NYC DEP Corrosion Control Research

Expert Panel Workshop

NYC DEP Corrosion Control Research Expert Panel Workshop

Final Report

Prepared For:

New York City Department of Environmental Protection

Expert Panel:

Dr. Vernon Snoeyink, Professor Emeritus, University of Illinois at Urbana-Champaign

Dr. David Cornwell, President, Cornwell Engineering Group, Inc.

Jonathan Cuppett, Research Manager, The Water Research Foundation

For more information, contact:
The Water Research Foundation

1199 North Fairfax Street, Suite 900
Alexandria, VA 22314-1445
P 571.384.2100

6666 West Quincy Avenue
Denver, Colorado 80235-3098
P 303.347.6100

www.waterrf.org
info@waterrf.org

Table of Contents

Overview

An Expert Panel Workshop was convened on March 20, 2019 at NYCDEP's (DEP) Kingston location to help the New York City Department of Environmental Protection (DEP) 1) evaluate their corrosion control research portfolio and identify areas for potential further study, and 2) understand the mechanisms of microbial influenced corrosion (MIC) on stainless steel piping and evaluate if the current Microbiological Corrosion Prevention Plan is adequate.

The Water Research Foundation identified and provided travel support to Expert Panel members Dr. David Cornwell, Dr. Vernon Snoeyink, and Jonathan Cuppett, and DEP invited staff from the Bureau of Water Supply (BWS) and the Bureau of Water and Sewer Operations (BWSO) to participate in the workshop.

This report provides the Expert Panel recommendations to DEP and summarizes the workshop.

Expert Panel Summary and Recommendations

Distribution System Corrosion Control

The Panel is of the opinion that increasing the orthophosphate dose from 2 mg/L to 3 mg/L, as PO_4, and increasing the pH to the 7.5 to 7.7 range, will decrease the concentration of lead released from lead service lines. DEP could make these changes full scale without a testing program and use sentinel homes to track results, or it could first carry out a research program to quantify the magnitude of the lead concentration reduction these changes would accomplish. If the alternative of going directly to full-scale is chosen, the effect of the change in quality should be carefully monitored using tools such as lead release profiles at sentinel homes as indicators of the effectiveness of the changes.

The Panel reviewed DEP's corrosion control and research program. Assuming that further study will be done before dosage and/or pH is increased full-scale, it recommends that the City Island research program be modified and expanded, or a new pipe loop study be developed using Cat/Del water, or both. The study should include a determination of the importance of iron and manganese, if these elements are found in the scale, and disinfection by products, because changes in concentrations of the latter will occur if changes in pH are made. The City Island program is limited by the small number of residences with lead service lines available for study, and by the quantity and type of water available for the study. Pilot studies should be carried out using pipes harvested from the distribution system with scales that are typical of those that are formed under typical operating conditions. Information from studies using pipes such as the yard pipe now in use at City Island are not likely to yield useful information for full-system corrosion control because of the nature of the scale on these pipes and the flow control regime. The study should evaluate the benefits of increasing PO_4 dose, increasing pH, using Croton water versus Cat/Del water, and should include the use of house lead concentration profiles to supplement the information obtained using one-liter first-draw samples. Pipes harvested from residences with different water consumption patterns should be considered for use as well. Scale analyses are recommended for the purpose of relating lead release rate to the composition of the lead scale layers and the composition of the water.

The panel recommends that a detailed plan be developed for the above recommended study if it is to be undertaken.

Microbial Influenced Corrosion (MIC)

The panel is of the opinion that MIC has not been conclusively identified as a major cause of the observed corrosion in stainless steel pipes. Sediment deposits and the long stagnation time also are potentially important factors. Additional monitoring of sediment accumulation, microbial activity using adenosine triphosphate (ATP) test kits, and key water quality parameters, such as pH, dissolved oxygen and alkalinity, is recommended. It is unlikely that flushing, whether once per six months or at a much greater frequency, will have any useful benefit because biofilms develop rapidly (days to weeks) and it is difficult to remove biofilms by scouring.

The panel recommends that camera footage inside the pipes be obtained where accessible for better understanding of conditions within the pipe.

Appendix A: Expert Panel Workshop Agenda

Water Research Foundation Corrosion Control Workshop

March 20, 2019

Time	Activity	Presenter
8:30 am	Welcome and Introductions	Lori Emery
8:45 am	The Water Research Foundation Update	Jennifer Warner/Jonathan Cuppett
9:00 am	Statement of Today's Objectives	Lori Emery
9:05 am	NYC Lead Program Compliance History	Steve Schindler
9:30 am	DEP's Current Corrosion Control Research	Salome Freud
10:15 am	Break	
10:30 am	Questions from Panel	Panel
11:00 am	Source Water Operations Microbial Influenced Corrosion (MIC) Issues/Mitigation Approach	Tina Johnstone/John Vickers
11:20 am	In-City Corrosion Issues	Roopesh Joshi
11:45 am	Questions from Panel	Panel
12:00 pm	Working Lunch (provided)	Facilitated Discussion
1:00 pm	Panel Feedback/Recommendations	Panel
2:00 pm	Next Steps/Summary Report	Panel/Schindler/Johnstone/Joshi
2:30 pm	Thanks to Panel, Next Steps, Adjourn	Emery/Warner

Appendix B: Expert Panel Workshop Participants

Name	Title	Bureau	Email
Borchert, Dale	Chief, Process Control, WTO, Upstate	BWS	BorchertD@dep.nyc.gov
Cornwell, David	President, Cornwell Engineering Group	Panel	DCornwell@cornwellinc.com
Cuppett, Jonathan	Research Manager	Panel	jcuppett@waterrf.org
DeKoskie, Anita	Special Assistant to L. Emery, Research Applications	BWS	adekoskie@dep.nyc.gov
Dewan, Allison	Senior Technical Advisor, Research Applications	BWS	BennettA@dep.nyc.gov
Emery, Lori	Director, Research Applications	BWS	LEmery@dep.nyc.gov
Farmwald, Jennifer	Senior Manager, External Relations, Research Applications	BWS	JFarmwald@dep.nyc.gov
Farnan, Mike	Director, Field Operations	BWSO	mfarnan@dep.nyc.gov
Freud, Salome	Chief, Distribution Water Quality Operations	BWS	SalomeF@dep.nyc.gov
Gjonbalaj, Flake	Technical Assistant, Chief Distribution Water Quality	BWS	FGjonbalaj@dep.nyc.gov
Glaser, Carla	Section Chief, Distribution Science & Planning	BWS	CarlaG@dep.nyc.gov
Johnstone, Tina	Director, Source Water Operations	BWS	JohnstoneT@dep.nyc.gov
Joshi, Roopesh	Chief, Structures and Facilities, Capital Program Management	BWSO	RJoshi@dep.nyc.gov
Keesler, James	Technical Services Engineer/Mechanical Engineer	BWS	JKeesler@dep.nyc.gov
Le, The	Assistant Civil Engineer	BWSO	TLe@dep.nyc.gov
Lewis Askildsen, Kirsten	Special Assistant to Steve Schindler, Director Water Quality	BWS	LewisK@dep.nyc.gov
Michaud, Daniel	Chief, Tunnel & Aqueduct Rehabilitation Programs	BWS	Dmichaud@dep.nyc.gov
Railing, Jason	Technical Advisor, Research Applications	BWS	railingj@dep.nyc.gov
Reaves, Adam	Director, Water Treatment Operations	BWS	AReaves@dep.nyc.gov
Schindler, Steven	Director, Water Quality	BWS	SchindlerS@dep.nyc.gov
Snoeyink, Vernon L	Professor Emeritus, University of Illinois	Panel	snoeyink@illinois.edu)
Vickers, John	Chief, Western Operations/Administrative Engineer	BWS	JVickers@dep.nyc.gov
Warne, Matthew	Manager, Quality Assurance	BWS	MWarne@dep.nyc.gov
Warner, Jennifer	Regional Liaison, WRF	WRF	jwarner@waterrf.org

Appendix C: Expert Panel Workshop Minutes

The Water Research Foundation Update: Jonathan Cuppett

An overview of lead and copper corrosion research funded by The Water Research Foundation can be obtained by typing "lead" in the search field at http://www.waterrf.org. There are many active and published research projects of significance to today's discussion. Information about these projects, including current status of active projects and downloads of completed and published reports, can be obtained by typing the referenced project number into the search field at http://www.waterrf.org.

- Active Research
    - Project 4713 "Full Lead Service Line Replacement Guidance" will evaluate strategies to reduce lead exposure after conducting full lead service line replacements (FLSLRs). The research will provide accurate and easily understood guidance and reference materials for staff at any U.S. or Canadian water system to use when planning and implementing FLSLRs. The research will be complete and published in 2020.
    - Project 4910 "Evaluating Key Factors that Affect the Accumulation and Release of Lead from Galvanized Pipes" will develop cutting edge tools that will evaluate links between galvanized iron pipe (GIP) and lead (Pb) release, by (1) scientifically assessing customers' concerns related to GIP corrosion and possible association with Pb in water, (2) characterizing the nature of iron (Fe) and Pb release to drinking water from known sources, and (3) examining Fe and Pb release from GIP using bench-scale testing. In addition, public education materials will be developed related to GIP and Pb release. The research will be complete and published in 2021.
    - Project 5032 "Analysis of Corrosion Control Treatment for Lead and Copper Control" will (1) evaluate analysis tools for, and risks from, changing and/or implementing corrosion control treatment (CCT), (2) explore the potential impact of various source water or treatment changes to CCT, (3) develop a framework addressing how to assess current CCT and the circumstances under which CCT should be evaluated, and (4) explore the impacts to both lead and copper. Proposals will be requested summer 2019 for this research.
- Published Research
    - Project 4586 *Optimization of Phosphorus-Based Corrosion Control Chemicals Using a Comprehensive Perspective of Water Quality* determined that clean and biologically stable water distribution systems can optimize lead and copper corrosion control while minimizing or eliminating the use of orthophosphate and other corrosion control chemicals, thereby providing financial, water quality, and environmental benefits for both drinking water and wastewater utilities. The research was published in 2017, including a chapter specifically talking about microbially-influenced corrosion (MIC).
    - Project 3109 *Non-Uniform Corrosion in Copper Piping – Monitoring Techniques* conducted bench and pilot scale tests to evaluate techniques for identifying and monitoring non-uniform internal corrosion (pinhole leaks) in copper premise and service-line piping. The research was published in 2009 and (1) provides a tool for

evaluating the consequences of changing treatment processes or water sources for the purpose of regulatory compliance, (2) provides methods to evaluate corrosion control strategies to mitigate pinhole leak problems, and (3) investigates rapid evaluation techniques that enable the propensity for pitting to be directly integrated into any treatment study.

  - Project 714 *Evaluation of the Effects of Electrical Grounding on Water Quality* evaluated the water quality degradation caused by metal leaching due to alternating and direct electrical currents. The research was published in 1994, studied different grounding scenarios to determine water quality effects, and included the use of a full-scale model home and verification studies in the field.

- Health Canada released their recent drinking water health guidelines in March 2019, and it could predict where the LCR may go. There is information in Health Canada guidelines about schools and large buildings.

Statement of Today's Objectives: Lori Emery

- This Expert Panel Workshop developed from identified gaps in Bureau of Water Supply's (BWS) corrosion research portfolio. Two corrosion challenges were identified by Bureau of Water Supply staff. The first was lead corrosion in the distribution system within the City, and the second was potential microbially influenced corrosion (MIC) in stainless steel raw water pipes. This Expert Panel Workshop grouped these challenges.
- BWS is trying to work with other Bureaus that are affected by corrosion challenges, including Bureau of Water and Sewer Operations (BWSO) and Bureau of Wastewater Treatment (BWT). Partners within the agency were invited to the Expert Panel Workshop to share this information and ultimately to learn from each other to optimize DEP's operations and management.
- The primary objective of today's workshop is to present to the Expert Panel members what DEP is doing regarding lead corrosion on the distribution side, and the potential MIC on the supply side, and ask the Expert Panel to advise the agency on what we could be doing differently so we can be sure we are making the right decisions.

NYC Lead Program Compliance History: Steve Schindler

- DEP has operated with a Filtration Avoidance Determination (FAD) since 1992. The FAD most recently signed in 2017, is good for ten years, and covers the Catskill/Delaware (Cat/Del) water supply, which provides ~90% of the water demand. The Cat/Del system has had a UV plant for disinfection (in addition to chlorination) since 2012. The Croton water supply provides ~10% of the water demand, is the oldest part of the system, and the Croton Water Filtration Plant has been in operation since 2015.
- DEP monitors ~1,000 sites in New York for the Lead and Copper Rule (LCR), Total Coliform Rule (TCR), and Stage 2 Disinfection By-Product Rule (Stage 2 DBP). The compliance monitoring program far exceeds state and federal requirements.

- DEP currently has 536 lead compliance sampling sites at customer taps; 300 of these sites have lead service lines, and 236 are have copper pipe joined by lead solder. The 90th percentile for lead in 2018 was 11 ppb.
- DEP is challenged by balancing LCR, revised TCR, and Stage 2 DPB compliance strategies.
- Past Corrosion Studies
    - 1991-1992: Corrosion Control Pipe Loop Study – established orthophosphate at 1 mg/L (as PO4) and pH 7.2
    - 1998-1999: Phase II Corrosion Control Study – resulted in orthophosphate dose of 2 mg/L (as PO4)
    - 2010: SeaQuest Corrosion Inhibitor Study – confirmed that orthophosphate was the best corrosion inhibitor
    - 2011: Expert Panel Desktop Corrosion Control Study – resulted in an increase of pH to 7.3
- New Corrosion Studies
    - Pilot study to assess orthophosphate dose of 3 mg/L
    - Pipe loop study
    - Lead profiles (2005 – present)
    - LSL replacement monitoring
    - Lead pipe scale analyses

Discussion

Vern has worked with Chicago and Denver on control of lead release. Chicago finds that the high aluminum levels resulting from alum coagulation at pH 7.6-7.8 in the summer, result in turbidity from an orthophosphate-aluminum precipitate. This precipitate also deposits on pipe walls, causing a decrease in the Hazen-Williams C factor, the constant in the Hazen-Williams equation that relates flow rate in pipes to energy loss. (This constant becomes smaller as energy loss at a given flow rate increases.) The turbidity is undesirable, but a possible beneficial aspect of residual aluminum is that some of it becomes part of the outer layer of lead pipe scales and may be an important factor in reducing the lead release from lower layers. Denver also coagulates with alum but at a lower pH, which results in lower aluminum residuals that do not form aluminum phosphate turbidity. Aluminum becomes part of the outer layer of lead pipe scales and appears to help reduce the amount of lead released. In both Chicago and Denver lead scales, silicon accumulates in the scale and appears to be an important component of low-lead-releasing scales. While Denver and Chicago scale analyses show the presence of aluminum in the outer scale layer, it should be noted that there are no published side-by-side studies of alum vs. no alum to the panels knowledge.

Alum is currently used in the Croton Water Filtration Plant when the plant is producing. Alum is also occasionally used to treat elevated turbidity in the Catskill aqueduct (Cat/Del system) following extreme events, but has not been used since spring of 2012 after Hurricane Irene.

Is there aluminum and silicon in the lead pipe scales, and is there a difference in the rate of lead release if these elements are present? Croton water may also have manganese which could accumulate in the scales and possibly be released along with lead if the oxidation reduction potential is reduced next to the pipe scale, as often happens during stagnation. Such knowledge could help DEP understand the impact of water quality changes on lead release behavior of pipes.

DEP's Current Corrosion Control Research: Salome Freud

- Corrosion control pilot study implemented at an isolated location on City Island to determine whether an increased orthophosphate dose of 3 mg/L (up from current system feed of 2 mg/) would make any difference in corrosion control.
- A chlorine booster station was retrofitted to feed orthophosphate at 3 mg/L. Monitoring the system at three locations – FDNY fire station (continuous feed), DEP wastewater pump station (pipe loops), and resident volunteers (profile sampling).
- DEP received a $5.3M grant from the NY Department of Health for lead service line replacements. DEP is taking the opportunity to conduct pre- and post-replacement profiles.
- DEP offers a $100 credit to homeowners for their water bill to help with lead sampling. Surprisingly few homeowners take the offer.

Discussion

- Ultimately, Vern suspects that increasing ortho from 2 mg/L to 3 mg/L would show an improvement (decrease) in lead levels. Dave commented that the particulate lead in the pilot study is so high, it's overwhelming the data set.
- Water use pattern strongly affects lead scale properties. The pipe used in the pilot study on City Island likely has characteristics that are much different than those in portions of the system that receive DEP water every day because the water use pattern, especially the long, non-use time, was not typical. The high particulate lead values likely result from using a pipe that had not been used for a long time period.
- In addition, flow rate through pipes affects scale formation and potentially particulate release. Flow monitoring and control so that the flow rate into each pipe is representative of customer water use may help stabilize the results.
- The lead data from the pilot study are likely not representative of those being experienced by consumers. Selection of pipes for pilot testing that are representative of those in the distribution system is very important for goals such as showing the effect of increasing orthophosphate dose and changing pH. The pilot should also be set up to mimic typical household water use flow patterns as well. The amount of water used per day and the flowrate are both very important pilot test parameters. The scales that develop depend on how much water goes through the pipe loops each day. For example, one hour of flow and followed by 23 hours of stagnation will develop a scale that has different lead releasing properties than a scale that is developed with a flow pattern of 2.5 minutes of flow and 57.5 minutes of stagnation per hour(I.e. a total of 1 hour of flow and 23 hours of stagnation per day). The scales in these two examples may have the same elemental composition but the scale porosity and friability would likely be different.
- Under normal "yard" operations that produced the scale on the pipe used in the pilot test, Vern expects soft, friable scale which would never represent a typical household.

- Ideally, the pilot would be equipped with an automatic on/off valve tied to a timer to simulate water use patterns
- The other challenge of the running the pilot test in the yard is that it drains to a sump with capacity limits, which limits the pipe flow.
- The panel agrees the best way to conduct a representative pilot would be to study actual homes on City Island. Turns out there are only ~10 homes with LSLs built in the target time period. Panel suggests you'll need more homes for a meaningful analysis. Also, changing the water supply from Croton to Cat/Del is an important complicating factor, as is the periodic shut down of the Croton supply.
- There was discussion that home sampling using an outside hose bib would be easier than obtaining house access. Hose bibs tend to be quite high in lead and not representative. Since the meeting we have found one vendor that makes a lead-free hose bibs for another project we have. It might be possible to replace hose bibs and flush the lines out to use them. This would require verification of representativeness.
- DEP distributed lead scale papers to the group via email during the meeting. Scale analysis was previously conducted by SUNY Buffalo. These analyses provide useful data on elemental composition and crystalline structure, and also provide useful information on composition versus scale thickness.

Source Water Operations Microbial Influenced Corrosion (MIC) Issues/Mitigation Approach: John Vickers

- DEP has observed possible MIC in two raw water lines.
    - West Delaware Release Chamber leak found during routine maintenance in 2011 in the bend of a 316 stainless steel wye (installed 1961). An earthquake in Virginia thought to be involved.
    - Croton Falls Pump Station leak observed in 2016 in a stagnant area of the station. A 316 stainless steel 84-inch line installed five years prior. Pitting and pinhole leaks observed in lower half of pipe. Pipes were full and pressurized. DEP metallurgists discovered MIC and that was the first time staff had heard the term.
- MIC prevention plan includes 1) inventory of all stainless steel pipes at risk in the watershed, 2) developed a flushing protocol that is conducted at least every six months that targets stagnant water, and 3) flushing procedure added to DEP's CMMS.
- Expert panel assistance is requested for 1) best approach for detecting MIC, 2) best approach for preventing MIC, 3) realistic expectations of success, 4) evaluation of the MIC prevention plan, 5) water quality impact on design considerations, and 6) what's on the horizon for future research.

Discussion

- DEP asked panel what other tests are suggested to help identify the cause of corrosion?
    - ATP and temperature testing – ATP is used to determine the biological activity of the water contained in the SS pipe. It is not specific to tell you what type of bacteria or other microorganisms are present, but it can be used to indicate if there is a significant amount of biological activity – or if there has been a change (increase) in activity. This

could be used to evaluate when flushing should occur. (Research Applications group has been in contact with an ATP test vendor – LuminUltra.) Temperature has an important effect on biofilm development.

- Vern noted that it's also important to determine whether the corrosion has been *induced* by bioactivity or *influenced* by bioactivity.
- Sediment can encourage biological growth so flushing out the sediment may also help.
- The evidence that was presented did not show that MIC was definitely playing a role, although it certainly could have been a factor. Oxygen and hydrogen ion concentration cells that develop because of sediment deposits, especially in stagnant water, could also have been a factor.
- Biofilms develop rapidly (days) and are not likely to be removed by flushing. Flushing once per six months is not likely to affect biofilms. Continuously flowing water that maintains disinfectant next to the pipe surface is needed, and if flowing water with disinfectant cannot be applied, it might not be possible to prevent the biofilm formation that causes MIC.
- It was recommended that DEP consider using cameras to look for sediment in the pipes.
- Dave asked about the weld material to make sure it is compatible with the pipe. Incompatibility between materials can be the cause of corrosion.

In-city MIC (Stainless Steel and Other Materials) Issues: Roopesh Joshi

- City Tunnel 3 was put in place in 1998 for redundancy so that Tunnels 1 and 2 (much older) could be inspected and rehabilitated as needed. However, corrosion was observed in Tunnel 3 so future work was delayed until this was evaluated.
- Similar to BWS raw water infrastructure corrosion, BWSO would like to confirm whether or not the observed corrosion is MIC. Also, they'll develop a detailed design to remove corrosion from affected components, protect from further corrosion, and apply lessons learned to future tunnel projects.

Discussion

- DEP asked the panel whether there are downsides to galvanic anode cathodic protection to mitigate corrosion?
    - Vern says spacing of the anodes is critical to make sure the whole external pipe surface is protected. External sacrificial anodes do not protect against corrosion inside the pipe.
    - A concern is that some of the iron rebar to support concrete is in contact with the SS pipe. This indicates an error in installation. If you do cathodic protection, do you harm the rebar and affect structural stability?
    - Panel advises to find a reputable company who knows cathodic protection to do the work because it has not had much experience in this area.

Stray Current Corrosion: Roopesh Joshi

Water infrastructure is susceptible to stray current corrosion that originates from nearby unprotected electrical utilities underground. Stray current corrosion differs from natural corrosion in that it is caused by an external electrical current and is independent of environmental factors like oxygen, chloride, or pH. Stray current corrosion damage is localized to where the current leaves the surface of the pipe.

DEP began studying stray current corrosion in response to multiple copper service line failures. Results of field study show evidence that the likely cause of failure due to stray DC current caused by buried, Verizon-owned, lead-sheathed communications cabling. Copper service lines act as an anode where electrons migrate from the surface of the copper line, through the soil, and to the lead-sheathed 48 V cable service that acts as the cathode.

This is a common issue near MTA and railyards. Another issue is that Verizon is installing fiber and no longer maintaining the old copper cabling. Some contractors are putting in PVC and sliding the copper line through. There is not as much trouble observed in ductile iron pipe.

Discussion

None. Lunch arrived. Topic came up later.

Facilitated Expert Panel Discussion on Lead Corrosion Research

The overarching research question is whether or not increasing orthophosphate dosing from 2 mg/L to 3 mg/L will positively impact corrosion control within DEP's water distribution system and result in lower lead levels.

- Panel says it makes sense to increase orthophosphate dose but appreciates that it is a huge cost and the improvement in corrosion control may need verification to justify the cost.
    - Coupon tests at the bench-scale could help *qualitatively* show improvement in corrosion control but may not quantify the reduction in lead release rate. Only pipe loops allow quantification. Dave indicated that there is some recent evidence that coupons can provide good predictions, but pipe loops using representative harvested pipes are still considered the most reliable. You could use short sections of harvested lead pipe or fresh, clean lead pipe for pipe loops, but 4 ft sections of harvested pipes are best. If limited on pipe, batch tests with harvested sections can help demonstrate the effects of ortho dosage.
    - Refer to Dave's October 2018 JAWWA paper on coupon study technique (it differs from a standard LCR Guidance manual methods).
- Ultimately strive to get more households in the City Island profiling test program. City Island is an ideal location to control treatment as it is isolated from other parts of the distribution system. There is also the ability to control water source (Cat/Del, Croton, or blend), although it has the disadvantage that the Croton plant is periodically shut down, which changes the source water quality when testing a change to the ortho dosage. Unfortunately, there are only ~12 homes with LSLs. Try to entice these homeowners to participate with water bill credits.
    - A question was raised about sampling hose bibs on the outside of the houses to avoid disturbing residents. Panel agrees this is not a good idea as hose bibs are always full of lead; rarely used with stagnation and usually made with old brass. Since the meeting we have found one vendor that makes a lead-free hose bibs for another project we have. It might be possible to replace hose bibs and flush the lines out to use them. This would require verification of representativeness.

- Panel says you could set up a sample tap off the service line, almost like setting up a loop. You'd need to identify several homes before you do the switch over and then sample regularly both before and after the switch over.
- Former DEP employee owns two of the houses and rents them out, doesn't want to bother tenants. If sample tap installation on the LSL is done and DEP does sampling, maybe he'd be more willing.

- DOH grant to replace LSLs will provide opportunity for more harvested pipe tests. There are ~1,400 homes that qualify for LSL replacement. Panel says to try to harvest at least four feet of pipe so that a 100 mL sample can be collected. Put these requirements into the contractor specifications (no pulling, traffic impacts, four feet of pipe saved, e.g.). However, if they are to be used in a pipe loop system, the system should be partially constructed before the pipe is harvested, so that the pipe loop can be installed immediately after harvesting and pipe loop operation can begin without delays.

Scale analysis work – The SUNY Buffalo Phase 1 report (December 2018) featured yard pipe that was used for the pipe loop and Phase 2 report (provided after the workshop and dated April 2019) analyzed harvested LSL from households.

- Vern noted Phase I report of yard pipe had a lot of crystalline material. The analysis procedure was somewhat unique, perhaps because the scale was very friable from the pipe having been out of use for a long period. The surface was brushed to remove the particles, which were then analyzed. The presence of particles containing lead that could be removed in this way is consistent with the unusual concentration of particulate lead in the pilot samples.
- Theoretical solubility curves do not apply if the lead solid is amorphous rather than crystalline, if the lead solid is covered by other deposits in the scale, and if sufficient time is not allowed for equilibrium to be achieved. The scale analysis showed a lot of lead carbonate compounds along with some lead phosphate. There was some plattnerite that would be indicative of a higher chlorine residual having been used in the past.
- Dave noted that in the Phase 2 report of household pipes, primarily amorphous compounds are found in the layer closest to the water. But then the lower layer was similar to Phase 1 with crystalline lead phosphates and lead carbonates. The amorphous outer layer has phosphorus, oxygen, a lot of iron and a fair amount of manganese, silicon, and a reasonable amount of aluminum.
- Schindler noted there is naturally occurring aluminum in DEP's source water that could contribute to that scale. Of the four pipes in the Phase 2 report, two were supplied by surface water and two were supplied by surface water under the influence of groundwater. DEP hasn't used groundwater since 2007 after phasing out an acquired ground water supply in 1997. All pipes in Phase 2 are from southeast Queens, supplied by Cat/Del water or possibly groundwater. No Croton water.
- Freud asked whether the pipe loops will continue shedding such a high level of particulate.
  - Continued production of high concentrations will likely occur unless additional solids can be precipitated in the scale in a way that makes it less friable.

- Dave noted the May 30th home profile shows the difference between filtered and total lead is no more than 10 ppb. When the total spikes the filtered lead also increases indicating possible lead dissolution and particulate release. The patterns with an LSL normally start low, increase in the middle and come back down. These spikes are more indicative of random particle release, yet the particulate matter was relatively low. additional tests may be warranted.
- Schindler asked if there is a way to better control particulate lead? What changes in corrosion control measures can you make to lock that up more particulate lead?
    - Vern noted there is a possible reason for high particle concentrations. Another system he was working on contained predominantly particulate lead in water samples and did not have anything other than lead solids in the scale (e.g., no calcium carbonate, no aluminum phosphate, no silica). Essentially, it was a lead phosphate and lead carbonate scale, and highly crystalline). The Scanning Electron Microscopy (SEM) photos showed the crystals had sharp edges that could easily be broken off, for example by hydraulic forces, which was a possible cause of the high concentration of particles. Vern wonders if the scale in areas fed by Cat/Del water has a similar structure. Cat/Del water is very low in minerals and alum coagulation is not used, which would produce an aluminum residual. Understating what is in the scales would help us understand scale behavior. Evaluating scales from pipes served primarily by different water sources may provide additional insights.
    - Schindler asked if it is possible that an increase in pH could form scales that are more protective than we have?
        - Vern thought so and is of the opinion that this would be an important factor to investigate in a testing program.
    - Schindler noted an Expert Panel was convened a few years ago to look at that. Steve thinks the recommended range was 7.2- 7.5/7.6. All of the literature says you want to be on the high end of that scale and we have been reluctant to do that because of DBPs and other issues such as total coliforms.
    - Vern said if you were able to set up a pipe loop system, one of the recommendations would be good to look at higher pH such as 7.7 instead of 7.2 or 7.3. The impact on DBP formation should be investigated at the same time
    - Freud noted that could be done but then we'll have total coliform problems and THM problems. Chlorine isn't as effective at the higher pHs.
    - Vern says that doesn't sound right. Chlorine is used in many distribution systems at much higher pH to effectively control coliform. However, if there is concern about this issue, as well as DBP formation, it could also be investigated.
    - Freud posits that will only feed DBPs.
    - Schindler agrees DBPs are an issue but it's worth looking at it in terms of pipe loop or coupon study and obviously we have other issues we'd have to worry about with that.
    - Dave noted if you target pH 7.2 or 7.3, how often do you get to 7.1 or 7.0? Sometimes targets are set higher so you have more room to go either way. Vern said that was a major issue in Newark (pH dropping down to 7.0 and below).

    - Glaser noted that 16,000 distribution samples were collected in 2018, and the average pH was 7.4 (7.0 was the lowest of any sample).
- Borchert asked whether alkalinity is a factor.
    - Vern says the most important role alkalinity plays is that it stabilizes pH, but carbonates are incorporated into lead scales as lead carbonates, as shown in the scale analysis reports. They are playing a role. I'd rather have the lead phosphates because they have a lower solubility than lead carbonates, but they both form even when orthophosphate is used as the inhibitor.
    - Schindler noted the system is fairly stable and over the past several years the LCR compliance 90th percentiles have been at or close to 11 ppb.
- Dave asked about chlorine and Glaser responded that the residual range is 0-1.3, average of 0.6.
- Dave noted a fairly strong manganese peak in the outer amorphous layer. If chlorine is present, the manganese is in the insoluble oxidized form. If the chlorine residual is lost, for example, during stagnation, the manganese can leave the scale and take the lead with it.
- Vern acknowledged that manganese is an interesting element to study and it should be part of any corrosion control study. In the Washington DC aqueduct pipe loop, iron and manganese coming into the pipe loop was very low, and was higher coming out. They analyzed the scale and found that it contained manganese and iron. When we did an analysis of the effluent, we found that the manganese correlated very nicely with particulate lead, consistent with what Dave just said. The iron also correlated with lead. Apparently, the water right next to the scale lost chlorine and oxygen, allowing the iron and manganese to be reduced and go into solution. As it diffused into the portion of the bulk water containing oxygen and chlorine, it would be oxidized and form iron and manganese particles that would then adsorb lead ion, thus creating particulate lead. The concentrations weren't very high, but the data showed the mechanism. It's important to note that the manganese concentration was 0.01- 0.02 mg/L, well below the 0.05 mg/L secondary MCL.
- In summary, bench test with coupons can be done to get an indication of corrosion control with different ortho dosing and screen several variables like pH and Croton verses Cat/Del water. Pipe loops would then be used to evaluate the key findings and variables from the coupon studies. Given the current situation in NYC, coupon studies to screen several conditions may not be necessary.

Facilitated Expert Panel Discussion on Microbial Influenced Corrosion

- Vern asked what the suspended solids levels are. If sediment is building up in the pipe, it may be creating oxygen concentration cells that cause localized corrosion, similar to the way biofilms act in MIC. The sediment may also be promoting biofilm development. How do you eliminate the suspended solids in your raw water if this is an important mechanism? I don't see a good way to do that other than regular flush with camera verification. The flushing frequency to remove sediment would depend on the rate of sediment accumulation. The use of a camera to check deposits and accumulation will help define the frequency.

- Dave said you can have suspended solids that will not show up in the drinking water, but it's possibly collecting in the pipe.
- Consider ATP testing to understand bioactivity and changes in bioactivity.
- Schindler asked whether there are solutions to take the sediment out remotely, if found?

Appendix D: NYC DEP Lead Corrosion Control Study Summary

The Bureau of Water Supply (BWS) in DEP is undertaking a four part study to assess the effects of increasing the levels of the corrosion control chemical PO_4. The study components are:

1) Piloting an increased PO_4 dose on City Island in the Bronx
2) Profile sampling of homes located on City Island
3) Sampling of pipe loop (made from harvested lead service lines (LSLs) from within the NYC distribution system) set up at the Bureau of Wastewater Treatment (BWT) pump station on City Island
4) Scale testing of LSL pipe removed from numerous locations within the NYC distribution system

Piloting an increased PO_4 dose on City Island in the Bronx

DEP has retrofitted the chlorine booster facility in Pelham Bay Park to be a phosphoric acid booster station. The flow meters were upgraded, and strap-on flow meters were added to enable flow paced dosing to raise the background PO_4 levels for only the water feeding City Island. The target dose will be 3 ppm, but theoretically can be raised to as high as 4 ppm under the existing Optimal Water Quality Parameters established by the New York State Department of Health (DOH) for DEP. A request for Approval of Completed Works detailing the retrofit of the booster station was submitted and was final approved by DOH on December 11, 2018. The booster station is scheduled to be activated on July 25, 2019.

The increased dose will be studied by collecting samples at private homes on City Island, and from a pipe loop installed at the BWT pump station on City Island. In addition, water quality instrumentation has been set up at a fire station down the street from the BWT pump station, FDNY Engine 70/Ladder 53, at 169 Schofield St, City Island, Bronx, NY 10464. The instrumentation is continuously monitoring PO_4, specific conductivity, turbidity, temperature, pH, and chlorine residual levels.

Sampling station 11750, located on City Island Avenue between Carroll Street and Schofield Street, connected to a 20 inch main, is routinely monitored for daily field and lab parameters, as it is a Revised Total Coliform Rule compliance site. Normal monitoring will continue at this site.

Profile sampling of homes located on City Island

For this component of the study, DEP is creating lead profiles of individual homes' plumbing to evaluate the impact of different orthophosphate levels. Profiling is used to identify the point at which lead or other metals levels peak, which in turn is used to help locate the source(s) of lead in household drinking water. These may include lead content in fixtures, lead solder, or a lead water service line. This study is designed to evaluate the impact of increasing orthophosphate concentration from the existing operational maintenance dose of 2 ppm to 3 ppm.

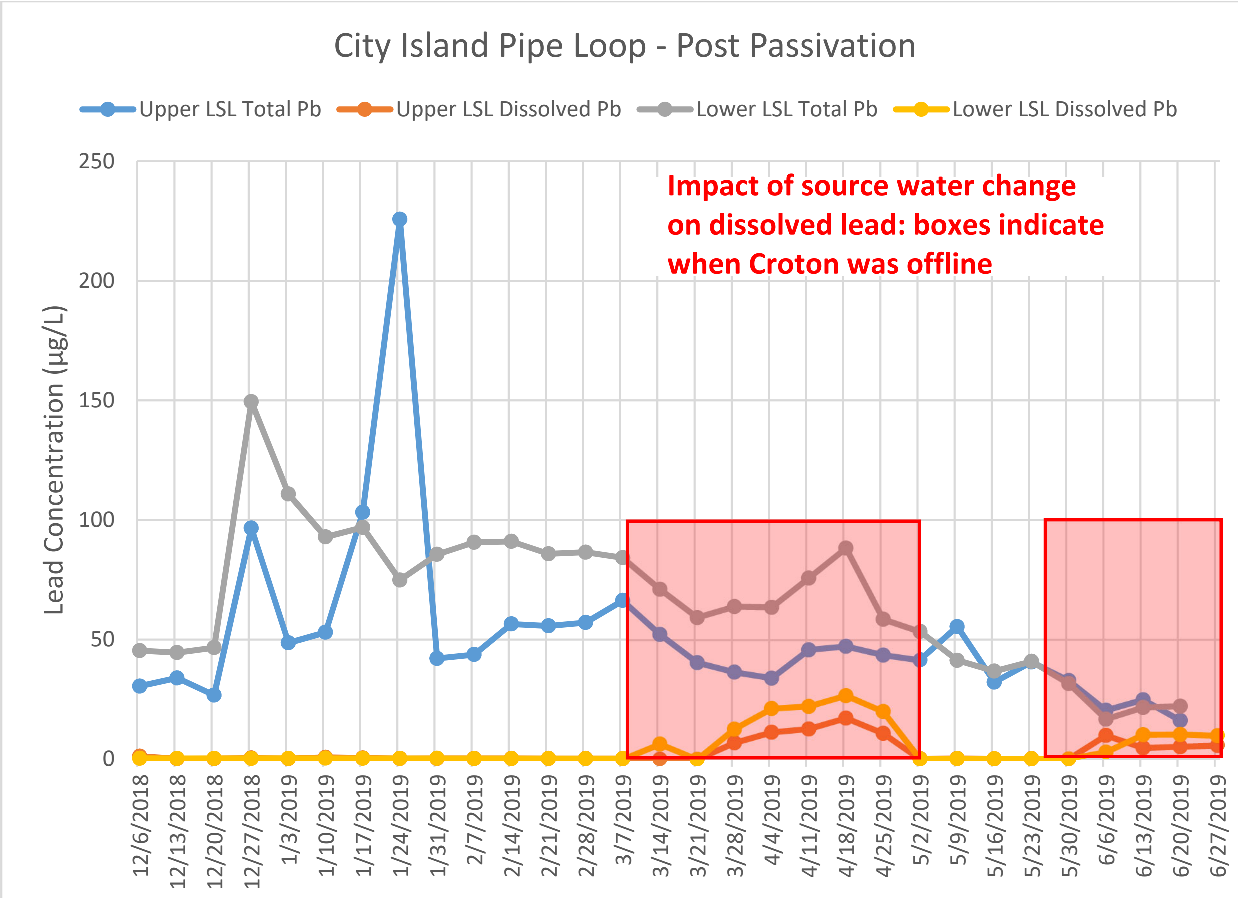
At the suggestion of the workshop expert panel, DEP has added control homes (sites without LSLs) to the locations that are being profiled as a part of the study. Preliminary profile samples (pre booster station activation) have been collected at six homes, plumbing details listed below:

- Home 1: lead SL with copper interior piping

- Home 2: lead SL with copper interior piping
- Home 3: copper SL with copper interior piping (home had a partial LSL removed in May 2019)
- Home 4: copper SL with copper interior piping
- Home 5: copper SL with copper interior piping
- Home 6: inspection pending, tap card indicates lead SL

Sampling of pipe loop

A pipe loop, made from ~ 20 foot of LSL discovered and harvested from a DEP yard in the Bronx, was installed at the Bureau of Wastewater Treatment (BWT) pump station located at 191 East Schofield Street, City Island, Bronx, NY 10464, as two (2) 7.5 foot pipe loops. Solenoid valves with timers were installed to routinely run fresh water through the LSL, simulating the daily use of an occupied home. Staff sample the water from the pipe loop to determine the effect of the increased orthophosphate dose. Over time, depending on the operation of the Croton Filtration Plant, both Croton and Catskill/Delaware water can be studied, as can be seen in the graph below. When the Croton supply is turned off, the dissolved lead in the samples collected from the loop increases. The graph also shows improvement with passivation/stabilization, with total lead levels decreasing over time.



The expert panel expressed concern that the pipe used for the loop did not come from a residence or a building with regular water use, and they thought the scale might not reflect conditions seen when water regularly flows through a pipe. In response to these concerns, flushing of the loop has been increased from once to twice a day. Additionally, DEP has identified additional lead service lines from New York City Housing Authority (NYCHA) residences that are being used to construct more pipe loops. A control loop has been set up at the Distribution Laboratory, as this location never receives Croton water and will not have any changes to the PO_4 dose. DEP also has plans to install another loop at the BWT pump station on City Island. Furthermore, DEP is investigating using some of the pipe for a coupon study, which would be carried out using the protocol outlined in a Cornwell paper to be published in the October 2019 issue of the *Journal of the American Water Works Association*.

Scale Testing

Two (2) LSLs, initially identified on City-owned properties, one from the yard at the Jerome Park Pump Station in the Bronx, a DEP facility, and the second from a Department of Transportation (DOT) facility located at 1400 Williamsbridge Road in the Bronx were harvested. Four (4) additional LSLs were identified and harvested from NYCHA owned single family homes located in Southeastern Queens. Two

(2) of the four (4) NYCHA LSLs may have been fed from the groundwater supply in the past. Segments of the pipe were sent to SUNY Buffalo for analysis. DEP has no plans for further scale analysis at this time.

Report conclusions for the first two (2) LSLs from City-owned properties were as follows:

Two distinct scale layers were observed on the internal pipe surface, with the outer layer being dark brown and the inner layer light gray. An inconsistent orange/brown layer was also found on the small pipe and is attributed to rust (i.e., iron oxide). Scanning electron microscope with energy-dispersive X-ray spectrometer (SEM-EDS) analysis show that outer layer scales contain more mineral elements than inner layers due to deposition of chemicals from water. The inner scales have higher lead and lower oxygen content. X-ray diffraction (XRD) results demonstrate that lead carbonate, phosphate, and oxide are the main crystalline species on the pipe surface. S-inner is dominated by hydrocerussite, while S-out includes lead hydroxyapatite and plattnerite. In contrast, outer and inner scale layers of the large pipe are predominantly cerussite. Different crystal species for scales associated with the two pipe segments are likely associated with different water conditions in the service lines.

Report conclusions for the four (4) LSLs from NYCHA properties were as follows:

For pipes 1-3, two distinct scale layers were observed on the internal pipe surface, with the outer layer being dark brown (variable thickness) and the inner layer light gray. Pipe-4, uniquely, contained only one scale layer that was orange in color and significantly thicker than what collected on Pipes 1-3. SEM-EDS shows that upper layer scales contain more mineral elements than lower layers, likely due to deposition from water. Lower layer scales have higher lead content and lower oxygen content. XRD results demonstrate that lead carbonate, lead orthophosphate, and lead oxide are the main crystalline species touching the pipe surface, and, more generally, lower layer scales have more crystalline species and stronger signal strength than upper layer samples. Different crystalline species for scales associated with the pipe segments are likely associated with different water conditions in the service lines.

Appendix E: Workshop Presentations

THE Water Research FOUNDATION

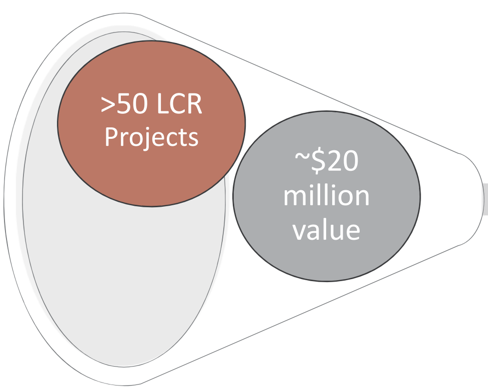
WRF Lead and Copper Corrosion Research

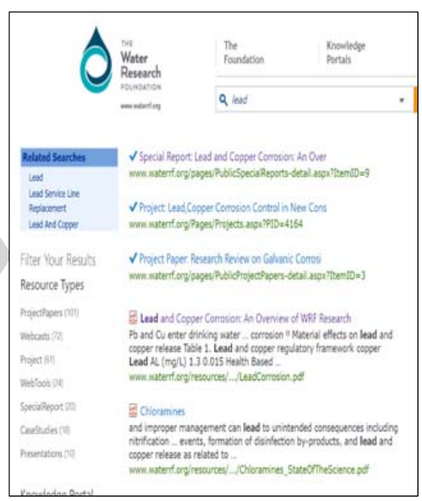
WRF/NYC DEP Corrosion Control Workshop

March 20, 2019

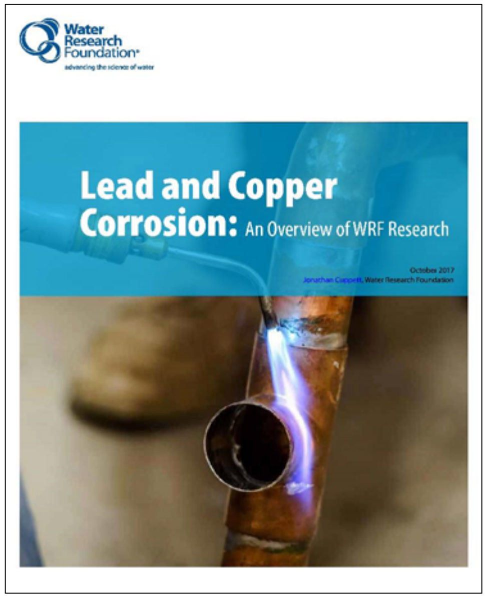
Jonathan Cuppett, Research Manager

WRF Lead Research since late 1980's



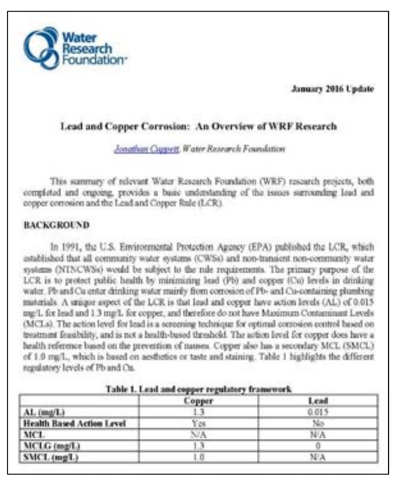


LCR Research



Lead and Copper Corrosion: An Overview of WRF Research

1. List of all Projects
2. Ongoing Projects
3. Project Summaries
4. Summary of Common Themes



Water Research Foundation

January 2016 Update

Lead and Copper Corrosion: An Overview of WRF Research

Jonathan Cuppett, *Water Research Foundation*

This summary of relevant Water Research Foundation (WRF) research projects, both completed and ongoing, provides a basic understanding of the issues surrounding lead and copper corrosion and the Lead and Copper Rule (LCR).

BACKGROUND

In 1991, the U.S. Environmental Protection Agency (EPA) published the LCR, which established that all community water systems (CWSs) and non-transient non-community water systems (NTNCWSs) would be subject to the rule requirements. The primary purpose of the LCR is to protect public health by minimizing lead (Pb) and copper (Cu) levels in drinking water. Pb and Cu enter drinking water mainly from corrosion of Pb- and Cu-containing plumbing materials. A unique aspect of the LCR is that lead and copper have action levels (AL) of 0.015 mg/L for lead and 1.3 mg/L for copper, and therefore do not have Maximum Contaminant Levels (MCLs). The action level for lead is a screening technique for optimal corrosion control based on treatment feasibility, and is not a health-based threshold. The action level for copper does have a health reference based on the prevention of nausea. Copper also has a secondary MCL (SMCL) of 1.0 mg/L, which is based on aesthetics or taste and staining. Table 1 highlights the different regulatory levels of Pb and Cu.

Table 1. Lead and copper regulatory framework

	Copper	Lead
AL (mg/L)	1.3	0.015
Health Based Action Level	Yes	No
MCL	N/A	N/A
MCLG (mg/L)	1.3	0
SMCL (mg/L)	1.0	N/A

Current WRF LCR Research Efforts

- Lead and Copper Management Research Area
- Research Area = research topic of high interest to WRF subscribers
- 13 total research areas
- Started in 2017
- 2 projects funded to date

LCM Research Area Objectives

- Service Lines
- Corrosion Control
- Large Buildings
- Sampling
- Communication

Current LCM Research Agenda

Year	Project
2017	Full Lead Service Line Replacement Guidance (4713)
2018	Evaluating Key Factors that Affect the Accumulation and Release of Lead from Galvanized Pipes (4910)
2019	Analysis of Corrosion Control Treatment for Lead and Copper Control

Projects funded outside of the LCM Research Area

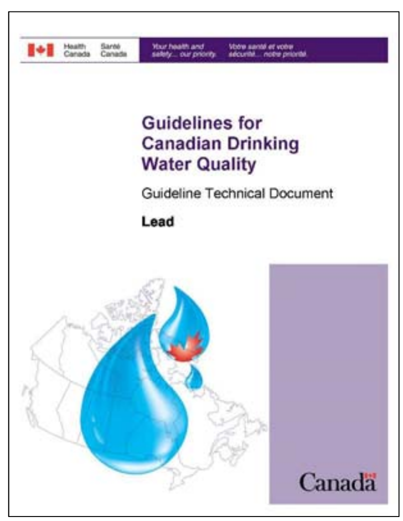
#		Year Pub.	Title
4965	EPA	2022	Development of a Community-Based Lead Risk and Mitigation Model
4686	EO	2019	Processes Controlling the Time for Orthophosphate to Achieve Effective Corrosion Control
4693	EO	2019	Service Line Material Identification Techniques
4698	FRS	2019	Evaluation of Electrical Resistance For Lead Pipe Detection
4658	TC	2018	Corrosion of Nonleaded Pump Impeller Alloys
4584	TC	2018	Evaluation of Flushing to Reduce Lead Levels
4586	**TC**	**2017**	**Optimization of Phosphorus-Based Corrosion Control Chemicals**
4351	EPA	2017	Evaluation of Lead Service Line Lining and Coating Technologies
4569	EO	2015	Evaluation of Lead Sampling Strategies
4409	EO	2015	Controlling Lead in Drinking Water

Other Lead and Copper Corrosion Projects of Interest

#	Year Pub.	Title
3109	2009	Non-Uniform Corrosion in Copper Piping--Monitoring Techniques
714	1994	Evaluation of the Effects of Electrical Grounding on Water Quality

Health Canada Drinking Water Lead Guidelines

- Released March 2019
- Random Daytime and 30 minute stagnation sampling
- Schools, multi dwellings, and large buildings



Thank you

Comments or questions, please contact:

jcuppett@waterrf.org

For more information visit:

www.waterrf.org

Environmental Protection

WRF Corrosion Control Workshop

March 20, 2019

Bureau of Water Supply
Department of Environmental Protection

Vincent Sapienza, Commissioner
Paul V. Rush, Deputy Commissioner, BWS
Steven Schindler, Director, Water Quality

THE CITY OF NEW YORK,
Bill de Blasio, Mayor

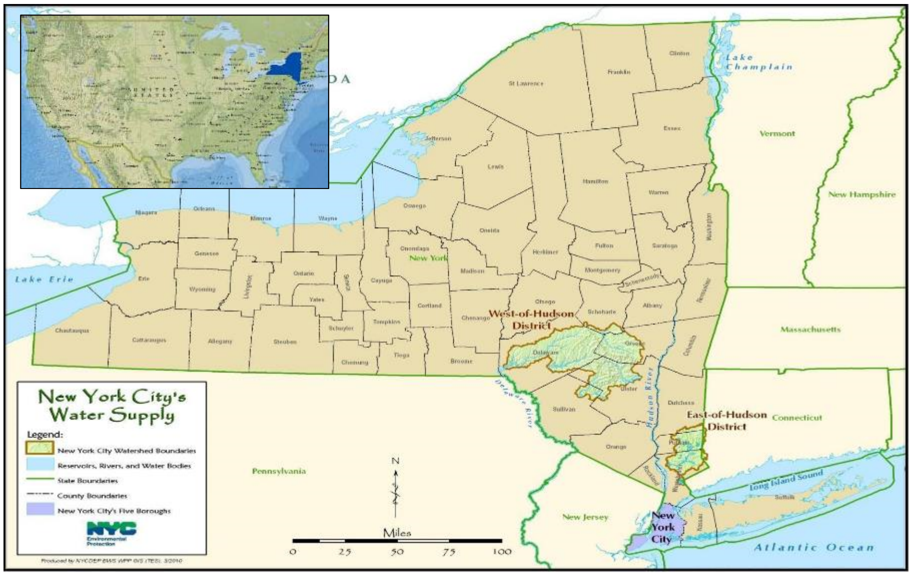
1

Agenda

1) Water Supply Overview
2) Distribution WQ Monitoring
3) NYC Lead Compliance Program
4) NYC Free Residential Lead Testing Program
5) Lead Data
6) NYC Lead Research

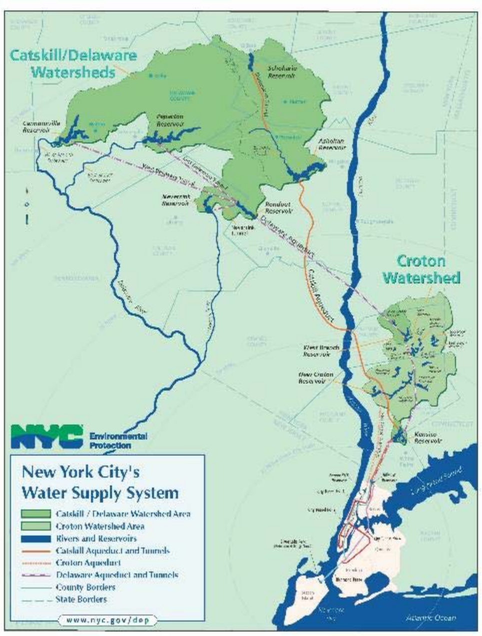
2

New York City Water Supply



3

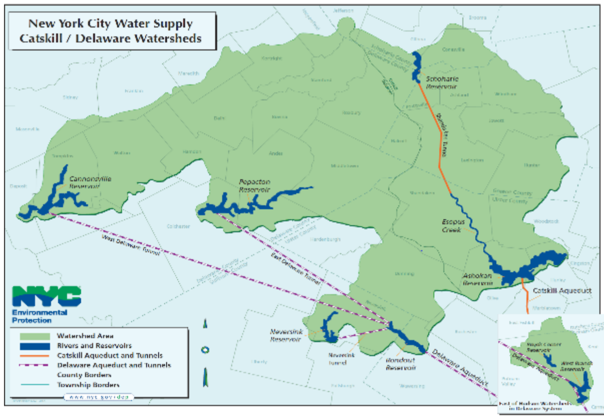
New York City Water Supply Overview



- Primarily a surface water supply
- 19 reservoirs & 3 controlled lakes
- System Capacity: 570 billion gallons
- Delivers over 1 billion gallons per day
- Serves 9.6 million people (~1/2 of the population of New York State)
- Source of water is a 2,000 square mile watershed in parts of 8 upstate counties
- Operated and maintained by the New York City Department of Environmental Protection (NYCDEP)

4

New York City Water Supply Overview



CATSKILL / DELAWARE SUPPLY

- Supplies about 90% of average daily needs
- Last reservoir placed into full service in 1967
- Rural, mountainous watershed
- Unfiltered system - City has a FAD for these supplies since 1992
- Cat/Del UV Disinfection Plant on-line in 2012

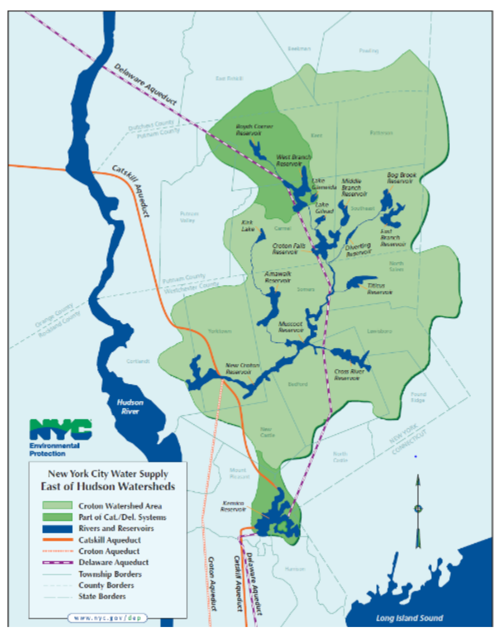

Pepacton watershed

New York City Water Supply Overview


New Croton Dam and Spillway

CROTON WATER SUPPLY

- Historically supplies about 10% of City's average daily needs
- Located east of the Hudson River
- Oldest part of the system, primarily built in the 19th century
- Croton Filtration Plant went on-line in 2015



6

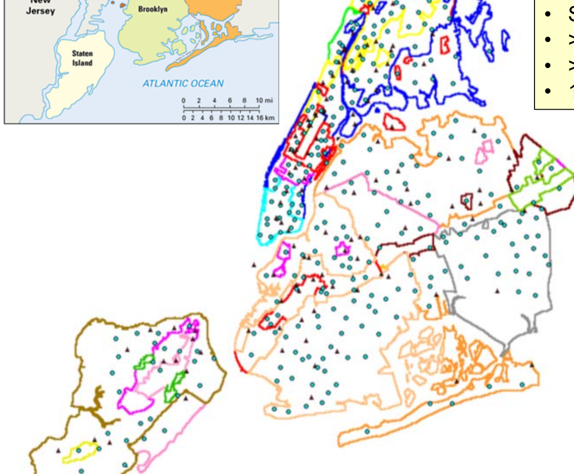
New York City Water Supply Overview

- Catskill/Delaware water is distributed via 3 large City tunnels
- Croton water is distributed via:
  - o New Croton Aqueduct
  - o Trunk mains in the Bronx
  - o Pumping into City Tunnel 1 or 3 (and Tunnel 2 in the future)
- Blending ratio is dependent on Croton flow

7

Distribution Water Quality Monitoring

- DEP performs water quality monitoring far greater than required by federal and State regulations.



- ≈ 1,000 sampling locations in NYC
- Samples collected 365 days/year
- > 37,500 samples annually
- > 410,000 analyses annually
- 1 Distribution Laboratory

Distribution Sampling Sites Over Pressure Zones

8

NYC Compliance Lead Monitoring Program

NYC Environmental Protection

- Monitoring occurs at customer taps
- Samples are collected by the customer using DEP lead test kits
- Monitoring is conducted annually

Compliance Monitoring
- Annual period (June 1 – September 30)
- Must have >100 sites in compliance pool
- Pool must be 50% LSL / 50% copper lead solder

Public Education Information
- Provide notification and results to sampled customers
- Provide text in the Consumer Confidence Report (CCR)
  - Details how to minimize risk of exposure
  - Contains information on the Free Residential Lead Testing Program

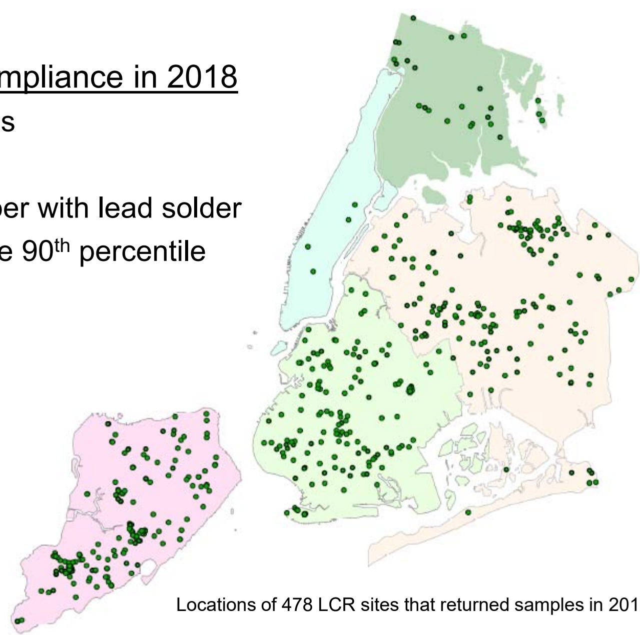
9

LCR Compliance Pool

NYC Environmental Protection

<u>NYC Lead Compliance in 2018</u>

- 536 total sites
  - o 300 LSL
  - o 236 copper with lead solder
- 11 ppb for the 90th percentile

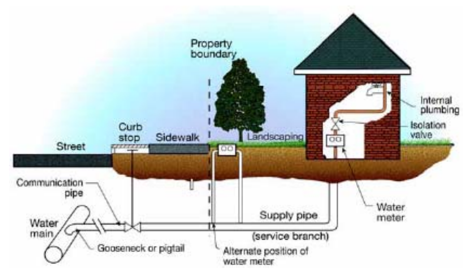


Locations of 478 LCR sites that returned samples in 2018

10

Corrosion Control History

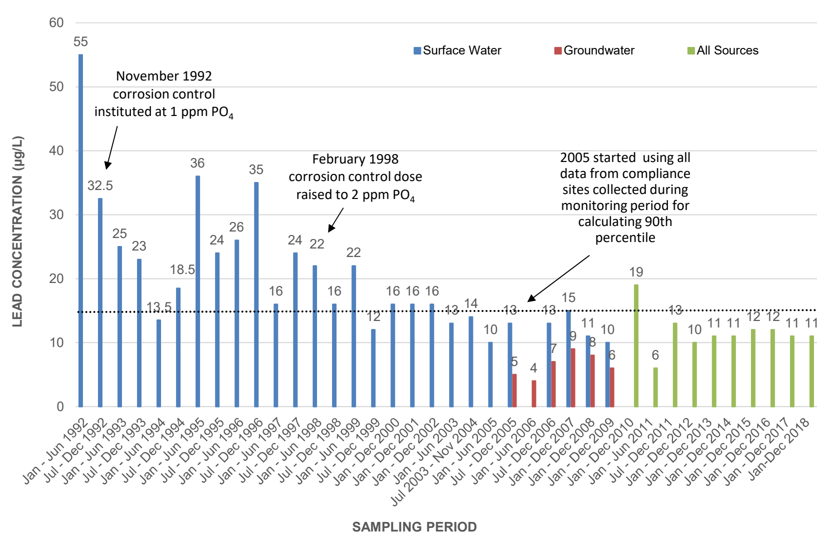
- The Lead and Copper Rule (LCR) was published in 1991 to control lead and copper in drinking water.
- DEP began corrosion control in November 1992
  - o Orthophosphate at 1 mg/L (as PO4) and pH adjustment to 7.2
- DEP was out of compliance and adjusted corrosion control in February 1998
  - o Orthophosphate at 2 mg/L (as PO4), pH 7.2
- DEP has been largely in compliance since 1998; last exceedance was in 2010
- DEP must balance strategies to meet compliance with LCR, RTCR, and Stage 2 DBP Rules



11

LCR Compliance History

At-the-Tap 90th Percentile Lead Concentrations



The Groundwater System was acquired by DEP in 1997. Between 2005 and 2009 the 90th percentile concentration was calculated separately for the groundwater and surface water systems.

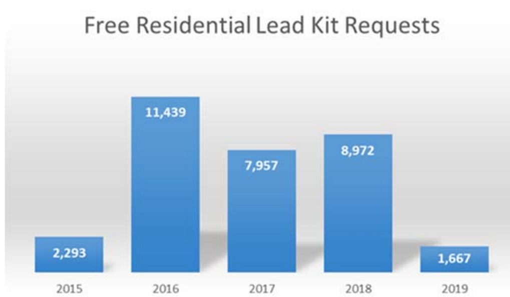
12

NYC Free Residential Lead Monitoring Program

NYC Environmental Protection

- Free program to consumers accessible via calling 311 or visiting the 311 website
- Samples are taken by customers and shipped directly to the DEP Kingston Laboratory
- Kit contains 2 bottles (1st draw and 1-2 minute flush)

- On average we have a 50% return rate
- Data collected are submitted to NYC Health Department
- Results and recommendations are also sent to the customers
- If results are 15 ppb or greater, DEP automatically sends a free 3-bottle retest kit, which adds a 5 minute flush sample



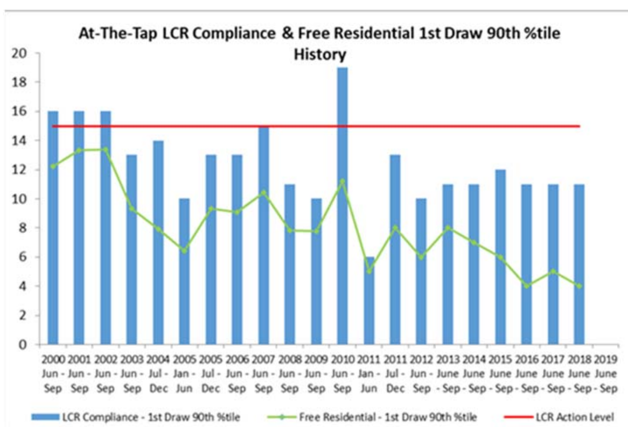
13

Free Residential Lead Testing Program

NYC Environmental Protection

Data are mined and used for many purposes:

- Indicator for compliance
- Evaluate levels collected at different flush periods
- Evaluate impact of construction activities



Program is being expanded as part of LeadFreeNYC and kit requests are expected to double in the next year.

14

Lead Data

Sample Type	Year	# Samples	Avg Pb (ppb)	# Samples = 0 ppb	# Samples >5 ppb	# Samples > 10 ppb	# Samples >15 ppb	% = 0	% >5 ppb	% >10 ppb	% >15 ppb
LCR Compliance	2014	191	34	61	54	22	15	32%	28%	8%	8%
FR first draw		948	11	520	125	62	43	55%	13%	7%	5%
FR 1-2 min flush		952	3	723	102	64	49	76%	11%	7%	5%
FR 5 min flush		24	4	9	4	2	2	38%	17%	8%	8%
Complaint Imm		162	5	85	30	16	13	52%	19%	10%	8%
Complaint 5MF		163	0	151	1	0	0	93%	1%	0%	0%
LCR Compliance	2015	350	6	120	91	43	23	34%	26%	12%	7%
FR first draw		1041	13	629	116	67	45	60%	11%	6%	4%
FR 1-2 min flush		1042	2	824	91	58	42	79%	9%	6%	4%
FR 5 min flush		28	6	5	6	5	4	18%	21%	18%	14%
Complaint Imm		121	13	76	16	15	8	63%	13%	12%	7%
Complaint 5MF		133	1	116	4	2	0	87%	3%	2%	0%
LCR Compliance	2016	498	15	174	126	54	34	35%	25%	11%	7%
FR first draw		5253	5	3576	369	187	128	68%	7%	4%	2%
FR 1-2 min flush		5262	1	4482	242	142	96	85%	5%	3%	2%
FR 5 min flush		70	3	23	9	5	1	33%	13%	7%	1%
Complaint Imm		160	3	98	20	9	8	61%	13%	6%	5%
Complaint 5MF		169	0	157	2	0	0	93%	1%	0%	0%
LCR Compliance	2017	487	6	162	124	51	26	33%	25%	10%	5%
FR first draw		3602	7	2499	248	143	105	69%	7%	4%	3%
FR 1-2 min flush		3602	2	3099	175	104	63	86%	5%	3%	2%
FR 5 min flush		72	3	28	8	5	3	39%	11%	7%	4%
Complaint Imm		144	3	85	18	8	6	59%	13%	6%	4%
Complaint 5MF		144	0	131	0	0	0	91%	0%	0%	0%
LCR Compliance	2018	481	6	157	105	49	26	33%	22%	10%	5%
FR first draw		3942	12	2749	289	147	110	70%	7%	4%	3%
FR 1-2 min flush		3942	2	3360	179	100	68	85%	5%	3%	2%
FR 5 min flush		100	2	38	7	6	4	38%	7%	6%	4%
Complaint Imm		207	9	135	31	22	17	65%	15%	11%	8%
Complaint 5MF		207	0	201	2	0	0	97%	1%	0%	0%
Totals/Averages		**33497**	**6**	**24473**	**2594**	**1388**	**939**	**61%**	**12%**	**6%**	**4%**

LCR Compliance = always first draw **Complaint Imm = Immediate draw after unknown stagnation**

FR = Free Residential Testing Program **Complaint 5 MF = 5 min flush after unknown stagnation**

15

NYC Lead Research

Past Studies

- 1991-1992: Corrosion Control Pipe Loop Study – established orthophosphate at 1 mg/L (as PO4) and pH 7.2
- 1998-1999: Phase II Corrosion Control Study – resulted in orthophosphate dose of 2 mg/L (as PO4)
- 2010: SeaQuest Corrosion Inhibitor Study – confirmed that orthophosphate was the best corrosion inhibitor
- 2011: Expert Panel Desktop Corrosion Control Study – resulted in an increase of pH to 7.3

New Studies

- Pilot study to assess orthophosphate dose of 3 mg/L
- Lead profiles (2005 – present)
- LSL replacement monitoring
- Lead pipe scale analyses

16

DEP's Current Corrosion Control Research

Salome Freud, Chief, Distribution Water Quality

March 20, 2019

Agenda

- Phosphoric acid chemical feed system upgrades
- Optimizing corrosion control pilot study
- Home profile studies
- Lead pipe scale analysis
- Evaluation of random daytime sampling
- Post LSL replacement monitoring results
- Future LSL replacement pre and post monitoring

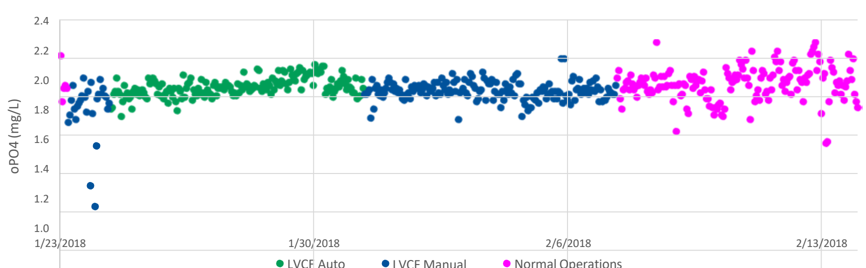
2

Phosphoric acid chemical feed system upgrades

3

Chemical Feed System Upgrades

- DEP investigated methods of improving phosphoric acid application at Hillview for the 3 tunnels moving towards flow paced treatment.
- A Liquid Vacuum Chemical Feed (LVCF) system was piloted from 1/24/18 to 2/14/18
- Variation of orthophosphate (oPO4) levels was greatly reduced when LVCF was used instead of “normal operations” with manual adjustment of metering pumps

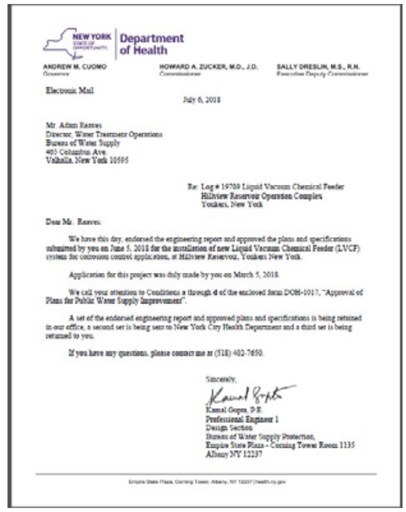


4

Chemical Feed System Upgrades

NYC Environmental Protection

- 7/6/2018: received approval from NYSDOH to permanently install LVCF systems for oPO_4 dosing at Hillview
- 10/5/2018: activated LVCF at Tunnel 1 injection point
- By mid March 3/##/2019: activated LVCF at Tunnel 2 and 3 injection points



NEW YORK STATE OF OPPORTUNITY. | Department of Health

ANDREW M. CUOMO, Governor — HOWARD A. ZUCKER, M.D., J.D., Commissioner — SALLY DRESLIN, M.S., R.N., Executive Deputy Commissioner

Electronic Mail

July 6, 2018

Mr. Adam Reeves
Director, Water Treatment Operations
Bureau of Water Supply
465 Columbus Ave.
Valhalla, New York 10595

Re: Log # 19789 Liquid Vacuum Chemical Feeder
Hillview Reservoir Operation Complex
Yonkers, New York

Dear Mr. Reeves:

We have this day, endorsed the engineering report and approved the plans and specifications submitted by you on June 5, 2018 for the installation of new Liquid Vacuum Chemical Feeder (LVCF) system for corrosion control application, at Hillview Reservoir, Yonkers New York.

Application for this project was duly made by you on March 5, 2018.

We call your attention to Conditions a through d of the enclosed form DOH-1017, "Approval of Plans for Public Water Supply Improvement".

A set of the endorsed engineering report and approved plans and specifications is being retained in our office, a second set is being sent to New York City Health Department and a third set is being returned to you.

If you have any questions, please contact me at (518) 402-7650.

Sincerely,

Kamal Gupta, P.E.
Professional Engineer 1
Design Section
Bureau of Water Supply Protection,
Empire State Plaza - Corning Tower Room 1135
Albany NY 12237

Empire State Plaza, Corning Tower, Albany, NY 12237 | health.ny.gov

5

Continuous Orthophosphate Monitoring

NYC Environmental Protection

- In order to help operators further optimize treatment, 2 different continuous monitoring oPO_4 analyzers were evaluated side by side during a period of ~6 months
- 9/26/2018: based on data collected the instrument most suitable to current and future operational dosing levels was selected
- To date, selected instrument has been installed at 4 out of 6 identified locations (5 entry points, 1 monitoring location in City Island)

6

Continuous Orthophosphate Monitoring

- Location and installation date details:

Location	Installation Date	Notes
Tunnel 1 / Shaft 3	6/5/2018	Currently using LR unit. HR unit will be installed at future date
Tunnel 2 / 3A Building	2/1/2019	
Tunnel 3 / 3B Building	TBD	Pending completion of WQMON station *by end of 2019*
NCA / Shaft 26*	1/9/2019	
CFP Tunnel 2 Building	TBD	Pending completion of WQMON station *by end of 2019*
City Island	11/27/2019	

*Substitute for EP – downstream on the aqueduct. Unable to install at EP/GH5 due to lack of sewer connection.

7

Optimizing corrosion control pilot study

8

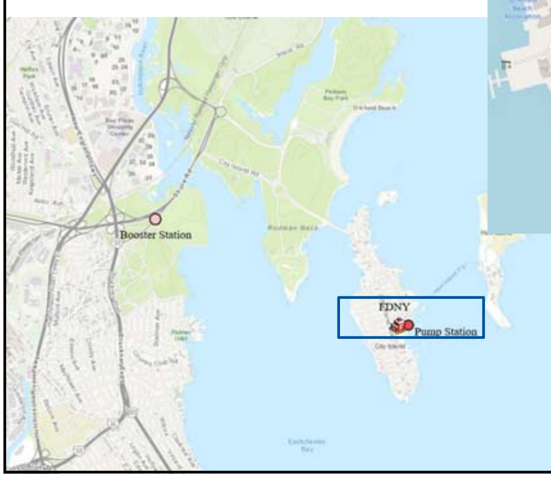
Optimizing Corrosion Control Pilot Study

- Pilot testing of oPO_4 dose increase in isolated area of NYC – City Island
- Chlorine booster station was retrofitted to feed oPO_4 to boost concentration from 2 mg/L to 3 mg/L
- Monitoring locations for study:
  - FDNY Fire Station – continuous oPO_4 monitoring
  - DEP wastewater pump station – lead pipe loops
  - Resident volunteers – profile sampling
- Monitoring plan for the City Island Pilot Study is still being finalized and needs DOH approval
  - Dose will not be increased until approval is granted
  - Baseline data has been obtained from lead pipe loops and two study homes

9

Optimizing Corrosion Control Pilot Study

City Island:
oPO4 booster station and
monitoring locations

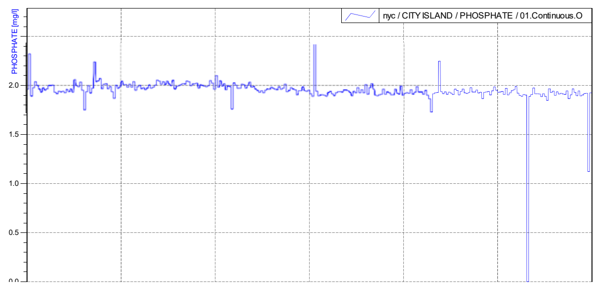


10

Optimizing Corrosion Control Pilot Study

Continuous oPO_4 analyzer:

- Installed at FDNY E70/L53
- Data can be viewed remotely

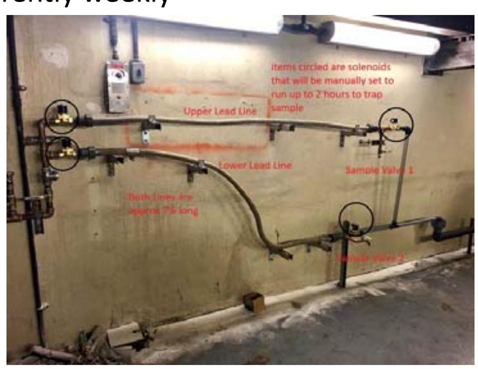


11

Optimizing Corrosion Control Pilot Study

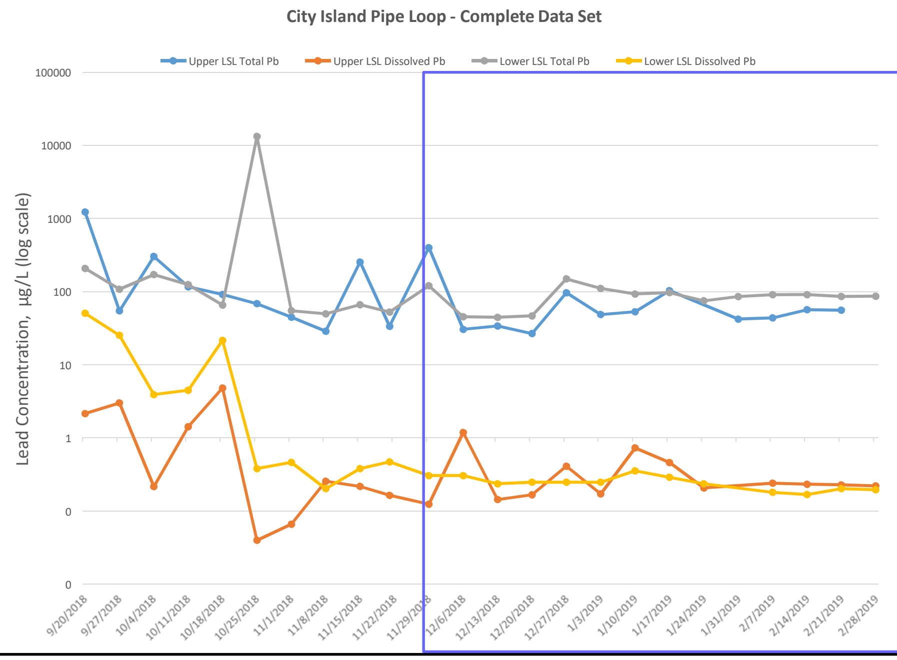
Pipe Loops:

- Two ~7 ft lengths of LSL harvested from NYC distribution system were installed inside a DEP-BWT pump station
- Pipes conditioned with fresh water daily
- Sampling commenced on 9/20/2018, currently weekly



12

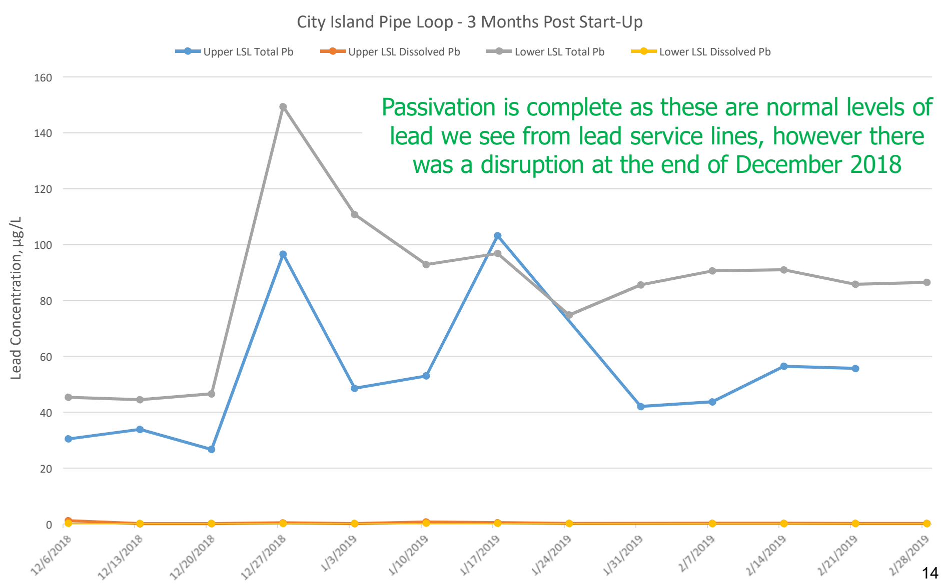
Optimizing Corrosion Control Pilot Study



13

Optimizing Corrosion Control Pilot Study

Looking from 12/6/2018 to current date with <u>non logarithmic scale:</u>

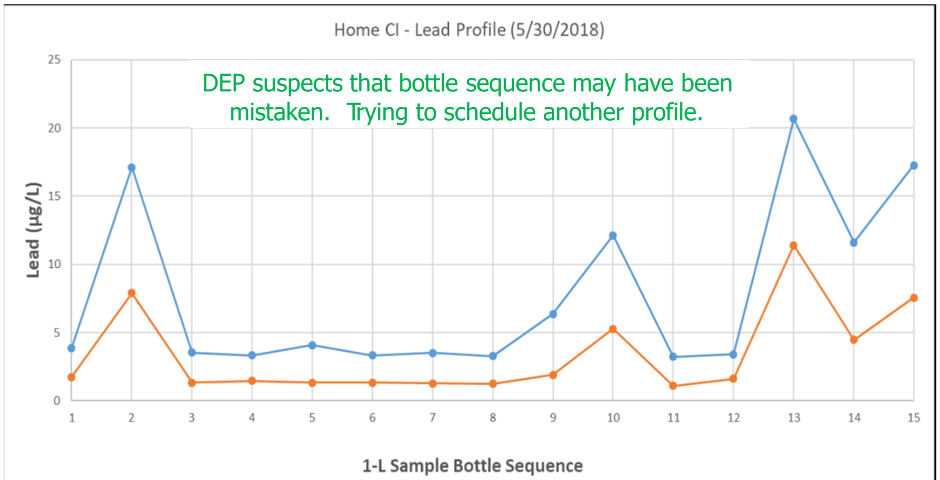


14

Optimizing Corrosion Control Pilot Study

Profile Sampling of Home 1 CI

- ¾" diameter LSL with ¾" diameter brass interior piping
- First lead profile completed on May 30, 2018

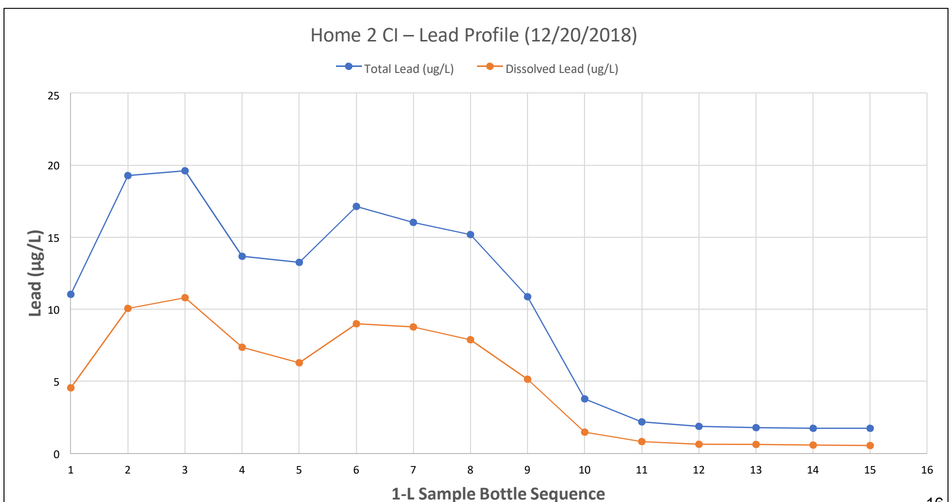


15

Optimizing Corrosion Control Pilot Study

Profile Sampling of Home 2 CI

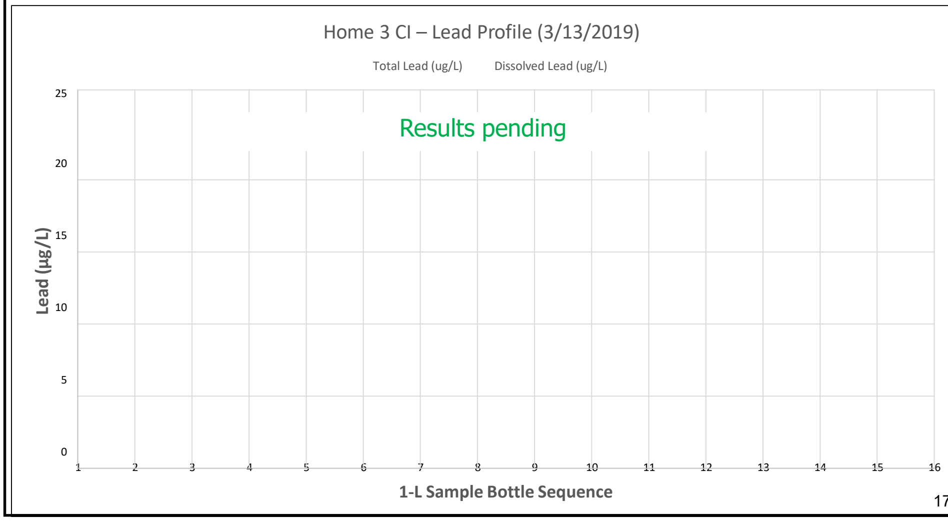
- ¾" diameter LSL with ¾" diameter copper interior piping
- First lead profile completed on December 20, 2018



16

Optimizing Corrosion Control Pilot Study

Profile Sampling of Home 3 CI
- 1¼” diameter copper SL with copper interior piping → “Control Group”
- First lead profile completed on March 13, 2019



17

Optimizing Corrosion Control Pilot Study

- At the request of DOHMH, DEP is attempting to included more homes on the City Island as part of the profiling component of this study, including homes that do not have lead service lines (LSLs) or any lead solder or components in their plumbing
- DEP is reviewing records of housing stock and actively reaching out to try and recruit more participants

18

Home profile studies

19

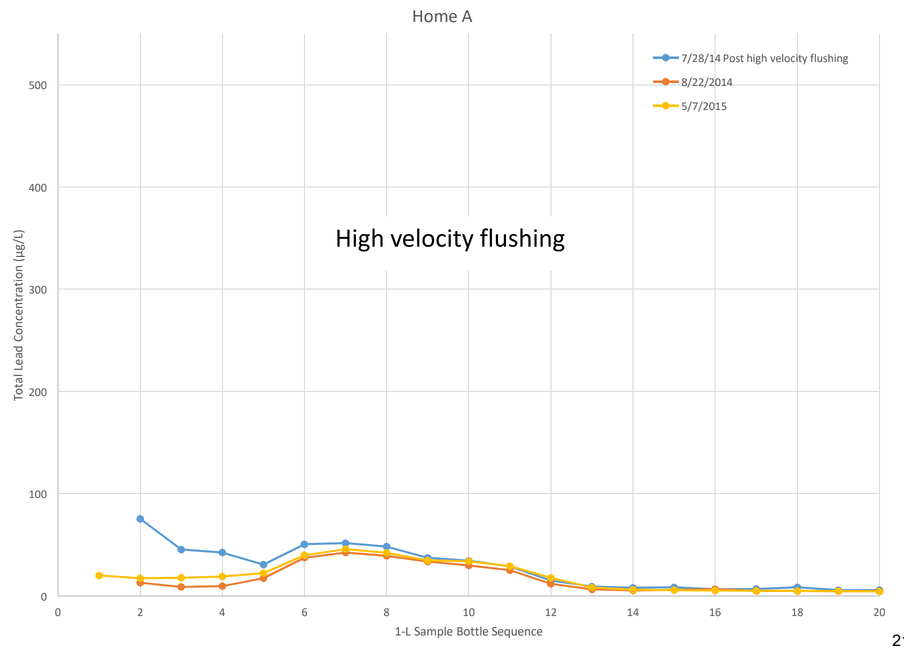
City-wide Home Profile Studies

NYC Environmental Protection

- DEP has and continues to conduct profile sampling at numerous homes
- Various conditions have been evaluated since studies started ~5 years ago
  - o Effects of full house high velocity flushing
  - o Effects of partial lead service line replacement (PLSLR)
  - o Seasonality
  - o Varying stagnation periods

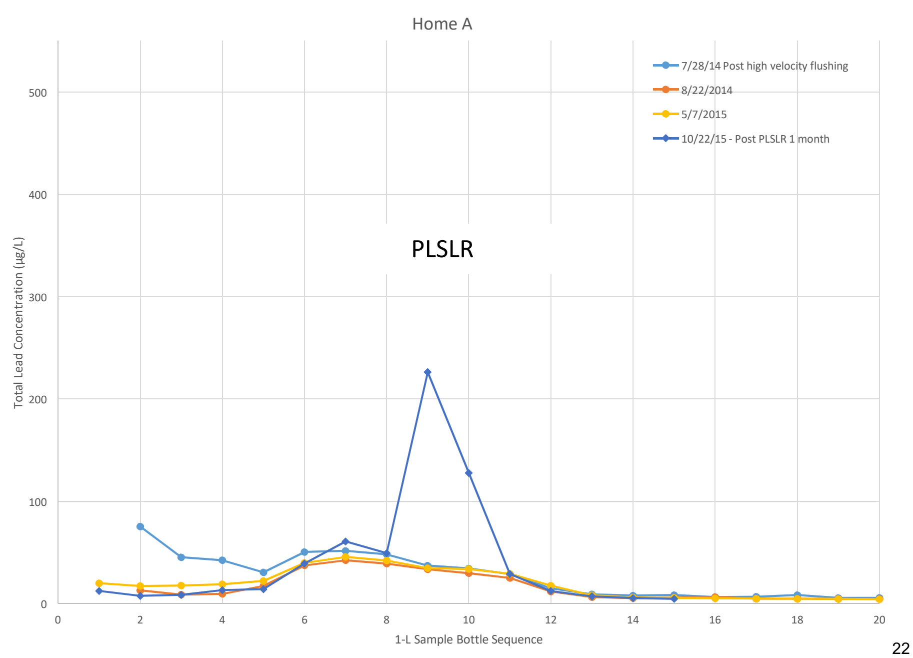
20

City-wide Home Profile Studies



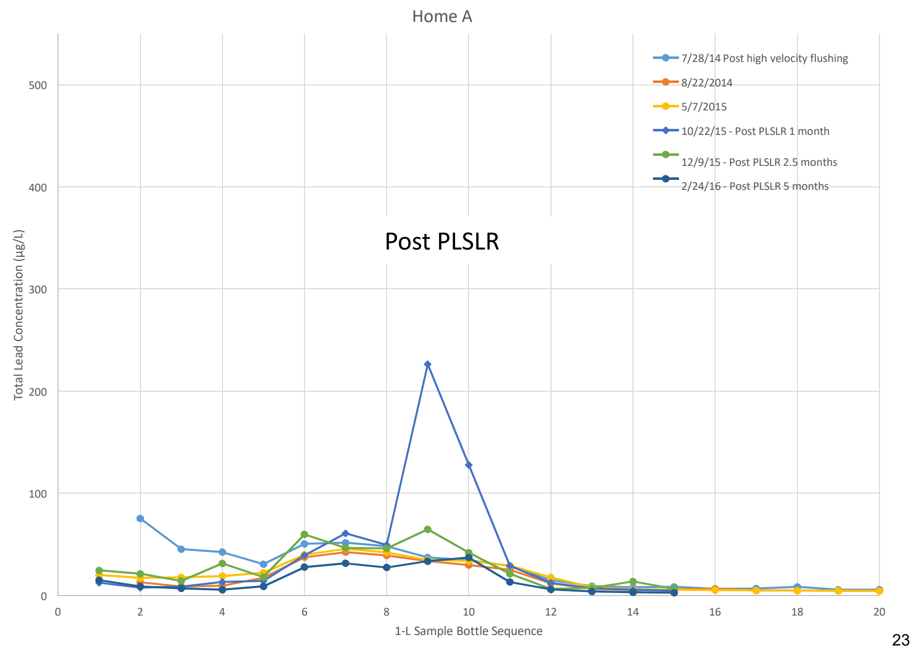
21

Home Profile Studies



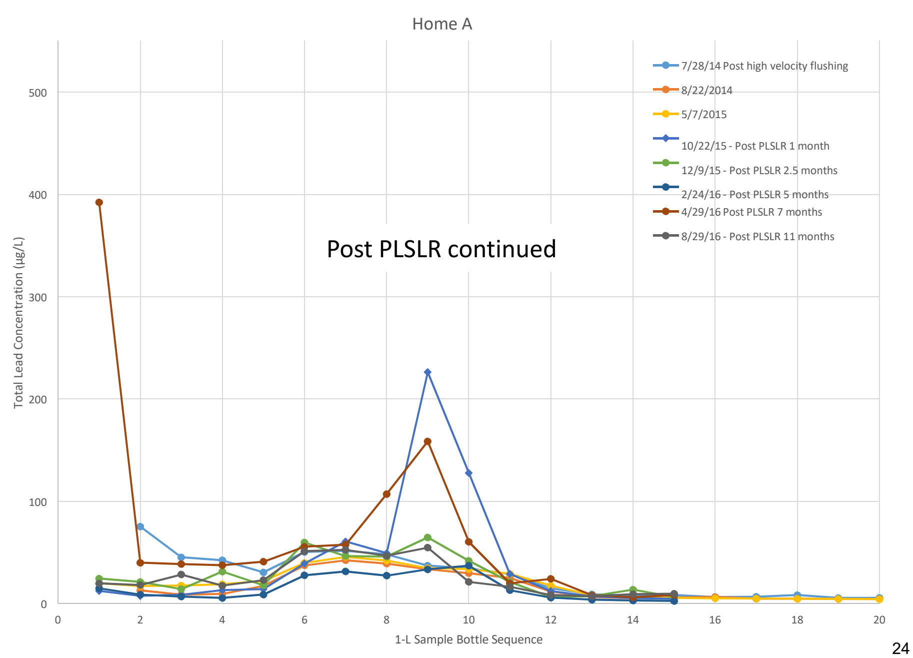
22

Home Profile Studies



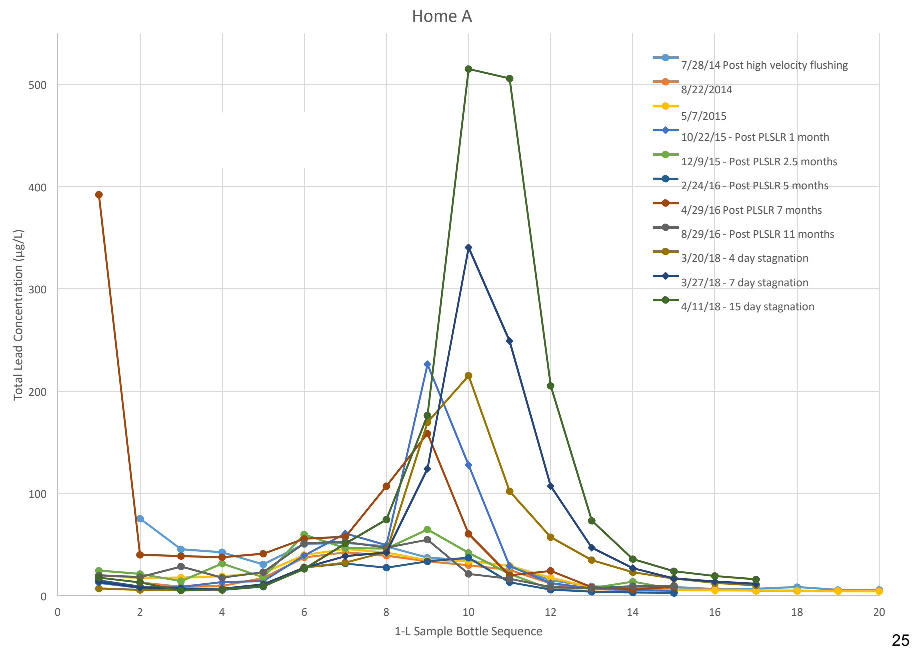
23

Home Profile Studies



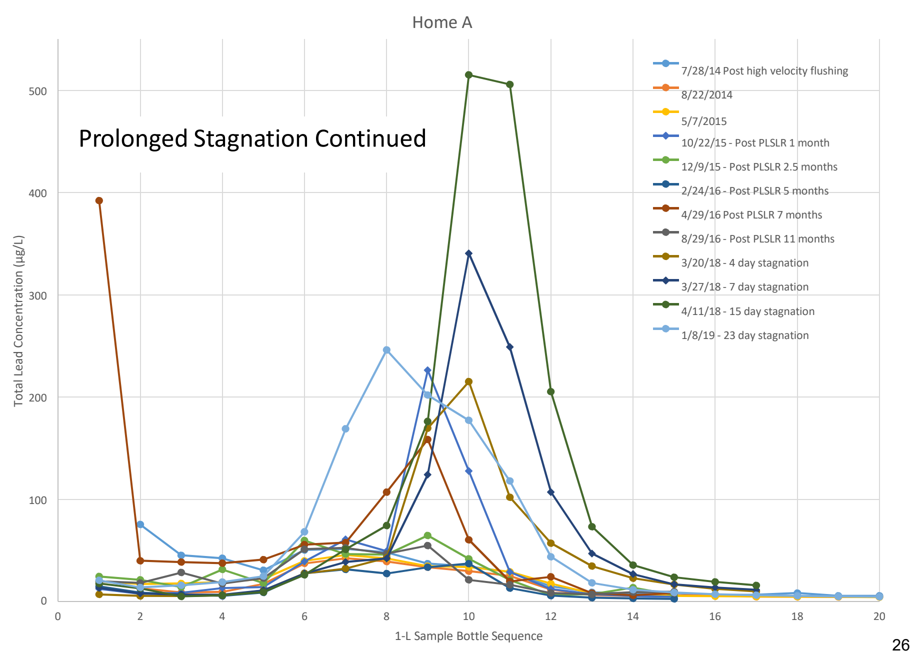
24

Home Profile Studies



25

Home Profile Studies



26

Lead pipe scale analysis

27

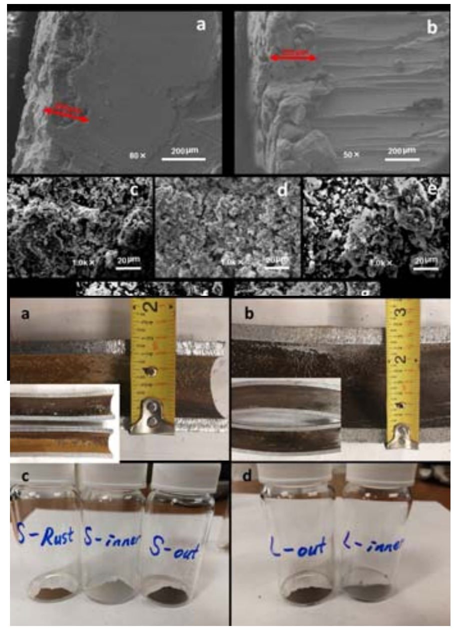
Lead Pipe Scale Analysis

- In order to identify the the lead corrosion products that have formed over time, and understand the solubility of lead and the potential for its release in different areas of the distribution system, six segments of lead pipe were harvested from the NYC distribution system
  - Two from City work yards located in the Bronx without constant water use
  - Two from single family homes located in Queens that were supplied groundwater in the past
  - Two from single family homes in Queens that were only supplied surface water

28

Lead Pipe Scale Analysis

- Analysis performed by SUNY Buffalo – Alan J. Rabideau & John D. Atkinson
- Analysis includes:
  - o X-ray diffraction (XRD)
  - o Scanning Electron Microscopy
- Results pending from one home
- LSL pipe loops on City Island will be sent for analysis after the study is completed



29

Evaluation of random daytime sampling

30

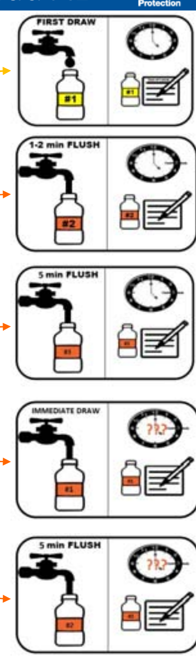
Impact of Random Day Time Sampling on Lead AL

- The Long Term Revisions to the Lead and Copper Rule (LTR LCR) may change sample requirements from initial draw to random day time and may lower the Action Level (AL)
- DEP evaluated potential impact on the 90th percentile from such a sampling change using existing data collected from:
  - o Free residential (FR) lead testing program
  - o Complaint sampling of internal residences
- Data sets were analyzed to evaluate impact of random day sampling on lead levels against a 5ppm, 10ppm, and 15ppm AL

31

Impact of Random Day Time Sampling on Lead AL

- Time period of analysis: 2014 to 2018
- Sample types for analysis:
  - o LCR compliance, first draw (used as control)
  - o FR, first draw
  - o FR, 1-2 minute flush
  - o FR, 5 minute flush
  - o Complaints, immediate draw after unknown stagnation
  - o Complaints, 5 minute flush after unknown stagnation



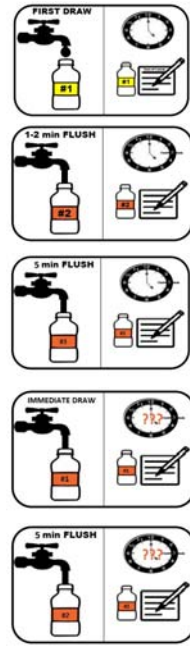
2

Evaluation of Random Day Sampling on Lead Levels

NYC Environmental Protection

- Evaluated data sets against lower AL of 10ppb:
  - o Since 2017, LCR compliance, FR 5 minute flush, and Complaints immediate samples would not have consistently met a 10ppb 90th percentile AL

Sample Type	Year	# Samples	Min Pb (ppb)	Avg Pb (ppb)	Max Pb (ppb)	# Samples = 0 ppb	# Samples >5 ppb	# Samples > 10 ppb	# Samples >15 ppb	% = 0	% >5 ppb	% >10 ppb	% >15 ppb
LCR Compliance	2014	191	0	34	4960	61	54	22	15	32%	28%	8%	8%
FR first draw	2014	948	0	11	3641	520	125	62	43	55%	13%	7%	5%
FR 1-2 min flush	2014	952	0	3	173	723	102	64	49	76%	11%	7%	5%
FR 5 min flush	2014	24	0	4	22	9	4	2	2	38%	17%	8%	8%
Complaint Imm	2014	162	0	5	105	85	30	16	13	52%	19%	[illegible]	8%
Complaint 5MF	2014	163	0	0	7	151	1	0	0	93%	1%	0%	0%
LCR Compliance	2015	350	0	6	110	120	91	43	23	34%	26%	[illegible]	7%
FR first draw	2015	1041	0	13	9655	629	116	67	45	60%	11%	6%	4%
FR 1-2 min flush	2015	1042	0	2	74	824	91	58	42	79%	9%	6%	4%
FR 5 min flush	2015	28	0	6	40	5	6	5	4	18%	21%	[illegible]	14%
Complaint Imm	2015	121	0	13	698	76	16	15	8	63%	13%	[illegible]	7%
Complaint 5MF	2015	133	0	1	12	116	4	2	0	87%	3%	2%	0%
LCR Compliance	2016	498	0	15	4726	174	126	54	34	35%	25%	[illegible]	7%
FR first draw	2016	5253	0	5	6768	3576	369	187	128	68%	7%	4%	2%
FR 1-2 min flush	2016	5262	0	1	573	4482	242	142	96	85%	5%	3%	2%
FR 5 min flush	2016	70	0	3	30	23	9	5	1	33%	13%	7%	1%
Complaint Imm	2016	160	0	3	88	98	20	9	8	61%	13%	6%	5%
Complaint 5MF	2016	169	0	0	10	157	2	0	0	93%	1%	0%	0%
LCR Compliance	2017	487	0	6	190	162	124	51	26	33%	25%	[illegible]	5%
FR first draw	2017	3602	0	7	5924	2499	248	143	105	69%	7%	4%	3%
FR 1-2 min flush	2017	3602	0	2	1519	3099	175	104	63	86%	5%	3%	2%
FR 5 min flush	2017	72	0	3	52	28	8	5	3	39%	11%	7%	4%
Complaint Imm	2017	144	0	3	67	85	18	8	6	59%	13%	6%	4%
Complaint 5MF	2017	144	0	0	3	131	0	0	0	91%	0%	0%	0%
LCR Compliance	2018	481	0	6	277	157	105	49	26	33%	22%	[illegible]	5%
FR first draw	2018	3942	0	12	15483	2749	289	147	110	70%	7%	4%	3%
FR 1-2 min flush	2018	3942	0	2	690	3360	179	100	68	85%	5%	3%	2%
FR 5 min flush	2018	100	0	2	22	38	7	6	4	38%	7%	6%	4%
Complaint Imm	2018	207	0	9	495	135	31	22	17	65%	15%	[illegible]	8%
Complaint 5MF	2018	207	0	0	7	201	2	0	0	97%	1%	0%	0%



3

Post LSL replacement monitoring results

34

NYCHA Lead Service Line Replacement Results

- DEP replaced LSLs at 43 single family homes owned by NYCHA in November and December 2018
- Home owners were provided specific flushing instructions to be followed post LSL replacement
  - Initial full house 30 min flush. Repeat every 2 weeks for 3 months
  - Daily mini flush of 5 min for 6 months. Flush each morning or after stagnation > 6 hours
- A free lead test kit, consisting of a first draw sample and a 1-2 minute flush sample, was sent to each home 30 days after the LSL replacement
- To date, 10 valid kits have been returned to DEP all with 0ppb lead
  - The average days between LSL replacement and sampling was 41, with a total range of 31 to 69

35

Future LSL replacement pre and post monitoring

36

Future Lead Service Line Replacement

- DEP received a $5.3 million grant from DOH for LSL replacements
- LSL replacements will be offered to all single family homeowners who are part of the Home Energy Assistance Program (HEAP)
  - 1,110 residences potentially qualify to apply
  - DEP will provide additional funding as needed
- Lessons learned from NYCHA LSL replacements can be applied to this project to refine flushing instructions
- Pre-replacement lead testing will be offered to further our understanding of the impact of the replacement and its effect on lead risk exposure

37

Open Discussion and Questions

Reminder of topics discussed:

- Phosphoric acid chemical feed system upgrades
- Optimizing corrosion control pilot study
- Home profile studies
- Lead pipe scale analysis
- Evaluation of random daytime sampling
- Post LSL replacement monitoring results
- Future LSL replacement pre and post monitoring

For more information…

Visit the DEP website at
www.nyc.gov/dep

Follow us on Facebook
for more info about events
and projects, photos and
other watershed updates:
facebook.com/nycwatershed

Microbiologically Influenced Corrosion

WRF Corrosion Control Workshop

March 20, 2018

Tina Johnstone, Director, Source Water Operations

Agenda

- Stainless Steel Background
- MIC Background
- WDRC Findings
- CFPS Findings
- DEP MIC Prevention Plan
- Panel Assistance

2

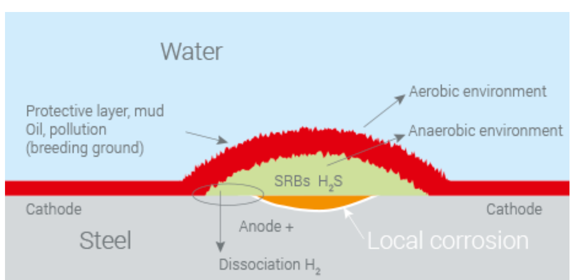
Stainless Steel Background

- WRF Project #4431 – Guidelines for the Use of Stainless Steel in the Water and Desalination Industries
- 6 different grades and more than 120 compositions available
- Water industry typically uses 304/304L and 316/316L (L = low carbon)
- Pitting Resistant Equivalent Number (PREN)
- Higher PREN = higher protection
- 304/304L PREN = 19
- 316/316L PREN = 25
- Corrosion can occur in crevice (joint) or surface (pitting)

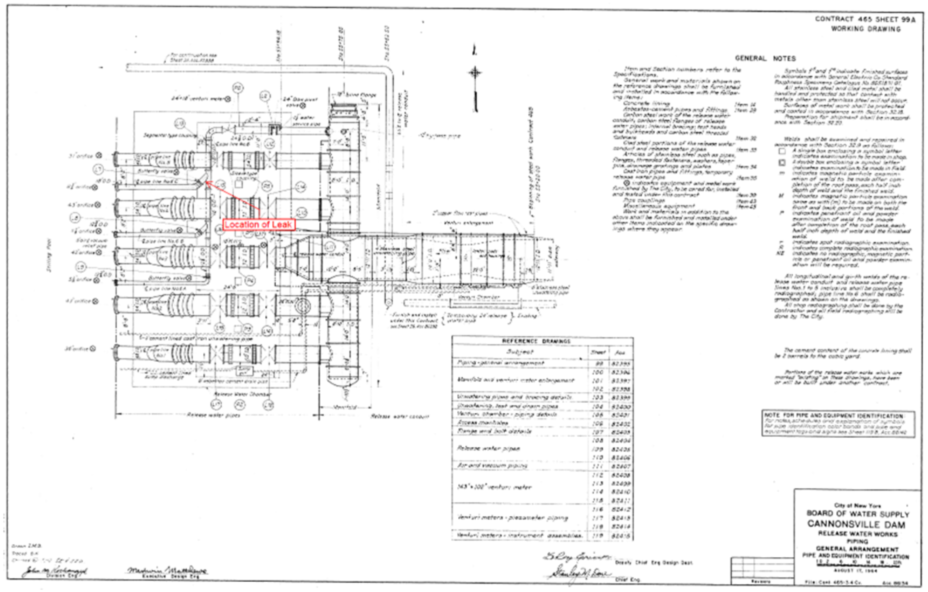
3

MIC Background

- MIC – Microbiologically Induced Corrosion
- Can be caused by many different microorganisms (bacteria, fungi, algae)
- Water industry culprits usually bacteria (acid producers, sulfate reducers, oxidizing bacteria)
- Bacteria need suitable conditions to grow (pH, temp, etc.)
- Flow velocity highly important – decrease in flow = increase in biofilm growth
- Sulfate reducing bacteria (SRB) most often considered in MIC cases
- Test are available for SRB – presence/absence seems more important than quantification
- One established, difficult to eliminate
- Best to prevent stagnation and not allow bacteria to establish



Findings at West Delaware Release Chamber



5

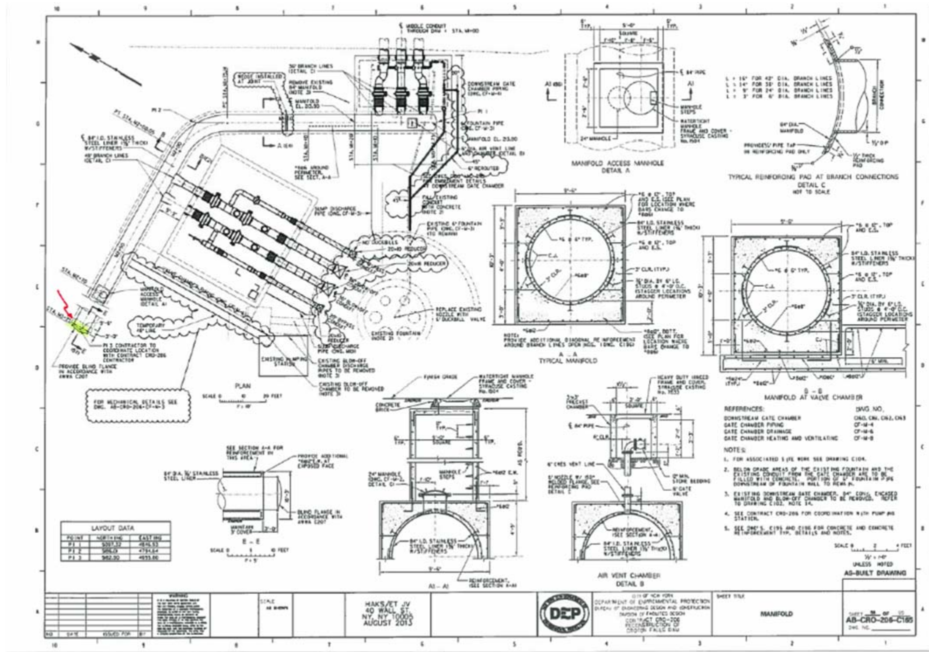
Findings at West Delaware Release Chamber

- 316 SS wye installed in 1961
- Leak found Nov. 2011 during routine maintenance
- V-notch crack across arc weld
- Crack origin determined to be at outer surface
- Leak not at entire length of crack

- No crack on adjacent Line 6B
- MIC not conclusively determined or ruled out in this case
- Could be inspected if line is replaced

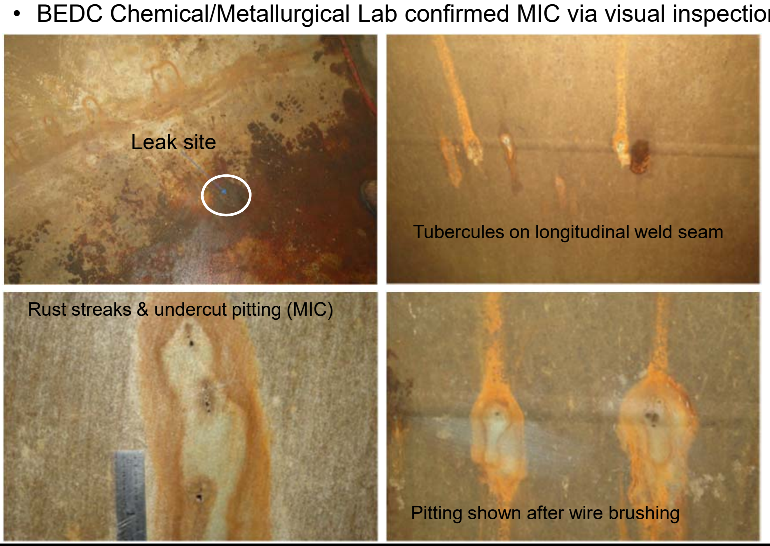
6

Findings at Croton Falls Pump Station



Findings at Croton Falls Pump Station

- 316 SS 84 in pipe installed 5 yrs prior – stagnant – little to no flow
- Leak found mid-2016 – multiple locations with pitting found
- Most rust & pitting in lower half of pipe
- BEDC Chemical/Metallurgical Lab confirmed MIC via visual inspection



8

DEP MIC Prevention Plan

Region	Facility	Piping/Valve	Remarks
Downsville	West Delaware Release Chamber	24-in Pipe - Line 6	Line 6 becomes stainless steel past the Y-Coupling. The fittings throughout are also stainless steel. These lines have not been operated for a number of years.
		12-in Pipe - Line 6A	
		12-in Pipe - Line 6B	
		18-in Pipe - Line 6C	
Grahamsville	Neversink Intake Chamber	24-in Polyject Release Valve - North Line	Not operated since March 2016
		24-in Polyject Release Valve - South Line	Primary line - regularly operated
		24-in Polyject Release Valve - Conservation Line	Not operated since November 2012
Shokan	Ashokan Lower Gate Chamber	Equalization Line 2	Lines are regularly used, however, may go months at a time without being operated.
		Scour Valve 2	
		Equalization Line 3	
		Scour Valve 3	
		Equalization Line 4	
		Scour Valve 4	
		Equalization Line 5	
		Scour Valve 5	
	Gilboa Dam - Interior Gallery	Drain Lines	

Region	Facility	Piping/Valve	Remarks
Highlands	Boyd's Corner - Valve House	30-in Pipe - Line 1	Lines are normally not used past the Y-Coupling whre the lines split into the 20-in line. There would a signifiant duration in contact with raw water in this location. Valves are operated every six months.
		30-in Pipe - Line 2	
		20-in Pipe - Line 3	Only one of the lines is used for release at a time. If the releases are not being properly alternated per line, there could be significant time in contact with stagnant raw water.
		20-in Pipe - Line 4	
	Croton Falls - Downstream Gate Chamber	36-in Pipe - North	All three lines (3) lines feed into 84-in diameter manifold.
		36-in Pipe - Middle	
		36-in Pipe - South	
		84-in dia. Manifold	Microbiological Corrosion (MIC) has caused pinhole leaks.
	Croton Falls - Valve Chamber	36-in Pipe - West	Rarely used.
		36-in Pipe - East	
		20-in Pipe - Conservation West	Regularly used in conjunction.
		20-in Pipe - Conservation East	
	Shaft 10 - West Branch Effluent Chamber	North Valve Line 1	Lines N1-N3 and S1-S3 are regularly used. Lines N4-N5 and S4-S5 are used less. R1 and R2 are rarely used because they require all ten (10) previous lines to be open prior due to the amount of head behind the valves.
		North Valve Line 2	
		North Valve Line 3	
		North Valve Line 4	
		North Valve Line 5	
		Rectangular Valve Line 1	
		Rectangular Valve Line 2	
		South Valve Line 1	
		South Valve Line 2	
		South Valve Line 3	
		South Valve Line 4	
		South Valve Line 5	
	Shaft 11	Riser Cap	Stainless steel riser cap is in contact with stagnant raw water often.
	Amawalk Dam	Multijet Valve	Lines are used regularly
	Bog Brook Dam	Multijet Valve	Lines are used regularly
	Cross River Dam	Multijet Valve	Lines are used regularly
	Croton Falls Dam	Multijet Valve	Lines are used regularly
	Diverting Dam	Multijet Valve	Line with valve is not regularly used.
	Sodom Dam	Multijet Valve	Lines are used regularly
	New Croton Dam	Multijet Valve	No water has flowed through lines.
	Titicus Dam	Multijet Valve	Lines are used regularly
	West Branch Dam	Multijet Valve	Lines are used regularly

- In response to finding MIC at CFPS
- Concern about other facilities with stainless steel and stagnant water
- Not feasible to dry lines between use
- DEP inventoried stainless steel piping in watershed at risk
- Developed flushing protocol
- Stainless steel piping flushed at least every 6 months
- More than 50 lines across watershed
- Procedure added to Computerized Maintenance Management System (CMMS)

9

Assistance from the panel

- Best approach for detecting MIC
- Best approach for preventing MIC
- Realistic expectation of success
- Evaluation of the DEP MIC Prevention Plan
- Water quality impact on design considerations
- Anything new on the horizon – future research

10

Investigation & Remediation of Corrosion Issues in City Tunnel 3

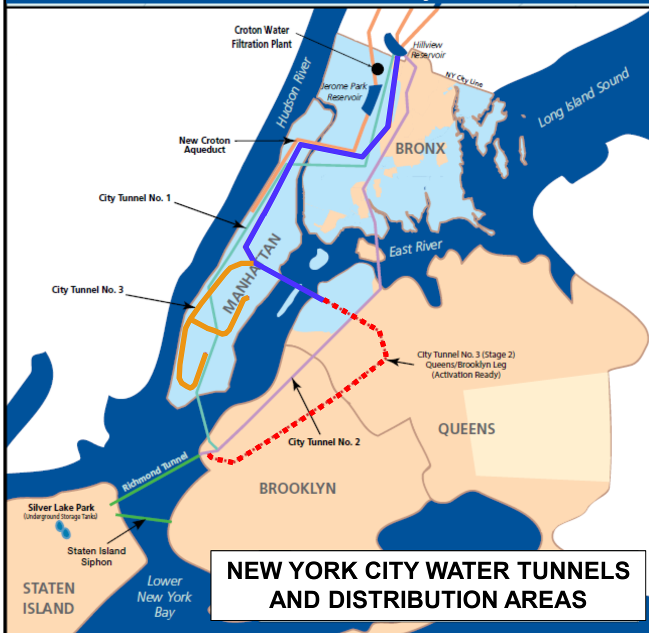
March 20, 2019

Presentation Outline

- City Tunnel 3
- Corrosion Remediation Project
  - Topics for Discussion
    - MIC
    - Cathodic Protection

2

City Tunnels



City Tunnel No. 3

- Stage 1
  - In service from 1998
  - 13 Miles long
- Stage 2 Manhattan leg
  - In service from 2013
  - 9 Miles long
- Stage 2 Queens/ Brooklyn leg
  - Activation Ready
  - 11 Miles long

3

City Tunnel 3 Shafts and Chambers

Tunnel system:

- Valve Chambers to control flow
  - Van Cortland Park Valve Chamber
  - Central Park Valve Chamber
  - Roosevelt Island Valve Chamber
- Numerous distribution shafts

http://media.gettyimages.com/photos/opening-of-new-york-citys-third-water-tunnel-the-valve-chamber-below-picture-id97334377?s=612x612

4

Project Need

Underground chambers

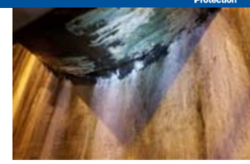
- Most of the piping were installed in the 1980s
- Designed to allow groundwater
- Not all laterals are in operation

Environment inside the deep chambers

- Cool (40°F - 50°F)
- Damp (around 90% relative humidity)
- Condensation on metallic components

Over the years……..

- Signs of Corrosion
- Coating failures



5

Project Objectives

DEP initiated the project:

- To determine the root causes of corrosion
- Develop a detailed design to remove corrosion on affected components
- To protect the components from further corrosion
- To apply lessons learned from this project to future tunnels

If left unaddressed, corrosion may lead to:

- Significantly reduced life expectancy of equipment
- Potential significant leaks
- An emergency tunnel shutdown
- Service interruptions
- Significant financial consequences

6

Corrosion Mechanisms

Corrosion of Pipes in Valve Chambers

- Oxygen driven corrosion
  - ➢ Low temperature
  - ➢ Very high humidity
  - ➢ Dissimilar metals
- Microbiologically influenced corrosion (MIC)
- Localized Corrosion of Stainless Steel

Corrosion mechanisms for Cast-in-place concrete

- Carbonation
- Chloride attack

7

Major Findings - Carbon steel components

Galvanic Corrosion

Carbon steel cradle on top of stainless steel base

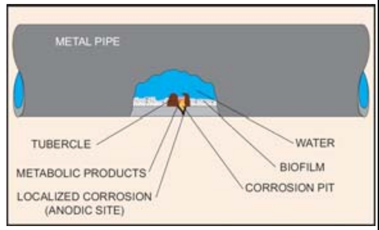
Carbon steel counterweight and stainless steel arm

8

Major Findings - MIC

Borescope Inspection of Sump Discharge Piping

- At each circumferential weld, tubercles consistent with MIC were observed.
- Both interior and exterior stains tested for the presence of bacteria commonly associated with MIC using a MICkit® 5 test kit.
- Positive indication for bacteria commonly associated with MIC



Simplified diagram showing MIC corrosion


Tubercles at weld


Interior of removed pipe section showing thin scale

9

Major Findings

- Of the three valve chambers assessed:
  - Van Cortlandt Park Valve Chamber is comparatively in the best condition
  - Roosevelt Island Valve Chamber is comparatively in the worst condition
- Chloride contents:

	Van Cortland Park VC	Central Park VC	Roosevelt Island VC
Chloride Concentration (ppm)	59-989[1]	52-148	10-1070[2]

[1] Out of the seven samples collected from Van Cortland, only one sample had chloride content of greater than 500 ppm, and the average chloride content, excluding that sample, was 167 ppm.

[2] Six out of twelve samples had chloride content beyond 200 ppm.

10

Proposed Mitigation - MIC

Handling Suspected MIC

- Camera inspection around sleeve coupling location of laterals

- Possible mitigation include:
  - Disinfection – shock treatment
  - Mechanical Removal

- Recommendation for mitigation cannot be made until extent of damage to stainless steel internals is known.

11

Proposed Mitigation – Concrete (RIVC)

Galvanic anode cathodic protection is recommended for RIVC around laterals:

- Consists of multiple anodes (E.g. every 2 feet spacing)
- Anodes can be various shapes (e.g. ribbons tied to rebar, anode mesh placed on the surface of concrete, etc.)
- Depletes every 15 to 20 years
- Less maintenance after installation
- Low capital and maintenance cost compared to Impressed Current CP
- No known negative consequence

12

Stray Current Corrosion

NYC DEP BWSO

March 20, 2019

Stray Current Corrosion

Water infrastructures are susceptible to stray current corrosion that originate from nearby unprotected electrical utilities underground

- Damage from stray current corrosion is different from natural corrosion because it is caused by an external electrical current and is independent of such environmental factors including oxygen concentration, chloride or pH
- Stray current corrosion damage is localized to where the current leaves the surface of the pipe

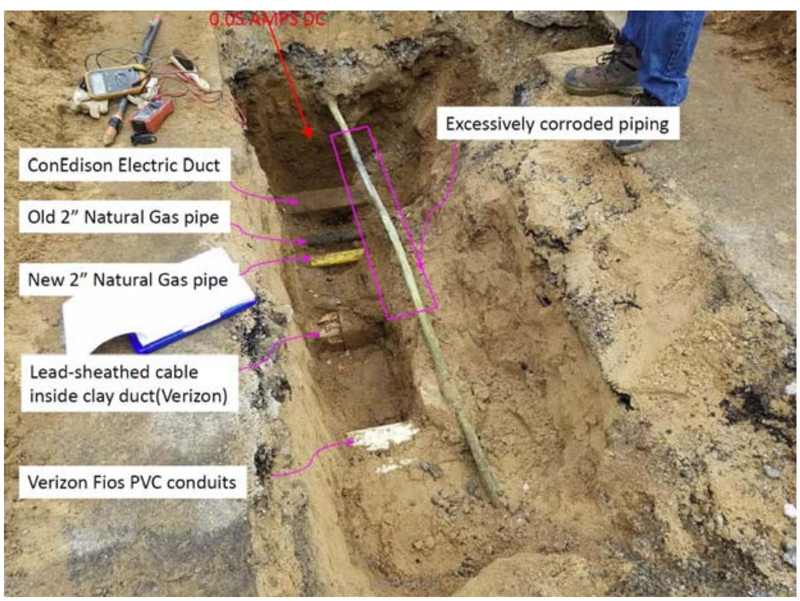
2

Water Service Lines

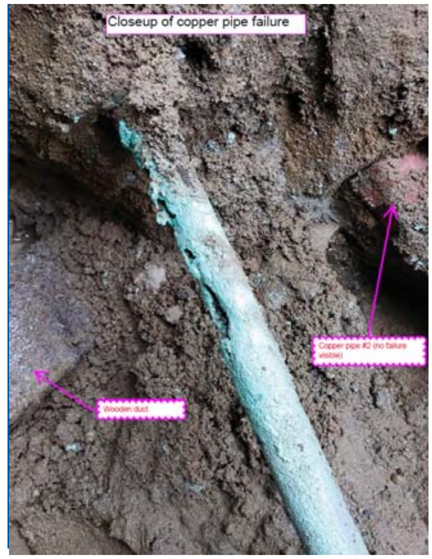
DEP issued an investigation in response to multiple copper service water piping corrosion failures

- The results of the field studies shows evidence that the likely cause of failures of the 1-in copper service lines was due to stray DC current caused by a buried, Verizon-owned, lead-sheathed communications cable
- Copper service water piping acts as the anode. Whereas electrons migrate from the surface of the copper line, through the soil, and to the Verizon lead-sheathed 48 Volt cable service that acts as the cathode

188th Street, Queens NY

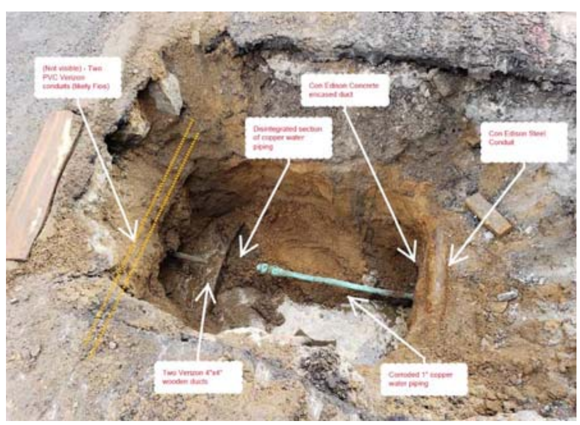


Merrick Blvd, Queens NY



5

Avenue D, Brooklyn NY



6

Appendix F: Expert Panel Bios

Dr. Vernon L. Snoeyink is Emeritus Professor of Environmental Engineering in the Civil and Environmental Engineering Department at the University of Illinois, and an independent consultant. He received B.S., M.S., and Ph.D. degrees from the University of Michigan while specializing in civil engineering and water quality control studies. At the U of I he was the Ivan Racheff Professor of Environmental Engineering and Director of a National Science Foundation Science and Technology Center. Formation and control of scales in distribution systems owing to corrosion reactions and mineral deposition, and the release of contaminants from these scales, has been a primary focus of his research and consulting work. He co-authored the text Water Chemistry and was co-editor of the American Water Works Association Research Foundation book Internal Corrosion of Distribution Systems. Dr. Snoeyink is a member of the National Academy of Engineering and is a past recipient of the Clarke Prize from the National Water Research Institute.

Dr. David Cornwell is CEO of Cornwell Engineering Group. He received his doctoral degree from the University of Florida where he is currently an Adjunct Professor. He is working closely with many utilities, the Water Research Foundation and AWWA on reducing lead levels in water at the home. Dr. Cornwell has over 50 publications, has served on many AWWA committees and is recipient of the A. P. Black Research Award and AWWA Honorary Member Award.

Jonathan Cuppett is a Research Manager with The Water Research Foundation where he leads WRF’s lead and copper corrosion research portfolio. His current focus is on developing research that helps water utilities comply with the lead and copper rule. Jonathan was a technical reviewer for the AWWA M58 “Internal Corrosion Control in Water Distribution Systems” and has been the PI for multiple EPA grants related to lead corrosion. He received a B.S. from Penn State University and a M.S. from Virginia Tech in Environmental Science and Engineering.