Parsons, Susan

From: Dee White <deewhite1@mindspring.com>
Sent: Monday, March 06, 2017 1:23 PM
To: Moore-Love, Karla
Subject: Agenda item 215/235 for March 8 PWB contract with Confluence
Attachments: 2nd Quarter - PWB WQ Corrosion Study.pdf

Karla,

Please include these documents in the record for this agenda item. Please also send me a receipt that you have received. THANKS so much.

Dee White

QUARTERLY REPORT

WATER QUALITY CORROSION STUDY 2ND MONITORING PERIOD REPORT - DRAFT

PWB CONTRACT# 30003222

B&V PROJECT NO. 182435

PREPARED FOR

City of Portland, Portland Water Bureau

AUGUST 1, 2016

City of Portland, Water Bureau

WATER QUALITY CORROSION STUDY

Quarterly Data Report – Q2 2016

Acknowledgements

Data Analysis by: Abigail Cantor, PE, Process Research Solutions, LLC

Reviewed by: Melinda Friedman, P.E., Confluence Engineering Group, LLC

Table of Contents

Appendices

Figures

Tables

Abbreviations and Acronyms

A list of abbreviations and acronyms used in this Technical Memorandum (TM) are summarized in the following list:

ATP	Adenosine Triphosphate
DOC	Dissolved Organic Carbon
Fe	Iron
GIS	Geographic Information System
HPC-R2A	Heterotrophic Plate Counts
IQR	Interquartile range
JMP	Joint Monitoring Plan
LCR	Lead and Copper Rule
mg/L	milligrams per Liter
Mn	Manganese
ND	Non-detect
NTU	Nephelometric Turbidity Units
ORP	Oxidation Reduction Potential
PRS	Process Research Solutions, LLC
PWB	City of Portland, Portland Water Bureau
Q1	First quarter
Q4	Fourth quarter
Study	Water Quality Corrosion Study
TCR	Total Coliform Rule
TM	Technical Memorandum
TM2	Technical Memorandum 2 – Distribution System Sampling Plan
ug/L	Micrograms per liter
UCL	Upper Control Limit
WQSS	Water Quality Sampling Stations
Zn	Zinc

1 Introduction

The Portland Water Bureau (PWB) is conducting a Water Quality Corrosion Study (Study) to document baseline water quality conditions and identify the causes of lead release in the PWB distribution system. At the end of the study the results will assist PWB in understanding the potential impact future operational or treatment changes could have on lead release in the distribution system. TM2 – Distribution System Sampling Plan (TM2) was developed earlier in this study to aid in the collection of the information necessary to answer specific questions and hypotheses regarding water quality in the PWB distribution system.

The monitoring quarters are defined in order to best align with seasonal temperatures. In this way, each quarter will be representative of a season with data influenced by a narrower temperature range than if the period was divided otherwise. For the purposes of the quarterly reports generated for this project the monitoring quarters are aligned as shown in Table 1.

Table 1 Monitoring Quarter Date Ranges

Quarter	Date Range	Notes
Q4 2015*	Sep 2015 - Nov 2015	Typical nitrification season
Q1 2016*	Dec 2015 - Feb 2016	Typical winter conditions
Q2 2016*	Mar 2016 - May 2016	Typical spring conditions
Q3 2016	Jun 2016 - Aug 2016	Typical summer conditions
Q4 2016	Sep 2016 - Nov 2016	Typical nitrification season

* Indicates the quarters analyzed in this monitoring report.

Monitoring periods Q4 2015 – Q2 2016 are described in this report, with a focus on data collected during the second quarter (Q2) 2016.

It should be noted that the main intent of the quarterly reports is to analyze the data sufficiently to determine if any changes are warranted to the sampling plan moving forward. While the quarterly reports will identify preliminary trends in the data observed during the reporting period, it should be acknowledged that conclusions regarding any trends in the data should not be made until the remaining quarters' data have been collected. At the end of the study a final report will be assembled which interprets all of the data collected during the 5 quarters of monitoring. Any conclusions or extrapolation to what may be occurring in the actual distribution system will be reserved for the final report to allow for interpretation of all available data and should not be made from the data collected during this quarter alone.

2 Data Analysis

2.1 SUMMARY OF AVAILABLE DATA

This section summarizes the data that was collected during this sampling period. The data are organized according to the sampling pool for which the data are collected as described in TM2.

Data was collected during the current monitoring period from the following sample pools:

Operations data. The PWB maintains a log of operational changes that may have an impact on distribution system water quality.

Total Coliform Rule Monitoring Sites. The PWB collects water quality parameters at 89 sites, with approximately 250 samples collected per month.

Nitrification Route Sites. The PWB developed a Nitrification Monitoring and Action Plan in 2013 that identifies approximately 45 sites per week for nitrification parameter monitoring. While some of these sites are also Total Coliform Rule (TCR) sample sites, a few were established specifically for the nitrification monitoring. Nitrification data is only collected during the Fall, as nitrification is typically highest during the Fall. As such, nitrification route sites were not analyzed this quarter.

Data collected from customer taps (compliance and voluntary). A lead and copper rule (LCR) compliance sample round occurred during this monitoring quarter. Other water quality parameters data were taken from various flowing water sites in the distribution system to accompany the residential stagnating water samples for metals according to the LCR requirements. Approximately 550 voluntary customer samples were received during this monitoring period.

Supplemental in home sampling. Follow up residential customer sampling was performed during this period at 5 customer homes.

Monitoring Stations and Extended Water Quality Monitoring Sites. The PWB purchased and installed three Process Research Solutions (PRS) monitoring stations to better monitor for various flowing water and stagnation sample parameters. The monitoring stations and a description of the water quality parameters monitored are described in more detail in TM2. The data collected from the monitoring stations during this monitoring period is described in this quarterly report.

The following sections summarize the data collected this monitoring period for each sampling pool.

2.2 DATA ANALYSIS TECHNIQUES

The data analysis techniques used in this study were defined previously in TM2. One additional data analysis tool used in these quarterly reports is box and whisker plots. The horizontal line inside the box is the median, the lower and the upper edges of the box are 25th and 75th percentiles (respectively), the whiskers extend to values that are within 1.5 times the interquartile range (75th minus 25th percentile) from the box's edge, and points plotted beyond the whiskers are outliers.

Additional details of box and whisker plots can be found in Appendix A.

2.3 OPERATIONS DATA

The PWB maintains a log of operations data so that any observations from the data can be associated back with any operational changes made during the monitoring period. There were not any relevant operational events recorded during the Q2 monitoring period. Previously, during the

Q4 2015 and Q1 2016 monitoring periods, the following operational activities impacted water quality observed in the distribution system:

- Groundwater was used to augment supply from approximately June 11 through November 4, 2015. Groundwater comprised between 20% and 40% of the total supply during June through August, and between 40% and 75% for much of September and October. This represented a higher than average usage of groundwater during a typical operating year for the PWB.
- On December 16th 2015 the chloramine dosing target was reduced from 2.5 mg/L to 2.2 mg/L (target has remained at 2.2 mg/L since December).

The full operations log is included as Appendix B.

2.4 TCR DATA

Samples are collected from 89 TCR sites and analyzed for water temperature, pH, total chlorine residual, and turbidity. The TCR data presents a good opportunity to observe general water quality parameters in the distribution system as the TCR sites are spread throughout the system. This section summarizes the water quality data collected from the TCR sites during this monitoring period. Additional discussion and extrapolation of what this data may indicate related to overall water quality in the PWB water system will be reserved for the final report.

2.4.1 Turbidity

Turbidity values from 89 TCR sites from Q4 2015 through Q2 2016 are shown in Figure 1 below. Observing the data from all the sampling sites on one graph is a valuable way to visualize system wide and seasonal trends. As observed, the turbidity was consistently below 0.5 Nephelometric Turbidity Units (NTU) throughout the distribution system during Q2 2016, with the exception of a few sites which had turbidities around 1 NTU during the beginning to middle of March. This is a similar turbidity pattern as has been observed throughout the study period with the exception of the elevated turbidity (approximately 2 NTU) observed between November 2015 and January 2016 due to rains and runoff event in the Bull Run watershed.

The sites with the highest average turbidity (greater than 0.5 NTU) sorted from highest to lowest, include the following. These are shown spatially on the GIS plot in section 2.4.5.

- WQSS0204 - SW 52nd Ave & Santa Monica
- WQSS0003 - 72ND & HARRISON, 2036 SE 72nd Ave

The sites with the most variable turbidity (greater than 1 NTU), defined from Shewhart control statistics as the upper control limit minus the lower control limit, sorted from highest to lowest, include the following. These are shown spatially on the GIS plot in section 2.4.5.

- WQSS0003 - 72ND & HARRISON, 2036 SE 72nd Ave
- WQSS0204 - SW 52nd Ave & Santa Monica
- WQSS0024 - Portland Airport -NE
- WQSS0215 - SE 82nd & Malden
- WQSS0225 - 2847 NW Westover Rd

- WQSS0180 - Legacy Emmanuel 2 -North

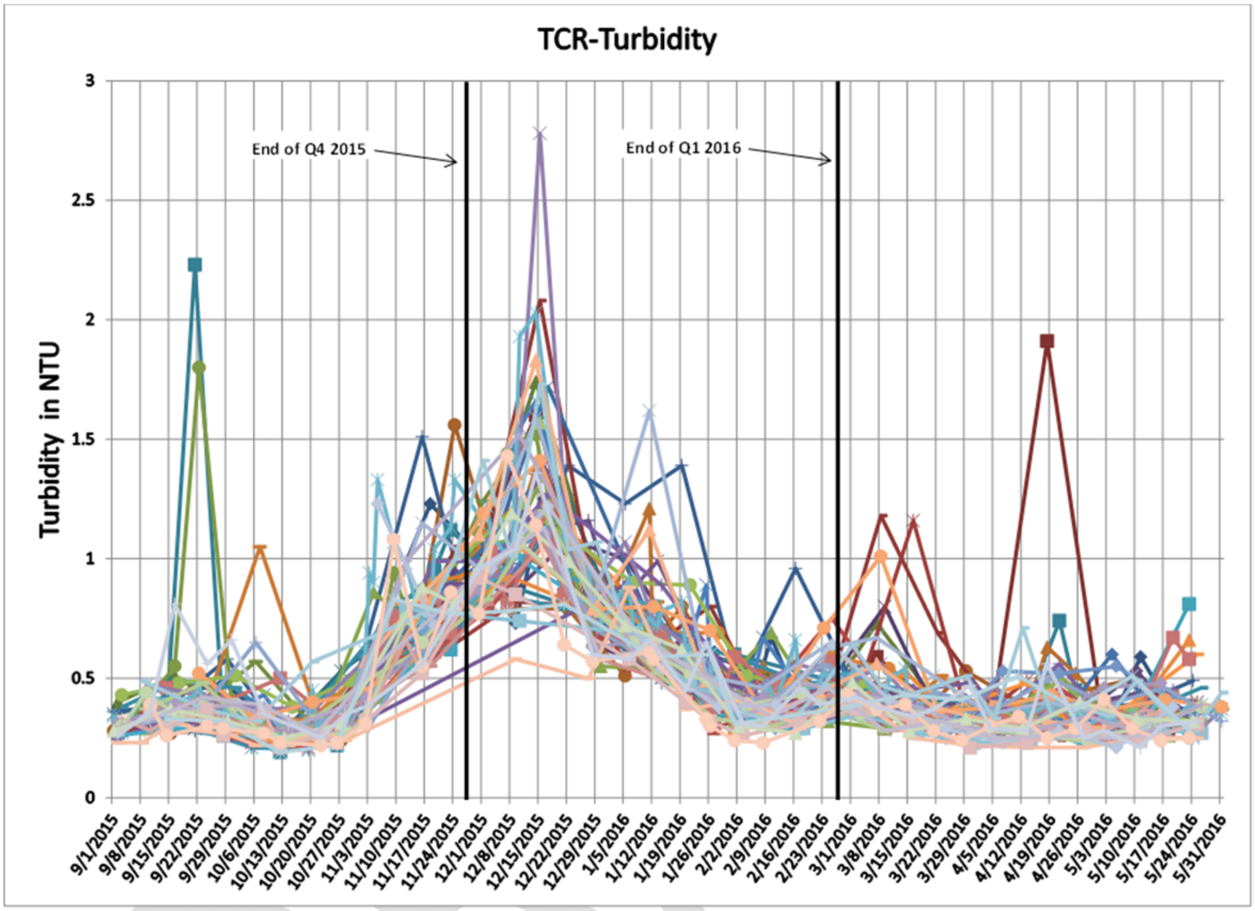

Figure 1 Turbidity values from Q4 2015 through Q2 2016 for 89 individual TCR sites.

2.4.2 Chlorine residual

Total chlorine residuals from 89 TCR sites for Q4 2015 through Q2 2016 are shown in Figure 2. The chlorine residuals during Q2 2016 were similar to that observed during Q1 2016, with the residuals generally spread between 1.5 mg/L and 2.2 mg/L.

There are a few sites with persistently lower chlorine residuals than the system wide average. The sites with the lowest average chlorine residual (less than 1.5 mg/L), sorted from lowest to highest, include the following. These are shown spatially on the GIS plot in section 2.4.5.

- WQSS0095 - SE 9th & Ochoco
- WQSS0097 - SW Riverwood Rd
- WQSS0031 - Engine 7 -SE
- WQSS0065 - SE 144th & Harney

- WQSS0178 - NE 46th & SIMPSON
- WQSS0038 - Hayden Island Mobile Park -North

The sites with the most variable chlorine residuals (greater than 1 mg/L), defined from Shewhart control statistics as the upper control limit minus the lower control limit, sorted from highest to lowest variability, include the following. These are shown spatially on the GIS plot in section 2.4.5.

- WQSS0053 - Margaret Scott Elementary -NE
- WQSS0178 - NE 46th & SIMPSON
- WQSS0018 - NW 24th & NW Hoyt
- WQSS0189 - Willamette Heights Tank -NW
- WQSS0097 - SW Riverwood Rd
- WQSS0069 - NE Cornfoot & Alderwood

It should be noted that none of the sites with high or variable turbidity are the same as those with low or variable chlorine, suggesting that the source of turbidity is not exerting a disinfectant demand.

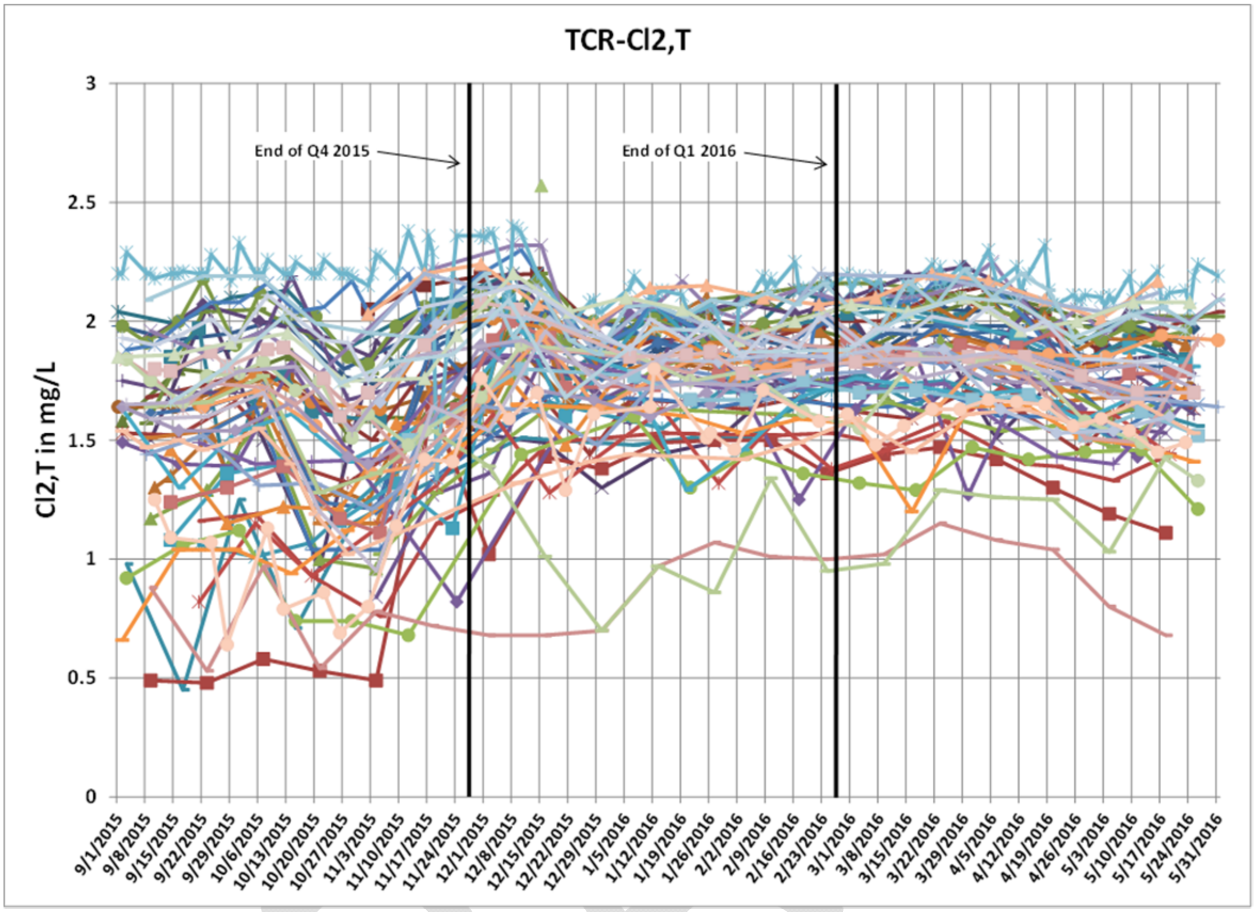

Figure 2 Total chlorine residual from Q4 2015 through Q2 2016 for 89 individual TCR sites.

2.4.3 pH

TCR sites are monitored routinely for pH and give a good indication for how the pH changes throughout the distribution system. pH values at 89 TCR sites are shown in Figure 3 below. As observed in the graph, the Q2 2016 pH was generally higher than during the previous quarter, with pH values generally between 7.8 and 8.1 throughout the distribution system. The PWB should investigate the cause of elevated pH at two WQSS (WQSS 0068 and WQSS 0159) to determine if this is coming from new cement pipe or some other reason.

Only one site had an average pH of below 7.8 – site WQSS0009 had an average pH of 7.7. The variability in pH throughout the distribution system was similar to the previous quarter. The sites with the most variable pH (greater than 1 unit), sorted from highest to lowest variability, include the following. These are shown spatially on the GIS plot in section 2.4.5.

- WQSS0068 - Airport Way -NE
- WQSS0189 - Willamette Heights Tank -NW
- WQSS0011 - Smith School - SW
- WQSS0012 - Hayhurst - SW

- WQSS0009 - Duniway School -SE
- WQSS0197 - SE 74th & Evergreen
- WQSS0062 - Engine 11 -SE
- WQSS0093 - NW Millpond & Brittney
- WQSS0170 - NE 81st & Failing
- WQSS0185 - NE 29TH & BRYANT

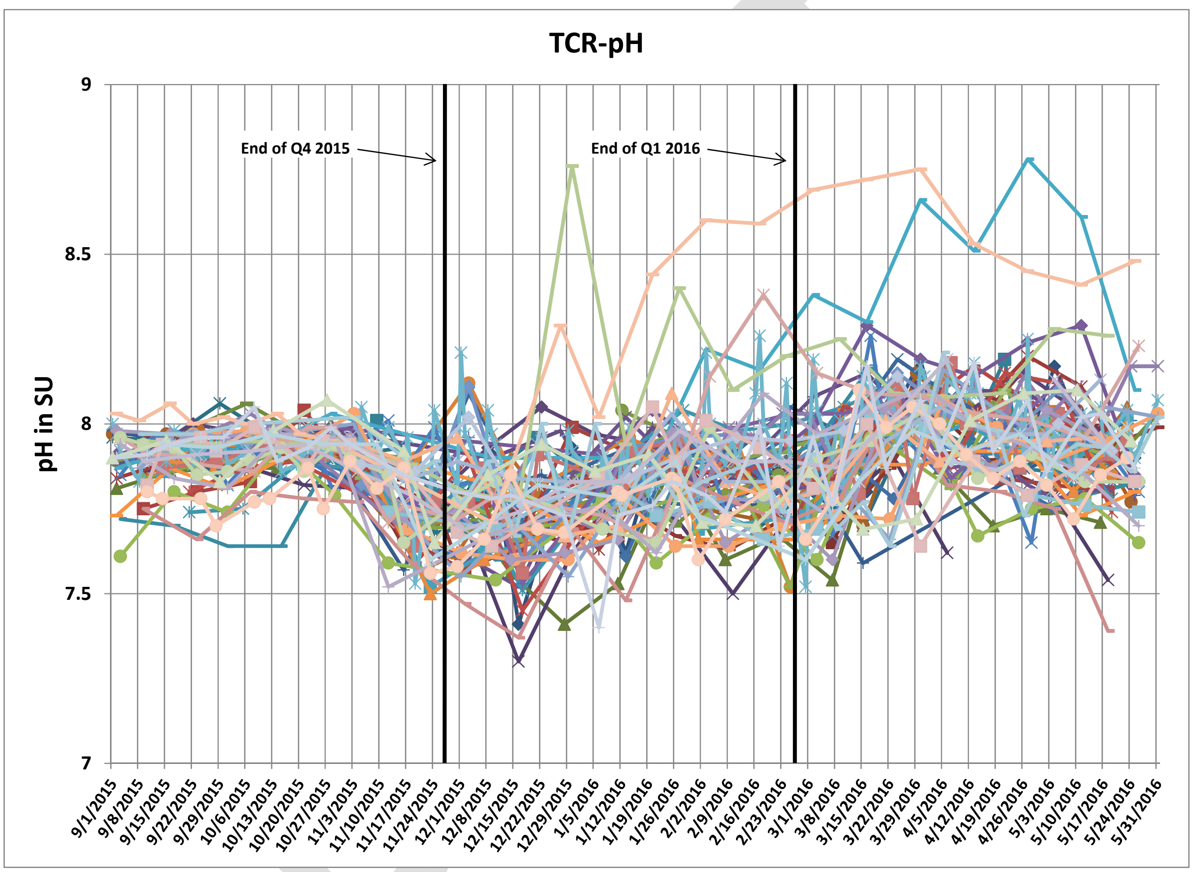

Figure 3 pH values from Q4 2015 through Q2 2016 for 89 individual TCR sites

2.4.4 Temperature

Temperature is monitored routinely at 89 TCR sites and gives a good indication for system wide and seasonal trends. Temperature values are shown in Figure 4 below. As observed in the graph, the temperature climbed steadily throughout Q2, from an average of approximately 8 degrees C at the beginning of the quarter to approximately 15 degrees C, due to the warming of ambient temperatures.

The five sites with the highest average temperature (average temperature greater than 13 degrees C for the quarter), sorted from highest to lowest, include:

- WQSS0169 - NE 24th & Emerson
- WQSS0095 - SE 9th & Ochoco
- WQSS0159 - NE 162nd Ave & Stanton
- WQSS0031 - Engine 7 -SE
- WQSS0038 - Hayden Island Mobile Park –North

It should be noted that three of the 5 sites with higher temperature were also identified as sites with lower chlorine.

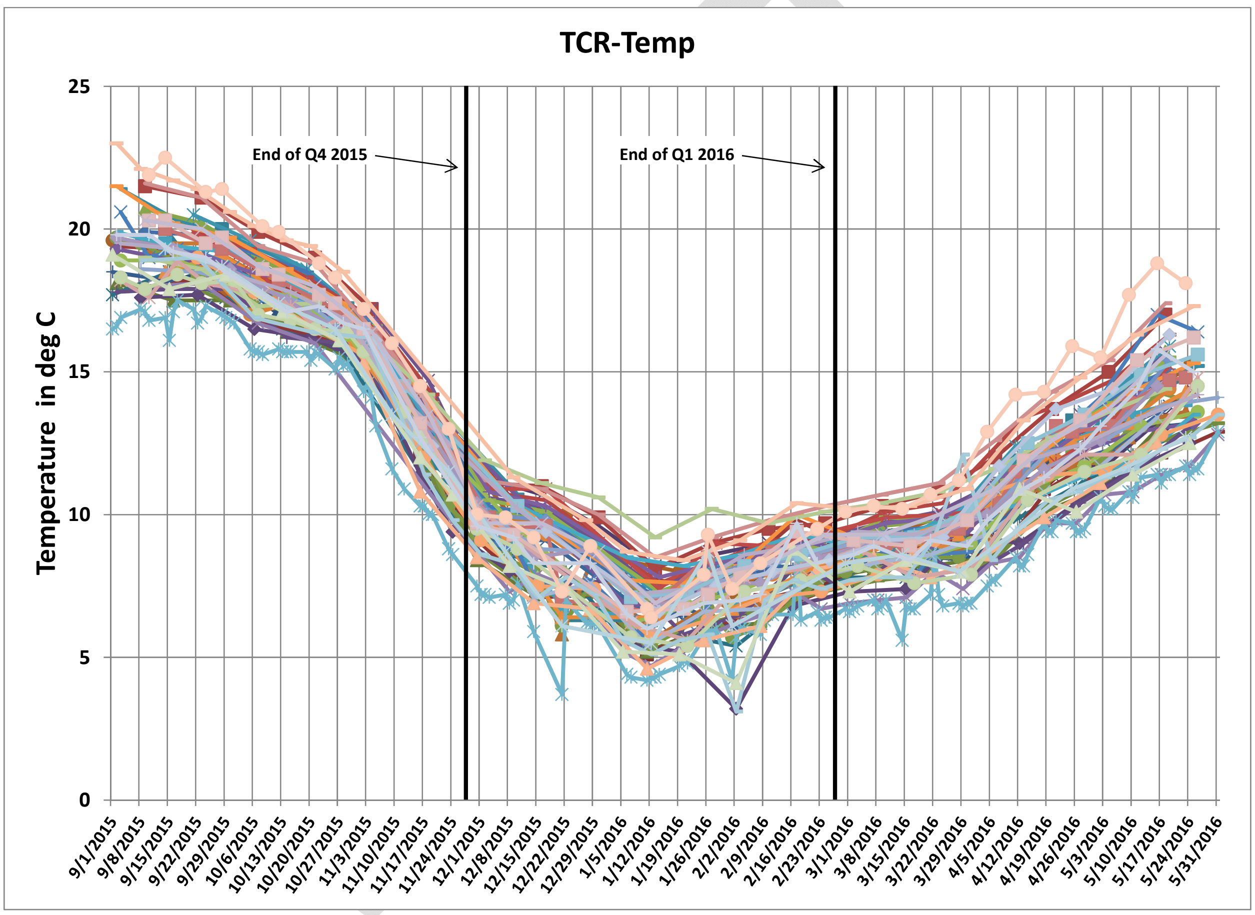

Figure 4 Temperature values from Q4 2015 through Q2 2016 for 89 individual TCR sites.

2.4.5 GIS analysis

The water quality results from the TCR sampling were plotted in GIS to help visualize any spatial patterns of water quality. This is shown for pH, total chlorine, and turbidity in Figure 5, Figure 6, and Figure 7 below.

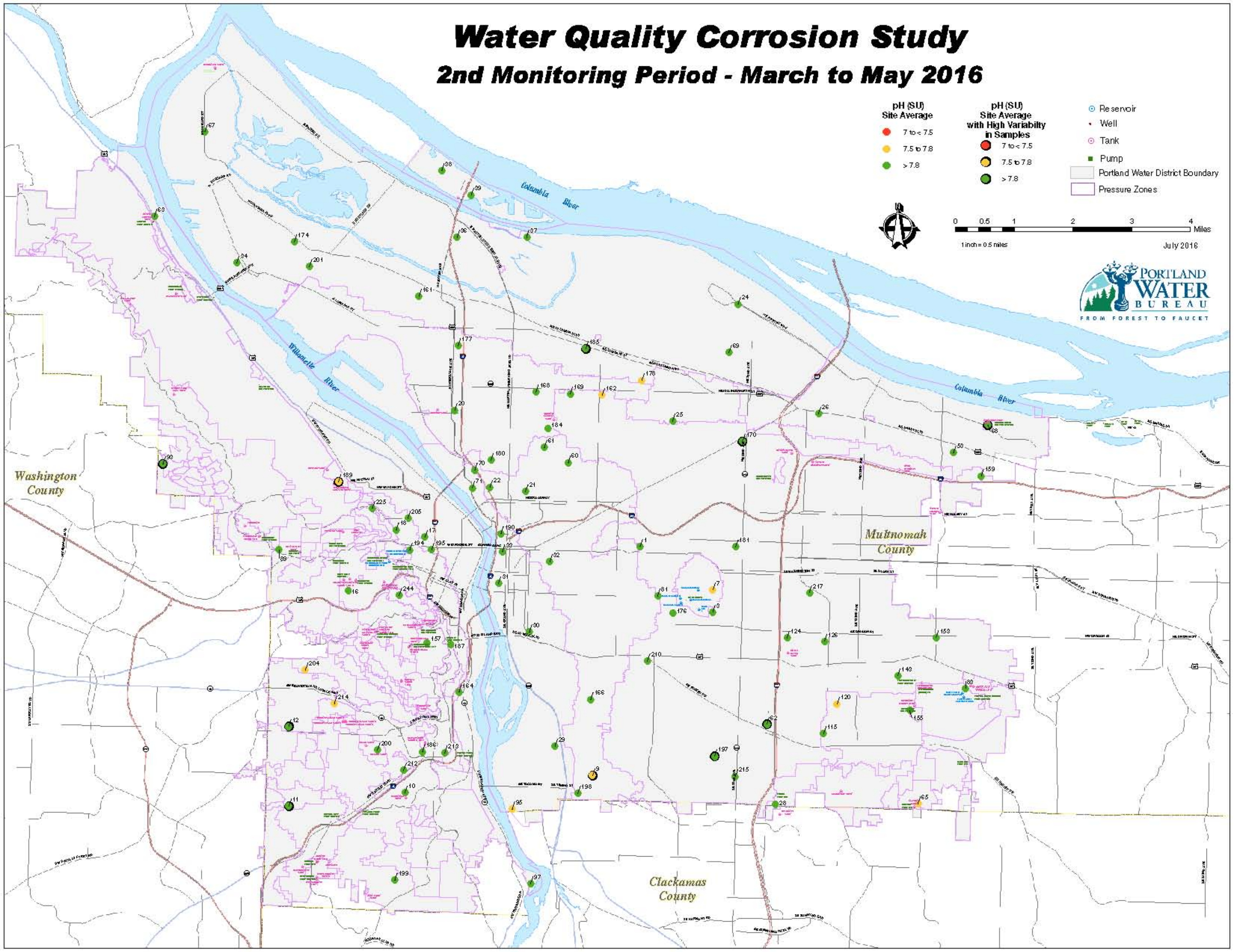

Figure 5 GIS plot showing spatially the pH values throughout distribution system.

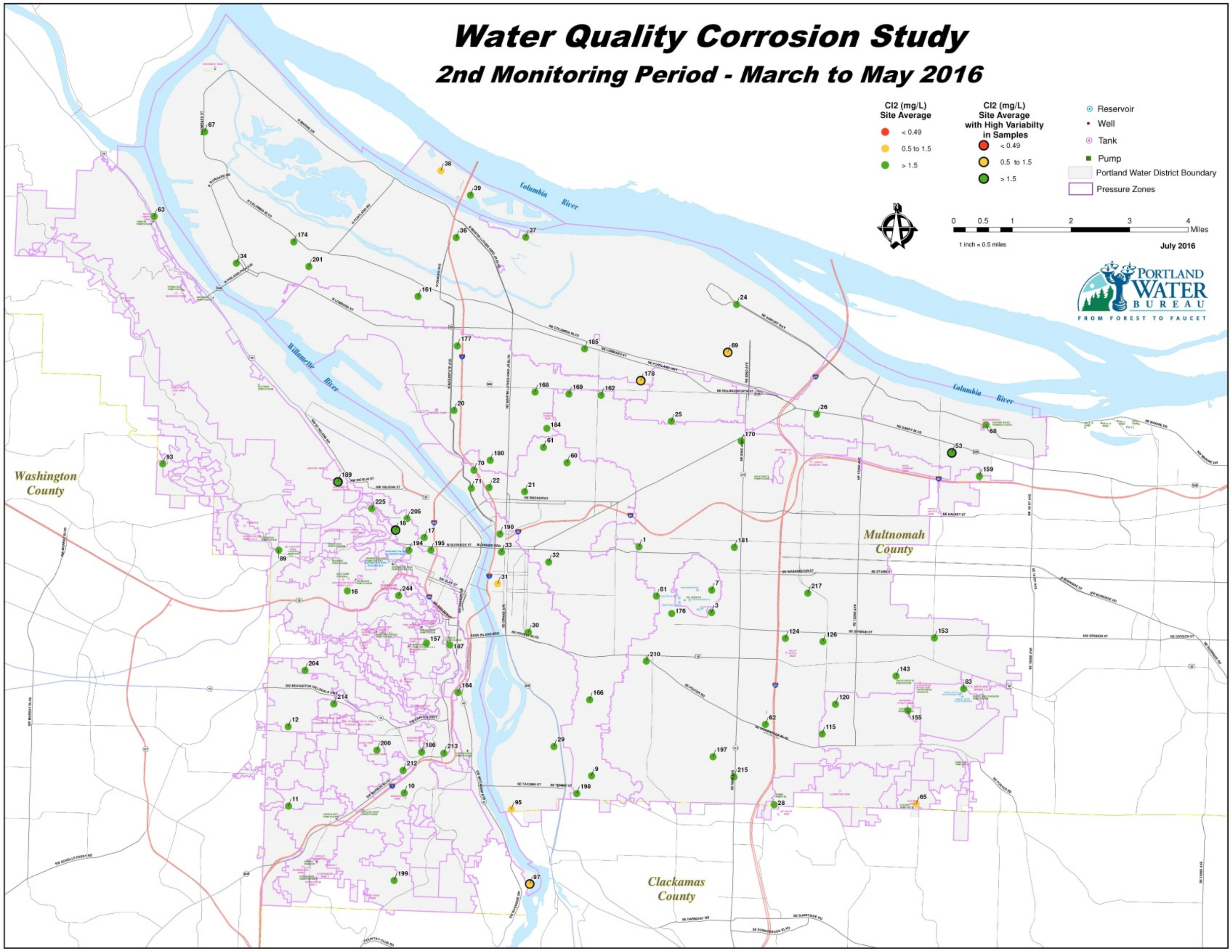

Figure 6 GIS plot showing spatially the total chlorine values throughout distribution system.

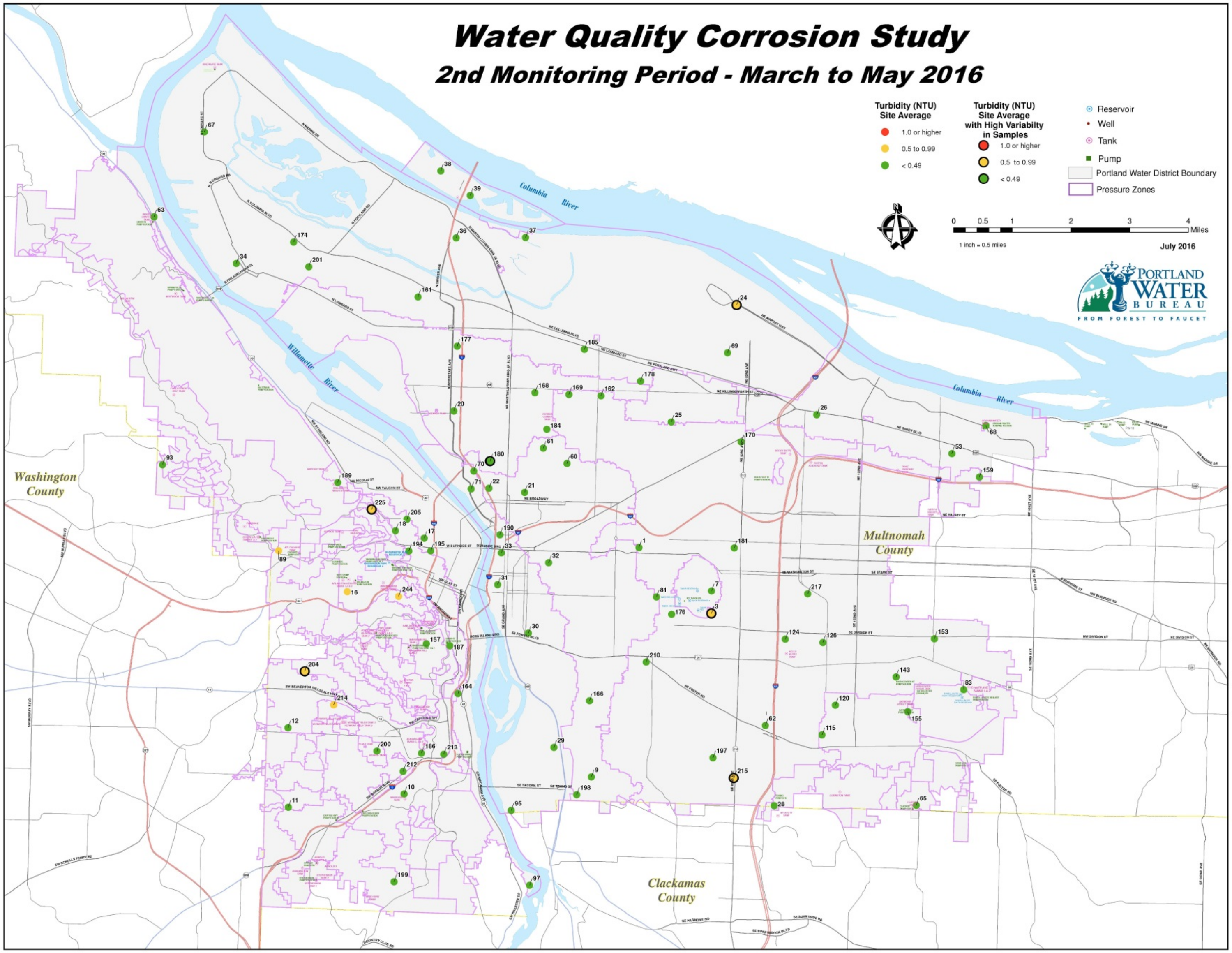

Figure 7 GIS plot showing spatially the turbidity values throughout distribution system.

2.4.6 Summary of TCR data

In summary, the following observations were made from a review of the TCR data:

- Overall, the TCR data indicate good water quality control during the quarter. There were no water quality upsets observed.
- The turbidity was consistently below 0.5 NTU throughout the majority of the distribution system during Q2 2016.
- The chlorine residual was generally between 1.5 and 2.2 mg/L during Q2 2016. There are a few sites with chlorine residuals consistently below 1.5 mg/L. Three of the five sites with lower chlorine residual observed during this quarter were also sites with elevated temperature.
- The pH was higher in most of the distribution system during Q2 2016, with values generally between 7.8 and 8.1.
- The temperature increased steadily during Q2 2016, reaching approximately 15 degrees C by the end of the quarter.
- No spatial patterns of poor water quality were observed.
- It should be noted that a more complete set of water quality parameters was monitored at two of the TCR sites (extended WQSS). This data is presented in section 2.9 below.

2.5 NITRIFICATION DATA

The PWB monitors select sites to determine the extent to which nitrification is occurring within the Portland distribution system. This data is only collected during the Fall, when nitrification is expected to be at its highest. The data from Q4 2015 was presented in the first monitoring period report. Nitrification data is expected to be collected again during Q4 2016, and will be analyzed again at that time.

2.6 LEAD AND COPPER COMPLIANCE DATA

2.6.1 Lead and copper compliance data (Tier 1 Homes)

The PWB collected a compliance round of LCR Tier 1 home sampling during Q2 2016. Compliance samples were collected by the residential customers. Most of the samples were collected between April 13th and April 27th, with a few samples collected between March 15th and March 17th. The samples were analyzed for total lead (Pb), copper (Cu), iron (Fe), manganese (Mn), and zinc (Zn). The 90th percentile copper concentration was 330 ug/L, well below the action level of 1,300 ug/L.

A frequency distribution of the joint monitoring plan (JMP) and PWB only compliance lead sample results are shown in Figure 8 below. The 90th percentile lead concentration of the JMP compliance dataset was 13.1 micrograms per liter (ug/L). Ten of the 114 homes had a lead concentration equal to or greater than the action level of 15 ug/L, with the highest lead sample having a concentration of 648 ug/L. While lead speciation was not performed, it is presumed that the majority of the lead in the highest samples is in particulate form.

Of the 114 samples from the JMP, 31 of the samples were from the PWB system, while the remaining homes are from wholesale customers. A review of the compliance samples from the PWB system only shows that 3 of the 31 homes were over the action level of 15 ug/L with a 90th percentile concentration of 13.1 ug/L (same 90th percentile as for the JMP set of data). The two highest lead concentrations (greater than 100 ug/L) from the JMP were not from the PWB system, but rather from wholesaler systems.

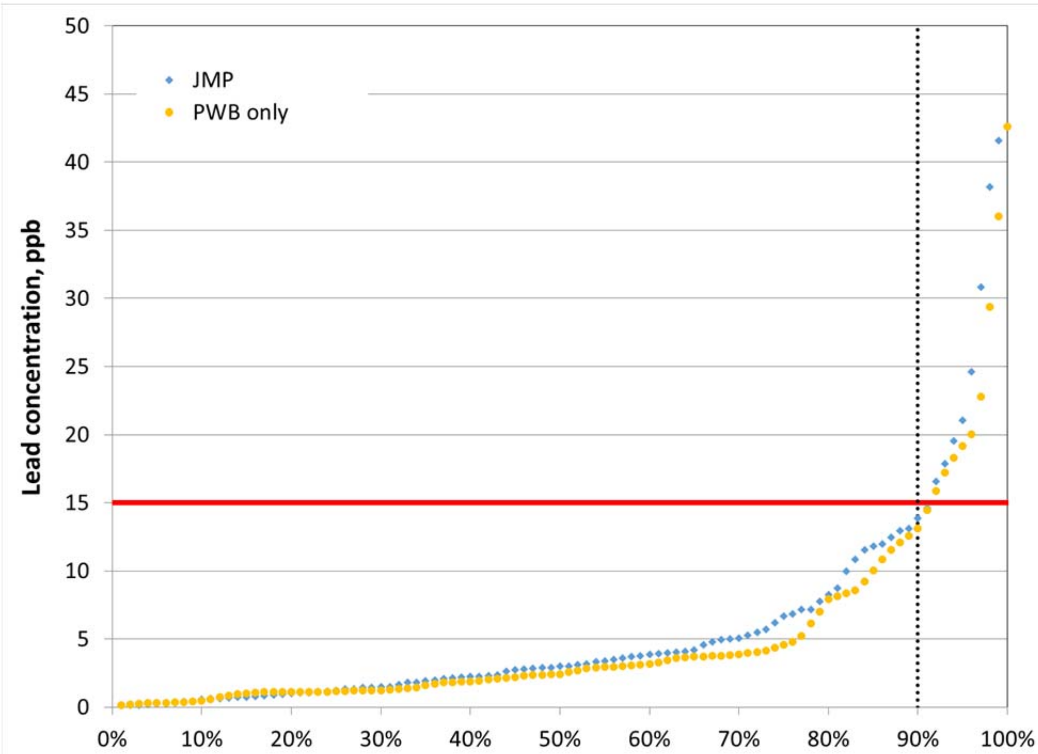

Figure 8 Results for LCR compliance lead sampling from Q2 2016 from joint monitoring plan (114 samples) and PWB subset of homes (31 samples).

Note that the graph above is cutoff at 50 ppb for clarity, but the maximum lead value from the JMP sample set was 646 ug/L.

An analysis of additional metals (Zn, Fe, Mn) concentrations was performed together with lead and copper analysis. The concentration data for iron, manganese, and zinc are shown in Figure 9 below. The higher concentrations are likely due to pipe wall scale release, though speciation between dissolved and particulate form was not conducted on compliance samples to verify. Levels were well below associated secondary MCLs for iron and manganese in the vast majority of samples, and all samples were well below the secondary MCL for zinc.

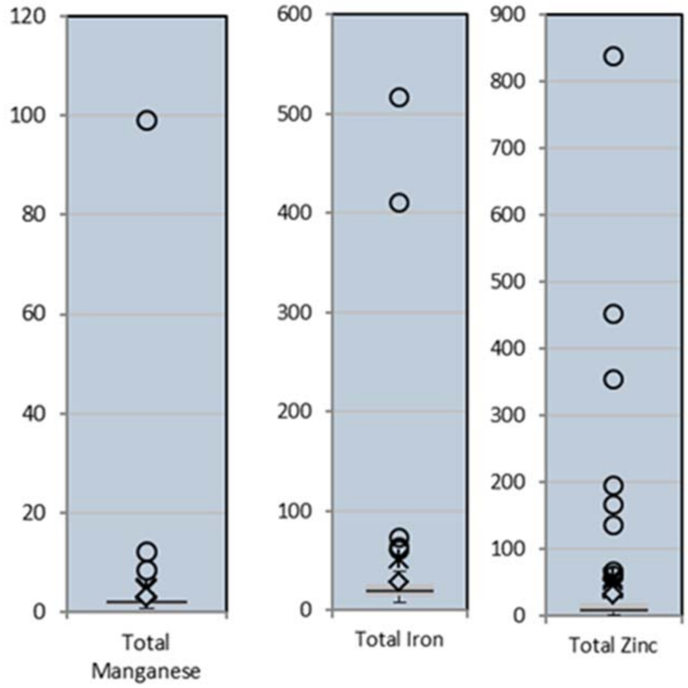

Figure 9 Metals concentration (ug/L) collected as part of LCR compliance sampling from 114 sites

The horizontal line inside the box is the median, the lower and the upper edges of the box are 25th and 75th percentiles (respectively), the whiskers extend to values that are within 1.5 times the interquartile range (75th minus 25th percentile) from the box's edge, and points plotted beyond the whiskers are outliers. Additional details of box and whisker plots can be found in Appendix A.

Pearson's coefficients were generated in MS Excel® between the various metals concentrations. This provides a rapid means for determining if two parameters are trending together – coefficients greater than 0.5 indicate a higher probability that the two variable trend together. The Pearson's coefficient between lead and zinc for the whole JMP set of data was between 0.5 and 0.6, indicating that the lead data may be trending with the zinc data. When considering only the PWB set of data, the coefficients between all metals were less than 0.5, indicating the data does not trend together as often. This data should continue to be monitored throughout the study to strengthen the statistical analysis. It should be noted that only the total concentrations of each metal are known – the relationship between just the particulate fraction of metals would be expected to be stronger if scale release is contributing towards the higher metals concentrations.

2.6.2 Lead and copper compliance water quality parameter data

Water quality parameter samples were collected as part of the LCR sampling program and analyzed for pH and alkalinity. Note that these are not paired samples with the lead samples, as the samples discussed below were collected in the distribution system and not from customer taps. Therefore this data can only be interpreted as what the general conditions were during the time of compliance sampling, and should not be used to draw correlations between individual lead samples and water quality parameters such as pH. Samples were collected towards the end of April 2016, approximately during the same time as the majority of the compliance lead samples were collected.

Twenty-seven WQP samples were collected and analyzed for pH and alkalinity. A handful of samples were also analyzed for total chlorine, temperature, and conductivity, though these were from the wholesaler systems and are not presented here.

The pH and alkalinity data collected during Q2 2016 are summarized in the box and whisker plots below. With the exception of one low pH value, both the pH and alkalinity data are similar to past WQP data when the system has been fed by all surface water.

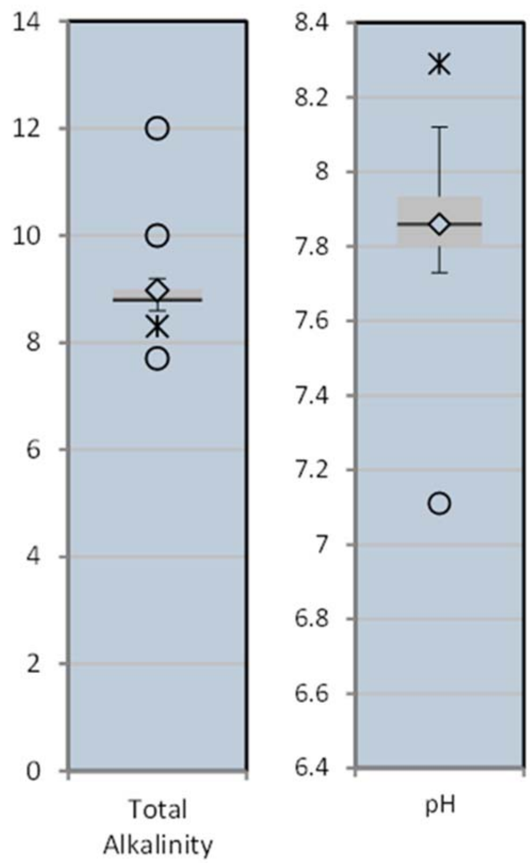

Figure 10 Alkalinity (mg/L as $CaCO_3$), and pH (standard units) for 27 water quality parameter compliance samples collected in Q2 2016.

2.6.3 GIS analysis

The results from the LCR compliance lead samples were plotted in GIS to look for spatial patterns of lead release within the Portland system. These are shown together with the voluntary customer lead data in section 2.7 below.

2.6.4 Summary of LCR compliance data

In summary, the following observations were made from a review of the LCR compliance data:

- A Tier 1 home compliance round of lead and copper sampling took place during Q2 2016. The 90th percentile lead concentration was 13.1 ug/L overall from the set of homes in the JMP. Two samples had lead concentrations greater than 100 ug/L, from Portland Wholesale customers. The 90th percentile lead concentration from just the set of PWB Tier 1 homes (31 samples) was also 13.1 ug/L.
- Both the JMP and the Portland-only data were very similar to the previous compliance sampling round conducted during Q4 2015.
- An examination of Pearson's coefficients indicates that lead is likely trending together with zinc in the compliance samples when considering the entire JMP data set. This relationship will continue to be monitored. Relationships with iron and manganese are not as strong.
- The next round of LCR compliance sampling is scheduled to take place during Q4 2016.

2.7 VOLUNTARY CUSTOMER LEAD DATA

The PWB has a program in place that allows customers to request that a stagnation sample be collected from the home and analyzed for lead by the PWB.

2.7.1 Metals analysis

The PWB analyzed approximately 550 samples during the monitoring period for customers requesting lead testing. Voluntary customer samples were analyzed for total lead (Pb), copper (Cu), iron (Fe), manganese (Mn), and zinc (Zn). It should be noted that due to the high volume of samples received by PWB, analysis of iron, manganese, and zinc were discontinued partway through this monitoring period, and so data for these metals only exists for a portion of the monitoring period.

The 90th percentile lead concentration of the voluntary customer dataset was 5.0 ug/L in Q2 2016, up slightly from 4.3 ug/L in Q1 2016. Fifteen of the 550 samples (2.7%) were over the action level, compared to 4 of 271 samples (1.4%) over the action level in Q1 2016. It should be noted that individual voluntary customer samples do not necessarily have a source of lead in the homes, explaining why the values are lower overall than the set of compliance Tier 1 homes reported above. It should be noted that while the pool of homes included in each quarter are not the same and direct comparisons between the rounds are not necessarily valid, an analysis of the data in this way can provide indications on trends in lead release throughout the system.

The Pearson's coefficients were generated in MS Excel® to determine if the lead release data are trending together with any of the other metals. The coefficients were between 0.5 and 0.8, indicating a likelihood that both lead and copper are trending with Fe, Mn, and Zn. It is not anticipated that iron, manganese, or zinc data will be collected in the future due to the large volume of samples received by PWB. It should be noted that only the total concentrations of each metal are known – the relationship between just the particulate fraction of metals is expected to be stronger due if scale release is contributing to the higher metals concentrations.

2.7.2 GIS analysis

The results from the lead analyses for LCR compliance as well as voluntary customer results were plotted in GIS to better visualize the lead release data spatially. This is shown in Figure 11 below. As indicated in the graph, there is no obvious spatial pattern to the lead release observed in the system.

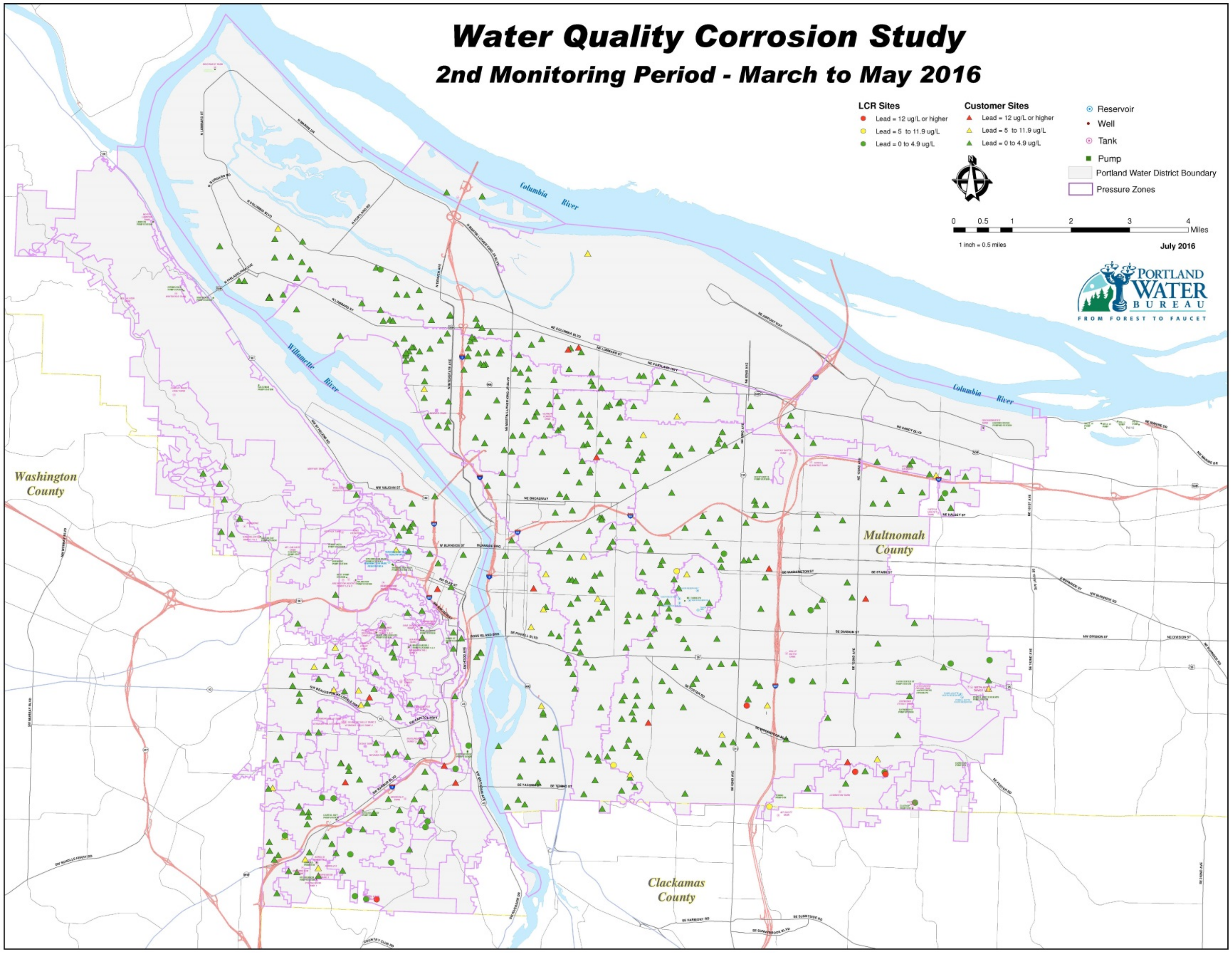

Figure 11 GIS plot of lead concentrations observed during Q2 2016.

2.7.3 Summary of voluntary customer lead data

In summary, the following observations were made from a review of the voluntary customer lead data:

- 2.7% of the homes were over the action level during Q2 2016, compared to 1.4% of the homes during Q1 2016. Overall the range of data is similar between the two sampling quarters.
- Lead (and copper) concentrations are trending together with concentrations of iron, manganese, and zinc.

2.8 SUPPLEMENTAL RESIDENTIAL CUSTOMER TESTING

A more detailed testing protocol is described in TM2 for collecting additional water chemistry data at residential customer homes from a select group of voluntary customer homes. The intent is to capture water quality data together with lead release across homes with a spread of lead concentrations. This data set is expected to generate water quality data paired with the lead analysis to aid in identifying the specific mechanisms of and factors influencing lead release in the Portland water system.

Follow up sampling in residential customer homes was performed during this monitoring period at five (5) homes. While it is difficult to reach statistically defensible conclusions from analysis of only five samples, the framework for future analysis is laid out here, to be developed further as more data is collected. The PWB should continue to prioritize collection of the supplemental residential samples.

2.8.1 General conclusions from supplemental customer sampling

In summary, the following observations were made from a review of the supplemental residential sampling.

- Four of the five homes had total stagnation lead concentrations between 10 and 12 ug/L. The fifth sample had a total stagnation lead concentration of 46 ug/L.
- The following observations were made from the home with the highest lead concentration:
  - Two-thirds of the lead was in dissolved form; one-third of the lead was in the particulate form.
  - The pH of the home was 7.7 before stagnation and 7.6 following stagnation, in line with the other homes sampled.
  - Related to biostability, this was the home with the highest temperature, the largest decay of monochloramine residual with stagnation, and highest release of free ammonia following stagnation.
  - This was the home with the highest concentration of zinc following stagnation. The zinc concentration increased from approximately 2 ug/L in the flowing water sample to 41 ug/L in the stagnation sample, almost entirely in the dissolved form.
  - This home had the second lowest copper concentration.

A review of the data yields the following additional observations:

- The two homes with the highest stagnation zinc concentration had the greatest decay of monochloramine with stagnation.
- Two-thirds of the lead was in dissolved form in four of the five lead samples. The fifth home showed roughly a 50/50 split between particulate and dissolved lead.
- The pH of all homes was between 7.5 and 7.8 before stagnation, with most homes exhibiting a 0.1 to 0.2 drop in pH units with stagnation.

2.9 PRS MONITORING STATION AND EXTENDED WQ SAMPLE STATION DATA

Data from the three monitoring stations and the two extended water quality stations are presented in this section. The PRS Monitoring Stations were started up with flowing water in October 2015, during the middle of Q4 2015. Samples from the test chambers were not taken until a month after startup to allow for the development of metal plate surface scales and biofilm. Therefore, the data collected from the stagnation chambers began in Q1 2016 and is ongoing.

The monitoring stations are installed at the following sites:

- Powell Butte (defined as "Entry point" for the purposes of this study, EP)
- Willalatin Tank. (DS 1)
- Vernon Low Tank. (DS2)

Analysis was conducted on the flowing water entering the monitoring stations, as well as on the stagnant water that has been in contact with metal test chambers (23 hour per day stagnation period). The test chamber materials were selected to represent the sources of lead known to have been used historically by PWB water customers. It should be noted that there are no lead service lines in PWB's service area; lead was selected to show the exaggerated response of lead to other water quality conditions. The following test chambers are in use:

- Lead.
- Copper with Lead Solder Connection.
- Galvanized Iron.
- Brass.

The Monitoring Stations are designed to exaggerate the release of lead and copper into the water. This exaggeration serves to magnify the factors that are at work in the distribution system that shape water quality and allow for better understanding of the relationships between parameters. It should be noted that for this reason the concentrations of metals detected in the monitoring stations are not necessarily reflective of the concentrations that are present in customer tap samples.

The same data collected at the influent of the monitoring stations are also collected from 2 additional extended water quality sampling stations (WQSS) selected from the TCR sites and are also reported in this section. These extended WQSS provide more detailed water quality information from the distribution system than is collected at all TCR sites. The extended sites for sampling are WQSS 0031(DS 3) and WQSS 0093 (DS 4).

All of the parameters describing uniform corrosion, biostability, and scale release were monitored in the monitoring stations and extended WQSS.

The monitoring stations are identified by codes which consist of two parts: PRS-XX-YY

XX and YY for each monitoring station vary depending on the station location and the test chamber material, as shown below. This code is applicable to the figures throughout this chapter.

XX (Station Location)	YY (Test Chamber Material)
Powell Butte (PB)	Brass (BR)
Willalatin Tank (WI)	Copper with Lead Solder Connection (CU)
Vernon Low Tank (VE)	Lead (PB)
	Influent Flowing (FL)
	Galvanized Iron (GA)

2.9.1 Lead release in the PRS monitoring station data

Time series plots of dissolved, particulate, and total lead concentration in the flowing water and stagnation chambers since the beginning of the study are found in Figure 12, Figure 13, and Figure 14 below. These time series plots provide a useful way to monitor trends in the lead release data. As observed, lead release was higher initially, and has since trended downward. Elevated initial lead concentrations are often observed during startup, however there was also a system-wide change in water quality (increase in turbidity and some metals) observed at the same time due to heavy rains, and so the effects from startup and elevated turbidity are confounding events which make it difficult to draw cause and effect relationships with respect to the increased lead observed during November and December. The highest dissolved, particulate, and total lead were consistently observed from the Vernon Low Tank monitoring station.

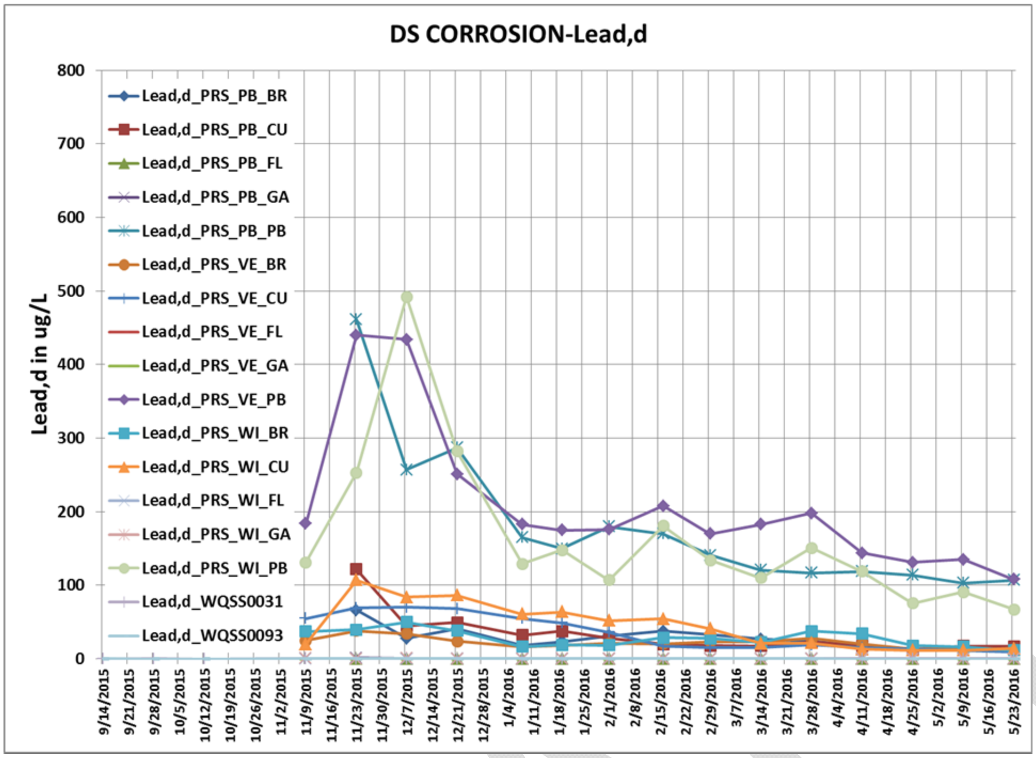

Figure 12 Dissolved lead concentrations from PRS monitoring station data for Q1 2016 through Q2 2016.

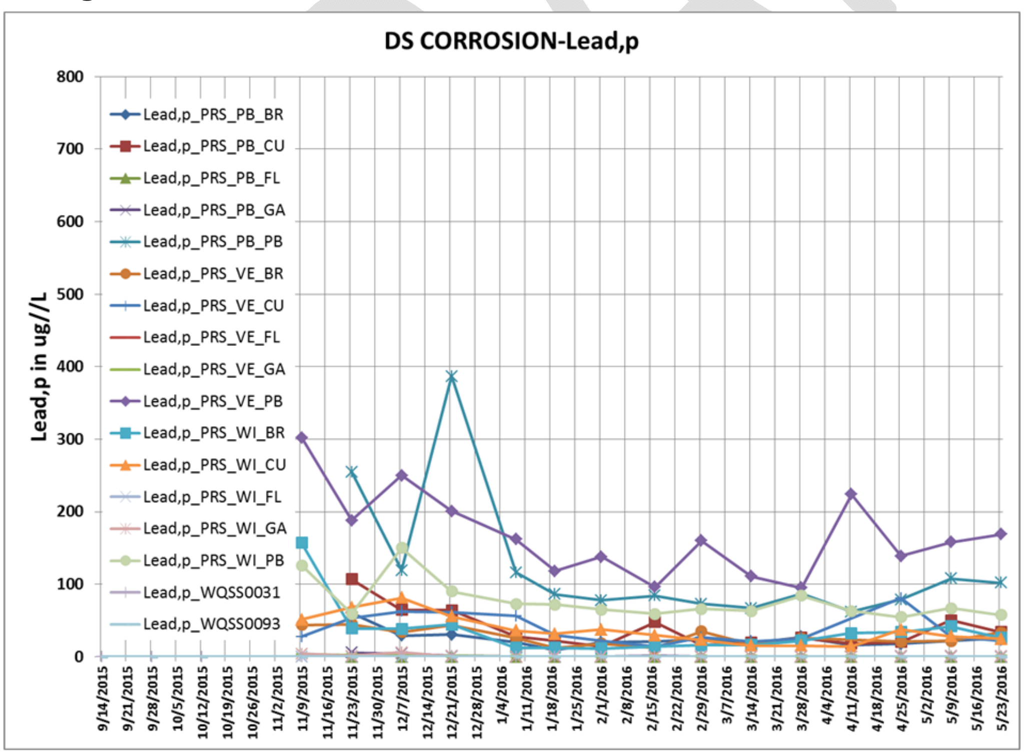

Figure 13 Particulate lead concentrations from PRS monitoring station data for Q1 2016 through Q2 2016.

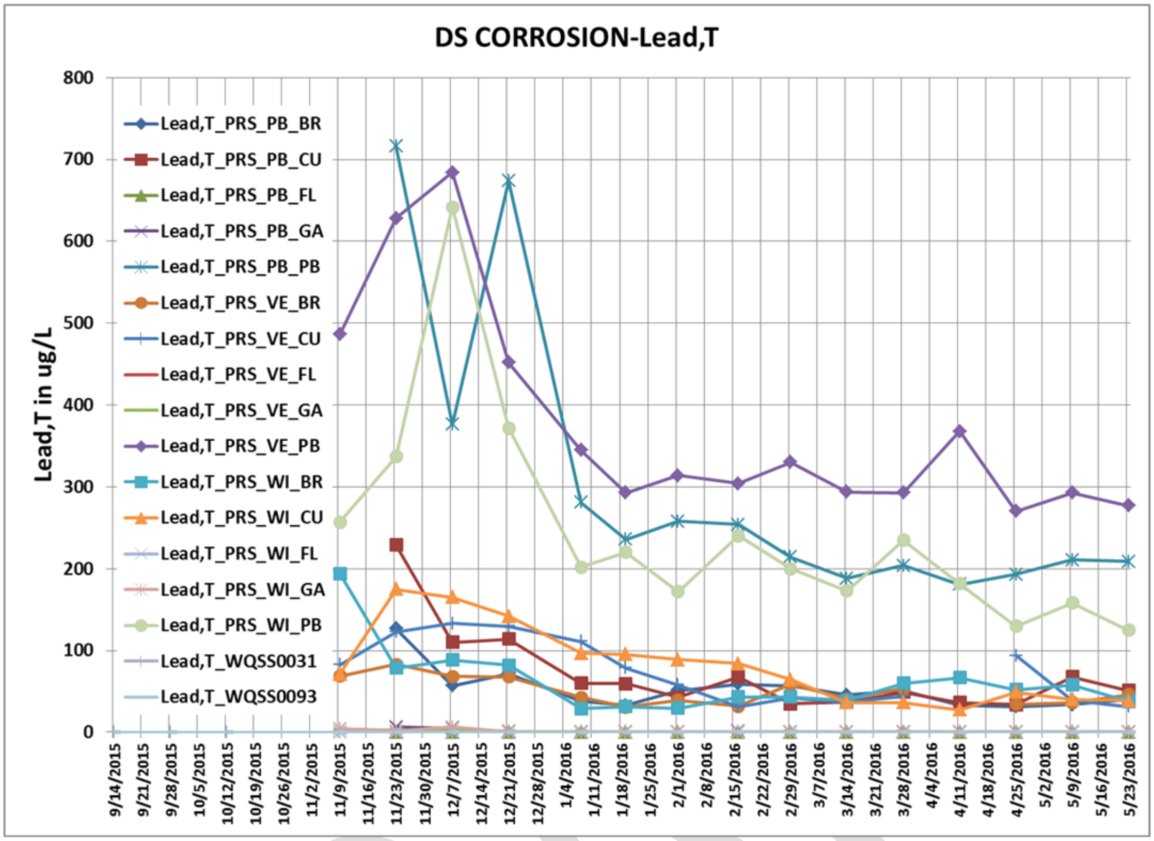

Figure 14 Total lead concentrations from PRS monitoring station data for Q1 2016 through Q2 2016.

A comparison of lead release between monitoring station locations and test chambers can be observed using Shewhart control chart statistics plot, shown in Figure 15 below. The highest lead comes from the lead stagnation chambers, followed by the copper/lead solder chamber and brass chambers. This highest average lead concentration is from the lead chamber in the Vernon Low Tank monitoring station. It should be noted that this site has the highest concentration of lead and copper entering the station, as discussed in the flowing water section below. The galvanized steel test chambers did not show significant lead at any test station. Lead is monitored in the galvanized chambers because the zinc coating on the galvanized steel contains lead.

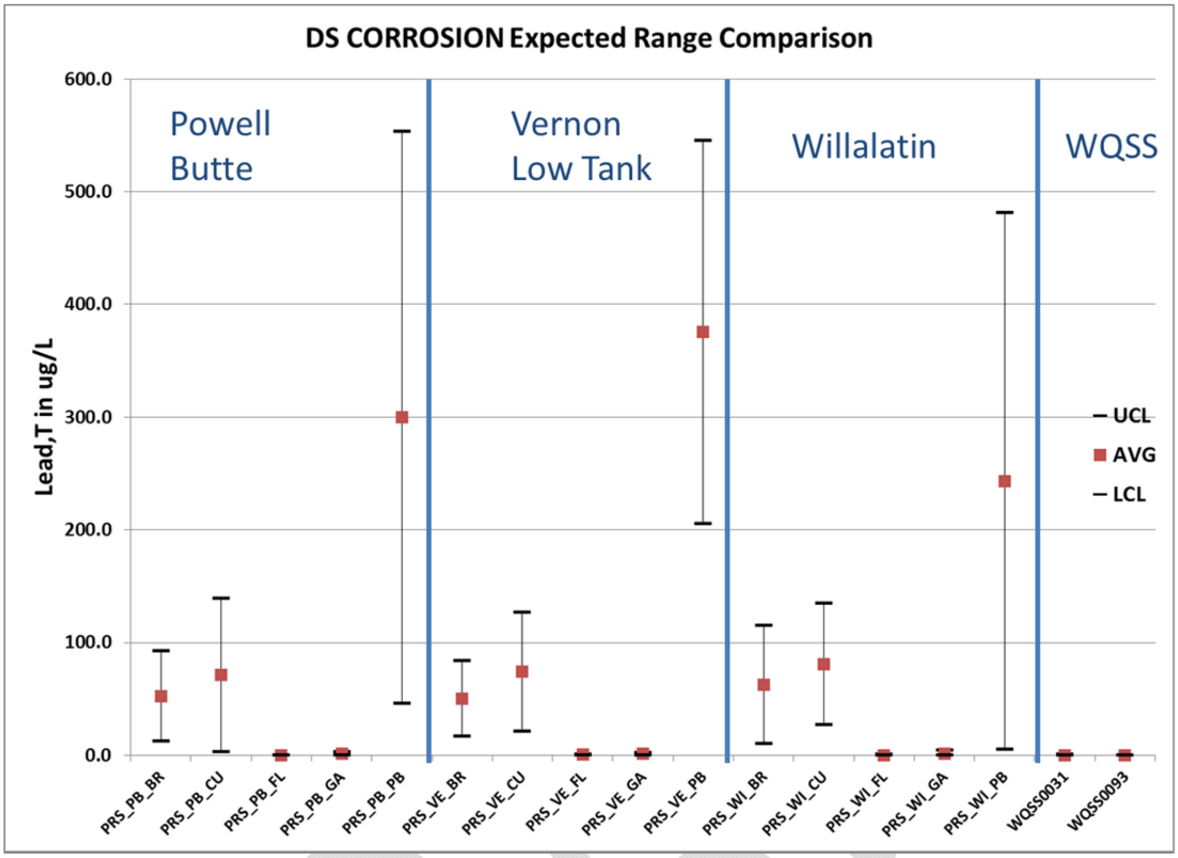

Figure 15 Total Lead concentrations from PRS monitoring station data for Q1 2016 through Q2 2016.

Red squares indicate the average lead concentration for each location and test chamber. The "whiskers" emanating from the average indicate the expected range of the data at that site where 99% of the data will fall as calculated by the Shewhart Control Chart statistical concept of variation.

2.9.2 Categories of lead release

Water quality parameters are monitored at the PRS monitoring stations to allow for paired sample analysis between lead release and the various water quality parameters describing the potential mechanisms of lead release. These data are presented in the sections below according to the mechanism of lead release which the water quality parameters describe.

2.9.2.1 Uniform Corrosion

Roughly 50% to 70% of the lead measured in the PRS monitoring stations was in the dissolved form, indicating solubility processes such as in uniform corrosion were occurring in the test chambers. The parameters describing carbonate chemistry (pH, alkalinity, hardness, and temperature), chloride and sulfate chemistry, and ORP were monitored along with lead release in the test chamber effluents to determine if relationships existed between the water quality parameters and lead release.

The pH in the test chambers can be observed in Figure 16 below. As observed, the pH is generally close to 8.0 in the flowing water samples, with a drop of about 0.2 pH units in the test chambers following the stagnation period compared to the flowing water pH.

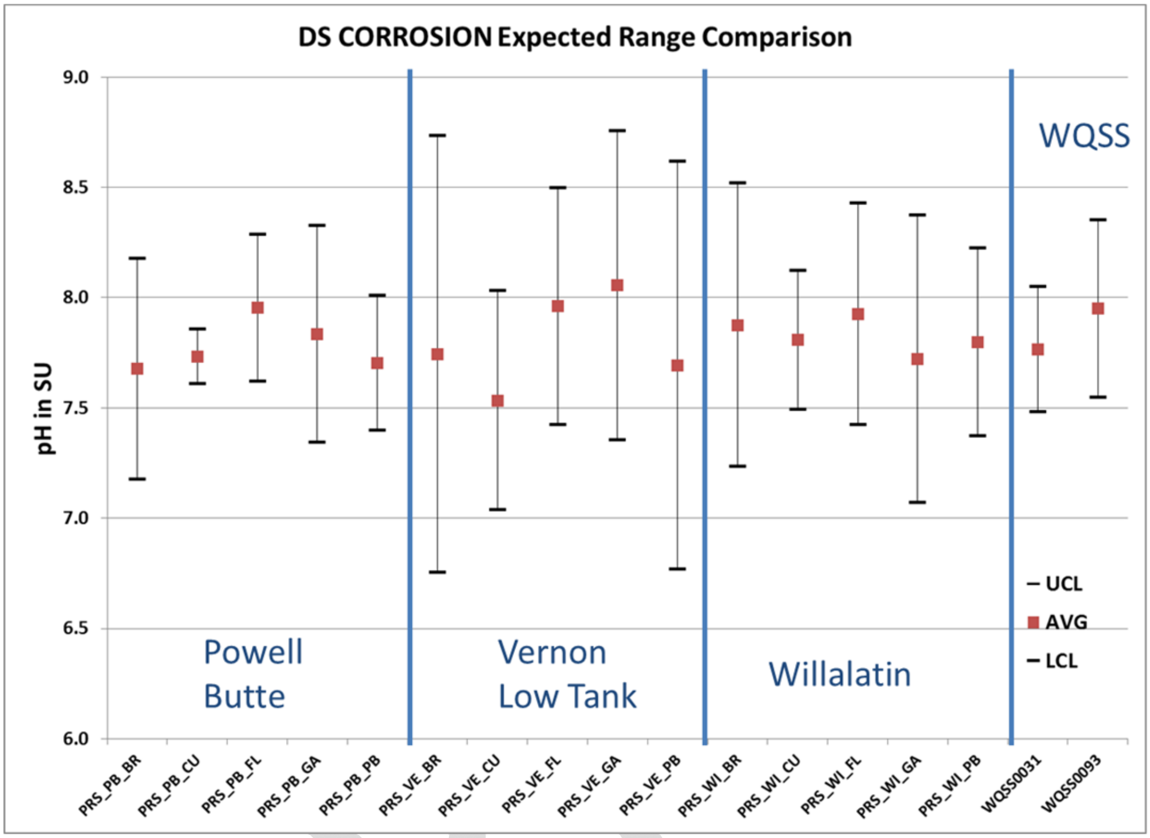

Figure 16 pH expected values in the flowing water entering the test chambers (FL) and the various test chambers after stagnation.

Red squares indicate the average lead concentration for each location and test chamber. The "whiskers" emanating from the average indicate the expected range of the data at that site where 99% of the data will fall as calculated by the Shewhart Control Chart statistical concept of variation.

The alkalinity and hardness of all stations was very similar, approximately 10 mg/L as CaCO3. This is typical when the PWB is served by its surface water supply. The remaining parameters describing uniform corrosion are similar between the various station locations and are typical of when the PWB is served by its surface water supply.

More detailed statistical analysis will be performed in the final report after all the data is accumulated to determine if there exists a correlation between lead release and any of the water quality parameters describing uniform corrosion processes.

2.9.2.2 Biostability

The ATP at all monitoring station locations is shown in Figure 17 below. ATP is a measure of overall microbial activity and an increase in ATP indicates an increase in overall microbial activity. ATP is in general low, and the ATP is similar in the influent flowing water and the stagnating test chambers, indicating good microbial control with the water characteristics. ATP was slightly elevated system-wide following the switch to surface water in November, was lower during December and January, and increased again between February and April. The ATP was then lower in May. This data will continue to be monitored during the next quarter as temperatures are expected to increase during the summer season.

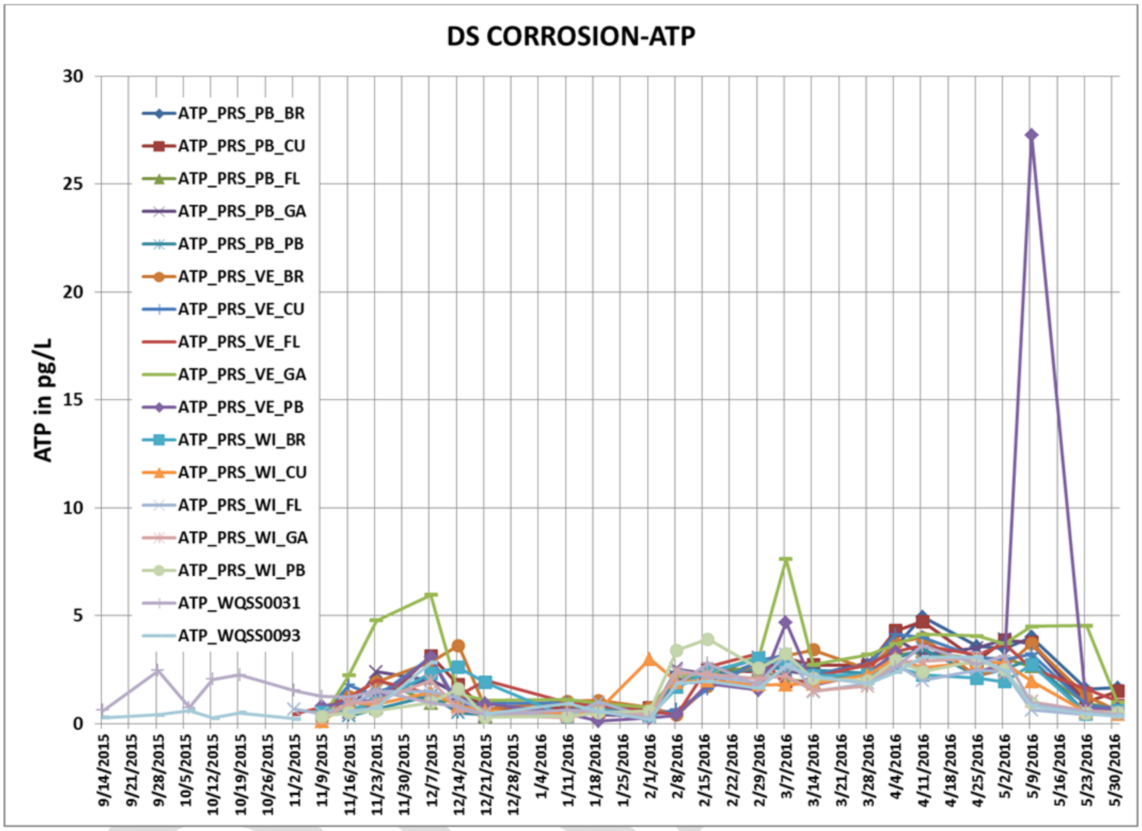

Figure 17 ATP at PRS monitoring station locations

Another measure of biostability is the decay of chloramine residual, followed by release of free ammonia and generation of nitrate and nitrite. The monochloramine residuals from the monitoring stations are shown in Figure 18 below. As observed, Willalatin has a consistently lower chloramine residual than the other sites. It also had the highest concentrations of nitrite and nitrate, indicating that nitrification is likely actively occurring in that site. It should be noted that these same trends were observed in the water flowing into the Willalatin station, as discussed further in the section on flowing water sites below. This trend will continue to be monitored.

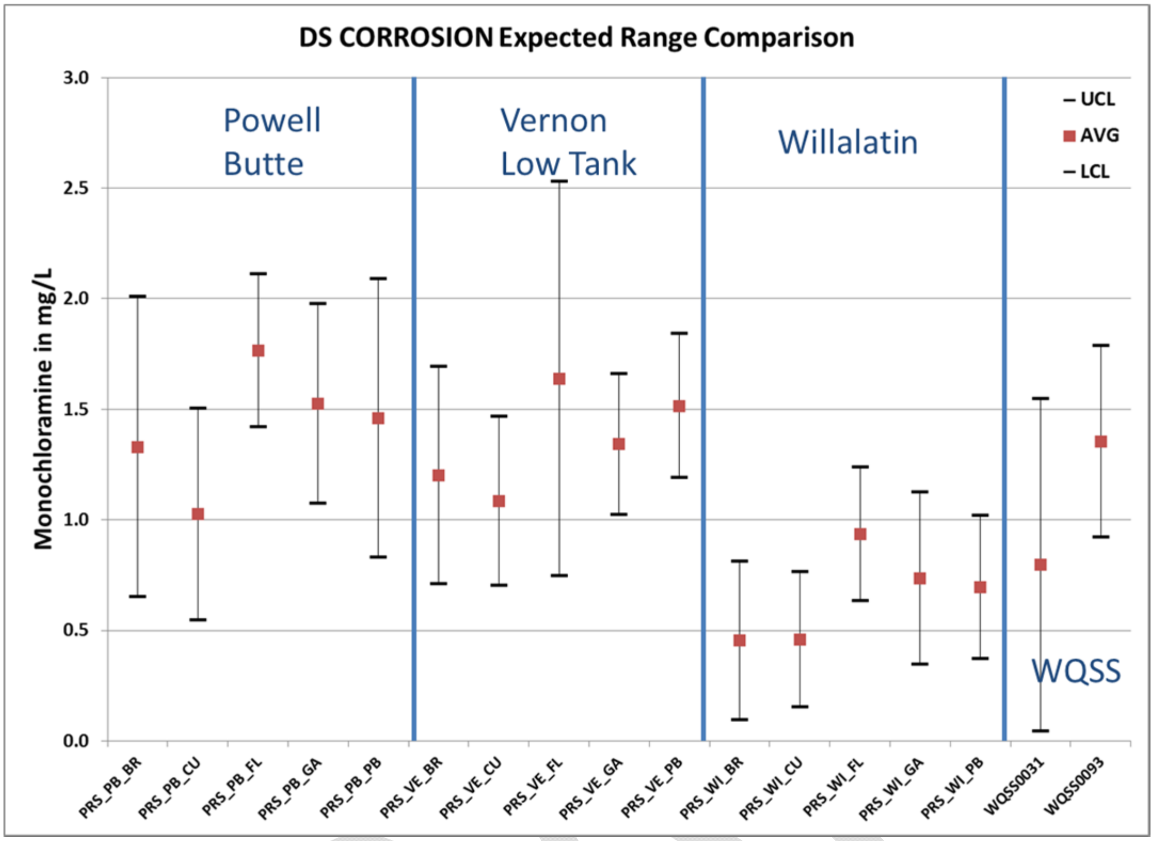

Figure 18 Monochloramine residuals observed in the monitoring stations.

More detailed statistical analysis will be performed in the final report after all the data is accumulated to determine if there exists a correlation between lead release and any of the water quality parameters describing biostability.

2.9.2.3 Scale release

Roughly 30% to 50% of the total lead detected at the PRS monitoring stations was in particulate form in most samples indicating that scale release is contributing towards total lead release in the monitoring stations. Many of the spikes in total lead observed in the monitoring stations (in particular for the lead chamber from Vernon Low Tank) were attributed to particulate lead.

The dissolved, particulate, and total iron concentrations for all monitoring stations from Q1 2016 to Q2 2016 are shown in the figures below. Note that aluminum and manganese follow similar patterns as the iron; the concentrations of these metals trend together very strongly. The December spike in particulate metals in the test chamber effluent is of interest because it was associated with the spike in particulate lead, indicating that release of metal scale containing iron, manganese, aluminum, and lead is likely responsible for that lead spike in the PRS test chamber effluent. The metals concentrations were noticeably lower from January through May.

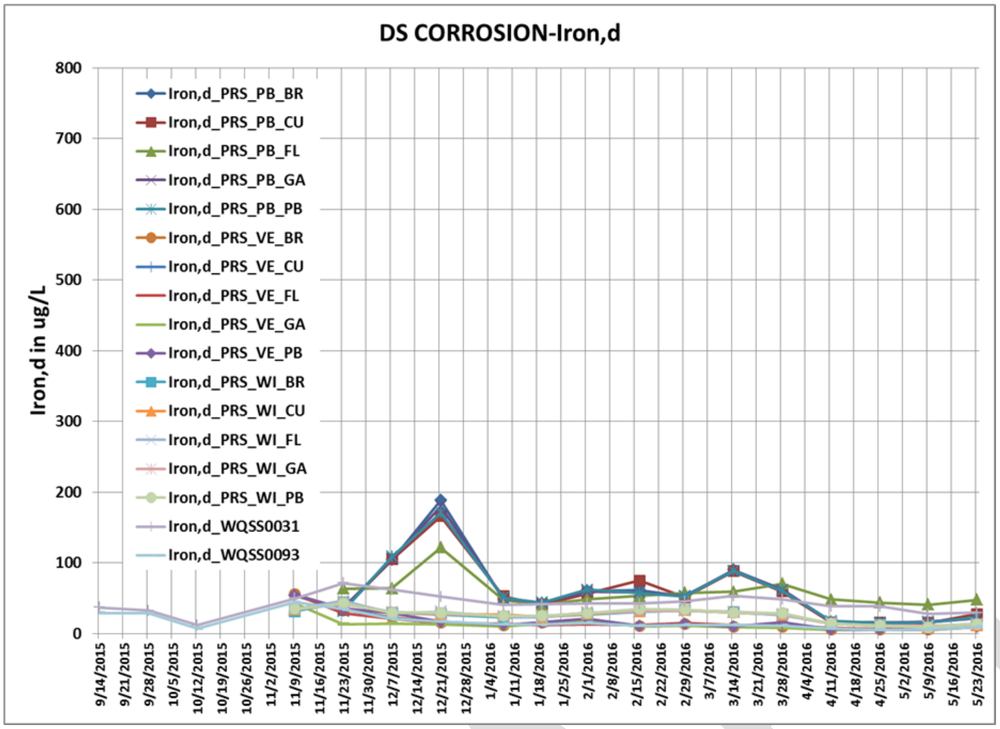

Figure 19 Dissolved iron concentration from Q1 2016 through Q2 2016 for all monitoring stations.

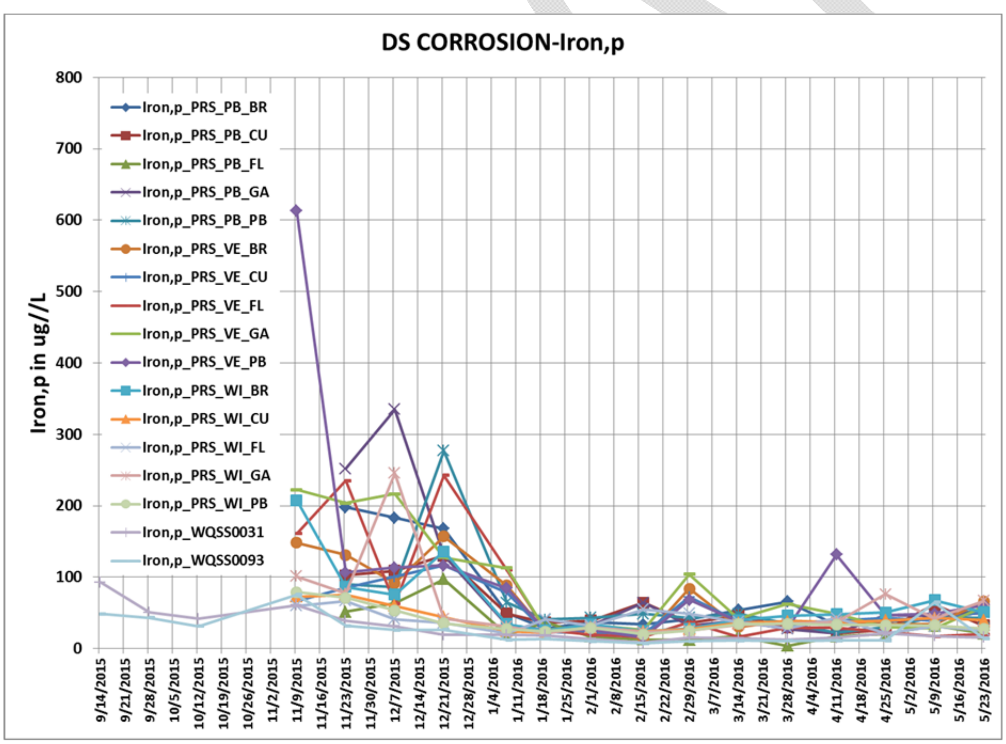

Figure 20 Particulate iron concentration from Q1 2016 through Q2 2016 for all monitoring stations.

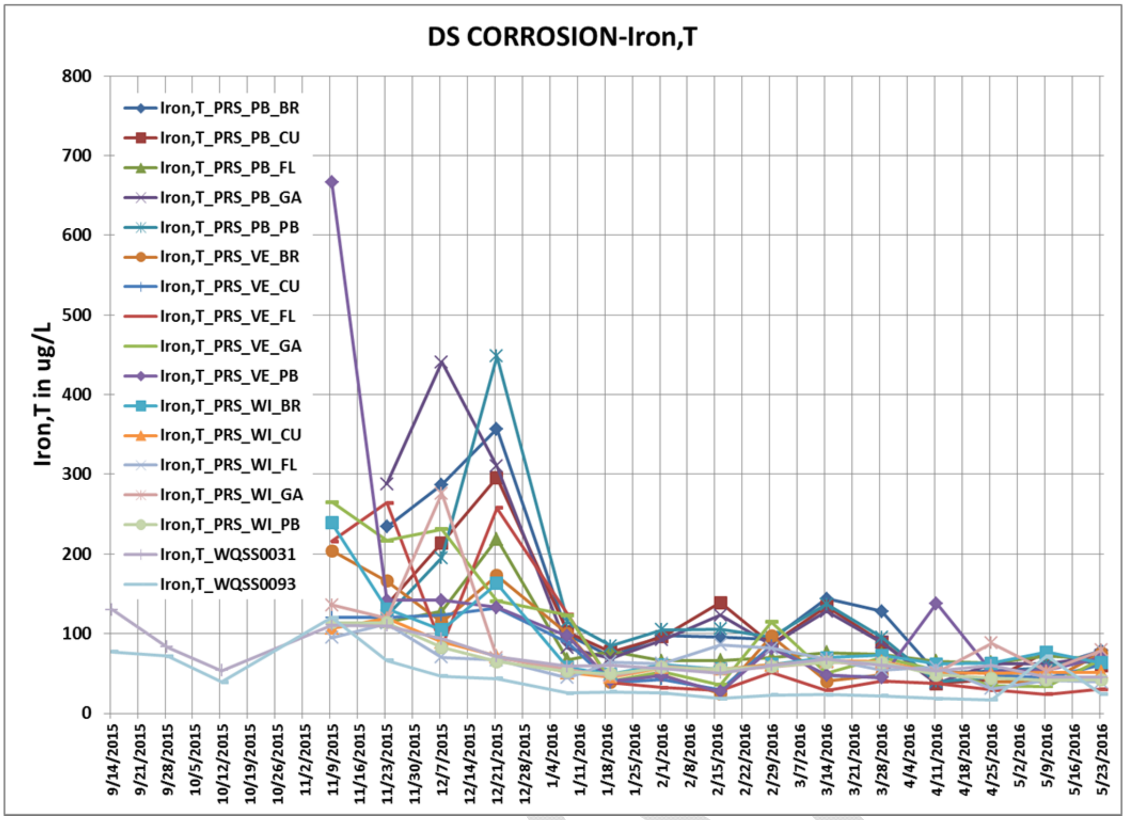

Figure 21 Total iron concentration from Q1 2016 through Q2 2016 for all monitoring stations.

More detailed statistical analysis will be performed in the final report after all the data is accumulated to determine if there exists a correlation between lead release and any of the water quality parameters describing scale release.

2.9.3 Extended WQSS data

Two TCR sites (WQSS 0031and WQSS 0093) were selected to monitor additional water quality parameters than are monitored at the remainder of the TCR sites. In this way the extended WQSS provide an excellent opportunity to gather additional details on water quality in the distribution system. These stations, along with the flowing water samples from the three monitoring stations, also provide information on the amount of lead being released from the PWB distribution system itself, since the water has not been in contact with customer premise plumbing or service lines.

2.9.3.1 Lead and metals

The lead concentration was monitored in the flowing water samples collected at the extended WQSS and monitoring station locations. As shown in Figure 22 below, the Vernon Low Tank and Willalatin have higher total lead concentrations than the other sites, with particulate lead observed up to 0.6 ug/L. The dissolved lead was very similar amongst all sites, at approximately 0.2 ug/L.

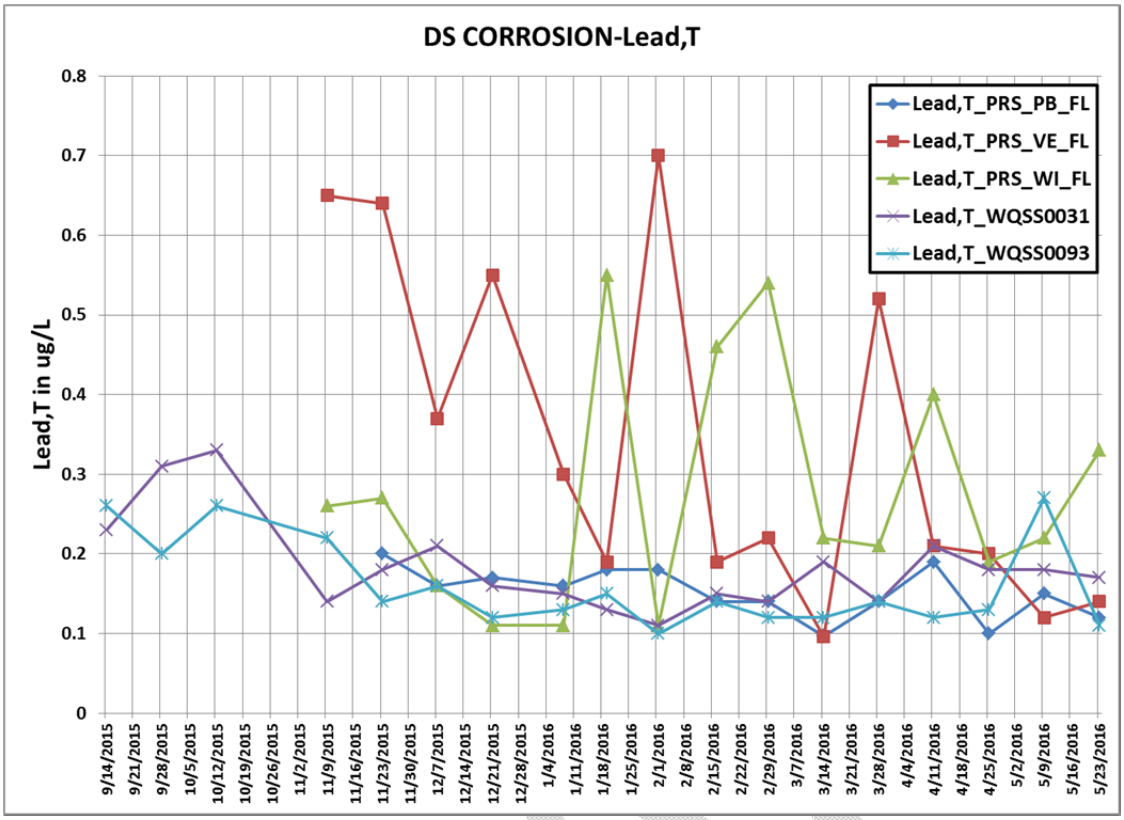

Figure 22 Total lead concentration measured at five sites in the distribution system.

The copper concentrations at the flowing water sites are shown in Figure 23 below. As shown, Vernon Low Tank has had a consistently higher copper concentration than the remaining sites. Both the dissolved and particulate copper concentrations are elevated at Vernon Low Tank. This trend will continue to be monitored for its impact on lead release.

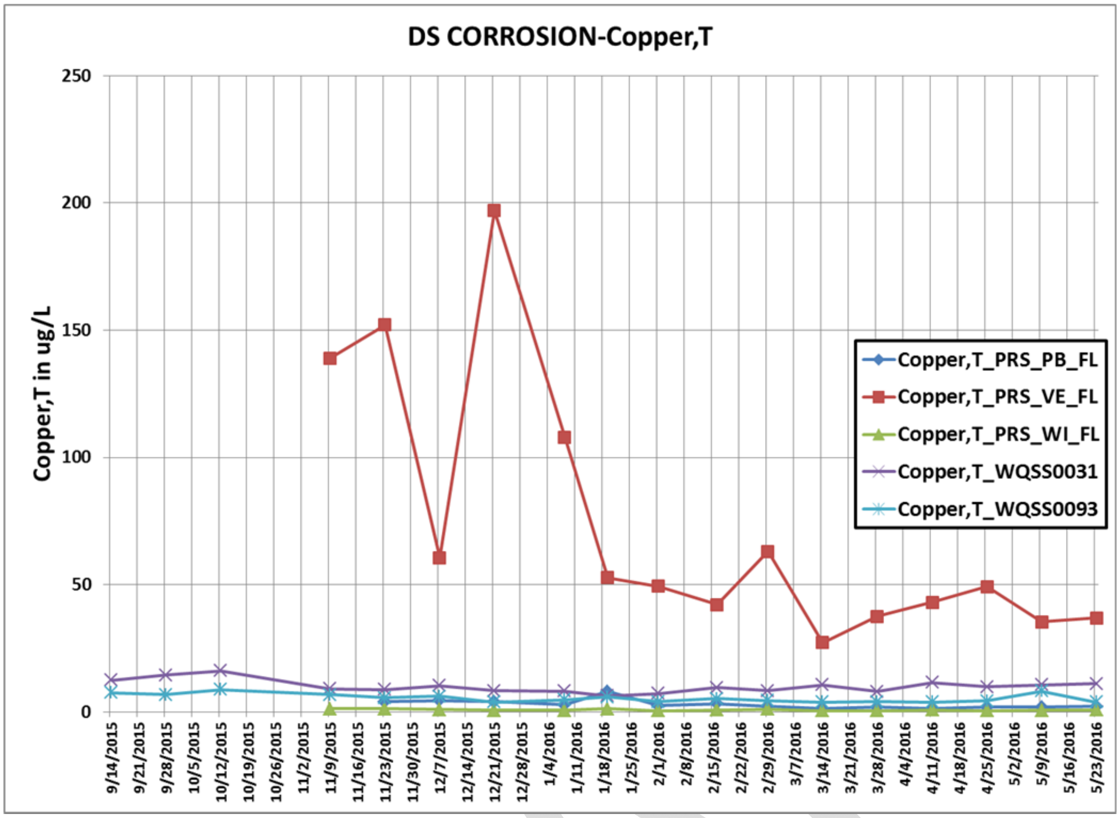

Figure 23 Total copper concentrations at five flowing water sites in the distribution system.

The total iron concentration measured at the distribution system flowing water sites is shown in Figure 24 below. As indicated, after some early spikes in iron, the concentration has been consistently lower throughout the distribution system. Aluminum and manganese exhibit similar temporal patterns. It should be noted that the metals concentrations observed were all well below any secondary MCL for these metals – the "elevated" levels are only of significance in that these metals are known to combine with lead and then transport together when the metal scales release from the pipe wall surface.

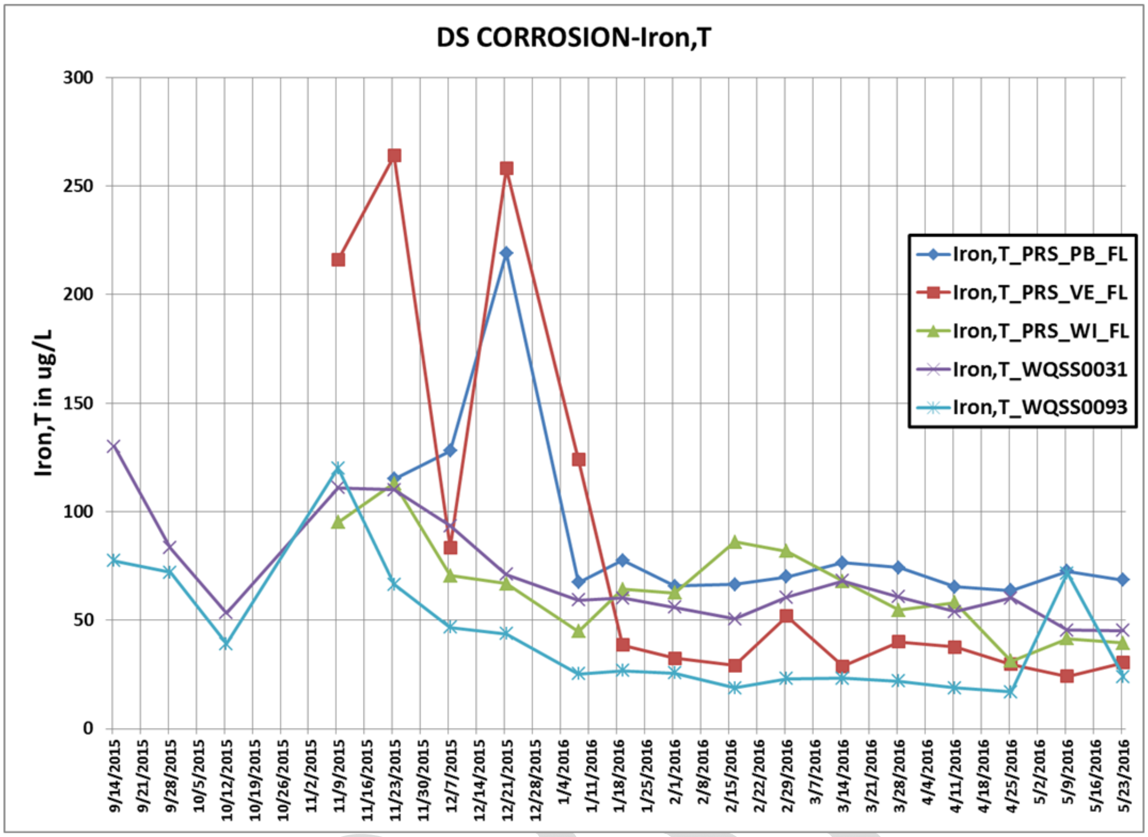

Figure 24 Total iron concentration measured at five sites in the distribution system.

2.9.3.2 pH

The pH was monitored at the five distribution system sites and is shown in Figure 25 below. As observed, after some initial higher variability at the Vernon Low Tank site, the pH was similar amongst the three sites with monitoring stations, generally around 8.0. WQSS0031 consistently had the lowest pH, generally around 7.8.

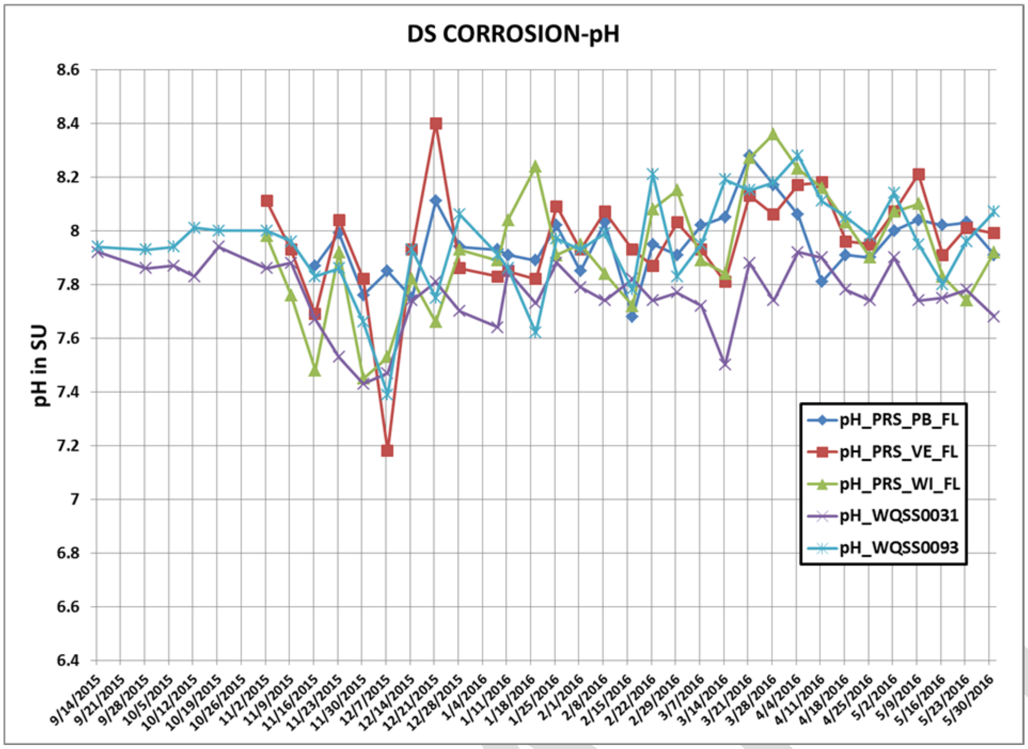

Figure 25 pH observed at five distribution system sites from Q1 2015 through Q2 2016

2.9.3.3 Biostability

The ATP and monochloramine were monitored at the five distribution system sites and are shown in Figure 26and Figure 27, below. The pattern of biological activity as measured by ATP is very similar amongst the five sites, with an increase observed between February and April. The ATP levels were dropping towards the end of the quarter. The monochloramine were lower at Willalatin and WQSS0031 than the other stations.

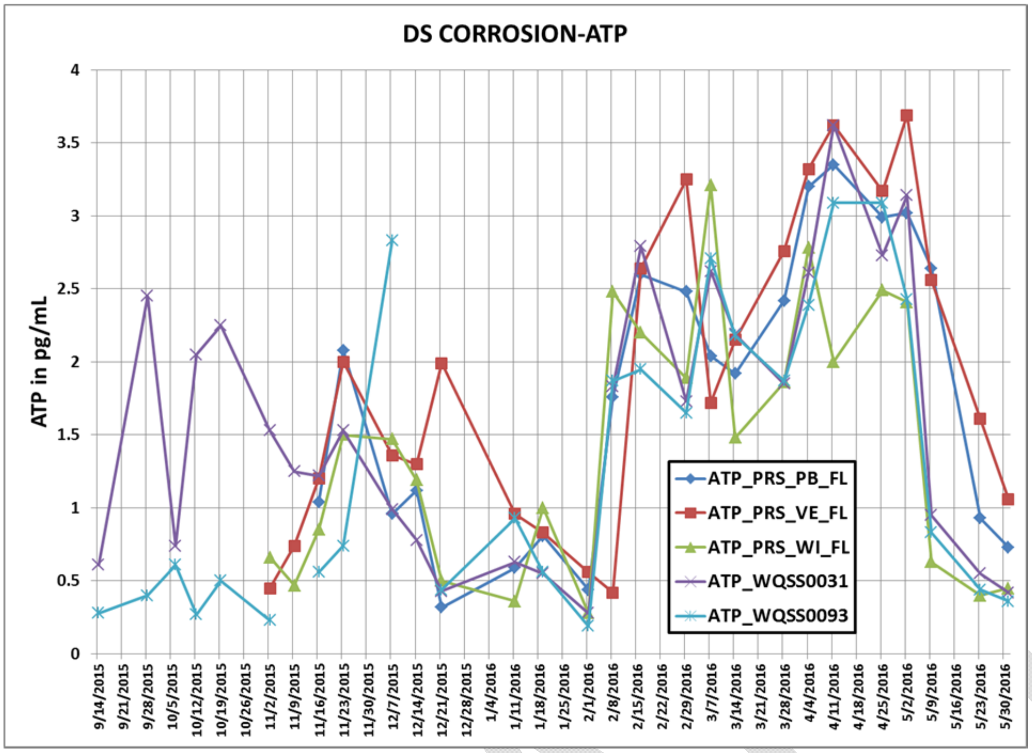

Figure 26 ATP measured at flowing water sites in the distribution system.

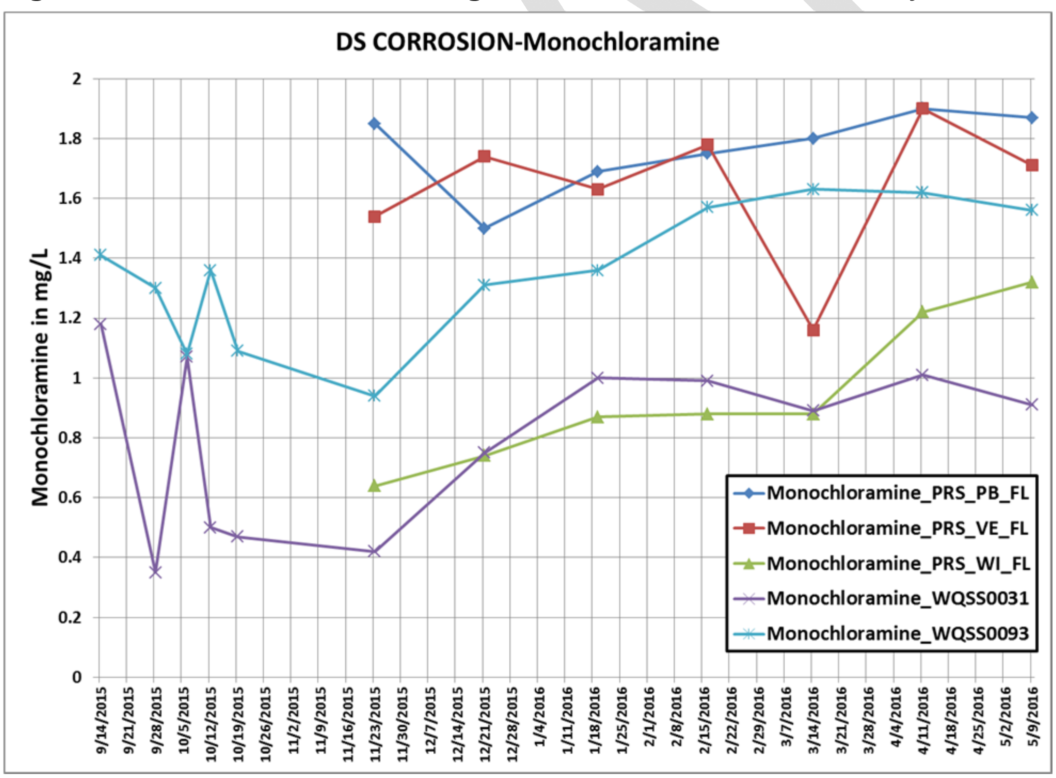

Figure 27 Monochloramine residual measured at flowing water sites in the distribution system.

2.9.4 Summary of PRS monitoring station and extended WQSS data

In summary, the following observations were made from a review of the PRS monitoring station and extended WQSS data:

- In most samples lead release was approximately 50% to 70% attributable to soluble lead, and 30% to 50% attributed to particulate lead. This is similar to the data observed from the supplemental residential samples.
- The elevated lead observed at the beginning of the study may have been due to startup effects, or to the elevated turbidity and metals (iron and manganese) that was present from heavy rains during the switch to surface water.
- Lead has been trending downwards in the monitoring stations, suggesting that the water may be forming protective scales on the metal chamber surfaces. Scales are anticipated to be harvested and analyzed at the end of the study period.
- The highest lead released was observed in the lead test chamber from Vernon Low Tank monitoring station location.
- The extended WQSS data suggest that iron, manganese, and aluminum were elevated (compared to background levels, still below secondary MCLs) in the distribution system during November and December, but have been consistently lower since January.

2.10 QA/QC DATA

The QA/QC data is collected regularly to ensure accuracy of the field measurements. The QA/QC data indicates that the analyses have a high degree of both accuracy and precision. The average recovery (accuracy) and precision are shown in Table 2 below.

Table 2 Average Recovery and Precision

Item Measured	Units	Average Accuracy (average percent recovery)	Average Precision (+/-)
ATP- UltraCheck duplicate	RLU	-	1733
ATP-PRS_PB_Fl duplicate	pg/mL	-	0.57
Cl2, T	mg/L	-	0.216
Conductivity	uS/cm	91.3%	1.33
ORP	mV	96.6%	61.4
pH	SU	100.4%	0.315*
Temperature	deg C	-	1.95
Turbidity	NTU	99.7%	0.25

*NOTE: The precision of the pH measurement has improved and is currently less than 0.1.

3 Preliminary Observations

This section identifies the major observations made during this quarter.

3.1 DEVIATIONS FROM SAMPLING PLAN

Fewer supplemental residential samples have been collected up to this point in the study than was recommended.

3.2 FIELD SAMPLING NOTES AND OBSERVATIONS

Field sampling was conducted according to the monitoring plan.

On April 11, 2016 there was an insufficient sample volume from the lead test chamber at the Vernon site. Further research revealed that low test chamber volumes were typical at the Vernon station but enough volume was collected for the required samples. Following this event all three of the PRS stations were inspected and it was determined that excess pipe thread sealant had become lodged in the check valves and was preventing the valves from sealing properly. This resulted in partial drainage of the test chambers during sampling. Due to the configuration and hydraulics of the stations cross contamination between test chambers was determined to be unlikely. The check valves on all three PRS stations were replaced and a ball valve was added to the outlet side of each test chamber as an additional precaution.

Sampling protocols were revised to ensure that the test chambers are not hydraulically connected during sampling. The revised protocol requires the sampler to close both the inlet and outlet valves on each test chamber prior to taking the sample from the chamber. Thread sealant also becomes lodged in the needle valves reducing flow to the test chambers. Exercising of the needle valves releases the thread sealant and returns flows to normal. Thread sealant has also been observed in some of the test chamber samples.

3.3 LAB ANALYSIS NOTES AND OBSERVATIONS

Laboratory analysis was conducted according to the monitoring plan. There were no anomalies in laboratory data to be reported.

3.4 SUMMARY OF DATA TRENDS

Data trends which are indicative of specific mechanisms of lead release are identified below. The intention of this section of the report is to identify trends in the data from this monitoring period which should continue to be observed throughout the remaining monitoring quarters. Sufficient data may not yet be available to draw final conclusions about what mechanisms are or are not contributing to lead release throughout the Portland water system. Any conclusions or extrapolation of the current data will be reserved for the final report after one full year of data is evaluated.

3.4.1 Uniform corrosion

Approximately 50 to 70% of the total lead observed in the PRS monitoring station test chamber effluent and the supplemental customer sampling was in the dissolved form, indicating solubility processes related to lead release are occurring. In general the water quality parameters describing uniform corrosion, such as pH, are relatively stable throughout the distribution system. The collection of additional data as prescribed in the monitoring plan is expected to help determine the extent to which specific water quality parameters are influencing lead release from uniform corrosion in the Portland water system. A discussion on uniform corrosion indices in the PWB system is included below.

DIC is a direct measure of the available carbonate species in the water that can react with lead and copper to form the passivating scales. The DIC throughout the PWB system is generally between 2 and 3 mg/L as C. While not a direct measure of uniform corrosion, a useful parameter to measure the tendency for calcium carbonate precipitation is the calcium carbonate precipitation potential, CCPP. The CCPP is the PWB system is generally between -6 and -7, indicating a very low potential for formation of calcium carbonate layer.

Chloride and sulfate can form complexes with metals that are orders of magnitude more soluble than carbonate compounds. Therefore, there is the potential that the presence of chloride and sulfate can enhance the corrosion of metals. One measure of the contribution of chloride and sulfate to corrosion is the Larson's ratio (LR), defined as:

$$LR = alkalinity / (Cl^{-} + SO4^{2-})$$

It is generally recommended to maintain a LR greater than 5 to ensure carbonate reactions are predominantly controlling lead solubility. The LR in the PWB system is generally between 2 and 3, indicating that chloride and sulfate may be inhibiting lead carbonate formation and contributing towards increased lead solubility.

Another ratio which has been shown to influence lead release is the chloride to sulfate mass ratio (CSMR). Higher CSMR values have been shown to increase galvanic corrosion in the case where lead is directly coupled to a dissimilar metal, such as when lead solder is used on copper piping. While guidance varies, the literature suggests that values greater than 0.6 can increase the risk of galvanic corrosion due to the ratio of chloride to sulfate. The CSMR in the Portland system when served by surface water (as was the case during Q2 2016) is between 7 and 8.

3.4.2 Biostability

Overall ATP levels are low and suggest good microbial control in the PWB system. Microbial activity as measured by ATP was slightly elevated system-wide following the switch to surface water in November, was lower during December and January, and increased again between February and April. The ATP appears to be again dropping in May. During the next quarter the water temperature is expected to increase as summer continues, which may cause an increase in microbial activity. This data will continue to be monitored.

3.4.3 Scale release

Particulate lead release accounted for approximately 30% to 50% of the total lead release observed in most of the test chambers and supplemental customer sampling. Occasional spikes in total lead observed in the test chamber effluents during Q1 2016 were predominantly in the particulate form. These spikes in lead were strongly associated with similar spikes in particulate iron, manganese, and aluminum, indicating that release of these metal scales is contributing to the lead spikes observed in the PRS monitoring station test chambers.

3.4.4 Lead release in the distribution system

Lead concentrations were monitored at WQSS and PRS monitoring station inlets to determine if there are any significant sources of lead from the actual distribution system (as opposed to service line and customer premise plumbing). Dissolved lead was typically below 0.2 ug/L in these samples, with particulate lead accounting for some results up to 0.6 ug/L. Lead will continue to be monitored at the extended WQSS and monitoring station inlets during Q3 2016 and will provide additional information related to lead release in the distribution system.

4 Next Quarter Look-Ahead

4.1 RECOMMENDED CHANGES FOR NEXT QUARTER

The following are recommended changes to the monitoring plan based upon the data analyzed this monitoring period.

- More prioritization should be given to the supplemental residential customer water chemistry and lead sampling during the next quarter. It was anticipated that the supplemental sampling be conducted in 50 homes throughout the year. To date supplemental sampling has been conducted in five homes.
- Discontinue the measurement of cadmium, chromium, cobalt, as they are found at concentrations below the detection levels.
- Continue monitoring for remaining parameters at the frequencies described in TM2.

4.2 ANTICIPATED PROJECT SCHEDULE

The following outlines the next steps in the PWB Water Quality and Corrosion Study.

- The Q3 2016 quarterly report will be prepared covering data collecting from June through August, 2016.
- Final report and workshop to be scheduled after Q4 2016 data are analyzed

Abigail Cantor
Process Research Solutions, LLC
April 18, 2016

Appendix A - Box and Whisker Plots

Every set of data has its own distribution of values. Two sets of data may have the same average value but one set may have a higher maximum. Or, one set may have more of its data in a certain smaller range. It is good to compare datasets by their distributions to get a complete picture of similarities or dissimilarities between the situations that produced the data.

A set of data can be described using five parameters:

1. Minimum value
2. Maximum value
3. Middle value (median)
4. A value that divides the data between the median and the minimum
5. A value that divides the data between the median and the maximum

There are several statistical methods by which to determine the dividing points. It is important to be consistent in which technique is used in a project so that all datasets are compared in the same way.

There is another option to add to the Box and Whisker Plots. That is, instead of just dividing the data between the median and the maximum and the median and the minimum, a "reasonable" value can be calculated as a maximum and also a minimum of the dataset. Then, any actual value outside of these "reasonable" boundaries can be viewed as "outliers".

To define this "reasonable" range, the "interquartile range" or IQR is calculated for a box plot. This is the difference between the value of the third quartile and the value of the first quartile. It has been defined that any outlier is a value that lies outside 1.5 times the IQR. (1.5 is an arbitrary value but has been used since John Tukey, a statistician, introduced the technique in 1977.) Values at over 3.0 times the IQR are "extreme outliers".

On the Box and Whisker Plots used in this project, an outlier is denoted by "x". An extreme outlier is denoted by "o".

Features of the Box and Whisker Plot are:

- X=extreme outlier
- O=outlier
- T or upside down T= maximum or minimum value that is not an outlier. It is either the actual maximum or minimum value of the dataset when no outliers are present or 1.5* IQR when outliers are present.
- Bottom line of the 'box'=First quartile value
- Middle line of the 'box'=Second quartile value (median)
- Top line of the 'box'=Third quartile value
- Third quartile value minus First quartile value = interquartile range (IQR)

Appendix B - Corrosion Study Operations Log

Start Date	End Date	Event	Questions/Comments
11/2/2009	present	Reservoir 6 South Cell off line PERMANENTLY	date is approximate
10/1/2010	present	Reservoir 6 North Cell off line PERMANENTLY	
7/20/2011	7/21/2011	Reservoir 3 out of service	
7/21/2011	11/8/2011	Reservoir 3 in service	
9/9/2011	present	Reservoir 4 off line PERMANENTLY	
11/8/2011	3/23/2012	Reservoir 3 out of service	
1/21/2012	1/31/2012	Turbidity event in watershed; Groundwater activated	Range of Daily GW Production: 18 - 83.6 MGD; Total Volume Pumped: 0.82 BG
2/23/2012	2/27/2012	Turbidity event in watershed; Groundwater activated	Range of Daily GW Production: 23.6 - 52.4 MGD; Total Volume Pumped: 0.22 BG
3/23/2012	7/20/2012	Reservoir 3 in service	
7/20/2012	8/3/2012	Reservoir 3 out of service	
8/3/2012	10/18/2012	Reservoir 3 in service	
8/6/2012	8/23/2012	Groundwater Maintenance Operation	Range of Daily GW Production: 0-5 MGD; Total Volume Pumped: 0.03 BG
10/18/2012	4/22/2013	Reservoir 3 out of service	
4/22/2013	6/12/2013	Reservoir 3 in service	
6/12/2013	7/3/2013	Reservoir 3 out of service	
7/3/2013	9/18/2013	Reservoir 3 in service	
7/30/2013	8/8/2013	Groundwater Maintenance Run for summer 2013	Range of Daily GW Production: 0-5 MGD; Total Volume Pumped: 0.03 BG
9/1/2013	present	Switched from a systematic flushing program to a targeted flushing program due to Berth TC event	
9/18/2013	present	Reservoir 3 out of service	
10/2/2013	12/3/2013	Increased target chlorine residual at Lusted Hill from 1.8 mg/L to 3.0 mg/L.	
12/4/2013	1/16/2014	Reduced target chlorine residual at Lusted Hill from 3.0 mg/L to 2.5 mg/L.	
1/16/2014	6/10/2014	Reduced target chlorine residual at Lusted Hill from 2.5 mg/L to 2.2 mg/L.	
5/19/2014	6/29/2015	Powell Butte floating on the inlet or outlet main to permit thrust harness replacement at 162nd Ave. conduit interties.	
3/10/2014	3/12/2014	Testing of Dam 2 North Tower gates	
4/1/2014	present	Began using Dam 2 North Tower gates	see "North Tower Gate Positions" for gates in use and percent open

6/6/2014	6/6/2014	Inadvertent opening of N. Tower lower gate	A few hours only and resulted in lower water temps and increased chlorine demand
6/10/2014	12/9/2014	Increased target chlorine residual at Lusted Hill from 2.2 mg/L to 2.5 mg/L.	
7/9/2014		Powell Butte II West Cell was placed into service.	
7/1/2014	7/9/2014	Groundwater Maintenance Operation + supplemental supply due to Conduit 3 break/repair.	Range of Daily GW Production: 0-27.8 MGD; Total Volume Pumped: 0.12 BG
7/28/2014	11/19/15	Powell Butte 1 South Cell out of service	
8/15/2014		Powell Butte II East Cell placed into service	
10/28/2014	11/19/15	Powell Butte 1 North Cell out of service	
10/29/2014	11/14/2014	Switched from N. Tower to S. Tower during this period	Sheen on Diversion Pool; related to Powerhouse 2 Operations
12/9/2014	6/8/2015	Reduced target chlorine residual at Lusted Hill from 2.5 mg/L to 2.2 mg/L.	
12/23/2014	12/29/2014	Increase in turbidity at Diversion Pool	Elevated turbidity also observed at upper elevations in Reservoir 2. Switched from N. Tower to S. Tower during this period to pull water from lower elevations.
2/26/2015	present	Westside connected directly to Conduit 2 and/or 3	
5/11/2015	present	New regulator was activated. It supplies WP229 and Palatine area from 30" Tabor 411 bridge crossing to 16" main in SW Macadam Ave. Regulator is called ***SW***	Keep for now; may not be relevant to corrosion study
6/1/2015	11/1/2015	Seasonal mitigation of nitrification by managing storage	Approximate dates
6/8/2015	12/16/2015	Increased target chlorine residual at Lusted Hill from 2.2 mg/L to 2.5 mg/L.	
6/11/2015	6/29/2015	Groundwater activated to meet system demands due to scheduled work on conduit #4; also used as annual GW maintenance run	See demand sheet for % supply from GW.
6/30/2015	7/15/2015	Groundwater off	
6/29/2015	present	Powell Butte returned to normal operation with separate inlet & outlet mains. (End of Powell Butte float for thrust harness project at 162nd Ave conduit interties)	
7/15/2015	present	Stopped booster chlorination at Washington Park	
7/16/2015	11/4/2015	Groundwater re-started for summer supply	See Demand spreadsheet for % supply from GW.
8/6/2015	present	Reservoir 1 taken out of service	
11/3/2015	11/18/2015	Partial use of S. Tower during this period	Sheen on Diversion Pool; related to operation of North Howell Bunger Valves
11/4/2015		Groundwater off, no longer needed for summer supply	
11/19/2015	2/4/2016	Powell Butte 1 (North & South cells) in service	
12/2/2015	present	Reservoir 5 off line PERMANENTLY	
12/16/2015	present	Reduced chlorine dosing target to achieve 2.2 mg/L at Lusted Hill	
2/4/2016	present	Powell Butte 1 (North & South cells) taken out of serivce	