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MEMORANDUM

TO: Trevor Walter, PE

FROM: Kevin Young, PE (Lic. MN, VA)

DATE: November 25, 2024

RE: 2024 Well Rehabilitation Project Summary
SEH No. BAXTE 177535 14.00

On January 25, 2024, Thein Well provided the City of Baxter (City) well inspection reports for Wells 1(R), 2(R), 3, and 4(R) which recommended that each well be rehabilitated. The City contracted with SEH in February 2024 to assist with the well rehabilitation project. This memorandum summarizes the results of the 2024 well rehabilitations.

SEH assisted the City in collecting samples from Well 3 to send to Water Systems Engineering, Inc. of Ottawa, KS, to perform a complete well profile analysis. The well profile report (attached) concluded:

- Well 3 had “an increased potential for iron-related fouling downhole and in the produced water.”
- Manganese was identified at levels exceeding the fouling threshold of 0.1 mg/L in all samples.
- The organics and nutrients in the well could indicate future growth of microbial populations in the well as it ages.

Based on the results, Water Systems Engineering, Inc. recommended the following chemical and mechanical cleaning for Well 3. The recommended chemicals and cleaning procedures were specified for all wells and adjusted based on the site and well conditions during the rehabilitations.

- Pull pump equipment and visually inspect for corrosion or degradation.
- Mechanical pre-treatment (brushing).
- Combined chemical and mechanical cleaning using the following chemicals.
  - Johnson Screens Nu-Well 120 Phosphoric Acid (75% strength) 45 gallons
  - Johnson Screens Nu-Well 310 Biodispersant 20 gallons
  - Potable water for blending 300 gallons
- Blend chemicals and introduce to well. Surge chemicals using surge block.
- Pump well until pH and conductivity return to normal and visible turbidity is zero.
- Disinfect well and leave overnight.
- Final disinfection.
- Disinfect piping and equipment prior to placement.
- Collect bacteriological samples for regulatory testing.

Short Elliott Hendrickson Inc., 13822 Bluestem Court, Suite 150, Baxter, MN 56425-6005
218.855.1700 | 866.852.8880 | 888.908.8166 fax | **sehinc.com**

WELL 3 REHABILITATION – 04.12.2024 – 04.25.2024

Thein began the initial rehabilitation for Well 3 by pulling the pump and associated equipment on April 12. The pre-rehabilitation specific capacity for the well was 12.9 gpm/ft. The well was televised after flushing and allowing the well to sit stagnant for two days.

The project kick off meeting was held on site on April 15. Mechanical cleaning was then completed with the wire brush and the casing was bailed. The following day, chemical cleaning began with the addition of 70 gallons of Nu-Well 120/Nu-Well 310. The next morning, the pH was at 4, therefore, Thein added another 28 gallons of Nu-Well 120/Nu-Well 310 to bring the pH back down to 3.

Surging was completed and the well was pumped to remove the chemical and return the water to a normal pH. Performance pumping took place on April 19 and the specific capacity was calculated to be 16 gpm/ft pumping at 600 gpm, representing a 20% increase in specific capacity.

On April 22, Thein televised prior to chlorinating the well and pumping to waste. The pumping equipment was replaced, and the well was put back in service following receipt of bacteria testing results on April 25. Thein Well replaced 42 feet of drop pipe in Well 3 due to concerns over pitting and corrosion on the pipe.

Since the rehabilitation was not able to return Well 3 to it’s 2023 inspection specific capacity, the City asked SEH to review the results with Thein Well and evaluate whether a second rehabilitation would be beneficial. Well 1 required back-to-back rehabilitations in 2011 to return its capacity to near design conditions.

WELL 2 REHABILITATION – 04.25.2024 – 05.06.2024

Following the rehabilitation of Well 3, Thein began pulling pump and equipment from Well 2 on April 25. The pre-rehabilitation specific capacity for the well was 19.8 gpm/ft. The well was flushed and allowed to sit stagnant for two days before televising.

Well 2 was televised on April 29 before mechanical cleaning by wire brushing was completed. Televising for this well showed a similar state of the screen as Well 3, with minimal build up visible on the screen. The following day, Thein jetted the well for 8 hours, at which point, the specific capacity plateaued so jetting was stopped. After jetting was complete, 70 gallons of Nu-Well 120/Nu-Well 310 chemical was added to Well 2 for the initial chemical treatment on May 1. When the pH was verified the next day, it had remained below 2, therefore, additional chemical was not added. Surging was completed and the well was pumped to remove the chemical and return the water to a normal pH.

On May 2, Thein completed performance pumping of the well until there was no more improvement in specific capacity. The final specific capacity was 21.0 gpm/ft, an approximately 6% increase from the initial specific capacity of 19.8 gpm/ft. On May 6, Thein televised prior to chlorinating the well and pumping to waste. Pumping equipment was replaced and the well was put back in service following receipt of bacteria testing results on May 7.

WELL 3 ADDITIONAL REHABILITATION – 6.7.2024 – 6.19.2024

Since the initial Well 3 rehabilitation was not able to restore the specific capacity to January 2023 values, the City decided to conduct a second rehabilitation utilizing WaterSafe AR for the chemical treatment. Thein Well previously used WaterSafe AR successfully in Baxter and other cities so it was decided to use it for the second rehabilitation instead of the Johnson Screens Nu-Well chemicals in an attempt to further increase the Well 3 specific capacity. The starting specific capacity for this rehabilitation was 16.0 gpm/ft.

The Well 3 pump equipment was pulled and jetting began on June 10. Thein continued to jet at approximately 175 gpm and monitor specific capacity. On June 11, chemical treatment began with the addition of 180 gallons of WaterSafe AR to the well. Surging began and continued the following day, while the chemical mixture was left in the well overnight. At the conclusion of the second day of surging, chlorine and acetic acid were added to the well and left overnight for disinfection. On June 19, Thein removed the surge block and began pumping the well and chlorine to waste, followed by collecting bacteria testing samples. Pumping equipment was replaced and the well was put back in service following receipt of bacteria testing results.

The final specific capacity for Well 3 was 18 gpm/ft, resulting in a 13% increase in specific capacity for this rehabilitation and a total of nearly 40% increase in specific capacity between both rehabilitations.

Following the rehabilitation of Wells 2 and 3, the City decided to delay the rehabilitations of Wells 1 and 4 until the fall of 2024.

WELL 4 REHABILITATION – 09.09.2024 – 09.16.2024

After the Well 3 rehabilitation was complete in June 2024, SEH reached out to Johnson Screens for a recommendation to improve the rehabilitation results. Johnson Screens recommend adding Nu-Well 400 to the chemical solution used for cleaning. Nu-Well 400 is a dispersant chemical which is designed to increase the chemical penetration into the aquifer formation to improve the cleaning process.

Thein began the rehabilitation of Well 4 by pulling the pump and equipment on September 9. The initial specific capacity for the well was 13.8 gpm/ft. The well was televised the following day. Thein then began jetting and pumping to loosen material on the screen. On September 11, Thein added 20 gallons of Nu-Well 310, 50 gallons of Nu-Well 120, and 1 gallon of Nu-Well 400 to the well to react overnight. The following day, Thein began surging and continued throughout the day.

The pH in the well remained adequately low overnight and additional chemical did not need to be added. Thein continued surging throughout the following day. Thein started and stopped pumping to “burp” any extra chemical out. The post-rehabilitation specific capacity was 21.1 gpm/ft at a pumping rate of 590 gpm. Thein then put chlorine in the well for disinfection over the weekend. Thein televised on September 16 and collected bacteria samples for analysis. Bacteriological testing results were received on September 18 before the well was put online.

When the drop pipe was removed from Well 4 it was found to have corrosion pitting and was recommended to be replaced. All the drop pipe was replaced. Thein left the abandoned well drop pipe for Well 4 per the City’s request.

WELL 1 REHABILITATION – 09.23.2024 – 09.30.2024

Thein began pulling the pump and equipment from Well 1 on September 23. The initial specific capacity for the well was 18.9 gpm/ft with the well being pumped at 270 gpm. The well was televised the next day, followed by jetting and pumping to loosen material on the screen. On September 24, Thein added 20 gallons of Nu-Well 310, 50 gallons of Nu-Well 120, and 1 gallon of Nu-Well 400 to the well to react overnight. The following day, Thein began surging and continued throughout the day.

The pH of the water in the well remained at an acceptable level so no additional chemical was added and Thein continued to surge on September 26. The next day, Thein installed the pump and pumped to determine the specific capacity. Thein recorded the final specific capacity at 22.2 gpm/ft being pumped at 633 gpm. On September 30, Thein completed post-televising of the well and collected bacteria testing samples. The well was placed in service upon receipt of bacteria testing results on October 2. After the wells were placed back in service, Thein assisted with identifying the depth of the well level transducers. Their report of the transducer level is attached.

SUMMARY OF REHABILITATION RESULTS

The results of the 2024 well rehabilitations are presented below in terms of both flow and specific capacity.

Flow

When the wells were drilled the well pumps were capable of individually producing more than 700 gpm, which was not advised. In 2013, the well pumps were replaced to target a flow rate of 700 gpm. During the 2023 well inspection by Thein Well, all pumps could produce about 700 gpm before the historically high water demand experienced during the summer of 2023 required all four (4) wells to run at the same time for the first time since the wells were drilled.

The maximum flow rate from each well, with all four (4) wells running for a short period of time, was tested on November 21, 2024, after the 2024 rehabilitation work was complete. The testing information is provided in Table 1, and only Well 3 was capable of pumping more than 600 gpm to the WTP. **The total pumping capacity from the well pumps is nearly 500 gpm less than the 2013 design flow rates.**

Table 1 – Historical Well Flow Comparison

	Current Max. Flow Rate (all wells running) (11/21/2024)	2023 Well Inspection Pumping Rate	2013 Design Flow	Difference (Current Flow – Design Flow)
Well 1R (gpm)	585	691	700	-115
Well 2R (gpm)	578	674	700	-122
Well 3 (gpm)	628	741	700	-72
Well 4R (gpm)	513	661	700	-187
Total Capacity	2,304 gpm	2,767 gpm	2,800 gpm	-496 gpm
	3.3 MGD	4.0	4.0	-0.7
Firm Capacity (1)	1,676 gpm	2,026 gpm	2,100 gpm	-424 gpm
	2.4 MGD	2.9 MGD	3.0 MGD	-0.6 MGD

Notes: (1) Firm capacity is defined as the capacity with the highest capacity pump/well out of service.

Source: City Records

Reduced pumping rates are often correlated to clogged well screens, pump or motor issues, declining water levels, or changing aquifer conditions. Knowing the wells screens are not clogged after rehabilitation, the reduced flows can be correlated to the lower pumping water levels. It is also possible that the pump impellers are experiencing some wear and are no longer able to pump at their original capacity or that the aquifer conditions changed outside of the radius that can be reached by the typical well rehabilitation methods used. Discussion on increasing well flow by replacing pumps is included below.

Specific Capacity

Specific capacity is the volume of water that can be pumped from a well per foot of decreased water level during pumping, measured in gallons per minute of foot of drawdown (gpm/ft). It is often tracked to use as an indicator of well condition. The 2024 well rehabilitation efforts increased the specific capacity of each well when compared to the pre-rehabilitation specific capacities with improvements ranging from 6% to 53%, as presented in Table 2. However, **none of the wells had the specific capacity restored to their March 2023 levels**. The specific capacities were restored to 52-60% of the March 2023 specific capacities.

Table 2 – Historical Well Specific Capacity Information

Description	Well [(1)]			
	1R	2R	3	4R
March 2023 Specific Capacity (gpm/ft)	41.0	34.9	34.9	36.1
2024 Pre-Rehabilitation Specific Capacity (gpm/ft)	18.9	19.8	12.9	13.8
2024 Post-Rehabilitation Specific Capacity (gpm/ft)	22.2	21.0	18.0	21.1
% Increase from 2024 Rehabilitation	17%	6%	40%	53%
Well Rehabilitation Trigger[(2)] Specific Capacity (gpm/ft)	17.8	16.8	14.4	16.9

Notes:
[(1)] Individual well specific capacities calculated while on the single well is running. Running multiple wells in the well field will cause the specific capacity to be calculated at a lower value due to well interference.
[(2)] "Trigger" specific capacity represents a decrease in specific capacity of 20%, at which time the City should consider rehabilitating the well.

Source: Thein Well Inspection Reports, City Records

For reference, Figure 1 presents the historical specific capacity of the City's four (4) existing wells, including the pre- and post-rehabilitation specific capacities from 2024. This data shows that there was a slight decreasing trend in specific capacity from about 2015 to 2023 before the specific capacity dropped sharply due to the high 2023 water demands caused by a drought.

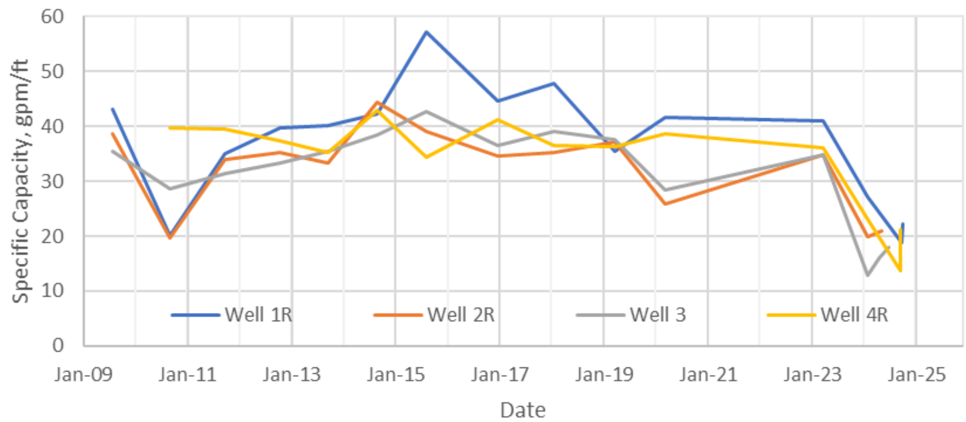

Figure 1 – Historical Well Specific Capacity

2025 WATER DEMAND PROJECTIONS

It is important to look ahead to 2025 and begin to plan for the possibility of high summer demands like those experienced in 2023 to determine if the wells will be able to meet the City's water demand. As part of a separate project to update the City's water distribution system hydraulic model, SEH evaluated recent summer demands to calculate potential 2025 demands. The results are summarized below.

2025 demand projections were calculated in terms of average summer day (ASD) and maximum summer day (MSD) and are presented below. Instantaneous flows are provided in both 24-hour and 18-hour intervals, as staff try to limit the WTP run time to about 18 hours per day to allow the well field to recharge.

- **ASD**: 2.5 million gallons per day (MGD), which equates to 1,740 gpm over a full 24-hour day or 2,320 gpm over 18 hours.
- **MSD**: 2.96 MGD, which equates to 2,075 gpm over a full 24-hour day or 2,740 gpm over 18 hours.

By comparing the above post-rehabilitation well flows data above to potential 2025 water demands it is possible to project if the wells will be able to meet the City's short-term needs until Wells 5 and 6 are constructed. Figure 2 presents the 2023 and 2024 water demands and includes horizontal lines representing the 2025 ASD and MSD and dots representing various well flow scenarios, described below:

- **1,800 gpm – 18 hrs**: This flow scenario represents a conservative 450 gpm being pumped out of each of the existing four (4) wells for 18 hours per day. This scenario provides an indicator of flows if the pumping rates continue to drop. When compared to the projected 2025 ASD, the City would need to purchase about 600,000 gallons per day (420 gpm) from Brainerd on average.
- **2,300 gpm – 18 hrs**: This flow scenario represents pumping the four (4) existing wells at the current pumping capacity of between 510-630 gpm per well for 18 hours per day. This scenario represents flows if the well pumps maintain their current capacity and the well condition stabilizes after the 2024 rehabilitation. In this scenario, the City would be able to produce the projected 2025 ASD flows, but would fall short of producing the projected 2025 MSD flows without extending the WTP run time. The City would need to purchase about 400,000 gallons per day from Brainerd to meet maximum day demands.

- **2,300 gpm – 24 hrs**: This flow scenario represents pumping the four (4) existing wells at the current pumping capacity of between 510-630 gpm per well for 24 hours per day. This scenario represents flows if the well pumps maintain their current capacity and the well condition stabilizes after the 2024 rehabilitation. In this scenario, the City would be able to produce both projected 2025 ASD and MSD flows. However, the aquifer may not recharge as desired if the wells are pumped 24 hours per day for extended periods of time and the City may experience issues like those of 2023. The City may not need to purchase water from Brainerd in this scenario.

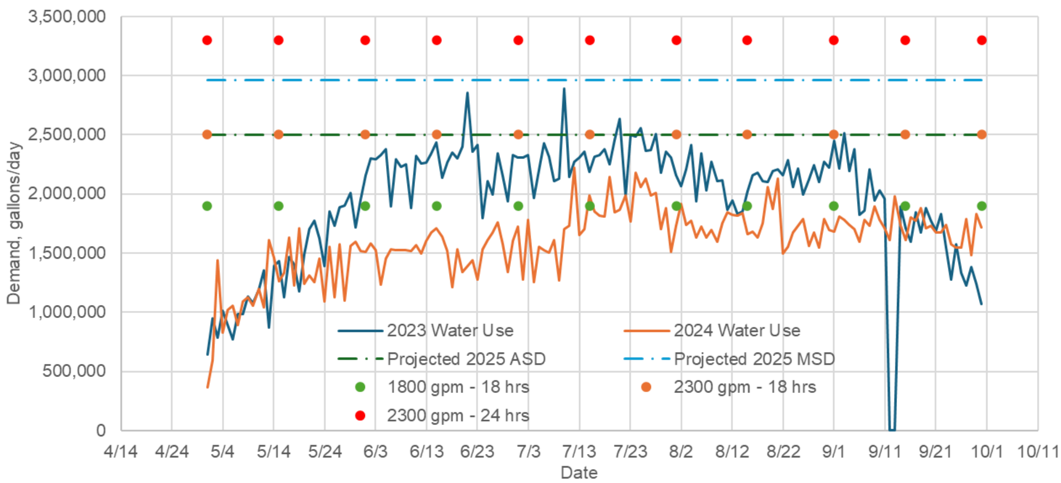

Figure 2 – 2023/2024 Summer Demands & 2025 Flow Projections

Based on the projected 2025 water demands, the City may need to purchase up to roughly 600,000 gallons per day (420 gpm) from Brainerd to meet ASD demands if the well field is only able to sustainably produce 1,800 gpm over 18 hours per day. If the well field is able to sustain 2,300 gpm the City would likely keep up with demands on an average day. However, up to 1,000,000 gallons per day (700 gpm) may need to be purchased on an intermittent basis to meet MSD demands. **The volume of supplemental water that may be needed will depend on well/pumping conditions, weather (which impacts water demand), and operational limitations of the interconnect.**

In its current configuration, the minimum gravity flow through the interconnect with no pumps running is about 300 gpm, or 0.43 MGD. A modulating valve actuator could be installed to adjust gravity interconnect flows from Brainerd to less than 300 gpm, but the existing valves require manual adjustments. During the summer of 2024, Brainerd Public Utilities (BPU) requested that Baxter purchase a consistent volume of water to reduce the stress on their system. The City of Baxter currently charges $3.68/1,000 gallons while BPU charges $4.10/1,000 gallons for commercial customers.

If the minimum flow of 300 gpm was purchased from BPU consistently throughout the summer, it would cost the City about $27,600 more than customers would be charged for the water. For comparison, the average cost of the well rehabilitations completed in 2024 was nearly $32,000 per well, not including engineering, meaning the added cost of purchasing supplemental water from Brainerd is estimated to be less than the cost to rehabilitate one well.

RECOMMENDATIONS

- **Operate multiple wells at lower flow rates to reduce the drawdown** in the well field. For example, rather than pumping two (2) wells at 700 gpm each to produce 1,400 gpm the City could use three (3) wells each pumping about 465 gpm to keep the water level in the wells higher. Pumping from a higher water surface elevation in the aquifer also reduces the amount of electricity used to pump the water. SEH recommends targeting a pumping water level of less than about 60' across the well field, consistent with the summer 2024 recommendations. This recommendation is not a hard limit, as operators need to balance water production and pumping water level. If pumping levels begin to follow a dropping trend as demands pick up, water may need to be purchased from Brainerd.
  - The maximum pumping level for the wells is about 80' to maintain a required column of water over top of the pump without breaking suction. However, as the pumping level drops below 60' it is anticipated that the formation in the vicinity of the well will foul at an increased rate like it did in 2023, so there may be diminishing returns from dropping the pumping level below 60' to not purchase water from Brainerd.
- **Replace pumps for Wells 1 and 4 to achieve up to 700 gpm from each well.** The existing well pumps are no longer capable of producing 700 gpm as they were designed. This is likely due to a combination of lower pumping water levels or pump/impeller wear. Prior to the filter rehabilitation project when variable frequency drives (VFDs) were installed, the City relied on pump impellers being trimmed to target a desired flow. Now that VFDs are in place, the City has more flexibility to operate the wells at varying flow rates and dial the VFD speed back to reduce the flow rate as aquifer conditions require.
  - It is recommended that the City's future well field operation strategy consist of primarily operating existing Wells 1 and 4 with the proposed Wells 5 and 6 to maximize pump spacing and reduce interference between the wells. In this case Wells 1 and 4 would still be relied on to produce up to 700 gpm. When Wells 2 and 3 are used it would be recommended to pump Wells 1 and 3 <u>or</u> Wells 2 and 4, again to minimize interference between the wells. Wells 5 and 6 would be allowed to pump with either previous combination or with Wells 2 or 3. Assuming Wells 5 and 6 are constructed with a 700 gpm capacity, this would not require Wells 2 and 3 to produce 700 gpm in the short-term.
  - SEH recommends purchasing new pumps for Wells 1 and 4 so they are able to pump 700 gpm to the WTP, but dial the speed setting back during lower demand periods or as aquifer conditions require to reduce stress on the aquifer.
  - Thein Wells has indicated that the lead time for new pumps matching the existing pump model would be about 5-6 weeks after the pump is ordered. The lead time could be reduced to about 4 weeks if a different pump manufacturer was selected.
  - Thein Wells reported that it will be cheaper to install new pumps than to pull the pumps, replace the impellers, and then reinstall them. It is estimated that each new pump will cost about $15,000.
- **Drill additional production wells** to relieve the stress on the existing well field. SEH is currently under design on proposed Wells 5 and 6. It is anticipated that the wells will be drilled during the summer of 2025, but it is unlikely that they will be able to pump water to the WTP until the end of the summer high demand period.
- **Monitor specific capacity.** If the individual well specific capacities drop to the Well Rehabilitation Trigger Specific Capacity provided in Table 2, the well(s) should be rehabilitated. The Well Rehabilitation Trigger Specific Capacity is based on the specific capacity dropping 20% from the 2024 post-rehabilitation level.

- **Discuss wholesale water rates with Brainerd Public Utilities.** While the volume of water that may be required to supplement flows from Baxter's wells can't be quantified to an exact number, it could be up to 85 million gallons during the summer of 2025. Similar to 2021 when the City purchased all of its water from Brainerd when the WTP was offline for filter reconstruction, the City should discuss water rates with BPU prior to summer demands picking up. Also, it may be beneficial to install a modulating flow control valve at the interconnect if supplemental flows less than 300 gpm would be sufficient to meet the City's water demand.

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Attachments:

– Water System Engineering, Inc. Well Samples Report
– Well Figures
– Well Summary Table
– Thein Well Level Transducers Measurement Summary

c: Trevor Thompson, Assistant City Engineer

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Date: April 25, 2024

Lab Report No. 22986

Brian Berent
City of Baxter
13190 Memory Wood Dr.
Baxter, MN 56425

Project Description: City of Baxter, MN, Well No.3; Samples dated 02/29/2024
Complete Well Profile (1); Job Reference: Baxter Well No.3

Test Description:

The Complete Well Profile analysis is designed for comparative analysis of two samples, typically one static and one pumping sample. The Complete Well Profile utilizes a series of inorganic chemical and microbiological tests to identify fouling and corrosion issues with potential impacts on the operation of the sampled well. The tests include a number of inorganic chemical parameters such as pH, total dissolved solids/conductivity, hardness, alkalinity, oxidation reduction potential (ORP), bicarbonate, carbonates, silica, sodium, potassium, chloride, iron, manganese, phosphate, nitrate, sulfate, and total organic carbon (TOC). Biological assessment is designed to quantify the total bacterial population, identify two dominant populations of bacteria, assess anaerobic conditions, and identify the presence of iron related bacteria and sulfate reducing organisms. Also included are tests for Adenosine triphosphate (ATP), heterotrophic plate count (HPC), and a microscopic evaluation; and in potable systems, total coliform and E. coli coliform presence/absence.

Testing Procedures:

All laboratory testing procedures are performed according to the guidelines set forth in *Standard Methods for the Examination of Water and Wastewater* as established by the American Public Health Association (APHA), American Water Works Association (AWWA), and Water Environment Federation (WEF). Corrosion analyses are performed in accordance with the guidelines as set forth by the National Association of Corrosion Engineers (NACE). In general, these methods are approved by both the Environmental Protection Agency (EPA) and AWWA for the reporting of water and/or wastewater data.

Sample collection and shipment is the responsibility of the customer, performed according to protocol and procedures defined by the laboratory in advance of the sampling event with regards to the specific project and nature of the problem.

Disclaimer:

The data and interpretations presented are based on an evaluation of the samples and submitted data. Conclusions reached in this report are based upon the data available at the time of submittal and the accuracy of the report depends upon the validity of information submitted. Any recommendations presented are based on laboratory and field evaluations of similar fouling occurrences within potable water systems. Further investigative efforts, such as efficiency testing, site inspection, video survey, or other evaluation methods may offer additional insight into the system's condition and the degree of fouling present.

Client: City of Baxter
Date: April 25, 2024
Lab Report No. 22986

Re: City of Baxter, MN, Well No.3; Samples dated 02/29/2024
Complete Well Profile (1); Job Reference: Baxter Well No.3

ND - Not Detected
NA - Not Applicable
* as $CaCO_3$

	Well 3 Casing	Aquifer (after 20 min)	Detection Limits
pH Value	7.47	7.48	NA
Phenolphthalein Alkalinity*	ND	ND	4 mg/l
Total Alkalinity*	156	164	4 mg/l
Hydroxide Alkalinity*	ND	ND	4 mg/l
Carbonate Alkalinity*	ND	ND	4 mg/l
Bicarbonate Alkalinity*	156	164	4 mg/l
Total Dissolved Solids	270	265	1.0 mg/l
Conductivity (µm or µS/cm)	375	368	NA
ORP (mV)	271.2	267.6	NA
Langelier Saturation Index (at 16°C)	- 0.29	- 0.23	NA
Total Hardness*	156	188	4 mg/l
Carbonate Hardness	156	164	4 mg/l
Non Carbonate Hardness	ND	24	4 mg/l
Calcium*	140	152	4 mg/l
Magnesium*	16	36	4 mg/l
Sodium (as Na)	11.00	10.50	0.02 mg/l
Potassium (as K)	0.1	0.1	0.1 mg/l
Phosphorus, Reactive (as PO_4^{3-})	ND	ND	0.06 mg/l
Chlorides (as Cl)	28.7	28.4	1 mg/l
Nitrate (Nitrogen)	ND	ND	0.3 mg/l
Chlorine (as Cl)	ND	ND	0.02 mg/l
Dissolved Iron (as Fe^{2+})	ND	ND	0.02 mg/l
Suspended Iron (as Fe^{3+})	0.05	0.02	0.02 mg/l
Iron Total (as Fe)	0.05	0.02	0.02 mg/l
Iron (resuspended)	3.76	4.05	0.02 mg/l
Copper (as Cu)	ND	ND	0.04 mg/l
Manganese (as Mn)	0.291	0.413	0.007 mg/l
Sulfate (as SO_4)	ND	ND	2 mg/l
Silica (as SiO_2)	17.5	17.5	1.0 mg/l
Tannin/Lignin	ND	ND	0.1 mg/l
Total Organic Carbon (C)	1.6	1.5	0.3 mg/l

Biological Analysis:

	Well No.3 Casing	Well No.3 Aquifer	Detection Limit
Plate Count (colonies/ml)	2	1	NA
Anaerobic Growth (%)	<10	<10	NA
Sulfate Reducing Bacteria	Negative	Negative	NA
Fe/Mn Oxidizing Bacteria	Negative	Negative	NA
ATP (cells per ml) Initial	26,000	61,000	NA
ATP (cells per ml) 24 Hour	67,000	97,000	NA
Total Coliform	Negative	Negative	NA
E. Coli	Negative	Negative	NA
Bacterial Identification	-	*Acidovorax tempereans*	NA

Microscopic Evaluation:

Casing: Heavy visible bacterial activity, low crystalline debris, very low number of protozoa, low amount of plant particulate, very low iron oxide with a moderate amount of iron oxide entrained biomass.

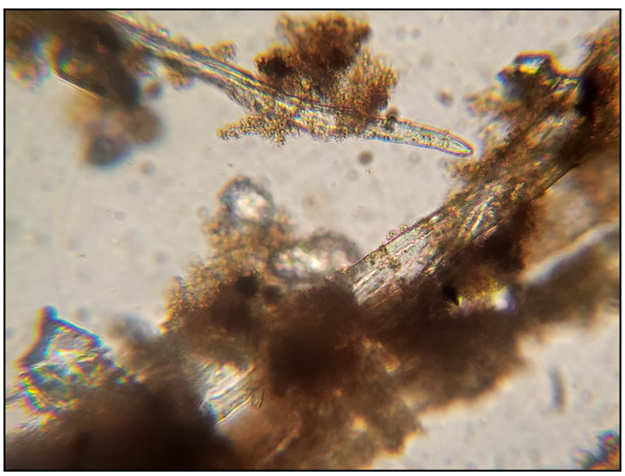

Figure 1: Plant particulate and biomass at 200x magnification

Aquifer: Heavy visible bacterial activity, very low amount of plant particulate, very low iron oxide with a moderate amount of iron oxide entrained biomass.

Observations:

Samples were submitted for the City of Baxter, MN for Well No. 3 for analysis due to low production and upcoming rehabilitation plan. Upon arrival in the laboratory, the initial testing noted a neutral pH value in the casing and aquifer sample. The Oxidation Reduction Potential (ORP) measurements for the well samples were high and indicate an oxidative environment is present. With ORP levels at this point it is sufficient to expect oxidation of metals such as iron and manganese. An oxidative environment such as this will also impact corrosion rates as well as aerobic bacterial stimulation and activity.

Total alkalinity was in the expected range in the casing and aquifer sample. The alkalinity contribution in the samples were solely from bicarbonate (HCO_3^-) ions, as carbonate and hydroxide ions were not identified. These values, in conjunction with the pH suggest moderate buffering capability within the water chemistry. Although not excessive, the total alkalinity level and pH are sufficient to impact chlorination efforts as a result of the buffering capability. Total dissolved solids (TDS) levels, calculated as a function of electrical conductivity, were measured in expected concentrations for the region.

The Langelier Saturation Index (LSI) calculation predicts scale formation and the likelihood for chemical corrosion. The calculated LSI values for both samples were slightly negative, but still within the expected range for regional groundwater conditions. Negative values indicate an undersaturated environment with a reduced likelihood of calcium scale development and the potential for chemical corrosion to occur.

Water hardness measures the calcium (Ca^{2+}) and magnesium (Mg^{2+}) concentrations in groundwater. Total Hardness was elevated in the aquifer sample. Hardness levels at greater than 180 mg/L are considered very hard and highly mineralized. The calcium levels are on the higher end of the expected range and could be influencing hardness concentrations, impacting the potential for scale and influencing treatment measures.

Dissolved iron, suspended iron and iron total were either not detected or minimal amounts were identified in both samples. Resuspended iron, a test that accounts for dissolved and suspended iron as well as iron that has been mobilized by bacteria, was found in elevated amounts in the casing and aquifer samples. Typically, resuspended iron concentrations above 1.0 mg/l indicate an increased potential for iron-related fouling downhole and in the produced water. In the microscopic evaluations, it was identified to have iron oxide entrained biomass which will impact these concentrations.

Manganese, a mineral that behaves very similar to iron in its fouling characteristics, was detected at levels exceeding the fouling threshold of 0.1 mg/l in both of the Well 3 samples. At these levels, manganese scale is likely, especially in areas seeing more oxidation such as in the vicinity of the pump.

Total Organic Carbon (TOC) is used as an indicator of water quality and the potential for bacterial stimulation and biofouling. Elevated levels of TOC were detected in both samples. These TOC values suggest a potential for the concentrating of organics within the well which could lead to an increase in microbial activity downhole.

Biological analysis of the samples included heterotrophic plate count (HPC) and adenosine triphosphate (ATP) analysis. The observed level of plate growth was limited in both samples despite a high degree of visible bacterial activity and moderate amounts of biomass noted microscopically. The initial ATP counts were in the average range for the well samples. A second evaluation conducted following a 24-hour period under ideal environmental conditions reported levels that increased and were still within the expected range for an active well. As a point of reference, potable wells typically exhibit an ATP range of 10,000 to 70,000 cpm, with values in excess of 100,000 cpm a concern for biofouling.

Anaerobic growth, reported as a percentage of the total population, was expected at less than 10% in both samples. Typically, as anaerobic levels increase, biofouling becomes more dynamic with increases in the occurrence of total coliforms and problematic bacteria. Testing for sulfate reducing bacteria (SRB), a nuisance anaerobe associated with H_2S generation, was negative in the casing and aquifer sample. Sulfate-related bacterial effect water quality in regard to taste and odor as hydrogen sulfide (H_2S) and can impact pH levels, influencing the corrosion potential.

Testing for the presence of iron and manganese-oxidizing bacteria was negative in both the casing and aquifer samples. Microscopic evaluation of both samples reported a very low rate of iron oxide with moderate amounts of iron oxide entrained biomass in both samples.

Total coliform tests, including environmental coliforms were negative in both of the Well No. 3 samples. *E. coli* specific coliform testing was negative for each of the well samples.

Microscopic evaluation of the well samples noted heavy visible bacterial activity along with plant particulate, iron oxide and iron oxide entrained biomass present. In the casing sample, it was reported that crystalline debris and protozoa were also present.

Identification of the dominant bacteria within the samples included species of soil bacterium. Background on the identified species is provided below.

Acidovorax temperans is an aerobic, gram negative soil bacterium. The bacteria's presence in the sample is likely a relation to the area of recharge for the well and aquifer, reflecting interaction with the upper soil horizons.

Microscopic evaluation of the samples reported a high level of visible bacterial activity in both samples. Crystalline debris and plant particulate were identified in the samples as well as a moderate amount of iron oxide entrained biomass.

Interpretations and Recommendations:

The Well No. 3 samples exhibit an elevated potential for iron related fouling. Although iron bacteria were not present, the samples each exhibited a concentrating of iron oxide and iron oxide entrained biomass. Iron and manganese were both present at concentrations in which scale development is expected.

While the microbial populations were limited in size, visible activity was high. Additionally, organics and nutrients are concentrating in the well which could lead to expansive growth as the well ages.

Submitted operation and efficiency data indicates that the well is experiencing a sharp decline in production capability. Based on the analysis, a combined chemical and mechanical cleaning is recommended. In addition, once fully flushed, a multi-volume, pH adjusted chlorination is advised. The goal of a more enhanced chlorination effort is to expand the reach of the cleaning efforts thereby extending the treatment life.

A video survey of the sampled well is highly recommended prior to conducting any maintenance or treatment efforts. This valuable resource will not only provide a pre-rehabilitation assessment of the well structure, but will aid in the directing of mechanical treatment efforts. The goal of the survey is to assess structural integrity of the well and current conditions downhole that may not be accurately reflected in the submitted sample. Furthermore, this will allow an evaluation of the amount (and type) of fill present in the lower extension of the well.

Recommended treatments are based upon well specification and design information provided, which are summarized below:

Well No. 3 Information:

Total depth:	136-ft
Diameter:	12-in
Statice water level:	33-ft
Single well volume:	605 gallons
Treatment volume:	900 gallons
Disinfection Volume	2,000 gallons
Avg. Total alkalinity	160 mg/l $CaCO_3$
Aquifer Conductivity:	368 µS/cm

Rehabilitation:

NW-120 Phosphoric acid (75% strength)	45 gallons
NW-310 Biodispersant	20 gallons
Potable water for blending	300 gallons

Disinfection

Sodium Hypochlorite (12% active)	5 gallons
NW-410 chlorine enhancer	4 gallons
Potable Water	2,000 gallons

Prior to any treatment efforts, the pump should be pulled and evaluated for signs of corrosion or material degradation which can be addressed, modified or replaced while outside of the well. Place the column pipe and pumping equipment on an elevated rack, power-wash, and treat with a 50-ppm sodium hypochlorite solution before re-installing into the well.

Next (and depending upon the results of video survey), begin with mechanical pre-treatment of the well. Brush the well casing and screened zone in an effort to knock loose scale and biomass accumulations. Use of an appropriately sized, nylon brush is recommended to disrupt accumulations yet reduce physical damage to the well and potential development of additional reactive surfaces. Once the entire well has been brushed, remove the disrupted material and pre-existing fill from the bottom of the well. Bail or airlift in an effort to purge the disrupted material from the well. Evacuate the material until visual turbidity has lessened and the conductivity has returned to a near normal background level for the wells (approximately 400 µS/).

Again, record the achievable well depth to confirm removal of material from the bottom of the well. Once mechanical pretreatment and subsequent evacuation is complete, a combined chemical and mechanical cleaning process should then be enacted.

Prepare a chemical solution comprised of Johnson Screen's 6% NW-120 phosphoric acid (75% strength), 3% NW-310 biodispersant, and potable water for introduction into the well. Phosphoric acid is a strong, slow reacting mineral acid that is recommended to target the concentration of iron scale identified within the well without jeopardizing the well structure. NW-310 biodispersant is recommended as a polymeric enhancer that improves the activity of acids towards mineral scale while improving the disruption and penetration of biomass. Additionally, the NW-310 aids in the removal of the disrupted materials following treatment. The treatment concentrations for each well in percent weight/volume below, are based upon a total treatment volume equivalent to 1.5-times the standing well volume.

Blend the chemicals on the surface and introduce evenly into the well. For blending of the acid treatment solution, mix the chemicals in this order: water, acid, biodispersant. Mix lightly. Surge the introduced chemicals using a surge bock which appropriately compliments the inner diameter of the well. Surge the entire well column over a twenty-four-hour period focusing a larger percentage of the time on the screened zones and lower extension of the well. During treatment, periodically monitor the activity of the chemical solution, maintaining a pH below 3 during the treatment process. If during acid treatment, the downhole pH rises to a level above 3.0, add additional acid and water to lower the pH. No additional dispersant should be needed.

Once surging is complete, thoroughly airlift or pump the well until the pH has returned to normal (6.5 or greater), the conductivity has returned to near normal background levels for the wells (approximately 400 μS/cm), visible turbidity is zero, and clear water is being evacuated. Begin evacuation from the lowest extension of the well moving upwards as conditions improve. Collect and neutralize the evacuated material above ground according to state and local regulations.

Following cleaning efforts, the well should be disinfected. The use of a pH adjusted method of disinfection is recommended based on the observed biomass and microbial activity. Use of alternative disinfection chemicals, such as chlorine dioxide or hydrogen peroxide, are not advised.

Final chlorination should then utilize sodium hypochlorite in a pH adjusted chlorination treatment of a 300-ppm chlorine level in a pH range of 6.5 to 7.0. The volume of the disinfection solution should be equivalent to 3-times the standing well volume within the well. This larger volume is utilized to flood the borehole with the disinfection solution in order to increase the effectiveness of treatment as well as the effective treatment area. Utilization of Johnson Screen's NW-410 product, an NSF approved chlorine enhancing chemical is strongly encouraged to aid in both effective disinfection as well as to increase the treatment area. The disinfection volumes below are based upon a total disinfection volume roughly equivalent to 3-times the standing well volume for each of the wells.

The disinfection solution should, likewise, be blended above ground and introduced into the well by a tremie pipe. In preparing the chlorine treatment above ground, mix the chemicals in this order: water, chlorine enhancer, check the pH (not below 5.5), add chlorine. Mix lightly. Efforts should be made to evenly disperse the disinfection solution evenly throughout the well and screened zones. Once the solution is placed into the well, it should be lightly agitated with a single disc surge block or similar tool to supply agitation and dispersion throughout the well columns and screened zones. During disinfection, if the chlorine residual has dropped to below 100 ppm, add additional sodium hypochlorite in to raise it to that level.

Allow the chlorine solution to remain downhole overnight. Following this period, begin evacuation of the well from the bottom, working upwards, until a minor residual (~ 50 ppm) is present and all debris has been evacuated from the well. At this time, the permanent pump and column pipe can be placed back into the well and utilized to purge the remaining chlorine solution from the well.

Prior to placing the piping and associated equipment back into the well, disinfect using a handheld or Hudson type spray rig with a 100-ppm sodium hypochlorite solution. Using 12% sodium hypochlorite, mix 5-ml of chlorine with every 1-gallon of potable water to achieve the desired concentration.

With the pump installed, actively pump the well until the conductivity has returned to a near normal background level for the wells (approximately 400 µS/cm,).

Evacuated material should be collected above ground in a storage tank, neutralizing rapidly with sodium bisulfate or sodium thiosulfate, and dispose of according to local and state regulations.

Please Note: Chlorine consumption may occur downhole as a result of iron, bacterial count, ORP values, and pH adjustment. Field monitoring during all phases of the recommended treatment procedures is advised. Additional sodium hypochlorite and physical agitation may be required, and as such, adjustments to these procedures may be necessary.

Following disinfection, collect representative samples for required regulatory testing. While awaiting test results, actively cycle the well sufficient to turn over the entire column at least once a week. This will provide additional benefit by limiting stagnation within the well environment which can reduce the benefits of disinfection efforts.

If you have any questions regarding these recommendations or require additional information, please contact our office.

Michael Schnieders, PG, PH-GW
Hydrogeologist

Baxter Well Information

	Well Field	Mapleton Rd WTP			
Well Information	Baxter Well Number	1R	2R	3	4R
	MDH Well Number	4	5	6	7
	Unique Well No.	752207	741694	733068	752208
	Address	Baxter 133 29 13 SW1/4 SW1/4 SE1/4	Baxter 133 29 13 SW 1/4 SW 1/4 SE 1/4	Baxter 133 29 13 SW 1/4 SW 1/4 SE 1/4	Baxter 133 29 13 SW 1/4 SW 1/4 SE 1/4
	Year Drilled	2007	2006	2006	2007
	Well Depth (completed)	132	121	136	135
	Aquifer	QWTA	QWTA	QWTA	QWTA
	Capacity (gpm) - Original	700	700	700	700
	Flow Rate (gpm) - 11/2024	585	578	628	513
	Static Water Level (ft bgs) - Original	30.7	29.7	28.6	27.8
	Pumping Water Level (ft bgs) - Original	48.5	47.9		50.7
	Specific Capacity (gpm/ft) - Original	39.3	38.6	34.3	30.6
	Specific Capacity (gpm/ft) - 10/2024	22.2	21.0	18.0	21.1
	Casing Diameter (in)	12	12	12	12
	Casing Depth (ft)	102	96	111	105
	Screen Diameter (in)	12	12	12	12
	Screen Length (ft)	30	25	25	30
	Screen Set Between (ft)	102 - 132	96 - 121	111 - 136	105 - 135
	Year Televised	2024	2024	2024	2024
	Year Cleaned	2011 2024	2011 2021/2022 2024	2013 2021/2022 2024	2011 2024
Well Pump Information	Pump Manufacturer	Goulds	Goulds	Goulds	Goulds
	Model Number	2-Stage 7THC	2-Stage 7THC	2-Stage 7THC	2-Stage 7THC
	Pump Type	Submersible	Submersible	Submersible	Submersible
	Pump Capacity (gpm)	700	700	700	700
	TDH	131	131	131	131
	Year Installed/Replaced	2007 2013	2007 2013	2007 2013	2007 2013
	Pump Set Depth (ft)	95.5	91	93	99.5
Well Pump Motor Information	Motor Manufacturer	Hitachi	Hitachi	Hitachi	Hitachi
	Motor Type	Submersible	Submersible	Submersible	Submersible
	Starter[2]	VFD	VFD	VFD	VFD
	Horse Power	40	40	40	40
	Year Installed/Replaced	2007 2013	2007 2013	2007 2013	2007 2013
	Voltage	460	460	460	460
	RPM	3450	3450	3450	3450
	Emergency Backup	WTP Gen.	WTP Gen.	WTP Gen.	WTP Gen.

[1] *When pumps are pumping alone*

[2] *FV=Full Voltage; VFD=Variable Frequency Drive*

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November 5, 2024

Baxter Water Level Readings take 10/11/2024

Well 1R:

- Static Water Level = 30.08’ from top of well – Manual Reading
- Static Water Level = 29.00’ from top grade/concrete – Manual Reading
- Static Water Level = 30.50’ on SCADA
- Transducer is hung 98.92’ from top of well to bottom of transducer
- Transducer measures 3.5” in length

Well 2R:

- Static Water Level = 30.17’ from top of well – Manual Reading
- Static Water Level = 29.33’ from top grade/concrete – Manual Reading
- Static Water Level = 35.20’ on SCADA
- Transducer is hung 94.33’ from top of well to bottom of transducer
- Transducer measures 3.5” in length

Well 3R:

- Static Water Level = 30.08’ from top of well – Manual Reading
- Static Water Level = 28.83’ from top grade/concrete – Manual Reading
- Static Water Level = 103.8’ on SCADA
- Transducer is hung 104.42’ from top of well to bottom of transducer
- Transducer measures 3.5” in length

Well 4R:

- Static Water Level = 26.75’ from top of well – Manual Reading
- Static Water Level = 25.42’ from top grade/concrete – Manual Reading
- Static Water Level = 103.8’ on SCADA
- Transducer is hung 97.83’ from top of well to bottom of transducer
- Transducer measures 6.5” in length