CORROSION CONTROL DESKTOP STUDY

Prepared for:

San Bernardino County Service Area-70 Cedar Glen

Cedar Glen, California

System # 36-10026

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&

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SECTION 1: INTRODUCTION

County Service Area 70 Cedar Glen (CSA-70 CG) is a water district within the San Bernardino County Special Districts Department, Water and Sanitation Division. CSA 70 CG provides water service to approximately 1,154 customers. The water system consists of a horizontal water well, perched water tunnel, connection with Crestline Lake Arrowhead Water Authority (CLAWA), and five water reservoirs with a combined capacity of 741,600 gallons. There are currently 312 service connections.

In November 2010, CSA-70 CG received a letter from the State Water Resources Control Board Division of Drinking Water (DDW) stating that based on home tap monitoring results under the Lead and Copper Rule (LCR), CSA-70 CG was to prepare a corrosion control desktop study as required in Title 22 and conduct two rounds of home tap and water quality parameter monitoring. Two additional rounds of home tap monitoring were conducted, but a corrosion control study was not prepared. In December 2012 CSA-70 CG received a Notice of Violation (NOV) for failure to "...measure the indicated water quality parameters or conduct a corrosion control study by October 19, 2012 as requested by a November 15, 2010 letter and July 20, 2012 sanitary survey report..." The NOV also required CSA-70 CG to conduct an additional two rounds of home tap lead and copper monitoring (with the next round of monitoring due between January and June 2013).

This document includes the analysis conducted under the desktop study and its outcome. The study was conducted in conformance with the requirements of Title 22, Chapter 17.5, Article 5, section 64683. The focus of this desktop study is a review of data for 2010 through 2015; however, limited data for 2009 and 2016 were available and included in the review.

Organization of Desktop Study

The following is an outline of the sections of this desktop study:

1. Introduction
2. Description of the Lead and Copper Rule
3. Water Quality Parameters and Corrosion Control Indices
4. Description of the CSA-70 CG System
5. Source Water Quality
6. Review of Customer Complaints
7. Review of Home Tap Results
8. Lead and Copper Results for Homes Served by CLAWA
9. Corrosion Control Treatment Evaluation
10. Summary, Conclusions and Recommendations

SECTION 2: DESCRIPTION OF THE LEAD AND COPPER RULE

The LCR requires community water systems to monitor for lead and copper at a specified number of taps within homes. The LCR includes a treatment technique to optimize corrosion control treatment, source water monitoring (and possibly treatment), lead service line replacement and public education requirements. The LCR established Action Levels for lead (0.015 mg/L) and copper (1.3 mg/L). The 90th percentile of the home tap lead and copper results during each monitoring period are compared against the respective Action Levels.

Public water systems that serve between 501 and 3,300 customers are required to collect 20 home taps samples during each routine LCR monitoring event. In addition, each LCR monitoring period, water systems serving 501 to 3,300 customers are required to collect two samples from the distribution system to test for water quality parameters (pH, alkalinity, calcium conductivity, temperature and corrosion inhibitors if used). If the system is approved to conduct reduced monitoring, then 10 home tap samples are required and two sample locations for water quality parameters.

When the 90th percentile results exceed an Action Level (either lead or copper) the public water system is required to evaluate methods of corrosion control and recommend to the State an approach to minimize lead and copper levels at home taps.

SECTION 3: WATER QUALITY PARAMETERS AND CORROSION CONTROL INDICES

The following section presents a brief description of water quality parameters that are related to the corrosivity of water. In addition, descriptions are presented of commonly used corrosion indices that are included in this evaluation.

Water Quality Parameters

The following water quality parameters are related to the corrosivity of water and are included in this desktop evaluation:

Temperature: Warmer water temperatures could increase corrosion rates and also increase the tendency for calcium carbonate ($CaCO_3$) to precipitate.

pH: pH is the major factor that determines the solubility of most metals (Schock, AWWA Water Quality and Treatment, 1990). Higher pH may decrease corrosion rates and can help protect distribution system piping, whereas a lower pH may increase the corrosion rate of metals. The pH of water can vary as the water moves through a distribution system.

Alkalinity: The alkalinity of water is a measure of its ability to resist pH change. In natural waters, alkalinity is calculated as the sum of carbonate, bicarbonate and hydroxide equivalents and is reported as mg/L as $CaCO_3$. Waters with a higher alkalinity have a greater "buffering capacity" (i.e., a stronger capacity to resist changes in pH).

Chloride and sulfate: Chloride and sulfate ions could cause pitting of metallic pipe by reacting with metals in solution and causing them to stay soluble. This prevents the formation of protective metallic oxide films on the surface of the pipes. Research indicates that chloride is about three times as active as sulfate in causing this effect (see discussion below on Chloride to Sulfate Mass Ratio, CSMR).

Dissolved inorganic carbonate (DIC): DIC is an estimate of the amount of total carbonates in water measured as mg C/L. The level of DIC in the water can impact the stability of pH and relates to the buffering capacity of water.

Hardness: Hardness is a measure of calcium and magnesium in water and is reported as $CaCO_3$. Hardness is important because calcium and magnesium compounds can interfere with corrosion control efforts because they are less soluble at higher pH values than at lower pH. Hardness needs to be taken into consideration when evaluating corrosion control treatment approaches as treatment may lead to unintended impacts such as increased scaling within the distribution system.

Total Dissolved Solids (TDS)/Conductivity: The water's conductivity is important for corrosion activity in terms of completing the electrochemical circuit responsible for corrosion reactions. The type of ions that compose the TDS can be important factors affecting corrosion.

Corrosion Indices

The CSA-70 CG desktop study includes the calculation and evaluation of corrosion indices, primarily the Langelier Saturation Index (LSI) and the Calcium Carbonate Precipitation Potential (CCPP). The LSI and CCPP are used to assess the tendency of water to be corrosive or non-corrosive towards distribution system materials. Both of these indices are based on corrosion control through $CaCO_3$ saturation and the belief that a slight oversaturation of $CaCO_3$ may promote its precipitation and formation of a thin protective layer within distribution system piping. Calculations of the Aggressive Index, Larson Index, and the chloride to sulfate mass ratio (CSMR) are also presented in this desktop study. The following presents a brief description of the guidelines used to interpret the various corrosion indices.

Aggressive Index: The concept of an Aggressive Index (AI) was initially developed as a guide for determining whether asbestos/cement pipe was the appropriate material for a given solution. The AI is a simplified form of the Langelier Saturation Index and is calculated using the pH, total alkalinity and the calcium hardness of a given water. The general guidelines for interpreting the calculated AI are as follows:

AI > 12 – the water is non-aggressive
AI = 10 – 11.9 – water is moderately aggressive
AI < 10 – water is aggressive

Langelier Saturation Index (LSI): Calculated based on the difference between the pH of the water and the "saturation pH" (pH_s). The LSI is used to predict the calcium carbonate stability of water, that is, whether the water will precipitate, dissolve, or be in equilibrium with calcium carbonate. The following general guidelines are used for interpreting LSI results:

LSI < 0	Water is under saturated with $CaCO_3$ and tends to dissolve $CaCO_3$
LSI = 0	Water is in equilibrium with $CaCO_3$, a layer of $CaCO_3$ is neither precipitated nor dissolved
LSI > 0	Water is supersaturated with $CaCO_3$ and tends to precipitate $CaCO_3$

Water with a positive LSI is expected to precipitate a film of $CaCO_3$ onto the surface of the pipes. This would protect the metal pipe surface from the corrosive nature of water. Alternatively, water with a negative LSI would not precipitate a film of $CaCO_3$, and therefore, does not protect the metal surface from the corrosive nature of water. Water with a negative LSI is not more corrosive than water with a positive LSI. It is merely that water with a negative LSI is not as protective of the pipe surfaces as water with a positive LSI. The extent of the deviation of the LSI from "zero" is also an indicator of the severity of precipitation (LSI>0) or dissolution (LSI<0) of $CaCO_3$.

Langelier Saturation Index at 60 °C: Used to predict the calcium carbonate stability of water, that is, whether the water will precipitate, dissolve, or be in equilibrium with calcium carbonate in a hot water heater.

Calcium Carbonate Precipitation Potential (CCPP): The CCPP calculates the theoretical amount (mg/L) of $CaCO_3$ that will precipitate or dissolve from the solution as it comes to equilibrium under given water quality conditions. The following general guidelines are used for interpreting CCPP results:

CCPP < 0	Water tends to dissolve $CaCO_3$
CCPP = 0	Water is in equilibrium with $CaCO_3$, and a layer of $CaCO_3$ is neither precipitated nor dissolved
CCPP > 0	Water tends to precipitate $CaCO_3$

Chloride to Sulfate Mass Ratio (CSMR): Chloride and sulfate ions could cause pitting of metallic pipe by reacting with metals in solution and causing them to stay soluble. This prevents the formation of protective metallic oxide films on the surface of the pipes. Research indicates that chloride is about three times as active as sulfate in causing this effect. The ratio of chloride to sulfate has been used as a potential indicator of the corrosivity of water (a CSMR greater than 0.5 could be associated with increased leaching of lead from solder and brass fixtures).

Larson Index (LI): Evaluates effect of chloride, sulfate and bicarbonate alkalinity on corrosion of metallic pipes including pitting of copper pipes, and potential disruptions of existing iron scales, which may lead to red- or brown-water occurrences and increased turbidity levels. The following general guidelines are used for interpreting LI results:

LI < 0.2 water considered to be non-corrosive
LI > 0.3 water is potentially corrosive

SECTION 4: DESCRIPTION OF THE CSA-70 CG SYSTEM

CSA-70 CG provides drinking water to approximately 1,154 residents of Cedar Glen located in San Bernardino County. There are approximately 312 service connections in the system.

Lake Arrowhead borders the Cedar Glen community on the west. The service area is approximately 0.62 square miles. Water supply for CSA-70 CG consists of the following:

- horizontal well (Pine Well)
- perched water tunnel (Tunnel),
- purchased treated surface water from Crestline Lake Arrowhead Water Authority (CLAWA)

In the past four years CSA 70 CG has upgraded transmission lines in the distribution system from steel to PVC piping.

The 2003 Old Fire destroyed over 300 homes in Cedar Glen. An approximate estimate is that 60 or so homes have been rebuilt (with new plumbing and fixtures).

Table 1 presents the four pressure zones within the CSA-70 CG distribution system and the source of supply for each zone.

Table 1. CSA-70 CG Pressure Zones

Pressure Zone	Primary Source of Supply*
5180 Cypress	Tunnel & Horizontal Well
5370 Balsam	Tunnel
5468 Western	Tunnel and purchased CLAWA water
5580 Pneumatic	Tunnel and purchased CLAWA water

*There are 2 PRVs installed in the distribution system: (1) 5468 zone to the 5370 zone, (2) 5370 zone to the 5180 zone. Through activation of these PRVs, it is possible for CLAWA water to be distributed to all four pressure zones.

In March 2010, the 415,000 gallon Western Tank came online and can provide blending of Tunnel and CLAWA water.

Figure 1 presents the CSA-70 CG sources of supply for 2010 through 2015. The Pine (Horizontal) well has not supplied water to the system since January 2010. The brackets in Figure 1 indicate each of the six month LCR monitoring periods during 2010-2015. Throughout this period of time, the Tunnel Supply has been the primary source of supply (historically, the Tunnel provided roughly 90% of the water to the CSA-70 CG system and the Pine well provided the remaining water). Available records indicate that CSA-70 CG purchased a limited amount of treated surface water from CLAWA during 2010 through 2015.

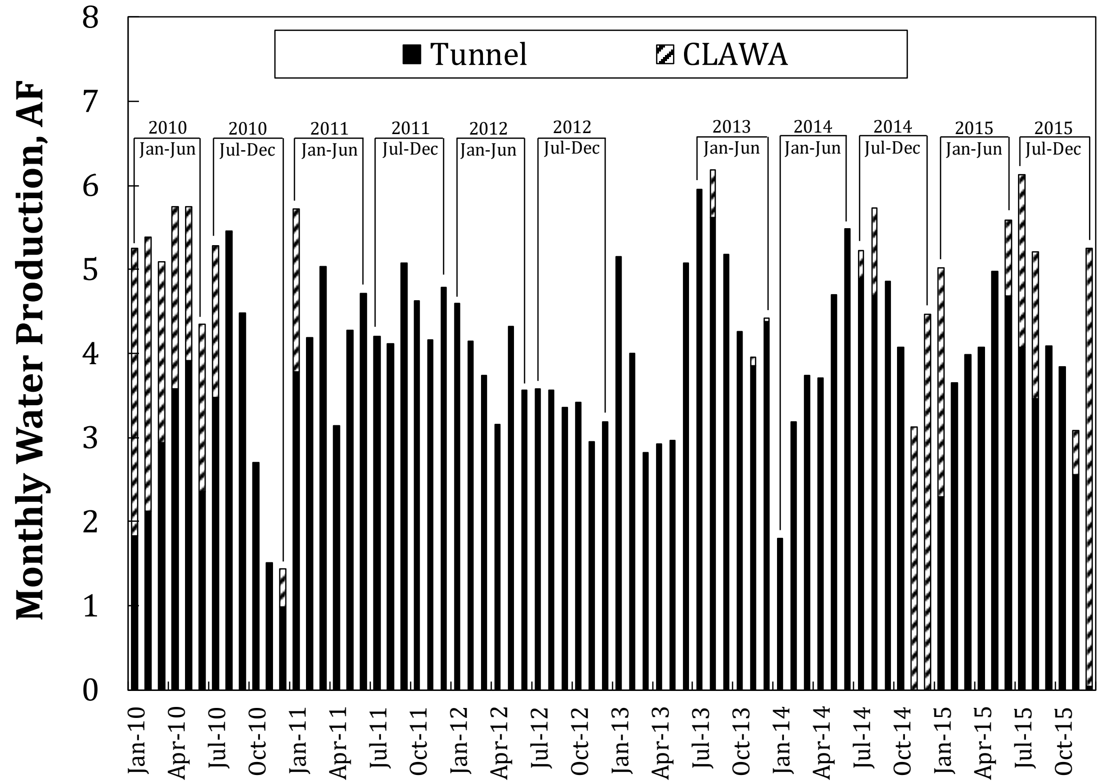

Figure 1. CSA-70 CG Sources of Supply (2010 – 2015)

Treatment for the Tunnel water supply consists of addition of 12.5% sodium hypochlorite with a target chlorine residual of 0.5-1 mg/L before distributing the water to customers.

The service area consists primarily of residential customers with a limited amount of commercial development. The distribution system consists of piping one inch to eight inches in diameter. Seventy-five percent of the 8-inch diameter piping is PVC. Service connections are steel, galvanized, copper, PVC and PE. There are no known lead service lines in the CSA-70 CG service area.

SECTION 5: SOURCE WATER QUALITY

This section of the desktop study presents water quality data for CSA-70 CG's sources of supply.

Pine Well. As indicated in Figure 1, the Pine (Horizontal) well was not used to supply the CSA-70 CG distribution system during the years evaluated 2010 through 2015. However, for completeness, Table 2 presents results for water quality parameters and calculated corrosion indices (LSI, CCPP, CSMR and LI) for the Pine Well.

Table 2. Pine (Horizontal) Well Water Quality

Parameter	Average	May 2006	March 2010
Alkalinity (Total) as $CaCO_3$ (mg/L)	99	88	110
Calcium (mg/L)	24	19	29
Chloride (mg/L)	5.2	4.5	5.9
Hardness (Total) as $CaCO_3$ (mg/L)	85	70	100
pH, Laboratory	7.35	7.2	7.5
Source Temperature (^oC)	20	--	20
Specific Conductance (μmhos/cm)	200	180	220
Total Dissolved Solids (mg/L)	130	120	140
Sulfate (mg/L)	2.8	2.7	2.9
DIC (mg/L as C)		23.9	28
CSMR		1.7	2.0
LSI		-0.85	-0.29
CCPP		-18.4	-6.3
Larson Index		0.10	0.10

***Tunnel Supply**.* CSA-70 CG's main source of drinking water is the perched Tunnel supply. Table 3 presents a summary of water quality data for the Tunnel supply. The results presented in Table 3 are based on data collected on four separate occasions during 2010-2015 (the results for each of the four sampling events are presented in Appendix A). The Tunnel Water supply has a moderate amount of calcium, hardness, alkalinity and total dissolved solids. The DIC results presented in Table 3 were calculated using the USGS PHREEQC[1] program. From the DDW online water quality database, iron and manganese results in 2013 and 2016 were ND. During one of the four monitoring events, the pH was less than 7.

[1] The computer program PHREEQC, version 3, developed by the United States Geological Survey (USGS), with the database phreeqc.dat was used to calculate DIC values, as well as calculating the LSI and CCPP values reported in this desktop study.

Table 3: Tunnel Water Quality (2010-2015)

Parameter	Average	Minimum	Maximum
Alkalinity as $CaCO_3$ (mg/L)	87	84	91
Calcium (mg/L)	18	17	20
Chloride (mg/L)	5.6	5.2	5.8
Hardness as $CaCO_3$ (mg/L)	78	67	100
pH (Laboratory)	7.4	6.8	7.7
Temperature (^oC)	20	20	20
Specific Conductance (µmhos/cm)	183	180	190
Sulfate (mg/L)	1.9	1.5	2.7
Total Dissolved Solids (mg/L)	113	110	120
DIC, mg/L as C	23.8	21.2	29.7

Using the results from the four individual Tunnel sampling events (Appendix A), Table 4 presents the calculated minimum, maximum and average values of corrosion indices for the Tunnel water supply. The LSI and CCPP indices were calculated using the USGS PHREEQC program. Based on the average values, the AI indicates that the water is moderately aggressive. The calculated average LSI and CCPP values indicate that the water does not have a tendency to precipitate a protective layer of $CaCO_3$ on the surface of pipes. The CSMR values provide a general indication that the water is corrosive, while the calculated Larson Index values would indicate a non-corrosive water.

Table 4. Calculated Corrosion Indices for Tunnel Supply (2010-2015)

Corrosion Indices	Average	Minimum	Maximum
Aggressive Index	10.9	10.3	11.3
Langelier Index @ 60 ^oC	-0.2	-0.8	0.2
Langelier Index at Source Temp	-0.7	-1.4	0.0
CSMR	3.1	2.1	3.6
CCPP (mg/L as $CaCO_3$)	-18.8	-50.9	-5.4
Larson Index	0.11	0.11	0.13

CLAWA Supply. CLAWA's raw water supply is Silverwood Lake, a reservoir on the East Branch of the State Water Project. CLAWA owns and operates the Lake Silverwood Water Treatment Plant (WTP), a 5 MGD solids contact clarifier with multi-media pressure filters. Filtered water is disinfected with chlorine. Treated water pH is adjusted with sodium hydroxide with a target pH of 8.1 – 8.3.

For preparation of this LCR desktop study, CLAWA was contacted and water quality data was obtained from the sample location representative of water purchased by CSA-70 CG. That sample location was identified by CLAWA as Booster Station #3. In addition, water quality data for CLAWA was obtained from the California Division of Drinking Water's online water quality database "Drinking Water Watch" (accessed July 2016, https://sdwis.waterboards.ca.gov/PDWW/).

According to available records, CLAWA water was purchased by CSA-70 CG during limited periods of time in the years 2010 through 2015 (see Figure 1). Quarterly water quality data for the CLAWA supply was provided by CLAWA for 2011 through the first two quarters of 2016. Using this quarterly water quality data the minimum, maximum and average values are presented in Table 5.

Table 5. CLAWA Quarterly Water Quality Parameters (2011 – 2016)

Parameter	Average	Minimum	Maximum
Alkalinity as $CaCO_3$ (mg/L)	84	69	90
Calcium (mg/L)	27	20	30
Chloride (mg/L)	92	78	110
Hardness as $CaCO_3$ (mg/L)	107	90	120
pH (lab)	8.0	7.7	8.2
Specific Conductance (µmhos/cm)	618	510	720
Sulfate (mg/L)	78	41	93
Total Dissolved Solids (mg/L)	350	290	410
DIC, mg/L as C	20.5	17.2	21.9

Using the results presented in Table 5, Table 6 presents calculated corrosion indices for the CLAWA water supply. The calculated average AI indicates that the water would be considered moderately aggressive. The average calculated LSI and CCPP indices (calculated using the USGS PHREEQC model) indicate that the water does not in general have a tendency to deposit a $CaCO_3$ layer on the surface of pipes. The calculated LSI at 60 ^{o}C, as representative of conditions in a water heater, indicates that the water would have a slight tendency to deposit $CaCO_3$. The CSMR indicates that the water has a tendency to be corrosive to lead in solder and brass fixtures.

Table 6. Calculated Corrosion Indices CLAWA Supply (2011 – 2016)

Parameter	Average	Minimum	Maximum
Aggressive Index	11.7	11.2	12
LSI at Source Temp	-0.1	-0.58	0.11
LSI at 60 ^{o}C	0.5	0.03	0.77
CSMR	1.2	0.9	2.2
CCPP	-0.9	-5.1	1.3
Larson Index	1.8	1.1	2.3

SECTION 6: REVIEW OF CUSTOMER REPORTS

Records of CSA-70 CG customer reports were reviewed for the period 2011 through 2015. The customer calls were reviewed for any possible indications of corrosion in the distribution system. There was one customer call regarding brown water in June 2012 (the record indicates staff believed problem may have been due to a problem with the meter). During 2011-2015, there were six calls logged as “dirty” water. The record for one of the “dirty” water calls indicated that the customer states there were “rocks and sediment” in the water. There were no details available for the other five customer calls regarding “dirty” water. There were no customer calls indicating excessive mineral deposits or clogging of hot water heaters.

SECTION 7: REVIEW OF HOME TAP RESULTS

The following section presents a review and discussion of the home tap lead and copper results for CSA-70 CG.

The results in Table 7 are taken from the December 19, 2012 letter from DDW to CSA-70 CG and present lead and copper 90th percentile results from August 1998 through November 2011.

Table 7. Lead and Copper Home Tap Results (1998 – 2011)

Sample Date (a)	Lead 90th Percentile (mg/L)	Copper 90th Percentile (mg/L)
August 1998	0.012	0.66
January 2002	0.021	0.38
August 2002	0.005	0.19
April 2003	0.0088	0.27
May 2005	0.013	2.9
October 2006	0.012	1.9
September 2007	0.016	1.8
August 2010	0.010	1.9
May 2011	0.016	2
November 2011	0.008	2.5

(a) Ten homes were sampled in November-December 2009. The 90th percentile lead for the ten homes was 6.2 μg/L, and for copper the 90th percentile was 1,600 μg/L.

CSA-70 CG has conducted a number of rounds of home tap monitoring after the November 2011 monitoring event. The dates for those six-month monitoring events, 90th percentile values and the number of home tap samples are presented in Table 8.

Table 8. Lead and Copper Home Tap Results (2012 – 2015)[2]

Sample Period	Lead 90th Percentile (mg/L) [# of samples]	Copper 90th Percentile (mg/L) [# of samples]
January – June 2012	0.0078 [21]	1.8 [21]
July – December 2012	0.015 [26]	0.970 [26]
January – June 2013	--	--
July – December 2013	0.027 [20]	0.950 [20]
January – June 2014	0 [7]*	1.4 [7]*
July – December 2014	0.0054 [26]	1.2 [26]
January – June 2015	0.0063 [23]	0.960 [23]
July – December 2015	0 [21]	0.990 [21]

*Six-month monitoring period when less than 20 samples were collected.

[2]As described later in this desktop study, Title 22 states if a small or medium size system has an action level exceedance, but then has two consecutive monitoring periods without an action level exceedance, that system may cease proceeding with a corrosion control study and/or corrosion treatment installation. As presented in Table 8, the four most recent consecutive monitoring periods have been without an exceedance of the lead action level (only seven homes were sampled in January to June 2014), and the three most recent consecutive monitoring periods have been without an exceedance of the copper action level.

For each six month LCR monitoring event from 2010 through 2015, Figure 2 presents a distribution of the individual home tap lead results. With the exception of the July to December 2013 sample results, for all of the six month monitoring periods presented in Figure 2 the majority of homes had a lead result less than 5 µg/L. The highest 90th percentile (27 µg/L) and the most homes above the lead AL (six) were recorded in the July to December 2013 monitoring event. During 2014 and 2015, CSA-70 CG conducted four consecutive rounds of six-month home tap monitoring. During each of these six-month monitoring periods, approximately 85% or more of the homes had a lead concentration less than 5 µg/L (for the January to June 2014 monitoring event, only seven homes were sampled). And in both six-month monitoring events in 2015, no home tap results were above the lead AL. In August 2016, home tap samples were collected from ten homes. The lead results were ND for all ten homes.

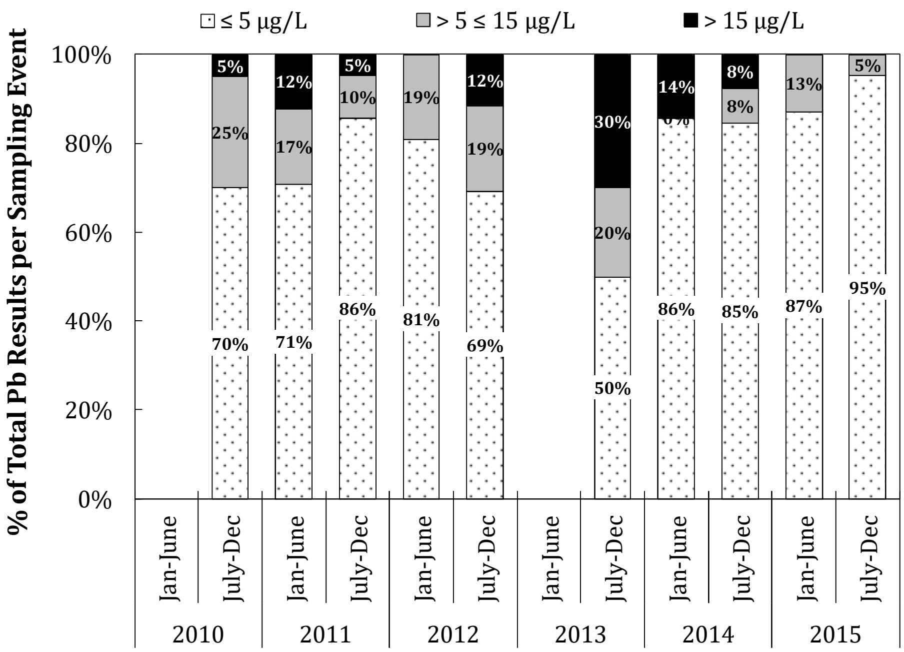

Figure 2. Distribution of Lead Home Tap Results (2010-2015)

Figure 3 presents a distribution of the individual home tap copper results for each six month monitoring event from 2010 through 2015. With the exception of the January to June 2014 sample results, for all of the six month monitoring periods presented in Figure 3, 50% or more of homes had a copper result less than 650 µg/L (one-half of the Action Level). Note that during the January through June 2014 monitoring event, only 7 homes were tested, and two had results above the copper AL. During the years 2014 and 2015, CSA-70 CG conducted four consecutive rounds of six month home tap monitoring. During the three most recent six-month monitoring periods presented in Figure 3, there is a trend of decreasing copper concentrations, and in the three most recent monitoring periods all but one home was below the copper action level (and the 90th percentile was less than the copper Action Level during all three monitoring periods). During August 2016, home tap samples were collected from ten homes. The copper results in the ten homes ranged from ND to 1.5 mg/L, with a 90th percentile result of 0.59 mg/L.

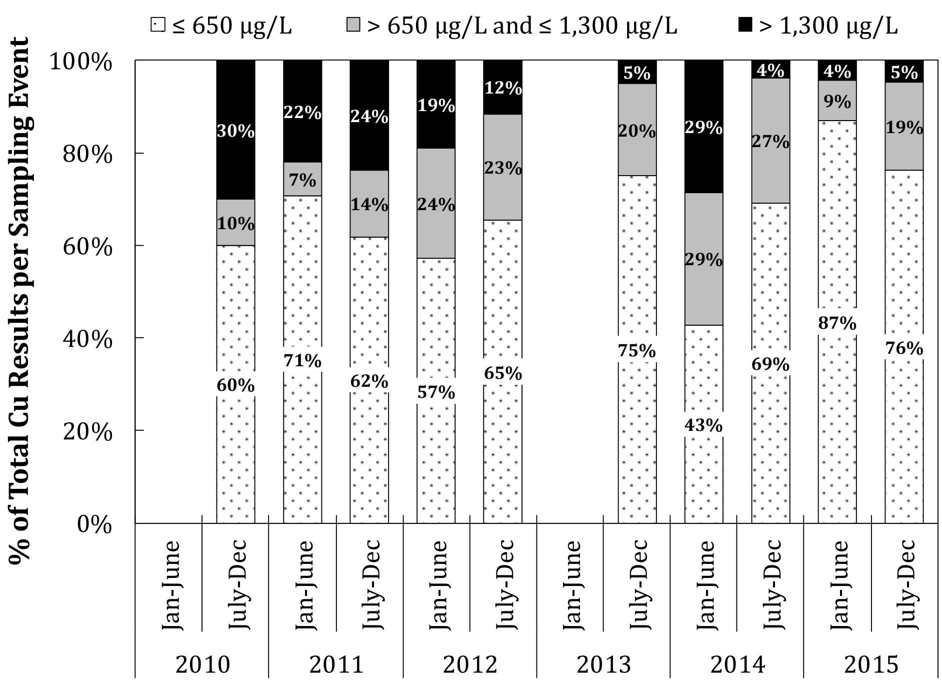

Figure 3. Distribution of Copper Home Tap Results (2010-2015)

The next sections of this desk-top study present a review of the home tap results in light of available water quality data and calculated corrosion indices.

Assessment of Lead Home Tap Results and Corrosion Indices. Figures 4, 5 and 6 present the 90th percentile lead results together with the average pH, LSI and CCPP values, respectively. The pH, LSI and CCPP values presented in Figures 4, 5 and 6 are based on the available water quality data collected during a given six-month monitoring period.

During the period of this study, there were two six month monitoring periods where the 90th percentile result was greater than the lead AL (January to June in 2011 and July to December 2013). During 2014 and 2015, CSA-70 CG conducted four consecutive six month LCR monitoring events. The 90th percentile lead results were low for all four periods. During two of the six-month monitoring periods, the 90th percentile results were ND and for two monitoring periods the 90th percentile results were 6.3 µg/L and 5.4 µg/L, respectively.

Title 22, Chapter 17.5, Article 2, Section 64673(e) states that a small or medium-size system may cease completing a corrosion control study and/or corrosion treatment installation if the "system does not have an action level exceedance during each of two consecutive periods." As indicated in Table 8 and in Figure 4, CSA-70 CG has not had a lead Action Level exceedance during the most recent four consecutive monitoring periods. And as indicated in Table 8 and in Figure 7 in the next section, CSA-70 CG has not experienced a copper Action Level exceedance in the three most recent monitoring periods. While it does not apply to a small system, the recent CSA-70 CG home tap results also meet the description in Title 22, section 64674 that describes situations where large systems are not required to prepare a corrosion control study if the difference between highest source water monitoring result is less than the detection level for purposes of reporting (DLR) for lead (5 µg/L).

In Figures 4, 5 and 6 limited water quality data was available to determine pH, LSI and CCPP values only during a limited number of six-month monitoring events. Reviewing Figures 4, 5 and 6, there does not appear to be an association between the 90th percentile lead values and pH, LSI or CCPP.

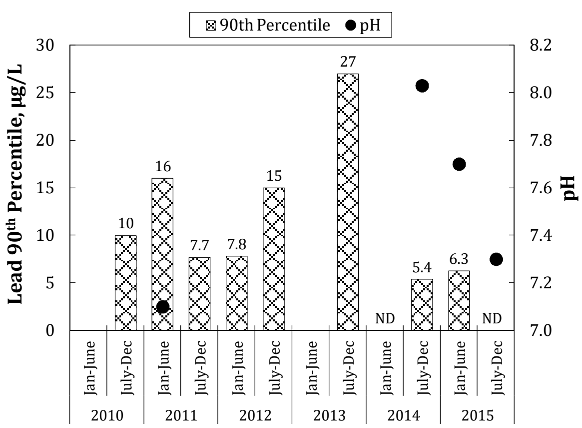

Figure 4. Lead Home Tap Results and Measured pH (2010 – 2015)

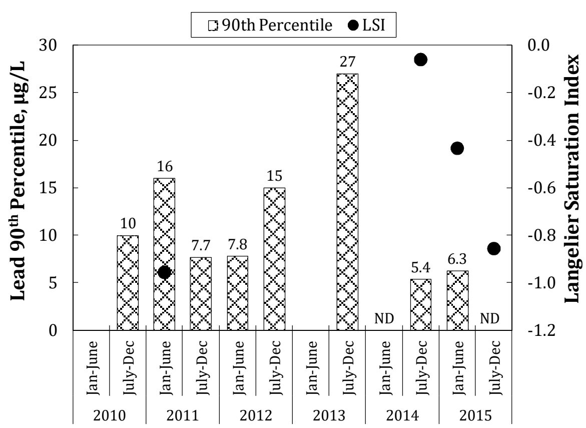

Figure 5. Lead Home Tap Results and LSI (2010 – 2015)

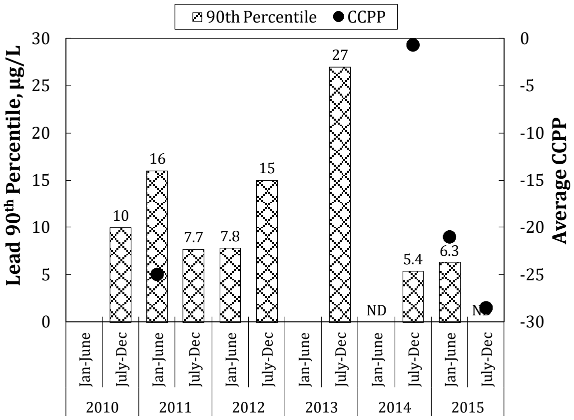

Figure 6. Lead Home Tap Results and CCPP (2010 – 2015)

Distribution System Location of Lead Results. As indicated in this section, the lead 90th percentile values have decreased during the most recent four LCR monitoring events. To provide an assessment of where homes within the distribution system were tested, Cedar Glen staff prepared distribution system maps presenting the location of each home sampled and the result for that home. The maps are presented in Appendix B. Figure B1 presents all of the homes tested in the period 2010 through 2016. Figures B2 through B8 present the homes for each individual LCR monitoring event. For example, In August 2016, Cedar Glen collected LCR tap samples from ten homes. All of the lead results were ND and are presented in Figure B2. Figure B3 presents the results for monitoring conducted during 2015, Figure B4 presents the results for the 2014 monitoring, etc.

The following observations are made from the figures in Appendix B. First, from Figure B1 the homes sampled during 2010 through 2016 appear to be well distributed throughout the distribution system and representative of different sources and pressure zones. Second, the lead results appear to be randomly distributed throughout the distribution system and there does not appear to be a particular area where elevated levels were detected. Finally, consistent with results presented in Figure 2, reviewing the maps from year 2010 (Figure B8) through year 2016 (Figure B2) there has been a general improvement (and reduction) in the lead levels. Information was not available as to specific homes destroyed in the 2003 Old Fire or specific types of home plumbing material and fixtures.

Assessment of Copper Home Tap Results and Corrosion Indices. To provide additional information on potential trends in data, the home tap results were used to determine the 50th percentile values for copper, in addition to the 90th percentiles.

Figures 7, 8 and 9 present the 50th and 90th percentile copper results for each six-month monitoring period. Using averages of the available water quality data collected during a given six-month monitoring period, Figures 7, 8 and 9 present the pH, LSI and CCPP values, respectively. As can be seen in these figures, water quality data was available to determine pH, LSI and CCPP values during only a limited number of six-month monitoring periods. Similar to the observations from Figures 4, 5 and 6, there does not appear to be an association between pH, LSI, CCPP and the levels of copper measured in home tap samples.

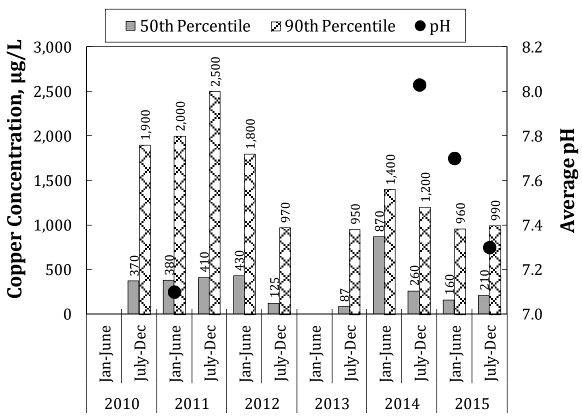

Figure 7. Copper Home Tap Results and pH (2010 – 2015)

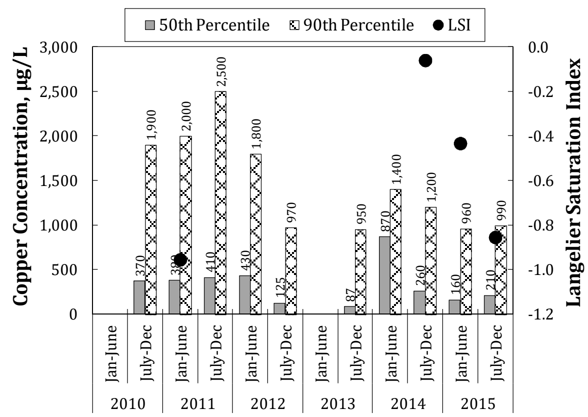

Figure 8. Copper Home Tap Results and LSI (2010 – 2015)

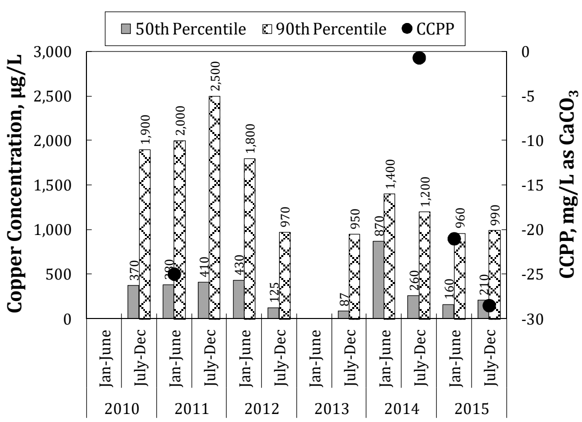

Figure 9. Copper Home Tap Results and CCPP (2010 – 2015)

Distribution System Location of Copper Results. As indicated in this section, the copper 90th percentile values have decreased significantly during the most recent four LCR monitoring events when compared to historical results. Cedar Glen staff prepared distribution system maps presenting the location of each home sampled and the copper result for that home. The maps are presented in Appendix C. Figure C1 presents all of the homes tested in the period 2010 through 2016. Figures C2 through C8 present the homes for each individual LCR monitoring event. For example, In August 2016, Cedar Glen collected LCR tap samples from ten homes. The 90th percentile copper value for the 10 homes was 590 µg/L and one home exceeded the Action Level. The 2016 copper results are presented in Figure C2. Figure C3 presents the results for monitoring conducted during 2015, Figure C4 presents the results for the 2014 monitoring, etc.

The following observations are made from the figures in Appendix C. As stated in the discussion of lead results above, during 2010 through 2016 the homes sampled during LCR monitoring events appear to be well distributed throughout the distribution system and representative of different sources and pressure zones. Second, the copper results appear to be randomly distributed throughout the distribution system and there does not appear to be a particular area where elevated levels were detected. And finally, reviewing the maps from year 2010 (Figure C8) through year 2016 (Figure C2) there has been a significant improvement (and reduction) in the copper levels.

As indicated in the results presented in Figure 3 and the maps presented in Appendix C, there has been an improvement in copper results during recent LCR monitoring events. This improvement may be due to a number of factors: (1) rebuilding of homes destroyed during the 2003 Old Fire, (2) replacement of plumbing and fixtures.

There has been research into the effects of copper pipe aging under various water quality conditions (Lagos, et al, 2001), but it is not known if that has played a role in the decreasing copper concentrations measured in Cedar Glen.

Flow Weighted Calculations of pH. In an effort to provide some additional insight into CSG-70 CG's home tap results, the USGS PHREEQC model was used to generate flow weighted pH values based on the amount of Tunnel water and purchased CLAWA water used during a one month period, 90th percentile results and the available water quality data. Figures were generated with this information and are presented in Appendix D. Three figures (D1 – D3) were generated using the lead home tap 90th percentile results (pH, LSI and CCPP) and three figures (D4 - D6) were prepared using the copper home tap 90th percentile results (pH, LSI, and CCPP). These figures are presented in Appendix D and appear to indicate a reduction in the levels of lead and copper associated with an increasing pH. These figures should be reviewed with caution, however, as they likely are not representative of actual conditions within the CSA-70 CG distribution system during the various six month monitoring periods.

SECTION 8: LEAD AND COPPER RESULTS FOR HOMES SERVED DIRECTLY BY CLAWA

CLAWA provides water supply to wholesale and retail customers. The service area includes approximately 14,750 service connections. Approximately 1,200 of those service connections are served directly by CLAWA. Figures 10 and 11 present the 90th percentile lead and copper results, respectively, from homes served directly by CLAWA from 2001 through 2014. Out of total of 10 LCR monitoring events, the 90th percentile for lead was above the AL on two occasions, in 2001 and 2011. For the four most recent monitoring events (2012 - 2014), the 90th percentile results have been ND. All of the copper 90th percentile results have been well below the AL, and for the last four monitoring events (2012 – 2014), the highest 90th percentile result was 0.095 mg/L.

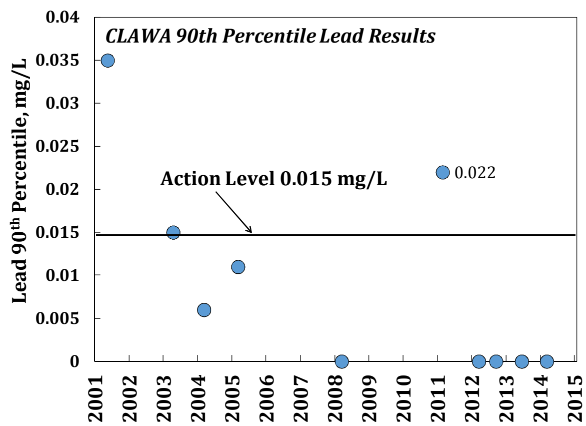

Figure 10. CLAWA 90th Percentile Lead Results (2001 – 2014)

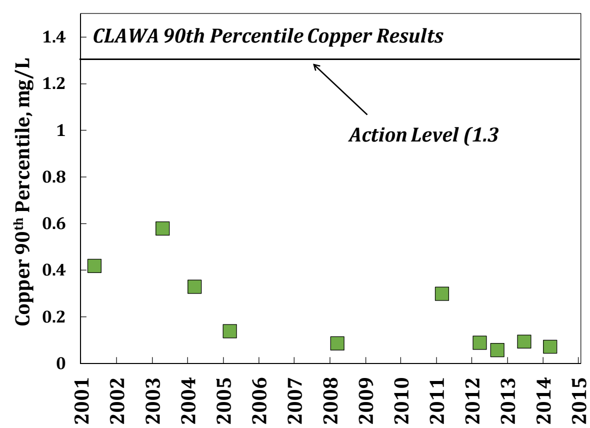

Figure 11. CLAWA 90th Percentile Copper Results (2001 – 2014)

An additional analysis was conducted to evaluate the (1) percent of CLAWA water used in a given month and (2) model generated flow weighted pH values against home tap results.

Figures 12 and 13 were prepared by plotting the percent of CLAWA water used in a given month against the home tap results for the month that a given home was sampled. The small number of homes that were sampled for lead and copper during 2009 and 2016 were included in this analysis. Figures 12 and 13 indicate a reduction in lead and copper concentrations with an increasing percentage of CLAWA water used.

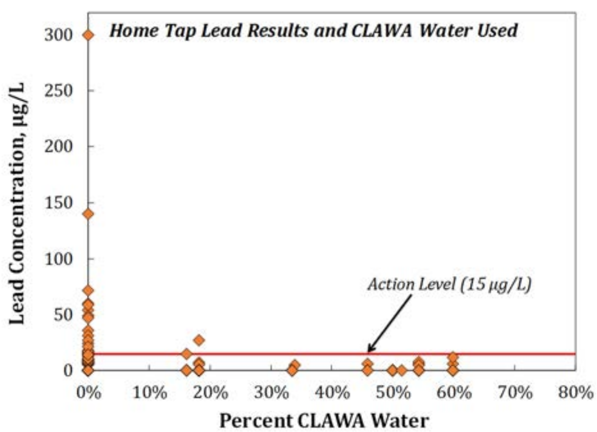

Figure 12. Individual Home Lead Results and Percent CLAWA Supply (2009 – 2016)

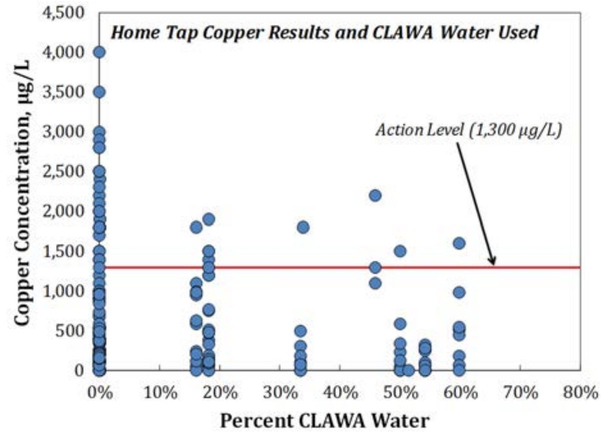

Figure 13. Individual Home Copper Results and Percent CLAWA Supply (2009 – 2016)

Similar to Figures 12 and 13, the next step was to plot the percent of CLAWA supply used against the 90th percentile results for lead and copper. These results are presented in Figures 14 and 15. The percent of CLAWA supply shown in Figures 14 and 15 is the average of CLAWA water used in each month of that six-month monitoring period. Figures 14 and 15 appear to show an improvement in the 90th percentile lead and copper results and the percent of CLAWA water used during that six-month period.

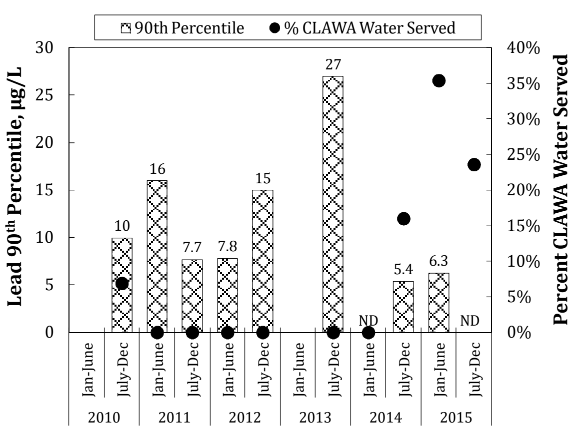

Figure 14. 90th Percentile Lead Results and Percent CLAWA Supply (2010 – 2015)

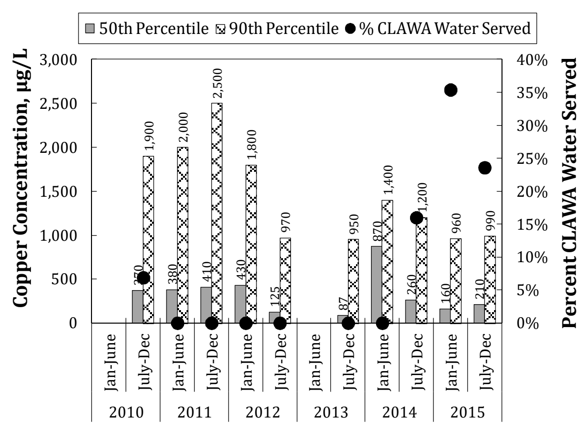

Figure 15. 90th Percentile Copper Results and Percent CLAWA Supply (2000 – 2015)

The PHREEQC model was then used to evaluate the association of individual home tap results with a flow weighted pH. The monthly blend of Tunnel water and purchased CLAWA water along with the average pH of Tunnel water (7.4 from Table 3) and quarterly pH values for the CLAWA supply and additional water quality data was inputted into the PHREEQC model.

Home taps lead and copper results in a given month were plotted against this monthly flow weighted pH value. These results are presented in Figures 16 and 17 and indicate a trend in reduced lead and copper levels as the pH increases. It is important to note that the results presented in Figures 16 and 17 are highly theoretical and likely do not represent actual conditions in the distribution system at the time of sample collection for a given home.

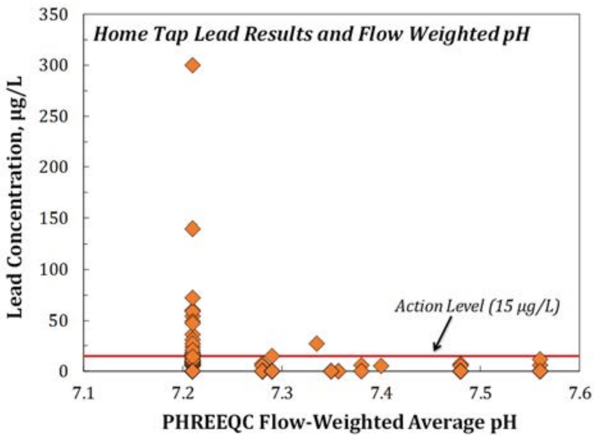

Figure 16. Lead Results from Individual Homes and Flow Weighted pH (2009 – 2016)

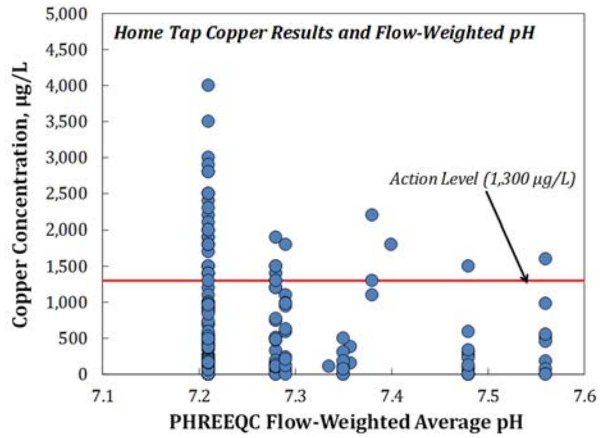

Figure 17. Copper Results from Individual Homes and Flow Weighted pH (2009 – 2016)

SECTION 9: CORROSION CONTROL TREATMENT EVALUATION

Table 9 presents a description of the treatment approaches to be investigated as part of this desktop corrosion control study.

Table 9 – LCR Corrosion Control Treatment

Treatment Approach	General Description
Alkalinity and pH adjustment	The objective of alkalinity and pH adjustment is to decrease the solubility of the metal and form less soluble metal compounds (i.e., metal carbonate and metal hydroxides). These less soluble compounds can adhere to a pipe's surface and form a protective scale.
Use of inhibitors	The use of phosphate or silicate based compounds to form less soluble metal compounds, which can adhere to interior pipe surfaces and protect the surface from corrosion.

Evaluation of Corrosion Control Options for the CSA-70 CG (Tunnel) Supply. The following presents a review of applying corrosion control treatment approaches to CSG 70 CG water (the Tunnel supply):

<u>pH and alkalinity adjustment</u>: The solubility of metals is dependent upon the form of the metal in solution. The impact on corrosion due to pH adjustment is related to the formation of less soluble metal species (typically, hydroxyl-carbonate compounds). As described previously, LSI and CCPP indices can provide an indicator of water's tendency to deposit a protective layer of $CaCO_3$.

Using average water quality results for the Tunnel supply (Table 3), Figures 16 and 17 were generated to indicate the potential impact on LSI and CCPP indices with increasing the pH. Each figure was generated using the average water quality data and increasing the pH by 0.2 increments up to a final pH of 8.4. These theoretical calculations support the idea that increasing the pH of the Tunnel supply to 8.4 would improve the LSI and CCPP indices such that the water would have a tendency to deposit a protective $CaCO_3$ layer.

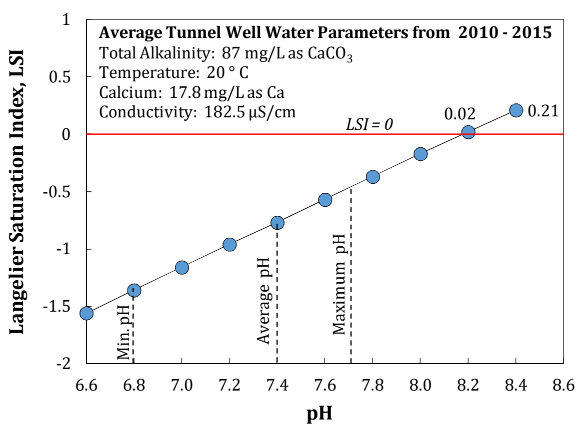

Figure 16. Calculated LSI With Increasing pH

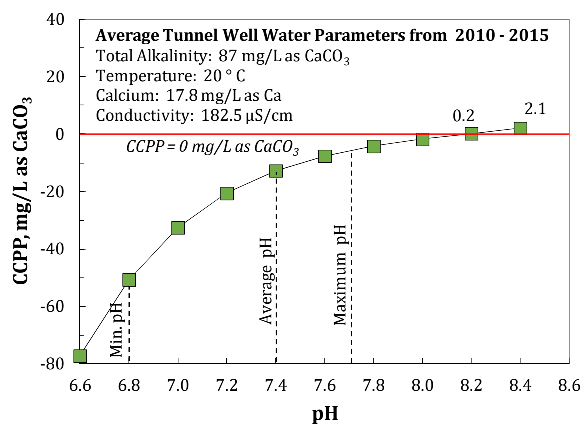

Figure 17. Calculated CCPP with Increasing pH

Lead and Copper Solubility Diagrams. Appendix E, Figure E1 and E2, present lead and copper solubility diagrams for the Tunnel water supply. There are three points, A, B and C on the lead and copper solubility diagrams. In Figure E1, Point A reflects the average measured Tunnel pH of 7.4, Point B represents adjusting the pH to 8.2 and Point C reflects adjusting the pH to 8.4. The theoretical lead solubility is calculated for each point and is indicated below the figure. The lead solubility diagram indicates that adjusting the pH from 7.4 to 8.4 would theoretically lead to the development of a more stable lead complex and a slight (26%) reduction in lead solubility. Figure E2 presents a copper solubility diagram. Point A reflects the average measured pH of 7.4, Point B represents adjusting the pH to 8.2 and Point C reflects a pH adjustment to 8.4. An increase to pH 8.4 indicates a theoretical 82% reduction in copper solubility.

Phosphate and Silicate Inhibitors: phosphate and silicate based compounds can inhibit metal corrosion through the formation of less soluble metal compounds that can adhere to the pipe surface and provide protection against corrosion.

There is limited information available on the effectiveness of silicate based corrosion inhibitors in municipal water systems. Silicate-based corrosion inhibitors can inhibit the oxidation and release of metals, including lead. One report indicates that it is unclear whether the impact is due to the presence of silicate or due to the resultant elevated pH. They are mainly used is soft waters with low pH and a high dissolved oxygen concentration and will not be carried forward in this review.

Several different types of phosphates are used for corrosion control, including polyphosphates, orthophosphates, glassy polyphosphates and bimetallic polyphosphates as well as blends of ortho- and polyphosphates and the use of zinc along with the phosphate inhibitor. The mechanism for corrosion control is the formation of phosphate complexes which can passivate the metal surface. Phosphate inhibitors requires specific zones of pH, DIC (or alkalinity) and phosphate level to be effective for corrosion control. Reactions with calcium, magnesium and iron can alter chemical dosage, as well as the DIC and pH required for optimal performance.

Polyphosphate sequestering agents are available in various forms (sodium tripolyphosphate, sodium hexametaphosphate, etc). Polyphosphates can sequester calcium ions, thus a fairly significant dose likely would be required to meet the calcium demand of the Tunnel supply. Orthophosphates (i.e., mono, di and tri-basic sodium phosphate) can form protective films and can be effective in reducing lead leaching. The reported optimal pH for orthophosphate is approximately 7.4, but orthophosphates have been reported to be effective over a pH range of 7.2 to 7.8. Typical orthophosphate doses in the US are 0.5 – 3.0 mg/L as PO_4, (0.2 to 1.0 mg/L as phosphorous (P)).

CLAWA is targeting an elevated pH for corrosion control that would not be optimal for the performance of a phosphate inhibitor. Given that CSA-70 CG periodically purchases treated water from CLAWA, an evaluation of the use of a phosphate inhibitor is not recommended and will not be carried forward.

SECTION 10: SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Summary. CSA-70 CG is a small public water system serving 1,154 residents in San Bernardino County. The primary source of water is the "Tunnel" supply. CSA-70 CG periodically purchases treated surface water from CLAWA.

Between 1998 and 2011 CSA-70 CG conducted and reported to DDW the results from ten LCR home tap monitoring events. During that period of time, the 90th percentile values exceeded the lead Action Level during monitoring events and exceeded the copper action level during six monitoring events.

In November 2010 CSA-70 CG received a letter from DDW requiring additional home tap monitoring and the preparation of a corrosion control study. In December 2012 CSA-70 CG received a NOV from DDW for failure to monitor for water quality parameters and failure to prepare a corrosion control desktop study. This report is the corrosion control desktop study prepared in response to that NOV.

Using available water quality and production data for the Tunnel and CLAWA supplies the focus of this desktop study is on the period 2010-2015. The corrosion indices evaluated in this desktop study indicate that the Tunnel supply does not have a tendency to deposit a protective $CaCO_3$ layer. The calculated CSMR suggests that the Tunnel supply would be considered a corrosive water towards lead in solder and brass fixtures. The calculated AI suggests that the water is moderately corrosive.

During the period 2010-2015, CSA-70 CG conducted and reported to DDW the results from of seven additional six-month LCR home tap monitoring events. The lead 90th percentile results during the four most recent monitoring events were all below the lead Action Level. In addition, during the three most recent six-month monitoring events, the 90th percentile copper results were below the copper Action Level. According to Title 22 regulations, this is a condition where a small public water system may cease installation of corrosion control treatment.

Conclusions. Available water quality conditions indicate that adjusting the pH of the Tunnel supply could provide benefits to reducing the levels of lead and copper. However, beginning with the LCR home tap monitoring events in 2012, and especially the results for 2014 and 2015, there has been an improvement in the levels of lead and copper in first draw home tap samples without any treatment. Information is not available to determine whether the improvement has been due to rebuilding of homes, replacement of plumbing and fixtures, or changing water quality conditions. As stated above, according to Title 22 drinking water regulations, these recent results indicate that CSA-70 CG's conditions may cease moving forward with the installation of corrosion control treatment.

Recommendations. The recommendations from this desktop study are to proceed as follows: (1) proceed now with sizing, cost estimate and design of a chemical feed system (sodium hydroxide or sodium bicarbonate) to adjust pH of the Tunnel supply, and (2) conduct an additional round of home tap monitoring during 2017.

The six month monitoring period should occur during June – September 2017. The following steps should be part of this 2017 monitoring event:

- CSA-70 CG review the home sample pool to ensure that it still consists primarily of Tier 1 sample sites, if available, in the distribution system.
- Collect monthly water quality samples from distribution system locations in each pressure zone as well as from each source in operation. Samples should be analyzed for the following water quality parameters: pH, alkalinity, temperature, hardness, calcium, chloride, sulfate, and conductivity.
- For the home tap samples, in addition to lead and copper, samples should be analyzed for the presence of nickel and zinc, as an indicator of brass fixtures as a potential source of copper.
- For the home tap samples, if purchased CLAWA water is being used to supply the CSA-70 CG distribution system during the monitoring period, add a test for chloride to the home tap samples (based on the available water quality data provided, the levels of chloride in the Tunnel and CLAWA supplies are very different, thus chloride can be used as an indicator as to whether the home was served by the Tunnel supply, CLAWA supply or a blend).

If either the lead or copper action level is exceeded during the 2017 monitoring event, CSA-70 CG should proceed with installation of treatment to adjust pH of the Tunnel supply.

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Appendix A

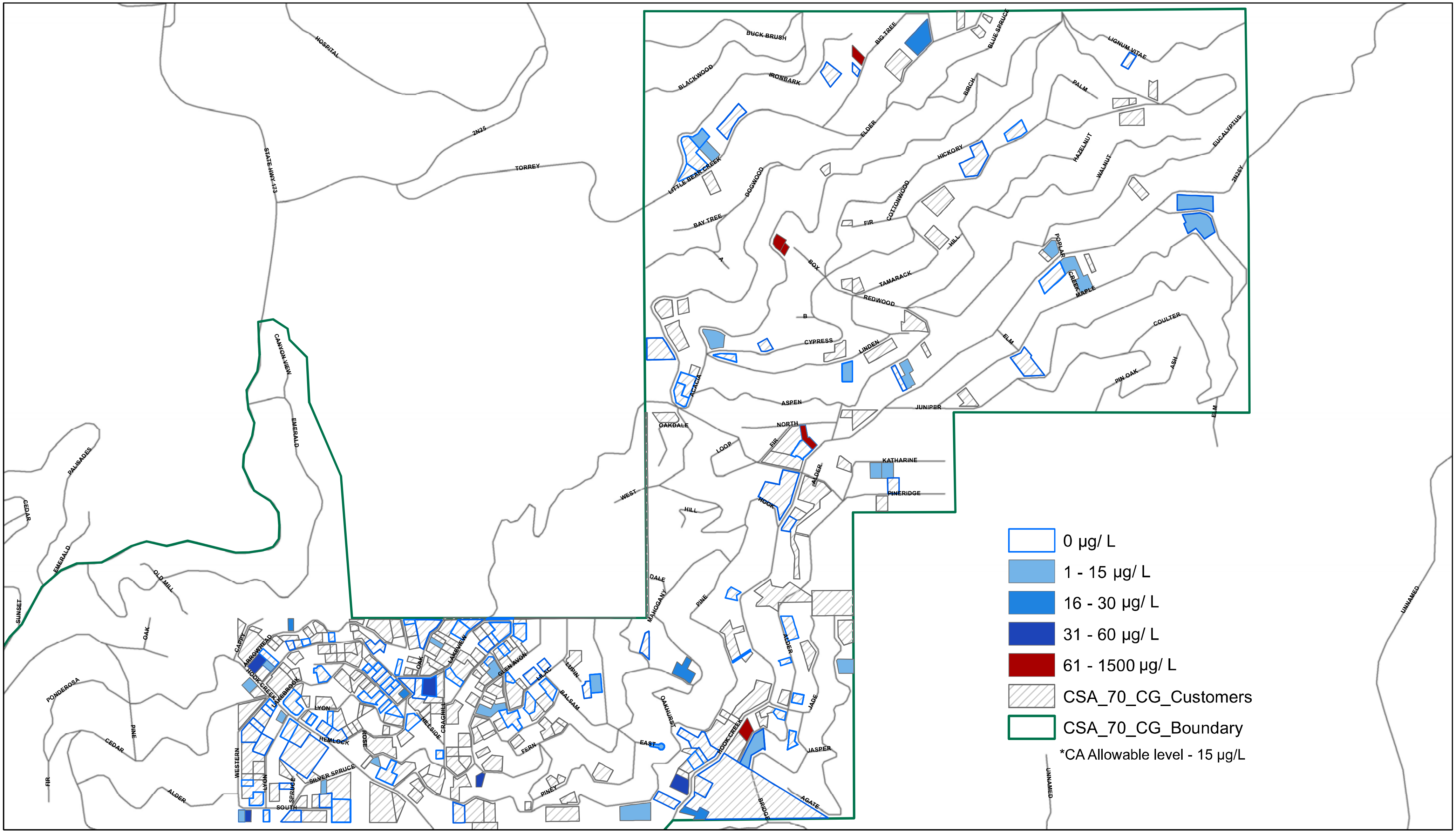
Water Quality Data for Tunnel Supply

Parameter	Sample Date 3-Mar-10	11-Feb-13	28-Feb-13	28-Oct-15
Aggressive Index	11.23	11.25	10.97	10.34
Total Alkalinity (mg/L as CaCO3)	87	84	86	91
Calcium	20	17	17	17
Chloride	5.8	5.2	5.7	
Hardness (mg/L as CaCO3)	100	67	67	
Langelier Index at 60 ^{o}C	0.2	0.08	-0.19	-0.83
Langelier Index at Source Temp	0	-0.52	-0.8	-1.44
pH	7.6	7.7	7.4	6.8
Source Temperature ^{o}C	20	20	20	20
Specific Conductance	180	180	180	190
Sulfate	2.7	1.5	1.6	
Total Dissolved Solids	110	110	120	
CSMR	2.1	3.5	3.6	
LSI	-0.51	-0.5	-0.79	-1.36
CCPP	-6.63	-5.36	-12.23	-50.93
DIC, mg/L as C	22.02	21.02	22.47	29.71
Larson Index	0.13	0.11	0.11	

Appendix B

Distribution System Maps

and Home Tap Lead Results



SAN BERNARDINO COUNTY

EO Revised 2-27-17

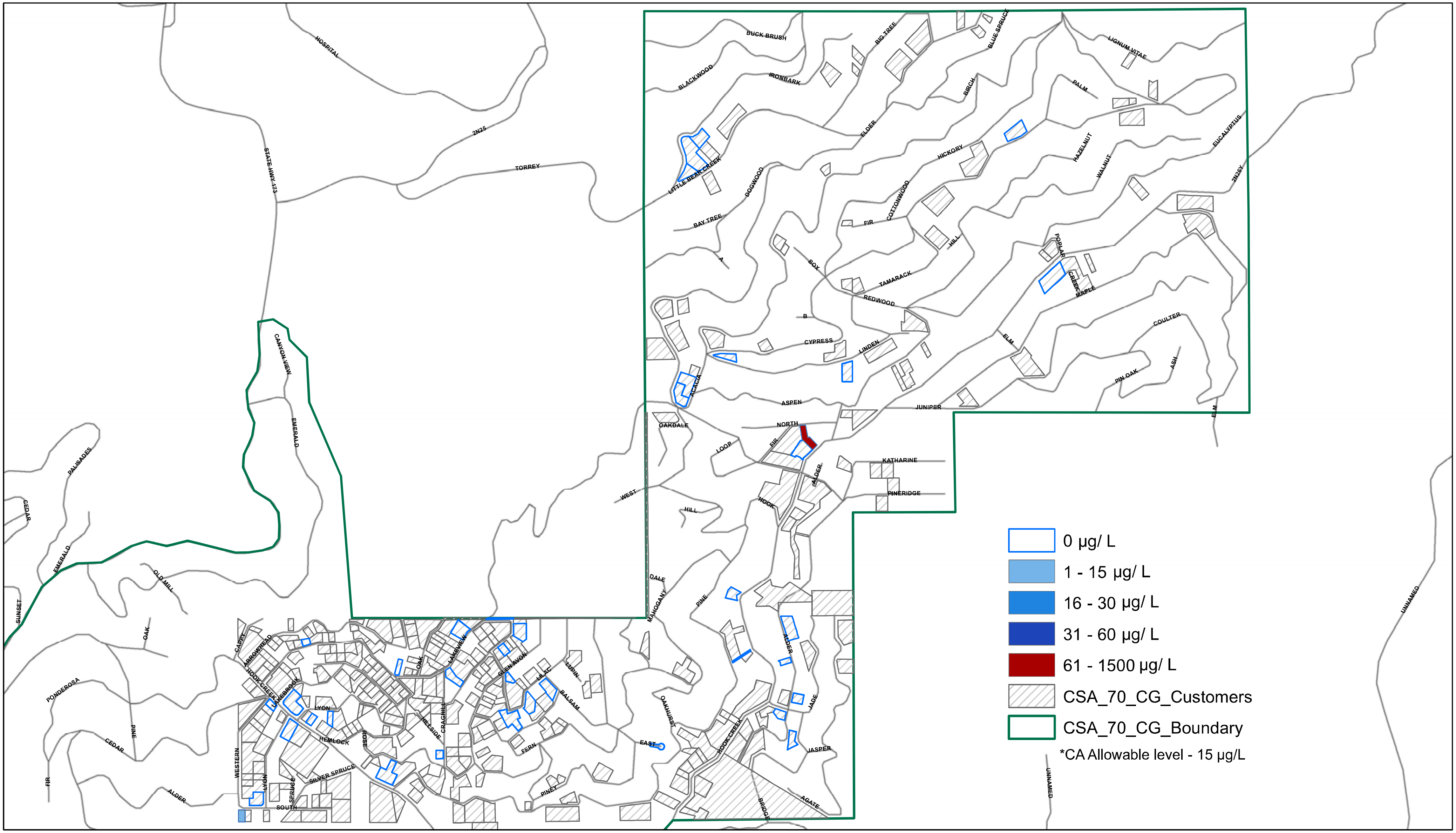
Lead Occurrence 2010-2016

CSA 70 CG: Cedar Glen

Figure B-1

0 0.125 0.25 0.5 Miles

N



SAN BERNARDINO COUNTY

EO Revised 2-27-17

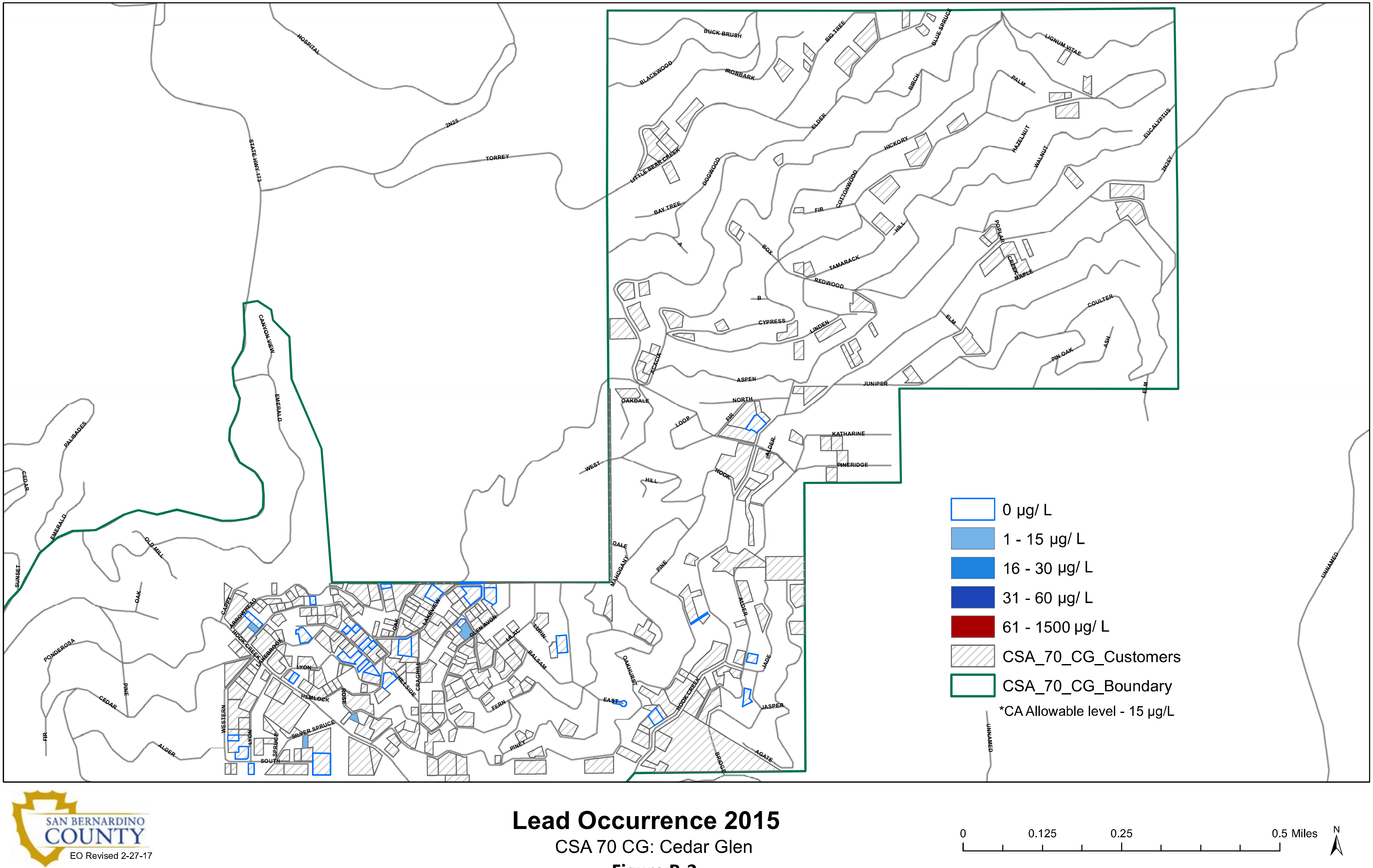
Lead Occurrence 2016

CSA 70 CG: Cedar Glen

0 0.125 0.25 0.5 Miles

N

Figure B-2

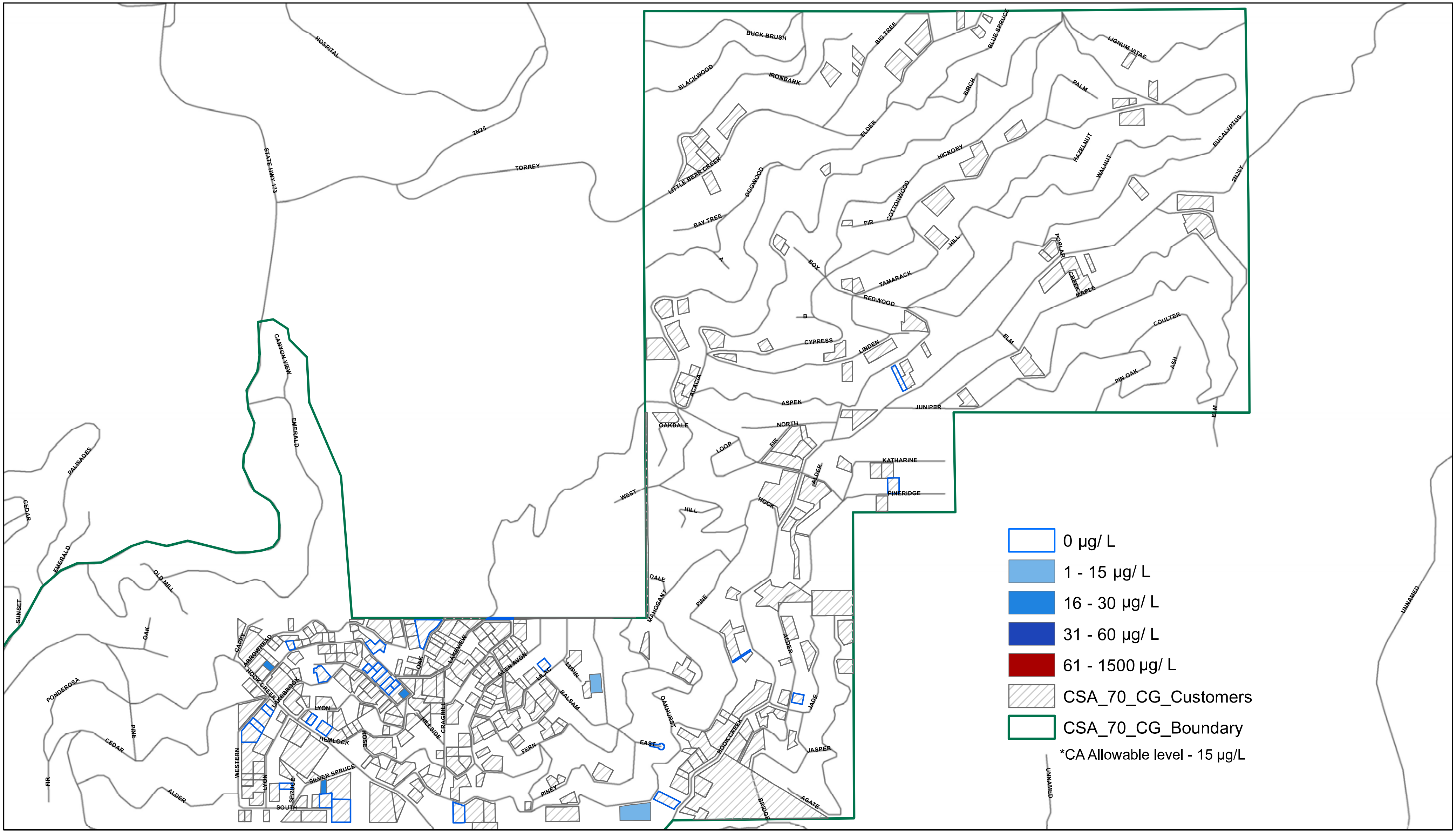


SAN BERNARDINO COUNTY
EO Revised 2-27-17

Lead Occurrence 2015

CSA 70 CG: Cedar Glen

Figure B-3



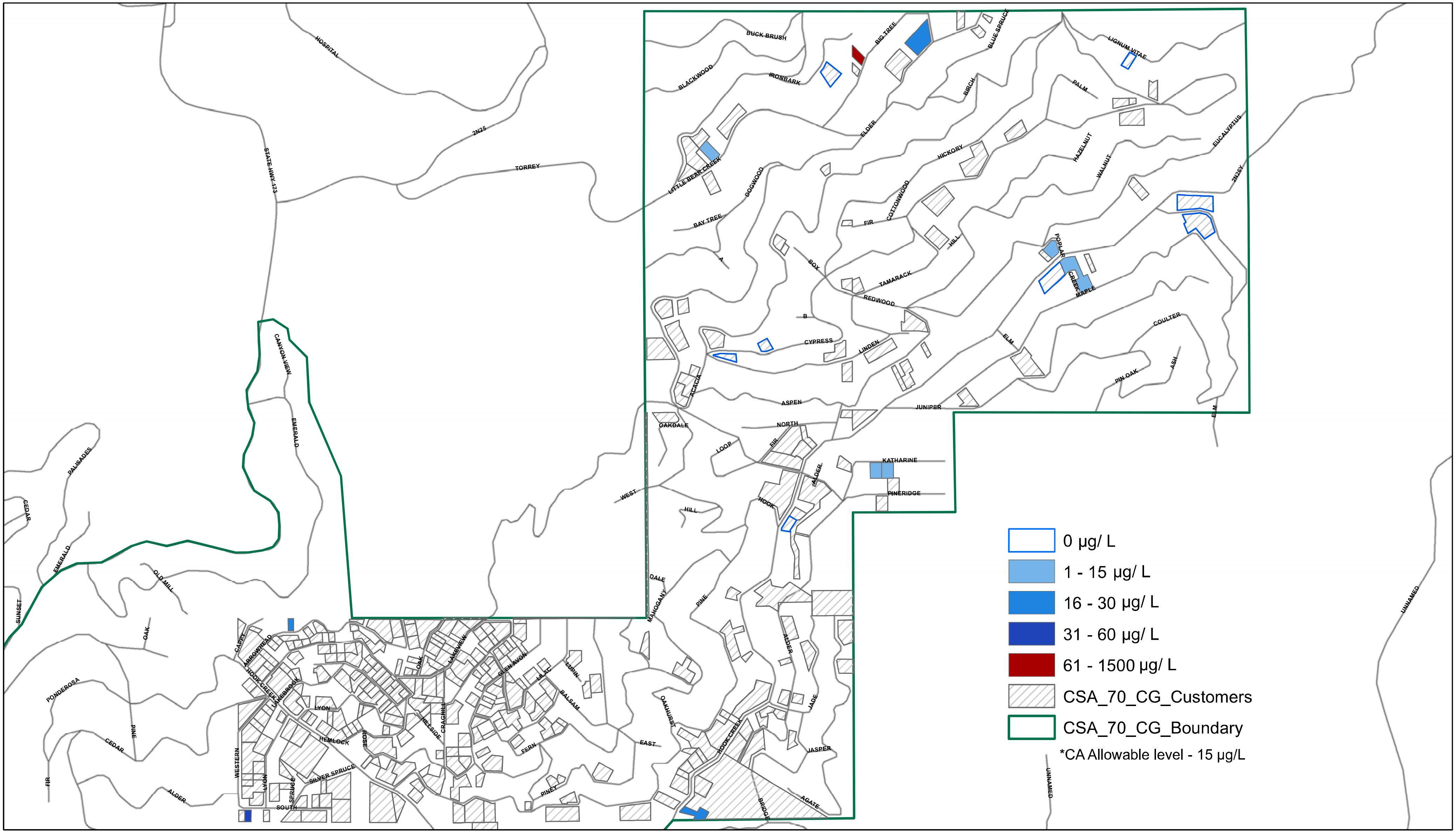
SAN BERNARDINO COUNTY

EO Revised 2-27-17

Lead Occurrence 2014

CSA 70 CG: Cedar Glen

Figure B-4

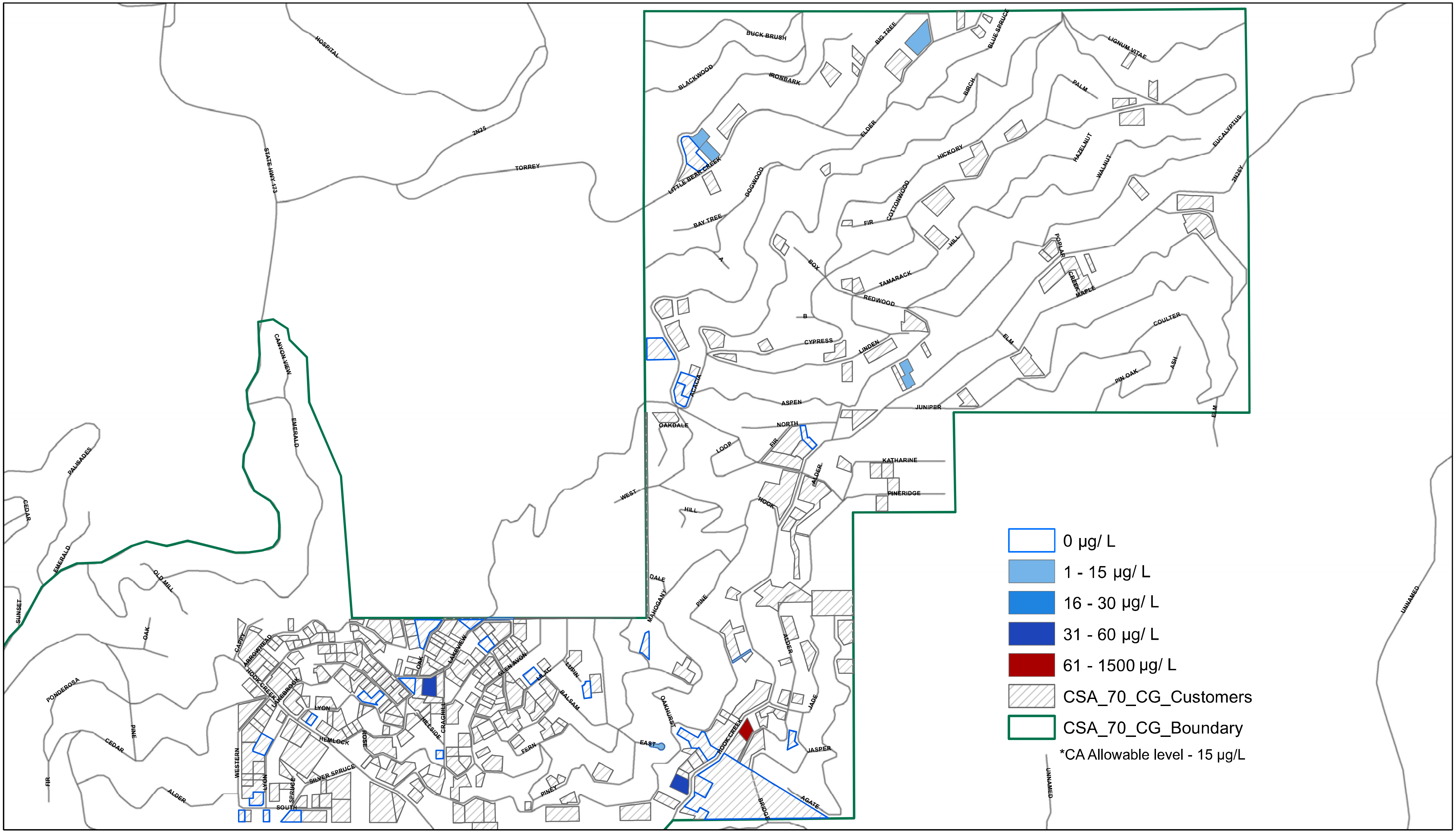


SAN BERNARDINO COUNTY
EO Revised 2-27-17

Lead Occurrence 2013

CSA 70 CG: Cedar Glen

Figure B-5



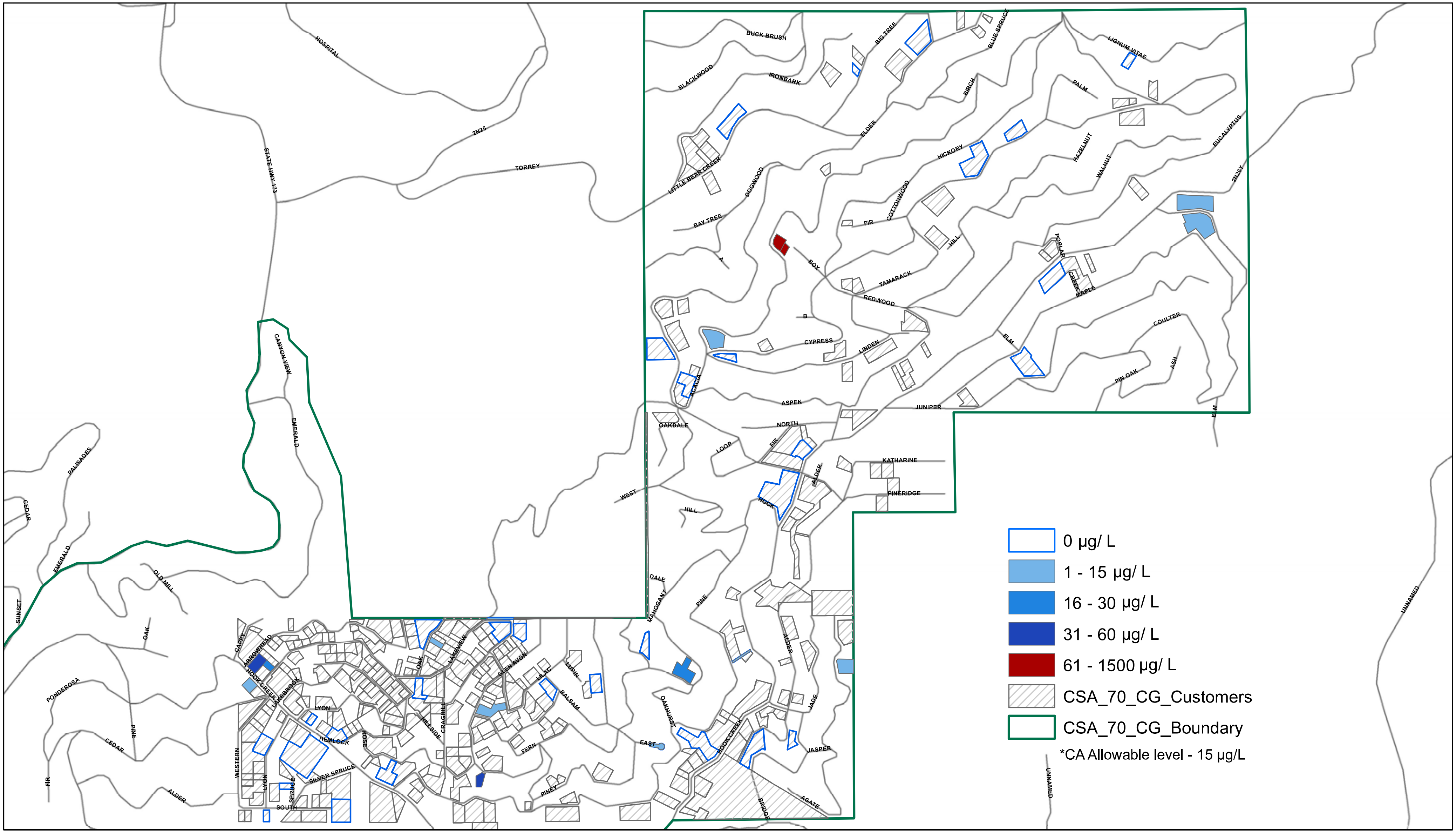
SAN BERNARDINO COUNTY

EO Revised 2-27-17

Lead Occurrence 2012

CSA 70 CG: Cedar Glen

Figure B-6



SAN BERNARDINO COUNTY

EO Revised 2-27-17

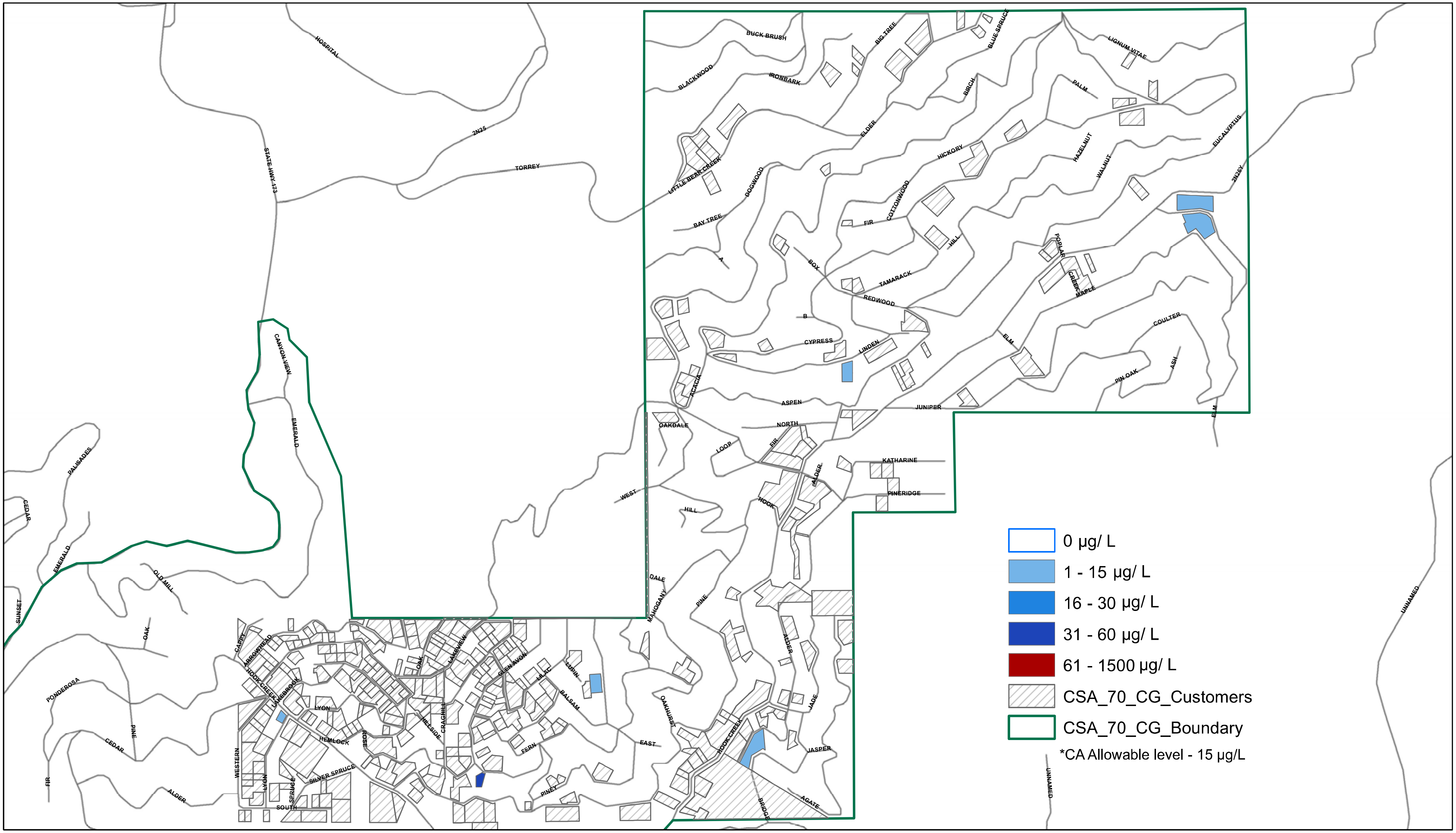
Lead Occurrence 2011

CSA 70 CG: Cedar Glen

Figure B-7

0 0.125 0.25 0.5 Miles

N



SAN BERNARDINO COUNTY
EO Revised 2-27-17

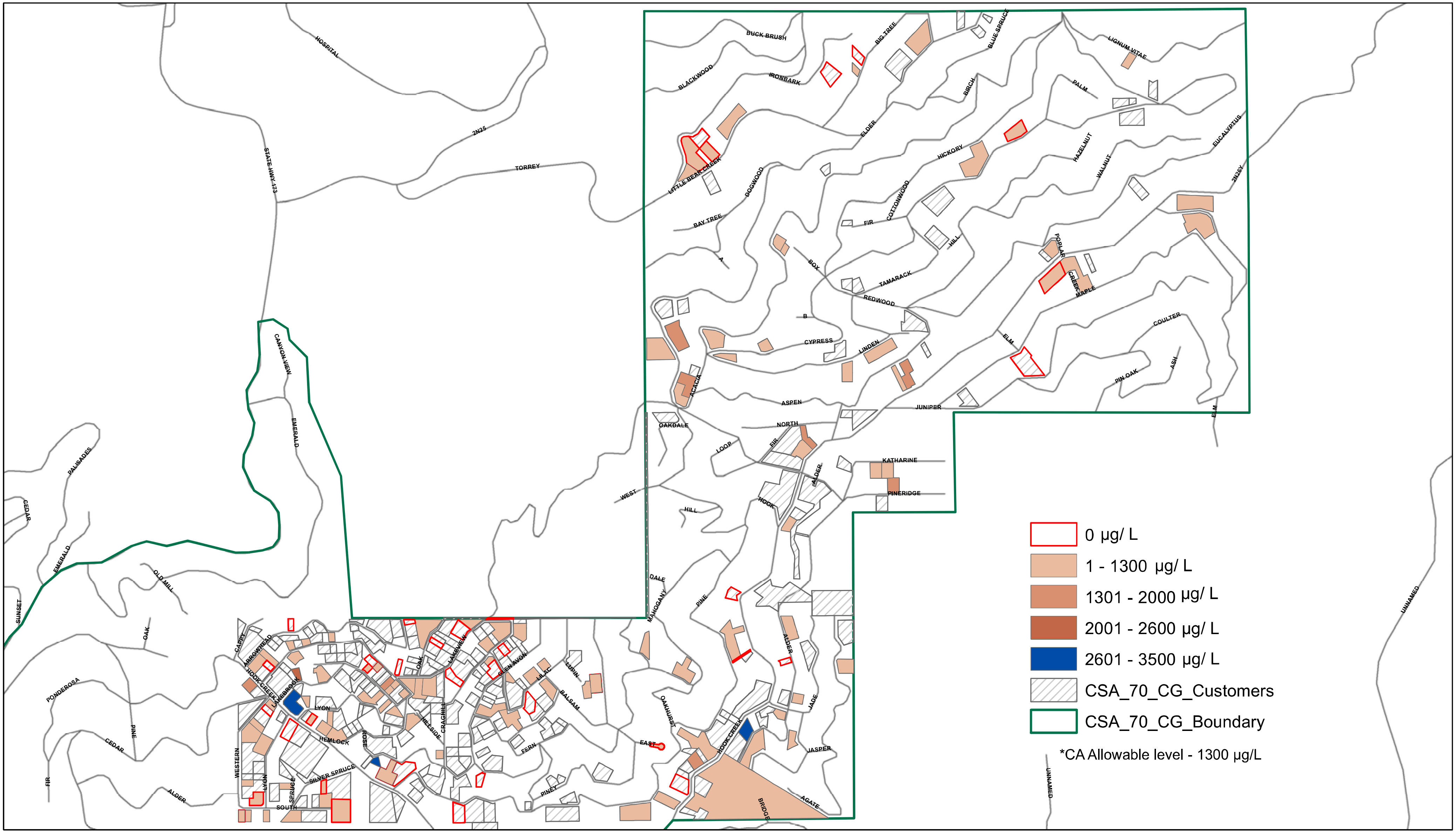
Lead Occurrence 2010

CSA 70 CG: Cedar Glen

Figure B-8

Appendix C

Distribution System Maps
and Home Tap Copper Results

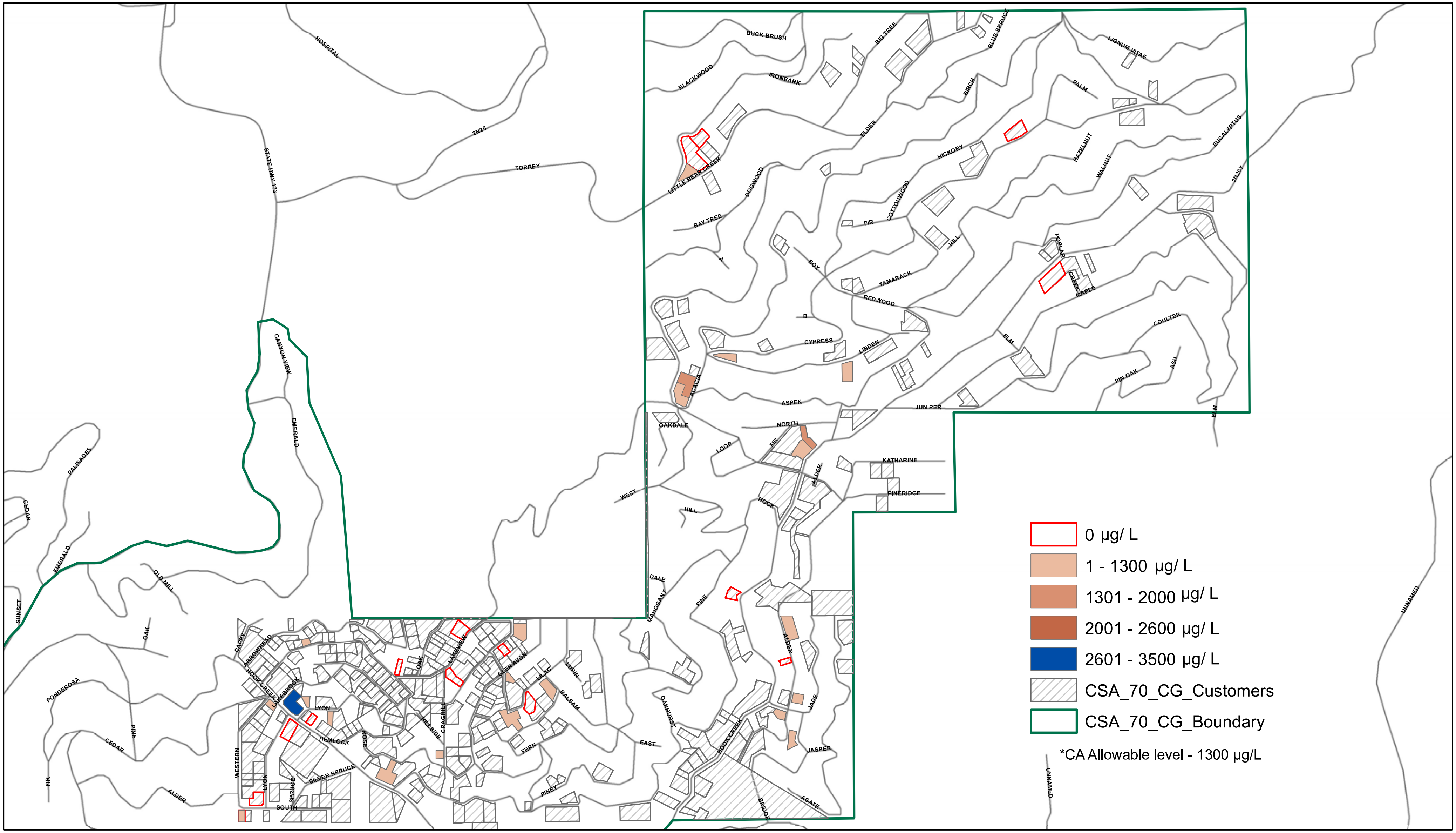


SAN BERNARDINO COUNTY
EO Revised 2-27-17

Copper Occurrence 2010-2016

CSA 70 CG: Cedar Glen

Figure C-1



SAN BERNARDINO COUNTY

EO Revised 2-27-17

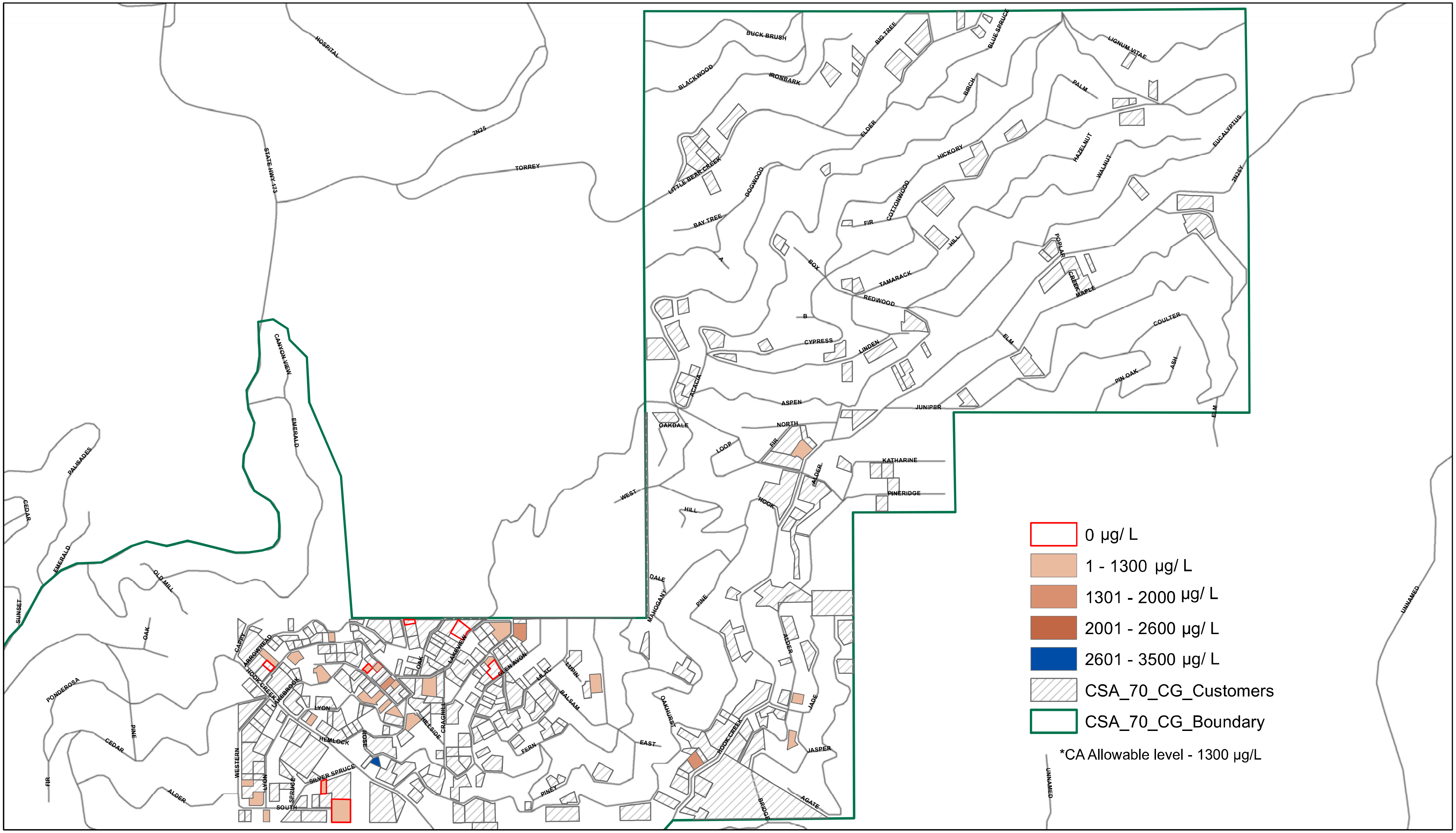
Copper Occurrence 2016

CSA 70 CG: Cedar Glen

Figure C-2

0 0.125 0.25 0.5 Miles

N



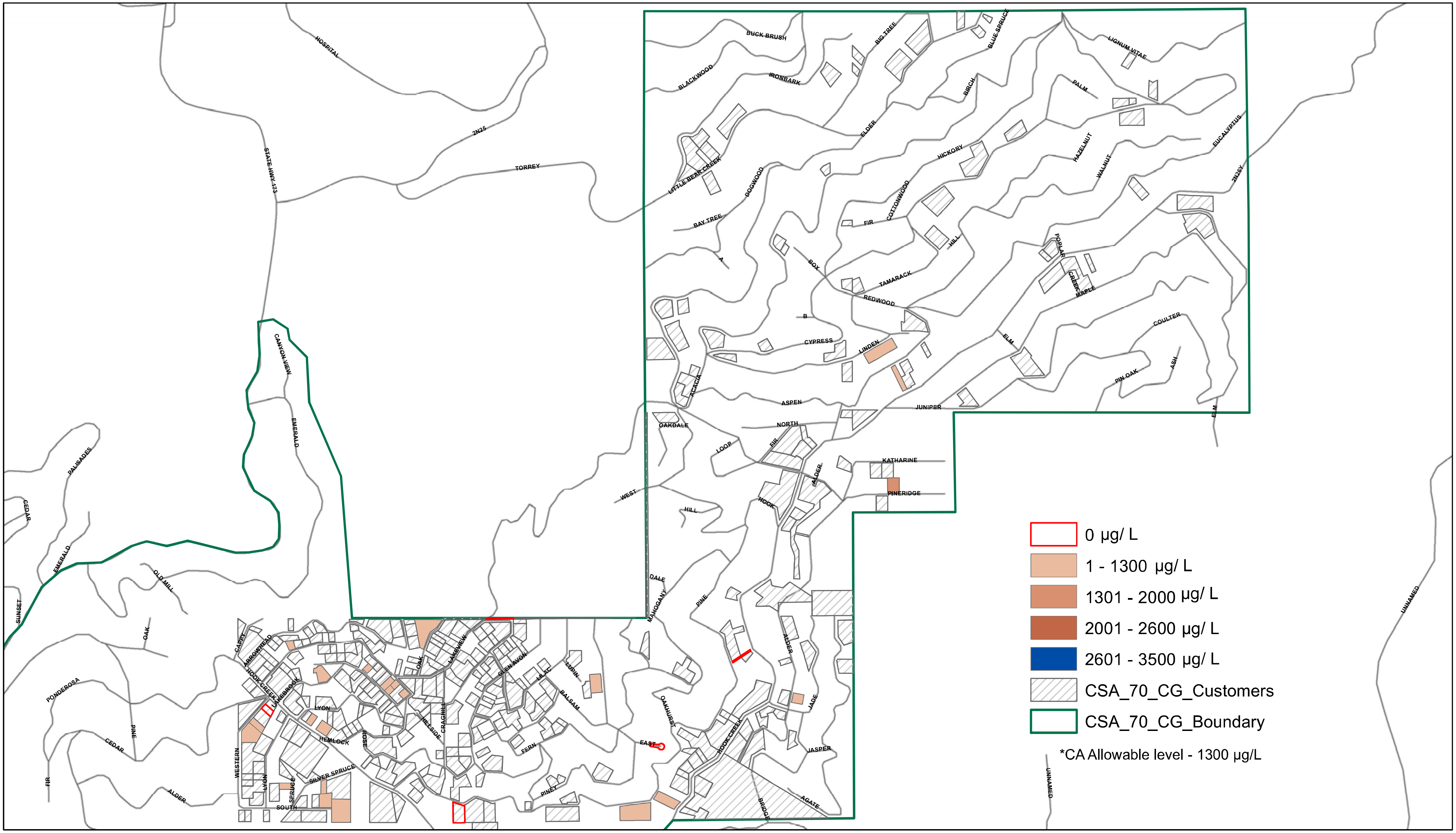
SAN BERNARDINO COUNTY

EO Revised 2-27-17

Copper Occurrence 2015

CSA 70 CG: Cedar Glen

Figure C-3



SAN BERNARDINO COUNTY

EO Revised 2-27-17

Copper Occurrence 2014

CSA 70 CG: Cedar Glen

Figure C-4

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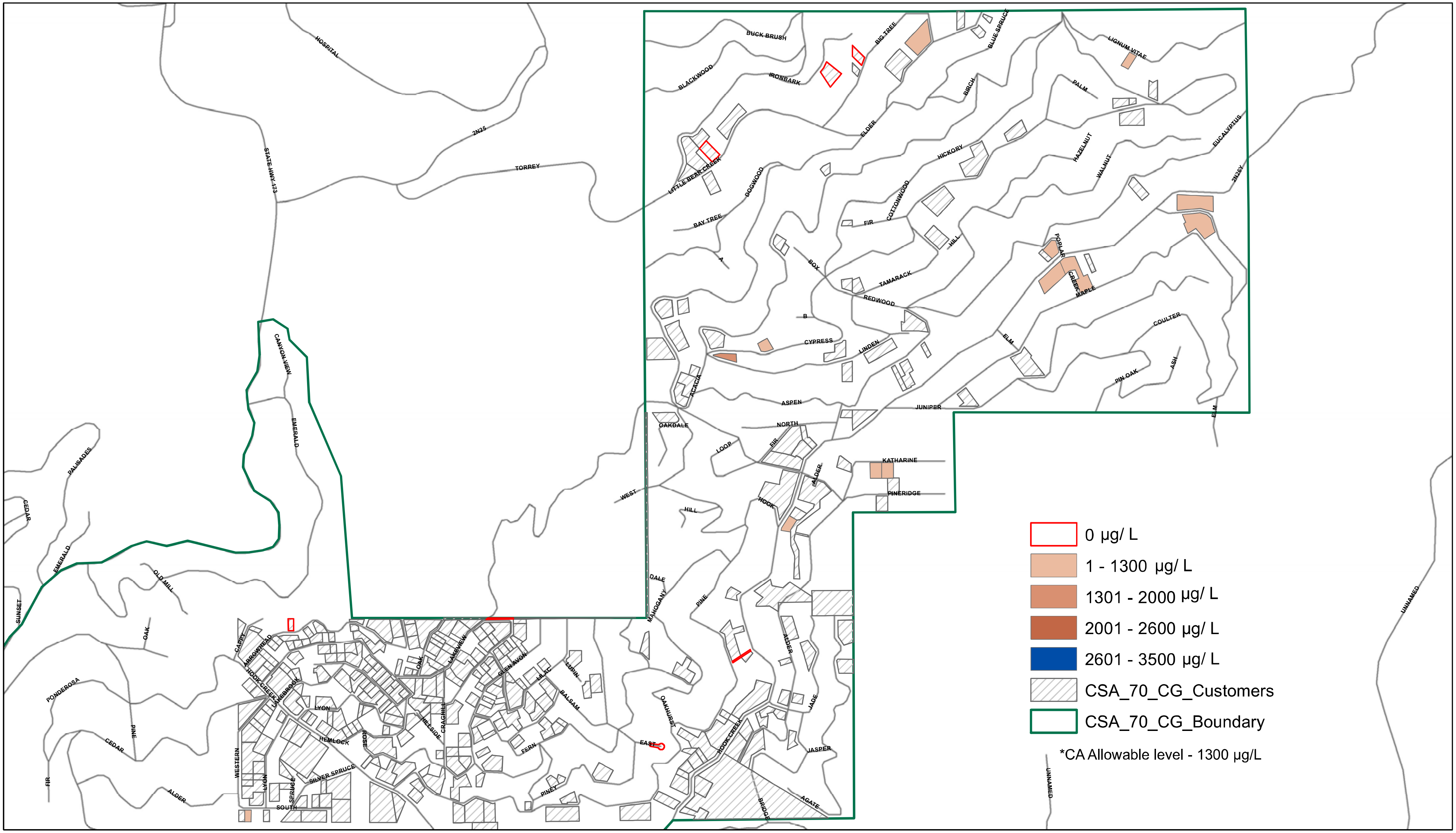
N



SAN BERNARDINO COUNTY
EO Revised 2-27-17

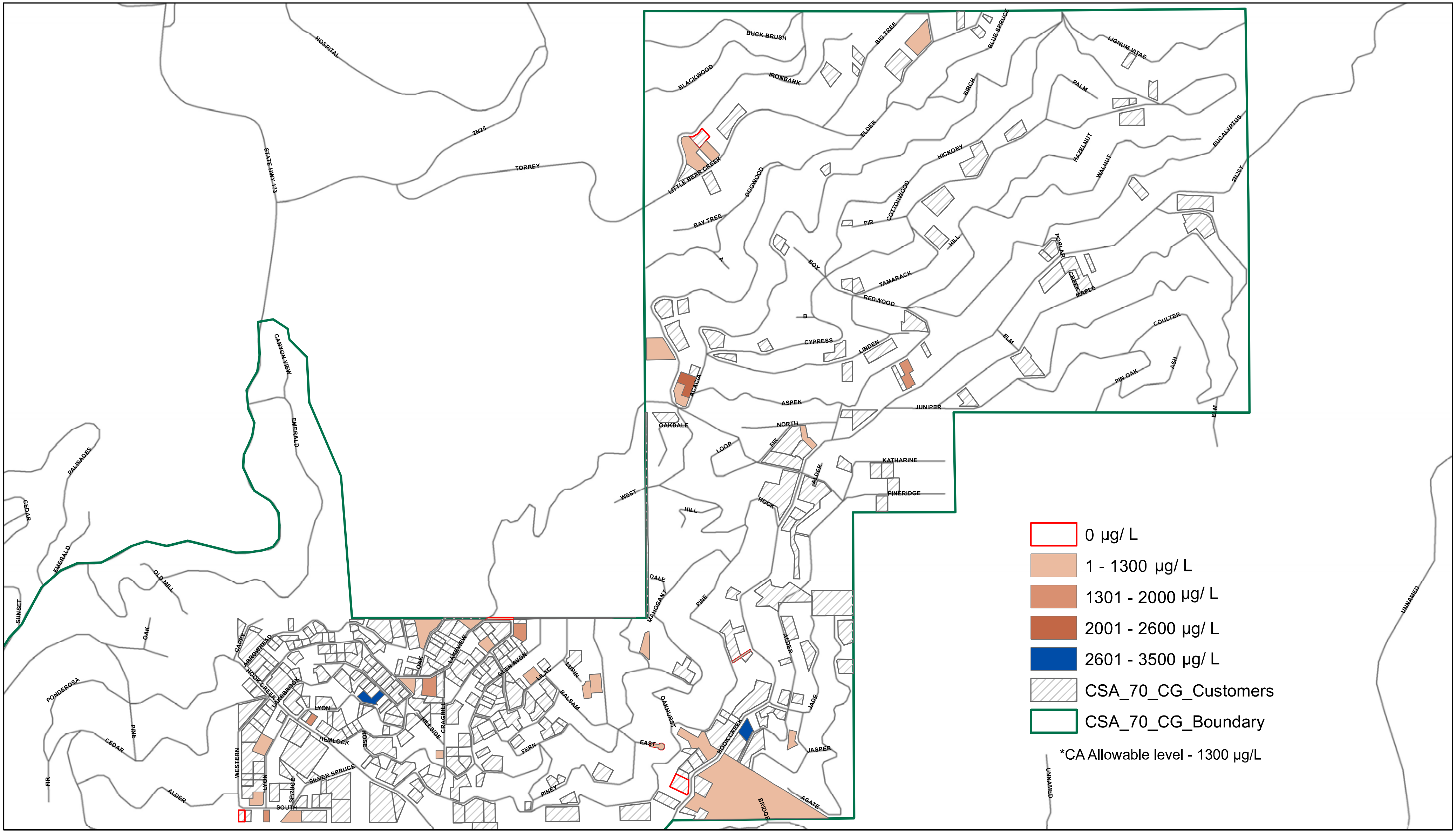
Copper Occurrence 2013

CSA 70 CG: Cedar Glen

Figure C-5

0 0.125 0.25 0.5 Miles

N



Copper Occurrence 2012

CSA 70 CG: Cedar Glen

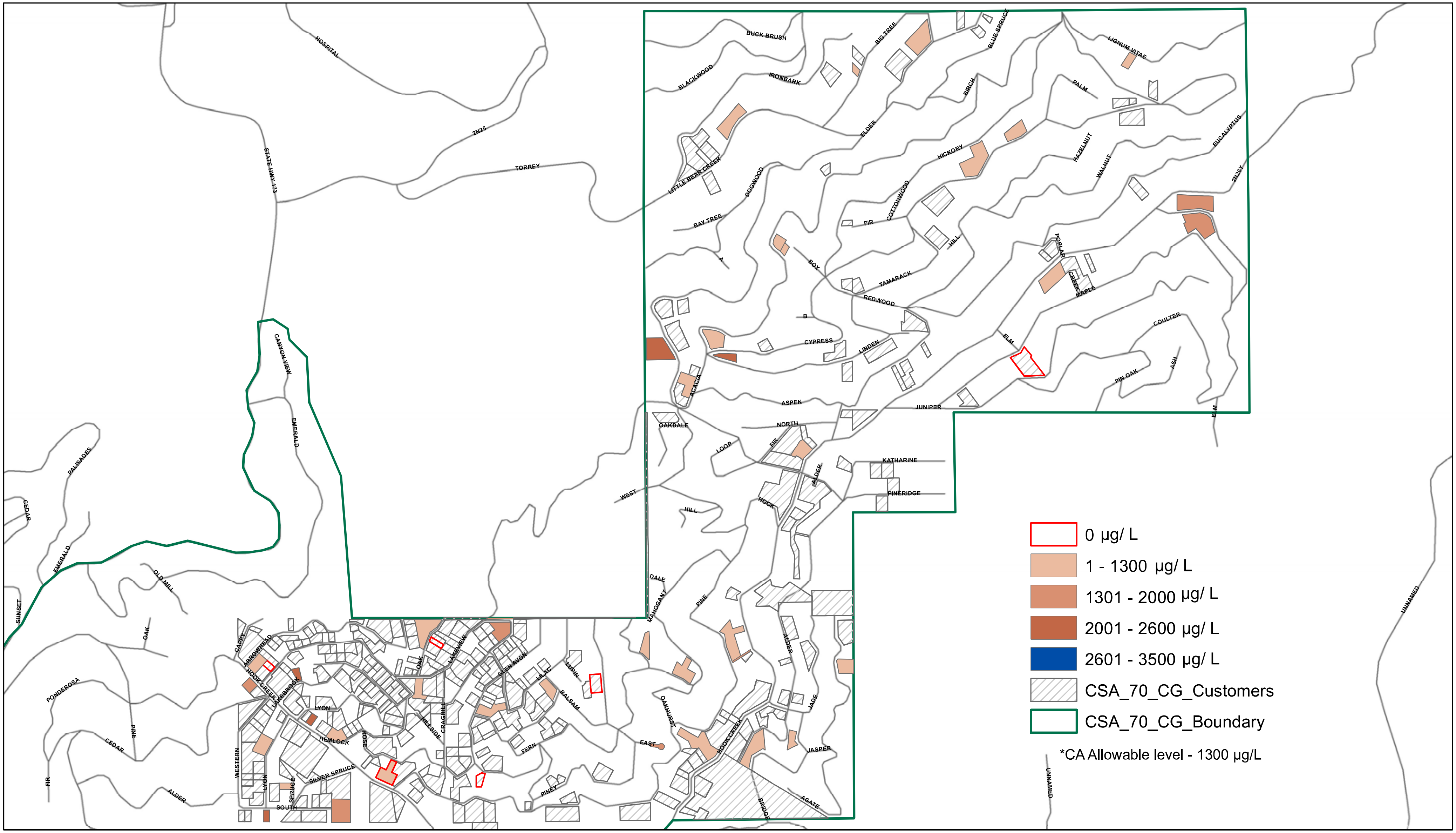
Figure C-6

SAN BERNARDINO COUNTY

EO Revised 2-27-17

0 0.125 0.25 0.5 Miles

N



SAN BERNARDINO COUNTY

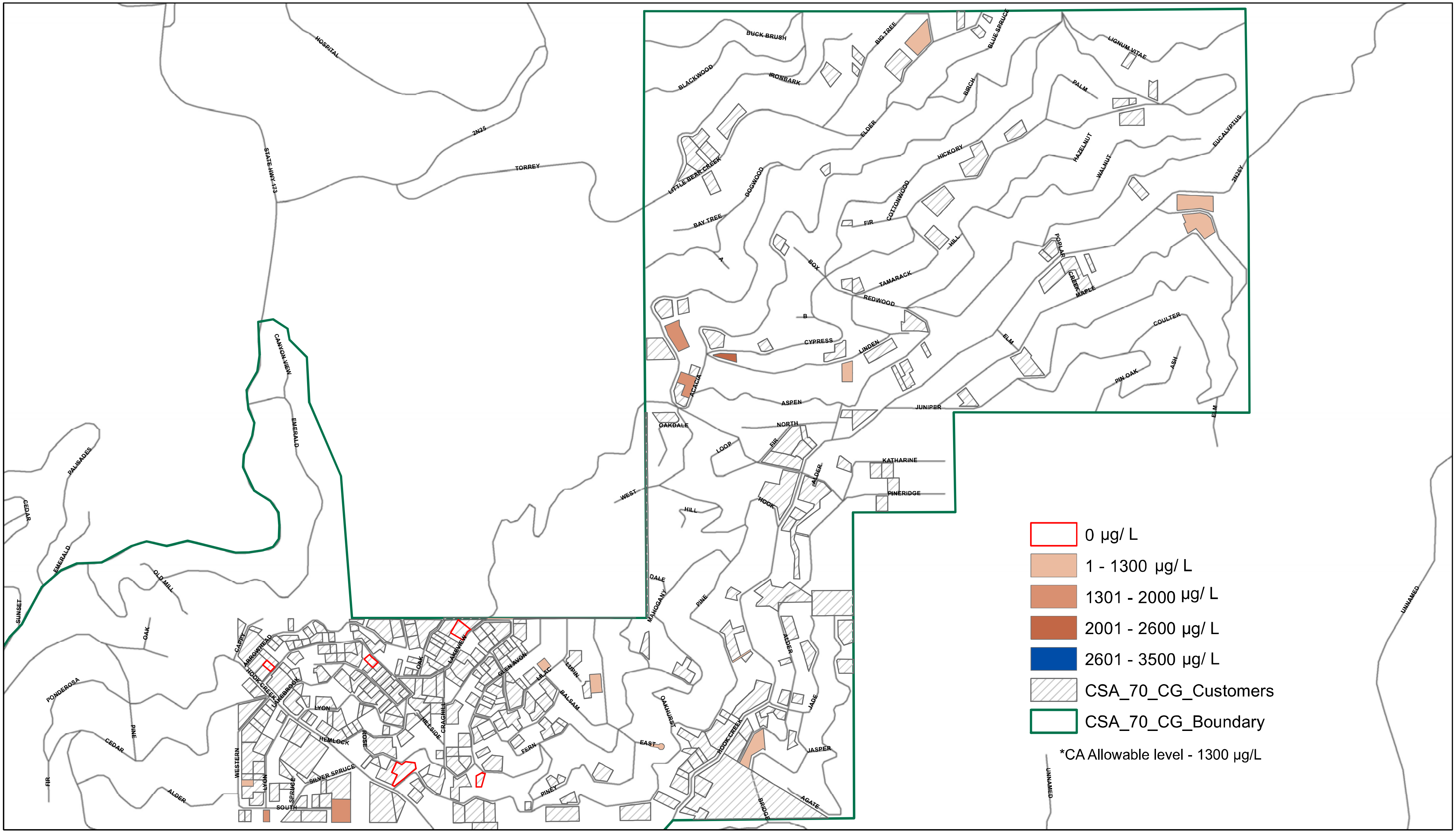
EO Revised 2-27-17

Copper Occurrence 2011

CSA 70 CG: Cedar Glen

Figure C-7

0 0.125 0.25 0.5 Miles N



SAN BERNARDINO COUNTY

EO Revised 2-27-17

Copper Occurrence 2010

CSA 70 CG: Cedar Glen

Figure C-8

0 0.125 0.25 0.5 Miles

N

Appendix D

Lead and Copper 90th Percentile Results

And Flow Weighted pH, LSI and CCPP

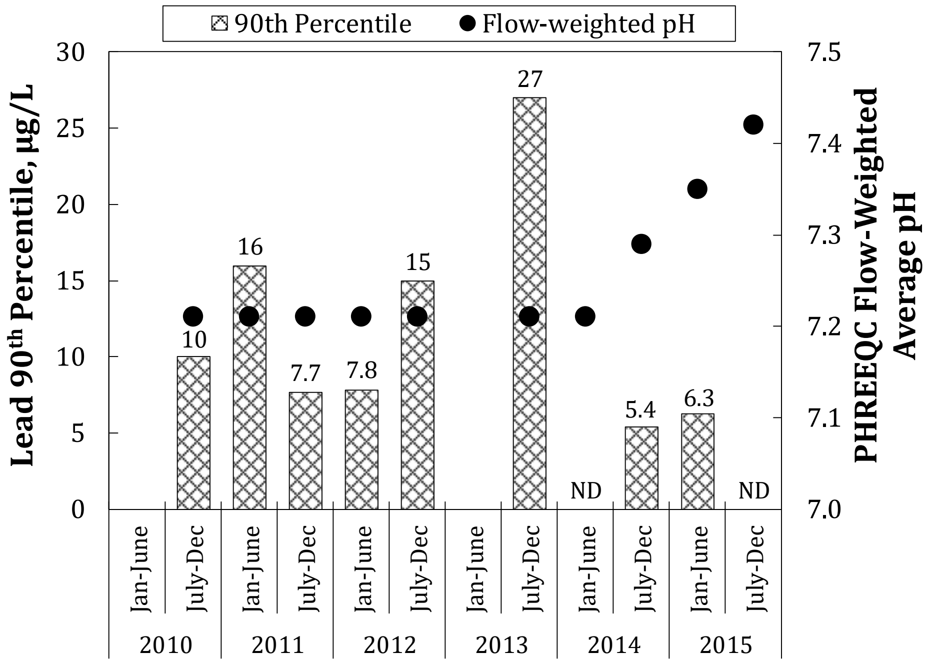


Figure D-1. Lead Results and Flow Weighted pH (2010-2015)

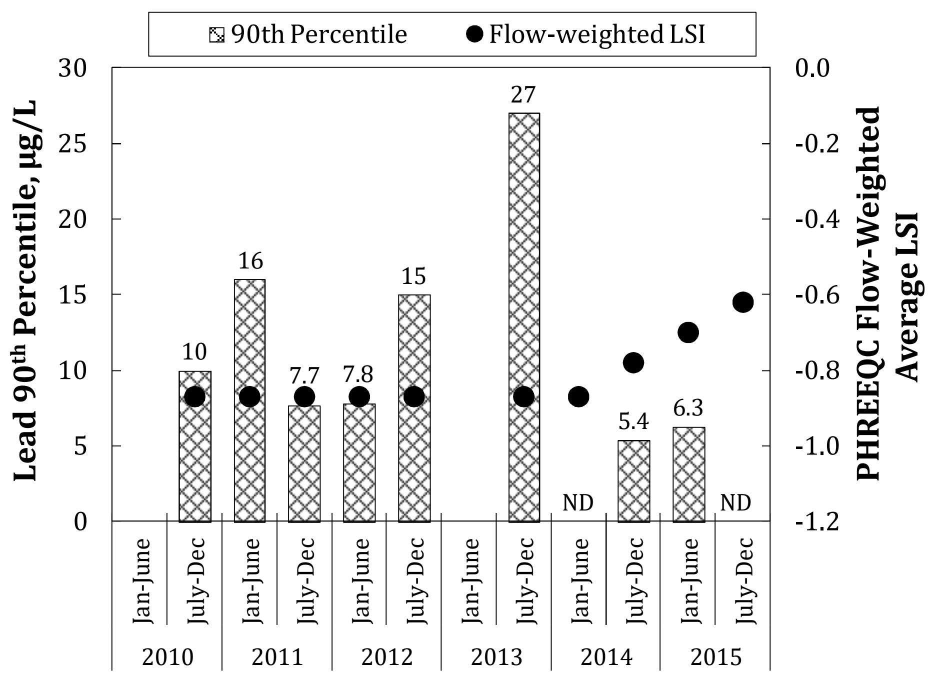


Figure D-2. Lead Results and Flow Weighted LSI (2010-2015)

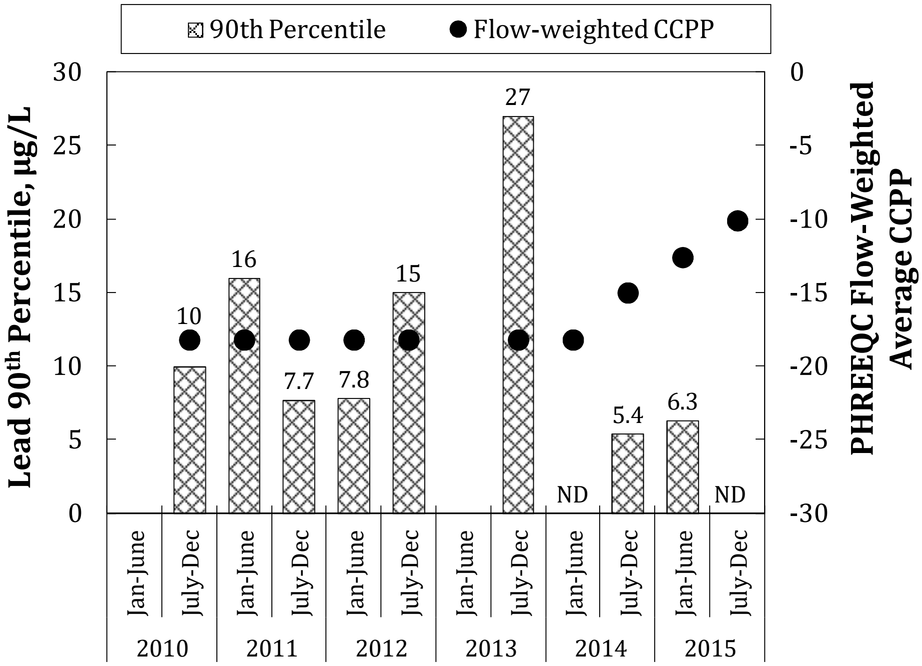


Figure D-3. Lead Results and Flow Weighted CCPP (2010-2015)

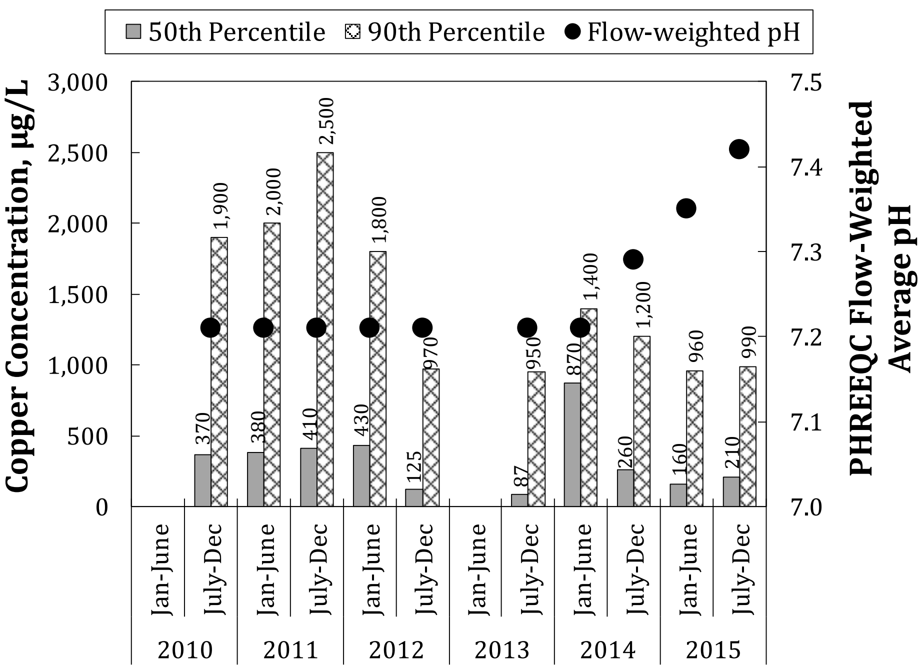


Figure D-4. Copper Results and Flow Weighted pH (2010-2015)

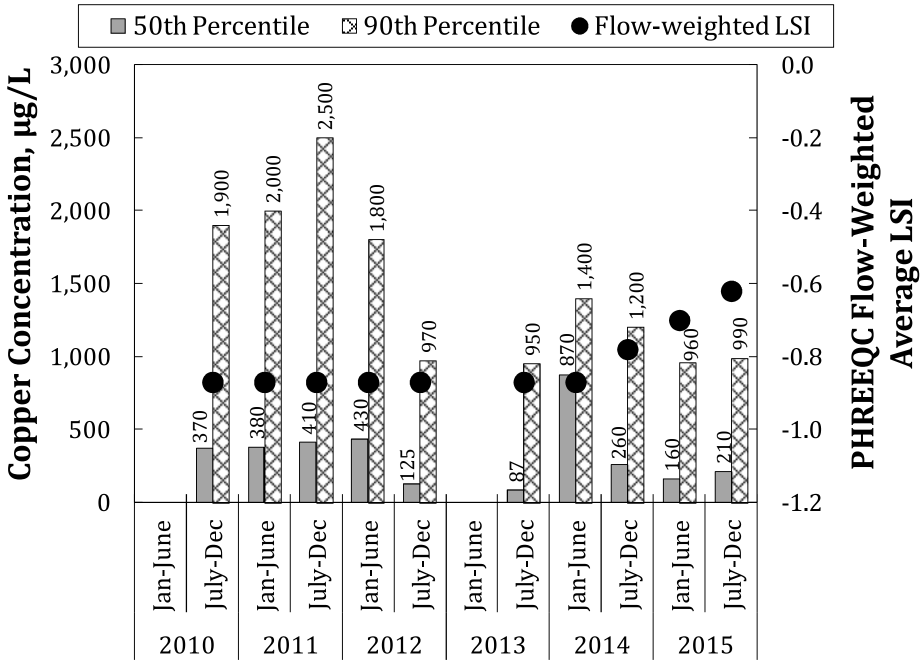


Figure D-5. Copper Results and Flow Weighted LSI (2010-2015)

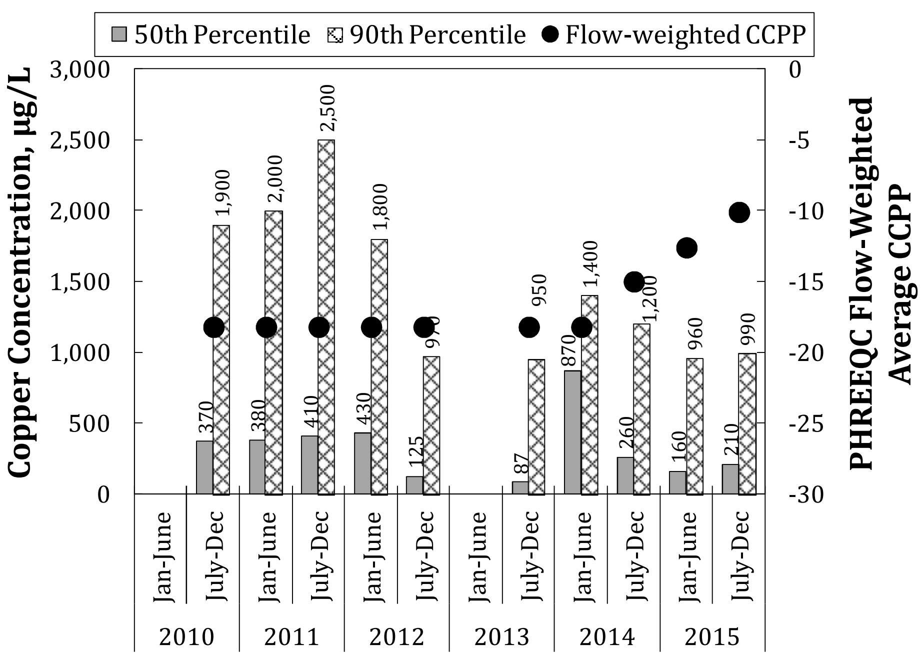


Figure D-6. Copper Results and Flow Weighted CCPP (2010-2015)

Appendix E

Lead and Copper Solubility Contour Diagrams

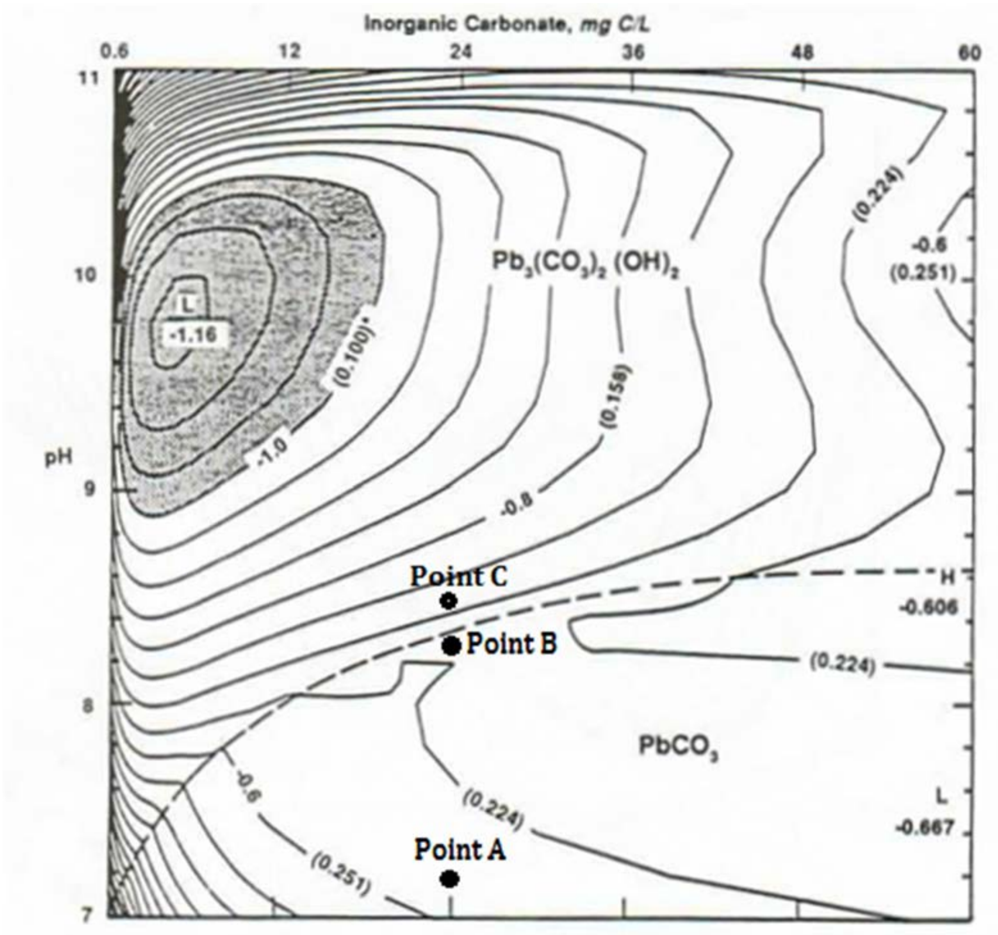


Figure E1. Contour Diagram of Lead Solubility
Ionic Strength: 0.01 M; Temperature: 25 °C

Point A: Average Tunnel Well water pH=7.4 and DIC = 24 mg C/L
Theoretical Lead Solubility is $10^{-0.6}$ = 0.25 mg/L
At the given average pH and DIC, lead solubility is controlled by $PbCO_3$ (cerussite)

Point B: If Tunnel Well water is adjusted to pH = 8.2 and DIC = 24 mg C/L
Theoretical Lead Solubility is $10^{-0.667}$ = 0.215 mg/L

Raising the pH to 8.2, while maintaining the same DIC, would result in a more stable $PbCO_3$ deposit as marked on the diagram as “low solubility point”, which is designated by “L.”

Point C: If Tunnel Well water is adjusted to pH = 8.4 and DIC = 24 mg C/L
Theoretical Lead Solubility is $10^{-0.73}$ = 0.186 mg/L
At the given average pH and DIC, lead solubility is controlled by $Pb_3(CO_3)_2(OH)_2$ (hydrocerussite), which is a more stable precipitate than $PbCO_3$

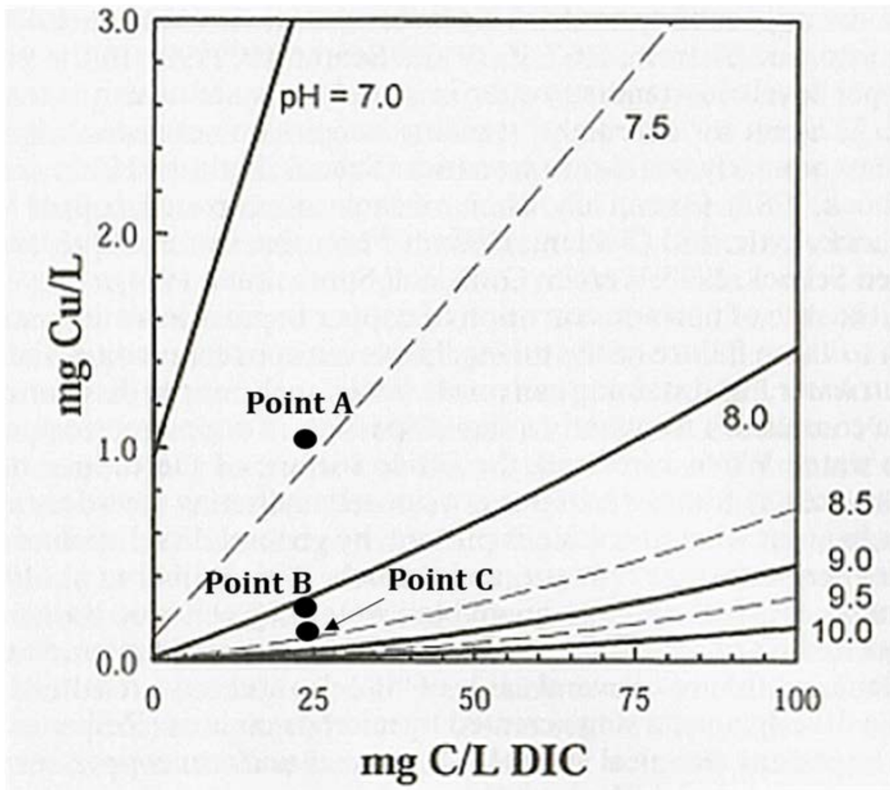


Figure E2. Copper Solubility assuming equilibrium with cupric hydroxide ($Cu(OH)_{2(s)}$). Computed for 25 °C, Ionic strength = 0.02.

Point A: Average Tunnel Well water pH=7.4 and DIC = 24 mg C/L
Theoretical Copper Solubility is 1 mg/L.

Point B: If Tunnel Well water is adjusted to pH = 8.2 and DIC = 24 mg C/L
Theoretical Copper Solubility is approximately 0.23 mg/L.

Point C: If Tunnel Well water is adjusted to pH = 8.4 and DIC = 24 mg C/L
Theoretical Copper Solubility is approximately 0.18 mg/L.