Executive Summary

Introduction. The City of Sarnia (City) services a population of approximately 72,000 with purchased treated drinking water from the Lambton Area Water Supply System (LAWSS). As required under Schedule 15.1 of O. Reg. 170/03 under the *Safe Drinking Water Act, 2002*, the City participated in the legislated community lead testing program between 2008 and 2010.

Based on results from the community lead testing program, the City of Sarnia triggered the requirement to prepare a Corrosion Control Plan (CCP). After consulting with LAWSS about the possibility to implement corrosion control treatment at the LAWSS WTP, this option did not appear to be feasible in this two-tiered system since the other LAWSS municipalities did not require corrosion control treatment. The City therefore sought regulatory relief in 2010 from a) conducting residential sampling as part of the legislated community lead testing program, and b) preparing a Corrosion Control Plan (CCP) under Schedule 15.1. Instead of corrosion control treatment, the City proposed to continue its existing practice of replacing publicly-owned lead service lines (LSLs) as encountered, as a means to remove lead from the Sarnia Water Distribution System, thus controlling lead measured at the tap.

The MOECC requested in 2016 that the City submit a Lead Reduction Plan, per Section 10.0 of the MOECC's *Guidance Document for Preparing Corrosion Control Plans for Drinking Water Systems (Guidance Document)*, through Conditions 1.10 and 1.11 of Schedule D, as outlined in the City of Sarnia's Municipal Drinking Water Licence (MDWL) for the Sarnia Water Distribution System (Licence Number 037-101, Issue Number 5, dated June 1, 2017). This LRP was prepared in response to these conditions. As a measure of due diligence, the City has chosen to assess and evaluate both chemical treatment alternatives and lead source reduction alternatives within this Plan.

Background. The Sarnia Water Distribution System receives water from the LAWSS water treatment plant (WTP) which is situated in the City of Sarnia on the southern tip of Lake Huron at the headwaters of the St. Clair River. The LAWSS WTP draws its source water from Lake Huron via the St. Clair River.

The LAWSS WTP uses chemically assisted direct filtration with disinfection. The facility consists of an intake system, a low lift pumping system, a treatment system, and distribution pumping system that supplies water to six drinking water systems (DWSs), including the City of Sarnia, the Township of St. Clair, the Town of Plympton/Wyoming, the Village of Point Edward, the Township of Warwick, and the Municipality of Lambton Shores. The Sarnia Water Distribution System (SWDS) is considered to be a "flow-through" system, in that water from the LAWSS WTP must first pass through the Sarnia system before reaching LAWSS's other municipal customers.

Approximately 57% of the watermains in Sarnia are iron-based, including cast and ductile iron. Sarnia's oldest watermains date from pre-1900, and the age of watermains generally decreases moving east from the older portion of the City. The City has developed a preliminary, conservative estimate for the number of LSLs in the SWDS, based on the age of watermains. Of the City's 25,000 service connections, the City estimates that there could be:

- 4,483 known or suspected **public LSLs**
- 8,643 known or suspected **private LSLs**

The potential geographic extent of known or suspected LSLs is consistent with the area bound by Front St., Exmouth St., Murphy Rd., and Campbell St.

Sarnia has embarked on a long-term capital replacement program targeting aged infrastructure over the next decade and beyond. For the past several years, focus has been placed on sewer separation (which includes replacement of all utilities in City-owned right-of-ways). As lead services became a concern following the Schedule 15.1 lead testing program, greater emphasis has been placed on targeting areas with LSLs, in addition to the City's other considerations.

Taking advantage of the excavation of the road and replacement of the entire watermain, replacement of multiple public LSLs can be carried out efficiently during these projects. The City estimates a cost of approximately $4,000 per replacement (for the public portion of the LSL) when carried out during these capital replacement projects. Outside of capital replacement projects, the City replaces public LSLs as encountered during distribution system repairs and related activities or when requested by the homeowner. The City estimates a cost of approximately $10,000 per replacement (for the public portion of the LSL) when carried out as a single replacement outside of capital replacement projects.

Water quality review. A detailed review of LAWSS's raw and treated water quality, water quality in the SWDS, and water quality at the tap was carried out. A summary of baseline water quality conditions is presented in Table ES-1. The origin of target corrosion by-products and their sources are presented in Table ES-2 and Table ES-3, respectively.

Table ES-1. Summary of Baseline Conditions for Corrosion Control

Facility	Flow Rates (ML/d)	pH	Alkalinity (mg/L as $CaCO_3$)	Other Considerations Average (Range)
Lambton Area Water Supply System WTP	Rated: 181.8 2012-2016 Average: 53.8	Average: 7.56 Typical range: 7.3 to 7.8 Absolute range: 6.75 to 8.10	Average: 72 Range: 65 to 78	DIC, mg/L: 18.5 (17.1 to 20.1) *Tr.* Lead, µg/L: 2.7 (<0.02 to 94) *Tap* Iron, µg/L: 1.3 (0 to 10) *Tr.*; 488 (17 to 1,120) *DSS* Manganese, µg/L: 0.7 (0.1 to 7.8) *Tr.*; 25 (0.4 to 59) *DSS* Aluminum, µg/L: 92 (7 to 2,380) *Tr.*; 555 (191 to 1,530) *DSS* Calcium, mg/L: 27 (26 to 28) *Tr.*; 29 (28 to 32) *DSS* Sodium, mg/L: 6.3 (5.7 to 6.6) *Tr.*

Note: Tr. – Treated water; Tap – Tap water; DSS – Distribution system, pipe scale

Table ES-2. Summary of Origin of Target Corrosion By-Products for Corrosion Control

Parameter	Source Water	Treated Water	Distribution System	Premise Plumbing
Primary corrosion by-products				
Lead	Negligible	Negligible	Negligible	Present
Copper	Negligible	Negligible	Not measured	Not measured
Iron	Present (Measured up to 33% of the AO)	Negligible	Present in watermain scale	Not measured
Other parameters for consideration (secondary impacts)				
Aluminum	Present (Measured up to 69% of the OG)	Present (Regularly exceeds the AO during the summer)	Present in watermain scale	Not measured*
Calcium	Present	Present	Present in watermain scale	Not measured*
Sodium	Present	Present	Not measured; no change expected from treated water	Not measured*
Manganese	Present (Measured up to 16% of the AO)	Present (Measured up to 16% of the AO)	Present in watermain scale	Not measured*

*No change expected from distribution system

Table ES-3. Source Summary Table

Contaminant	Source	Location	Extent/Results				
			No. of Samples	Avg	Min	Max	Significant (Y/N)
Lead, µg/L	Director's Order, 2007	Tap	21	5.7	0.06	32.4	**Y**
	Schedule 15.1 (5 rounds)		445	2.7	0.04	46.2	
	Summer 2017 sampling (3 homes)		5	63.0	0.44	94.1	
	Director's Order, 2007	Distribution System (bulk water)	3	0.43	0.21	0.65	N
	Schedule 15.1 (15 rounds)		160	0.16	<0.01	1.34	
	Summer 2017 sampling (hydrants)		12	0.19	<0.01	0.47	
Iron, µg/L	Summer 2017 sampling (hydrants)	Distribution System (pipe scale)	10	488	17	1,120	Bulk water: N Scale: Y

From this review, the following key observations are relevant in the context of lead release and corrosion control.

- The variability in treated water is high (-0.81/+0.35 pH units though typically within ±0.25 pH units). Tighter control of treated water pH (i.e., ±0.1 pH units) is usually preferred for control corrosion.
- Treated water is not a significant source of the corrosion-related metals, lead, copper, and iron.
- Treated water from the LAWSS WTP seasonally exceeds the operational guideline (OG) for aluminum. Aluminum was present (predominantly in the particulate form) in watermain scale at high concentrations. If a phosphate-based corrosion control approach is implemented, a unidirectional flushing program will be required to remove this accumulation of aluminum, which will otherwise react with phosphate.
- Under typical water quality conditions observed in the Sarnia Distribution System, the alkalinity is such that it does not cause the calcium carbonate precipitation potential (CCPP) to exceed 7 mg/L as $CaCO_3$, meaning that excessive precipitation of calcium carbonate is not expected under existing conditions in this system.
- The distribution system is not considered to be a source of lead measured at the tap.
- Though high levels of iron (predominantly in the particulate form) were present in the scale from cast iron watermains, the City has not typically received discoloured water complaints. It is likely that iron is present in the scale formed over decades on LSLs and premise plumbing, which has implications for the sorption of lead and its subsequent release.
- Manganese was present in the watermain scale at appreciable concentrations considering the trace level of manganese typically observed in the treated water. If treatment-based corrosion control is implemented, watermain scales may destabilize during the acclimation period, which could potentially result in the release of manganese (potentially above the AO of 50 µg/L).
- The geographic extent of lead exceedances observed during residential Schedule 15.1 sampling was limited to the City’s estimated lead zone.
- Results from residential sampling suggest that both premise plumbing and the service lines are contributing to lead measured at the tap, however additional studies such as lead profile testing and plumbing surveys at individual homes would be required to confirm this.
- The highest lead result observed during Schedule 15.1 sampling was 46.2 µg/L, which was identified as a post-LSL-replacement lead spike. The majority (86%) of sites sampled had lead levels at or below 5 µg/L.
- Lead spikes of 19.3 and 46.2 µg/L were observed in two of seven homes sampled three to eight months following LSL replacement. Lead spikes following LSL replacement are typically associated with particulate lead release. The occurrence of post-replacement lead spikes in the Sarnia system demonstrates that a lead management strategy based on LSL replacement will require measures to mitigate the impact from post-replacement lead spikes, to protect vulnerable populations.
- Post-replacement tap water lead levels were well below the MAC in five of seven homes sampled following LSL replacement. Post-replacement lead levels in these homes were low, ranging from 0.12 to 1.83 µg/L, demonstrating the benefit of LSL replacement.
- At one of these homes, a pre-replacement lead sample had been collected. Removal of the LSL (not known whether full or partial) at this location resulted in a 90% reduction in lead compared to the pre-replacement level (18.4 µg/L prior to replacement and 1.83 µg/L post-replacement).

A summer sample was collected from this home in 2017 (approximately 9 years following replacement); the lead level measured at the tap was low (0.33 µg/L), demonstrating long-term reduction.

- Additional sampling was carried out in summer 2017 at two homes where a partial (City-side) LSL replacement had occurred 40 years previously, in 1977. Lead measured at these houses was high; in one case, lead was measured at more than nine times the MAC. Lead levels of this magnitude suggest that further data need to be collected to demonstrate the merits of partial LSL replacement, and confirms that partial LSL replacement may not be suitable or effective in all circumstances.

Identification of lead reduction alternatives. Based on the treated water pH and dissolved organic carbonate (DIC), two potential *treatment* options for the Sarnia system were identified as follows:

1. Raise the pH in 0.3 unit increments using caustic or soda ash or potash, or
2. Add orthophosphate

Corrosion control based on upward pH adjustment in this water may be bound by the following limitations:

- Upper limit around 8.6 based on managing excessive calcium carbonate precipitation under summer temperature conditions.
- A greater degree of pH instability can be expected in the range of 8.0 to 8.5 (due to lower buffer intensity); this may be manageable through other water quality adjustments (e.g., increasing alkalinity and DIC).

A desktop assessment of theoretical lead solubility suggested that:

- **pH adjustment:** Below pH 8.3, only marginal reductions in lead solubility would be expected, whereas a larger reduction in lead solubility would be expected if the pH is increased beyond 8.6. However as previously noted, caution should be taken in increasing the pH above 8.6 in this water to avoid excessive calcium carbonate precipitation.
- **Orthophosphate:** Lead solubility (due to uniform corrosion) would be expected to decrease by approximately 85% at an orthophosphate dosage of 2 mg/L as PO_4. This reduction is significantly higher than that which would be expected from increasing the pH to 8.6.

The desktop assessment does not address lead release from mechanisms other than uniform corrosion (e.g., lead scale dissolution and particulate release) and cannot be used to predict treatment conditions that would be needed to achieve compliance, which must be assessed through a pipe loop study.

In addition to treatment-based lead reduction approaches (pH adjustment and phosphate-based inhibition), a non-treatment approach consisting of LSL replacement was also considered.

Identification of potential impacts. Based on the review of system characteristics, the water quality assessment, and a review of analogous systems, potential secondary impacts and implementation issues associated with the implementation of pH adjustment, phosphate-based inhibition, and LSL replacement were identified, as well as potential mitigation measures to address these impacts and issues. These are summarized in Table ES-4.

Development of alternatives. Based on the assessment of secondary impacts and implementation issues, seven lead management alternatives were initially developed for Sarnia. These alternatives were based on the three approaches previously identified: LSL replacement; phosphate-based treatment; and treatment based on pH adjustment. A fourth approach based on LSL replacement with a focus on interim investigation was included as an "interim alternative". The alternatives consisted of the following:

- **LSL-based alternatives:**
  - Option A: Accelerated LSL replacement within 15 years
  - *Option B: Accelerated LSL replacement within 25 years*
    - *Screened out because the LSL replacement period was too long*
- **Treatment-based alternatives:**
  - Option C: Treatment with phosphate (indefinite) with LSL replacement within 50 years
  - *Option D: Treatment with pH adjustment (indefinite) with LSL replacement within 50 years*
    - *Screened out because not expected to provide adequate lead reduction*
  - Option E: Treatment with pH adjustment (indefinite) with accelerated LSL replacement within 40 years
- **Alternatives based on LSL replacement with interim investigations:**
  - Option F: Interim data collection period (3 years) focused on verification sampling and treatment investigations, with full homeowner support, followed by re-evaluation of alternatives
  - *Option G: Interim data collection period (3 years) focused on verification sampling and treatment investigations, with minor homeowner support, followed by re-evaluation of alternatives*
    - *Screened out because it does not provide an adequate level of interim protection*

The program components for these alternatives were defined based on the need for mitigation measures as identified in Table ES-4. Figure ES-1 provides an overview of the program components included with the four options (A, C, E, and F) that were carried forward for further consideration.

Table ES-4. Potential Secondary Impacts, Implementation Issues, and Related Mitigation Measures for Sarnia

Secondary Impact	Mitigation	LSL Replacement	Phosphate	pH Adjustment
Particulate lead spikes	• Provide POU filters • Post-replacement monitoring	●	●	●
Ability to reduce lead levels measured at the tap	• Combine treatment with accelerated LSL replacement to achieve compliance • Encourage full LSL replacement through tailored public outreach program • Homeowner support program (loan/grant) • Post-replacement monitoring	●	●	●
Low homeowner participation	• Tailored public outreach program • Homeowner support program (loan/grant) • Provide POU filters	●	●	●
Lead release from sources other than LSLs	• Tailored public outreach program	●		
Interim exposure to lead	• Tailored public outreach program • Verification sampling • Provide POU filters	●	●	●
Implementation in a Two-Tier System	• Investigate these concerns prior to implementing treatment		●	●
Reaction of phosphate with other constituents (Al, Fe, Ca)	• Coagulation optimization to reduce treated water aluminum • Pre-filter orthophosphate dosing • Unidirectional flushing to manage accumulation of precipitate		●	
Increased bacteria	• Distribution system monitoring • Unidirectional flushing		●	●
Wastewater impacts	• Increase chemical use at WWTP to meet phosphorus discharge limit		●	
Storm sewer impacts	• Maintain phosphate residual below the storm sewer discharge limit		●	
Calcium carbonate precipitation	• Maintain pH at or below 8.6			● *(summer)*
Iron corrosion	• Manage through UDF	● *(existing)*	● *(existing)*	*Improvement relative to current conditions*
Release of pipe scale constituents	• Manage through UDF		●	●
Increased DBPs	• Distribution system monitoring			●

	Option A *Replace LSLs*	Option C *Phosphate*	Option E *pH*	Option F *Investigation*
Verification sampling	590 /yr	180 /yr	220 /yr	1,200 /yr
Replace public LSLs	150 /yr	40 /yr *(current practice)*	60 /yr	85 /yr
Private LSL loan	50 /yr			50 /yr
POU filters	250 /yr	140 /yr	160 /yr	185 /yr
Public outreach	✓	✓	✓	✓
Monitoring	Residential	Residential Dist. System	Residential Dist. System	Residential
Municipal impact study		✓	✓	✓
Treatment trial		✓	✓	✓
Design & construction		✓	✓	
Watermain flushing	✓ *(current practice)*	✓ *(increased)*	✓ *(increased)*	✓ *(current practice)*
Re-evaluate				✓

Figure ES-1. Summary of Program Components for Options A, C, E, and F

Rationale for preferred alternative. There is currently limited information about the actual number of LSLs in the City of Sarnia. In 2017, an estimate was developed using very conservative assumptions. This 2017 estimate of the number of LSLs in the Sarnia Distribution System is therefore likely much larger than the actual number of LSLs in the system. The City cannot make a defensible decision or financial commitment to carry out accelerated LSL replacements at the rate dictated by the 2017 estimate of LSLs. Further, LAWSS cannot defensibly justify implementing corrosion control treatment to its members without sufficiently identifying and quantifying impacts on the latter, particularly when the LSL replacement alternative is poorly defined due to the conservative estimate of the number of LSLs.

Based on these circumstances, "Option F" describes the first three years of a lead management strategy which is based on eliminating all suspected LSLs within 15 years (which is typically the maximum duration accepted by the MOECC), either by confirming non-leaded material via available information or, where LSLs are present, actually replacing the LSL. During this three-year period, focus is placed on developing required programs, accelerated LSL verification, and investigating treatment options, with LSL replacement continuing at higher than current rates. This rate of replacement however is lower than that which would be required to replace all LSLs in 15 years, based on the 2017 estimated number of LSLs in the Sarnia Distribution System.

As shown in Figure ES-2, the objective of this interim plan is to collect the information that is needed for the City and LAWSS to defensibly commit to a lead management program for the City of Sarnia, namely:

- Refining the LSL estimate to a more realistic number upon which to build a financially sound plan.
- Confirming the level of homeowner participation in conducting private LSL replacements.
- Confirming the level of public health protection provided by LSL replacement in combination with interim protection measures such as filters (i.e., through reductions in lead measured at the tap).

- Assessing the feasibility of implementing corrosion control treatment at the LAWSS WTP, in terms of:
  - o Understanding the impacts of corrosion control treatment on the LAWSS member municipalities.
  - o The ability of different corrosion control treatment alternatives to control lead measured at the tap, within the Sarnia Distribution System.
  - o The ability to minimize interference with existing water treatment processes at the LAWSS WTP (specifically, coagulation due to seasonally elevated aluminum residuals).

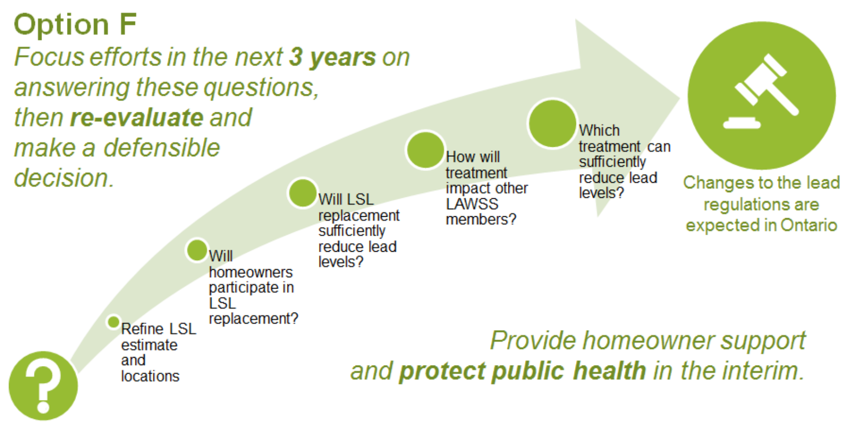

Figure ES-2. Rationale for selecting Option F

As shown in Figure ES-3, the commitment to replace all LSLs in 15 years (by 2034) will be re-evaluated at the conclusion of the three-year interim period, based on the totality of information collected over the course of this three-year interim plan. If, based on this re-evaluation, it is determined that the remaining LSLs cannot be removed by 2034 (12 years starting in 2022) and/or that LSL replacement on its own does not provide a sufficient level of public health protection, a course correction can be made and corrosion control treatment will be negotiated with the LAWSS Board. Alternatively, if replacing the remaining LSLs by 2034 is determined to be feasible, the City can develop a realistic, fiscally-sound plan to replace the remaining LSLs in 12 years.

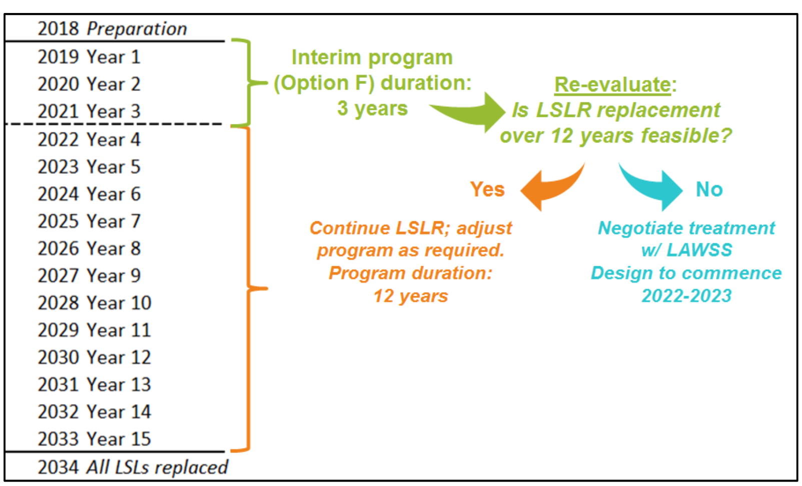

Figure ES-3. Overview of Option F (interim three-year plan)

Advantages of "Option F" include:

- **Protection of vulnerable populations.** By kick-starting the multiple programs that are required in support of lead management, such as public outreach and education, homeowner assistance (loan for private LSL replacement), interim/temporary lead reduction measures (filters), and monitoring, "Option F" provides protection of vulnerable populations during this interim period. These programs would be required regardless of whether the City moves forward with an LSL replacement approach or a treatment approach.
- **Planning for potential future corrosion control treatment.** "Option F" includes background studies in support of a corrosion control treatment approach. Corrosion control treatment can therefore be implemented in 2022-2023 (moving into the design phase) should it be deemed necessary at the end of the three-year period. In other words, "Option F" does not delay the possible implementation of corrosion control treatment relative to what would be possible if a decision was made *today* to implement corrosion control treatment.
- **Adaptable.** By allowing for a course correction (if needed) in 2022, "Option F" provides the City and LAWSS with the flexibility to adapt to upcoming changes to Ontario's regulatory framework related to lead.
- **Fact-based decision-making.** By focusing on LSL replacement and the collection of required information while protecting vulnerable populations over an interim period, "Option F" sets the City and LAWSS on track to make a defensible decision at the end of the interim period.

Phased implementation plan. Since key program components require a considerable amount of time and effort to develop and implement, the three-year interim plan will commence in 2019 (Year 1), and will conclude at the end of 2021 (Year 3). The (previously allocated) lead management budget for 2018 will be used for 2018 program development activities in support of implementing the three-year plan in 2019. The following is a high-level overview of the plan's implementation:

1. **LSL verification program**
   - Verification sampling (starting in 2019) will aim to verify 1,200 homes annually. Pre-construction verification sampling will occur in summer 2018.
   - Records review to refine the LSL database will commence summer 2018, and will continue on an ongoing basis.
2. **LSL replacement program**
   - Because the City cannot control how many LSLs will be encountered during sewer separation / watermain replacement projects and operations projects, nor the level of homeowner participation for private LSL replacement, the number of annual LSL replacements is expected to vary from year to year. It is estimated that between 75 to 85 public LSLs, and approximately 60 private LSLs will be replaced annually during the three-year program, starting in 2019.
3. **Treatment and distribution system maintenance**
   - The City will negotiate with LAWSS for the completion of a member municipality impact study in 2019, to determine whether corrosion control treatment is feasible in the LAWSS system by assessing and quantifying potential impacts to the member municipalities of LAWSS.
   - If treatment is determined to be feasible, the City will negotiate with LAWSS for the completion of a pipe loop study (commencing in 2020) to investigate the ability of the treatment alternatives to control lead in the Sarnia Distribution System. A coagulation

optimization study may also be conducted if phosphate-based inhibition is identified, through the pipe loop study, as the preferred approach.

- The interim lead management strategy will be re-evaluated in 2021 based on the information gathered during the three-year period.

4. **Homeowner support program**
   - A loan program for private LSL replacement is recommended to be developed in 2018 for rollout in 2019. It is estimated that 50 loans will be offered per year, at a maximum cost of $2,000 per loan.
   - A point-of-use filter program is recommended to be developed in 2018 for rollout in 2019. This will consist of a filter rebate program (estimated at 100 filter rebates for $40 each) that will be offered annually to households with vulnerable populations following the detection of lead through verification sampling. Additionally, filters are recommended to be provided to homeowners for free for a period of six months following any public LSL replacement, to reduce exposure to “lead spikes”.
5. **Public outreach program**
   - Communication materials to meet immediate needs will be updated in 2018.
   - A communications plan will be developed in 2018, for rollout in 2019. This plan will document target audiences, key messaging, communication formats and mediums, the timing of communications, communications protocols and lines of communication, and internal training needs. Additional communication materials for the public outreach program (as defined in the communications plan) will be developed.
   - An initial public outreach campaign will be rolled out in 2019. This will include communication with community partners.
   - A communication blast will occur annually to solicit participation in the verification sampling program and LSL replacement program.
6. **Monitoring for effectiveness**
   - Residential post-replacement sampling will use the Schedule 15.1 sampling protocol at approximately 6 and 12 months following replacement. Samples will be analysed for total lead and total iron.