LOCKWOOD, ANDREWS & NEWNAM, INC.
FINAL

Operational Evaluation Report

City of Flint

Trihalomethane Formation Concern

August 27, 2015
In Response to May 2015 Sample Results

Lockwood, Andrews & Newnam, Inc.
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EXECUTIVE SUMMARY

Environmental Protection Agency (EPA) and Michigan Department of Environmental Quality (MDEQ) regulations require that public water suppliers test drinking water quarterly throughout the distribution system for disinfectant by-products (DBP's). Two categories of DBP's, tri-halomethanes (THM) and halo-acetic acids (HAA5), are regulated and must be tested for. The City of Flint began operation of their water treatment plant (WTP) full time with the Flint River as the source on April 25, 2014. Since that time, six quarters of samples taken have resulted in annual average violations for total THM. Prior to the first violation (Nov. 2014), the City hired Lockwood, Andrews & Newnam, Inc. (LAN) to complete this Operational Evaluation Report (OER) in conformance with EPA guidelines with the goal to determine the cause(s) of high levels of THM and evaluate possible solutions.

The EPA promulgated the Stage 2 Disinfectants and Disinfection By-Products Rule (DBPR) in January 2006 which set maximum contaminant levels (MCLs) for total trihalomethanes (TTHM) and HAA5 based on an annual running average, tested quarterly, for a given sampling location. The City of Flint reports levels from 8 sampling test locations. Of the six quarterly sampling cycles since Flint began operating the WTP full time, HAA5 levels have been acceptable but TTHM levels have exceeded the MCL. One sampling site was in violation following the May 2015 sampling cycle and results from August 2015 sampling indicate all sites are now within compliance.

A number of issues were identified as possibly contributing to the initial high THM levels measured.

1. Inefficient ozone system functionality which led to in increased chlorine feed.
2. Upstream source influences in terms of increased chlorine demand.
3. Bypass stream around softening contributed to chlorine demand and increased total organic carbon (TOC) levels in the effluent.
4. Unlined cast iron pipes in the distribution system contributing to chlorine demand.
5. High water age in the distribution system due to:
    a. Broken valves causing less than ideal flow patterns
    b. Inefficient pump station pressure zones
    c. Water storage volumes in excess of that needed for today's demands
    d. Oversized water mains
    e. Low water demands
6. High chlorine demand in filters.
7. High THM formation potential (THMFP) in source water.
8. Less than optimal removal of THM precursors.

A graphical representation of how the factors above relate to the timing of THM compliance sampling is shown as Table 1. Compliance sampling dates are hatched. Each row in Table 1 describes a factor that can lead to increased THM levels and the table defines when each of those factors applied. Note the convergence of nearly all factors around the second sampling period on August 21, 2014 to create what appears to have been a worst case scenario. The table also shows that the factors listed as those that the City can control have been addressed prior to 2015 sampling periods. Monthly operating report data up to August 1, 2015 is depicted on the Table.

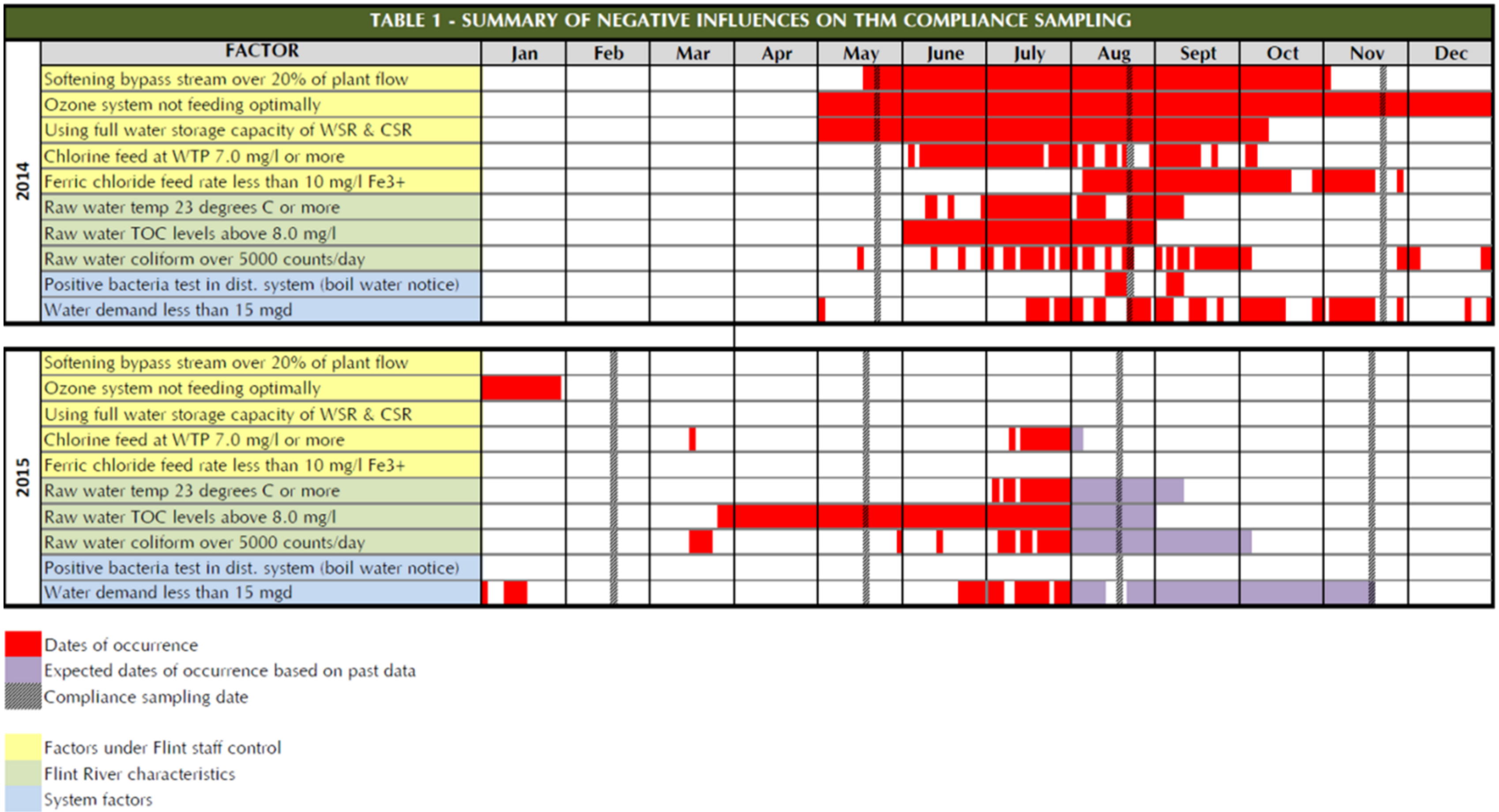
TABLE 1 - SUMMARY OF NEGATIVE INFLUENCES ON THM COMPLIANCE SAMPLING
FACTOR
Jan
Feb
Mar
Apr
May
June
July
Aug
Sept
Oct
Nov
Dec
2014
Softening bypass stream over 20% of plant flow
Ozone system not feeding optimally
Using full water storage capacity of WSR & CSR
Chlorine feed at WTP 7.0 mg/l or more
Ferric chloride feed rate less than 10 mg/l Fe3+
Raw water temp 23 degrees C or more
Raw water TOC levels above 8.0 mg/l
Raw water coliform over 5000 counts/day
Positive bacteria test in dist. system (boil water notice)
Water demand less than 15 mgd
2015
Softening bypass stream over 20% of plant flow
Ozone system not feeding optimally
Using full water storage capacity of WSR & CSR
Chlorine feed at WTP 7.0 mg/l or more
Ferric chloride feed rate less than 10 mg/l Fe3+
Raw water temp 23 degrees C or more
Raw water TOC levels above 8.0 mg/l
Raw water coliform over 5000 counts/day
Positive bacteria test in dist. system (boil water notice)
Water demand less than 15 mgd
Dates of occurrence
Expected dates of occurrence based on past data
Compliance sampling date
Factors under Flint staff control
Flint River characteristics
System factors

ACTION PLAN

The City of Flint has signed an agreement with the Karegnondi Water Authority (KWA) to purchase raw water drawn from Lake Huron. The KWA system is currently under construction and expected to be operational by late 2016. The water supply from Lake Huron will have entirely different water quality characteristics from the Flint River and those characteristics are expected to yield drastically reduced DPB formation. With that, non-structural options to help reduce THM levels are much preferred over solutions requiring new construction. Therefore, two categories of actions have been devised: Stage 1 being actions that can be completed relatively quickly without major construction and Stage 2 consisting of either long term actions or solutions requiring major construction. The City is actively working to complete Stage 1 actions as soon as possible. Stage 2 actions are to be implemented only if Stage 1 actions are ineffective in adequately reducing TTHM levels and therefore Stage 2 is contingent upon the outcome of Stage 1. As of the date of this report, status updates for action items are shown in red.

Stage 1 – Immediate Actions

- Hire third party water quality expert to complete independent 'water audit'
  - The City hired Veolia Water to review all water quality related operations, procedures, actions taken and planned responses. Recommendations from Veolia were provided in a report and technical memo dated 3/12/15 and 3/30/15 respectively.
- Obtain an in house THM analyzer to allow regular operational monitoring of THM levels
  - THM analyzer was installed 2/17/15.
- Hire ozone system manufacturer to troubleshoot ozone system
  - Manufacturer and controls programmers performed on site evaluations followed by corrective modifications in January 2015.
- Bench scale jar testing
  - Match existing process and assess possible areas of improvement
    - Existing process was simulated and an evaluation of existing chemical feed dosages was completed by LAN.
    - Existing process TOC profile was developed by Veolia.
  - Simulate potential modifications to treatment process
    - Soda ash softening evaluation completed and PAC feed testing was completed by LAN.
  - Evaluate coagulation and flocculation polymer aid feeds to assist with TOC removal
    - Evaluations of polymer aids completed by LAN and PVS Technologies.
- WTP operational changes
  - Discontinue softening bypass stream to reduce chlorine demand
    - Operational directive has been set to soften no less than 80% of flow.
  - Disinfection of filter beds to reduce chlorine demand
    - Utility Service Group contracted by City and condition assessment completed. Controls improvements have been completed.
  - Begin coagulation and flocculation polymer aid feeds to assist with TOC removal if bench scale test results are positive
    - Jar testing completed to date has not indicated a meaningful benefit to feeding coagulation/flocculation polymer aids. Increased ferric doses have been implemented at the WTP based on positive jar test results.

- Increase water main flushing efforts to minimize stagnant water
  - Flushing efforts are ongoing as needed based on chlorine residual levels measured in the system.
- Water system modeling to identify areas with high water age and potential solutions
  - The water model has been improved and preliminary results, including system wide water age, have been produced. Water demand updates and reconciliation with operator's data are underway with expected completion in mid June, 2015.
  - Cedar Street Pump Station potential recirculation
    - Water model analysis to be completed Sept-Oct, 2015.
  - West Side Pump Station potential recirculation
    - Water model analysis to be completed Sept-Oct, 2015.
  - Storage tank volume use
    - Operating levels of West Side and Cedar Street reservoirs have been lowered to reduce water age. Possible elimination of WS or CS to be evaluated Sept-Oct, 2015.
  - Possible broken closed valve locations
    - Model has been updated with known broken valve locations. Model results are being evaluated for indications of other possible broken valves. City has also initiated valve assessment program.
  - Locations in need of flushing
    - High water age areas have been identified in the water model. Further evaluation is expected to be done by November 1, 2015 to determine most effective flushing points.

Stage 2 – Contingent Actions

- Replace filter media with granular activated carbon (GAC) media
  - Filter anthracite media was replaced with GAC media July – August 2015.
- Fix ozone system
  - Repairs have been made to gauges and programming and the system is producing proper ozone and functioning under manual operation. Further minor repairs are planned for the 1st quarter 2015 to allow automatic operation.
- Start feeding coagulation and flocculation polymer aids to lower TOC, if not completed in Stage 1
  - Polymers evaluated by LAN did not demonstrate notable benefit.
  - PVS Technologies evaluated a proprietary polymer that showed little benefit.
- Convert to lime and soda ash softening
  - Option deemed unnecessary due to effectiveness of new GAC media.
- Change disinfectant to chloramine or chlorine dioxide until KWA
  - Option deemed unnecessary due to effectiveness of new GAC media.
- Install pre-oxidant feed (permanganate) at intake to optimize ozone disinfection
  - Option deemed unnecessary due to effectiveness of new GAC media.
- Implement advanced treatment for THM precursor removal
  - Option deemed unnecessary due to effectiveness of new GAC media.

- Increased main flushing based on water modeling results
    - Water model analysis to be completed Sept-Oct, 2015.
- Continue valve replacements with water model assistance
    - Water model analysis to be completed Sept-Oct, 2015.
- Emphasize cast iron pipes on water main replacement priority list
    - Flint has bid replacement of over 2 miles of 24" steel pipe along Dupont and Bishop Streets to be completed when and if the City can allocate funds. The water main section is considered a critical transmission main, and is expected to contribute to decreases in water age when complete.

THM samples have been taken and tested 6 times for regulatory reporting since the City began using the Flint River for supply. Numerous additional sets of samples have been taken by the City for internal operational monitoring. Compliance samples were taken in May 2014, August 2014, November 2014, January 2015, February 2015, May 2015, and August 2015. The average of all eight sample sites in August 2014 was 142.1 ug/l and the most recent average of samples taken in August 2015 was 63.6 ug/l. The MCL defined by the EPA is 80 ug/l.

I. BACKGROUND

The City of Detroit Water and Sewer Department (DWSD) has historically provided drinking water for the City of Flint and Genesee County. In the late 1990's growing concern regarding the reliability of the DWSD supply prompted the City of Flint to upgrade their existing water treatment plant (WTP). Those improvements, defined as Phase I, were completed in 2005 and were intended to allow the Flint WTP to operate, using the Flint River as the source, for an extended period of time in the event that supply from the DWSD was temporarily interrupted. Additionally, the Phase I improvements set the stage for Flint to break free from dependence on the DWSD supply and water charges over which they had no control.

A. WATER SUPPLY TRANSITION

1. Detroit Water and Sewer Department (DWSD)

Prior to spring of 2014, the Genesee County and Flint region had been provided drinking water by the DWSD. However, due to excessive cost increases and reliability issues with the DWSD system other options had to be explored.

2. Karegnondi Water Authority (KWA)

In 2010 the Karegnondi Water Authority (KWA) was formed for the purpose of developing a new water supply from Lake Huron to serve the region in lieu of the DWSD supply and the City of Flint elected to join. The KWA expects the new system which is currently being constructed to become operational by the fall of 2016.

3. Flint River – Interim Period

With a renewing water supply agreement between Flint and the DWSD being terminated by the DWSD (effective April 30, 2014) and the KWA system not expected to be operational until late 2016, the City of Flint decided to initiate operation of the existing WTP full time utilizing the Flint River as the interim water source. A variety of WTP improvements were necessary for the Flint plant to become a full time plant. For purposes of this report, Phase II improvements to the Flint WTP are improvements intended to allow the plant to operate full time with either the Flint River as the source or the KWA supply as the source.

B. TTHM VIOLATIONS

The EPA and MDEQ method of determining if TTHM sample results exceed the MCL uses a locational running annual average (LRAA). Flint's first TTHM violation was cited by the MDEQ following the third cycle of sampling completed in November 2014. Of the 8 sampling sites, 4 were in violation. At that time the MDEQ used the following calculation for determining if the MCL had been violated:

(2 x current quarter value + previous 2 quarter values) / 4 = Operational Evaluation Value

Flint has now completed tests for 6 quarters and a straight annual running average applies. Based on samples taken on August 18, 2015 there are no longer any sites in violation of the THM MCL limit. The August 2014 average across all test sites was 142.1 ug/l and the August 2015 average is 63.6 ug/l. Test results are tabulated in Table 2. HAA5 sample results are shown in Table 3, of which Flint has had no violations.

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TABLE 2 – TTHM TEST RESULTS (ug/L)								
Sample Location	**5/21/14**	**8/21/14**	**11/21/14**	**2/17/15**	**5/18/15**	**8/18/15**	**May/15 LRAA**	**Aug/15 LRAA**
WTP Tap	56	86	33	-	~35	~25	n/a	n/a
1) 3719 Davison McDonalds	162.4	145.3	58.6	16.2	51.4	75.5	67.9	50.4
2) 822 S. Dort Hwy BP Gas Sta.	75.1	112.0	36.2	19.9	46.1	54.9	53.6	39.3
3) 3302 S. Dort Hwy Liquor Palace	111.6	127.2	33.3	16.8	63.5	53.2	60.2	41.7
4) 3606 Corunna Taco Bell	79.2	181.3	33.9	18.1	54.7	61.9	72.0	42.2
5) 2501 Flushing Univ. Market	106.4	196.2	93.6	24.5	59.8	70.6	93.5	62.1
6) 3216 MLK Salem Housing	82.2	112.4	50.1	28.5	72.7	90.3	65.9	60.4
7) 5018 Clio Rite Aid	88.2	144.4	53.6	19.2	60.5	59.5	69.4	48.2
8) 6204 N. Saginaw N. Flint Auto	96.5	118.3	41.1	14.9	45.2	42.6	54.9	36.0

TTHM MCL = 80 ug/l

TABLE 3 – HAA5 TEST RESULTS (ug/L)								
Sample Location	**5/21/14**	**8/21/14**	**11/21/14**	**2/17/15**	**5/18/15**	**8/18/15**	**May/15 LRAA**	**Aug/15 LRAA**
WTP Tap	36 (taken June 14, 2014)						n/a	n/a
1) 3719 Davison McDonalds	64	43	16	9.0	16	15	21.0	14.0
2) 822 S. Dort Hwy BP Gas Sta.	38	40	21	9.0	16	11	21.5	14.3
3) 3302 S. Dort Hwy Liquor Palace	52	31	15	9.0	17	14	18.0	13.8
4) 3606 Corunna Taco Bell	50	24	15	9.0	16	13	16.0	13.3
5) 2501 Flushing Univ. Market	55	17	24	9.0	15	13	16.3	15.3
6) 3216 MLK Salem Housing	41	25	5	2.0	10	2	10.5	4.8
7) 5018 Clio Rite Aid	49	30	17	9.0	22	15	19.5	15.8
8) 6204 N. Saginaw N. Flint Auto	48	37	18	9.0	17	10	20.3	13.5

HAA5 MCL = 60 ug/l

C. WATER TREATMENT PLANT RECENT IMPROVEMENTS & STATUS

1. Phase I WTP Improvements

Since 1965, the Flint WTP has remained a secondary or backup supply system to the DWSD primary supply. Typically the secondary supply for a public water system is expected to be needed only during emergency situations and normally is designed for short term operation such as providing the average daily demand for a few days. Conversely, Phase I improvements were designed with the intent to upgrade the Flint WTP in order to allow for an extended short term period (6 weeks) because of the perceived high risk that the DWSD supply would fail and remain out of service for an extended duration. Regardless, the Flint WTP was still intended to serve as a standby plant and as such the Phase I improvements lacked redundancies that would be required for a primary supply WTP.

2. Past Pilot Study & Testing

During design of the Phase I improvements a treatability study was completed by Alvord, Burdick & Howson, LLC (AB&H) in 2002. The Treatability Study evaluated the current treatment processes that are in place at the Flint WTP today with the Flint River as the source. The report recommended the following:

TABLE 4 – 2002 WTP TREATMENT RECOMMENDATIONS

Treatment	Purpose	Point of Application	Dosage (mg/l)
Sodium permanganate	Zebra mussel control	Intake	0.3
Ozone	Taste & odor removal, disinfection	Diffusor basin	1.5
Ferric chloride	Coagulation	Rapid mix	40
Coag aid polymer	Turbidity & TOC removal	Rapid mix	2.0
Floc aid polymer	Turbidity & TOC removal	Floc basin	0.05
Lime	Softening	Softening basin	175
Soda ash	Softening	Softening basin	52
Carbon dioxide	pH adjustment	Recarb basin	37
Media filters	Filtration	N/A	Na
Chlorine	Disinfection	Filter effluent	1.0

Of the recommended items, zebra mussel control, coagulant and flocculation polymer aids, and soda ash feed have not been incorporated into the treatment process.

3. Phase II WTP Improvements for Full Time Operation

Phase II WTP improvements are those needed to convert the Flint WTP from a back-up supply to a primary supply plant. A number of improvements have already been constructed as they were necessary to operate full time when treating water from the Flint River. The improvements under the title of Phase II that have been completed or are nearly complete include installation of the future raw water feed connection point and valving for the KWA supply, upgrades to the lime sludge lagoon, the lime sludge lagoon decant and disposal system, decant pump station and force main, installation of mid-point chlorination before filtration, new oxygen / nitrogen storage facilities for the ozone system, and upgrade of the electric feed sub-station.

Additional improvements to the Flint WTP that are to be completed to become part of the normal treatment process using water supplied by the KWA are:

- New coagulant feed system
- Electrical
  - Pump Station #4 upgrades (under construction)
  - SCADA and controls upgrades
  - Filter transfer pump station feeders
- Pump replacements and VFD installation in the low and high service pump station (under construction)
- Filter transfer pump station to Dort Reservoir
- Facility security improvements

II. SOURCE WATER EVALUATION

A. DATA ANALYSIS

Based on past data collected and the 2002 Treatability Study by AB&H, the Flint River water quality varies seasonally with higher hardness and alkalinity experienced in the winter. Higher magnesium concentrations are also experienced in the winter, adding difficulty to the settling process due to neutrally buoyant floc. General water quality average characteristics recorded for the 2002 Treatability Study as compared with average characteristics recorded in 2014 are shown in Table 5 below.

TABLE 5 – FLINT RIVER WATER QUALITY CHARACTERISTICS							
Period	**Turbidity NTU**	**TOC Mg/l**	**Alk. Mg/l**	**Hardness Mg/l as CaCO3**	**pH**	**Total Col. Count/day**	**THMFP Mg/l**
2001 Apr–Oct	7.9	9.4	215	272	8.1	870-1230 (7300 max)	410
2014 May–Oct	8.3	10.3 5/22/14	207	252	8.2	1900-9000 (48,300 max)	187

The Flint River characteristics do not appear to have changed significantly over the past 10+ years. Note that near the time Flint initiated withdrawal from the Flint River investigation by City staff revealed a sewer leak upstream of the plant that may have contributed to the total Coliform count. The leak was subsequently repaired.

B. CONCLUSIONS

Considering the minor changes in Flint River water quality, much of the information contained in the 2002 Treatability Study by AB&H remains relevant today. Data from that report assumed to be consistent today include the following:

- Flint River is influenced by groundwater from a dolomitic aquifer
- Hardness varies seasonally with higher hardness and alkalinity in the winter
- Hardness, alkalinity, magnesium concentrations tend to be reduced by run-off

In development of the 2002 Treatability Study, processes were simulated which resulted in low THM levels. Therefore, information contained in that report was used to assist with establishing a baseline jar testing procedure as discussed further in Section **III**.

III. TREATMENT PROCESS EVALUATION

A. EXISTING PROCESS DESCRIPTION

The existing WTP consists of an intake with screening from the Flint River, low lift pumping, ozonation, rapid mix, flocculation, settling, softening, recarbonation, filtration, storage and high service pumping. A process diagram is shown as Figure 1.

1. Intake

A 72" diameter pipe draws water from the Flint River through 2 traveling screens to the low lift pump structure. No chemicals are currently fed for Zebra mussel control or pre-oxidation as recommended by the 2002 Treatability Study. Manual removal of zebra mussels is more economical than installation of chemical feed equipment considering the short term need.

2. Ozone

There are 2 ozone generators designed to provide adequate ozone for a WTP flow of up to 36 mgd. There are 3 ozone contact basins. The ozone generators were designed to produce 900 lbs/day at 10% concentration and up to 1300 lbs/day at 6% concentration each. Prior to recent repairs, readings indicated a production rate of approximately 700 lbs/day at 4% concentration. It is possible that before the recent improvements the ozone feed might not have been optimized. In fact, it is known that less than optimal ozonation previously led to increased chlorine feed which would have contributed to THM formation.

3. Rapid Mix

East and West rapid mix chambers allow chemical feed prior to the flocculation basins. Each rapid mix chamber is equipped with a 5 hp mixer.

4. Coagulation / Flocculation

The WTP contains two equally sized flocculation basins, east and west, and each basin provides tapered or gradually slowed mixing from inlet to outlet. There are fifteen 2 hp mixers for each basin with VFDs to control mixing speed. The 2002 Treatability Study recommended feeding both coagulation and flocculation polymer aids. Neither polymer aid is being used today because turbidity and TOC removals have been sufficient to meet regulatory requirements.

5. Settling

Primary clarification takes place within 3 basins containing plate settlers. The settlers are operating as designed but are due for cleaning.

6. Softening

Again, there are two basins for softening: east and west. Each basin is 120' in diameter and contains a solids contact softening unit. Each softening basin/unit has a design capacity of 18 mgd. The east clarifier has an effluent weir imbalance that the City intends to fix when low demands allow for construction. Low lift pumping limitations, flow control to the basins, malfunctioning polymer feed pumps, control restrictions on residuals removal, and fluctuating demands have made it difficult for WTP staff to stabilize the softening process. Softening is accomplished by feeding lime. The decision was made by the City not to feed soda ash in order to remove non-carbonate hardness because acceptable hardness levels could be achieved with lime feed only and softening is short term until Lake Huron water becomes available. Lime and soda ash softening is a possible consideration to assist with TOC removal and thus reduce THM formation.

7. Recarbonation

Recarbonation for pH adjustment is accomplished in east and west recarbonation basins between and to the north of the softening basins. Carbon dioxide storage and feed equipment is located west of the recarbonation basins.

8. Filtration

Filtration is accomplished with 12 dual media filters, equally sized and designed to filter 3.0 mgd each. Sand and anthracite media was replaced in July and August 2015 with new sand and GAC at depths of 12″ and 18″ respectively. Prior to spring of 2014, the filters had been operated intermittently over the years due to the standby nature of the WTP and until recently, chlorine injection took place downstream of the filters. It is possible some microbial growth had developed in the filters leading to increased chlorine demand which could have contributed elevated TTHM. Late 2014, the City recently hired a contractor to upgrade the electrical controls for the filters and that work has been completed.

9. Disinfection

Disinfection is provided by ozonation and by feeding chlorine. Ozonation occurs at the front end of the WTP. Chlorine is fed prior to filtration and prior to finish water storage / high service pumping. The intermediate chlorine injection location was recently constructed under the Phase II, Segment 1 contract.

10. Clear Well & Pumping

The pump building sits adjacent to a 3 MG clear well and contains both low and high service pumps.

B. JAR TESTS / EXPERIMENTS

1. Approach

There are several well practiced methods by which DBPs can be reduced. First, the disinfectant can be changed to an alternate that has a lower tendency to form DBPs. Second, additional treatment systems such as activated carbon or air stripping (depending on the nature of the precursors) can be added to remove DBP precursors. Lastly, the existing treatment processes can be optimized to remove as much DBP precursor as possible. Of these options, optimizing existing treatment processes is the only strategy that does not require the construction of new and expensive facilities. It is anticipated that Flint will be receiving Lake Huron water by late 2016 and this water will have a completely different chemistry from the Flint River. Major process changes instituted to address THM levels using Flint River water are likely to be unnecessary for Lake Huron water and may even be inappropriate. Therefore, those options which require addition of new treatment processes are undesirable at this time. In recognition of this upcoming change in water source, efforts for this study have concentrated on improving the existing processes, rather than adding new ones. New treatment processes will only be recommended if operational changes to the existing treatment train prove ineffective.

Recent sample test results suggest that most of the DBPs are formed in the distribution system rather than within the treatment plant. Therefore, the most logical approach is to reduce the DBP formation potential (DBPFP) rather than simply lowering the levels of DBPs leaving the plant. During bench scale testing, formation potential (FP) levels were the primary indicator of success or failure of proposed process modifications.

2. Protocol

Bench scale pilot testing is intended to reflect actual plant operating and hydraulic conditions so the bench scale treatment units were sized based on various dimensionless factors to ensure the pilot treatment matched the actual system. Bench scale ozonation was not practical due to time and cost limitations. Therefore, water samples were withdrawn from the plant ozone basin effluent. These samples were transported to the laboratory and dispensed into square testing jars. The jars were used to simulate rapid mix, three-stage flocculation, and settling. Rapid mix and flocculation conditions were matched to the plant based on "Gt" values. The "G" value is a measure of the mixing intensity and is a function of mix time, viscosity of the liquid, and mixing power applied to the water. "Gt" then, is a size scaling factor where time has been accounted for. Settling time was scaled to match the shorter settling depth of the testing jars. After settling, samples were decanted from the test jars. The decanted samples were then lime softened; softening conditions were similarly matched on the basis of "Gt". Carbon dioxide was sparged into the samples to reduce the pH. The water was then vacuum filtered through filter paper, sized to simulate the plant's dual media filters. The samples were dosed with excess chlorine and allowed to react for seven days at 25° C before testing for DBPs to determine the formation potential.

The following conditions were applied during testing to properly match small scale testing to actual plant processes.

TABLE 6 – BENCH SCALE TEST MIXING INTENSITIES			
Process	**G**	**Duration**	**Mix RPM**
Ozonation	Plant	-	-
Rapid Mix	200	44 sec	160
Flocculation, Stage 1	50	9 min	55
Flocculation, Stage 1	25	9 min	30
Flocculation, Stage 1	12	9 min	19
Settling	N/A	10 min	-
Softening	TBD	10 min	-
Recarbonation	N/A	N/A	-

The primary variables during testing were chemical additions and chemical dosages. Specific chemicals and dosages used for initial testing conditions were selected to reflect current plant usage and the recommendations of the 2002 Treatability Study:

TABLE 7 – BENCH SCALE TEST CHEMICAL FEED RATES			
Chemical	**Current Usage**	**2002 Study**	**Test Values**
Ozonation	4.66 mg/l	1.5 mg/l	
Ferric Chloride	7.7 mg/l Fe^{3+}	40 mg/l Fe^{3+}	7.7 – 80 mg/l Fe^{3+}
Coagulant Aid Polymer	Not used	2.0 mg/l	1 – 2 mg/l
Flocculation Aid Polymer	Not used	0.05 mg/l	0 – 0.05 mg/l
Powdered Activated Carbon	Not used	N/A	20 – 100 mg/l
Lime	120 mg/l	175 mg/l	120 – 175 mg/l
Soda Ash	Not used	52 mg/l	0 – 52 mg/l
Cationic Softening Polymer	3.13 mg/l	Not used	3.13 mg/l
Anionic Softening Polymer	0.88 mg/l	Not used	0.88 mg/l
Fluoride	0.45 mg/l	1 mg/l	Not used
Carbon Dioxide	32 mg/l	37 mg/l	Fed to reach pH of 7.5 +- 0.3
Chlorine	6.3 mg/l	1 mg/l	10 mg/l

3. Considerations

The 2002 Treatability Study did not note significant formation of DBPs. This may be a function of different Flint River water chemistry at that time. However, recognizing the considerable differences in chemical usage and dosages between that study and current operations, those differences in chemical use and dosage are an obvious starting point for optimizing treatment to prevent DBP limit exceedance.

Although it is believed that optimization of current treatment can correct the DBP issue, should optimization of present treatment prove insufficient, alternate residual disinfectants (chloramines and chlorine dioxide) could be investigated as additional treatment measures.

4. LAN Test Results

Two rounds of jar testing were completed by LAN during the weeks of December 15, 2014 and January 26, 2015. Detailed test data is included in Appendix A. Testing results can be summarized as follows:

- Increased dosages of ferric chloride resulted in higher reduction of THMFP.
- The currently utilized feed rate of lime at 120 mg/l is appropriate
- Softening with soda ash in addition to lime resulted in minor additional THMFP reduction – in the range of 0% - 10%.
- The benefits of using a cationic polymer during softening at a dosage range of 0.31 - 3.13 mg/l to help reduce THM's are unclear
- The benefits of using an anionic polymer during softening at a dosage range of 0.09 – 0.88 mg/l to help reduce THM's are unclear
- Feeding PAC was ineffective in reducing THMFP within the dosage range of 20 – 100 mg/l.

5. Testing by Others

In addition to jar testing completed by LAN, the chemical supplier who provides ferric chloride for the City, PVS Technologies, ran tests using their recommended flocculant polymer aid. Plus, Veolia Water completed jars testing of their own the week of February 16th to analyze other process details and current WTP parameters. Experiments completed by PVS Technologies showed very little TOC removal beyond that obtained with straight ferric chloride feed.

6. Conclusions

Increasing the dose rate of ferric chloride is an operational change that can easily be implemented without the need for any additional equipment. Test results show that over 40% THMFP removal can be obtained with a dosage of 60 mg/l Fe^{3+} or higher. Increased dosing of ferric chloride would be most ideal coupled with regular raw water TOC monitoring so that TOC levels would dictate the appropriate ferric chloride feed rate.

Softening with soda ash in addition to lime is another option the City should consider if increased ferric chloride doses are not adequate to maintain THM levels under the MCL, particularly during warmer months. Again, monitoring of TOC in the raw water could provide useful information of when lime/soda ash softening is necessary.

IV. DISTRIBUTION SYSTEM EVALUATION

EPA guidance for the distribution evaluation portion of an OER is focused on identification and isolation of a specific portion of the distribution system that led to the exceedance. The circumstances of Flint's apparent pending TTHM exeedances are unusual in that a new supply has been implemented which clearly corresponds to the high TTHM sample results. Although the new source is one element in increased TTHM levels, value remains in evaluating the distribution system since water age is also a critical factor. Additionally, there may be distribution improvements that can be made to help alleviate the problem.

A. INFRASTRUCTURE

1. Piping

According to the most recent MDEQ Sanitary Survey, the distribution system is estimated to contain 70% cast iron, 20% ductile iron, 2% concrete and 8% steel water mains. Based on discussions with City staff, the percentage of cast iron pipe may be higher than that stated in the MDEQ Sanitary Survey. Unlined cast iron pipe can become pitted, allowing colonization sites for microorganisms leading to chlorine demand. Additionally, much of the piping in the system is aged and in poor condition. Increased chlorine demand could be resulting from biofilm in older pipes and from main breaks/repairs. The extent of contribution is not known but any water main replacement project will decrease chlorine demand somewhat if constructed properly. Unfortunately, water main breaks may also assist with decreasing water age by providing unintentional flushing. All things considered, it is impossible to quantify the impact existing piping has on THM formation without extensive research and long term study.

The City utilizes City Point software and GPS equipment to document main breaks and prioritize replacements. However, main break information is more pertinent to rusty water complaints and has little relevance to THM levels. Areas that have been targeted for main replacements include the transmission main from the WTP west to Dupont and south to the West Side reservoir, Fenton Road, Atherton Road, Dort Highway, Averil Street, and Boulevard Drive.

2. Storage

There are 4 finish water storage tanks and 1 raw water tank as tabulated below:

TABLE 8 – STORAGE TANKS

Name	Type	Water	Volume (MG)	Operating		Absolute	
				LWL	HWL	Bottom	OF
Dort Reservoir	Ground	Raw	20	-	-	730	750
WTP Tank	Elevated	Finished	2	883.0	896.0	863.0	898.0
WTP Clear Well – PS #4	Ground	Finished	3	11'	15'	708.5	726.0
Cedar Street Reservoir	Ground	Finished	20	-	11'	737.2	757.2
Westside Reservoir	Ground	Finished	12	-	12'	761.8	779.0

The MDEQ typically recommends providing a minimum finish water storage volume of 1/3 the maximum daily demand (MDD). According to the 2013 MDEQ Sanitary Survey, the 5 and 10 year MDDs are 21.57 mgd and 30.05 mgd respectively. A common rule of thumb for clear well storage volume at a WTP is 10% of the design flow rate. Another general guideline for reliability is to provide total storage to allow for 2 X the average daily demand plus fire flow demand. For this analysis, fire flow is assumed to be 2,500 gpm for either one industrial fire (2,500 gpm) or a combination of one residential (1,000 gpm) and one commercial (1,500 gpm) fire at a 4 hour duration which results in a total volume of 600,000 gallons. These go-by approximations are summarized below with the applicable flow rates and are compared to the existing storage volumes currently being utilized.

Common Practice	Flow Rate	Recommended Volume by ROT	Volume In Use
Clear well 10% of Design Flow	18 MGD	1.8 MG	3.0 MG
Finish Storage = 1/3 MDD	30.05 MGD	10.0 MG	37 MG
Total Storage = 2 * ADD + FFD	13.87 MGD	28.3 MG	57 MG

Based on the values above, it appears the storage volume used in the Flint system could be decreased without negatively effecting reliability. The appropriate volumes of individual tanks will be further evaluated using the water system model and discussed in Section V (C).

All reservoirs have baffling to minimize stagnant water. Also, all tanks have been maintained and are in reasonable condition. The Westside reservoir has an exposed roof that is in need of rehabilitation, but its current condition has no influence on THM formation.

3. Pump Stations

All pump stations are in good condition but pumps are generally oversized. As an independent consideration, oversized pumps are not a contributing factor to high THM levels. Control of pumps and pressure zones are discussed in detail below.

B. OPERATIONS AND MAINTENANCE

1. Pump Station & Storage Operations

Pump stations and storage tank levels are controlled as shown in Table 9.

TABLE 9 – PUMP STATION CONTROLS

PS Name	Control Point	On Point	Off Point
PS No. 4 Raw	Operator	-	-
PS No. 4 Finish	Match plant flow	-	-
Westside	System pressure (elevated tank)	22.5′	33′
Cedar Street	System pressure (elevated tank)	22.5′	33′
Torrey Road	Distr. – Brown/Bradley	< 45 psi	> 45 psi

Prior to the first TTHM violation, Cedar Street and Westside pump stations were operated as needed and were alternated. Typically, Cedar Street was run in the morning and Westside was run in the evening and reservoirs for each were filled during low demand periods at night.

Westside, Cedar Street and Torrey Road pump stations are used to boost system pressure when high demands warrant it, but there are not well defined pressure zones within the system. Therefore, the possibility exists that water is being recirculated allowing for increased water age.

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2. Booster Disinfection Practices
Booster disinfection is provided at the Cedar Street and Westside pump stations. When sustained residuals are not provided by chlorine feed at the WTP, sodium hypochlorite is applied at the reservoirs while being filled.

3. Changes in System Demands
Water demands in the City have been declining since the 1960's as the population has dropped. As a result, many of the water system components are oversized including storage tanks and water mains which both increase the time for water to reach the user.

From a short term perspective, Flint demands tend to increase in summer as is ordinarily expected but also in the winter due to water main breaks. The MDD for Flint often occurs in winter. Regarding THM formation, with lower temperatures and higher flows in the winter, THM levels taken at the distribution sample points are expected to be lowest for February sampling quarters than all others.

C. WATER SYSTEM HYDRAULIC MODELING

As part of this report, the City provided a hydraulic water model, originally developed by Potter Consulting, for LAN to update. Thus far, LAN has modified the model to be capable of extended period simulations, modified controls to reflect current operations, revised the piping to include known broken valve locations, updated pump curves, checked pipe diameters, updated system demands, and developed preliminary water age results throughout the entire system. Water age shown in the revised model corresponds for the most part to TTHM levels at the sampling sites. However, LAN has also identified several issues affecting the model that require further attention to allow for usable and reliable results. Those issues include accurate quantification of lost water and confirmation of the status of valves throughout the system. Preliminary water age results are presented in Table 10. Revised results will be provided when the hydraulic model has been fully updated.

TABLE 10 – PRELIMINARY WATER AGE FROM WATER MODEL

Sample Point	Location	Address	Water Age (Hrs)	May/15 LRAA THM (ug/l)
1	McDonalds	3719 Davison	25	68
2	BP Gas Station	822 S. Dort Hwy	18	54
3	Liquor Palace	3302 S. Dort Hwy	14	60
4	Taco Bell	3606 Corunna	340	72
5	Univ. Market	2501 Flushing	305	94
6	Salem Housing	3216 MLK	45	66
7	Rite Aid	5018 Clio	41	69
8	N. Flint Auto	6204 N. Saginaw	37	55

It is anticipated that topics shown below in italicized font will be detailed after the model is updated in Sept-Oct, 2015.

1. Simulation of Existing System
Match existing conditions. Chlorine and THM data may be used to verify model results. We have chlorine feed data at plant and residuals at 10 locations in each MOR, May 2014 – July 2015.

2. Identification of Water System Deficiencies

Specific issues to look at:

- *Water age in entire system*
- *Possible recirculating water through pump stations*
- *Use of storage tanks – volumes in particular*
- *Indications of broken valves*
- *Effectiveness of booster disinfection*

V. RECOMMENDATIONS TO MINIMIZE FUTURE OEL EXCEEDANCES

A. SOURCE

The City of Flint has already committed to the change from the Flint River as the water source to Lake Huron under the KWA system, planned for late 2016. The risk of future TTHM limit violations will decline substantially with the use of water from Lake Huron due to much lower DBP precursors. It is important to recognize that the Flint River will become strictly an emergency supply when the KWA supply becomes available and any investments toward the Flint River should be contemplated accordingly. Recommendations discussed below in this section apply to the Flint River as the source.

Reverting to supply from the DWSD until the KWA supply is available as an option. However, based on information provided by the City of Flint, the annual cost to receive water from the DWSD would be at least $16,000,000/year or $1,333,000/month. Therefore, utilizing the DWSD for interim supply is cost prohibitive under the terms defined by the DWSD.

1. Watershed Management

A volunteer group entitled the Watershed Coalition performs various tasks related to managing the Flint River watershed such as spring cleanups and annual benthic studies to evaluate the river 'health'. No additional action is recommended at this time.

2. Monitoring

The City documents daily raw water flow, pH, alkalinity, carbonate and non-carbonate hardness, chloride, temperature, turbidity and coliform count as part of standard preparation of Monthly Operating Reports (MOR). WTP staff have obtained and installed TOC and THM analyzers. The THM analyzer is set up as an on-line plant tap monitor and operations personnel have begun taking samples most days to track TOC levels throughout the treatment process. It is recommended to implement TOC tracking as a strict daily procedure which would provide staff the data needed to establish correlations to predict distribution system THM formation.

3. Intake Operations

The 2002 Treatability Study recommended pre-oxidation in the form of sodium permanganate as a feed at the intake. It is possible the addition of a pre-oxidant such as hydrogen peroxide or some type of permanganate could enhance the ozone process. Veolia evaluated permanganate demand during jar testing the week of February 16th, 2014 and recommended implementation at a dosage of 0.5 mg/l – 1.2 mg/l to achieve 10% additional TOC removal.

4. Seasonal Strategies

Past data indicates the Flint River is influenced by groundwater and in particular, dolomitic spring water. The result is hard water with high concentrations of magnesium and sulfate. Also, hardness and alkalinity are higher during the winter. Upon initiation of supply from the Flint River, the City made the decision to soften with just lime to focus on removal of carbonate hardness. One potential modification that could assist with TOC removal and thus decrease THMFP would be lime and soda ash softening. A temporary caustic soda feed system is recommended to be put in place in case the need for optimized softening arises.

5. Upstream Contamination Issues

Upstream contamination issues are extremely difficult to prevent and even if detected are difficult to locate. Evaluation of raw water data collected for MORs is the easiest manner in which to detect upstream contamination issues because the data is already collected for treatment purposes. In fact, high total Coliform readings in the past have signaled potential issues that the City was able to identify and remove.

An upstream monitoring and warning system could be established to attempt to detect water quality issues or spill event type contamination early enough to adjust treatment procedures or cease intake prior to the contamination reaching the WTP. However, given the imminent conversion to the KWA supply, the period of full time use would likely be far too short to achieve payback on the capital expenditures.

B. TREATMENT PROCESS

1. Operational Recommendations

- Increase ferric chloride dosage: Previous testing in the 2002 Treatability Study, jar testing completed by LAN, and a review of 2014 ferric chloride dosages compared to THM levels leaving the WTP support that increasing the ferric chloride dosage would help reduce THM formation.
- Increased monitoring: Currently, the MDEQ does not require daily reporting of raw water TOC or finished water TTHM levels. However, daily tracking of such levels would allow the City to develop a correlation between the two, thus providing a predictive tool to help manage TTHM levels.
- Coagulation and flocculation polymer aids: The 2002 Treatability Study suggested the use of coagulation and flocculation polymer aids. These polymer aids were shown in the 2002 Treatability Study to increase TOC removal and thereby reduce THMFP but jar testing by LAN and PVS Technologies did not indicate clearly defined benefits. Addition of coagulation and flocculation polymer aids should be categorized as a future consideration that would require further evaluation.
- Discontinue softening bypass: In early summer of 2014 the City was bypassing a portion of flow around the softening basins because hardness levels did not warrant softening of the full stream. However, this practice was discontinued because it was believed the bypass stream was contributing to chlorine demand and preliminary data has supported that belief. Chlorine demand dropped 0.5 – 1.0 mg/l following elimination of the bypass stream in early November 2014.
- Soften with lime and soda ash: Research has shown that enhanced softening with both lime and soda ash may provide additional TOC removal. Veolia did not recommend this option after conducting jar tests.
- Disinfection of filter beds: Recommendation is no longer applicable since media has been replaced.
- Optimization of all existing treatment processes: Depending on bench scale testing conditions and results, slight modifications to all treatment processes might in order to replicate lower DPBFP.
- Discontinue or adjust softening anionic polymer feed: Some anionic polymers have been found to increase TOC. However, Veolia provided no recommendation to change polymers following their evaluation.

2. Infrastructure Change Recommendations

- Fix and/or replace faulty ozone equipment: Since the ozone equipment was installed it had not been used extensively on a full time basis. Following minor complications, the City hired the equipment manufacturer and a programmer to troubleshoot the system. Replacement of faulty gauges and redesign of the control program have allowed the system to operate properly since January 2015.
- Replace filter media with GAC media: GAC media could help reduce THM levels by reducing both TOC and chlorine demand. For this consideration, the intermediate chlorine feed location should be relocated to a point downstream of the filters. The City elected to pursue this option and 6 filters were completed in July 2015 and the remaining 6 were completed in August 2015. Provisions are also being considered for adding more GAC media and/or regeneration of media next summer.
- Change disinfectant to chloramine or chlorine dioxide: If other options prove to be ineffective, conversion to another disinfectant should be fully evaluated. Various characteristics of chloramination indicate an advantage over chlorine dioxide, but a full analysis would provide clarity as to which would be preferred.
- Install pre-oxidant chemical feed: Hydrogen peroxide or a form of permanganate as a pre-oxidant can enhance the activity of the ozone. Chemical feed could be installed at the intake structure or low service pump station, depending on the reaction time required. Use of a pre-oxidant at the intake might also provide the additional benefit of disinfection credit for ozonation with the MDEQ if an ozone residual can be obtained at the ozone process effluent as a result.
- Repair upstream sewer leak: a sewer leak upstream of the WTP intake was discovered in early summer 2014 and has been repaired by the City.

C. DISTRIBUTION SYSTEM

Potential distribution issues related to water quality issues discussed in Section IV included old cast iron pipe, oversized infrastructure, and remote storage/pump station locations and operations that might be less than ideal. Recommendations to address those issues are offered in this section.

1. Manage Water Age

a) Storage Tanks

Considering the excess storage capacity discussed in Section IV, in the short term it is recommended that operational changes be implemented immediately to reduce the overall volume of water stored to decrease water age. Immediate operational recommendations include lowering high water levels of reservoirs other than the elevated tank, to reduce the total system wide usable storage volume to 30-37 MG.

In the long term, LAN recommends development of the most ideal options for water model evaluation. Excess storage volume and tank locations within the water system afford Flint numerous options to reduce the amount of storage volume utilized. As a starting point, two recommendations are presented below.

Option 1

- Take West Side reservoir and pump station out of service
- Cut storage volume used in half at Cedar Street reservoir
- Adjusted system wide storage volume would be 35 MG

Option 2

- Take Cedar Street reservoir and pump station out of service
- Adjusted system wide storage volume would be 37 MG

b) Residence Time in Pipes

Completely redesigning and replacing the water system to match today's demands is not feasible financially and would be a waste of infrastructure with remaining useful life. Going forward, it is recommended that any future main replacement projects be evaluated for possible downsizing. When the water model is fully updated, it will provide a valuable tool in determining which mains can be downsized and to what extent. Replacement of broken valves and valve exercising are also recommended, which are programs that have already been implemented into Flint's regular operations.

Operationally, hydrant flushing is recommended as needed to minimize water age in low flow areas. Again, the updated water model should be used to locate high water age areas and optimal flushing points.

2. Reduce Disinfectant Demand

Recommendations to reduce disinfectant demand are similar to those described above to reduce water age. Replacement of old cast iron pipes would lead to a reduction of disinfectant demand on the distribution side, but realistically can only be accomplished over a prolonged period of time. In the meantime, hydrant flushing is the most viable means of reducing disinfectant demand in piping. From a storage standpoint, all reservoirs and tanks should be regularly inspected and maintained to prevent entrance of any outside contamination that would contribute to disinfectant demand. Cleaning of all tanks is recommended as well as investigation into stagnant water prevention options.

3. Water Modeling of Recommendations [yet to be completed]

Determine best flushing locations to reduce water age
Evaluate changes in storage tank operations to reduce water age
Valves to close/add to improve pressure zones, reduce recirculation
Optimization of pump station use – smaller pumps? Shut down?
Evaluate booster disinfection

D. BOOSTER DISINFECTION

Decreasing chlorine feed at the WTP and adding booster disinfection in the distribution system is an alternative intended to reduce the reaction time at higher concentrations of chlorine to reduce DPB formation. Extensive looping and branching within the existing system complicate how to best implement and utilize booster disinfection. Water system modeling is recommended to gage the effectiveness of existing feed point locations and dosages. Further discussion and details will be provided when the distribution evaluation results are available.

E. CATEGORIZATION OF ACTIONS

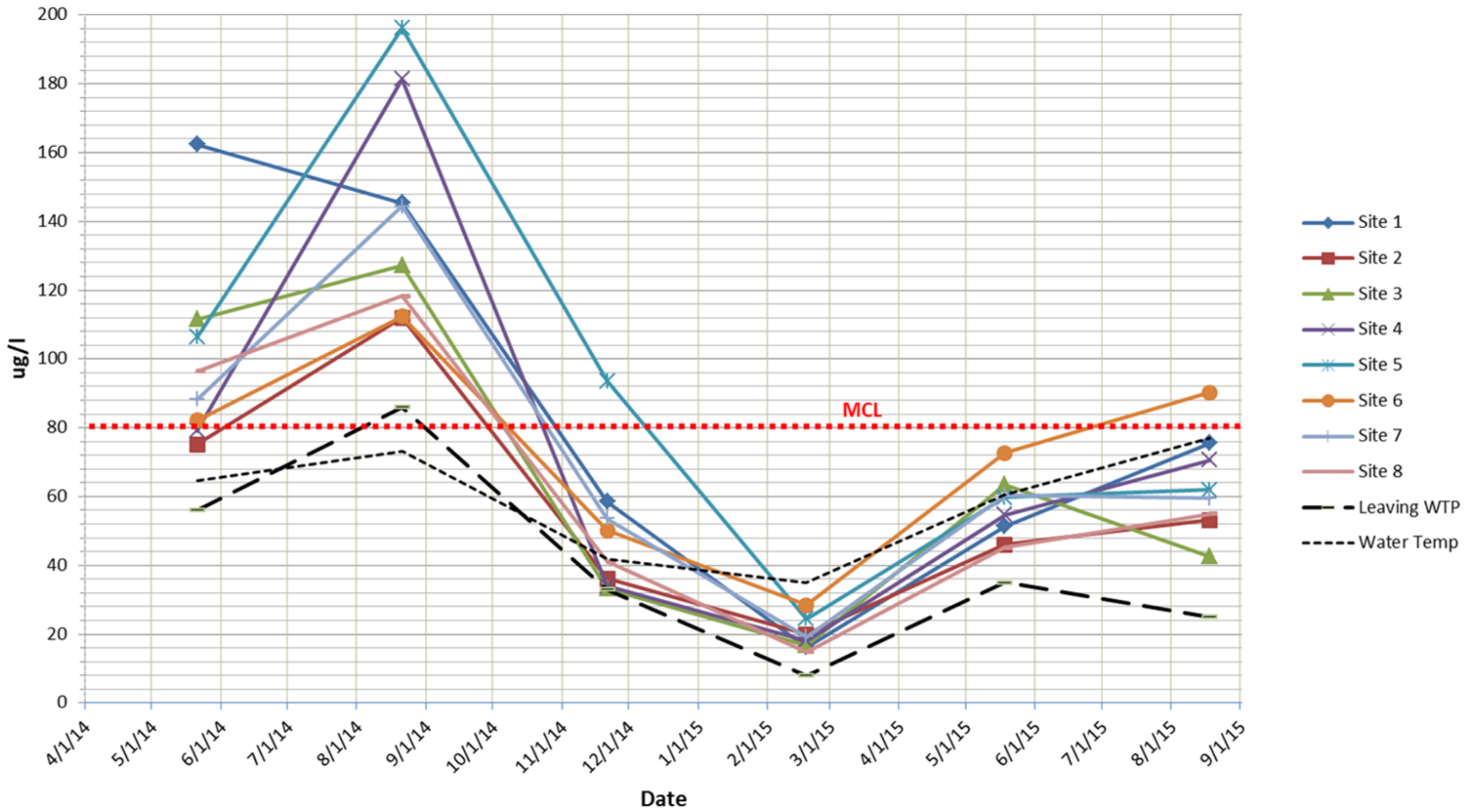
Considering that the Flint River is being used as the water source only until the KWA supply is available (expected late 2016), options to address high THM formation that require new construction or extensive time to implement are not preferred. On the other hand, the City understands THM sample results to date dictate that some action is necessary. Two categories have been developed to assist the City in prioritizing actions to take. Stage 1 consists of actions that can be completed relatively quickly without major construction and Stage 2 actions are either long term actions or solutions requiring major construction. Stage 1 actions are to be completed first followed by evaluation of the results prior to consideration of Stage 2 actions. Grouping of actions are shown in the table below.

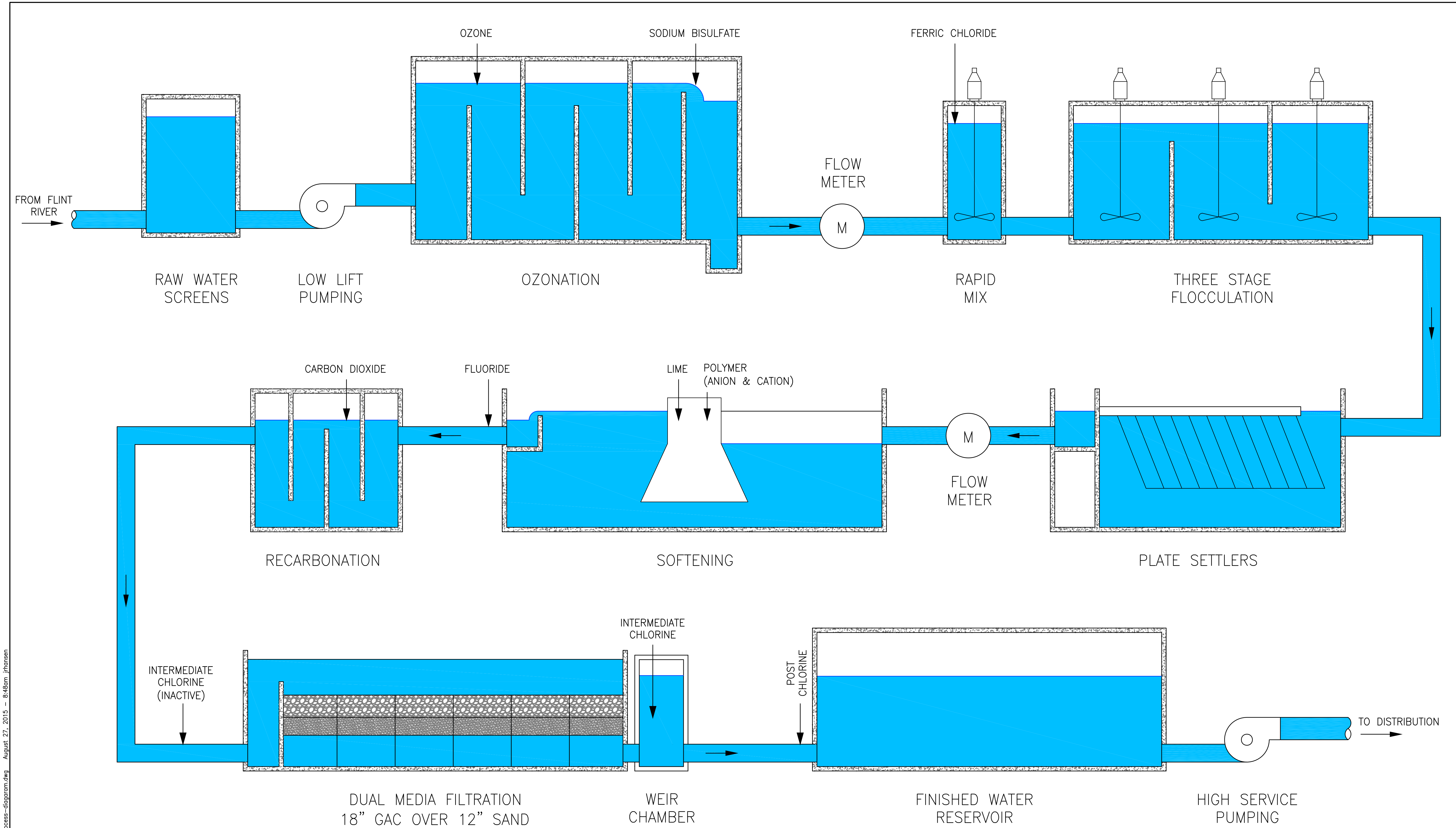
TABLE 11 – ACTION PLAN

	Action	Purpose	Status
Stage 1	Hire water consultant to complete 'water audit'	Third party review of actions and operations to make sure no options are being missed	Complete
Stage 1	Increased water quality monitoring – obtain THM and TOC analyzers	Provide information needed to adjust WTP operations to match changing raw water quality	Complete
Stage 1	Troubleshoot ozone feed system	Reduce chlorine feed and increase TOC removal	Complete
Stage 1	Bench scale jar testing	Optimize treatment process and evaluate possible modifications	Complete
Stage 1	Discontinue softening bypass	Reduce chlorine demand	Complete
Stage 1	Disinfect filters	Reduce chlorine demand	Complete
Stage 1	Increased water main flushing	Reduce water age / stagnant water	Ongoing
Stage 1	Water system modeling evaluation	Determine areas with high water age and reasons	Partially complete
Stage 1	Modify booster disinfection feeds, if appropriate	Decrease water age	Not yet evaluated
Stage 2	Repair ozone system	Reduce chlorine feed and increase TOC removal	Complete
Stage 2	Continue increased water main flushing	Reduce water age / stagnant water	Ongoing
Stage 2	Replace filter media with GAC	Reduce TOC and chlorine demand	Complete
Stage 2	Continue valve replacements based on water model	Reduce water age / stagnant water	Ongoing
Stage 2	Convert to lime and soda ash softening	Increase TOC removal	Future consideration
Stage 2	Change disinfectant to chlorine dioxide	Reduce THMFP	Future consideration
Stage 2	Install pre-oxidant feed at intake	Optimize ozone disinfection, reduce chlorine	Future consideration
Stage 2	Implement coag. & floc. polymer aids, if appropriate	Increase TOC removal	Future consideration
Stage 2	Place priority on replacing cast iron water mains	Reduce chlorine demand	Ongoing

Samples were taken August 18th, 2015 for the latest round of quarterly testing. The City has implemented many of the Stage 1 actions and installed GAC media in the filters and THM test results have significantly improved (decreased) since May and August 2014. All sampling results are shown on Chart 1.

CHART 1
THM Sampling Test Results





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Genesee County

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PLANNING ENGINEERING PROGRAM MANAGEMENT
1311 S. Linden Road, Suite B
Tel 810-820-2682 Fax 810-820-2703
www.lan-inc.com

CITY OF FLINT
WATER TREATMENT PLANT

REVISIONS

NO.	DESCRIPTION	DATE

FILE LOG

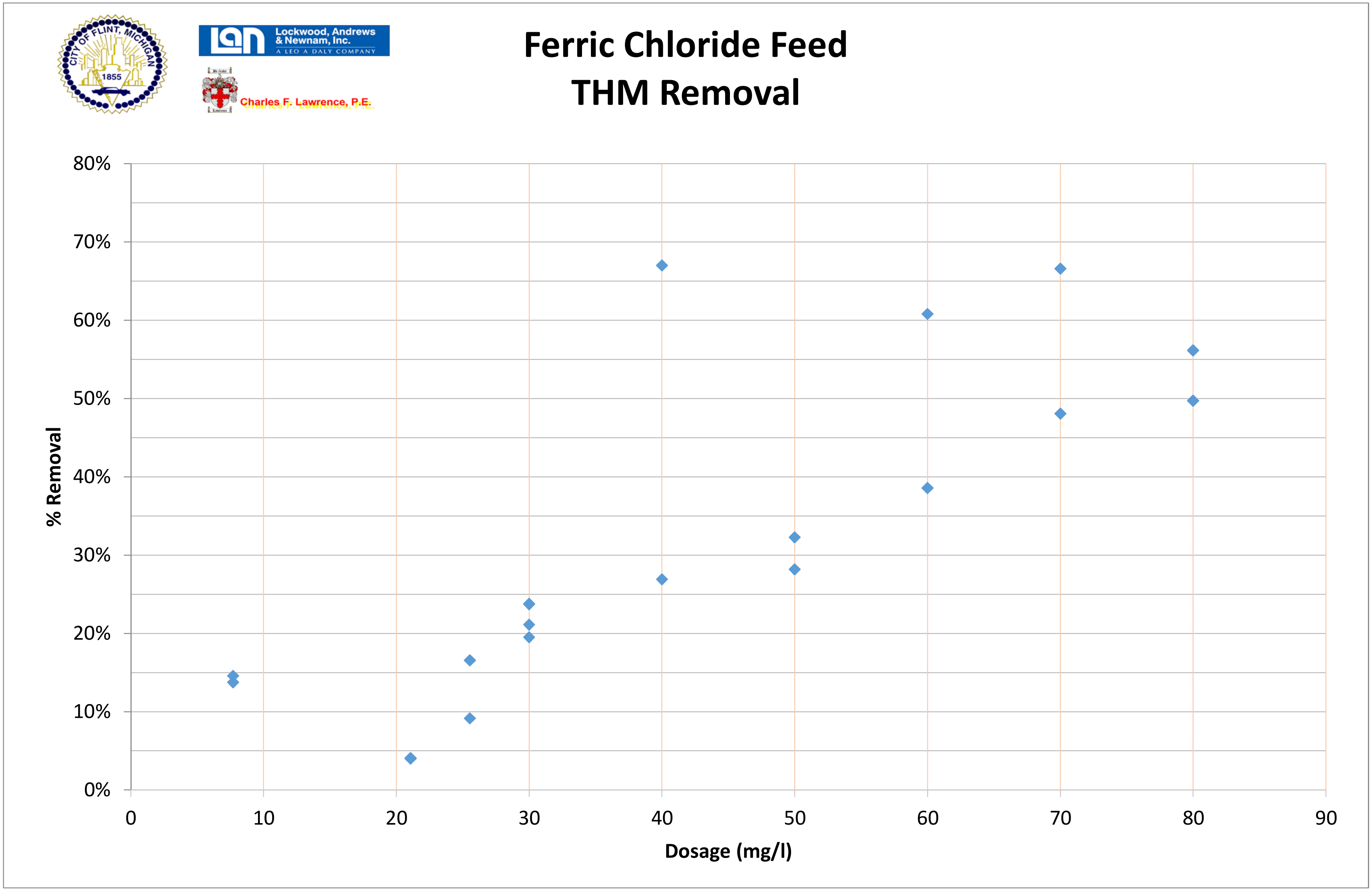
ACTIVITY	BY
Manager	JWG
Design	
Drawn	JRH
Check	JRH

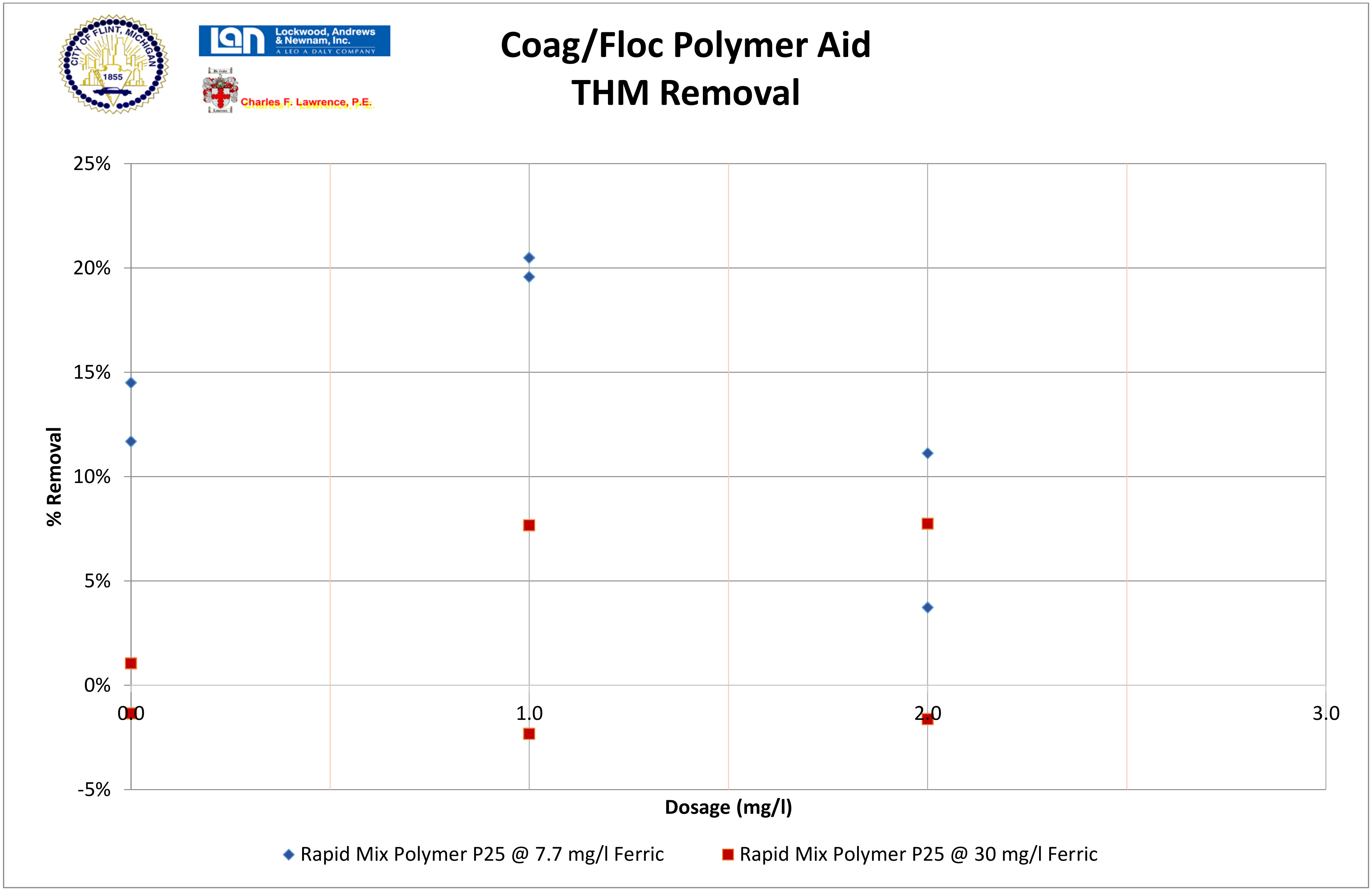
WATER TREATMENT PLANT
PROCESS DIAGRAM

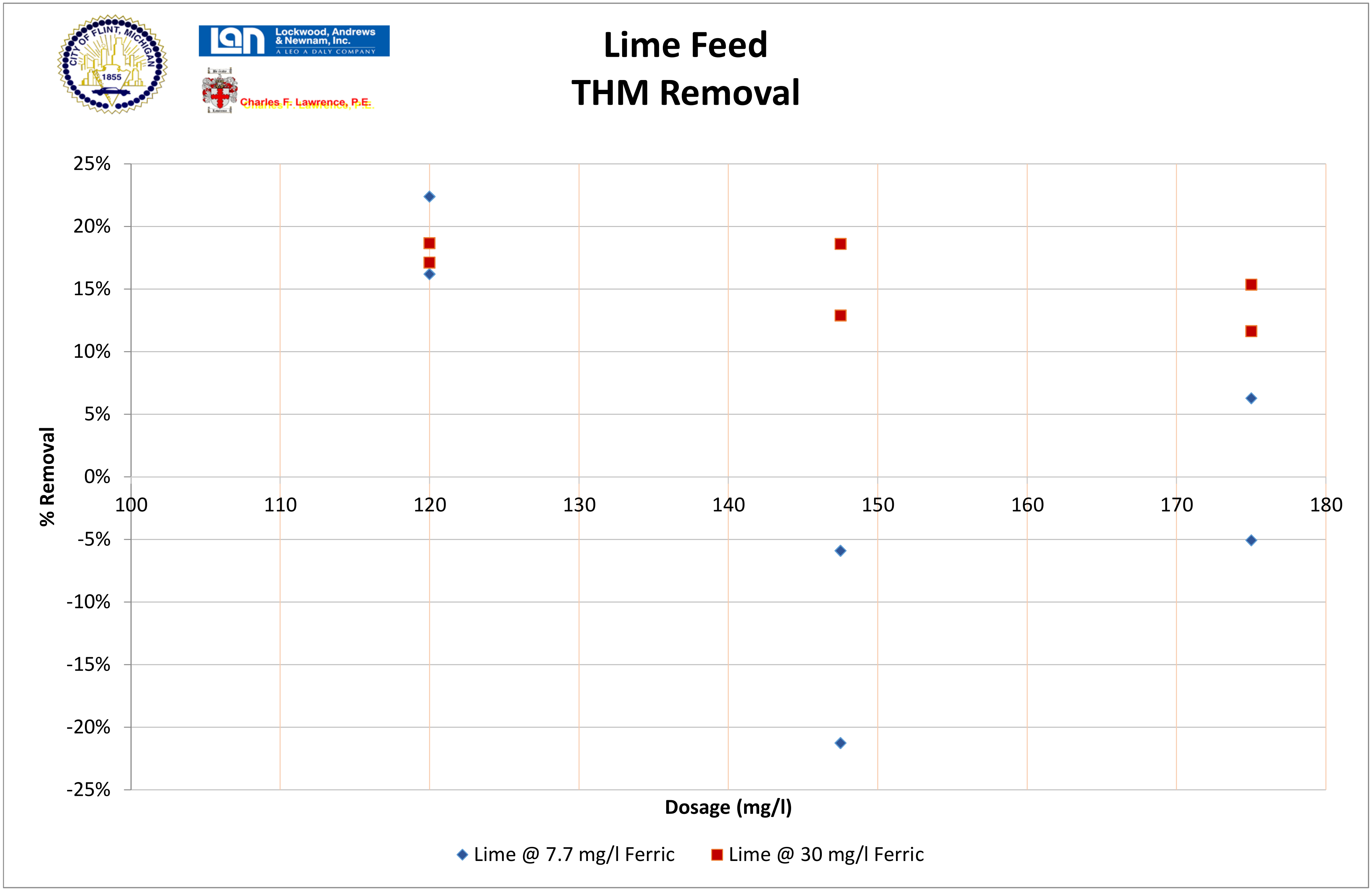
Project No. 130-10701-001
Date Aug. 27, 2015

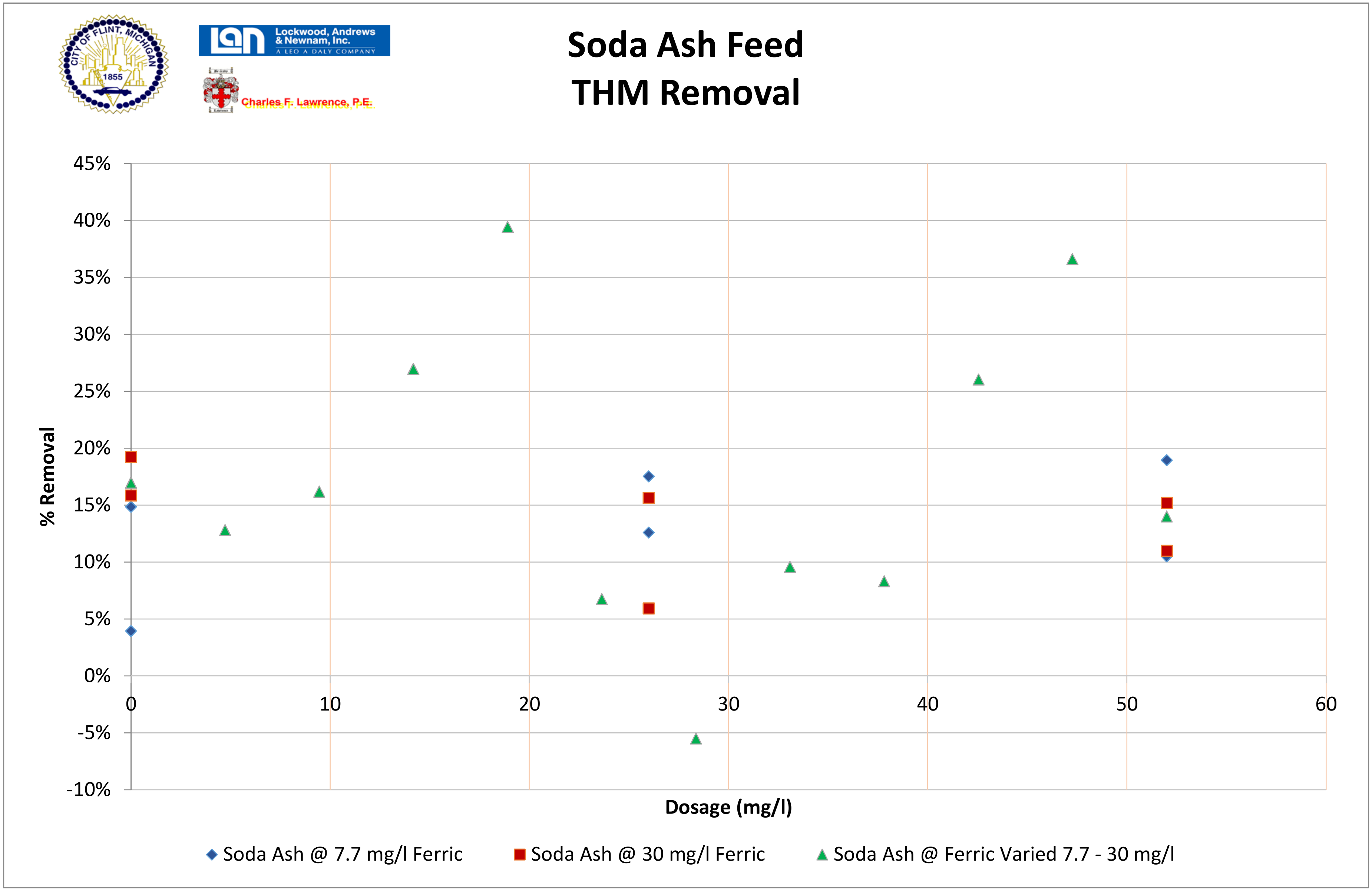
Sheet
FIG 1

APPENDIX A
JAR TEST DATA


Lockwood, Andrews & Newnam, Inc.
A LEO A DALY COMPANY
Charles F. Lawrence, P.E.
Ferric Chloride Feed
THM Removal
% Removal
80%
70%
60%
50%
40%
30%
20%
10%
0%
0
10
20
30
40
50
60
70
80
90
Dosage (mg/l)


CITY OF FLINT, MICHIGAN
1855
Lockwood, Andrews & Newnam, Inc.
A LEO A DALY COMPANY
Charles F. Lawrence, P.E.
Coag/Floc Polymer Aid
THM Removal
25%
20%
15%
10%
5%
0%
-5%
% Removal
0.0
1.0
2.0
3.0
Dosage (mg/l)
Rapid Mix Polymer P25 @ 7.7 mg/l Ferric
Rapid Mix Polymer P25 @ 30 mg/l Ferric


Lime Feed
THM Removal
Lockwood, Andrews & Newnam, Inc.
A LEO A DALY COMPANY
Charles F. Lawrence, P.E.
% Removal
25%
20%
15%
10%
5%
0%
-5%
-10%
-15%
-20%
-25%
100
110
120
130
140
150
160
170
180
Dosage (mg/l)
Lime @ 7.7 mg/l Ferric
Lime @ 30 mg/l Ferric



Lockwood, Andrews & Newnam, Inc.
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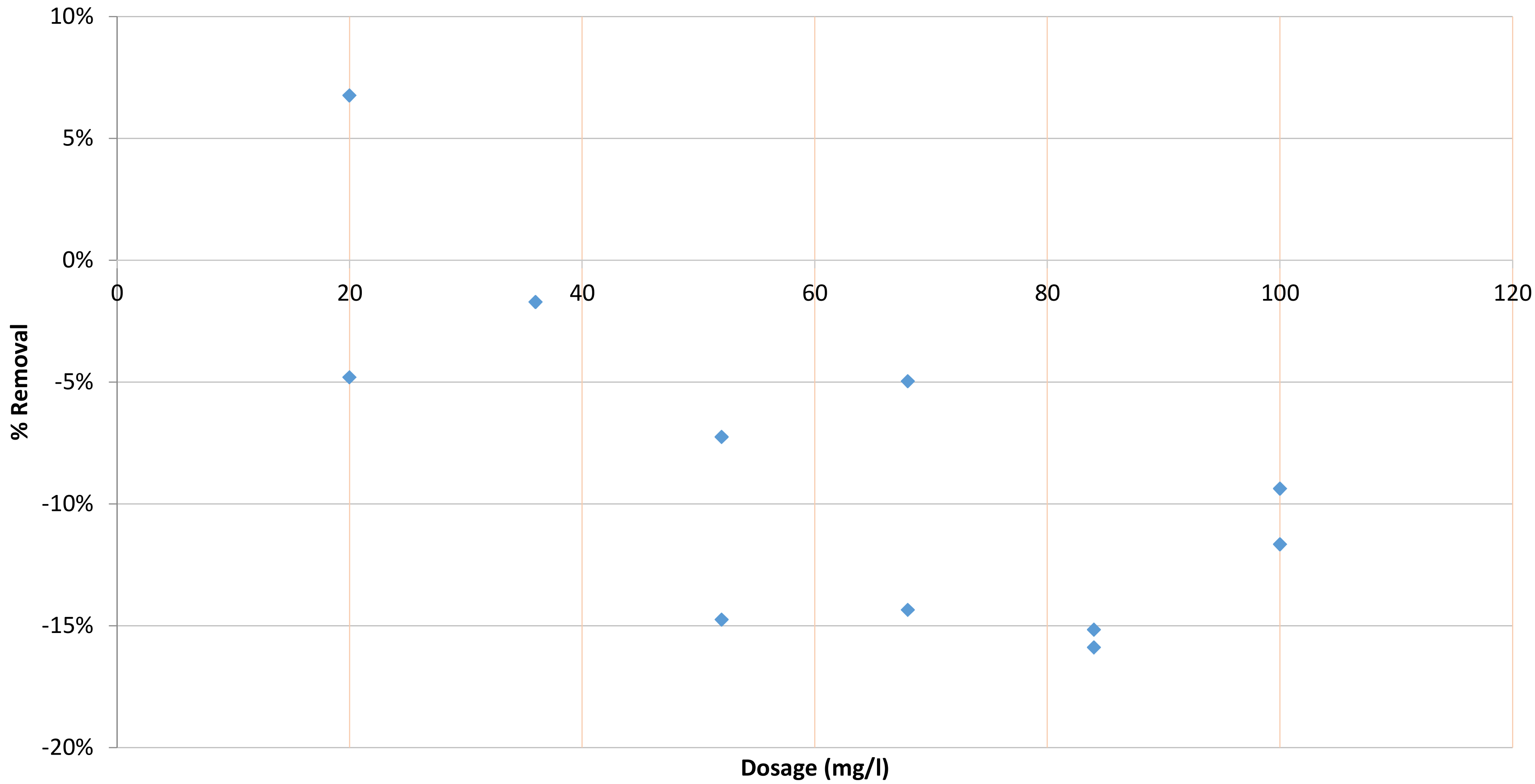
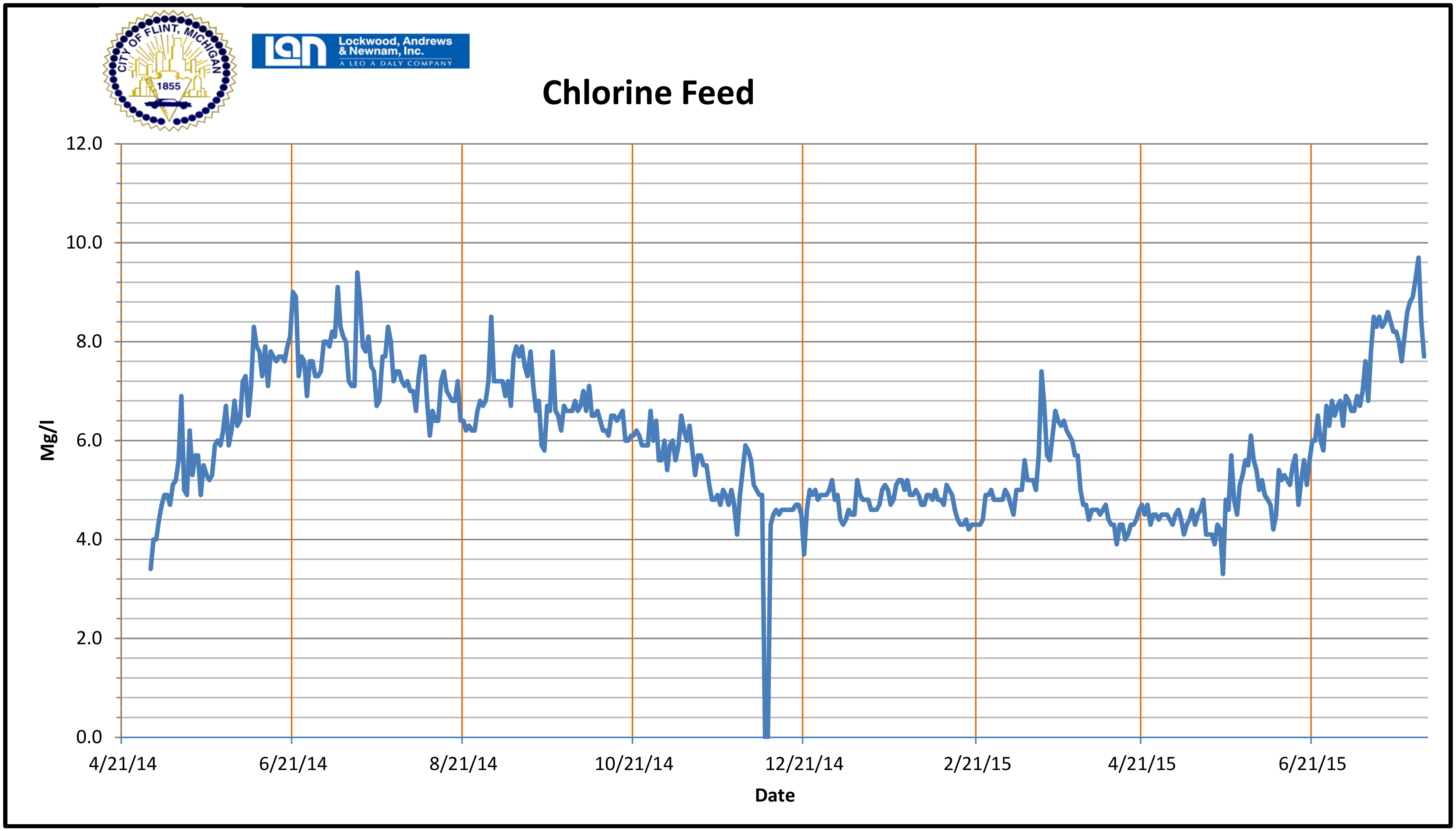
Charles F. Lawrence, P.E.
Soda Ash Feed
THM Removal
45%
40%
35%
30%
25%
20%
15%
10%
5%
0%
-5%
-10%
% Removal
0
10
20
30
40
50
60
Dosage (mg/l)
Soda Ash @ 7.7 mg/l Ferric
Soda Ash @ 30 mg/l Ferric
Soda Ash @ Ferric Varied 7.7 - 30 mg/l

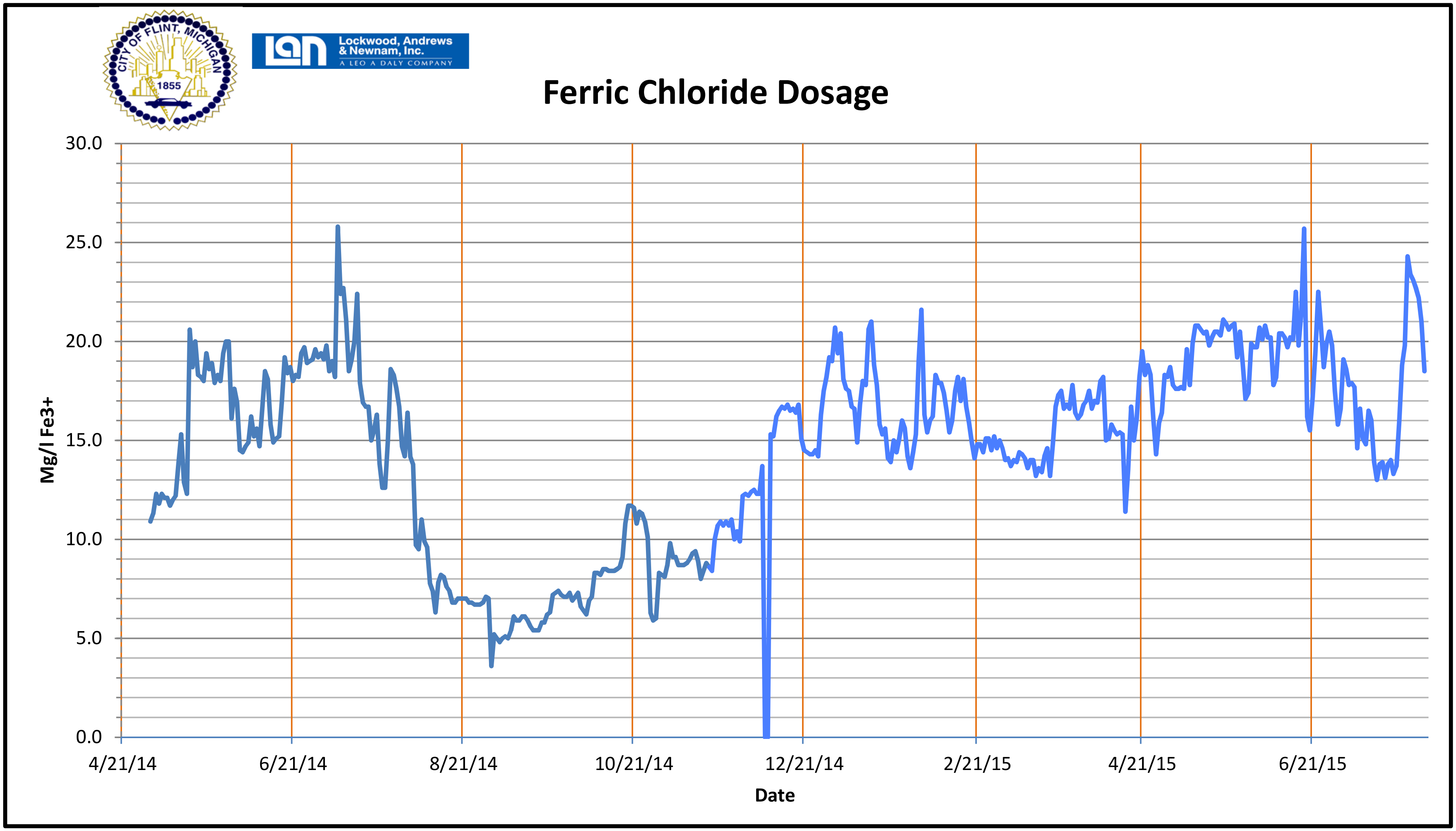
PAC Feed
THM Removal

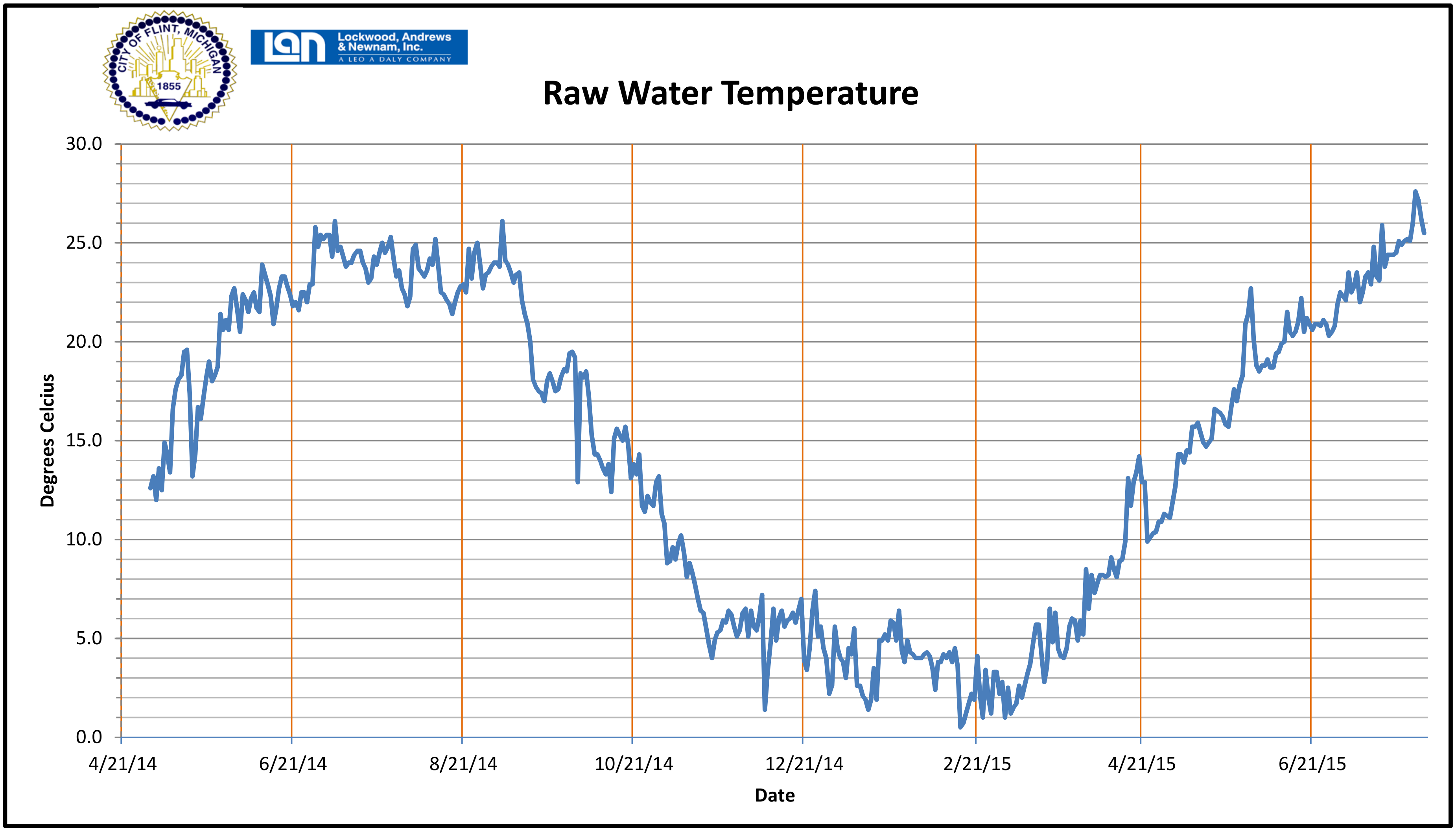


APPENDIX B
WTP DATA



CITY OF FLINT, MICHIGAN
1855
LAN
Lockwood, Andrews & Newnam, Inc.
A LEO A DALY COMPANY
Chlorine Feed
12.0
10.0
8.0
6.0
4.0
2.0
0.0
Mg/l
4/21/14
6/21/14
8/21/14
10/21/14
12/21/14
2/21/15
4/21/15
6/21/15
Date


CITY OF FLINT, MICHIGAN
1855
Lockwood, Andrews & Newnam, Inc.
A LEO A DALY COMPANY
Ferric Chloride Dosage
Mg/l Fe3+
30.0
25.0
20.0
15.0
10.0
5.0
0.0
4/21/14
6/21/14
8/21/14
10/21/14
12/21/14
2/21/15
4/21/15
6/21/15
Date



Raw Water Temperature
Lockwood, Andrews & Newnam, Inc.
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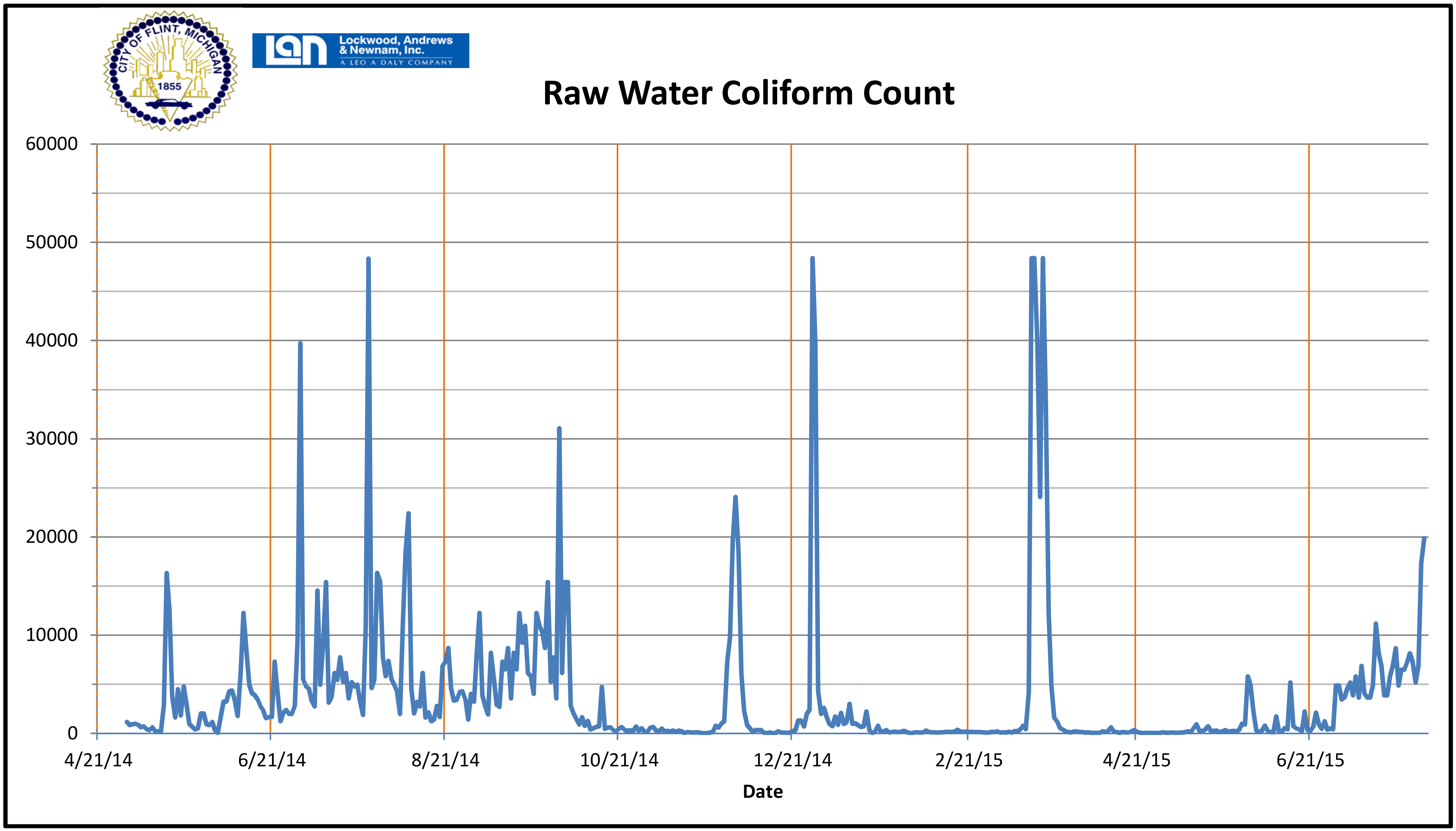
1855
Degrees Celcius
30.0
25.0
20.0
15.0
10.0
5.0
0.0
4/21/14
6/21/14
8/21/14
10/21/14
12/21/14
2/21/15
4/21/15
6/21/15
Date


Lockwood, Andrews & Newnam, Inc.
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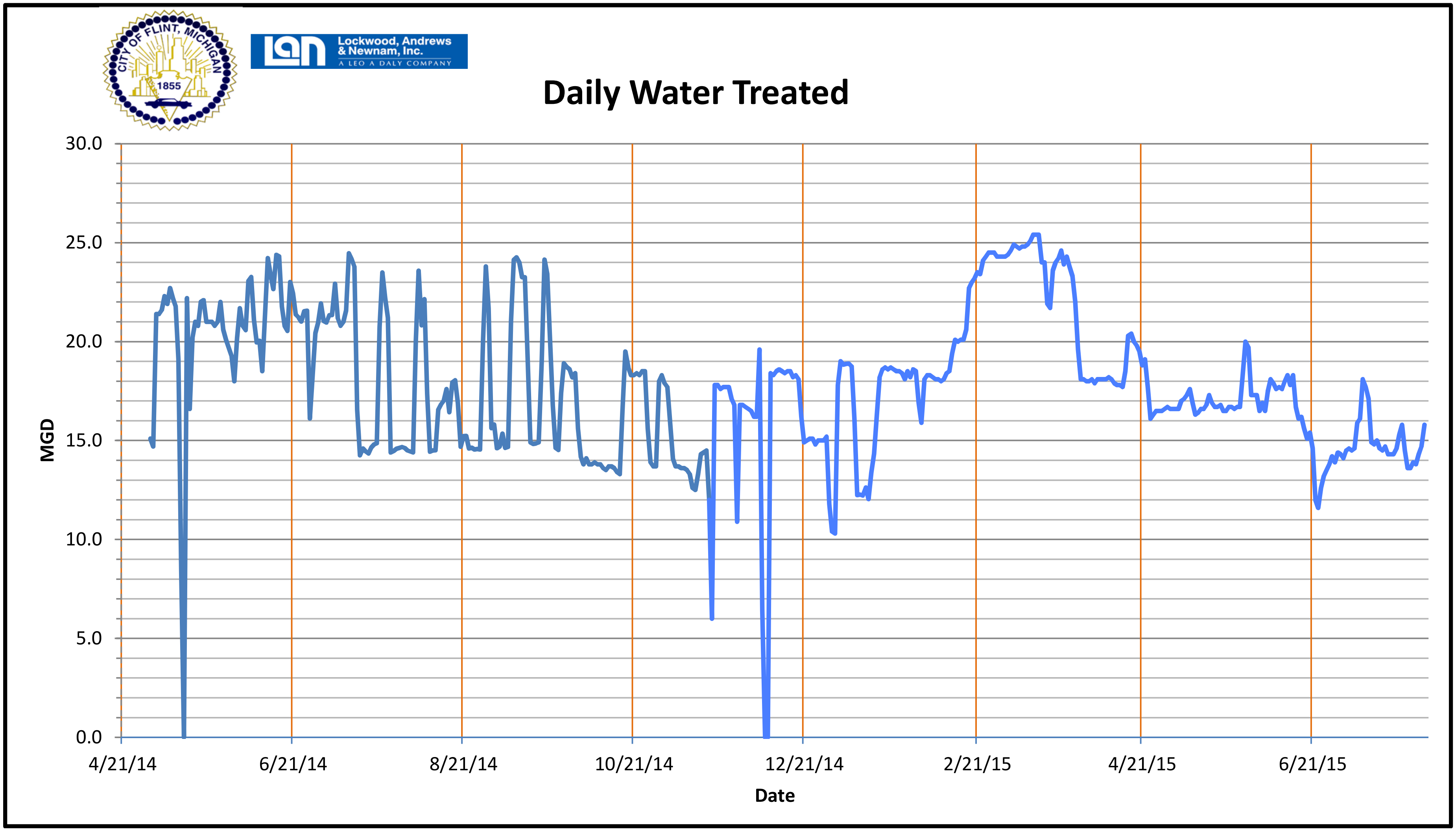
Raw Water Coliform Count
60000
50000
40000
30000
20000
10000
0
4/21/14
6/21/14
8/21/14
10/21/14
12/21/14
2/21/15
4/21/15
6/21/15
Date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CITY OF FLINT, MICHIGAN
1855
Daily Water Treated
MGD
30.0
25.0
20.0
15.0
10.0
5.0
0.0
4/21/14
6/21/14
8/21/14
10/21/14
12/21/14
2/21/15
4/21/15
6/21/15
Date

Operational Evaluation Report
Trihalomethane Formation Concern

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