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2021

## My Private Lead Service Line Replacement

Lillian C. Jeznach

*Roger Williams University*, [ljeznach@rwu.edu](mailto:ljeznach@rwu.edu)

Joseph E. Goodwill

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### Recommended Citation

Jeznach, L.C., & Goodwill, J.E. (2021). My Private Lead Service Line Replacement. *Journal-American Water Works Association*, 113(1), 40-48.

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# **My Private Lead Service Line Replacement**

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Lillian C. Jeznach and Joseph E. Goodwill

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Accepted for publication in the Journal of the American Water Works Association (JAWWA)

4 **3 Key Takeaways:**

- 5 1. A homeowner’s decision to replace their lead service line can be confounded by factors  
6 including their understanding of the science, their perceptions of their lead exposure  
7 risks, and the cost of the work.
- 8 2. First draw and 5-minute flush samples may not capture the peak lead concentration,  
9 further confounding a customer’s replacement decision.
- 10 3. In my case, lead service line replacement significantly lowered lead concentrations after  
11 stagnation based on sequential sampling.

12

13 The science around lead service line (LSL) replacement and drinking water quality is important  
14 to water professionals, but they are also topics of concern, and often confusion, for private  
15 homeowners may have to weigh the documented risks of lead exposure in the context of their  
16 own lives (e.g. what is the age of the house? Are there pregnant women or children at home?)  
17 against potentially expensive, even cost prohibitive replacement options.

18 My unique position as both an environmental engineer, professor, and a homeowner with an LSL  
19 made me well aware of the documented risks of lead in the literature, but even with my informed  
20 perspective, I found the decision to replace was not so straightforward given the information  
21 from my local utility’s free lead sampling program, weighing the replacement costs, and the  
22 other impacts the replacement might have on my property. So together with a colleague, one of  
23 my undergraduate students, and my husband (who is also an engineer by training and willing to  
24 go along with my experiment) we decided to capture a homeowner’s decision-making process  
25 based on our scientific backgrounds and engineering judgement. Our experience may be helpful

26 in communicating the potential benefits of a full lead service line replacement to homeowners  
27 who must start the process of replacing a private LSL.

28

## 29 **LEAD AND MY HOME**

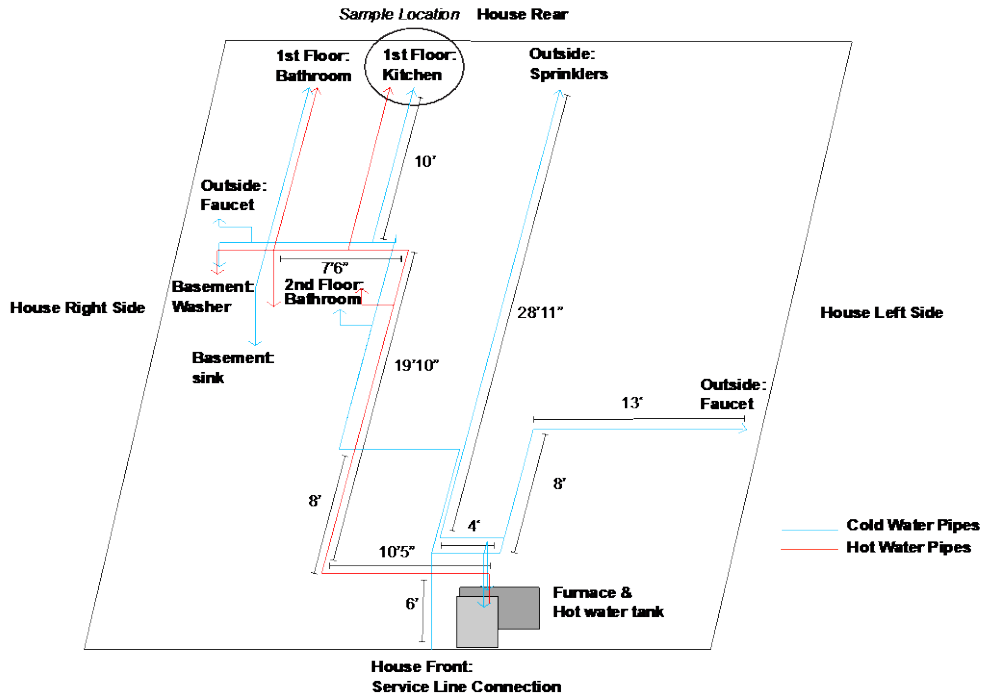
30 Lead in drinking water originating from LSLs and other premise plumbing is a serious public  
31 health concern, particularly for its effects on the cognitive development of children. LSLs are the  
32 largest source of lead in drinking water when they are present in public systems. Most countries  
33 have banned the use of new lead pipes in drinking water distribution systems, but there are  
34 legacy lead pipes in many drinking water systems throughout the industrialized world including  
35 the US. Because lead is a toxic metal and harmful to humans, particularly pregnant women and  
36 children, at very low exposure levels, the maximum contaminant level goal set by the United  
37 States Environmental Protection Agency (USEPA) for lead in drinking water is zero.

38 USEPA sets action levels for lead and copper sampled at the consumer's tap after 6 hours  
39 stagnation, and if lead concentrations exceed 15 ppb or copper concentrations exceed 1.3 ppm in  
40 more than 10% of customer taps sampled, the system must take additional actions to control  
41 corrosion, e.g., additional water quality parameter monitoring, source water  
42 monitoring/treatment, corrosion control, and public education (USEPA, 1991). One action that a  
43 utility might take is to fully replace or partially replace lead service lines within their distribution  
44 network.

45 Replacing LSLs can be confounded by ownership differences across the length of pipe  
46 depending on local ordinances, right-of-ways, and property history. It is common for LSLs to

47 have a portion under ownership of the water provider, often from the curb to the water meter,  
48 with the rest of the pipeline belonging to the homeowner. A full LSL replacement replaces the  
49 entire line, both public and private sections, from the utility-owned water main to the private  
50 residence. Full replacement is considered the best option since it completely removes any lead  
51 pipe that could contact the potable supply (assuming the household plumbing is lead free).  
52 However, replacing a service line is costly and requires homeowner consent and cooperation. In  
53 many cases, public water utilities pay to replace the public system's portion of the water  
54 distribution system while the homeowners choose to replace the private service line to their  
55 homes (i.e., full LSL replacement), or they may decide they cannot or won't, keeping some lead  
56 pipe in their plumbing network (i.e., partial LSL replacement).

57 My home is a 1920's American Foursquare (four bedroom, 1.5 bath – see Figure 1) located just  
58 outside of Providence, Rhode Island. The home had a partial lead line at the time I bought it in  
59 the Summer of 2017, and in my case, the utility owned public main under the street had also  
60 been recently replaced. The length of the LSL from the curb stop to the basement is  
61 approximately 40 ft. Taking the age of the home into consideration, interior plumbing appears to  
62 be a mixture of copper and possibly brass. It is likely that lead solder was used in some areas of  
63 the interior plumbing system, although this was not thoroughly examined or confirmed because  
64 of some of the premise plumbing is not immediately accessible.



65

66

Figure 1: Home plumbing schematic

67 Our drinking water is provided by Providence Water (PW), which draws water from the Situate

68 Reservoir in Rhode Island. The reservoir has low pH, alkalinity, and turbidity, and it has

69 seasonal turnovers as typical for water bodies in the northeastern US. Raw water is treated

70 conventionally with aeration, coagulation-flocculation, sedimentation, filtration, and disinfection.

71 Additionally, the water receives fluoride as well as lime addition, and the pH is adjusted for

72 corrosion control through the distribution system. A small portion of the PW system also

73 receives orthophosphates as a pilot program for improved corrosion control.

74 PW has tracked recent elevated levels of lead in some homes and buildings within their

75 distribution network that violate USEPA's Lead and Copper Rule. In 2018, PW's 90th percentile

76 level was 22 ppb, which is above the lead action limit of 15 ppb. PW has responded by investing

77 45 million dollars to replace LSLs, and it has made changes to its treatment process to improve

78 corrosion control including maintaining a high pH (~10) in the distribution system and piloting  
79 orthophosphate as a corrosion inhibitor.

80 PW is also increased rehabilitating water mains, improved flushing programs, and expanding  
81 public education about lead in drinking water. Besides mailing informational pamphlets, PW also  
82 provides a “lead service location map” on their website ([www.provwater.com](http://www.provwater.com)) where  
83 homeowners can identify if they currently have a utility-owned public lead service line. PW also  
84 offers lead testing kits free of charge to its customers; for those testing PW water in their homes,  
85 free kits are picked up and dropped off at their Providence office. If a homeowner has a privately  
86 owned lead service line, PW has incentivized replacement of the old line with a 0% interest 10-  
87 year loan program – this decreases the upfront expense of the replacement cost, roughly \$3,500,  
88 as noted in flyers mailed to homeowner customers of PW in the spring of 2020.

## 89 **APPROACHING THE DECISION AS A SCIENTIST AND HOMEOWNER**

90 Even though I am well informed about the risks of lead exposure from LSLs from my  
91 professional experience, I found my questions as a homeowner, specifically the options and their  
92 costs, delayed my decision to replace the line. Together with my husband, we tried to assess the  
93 various ways we could be exposed to lead in our home. Typically, we only drank water from the  
94 refrigerator equipped with a filter (NSF 53 certified to remove lead), and we are both healthy  
95 adults. However, I was pregnant and that put me in the at-risk category, since lead  
96 bioaccumulates and can be transferred from the mother’s bones to the fetus, possibly affecting  
97 fetus brain development.

98 As parents-to-be, we were interested in minimizing exposure from the potential sources of lead  
99 in our home, such as lead-based paint, solder in plumbing, and fixtures. Lead solder from

100 premise plumbing can contribute lead to water, and given the age of the house, we likely had this  
101 throughout our system. There is also lead paint inside and outside of the house, but a lead paint  
102 inspector encapsulated any chipping lead paint throughout, so we considered the risk of lead  
103 exposure via paint to be low after these minor fixes were made.

104 Our second consideration was the cost to replace our LSL, i.e., could we afford it with other  
105 expenses? Should we get a loan? At the time of the replacement, Providence water was offering  
106 a 0% 3-year loan at the time to replace the private side of the LSL. The utility now offers a 10-  
107 year 0% interest loan. How does the cost of replacement compare to purchasing filters and only  
108 drinking filtered water? We estimated based on the cost of a typical (Brita) filter, average  
109 household water consumption, and the life of a filter that after 20 years the cumulative cost of the  
110 filter would be greater than the LSL replacement, assuming the LSL replacement is \$5,000.

111 When we asked a realtor about whether or not this investment would increase the value of our  
112 home, he thought that it might, but it certainly would not decrease the value. Therefore, if we just  
113 considered the costs of the replacement, replacing the LSL would makes sense if we planned on  
114 being in our home for a long time (20 years) but using a Brita type filter if we planned on only  
115 living there for a few years. Of course, committing to using a filter for drinking water would  
116 require that we remember to keep up with filter replacements in order to effectively remove the  
117 lead from the water.

118 Our other considerations were mostly cosmetic concerns, but they are valid issues to keep in  
119 mind as they will likely be important to most homeowners. The sidewalk in front of the house by  
120 the curbstop would be excavated and would need to be replaced at our expense by a contractor.  
121 Our lawn would need to be excavated (much to my husband's disappointment), and we were told



122 that excavation could increase up to our porch if the line could not be pulled out of the soil from  
123 a distance. If they needed to excavate under the porch then it would require further work by a  
124 contractor to fix at our expense. The sprinkler system would also need repairs after the  
125 replacement as the excavation would likely go through the sprinkler line.

126 As an engineer, I suspected that the greatest risk of exposure to lead was likely the service line to  
127 the home. Even though our home's premise plumbing likely has lead solder, I assumed that the  
128 40 ft long LSL was the largest potential source of lead based on surface area exposure if water  
129 lay stagnant during periods of no use. The LSL also takes the most time to flush given its  
130 distance from the tap. Additionally, if water quality from the utility were to change and lead were  
131 inadvertently released from the LSL as a result of changing water conditions at the treatment  
132 plant, we would be at a greater risk. I decided that collecting some data on my current lead  
133 concentrations after periods of stagnation would increase my confidence in my hypothesis that  
134 the LSL posed a risk to lead exposure in our home. Additionally, Providence, RI, has prior  
135 violations of the LCR and so further collection of data from a typical older home in the area  
136 before and after a LSL replacement would make an interesting case study.

137 Many water utilities offer various forms of lead testing for their customers, some free and some  
138 at a cost. I followed the directions on the home test kit that I picked up for free from PW, then  
139 sampled from my kitchen sink after an 8-hour stagnation in two 0.5 L sample bottles. This  
140 scenario is inherently conservative since it mimics typical overnight minimal water use  
141 conditions and increases the opportunity for higher lead levels at the location where someone  
142 living in the home may consume water following the stagnation. No other water was running at  
143 the time of the sample collection. I collected a first draw sample and a 5-minute flush sample,

144 which represented the water quality after approximately 17 L of water were flushed from the  
145 plumbing. The next day I returned the samples to PW and waited for the analysis.

146 The first sample collected from the first draw of 0.5 L of water from the faucet after stagnation  
147 contained 4.5 ppb of lead while the the sample collected after 5 minutes of flushing contained 3.1  
148 ppb of lead. Both results were less than the lead action level, and if I didn't have some  
149 background on the science of lead, I might have thought that although I have a LSL, there was  
150 little risk from these low lead levels.

151 What if the results from my lead test were compared to sequential sampling of lead after  
152 stagnation – would I feel more confident making the decision to replace my LSL? I was able to  
153 determine how many liters of water to collect in order to draw water that has been stagnated in  
154 the service line based on measuring temperature changes in the water prior to the sampling  
155 effort. The hot water tank in my basement is directly next to the service line entrance to the  
156 basement. When I turn on the hot water after things have sat overnight, it takes approximately 4L  
157 of water running through the pipes before it becomes increasingly warmer, indicating water  
158 originating from the hot water tank had reached the tap (see Figure 2). Based on this information,  
159 I determined that 15 sequential samples from the kitchen faucet (two 250 mL and thirteen 1 L  
160 samples) were required to analyze for lead. I assumed samples prior to 4 L originated from the  
161 house plumbing and samples after 4 L originated from the lead service line outside the house.

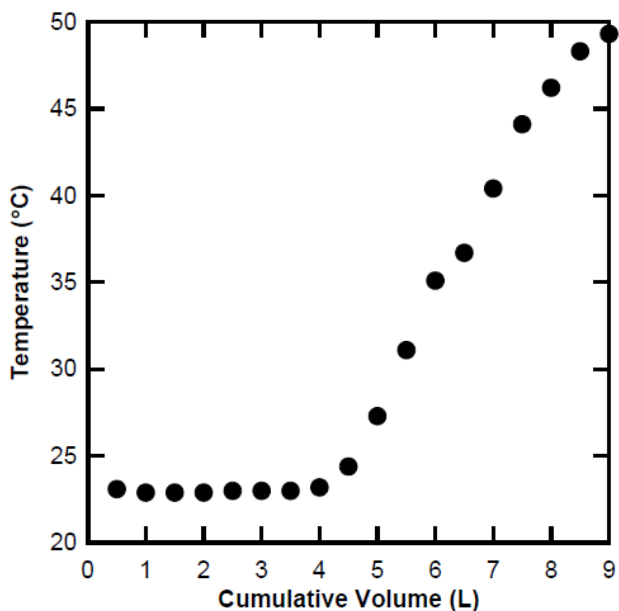


Figure 2: Preliminary Water Temperature Sampling

162  
 163  
 164 After an 8 hour stagnation period, sequential samples were collected and each were analyzed for  
 165 temperature, conductivity, pH, and free chlorine by myself, with assistance by my colleague  
 166 Joseph Goodwill (Assistant Professor of Civil and Environmental Engineering at the University  
 167 of Rhode Island), and my undergraduate student, Ashley Bosse. It was a hot day in August when  
 168 the samples were drawn and we noted a temperature change after 4 L of water were sampled,  
 169 presumably when cooler water was withdrawn from the service line in the ground. Conductivity  
 170 was within the expected range for treated surface water and it didn't change significantly with  
 171 cumulative volume. Free chlorine increased with increasing cumulative volume collected, which  
 172 is expected since chlorine residual decays as water ages. Finally, pH was also consistent with  
 173 cumulative sampled volume; PW maintains a high pH (around 10) in the distribution system as  
 174 part of its lead corrosion control strategy.

175 The samples were analyzed for lead, copper, and iron using ICP-MS. Average copper and iron  
 176 concentrations were 1.68 ppb (standard deviation of 0.68 ppb) and 53.8 ppb (standard deviation

177 of 2.5 ppb), respectively. The copper concentration was well below the action level of 1.3 ppm.  
178 In general, there was no significant change in copper or iron concentrations between sequential  
179 samples.

180 Lead concentrations averaged 11.8 ppb (standard deviation of 7.2 ppb) and a slug of higher lead  
181 concentrations were withdrawn from the faucet between 3.5 L and 7.5 L with a maximum  
182 concentration of approximately 30 ppb measured at the cumulative withdrawal volume of 5.5 L –  
183 note, this is twice the lead action level of 15 ppb. Based on when the water changed temperature,  
184 the spike in lead levels measured between these cumulative collected volumes is consistent with  
185 our previous estimate of water originating from pipes from outside the house after 4 L were  
186 drawn. After 7.5 L of water were drawn, the lead concentration decreased to approximately 9  
187 ppb.

188 Based on the results of sequential sampling, I felt more confident in spending money to replace  
189 my lead service line. The data supported that the lead was coming from the service line, so  
190 replacing this service line should minimize the risk of exposure after stagnation periods and in  
191 the event there was an inadvertent change in finished water quality from the utility, like lower  
192 pH, that could easily result in more pipe corrosion and lead release.

## 193 **THE REPLACEMENT**

194 In August of 2018, a local contractor, in collaboration with PW and the city, replaced my LSL.  
195 Work was carried out over a course of one day following standard service line replacement  
196 protocols. After water service was shut off at the curb stop, the LSL was disconnected in the  
197 basement at the water meter, and two concrete pads of the sidewalk were excavated. An attempt

198 was made to remove the LSL by pulling it out from the excavated sidewalk area; unfortunately,  
199 this didn't work, so approximately 20 ft the front lawn had to be excavated.

200 The LSL was 3/8 inches in diameter and replaced by a 1-inch type k copper pipe. Following  
201 replacement and reconnection, the excavation of the front lawn was backfilled. Water was  
202 flushed through all household plumbing by the contractor in accordance with replacement  
203 guidelines as follows. Outdoor spigots were opened completely and flushed for 15 minutes.  
204 Indoor fixtures (with aerators removed) were flushed with cold water beginning on the first floor  
205 and ending on the second floor for 30 minutes each.

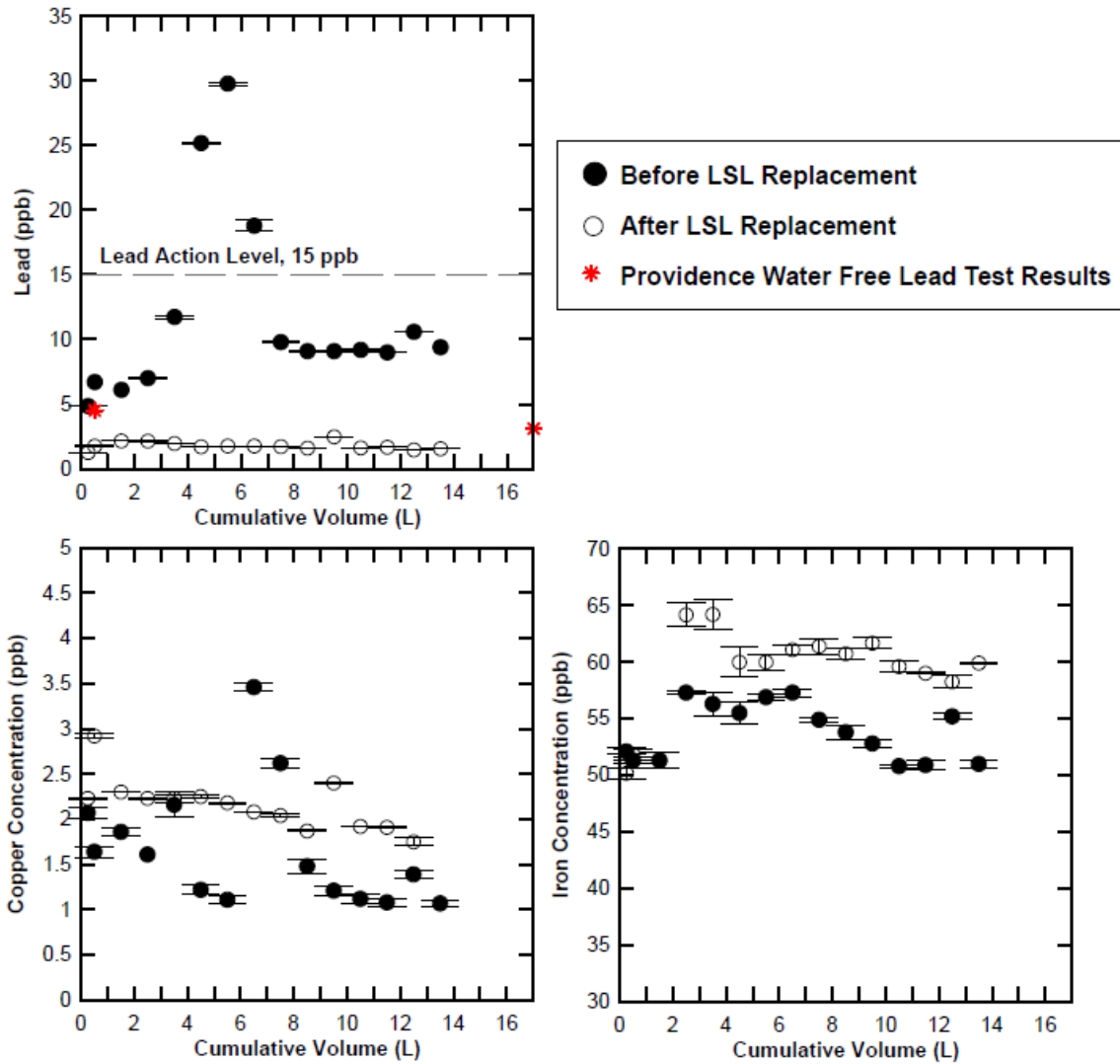


206  
207 Figure 3: A comparison of old and new service lines (A); old lead line (B) and the new  
208 copper line (C)

209 Several months after the replacement, I collected more sequential samples after an 8-hour  
210 stagnation period from my kitchen sink tap as a comparison with pre-replacement water quality  
211 using the same sampling methods. No significant differences in temperature, pH, specific  
212 conductivity, or free chlorine before and after the replacement of the service line were found.  
213 Average iron and copper concentrations increased slightly after the replacement, as shown in

214 Figure 4. The average iron concentration was 60.2 ppb (standard deviation of 4.9 ppb) and the  
215 average copper concentration was 2.59 ppb (standard deviation of 1.67 ppb).

216 The most notable difference in metals concentrations were the lead concentrations before and  
217 after service line replacement (Figure 4). After replacement, the average lead concentration was  
218 1.8 ppb (standard deviation of 0.3 ppb), which was over 6.5 times smaller than the pre-  
219 replacement average of 11.8 ppb, and well below the action level. Concentrations of lead also did  
220 not significantly change with sequential samples. With these results in hand, I felt good with the  
221 decision to replace my LSL.



222

223

Figure 4: Metal concentrations before and after LSL replacement

224 **WHAT I LEARNED**

225 A homeowner’s decision to replace their lead service line can be confounded by many factors,  
 226 including an understanding of the science of lead in drinking water, the relative importance of  
 227 different exposure risks to lead in the home, the physical replacement procedure, and the costs. I  
 228 made my decision to replace my LSL from a uniquely informed perspective, however, most

229 customers don't have this advantage or investigative resources. I hope that my experience helps  
230 utilities better relate to homeowners and communicate information they find helpful.

231 Over the last several years, PW has increased outreach on LSL replacements, yet many of my  
232 neighbors have chosen not to have theirs replaced. This is evident on the PW lead service online  
233 LSL locator, where of the 35 houses on my street, most built before 1940, only 9 have  
234 "suspected of confirmed non-lead or other material", indicating they have likely replaced their  
235 original LSL. The other houses in my area have "suspected or confirmed lead" according to the  
236 public records available online. This highlights the need for more and better communication by  
237 utilities to homeowners about the risks of lead exposure and any financial incentives they offer to  
238 ease the financial burden of replacement.

239 Although free lead tests are offered by the PW to homeowners, these can underestimate lead  
240 exposure from drinking water based on the results of my own case study. The lead  
241 concentrations in Figure 4 clearly illustrate this, where the red asterisks represent the test kit  
242 samples below the lead action level. Risk of lead exposure can be masked depending on the  
243 sampling procedure if the elapsed volume at the time of the sample does not contain high  
244 concentrations of lead. This result may be confusing and misleading to customers who are trying  
245 to assess the risks of lead exposure from their water and do not understand why concentrations  
246 may vary.

247 Withdrawing sequential volumes of samples from the faucet in this case fully captured the water  
248 quality changes at the faucet after stagnation, helping to characterize the exposure patterns of  
249 peak lead levels. It was evident from our sequential sampling approach that the highest



250 concentrations of lead occurred between 3 and 7 L of sequential volumes for this particular  
251 home.

252

253 Before my LSL was replaced, lead concentrations exceeded the lead action level of 15 ppb,  
254 which, while not a violation, represents higher lead exposure risk. Sample methods that include  
255 only first draw and 5 minute flush samples (approximately 17 L of cumulative volumes for this  
256 home) did not capture the spike of lead at the faucet and therefore did not indicate an exposure  
257 risk. This sampling method could allow a utility to meet SDWA requirements, even if consumers  
258 are exposed to periodic elevated lead levels once a day or more. However, comparing results  
259 from sequential sampling to the first draw and 5-minute flush method confirms that the utility's  
260 advice to consumers is useful, namely, that flushing water for 5 minutes decreases the risk of  
261 lead exposure (Providence Water). However, it falls to the consumer to remember the 5-minute  
262 flush protocol after stagnation, which can be hard to remember and/or cumbersome for some  
263 consumers or difficult to follow for small children.

264 My story highlights the water quality benefits of complete LSL replacements to homes where  
265 legacy LSLs have already been partially replaced by the water utility. The most significant water  
266 quality benefit after the LSL replacement was the decrease in lead concentrations after a period  
267 of stagnation to a maximum concentration of only 1.8 ppb. Although there is still a small amount  
268 of lead in the drinking water in this home, likely due to lead solder in the original interior  
269 plumbing, the risk of higher lead concentrations occurring at my tap was greatly reduced by  
270 removing my LSL. I have peace of mind knowing that the lead levels at the taps in my house will  
271 be low, and I don't need to remember to flush out my plumbing after stagnation. I hope my

272 example helps utilities better communicate with local homeowners about the risks of lead service  
273 lines and the benefits of replacing them.

## 274 **ACKNOWLEDGEMENTS**

275 I would like to thank Chris Jeznach and Wystan Carswell for their assistance in the data  
276 collection before and after the LSL replacement. I would also like to thank my undergraduate  
277 student assistant, Ashley Bosse, for her help analyzing samples. Findings presented in this paper  
278 do not represent the official views of Providence Water.

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