Madison Water Utility
Tom Heikkinen – General Manager
Alan L. Larson; PE, BCEE – Principal Engineer

119 E. Olin Avenue
Madison, Wisconsin 53713
Telephone: 608 266-4651
Madisonwater.org

MEMORANDUM

Date: January 31, 2017
Update to November 29, 2016 report

To: Water Utility Board

From: Al Larson, PE, BCEE
Principal Engineer

Re: Iron and Manganese Treatment Costs - Update
Board Education Session

Background

Madison Water Utility commissioned its first iron and manganese filter at Well 29 in April 2009 following water quality complaints concerning discolored water. The well has produced over 550 million gallons per year since filter installation. A second filter was installed at Well 7 and it was commissioned in June 2015 and has produced over 267 million gallons in the year since it was put into operation. We are working with the pump operators to increase use of Well 7 to take advantage of the water quality produced by the filtration system. A Fe and Mn filtration system will be installed with the construction of Well 31 and a filtration system addition for Well 19 is budgeted for 2019.

When either iron or manganese exceed the secondary standard (SCML) established by the USEPA, 0.3 mg/l for iron and 0.050 mg/l for manganese, frequent colored water complaints, staining of plumbing fixtures and laundry, and concerns about water safety will occur. These colored water events will reduce the confidence and trust in the water utility. Iron and manganese have also been reported to concentrate other contaminates in the sediment that accumulates in the distribution system.

The filtration system selected for the Madison system uses a high rate manganese dioxide or “Pyrolucite” catalytic filter media and chlorine as an oxidant. The filters are approved for a loading rate of 12 gpm/ft^2 resulting in a very small footprint. This small footprint minimizes the size of the building resulting in lower capital costs. The system uses pressure filters that are backwashed based on time every 20 to 24 hours at Well 29 and based on a treated water volume of 3 million gallons at Well 7. Over 94% of the backwash water is recycled with the remaining “sludge” being wasted to the sanitary sewer system.

Water quality from filtration is excellent with iron and manganese levels reduced over 90% to well below the SMCL. A catalytic filter system is not a system that can be ramped up or down to improve or reduce treatment efficiency. If water is applied to the filter it will remove the maximum amount of contaminant possible. To reduce treatment efficiency would require blending of lower quality water or bypassing the treatment train. This treatment strategy could reduce the size of the filtration facility and thus capital and operating costs.

Other Studies and Reports

In December 2014 as a part of the Well 31 work, SEH Inc. conducted an operating cost study of iron and manganese filtration. The study included blending options in an effort to reduce costs. That study is attached for reference.

Iron and manganese filtration pilot studies were completed for Wells 29, 7 and 8 as a part of the design process. These pilot studies evaluated several treatment methods and recommended the use of Pyrolucite media with chlorine oxidation at a maximum rate of 12 gpm/ft^2. These reports are available for additional information and background if needed.

A January 28, 2008 report from Larry Nelson to the Madison Water Utility Board on Prioritization of the Construction of Water Treatment Facilities for the Removal of Iron and Manganese at Well site is attached for your information and use.

Questions

Several questions have been posed with regard to the energy and operational costs of removing iron and manganese within the Madison system. This memorandum will attempt to address those questions as asked to provide a basis of information for considering future investment in water treatment at Madison wells.

1. **Describe Well 29 Fe and Mn Filtration Operational History:**

The pyrolucite media filtration system went on line at Well 29 in April 2009 with a capacity between 1,100 and 1,200 gpm or 1.58 to 1.73 million gallons per day. The filter has operated 24/7/365 since that time with the exception of a well pump failure in early 2012 and another mechanical failure in late 2013. The average annual water production for Well 29 has been approximately 550 million gallons. Water quality from the filtration system at Well 29 has been excellent and complaints have been eliminated.

2. **What are the annual costs for operations and maintenance for an iron and manganese filtration system. Include daily, weekly, monthly periodic and irregular maintenance needs.**

The actual energy intensity for the Well 29 facility for its operation is 1,818 kwh/MG produced. This equals an annual energy cost of approximately $120,000. To estimate the energy required for filtration, Well 29 was compared to wells with no filtration. Based on this comparison filtration energy requirements are estimated to be 116 kwh/MG or a current annual energy cost of $7650 for filtration or 6.4% of the total energy used. A plot of the

energy intensity for Well 29 since 2005 is included for your information and use. A second plot of energy intensity for Well 7 is also included for comparison purposes.

Discussion with Joe DeMorett, Water Supply Manager, and Doug VanHorn, Maintenance Supervisor, indicates the following additional operation and maintenance requirements specifically for a filtration system.

1	Daily	Rounder time for Fe & Mn Samples	$5,840
2	Weekly	No additional work required	$0
3	Monthly	Fe & Mn Samples – Independent Lab	$360
4	Quarterly	Backwash Basin Cleaning	$6,640
5	Annual	Backwash Valve Maintenance	$2,000
6	Sewer Costs	Sludge Disposal Costs at $4.50 per million gallons produced	$3,100
		Annual Total	$17,940
		Cost per Million Gallons (550 MG/yr)	$32.62
		Cost per Thousand Gallons	$0.033

3. What is the operational electrical use of the treatment system?

Looking at the MGE monthly bills for Well 29 and Well 7, the expected energy intensity for iron and manganese filtration is 116 kwh per million gallons. For an annual production of 550 million gallons this equals 63,800 kwh/year required. As a comparison the energy requirement for the VOC stripper at Well 15 is 353 kwh per million gallons treated or 194,150 kwh/yr.

Please refer to the attached energy intensity charts for additional information regarding energy use at other wells.

4. What is the additional cost per gallon of water compared to similar wells without treatment, such as well 19 and 28? Please include capital costs and O & M.

Typical Unit Well Operation and Maintenance costs are estimated as follows. Note that these costs are also a part of any filtration system and would be added to the costs estimated above:

Estimated Standard Unit Well Operating Cost per MG Produced

1	Daily	Rounder time	$7,760
2		Management, Operator, SCADA Service and Replacement	$35,400
3	Weekly	Cleaning and minor maintenance	$8,280
4	Monthly	Instrument cleaning and calibration	$4,250
5	Quarterly	No additional work required	$0
6	Annual	Well work and servicing	$2,125

7	Annual	Misc. Materials	5,000
8	Annual	Chemical Costs	15,125
		Annual Total	$77,940
		Cost per Million Gallons (550 MG/yr)	$141.71
		Cost per Thousand Gallons	$0.142

Total unit well facility cost per MG produced

1	Capital Costs	Based on $4.5 million capital costs and a 50 yr life	$147,500
2	Repair Costs	Based on equipment value of $600,000 and 3% per yr	$18,000
3	Replacement Costs	Assume 25 year equipment life expectancy	$32,600
4	Energy Costs	2136 kwh/MG avg for Wells 19 & 28, 550 MG/yr and an average of 12¢/kwh	$141,000
5	Annual O & M	As noted in table above	$77,940
		Total Annual O & M Cost	$417,040
		Cost per Million Gallons based on 550 MG	$758
		Cost per Thousand Gallons	$0.758

Additional costs for adding iron and manganese filtration to an existing unit well are estimated as follows:

1	Filtration Capital Costs	Based on $3.5 million capital costs and a 50 yr life	$114,700
2	Filtration Repair Costs	Based on equipment value of $500,000 and 2% per yr	$10,000
3	Filter Replacement Costs	Assume 25 year equipment life expectancy	$27,100
4	Filtration Energy Costs	116 kwh/MG, 550 MG/yr and an average of 12¢/kwh	$7,656
5	Annual O & M	As noted in table above	$17,940
		Total Annual Cost for Filtration based on 550 MG	$177,396
		Additional Cost per Million Gallons for Filtration	$323
		Additional Cost per Thousand Gallons for Filtration	$0.323

Assuming that a total of 10 filtration plants were to be added to the existing 22 wells, this would increase annual costs by an estimated $1,774,000. Based on a total sale of 8 billion gallons per year, increase in costs would be approximately 22¢ per 1,000 gallons sold or a rate increase of approximately 7-1/2%.

5. What are the potential approaches for treating water to SMCL standards for Fe and Mn, but not beyond?

Except for Well 8, which currently operates for 6-8 weeks each year, none of the City's other twenty-one wells exceed the secondary maximum contaminant level [SMCL] for iron or manganese. Iron and manganese filtration is currently provided at two wells – Well 7 and Well 29. Water quality for raw water pumped from these wells are as follows:

	Iron (mg/L)	Manganese (µg/L)
Well 7	0.38	30
Well 29	0.36	65

Blending is one approach to meeting the SMCL [0.3 mg/L iron and 50 µg/L manganese]; however, this approach is usually implemented where two nearby sources have differing water qualities. In order words, one source has low iron and/or manganese while the other source is significantly higher. Water quality goals can be achieved by blending the two well sources in a single facility without the need for further capital investment – i.e. construction of a filter plant. If blending were applied at a treated well source, such as Well 7 or Well 29, a 3:1 blend (untreated : treated) could achieve the water quality goal of minimally meeting the SMCL.

The concept of blending or bypassing to reduce treatment costs was explored in depth by SEH in their Well 31 report. That report is attached for your information and use.

6. Please provide a summary of Fe and Mn discolored water complaints received by the Utility at service areas provided untreated water. For example Well 19

Water quality calls are tracked by aldermanic district. Districts with the highest number of colored water calls [2, 4, 6, 13, 14, and 18] are generally served by wells with iron levels around 0.2 mg/L and manganese in excess of 30 µg/L. On the other hand, districts with very few colored water calls have iron below 0.01 mg/L and manganese under 10 µg/L.

Table 1 summarizes the water quality calls received from consumers within each of the City's twenty aldermanic districts over the three-year period of 2013-2015. During this time period, a total of 640 colored water calls were received by the Water Utility.

Table 2 identifies the aldermanic districts from which the most and least colored water calls are received as well as the wells, including their corresponding iron and manganese levels, that primarily serve each of these districts. Over 56% of colored water calls originated from six districts. Nearly all of these districts are served by wells with elevated levels of iron and manganese.

Table 1.

Alder District	All Calls	Color Calls	Days/Call	Rank
01	36	12	91.25	16
02	104	68	16.10	3
03	61	24	45.63	9
04	65	38	28.82	5
05	68	23	47.61	10
06	132	81	13.52	2
07	30	2	547.5	20
08	26	15	73.00	13
09	61	23	47.61	10
10	63	13	84.23	14
11	68	13	84.23	14
12	79	26	42.12	8
13	148	91	12.03	1
14	86	38	28.82	5
15	91	20	54.75	12
16	60	12	91.25	16
17	50	8	136.9	18
18	86	48	22.81	4
19	108	33	33.18	7
20	22	3	365.0	19

Table 2.

Most Calls

Alder District	Neighborhoods	Well Source	Iron (mg/L)	Manganese (µg/L)
02	Isthmus	24,17	0.21	31
04	Capitol - West	24, 17, 27	0.21	31
06	Isthmus, Near East	24, 17, (8)	0.21	31
13	Near West, South	27, 18	0.15	30
14	South	30, 18	0.21	15
18	North	13	0.02	4

Fewest Calls				
Alder District	Neighborhoods	Well Source	Iron (mg/L)	Manganese (µg/L)
01	Southwest	26	<0.01	10
07	Southwest	20	<0.01	1
10	West	12, 20, 19	0.20	44
11	West	12, 14	<0.01	<1
Alder District	Neighborhoods	Well Source	Iron (mg/L)	Manganese (µg/L)
16	Southeast	9	<0.01	11
17	Northeast	15, 29	<0.01	3
20	West	20, 12	<0.01	1

7. Discuss related issues such as the cost of flushing in neighborhoods that receive untreated water.

Flushing

Flushing is conducted by Well service area. A typical area will take approximately 3 weeks to flush. It is estimated that an area costs $10,000 per flush in labor and equipment costs. A complete flush of a well service area requires between 2 and 3 million gallons of water to complete. Cost to produce a million gallons of water is estimated to be approximately $1,000. Filtering the water and reducing the iron and manganese levels to near non-detectable levels will reduce the flushing requirements from potentially twice per year to once every 2 or 3 years. Filtration could save approximately $12,000 per year. Reducing the need to flush the system will also save water thereby conserving our valuable groundwater resource.

Complaints

Within months of putting Well 29 went on line in 2005 the Utility was flooded with water quality calls. Complaints of colored water were common and resulted in the limited use of the well from 2006 to 2009. Following the installation of the filter at Well 29 in 2008/2009 the colored water calls from the area are virtually non-existent.

A similar result was observed when the Well 7 filter went on line. During public meetings prior to construction, citizens reported stained plumbing fixtures and discolored water. Following start up of the filter, citizens reported excellent water quality that even tasted better.

Water Production

Wells that have elevated levels of iron and manganese are not used by the Utility to their full capacity. This is an operational decision to minimize impact to customers and reduce the risk of colored water events. When Well 29 went on line the large number of complaints resulted in the well being only used seasonally and to provide surplus capacity. Following

construction of the filter, the well is used year around and is operating at full capacity. The inability to fully use a supply source will result in the need for additional wells. Total water production from Well 7 will also increase due to the improved water quality.

Contaminate Concentration

Recent research has indicated that iron and manganese silts will attract and concentrate other contaminates such as arsenic and lead. A disturbance of the silts in a pipe may result in high levels of regulated contaminates being distributed through the piping system.

Customer Trust and Confidence in the Water Utility

Iron and manganese, while listed as a secondary contaminate by the USEPA, causes staining of plumbing fixtures and laundry, colored water events, and may result in taste and odor problems. Any of these events will reduce the trust and confidence in the Water Utility.