United States
Environmental Protection
Agency

Strategies to Achieve Full Lead Service Line Replacement

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Contents

1 Introduction

The purpose of this document is to demonstrate how individual household lead service line replacement (LSLR) is motivated by increased public education proposed in the revised Lead and Copper Rule (LCR). Proactive community LSLR programs are similarly motivated and facilitated by the designation of lead as a priority for low cost federal funding and financing programs. These programs could expand LSLR across the country beyond that required by the proposed revisions to the LCR.

In addition, this document identifies challenges to LSLR that many communities face and the strategies of states and communities across the country that have overcome these challenges. This document supports the proposed Lead and Copper Rule Revisions (LCRR), which would require certain water systems to conduct full LSLR. This document shows several examples of states and local communities that are achieving full LSLR. In addition, it provides estimates of the numbers of LSLRs that will occur as a result of actions under the proposed LCRR.

Numerous studies have evaluated the contribution of lead in drinking water from different sources (*e.g.*, service lines, faucets, meters). A study published by American Water Works Association (AWWA) Water Research Foundation (2008) "Contributions of Service Line and Plumbing Fixtures to Lead and Copper Rule Compliance Issues" (Sandvig et al, 2008) estimates that 50 percent – 75 percent of lead in drinking water comes from lead service lines (LSLs). Given that LSLs are the greatest contributer of lead in drinking water, identifying the locations and removing this source of lead is a critical component of the proposed rule.

While LSLR is a component of the current Federal LCR, it is required only after all other actions to control lead levels at the tap have been attempted. Public water systems (PWSs) triggered into LSLR due to a failure to meet the lead action level[1] in tap samples[2] taken after installing corrosion control and/or source water treatment must replace the portion of the lead service line (LSL) that it owns at an annual rate of 7%. In cases where the water system does not own the entire LSL, the system must offer to replace the customer-owned portion at his or her expense. If the customer elects not to have his or her portion replaced, the water system is not required to replace the customer-owned portion. In addition, water systems are not required to replace the customer-owned portion of the line where doing so would be precluded by State, local, or common law (40 CFR 141.84(d)).

In most communities, LSLs are partially owned by the water system and partially owned by the customer. The PWS typically owns the portion of the line from the water main to the curb stop or meter. In many cases, the water system retains the authority to access and maintain the customer-owned portion of the service line although the expense of performing the work is placed on the customer. In those instances where a PWS subject to LSLR does not replace the customer-owned portion of the

[1] The lead action level is exceeded if the concentration of lead in more than 10 percent of tap water samples collected during any monitoring period conducted in accordance with §141.86 is greater than 0.015 mg/L (i.e., if the "90th percentile" lead level is greater than 0.015 mg/L) (40 CFR §141.80(c)).

[2] These regulations establish a treatment technique that includes requirements for corrosion control treatment, source water treatment, LSLR, and public education. These requirements are triggered, in some cases, by lead and copper action levels measured in samples collected at consumers' taps.

service line, the PWS can meet the LSLR requirements of current Federal LCR by completing a partial LSLR.

The U.S. Environmental Protection Agency (EPA) is proposing revisions to the LCR to include requirements for full LSLR and to limit partial LSLR[3] and prohibit the "test-out" provision[4]. Although there are significant health benefits from full LSLR, full LSLR can be expensive at an average cost of $4,700, ranging from $1,200 to $12,300 per line replaced (see Chapter 5 of the LCRR Economic Analysis, docket number EPA-HQ-OW-2017-0300 at https://www.regulations.gov). In addition to cost, the EPA is aware of implementation challenges that can be encountered when conducting full LSLR such as: issues of who owns or is responsible for maintaining or repairing the LSL; how to gain access to private property; and statutory and regulatory requirements that may impact cost recovery, especially for replacement of the customer-owned portion of the LSL.

Despite these challenges, individual households and communities around the country have prioritized LSLR and are proactively addressing the risk of lead in their water distribution system by developing and executing full LSLR programs. The EPA is aware of many water systems with proactive LSLR programs (EDF, 2019) and has been studying them to understand how water systems are overcoming challenges to achieve full LSLR. While every community is different, the EPA finds that LSLR programs can be structured in ways to overcome potential legal, financial, and practical challenges related to full LSLR. Further the EPA estimated the number of full LSLRs, including customer-owned portions, that may occur as a result of proposed LCRR enhanced public education and increased customer awareness regarding LSLs.

Additionally, the EPA anticipates the proposed changes to the LCRR public education requirements will build upon customer's willingness to allow the water system to access their property and perform a full LSLR and increase customer interest in having their portion of an LSL replaced. These proposed requirements will enhance transparency, risk communication, and public outreach and are anticipated to increase public awareness of the risks associated with lead in drinking water and the benefits of full LSLR.

[3] The Current Rule only requires systems to replace the portion of the LSL that they own. Often, the system's ownership stops at the homeowner's property line, and the homeowner's portion is not required to be replaced.
[4] An LSL can "test out" if all samples from the LSL are at or below the lead AL. "Tested-out" LSLs are considered to be replaced.

2 Assessment of Projected Household Initiated Voluntary Lead Service Line Replacement as a Result of Revisions to Public Education

The proposed LCR revisions include improvements to public education provisions, such as: (1) an updated mandatory statement on health effects and added mandatory statement on LSLs in the Consumer Confidence Report; (2) notification and provision of public education for households within 24 hours of exceeding the lead action level; (3) public access to an inventory of water system-owned and customer-owned LSLs; (4) notification and provision of public education for households with an LSL, including information on programs available to replace LSLs; (5) public outreach activities required for systems that do not meet their annual LSLR goal; and (6) annual outreach by systems to state and local health agencies that serve sensitive populations. By improving transparency, risk communication, and public education and outreach, proposed revisions to the LCR are anticipated to increase public awareness, increase rates of consumer-initiated LSLR, and further reduce sources of lead.

The impact of the proposed public education provisions on consumer-initiated LSLR, hereafter referred to as voluntary LSLR, can be projected by examining the impact of past public education efforts. However, there is a lack of literature evaluating LSLR in the context of public education. Given these limitations, projections can also be estimated from studies of other, comparable risk reduction behaviors. Risk reduction behaviors that share many similarities with voluntary LSLR include high-cost, effective forms of radon and lead paint remediation. The behaviors are similar in that costs are comparable[5] (Riesenfeld et al., 2007; Zhang et al., 2011; HUD, 1990; USEPA, 2016a), the action that reduces the health risk is generally a one-time behavior, actions are considered “home improvement” measures, mitigation actions can occur at the point of home sale, and the health hazards are generally “invisible” (USEPA, 2018; USEPA, 2016b; USEPA, 2016c).

The EPA conducted a literature review on risk reduction behaviors that are similar to voluntary LSLR and have been evaluated in the context of health education interventions. Based on these findings, the EPA provides 35-year projections of national voluntary LSLR with proposed revisions to the LCR public education requirements. Lastly, the EPA presents a recommendation for projecting national voluntary LSLR rates.

2.1 Methods

The EPA conducted a literature search to identify studies that evaluate the impact of health education interventions on risk reduction behaviors similar to voluntary LSLR. These behaviors included high-cost radon and lead paint remediation methods that are effective at reducing radon and lead levels in the home. While remediation was the primary outcome of interest, the review also included studies on related outcomes such as knowledge and testing to provide context, although these were not considered in further analyses presented in this report. Studies were identified through PubMed, Google Scholar, and the EPA Desktop Library. Key search terms included “public education,” “campaign,” “real

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[5] Cost ranges for effective forms of remediation include $800-$2,500 for radon remediation of a home (USEPA, 2010), $2,000-$12,000 for lead paint abatement of a home (HUD, 1990), and $2,500-$5,500 for full LSLR (USEPA, 2016a).

estate disclosure,” “radon,” “lead paint,” “remediation,” and “mitigation.” Relevant studies cited in the identified literature were also reviewed.

After conducting the literature review, data was extracted on remediation rates measured in the presence of health education interventions. These remediation rates were then used to project different estimates of voluntary LSLR with the enhanced public education put forth in the proposed revisions to the LCR over the next 35 years. These projections were extrapolated to the national level using estimates of the number of lead service lines in the United States.

2.1.1 Literature Search and Study Evaluation

Twelve peer-reviewed studies evaluating risk reduction behaviors and related outcomes were identified (see Exhibit 1. Summary of Studies Identified in Literature Search). All of the studies measured radon-related outcomes. Ten of the studies assessed the impact of health education interventions on radon knowledge, testing, and remediation. Interventions included several different sources of radon information: traditional public education campaigns (Doyle et al., 1990; Desvousges et al., 1992; Wang et al., 1999; Wang et al., 2000; Riesenfeld et al., 2007; Poortinga et al., 2011; Zhang et al., 2011; Bain et al., 2016), primary care providers (Nissen et al., 2012), realtors (Doyle et al., 1990), and radon notification policies (Neri et al., 2018). The remaining two studies assessed radon-related outcomes in the absence of intervention (Ford & Eheman, 1997; Ryan & Kelleher, 1999). No studies measuring lead paint remediation associated with health education were identified. General findings from the literature included the following:

- The general population frequently reports an awareness of radon as a problem; however, understanding of radon risk is lacking (Doyle et al., 1990; Nissen et al., 2012).
- Of those aware of radon, rates of home radon testing are generally low (Doyle et al., 1990; Ford & Eheman, 2007); however, testing rates are higher when performed at the point of home sale (Doyle et al., 1990; Riesenfeld et al., 2007).
- When residents are informed of high home radon levels, remediation rates are generally low (Doyle et al., 1990; Riesenfeld et al., 2007; Nissen et al., 2012).
- Primary barriers to remediation are cost (Wang et al., 1999; Ryan & Kelleher, 1999; Riesenfeld et al., 2007), low perceived radon risk or a lack of concern over high radon test results (Doyle et al., 1990; Wang et al., 1999; Riesenfeld et al., 2007; Nissen et al., 2012), indecision (Ryan & Kelleher, 1999), and perceived complexity of radon remediation (Doyle et al., 1990).

Of the ten studies evaluating the impact of health interventions, four studies specifically measured radon mitigation, the primary outcome of interest, and were considered in projecting voluntary LSLR. These included studies evaluating radon remediation levels among households exposed to the following interventions: a public education campaign in Washington DC (Doyle et al., 1990), a public education campaign in New York (Wang et al., 1999), a testing and outreach program in Vermont (Riesenfeld et al., 2007), and real estate disclosure in Boulder, Colorado (Doyle et al., 1990). Studies with the largest sample sizes were preferred for projecting voluntary LSLR. Therefore, subsequent analyses used the two studies that evaluated public education campaigns in Washington DC (Doyle et al., 1990) and New York (Wang et al., 1999). The selected studies and projections are described below.

Study Summary: Public education campaign in Washington DC: "An Evaluation of Strategies for Promoting Effective Radon Mitigation" (Doyle et al., 1990)

Doyle et al. (1990) studied the success and effectiveness of an intensive mass-media radon information and awareness program in Washington DC, a high radon area. The health intervention included a mass-media campaign which consisted of printed advertisements in newspapers, public service announcements on television, and discounted radon test kits. The campaign was conducted in January and February of 1988 and was evaluated at the end of the same year. The campaign resulted in 100,000 test kits purchased and 55,830 test kits completed and returned to obtain test results (55% of total tests purchased). These results represent 6.5% of the Washington DC population estimated to have home radon levels above the EPA action level of 4 pCi/L. A sample of households who participated in the program who returned radon test kits were mailed paper surveys to assess radon knowledge, testing results, and mitigation behaviors. A stratified random sampling design was used to survey 1,000 households equally distributed across 4 radon levels (<4, 4-20, 20-50, and >50 pCi/L); due to loss of useable addresses, a total of 920 households were surveyed (<1% of total test kits purchased). The response rate was approximately 77%.

Doyle et al. (1990) evaluated the results of the program as a multi-stage process characterized by transition rates from initial awareness of radon risk, buying a test kit (testing uptake), performing and returning the test, and mitigation. Those who claimed mitigation reported a variety of mitigation methods ranging from opening a basement window (low-cost) to hiring a certified professional to perform mitigation such as sub-slab depressurization (high-cost). While low-cost mitigation methods are not reliable for effectively eliminating the threat of radon, high-cost methods conducted by a certified professional are more effective. Doyle et al. (1990) addressed this issue with self-reporting by differentiating between "claimed" and "confirmed" mitigation, where confirmed mitigation referred to a remediation method that effectively reduced home radon levels. This was determined based on whether remediation was conducted by a certified professional and/or through radon retesting following remediation to confirm radon levels had been reduced.

Of the 920 households, 73% tested above the EPA action level and 1.2% claimed mitigation. Of the 1.2% of households that claimed mitigation, one-third (0.4%) retested to confirm mitigation was effective. Survey results were extrapolated to absolute population estimates of the entire pool of single-family homes in the Washington DC area predicted to have radon levels over the EPA action level. Of the 933,630 single-family homes, Doyle et al. (1990) predicted 381,714 single-family homes would require mitigation and 376 homeowners would complete effective radon remediation. Based on this extrapolation, less than 0.1% of all households needing radon mitigation would successfully mitigate and reduce home radon levels.

Analysis

The 0.1% annual rate of confirmed mitigations for homes which require radon remediation in the Washington DC area can be used to project estimates of voluntary LSLRs in the Washington DC area and nationally due to increased public awareness from proposed updated public education provisions of the LCR. The 0.1% confirmed mitigation rate can be considered a multiplier (0.001) which can be applied to the total pool of LSLs in the Washington DC area and nationally. The estimated number of LSLs present in the Washington DC area is approximately 48,000 (Government of the District of Columbia, 2018), and the national estimate of LSLs ranges from 6.1 million (Cornwell et al., 2016) to 10 million (USEPA, 1991). For the Washington DC area, this results in 48 voluntary LSLRs estimated to occur per year, or approximately 1,680 voluntary LSLRs in the next 35 years. Nationally, this results in approximately 6,100 to 10,000 voluntary LSLRs estimated to occur annually, or approximately 213,500 to 350,000 voluntary LSLRs in the next 35 years. An example of this calculation is 0.001 x 6.1 million LSLs x 35 years = 213,500 LSLs.

Study Summary: Public Education Campaign in New York: "Radon Mitigation Survey among New York Residents Living in High Radon Homes" (Wang et al., 1999)

Beginning in 1987, the New York State Department of Health (NYSDOH) launched a campaign to increase radon awareness, testing, and remediation in accordance with the EPA's 1986 radon guidelines (Wang et al., 1999; USEPA, 1992). To evaluate the effectiveness of the program, Wang et al. (1999) conducted a cross-sectional telephone survey to measure rates of radon remediation among high radon homes[6] in New York that had been exposed to NYSDOH's campaign efforts. Drawing their sample from the NYSDOH database of radon testing results, Wang et al. (1999) selected all homes with radon levels greater or equal to 370 Bq/m^3 and used stratified sampling by county to select homes with radon levels greater than 148 Bq/m^3 but less than 370 Bq/m^3 (n=1,522). Of the 1,522 households contacted, 1,113 completed the survey (73% response rate). Wang et al. (1999) found that 60% (665 of 1,113) of households participating in the study reported taking remedial action. Specifically, 32% (356 of 1,113) reported installing a powered ventilation system while 26% (294 of 1,113) reported either opening windows and doors (5.2%; 58 of 1,113) or sealing cracks and openings (21%; 236 of 1,113) (Wang et al., 1999). This meant that 32% of participants were willing to engage in a higher cost, more complex and effective form of radon remediation while 26% reported using a lower cost, simpler but less effective method.

Analysis

Based on the 32% of surveyed homes that reported performing high-cost radon mitigation in Wang et al.'s (1999) study, and the eight-year period over which NYSDOH's radon education efforts had been active, the EPA calculated a rate of 4% of high radon homes in the study mitigating per year of the program. Given there were approximately 2,932 high radon homes in New York according to NYSDOH's testing database at the time of the study, this corresponds to approximately 1.5% of high radon homes in New York remediating per year with exposure to NYSDOH's radon campaign (Wang et al., 1999). Using this 0.015 annual radon remediation rate to project voluntary LSLR with enhanced public education and given that there are approximately 360,000 LSLs in New York (Cornwell et al., 2016), it is estimated that 5,400 LSLs would be replaced per year. At this rate, 189,000 LSLs in New York would be replaced over 35 years. Extrapolating these values to the national level, approximately 3.2 to 5.25 million LSLs of the total 6.1 to 10 million estimated LSLs in the United States (Cornwell et al., 2016; USEPA, 1991) would be replaced in that 35-year period.

2.2 Results

[6] Radon levels greater than or equal to 148 Bq/m^3, or 4 pCi/L, on the first floor or above (Wang et al., 1999).

The EPA conducted a review of the literature to estimate projections of voluntary LSLR with proposed revisions to the LCR public education requirements. High-cost radon remediation was identified as a relevant risk reduction behavior that has been evaluated in the literature on health education. These risk reduction behaviors are similar in that a homeowner may choose between a low-cost and high-cost method to mitigate an environmental health risk in the home. If a homeowner becomes aware that their residence is serviced by an LSL as a result of proposed revisions to the LCR public education requirements, the homeowner may choose a low-cost option to reduce lead levels at the tap such as a point-of-use device or pitcher filter, or a higher cost option of replacing the LSL. These low-cost options are effective at removing lead at the tap; however, they do not remove the source of lead contamination (the LSL). Similarly, low-cost options for radon reduction include opening windows and installing a fan in a basement window; however, these methods do not effectively eliminate or reduce radon from entering a home. In contrast, higher cost forms of radon remediation such as sub-slab depressurization are more effective at reducing radon levels and therefore were found to be more suitable for estimating voluntary LSLR projections.

Projections of voluntary LSLR were estimated from two studies evaluating the impact of public education campaigns on radon remediation in the United States: Doyle et al (1990) and Wang et al. (1999). When making estimates from the Doyle et al. (1990) study, confirmed (effective) mitigation rates for homeowners were used for projecting rates of voluntary LSLR. This provided a method to measure effective radon mitigation which is most relevant to LSLR, whereas self-reported (claimed) mitigation rates, which may include low-cost, less effective actions, may inflate the number of remediations which effectively reduce radon in the home. This highlights the importance of using confirmed mitigation rates for projecting voluntary LSLR, which Doyle et al. (1990) provide. The target audience of the radon health education campaign in the Washington DC area and subsequent surveys were single-family homeowners; similarly, the intended audience for LSLR are consumers, usually homeowners, who are willing and able to pay the cost of a full LSLR. However, in most communities, LSLs are partially utility-owned and partially owned by the homeowner. Doyle et al. (1990) did not specify if the full cost of radon remediation was the burden of the homeowner; therefore, remediation cost may have been subsidized. To estimate the voluntary LSLR projection, the EPA assumed the full cost of radon remediation was paid for by the homeowner; however, this may result in an underestimation of the total number of full LSLRs initiated by a homeowner as funding sources may be available to offset the full cost of replacement, such as: water systems using rate payer revenue; using federal, state, and local grant and loan programs; and using special assessments, tax levies, and surcharges.

Projecting voluntary LSLR from the Wang et al. (1999) study resulted in a higher estimated remediation rate as compared to the rate predicted from the Doyle et al. (1990) study. Although Wang et al. (1999) did not directly measure the impact of NYSDOH’s extensive radon campaign, the large proportion of surveyed homes exposed to the campaign that reported engaging in radon remediation (60%), and specifically high-cost remediation (32%), suggests that it is a contributing factor (Wang et al., 1999). The projected LSLR rate was calculated using the percentage of households specifically undergoing high-cost remediation (defined in the study as installation of a powered ventilation system), rather than the rate of overall remediation which includes low-cost, less effective methods in order to more closely approximate the cost burden of voluntary LSLR. A unique feature of the Wang et al. (1999) study that distinguishes it from the study by Doyle et al. (1990) was that over a quarter of the respondents were enrolled in a radon diagnostic assistance program which provides eligible homeowners with up to $300 of financial assistance towards radon mitigation (n=297 of 1,113). Because this reduces the number of households who experience cost as a barrier, this may have inflated the rate of high-cost radon remediation, thereby overestimating the rate of voluntary LSLR. However, the proposed LCR revisions include provisions for focusing resources on LSLR, thereby lowering the cost on the homeowner. Therefore, this factor alone does not necessarily limit the study's suitability for projecting LSLR. Additionally, the sample was comprised predominantly of homeowners (n=1,091 of 1,113), while only 22 participants were renters and were significantly less likely to report high-cost mitigation. This may have contributed to a larger remediation rate. However, homeowners also represent the target audience of public education around voluntary LSLR. The high remediation rates reported by Wang et al. (1990) may also reflect a potentially more proactive sample relative to the general population, in that all study respondents had requested a radon detector from NYSDOH for a small fee in the past. While NYSDOH's campaign likely also encouraged homeowners with high radon levels to obtain a radon detector, the fact that the study sample was selected from this pool may reduce its applicability for projecting voluntary LSLR.

The EPA used the confirmed and effective radon mitigation rates from the Doyle et al. (1990) study to estimate a national 35-year voluntary LSLR projection (213,500-350,000 projected LSLRs). The evaluation of the radon public education campaign presented in Doyle et al. (1990) provides confirmed radon remediation rates which represent the most analogous health risk reduction behavior to LSLR identified in this research. As compared to the self-reported rates of high-cost radon mitigation measured in Wang et al. (1990), confirmed mitigation rates are more accurate at estimating frequencies of radon mitigation that successfully reduce radon in the home. The mitigation rates reported by Doyle et al. (1990) are either confirmed through retesting to verify the mitigation was successful or consist of mitigations performed by a professional contractor. The EPA prefers to estimate national voluntary LSLR projections based on remediation rates from Doyle et al. (1990) as these estimates represent confirmed mitigation rates and the study is cited in nearly all published and peer-reviewed research assessing the efficacy of health education campaigns focusing on radon risk reduction and remediation.

The EPA is proposing changes to the public education requirements in the proposed LCRR which enhance transparency, risk communication, and public outreach. These proposed revisions are anticipated to increase public awareness and support informed decision making, and thereby increase customer willingness to pay for LSLR and result in customer-initiated LSLR efforts. To estimate the number of consumer-initiated LSLRs associated with improvements to LCRR public education, the EPA investigated the efficacy of health education campaigns on comparable risk reduction behaviors. Based on this analysis, the EPA projected approximately 213,500 to 350,000 voluntary, customer-initiated LSLRs to occur in the United States in the next 35 years. It is also expected that customer willingness to pay for water system-initiated LSLR would increase.

2.3 Uncertainty

Projecting voluntary LSLR based on studies of other risk reduction behaviors involved several limitations and assumptions. The EPA's voluntary LSLR projection estimates will vary from the actual number of consumer-initiated LSLs replacements rates as the assumptions and limitations detailed below introduce a variety of unquantified uncertainties that will result in over- and under- estimation of the projections. First, it is important to note that all the projections were based on studies of radon remediation. While some relatively more expensive forms of radon remediation are comparable to LSLR in terms of cost, there are differences between these two behaviors that may differentially affect people's willingness to remediate. For example, there may be greater awareness and perceived risk around lead than radon (Doyle et al., 1999). This may particularly be the case given ongoing events and media attention relating to lead-contaminated drinking water across the United States, most notably in Flint, Michigan. Conversely, LSLR may be perceived as more complex than comparatively high-cost radon remediation. Given these differences, it would have been helpful to develop estimates based on a more diverse array of risk reduction behaviors comparable to voluntary LSLR, particularly those involving lead, such as lead paint removal. However, no other studies were identified in this review. Despite this limitation, cost is a significant structural barrier to risk reduction that lends support to using radon remediation to estimate voluntary LSLR.

The projections are also limited by the age of the studies applied in the analyses, which were twenty to thirty years old. Given improvements in risk communication and development of health promotion programs, as well as the growth of the internet and social media to increase information access and exchange in the past thirty years, these estimates may underestimate the impact of health education on voluntary LSLR. While more recent studies were identified in the review, they measured levels of awareness and testing, but not remediation. There was one study conducted in the past fifteen years that measured remediation with health education (Riesenfeld et al., 2007); however, the sample size was much smaller than those in the selected studies. More research is needed in this area. Despite the lack of recent data identified in this review, the Doyle et al. (1990) study remains one of the most cited works in the literature on interventions promoting radon remediation.

In order to project voluntary LSLR from the Doyle et al. (1990) and Wang et al. (1999) studies, many assumptions were made. Making these projections involved assuming that the success of the Washington DC and New York radon health education campaigns would be comparable to the success of the public education requirements of the proposed LCR revisions, in spite of programmatic differences existing between the three. Moreover, there are external validity concerns with generalizing results from Washington DC or New York to the entire United States which is substantially larger and more diverse in terms of the geographic distribution of LSLs and lead risk exposure, access to resources and economic power, as well as the relationship and dynamics of engagement between communities, water systems, and states.

Additionally, it was assumed that living in a high radon area and the associated radon exposure risk were analogous to the presence of an LSL and associated lead exposure risk. However, properties with LSLs are systematically different from properties with high radon levels. The 1986 Amendments to the Safe Drinking Water Act banned the use of LSLs and states were required to implement the ban in 1988; therefore, LSLs are most commonly connected to older single-family homes and properties. In contrast, radon arises naturally from the soil beneath a property's foundation, and the age of the property does not affect radon levels. Not accounting for differences in property characteristics introduces uncertainty into the voluntary LSLR projections given that high-cost home improvement renovations often occur at the point of home-sale. The voluntary LSLR projections using the Doyle et al. (1990) and Wang et al.

(1999) studies do not account for such variation in property characteristics and whether mitigation occurred during a real estate transaction.

To estimate voluntary LSLR from the Doyle et al. (1990) study, the EPA made several assumptions. Because the duration of the intensive mass-media campaign was less than a year, the 0.1% confirmed remediation rate is valid for a short, one-time public health campaign. To calculate a 35-year projection of voluntary LSLR, the rate is assumed to have an impact beyond one year and a constant annual impact for 35 years. Making projections from the Wang et al. (1999) study involved several assumptions of its own. An eight-year exposure period to the radon public education campaign was assumed based on the campaign beginning in 1987 and the survey being administered in 1995; however, survey respondents may not have been exposed for the full campaign period. As a result, this approach may underestimate the radon remediation rate and, therefore, projected voluntary LSLR.

When making projections from both studies, the effect of the campaign and radon remediation rate were assumed to remain constant over the campaign period. However, the effectiveness of the campaign may have varied over time, along with other factors which could in turn affect the radon remediation rate, resulting in an over- or under-estimate of projected voluntary LSLR. Similarly, sustained public interest in removal of LSLs was assumed, which could either over- or under-estimate the LSLR rate. It was also assumed in both analyses that the national or state estimate of LSLs does not incrementally decrease annually, resulting an in an overestimate of the projected LSLR rate. Furthermore, there is significant uncertainty in developing a national LSL estimate as few community water systems have an accurate count of the total number of LSLs in their distribution system.

In addition to the limitations of the projections and studies selected, there were also limitations to the literature review. Because this was not a systematic review, studies may have been missed that would have been useful for projecting voluntary LSLR. There may have also been other risk reduction behaviors comparable to voluntary LSLR that were not identified in this literature search.

In spite of these limitations, these estimates project increases in voluntary LSLR over the next 35 years with the proposed LCR revisions. Given the limited literature that are available on voluntary LSLR, basing projections on similar risk reduction behaviors that have been evaluated with health education helps the EPA to estimate the impact of the proposed LCR revisions.

3 Challenges of Establishing LSLR Programs: Ownership, Control, and Access

In many communities, LSLs are partially owned by the water system and partially owned by the customer. The portion of the service line that the PWS owns is typically the portion of the line from the water main to the property line, although some systems use the water meter or the curb stop (which are not necessarily at the property line) as the point of reference for ownership. In addition: (1) ownership of the real property on which the service line is located does not always determine ownership of the service line, and (2) ownership of the service line or of the real property on which the service line is located may not be the only indicator of who is responsible for the repair and replacement of the service line. This is because in many cases, the utility retains the authority to access and maintain the customer-owned portion of the service line although the expense of performing the work is placed on the property owners. The details (e.g., who owns the line, who is responsible to maintain or repair it, who is responsible for the costs of the maintenance, repair and replacement) are usually spelled out in the local water utility tariff (i.e., water rate) and will vary among PWSs and communities.

To complete full LSLR the water system may, in many cases, need to identify the current owner of the service line, secure permission for the work, schedule services, and gain access to the interior of a building. Many PWSs and States have mechanisms to overcome the issues of ownership, control and access including securing express consent of the owner, instituting mandatory LSLR or through regulatory authorities that provide PWSs with access to customer-owned LSLs.

3.1 Consent of the Customer

In many instances, the PWS may have the right to access private property for certain activities, such as inspection or monitoring, which are typically granted in state or municipal codes. LSLR and its associated activities (digging, construction, impacting surrounding property) could be covered by the general maintenance activities included in the tariff. However, it is possible that access rights for LSLR are not specifically authorized by the tariff, or that the tariff does not clearly establish these access rights for LSLR. In those cases, the water system may seek to obtain voluntary consent from the customer to conduct full LSLR. The following examples show how some water systems sought consent to undertake their LSLR programs.

- In Flint, MI, where ownership of the LSL is split between the city and the customer, the city had to obtain homeowner consent to conduct full LSLR. The city utilized volunteers from the AARP to mail consent cards and go door-to-door to obtain a signature from the owner (and the tenant in a rented unit) to gain permission to replace the LSL. Identifying and tracking down customers, however, sometimes presented logistical challenges. Securing permission and locating absent owners increased the time needed to complete the LSLR project (Derringer, 2016). There is also an online opt-in form granting the City permission to conduct full LSLR on the City of Flint's Fast Start website. The website shows that as of September 6, 2019, Flint has successfully replaced approximately 9,200 LSLs with less than 900 left to replace, so the city has shown overall success in obtaining consent from homeowners to conduct LSLR (City of Flint, MI, 2019).

- The Lansing, MI Board of Water and Light (BWL) bought the customer-owned service lines from homeowners and building owners in 1927 to address extensive leakage issues (Gell and McEntire, 2016). Despite owning the whole service line, BWL still had to seek permission from the homeowner to complete its full LSLR program. The BWL's "Rules and Regulations for Water Service" state that the "Customer Water Service shall be furnished, installed, owned and maintained by the Board" (Water Rule and Regulation 11, Lansing BWL, 2015)[7]. The rules also require that customers "provide and maintain appropriate access and working space" around service lines and other BWL-owned water facilities, and they authorize BWL personnel to access infrastructure on customers' property as necessary (Water Rule and Regulation 4, Lansing BWL, 2015). Even with this authority, however, water system personnel required permission to enter residents' basements to disconnect the LSL from the meter and connect the new copper line (Clark, 2016). To ensure consent would be obtained by all customers, BWL conducted a multi-component outreach program to educate city residents about LSLs and promote coordination with customers (Hamelink et al., 2016; Lansing BWL, 2016). While there were some instances of coordination and scheduling problems, for the most part, the LSLR was welcome and BWL did not have to enforce access rights. The last LSL in Lansing was removed in December 2016 (Lansing BWL, 2016).

The EPA is aware of several other successful LSLR programs where customer consent was required to conduct the full LSLR (EDF, 2019; and "LSLR Rate Analysis" in the LCRR docket under EPA-HQ-OW-2017-0300 at https://www.regulations.gov). While the approach of obtaining customer consent can sometimes present challenges from individual homes, the EPA is not aware of any LSLR program where it has proved to be a major or widespread impediment to the overall success of the program. Customer consent could be obtained more efficiently by combining it with water utility bills or other mailers, obtaining consent by phone, during an in-person lead service line inventory inspection, or by coupling it with other infrastructure work.

3.2 Mandatory LSLR

In contrast to LSLR programs structured around a customer voluntarily agreeing to full LSLR, some communities have instituted LSLR programs which require the customer to replace their portion of the LSL. Under this scenario, consent by the individual customer is not sought since the community determined this action was needed by municipal ordinance. While the ordinance itself could specifically grant private property access to the water system, it could also require the customer to hire a licensed contractor to perform the work, eliminating the need for the water system to access private property.

- The Madison Water Utility in Wisconsin, for example, required customers to replace their portion of the LSL with a private contractor while the water system simultaneously replaced the water system-owned portion (MGO, 2000). Non-compliance with the ordinance resulted in a fine of $50-$1,000 per day. The water system referred non-compliant customers to the city

[7] The Lansing BWL's Rules and Regulations for Water Service define "customer water service" as "those pipes, valves and appurtenances owned and maintained by the Board installed between a Water Main and Customer Piping."(Water Rule and Regulation 11, Lansing BWL, 2015).

attorney's office. The water system was able to replace all LSLs in the distribution system (Madison Water Utility, 2019).

- The Cincinnati City Council passed ordinances in 2016 and 2017 requiring the Greater Cincinnati Water Works (GCWW) to develop and implement an LSLR program to replace the remaining LSLs (both water system-owned and customer-owned) in the city within 15 years, or approximately 7% per year. Customers must either participate in the water system's LSLR program in which the water system would cover 40 percent of the cost, or customers must hire a plumber who is certified with GCWW to replace the LSL. Customers must decide how they will replace their portion of the LSL within 30 days after receiving notice from GCWW that they are required to replace the LSL (GCWW, 2018; EDF, 2019).

- Milwaukee, WI's mandatory LSLR program requires customers to replace customer-owned LSLs if a leak is detected in the LSL or if the water system-owned portion is removed on a planned or emergency basis and prohibits the repair of any LSLs and any reconnection of a customer-owned LSL to the city's system. The city is required to notify the customer in the event of a leak or failure and must provide notice at least 45 days before the commencement of a planned replacement of the water system-owned LSL. Upon receipt of notice, the customer has 10 days to either replace the LSL by contracting with a licensed contractor or authorize the city contractor to replace their portion of the LSL. Access to private property is not an issue as the homeowner can either use a licensed contractor or provide consent to the city contractor to replace the customer-owned LSL. Those that use the city contractor must sign a hold-harmless agreement freeing the city from liability for damage done in performance of the LSLR and sign a temporary right of entry and construction entry (Milwaukee, 2016). Fond du Lac, WI and several other WI municipalities have an ordinance like Milwaukee's, where the homeowner must replace the customer-owned LSL with a hired contractor or give consent to city contractors to replace it (LSLR Collaborative).

There are also mandatory LSLR programs in which the system is required to replace both water system-owned and customer-owned LSLs. However, full replacement may still be contingent upon the customer's consent.

- The State of Michigan recently updated their State LCR with a mandate that water systems proactively replace five percent of their LSLs each year. While the regulation requires the water system to fully finance and conduct both the water system-owned and customer-owned LSLR, customers are allowed to refuse the LSLR. In that case, the water system must not conduct a partial LSLR, leaving the full LSL intact (MI DEQ, 2017b). Since Michigan's mandatory LSLR requirement applies to the water system, not to the customer, the water system can offer the LSLR to another customer in its distribution system who is served by an LSL to meet its replacement target.

3.3 State and Local Authority to Enter Granted Through Regulation

Some states and municipalities provide the water system with the authority described in the tariff to enter private property for the purposes of inspection, monitoring, or to determine compliance with State drinking water standards. Potential limitations to this authority could include: (1) LSLR activities may not necessarily be covered by this right to enter authority; (2) in some states, the right to enter for the specifically stated purposes is limited to the property owned or controlled by the PWS; and (3) the state may need to secure a court issued warrant if access is denied. While it is possible that a state or municipality may grant the water system access rights to conduct the LSLR, there are several examples, as mentioned in the previous section, where the customer hires a contractor to perform the work on private property, avoiding the need for the water system to gain access to the private property.

One approach to the issue of access is a short-term approach taken by Milford, MA. The Milford Water Company amended the Company's Rules and Regulations so that customer-owned LSLs, while otherwise the responsibility of the customer, will be replaced by the Company (at the Company's expense), but only for a finite period. After this period, the responsibility and the cost of maintaining the service line would presumably return to the customer. The revised Department of Public Utilities (DPU) Rules and Regulations, M.D.P.U. No. 22-4(c) state that:

> *Service pipe from the curb valve to the customer's premises will be maintained by the customer at his expense and in a manner satisfactory to the Company; . . . and provided further, that for the period of January 1, 2017 through and including December 31, 2018, the replacement by the Company of any portion of the service pipe which contains materials other than copper, steel or plastic shall be at Company expense for the first one hundred (100) feet from the curb valve.*

4 Assessment of Projected Community Lead Service Line Replacement Programs as a Result of Availability of Low Cost Federal Funds

The EPA supports states and cities in fully utilizing the suite of funding and financing options provided by the federal government to address lead in drinking water. The Drinking Water State Revolving Fund allows states to finance high priority infrastructure investments, including the replacement of lead service lines to protect human health. In FY 2018, the Water Infrastructure Finance and Innovation Act (WIFIA) loan program invited 39 projects in 16 states and Washington, D.C. to apply for loans totaling up to $5 billion to help finance over $10 billion in water infrastructure investments. 12 of these projects are to reduce lead or other contaminants in drinking water. In FY 2019, the EPA once again prioritized projects that reduce exposure to lead when announcing the availability of $6 billion for new WIFIA loans. Additional opportunities to fund full LSLR include the EPA's Water Infrastructure Improvements for the Nation Act grant programs and HUD's Community Development Block Grants.

The Drinking Water State Revolving Fund (DWSRF) has funded numerous water system infrastructure projects, including lead service line replacement (LSLR). To better understand the effect of the DWSRF on LSLR, the EPA estimated the number of proactive and compliance-based LSLR that may be funded by DWSRF over a 35-year period. The EPA found that over this timeframe, approximately 149,200 full LSLR are expected to occur using DWSRF funding in part or in whole with approximately 9 percent of funds being used for proactive LSLR.

Although additional EPA funding mechanisms exist to fund full LSLR, the Water Infrastructure Finance and Innovation Act (WIFIA) and America's Water Infrastructure Act (AWIA) grant programs are newer programs, and there is not data available to estimate future LSLR demand. Thus, the estimate presented by this analysis will undercount the number of LSLRs that will occur in practice as a result of longstanding EPA funding and financing mechanisms. Furthermore, other federal funding programs, such as the Department of Housing and Urban Development's (HUD) Community Development Block Grants (CDBG) have been used for full LSLR, however the EPA lacks the data required to project future LSLR from other federal sources.

4.1 Background

The DWSRF program was created as part of the 1996 Amendments to the Safe Drinking Water Act (SDWA). The DWSRF is structured as a federal-state partnership through which a permanent drinking water infrastructure revolving loan fund has been created in every state. The federal government provides capitalization grants to states. States provide a 20% match for those grants. The principal objective of the DWSRF is to facilitate compliance with national primary drinking water regulations or otherwise significantly advance the public health protection objectives of the SDWA. States are required to give priority for the use of DWSRF project funds to:

- address the most serious risks to human health;
- ensure compliance with the requirements of the SDWA; and
- assist systems most in need on a per household basis according to state affordability criteria.

In 2011, the EPA asked the Science Advisory Board (SAB) to evaluate the current scientific data on partial LSLR. The SAB concluded that partial LSLRs have not been shown to reliably reduce drinking water lead levels in the short-term of days to months, and potentially even longer (USEPA, 2011). The Lead and Copper Rule Revisions (LCRR) emphasize full LSLR over partial LSLR. In 2016, the EPA issued a memo clarifying the DWSRF funds can be used to fund full LSLR including replacement of the customer-owned portion of the LSL (USEPA, 2016). The EPA is aware of several public water systems that are utilizing DWSRF to fund full LSLR in full or in part (USEPA, 2019). For example, Green Bay, WI is using DWSRF principal forgiveness funds, in addition to local funding raised from their stadium tax, to subsidize customer replacement of their LSL. The EPA estimated the demand for DWSRF funds and the associated number of LSLR in the next 35 years.

4.2 Methods

The EPA queried DWSRF project descriptions for relevant keywords, such as "service line," and compiled the resulting 217 DWSRF applications (see attached "Future LSLR from SRF.xlsx"). The EPA categorized the project descriptions for lead service line replacement activities as follows:

- Project descriptions that explicitly mention LSLR.
- Project descriptions that may involve LSLR.
- Project descriptions that likely do not involve LSLR.

In developing the projection, the EPA only included DWSRF projects with an initial loan date of 2016 or later. The EPA's Office of Groundwater and Drinking Water issued a memo in 2016 that clarifies DWSRF funds can be used for replacement of the customer-owned portion of LSLR. This clarification creates a new baseline from previous DWSRF utilization as it expands the universe of LSLs that can be replaced with DWSRF funding and facilitates full LSLR.

The EPA assumed that all LSLs were fully replaced. In some cases, the DWSRF project description stated that SRF funds would be used to assist the customer in replacing their portion of the LSL. The proposed LCR revisions include a provision that would require the water system to remove the portion of the LSL it owns when the customer-owned portion is replaced, resulting in full LSLR. It is also possible that the water system-owned portion was never made of lead or has been partially replaced by the water system in the past. Under these circumstances, replacing just the customer portion would result in a full LSLR. The DWSRF project descriptions sometimes described that the funding would apply to the water system-owned portion only. The EPA assumed full LSLR given the recent knowledge of the dangers of partial LSLR and reasonable scenarios of how a full replacement could take place. For example, the customer portion of the LSL may not be made of lead or may have already been replaced. Alternatively, if the customer portion is an LSL, various funding and financing strategies have been demonstrated across the country, which could fully fund or subsidize the customer-owned LSLR. For example, some systems have used rate revenue, or the customer could pay full or a subsidized cost for the replacement through a different grant or loan program. The proposed LCR revisions includes enhanced public education to consumers served by an LSL, which could increase the likelihood that customers will be willing to replace their LSL. For these reasons, when DWSRF is used for replacement of the water system's portion, the EPA assumes the LSL will be fully replaced. Finally, where the DWSRF project description did not specify ownership, the EPA assumed that the LSL would be fully replaced, for these same.

To estimate the number of LSLR from each project, the EPA examined the project description and the loan or grant amount. Some project descriptions explicitly state how many LSLs would be removed using the funding. If the project description did not provide a number of LSLRs, the loan or grant amount was divided by the average unit cost of a LSLR to calculate the expected number replaced.

The EPA took the average of the number of full LSLR included in DWSRF applications in 2016, 2017, and 2018 to determine the average annual DWSRF utilization for LSLR. This rate was multiplied by 35 to calculate the total number of LSLR that could occur from DWSRF over a 35-year timeframe.

To determine if the funds would be used for proactive LSLR, the EPA determined whether the water systems using SRF for LSLR had exceeded the lead action level within two years of their DWSRF loan application. If so, the EPA assumed that the DWSRF funding was being used for rule compliance purposes. Otherwise, the EPA assumed proactive LSLR was conducted.

4.3 Results

The analysis (refer to "Analysis of SRF for LSLR" in the LCRR docket under EPA-HQ-OW-2017-0300 at https://www.regulations.gov)). estimates that 149,200 lead service line replacements could occur from DWSRF funds in the next 35 years. This represents 1.5-2.4% of the estimated 6.1 million to 10 million LSLs nationwide. It is estimated that approximately 9% of the DWSRF funding is being used for LCR compliance purposes, while the remainder funds proactive LSLR.

4.4 Uncertainty

The EPA analysis included LSLRs only when they were not coupled with other infrastructure work, unless the project description explicitly stated the number of LSLs replaced. The EPA took a conservative approach of excluding these LSLR from the analysis, which may result in an under estimation of full LSLRs due to DWSRF funding. It is also possible that DWSRF projects that only listed work such as main replacements would incidentally remove LSLs without explicitly describing LSLR in its project description, which would also result in an under estimation.

The EPA assumes sustained interest in LSLR over thirty-five years. As proposed, the LCR revisions include provisions such as publicly-available LSL inventories and improved public education, which is expected to sustain demand for full LSLR over time. The EPA did not include a coefficient to increase or decrease the rate of DWSRF utilization for LSLR over the 35-year period of analysis. It is possible that EPA funding resources decrease over time, or that interest in LSLR decreases or competes with funding for other priorities.

As proposed, water systems that exceed the lead trigger level or lead action level would be required to remove LSLs as part of a goal-based or mandatory program. It is estimated that the proposed rule will result in 146,000 mandatory full LSLR and 240,000 goal-based full LSLR, or an additional 97,000 and 240,000 LSLR from the current LCR over 35 years. While the EPA is aware of several water systems using SRF funds for proactive LSLR, a few are using SRF for compliance with the LCR. The EPA's estimate of DWSRF utilization for LSLR likely includes both proactive and compliance-based LSLR, however it is unknown what percentage of the estimate is proactive versus compliance-based.

The EPA conducted a separate estimate of future LSLR that may result from improved lead public education (see Section 2, "Assessment of Projected Voluntary Lead Service Line Replacement with

Health Education”). The analysis is based on efficacy of public education in compelling homeowners to implement radon remediation, to estimate the number of homeowners that would have their LSL replaced. The study used as a basis for this analysis (Doyle et al.,1990) did not account for subsidized homeowner radon remediation. Because DWSRF provides subsidization for LSLR, in whole or in part, it is expected that more LSLR will occur than estimated from the radon study assumptions. While there is likely to be some overlap between the two estimates (i.e., customers who are willing to pay full cost for LSLR but utilize DWSRF subsidy offered by their water system), the EPA expects these two estimates to be mostly additive, however it is unknown to what extent.

5 Financing Full LSLR

The EPA has estimated an average cost of full LSLR of $4,700, ranging from $1,200 to $12,300 per line replaced (see Chapter 5 of the LCRR EA, docket number EPA-HQ-OW-2017-0300 at https://www.regulations.gov). As PWSs work to develop and implement LSLR programs, they have continued to find ways to fund and/or recover costs from LSLR in their communities. As further described below, PWSs have been using rate payer revenue; using Federal, State, and local grant and loan programs; imposing special assessments, tax levies, and surcharges; and finding other, creative ways to help fund LSLRs.

Ownership can also impact funding sources and cost recovery mechanisms for full LSLR that are available to a PWS. The ownership structure of the PWS may affect whether the PWS can use rates to cover the costs associated with LSLR programs (e.g., privately owned systems may be limited by public service agency regulations), the process by which the PWS can change rates (e.g., public service agency regulatory process, local government process), and other cost recovery mechanisms available to the PWS (e.g., surcharges, tax assessments, tax liens).

In addition, state constitutional prohibitions on using public funds for private purposes may prevent public funds from being used for full LSLR. These prohibitions are generally designed to ensure that the state and all its political subdivisions (e.g., a county, city, village or township), only use its resources to carry out designated governmental functions, and that public funds are preserved for public use and for the public's benefit. There are many situations, however, where expenditures may benefit both public and private interests. In these cases, if the primary purpose for the expenditure is a public one (i.e., the promotion of the public health and safety or general welfare of all the inhabitants or residents), then the expenditure may not be prohibited even if an individual is incidentally benefitted. For example:

- Goho et al. (2019) conducted an in-depth review of 13 states (Illinois, Ohio, Michigan, New York, New Jersey, Missouri, Indiana, Texas, Minnesota, Wisconsin, Massachusetts, Florida, and Pennsylvania) that collectively have an estimated 4.2 million LSLs (over two-thirds of the nation's remaining LSLs), and found that none of these states have constitutional or statutory prohibitions on the use of rate funds to replace LSLs on private property. However, some differences exist for publicly-owned and investor-owned utilities. Six of these states (Michigan, New Jersey, Missouri, Indiana, Wisconsin and Pennsylvania) have adopted policies that explicitly support this practice. See Section 5.1.

- In Washington State, the Attorney General found that municipal sewer districts have statutory authority to use public funds to repair or replace side sewers located on private property if doing so will increase sewer capacity (McKenna, 2009).

- In Texas, the legislature, by general law, can authorize a city or town to expend public funds for the relocation or replacement of water laterals on private property if the relocation or replacement is done in conjunction with, or immediately following, the replacement or relocation of water mains serving the property. The general law passed by the legislature must authorize the city or town to place a lien on the property, with the consent of the owner of the private property, for repayment of the lateral's replacement costs (TX Const. art. XI, § 12).

Full LSLR could serve a number of public purposes, including but not limited to the wide and well-documented public health and societal benefits associated with lead exposure reduction and lower risk and liability associated with the complete elimination of the lead hazard. Therefore, given that some states and municipalities allow public spending with incidental private gain, it may be possible in many cases to use public resources to help finance customer-owned LSLR.

Within this framework, some PWSs are finding cost recovery mechanisms and funding sources (and combinations of those mechanisms and sources) that help to facilitate full LSLR within their communities.

5.1 Using Ratepayer Revenue

One option for water systems to recover the costs associated with LSLR is to increase water rates paid by all customers. Goho et al. (2019) specifically looked at the laws in 13 States having most of the LSLs in the country and found that they support the use of ratepayer funds to pay for full LSLRs. The authors noted that while they did not look at the laws in the other 37 States or the District of Columbia, they indicated that they would expect them to also follow the recent trends and approve the use of ratepayer funds to replace customer-owned LSLs.

The use of rate payer revenue to fund LSLR helps spread out the cost of the full LSLR program to all water system customers, including those not served by an LSL. Rate subsidization can be especially effective in systems when there is a small proportion of LSLs to the total service line inventory as can be seen in:

- Quincy, MA where less than one percent of service lines were LSLs and the LSLR program will result in an increase per customer of approximately $6 per year or $60 total (Ronan, 2016).
- Milford, MA where three percent of service lines throughout their system are LSLs and the system plans to recover costs with a rate increase of about $4 per customer per quarter (Commonwealth of Massachusetts DPU, 2016).
- Pennsylvania American Water, a privately-owned utility, filed a rate case petition to the State Public Utility Commission (PUC) to replace customer-owned LSLs over 10 years as it replaces water mains, as well as coordinate customer requests to replace LSLs. The system estimates there are 18,000 LSLs in its distribution system, or about three percent of all service connections. The cost impact on customer water bills for the replacement program would be approximately 10 cents per month, which the water system proposed to recover in a future rate case or using the existing Distribution System Improvement Charge (DSIC) mechanism (DeCusatis, 2018).
- York Water Company, a privately-owned water system in Pennsylvania, received permission from the State Public Utilities Commission to incorporate the costs of customer-owned LSLR into its rate structure. The agreement will fund the full replacement of all remaining LSLs in the service area by 2020 and even reimburse homeowners that have conducted LSLR on their own in the past. (Arnold, 2017). The PUC approved a rate increase of about a dollar per month for residents to cover this and other infrastructure improvement projects (Klar, 2019).

Publicly-owned water system rates are generally set by local government and are not generally subject to oversight by the state, with one notable exception being Wisconsin (Goho et al., 2019). Rate increases by publicly-owned water systems, if used specifically for customer-owned LSLR, may be limited by public fund usage laws (see discussion above).

In many states, privately owned systems are regulated by a Public Service Agency (e.g., a PUC or Public Service Commission (PSC)) and therefore, to increase rates, these systems may need to:

- Complete a Public Service Agency process of changing rates (i.e., notice and hearing) although in some states there are emergency rate increase provisions that could be applied in the LSLR context that would bypass the notice and hearing requirements.
- Provide justification for the rate increase (e.g., show that the increase is needed to cover environmental compliance costs or unanticipated repairs or improvements; or that a rate change is necessary to continue providing adequate and efficient service).
- Prove that rates are fair and just or apply equally across all service groups. Water system rates are subject to either public service commission or municipal government oversight, who often prohibit rates that are "discriminatory," "unjust," "inequitable," or other related criteria. Often it is not specified whether providing financial assistance to the homeowner to conduct a customer-owned LSLR would be prohibited under these criteria. The Wisconsin example below (page 25) illustrates how this challenge played out at the state level.

Depending on the time frame surrounding the rate change process, systems can potentially use rate revenue to either fund the LSLR program directly or to pay back funding obtained through another mechanism such as loans. For example:

- In Lansing, MI, the city treated the LSLR program as a capital project, supported solely by water rates (Lansing BWL, 2016). The Board of Water and Light's (BWL) rates are established by its governing body, the Board of Commissioners and are not set or regulated by the state's Public Service Commission (Lansing BWL, 2014). The 130-year-old BWL is a wholly owned city subsidiary, so it could easily build the cost of new infrastructure into its rates. BWL also owns the entire service line (Clark, 2016).
- Quincy, MA approved a proposal to fund its LSLR program with a $1.5 million no-interest loan from the Massachusetts Water Resources Authority (MWRA)[8] which supplies Quincy's water. The 10-year loan will allow the city to pay for the replacement of the approximately 150 customer-owned LSLs in the city. Quincy plans to repay the MWRA loan by increasing rates, which will cost the individual ratepayer about $6 per year or $60 total (Ronan, 2016).
- Milford, MA has structured a similar arrangement where the Milford Water Company is initially covering the cost of the program through Drinking Water State Revolving Fund (DWSRF) monies to encourage full participation from Milford citizens (MassDEP, 2017) but plans to recuperate these costs with a rate increase of about $4 per customer per quarter (D.P.U. 16-192, Information Request DPU-1-10). Rate increases would not affect customers immediately as the

[8] The MWRA is a public authority that provides wholesale water to 50 communities, most which are in the greater Boston and the Metro West areas of Massachusetts.

Company has to apply for a rate increase during its next rate case, which it planned to do in mid- to late-2017 (Milford Daily News, 2018). Below market-interest financing available through the DWSRF enabled the city to minimize the future rate increase.

As discussed by Goho et al. (2019), six states have recently changed state laws or regulations to allow for or clarify that rate revenue can be used to provide customer assistance to replace a customer-owned LSL.

- Michigan's Department of Environmental Quality (MDEQ) revised the State's version of the LCR in June 2018 requiring utilities to replace the entire LSL at no cost to the customer, implying that ratepayer funds would be used for this. However, in December 2018, Detroit, MI and other municipalities filed a lawsuit challenging the MDEQ rules.
- In 2017, the Indiana General Assembly enacted legislation allowing the Indiana Utility Regulatory Commission (IURC) to approve an investor-owned utility's proposal to pay for LSLR on private property with ratepayer funds.
- The Missouri Public Service Commission determined in May 2018 that the Missouri American Water Company (MAWC) could fund its LSLR program through a rate increase approved for infrastructure improvements. MAWC performs full LSLR when discovered during a water main replacement. This decision has been challenged in court.
- New Jersey enacted legislation in August 2018 authorizing municipalities to replace LSLs on private property if the work is an environmental infrastructure project and is funded by loans from either the New Jersey Environmental Infrastructure Trust or the State's Department of Environmental Protection.
- The Wisconsin State Legislature passed the "Leading on Lead Act", that allows municipalities to provide financial assistance for customer-owned LSLRs. The legislation specifically deems that it is "not unjust, unreasonable, insufficient, unfairly discriminatory, or preferential or otherwise unreasonable or unlawful for a water public utility to provide financial assistance to a customer solely for replacing LSLs if the financial assistance is allowed by local ordinance." (The Wisconsin PSC has in the past interpreted its statute to mean that user rates cannot be used to recover the cost of customer-owned LSLR by the utility because "it would be unreasonable and unjustly discriminatory if public dollars generated through utility rates were used to subsidize a direct benefit to an exclusive group of private property owners" (WI Ct. App, 2002).) In addition, under the bill, if a public water utility provides financial assistance for replacing LSLs, the PSC must include the cost of providing that financial assistance in its determination of water rates (WI Assembly, 2017 and Senate, 2017).
- In Pennsylvania, the 2017 passage of Act 44 allows municipal authorities to use public funds and public employees to perform customer-owned LSLR and replacement of sewer laterals if the municipal authority determines that such action will benefit public health or the public water supply system. (PA Assembly, 2017). The passage of Act 120 in 2018 authorizes the State Public Utilities Commission to allow water utilities under its authority (primarily privately-owned water systems) to use ratepayer revenue to finance the proactive replacement of customer-owned lead service lines as well as damaged customer-owned sewer laterals. The work is to be

conducted concurrent with main replacement or under a Commission-approved replacement program (PA Assembly, 2018).

5.2 Using Non-Ratepayer Revenue

Some systems have accessed other cost recovery mechanisms such as federal, state, and local loans and grants; the levy of a tax lien or the imposition of special assessments (applicable to publicly-owned systems) or surcharge; or other creative ways to fund their LSLR programs.

5.2.1 Federal Funds for Water System-Owned and Customer-Owned LSLR

There are many federal programs that may be used to fund LSLR programs. These include the Drinking Water State Revolving Fund (DWSRF), Water Infrastructure Finance and Innovation Act (WIFIA) Program, Water Infrastructure Improvements for the Nation (WIIN) Act of 2016 grant programs, and U.S. Department of Housing and Urban Development's (HUD) Community Development Block Grant (CDBG) Program. The list below includes a brief description of each federal program, as well as examples of LSLR projects (where available).

- **Drinking Water State Revolving Fund (DWSRF):** The DWSRF offers below market-interest financing and funding opportunities for LSLR (USEPA, 2019b). Through the DWSRF Program, the EPA allocates annual capitalization grants to states. Part of the funds are set-asides that States may elect to use for drinking water program management and activities. The balance, along with a 20 percent State match, is placed into a dedicated loan fund to finance eligible water system infrastructure improvement projects (USEPA, 2018a). The EPA's DWSRF annual allocations for fiscal year 2018 totaled $1.057 billion. States are providing funding from their DWSRF to facilitate LSLR projects and are taking steps to modify their DWSRF programs to prioritize LSLR. For example: Milford, MA received $1,158,000 financing from the MA DWSRF for its LSLR project (MassDEP, 2017); Washington's Department of Health modified the eligibility criteria for DWSRF construction loans to prioritize LSLR projects (WA DOH, 2016); and Michigan submitted a supplemental Intended Use Plan (IUP) to EPA, to allocate $40 million in DWSRF for LSLRs in Flint (MI DEQ, 2017).

  An EPA analysis determined the number of full LSLR that may be conducted as a result of DWSRF funding over a 35-year timeframe. The DWSRF will fund the replacement, in whole or in part, of an estimated 149,200 LSLR over 35 years.

- **Water Infrastructure Finance and Innovation Act (WIFIA):** The Water Infrastructure Finance and Innovation Act (WIFIA) program provides funds to eligible water projects through long-term, low-cost supplemental loans for regionally and nationally significant projects (USEPA, 2016b). In FY 2018, 39 projects in 16 States and Washington, D.C. were selected and invited to apply for WIFIA loans; 12 of these are to reduce lead or other contaminants in drinking water For example, American Water Capital Corporation in St. Louis, MO was invited to apply for $84 million in WIFIA loan funding to support its project to replace approximately 100 miles of main and adjacent customer-owned LSLs (USEPA, 2018b). In 2019, the EPA announced the availability of $6 billion for WIFIA loans and once again prioritized projects that reduce exposure to lead.

- **Water Infrastructure Improvements for the Nation (WIIN) Act:** Under the WIIN Act, which was enacted in December 2016, three new grant programs were established related to reducing lead in drinking water (assistance for small and disadvantaged communities, reducing lead in drinking water, and lead testing in school and child care drinking water program) (USEPA, 2019). In 2017, $100 million was approved for communities for which the President had declared an emergency relating to public health threats associated with lead or other contaminants in drinking water (USEPA, 2017). At that time, Flint, MI was the only eligible community for this funding. The city allocated $40 million of these funds towards LSLR. In 2018 and 2019, Congress appropriated $25 million under the WIIN Act for reducing lead in drinking water across the country, including activities such as full LSLR.

  Community Development Block Grants (CDBG): The Department of Housing and Urban Development (HUD) has administered the CDBG program since 1974 and provides resources for community development needs. CDBG funded projects must benefit low- and moderate-income populations, prevent or eliminate slums or blight, or address urgent community development needs, particularly those that present an immediate threat to public health (having a particular urgency because existing conditions pose a serious and immediate threat to the health or welfare of the community for which other funding is not available (HUD, no date). North Providence, RI's "Remove the Whole Lead Pipe Program" uses CDBG funds from HUD to fund customer-owned LSLR at no cost to the homeowner. The grant is a one-time assistance program and does not change ownership or maintenance responsibilities of the customer for the new service line. The town has a goal of replacing every LSL in the community (Town of North Providence, RI, 2019).

5.2.2 State and Local Loan and Grant Programs

There are many local and state loan and grant programs that systems could access to help fund full LSLR. Several states have taken action through prioritization of DWSRF funds for full LSLR or enacting legislation to facilitate full LSLR financing. Some examples include:

- The Wisconsin Department of Natural Resources (DNR) established a two-year program (State Fiscal Years 2017 and 2018) to help disadvantaged municipalities replace LSLs on private property for projects that result in full LSLR. Funding for LSLR on private property is in the form of principal forgiveness (PF). According to the WI DNR, "PF is additional subsidy, provided by the Federal government, to assist municipalities that would experience significant hardship raising revenue necessary to finance needed infrastructure projects;" it reduces the size, and therefore the annual payment and interest, of a Safe Drinking Water Loan Program (SDWLP) loan (WI DNR, 2015). Projects must result in full LSLRs and municipalities have three years from the date of their loan closing to expend funds for the LSL program. Between 2017 and 2018, 44 water systems in Wisconsin received funding for LSLR (WI DNR, 2018).

- The Massachusetts Water Resources Authority (MWRA) established two loan programs that are being used for LSLR projects.

  - The Local Water System Assistance Program (LWSAP) provides $210 million in interest-free loans to member water communities to perform PWS improvement projects. Community loans are repaid to MWRA over a 10-year period. Loan funds are approved for distribution from fiscal year 2011 through fiscal year 2020. A few MWRA communities have used LWSAP loans to fund LSLR projects (MWRA, 2017b).

  - Lead Loan Program (LLP) is an addition to the LWSAP that provides up to $100 million in interest-free loans to up to 45 of MWRA's member communities. These are also 10-year interest free loans that must be used to, "create local programs to fully remove LSLs from community water mains all the way to the home or business" (MWRA, 2017a).

- In Washington, D.C., new legislation allocates District funds to support DC Water's full lead service line replacement program. Residents can receive assistance to cover 100% of customer-side replacement costs when DC Water replaces the portion of lead service line in public space during capital improvement projects and repairs. Additionally, the legislation allocates funds to redress previous partial lead service line replacements. Residents can apply for assistance awarded based on household income to cover 50-100% of replacement costs for properties wherein lead service lines remain only on the customer-side. Funds have been included in the District's Fiscal Year 2020 budget that begins October 1, 2019 (City of Washington, D.C., 2018).

- In New York, the legislature's Clean Water Infrastructure Act of 2017 required the State health department to create a Lead Service Line Replacement Program (LSLRP). The program covers the cost of full LSLR and associated activities such as administration fees and yard restoration. The appropriated $20 million was distributed equally among 10 regions of the state, reaching 26 municipalities. Municipalities were chosen based on three criteria: lower median household income relative to surrounding municipalities, age of housing stock, and elevated average blood lead levels (NY DOH, 2018).

- New Jersey's Environmental Infrastructure Financing Program (also called "Water Bank") details LSLR eligibility and prioritization for DWSRF funds statewide. Water systems that exceed the lead action level can be given loans with 90 percent principal forgiveness. The loans are capped at $1 million per municipality and are prioritized for communities whose median household income (MHI) is less than the county average MHI. The program notes that other lead service line projects are available for Water Bank financing and receive the base rate, affordability rate, or Nano financing. Trenton, NJ applied for the principal forgiveness funds after exceeding the action level (TWW) (NJ DEP, 2018).

  - Nano and Nano-lite financing may also be used for small drinking water systems serving fewer than 10,000 customers. These systems would be ranked and would receive 75 percent Department of Environmental Protection (DEP) interest-free financing and 25 percent I-Bank Market Rate financing. Small systems serving fewer than 500 people would receive 50 percent principal forgiveness in addition to 25 percent DEP interest-free financing and 25 percent I-Bank Market Rate financing (NJ DEP, 2018).

  - A New Jersey Water Supply Remediation "sub-account" can provide zero interest loans for a term of not more than 10 years with a maximum amount for any single loan of $10,000 "to owners of single-family residences, whose source of potable water violates primary drinking water standards or violates a standard for . . . lead" (NJ DEP, 1999). The loan program is managed by the New Jersey Housing and Mortgage Finance Agency and loan priorities are based on those of the State's DWSRF program. A bill passed by

Pennsylvania's State legislature in 2017 allows for the government, through the State's Pennsylvania Infrastructure Investment Authority (PENNVEST) [9] fund, to finance the "improvement, extension, repair or rehabilitation" of customer-owned lead service lines and sewer laterals. To use these funds, the government must deem such activity will benefit the public water system. The law specifies that ownership or control of the customer-owned LSL or lateral does not change should a water system provide financial assistance to the homeowner to replace the customer's LSL or sewer lateral (PA Assembly, 2018b). PENNVEST allocated $49 million ($13.6 million in grant dollars and the other $35.4 million through a 1 percent low-interest loan) to finance 28,000 full LSLR for the Pittsburgh Water and Sewer Authority (PWSA) (PENNVEST, 2018).

- Providence Water is offering three-year zero percent interest loans to property owners for customer-owned LSLR in part due to low participation in the system's LSLR program (Providence Water, 2019). In response to a Rhode Island Public Utilities Commission (RIPUC) data request, Providence Water reported that "only 2% of customers have replaced the private side [customer-owned] of the lead service when Providence Water replaces the public side [water system-owned] of the lead service" (Providence Water, 2017).

5.2.3 Special Assessments, Tax Levies, and Surcharges

Systems may have the ability to impose special assessments, tax levies, and surcharges to help fund LSLR programs or help homeowners pay for the replacements. For example:

- In Fond du Lac, WI homeowners are responsible for the cost of replacing customer-owned LSLs but can spread the cost out over 10 years through a special assessment on the tax bill if the homeowner chooses to have a city contractor complete the replacement (Fond du Lac WI, no date). This ordinance allows property owners on their property tax bill, to finance special assessments of $500 to $5,000 over a 5-year-period, or $5,001 or greater over a 10-year period (Fond du Lac, 1993). This installment option also includes interest, determined by the city's borrowing rate plus 2 percent. Fond du Lac's Public Works Director noted that the city had not used this type of assessment in the past but that this is a new type of public improvement project (Roznik, 2017c). On other recent assessments, the interest rate amounted to 4.25 percent (Roznik, 2017b).

- In Milwaukee, WI, customers are responsible for the cost of customer-owned LSLR which can be paid in a lump sum payment or paid as a special assessment on taxes over 10-years. The installment payment plan includes the imposition of an interest rate of the prime rate plus one percent. The interest rate in effect at the time the special assessment is levied shall be fixed for the 10-year duration of the installment payments (Milwaukee, 2016). The city however, is

[9] PENNVEST has been empowered by Pennsylvania state law, Pennsylvania Infrastructure Investment Authority Act 16 of 1988, to administer and finance the Clean Water State Revolving Fund (CWSRF) and the Drinking Water State Revolving Fund (DWSRF) pursuant to the federal Water Quality Act of 1987, as well as to administer the American Recovery and Reinvestment Act of 2009 (ARRA) funds. PENNVEST also finances, through the issuance of special obligation revenue bonds, water management, solid waste disposal, sewage treatment and pollution control projects undertaken by or on behalf of private entities. (See http://www.pennvest.pa.gov/Pages/default.aspx).

currently offering a subsidy to certain eligible homeowners.[10] This subsidy is expected to cover up to 2/3 of the cost of LSLR for eligible property owners. (Behm, 2016).

- In Syracuse, NY homeowners have the option of making a lump-sum payment of the total cost before April 1 of the calendar year in which the Commissioner certifies the cost of the LSLR, or they can repay the cost through 10 equal annual installments on the property's annual city tax bill, plus a seven percent annual interest rate. Each annual installment can be paid in four equal installments in the applicable tax year, on the same general city tax schedule including all interest, fees and penalties which are applicable to the general city taxes (Syracuse, 1974).

Some states regulate these cost recovery mechanisms, which may be leveraged to fund LSLR. For example,

- In Michigan, a municipality operating a water distribution system has a lien on the property to which it supplies water as security for the collection of water rates, assessments or charges (MI Legislature, 1939); can levy a tax or special assessment for the improvements on a water supply system (MI Legislature, 1955); and can authorize the giving of "contributions" or "gifts" from the system's operating revenues if the governing body of the municipality determines that these are in the public interest and the legislative body of the municipality approves (MI Legislature, 1939; MI Legislature, 1969).[11]
- Public utilities in Missouri can make rate adjustments outside of the regular rate-case requirements to cover certain environmental costs (i.e., the Environmental Cost Adjustment Mechanism or ECAM) when several conditions are met, including: the utility being ineligible for the infrastructure system replacement surcharge (ISRS); that the costs are not a result of negligence on the part of the utility; and that the costs are in response to a federal, state, or local law pertaining to the regulation or protection of health, safety and the environment (MO PSC, no date).
- Public Utilities Commission of Ohio (PUCO)-regulated utilities[12] may be able to fund LSLRs by applying to the Commission to "collect an infrastructure improvement surcharge . . . from customers located in the company's affected service areas and subject to affected schedules" (OH Code, 2003).

5.2.4 Creative Funding Mechanisms

Systems are also finding novel ways to fund and reduce the cost of full LSLR.

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[10] To be eligible for the subsidy, the property must be a less than 5-family dwelling and the owner must agree to have the work performed by a city contractor, sign a hold-harmless agreement, and execute a temporary right of entry and construction easement (Municipal Code art. 2 §225-22.5 sub. 9b).

[11] Note that water distribution system is not specifically defined in the Municipal Water Liens section of the statute (Mich. Comp. Laws § 123.161-123.167). According to Mich. Comp. Laws § 124.281 "water supply system," includes "all plants, works, instrumentalities, and properties used or useful in connection with obtaining a water supply, the treatment of water, or the distribution of water"

[12] PUCO regulates investor-owned water companies throughout the State, and thereby does not regulate municipalities, counties, cooperatives or water districts (Ohio Rev. Code § 4905.02).

- The Wisconsin PSC previously did not permit water utilities to use rate-payer money to reimburse property owners for LSLR. To address this cost barrier, Madison Water Utility rented space on top of utility-owned water towers to cell phone companies and used the generated revenue for the Lead Service Replacement Program. Madison Water Utility also coordinated 20 percent of replacements with pre-planned main replacement projects between 2007 and 2012 (Madison Water Utility, 2019).

- In Kalamazoo, MI, the city created the “Foundation for Excellence” (Kalamazoo, 2019), which is a collaboration between the city and private donors to, among other things, “make key investments to create a vibrant, forward-looking community that benefits everyone”. The city replaced 120 LSLs in 2016; however, at least 2,917 remained. The Foundation has funded 68 LSLRs (Barrett, 2017) and continued funding will allow the city to accelerate the replacement of the LSLRs.

- Green Bay, WI, in addition to DWSRF funding, used $300,000 from Lambeau Field sales tax rebates to provide grants to property owners for changing out their lead pipes (Srubas, 2017).

5.3 Targeting LSLR to Communities Most in Need

One implication of the high cost of LSLR is potential environmental justice (EJ) concerns, as the customer-owned replacement cost may not be easily accessible to all customers. Loan or grant programs, like some of those mentioned in Section 3 (e.g., New Jersey and Wisconsin), may lead to better EJ outcomes because they decrease the cost to the customer for customer-owned LSLR. There are some examples where water systems have directly addressed EJ concerns in their LSLR program structure that prioritize funding to communities with the greatest need. For example:

- In a new program to be implemented in October 2019, the D.C. government will pay for 50 percent or more of the cost of customer-owned LSLR for moderate to low income homeowners served by DC Water. This is for cases where the water system-owned portion is not an LSL (Morris, 2018).

- Galesburg, IL gives higher priority for LSLR grants to homes with low to moderate income (based on HUD’s Low-Income Limits Documentation System), and have children aged six and under living at the address (Galesburg, 2016).

- The Wisconsin Department of Natural Resources (DNR) established a two-year program (SFY 2017 and SFY 2018) to help disadvantaged municipalities replace LSLs on private property for projects that result in full LSLR. Funding for LSLR on private property is in the form of principal forgiveness, which means no debt is incurred on behalf of the municipality for these funds. The program is intended to assist individuals in disadvantaged municipalities since currently in WI, user rates cannot be used to replace the customer-owned portion of the LSL (DNR, 2018).

- New York’s LSLRP (Lead Service Line Replacement Program) awards funds to municipalities with the highest need, based on three criteria: age of housing stock, median household income relative to neighboring municipalities, and elevated average blood lead levels (NY DOH, 2018).

- In Pittsburgh, low-interest loans are available to homeowners meeting income eligibility requirements for customer-owned LSLR through the Urban Redevelopment Authority's ROLL program. (Pittsburgh URA)

6 The Cost of LSLR

Cost is perhaps one of the main barriers of proactive full LSLR for water systems and customers. To surmount this barrier, municipalities have sought various financing options, as outlined in the previous section. Another strategy they've utilized is to reduce the overall cost of LSLR by coupling LSLR with existing infrastructure projects and incorporating LSLR best practices to optimize the efficiency of LSLR. Some are taking the approach of targeting assistance to the customers with the greatest need.

6.1 Coupling LSLR with Other Infrastructure Projects

The EPA assumes that on average systems will replace one percent of pipes annually as part of their infrastructure replacement programs[13]. To increase efficiencies and reduce costs of LSLR, water systems have coupled the customer-owned and water system-owned replacements. For example:

- When conducting main replacements, emergency work, and Department of Transportation (DOT) construction projects, DC Water replaces existing water system-owned LSLs and will offer to coordinate the replacement of the customer-owned LSL at the customer's expense (DC Water Construction Project Replacements). If a property owner meets specific requirements[14] and agrees to pay for the customer-owned LSLR, DC Water will coordinate and replace the water system-owned portion at the same time (DC Water Voluntary Replacements).
- Providence Water in Providence, RI continued to replace LSLs as part of its water main replacement program and during local and State road resurfacing projects even though the Rhode Island Department of Health (DOH) suspended the mandatory LSLR program (Providence Water, 2016). Providence Water has also continued to replace the water system-owned LSLs when a property owner voluntarily replaces their customer-owned portion (Providence Water, 2019).
- Both Milwaukee, WI and Fond du Lac, WI have passed ordinances that require customers to replace the customer-owned LSLs if among other things, the utility-owned portion is being removed on a planned or emergency basis (Municipal Code art. 2 §225-22.5 and Municipal Code § 642-5G). Both ordinances require the city to notify the customer before the commencement of a planned water system-owned LSLR and upon receipt of notice, the customer has a certain

[13] As reported in the 1991 LCR Regulatory Impact Analysis (USEPA, 1991), the 1988 American Water Works Association (AWWA) Lead Information Survey (LIS) found that approximately 1 percent of all LSLs are replaced each year as part of ongoing utility replacement programs. The Regulatory Impact Assessment did not indicate if these replacements were customer portion or water system portion, or full replacements of the entire line.

[14] The eligibility requirements include verification of property owner, proof of LSL on private property (i.e., photo evidence, home or plumber inspection report, or other form of professional verification), having hired DC Water contractor (or if using a private plumber, an approved permit and coordination with the DC Water contractor is required), and water service pipe otherwise up to code. To avoid redundancy in excavation, water main or DOT construction must not already be planned for that location.

number of days to either replace the LSL by contracting with a licensed contractor or authorize the city contractor to replace their portion of the LSL.[15]

- To help reduce costs to customers with LSLs, the Madison Water Utility crews left trenches open after replacing water system-owned lines so that private plumbers could immediately replace customers' lines for a lower cost (Madison Water Utility).
- Ft. Worth, TX's water system always replaces LSLs during main replacement. Also, as a precursor to another project, the city is obtaining GPS coordinates for every meter. At that time, staff will also check and record if the service line or private plumbing is lead (Ft. Worth Water Department).

6.2 Incorporating LSLR Best Practices to Improve Efficiency

As increasing public attention has been given to lead in drinking water and the replacement of LSLs, PWSs and municipal efforts (and joint PWS/municipal/state efforts) are bringing about proactive LSLR that go above and beyond the requirements of the current LCR. As more LSLR programs are implemented, systems are becoming more effective at prioritizing LSLR in locations with the greatest need, increasing the efficiency of LSLR, reducing costs in other areas of the LSLR program, and applying lessons learned toward subsequent LSLR efforts. For example, Lansing, MI reports that substantial efficiencies have been gained during their 12-year LSLR program. The Board of Water and Light (BWL) crews have learned over 12 years how to remove LSLs more efficiently: an LSL can be removed in about four hours at a cost of about $3,600 as compared to when the work first started, the cost per line was about $9,000 (Lacy, 2016). Depending on crew availability, the replacement pace was two to four service lines per day (Lansing BWL Lead Water Services Survey). Learning from other water utility LSLR programs as well as the ANSI/American Water Works Association standard operating procedures and best practices for identifying and replacing LSLs (AWWA, 2017), a system can reduce the overall cost of their LSLR program and the direct cost to customers as well.

Efficiencies can also be gained during inventory development. Water systems have reduced costs by:

- Asking customers to self-identify LSLs (e.g., Lansing Board of Water & Light) rather than deploy water system personnel to conduct inspections;
- Sending surveys and holding community meetings to show people how to locate their service line and do a scratch test to check for lead (City of Madison);
- Potholing as opposed to digging with a backhoe;
- Disclosing LSLs upon real estate change. The Environmental Defense Fund reports that three States (Connecticut, Delaware and New York) require sellers to disclose whether there are lead

[15] As of April 26, 2017, the mandatory customer-owned replacements in Fond Du Lac have been put on hold. The contractor with the low bid for the project was unable to secure a performance bond, and the subsequent bid was too high and would have forced an unreasonable increase in costs to the customers. For 2017 at least, the LSLR program is voluntary with customers being eligible for a subsidy if they meet certain timelines and use a plumber from the City's pre-qualified list (LSL Voluntary Replacement FAQ). The 148 homeowners that had been scheduled for LSLR during the summer of 2017 will be given a waiver from the ordinance's requirements (Roznik, 2017).

pipes, 27 States and D.C. have provisions that are silent or ambiguous on lead pipes or that disclosure of lead pipes is voluntary, and that the remaining 20 States have limited or no disclosure requirements related to LSLs. These disclosures could be used to add to or confirm a PWS's inventory of LSLs, however they are limited in that: (1) disclosure is required only if the property owner knows of the LSLs; (2) the owner does not always have a duty to find out if there is a LSL; and (3) the PWS may not be told since the duty to disclose exists between the buyer and seller.

- In Pittsburgh, field crews are identifying LSLs using an innovative method developed by Field Operations staff of accessing the curb box and taking photos of the exposed service line to document the pipe material. This method avoids costly and potentially disruptive excavations (Pittsburgh, 2018).

- Researchers used a predictive, statistical model to help identify and prioritize LSLs for replacement in Flint, MI. The research team combined datasets from existing pipe materials information, tap water sample results, and city records to determine which service lines were most likely to be LSLs. The study asserts that use of the algorithm reduced the error rate (excavations of copper service lines thought to be LSLs) to 2%, which lowered the effective cost of each replacement by 10% and yielded approximately $10M in potential savings (Abernethy et al., 2018).

- Although they do not remove the lead source, pipe lining and coating technologies can be an alternative to LSLR. A Water Research Foundation Report investigated these technologies and found that they can reduce or eliminate lead release from LSLs (WRF, 2017). These technologies require consideration of site-specific factors, so if a water system is evaluating these technologies, its decision-making process may increase in complexity. For example, the condition of the current service pipe, including scale deposits, corrosion, and bends or kinks may prevent the use of a lining or coating technology. Another consideration is the possibility of reduced water pressure at the residence, as the technologies reduce pipe diameter. Finally, the uncertainty of the technologies performance over time may require additional monitoring to ensure lead levels at the tap remain low. The added costs of site-specific evaluation, continued monitoring, and eventual re-lining of the service pipe when it reaches the end of its useful life, may reduce the cost savings associated with lining and coating technologies relative to full LSLR, especially when compared to less expensive LSLR methods such as trenchless replacement.

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Exhibit 1. Summary of Studies Identified in Literature Search for "Assessment of Projected Household Initiated Voluntary Lead Service Line Replacement as a Result of Revisions to Public Education "

Author	Study	Intervention	Sample	Methods	Outcomes	Comments
Bain et al., 2016	Examines a multi-faceted communications effort (material distribution, media engagement) and integrated health campaign (led by a statewide coalition of organizations known as the Iowa Radon Coalition (ICCC) to increase radon testing and remediation in Iowa.	To increase radon awareness, testing, and remediation	General population of Iowa which represents a high radon area where the majority of homes have radon levels above the EPA action level. A specific study sample is not defined.	Qualitative and quantitative data were collected on radon knowledge, testing, and mitigation. Radon knowledge was assessed through pre- and post-tests at educational sessions and events. Statewide testing data from test kit labs and mitigation data were used. Data on program impact were collected but methods were not specified. No sampling strategy was specified.	Before implementation of the interventions in 2009, the number of radon tests completed in Iowa was 19,600. In 2014, after implementation, 23,500 radon tests were completed (increase of 20%). In 2009, the number of mitigations completed by certified mitigators was 2,600; in 2014, mitigations increased to over 5,400. The number of certified mitigation specialists in the state increased from 54 in 2009 to 76 in 2014. The study does not quantify remediation rate as a direct result of a public health campaign.	Radon levels, radon testing and remediation rates were collected by the Iowa Department of Public Health. There is no control group for comparison. The Iowa Radon Coalition offers yearly community grants for radon awareness and testing projects. A collaborative approach was used to increase levels of awareness, testing and mitigation, and to introduce a comprehensive radon control policy in Iowa by engaging partners and stakeholders across the state. Interventions are initiated by the coalition, and community partners and stakeholders modify and implement the interventions based on characteristics of the community. Examples of interventions are community-based projects and educational events with radon test-kit distribution, IRC and ICC working with the Iowa Bankers Association to offer low-interest loans for radon mitigation, the ICC partnering with a healthy homes program to provide testing and mitigation services to communities with low socioeconomic status.
Desvousges et al., 1992	Comparison of two pilot programs for encouraging radon testing: a targeted mass-media campaign (radio public service announcements, local newspaper advertisements, informational flier inserts in utility bills) and a mass-media campaign with a community outreach program (radon	To increase radon testing	Three communities in Maryland that have high home radon levels. The study included a baseline telephone survey of randomly selected homeowners (initial attitudes, knowledge and levels of radon testing) in each community and a	Comparison of three communities subject to 1) targeted mass media campaign (Hagerstown), 2) mass media and a community outreach program (Frederick), and 3) control group with no special radon testing information (Randallstown).	Baseline survey response rates were 48% (Randallstown), 58% (Frederick), and 64% (Hagerstown). Follow-up survey response rates were ~80% for all three cities. Media campaigns and community outreach programs resulted in increased awareness, attitudinal changes and knowledge. Frederick (media campaign + community outreach program) reached 15% radon testing during the 3 months of the program, whereas Hagerstown and Randallstown remained at 5% testing. Across each community, people viewed	Demographic data was collected in the baseline survey. Respondents cited expense as a reason for not mitigating. Testing rates were higher among respondents with higher income and education levels. Study population was not focused to only homes with high radon levels.

	awareness week, posters and presentations).		follow-up survey with the same respondents (n=500).		mitigation as expensive. A sizeable percentage of people, 40% in Frederick and Hagerstown, and 70% in Randallstown, felt property values would decrease if radon were fixed.	
Doyle et al., 1990	Evaluation of existing radon testing and remediation strategies through two studies evaluating (1) a traditional radon information and awareness campaign (advertisements in newspapers and TV, discounted radon test kits) targeted at the general population in Washington DC and (2) radon disclosure at the time of home sale in Boulder, CO.	To increase radon testing and remediation rates	Two cities were evaluated. Washington DC and Boulder, Colorado. Households in the Washington DC area (high radon area) who had purchased radon test kits as part of an intensive information and awareness program (n=920), and homebuyers in Boulder, CO (n=303).	Washington DC sample: Paper-based survey of questions on radon levels, remediation. A mail survey was conducted of those who returned test kits: a stratified random sampling design was used to sample households across 4 radon levels (<4, 4-20, 20-50, >50 pCi/l). 920 households were sent surveys (<1% of total test kits purchased). Boulder, CO sample: 495 homebuyers were identified through lists of names published in a local newspaper that publishes all home sales and contacted via phone survey.	Washington DC: Response rate: 77% (708 of 920). 100,000 radon test kits were purchased (representing 6.5% of the target population) as a result of the campaign. 55,830 test kits (55% of total) were returned. Of the 920 surveyed households, 73% tested above the EPA action level. 1.2% claimed some sort of remediation. Of the 1.2% who claimed remediation, only one-third (0.04%) retested to confirm mitigation was effective. Survey results were extrapolated to absolute population estimates and transition rates (from testing to confirmed successful mitigation) of the entire pool of single-family homes estimated to have high radon levels in the DC area. <0.1% of all single-family homes needing mitigation would successfully mitigate. Boulder, CO: Response rate: 61% (303 of 495). 50% (154 of 303) of recently purchased homes were tested for radon gas at the time of home sale and that this testing was often motivated by information provided by a realtor. Of the Boulder sample, 54% of the homes with elevated radon levels underwent mitigation (65 households or 21% of the original sample).	Results suggest that the education campaign to the DC area may have encouraged households to try their own remediation measures instead of contacting a professional. Results from Boulder suggest that a radon information and awareness program targeted at the point of home sale, when the transaction context provides a strong economic incentive to repair any problems a home might have, could be highly effective in comparison to information targeted at the general public. No intensive health campaign had been conducted in Boulder, so any testing that occurred was motivated by generally available radon information. The authors argue the most important bottlenecks are getting people to purchase test kits, and when residents are notified of high radon levels but often fail to take mitigatory action, or the action taken is ineffective. This report also presents an extensive review of potential legal strategies for addressing radon disclosure at the time of real estate transfer.
Ford and Eheman, 1997.	To examine data from the 1990 and 1991 National Health Interview Survey (NHIS) to study radon control activity behavior	No direct intervention	Nationally representative sample of the U.S. population participating in the NHIS which included questions on home radon testing and mitigation. (n=41,104).	NHIS employed a multistage complex sampling design. Interviews were conducted in person. Data was analyzed using SESUDAAN software and proportions were calculated to obtain national estimates. Raw survey data and weighted proportions with standard errors were calculated.	Response rates were 86.3% (1990) and 92.2% (1991). From the 1990 survey, participants who were aware of radon 5.2% had their home tested. Those who had their home tested, 28% of homes had high radon levels (>148 Bq/m^3), and 19.8% of homes with high radon levels indicated that physical modifications (mitigation) to the home were completed. 1991 survey responses on mitigation in homes with high radon levels were 48.4%; however, this increase in mitigation rates may be due to the large standard error in the estimates (+/- 14.4%).	Method of mitigation was not specified in the surveys. Demographic data was not analyzed.

Neri et al., 2018	Study radon knowledge in diverse populations with varying radon-related laws to inform radon-related cancer control practices and activities	To increase radon testing	Homebuyers who purchased single-family homes in four states: Illinois, Minnesota, North Carolina, and Ohio. (n=3,000)	Paper-based survey mailed to homebuyers. 750 surveys were sent to homebuyers in each state. IL and MN had existing radon notification policies, IL and OH had existing state-managed professional licensure requirements, and NC had no existing radon-related policies.	Overall response rate was 33% (n=995); 39% in NC and MN, 33% in IL; and 21% in OH. 86% of all survey respondents reported hearing of radon-related health issues regardless of state policies. Real estate agents and home inspectors were cited as the most common sources of radon information, 69% and 65%, respectively. 58% of all respondents reported their home tested for radon, regardless of state policies. A majority of respondents had discussed radon with their real estate agent (60%) or signed paperwork for radon testing (51%). Respondents in states with notification policies were significantly more likely to discuss radon testing with their real estate agent.	No data on mitigation were provided. Survey included demographic information.
Nissen et al., 2012	Study radon intervention in a primary care setting to increase radon testing and mitigation.	To enhance radon risk perception, and increase radon testing and remediation rates	Patients at two primary care clinics located in Minneapolis MN - a high risk area for radon. (n=797).	Primary care providers and clinic staff provided radon risk and testing information to patients. A written baseline survey and follow-up survey were given to patients.	Baseline survey response rate: 86% (692). 25% of homeowners reported that their homes had been tested. Remaining ~75% (521 homeowners) indicated either their home had never been tested or were unsure if their home had been tested. Of this subset, 250 homeowners participated in a follow-up study and survey (received a discounted radon test kit and contacted 12 months later). Of the 24 respondents from the follow-up survey who had high radon levels, only 12 had their home mitigated. <3% who tested their homes did so at the recommendation of a healthcare professional, and <20% who tested their home did so at the recommendation of a realtor.	Study did not report demographic information. Authors state the effectiveness of this intervention was minimal. Despite receiving radon information at the clinic and a coupon for a discounted radon test kit, only 14.4% of participants in the follow-up study tested their homes in the following year.
Poortinga, Bronstering, & Lannon, 2011	Population-based study evaluating a locally directed radon roll-out program aimed at increasing radon awareness and testing rates in radon-affected areas of England and Wales.	To increase radon awareness and testing rates	Residents age 16 and older of actionable and nonactionable radon-affected areas of England and Wales, including participating and nonparticipating areas in local radon roll-out programs (n=1,578).	Cross-sectional study assessing radon awareness, risk perceptions, and behavior. A multi-stage sampling strategy was used to select areas based on radon affectedness, participation in radon program, geographic location, and population density. In person interviews were conducted using computer-assisted personal interviewing.	The study surveyed 1,578 participants. Participants living in local areas participating in the radon roll-out program were more than two times (167%) as likely to have tested their homes than participants living in nonparticipating areas (OR 2.67 (95% CI 1.83-3.89, p<0.001)).	The concept behind this locally-directed program was that households would be more likely to carry out testing (offered) and remediation if they have someone local (i.e. Local Authority - local government organization) who they can go to with questions. As part of the program, local authorities actively contacted households and supported high radon homes by providing advice on remediation options at "radon road shows" and free house visits. No data on mitigation were provided. Demographic variables measured

						included age, gender, "social grade," and homeownership.
Riesenfeld et al., 2007	To evaluate radon mitigation practices of Vermont residents participating in a voluntary state health department radon testing program found to have high radon levels	To increase radon mitigation	Sample of Vermont residents with high household radon levels ((≥148 Bq/m^3) that received and returned free radon test kits from the VT Health Department between 1995 and 2003 (n=286).	Paper-based survey sent to homes by mail containing questions on radon awareness, testing and mitigation behavior, barriers to mitigation, and demographic data. Authors included a one dollar incentive to complete and return the survey.	Response rate: 63% (179). 89% stated they were concerned about their radon level, and 74% tested because they were concerned for their health. 16% (28) of homeowners stated testing was done as part of a real estate transaction. Mitigation rate was 43% (76); of the homes that were mitigated, 67% (51 of 76) were completed by a contractor, and 32% (24 of 76) were completed by a member of the home or friend. 47% (36 of 76) claimed mitigation costs exceeded $1,000, 32% (24 of 76) claimed mitigation costs were between $100-$1,000, and 19% (14 of 76) claimed mitigation costs were under $100. Common reasons for not mitigating was lack of concern for elevated radon and expense. A motivating factor to remediate was concern for real estate value.	Authors suggest associating radon testing with real estate transactions is likely to influence residents to mitigate as home value appears to be a significant concern. Demographic information was collected. For the respondents who mitigated, the types of mitigation performed were ventilation systems, cracks sealed, or doors/windows opened; respondents could indicate multiple answers for the type of mitigation performed, so there is not a direct correlation between cost and mitigation action. However, the EPA assumed mitigations performed by a certified contractor and mitigation cost over $1,000 are sufficient in reducing home radon levels
Ryan, D. and Kelleher, C., 1999	Investigate radon mitigation actions of households with high radon levels in the Galway, Ireland area.	To increase radon testing and mitigation	All households with high radon levels measured by the Radiological Protection Institute of Ireland in the Galway area between 1989-1999. (n=237).	Qualitative and quantitative data on participant testing and mitigation experiences, attitudes and risk perception of hazardous substances, and radon knowledge collected via paper-based survey and in-person interviews. The entire sample pool (n=237) was surveyed via paper-based questionnaire. A face-to-face interview was conducted with 10% (14) of all households who participated in the paper-based survey.	Written survey response rate was 61% (141). 43% accurately recalled their radon level. 65% (91 of 141) of respondents stated some kind of mitigation had been taken, but in most cases, this is related to minor home modification (frequently opening of windows); respondents claimed remediation costs ranged from $26-$2,600. Of the respondents who claimed some sort of remediation, 59% (83) performed a partial modification or a minor home modification (opening of windows), 6% (9) performed complete radon remediation. Primary sources of radon information were literature, the media, and family members: 48%, 40%, and 18%, respectively. Disincentives to action were indecision (41%) and expense (29%).	For the 6% of respondents who performed complete mitigation, we are assuming the cost was near the higher end of the claimed remediation cost ($2,600). For the 59% who performed partial (insufficient) or minor home modification, we are assuming the remediation cost was near the lower end of the claimed cost ($26). No radon testing/remediation targeted health campaign to the Galway area was reported in the study.
Wang et al., 1999	Survey of radon remediation in high radon homes (≥148 Bq/m^3) in New York State that have been exposed to the New York State Department of Health's (NYSDOH's) radon awareness,	To increase radon awareness, testing, and mitigation	Adult residents in high radon homes (≥148 Bq/m^3) in New York recorded in NYSDOH's radon testing database (n=1,522).	Cross-sectional statewide telephone survey administered from Sep. 1995 to Jan. 1996 to assess radon risk perceptions, testing, and remediation. Using NYSDOH database of radon testing results,	Response rate: 73% (1,113 of 1,522). Overall, 60% of survey respondents (665 out of 1,113) reported performing some form of radon mitigation in their homes: 26% (294 out of 1,113) reported opening windows/doors or sealing cracks/openings (low-cost method), while 32% (356 out of 1,113) reported installing a powered system to increase	All survey respondents had requested a radon detector (for a small fee) from NYSDOH before and had their testing results recorded in NYSDOH's database. Therefore, all respondents had been exposed to NYSDOH's radon public awareness campaigns.

	testing, and remediation campaign.			authors sampled all homes with radon levels ≥370 Bq/m3 and used stratified sampling by county to select homes with radon levels between 148 Bq/m^3 and 370 Bq/m^3.	ventilation or draw out radon (high-cost method). About a quarter of respondents participated in a radon diagnostic assistance program which provides eligible homeowners with up to $300 of financial assistance towards radon mitigation (297 of 1,113). 77% (229 out of 297) of these participating homes reported performing some form of radon mitigation compared to 53% (436 out of 816) of non-participants. Overall, 72% (480) of homes cited publicity about radon health effects as the reason they performed radon mitigation. 26% (165) of homes reported requesting radon mitigation information from NYSDOH and 76% (480) from a radon contractor.	Some respondents were enrolled in a radon diagnostic assistance program that provided up to $300 towards mitigation expenses for eligible participants. These respondents had a higher rate of overall remediation (high- vs. low-cost methods not specified) compared to respondents not in the assistance program. The study also looked at mitigation rate by age, household income, homeownership, and home radon levels, and examined mitigation type (high vs. low cost) by household income and home radon levels. The low-cost method was used by 74% (99) of the highest income households in the study ($75,000+) but only 18% (2) of lowest income households (<$12,500). In contrast, 82% (9) of lowest income households reported opening windows/doors or sealing cracks and openings to reduce radon levels (low-cost) compared to 25% (34) of highest income households.
Wang et al., 2000	Survey of radon awareness and testing in high-radon counties targeted by public awareness programs and not high-radon counties of New York State.	To increase radon awareness and testing rates	Adult residents in high-radon (≥148 Bq/m^3) and not high-radon counties of New York State (n=1,209).	Cross-sectional statewide telephone survey administered from Nov. 1995 to Jan. 1997 to assess radon awareness, testing, and remediation. Half of interviews were conducted in high-radon counties (targeted by public awareness programs) and half in not high-radon counties. Authors decided what number of interviews to conduct per county based on the number of owner-occupied housing units indicated in the 1990 U.S. Census.	The study surveyed 1,209 participants. Greater radon testing was found in counties with higher radon levels (18%, 93 out of 510) compared to other counties (12%, 59 out of 483) among the 993 respondents aware of radon (i.e. who have heard of radon). Among respondents aware of radon, 45% (69 out of 152) conducted self-tested for radon, while 24% (37 out of 152) had testing conducted by radon contractors and 5% (8 out of 152) had testing done by the Health Department. In high-radon areas (targeted by public awareness programs), 48% (45 out of 93) of households self-tested while 20% (19 out of 93) hired a contractor and 6% (6 out of 93) had testing done by the health department. In other areas (not targeted by public awareness programs), 41% (24 out of 59) of households self-tested while 31% (18 out of 59) hired a contractor and 3% (2 out of 59) had it done by the health department. Among respondents aware of radon, 152 (15%) had their homes	Authors attributed findings at least in part to NYSDOH public awareness programs which target high radon areas but did not directly evaluate them. No data on mitigation were provided. The focus of the study was on radon knowledge and the relationship between knowledge and radon testing. The study also looked at radon knowledge by sex, age, education level, homeownership, county of residence (high/low radon county). The authors also looked at testing by these demographic variables but only among respondents who have heard of radon.

					tested, of which 12 (8%) got a positive test result (>148 Bq/m^3), of which 5 (42%) took remedial action. Because numbers were small, remediation was not included in analysis.	
Zhang et al., 2011	Audit and survey of the UK radon program. London homeowners who had high levels of radon in their homes were sent surveys on radon knowledge, mitigation actions, and demographic information.	To increase radon testing and mitigation	All London householders in the national radon database that have a test finding high radon levels (>195 Bq/m^3) since 2000. (n=8,834).	Paper-based survey of radon levels, perceptions of radon program and provided information and support, mitigation, and demographic information. Tenants in private housing were included in the sample, but not tenants in social housing where mitigation responsibility falls elsewhere. An unconditional logistic regression model was used to estimate the odds ratio for remediation, comparing remediated and unremediated homes.	Response rate: 49% (4,326). 30% (1,441) of respondents stated that they had done some method of remediation to reduce radon levels. 17% (767 of 4,324) reported mitigation cost; remediation methods and costs were reported ranging from $650-$4,000. For those who adopted an effective method, reported costs ranged from $1300-$4000. 79% (606 of 767) of those who remediated claimed they spent less than $1300, and 21% (161 of 767) spent more than $1,300 on remediation. Factors that predicted low remediation rates were high radon level, long length of time in the residence, smoking, and being an older (65+) resident.	Householders with higher incomes and higher socio-economic status were more likely than others to remediate. Authors suggest socioeconomic status is likely to influence remediation rate and likelihood of responding to the survey; therefore, the remediation rate reported in this study may be inflated.