COUNCIL REPORT

M&C No.	2019 - 24
Report Date	February 06, 2019
Meeting Date	February 11, 2019
Service Area	Saint John Water

His Worship Mayor Don Darling and Members of Council

SUBJECT: West Saint John – Corrosion Control Investigation

OPEN OR CLOSED SESSION

This matter is to be discussed in open session of Common Council.

AUTHORIZATION

Primary Author	Commissioner/Dept. Head	City Manager
J. Brent McGovern	***J. Brent McGovern***	***John Collin***

RECOMMENDATION

It is recommended that Common Council receive and file this report.

EXECUTIVE SUMMARY

Saint John Water has continued to work with CBCL Limited and Dalhousie University's Centre for Water Resources to better understand the possible causes of leaking copper pipes reported in West Saint John during the first few months of 2018. Saint John Water received a final report from CBCL Limited dated February 5, 2019 which is attached and within the report are the studies from Dalhousie University.

Dalhousie University's Centre for Water Resources were engaged to provide analyses and reporting (see Appendices A and B of the CBCL report). CBCL was engaged to review the results from Dalhousie University, to comment on industry best practices for corrosion control and to provide recommendations to Saint John Water moving forward. The report provides a number of findings which can be summarized as follows:

a. It is likely that when the switch from surface to ground water took place, the scale existing in the pipes was disrupted before a new scale (based on changed water quality) could be developed;
b. When the existing scale was disrupted the corroded pipe in the system was exposed and leaks began to occur and this was a short-term transition;
c. The stagnation study by Dalhousie University produced results which were not predicted from the copper solubility models found in literature;

d. It is not known whether the copper measured by the Dalhousie University testing was comprised of new corrosion or decomposition (dissolution) of pre-existing scale however it is anticipated to be pre-existing scale based upon the results in Appendix B of the Dalhousie University Report;
e. The scale which had formed in the copper pipes removed from private citizens' homes and analyzed is largely amorphous (does not have a distinct, identifiable crystalline structure);
f. Spruce Lake water had low alkalinity, low pH and moderate organics and was corrosive whereas the South Bay Wellfield has a higher pH, moderate alkalinity and is non-aggressive hard water;
g. In Atlantic Canada, it is not common to switch from an untreated surface water to groundwater and those communities which did switch did not experience similar reports of issues;
h. Those communities which did change from surface to ground water did not employ use of orthophosphates;
i. There is limited literature, research and documents available for utilities permanently switching a water source (surface to ground water) or water quality within a water distribution system; and
j. The corrosion and leak event was not expected.

PREVIOUS RESOLUTION

At a meeting of Common Council on February 20, 2018 is was "*RESOLVED that as a result of the copper pipe leakage review completed to date and based upon the opportunity to stabilize copper pipe scale, your City Manager is recommending that Council direct staff to undertake the following actions:*

- *Over approximately the next month install a temporary orthophosphate treatment system at the South Bay Water Treatment Facility (formerly the Spruce Lake Water Treatment Facility) to assist in stabilizing the existing scale formation on copper pipes.*
- *Report back to Council within approximately 5 months once research is completed and results available."*

STRATEGIC ALIGNMENT

This report aligns with Council's Priority for Valued Service Delivery by investing in sustainable City services and municipal infrastructure.

REPORT

Background

There were reported copper pipe leaks in West Saint John from approximately 4% of the 5,400 West Saint John customers after the source water switch from Spruce Lake to the South Bay Wellfield and therefore there was a need to conduct an investigation into the reported leaks. The reported leaks were not

localized to specific neighborhoods' in West Saint John, there were no abnormal increases in watermain breaks or in leaks in City owned copper water services and Saint John Water had not increased the water pressure in the water system during or after the switch. Water pressures in West Saint John are governed by the water levels in the water storage tanks which have remained the same for many years.

As a result of the leaks reported, CBCL Limited and Dalhousie University were engaged by the City to provide recommendations with regards to *corrosion control* within the system and to *lead the investigation* into the potential causes of copper pipe leaks.

Dalhousie University's Centre for Water Resources were engaged to provide preliminary analyses and reporting (see Appendices A and B of the attached CBCL report). CBCL was engaged to review the results, to comment on industry best practices for corrosion control and to provide recommendations to Saint John Water moving forward. Saint John Water recently received a Final Report from CBCL Limited dated February 5, 2019 which included two reports from the Centre for Water Resources Studies at Dalhousie University.

As previously reported to Common Council with respect to corrosion control and during the reports of leaking copper pipes in early 2018, industry experts examined available options for temporary corrosion control treatments including pH adjustment and treatment with a corrosion inhibitor. After an expert review it was recommended and the City installed an orthophosphate treatment system in March 2018 to help promote copper pipe scale stabilization and to reduce apparent corrosion to the extent possible.

Investigation Analyses

As part of the investigation analyses into copper pipe leaks Dalhousie University's Centre for Water Resource Studies completed two bench scale experiments. The first was the analysis of copper corrosion scaling in West Saint John pipe samples and the second was to perform a stagnation study to predict copper release using water from Spruce Lake (surface water)and water from the South Bay Wellfield (groundwater).

Copper Corrosion Scaling Findings

As stated in the CBCL report "*The initial analysis found that the scaling present was largely amorphous (does not have a distinct, identifiable crystalline structure) with some cuprite and malachite present (common copper scale materials), but not well defined. As such, the analyzed scale did not match copper scaling composition that is typically cited in literature. Amorphous corrosion scales commonly occur on copper piping; however as the composition of the scaling can vary greatly between systems, there is little research completed on amorphous scaling and copper solubility.*" Figure 1 below shows examples of copper plumbing corrosion.

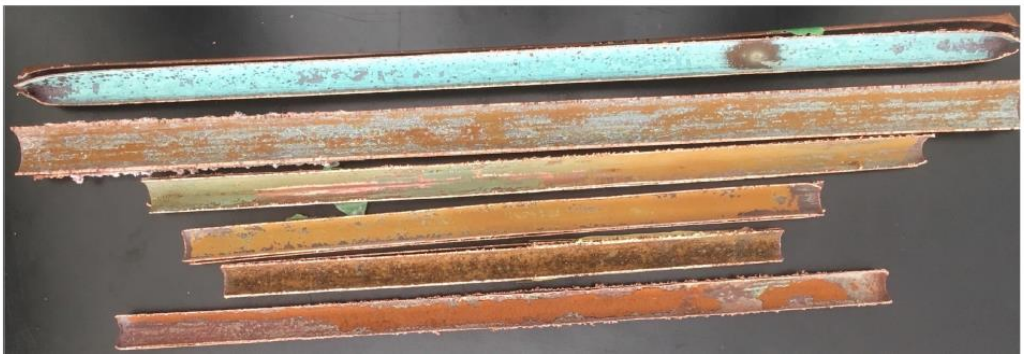

Figure 1. Sections of Copper Pipe cut longitudinally for scale analyses

Stagnation Study Findings

The stagnation study was performed in two phases. The **first phase** investigated the effects of pH, free chlorine concentration and orthophosphate addition on copper release to groundwater while holding values constant as part of the experiment. CBCL stated within the report, that the addition of orthophosphate was statistically significant in decreasing copper release to the groundwater.

The **second phase** of the stagnation study looked at the difference in copper release when the pipes were conditioned with surface water and groundwater. Using the pipe samples removed from citizens' homes and specific water quality representative of West Saint John, the results showed that the pipes conditioned with groundwater released more copper than the pipes which were conditioned with surface water. This varied from the copper concentrations predicted from the copper solubility models found in literature, which predicted the surface water to have higher copper release levels. Whether the copper measured was comprised of new corrosion or decomposition of pre-existing scale is not known.

The pH level for the surface water tested represented the surface water at the time of the switch to groundwater, but the pH was higher than what was historically experienced by West Saint John. To understand the effect of this difference, supplemental testing was completed by Dalhousie (Appendix B) to compare copper release between pipes conditioned with surface water at pH values of 5.5 and 6.8. It was found that for aged pipe the copper release was highly variable at either pH level and there were no clear results. For new pipe however, the copper release was consistently higher at the lower pH as was expected from historical water quality.

Cuprosolvency is a term used to describe the ability of copper to dissolve in water. The results from the Centre for Water Resources Studies differ from industry models used to predict cuprosolvency in premise plumbing. CBCL in its review of the results stated, "*Under the operating life of premise plumbing systems in West Saint John, the historically low pH/alkalinity water undoubtedly resulted in high rates of copper corrosion that occurred for many years. This can be demonstrated through an abundance of literature (Schock et al., 1995; Millette et al., 1987; Schock & Lytle, 2011). Existing pipes had developed stable scaling from the corrosion which helped limit leaks and helped maintain*

structural pipe integrity. When the water supply transitioned to the higher pH, higher alkalinity water, it is likely that a transient event occurred where the existing scale was disrupted before a new, passivating scale (based on the changed water quality) could be formed. As the existing scale was disrupted, the corroded pipe in the system was exposed and leaks began to occur. This is different than the deterioration of pipe material due to new corrosion. Transient events can vary in length from hours to months and it appears that the one experienced in West Saint John occurred over several months. Such occurrences are not well documented elsewhere and not anticipated from existing corrosion models."

As CBCL states in their report, "*In terms of rationalizing all the information collected to date around the issue, the current evidence suggests that copper pipe systems in West Saint John have undergone changes as a result of a transitioning event, which stands out from anticipated outcomes based on current science and solubility models.*" It is also important to highlight the fact that the City does not have information on what a typical year would look like when it comes to premise copper pipe leaks therefore there is no ability to compare the reported copper pipe leak event to historic baseline premise copper pipe leak data.

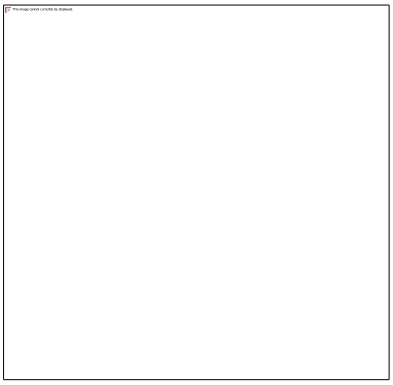

Figure 2. West Saint John Copper Pipe

Figure 3. West Saint John Copper Pipe Close-up

This result aligns with the theoretical understanding communicated in January and February 2018 when some customers were reporting leaking copper pipes. See Figures 2 and 3 for a visual example of the scale existing on a copper pipe that came out of a West Saint John home.

CBCL reported changes in **pH, alkalinity and dissolved inorganic carbon (DIC)** can play a significant role in either limiting or promoting corrosion.

For **pH** as stated in the CBCL Report "*Low pH increases corrosion of most pipes as it increases metal solubility, which results in deterioration of pipes and higher concentrations of metals, such as iron, lead and copper, in the drinking water. As previously mentioned, the source water switch to the South Bay wells resulted in a pH increase to approximately 7.9, which is considered less corrosive than Spruce Lake water."*

Alkalinity provides a measure of the waters ability to resist pH changes. In low alkalinity water (Spruce Lake), chemical additions or reactions in the distribution

system can cause rapid changes in pH which can be challenging in controlling corrosion. The CBCL report states "*With the change to the South Bay Wellfield, the source water now has moderate to high alkalinity which provides additional buffering capacity to the system compared to the low alkalinity of Spruce Lake."*

As stated in the CBCL report "*The moderate DIC concentrations of the South Bay wells can be a benefit for reducing copper corrosion as it can help buffer pH changes within the system and form passivating scales.*" The report further notes that "*the DIC in Spruce Lake was approximately 10 mg/L, a low value. The South Bay wells have a DIC concentration of 30 mg/L, which is considered a moderate value.*"

Switching of Source Waters

The CBCL report highlighted *"Examples of municipalities in Atlantic Canada that switched water supplies similar to West Saint John over the last 20 years include Sydney, NS (chlorinated surface water to ground water), Bridgetown, NS (chlorinated surface water to ground water) and Annapolis Royal, NS (chlorinated surface water to ground water). With the switch to ground water, these utilities did not experience reports of major copper pipe leaks within premise plumbing systems as experienced in West Saint John."* It should also be noted that these municipalities did not employ the use of orthophosphates. Below is Table 2-2 from the CBCL Report.

Table 2-2: Example Water Supply and Treatment Changes across Atlantic Canada

Location	Previous Water Source	Current Water Source	Corrosion Inhibitor Used
Sydney, NS	CLSW	GW	No
Bridgetown, NS	CLSW	GW	No
Annapolis Royal, NS	CLSW	GW	No
Dartmouth, NS	CLSW	SW	Yes
Yarmouth, NS	CLSW	SW	Yes
Lunenburg, NS	CLSW	SW	Yes
North Sydney, NS	CLSW	SW	Yes
Moncton, NB	CLSW	SW	Yes
Antigonish, NS	CLSW	SW	Yes
Glace Bay, NS	CLSW	SW	Yes
St. John's (3 locations), NL	CLSW	SW	No
New Glasgow, NS	CLSW	SW	Yes

CLSW – Untreated surface water (disinfection only)
SW – Treated surface water supply (coagulation/filtration)
GW – Groundwater supply with disinfection (may have additional treatment)

The CBCL report further notes that "*While the drinking water industry is well known for having procedures which have become industry best practices, there are limited documents available outlining procedures for switching a water source or water quality within a distribution system. Some technical documents are available for utilities who practice blending of multiple water sources (Fleet et*

al., 2001; Taylor et al., 2006; Dewis et al., 2010), but limited information is available for utilities permanently switching a water source. Even less information is available for systems switching from surface water to ground water."

CBCL reported that "*From a water quality standpoint, the source water switch from Spruce Lake to the South Bay Wellfield is considered low risk as the water quality was changing from a corrosive water to one that was less corrosive. Significant sampling was completed both at the wells and in the distribution system prior to the switch, however with regards to corrosion within the distribution system, the study was not as intensive as that for a system deemed a higher risk.* See Figure 4 below (Figure 3-1 in the CBCL report) as the figure provides guidance as to when orthophosphate addition is required. As shown in the points plotted within the figure, South Bay is deemed to be noncorrosive and Spruce Lake is deemed to be corrosive.

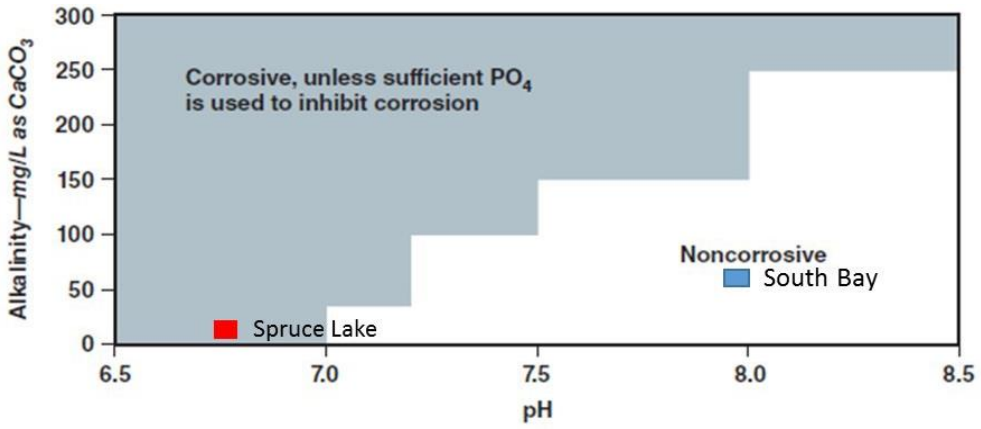

Figure 4. (Figure 3-1 from CBCL report) Conditions that are Corrosive to Copper as Defined by the Lead and Copper Rule Working Group of the National Drinking Water Advisory Committee

CBCL further states *"As part of the Safe, Clean, Drinking Water Project, the City of Saint John completed an evaluation of the distribution system with a focus on the public infrastructure, including an assessment of existing pipe corrosion scales prior to the switch in water quality. However, the investigation did not focus on the effect of the water quality switch on premise plumbing. This is reflective of the water industry's research and regulatory focus, where efforts to understand effects on public infrastructure and not private infrastructure have dominated. Utilities have traditionally been responsible for providing safe drinking water to the property line of the customer and was not responsible for what occurred in the premise plumbing. Only recently has the focus for monitoring distribution systems begun to evolve to incorporate the complete network analysis, including private, premise piping. This is reflected in emerging practice guidance from both the EPA and Health Canada on corrosion control. As the research progresses, guidance and regulatory documents will be developed, but there currently is a lag in these documents becoming available compared to those available for public infrastructure."*

Corrosion Control

CBCL reported "*There are no known municipalities with a ground water source using orthophosphates in the region, which is a reflection of the lower corrosion potential of ground water sources. Table 2-3 shows typical raw water quality results for three communities that currently use orthophosphates along with the water quality from the South Bay Wellfield. It is the significant differences in parameters such as pH and alkalinity (i.e. mineral balance) that require the surface water source systems to need orthophosphate for corrosion control.*"

In the period during the switch the City performed extensive system flushing to limit impacts to water quality during the switch. Since the switch occurred, the City implemented a heightened monitoring program, including an increase in distribution system sampling and stagnation sampling. When reports of copper leaks occurred, the City promptly looked to develop a prevention strategy to mitigate the reports that were occurring. The City implemented a temporary orthophosphate system as a corrosion control method and continued to monitor the distribution system and premise plumbing for further copper pipe leaks.

Table 2-3: Raw Water Quality of Example Communities using Orthophosphate in Atlantic Canada

Parameter	Units	MAC/AO	South Bay Well #1	South Bay Well #2	Halifax (Pockwock)	Moncton	Windsor
			2013-2014 (Average)	2014	2016 (Average)	2012-2015 (Average)	2016 (Average)
Alkalinity	mg/L as CaCO3		98	106	<1.0	11.3	<5
pH		6.5-8.5	8.01	8.02	6.1	7.03	6.5
Turbidity	NTU	1	0.5	0.7	0.32	2.96	1
TOC	mg/L		1	1.9	2.9	4.18	4.3
Colour True	Pt-Co	15	7.8	<5	14.5	32	16
Conductivity	uS/cm		443	444	32	47	22
Chloride	mg/L	<250	41	38	7.2	2.73	3
Calcium	mg/L		55	65	1.1	3.93	0.9
Magnesium	mg/L		8.9	7.4	0.38	0.7	0.3
Hardness	mg/ L as		174	194	4.4	12.7	10
Manganese	mg/L	<0.05	0.053	0.022	0.028	0.12	0.063
Iron	mg/L	<0.3	0.084	0.10	<0.051	0.26	0.25
Aluminium	mg/L	<0.1	0.023	0.029	0.104	0.096	0.091
Copper	mg/L	1	0.066	0.003	0.033	<0.002	0.005
Lead	mg/L	0.01	<0.0005	0.0031	<0.0005	0.00024	<0.0005

CBCL highlights that the Cities of Guelph and Charlottetown have similar water quality as the South Bay Wellfield and they do not use a corrosion inhibitor and

that "*based on these water qualities a corrosion controls treatment would not be required for the South Bay Wellfield*. *However, as experienced in West Saint John, there are multiple factors that can contribute to the need for corrosion control treatment, including pre-existing corrosion and corrosion scaling in mature distribution systems.*"

The study showed that the addition of orthophosphate was beneficial for reducing copper release from both mature and new pipe from West Saint John and CBCL recommends that orthophosphate addition continue until additional testing is completed and sufficient evidence is available which can prove a reduction in orthophosphate would not introduce corrosion issues or leaks.

Ongoing Testing

As a result of the reported leaks that occurred, the City developed a monitoring program for the distribution system and it will continue to evolve as more information is collected. The City is incorporating pipe racks as shown in Figure 4 below in several locations within the water distribution system, which contain sections of copper pipe. These sections of copper pipe can be representative of copper premise plumbing within the system. The pipe racks will allow the city to collect information relating to the ongoing monitoring of the effects of orthophosphate addition on premise plumbing.

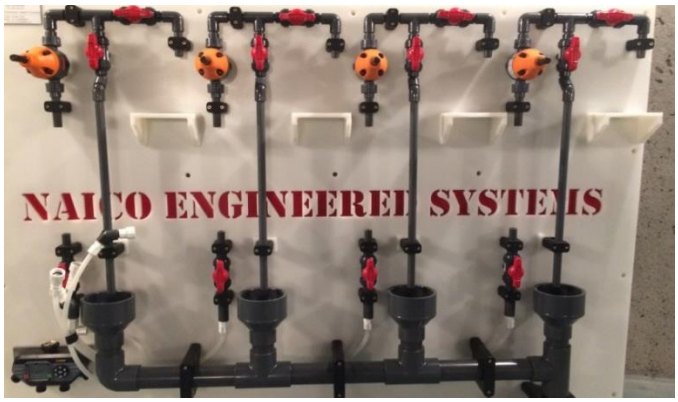

Figure 5. One of the new pipe racks being incorporated into the Saint John water systems

Communication

This report, the Council presentation as well as the CBCL report and the Dalhousie University reports prepared by the Centre for Water Resource Studies will be posted on the west water page www.saintjohn.ca/westsidewater .

SERVICE AND FINANCIAL OUTCOMES

Reports of leaks occurring in properties in West Saint John appeared to peak in January of 2018 and then dropped off to the point of no leaks being reported since June of 2018 with only one new civic address leak being reported to Saint John Water for the months of April, May and June of 2018.

INPUT FROM OTHER SERVICE AREAS AND STAKEHOLDERS

Saint John Water continues to work with Department of Health and Department

of Environment and Local Government and these reports have been shared with both Departments.

ATTACHMENTS

CBCL Limited Report titled "*West Saint John – Corrosion Control Investigation*" completed with Reports titled *"Understanding copper pipe corrosion in West Saint John*" and "*Evaluating the effect of pH on copper release in West Saint John*" from the Centre for Water Resource Studies (Dalhousie University).