

DENVER WATER LEAD REDUCTION PROGRAM

ANNUAL REPORT – 2021

Version 1.0: January 28, 2021

Presented by: Denver Water



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LIST OF ACRONYMS

ALSLR	Accelerated Lead Service Line Replacement
CCT	Corrosion control treatment
CDPHE	Colorado Department of Public Health and Environment
COE	Communications, Outreach and Education
EPA	Environmental Protection Agency
HE&EJ	Health equity and environmental justice
LCR	Lead and Copper Rule
LSL	Lead service line
LSLR	Lead service line replacement
OCCT	Optimal corrosion control treatment
Order	Variance Order

EXECUTIVE SUMMARY

The Annual Program Year Report presents the comprehensive evaluation of the Lead Reduction Program performance to date using the equivalency model described in the Lead Reduction Program Plan. As required by the Order, the comprehensive evaluation uses inputs based on actual implementation since Jan. 1, 2020, through Dec. 30, 2021. This Annual Program Year Report also includes Denver Water’s assessment of the metrics that were achieved during calendar year 2021.

All performance metrics required in the Order have been achieved or exceeded:

- Results from lead sampling indicate that lead levels are declining at both LSL homes and copper plumbing with lead solder homes following operation with higher pH in the distribution system. The 90th percentile lead levels continued to be measured less than 5 µg/L in 2021.

TABLE ES-1. CCT PERFORMANCE BASED ON OVERALL 90TH PERCENTILE LEAD CONCENTRATION

LCR Six-Month Sampling Period	2019	2020	2021
Spring Overall 90th Percentile Lead Concentration	10.0 µg/L	6.7 µg/L	4.1 µg/L ¹
Fall Overall 90th Percentile Lead Concentration	11.0 µg/L	4.4 µg/L	4.4 µg/L ²

¹ See letter sent to CDPHE dated Aug. 2, 2021.

² See letter sent to CDPHE dated Jan. 18, 2021

- By the end of 2021, a total of 4,794 LSL replacements were completed, exceeding the minimum number of annual replacements required under the Order (4,477).
- Responses from the filter adoption survey suggest that 81% of customers are using their filters for drinking, cooking, and to prepare formula if formula-fed infants reside at the household.
- Approximately 89% of samples collected from filters in the customer’s homes had no measurable lead.

The equivalency model demonstrates that the holistic approach of the LRP is as effective and efficient as an alternative treatment technique as compared with orthophosphate treatment, and in fact exceeds performance predicted with orthophosphate. Overall, the performance of the second program year (2021) is either equal or better than the performance of the first program year (2020).

There is no change requested to the baseline inventory of 63,955 estimated lead service lines. Therefore, 4,477 lead service line services remain as the target for replacement in 2022.

Minor deviations from the Order are described at the end of this submission, related to administration of the LRP including health equity and environmental justice reporting and notification protocols and clarification for the yearly required investigation counts.

INTRODUCTION

Denver Water is committed to significantly reducing the lead exposure levels to customers from lead service lines and plumbing. The Lead Reduction Program provides a holistic and permanent lead reduction approach that will significantly reduce lead exposure to our customers and be less harmful to the environment.

On Dec. 16, 2019, the EPA approved Denver Water's variance request in the form of a Variance Order (Order) for an initial three-year period to provide the opportunity to demonstrate the LRPP will effectively reduce lead in drinking water over the 15-year period requested. In January 2020, Denver Water began implementation of the Lead Reduction Program Plan (LRPP) in accordance with EPA's Order and the Nov. 15, 2019, letter from CDPHE regarding conditional approval of the request for modification of optimal corrosion control treatment (OCCT).

This annual report was prepared in compliance with paragraph 7.C of the Order and commitments in the 2019 LRPP. The report addresses the second program year for the period of Jan. 1 through Dec. 30, 2021. Twelve monthly reports and two semi-annual reports have been provided to CDPHE for this time period. This annual report includes information from the monthly and semi-annual reports and additional reporting as required by the Order. Work completed in support of the Order requirements, including the communications, outreach and education activities, are included in detail in each semi-annual report.

C. Annual Program Year Reports. No later than 30 Days following the end of a Program Year, Denver Water must submit a Program Year report to CDPHE and EPA, containing a summary of the information and data required under this paragraph for the previous Program Year, including an assessment of which metrics were achieved. The Annual Program Year Report must include a comprehensive evaluation of LRPP performance to date using the equivalency model described in the LRPP with updated inputs based on actual LRPP implementation for: 90th percentile lead levels at LSL and copper with lead solder sites after operation of increased pH and alkalinity adjustment as CCT, number of LSLRs conducted, filter adoption rate, and filter performance in the field. This requirement remains in effect for the term of the variance. The Program Year report must also document any deviations from the LRPP during the most recent Program Year. If CDPHE or EPA provides any comments or requests related to the annual report, Denver Water must provide a written response within 30 Days that addresses any identified comments/requests.

Text is taken verbatim from the Order, dated Dec. 16, 2019.

What to Expect in this Annual Report: Reporting on LRP Activities

The purpose of the annual report is to present the results from the evaluation of the performance of the Lead Reduction Program in anticipation of an extension to the Order beyond the initial three-year period (see Table 1) and to provide an assessment of the metrics that were achieved for the time period of Jan. 1, 2021, through Dec. 31, 2021. The semi-annual reports document the implementation of the LRP and actions taken to reduce lead. A summary list of documents that were submitted to CDPHE and EPA in 2021 is included in the semi-annual reports.¹ The documents were previously submitted and therefore are not appended to this annual report. In addition to providing the second program year metrics, year over year comparisons are provided below in select tables.

TABLE 1. WHAT TO EXPECT IN THIS ANNUAL REPORT

Item	What to Expect in this Annual Report
Paragraph 7.C of the Variance Order	<p>This Annual Report contains a summary of the information and data for the previous Program Year, including an assessment of which metrics were achieved. The Annual Report also provides a comprehensive evaluation of LRPP performance to date using the equivalency model described in the LRPP with updated inputs based on actual LRPP implementation for:</p> <ul style="list-style-type: none"> • 90th percentile lead levels at LSL and copper plumbing with lead solder sites after operation of increased pH and alkalinity adjustment as CCT. • Number of LSL replacements conducted. • Filter adoption rate. • Filter performance in the field.
Additional Requirements	<p>This section of the Annual Report summarizes submissions to EPA and CDPHE as identified in the LRPP.</p> <p>A summary and discussion of learning by doing is submitted separately.</p>
Deviations (7.C)	<p>This section documents deviations from the LRPP during the 2021 Program Year.</p>
Appendices	<p>Appendices attached to this Annual Report include a summary of the number and type of LSL replacements completed, changes to the status (p-value) of service lines in the inventory, analysis of sociodemographic data collected from the filter adoption survey, and a summary of properties where an emergency repair resulted in a partial lead service line replacement.</p>

ASSESSMENT OF METRICS ACHIEVED

Compliance Metrics per Paragraphs 2.C, 3.D, 4.I, 5.G and 6.B

As required by the Order, the performance metrics for the five elements of the Lead Reduction Program, including the application of corrosion control treatment, the development – and regular updates – of the LSL inventory, the replacement of lead service lines, and the distribution of filter outreach and education materials, have been achieved. The overall performance of the LRP is evaluated by modeling performance under the conditions of the Order

¹ See First Semi-Annual Report for 2021 submitted July 8, 2021 and Second Semi-Annual Report for 2021 submitted Jan. 7, 2022.

and comparing it to modeling performance with orthophosphate. A summary of the required performance metrics from the Order is provided in Table 2.

TABLE 2. SUMMARY OF COMPLIANCE METRICS FOR 2021

Paragraph	Description	2021 Results
2.C	<p>C. Corrosion Control Treatment Metric. Consistently <u>maintain in all parts of the System a minimum target pH of 8.5 during the first year of operation</u> under this Order.</p> <p>In the future, maintain pH and alkalinity within the ranges designated by CDPHE in its modification decision under Section 11.26(3)(d)(ii) of 5 CCR 1002-11.</p>	<p>Achieved.</p> <p>Implemented March 3, 2020.²</p> <p>CDPHE issued the requirements change notice regarding the water quality parameters for CCT on June 9, 2021.³</p> <p>Maintained pH and alkalinity within the ranges designated by CDPHE.³</p>
3.D	<p>D. LSL Inventory Compliance Metric. <u>Investigate a minimum of 1.4% of the total estimated number of suspected and possible LSLs</u> in the LSL Inventory each Program Year (based on a subset of Y as described in paragraph 3.A above), as adjusted.</p> <p>These investigations are performed independently of the LSL replacements.</p>	<p>Achieved.</p> <p>Completed 4,562 investigations independently of the 2021 ALSLR Program.</p>
4.I	<p>I. Accelerated LSL Replacement Compliance Metric. <u>Annually achieve at least a 7.0% cumulative average Program Year LSL replacement rate</u> as determined based on reporting required in paragraph 7.B.</p>	<p>Achieved.</p> <p>Completed 4,794 LSL replacements in 2021.</p>
5.G	<p>G. Filter Communication Compliance Metric. <u>Make direct contact with lead outreach and education materials to 95% of all customers enrolled in the Filter Program</u> in every Program Year. . . Compliance shall be documented by mailing lists and mail receipts, lists of customer email addresses for customers who elect to receive email communication, or other forms of documentation approved by CDPHE.</p>	<p>Achieved.</p> <p>Provided outreach and education materials to over 95% of all customers enrolled in the Filter Program.⁴</p>
6.B	<p>B. Comprehensive LRPP Performance Metric. Demonstrate to EPA's satisfaction, using the updated equivalency model results as reported under paragraph 7.C, that the <u>combined actual performance of the LRPP as implemented continues to be "at least as efficient as" orthophosphate treatment in reducing lead exposure</u> on an annual basis. Account for the CCT optimization period in this demonstration.</p>	<p>Achieved.</p> <p>See this report for the model output demonstrating that the LRP is more efficient than orthophosphate treatment.</p>

² pH adjustment was introduced on March 3, 2020, at Marston and Foothills and May 1, 2020, at Moffat. CDPHE confirmed distribution system equilibrium was established on Aug. 14, 2020.

³ See Appendix REG-2 of the Second Semi-Annual Report for 2021.

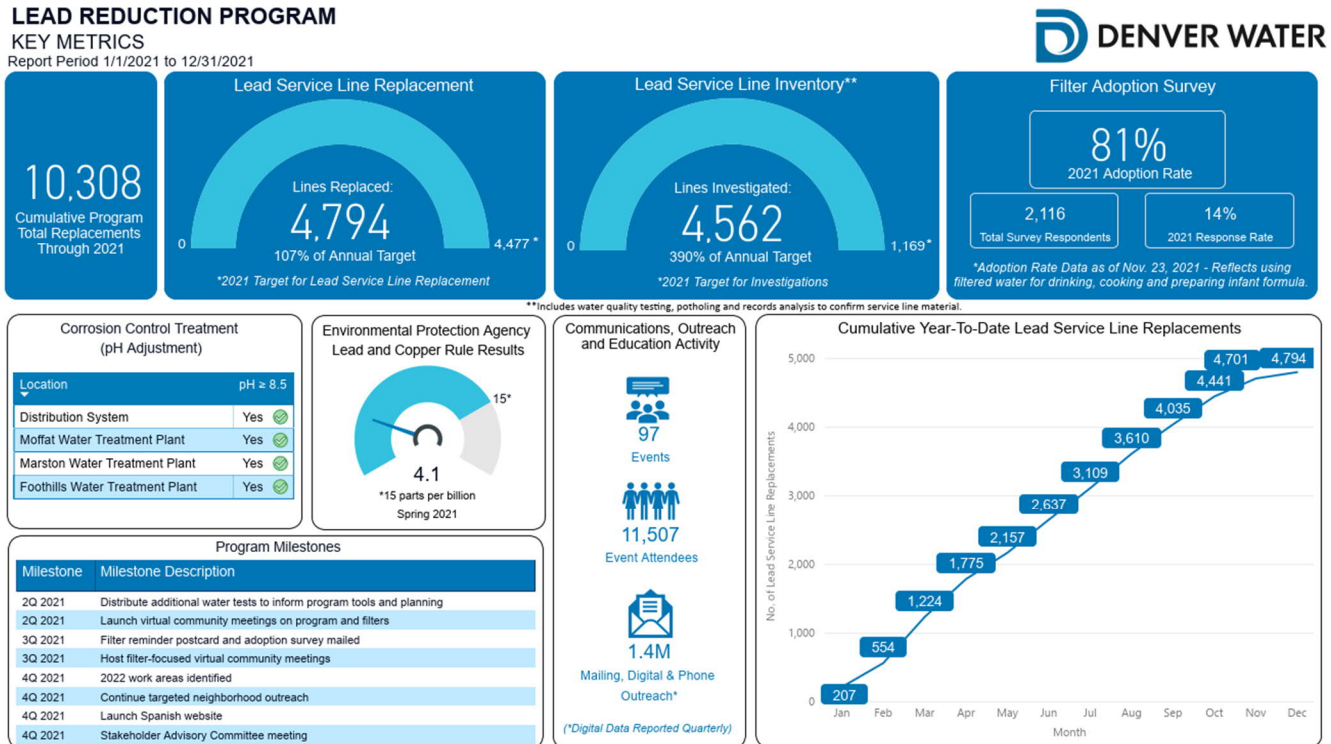
⁴ See Second Semi-Annual Report for 2021. Communicated to CDPHE on Aug. 9, 2021.

Performance Dashboard

A dashboard communicates key metrics to share the progress of the Lead Reduction Program with the public. The dashboard with data for the second program year for the period of Jan. 1 through Dec. 30, 2021, was posted on the Denver Water LRP website on Jan. 24, 2021, in both English and Spanish. The dashboard can be accessed at:

<https://www.denverwater.org/your-water/water-quality/lead/dashboard>.

FIGURE 1. DASHBOARD OF METRICS ACHIEVED IN SECOND PROGRAM YEAR



DATA USED TO EVALUATE THE LRP PERFORMANCE

In this section the sources of data used with the equivalency model are described in the context of the performance metrics identified in the Order.

Corrosion Control Treatment

Section 2.B.i of the Order requires that Denver Water comply with the LCR sampling pursuant to Section 11.26(2) of 5 CCR 1002-11 and 40 C.F.R. Section 141.86. Section 2.C of the Order also requires that Denver Water maintain pH and alkalinity within the ranges designated by CDPHE in its treatment modification decision issued on Nov. 15, 2019 and change notice issued on June 9, 2021.

Corrosion control treatment with pH adjustment is used to manage lead release from homes with copper plumbing with lead solder, although homes with a lead service line that opt out of the LRP are also offered some protection from pH adjustment. Treatment to adjust pH above 8.5 was initiated at the Marston and Foothills Water Treatment Plants on March 3, 2020; treatment was initiated at the Moffat Water Treatment Plant when it was returned to service on May 1, 2020. The positive impact of a higher and more consistent pH in treated water to reduce lead levels measured at the customer's tap is shown in Figure 2 and Figure 3, based on compliance samples and customer-requested samples.

The cumulative 90th percentile lead level in the system before the pH change on March 3, 2020, was approximately 13 µg/L. Soon after the pH stabilized at 8.8, the lead levels started declining and leveled out by August of that same year to a 90th percentile lead concentration below 5 µg/L. This represents a greater than a 60% decrease in lead levels.

The calculated 90th percentile lead concentration for the spring and fall LCR six-month sampling periods are shown in **Error! Reference source not found.** When 2021 results are compared with 2019 (before operating with pH adjustment) and 2020 (which includes a period with pH adjustment), a decrease in lead release is observed in the metric used as a basis of compliance with the Lead and Copper Rule.

TABLE 3. CCT PERFORMANCE BASED ON THE OVERALL 90TH PERCENTILE LEAD CONCENTRATION

LCR Six-Month Sampling Period	2019	2020	2021
Spring Overall 90 th Percentile Lead Concentration	10.0 µg/L	6.7 µg/L	4.1 µg/L ¹
Fall Overall 90 th Percentile Lead Concentration	11.0 µg/L	4.4 µg/L	4.4 µg/L ²

¹ See letter sent to CDPHE dated Aug. 2, 2021.

² See letter sent to CDPHE dated Jan. 18, 2021.

FIGURE 2. CORROSION CONTROL TREATMENT PERFORMANCE AT PROPERTIES WITH LEAD SERVICE LINES

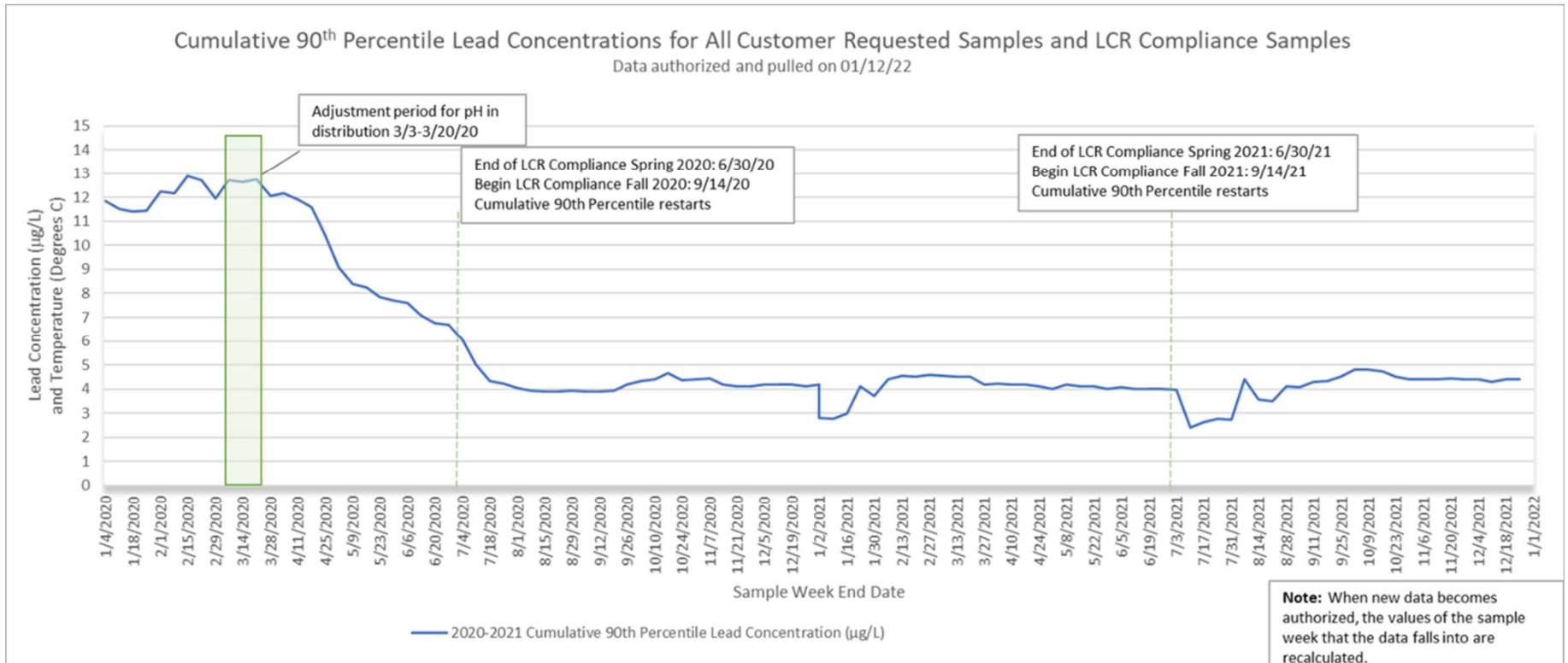
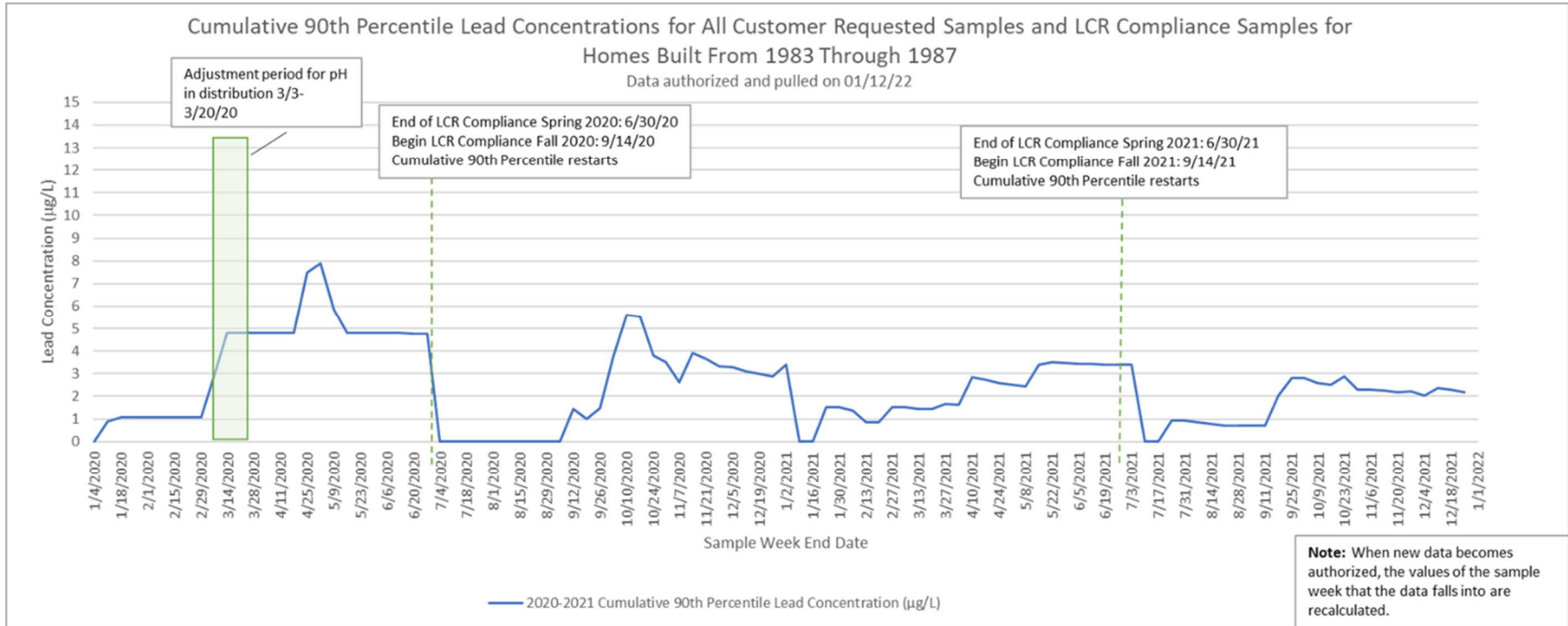


FIGURE 3. CORROSION CONTROL TREATMENT PERFORMANCE AT PROPERTIES WITH COPPER PLUMBING AND LEAD SOLDER



Integrating Data for Lead Levels into the Equivalency Model

The equivalency model uses actual lead levels measured from customer taps to represent lead levels from i) properties with copper plumbing and lead solder and ii) properties with no other known source of lead (i.e., non-lead in the LSL Inventory). Additionally, the model uses actual lead levels from filter performance sampling in the field to represent the reductions to lead levels at LSL homes that use a filter.

For properties with an LSL (i.e., known lead in the LSL Inventory) lead levels are represented by data collected from the pipe rack studies.⁵ This was necessary because the only data available for orthophosphate treatment applied to LSLs were generated by the pipe rack studies. This is a conservative approximation of lead release, as the pipe rack studies have been shown to release higher concentrations of lead than observed in the field.

Finally, to model lead levels after LSL replacement, the properties are treated as copper plumbing with lead solder because the premise plumbing may still contain lead/tin solder.

LSL Inventory and Investigations

Investigations

Section 3.D of the Order requires that “Denver Water . . . [i]nvestigate a minimum of 1.4% of the total estimated number of suspected and possible LSLs in the LSL inventory each Program Year. . .”

As required by the Order, Denver Water continues to conduct investigations of LSLs and make refinements to the LSL Inventory of service line materials connected to its water system. Investigations are performed at properties to improve the assumptions that were used to develop the LSL Inventory. Investigations are counted by property and may include desktop evaluation of available data from Denver Water, assessors, permits, distributors, and customers; water quality sampling; potholing and/or visual inspection. After 15 years of the LRP, there should be no remaining properties in the LSL Inventory categorized as suspected or possible lead and known LSLs should be replaced. The number of properties which are investigated to support a determination of known lead or non-lead are counted toward the required 1.4% of the LSL Inventory investigated each year.⁶

⁵ See Lead Reduction Program Plan for a description of the pipe rack studies.

⁶ The difference in inventory counts from the Second Semi-Annual Report for 2021 and this annual report is due to the differing data cut-off dates: Dec. 3 and Dec. 30, respectively.

Definitions used to categorize the service line material:⁷

Known Lead =	based upon direct evidence that gives a 100% estimated probability that a service line is an LSL.
Suspected Lead =	based upon available data that provides an estimated probability value between 80 to 99% that a service line is an LSL (i.e., homes built before 1951).
Possible Lead =	based on conflicting or missing data that provides an estimated probability value between 50 to 79% that a service line is an LSL.
Unlikely Lead =	2% estimated probability of finding lead.
Non-Lead =	0% likelihood of finding lead.

An investigation is counted if all the following conditions apply:

- 1) The property is originally classified as a suspected or possible lead service (see paragraphs 3.B and 3.D in the Order).
- 2) The investigation was performed independently of LSL replacement and not as part of the 2021 ALSLR Plan (see paragraph 3.D in the Order).
- 3) The investigation was not the result of a customer-requested water quality sample (see paragraph 1.J in the Order).

Investigative potholing is used at properties to improve the knowledge of the inventory at properties that are not included in the 2021 ALSLR Plan. A three-point verification is used to determine the status of a service line:

- 1) Pothole between the main to water meter and again between the water meter to the building.
- 2) Visual inspection inside the building where the service line enters.
- 3) Sample for water quality.

Potholing can be used in combination with other investigative methods to determine that a property is designated “unlikely lead” or “non-lead” (i.e., p-value of 0.02 or 0, respectively). To confirm “unlikely lead” or “non-lead”, there can be no lead or galvanized visually observed from potholing and interior inspections and there can be no contradictions with the desktop records review and/or water quality sampling results.

In some cases, additional investigative steps are necessary to confirm non-lead. A four-point or five-point investigative process is used when either the interior inspection where the

⁷ As defined in paragraphs 1.k, 1.w, and 1.r of the Order for known, suspected and possible lead, respectively. Note that the definition of lead includes galvanized materials.

service line enters is not possible and/or water quality testing is inconclusive (between 1 and 3 µg/L) or not available.

In the absence of an interior inspection where the service line enters, a four-point investigative process is used to determine the material of a service line and includes four visual confirmations of the material:

- 1) Two potholes from the main to water meter.
- 2) Two potholes from the water meter to the building.
- 3) Water quality sample result less than 1 µg/L.

In the absence of a water quality result, or when a water quality result is inconclusive, a five-point investigative process is used to determine the material of a service line and includes five visual confirmations of the material:

- 1) Two potholes from the main to water meter.
- 2) Two potholes from the water meter to the building.
- 3) Inspection at the interior connection.

The total number of investigations completed in the second program year is shown in Table 4.

TABLE 4. NUMBER OF INVESTIGATIONS COMPLETED IN 2021

Number of Properties Investigated ¹	2020	2021
Required Number of Investigations per Year	1,168 (1.4% of suspected and possible lead services from the September 2019 inventory)	
Number of Investigations Completed	3,326 ²	4,562
Number of Investigations Deducted due to Customer Requested Samples	351 ³	N/A

¹ Number meeting criteria of “investigation”, i.e., independent of the 2020 or 2021 ALSLR Program.

² From Annual Report for 2020.

³ See letter from Denver Water to EPA and CDPHE dated Nov. 19, 2021 to acknowledge the deduction.

Integrating the LSL Inventory into the Equivalency Model

The initial LSL Inventory and the inventory from Dec. 30, 2021, are used as an input to the equivalency model to evaluate performance. An overview of the LSL Inventory is provided in Table 5.

TABLE 5. LEAD SERVICE LINE INVENTORY AS OF DEC. 30, 2021

Status of Service Line	Sept. 6, 2019 Submittal (Aug. 8 Data)	Feb. 5, 2020 Submittal (Jan. 28 Data)	Jan. 29, 2021 Submittal (Dec. 30 Data)	Jan. 28, 2022 Submittal (Dec. 30 Data)
	BASE INVENTORY ¹	²	2020 YEAR END INVENTORY ³	2021 YEAR END INVENTORY ^{3,4}
Known Lead	1,066	1,149	7,507	13,275
Suspected Lead	61,374 ⁵	60,549 ⁵	54,178	48,224
Possible Lead	22,106 ⁵	21,788 ⁵	19,894	18,508
Unlikely Lead	89,388	90,745	88,475	88,049
Non-lead	145,766	146,528	150,642	152,623
Total Number of Services	319,700	320,759	320,696	320,679
TOTAL ESTIMATED Number of Lead Service Lines	63,955	63,195	63,211	63,276

¹ The “base inventory” is the basis for the 7% LSL replacements per year.

² Provided an initial inventory within 35 days of the effective date of the Order, per paragraph 3.A.

³ The “year end inventory” is used in the application of the equivalency model to evaluate the performance of the LRP.

⁴ The 2020 and 2021 year-end inventory counts for “known lead” include properties with either known lead or that have had a lead service line replaced.

⁵ “Possible lead” includes service lines where $0.5 \leq p\text{-value} < 0.8$. In the Base Inventory and Feb. 5, 2020, submittal, service lines with $p\text{-value} = 0.7$ were included as “suspected lead.” This was revised in the Third Quarterly Report for 2020.

Number of LSL Replacements Conducted

Section 4.A of the Order provides that “[e]ach Program Year, Denver Water shall replace at least 7.0% of the estimated number of LSLs in its distribution system, or a rate of at least 4,477 LSL replacements each year, whichever is higher.” The overall intention of this requirement is to ensure that all lead service lines are replaced within 15 years following the effective date of the Order.

For the period of Jan. 1 through Dec. 30, 2021, Denver Water fully achieved this metric replacing 4,794 lead service lines. The data for the year-end inventory⁸ are summarized as follows:

- Replacements completed by ALSLR contractors between Jan. 11 and Dec. 2, 2021, the last day of the year that contractors worked in the field.⁹

⁸ See Appendix A-2 Line by Line p-Value Changes by Status (Dec. 4 to 30, 2021) and previous semi-annual reports.

⁹ Properties with a $p\text{-value} \geq 0.5$ in the 2021 ALSLR Plan are verified prior to replacement and are not counted as replaced if copper is observed upon full excavation or pulling the entire service.

- Replacements completed by Transmission and Distribution (T&D) between Jan. 1 and Dec. 29, 2021, including from water main projects, emergency repairs, and critical customers (such as schools and childcare facilities).¹⁰
- Replacements completed by third parties, including tap cuts (cut and reactivated in 2021), reimbursements and properties inspected by Denver Water completed between Jan. 4 and Dec. 28, 2021.¹¹
- There were 19 replacements documented in areas served by distributors.

Based on the base LSL Inventory set forth in Table 5, 7% is equivalent to 4,477 LSL replacements per year and this was maintained as the target for 2022. The number and dates of replacements are used as an input to the equivalency model. The total number of replacements presented in Table 6 is the total for the year and therefore contains more replacements than reported in the Second Semi-Annual Report for 2021.

TABLE 6. TYPE OF LSL REPLACEMENTS COMPLETED IN 2021

Type of LSL Replacement Jan. 1 through Dec. 30, 2021	Denver Water (Water main, Emergency, and ALSLR) ¹	Third Party (Developer, Homeowner, and Other) ²	Total
Full Lead Replacement³	2,225	355	2,580
Partial Lead Replacement, such that no Lead Remains After Replacement⁴	1,748	15	1,763
Full Galvanized Replacement	11	0	11
Partial Galvanized, such that no Lead or Galvanized Remains After Replacement	431	9	440
TOTAL REPLACEMENTS⁵, with No Lead Remaining After Replacement	4,415	379	4,794
Emergency Repair, Partial Replacement (i.e., consent NOT granted, lead remains in the ground)⁶	36	3	39

¹ Includes LSL replacements completed as part of water main replacements, emergency repairs, scheduled replacements, and ALSLR individual and geographic replacements completed by Denver Water or its contractors.

² Includes LSL replacements completed by developers, property owners and other government agencies.

³ Includes LSL replacements described as lead-lead, lead-galvanized, lead-unknown and galvanized-unknown. This also includes unknown-unknown or copper-copper at properties with p-value ≥ 0.5 where the service line was replaced by someone other than the ALSLR contractors (such as a third party).

⁴ Includes LSL replacements described as lead-copper, lead-PEX and copper-unknown. For copper-unknown, if copper is observed at three or more points yet the p-value is ≥ 0.5 , the replacement is included in the LSL replacement count.

⁵ See Appendix A-1 Addresses and Types of Replacement (Dec. 4 to 30, 2021, and Replacements not Previously Reported), and the First and Second Semi-Annual Reports for 2021.

⁶ See Appendix A-4 Properties with a Partial Replacement (Cumulative since LRP Inception).

¹⁰ The last replacement of 2021 was on Dec. 29. T&D replacements are counted as a LSL replacement if i) the initial p-value is ≥ 0.5 regardless of what field crews report for the “prior” material or ii) documentation from another source indicates that lead or galvanized is observed.

¹¹ The last tap cut and reactivation replacement was on Dec. 28, 2021. The last reimbursement and the last inspection of a third-party replacement was on Dec. 21, 2021, and Oct. 12, 2021.

TABLE 7. YEAR OVER YEAR COMPARISON OF LSL REPLACEMENTS

	2020	2021
Total Number of Replacements	5,287 ¹ (8.3% of 63,955)	4,794 ² (7.5% of 63,955)
Number of Replacements Reported after Submission of the Annual Report for 2020³	227	N/A
Cumulative Total Number of Replacements	5,514	10,308
Cumulative Average Annual Replacement at End of Program Year⁴	N/A	5,154 (8.1% of 63,955)

¹ From the Annual Report for 2020.

² Replacements in 2021 completed Dec. 4 through 30, 2021 are included in this number, consistent with Table 6.

³ Replacements in 2020 not previously reported occurred at properties confirmed after the data cut-off used to prepare the 2020 reports. Details are described in Appendix A-1 (42 additions) plus 185 net replacements (234 additions, 49 removals) from 2020 as reported in the First and Second Semi-Annual Reports of 2021.

⁴ Per the Order, the cumulative average must be calculated using the total number of LSLs replaced during the term of the Order divided by the total estimated number of known, suspected, and possible LSLs, consistent with the initial LSL inventory. The average of 4,984 and 5,514 is 5,154 replacements per year. As a percentage, 5,154 of 63,955 is 8.1%.

Filter Adoption Rate

Under section 5.E.i of the Order, “Denver Water must conduct a survey each program year of randomly selected customers enrolled in the Filter Program to receive a minimum of 1,059 responses. The survey must inquire: whether the customer has used the filter for water to make infant formula (if applicable); cooking and drinking; or is using bottled water or a filter device that is certified NSF/ANSI (53) for lead removal not provided by Denver Water for infant formula, cooking and drinking.”

Filters are used to reduce exposure to lead before the lead service line is replaced and for six months following LSL replacement. The rate of filter adoption by customers enrolled in the LRP is used as an input in the equivalency model.

Filter adoption assumes customers are accepting, installing, using, and maintaining their pitcher filter properly, including replacing the filter cartridge at the appropriate time and using the pitcher filter for drinking, cooking, and infant formula, as applicable. The minimum filter adoption rate identified in the Lead Reduction Program Plan necessary to match the performance of the orthophosphate alternative is 65%.

Overview of Survey Employed to Estimate the Filter Adoption Rate

It was previously determined that for a filter adoption rate of at least 60%, a minimum of 1,059 filter adoption survey responses are required to estimate the filter adoption rate with at least 95% confidence and no more than 5% error.¹²

The questionnaire for the formal Filter Adoption Survey was approved by EPA on Sept. 10, 2020.¹³ In the first week of Aug. 2021, the survey questionnaire was mailed to 15,000 random properties, equivalent to approximately 16% of customers enrolled in the Filter Program. The Filter Adoption Survey participants submitted survey responses online or mailed in hard copy responses. Survey respondents were requested to answer questions 1-3 (regarding filter adoption for filtered water used for drinking, cooking, and infant formula) for inclusion in the analysis and calculation of the overall percent filter adoption. A total of 2,116 survey responses were received between Aug. 11 and Nov. 23, 2021. The response rate of almost 14% is indicative of the public's interest – and support – of the LRP.

SURVEY QUESTIONS:

1. **Do you always, or most of the time, use your pitcher provided by Denver Water for drinking water?**
 - Yes.
 - No – I use unfiltered tap water.
 - No – I use bottled water, or a different type of filtration system certified to remove lead in accordance with NSF/ANSI 53 standards (e.g., fridge, under the sink filter, sink-mounted filter).
2. **Do you always, or most of the time, use your pitcher when you are cooking foods where water is a base ingredient (examples: making rice, beans, soup)?**
 - Yes
 - No
- 2a. **If your answer to No. 2 above is no, why are you not using the pitcher for cooking?**
 - Prefer to use unfiltered tap water.
 - Prefer to use bottled water for cooking food.
 - Prefer to use a different type of filtration system certified to remove lead in accordance with NSF/ANSI 53 standards (e.g., fridge filter, under the sink filter, sink-mounted filter).
 - Do not cook.
 - Other

3. **Do you have a formula-fed infant (under 24 months of age) in your household?**
 - Yes
 - No
- 3a. **If yes, what water do you always use to mix the formula (select all that apply)?**
 - Not applicable (I don't feed formula to my infant, or use pre-mix/ready mix)
 - Water from the pitcher filter
 - Bottled water
 - Water filtered by an alternative filter device (fridge filter, under the sink filter, sink-mounted filter or other filter) certified to remove lead in accordance with NSF/ANSI 53 standards
 - Unfiltered tap water

¹² See Appendix III.C.1 (Filter Adoption) of the Lead Reduction Program Plan.

¹³ See the Third Quarterly Report for 2020 (Appendix FIL-29 OMB Approved Adoption Survey Questions).

Definitions Used to Calculate the Filter Adoption Rate

Definitions are provided in Table 8 to describe the consistent application of the data from the filter adoption survey when measuring the filter adoption rate. The percentage filter adoption for drinking and/or cooking and infant formula is used as a single input in the equivalency model.

TABLE 8. DEFINITIONS FOR FILTER ADOPTION RATE AS USED IN THE EQUIVALENCY MODEL

YES to filter use for drinking water	=	Q1 yes pitcher filter + Q1 alternative filter/bottled water
YES to filter use for cooking	=	Q2 yes + [Q2 no <u>and one of</u> Q2a bottled water + Q2a alternative filter + Q2a do not cook + applicable Q2a other]
YES to formula-fed infant¹	=	Q2 yes + [<u>and one or more of</u> Q3a N/A + Q3a pitcher filter + Q3a bottled + Q3a alternative filter]
TOTAL Filter Adoption Rate (as defined in the Order)	=	1 x (yes drinking, yes cooking, yes formula-fed infant) + 0.5 x (yes drinking, yes formula-fed infant only) ÷ total eligible responses
Percent filter adoption for drinking	=	(YES to filter use for drinking water) ÷ total eligible responses
Percent filter adoption for cooking	=	(YES to filter use for cooking) ÷ total eligible responses
Where total eligible responses	=	mailed responses with answers to Q1, Q2 and Q3 + electronic responses using the “submit” button

¹ Includes customers that responded that they do not have a formula-fed infant in their household and customers that are not expecting.

Using the definitions of Table 8 and in accordance with paragraph 5.E.ii of the Order, the total filter adoption rate for 2021 is calculated at 81%. This percentage is used in the equivalency model and shown in Table 9 with the year over year comparison shown in Table 10. Filter adoption rates for drinking, cooking and formula preparation are provided in Table 11.

TABLE 9. YEAR OVER YEAR COMPARISON OF FORMAL FILTER ADOPTION SURVEY

	2020 ¹	2021
Number of OMB Approved Filter Surveys Mailed	20,000	15,000
Number of OMB Approved Filter Surveys Received	3,987	2,116
Filter Adoption Rate used in the Equivalency Model	80%	81%

¹ From the Annual Report for 2020.

TABLE 10. YEAR OVER YEAR COMPARISON OF FILTER ADOPTION RATE ESTIMATES

Question	Percent 2020 ¹	Percent 2021
Q1. Filtered or bottled water used for drinking water	93%	94%
Q2. Filtered or bottled water used for cooking ²	68%	71%
Q3. Filtered or bottled water used for formula-fed infant in households that self-identify as an existing or expecting family ³	97%	93%
Total Filter Adoption Rate as used in the equivalency model⁴	80%	81%

¹ From the Annual Report for 2020.

² Includes those customers that responded that they do not cook.

³ Although the number of respondents using unfiltered tap water for formula preparation remained the same (i.e., three in 2020 and three in 2021), the calculated percentage declined because the total number of responses to question 3 declined (83 responses in 2020 compared with 44 in 2021). This had the effect of magnifying the impact of each “no” response.

⁴ As described in paragraph 5.E.ii the Order and the number used in the equivalency model.

TABLE 11. 2021 FILTER ADOPTION RATE ESTIMATED FROM FILTER ADOPTION SURVEY

Question	Total Responding Yes	Total Responses to Question	Percent Yes
Q1. Filtered or bottled water used for drinking water	1,994	2,116	94%
Q2. Filtered or bottled water used for cooking¹	1,497	2,116	71%
Q3. Filtered or bottled water used for formula-fed infant in households that self-identify as an existing or expecting family	41	44	93%
Total Filter Adoption Rate as used in the equivalency model²			81%

¹ Includes those customers that responded that they do not cook.

² As described in paragraph 5.E.ii the Order and the number used in the equivalency model.

Filter Performance in the Field

Section 5.F.ii of the Order requires that Denver Water “confirm performance of pitcher filters (distributed to customers) in use at Customer Premise.” To confirm that customers enrolled in the Filter Program are effectively using filters to reduce lead exposure, the Order requires that “Denver Water must collect samples from filters in at least 50 locations in use by customers enrolled in the Filter Program who are also enrolled in Denver Water's LCR compliance tap

sampling program.” Results can be used to identify poor performing filters if lead breakthrough is measured; this was the case for one property in 2021.¹⁴ Field testing of pitcher filters has shown high degrees of lead control. The filter effluent from 111 field tests resulted in 99 measurements that were below the method detection limit of 1 µg/L.^{15,16}

Integrating Filter Adoption and Performance into the Equivalency Model

The filter adoption rate is used in the equivalency model by randomly selecting the number of remaining lead service lines equal to the adoption rate. For example, in 2021, there were an estimated 63,211 lead service lines at the beginning of the year¹⁷, with 4,794 being replaced by the end of the year.¹⁸ The adoption rate of 81%¹⁹ is interpreted as 51,201 are filtered and 12,010 are assumed unfiltered. These service lines are assigned lead concentrations randomly drawn from the observed distribution of lead in filter effluent generated from filter performance testing in the field. This reduces lead concentrations assigned to properties with a lead service line and protected via the pitcher filter to concentrations far below the expected levels that would have occurred with only the addition of orthophosphate.

The results of the 2021 filter adoption survey were analyzed to identify sociodemographic factors that may correlate to lower or higher filter adoption. Using the survey results, strategies and efforts to target communities with lower adoption rates and address key themes from the survey are identified.²⁰

LRP PERFORMANCE USING THE EQUIVALENCY MODEL

Section 7.C of the Order requires a “comprehensive evaluation of the LRPP performance using the equivalency model described in the LRPP with updated inputs based on actual LRPP implementation for: 90th percentile lead levels at LSL and copper with lead solder sites after operation of increased pH and alkalinity adjustment as CCT, number of LSL replacements conducted, filter adoption rate, and filter performance in the field.” The metric is produced using actual performance data for various elements of the LRP to show the program “as implemented continues to be ‘at least as efficient as’ orthophosphate treatment in reducing lead exposure on an annual basis.”

¹⁴ See First Semi-Annual Report for 2021 for details.

¹⁵ This number reflects a correction to the First Semi-Annual and Second Semi-Annual Report for 2021. 55 (54 in first semi-annual report) + 56 (60 in second semi-annual report) = 111 samples.

¹⁶ See First and Second Semi-Annual Reports for 2021 for individual results.

¹⁷ See Table 5.

¹⁸ See Table 6.

¹⁹ See Table 11.

²⁰ See Appendix A-3 Summary of Sociodemographic Indicators from 2021 Formal Filter Adoption Survey.

The equivalency model is a statistical model that compares modeled lead concentrations at each service line in the service area for conditions representing LRPP implementation versus the projected performance of orthophosphate, designated as optimal corrosion control treatment. LRP conditions include the use of pH and alkalinity adjustment as corrosion control treatment, accelerated lead service line replacement (in addition to replacements routinely carried out as part of water main projects, emergency repairs and by third parties), pitcher filters for lead reduction prior to LSL replacement, and communications, outreach and education. Conditions for OCCT include the use of orthophosphate and the historical average rate of routine lead service line replacements.

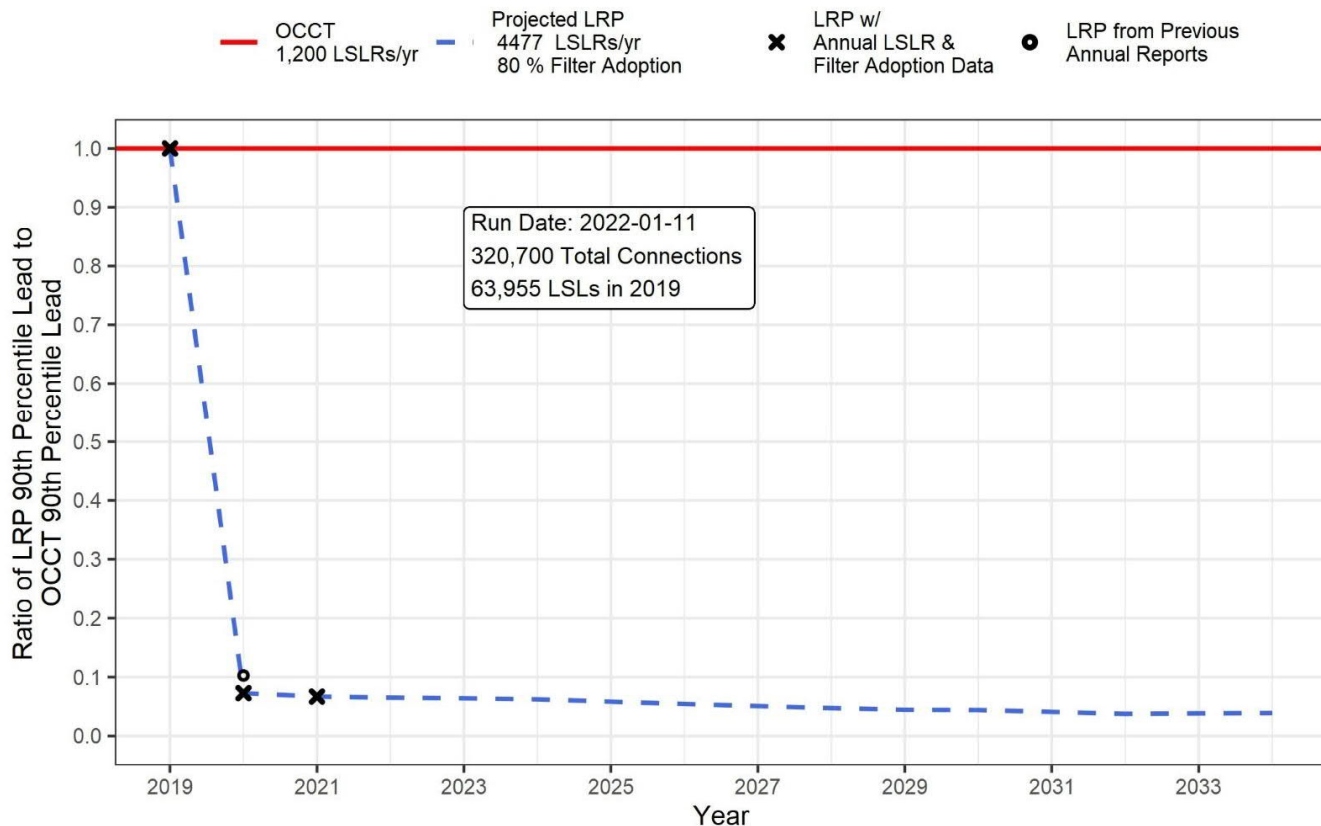
The equivalency model includes actual data from:

- 1) Lead concentrations from LCR compliance samples and customer requested samples at properties with copper plumbing and lead solder and other sites after operation of increased pH adjustment as CCT.
- 2) Number of LSL replacements conducted.
- 3) Filter adoption rate.
- 4) Filter performance in the field.

The primary output of the model is an indexed performance of the LRP to the presumed OCCT conditions for each year, as shown in Figure 4. The index is calculated as the 90th percentile lead concentration from the LRP model divided by the 90th percentile lead concentration from the OCCT model. Results less than or equal to 1.0 demonstrate the LRP is “at least as efficient as” OCCT and in compliance with the Order. The points in Figure 4 reflect actual conditions each year (shown as a black X), the lines reflect projected numbers for future years (shown in solid red for the OCCT condition and dashed blue for the LRP condition).

Lead service line replacements for OCCT conditions are based on the historical rate of 1,200 replacements completed annually, which is assumed constant. For the LRP condition, there were 4,794 confirmed LSL replacements in 2021, with future LSL replacements assumed equal to the 7% mandated annual target (7% of 63,955 = 4,477). A filter adoption rate of 80% was used for each year based on the 2020 and 2021 filter adoption rates.

FIGURE 4. EQUIVALENCY MODEL OUTPUT FOR 2021



The model outputs of Figure 4 indicate that the LRP approach has resulted in systemwide lead concentrations that are less than 0.10 times the expected OCCT lead concentrations when measured at the 90th percentile. These results indicate that systemwide lead concentrations are lower than they would have been under OCCT conditions. Thus, better performance of the LRPP is demonstrated compared with OCCT for 2021. If the LRP continues to obtain these metrics into the future, the LRP should be more efficient than OCCT for the duration of the program, as shown by the dashed blue line.

The value provided in the past annual report is shown with the black circle. This value differs from the current prediction because the most current water quality results and LSL replacement data were used. In the last report, 5,287 LSL replacements were confirmed in 2020. Since that time, additional LSL replacements were confirmed for a new total of 5,514. Although the additional LSL replacements were not counted toward the 7% target, they are counted in the model because they were verified to have happened in 2020.

The results of Figure 4 indicate that system-wide lead concentrations are lower than they would have been under OCCT conditions. Thus, Denver Water has again demonstrated better performance of the LRP compared with OCCT for 2021.

ADDITIONAL REQUIREMENTS AND DELIVERABLES

Since the effective date of the Order, Denver Water has documented milestones and submissions required in the Order and the LRPP. A summary of submissions and deliverables provided to CDPHE and EPA is provided in Table 12; actual documents have been provided previously.

TABLE 12. SUMMARY OF METRICS ACHIEVED IN 2021

Reference Paragraph	Metric and Description	Result
2.A	Begin adjustment of pH and alkalinity for CCT no later than March 20, 2020.	See First Quarterly Report for 2020 and March and May 2020 monthly reports.
2.B.iii	Monitor water quality parameters following LCR six-month reporting periods.	See CCT Implementation Plan first submitted on March 6, 2020 and approved by EPA on July 17, 2020.
2.B.iv	Identify and address elevated lead levels. Submit Elevated Lead Response Plan within 90 days of effective date.	See monthly reports for 2021 for response description (i.e., replace LSL). See CCT Implementation Plan first submitted March 6, 2020.
2.C	Maintain minimum target of 8.5 for pH across the distribution system during first year of operation.	See monthly reports for 2021 for data for pH measured in treated water and the distribution system.
3.A	Complete the initial LSL inventory no later than 35 days after the effective date. Maintain LSL inventory and update on annual basis to account for replacements.	See letter submitted Feb. 4, 2020. See semi-annual reports and this annual report.
3.B	Incorporate investigations of service line materials into the required LSL inventory annual updates.	See semi-annual reports and this annual report.
3.C	Publish LSL inventory to public map on the external customer website no later than 70 days after the effective date.	See letter submitted March 5, 2020.
3.D	Investigate a minimum of 1.4% of the total estimated number of suspected and possible LSLs in the LSL inventory each program year.	See semi-annual reports and this annual report.
4.A	Implement accelerated LSL replacement within 90 days of the effective date.	See letter submitted March 26, 2020.
4.E	Offer and conduct one-time lead sampling at homes where LSLs have been replaced within six months post-LSL replacement.	See semi-annual reports.
4.H	Undertake reasonable efforts to obtain permission from new property owner (if refused by previous) within 91 days of a change in account records. Maintain records of the specific addresses of all structures at which the property owner does not consent to LSL replacement.	See semi-annual reports.

Reference Paragraph	Metric and Description	Result
4.I	Achieve at least a 7.0% cumulative average Program Year LSL replacement rate.	See this report.
5.A	Initiate initial filter distribution, six months of replacement cartridges and education materials within 90 days of the effective date. Complete distribution of the educational materials, filters, and cartridges within 270 days of the effective date.	See letters submitted March 26 and Sept. 27, 2020.
5.B	Deliver replacement cartridges until six months after replacement of an LSL or until the time the service line of the property is confirmed as non-lead.	See semi-annual reports for 2021.
5.C	Provide new residents with filter educational materials no later than two weeks following the change in customer account. Distribute a new filter and replacement cartridges to new customer within 35 days of the change in customer account.	See semi-annual reports for 2021.
5.D	Offer free drinking water lead testing to select households and offer a filter and replacement cartridges if first draw shows lead concentrations above 3 µg/L.	See semi-annual reports for 2021.
5.E.i	Receive a minimum of 1,059 filter adoption survey responses.	See Second Semi-Annual Report for 2021 and this annual report.
5.F.i	Test lead removal effectiveness of twelve units of each type of filter within 90 days of effective date.	See letter submitted Feb. 13, 2020.
5.F.ii	Collect samples from filters in at least 50 locations enrolled in the Filter Program and also in the LCR compliance tap sampling program.	See semi-annual reports for 2021.
5.G	Make direct contact with lead outreach and education materials to 95% of all customers enrolled in the Filter Program in every Program Year.	See letter submitted Aug. 9, 2021.
6.B	Demonstrate using the updated equivalency model results that the LRPP is “at least as efficient as” orthophosphate treatment.	See this annual report.
7.B.i.a	Provide an elevated lead response plan within 90 days of the effective date.	See CCT Implementation Plan first submitted March 31, 2020.
7.B.i.b	Report elevated lead levels and actions taken to reduce exposure within 10 days after the end of each six-month period in the second Program Year.	See semi-annual reports for 2021.
7.B.i.c	Report results of all lead and copper compliance tap sampling and customer requested samples within 10 days after the end of each six-month period in the second Program Year.	See monthly and semi-annual reports for 2021.
7.B.i.d	Report CCT water quality parameters for pH and alkalinity monthly, no later than the tenth day of the following month.	See monthly reports for 2021.

Reference Paragraph	Metric and Description	Result
7.B.i.e	Report all lead and water quality results collected as part of the investigation of LSLs and post LSL replacement and service line material monthly, no later than the tenth day of the following month.	See monthly reports for 2021.
7.B.ii	Report the metrics of the LSL inventory within 10 days after the end of each six-month period in the second Program Year.	See semi-annual reports for 2021.
7.B.iii	Report the metrics of the LSL replacements within 10 days after the end of each six-month period in the second Program Year.	See semi-annual reports for 2021.
7.B.iv	Report the metrics of the filter distribution, refusals and performance within 10 days after the end of each six-month period in the second Program Year.	See semi-annual reports for 2021.
7.B.v	Report results achieved under the compliance metrics (2.C, 3.D, 4.I, 5.G and 6.B) within 10 days after the end of each six-month period in the second Program Year.	See semi-annual reports for 2021.
7.B.vi	Summarize the activities conducted under the COE program within 10 days after the end of each six-month period in the second Program Year.	See semi-annual reports for 2021.
7.B.vii	Summarize the activities conducted and designed under the HE&EJ principles within 10 days after the end of each six-month period in the second Program Year.	See semi-annual reports for 2021.
8.G	Begin a multi-media public information campaign and customer notification to notify customers of the Order within 90 days of the effective date.	Launched on March 23, 2020.
LRPP III.E (p 70)	Monthly trending of LCR compliance samples and customer requested samples.	See monthly reports and this annual report.
LRPP III.E (p 70)	Install automated pH control loops at all three treatment plants by March 2020.	Installed as described in Table 2.
LRPP III.E (p 65)	Targeted communications for 1983-87 homes to self-identify expecting and existing families with formula-fed infants and children up to 2 years of age; offer water quality sampling; provide filter if lead measured > 3 µg/L.	Described with sections 5.D and 7.B.vi. Outreach materials distributed Nov. 12, 2021.
LRPP III.E (p 71)	Complete distribution system modeling, evaluating pH, disinfection by-products and water age by Jan. 31, 2020. Submit nitrification control plan by June 30, 2020 to address sampling, monitoring and flushing. (Nitrification Control Plan dated July 7, 2020).	Revised plan submitted July 15, 2021.
Voluntary	Share results from continued operation of the pipe racks. (Lead Pipe Rack Results Technical Memo dated July 6, 2020, and covering sampling from Oct. 1, 2019, to June 15, 2020).	Submitted July 6, 2021, and remaining data to be submitted in early 2022.

Reference Paragraph	Metric and Description	Result
LRPP III.B (p 51)	Use results from investigations to update the predictive model which is used to plan and prioritize efforts of the COE Plan, ALSLR Program and Filter Program.	Ongoing. See semi-annual reports for 2021.
LRPP III.D (p 62)	Provide education and filters to residents of multi-family properties on the Service Line Refusal List.	Ongoing.
LRPP III.D (p 57)	Replace LSL at properties with consistently high lead release and critical care customers.	See elevated lead response summary in semi-annual reports.
LRPP III.D (p 58)	Complete approximately 2,000 investigations per year in the first five years of the Lead Reduction Program to update the predictive model and improve the quality of information in the LSL Inventory.	See Table 4 and semi-annual reports for 2021.
LRPP III.D (p 60)	Property owners will be reminded via English and Spanish signage placed at the limits (ends of streets) within geographic work areas four to five weeks in advance of construction.	Ongoing. Implemented July 20, 2020.
LRPP III.D (p 60)	Provide flushing instructions following LSL replacement.	Ongoing. Provided to all customers as part of the post-LSL replacement education package.
LRPP III.C (p 56)	If the localized filter adoption rate is less than 75%, additional outreach and education will be provided to that area.	Not applicable this reporting period (see Error! Reference source not found.).
LRPP III.C (p 55)	Survey filter use as part of ALSLR Program following LSL replacement.	Ongoing. See semi-annual reports.
LRPP III.E (p 64)	Targeted messaging to homes with copper piping and lead solder to flush the tap after periods of non-use.	Ongoing. See semi-annual reports.
LRPP III.F (p 74)	Engage Stakeholder Advisory Committee to support Learning by Doing element.	Ongoing. See semi-annual reports.
LRPP V (p 77)	Commitment to continue to consult and collaborate with the organizations and HE&EJ experts, stakeholders, community members and customers to continually improve upon integration of the HE&EJ principles with the LRP.	Ongoing. See semi-annual reports.
LRPP V (p 79)	Collaborate with other agencies to address lead exposure from all sources.	Ongoing. See semi-annual reports.

DEVIATIONS (AND CLARIFICATIONS)

Under paragraph 7.C of the Order, Denver Water is required to “document any deviations from the LRPP during the most recent Program year.” During the 2021 Program Year, input was sought from EPA on clarifications and, in certain instances, permission to deviate from the Order to address the administration of the LRP, as summarized below.

Deviations

- Modify schedule for reporting filter survey HE&EJ indicators from semi-annual reporting and instead include the reporting in the Annual Report for 2021, as prescribed by clause 7.B.vii of the Order. The analysis uses sociodemographic data from the formal filter adoption survey which continued to be collected through November of 2021. Results from the 2021 survey are appended to this report.
- Adjust submission protocols from a single email submittal to both EPA and CDPHE to direct submittals provided separately to CDPHE (via the secure portal) and EPA (via secure email) for routine reporting (monthly and semi-annual reports, for example) and non-routine reporting (details regarding elevated lead levels or the occurrence of lead breakthrough in the filter performance testing in the field, for example).
- Modify protocols to offer post-LSL replacement sampling to customers that seek reimbursement for replacements by third parties. The duration between completing the work to replace the service line and seeking reimbursement can exceed the six-month time frame to offer post-LSL replacement sampling. Offer letters continue to be provided to these customers, based on the date that Denver Water is notified of the request for reimbursement.

Clarifications

- Investigation metric: Per section 3.B. of the Order, investigations are undertaken using water quality sampling, potholing, visual inspections, or other means to support the determination of the service line material. Clarification was sought and confirmed on Jan. 5, 2022, that an investigation that confirms the current status of the service line without resulting in a change in its p-value (i.e., a material designation of lead) can be counted as an investigation to support the determination of the service line material.