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Rec'd 2-20-17

CONSENT

17-0182

January 30, 2017

PWS ID 4303648
Manitowoc-MC
Manitowoc County

Ms. Jennifer Hudon, Clerk
City of Manitowoc
900 Quay Street
Manitowoc, WI 54220

Mr. Nilaksh Kothari, General Manager
Manitowoc Public Utilities
1303 South 8th Street
P.O. Box 1090
Manitowoc, WI 54221-1090

Subject: REVISED 2016 Sanitary Survey Report for the Water Supply Serving the City of Manitowoc

Dear Ms. Hudon and Mr. Kothari:

The purpose of a sanitary survey is to evaluate the City of Manitowoc's source, facilities, equipment, operation, maintenance, and management as they relate to providing safe drinking water. The sanitary survey is also an opportunity to update the Department's records, provide technical assistance, and identify potential risks that may adversely affect drinking water quality.

On December 13 and 14, 2013, I conducted a sanitary survey of your water system. Also present were Rob Michaelson, Paul Aumann and Peter Dollhopf from MPU and Larry Landsness, Florence Olson and Corey Larson from the Department. On January 10, 2017, I met with Bill Jindra, from the City and Cindy Carter, Cara Zipperer and Dan Salm from MPU to discuss implementation of the cross connection and metering programs. On January 19, 2017, I met with Lisa Kuehn from the City to review well permits. At the completion of the survey, Rob Michaelson was briefed on the preliminary findings. This report outlines the final findings.

Significant Deficiencies

During the course of the sanitary survey, no significant deficiencies were identified. Significant deficiencies indicate noncompliance with one or more Wisconsin Administrative Code and/or represent an immediate health risk to consumers.

Deficiencies

During the course of the sanitary survey, no deficiencies were identified. Deficiencies are problems in drinking water systems that have the potential to cause serious health risks or represent long-term health risks to consumers. Deficiencies may indicate noncompliance with one or more Wisconsin Administrative Codes.

Recommendations

During the course of the sanitary survey, two (2) recommendations were identified. Recommendations are problems in the water system that may hinder your public water system from consistently providing safe drinking water to consumers.

Recommendation
1. The Department recommends routine maintenance of all chemical injectors. Please discuss recommended maintenance frequencies for the chlorine and phosphate injectors with your chemical supplier.
2. The polyphosphate used at Collector C is likely no longer effective as a corrosion control chemical because of its age. The Department recommends moving fresh AquaMag from your plant to Collector C during planned use of the well.

Non-Conforming Features

During the course of the sanitary survey, three (3) features that met code requirements at the time of construction, but would not be allowed in the current code, were discovered. This is referred to as a non-conforming feature. Correction is not required until a health risk is identified, problems with the operation of the water system occur as a result of this feature or this feature is located within a reviewable project. Non-conforming features are identified in sanitary survey reports so that you can plan and budget for them in the most cost-effective way.

Non-Conforming Feature
1. When pressurized chlorine gas is present, the leak detection equipment shall be equipped with an automatic chlorine cylinder shutdown valves to protect against entrance into the room when one or more tanks are leaking. SCADA alarm systems alone do not protect against on-site waterworks staff from entering the room. Whenever modifications are made to any of the gas chlorination systems, they must be upgraded to meet the requirements of s. NR 811.48, Wis. Adm. Code.
2. All line-shaft, vertical turbine pumps are to be supported by a concrete pump base which is installed to a height at least 12 inches above the pump station floor. Collector A pump bases are only 10" and Collector C pump bases are only 2 inches. This shall be corrected in accordance with s. NR 811.31(1) (a), Wis. Adm. Code when future well work is done.
3. The exterior inspection hatch on the Finished Water Pump Station Reservoir does not meet the requirements of section NR 811.64(7)(b), Wis. Adm. Code. The original plans for this hatch, which were approved on June 15, 2006, show a cover that overlaps 2 inches. The hatch that was installed is flush with the top surface. This hatch cover may remain, provided that MPU routinely inspects and maintains the internal seal and verifies that the discharge for the channel drain remains clear.

Reminders and Other Follow-Up

1. Following all water storage facility inspections, the Utility shall submit a completed Department inspection report (Form 3300-248) to me per s. NR 810.14(4), Wis. Adm. Code. Supplemental reports, photos or videos shall also be provided.

2. On an annual basis, the Utility must conduct and document inspections of the screening on the vents, overflows, watertight seals on the inspection hatches on your standpipe and ground storage reservoirs in accordance with s. NR 810.14(1), Wis. Adm. Code and make repairs as necessary. Documentation of this inspection can be a notation in your daily logbook, monthly report, receipt by a private contractor or any other method to show the date the work was completed.
3. During the inspection MPU staff brought up the possibility of installing a chlorine injection system in the southwest pressure zone in order to increase the distribution system chlorine residual during the summer months. If a chlorine system is approved and installed, MPU will be required to re-evaluate the disinfection by-product sites to determine if the boosting of chlorine increases the DBPs in this zone when compared to the results of the existing sites.
4. Relays of water mains require plan approval if any of the following have changed: size, material, or location (if it is not in the same trench as the original pipe).

System Summary

The water supply system is owned and operated by Manitowoc Public Utilities (MPU). The water supply system is composed of 2 raw water intakes, 2 shore wells, 5 low lift pumps delivering raw water to a submerged membrane filter treatment plant, 1 clearwell, 3 high lift pumps delivering water to the Manitowoc distribution system, 2 radial collector wells, 2 booster stations, 3 elevated storage tanks, 1 ground storage reservoir, 3 pressure zones and about 184 miles of water main. The system also includes a finished water reservoir and 4 high lift pumps that deliver water to Central Brown County Water Authority's (CBCWA) transmission main. Chemical addition of finished water consists of chlorine and fluoride for both the City of Manitowoc and CBCWA and polyphosphate for the City of Manitowoc only.

Unmanned operation of the water treatment plant was approved by the Department in July 29, 2008. The plant is manned for two shifts Monday through Friday, one shift on Saturday and one shift on Sunday. The approved Great Lakes Compact baseline for Manitowoc is 31.01 MGD.

History: The original groundwater system was established by Eugene and T.W. Gray in 1889. In 1911, the City purchased it and in 1938 the Reed Avenue tower was completed. In 1943, the capacity was expanded with the construction of Ranney collector wells (A and B) and a Ranney recharge well, along the shore of Lake Michigan. In 1958, an additional Ranney collector well (C) was added. The system expanded in the early 1970s after a 1969 study was conducted to determine the water quality of Lake Michigan for a future intake. From 1971 until 1999, the system operated with conventional surface water plant drawing water from Lake Michigan, and three wells discharging directly to the distribution system. In June 1989 the Ranney recharge well was abandoned and in October 2000 Collector B was abandoned due to VOC contamination.

In the late 1990's MPU constructed a continuous pressure microfiltration (CMF) plant north of the existing conventional plant and the existing conventional system went off-line in 1999. In 2006, MPU constructed a submerged microfiltration (SMF) plant within the footprint of the old conventional system. This plant went on-line in 2007. The purpose of this expansion was to add capacity in order to sell wholesale water to the Central Brown County Water Authority (CBCWA), who in turn feeds the Villages of Allouez, Bellevue, and Howard, the City of De Pere, and the Towns of Lawrence and Ledgeview. The CMF plant was placed into reserve in 2012.

Raw Water Intakes: Two intakes supply water from Lake Michigan to two shore wells. The north intake was installed in 1971. It is 48 inches in diameter, approximately 9250 feet long, located in 35 feet of water with three intake cones. The cones each have ½ -inch steel bars, six-inches on center as screening. The south intake was constructed in 2006. It is 60 inches in diameter, approximately 4000 feet long and is located in approximately 26 to 32 feet of water. The screen assembly consists of two, 66-inch diameter cylindrical wedge-wire screens, each approximately 18 feet long.

The screens have a maximum slot width of 9.5 mm and are constructed of copper alloy to deter zebra mussels. Maximum velocity through the slots is 0.4 fps. In 2008 and 2009, MPU evaluated the water quality from the two intakes to determine if the shorter one needed to be lengthened. On October 7, 2009, the Department approved the evaluation and concurred that the intake did not need extending.

Underwater inspection of the intakes has revealed minimal concern over zebra mussel encrustation.

Shore Wells: The shore wells and pumping stations are located adjacent to each other on the shore of Lake Michigan directly east of the microfiltration plants and MPU.

Filtration – Continuous Pressure Microfiltration Plant (CMF Plant - North Plant): The plant capacity was 11 MGD and operated with an inlet pressure of 35 psi and at a high head (130 feet). Due to the total flow requirements of approximately 12-16 MGD, the CMF plant is not needed for daily operation and in 2012, the plant was placed into long-term reserve status. Detailed operational information on the CMF plant can be found in the Department's 2011 Sanitary Survey.

Filters: Submerged Microfiltration Plant (SMF Plant - South Plant): The current plant has a capacity of 25 MGD using five cells or 20 MGD (n-1 condition), with an ultimate build out capacity of 40 MGD and operates with an inlet pressure of 12-15 psi and a lower head (60 feet) than the CMF plant used.

In 2006, the SMF plant was constructed in the former granular media filter area of the original conventional water treatment plant. The west filter area was configured into six cells, five of which hold membranes. The east filter area now comprises the strainers, a CIP make-up tank, CIP waste tank, and room for three future membrane cells.

Strainers: The raw water pumped from both shore wells discharges to a 42-inch line that splits into two, 30-inch lines that feed the two, automatic-backwash, straining filters. The strainers are located in a former granular filter area. The straining units are 30 inches in diameter, with stainless steel V-notch screens providing a 0.020 inch or 500 microns slot size. Each strainer is sized for a maximum flow of 28 MGD. The strainers automatically backwash based on head loss or elapsed time – generally 30 minutes. The backwash waste from the strainers is piped to the backwash reclaim tank.

Membranes: In 2006, five cells of US Filter Memcor SMF-S units, which are submerged (vacuum) microfiltration membranes, were installed. Each unit lies submerged in a cell of water. The membranes are an outside to inside hollow fiber made of chlorine resistant polyvinylidene fluoride (PVDF). The fibers have an outside diameter of 800 um and a nominal pore size of 0.1 microns.

In July 2010 MPU began replacing, under warranty, the membranes and re-coating the cell walls. The final cell was complete in September 2011. Each cell contains 19 racks, each rack containing seven manifolds/sub-modules of four Memcor S10V modules for a total of 532 modules. Each module contains 9,600 fibers with a surface area of 272.6 ft^2, for a total of 145,023 ft^2/cell (580,000 ft^2 for 4 cells). Each sub-module (manifold of four modules) is 46.7 inches long and 5.2 inches in diameter with vertical fibers and upward flow through the fiber. In each rack, there is one sub-module (clover) that was left with a blank; it is located directly in front of the raw water inlet line.

In 2013 and 2014, MPU replaced the membrane modules with Memcor S10N modules. The surface area of these modules is only 250 ft^2, for a total of 132,000 ft^2/cell (528,000 ft^2 for 4 cells). Also in 2013, MPU pilot tested Pall and Tonka pressure membrane systems and in 2014-2016 tested PWN ceramic membranes, to assist in determining the best way to add future capacity.

The typical operating trans-membrane pressures (TMP's) range from 2.5 to 12 psi with a maximum TMP of 14.7 psi. The membranes have an operating pH range of 2 to 10 and can normally tolerate up to 200 ppm of chlorine with a maximum of 1000 ppm.

Operation of flow through the membranes and chemical cleaning is automatic by the Memcor PLC system based on operator settings. A redundant backup PLC is provided. Both are tied to the main plant PLC to alarm with any problems. The flow rate through the membranes is controlled by constant adjustment of the cell feed control valve on the influent to maintain a constant water level in the membrane cells. Each of the five cells has a permeate pump which draws the water through the membranes under a low vacuum pressure.

The Flowserve 20ENY vertical turbine pumps are in pump cans. Each has a capacity of 7.6 MGD (5280 gpm) at 46.5 feet TDH and is powered by 100 HP motors with variable frequency drives. The pumps stop if the water level in the cells is too low, to prevent the membranes from being exposed to the atmosphere. An eductor from the compressed air system draws off any dissolved air on the suction side of the permeate pumps and an air release valve is located on the discharge line from each permeate pump. Permeate from the plant is transferred to the MPU clearwell and the CBCWA reservoir by a 42-inch pipe.

Two, 7.5-HP, Atlas Copco GA5-250C, rotary-screw, air compressors (22.7 cfm at 150 discharge pressure), operate the valves, integrity testing and run the vacuum prime eductor system. The oil used for the compressors is food grade. A 200-gallon receiver tank is provided for the valves and a 400-gallon receiver tank is provided for integrity testing and the vacuum prime eductor. The following filters are in place on the compressed air system:

	Coalescing and 1 micron Particulate Filters for Particulates	High Efficiency 0.01 micron Coalescing and Particulate Filters for Liquid Water and Air Aerosol
After each compressor	√	
After each air dryer		√
After process air receiver		√
After test air receiver		√

Backwash: The membranes are backwashed one cell at a time approximately every 30 minutes. After lowering the water level to the backwash level, a simultaneous back pulse of filtered water along with air scour from the bottom of the tank is used to backwash the membranes. The permeate pumps are used to pump permeate water at a rate of approximately 4500 gpm (6.5 MGD) from the 36-inch, filtrate header back through the membranes, flowing from inside to outside. Two air blowers (one duty, one standby), each 3800 scfm, provide air scour to loosen solids from the membranes.

After about two minutes, the backwash drain valve is opened, the pump and air scour stop, and the tank is allowed to fully drain removing all solids. The drain valve is then closed; the inlet valve opened and, upon filling, the cell can return to filtration beginning at a flow of 2100 gpm. The waste volume from a typical backwash is 5200 gallons and the waste flows through the existing backwash channels to the reclaim basin.

Maintenance washes: Chemically enhanced backwashes are performed every 48 hours (per Siemens 2010) and last 45 minutes. A maintenance wash is a short-cycle, chemical clean (15 to 30 minutes) which allows a longer period between standard chemical cleanings. A maintenance wash begins with a regular backwash, except the cell is filled with heated water from the CIP make-up tank.

The warm water is circulated and sodium hypochlorite is added at a dose of 75 to 100 ppm. The waste is discharged to the sanitary sewer and a standard backwash follows for rinsing.

Clean-In-Place (CIP): Normally occurs every 30 to 45 days. There are two components to the chemical cleaning. Sulfuric acid is used for inorganic fouling and sodium hypochlorite is used for organic fouling.

The CIP make-up tank is a 4,500 gallon concrete tank with two, 67 KW electric immersion heaters. The two-CIP, re-circulating pumps are Flowserve 3K8x6-16RV end-suction centrifugal pumps, each with a capacity of 1800 gpm. They circulate the water/acid/sodium hypochlorite solution from the CIP make-up tanks through the cells. A 7.5 KW in-line heater maintains the temperature of the solution as it is circulated. The chemical feed system is skid-mounted with built-in containment areas.

A CIP sequence is manually initiated based on elapsed time or TMP. The tank is first backwashed to remove excess solids. The tank is then filled to the backwash level with 35°C water from the CIP make-up tank. The water is then circulated while the sulfuric acid is fed into the line until a pH of 2.5 is achieved. After circulating for about 30 minutes, the solution is allowed to soak for a preset time of 1 to 4 hours before circulating for another 30 minutes. The solution is then discharged to the CIP waste tank. A backwash cycle is then used to rinse the membranes. Next, a similar cycle is started for sodium hypochlorite with a target concentration of 200 to 500 mg/l of free chlorine. The waste from the CIP waste tank flows at a controlled rate to the sanitary sewer.

Cross connection protection from the CIP system is provided by double block and bleed valves on the permeate lines, CIP supply lines and drain lines for each cell. When the blocking valves are closed, the bleed valves between them are open to drain. Limit switches verify valve operation.

Integrity testing: Done by a pressure decay test (PDT). PDTs are conducted on each cell every eight hours. In addition turbidity monitoring is provided for each cell. Turbidity levels above 0.1 NTU causes an alarm with operator evaluation to determine if a pressure decay test (PDT) is necessary. The PDT involves pressurizing the lumen side of the membrane with air and measuring the pressure decay. The source of air is the same compressed air system used for the operation of the valves.

For integrity testing, the inlet feed valve is closed and the tank level lowered to the backwash level (about 60%). The permeate valve is closed and the membranes are pressurized to at least 14 psi, which provides a resolution of 3 microns or larger. Once the pressure has been reached for 10 seconds, the air inlet valve is closed. After two minutes for stabilization, an initial pressure is recorded and two minutes later a final pressure is recorded. The PLC will calculate the pressure decay rate over the two minute test period and a corresponding log removal value based on methods developed by ASTM. The PLC then compares the test value to alert and alarm set points. An alert calls for an air test, requiring an operator.

An alarm shuts down the unit and requires a successful PDT and an operator to clear the alarm. After passing a test, the cell is returned to service after delay to allow air to be purged from the permeate piping.

The pressure decay integrity testing can only be done on an entire cell. The results of fiber cutting and pressure decay tests completed in early 2007 were used to develop the following operational criteria, which were later modified to reflect being placed in Bin 2:

	Normal Operation (Cells 1 – 5)	Swing Cell Operation (Cell 1)
Pressure Decay Test (PDT) Frequency	Every 8 hours	Every 4 hours*
Log Removal Value (LRV) alarm level (minimum)	4.3	4.8
Log Removal Value (LRV) shut down level	4.0	4.6
Visual bubble observation	Quarterly	

**in lieu of 5.0 log removal by particle counting*

Once the pressure decay test detects a problem, an air leak test is conducted to determine the source of leakage in the cell. For the air leak test, the membranes are pressurized with air similarly to the PDT, except the test pressure is limited to 4 psi. The operator stands on the platform above the membranes and visually looks for a stream of bubbles. The problem module along with its clover, or group of four modules, can be isolated from the rest of the rack until follow-up action is taken. To make the repairs, the rack is lifted from the tank and the leaking module is removed and placed in a casing and pressurized. The leaking fiber(s) is pinned on the upper end to isolate it. In addition to this, quarterly leak tests are run.

Wastewater: The backwash water from the raw water strainers and the membranes discharges directly to the reclaim basin. The reclaim basin has a total capacity of 342,000 gallons and has two cells. The first cell acts as an energy dissipation chamber and the second cell provides settling. When both plants are operating, the detention time is approximately 2.1 hours. The tank contains sludge drain lines and a decant line exists 13.5 feet off the floor. These lines discharge to an 18-inch pipe that connects to a pipe that discharges at the existing power plant outfall. The water is typically discharged to the power plant outfall and into Lake Michigan. If the TSS level in the weekly test is above 40 mg/l the reclaim basin water will be sent to the WWTP by opening the bottom drain valves of the reclaim basin. The swing cell at the submerged microfiltration plant can also be used, via two 1400 gpm reclaim pumps but to date has not. The reclaim line also contains two basket strainers with 1/16" screens. Backwash water from the swing cell, when used to filter reclaim water, will always go the WWTP. The reclaim basin is cleaned at least annually and more frequently, if necessary.

The spent caustic and acid solutions discharge to the sanitary sewer.

MPU Finished Water Clear Well: A 42-inch effluent line from the SMF plant discharges into the North Clearwell and the FWPS reservoir. The North Clear Well (overflow elevation 608.25), located under the plant, serves the City of Manitowoc. The South Clearwell remains off line.

If the SMF plant shuts down or the outflow from the North Clearwell is greater than the inflow, the pressure in the line supplying the North Clearwell will not be maintained above ground elevation as required by NR 811.37. MPU has a plant shut down level alarm to ensure that the water level in the North Clearwell level is higher than the ground level.

The North Clearwell has a north and south basin, as well as two levels, with the upper levels divided into east and west sections by the former rapid mix and settled water channels. The water enters in the lower level of the north basin flowing east the entire length of the north basin. It then passes through an opening into the lower portion of the south basin flowing west about two-thirds of the way, around a baffle wall and back to the east to an outlet feeding the high service pumps. The volume of the lower level of the North Clearwell is 1 MG assuming a high water level of 594.5 USGS. The upper chambers can provide up to an additional 700,000 gallons of storage. Because the upper chambers float and the water does not necessarily flow through them, the upper volume has not been used to calculate chlorine contact time. In 2011, MPU installed two submersible pumps, one in the southwest quadrant and one in the northeast quadrant.

These pumps draw from the lower level and discharge to the opposite side of the upper quadrant. This has resulted in the maintenance of more uniform chlorine residuals. The length to width ratio of the flow path through the lower level of the North Clearwell is good and tracer testing would likely show a baffling factor of 0.4. Without tracer testing, the Department will allow the use of a 0.2 baffling factor.

All vents are screened, the inspection hatches are watertight and the overflow from the reservoir extends beyond the reclaim basin and discharges through a screened elbow approximately one-foot above ground level. The North Clearwell was last emptied and inspected in 2016 during which time Collector C supplied the City with water.

High Lift Pumping from MPU's Finished Water Clear Well: Three, horizontal centrifugal high-lift pumps with the following capacities: 11, 8, and 6 MGD pump water out of the north clearwell and into Manitowoc's distribution system. The 6 MGD pump was equipped with a VFD in 2012.

Finished Water Reservoir (FWR): This facility is owned by Manitowoc and is used to supply CBCWA. It was constructed in 2006 and was last drained and inspected in 2016. Water from MPU's SMF plant discharges through a 42-inch line to a 226-foot by 70-foot, cast-in-place concrete finished water reservoir with a maximum water depth of 24.5 feet. The resulting volume is 2.87 million gallons. The floor elevation is 2 feet above the groundwater elevation of 580. The influent line from MPU's membrane plants includes a standpipe that terminates 22 feet above the floor elevation at 604.0. The standpipe was constructed in order to maintain pressure in the buried piping higher than the nearby ground elevation. The vents are screened, inspection hatches are watertight and the overflow (elev. 606.5) is a channel with a flapper that discharges through a 24-mesh screen to the parking lot.

A flexible PVC baffle within the reservoir results in a theoretical baffling factor of 0.5. This has yet to be verified by tracer testing and is likely not an issue due to the contact time of three days before the water arrives at the MMS. As a result, a 0.25 baffling factor was agreed to by the Department and MPU. The reservoir was constructed so that it is possible to bypass the reservoir and discharge directly to the pumping wells when the reservoir is out of service. The bypass arrangement is not eligible for the 0.25 baffling factor; however, MPU will calculate a T10 for the transmission main to be used when the FWR is off-line for inspection.

Finished Water Pump Station (FWPS): There are four, vertical turbine high-lift pumps, three at 8.5 MGD and one at 4 MGD that pump water out of the finished water reservoir through 18-inch lines into a common 48-inch header that carries water into the CBCWA pipeline. The 4 MGD pump and one of the 8.5 MGD pumps are equipped with VFDs. A recirculation line was added to the 48-inch high lift pump discharge line to allow pump testing as well as flow control. The recirculation line includes a 16-inch Singer anticipating relief valve with flow control, which discharges back into the reservoir through one of the access manhole covers. Historically, the discharge pressure at the FWPS was maintained at 173 psi to ensure a pressure of 55 psi at LW-1 in the CBCWA system. In September of 2011, the pressure was reduced to a range of 161 psi at 3.5 MGD to 173 psi at 13.2 MGD in order to achieve an operational pressure of 40 psi at LW-1 and no less than 20 psi at Denmark, the topographic high point. This change was made to reduce operating costs at the FWPS and reduce wear and tear on the transmission main from high operational pressures.

MPU has the ability to boost chlorine at the FWPS, but has not yet had to.

Surface Water Treatment Rule Summary: A complete summary is available in Department correspondence dated June 19, 2012. This summary will be re-issued this spring.

Log Removal Credits: The following table presents the log removal credits resulting from each treatment.

Removal/Inactivation Credits			
Treatment Process	Giardia	Viruses	Cryptosporidium
Microfiltration	3.0[1]	0.0	4.0[1,4]
Free Chlorine CT	0	4.0[2,3,6]	0.0
Total Provided	3.0	4.0	4.0
Total Required	3.0	4.0	4.0[5]

[1]Credit based on meeting the following testing requirements and operational requirements:
Pressure decay test on every cell every 8 hours of operating time
Membranes leak tested quarterly (bubble test at SMF)
For each cell:
Continuous check of LRV based on air hold test, water temp and flow rate
Air hold test alarms at 4.5 LRV for 1 minute
Air hold test shuts cell down at 4.3 LRV for 1 minute
Turbidity alarms when reading is at 0.06 NTU for 5 minutes
Turbidity shuts cell down when reading is at 0.1 NTU for 5 minutes
Turbidity levels are reviewed at the end of the month for EMOR reporting; the daily average of the max from each cell is reported
At EP 81, turbidity alarms at 0.2 NTU and shuts the plant down at 0.2 NTU for 60 minutes. This is an extra precaution.
[2]4-log CT values for viruses in Manitowoc's clear well; temperature dependent (pH 6-9), the low alarm level is set at 23 feet and high flow at 11 MGD. The critical water depth of 13.8 feet is the basis for the T_{10} calculations, but MPU prefers to operate above 23 feet.
[3]4-log CT values for viruses in the FWPS reservoir; temperature dependent (pH 6-9). MPU has a low water alarm set at 549.0 (17 feet of water).
[4]Credit based on operating membranes above 4.3 LRV
[5]LT2 ESWTR Bin 2 placement
[6] Inactivation ratio >1 at all times

Giardia: The membrane plant is credited with 3-log inactivation of giardia as long as MPU complies with the above testing, alarm and shutdown requirements.

Viruses: The Utility is meeting the required 4-logs of virus inactivation by free chlorine. Chlorine is added to the membrane effluent header and chlorine contact time is achieved in the clearwells. The following table represents the minimum CT that must be provided to achieve inactivation (for pH 6-9).

Temperature (°C)	CT Required (mg/L x min)
0.5	12
5	8
10	6
15	4
20	3

Crypto: The Department has granted the Utility 4-log removal credit based on the effectiveness of the membrane treatment plants. Raw water cryptosporidium monitoring, as required by the Long Term 2 Enhanced Surface Water Treatment Rule, resulted in the Utility being placed in Bin 2. This means that the Utility is required to provide a total of 4.0 logs of cryptosporidium removal/inactivation. The Utility has agreed to operate the membranes with the alarm level set at 4.5 LRV and the shut-down level at 4.3 LRV. These alarm and shut-down levels provide less than the 1-log cushion seen at other membrane plants in Wisconsin.

The table below shows the T_{10} times at various operating water levels. Neither of the reservoirs has been tracer tested. The CBCWA pipeline can be used for chlorine contact time if the FWPS Reservoir is drained for inspection. The pipeline between the FWPS Reservoir and the master meter station is 31.5 miles of 48 inch pipe. The resulting volume is 15.63 MG.

Condition (2010)	Flow Rate (MGD)	T_{10} Detention Times (min)			
		Flow to Manitowoc		Flow to CBCWA	
		North Clearwell Only (0.2 baffling factor)	South Clearwell Only[1] (0.1 baffling factor)	FWPS Reservoir (0.25 baffling factor and 1.42 MG)	Pipeline Only (used during clear well inspections)
Ave Day	5.2	55.4	23.0		
	6.8			75.2	3310
Min Day	3.8	75.8	31.5		
	5.8			88.1	3881
Max Day	7.6	37.9	15.7		
	9.9			51.6	2274
Design Capacity	11	26.2	10.9		
	20			25.6	1126

[1] Cannot use South Clearwell. If the North Clearwell is off line, MPU must use Collectors A and C to supply the City of Manitowoc

Chemical Addition: At the SMF plant, the primary chlorine feed point and the fluoride feed point is the 36-inch permeate line just prior to the south wall of the plant. There are secondary chlorine feed points located immediately before the MPU high lift service pumps and within the wet wells in the CBCWA finished water pumping station; however these have not been used.

All chemical lines containing sodium hypochlorite, fluoride and sulfuric acid have double containment with designated locations and operating plans to determine if leaks are occurring.

Gas chlorine is fed from 1 ton cylinders. The chlorine room serves both plants and has the capacity for seven, one-ton cylinders – three of which are on scales and in use. The SMF system is vacuum fed (500 ppd), is also flow-paced and has a post feed vacuum line to the FWPS (200 ppd. MPU feeds chlorine at 1.4 ppm so that the EP to the CBCWA is 1.1 to 1.2 mg/l and 0.9 mg/l at the master meter station.

Hydrofluosilicic acid (fluoride) is added to reduce the cavities in the teeth of children, in accordance with the City of Manitowoc's Municipal Code. The fluoride feed system was replaced in 2006 when the SMF plant was constructed and placed in the Finished Water Pump Station. Fluoride is stored in two, 4000-gallon bulk tanks and transferred to two, 95-gallon day tanks by a 20-gpd transfer pump. The room is constructed to serve as secondary containment. The fluoride system is flow-paced off of a signal from the flow meter as primary control. Secondary control of the fluoride system is satisfied by a solenoid on the fluoride feed line to each plant. The solenoid opens with the plant start/stop. The feed point is the discharge pipe leaving the SMF plant so MPU and CBCWA water receive the same dose to achieve 0.7 mg/l at the entry point.

The polyphosphate AquaMag is continuously added to the discharge of the MPU high service pumps from the clear well to reduce corrosive conditions within Manitowoc's distribution system, which had previously resulted in an exceedance of the action level for lead. The dose is maintained at 2.1 mg/l as product or 0.2 mg/l as orthophosphate. Bulk phosphate is stored in a double-walled, 3000-gallon tank from which it is transferred to a 45-gallon day tank.

Radial Collectors: The Utility has two, radial collector wells used to supplement the filtration plant and for emergency use within Manitowoc's distribution system only. Chlorine and polyphosphates are available for addition at each collector, which discharge directly to the southwest portion of the distribution system. Fluoride is not added at either collector well. A well head protection plan was developed for these wells in August 1994, but an ordinance was never adopted.

Collector A has a 2 MGD and a 4 MGD pump. Collector A has high hardness and is pumped to the distribution system only when necessary. Operation of the well and chemical feed systems is completely manual. Collector A has the capability to pump to waste and to obtain raw water samples. The pumps and the motors were installed in 1945. The well pumps were last pulled for inspection in 1999. Collector A was last used in July 2006 when electrical problems occurred with a high service pump and electrical problems and a water main break occurred at Collector C.

Collector C has two, 4 MGD pumps and, prior to construction of the SMF plant, had typically been used to supplement the CMF plant each month. The well can be brought on-line manually or it operates automatically based on a preset suction at the Southwest Booster station, which is located in the main pressure zone. Both well pumps at Collector C were last inspected in 2014.

Booster Stations and Storage: The system is separated into four pressure zones: Main, Northwest, Southwest and the Reduced Southwest.

The Main Zone is fed by the high-lift pumps at the microfiltration plants and contains the North Clearwell and the Reed Avenue Tower for storage. Pressure in this zone is controlled by the Reed Avenue 1.5 MG ellipsoid elevated storage tank with an overflow elevation of 765. The North Clearwell was drained and inspected in October 2016. The Reed Avenue tank was constructed in 1938, was painted in 2009, and was last inspected on August 15, 2014 by diving. The overflow at this structure is connected to a storm sewer; however, there is a screened section of pipe that acts as an air break.

The Northwest Zone is fed from the New York Avenue booster station. Here, two, horizontal-centrifugal pumps with VFD's and capacities of 1400 and 2800 gpm draw from the 5 MG New York Avenue ground storage reservoir and provide the zone with pressure. The booster station also has a back-up centrifugal pump equipped with a diesel engine drive with a capacity of 2100 gpm. The pump is run under full load quarterly and documented in an on-site log book. Chlorine injection is available at this station; however it has not been needed due to the constant turnover of the reservoir. A continuous chlorine analyzer is located at this station.

The New York Avenue reservoir was constructed in 1969 and was last inspected by diving on June 12, 2015. The vents are appropriately screened and the inspection hatches are watertight. There is no overflow from the reservoir; however, there are three levels of alarms for the water level within the reservoir.

The Northwest Zone also includes the 1.25 MG hydropillar at Basswood Drive with an overflow elevation of 850. The tower was constructed in 2009 and was inspected by diving on August 15, 2015. The overflow discharges through a screened elbow approximately two-feet above ground level. A continuous chlorine analyzer is located at the NW-Basswood tower.

The Southwest Zone is fed from the Main Zone by two, centrifugal booster pumps with capacities of 600 and 800 gpm located at the Southwest Booster Station. The station also includes a third centrifugal pump powered by a natural gas fueled engine drive with a capacity of 2600 gpm and operates automatically if the other pumps cannot feed the tower fast enough. The booster station has an in-line chlorine analyzer in place and emergency chlorine injection is available, though it has never been needed.

The Southwest Zone includes a 1.25 MG, hydropillar, elevated-storage tank located in the Industrial Park with an overflow elevation of 905. This tank was constructed in 1995. As part of a 2003 project to upgrade the Southwest Zone, the tank was raised 50 feet to 170.5 feet. The tank was last painted inside and out in 2013 and a new vent and riser man way were installed. The Tideflex mixing system was eliminated from the 2013 project and MPU instead installed a GridBee GS-12 mixer.

Distribution System

The distribution system is separated into three pressure zones by pressure reducing valves. The system is composed of 978,911 feet or 185 miles of water main. The Utility is aware of two areas of limited fire flows and has notified the fire chief.

There are 6,500 lead services in the distribution system according to the Utility's PSC report. There are no water mains that flow through sanitary or storm sewer manholes. There are three commercial customers that each have two connections to the distribution system. Each connection has a double check valve.

Manitowoc also has the ability to supply water to Two Rivers as a backup water supply to the Aurora Medical facility on the south end of Two Rivers. Appropriate agreements are in place.

Water Quality Monitoring

Your system has a good record of compliance with monitoring and reporting requirements. We appreciate your sampler's efforts in complying with these Safe Drinking Water Act requirements. This should continue to be given a high priority in the operation of you system.

Water quality complaints are logged by customer service staff, appropriate work orders are issued, complaints addressed and documented.

The most recent inorganic, organic and pesticide chemical analysis of the entry point to the distribution system indicates that the water meets all applicable drinking water standards. While Collector A is rarely used, annual VOC samples have shown low levels of trichloroethylene and tetrachloroethylene.

The Utility tested for cryptosporidium and giardia under Long Term 2 Enhanced Surface Water Treatment Rule between April of 2008 and March 2010. They were placed in Bin 2. All finished water results were negative. The second round of sampling began October 2016.

The natural hardness of the water leaving the treatment plant is 140 mg/l $CaCO_3$.

Fluoride residuals are monitored through daily grab samples from the entry point to the Manitowoc distribution system and from the entry point to the CBCWA transmission main. These sample locations are appropriate and are reported as distribution system samples on the System Operational Area page of the monthly reports. Fluoride concentrations are consistently being maintained at 0.7 mg/l and two monthly split samples are analyzed at the SLOH. Review of the monthly split sample results shows MPU's operator results are consistent with the lab results. MPU has always uses SPADNS for field fluoride testing at both locations. Review of the data has shown that the interference by polyphosphate in the EP 81 samples is negligible. The Department has issued an approval for continued use of SPADNS rather than an electrode method for fluoride monitoring at the Manitowoc entry point.

Orthophosphate levels are monitored through daily grab samples from the entry point and twice a week distribution system sampling. Levels are generally 0.4 mg/l at the entry point and 0.3 to 0.4 mg/l in the distribution system. Raw water orthophosphate levels are 0.1 mg/l.

The Utility is required to collect 40 bacteriological water samples from the distribution system every month. MPU routinely collects 44 samples, 11 samples each week from a pool of 13 sites. Free chlorine residuals are always determined at the time of sample collection. Bacti analyses are done in-house. In addition to bacteriological analysis within the distribution system, daily bacteriological testing is done on the raw and finished water (1/shift at Manitowoc EP and CBCWA EP) and on the entry point water Collector C when it's used. Quarterly raw water bacteriological and annual nitrate samples are taken at Collectors A and C.

The free chlorine residual is continuously monitored immediately after injection, at the entry point and at each storage structure and booster station with continuous chlorine analyzers. The twice a week chlorine residual in the distribution reported on the monthly reports is the lowest daily chlorine residual from the NW tower analyzer and is typically 0.2 mg/l. The Utility has been maintaining a free chlorine residual entering the distribution system at 1.1 to 1.2 mg/l and operates to that the chlorine level throughout the distribution system is never lower than 0.2 mg/l.

MPU began reduced monitoring under Stage 2 of the Disinfection By-Product Rule in the 4th quarter of 2013, which is quarterly at two sites (D-18 and D-26) in the distribution system.

The latest sampling for lead and copper was conducted in 2014 and showed 90th percentile levels of 7 ppb for lead and 230 ppb for copper with 30 samples. These levels are dependent on the addition of phosphate, as the Utility had previously violated the action level for lead. MPU is conducting sampling in accordance with their lead and copper monitoring plan using all Tier 1 sites confirmed to have a house-side lead service. Lead and copper sampling will be conducted in 2017.

Required Reports, Records, and Utility Programs

The City has maintained a good record of completion and submission of monthly pumpage reports required by the Department. Records and documentation of all maintenance work and program implementation is adequate except where noted.

MPU does all maintenance on their in-line analyzers. Turbidity monitors are calibrated quarterly and chlorine analyzers are calibrated monthly.

All dead-end mains are provided with appropriate flushing devices. Hydrants located at the end of dead-end mains are flushed annually. In addition, half of all remaining hydrants within the distribution system are flushed each year. This flushing frequency appears to be adequate. All of the hydrants are visually checked and the barrels drained each year. Appropriate records are being maintained and MPU has a General Discharge Permit for Hydro-Static Test water to cover these discharges. The Permit is dated February 26, 2009.

Valves located within the distribution system, including hydrant valves, are exercised and maintained on a five year schedule. Appropriate records are being maintained.

Small meters are replaced at a rate of 5 percent per year resulting in a 20-year life of meters, which is consistent with PSC requirements. Larger meters are tested in accordance with PSC 185.

The average daily pumpage for 2015 was 13.4 MG, which includes water pumped to CBCWA. The maximum day occurred on July 27, 2015 and was 19.8 MG. The annual water loss was 14 percent.

The normal pressure range within the distribution system is 35-100 psi. The lowest pressure is at the Southwest Booster station. In areas where the pressure is excessive, pressure reducers have been installed on the services.

The City's last fire flow study was conducted in 2016 and resulted in a drop in their rating to Class 2.

All water is sold either using an overhead fill line at the plant or from hydrants equipped with meters and backflow preventers.

The City adopted a cross connection control ordinance on April 8, 1981 and revised it in 2011. The written plan is dated February 15, 2014. In general, MPU staff inspect all single family and duplex residential properties when meters are changed (20-yr frequency). MPU provides public educational materials in lieu of inspections of typical bathroom and kitchen fixtures at each inspection. The last customer-wide mailing occurred May 2014 and is scheduled for mailing again this May. If violations are identified, the owner notifies MPU to be re-inspected.

Owners of the remaining residential, commercial, retail, industrial and public authority/institutional buildings must hire an inspector and provide the City Department of Building Inspection copies of the inspection report. Building Inspection staff collect, review, file, track compliance and conduct enforcement activities. The alternative inspection frequency of 2, 6, or 10 years was approved by the Department on February 17, 2012.

Typically the plumber/inspector does not return the required forms to the City until all corrections have been made. Those that didn't submit the required paperwork to the City after 90 days are sent a reminder letter. Those that don't respond are sent a third letter.

The City adopted a private well abandonment ordinance on June 25, 1991. The City Department of Building Inspection is responsible for managing this program which consists of $10, five-year permits. Bill Jindra, the City plumbing inspector, currently has records for 170+ well abandonments, 35 active permits and two expired permits. Bill Jindra inspects each property for cross connection from the well to the plumbing served by the municipal water system prior to issuing or reissuing a permit. In addition safe bacti samples and proof of a well inspection are provided prior to issuing or reissuing a permit. The City does an excellent job of managing this program, which has expanded over the years as the City has grown. Records show that in 1994 there were 30 abandonments and 11 permits, in 1996 there were 64 abandonments, 18 permits.

The City does not have a wellhead protection ordinance for Collectors and C. A wellhead protection plan was written in August 1994; however, the City has not adopted the plan under an ordinance.

The City maintains an Emergency Response Plan dated December 2004. The plan is routinely reviewed with all staff and was updated July 2014. An emergency chlorination plan is included. MPU maintains an emergency sampling cooler and it is stored in an appropriate location.

Certified Operator

MPU presently employs 11 staff as their certified operators. Peter Dollopf is the Operator-In-Charge for Groundwater and Rob Michaelson is the Operator-In-Charge for Distribution and Surface Water Treatment. All certified operators receive continuing education and every manned shift has a fully certified operator on duty.

Water System Security

All access hatches and doors to the plant, clearwell, booster stations, towers and reservoir are provided with locks, door guards, entrance alarms and dusk to dawn lighting. In addition, the clearwell and plant are equipped with security cameras.

Auxiliary power

Power is provided for the filtration plant through alternate electrical feeds equipped with automatic transfer switches. The New York Booster Station includes one pump with a diesel-fueled engine drive. The Southwest Booster Station includes one pump with a natural gas-fueled engine drive.

No auxiliary power exists at Collector A. At Collector C, there are MPU and WPS electrical feeds with an automatic transfer switch. All auxiliary power is exercised appropriately and log books are kept.

System Summary Information

A water system summary is attached. Please review this summary for accuracy. If there are changes that need to be made, please contact me at (920) 662-5414.

Capacity Development Evaluation

This sanitary survey serves as an evaluation of the capabilities of your water system. This system has been determined to have adequate technical, managerial, and financial capacity to provide safe drinking water because the ability to plan for, achieve, and maintain compliance with applicable drinking water standards has been demonstrated. In addition, MPU has developed a Water System Master Plan to aid in prioritizing their future system improvements. A simplified rate case of 3 percent went into effect June 1, 2015.

The next sanitary survey of your system is scheduled to take place in 2019. You will be contacted prior to the survey to schedule a date that is convenient for you. If you have any questions, you can reach me by phone at 920-662-5414 or by postal mail at the address on this letterhead.

Sincerely,

Wendy Anderson
Water Supply Engineer

Encl.

ecc: FILE
Larry Landsness/Florence Olson, DG/5
Rob Michaelson, Manitowoc Public Utilities
Bill Jindra, City of Manitowoc
Sara Burdette, CBCWA President

43603648 - MANITOWOC WATERWORKS
Water System Summary Information

Population: 34500
Owner: JENNIFER HUDON
900 QUAY
MANITOWOC, WI 54220-4543
(920) 686-6950 jhudou@manitowoc.org
Date ERP Complete: 12/09/2004
Date ERP Last Exercised/Updated:
Emergency Phone: (920) 374-0959
Emergency Fax: (920) 686-4376
Emergency E-mail: rmichaelson@mpu.org

Certified Operators

Name	Lic. #	Expires	Certifications
PAUL AUMANN	20752	07/01/2018	D1, G1, S1
BRIAN BRANAM	34187	05/01/2019	D1, GT, S1
JACOB CASEBEER	36287	05/01/2018	DT, GT, ST
PETER DOLLHOPF	23558	06/01/2017	OIC G, D1, G1, S1
ERIC DUENKEL	34593	05/01/2018	D1, G1, S1
CHRISTOPHER KLAWONN	33020	11/01/2017	DT, GT, ST
NILAKSH KOTHARI	24296	06/01/2017	D1, G1, S1
ROBERT MICHAELSON	33141	05/01/2018	OIC D, OIC S, D1, GT, S1
ZACHARY PETHAN	36850	05/01/2019	DT, GT, ST
NICHOLAS PONTO	36154	05/01/2019	DT, GT, ST
ANDREW SUKOWATY	35919	11/01/2019	DT, GT, ST

Affiliations

Name	Affiliation	Start Date	Phone
ROBERT MICHAELSON	SAMPLER	01/20/2016	920-686-4354
JENNIFER HUDON	PLAN_CON	06/24/2015	920-686-6950
JENNIFER HUDON	OWNER	02/12/2015	920-686-6950
JENNIFER HUDON	LEGAL_OWN	09/09/2015	920-686-6950
ROBERT MICHAELSON	EMERGENCY	01/23/2008	920-686-4354
WENDY ANDERSON	DNR_REP	06/21/2006	920-662-5414
PAUL AUMANN	CONTACT	06/11/2009	920-686-4356

Entry Points and Sources of Water (basic data)

ID	Name	WUWN	Type	Source	Depth
1	RANNEY WELL 1 COLLECTOR A	BG251	ENTRY PT/SOURCE	GW Source	66
3	RANNEY WELL 3 COLLECTOR C	BG253	ENTRY PT/SOURCE	GW Source	84
81	CITY OF MANITOWOC ENTRY POINT		ENTRY POINT	Permanent SW EP	
82	CBCWA ENTRY POINT		ENTRY POINT	Permanent SW EP	
101	NORTH RAW WATER PUMP STATION		SOURCE OF WATER	Surface Water Source	
102	SOUTH RAW WATER PUMP STATION		SOURCE OF WATER	Surface Water Source	

Storage

ID/Location	Type	Vol. (gal)	Firm Pumping Cap(gpm)	Height to Overflow (ft.)	Overflow Elev. (sea-level, ft.)	Aux. Power?	Last Int. Inspect Date	Type of Inspection	Model
New York Ave Reservoir	GSR	5,000,000	3500			Yes	06/12/2015	dive (2015), dry (2010)	

ID/Location	Type	Vol. (gal)	Firm Pumping Cap(gpm)	Height to Overflow (ft.)	Overflow Elev. (sea-level, ft.)	Aux. Power?	Last Int. Inspect Date	Type of Inspection	Model
Reed Ave Tower	ELE	1,500,000		127	765	No	08/15/2014	dive (painted 2009)	Ellipsoidal (radial arm)
Industrial Park Tower	ELE	1,250,000		160.5	905	No	09/25/2009	Dive (painted 2013)	Fluted Pillar
Clearwell South	GSR	830,000			598.5	Yes	02/08/2006		
Clearwell North	GSR	2,000,000			608.25	Yes	10/04/2016 06/08/2011	dry dive	
FWPS Reservoir for CBCWA	GSR	2,870,000	20,478	14.5	606.5	Yes	10/18/2016 06/23/2011	dry dive	
Basswood Dr/NW Tower	ELE	1,250,000		140	850	No	08/15/2014	dive (constr in 2009)	Fluted Pillar

Booster Stations

ID/Location	Type	Firm Pumping Capacity (gpm)	Aux. Power?
Booster in SW	ABOVE GROUND	3400	Yes

System Interconnects

ID/Location	Type	Capacity (gpm)	Metered?	Chemical Injection Capable?
Interconnect with Two Rivers 12" (Emergency)	BURIED		Yes	Unknown

Treatment Summary Data

Source ID	Type	Description	Approved	Objective(s)	Pump Model	Cap.	Stroke %	Speed %
1	401	Gaseous Chlorination, Post		Disinfection	Capitol Controls 200	100		
1	447	Inhibitor, Polyphosphate	11/30/1993	Corrosion Control	LMI B911-91S	38	25	
3	401	Gaseous Chlorination, Post		Disinfection	Capitol Controls 200	200		
3	447	Inhibitor, Polyphosphate	11/30/1993	Corrosion Control	LMI B911-91S flow control	38		
81	347	Filtration, Ultrafiltration	12/15/2005	Particulate Removal				
81	380	Fluoridation	06/15/2005	Other	ProMinent Gamma/L Gala 0220	132		
81	401	Gaseous Chlorination, Post	12/15/2006	Disinfection	Hydro Omni Valve	500		
81	447	Inhibitor, Polyphosphate	11/30/1993	Corrosion Control	LMI C711-715	60	50	50
82	347	Filtration, Ultrafiltration	12/15/2005	Particulate Removal				
82	380	Fluoridation	06/15/2005	Other	ProMinent Gamma/L Gala 0220	132		
82	401	Gaseous Chlorination, Post	12/15/2006	Disinfection	Hydro Omni Valve	500		

Inspector/Reviewer	Date	Report Date	Type	Agency	Response Due	Response Recd
ANDERSON, WENDY	12/13/2013	12/30/2013	SURVEY	DNR	02/13/2014	02/12/2014
ANDERSON, WENDY	12/08/2010	12/27/2010	SURVEY	DNR	02/15/2011	02/14/2011

Bacteriological Sampling History

Year	Distribution Safe	Distribution Unsafe	Confirmed Unsafe	Missed Samples	Raw Safe	Raw Unsafe	Fecal Positive?
2017	27			0			N
2016	535			0	7	1	N
2015	565			0	9	2	N
2014	565			0	7	1	N

Chemical Sampling History

Year	Sample Group	Source ID	Samples Taken	Missed Samples	MCL Violations
2017	LT2	102	0	1	0
2017	DBP		0	1	0
2017	FLUORIDE		2	0	0
2016	IOC	81	1	0	0
2016	IOC	82	1	0	0
2016	LT2	102	0	1	0
2016	DBP		8	0	0
2016	VOC	1	1	0	0
2016	VOC	81	1	0	0
2016	VOC	82	1	0	0
2016	VOC	3	1	0	0
2016	FLUORIDE		22	0	0
2016	NITRATE	1	1	0	0
2016	NITRATE	3	1	0	0
2015	IOC	81	1	0	0
2015	IOC	82	1	0	0
2015	DBP		8	0	0
2015	VOC	1	1	0	0
2015	FLUORIDE		24	0	0
2015	NITRATE	1	1	0	0
2015	NITRATE	3	1	0	0

Sample Group	Last Sampled
BACTI	2017
FLUORIDE	2017
IOC	2016
RAD	2014
PBCU	2014
NITRATE	2016
SOC	2014
VOC	2016
DBP	2016