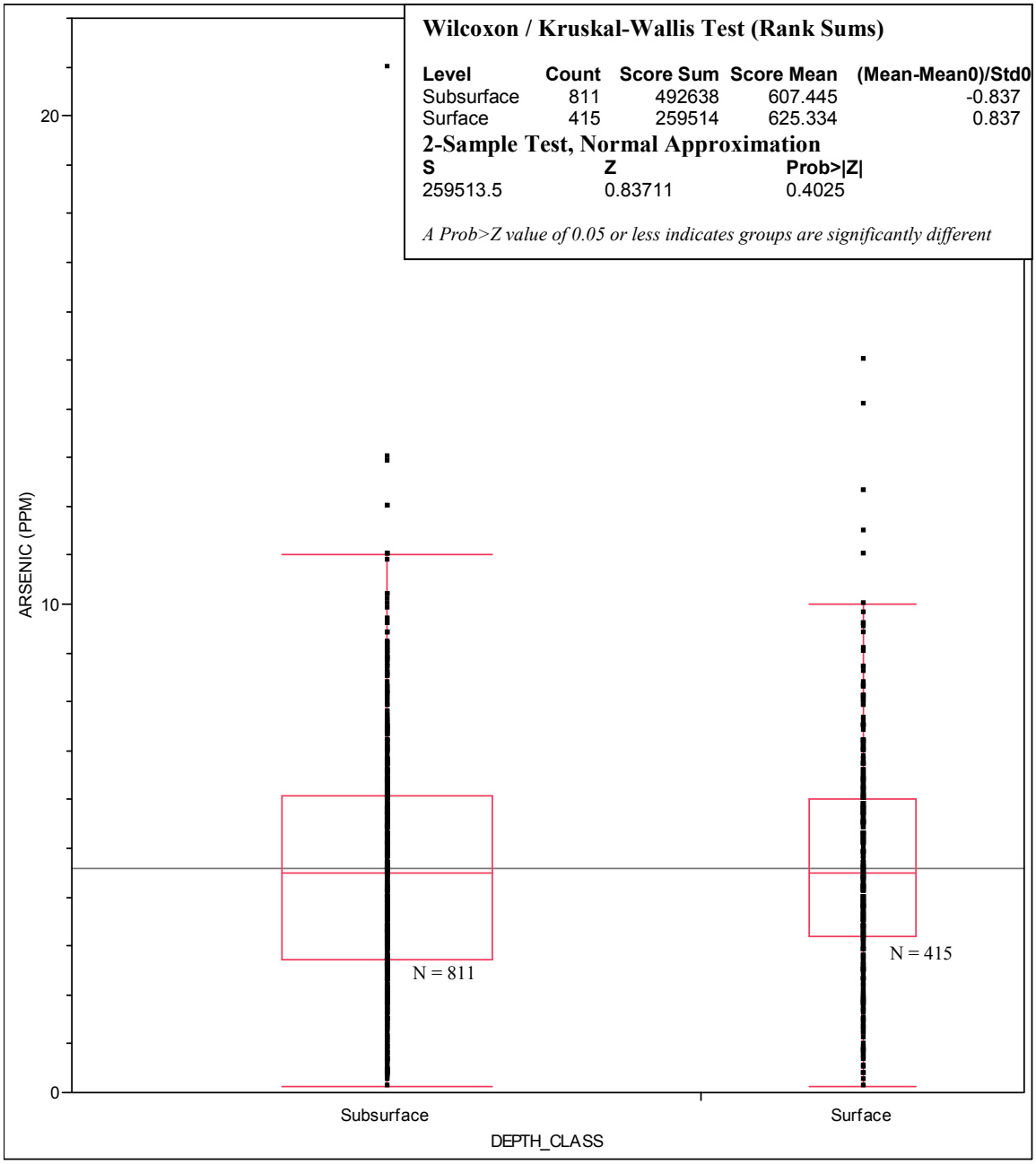
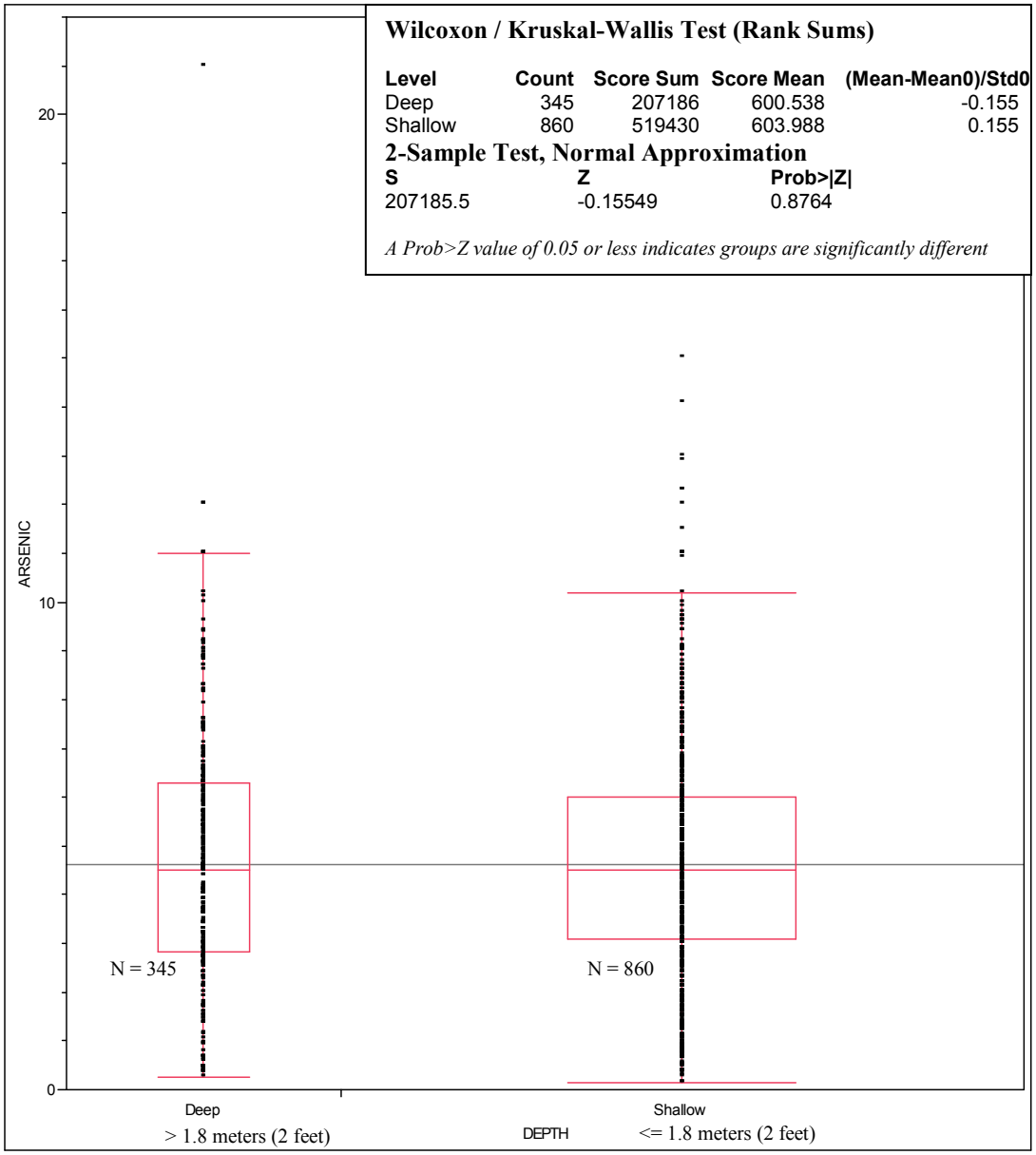


Figure 10 - Univariate plot of arsenic concentrations vs. sampling depth (shallow and deep)



(probability > |z|) of 0.88, likewise indicating there is no significant difference in arsenic concentrations between shallow and deep soil samples (95% confidence level).

4.4 Statistics by Soil Type and Significance Tests

The 77 sites are underlain by several geologic units, including Holocene bay mud, Holocene alluvium, Pleistocene alluvium, other Quaternary units, and Franciscan Complex bedrock (Table 4). Because only one site is located within the Franciscan Complex, it was excluded from this analysis. Eleven sites are underlain by several different Quaternary units that are not alluvial in origin. These sites were either underlain by dune sands, coastal/marine terrace deposits, or colluvium, and were grouped together as one category. Table 5 lists summary statistics for arsenic concentrations by soil unit. An ANOVA was performed to test whether grouping by soil type can explain some of the variation in background arsenic concentrations. An ANOVA was considered appropriate because the site medians follow a normal distribution, and because variances are equal. The F Ratio obtained from the ANOVA (3.85) indicates that the model fits the data at a 95% confidence level (probability > F is 0.013), and that group means are statistically different from the overall response mean.

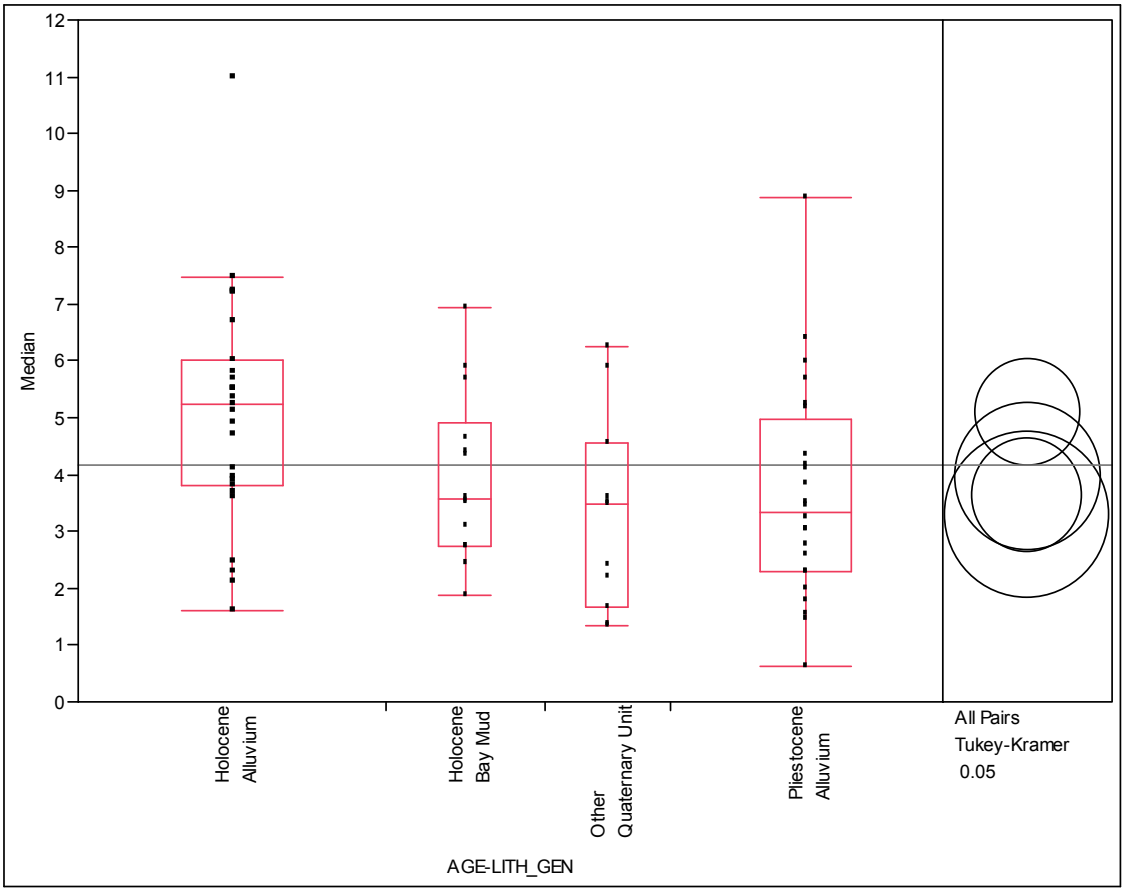
Table 5 – Statistics by soil unit and means comparison using Tukey test

Soil Type	Number	Mean	Min (mg/kg)	Median (mg/kg)	Max (mg/kg)	Tukey test*
Holocene alluvium	27	5.10	1.62	5.25	11	A
Holocene bay mud	14	3.97	1.89	3.58	6.94	A B
Pleistocene alluvium	24	3.65	0.61	3.35	8.86	B
other Quaternary unit	11	3.30	1.34	3.47	6.25	B

** Levels not connected by same letter are significantly different*

To make multiple comparisons between soil types, a Tukey test was performed, as shown in Figure 11 and Table 5. The comparison circles plot on the right side of Figure 10 is a visual representation of group mean comparisons. Circles for means that are significantly different either do not intersect or intersect slightly so that the outside angle of intersection is less than 90 degrees. If the circles intersect by an angle of more than 90 degrees or if they are nested, the means are not significantly different. Group means for Holocene alluvium, Holocene bay mud, Pleistocene alluvium, and other Quaternary units were 5.10 mg/kg, 3.97 mg/kg, 3.65 mg/kg, and 3.30 mg/kg respectively. According the Tukey test, Holocene alluvium has a group mean that is significantly higher than both Pleistocene alluvium and other Quaternary units, but there is no significant difference between Holocene bay mud and any other unit. In addition, there is also no statistically significant difference between group means of Pleistocene alluvium and other Quaternary units. The R^2 value of the ANOVA model is 0.14, indicating the groupings explains 14 percent of the overall variability of the sample group.

Figure 11 – Distribution of arsenic concentrations by soil type and Tukey-Kramer HSD comparison of means



5.0 DISCUSSION AND CONCLUSION

5.1 Summary of Results

The results of this study indicate that background arsenic concentrations within the urbanized San Francisco Bay Region are lower than many of the estimates found in the literature, and are only weakly correlated with the underlying Quaternary geologic unit. Based on the data screened from Geotracker, the mean and upper estimate (the 99th percentile) for the regional background level of arsenic is 4.61 mg/kg and 11.00 mg/kg, respectively. In increasing order, the mean concentration of site medians grouped by soil type are 3.30 mg/kg ("other" Quaternary units), 3.65 mg/kg (Pleistocene alluvium), 3.97 mg/kg (Holocene bay mud), and 5.10 mg/kg (Holocene alluvium). Arsenic concentrations within Holocene alluvium were found to be statistically greater than Pleistocene alluvium and "other" Quaternary units; but no statistically significant difference was found between Holocene Bay Mud, Pleistocene alluvium, and "other" Quaternary units. The ANOVA and Tukey test revealed that the differences between group means are not pronounced, accounting for only 14 percent of the variation in median values across the 77 sites included in this study.

While it was anticipated that non-point anthropogenic sources of arsenic might result in higher concentrations of arsenic within surface samples, there was no statistically significant difference found between surface and subsurface soil samples. Further accounting for the soil mixing and reworking that takes place in urban settings, there was likewise no statistically significant difference found between shallow (≤ 1.8 meters) and deep (> 1.8 meters) soil samples. These results provide further evidence that the anthropogenic influence on the sample sites as it relates to arsenic is minimal.

The relative differences in mean arsenic concentrations across the four soil types, despite being subtle, correlate well with the general expectation that finer grained soils would result in elevated arsenic concentrations relative to coarse grained soils (NAVFAC, 2002; Alloway, 1990). Helley et al. (1979) explains that Pleistocene alluvium, which extends out from the base of hills in the Bay Area, is generally a coarser-grained unit than Holocene alluvium on the bay plains. Further, the "other" Quaternary units—predominantly composed of dune sands, colluvium, and shallow marine terrace deposits—had the lowest mean arsenic concentration. These "other" units are generally clean sandy units, and/or coarse-grained as a result of their depositional environment. This is generally consistent with finding made by Gustavvson et al. (2001), who associated the Nebraska Sand Hills, the largest dune field in the Western Hemisphere with low concentrations of arsenic.

5.2 Other Potential Sources of Variability in the Regional Background

As explained in Chapter 2, there are a number of other factors besides Quaternary soil type that likely contribute to regional variability in background arsenic concentrations, including the geologic source material for the Quaternary soils, the anthropogenic background, and/or ongoing geochemical processes (e.g., weathering, leaching, or enrichment). Localized areas in the hills and mountains of the region may produce unusually high concentrations of arsenic due to favorable geologic environments such as ore deposits (i.e. former mercury mines) and presence of organic-rich shales or coal. It is reasonable to expect that depositional settings sourced from these regions may result in naturally elevated concentrations of arsenic within Quaternary-age sediments.

However, there are several limitations, both in this study's dataset and in the existing geologic environment, that limit the ability to test this idea. Firstly, there are inherent difficulties in associating alluvial soils to specific bedrock sources, especially

when the watershed is large and geologically complex. The influence of arsenic-rich geologic environments would become decreasingly detectable as a greater portion of the watershed is underlain by other bedrock units (i.e., distance from source). Secondly, while the general locations of former mercury and coal mines are known, shale and/or mudstones often occur in repeating sequences along with other sedimentary lithologies (e.g. sandstone). These sequences are frequently mapped together in the same formation, making it difficult to reliably estimate the portion of the watershed underlain by a specific lithology. Lastly, rather than being concentrated in one geographic location, shale-rich lithologies are fairly widespread throughout the Bay Area, making it unlikely a clear geographic pattern would be detected.

These limitations, along with the low geographic resolution of the data make correlations of high arsenic concentrations within Quaternary soils to specific source rocks speculative at best. If there were a strong source-rock influence on arsenic concentrations in Quaternary soils, it would be expected that sites with high arsenic values would be clustered and coincident with similar source regions. As discussed in Section 4.2 and shown in Figure 8, while the data in this study appears slightly clustered, it is also possible that it is the result of random chance. The lack of evidence for strong clustering or a striking geographic pattern may have more to do with the geographically sparse nature of the dataset than the absence of a source rock influence. The two general observations of 1) low median values along the northern end of the San Francisco Peninsula and the San Mateo and Santa Cruz County coastlines, and 2) high values in the eastern and southern Bay Area beg for a geologic explanation. Further study aimed at greater understanding of the relationship between arsenic concentrations found in Quaternary soils, and the geologic characteristics of their source regions would be valuable in further explaining natural variability in arsenic, and could possibly lead to the development of predictive tools.

An additional consideration which might influence the regional variability in background arsenic concentrations is broad land-use patterns and associated non-point sources of anthropogenic arsenic. It is important to recognize that regional land-use patterns often coincide with major changes in the underlying soil type. As illustrated in Figure 3, Holocene alluvium and bay muds underlie some of the most intensely developed urban and industrial areas, whereas Pleistocene alluvium more often underlies low-density residential areas. In addition, Holocene alluvium commonly supports prime agricultural soils and is likely to have supported agricultural uses prior to urban development, particularly in the eastern and southern Bay Area. Despite findings of no significant difference between surface and subsurface samples, it is difficult to fully dismiss the possibility that higher arsenic concentrations within Holocene alluvium are associated with concurrent variations in the anthropogenic background (e.g., the general type, intensity, and history of land development).

Due to its considerably greater age, it is also possible that Pleistocene alluvium in the study area was derived from different source rocks, or that geochemical processes that remove arsenic from alluvial soils have had a longer time to take place. It should also be recognized that the datasets for two of the geologic groups are small (n=11 for bay mud, n=14 for “other” Quaternary units), so the differences may also reflect a lack of a representative dataset. While a statistical correlation was identified between soil type and arsenic concentration, the actual processes governing those relations remain elusive.

5.3 Comparison of Findings with Other Background Studies

Despite the difficulties in clearly explaining sources of variation in the background dataset, statistics derived from the database provide defensible global estimates for background concentrations of arsenic within the flatland deposits of the Bay Area. The screening criteria avoided obvious sources of contamination and the

Geotracker database by nature contains primarily sites where fuels and organic solvents are the primary contaminant of potential concern. As discussed in Section 3.1, there is little to no correlation between metal and organic compound distributions, and the presence of organic co-contaminants has no effect on metal concentration background ranges.

The location and type of sample sites in this study is especially appropriate given they are representative of the geological and land-use settings where future environmental investigations are likely to be performed. A map of Geotracker site locations in the Bay Area instantly reveals that the vast majority of sites undergoing investigation and/or cleanup are located on urbanized flatland underlain by Quaternary-age geologic units. The commercial, industrial, institutional, and transportation-related land uses that are most often the subject of environmental investigations will continue to be predominantly located in such settings. Thus, the regional background estimates derived in this study may actually be more appropriate than background estimates derived from a pristine natural area, particularly if derived from bedrock units that naturally have anomalously high levels of arsenic.

The mean of 4.61 mg/kg and the proposed upper estimate of 11 mg/kg for the regional background concentration of arsenic found in this study are noticeably lower than upper limits from several other background studies of various geographic scope and scale (see Sections 1.3 and 1.5). The most obvious difference is with the background threshold value of 42 mg/kg for the Great Valley Sequence and 24 mg/kg for the “other” bedrock discussed in the LBNL (2002) study. The approach to screening sites/samples and the number of samples for this study was comparable to the LBNL study, though the approach to identifying outliers differed. The LBNL study used a uniform criterion of 50 mg/kg to eliminate outliers, whereas this study performed a site-by-site evaluation of

outliers based on individual site distributions (the lowest value identified as an outlier, for example, was 7.1 mg/kg). While this difference in approach may have resulted in some of the disparity between background estimates, it is not sufficient to account for the substantially higher background threshold value found in the Berkeley hills.

In the LBNL case, the difference can be reasonably explained by differences in the geological setting. The LBNL area is underlain by tertiary-age sedimentary rocks (the Moraga and Orinda Formations) which are highly variable in their lithology, but commonly contain repetitious layers of shale and sandstone. The Great Valley Sequence in the area is mapped as the Claremont Shale of the Monterey Group, which is a fine-grained organic-rich shale and mudstone formation. As discussed in Section 1.3 (see Table 1), there is general consensus in the literature that shales and fine-grained soils tend to have naturally higher levels of arsenic than other types of rocks. The fact that the LBNL found a significant difference between different bedrock types on-site, and their finding of relatively high background threshold values support this notion. The national study by Shacklette and Boerngen (1984) also reported noticeably higher background arsenic concentrations (7.2, <RL to 93 mg/kg), although this isn't unexpected based on the coarse scale of the study.

Several studies in flatland geologic environments found similar or lower background levels than reported in this study. Scott's (1994) study area was located in an urban portion of the Santa Clara Valley underlain by Quaternary alluvium and bay muds, and she found a lower mean background concentration of arsenic, although a similar range of values (2.28, <DL to 20 mg/kg). The study area for the UCR study focused on alluvial/agricultural soils—primarily in the central valley—and found a comparatively lower mean and range of arsenic concentrations (3.5, <RL – 11 mg/kg) (UCR, 1996).

The findings of this thesis suggest that the most commonly cited background estimates of arsenic—namely from LBNL (2002) and Shacklette and Boerngen (1984)—are too high and do not represent the flatland soils of the Bay Area. Based on the findings herein, ESA's performed in the urbanized Bay Area should not automatically conclude that arsenic detections are representative of background so long as they are within the ranges found in the prior literature. Future metals analyses in areas underlain by flatland soils of the Bay Area should carefully examine arsenic detections in exceedance of 11 mg/kg as possibly exceeding background levels. In such cases, additional tests (such as the Wilcoxon ranked-sum test) should be performed to answer with a set confidence level whether the data exceeding background truly represents a different population. If no other defensible geological or geochemical reason for the high concentrations is provided, then site related contamination should be suspected. The background threshold value of 11 mg/kg is nearly double the 99th percentile value of 6 mg/kg found in a recent arsenic background study of the urbanized flatlands of the Los Angeles area for LA Unified School District sites (CalEPA, 2005). The Los Angeles basin is surrounded by large granitic mountain ranges that are geologically distinct than those in the Bay Area, producing much sandier flatlands than the watersheds of the Bay Area. Thus, the lower value is reasonable from a geologic standpoint, given that arsenic is thought to be elevated in mudstones and shales.

The method used herein to obtain, compile, and analyze background data on arsenic can be repeated for a suite of other constituents of concern whose natural background level often exceeds risk-based screening thresholds. Examples include other naturally-occurring metals such as cadmium, selenium, or nickel, to name a few. The increasing accessibility of environmental data in multiple, easily queried formats presents opportunities to develop better background information. Publically available

environmental databases such as Geotracker provide an efficient and cost-effective means of establishing defensible regional background estimates.

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APPENDIX A

SUMMARY OF SOIL TYPE AND ARSENIC CONCENTRATIONS BY SITE

Site No.	Site Name	City	County	Soil Type	No. of Samples	Percent Above Reporting Limit	Mean (mg/kg)	St. Dev (mg/kg)	Min	Quartile, 25%	Median	Quartile, 75%	Max
1	2236 B NORTH TEXAS STREET	FAIRFIELD	Solano	Other Quaternary Unit	10	100%	4.3	0.8	3.0	3.3	4.6	5.0	5.3
2	Alameda Naval & Marine Corps Reserve Ctr. - Naval and Marine Corps Reserve Center, Alameda	Alameda	Alameda	Other Quaternary Unit	17	100%	6.9	2.7	2.4	5.5	5.9	8.6	12.0
3	Alameda Naval Air Station - Alameda NAS Bldg 594, Tank 594-1, 2	Alameda	Alameda	Holocene Bay Mud	46	100%	4.1	3.0	1.3	1.9	2.8	5.8	14.7
4	ARCADIA PARK	Oakland	Alameda	Holocene Alluvium	139	100%	5.4	1.6	0.6	4.2	5.5	6.4	9.4
5	Bay Division Pipeline	Fremont	Alameda	Pleistocene Alluvium	23	96%	2.3	0.6	<RL	1.7	2.3	2.7	3.3
6	BECK PROPERTY	PLEASANT HILL	Contra Costa	Other Quaternary Unit	7	100%	3.7	0.5	3.1	3.2	3.5	4.2	4.5
7	Bell Gas	Pittsburgh	Contra Costa	Pleistocene Alluvium	30	100%	4.4	1.8	1.2	3.2	4.1	5.8	8.3
8	BELTRAMO PROPERTY	MENLO PARK	San Mateo	Pleistocene Alluvium	9	100%	5.7	0.3	5.1	5.4	5.7	6.0	6.1
9	BP #11184 (FORMER)	San Francisco	San Francisco	Holocene Alluvium	11	100%	3.9	0.6	3.2	3.3	3.8	4.2	5.4
10	BP RICHMOND TERMINAL (formerly ARCO)	RICHMOND	Contra Costa	Holocene Bay Mud	14	100%	7.0	3.3	1.8	5.0	5.9	9.0	13.0
11	CALIFORNIA LINEN SUPPLY CO	Oakland	Alameda	Holocene Alluvium	81	100%	6.8	1.7	3.5	5.6	6.7	7.9	12.0
12	Call Mac Transportation	Livermore	Alameda	Pleistocene Alluvium	43	100%	5.4	1.7	0.8	4.1	5.2	6.6	9.4

Site No.	Site Name	City	County	Soil Type	No. of Samples	Percent Above Reporting Limit	Mean (mg/kg)	St. Dev (mg/kg)	Min	Quartile, 25%	Median	Quartile, 75%	Max
13	CALTRANS MAINTENANCE STATION	SOUTH SAN FRANCISCO	San Mateo	Pleistocene Alluvium	6	83%	2.4	0.9	<RL	1.9	2.6	3.0	3.4
14	CHEVRON	CONCORD	Contra Costa	Pleistocene Alluvium	9	78%	4.5	3.4	<RL	1.1	3.4	8.1	9.0
15	CHEVRON #9-0020	Oakland	Alameda	Other Quaternary Unit	9	100%	3.4	0.6	2.6	2.8	3.5	3.9	4.0
16	CHEVRON 9-1374	REDWOOD CITY	San Mateo	Holocene Bay Mud	5	100%	3.5	0.4	2.9	3.2	3.6	3.8	3.8
17	Chevron No 2510	Fremont	Alameda	Pleistocene Alluvium	11	100%	6.4	0.6	5.7	5.7	6.4	6.6	7.3
18	CHEVRON No. 1570	UNION CITY	Alameda	Holocene Alluvium	5	100%	11.6	5.8	5.5	7.1	11.0	16.5	21.0
19	Chrisp Company	Fremont	Alameda	Holocene Alluvium	11	100%	3.9	0.4	3.1	3.5	3.9	4.2	4.7
20	CHUNG PROPERTY / LANE METAL FINISHERS	OAKLAND	Alameda	Pleistocene Alluvium	16	100%	5.5	1.4	2.8	4.3	5.3	6.3	8.1
21	DANVILLE SQUARE SHOPPING CENTER	DANVILLE	Contra Costa	Holocene Alluvium	15	100%	5.8	0.6	4.8	5.2	6.0	6.4	6.7
22	DOWNEY PROPERTY	SANTA ROSA	Sonoma	Pleistocene Alluvium	16	25%	0.8	0.5	<RL	<RL	<RL	1.1	2.0
23	EXXON 7-4135 SM	SAN MATEO	San Mateo	Holocene Bay Mud	9	67%	2.4	1.4	<RL	<RL	1.9	3.6	4.8
24	FORMER CHEVRON SITE #301949 (9-7093)	RICHMOND	Contra Costa	Pleistocene Alluvium	6	100%	5.5	1.4	3.2	4.2	6.0	6.5	6.7
25	FORMER CHEVRON STATION # 21-3230	HAYWARD	Alameda	Pleistocene Alluvium	14	100%	8.3	2.0	5.1	7.0	8.9	10.2	11.0
26	Former Chevron-Mills Square Park	Livermore	Alameda	Holocene Alluvium	29	100%	5.3	1.2	2.2	4.5	5.4	6.2	7.6
27	FORMER MONTGOMERY WARDS SITE	PLEASANT HILL	Contra Costa	Holocene Alluvium	8	100%	5.6	0.3	5.3	5.3	5.5	6.0	6.1

Site No.	Site Name	City	County	Soil Type	No. of Samples	Percent Above Reporting Limit	Mean (mg/kg)	St. Dev (mg/kg)	Min	Quartile, 25%	Median	Quartile, 75%	Max
28	FORMER SHELL SERVICE STATION	SAN FRANCISCO	San Francisco	Holocene Alluvium	7	100%	2.3	0.6	1.5	1.9	2.3	3.0	3.2
29	Francis Plating	Oakland	Alameda	Other Quaternary Unit	19	100%	2.6	0.8	1.8	2.1	2.4	3.0	4.9
30	FREISMAN RANCH	LIVERMORE	Alameda	Pleistocene Alluvium	14	100%	4.2	2.6	2.5	2.6	3.1	4.9	10.0
31	GE IMATRON / CARAL MANUFACTURING	ALBANY	Alameda	Pleistocene Alluvium	38	100%	2.6	0.8	1.4	2.0	2.3	3.1	4.6
32	GOODYEAR TIRE AND RUBBER COMPANY	VALLEJO	Solano	Holocene Bay Mud	10	100%	5.1	1.2	3.9	4.1	4.7	6.0	7.4
33	HAVEN AVENUE INDUSTRIAL CONDOMINIUMS	MENLO PARK	San Mateo	Holocene Alluvium	17	82%	3.8	1.2	>RL	3.1	4.0	4.8	5.6
34	Jack London Square Area	Oakland	Alameda	Other Quaternary Unit	12	79%	2.1	2.0	0.1	0.7	1.9	4.2	6.3
35	KUNG PROPERTY	EAST PALO ALTO	San Mateo	Holocene Alluvium	7	86%	5.8	4.1	<RL	1.5	7.2	9.1	11.0
36	M. Toich and Sons	San Francisco	San Francisco	Holocene Alluvium	5	100%	1.9	0.4	1.4	1.5	2.1	2.1	2.2
37	Magnetics, Inc.	Sunnyvale	Alameda	Holocene Alluvium	41	46%	2.4	2.2	<RL	<RL	<RL	3.2	8.9
38	MAIN STREET & ARNOLD WAY	HALF MOON BAY	San Mateo	Pleistocene Alluvium	16	56%	1.9	1.3	<RL	<RL	1.6	2.5	4.3
39	MAZZEI AUTOMOBILE DEALERSHIP (FORMER)	ANTIOCH	Contra Costa	Holocene Alluvium	19	100%	5.2	1.5	3.2	4.1	4.9	6.3	8.8
40	Meikle Property	Santa Cruz	Santa Cruz	Other Quaternary Unit	16	50%	1.8	0.8	<RL	<RL	1.7	2.4	3.6
41	Milpitas Senior Housing Project	Milpitas	Alameda	Holocene Alluvium	61	97%	5.5	1.6	<RL	4.9	5.7	6.2	9.6

Site No.	Site Name	City	County	Soil Type	No. of Samples	Percent Above Reporting Limit	Mean (mg/kg)	St. Dev (mg/kg)	Min	Quartile, 25%	Median	Quartile, 75%	Max
42	Oakland Army Base - USTs 11A/12A/13A	OAKLAND	Alameda	Holocene Bay Mud	6	100%	2.4	0.3	1.8	2.2	2.5	2.6	2.7
43	Oakland International Airport	Oakland	Alameda	Holocene Bay Mud	8	100%	3.8	1.6	1.3	2.5	3.6	5.3	6.1
44	Oakland International Airport, S. Field Tank Farm	Oakland	Alameda	Holocene Bay Mud	31	100%	4.3	1.1	2.3	3.4	4.4	4.9	6.4
45	PACIFIC COAST TRANSPORTATION SERVICES	NEWARK	Alameda	Holocene Alluvium	8	100%	5.3	1.1	3.4	4.3	5.5	6.2	6.7
46	Parking Corporation of America	South San Francisco	San Mateo	Holocene Bay Mud	25	96%	3.5	2.0	<RL	1.9	3.1	4.7	9.7
47	PG&E ANTIOCH NATURAL GAS TERMINAL	OAKLEY	Contra Costa	Holocene Alluvium	9	100%	2.4	0.3	1.8	2.1	2.5	2.6	2.8
48	PGE Stone Substation	San Jose	Santa Clara	Holocene Alluvium	40	98%	5.5	1.9	<RL	4.2	5.1	6.7	9.1
49	Quality Tune-Up No. 6	San Jose	Santa Clara	Holocene Alluvium	10	100%	7.2	2.5	2.9	5.5	7.3	9.1	11.0
50	RAB MOTORS/CALTRANS	SAN RAFAEL	Marin	Holocene Bay Mud	6	100%	4.5	0.7	3.8	3.8	4.4	5.2	5.5
51	RAIN FOR RENT	OAKLEY	Contra Costa	Holocene Alluvium	21	100%	3.7	1.5	1.8	2.6	3.6	4.0	7.5
52	RUST PROPERTY	REDWOOD CITY	San Mateo	Holocene Alluvium	32	100%	5.0	2.0	1.2	3.4	5.3	6.3	9.6
53	Salz Leather Inc.	Santa Cruz	Santa Cruz	Other Quaternary Unit	8	88%	2.0	0.6	<RL	1.5	2.2	2.5	2.9
54	Santa Clara Former Maintenance	Santa Clara	Santa Clara	Holocene Alluvium	15	100%	4.1	1.1	1.8	3.4	4.1	4.9	5.9
55	Seeger Property	VACAVILLE	Solano	Holocene Alluvium	8	100%	7.6	0.9	6.2	7.0	7.5	8.2	9.1
56	SHELL	SANTA ROSA	Sonoma	Pleistocene Alluvium	6	100%	2.3	0.7	1.7	1.8	2.0	2.9	3.4

Site No.	Site Name	City	County	Soil Type	No. of Samples	Percent Above Reporting Limit	Mean (mg/kg)	St. Dev (mg/kg)	Min	Quartile, 25%	Median	Quartile, 75%	Max
57	SHELL #13-6019	San Leandro	Alameda	Pleistocene Alluvium	16	100%	5.8	4.7	1.4	1.9	2.8	11.0	14.1
58	SHELL / 7-ELEVEN #20009	Oakland	Alameda	Holocene Bay Mud	5	100%	6.8	0.7	5.8	6.1	6.9	7.4	7.7
59	Shell Equilon San Jose	San Jose	Santa Clara	Holocene Alluvium	14	100%	7.2	0.7	6.2	6.5	7.2	7.7	8.3
60	SHELL NAPA	NAPA	Napa	Pleistocene Alluvium	9	78%	2.2	1.5	<RL	<RL	1.8	4.0	4.4
61	SHELL NOVATO	NOVATO	Marin	Franciscan Complex	9	100%	7.7	3.0	3.4	4.3	8.6	9.8	12.0
62	SHELL SANTA ROSA	SANTA ROSA	Sonoma	Pleistocene Alluvium	13	92%	4.1	1.5	<RL	3.1	4.2	5.6	6.0
63	Shell Service Station	Cotati	Sonoma	Pleistocene Alluvium	9	100%	1.4	0.5	0.8	0.9	1.5	1.8	2.2
64	SHELL STATION	SANTA CRUZ	Santa Cruz	Other Quaternary Unit	57	89%	3.9	2.4	<RL	2.7	3.6	5.2	10.1
65	Shell Station #4003	San Francisco	San Francisco	Other Quaternary Unit	7	100%	1.4	0.3	0.9	1.3	1.3	1.7	1.7
66	Site A	Oakland	Alameda	Holocene Bay Mud	13	100%	2.9	1.2	0.4	2.1	2.7	3.8	5.8
67	SOUTHERN PACIFIC TRANSPORATION CO - FRANCES ST	SANTA ROSA	Sonoma	Pleistocene Alluvium	10	100%	4.5	1.0	3.0	3.7	4.4	5.3	6.1
68	Standard Oil Bulk Terminal	Fremont	Alameda	Pleistocene Alluvium	16	100%	3.2	0.6	1.9	2.8	3.3	3.4	4.5
69	TERMINAL AVE HOUSING DEVELOP.	MENLO PARK	San Mateo	Holocene Alluvium	14	100%	5.8	1.0	4.0	5.1	5.8	6.4	7.9
70	UNOCAL	SAN RAFAEL	Marin	Other Quaternary Unit	7	100%	4.4	2.8	4.6	5.7	6.3	6.8	8.3

Site No.	Site Name	City	County	Soil Type	No. of Samples	Percent Above Reporting Limit	Mean (mg/kg)	St. Dev (mg/kg)	Min	Quartile, 25%	Median	Quartile, 75%	Max
71	Unocal	San Anselmo	Marin	Holocene Bay Mud	26	100%	6.3	0.9	1.5	1.9	3.5	7.4	7.6
72	UNOCAL #4921	SAN JOSE	Santa Clara	Pleistocene Alluvium	14	100%	3.2	1.0	1.6	2.6	3.1	3.9	4.8
73	UNOCAL #5781	Oakland	Alameda	Pleistocene Alluvium	5	100%	4.2	1.3	3.2	3.3	3.5	5.5	6.2
74	UNOCAL 7499	Fremont	Alameda	Holocene Alluvium	9	100%	3.6	0.5	2.4	3.4	3.7	4.0	4.0
75	US Army MOTCO (formerly Concord NWS Tidal Sites) - CONCORD NWS - E-111	CONCORD	Contra Costa	Holocene Bay Mud	7	100%	6.2	1.2	5.1	5.4	5.7	6.8	8.7
76	Vallejo Unified School District - Adminstration	VALLEJO	Solano	Pleistocene Alluvium	20	95%	5.1	3.4	<RL	2.9	3.9	7.3	15.0
77	Wente Winery	Livermore	Alameda	Holocene Alluvium	58	100%	4.6	1.1	2.5	3.6	4.7	5.6	7.4