Technical Review of the Occurrence Analysis Supporting the Draft Hexavalent Chromium MCL by California Department of Public Health (DPH-11-005)

Submitted to:

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Table of Contents

List of Tables

List of Figures

EXECUTIVE SUMMARY

This document evaluates and provides technical review of the occurrence analysis supporting the draft Hexavalent Chromium MCL (DPH-11-005) proposed by the California Department of Public Health (CDPH, 2013a). A review of the CDPH chromium occurrence analysis revealed several assumptions that underestimate the number of sources likely to be impacted by a Cr(VI) MCL, and therefore, the cost of the proposed MCL. The following sections identify and explain these assumptions and estimates to improve the transparency and understanding of the draft Cr(VI) MCL. An alternative occurrence analysis based on more defensible assumptions is also provided to illustrate the likely impacts of the draft Cr(VI) MCL.

Table 1 provides a summary of the number of sources likely to be impacted by the 10 µg/L Cr(VI) MCL based on the range of estimates provided in this document and compared with the CDPH estimate. The estimates are characterized by the data used (hexavalent and total chromium), the data range for data, the threshold concentration (e.g. CDPH estimated sources with an average Cr(VI) concentration greater than or equal 10.5 µg/L to be impacted by the 10 µg/L MCL given the rounding procedure, while this analysis also considered a 20% margin of safety with no rounding for an 8 µg/L threshold), and if data were extrapolated for sources that did not have any chromium monitoring data. This analysis closely replicates the CDPH estimate of 311 sources impacted by the 10 µg/L Cr(VI) MCL using the assumptions and analysis included in the Statement of Reasons (CDPH, 2013a). When utilizing more recent data available through August 2013 and all available chromium data including total chromium data, 863 sources would be impacted by the 10 µg/L Cr(VI) MCL. By extrapolating known chromium occurrence to those sources without chromium data and applying a 20% margin of safety about the MCL since water utilities with occurrence at or greater than 8 µg/L are likely to implement treatment, we estimate as many as 1,360 sources to be impacted by the 10 µg/L Cr(VI) MCL, an estimate 437% greater than the CDPH estimate.

Table 1. Summary of the number of sources likely to be impacted by the 10 µg/L Cr(VI) MCL compared with the CDPH estimate.

Estimate (Table Reference)	Data Used	Date Range	Threshold Conc. (µg/L)	Extra-polation ?	Number of Sources Impacted	Percent of CDPH Estimate
CDPH estimate (Table 2)	Cr(VI)	1/1/2001 to 12/31/2009	10.5	No	311	100.0%
Replication of CDPH estimate (Table 3)	Cr(VI)	1/1/2001 to 12/31/2009	10.5	No	310	99.7%
CDPH estimate with extrapolation (Table 8)	Cr(VI)	1/1/2001 to 12/31/2009	10.5	Yes	642	206.4%
CDPH Estimate with most recent data (Table 13)	Cr(VI)	1/1/2001 to 8/15/2013	10.5	No	335	107.7%
CDPH Estimate at 8 µg/L (Table 14)	Cr(VI)	1/1/2001 to 8/15/2013	8.0	No	483	155.3%
Proposed estimate before extrapolation at 10.5 µg/L (Table 15)	Cr(VI) and Total Cr	1/1/2001 to 8/15/2013	10.5	No	863	277.5
Proposed estimate before extrapolation at 8 µg/L (Table 16)	Cr(VI) and Total Cr	1/1/2001 to 8/15/2013	8.0	No	1,195	384.2%
Proposed Estimate (Table 17)	Cr(VI) and Total Cr	1/1/2001 to 8/15/2013	8.0	Yes	1,360	437.3%

According to the CDPH documentation (CDPH, 2013a), small systems serving less than 200 service connections account for 43% of systems and 21% of the sources impacted by the

10 µg/L Cr(VI) MCL. This analysis using more recent data available through August 2013, all available chromium data including total chromium data, and applying a 20% margin of safety about the MCL indicates small systems serving less than 200 service connections account for 71% of systems and 46% of the sources impacted by the 10 µg/L Cr(VI) MCL. The major driver for the differences between these estimates is the CDPH reliance on observed Cr(VI) monitoring data, which exists for just 23% of small system sources. However, 72% of small systems have observed total chromium data, and related work (Seidel and Corwin, 2013) has demonstrated total chromium to be predominantly hexavalent chromium in California groundwater.

INTRODUCTION AND PURPOSE

The California-Nevada Section of the American Water Works Association, the Association of California Water Agencies, California Water Association, and American Water Works Association engaged Jacobs Engineering Group Inc. (Jacobs) to evaluate and provide technical review of the occurrence analysis supporting the draft Hexavalent Chromium MCL (DPH-11-005) proposed by the California Department of Public Health (CDPH, 2013a) and announced on August 23, 2013 in the Notice of Proposed Rulemaking. Hexavalent chromium [Cr(VI)] MCLs of 0.001, 0.005, 0.010, 0.015, 0.020, 0.025, and 0.030 mg/L (1, 5, 10, 15, 20, 25, and 30 µg/L or ppb) were considered; and a draft Cr(VI) MCL of 10 µg/L was proposed.

A review of the CDPH chromium occurrence analysis revealed several assumptions that underestimate the number of sources likely to be impacted by a Cr(VI) MCL, and therefore, the cost of the proposed MCL. The purpose of this document is to identify and explain these assumptions and estimates to improve the transparency and understanding of the draft Cr(VI) MCL. An alternative occurrence analysis based on more defensible assumptions is also provided to illustrate the likely impacts of the draft Cr(VI) MCL.

METHODOLOGY

The methodology used in this document was to 1) replicate the occurrence analysis by CDPH, 2) review and determine the sensitivity of the critical assumptions, and then 3) propose an alternate occurrence analysis to more completely estimate of the number of sources likely impacted by the draft Cr(VI) MCL.

The CDPH occurrence analysis will be replicated to verify the estimate of sources affected using the assumptions in the rulemaking materials. The replication will be used as the baseline to perform a sensitivity analysis on the assumptions. A sensitivity analysis will then be performed on the critical assumptions used by CDPH to determine the impact of those assumptions. The assumptions will be reviewed, and other assumptions will be proposed. Finally, a new occurrence analysis and estimate of sources impacted will be presented based on the proposed assumptions.

REPLICATION OF CDPH OCCURRENCE ESTIMATE

Jacobs replicated the CDPH occurrence analysis based on the documentation available (CDPH 2013a-c). The CDPH estimate of sources affected were reported in the Statement of Reasons (CDPH, 2013a) and are repeated here in Table 2.

Table 2. CDPH estimate of sources requiring treatment at an MCL of 10 µg/L.

Service Connections	<200	200 - 999	1,000 - 9,999	≥10,000	Total
Groundwater	64	13	81	152	310
Surface Water	1	0	0	0	1
Total	65	13	81	152	311

CDPH Water Quality and Analysis Database (WQAD) files were downloaded from the CDPH website on 9/17/2013[1]. A database was created consisting of all chromium data from STORE NUMBERs 01032 (hexavalent chromium), 01034 (total chromium), and A-044 (total chromium screening data for hexavalent chromium). All total chromium non-detects with a minimum reporting levels (MRLs) greater than 8 µg/L were removed from the dataset because a non-detect at this MRL may have been detectable at the lower concentrations of interest in our analysis. The chromium analytical results were linked to the WATSYS and SITELOC databases to add water type (groundwater or surface water) and status. System type (CWS, NTNC, etc) were added to the database from the California Drinking Water Watch website[2]. A size class field was added to the database for grouping by service connections: Group 1: <200, Group 2: 200 – 999, Group 3: 1,000 – 10,000, Group 4: >10,000 service connections.

The database created above was then queried to limit the records to the same parameters and ranges used by CDPH:

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[1] http://www.cdph.ca.gov/certlic/drinkingwater/pages/EDTlibrary.aspx

[2] http://drinc.ca.gov/DWW/JSP/SearchDispatch?number=&name=&county=All&WaterSystemType=All&SourceWaterType=All&PointOfContactType=None&begin_date=9%2F18%2F2011&end_date=9%2F18%2F2013&action=Search+For+Water+Systems

a. CA PWS TYPE: Community Water Systems (CWS) and Non-Transient Non-Community Water Systems (NTNCWS)
b. Sample Date: From 1/1/2001 to 12/31/2009
c. STATUS: Active Sources including Active Raw(AR), Active Untreated (AU), and Private Raw (PR)
d. XMOD: Blank (Detectable results only)
e. District: Not equal to 99

The results of the above query were further queried to calculate average concentration by sources, and limited by results greater than or equal to 10.5 µg/L (310 sources). Those 310 sources were arranged by the number of sources impacted by water type and size class. The results of our replication are presented in Table 3. The replication resulted in a close match of 310 sources affected compared to the 311 sources estimated by CDPH, indicating the process is indeed reproducible. The small differences between the two estimates are likely due to differences in the source databases (e.g. population served, service connection, or total sources) since CDPH completed their analysis using water system inventory data from November 2011 and this analysis was conducted using inventory data from September 2013.

Table 3. Jacobs replication of the CDPH estimate of sources impacted at an MCL of 10 µg/L.

Service Connections	<200	200 - 999	1,000 - 9,999	≥10,000	Total
Groundwater	58	16	79	156	309
Surface Water	1	0	0	0	1
Total	59	16	79	156	310

REVIEW AND SENSITIVITY OF CDPH OCCURRENCE ASSUMPTIONS

HANDLING OF SOURCES NOT REPRESENTED IN WQAD DATASET

The WQAD dataset used by CDPH does not include hexavalent chromium results for all the CWS and NTNC sources in California. The CDPH estimation of sources impacted is based solely on sources that have an average hexavalent chromium concentration equal to, or greater than 10.5 µg/L. CDPH is not accounting for Cr(VI) treatment costs for sources that do not have Cr(VI) data represented in the WQAD dataset. CDPH acknowledges this issue within the Statement of Reasons (CDPH 2013a, p. 21):

"As previously noted, the set of monitored sources consists mainly of those designated vulnerable to hexavalent chromium contamination or those from water systems that did not receive a monitoring exemption. Any additional monitoring costs due to hexavalent chromium detected during routine monitoring of sources that did not perform Unregulated Contaminant Monitoring Regulations monitoring would be relatively insignificant; treatment costs would be more significant, but difficult to estimate given the lack of data.

The hexavalent chromium monitoring data gap is primarily from small water systems (i.e., those with less than 200 service connections). A review of the small water system monitoring data shows that approximately 60% of the sources have not been monitored for hexavalent chromium. For sources previously not monitored, the rate of detection may be comparable to that for sources previously monitored. The number of sources exceeding an evaluated MCL may increase, with the impact increasing as the MCL becomes more stringent."

CDPH reports a total of 11,827 CWS and NTNC sources identified as active raw (AR), active untreated (AU), and purchased raw (PR) with the distribution by source type and size category shown in Table 4 (CDPH, 2013a, Table 1, p. 15). The Jacobs replication successfully identified 11,982 CWS and NTNC sources in California – 1.3% higher than the CDPH number (Table 5). Jacobs then counted the number of these sources that have hexavalent chromium data available, shown in Table 6 on a sources affected basis and in Table 7 on a percent of total sources basis. Results indicate a total of 5,431 sources, only 45% of all sources, have measured Cr(VI) data within the WQAD. This means that the 6,551 sources, 55% of all sources, not represented in the WQAD are not included in the CDPH analysis and assumed to not be impacted. As quoted above from the Statement of Reasons, CDPH indicates that approximately 60% of small water system sources have not been monitored for hexavalent chromium. This analysis indicates that 77% of systems serving fewer than 200 service connections have not monitored for hexavalent chromium. Even in the largest systems serving greater than 10,000 service connections, more than 26% of sources have not been monitored for hexavalent chromium. As stated by CDPH, the rate of hexavalent chromium detection in sources that have not been monitored may be comparable to that for sources previously monitored. Assuming sources that have never monitored for hexavalent chromium will not have hexavalent chromium fails to account for the likely occurrence as demonstrated in sources with monitoring data.

Table 4. CDPH summary of CWS and NTNC sources in California.

Service Connections	<200	200 - 999	1,000 - 9,999	≥10,000	Total
Groundwater	4,608	1,014	1,960	3,375	10,957
Surface Water	385	151	150	184	870
Total	4,993	1,165	2,110	3,559	11,827

Table 5. Jacobs summary of CWS and NTNC sources in California.

Service Connections	<200	200 - 999	1,000 - 9,999	≥10,000	Total
Groundwater	4,790	1,039	1,946	3,334	11,109
Surface Water	397	146	149	181	873
Total	5,187	1,185	2,095	3,515	11,982

Table 6. Number of sources in WQAD with hexavalent chromium results.

Service Connections	<200	200 - 999	1,000 - 9,999	≥10,000	Total
Groundwater	1,107	451	1,088	2,514	5,160
Surface Water	66	58	75	72	271
Total	1,173	509	1,163	2,586	5,431

Table 7. Percent of sources in WQAD with hexavalent chromium results.

Service Connections	<200	200 - 999	1,000 - 9,999	≥10,000	Total
Groundwater	23.1%	43.4%	55.9%	75.4%	46.4%
Surface Water	16.6%	39.7%	50.3%	39.8%	31.0%
Total	22.6%	43.0%	55.5%	73.6%	45.3%

Following the DPH statement in the Statement of Reasons that "…the rate of detection may be comparable to that for sources previously monitored", a more defensible assumption is that the rate of occurrence will be similar between the sources represented in the WQAD and the sources not represented in the WQAD. An extrapolation of these data results more than doubles the number of sources affected with a total of 642 sources affected compared to the 311 estimated in the statement of reasons (CDPH, 2013a). Results are shown in Table 8.

Table 8. Extrapolation of CDPH estimate to sources not represented in the WQAD.

Service Connections	<200	200 - 999	1,000 - 9,999	≥10,000	Total
Groundwater	251	37	141	207	636
Surface Water	6	0	0	0	6
Total	257	37	141	207	642

As part of the Unregulated Contaminant Monitoring Regulation Guidance (CDPH 2001), CDPH collected total chromium screening results for hexavalent chromium results using MRL of 1 µg/L. If the total chromium sample was less than 1 µg/L, then that source did not have to measure hexavalent chromium and is represented in the WQAD with an A-044 result. If the sample was greater than 1 µg/L, then the source required hexavalent chromium analysis and should be represented in the WQAD dataset. The number of sources represented by either hexavalent chromium data or screening data is 7,085 – increasing the total representation from 45% to 59%. These results are shown on a number of sources basis in Table 9 and on a percent basis in Table 10. However, the WQAD data suggest that not all the sources with a screening result above 1 µg/L were further tested:

- 78 sources with a total chromium screening result above 10 µg/L and no hexavalent chromium result;
- 137 sources with a total chromium screening result above 8 µg/L and no hexavalent chromium result;
- 1,234 sources with a total chromium screening result above 1 µg/L and no hexavalent chromium result.

Table 9. Number of sources represented in WQAD by hexavalent chromium or screening (A-044) data.

Service Connections	<200	200 - 999	1,000 - 9,999	≥10,000	Total
Groundwater	1,888	635	1,331	2,817	6,671
Surface Water	130	92	99	93	414
Total	2,018	727	1,430	2,910	7,085

Table 10. Percent of sources represented in WQAD by hexavalent chromium or screening (A-044) data.

Service Connections	<200	200 - 999	1,000 - 9,999	≥10,000	Total
Groundwater	39.4%	61.1%	68.4%	84.5%	60.1%
Surface Water	32.7%	63.0%	66.4%	51.4%	47.4%
Total	38.9%	61.4%	68.3%	82.8%	59.1%

Additionally, CDPH has extensive total chromium data available that could be used as a surrogate for hexavalent chromium. Seidel and Corwin (2013) related the total chromium to hexavalent chromium for groundwaters and surface waters, using CDPH data, and found that more than 98% of groundwater total chromium is hexavalent chromium. On the other hand, surface water total chromium is nearly all trivalent chromium. The number of sources represented in the WQAD by hexavalent chromium, screening data, or total chromium is 9,653, bringing the total representation up to 82%. These results are presented in Table 11 on a number basis and in Table 12 on a percent basis.

Table 11. Number of sources represented by hexavalent chromium, screening data, or total chromium data (excluding total chromium non-detects with an MRL > 8 μg/L).

Service Connections	<200	200 - 999	1,000 - 9,999	≥10,000	Total
Groundwater	3,476	859	1,703	3,093	9,131
Surface Water	232	102	113	105	552
Total	3,708	961	1,816	3,198	9,653

Table 12. Percent of sources represented by hexavalent chromium, screening data, or total chromium data (excluding total chromium non-detects with an MRL > 8 µg/L).

Service Connections	<200	200 - 999	1,000 - 9,999	≥10,000	Total
Groundwater	72.6%	82.7%	87.5%	92.8%	83.3%
Surface Water	58.4%	69.9%	75.8%	58.0%	63.4%
Total	71.5%	81.1%	86.7%	91.0%	81.9%

This analysis indicates that the CDPH approach to assess Cr(VI) impacted sources by using available Cr(VI) data only (e.g. 311 sources with average Cr(VI) concentrations greater than or equal to 10.5 µg/L) can be improved by utilizing available total chromium data, particularly since CDPH data indicate total chromium is predominantly hexavalent chromium in California groundwater sources.

IMPACT OF NOT UTILIZING MOST CURRENT DATA

In the CDPH estimation, sample data in the CDPH WQAD obtained after 12/31/2009 were excluded from the analysis. Inclusion of these data was investigated by holding all other assumptions consistent with the CDPH analysis. Results shown in Table 13 indicated 335 sources have an average Cr(VI) result greater than 10.5 µg/L over the period of record from 1/1/2001 to August 2013 (the time of downloading the WQAD database). This is an additional 25 systems impacted by a 10 µg/L MCL when using the most recent data, an increase of 8% over the statement of reasons estimate (CDPH, 2013a).

Table 13. Number of impacted sources after adding in data past 12/31/2009.

Service Connections	<200	200 - 999	1,000 - 9,999	≥10,000	Total
Groundwater	59	18	89	167	333
Surface Water	1	0	0	1	2
Total	60	18	89	168	335

THRESHOLD CONCENTRATION FOR INSTALLATION OF TREATMENT

Typical regulatory development efforts presume some margin of safety when considering sources likely to be impacted by a new regulation. For example as a part of the Stage 1 and 2

Disinfectants and Disinfection Byproducts Rule development, the USEPA M-DBP Technical Work Group recommended that the "compliance forecast methodology incorporate an operational safety margin of 20 percent to represent the operational level (i.e., 80 percent of the MCL) at which systems typically take some action to ensure consistent compliance with a new drinking water standard and the level at which systems target new treatment technologies to meet the standard." (USEPA, 2005). For the federal Arsenic Rule, USEPA applied a 20% margin of safety on the treatment goal to account for system reliability (USEPA, 2000). Drinking water utilities generally address potential compliance challenges with a new MCL (e.g. install treatment) if an impacted source has an observed concentration of 80% of the MCL or greater. The CDPH analysis determines potential impact by simply comparing the average of available monitoring results with the given MCL condition following data rounding procedures, but with no margin of safety. The CDPH WQAD results indicate that 77% of all sources with Cr(VI) data have three or fewer sample results to calculate that average value. It is inappropriate to base impact with the MCL and a subsequent treatment decision on the average concentration of so few sample results collected over a decade without some margin of safety. To illustrate the sensitivity of this assumption, Table 14 shows the number of sources impacted with calculated average concentrations at threshold concentrations from 10.50 down to 8.00 µg/L.

Table 14. Number of sources impacted at varying thresholds.

Threshold Concentration (µg/L)	Number of Impacted Sources
8.00	483
9.00	402
10.00	331
10.50	310

PROPOSED ALTERNATE OCCURRENCE ESTIMATE

ASSUMPTIONS

The database for this analysis used data from 1/1/2001 to August 2013 (the time of downloading the CDPH WQAD), not limiting sample results to those collected before

12/31/2009 as done by CDPH. Each source was represented by the best available chromium data in the WQAD as follows. If hexavalent chromium data were available, it was used. If no hexavalent chromium data were available, then total chromium from screening data or total chromium monitoring data were used. As described previously, Seidel and Corwin (2013) found that nearly all chromium found in California groundwater was hexavalent chromium, while surface waters had very little hexavalent chromium and was almost exclusively trivalent chromium. Therefore, if total chromium data were used to represent a groundwater source the average concentration was used. If total chromium data were used to represent a surface water source, a concentration of zero was assumed. The errors created from these assumptions should be small and will tend to offset each other. Further, all total chromium results exactly equal to 10 were removed and treated as sources with no data available (43 sources, most with a single result). These results are most likely mislabeled non-detects and are better represented as unrepresented sources. Two threshold concentrations were considered: 10.5 µg/L for direct comparison with the DPH analysis using rounding, and 8 µg/L to reflect a 20% margin of safety.

RESULTS FROM WQAD

Analysis of the WQAD data with the above assumptions at the 10.5 µg/L threshold concentration identified 863 impacted sources as shown in Table 16. This is a 277% increase over the 311 sources estimated by CDPH.

Table 15. Number of sources impacted utilizing most recent data and 10.5 µg/L average concentration threshold.

Service Connections	<200	200 - 999	1,000 - 9,999	≥10,000	Total
Groundwater	419	49	141	252	861
Surface Water	1	0	0	1	2
Total	420	49	142	252	863

Analysis of the WQAD data with the above assumptions at the 8 µg/L threshold concentration identified 1,195 impacted sources as shown in Table 16. This is a 384% increase over the 311 sources estimated by CDPH.

Table 16. Number of sources impacted utilizing most recent data and 8 µg/L average concentration threshold.

Service Connections	<200	200 - 999	1,000 - 9,999	≥10,000	Total
Groundwater	542	70	194	386	1,192
Surface Water	2	0	0	1	3
Total	544	70	194	387	1,195

EXTRAPOLATION

We have assumed that the rate of occurrence in sources not represented by the WQAD will be the same as the rate of occurrence in sources represented by the WQAD. A simple numerical extrapolation of the data was performed to determine the likely number of sources impacted. Each size and water type bin was divided by the percentage of sources represented in the WQAD dataset. This assessment utilized data available through August 2013 which results in an increased representation of sources with data from 82% to 87%. The resulting number of sources impacted is 1,361 compared to the 311 estimated in the statement of reasons (CDPH, 2013a), a 437% increase. Results are shown in Table 17.

Table 17. Estimated number of sources impacted utilizing most recent data, 8 µg/L average concentration threshold, and extrapolating for sources not represented in the WQAD data.

Service Connections	<200	200 - 999	1,000 - 9,999	≥10,000	Total
Groundwater	658	80	212	406	1,356
Surface Water	3	0	0	2	5
Total	661	80	212	408	1,361

The analysis was also extended to proposed MCLs of 5, 15, and 20 µg/L, all based on a factor of safety of 80% of the MCL. Results are presented in Table 18 on a number of sources impacted and in Table 19 as a percent increase over the estimate reported in the statement of reasons (CDPH, 2013a). Table 18 indicates 454 sources impacted of at an MCL of 20 µg/L, which is still about 50% higher than the CDPH estimate of 311 sources affected at the proposed MCL of 10 µg/L.

Table 18. Estimated number of sources affected by MCL and system size utilizing most recent data, 8 µg/L average concentration threshold, and extrapolating for sources not represented in the WQAD data.

MCL (µg/L)	Service Connections				Total
	<200	200 - 999	1,000 - 9,999	≥10,000	
Groundwater					
5	1,210	212	439	1,023	2,884
10	658	80	212	406	1,356
15	417	46	120	194	777
20	226	24	73	89	412
Surface Water					
5	4	0	0	2	6
10	3	0	0	2	5
15	1	0	0	2	3
20	1	0	0	2	3

Table 19. Percent increase in estimate of sources affected to those proposed by CDPH in Draft MCL.

MCL (µg/L)	Service Connections				Total
	<200	200 - 999	1,000 - 9,999	≥10,000	
Groundwater					
5	785%	441%	228%	243%	354%
10	1029%	613%	261%	267%	437%
15	1225%	911%	300%	299%	539%
20	1614%	2392%	385%	271%	615%
Surface Water					
5	218%	0%	n/a	n/a	199%
10	291%	n/a	n/a	n/a	451%
15	145%	n/a	n/a	n/a	306%
20	n/a	n/a	n/a	n/a	n/a

n/a: Cannot calculate percent increase since CDPH estimated 0 sources.

ESTIMATES OF IMPACTED SYSTEMS AND SOURCES

The CDPH Statement of Reasons presents both the numbers of affected systems and sources by system size and MCL condition (CDPH, 2013a Tables 6 and 7, respectively) as reproduced here in Table 20. CDPH reports small systems serving less than 200 service connections account for 55 systems (43% of 128 total) and 65 sources (21% of 311 total) impacted by the 10 µg/L Cr(VI) MCL. Table 21 presents the numbers of affected systems and sources by system size and MCL condition by following the previously described approach utilizing more recent data available through August 2013, all available chromium data including total chromium data, and applying a 20% margin of safety about the MCL. This analysis indicates small systems serving less than 200 service connections account for 432 systems (71% of 609 total) and 545 sources (46% of 1,195 total) the impacted by the 10 µg/L Cr(VI) MCL. The major driver for the differences between these estimates is the CDPH reliance on observed Cr(VI) monitoring data, which exists for just 23% of small system sources. However, 72% of small systems have observed total chromium data, and related research (Seidel and Corwin, 2013) has demonstrated total chromium to be predominantly hexavalent chromium in California groundwater.

Table 20. CDPH estimated number of systems and sources affected by MCL and system size.

MCL (µg/L)	Service Connections				Total
	<200	200 - 999	1,000 - 9,999	≥10,000	
Systems					
5	130	31	60	64	285
10	55	10	29	34	128
15	28	4	18	20	70
20	13	1	13	12	39
Sources					
5	156	49	192	421	818
10	65	13	81	152	311
15	35	5	40	65	145
20	14	1	19	33	67

Table 21. Estimated number of systems and sources affected by MCL and system size utilizing most recent data, all available data, and a 20% margin of safety about the MCL.

MCL (µg/L)	Service Connections				Total
	<200	200 - 999	1,000 - 9,999	≥10,000	
Systems					
5	785	103	147	106	1,141
10	432	43	68	66	609
15	281	25	43	42	391
20	152	15	27	26	220
Sources					
5	999	186	402	974	2,561
10	545	70	194	387	1,195
15	344	40	110	186	679
20	187	21	67	86	361

APPENDIX A: ASSESSMENT OF TOTAL ANNUAL COST AS PERCENTAGE OF MEDIAN HOUSEHOLD INCOME

Total capital cost, annual O&M cost, total annual cost and cost per connection estimates per source were developed following the CDPH Procedure for Cost Benefit Analysis of Hexavalent Chromium (CDPH, 2013c) and provided by WQTS, Inc. The underlying occurrence estimates for sources and systems impacted utilized Cr(VI) and total chromium data from 1/1/2001 through August 2013, and excluded surface water sources and all sources that rely on a mix of surface water and groundwater to avoid inappropriate source flow rate estimates and subsequent cost estimates. Costs for sources impacted at 10 μg/L were totaled by system. Total annual cost estimates by system were then compared with corresponding county-level median household income (MHI)[3] results to determine costs as a function of MHI by system size. Figure 1 and Figure 2 illustrate the population of estimated annual cost per connection by system size in a box and whisker format, where the top and bottom of the whiskers represent the 95th and 5th percentile values, the top and bottom of the box represent the 75th and 25th percentile values, and the median is shown within the box. Figure 2 limits the y-axis to $2,500 and less. The red line illustrates the CDPH estimated average cost per service connection (CDPH, 2013a, Table 8, page 24). Figure 3 and Figure 4 illustrate the same population results as a function of county-level MHI. Figure 4 limits the y-axis to 5% and less. These figures demonstrate the anticipated variability in system-level costs across the state, which the CDPH average values do not adequately represent.

[3] http://quickfacts.census.gov/qfd/download_data.html

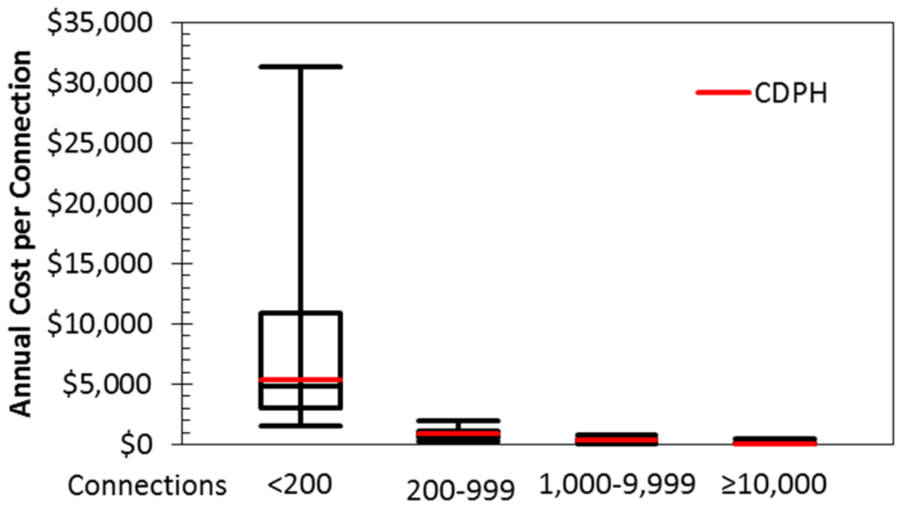

Figure 1. Estimated Total Annual Cost per Connection by System Size

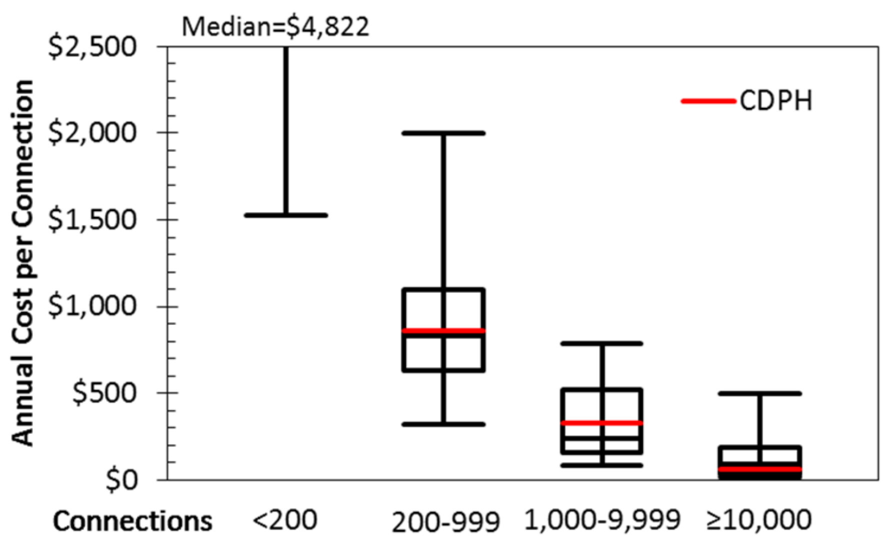

Figure 2. Estimated Total Annual Cost per Connection by System Size (showing $2,500 and lower)

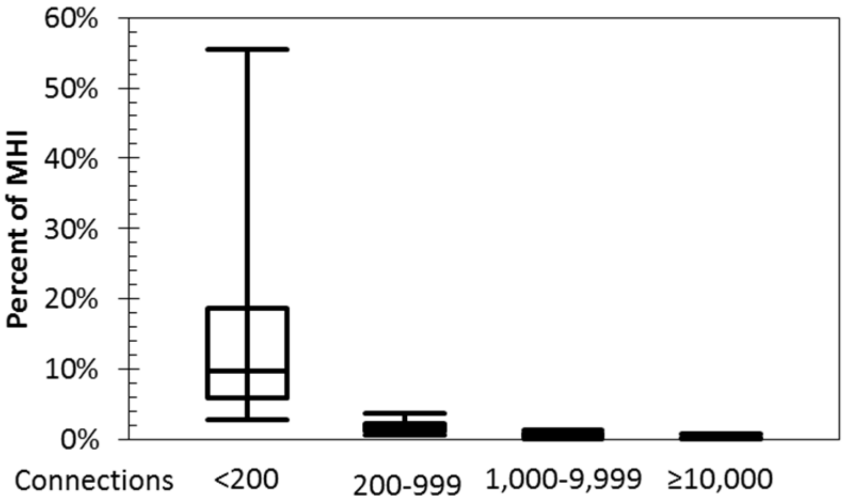

Figure 3. Estimated Total Annual Cost per Connection as a Percent of MHI

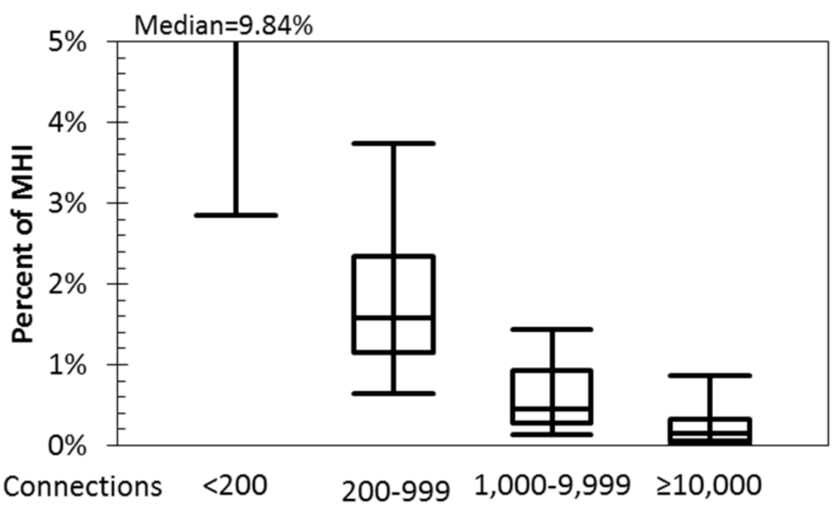

Figure 4. Estimated Total Annual Cost per Connection as a Percent of MHI (showing 5% and lower)

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