National Perchlorate Cost Update

WITAF #316

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American Water Works Association

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Executive Summary

The United States Environmental Protection Agency (USEPA) published a positive regulatory determination for perchlorate in 2011 and is expected to follow with a Notice of Proposed Drinking Water Rule (NPDWR). In order to provide comments to inform the regulatory process, AWWA requested that ARCADIS-US, Inc. (ARCADIS, formerly known as Malcolm Pirnie, Inc.) update previous estimates of the potential regulatory cost burden prepared by Malcolm Pirnie (2008), as reported by Russell et al. (2009).

Russell et al. (2009) reported an annual $164 million per year (2013 dollars) for water systems to comply with a 4 µg/L perchlorate maximum contaminant level (MCL). This study assumed that all contaminated sources/entry points would be treated using single pass ion exchange. The 2013 National Perchlorate Cost Update takes into account other compliance strategies that water systems may consider, including blending and source abandonment. For purposes of the 2013 update, California and Massachusetts water systems with perchlorate concentrations above 6 and 2 µg/L respectively, are removed from this analysis based on the assumption that these systems are in compliance with respective State MCLs or no longer in use.

The following key conclusions from this 2013 update are consistent with the prior assessment (Russell et al., 2009):

- National compliance costs for a perchlorate MCL ranging from 2 to 24 µg/L is smaller than estimated compliance costs for other drinking water regulations – e.g., $120 million per year for a 4 µg/L perchlorate MCL compared to $320 million per year (2013 dollars) for the Arsenic Rule at 10 µg/L.
- The relatively low national compliance costs reflect the small number of public water systems (PWSs) expected to be affected by a potential MCL of 4 µg/L (less than 3% based on 90th percentile perchlorate concentrations).
- Since a small number of PWSs are carrying the cost burden, cost impacts to individual systems are significant, particularly for small water systems (estimated costs for systems serving a population of less than 500 are approximately $3 per 1,000 gallons).

Some impacted PWSs may avoid treatment costs by abandoning high concentration sources. However most, if not all, of these systems will eventually incur costs to replace the lost water supply. This study demonstrates that opportunity costs for lost water (source abandonment) are comparable to treatment costs.

1. Introduction and Background

The American Water Works Association (AWWA) conducted an assessment of the national cost implications of a potential federal perchlorate regulation. The 2008 study (Russell et al., 2009) estimated the following:

1) the percent of water systems that could be impacted by a federal maximum contaminant level (MCL) for perchlorate between 4 and 24 micrograms per liter (µg/L), based on an analysis of data from the first Unregulated Contaminants Monitoring Rule (UCMR1), and

2) the national compliance costs associated with those regulatory levels.

Since the 2008 study was completed, the USEPA published a positive regulatory determination for perchlorate (USEPA, 2011). Additionally, water systems in California and Massachusetts have implemented perchlorate treatment strategies to comply with their State MCLs – 6 µg/L and 2 µg/L, respectively. California established an MCL of 6 µg/L in 2007 and Massachusetts set an MCL of 2 µg/L in 2006. USEPA was scheduled to propose a maximum contaminant level goal (MCLG) and MCL in February 2013 but delayed action pending receipt of the Science Advisory Board (SAB) report to the Administrator. The SAB report was submitted to the Administrator on May 29, 2013 recommending that the Agency proceed with the development of an MCL for perchlorate.

In anticipation of a Notice of Proposed Drinking Water Rule (NPDWR) for perchlorate, AWWA requested that ARCADIS U.S., Inc. (ARCADIS) update the 2008 cost study to:

- Account for State compliance requirements within California and Massachusetts in the projections of the percent of impacted water systems and associated costs of a federal NPDWR.
- Consider costs associated with source abandonment and/or blending, recognizing that some water systems may pursue those alternate compliance strategies in lieu of treatment.
- Consider compliance implications of a 2 µg/L MCL, in addition to 4, 6, 12, 18 and 25 µg/L. Occurrence and cost implications for a 2 µg/L MCL were not quantified in the previous study since the occurrence data generated by the first Unregulated Contaminant Monitoring Rule (UCMR1) is based on a sampling method with a method reporting limit (MRL) of 4 µg/L.
- Adjust national compliance costs to 2013 dollars.

2. Approach

The same general approach used in the 2008 cost study was applied in this update to estimate the percent of impacted water systems and national compliance cost implications. Figure 2-1 illustrates the steps. Table 2-1 highlights key differences between the approaches used in this 2013 Update to the 2008 Cost Study.

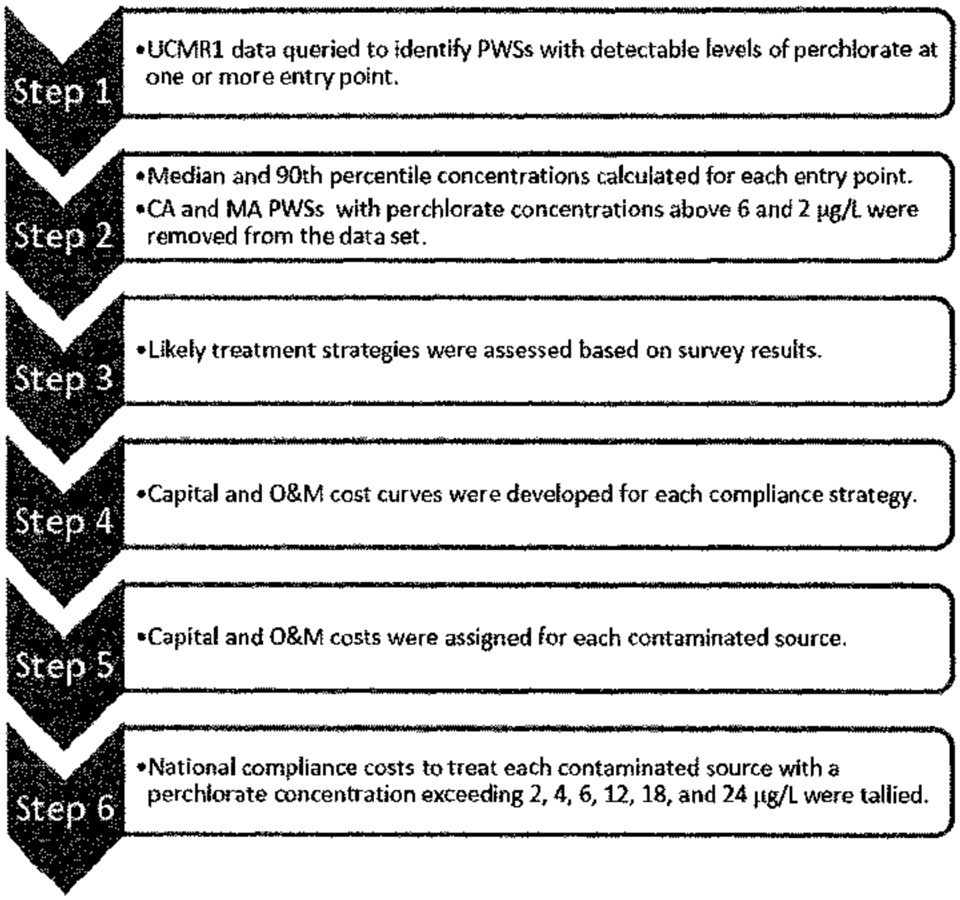

Figure 2-1: Steps to Identify the Compliance Costs for a Given Regulatory Level

Table 2-1: Comparison of Approach for 2008 Cost Study and 2013 Update

Category	2008 Cost Study	2013 Update
Data Set	UCMR1	UCMR1 for national projections; CDPH data for comparison
Water Systems	All impacted water systems	All impacted water systems, except CA and MA systems with perchlorate above the State MCLs
Potential MCLs	4, 6, 12, 18, 24 µg/L	2, 4, 6, 12, 18, 24 µg/L
Compliance Strategies	• Single pass ion exchange treatment at all impacted sources	• Single pass ion exchange • Blending • Source abandonment

CDPH – California Department of Public Health

2.1. Data Analysis

Perchlorate data included in the final UCMR1 database posted January 2006 on USEPA's UCMR website (www.USEPA.gov/safewater/ucmr/data.html) were used to estimate the percent and number of impacted Public Water Systems (PWSs) and associated national compliance costs. Table 2-2 summarizes characteristics of UCMR1 data. Under UCMR1, all community water systems (CWSs) and non-transient, non-community water systems (NTNCWSs) serving water to more than 10,000 people (large systems) were required to sample all entry points to their distribution system for perchlorate. Four quarterly samples collected over one year were required for surface waters and two samples collected over the course of one year were required for groundwater sources. Samples were collected between January 1, 2001 and December 31, 2003[1] and analyzed using USEPA Method 314.0 at a MRL of 4 µg/L.

A randomly selected subset of CWSs and NTNCWSs serving less than 10,000 people (small systems) were also required to sample for perchlorate (USEPA, 2001). A total of 797 small systems monitored all entry points to their distribution systems once between January 1, 2001 and December 31, 2003.

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[1] As reported in Brandhuber et al. (2009) some samples were collected outside of the specified date range, with samples collected as early as May 2000 and as late as October 2005.

Table 2-2: Summary of Occurrence Data Sources

Database	UCMR1	CDPH	MDEP
Geographic coverage	All 50 states plus territories and tribes	California	Massachusetts
Period of record	2001 – 2003[2]	1997 – 2012	2000 - 2012
Systems Sampled	All CWSs and NTNCWSs serving > 10,000 people; Subset of CWSs and NTNCWSs serving < 10,000 people	All PWSs	All PWSs
MRL	4 µg/L	4 µg/L But, data are available for lower MDLs	Data reported at a 1 µg/L MDL
Source water sampled	Treated drinking water[1]	Raw and treated drinking water	Raw and treated drinking water

[1] Untreated samples (SR sample code) were included for some systems with no treatment between the source and the entry point, pursuant to 40 CFR §141.40 (a)(5)(ii)(B).

While UCMR1 directed analysis for perchlorate at the entry points to the distribution system, sampling untreated sources was allowed at water systems with no treatment between the source and distribution system.[3] As a result, some systems also reported data for untreated sources. Appendix A provides a summary of perchlorate data for the different sample codes included in UCMR1 (i.e., entry points, untreated samples). This analysis was included to examine points set forth in the U.S. Chamber of Commerce (2012) letter to USEPA which challenged the inclusion of data from untreated sources in any assessment of perchlorate occurrence. Based on the analysis presented in Appendix A, all sample codes were included in the assessment of perchlorate occurrence and associated cost implications in this report to determine impact of this data.

California Department of Public Health (CDPH) data were evaluated to compare the estimated number of California water systems impacted at potential MCLs below the current state standard (i.e., 6 µg/L) based on the CDPH versus UCMR1 database. As illustrated in Table 2-2, the CDPH database includes perchlorate data at levels below

[2] Ibid.

[3] 40 CFR §141.40(a)(5)(ii)(B)

the 4 μg/L MRL. The CDPH database also includes samples collected at all PWSs within the state, facilitating a more comprehensive analysis of perchlorate detections in water systems serving less than 10,000 people for California systems.

The CDPH and Massachusetts Department of Environmental Protection (MDEP) datasets were used to identify water systems within those states with perchlorate detections for inclusion in a survey conducted for this study.

2.2. Evaluation of Impacted Water Systems

The final UCMR1 database was queried for all source waters/entry points with a detectable perchlorate concentration. As mentioned above, multiple samples were collected from each large system sample point during a 12-month period. To obtain a single perchlorate concentration associated with each sample point, non-detects were assigned a zero values and the 90^{th} percentile and median values were calculated for the given sample point. Both 90^{th} percentile and median values were assessed to obtain a range of the expected extent of perchlorate contamination.[4] Note that by assigning a zero value to non-detects, the calculated 90^{th} percentile and median concentrations for sources with both detects and non-detects could be less than the 4 μg/L MRL.

All California water systems with 90^{th} percentile or median perchlorate concentrations above 6 μg/L were removed from the dataset used to assess national compliance costs. Similarly, Massachusetts water systems with 90^{th} percentile or median perchlorate concentrations above the 2 μg/L State MCL were removed from the analysis.

Design and average flows for each source were calculated based on the regression equations developed by USEPA (2005):

[4] As an example, a sample point that was sampled two times over the course of one year had one detectable perchlorate concentration of 11.9 μg/L and one non-detect. The collection of two samples suggests the sample point correlates to a groundwater system. If a well was taken offline after perchlorate was detected in the first sample, the 90^{th} percentile value may be more representative. On the other hand, if the perchlorate detection in the first sample were attributed to analytical error, the median value would be more representative. Brandhuber et al. (2009) reported that 47% of UCMR1 sample locations had only one detection.

Surface Waters:

Design Flow (MGD) = $0.36971[\text{Population}]^{0.97757}/1000$

Average Daily Flow (MGD) = $0.10540[\text{Population}]^{1.02059}/1000$

Ground Waters:

Design Flow (MGD) = $0.39639[\text{Population}]^{0.97708}/1000$

Average Daily Flow (MGD) = $0.06428[\text{Population}]^{1.07652}/1000$

Population data retrieved from the USEPA Safe Drinking Water Information System (SDWIS) database for the 2008 cost study were used for the analysis of flow rates for the contaminated sources in this 2013 cost update. Updated population data were not used because it is not clear whether the sources included in UCMR1 samples are those that would be used to serve any increase in population at public water systems (PWSs) since UCMR1 sampling was conducted. Design and average daily flow rates were then estimated for each contaminated source/entry point by dividing the total flow for the PWS by the total number of sources in the PWS under consideration. The number of sources for each PWS was tallied based on the total number of sampling points included for that system during the UCMR1 sampling effort.

2.2. Single System Compliance Strategies and Costs

Compliance strategies that can be considered to reduce perchlorate concentrations prior to distribution include:

- Treatment using single pass ion exchange, regenerable ion exchange, reverse osmosis, or biological treatment;
- Blending; or,
- Source abandonment.

The 2008 cost study assumed installation of single pass ion exchange to reduce perchlorate concentrations at all contaminated sources/entry points for a high end estimate. The low end estimate assumed 10% of contaminated sources would be abandoned. Brandhuber et al. (2009) reported that 19% of water systems have taken raw water sources off-line due to perchlorate detections based on their phone survey of the 160 water systems with perchlorate detections in UCMR1. Six percent of water systems (9 of 70 respondents) indicated that blending with other water is used to manage perchlorate concentrations at entry points to the distribution systems. Based on these trends, the 2008 cost study was updated to assess alternate compliance strategies in the tabulation of national costs.

An electronic survey (Appendix B) was sent to water systems in California (84) and Massachusetts (11) with at least one perchlorate detection based on state data, to solicit information on strategies implemented by these systems to comply with the respective state perchlorate standards. For California water systems, perchlorate detections were based on a 4 μg/L method detection limit (MDL). For Massachusetts water systems, perchlorate detections were based on a 2 μg/L MDL. Surveyed systems in California included several water service companies that provide water to multiple systems throughout California and nationally.

Based on the distribution of responses, contaminated sources/entry points identified from UCMR1 were assigned compliance strategies (i.e., treatment, blending, source abandonment) using the Excel random number generator. The survey included questions regarding capital and operating and maintenance (O&M) costs associated with respective compliance strategies. To supplement the survey responses, engineering opinions of probable construction cost (OPCC) and annual operating costs (life cycle costs) were developed for blending and source abandonment data for use in the national compliance cost projections. The engineering opinions were developed based on installed costs for infrastructure (i.e., wells, pumps) implemented for a range of system sizes across the U.S. All reported costs were adjusted to 2013 dollars using the Engineering News Report (ENR) 20-Cities construction cost indices.

Best fit regression curves were developed using the Excel trendline function to correlate capital and O&M costs for each compliance strategy to system flow rate. The regression equations were then used to assign capital and O&M costs for each contaminated source/entry point identified from the UCMR1 data (and omitting California and Massachusetts water systems already required to comply with respective State MCLs).

2.3. National Cost Projections

After assigning capital and O&M costs for each contaminated source/entry point, the costs were tallied to identify total national costs for impacted water systems to comply with a given MCL. The following steps were followed to tally the total costs:

1. Contaminated sources/entry points for small PWSs (<10,000 people served) were separated from the data set. The capital and O&M costs estimated for these contaminated source waters needed to be scaled up since only 797 out of tens of thousands small PWSs nation-wide were sampled during the UCMR sampling effort.

2. The identified sources/entry points with 90th percentile or median perchlorate concentrations above each potential MCL were tabulated for each size category. For example, all contaminated sources/entry points for large PWSs

with perchlorate concentrations of 6 µg/L or higher were tabulated to determine costs associated with a perchlorate MCL of 6 µg/L. Similar data assessments were conducted for the small PWS data set. The total capital and O&M costs associated with each perchlorate MCL and for each size category were then summed.

3. The nation-wide costs associated with treating small PWSs for each potential perchlorate MCL were estimated by multiplying the costs associated with treatment for the 797 PWS sample-set by a factor of 85.4 (i.e., 68,036 small CWS and NTNCWSs nation-wide [USEPA, 2011], divided by 797 small PWS respondents for the UCMR sampling effort).

4. The total nation-wide capital and O&M costs for each potential perchlorate MCL were then calculated by summing the costs for the large systems and the factored costs for the small systems. Amortized capital costs and net present value O&M costs were calculated assuming 20 years of operation and for both a 3% and 7% interest rate.

As with the previous study, water systems with contaminated sources/entry points with design flow rates above 10,000 gpm were reviewed on a case-by-case basis to confirm perchlorate contamination warranting inclusion in the national cost estimates. The higher design flow systems were selected for analysis based on their greater contribution to national compliance cost estimates compared to smaller systems.

3. Percent of Water Systems Impacted by a NPDWR for Perchlorate

Table 3-1 summarizes the percent of water systems impacted by a NPDWR ranging from 2 to 24 µg/L based on 90th percentile perchlorate concentrations. The statistics are shown for the 2008 Cost Study (Column A), which included all water systems, and for this 2013 update with California and Massachusetts systems with concentrations above the State MCLs excluded (Column B).

The data show several trends:

- Only a relatively small percent of water systems would be impacted by a perchlorate MCL ranging from 2 to 24 µg/L. For example, only 3% of water systems would be impacted by a 4 µg/L MCL accounting for California and Massachusetts water systems that are already required to comply with State MCLs (Column B).
- Where perchlorate occurs, it is present at low parts per billion concentrations with less than 1% of PWSs impacted by a perchlorate MCL of 12 µg/L or higher.
- At potential MCLs above 6 µg/L, the percent of impacted systems estimated for this 2013 Update is about two thirds that of the previous 2008 Cost Study, reflecting omission of California water systems that are already required to comply with the State MCL. At MCLs below 6 µg/L, the estimated percent of impacted systems is similar in this 2013 Update (Column B) to the previous 2008 Cost Study (Column A) since both analyses include California water systems with perchlorate above the given value (2 or 4 µg/L).[5]

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[5] But none above 6 µg/L for the 2013 update.

Table 3-1: Estimated Percent of Water Systems Impacted by a Potential Perchlorate MCL[1]

Potential MCL	Percent of Impacted Systems	
	2008 Cost Study[2] All sample codes Column A	**2013 Update[3]** All sample codes Column B
2 ug/L	4.1%	3.8%
4 ug/L	3.4%	3.0%
6 ug/L	2.3%	1.4%
12 ug/L	1.0%	0.6%
18 ug/L	0.5%	0.3%
24 ug/L	0.3%	0.2%

[1]Based on 90^{th} percentile perchlorate concentrations

[2] California and Massachusetts systems included for all potential federal MCLs

[3]California systems with perchlorate above 6 µg/L excluded; all Massachusetts systems excluded

Figure 3-1 contrasts the percent of impacted water systems based on median versus 90^{th} percentile perchlorate concentrations calculated for each sampling location. The median and 90^{th} percentile perchlorate concentrations provide an estimated lower and upper bound in the absence of site-specific information for the sample points. As expected, the percent of water systems impacted based on median perchlorate concentrations is lower than the percent based on 90^{th} percentile values.

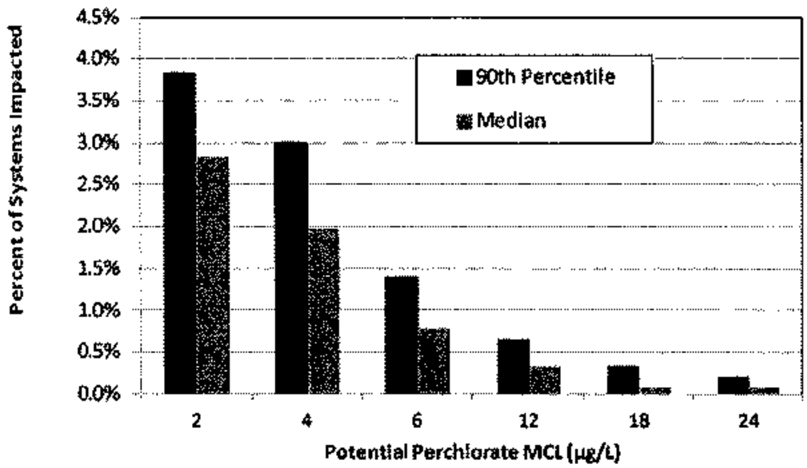

Figure 3-1: Percent of Water Systems Affected by a NPDWR

Figure 3-2 represents the estimated number of impacted systems for potential federal MCLs ranging from 2 to 24 μg/L, based on 90^{th} percentile perchlorate concentrations. The estimated number of impacted water systems was tallied by factoring in the subset of small systems included in UCMR1 sampling. Given data limitations associated with the small subset of water systems sampled, this number is considered to be a very rough estimate.

Based on the estimates, approximately 620 water systems would be impacted by a perchlorate MCL of 4 μg/L discounting California and Massachusetts water systems already required to comply with State MCLs. The number of water systems drops by half at 6 μg/L and then is exponentially lower for progressively higher MCLs. These estimates are comparable to those presented in Brandhuber et al. (2009). Differences are attributed to the disparate approaches used to account for non-detects and inclusion of California and Massachusetts systems in the Brandhuber et al. (2009) study.

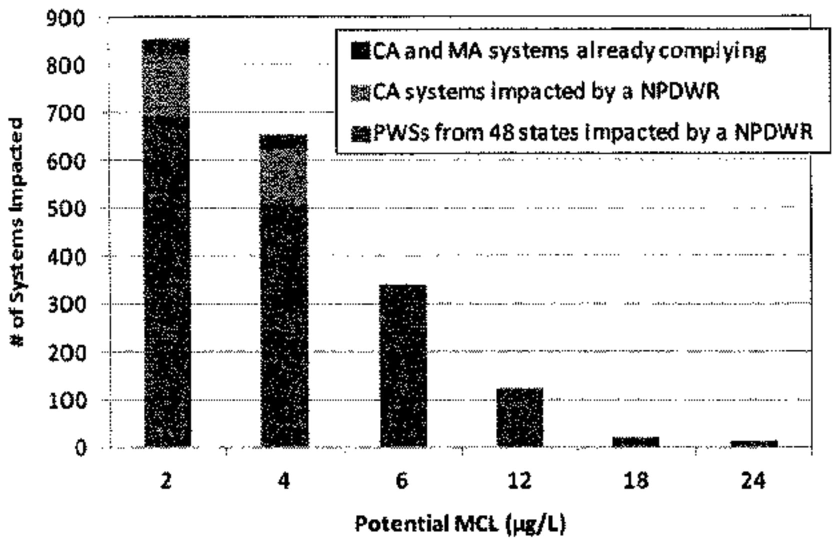

Figure 3-2: Estimated Number of Water Systems Impacted by a NPDWR for Perchlorate (Based on 90th Percentile Perchlorate Concentrations)

An estimated 130 California water systems would be impacted by a 2 µg/L MCL and 120 water systems would be impacted by a 4 µg/L MCL based on UCMR1 data. In comparison, the California Department of Public Health (CDPH) website reports that a total of 91 California water systems have perchlorate detections above the 4 µg/L MRL based on CDPH data collected between 2006 and 2011 at a 4 µg/L MRL. Differences in the number estimated from UCMR1 (Figure 3-2) and the number of impacted California water systems reported on CDPH website are attributed to the difference in the data sets (different data range, number of systems sampled) and analysis method (detections versus calculated 90th percentile and median perchlorate concentrations).

4. Compliance Strategies for Impacted Water Systems and Costs

An electronic survey was sent to 95 water systems in California and Massachusetts with at least one perchlorate detection based on state data (CDPH and MDEP databases; Table 2-2). Table 4-1 summarizes the water systems invited to and responding to the survey. Table 4-2 lists the number of responses by system size.

Table 4-1: Summary of 2013 Survey Responses

Water System	No. # Invited to Survey	Total Number / Percent Responding to Survey
California Water Systems	84	37 / 44%
Massachusetts Water Systems	11	3 / 27%

Table 4-2: Number of Responses by System Size

Population Served (System Size)	# of Survey Responses
Less than 500 (Very small)	2
501 – 3,300 (Small)	5
3,301 – 10,000 (Medium)	1
10,001 – 100,000 (Large)	24
More than 100,000	8

4.1. Survey Responses on Compliance Strategies

Twenty-one (21) of the forty (40) water systems that responded to the survey indicated that they have implemented at least one of the following three strategies to comply with the State MCL for perchlorate:

- Treatment – 12 survey responses
- Blending – 12 survey responses
- Source Abandonment – 4 survey responses

Of the twelve systems indicating treatment was implemented to reduce perchlorate concentrations, eleven systems had installed single pass ion exchange. One water system reported the use of reverse osmosis. No survey respondents reported the use of regenerable ion exchange or biological treatment.[6] These results are consistent with trends reported in Russell et al. (2009) where California water systems were preferentially implementing single pass ion exchange, with some systems switching from regenerable ion exchange to eliminate discharge of perchlorate-laden brine.

Some water systems indicated they have implemented more than one compliance strategy. Other water systems indicated that no compliance strategy has been implemented; these systems had perchlorate concentrations below the State MCL based on water quality data provided in response to the survey.

Figure 4-1 illustrates the number of water systems implementing the different compliance strategies by system size. The very small and small systems reported blending to comply with State MCLs, whereas larger systems used a range of strategies (i.e., treatment, blending, source abandonment) to meet State MCLs. The results, based on the limited data set, suggest that small systems will seek alternate solutions, if available, to minimize the capital and O&M cost burden associated with installation of treatment systems.

Based on the reported strategies implemented (i.e., 28), a distribution of compliance strategies was assumed to assign associated costs for the impacted sources/entry points identified from UCMR1 data. Treatment using single pass ion exchange was assumed for 43% of the perchlorate impacted sources, compliance via blending was assumed for 43%, and source abandonment was assumed for the remaining 14%.

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[6] As of the date of this 2013 Cost Update, one water system has installed biological treatment to reduce perchlorate concentrations in its source water. The system is scheduled to begin serving biologically treated water to the distribution system this year (2013).

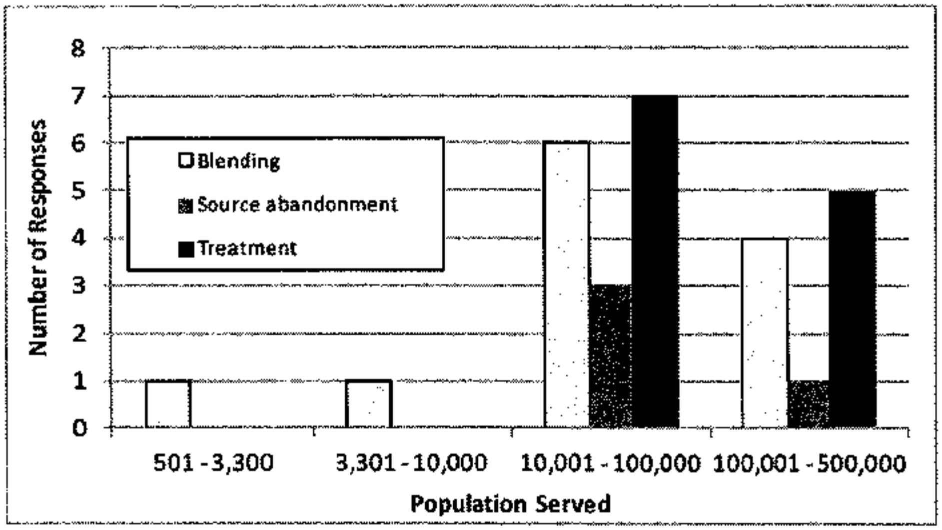

Figure 4-1: Survey Responses on Compliance Strategies Implemented

4.2. Single System Conceptual Compliance Costs

Capital and O&M cost curves were developed for each compliance strategy (i.e., treatment, blending, and source abandonment) based on reference cost data (Russell et al., 2009; Kennedy/Jenks, 2004), survey responses, and engineering OPCCs and life cycle costs. The complete set of cost curves is provided in Appendix C. Survey results used to develop the cost curves are presented in the following paragraphs.

4.2.1. Single Pass Ion Exchange Costs

Figure 4-2 shows the capital costs for single pass ion exchange reported by survey respondents for design capacities ranging from less than 50 to 5,000 gallons per minute (gpm). Costs are also shown for the previous 2008 Cost Study and a Kennedy/Jenks (2004) study conducted to support development of the California MCL, adjusted to 2013 dollars.

Capital costs reported in this survey were generally a little lower than the costs developed for the 2008 Cost Study and in the Kennedy/Jenks study. The survey only requested approximated capital costs for single pass ion exchange with no details requested on cost inclusions, whereas the 2008 Cost Study capital cost curve was developed based on costs for full-scale systems with all inclusions to construct, start-up, and commission single pass ion exchange treatment. Capital costs for both the 2008 Cost Study and the Kennedy/Jenks Study (2004) include indirect construction costs such as engineering and design. Since the survey responses were less detailed regarding cost inclusions, a capital cost curve was developed based on the 2008 Cost Study, updated to 2013 dollars, as represented by the line in Figure 4-2.

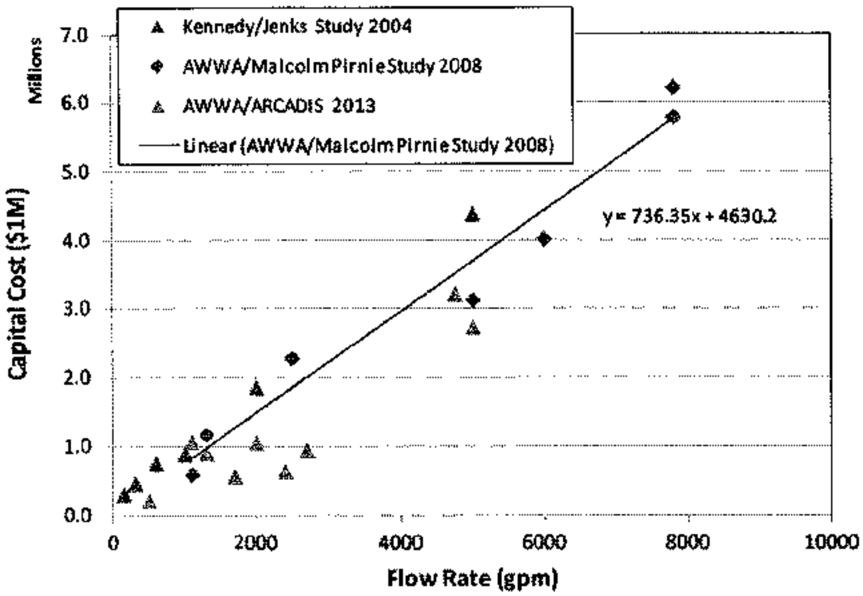

Figure 4-2: Capital Cost Curve for Single Pass IX Treatment (in 2013 dollars)

Recent resin costs were also reviewed to assess whether costs associated with the first fill of resin may explain the lower costs reported in this survey compared to the 2008 Cost Study and Kennedy/Jenks (2004). The updated quotes for perchlorate selective resins are equivalent to cited costs at the time of the 2008 Cost Study, in 2013 dollars.[7]

Surveyed water systems were also asked to provide annual O&M costs for single pass ion exchange treatment and indicate the major items contributing to those costs. Based on survey responses, primary costs to operate a single pass ion exchange system include resin replacement (8 of 12 responses), energy (7 of 12 responses), and laboratory analysis (2 of 12 responses). The reported annual O&M costs were in range of those developed for the 2008 Cost Study, escalated to 2013 dollars, based on full-scale operating costs (Appendix C).

[7] Based on information provided by three resin manufacturers for this study, perchlorate selective resin costs average $250 per cubic foot for an initial fill. Resin replacement costs range from $265 to 350 for turnkey service, including resin disposal.

4.2.2. Blending Costs

Table 4-3 summarizes capital investments required for blending to comply with state perchlorate MCLs, based on 12 survey responses. Installation of a new pump and improved instrumentation and control were the most common improvements implemented for blending. Of the five respondents indicating a new pump was installed, only one also indicated a new well was drilled. Based on follow-up interviews, the pumps installed at the other systems were installed to transfer other water supplies (i.e., other wells or purchased water) to the well production facility to enable blending. Storage tanks were added at one of these water systems to further facilitate blending.

Table 4-3: Capital Investments Required for Blending

Capital Investment	# of Responses
New Well	1
New Pump	5
Improved Instrumentation & Control	6
Additional Storage	1
Inline Mixers	1
Chloramination Station	1
Corrosion Control Chemicals	1
None – Already Blend for VOCs	1

Six water systems provided estimated costs associated with capital investments necessary to facilitate blending. The costs (Appendix C) covered a broad range, reflecting the variation in capital investments required for blending depending on site specific conditions (e.g., available water supply, available infrastructure, perchlorate concentrations). To reflect that variation, low and high end capital costs for blending were developed for this study (Table 4-4). The low end costs assume installation of new inline mixers, improved instrumentation and control (I&C), and 0.5 mile of piping to convey a low perchlorate water supply for mixing. The high end costs assume installation of a new well, pump, piping and improved I&C.

Table 4-4: Estimated Conceptual Capital Costs to Facilitate Blending[1]

Line Item	System Size					Assumptions
	200 gpm	500 gpm	2,000 gpm	5,000 gpm	8000 gpm	
New Well (Incl. pump and site piping)	$500,000	$1,200,000	$2,800,000	$6,400,000	$8,800,000	Based on installed costs for wells varying in depth from 300-ft to 1,200-ft and in varying geology
Inline Mixer	$5,000	$10,000	$21,000	$35,000	$45,000	Based on vendor quotes for 2,000 and 5,000 gpm mixers
Transmission Main	$100,000	$260,000	$660,000	$1,100,000	$1,300,000	Assumes 0.5 mile piping designed for 4 ft per second
Improved I&C	Minimum cost estimate assumes three signals at $1,000 per signal, plus $10,000 for an online perchlorate analyzer. Maximum cost estimate is based on 15% of equipment costs.					
Low End Cost	$120,000	$280,000	$690,000	$1,100,000	$1,400,000	New inline mixer, 0.5 mile piping, and improved I&C required
High End Cost	$580,000	$1,400,000	$3,200,000	$7,400,000	$10,200,000	New well, pump, additional piping and improved I&C required

Notes:

[1] All costs in 2013 dollars. Costs are order of magnitude and will vary depending on site specific conditions including well depth, geology, piping distance and materials, etc. Costs include indirect construction costs such as engineering, construction management, permitting, and contingency.

Water systems indicated labor (2 of 12), energy (5 of 12), and laboratory analyses (5 of 12) contribute most to O&M costs associated with blending. Based on these responses and reported conceptual level O&M cost, an O&M cost curve was developed for blending operations (Table 4-5).

Table 4-5: Estimated Conceptual Annual O&M Costs from Blending

O&M Line Item	System Size					Assumptions
	200 gpm	500 gpm	2,000 gpm	5,000 gpm	8000 gpm	
Labor	$25,000	$25,000	$25,000	$25,000	$25,000	Based on 1 hour operator per day ($50/hr), 0.5 hour mechanical technician ($55/hr) per day, 2 hour operator sampling each week
Analytical	$15,200	$17,600	$22,400	$24,800	$29,600	$200/sample; weekly analysis in blended water supply; monthly sampling in each source
Energy	$2,400	$6,000	$24,000	$59,000	$94,500	Additional energy to boost blended water 50 feet; $0.10/kWh; friction losses are not included
Estimated Total Annual O&M Cost	$52,000	$58,000	$81,000	$118,000	$150,000	

Survey responses also indicate opportunity costs associated with blending. Four of twelve water systems indicated that blending cannot be used to consistently achieve the target finished water perchlorate concentration without reducing source water production rates. Of those, three indicated that water is purchased from a wholesaler to make up the difference in their raw water supply to meet demands. Five of twelve water systems indicate additional strategies will need to be implemented in the future to achieve target finished water perchlorate concentrations.

4.2.1. Source Abandonment Costs

Table 4-6 lists strategies and associated capital investments reported to meet demands following abandonment of a perchlorate-contaminated source. Two of four water systems reporting that their perchlorate-contaminated source was abandoned indicated installation of a new well to meet demands. One system reported installation of a transmission main to convey purchased water to meet demands. The fourth system indicated the current supply is sufficent to meet demand (without the abandoned source), but that replacement water or treatment would be required in the future. This response demonstrates opportunity costs associated with lost water from abandoning a perchlorate impacted source.

Table 4-6: Strategies Implemented to Meet Demands following Source Abandonment

Capital Investment	# of Responses
New Well	2
Transmission Main to Convey Purchased Water	1

Based on the survey responses, capital cost curves for source abandonment were developed assuming a new well would be installed to meet demands. Capital costs were estimated for well decomissioning, installation of a new well, and an additional 0.5 mile of piping to convey the new source to the distribution system (Table 4-7). Annual O&M costs were estimated assuming additional energy to pump from a deeper well (300-ft deeper) and/or to convey water a greater distance, additional labor for monitoring and reporting, and for perchlorate laboratory analysis (Table 4-8).

Table 4-7: Estimated Conceptual Capital Costs due to Abandonment of Perchlorate Impacted Sources[1]

Line Item	System Size					Assumptions
	200 gpm	500 gpm	2,000 gpm	5,000 gpm	8,000 gpm	
Decommission old well	$26,000	$33,000	$44,000	$54,000	$69,000	Assumes average well depth of 450 feet. Estimate for 2,000 and 5,000 gpm assumes two wells requiring decommissioning
New well (incl. pump and site piping)	$500,000	$1,200,000	$2,800,000	$6,400,000	$8,800,000	Based on installed costs for wells varying in depth from 300-ft to 1,200-ft and in varying geology
Transmission main	$100,000	$260,000	$660,000	$1,100,000	$1,320,000	Assumes new well installed within 0.5 miles of distribution system
Improved I&C	$13,000	$13,000	$13,000	$13,000	$13,000	Minimum cost estimate assumes three signals at $1,000 per signal and $10,000 for an online perchlorate analyzer
Estimated Capital Cost	$640,000	$1,500,000	$3,500,000	$7,600,000	$10,000,000	

[1] All costs in 2013 dollars. Costs are order of magnitude and will vary depending on site specific conditions including well depth, geology, piping distance and materials, etc. Costs include indirect construction costs such as engineering, construction management, permitting, and contingency.

Table 4-8: Estimated Conceptual New Annual O&M Costs due to Abandonment of Perchlorate Impacted Sources

O&M Line Item	System Size					Assumptions
	200 gpm	500 gpm	2,000 gpm	5,000 gpm	8,000 gpm	
Labor	$20,000	$20,000	$20,000	$20,000	$20,000	Based on 1 hour operator per day ($50/hr) for increased monitoring/reporting
Analytical	$15,200	$17,600	$22,400	$24,800	$29,600	$200/sample; weekly analysis in blended water supply; monthly sampling in each source
Energy	$14,200	$35,000	$142,000	$354,000	$850,000	Assumes new well is 300-ft deeper than previous well and/or requires additional pressure for greater conveyance distance; $0.10/kWh; friction losses are not included
Estimated Total Annual O&M Cost	$49,000	$72,000	$184,000	$400,000	$900,000	

Costs were also assessed for installation of a transmission main to convey purchased water. Assuming purchased water costs at $600 per acre-feet,[8] total NPV source abandonment costs are estimated to be higher than for construction and operation of a new well. Since two survey respondents indicated installation of a new well versus one water system purchasing water, the capital and operating costs for a new well were used in the national compliance cost projections. Water sytems would likely select whichever strategy is most cost-competitive to replace lost water from the abandoned source under their site-specific conditions.

[8] National average wholesale municipal water cost was assumed to be 75% of the Metropolitan Water District of Southern California costs (~ $800/acre-ft, http://www.mwdh2o.com/mwdh2o/pages/finance/finance_03.html) in lieu of a reported national average. The AWWA and Raftelis Survey (2012) was reviewed but does not differentiate wholesale from retail water costs.

4.3. Comparison of Capital, O&M, and NPV Costs for Compliance Strategies

Figures 4-3 to 4-5 contrast the conceptual capital, O&M, and total net present value (NPV) costs associated with the perchlorate compliance strategies (i.e., treatment using single pass ion exchange, blending, or source abandonment) implemented for different system sizes. Capital costs are estimated to be highest for blending (high end costs) and source abandonment, primarily reflecting the cost associated with installing a new well (assumed depth). Capital costs for single pass ion exchange are estimated to be lower than the cost to install a new well for blending / source abandonment. Single pass ion exchange consists of stationary vessels and the first fill of resin. Additional costs may include pre-treatment (e.g., pH adjustment), land acquisition, installation of a new building. These additive costs were included in the national compliance projections following the same approach as the 2008 Cost Study, but are not reflected in Figure 4-5 since they are not expected to be required at all systems. Note that engineering and design costs are included in the full-scale costs used to develop the cost curve (Figure 4-2).

O&M costs are estimated to be highest for single pass ion exchange treatment for all system capacities evaluated (Figure 4-4). The higher O&M costs for single pass ion exchange reflect resin replacement and disposal costs. O&M for blending and source abandonment are expected to be significantly lower unless purchased water is used (in which case capital costs for these options would be lower). Energy for blending is assumed to only require 50-ft booster pumping capacity, whereas energy for source abandonment assumes pumping to draw water from a 300-ft deeper well than from the abandoned source.

Total net present value costs (20 year life-of-service, 3% discount rate) are highest for single pass ion exchange treatment across all system sizes evaluated. NPV costs for blending (high end) and source abandonment are in range of the estimated costs for treatment. Some water systems may be able to blend and/or abandon sources with lower near-term capital and O&M costs. However, the high end estimate for blending and cost estimates for source abandonment reflect opportunity costs associated with these compliance strategies, even if initial capital investments can be deferred in the near-term.

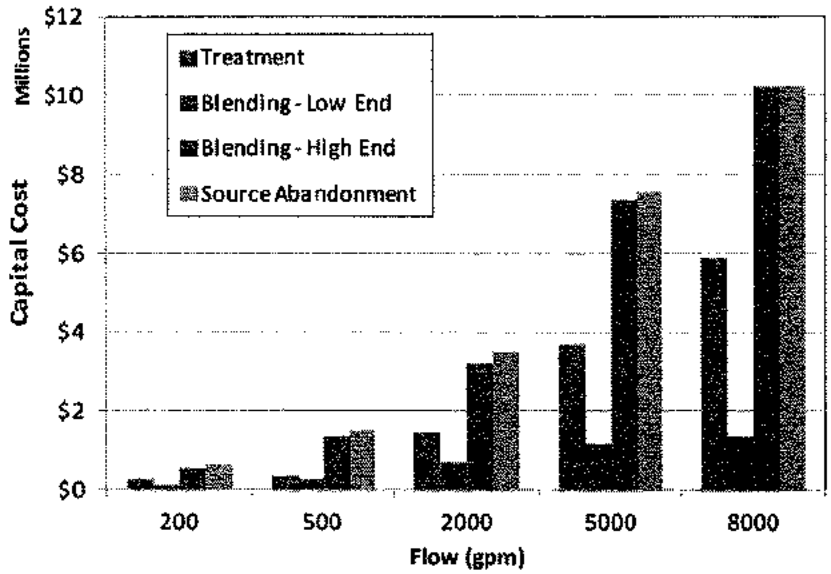

Figure 4-3: Conceptual Capital Costs for Treatment, Blending, or Source Abandonment

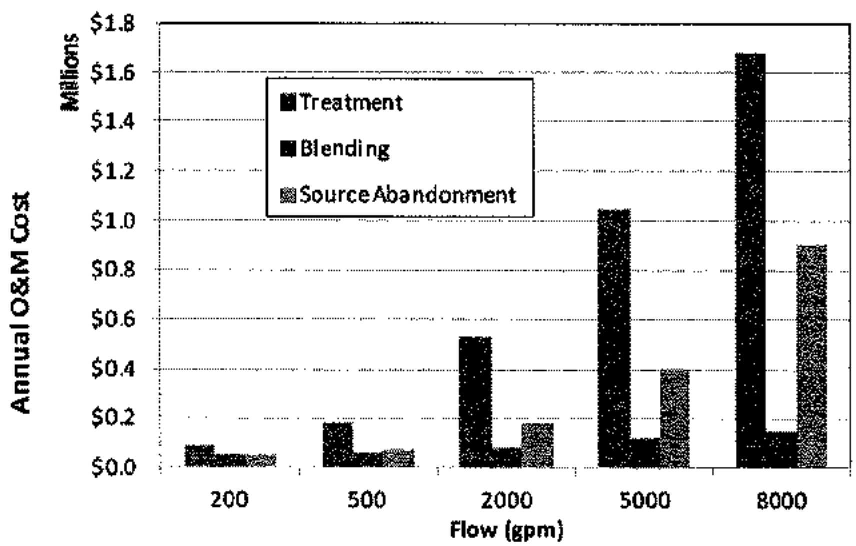

Figure 4-4: Annual Conceptual O&M Costs for Treatment, Blending, or Source Abandonment

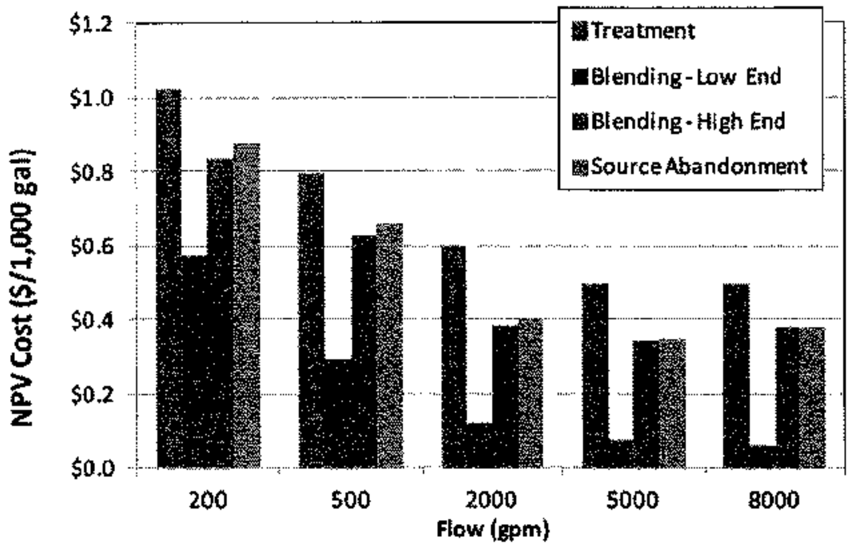

Figure 4-5: Net Present Value Conceptual Costs for Compliance Strategies
(Based on 20 year life-of-service and 3% interest rate)

5. National Compliance Costs

National compliance costs were updated from the 2008 Cost Study by assuming 43% of impacted sources/entry points with perchlorate concentrations above 2, 4, 6, 12, 18, and 24 µg/L would install single pass ion exchange treatment, 43% would blend, and 14% would abandon perchlorate impacted sources, based on 2013 survey responses. Capital and O&M costs associated with the assigned compliance strategies were calculated based on estimated flows for the contaminated sources/entry points using the cost curves developed based on survey responses and engineering opinions (Appendix C). California sources/entry points were omitted for potential federal MCLs of 6 µg/L and above and all Massachusetts sources/entry points were omitted from the national cost projections because the Massachusetts MCL is 2 ug/L.

Figure 5-1 shows total conceptual annualized costs for potential federal MCLs ranging from 2 to 24 µg/L based on a 20 year life-of-service and a 3% discount rate. Tabulated cost data (capital, annual O&M, NPV) at both a 3 and 7% discount rate is provided in Appendix D. Low end cost estimates are derived from perchlorate occurrence based on median concentrations for each source/entry point and assuming blending can be accomplished with existing sources (i.e., no new wells). High end costs are based on 90th percentile perchlorate concentrations for each source/entry point and assuming new wells are required for blending. At a 4 µg/L MCL, total conceptual annual costs are estimated to range from $40 to 120 million (Figure 5-1). The significant range reflects uncertainties regarding impacted systems (i.e., based on either median or 90th percentile perchlorate concentrations) and the site specific compliance costs (e.g., blending costs may be much lower if water systems can use existing sources rather than develop a new well). Even at the high end of the range (i.e., $120 million per year for a 4 µg/L MCL), national compliance costs for a perchlorate MCL are less than half of those estimated for the Arsenic Rule (e.g., $320 million per year for at 10 µg/L in 2013 dollars) reflecting the relatively small percent of water systems expected to be affected by a perchlorate regulation.

Russell et al. (2009) estimated a $160 million per year total annual national compliance cost to comply with a 4 µg/L MCL (in 2013 dollars), compared to $120 million per year estimated in this 2013 update (Figure 5-1). The difference reflects costs already incurred by California and Massachusetts systems required to comply with state standards (estimated $30 million per year), and slightly lower total costs for blending and source abandonment, which were not considered as potential compliance options in the previous study. As indicated in Section 2, the compliance costs for California and Massachusetts systems with perchlorate concentrations above the respective State MCLs were excluded for the purposes of this updated national cost assessment.

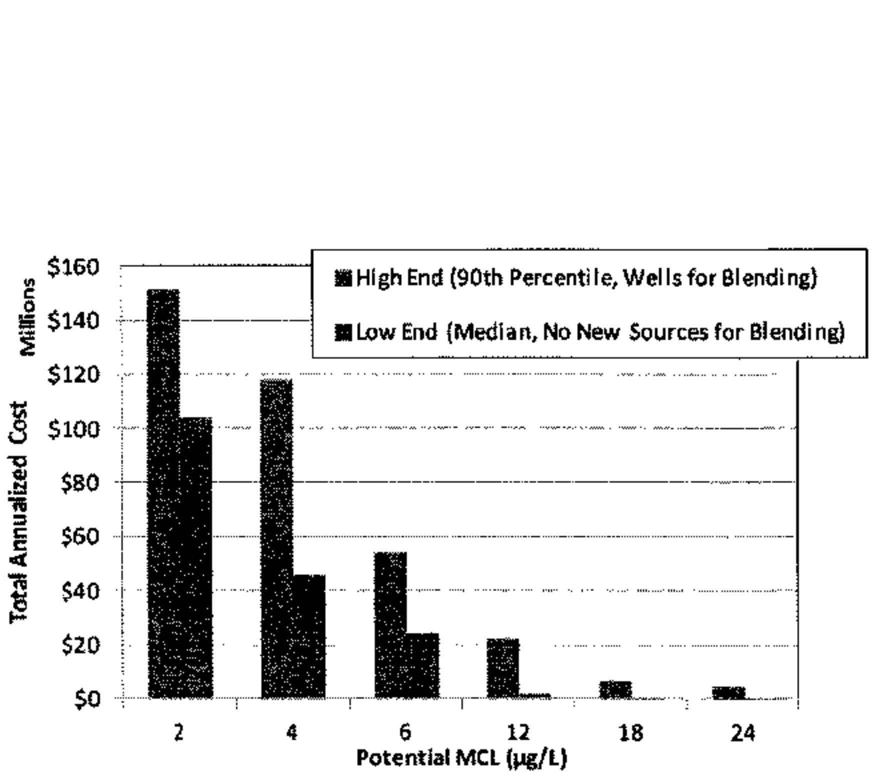

Figure 5-1: Total Conceptual Annualized National Compliance Costs for a Perchlorate MCL – 2013 Update (3% discount rate, 20 year life-of-service)

The total cost of compliance for an MCL of 4 µg/L is estimated to be $2.2 billion dollars ($1.1 billion in capital and $1.2 billion total NPV in operating costs) based on the 90th percentile perchlorate concentrations and operation of the systems for 20 years at a 3% discount rate (Table 5-1). In comparison, the estimated compliance cost for an MCL of 24 µg/L is much lower at approximately $0.08 billion. The significantly lower cost for the higher perchlorate concentration reflects the small number of PWSs that would be affected at that regulatory level (Figure 3-2).

Table 5-1: Total Conceptual National Capital, Annual O&M and NPV Compliance Costs for a Perchlorate MCL – 2013 Update (based on 90th percentile perchlorate concentrations, 3% discount rate, 20 year life-of-service)

Potential MCL (µg/L)	Capital Costs ($ Millions)	Annualized Capital Costs ($ Millions/yr)	Annual O&M ($ Millions/yr)	Total O&M (NPV) ($ Millions)	Total Annualized Cost ($ Millions/yr)	Total NPV ($ Millions)
2	$1,100	$73	$78	$1,200	$150	$2,200
4	$850	$57	$61	$910	$120	$1,800
6	$450	$30	$24	$360	$54	$810
12	$180	$12	$10	$150	$22	$330
18	$47	$3	$3.6	$54	$6.6	$100
24	$36	$2	$3	$45	$5	$81

Table 5-2 shows total annual costs by system size for MCLs ranging from 2 to 6 µg/L. Per system costs were calculated by dividing the estimated total annual cost for a given size category by the number of systems impacted and the average design flow for that category. The data show substantial costs for small water systems to implement perchlorate compliance strategies, with conceptual costs above $3 per 1,000 gallons for very small systems (systems serving < 500 people). These results indicate that while the total national compliance costs for a federal perchlorate MCL are low relative to other NPDWRs, the cost burden would be primarily placed on a small number of water systems. The highest cost burdens are estimated to be for small water systems due to economies of scale associated with treatment options.

Table 5-2: Impact of System Size on Per System Costs for a Potential MCLs at 2, 4, and 6 µg/L

System Size	Number of Systems Impacted[1]		Total Annual Compliance Costs (3% Interest Rate)	Per System Cost ($/1,000 gal)
	90th Percentile Perchlorate	Median Perchlorate		
2 µg/L MCL				
Very Small	256	256	$6.7 – 7.2 M	$3.2 – 3.4
Small	256	256	$14 – 19 M	$0.29 – 0.38
Medium	171	171	$38 M[2]	$0.34 – 0.35
Large	87	63	$15 – 35 M	$0.08 – 0.12
Very Large	53	38	$29 – 50 M	$0.03 – 0.04
Total	**823**	**784**	**$103 – 149**	**$0.03 - 3.4**
4 µg/L MCL				
Very Small	256	171	$4.4 – 7.2 M	$3.1 – 3.4
Small	85	85	$5.1 – 9.7 M	$0.32 – 0.60
Medium	171	85	$13 – 38 M	$0.24 – 0.35
Large	71	46	$10 – 30 M	$0.06 – 0.13
Very Large	39	26	$15 – 32 M	$0.02 – 0.03
Total	**622**	**413**	**$48 – 117**	**$0.02 - 3.4**
6 µg/L MCL				
Very Small	171	85	$2.3 – 4.0 M	$2.8 – 3.2
Small	85	0[3]	$0 – 9.7 M[3]	$0.60
Medium	85	85	$12 – 13 M	$0.22 – 0.24
Large	41	24	$6 – 18 M	$0.07 – 0.13
Very Large	10	4	$4 – 11 M	$0.04
Total	**392**	**199**	**$24 – 56**	**$0.04 - 3.2**

[1] Number of impacted systems serving less than 10,000 people was tallied by factoring in the subset of small systems included in UCMR1 sampling (e.g., 68,036 CWS and NTNCWS nationwide divided by 797 systems serving less than 10,000 people sampled in UCMR1). Given data limitations associated with the small subset of water systems sampled, this number is considered to be a very rough estimate.

[2] Range is not reported, since the difference in the low end ($38.2 million) and high end cost estimate ($38.3 million) is negligible when rounded to two significant digits.

[3] Within the subset of small systems sampled, none had median perchlorate concentrations above 6 µg/L; however, if all small CWS and NTNCWSs across the U.S. were sampled, a small portion would be expected to have perchlorate detections based on CDPH data.

6. Discussion

As with any attempt to assess the national costs associated with a potential drinking water regulation, the accuracy of the cost estimate is dependent on the information available to develop those costs (e.g., contaminant occurrence data, selection of appropriate technologies, and capital and O&M costs for a given treatment process, etc.). Assumptions must be made due to the magnitude of the studies (i.e., contaminated sources cannot be evaluated on a case-by-case basis) and the likely absence of data required for precise evaluation of costs. Data limitations and assumptions expected to have the biggest impact on the cost projections are discussed below.

6.1. Occurrence Data

UCMR1 is the most comprehensive set of national perchlorate data (Brandhuber et al., 2009). However, the database has several significant limitations that can impact accurate assessment of perchlorate occurrence, particularly at the lower concentrations that could be considered for a Federal MCL.

- UCMR1 samples were collected January 2001 to December 2003. Perchlorate data collected since 2003 have shown decreased concentrations in some sources as a result of remediation efforts. For example, perchlorate concentrations decreased more than 90 percent since 1998 at one of the Colorado River intakes for the Metropolitan Water District of Southern California due to the success of upstream remediation efforts (MWDSC, 2012). Perchlorate concentrations at the intake have consistently remained at or below 1 µg/L in the last year.
- Only 800 CWSs and NTNCWSs serving less than 10,000 people were required to monitor. Those 800 water systems account for less than 2% of the total number of CWSs and NTNCWSs throughout the United States. The USEPA and the State regulatory agencies carefully selected the small systems to attempt to provide a representative distribution of samples. However, a review of perchlorate occurrence in small systems across the state of California (based on CDPH data) suggests the UMCR1 subset was too small to capture a representative profile of perchlorate occurrence in small systems. Perchlorate was not detected at median or 90th percentile concentrations above 2 µg/L in any of the 48 California water systems serving less than 10,000 people sampled under UCMR1. In comparison, 200 systems serving less than 10,000 people sampled under CDPH's monitoring program (which

included all systems) showed 90th percentile perchlorate concentrations above 2 μg/L.[9]

- UCMR samples were analyzed at a MRL of 4 μg/L. A review of the CDPH data indicate that sample analysis at lower MDLs reveal more widespread occurrence of perchlorate than can be estimated based on UCMR1 data (or CDPH data at a 4 μg/L MRL). If EPA considers a NPDWR for perchlorate at or below 4 μg/L, limitations of the UCMR dataset will hinder accurate cost projections associated with a draft MCL. Recognizing these limitations, this cost assessment assessed occurrence and associated compliance costs at a 2 μg/L MCL based on the methodology described as a reference point for further consideration.

6.2. Compliance Cost Estimates

Table 6-1 highlights site-specific factors that could impact the estimated system costs associated with each compliance strategy considered in this study, and the overall accuracy of the national cost projections. A robust set of full-scale capital and O&M costs for single pass ion exchange treatment is available from the survey conducted for this study, the 2008 Cost Study (Malcolm Pirnie, 2008), and the Kennedy/Jenks study (2004). This data set includes full-scale costs for more than twenty water systems covering a range of design capacities and source water quality. Inherently, the data account for some of the site-specific variability expected to influence costs, particularly available infrastructure and water quality. Research suggests that nitrate concentrations have a stronger impact on perchlorate breakthrough than the influent perchlorate concentration (since perchlorate is present at μg/L, compared to mg/L for nitrate; Russell et al., 2008). Perchlorate breakthrough at 80% of the influent concentration occurred at 170,000 bed volumes for a water with nitrate at 13.5 mg/L as nitrogen (and influent perchlorate at 12 μg/L), compared to 240,000 bed volumes for water with nitrate at 7.3 mg/L as N (and influent perchlorate at 23 μg/L). Other water quality parameters also impact pre-treatment requirements.

Survey results indicate that site specific costs for blending can vary significantly depending on available water supply and infrastructure. The available water supply and infrastructure will significantly impact costs associated with blending and opportunity costs associated with source abandonment. Costs developed for this study did not account for the impact of water rights. For example, the State of Texas is subject to the rule of capture; groundwater rights are subject to land ownership above the aquifer. To extract additional groundwater, a water system may need to buy

[9] Systems serving less than 500 people were excluded from the assessment since some of these systems appear to be TNCWSs that would not be impacted by a federal MCL, because they are only required to comply with nitrate and coliform standards.

additional land (adding to the total cost) and submit permit applications and fees for the additional groundwater rights.

Costs to develop a new well to meet water demands for blending or source abandonment vary significant depending on the geology and the aquifer depth. A number of factors can impact the cost of transmission mains required to convey the new supply to the water system (e.g., distance, right-of-ways, pipe material).

Energy costs were assumed to be $0.10 per kilowatt hour (kWh) for the O&M cost estimates. This rate compares to a May 2013 commercial average cost of $0.10 per kWh (EIA, 2013); however, costs are variable across the U.S. Energy costs are projected to increase in the future, impacting associated O&M costs for different compliance strategies.

Table 6-1: Factors Influencing Compliance Costs

Compliance Strategy	Factors Influencing Costs
IX Treatment	• Land and infrastructure requirements (e.g., building, piping) • Water quality, particularly nitrate concentrations • Perchlorate treatment goal • Power costs
Blending	• Available water supply and infrastructure • Water rights and replacement water costs • Quality of any replacement water supply • Power costs
Source Abandonment	• Available water supply and infrastructure • Water rights and replacement water costs • Quality of any replacement water supply • Power costs

As with the 2008 Cost Study, source water monitoring costs were not included in the cost evaluation. An initial round of monitoring will likely be required following promulgation of an MCL to determine if water system sources are contaminated and require treatment. Subsequently, water systems may be required to monitor on an annual or triennial basis. CDPH estimated monitoring costs associated with their determination to regulate perchlorate (CDPH, 2007). The estimated annual monitoring costs were 2% of the total conceptual annualized treatment costs. Assuming a similar proportioning of monitoring to treatment costs at the national level, the omission of monitoring costs in this study is not expected to significantly affect the accuracy of the calculated compliance costs. However, it should be noted that for the small systems, the additional costs for monitoring could have an additive impact on rates.

6.3. Ground Truthing

In the 2008 cost study, several parameters with importance in the determination of compliance costs were evaluated for accuracy via an assessment of those parameters for a subset of water systems. These parameters included: the number of sources for a given water system, the population size, and estimated design and average flow for a given source/entry point.

Water systems with contaminated sources/entry points with flows greater than 10,000 gpm were also evaluated on a case-by-case basis since these sources/entry points contribute most to national compliance cost projections. The perchlorate concentrations and characteristics of these systems were reviewed in this update to assess previous conclusions regarding whether the systems should be included in the cost projections. Recent consumer confidence reports (CCRs) were downloaded from water system websites to review perchlorate concentrations. Based on the data and responses, the same approach was taken in this 2013 cost update for the systems with entry point flows greater than 10,000 as the 2008 Cost Study, with one exception. One water system was known to have abandoned a 5 million gallon per day wellfield used to provide water during peak summer demands following detection of perchlorate in the wells. For this 2013 update, estimated capital and O&M costs the system could incur if it needed to replace the lost water from the abandoned supply were included in the national cost projections (based on conceptual costs shown in Tables 4-7 and 4-8).

7. Conclusions

The previous cost study (Russell et al., 2009) was updated to assess the extent of perchlorate occurrence in PWSs throughout the United States taking into account current compliance with California and Massachusetts MCLs. Trends are generally consistent with the earlier study and indicate the following:

- The estimated annual costs for PWSs to comply with a 4 µg/L are $120 million per year, compared to $320 million per year for the 10 µg/L Arsenic Rule (adjusted to 2013 dollars).

- At the lowest assessed MCL (2 µg/L), the net present value of a perchlorate regulation is estimated to be $2.2 billion (based on 90th percentile perchlorate concentrations, 3% discount rate for 20 year service life). In contrast, the NPV compliance cost is estimated to be $0.08 billion at the highest evaluated MCL (24 µg/L), illustrating the wide range in national compliance costs depending on how EPA regulates.

- The cost burden would be primarily placed on a small number of systems. An estimated 3.8 and 3.0% of PWSs will be impacted by a 2 ug/L and 4 µg/L perchlorate MCL, respectively. If State MCLs were not already in place, the percentage of water systems impacted by a 2 ug/L and 4 ug/L MCL would be 4.1 % and 3.4%, respectively.

- In particular, compliance costs are estimated to be as high as $3 per 1,000 gallons for very small systems (systems serving < 500 people) that are unable to benefit from economies of scale.

- Impacted systems may avoid treatment costs by blending or abandoning high concentration sources; however, the opportunity costs are comparable to treatment costs.

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Appendix A

Evaluation of Samples with Sample Code SR for Untreated Water

Appendix A: Evaluation of Samples with Sample Code SR or Untreated Water

Sample codes included in UCMR1 are as follows:

EP – Entry point to the distribution system

SR – Untreated water collected at the source of the water system facility

MD, MR, and LD – Distribution system locations at the midpoint (MD), maximum residence time (MR), and location where the disinfectant residual is lowest (LD).

UK – Not definitively known

Table A-1 summarizes the number of detections for the different sample codes. Of the forty-four (44) water systems with perchlorate detections in untreated sources (i.e., SR sample codes), thirty-seven (37) are California systems already required to comply with the State MCL (Table A-2). Based on that analysis, all sample codes were included in the analysis of perchlorate detections and associated cost implications:

- Most detections with SR sample codes are CA systems that do not contribute to the national cost projections;

- Removal of SR sample locations is inconsistent with the exception outlined in 40 CFR §141.40 (a)(5)(ii)(B). Further if these sources are currently untreated but have perchlorate above a potential MCL, the water systems would be required to treat the source in response to a national primary drinking water regulation for perchlorate and thus should be included in analysis national compliance costs.

Table A-1: Summary of Perchlorate Detections by Sample Codes

Sample Code	# Samples with Detections	# Sample Locations with Detections	# PWS with Detections
All Codes	647	387	160[1]
EP	348	230	123
SR	288	152	44
MR, MD, LD	0	0	0
UK	11	5	3

[1] Several PWSs had perchlorate detections at more than one type of sample location; thus a sum of the PWSs with detections for the different samples codes is more than the number of PWSs with detections without drilling down by sample code.

Include for MCL less than 6 ppb
SR has highest perchlorate
EP has highest perchlorate

Table A-2: Water Systems with Detects at Untreated Sources (N = 44)

PWSID	State	Total # of Sample Points	# of SR sample locations	# of EP sample locations	Sample Location Type with Highest Perchlorate Conc	Max perchlorate	Max perchlorate at SR sample
CA1910017	CA	12	12		SR	4.2	4.2
CA1910022	CA	3	2	1	SR	6.2	6.2
CA1910063	CA	6	3	3	EP	15	4.8
CA1910087	CA	14	9	5	SR	6.7	6.7
CA1910124	CA	12	12		SR	35	35
CA1910126	CA	22	22		SR	12	12
CA1910143	CA	4	4		SR	8.9	8.9
CA1910167	CA	9	9		SR	5.42	5.42
CA1910205	CA	1	1		SR	7.2	7.2
CA3010038	CA	21	20	1	SR	4.4	4.4
CA3010046	CA	14	12	2	SR	8.9	8.9
CA3010092	CA	19	18	1	SR	6	6
CA3010094	CA	3	3		SR	5	5
CA3310009	CA	17	16	1	SR	7.5	7.5
CA3310016	CA	14	11	3	SR	7.2	7.2
CA3310021	CA	12	11	1	SR	4.6	4.6
CA3310031	CA	43	42	1	SR	42	42
CA3310037	CA	25	15	10	EP	13	12
CA3310038	CA	47	46	1	SR	4.4	4.4
CA3310044	CA	4	4		SR	10.3	10.3
CA3410004	CA	9	7	2	SR	4.14	4.14
CA3610004	CA	20	16	4	EP	7.5	4.3
CA3610012	CA	12	8	4	SR	21	21
CA3610013	CA	3	3		SR	5	5
CA3610014	CA	16	14	2	SR	7.7	7.7
CA3610018	CA	43	35	8	SR	9	9
CA3610029	CA	12	10	2	SR	4.4	4.4
CA3610034	CA	22	22		SR	12	12
CA3610037	CA	40	18	22	EP	67	18
CA3610038	CA	12	12		SR	33	33
CA3610039	CA	48	47	1	SR	6.8	6.8
CA3610041	CA	35	33	2	SR	15	15
CA3610043	CA	14	14		SR	4.7	4.7
CA3610057	CA	9	7	2	SR	5.2	5.2
CA3710006	CA	4	3	1	EP	4.3	4.2
CA3910012	CA	45	33	12	SR	19	19
CA5010017	CA	6	5	1	SR	4.4	4.4
FL2160200	FL	5	4	1	SR	200	200
NM3528616	NM	12	12		SR	20	20
NY2900000	NY	25	25		SR	8.87	8.87
NY2902824	NY	10	8	2	SR	4.2	4.2
NY2902826	NY	5	5		SR	4.02	4.02
NY2902845	NY	15	9	6	EP	11	4.7
NY5110526	NY	499	59	440	EP	12.1	6.6

Table A-3 compares the estimated percent of water systems impacted by potential MCLs ranging from 2 to 24 µg/L with and without untreated samples (SR sample codes) included. The estimated percent of water systems are slightly lower for potential MCLs of 2 and 4 µg/L if untreated water samples are excluded from analysis. At higher potential MCLs, exclusion of untreated samples has minimal impact. This trend reflects that most of the untreated water samples are for California systems that would be omitted from analysis and compliance considerations at potential federal MCLs at or above the 6 µg/L state MCL.

Table A-3: Estimated Percent of Water Systems Impacted by a Potential Perchlorate MCL[1]

Potential MCL	Percent of Impacted Systems	
	2013 Update[2] All sample codes	2013 Update[2] Excluding untreated samples (SR sample code)
2 ug/L	3.8%	3.0%
4 ug/L	3.0%	2.4%
6 ug/L	1.4%	1.4%
12 ug/L	0.6%	0.6%
18 ug/L	0.3%	0.3%
24 ug/L	0.2%	0.2%

[1]Based on 90th percentile perchlorate concentrations

[2]California systems with perchlorate above 6 µg/L excluded; all Massachusetts systems excluded

Appendix B

Survey: Understanding Perchlorate Compliance Strategies

American Water Works
Association

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Who: Malcolm Pirnie/ARCADIS on behalf of AWWA Government Affairs Office

What: Understanding Perchlorate Compliance Strategies

This survey is part of an American Water Works Association (AWWA) project to understand impacts to water systems associated with a pending National Primary Drinking Water Regulation (NPDWR) for perchlorate. The results of this survey will support AWWA comment developed for the NPDWR and inform stakeholders of potential implications of an impending perchlorate regulation.

You are receiving this survey based on results from California or Massachusetts sampling data indicating your water system had at least one sample with detectable levels of perchlorate. AWWA is specifically interested in insight you can provide on compliance strategies you may have implemented to respond to your State maximum contaminant level (MCL). The information you provide will assist AWWA in representing you and other water systems in its comment developed for the NPDWR.

As you complete this survey, **you will find it helpful to have your most recent perchlorate monitoring results at hand, as well as cost information for any compliance strategies you may have implemented.** In the absence of recent perchlorate data collected for state compliance, please refer to your UCMR1 perchlorate results.

The survey should not take more than 30 minutes to complete. You can either complete the survey electronically, by clicking the link provided below, or complete the attached Word version of the survey and mail electronically or by hard copy to Caroline Russell, 1717 W. 6th Street, Suite 210, Austin, TX 78703, caroline.russell@arcadis-us.com, 512-527-6082. If you think someone else in your utility would be better able to complete the survey, please send me an email with your question or concern. You may also contact Kevin Morley at kmorley@awwa.org or 202-326-6124 with any questions regarding the survey.

Respondents completing the survey by Friday, January 4th will be entered into a drawing to win a free Kindle Fire! Less than 100 utilities are part of this survey, so your chances are good. Thank you for your time!

(EDITORIAL NOTE – Pink highlighting pertains to questions only asked if the preceding question triggers the question).

	A. Contact Information
1	Name______________________________ Title______________________________ Email______________________________ Telephone__________________________ Address____________________________
	B. General System Information
2	Please enter your public water system ID (PWSID). If you do not know it, please enter the system name, city, and state. ________________

3	What population does your PWS serve? ☐ Less than 500 ☐ 501 – 3,300 ☐ 3,301 – 10,000 ☐ 10,001 to 100,000 ☐ 100,001 to 500,000 ☐ More than 500,000
4	How many entry points to the distribution system does your system have? ☐ None ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ Other ______
5	What are your water sources? ☐ Groundwater ☐ Surface water ☐ Mixture of groundwater and surface water

6	How many surface water sources have detectable levels of perchlorate based on your most recent State compliance data (in lieu of State compliance data, please refer to UCMR1 results)? ☐ None ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ Other (Number of intakes: ______) Please list maximum perchlorate concentration detected: ____________________ What is the source of this data (State compliance or UCMR1)? _______________

7	How many groundwater sources have detectable levels of perchlorate based on your most recent State compliance data (in lieu of State compliance data, please refer to UCMR1 results)? ☐ None ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ Other (Number of wells: ______) Please list maximum perchlorate concentration detected: ____________________ What is the source of this data (State compliance or UCMR1)? _______________
	C. Treatment Process (answer only if you have abandoned wells, installed treatment or implemented source blending for perchlorate)
8	What is your target finished water perchlorate concentration in parts per billion (ppb)? (if non-detect, list the reference detection limit) ________________ ppb

9	Which strategies have you implemented to reduce perchlorate concentrations? (please select all that apply:) ☐ Blending (if this box is checked, please answer question 9 to 13) ☐ Source (e.g., well) abandonment (if this box is checked please answer questions 14 to 19) ☐ Treatment (i.e., ion exchange, biological treatment, reverse osmosis) (if this box is checked please answer question 20 to …) ☐ Other ____________
	IF ANSWER TO QUESTION 9 IS BLENDING, PLEASE ANSWER QUESTIONS 10 TO 14
10	What is the average flow in gallons per minute (gpm) at the entry point in which blending is used to reduce perchlorate concentrations in the finished water? ______________ gpm

11	Can blending be used to consistently achieve the target finished water perchlorate concentration without reducing source water production rates? ☐ Yes ☐ No If no, please list all strategies to meet demands (please select all that apply:) ☐ Purchase water from wholesaler via tie-in ☐ Purchase and haul water ☐ Use stored water ☐ Other
12-a	What capital investments, if any, were required to facilitate blending? ☐ New well ☐ New pump(s) (including upgrades from fixed rate to variable frequency drives) ☐ Improved instrumentation and control (e.g., PLC, SCADA) ☐ Additional storage ☐ Other

12-b	What was the approximate capital cost and year incurred? Capital cost________________ Year incurred ________________
13-a	What is the approximate annual operating cost (including cost of lost water) to facilitate blending? ________________
13-b	Which items contribute most to operating costs? (please select top two line items) ☐ Labor ☐ Laboratory Analyses ☐ Energy ☐ Lost water ☐ Other:______________
14	Do you anticipate incorporating any additional strategies (e.g., well abandonment, treatment) to achieve target finished water perchlorate concentrations in the future? ☐ Yes ________________ ☐ No

	IF ANSWER TO QUESTION 9 IS SOURCE ABANDONMENT, PLEASE ANSWER QUESTIONS 15 TO 20
15	How many sources have been abandoned? ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ Other (Number: ______)
16	What is the cumulative average flow in gallons per minute (gpm) for sources that had to be abandoned? ______________ gpm
17	Please list all strategies to meet demands with contaminated sources out of service (please select all that apply:) ☐ Alternate supply developed (e.g., new well, use of surface water) ☐ Purchase water from wholesaler via tie-in ☐ Purchase and haul water ☐ Other

18-a	What capital investments, if any, were incorporated to augment the supply from alternate sources? ☐ New well ☐ New pump(s) (including upgrades from fixed rate to variable frequency drives) ☐ Improved instrumentation and control (e.g., PLC, SCADA) ☐ Transmission main for alternate sources ☐ Additional storage ☐ Other
18-b	What was the approximate cost of those capital investments and year incurred? Capital cost________________ Year incurred ________________
19-a	What is the approximate annual operating cost (including cost of lost water) associated with the strategies employed to meet demands with contaminated sources out of service? __________________

19-b	Which items contribute most to annual costs associated with well abandonment? (please select top two line items) ☐ Lost water ☐ Purchased water ☐ Operating costs for new supply ☐ Other:_____________
20	Do you anticipate incorporating any additional strategies (e.g., blending, treatment) to achieve target finished water perchlorate concentrations in the future? ☐ Yes _______________ ☐ No
	IF ANSWER TO QUESTION 9 IS TREATMENT, PLEASE ANSWER QUESTIONS 21 to 26
21	Which treatment processes have been implemented? (please select all that apply:) ☐ Single pass ion exchange ☐ Regenerable ion exchange ☐ Reverse osmosis ☐ Biological treatment ☐ Other:_____________

22	What is the design flow for the treatment system? ________________
23	What was the approximate capital cost for the treatment system and year of construction? Capital cost________________ Year constructed ________________
24	What is the average flow for the treatment system? ____________________
25	What is the average annual operating cost for the treatment system in 2012 dollars (ballpark)? ________________
26	Which are the two major items contributing to operating costs? (please check two boxes) ☐ Resin / membrane replacement ☐ Energy ☐ Labor ☐ Consumables (chemicals) ☐ Other:______________ ☐ Other:______________

D. Disinfection	
27	What is your disinfectant? (please select all that aply) Primary / Secondary Chlorine ☐ ☐ Chloramines ☐ ☐ Chlorine dioxide ☐ ☐ Ozone ☐ ☐ UV ☐ ☐ Other:____________ ☐ ☐
	IF CHLORINE OR CHLORAMINES, PLEASE ANSWER QUESTIONS 27-b and 27-c:
27-b	Is chlorine supplied as: ☐ Bulk hypochlorite ☐ Chlorine gas cylinders ☐ On-site chlorine generation (please list type of generator) ________________ ☐ Other ____________

27-c	Are measured perchlorate concentrations higher in finished water than in source water? ☐ Yes (please explain in the comment box) ☐ No Comment:______________
E. Survey Conclusion	
28	Are you willing to participate in a more detailed survey and/or phone interviews? ☐ Yes ☐ No

Thanks for your time completing this important survey!

Appendix C

Cost Curves for Compliance Strategies

Appendix C – Cost Curves for Compliance Strategies

C.1. Single Pass Ion Exchange Conceptual Cost Curves

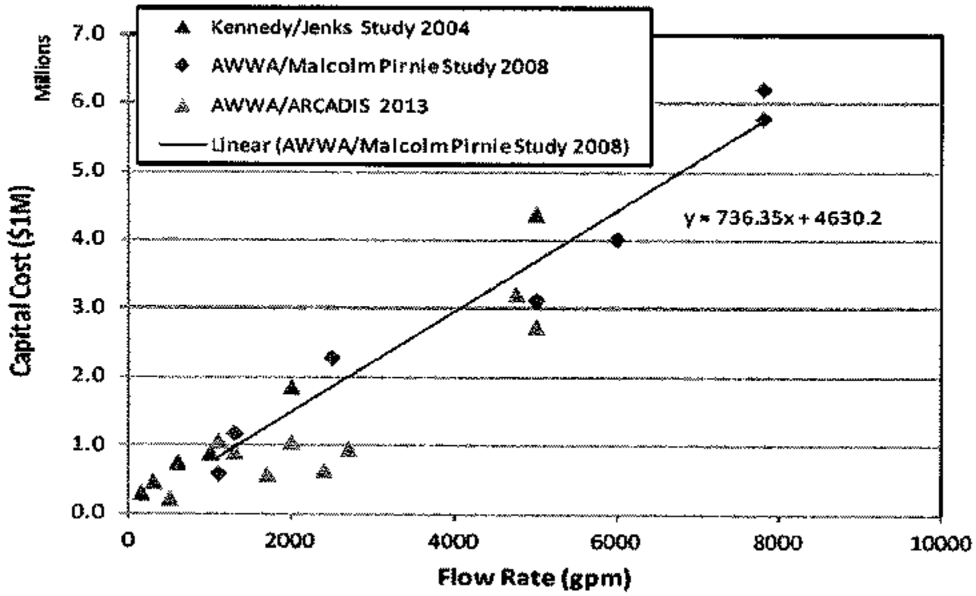

Figure C-1: Conceptual Capital Costs for Single Pass IX Treatment

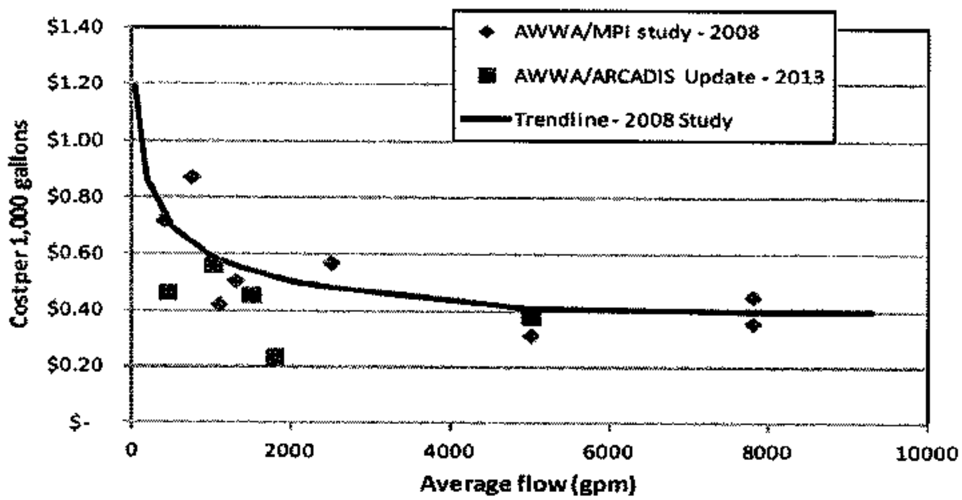

Figure C-2: Conceptual O&M Costs for Single Pass IX Treatment

C.2. Blending Conceptual Cost Curves

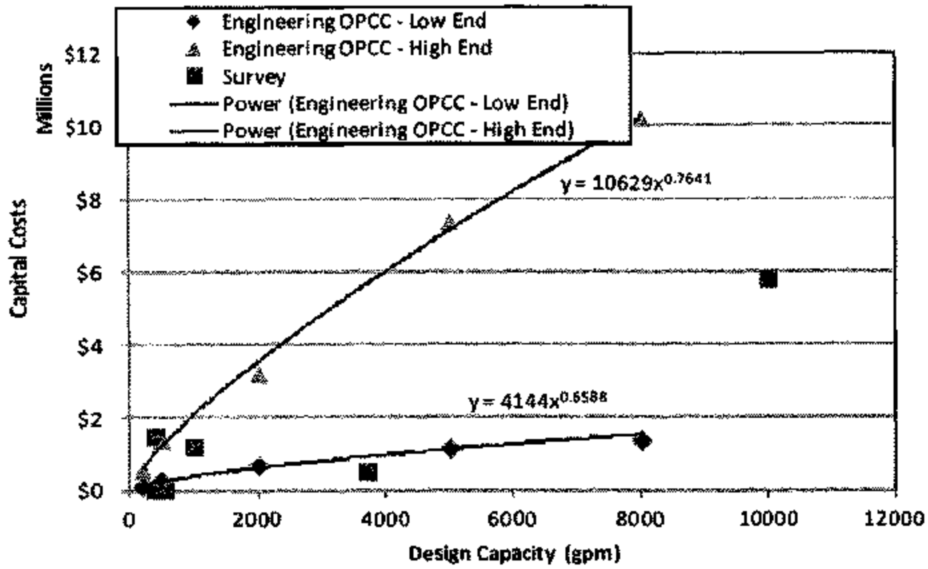

Figure C-3: Conceptual Capital Costs for Blending

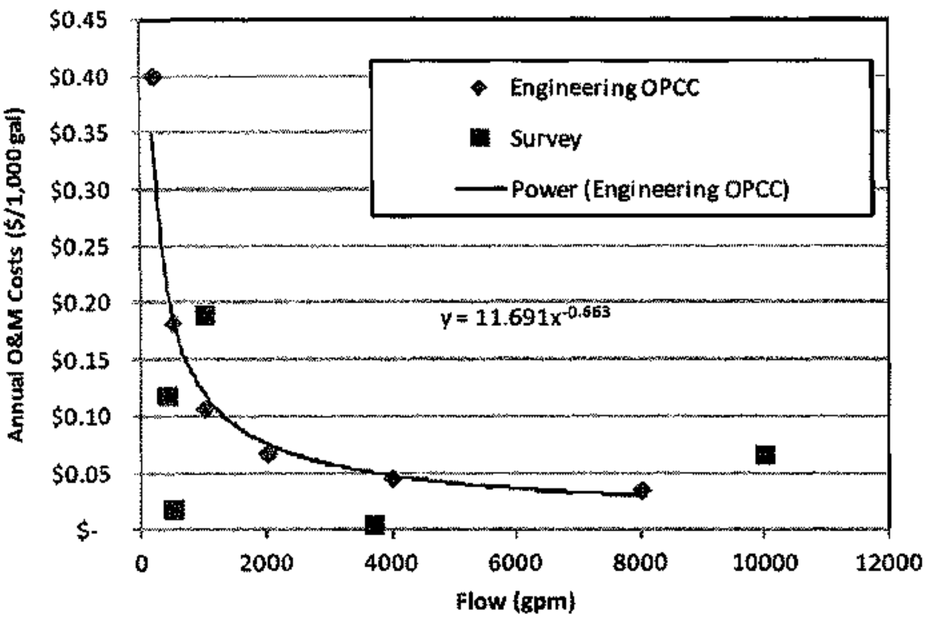

Figure C-4: Conceptual O&M Costs for Blending

C.3. Source Abandonment Conceptual Cost Curves

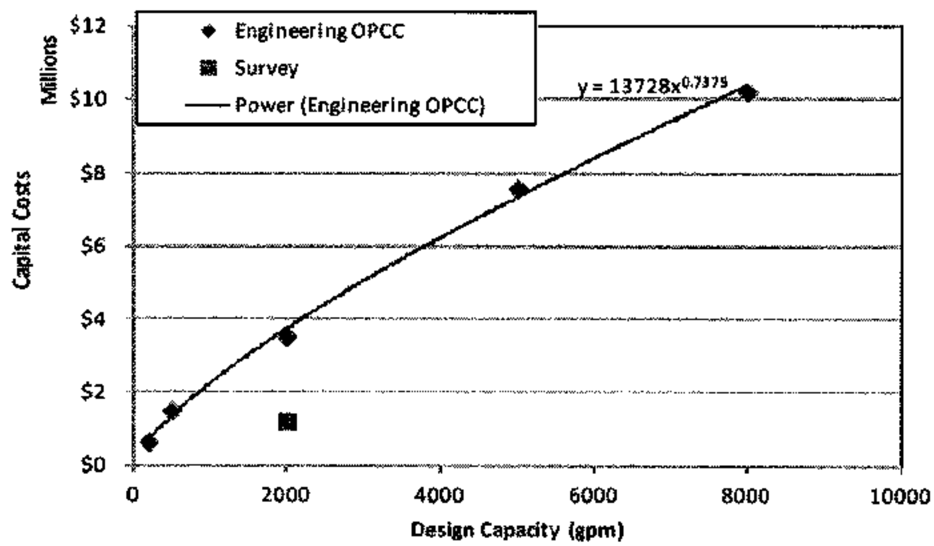

Figure C-5: Conceptual Capital Costs for Source Abandonment

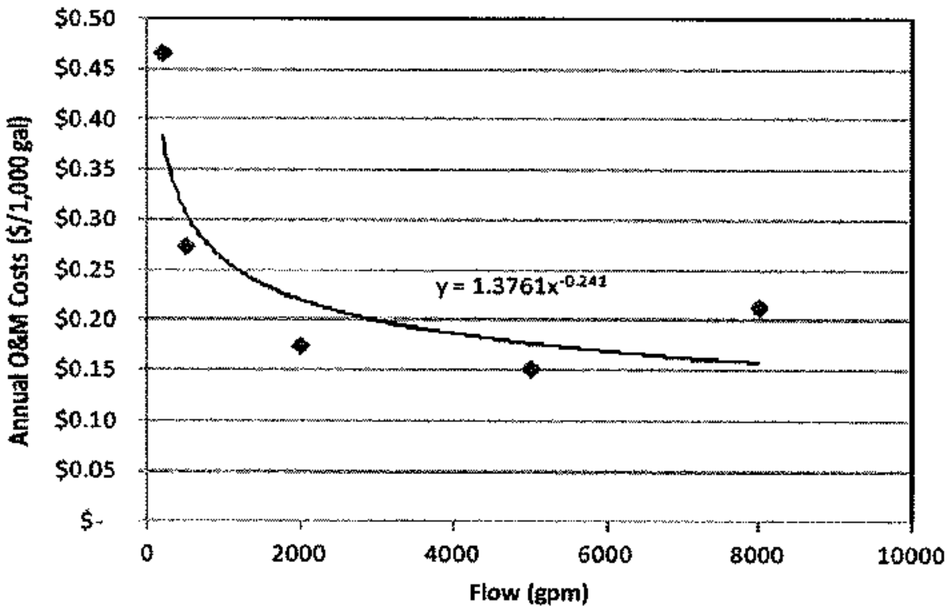

Figure C-6: Conceptual O&M Costs for Source Abandonment

Appendix D

National Compliance Costs at a 7% Interest Rate and 20 Year Life-of-Service

Table D.1. Estimated Cost to Treat All Sources Contaminated with Perchlorate – 90th Percentile Perchlorate Concentration and 3% Discount Rate

Potential MCL (µg/L)	Capital Costs	Annualized Capital	Annual O&M	NPV O&M	Annualized Cost	Total NPV
2	$1,080,000,000	$ 73,000,000	$ 78,000,000	$ 1,160,000,000	$ 151,000,000	$2,240,000,000
4	$ 850,000,000	$ 57,000,000	$ 61,000,000	$ 910,000,000	$ 118,000,000	$1,760,000,000
6	$ 450,000,000	$ 30,000,000	$ 24,000,000	$ 360,000,000	$ 54,000,000	$ 810,000,000
12	$ 180,000,000	$ 12,000,000	$ 10,400,000	$ 150,000,000	$ 22,400,000	$ 330,000,000
18	$ 47,000,000	$ 3,000,000	$ 3,600,000	$ 54,000,000	$ 6,600,000	$ 101,000,000
24	$ 36,000,000	$ 2,000,000	$ 3,000,000	$ 45,000,000	$ 5,000,000	$ 81,000,000

Table D.2. Estimated Cost to Treat All Sources Contaminated with Perchlorate – Median Perchlorate Concentration and 3% Discount Rate

Potential MCL (µg/L)	Capital Costs	Annualized Capital	Annual O&M	NPV O&M	Annualized Cost	Total NPV
2	$560,000,000	$ 38,000,000	$ 66,000,000	$ 980,000,000	$ 104,000,000	$1,540,000,000
4	$260,000,000	$ 17,000,000	$ 29,000,000	$ 430,000,000	$ 46,000,000	$ 690,000,000
6	$140,000,000	$ 9,400,000	$ 15,000,000	$ 220,000,000	$ 24,400,000	$ 360,000,000
12	$ 12,000,000	$ 810,000	$ 1,500,000	$ 22,000,000	$ 2,310,000	$ 34,000,000
18	$ 4,000,000	$ 270,000	$ 620,000	$ 9,200,000	$ 890,000	$ 13,200,000
24	$ 1,100,000	$ 70,000	$ 180,000	$ 2,700,000	$ 250,000	$ 3,800,000

Table D.3. Estimated Cost to Treat All Sources Contaminated with Perchlorate – 90th Percentile Perchlorate Concentration and 7% Discount Rate

Potential MCL (µg/L)	Capital Costs	Annualized Capital	Annual O&M	NPV O&M	Annualized Cost	Total NPV
2	$1,080,000,000	$ 102,000,000	$ 78,000,000	$ 830,000,000	$ 180,000,000	$1,910,000,000
4	$ 850,000,000	$ 80,000,000	$ 61,000,000	$ 650,000,000	$ 141,000,000	$1,500,000,000
6	$ 450,000,000	$ 42,000,000	$ 24,000,000	$ 250,000,000	$ 66,000,000	$ 700,000,000
12	$ 180,000,000	$ 17,000,000	$ 10,400,000	$ 110,000,000	$ 27,400,000	$ 290,000,000
18	$ 47,000,000	$ 4,400,000	$ 3,600,000	$ 38,000,000	$ 8,000,000	$ 85,000,000
24	$ 36,000,000	$ 3,400,000	$ 3,000,000	$ 32,000,000	$ 6,400,000	$ 68,000,000

Table D.4. Estimated Cost to Treat All Sources Contaminated with Perchlorate – Median Perchlorate Concentration and 7% Discount Rate

Potential MCL (µg/L)	Capital Costs	Annualized Capital	Annual O&M	NPV O&M	Annualized Cost	Total NPV
2	$560,000,000	$ 53,000,000	$ 66,000,000	$ 700,000,000	$ 119,000,000	$1,260,000,000
4	$260,000,000	$ 25,000,000	$ 29,000,000	$ 310,000,000	$ 54,000,000	$ 570,000,000
6	$140,000,000	$ 13,000,000	$ 15,000,000	$ 160,000,000	$ 28,000,000	$ 300,000,000
12	$ 12,000,000	$ 1,100,000	$ 1,500,000	$ 16,000,000	$ 2,600,000	$ 28,000,000
18	$ 4,000,000	$ 380,000	$ 620,000	$ 6,600,000	$ 1,000,000	$ 10,600,000
24	$ 1,100,000	$ 100,000	$ 180,000	$ 1,900,000	$ 280,000	$ 3,000,000

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