TECHNICAL MEMORANDUM

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To:	Clint Austin, P.Eng.	**Previous Issue Date:**	n/a
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Client:	Resort Village of Elk Ridge		
Project Name:	Water Treatment Plant Upgrades		
Subject:	Water Treatment Options		

Draft

1 INTRODUCTION

The Resort Village of Elk Ridge (the Village) has retained Associated Engineering (Associated) to assess the existing water treatment plant (WTP) and develop a plan to increase the water treatment capacity and improve treated water quality from the Village's WTP to meet *Saskatchewan Drinking Water Quality Standards and Objectives* (*SDWQSQ*) (EPB-507) for current and future Village populations. As part of the preliminary design stage, Associated has considered and evaluated following three expansion options using a comparison matrix for review purposes:

1. Option 1 - Greensand filtration with ultraviolet (UV) for primary disinfection.
2. Option 2 - Greensand filtration followed by chlorine gas for primary disinfection.
3. Option 3 - Membrane filtration addition.

The most favorable option agreed upon will then be developed into a preliminary design and eventually detailed design for the Village.

2 EXISTING TREATMENT EQUIPMENT

The existing treatment process at the WTP consists of chemical oxidization and detention followed by manganese greensand filtration and disinfection. Currently, raw water is provided from two groundwater wells and injected with sodium hypochlorite in the raw water header for chemical oxidation. This is followed by the above ground detention tank, after which the water flows into two manganese greensand filters. Sodium hypochlorite is injected into the filter effluent header for disinfection. Treated water is stored in two reservoirs, one located underneath the WTP building and the other adjacent to the building.

Detailed information for the process equipment is included in **Table 2-1**.

Table 2-1 Existing WTP Process Equipment

Component	Description
WTP rate capacity	• The current treatment capacity is 3.8 L/s.
Treatment System	
Greensand filters	• Quantity: two operated in parallel configuration. • Size: 1.22 m diameter x 2.13 m high. • Volume: 1,800 L. • Filter loading rate: 5.9 m/hour. • Filtration capacity: 3.8 L/s with both filters.
Backwash supply pump	• Model: Goulds D0000112. • 15 min/filter at a rate of 11 L/s.

A summary of the chemicals and their dosages are provided in **Table 2-2**.

Table 2-2 Chemical Dosages

Chemical/Injection Location	Storage	Chemical Dosage	Pump/Rate Capacity
Sodium hypochlorite/filter influent	12% solution	Approximate dosage: 11-12 mg/L, high of 13-14 mg/L.	Grundfos Alldos DDA rated at 7.5 L/hr
Sodium hypochlorite/reservoir influent	12% solution	Approximate dosage 0.75-1.75 mg/L	Grundfos Alldos DDI rated at 7.5 L/hr

The dosage of all sodium hypochlorite is above the maximum use level (MUL) as defined in NSF 60 as 12.36 mg/L. These standards are developed to assure that the treatment process does not add unsafe level of chemical or contaminants to the drinking water.

3 TREATMENT REQUIREMENTS

In order to determine which substances the treatment process needs to remove and to identify water quality issues that may arise during the useful lifetime of the upgraded and expanded water treatment system, raw water quality data was compared to both *SDWQSO* and Health Canada's *Guideline for Canadian Drinking Water Quality* (*GCDWQ)* in **Table 3-1**.

Table 3-1 Raw and Treated Water Quality Data

Parameter	Raw Water Well #1	Treated Water	Drinking Water Standards and Objectives	
	2023-2024	2025	*SDWQSO*[1]	*GCDWQ*[2]
Bicarbonate (mg/L)	656	597	None stated	None stated
Calcium (mg/L)	108	103	None stated	None stated
Carbonate (mg/L)	<1	<1.0	None stated	None stated
Conductivity (uS/cm)	913	926	None stated	None stated
Iron (mg/L)	1.84	<0.010	AO 0.3	AO 0.3
Magnesium (mg/L)	43	43.7	AO 200	None stated
Manganese (mg/L)	0.13	0.00034	AO 0.02	MAC 0.12/ AO 0.02
pH	7.96	8.12	7.0 - 10.5	7.0 - 10.5
Potassium (mg/L)	3.6	4.46	None stated	None stated
Sodium (mg/L)	36	45.8	AO 300.0	AO 200.0
Total alkalinity (mg/L, as calcium carbonate)	538	489	AO 500	None stated
Total ammonia (mg/L)	0.71	-	None stated	None stated
Total dissolved solids (mg/L)	570	550	AO 1,500	AO 500
Total chlorine (mg/L)	-	0.95	None stated	None stated
Free chlorine (mg/L)	-	0.54	None stated	None stated
Total trihalomethanes (THMS, mg/L)	-	0.11	MAC 0.1	MAC 0.1
Total haloacetic acids (HAAs, mg/L)	-	0.049	MAC 0.08	MAC 0.08
Total hardness (mg/L)	446	428	AO 800	None stated

Notes:
[1] Taken from Saskatchewan Water Security Agency's Drinking Water Quality Standards and Objectives unless otherwise indicated.
[2] Taken from Health Canada's Guidelines for Canadian Drinking Water.

Total haloacetic acids (HAAs) and trihalomethanes (THMs) were calculated by taking the annual average of the two sample results taken September 23, 2024 and January 7, 2025.

3.1 Ammonia

Naturally occurring ammonia levels in groundwater will consume free chlorine in the disinfection process, creating a combined chlorine or chloramine residual. Since the free chlorine is consumed by ammonia, the ratio of free chlorine to total chlorine is very low. If the ratio of free chlorine to total chlorine is less than 10% to 20%, the resulting free chlorine residual is generally considered inaccurate due to the interference that chlorine residuals have on the diethyl-p-phenylene (DPD) test result for free chlorine. An unreliable free chlorine residual in turn results in an unreliable primary disinfection log credit. A stable free chlorine is one that makes up 70% to 80% of the total chlorine. If ammonia is present in the water, a stable free chlorine can only be obtained if breakpoint chlorination is achieved. For breakpoint chlorination to be achieved, a chlorine dose of eight to ten times the ammonia presence is required in addition to whatever constituents are present in the raw water that will consume or combine with chlorine.

The current system relies on sodium hypochlorite for both chemical oxidation and primary disinfection, which currently due to the ammonia in the raw water has exceeded the MUL. To address this, an alternative treatment approach should be taken to meet primary disinfection while maintaining chemical usage below the MUL.

3.2 Iron and Manganese

SDWQSO and Health Canada's aesthetic objective (AO) for iron and manganese are 0.3 mg/L and 0.02 mg/L, respectively. In groundwater treatment processes, iron and manganese that have not been fully oxidized from their soluble forms into solid particles prior to or during filtration, are one of the leading causes of post filtration turbidity. The reduction of iron and manganese results in decreased colour, taste and odour of water, as well as reducing the staining of laundry and plumbing fixtures. Based on water samples that were collected and analysed at the time of the previously completed pilot study, the iron level in Village's raw water is 1.84 mg/L and the manganese level is 0.13 mg/L.

It is recommended that a water treatment process can reduce both iron and manganese levels to below Health Canada's AO. The soluble forms of iron and manganese need to be oxidized into their insoluble forms and then removed by filtration technologies such as manganese-greensand filtration, biological filtration or membrane filtration.

3.3 Total Dissolved Solids (TDS)

Total dissolved solids (TDS) refers to the dissolved minerals such as sodium, calcium, magnesium, hardness, alkalinity, bicarbonate, sulphate, chloride, potassium and carbonate present in water.

The TDS in the raw water was 570 mg/L, which is lower than the *SDWQSO* AO of 1,500 mg/L but it is higher than Health Canada's more stringent AO of 500 mg/L. The current treatment system is not capable of removing total dissolved solids from the raw water supply.

3.4 Total Haloacetic Acids (HAAs) and Trihalomethanes (THMs)

Currently, THMs and HAAs are the two major groups of chlorine disinfection byproducts (DBPs) regulated in drinking water supplies. The available Village data shows the levels of THMs and HAAs are currently near or above the regulated limits set by *SDWQSO* and *GCDWQ* guidelines.

This high level of DBPs is an indication of Village's raw source water containing high dissolved organic carbon (DOC) levels. DOC is a primary precursor for the formation of THMs and HAAs. During the disinfection process, typically performed with chlorine, DOC reacts with the disinfectant to form these harmful byproducts. Higher levels of DOC in water typically lead to higher concentrations of THMs and HAAs.

Balancing the need for effective disinfection with the desire to minimize byproduct formation requires careful management of treatment parameters such as chlorine dosage, contact time, and pH levels. The proposed upgrades will look to reduce the formation of HAAs and THMs using chloramines, which are effective at reducing the formation of DBPs.

4 TREATMENT SYSTEM MODIFICATION OPTIONS

Based on the treatment required listed in above section, Associated has reviewed three treatment process options to address the current water quality concerns. Biological filtration was investigated as an alternative treatment option in the 2022 BCL Engineering Ltd. report; however, a pilot study previously completed in 2024 showed that biological filtration was not effective at removing manganese or ammonia from the raw water supply. Therefore, this option has been disregarded as a viable option for the Village and has not been reviewed in further detail.

4.1 Option 1: Greensand Filtration with UV for Primary Disinfection Followed by Chloramination

Option 1 includes chemical oxidization, detention, manganese greensand filtration followed by an UV disinfection system for primary disinfection with chloramines for secondary disinfection. The existing greensand filtration system will be replaced with an expanded greensand filtration system to reduce the loading rate to allow for adequate removal of iron and manganese. Potassium permanganate will be injected into the raw water for iron and manganese oxidization. An above ground detention tank will be required to provide enough time for the chemical reaction to occur. Precipitated iron and manganese oxide will then be filtered out by or absorbed onto the greensand media. A building expansion will be required for a new electrical room and expanded treatment system.

A UV system will be used for primary disinfection to achieve 4-log virus reduction required for groundwater source. Sodium hypochlorite will be injected to form chloramine for the secondary disinfection. Due to the high hardness in the raw water supply, the UV system will be susceptible to scaling and due to this will require intermittent acid cleaning to remove the scale. A citric acid cleaning system will be required to remove scale from the UV system.

Greensand filtration is typically used to remove iron and manganese from the raw water; however, greensand filtration is not able to remove TDS, DOC, total organic carbon (TOC) or hardness from the raw water. The proposed option would reduce the sodium hypochlorite below the MUL. Option 1 would not improve the aesthetic parameters of the treated water, with treated water remaining high hardness and TDS.

5 OPTION 2: GREENSAND FILTRATION FOLLOWED BY CHLORINE GAS FOR PRIMARY DISINFECTION

Option 2 includes chemical oxidization, detention, manganese greensand filtration followed by chlorine gas for breakpoint chlorination and primary disinfection. The existing greensand filtration system will be replaced with an expanded greensand filtration system to reduce the loading rate to allow for adequate removal of iron and manganese. A chlorine gas will be injected into the raw water for oxidization and disinfection. An above ground detention tank will be required to provide enough time for the chemical reaction to occur. Precipitated iron and manganese oxide will then be filtered out by or absorbed onto the greensand media. With the high chlorine dosage, a proper ventilation system is required to ventilate chlorine off-gassing from the water. A building expansion will be required for a new electrical room and chlorine room. As the WTP is located on the golf course, provisions for a chlorine scrubber would be included for safety in the event of a chlorine gas leak. One concern with breakpoint chlorination is the formation of DBPs which include THMs and HAAs. A jar test should be performed with breakpoint chlorination to determine if DBPs formed during breakpoint chlorination is over the regulated limit.

Greensand filtration is typically used to remove iron and manganese from the raw water. However, greensand is not able to remove TDS, DOC, TOC or Hardness. Option 2 would not improve the aesthetic parameters of the treated water, with treated water remaining high hardness and TDS.

6 OPTION 3: MEMBRANE FILTRATION ADDITION

Option 3 includes chemical oxidization, manganese greensand filtration and followed by reverse osmosis (RO) membrane filtration. The existing greensand filtration system will be replaced with an expanded greensand filtration system to reduce the loading rate to allow for adequate removal of iron and manganese and provide additional flow to account for the membrane waste. Potassium permanganate will be injected into the raw water for the chemical oxidization of iron and manganese. A detention tank would be required to allow for chemical oxidation prior to filtration. Following the detention, the water would flow through greensand filters. Filtered water would be directed to a RO membrane transfer tank and repumped through a RO membrane treatment system. This tank would also allow the filters to be backwashed with filtered water that has not yet been run through the membrane system. Anti-scalant will be fed into the membrane feed water to inhibit potential scaling on the membrane surfaces. Provisions for the addition of sodium bisulphate in the membrane influent will be included to ensure no oxidant remains in the membrane feed water as this would damage the membrane surfaces.

Based on our experiences at other communities using the groundwater sources and same treatment process, the pH and the Langelier Saturation Index (LSI) of the permeate from the RO membranes can be adjusted by the injection of caustic downstream with the mixing of 5 to 10% membrane influent bypass. The LSI will be adjusted between -1 and 0 to ensure that is slightly scale forming to reduce the corrosive effects of the water on the distribution system.
A building expansion will be required to accommodate the expanded pre-treatment system, new RO membrane system and electrical room.

RO membrane filtration systems are effective at removing turbidity, particles, bacteria, viruses, and cysts, as well as addressing ammonia, TDS, hardness, DOC and TOC. Chemical requirements for membrane filtration include potassium permanganate and sodium hypochlorite (pre- and post-treatment), anti-scalant, caustic soda, and cleaning-in-place (CIP) solutions to maintain system performance. Raw water demands will increase with the RO membrane rejection.

7 EVALUATION MATRIX

The comprehensive analysis can be found in **Appendix A** along with key criteria used to evaluate the equipment options. These criteria include water quality and treatment, constructability and expandability, operability and maintainability, and redundancy. Equipment costs were evaluated separately in **Section 7**. Scores were assigned based on the follow rubric:
1 = Poor
2 = Fair
3 = Average
4 = Good
5 = Excellent

8 SUMMARY

When evaluating the categories, such as Water Quality and Treatment, Post-membrane Treatment received the highest total score for this category. Membrane filtration is more effective at reducing hardness, TDS, DOC and TOC, and avoiding disinfection byproducts (e.g., THMs/HAAs). In contrast, greensand filtration effectively removes iron and manganese but is not effective at reducing hardness, TDS, DOC, TOC and ammonia. This results in higher chlorine dosages required for primary disinfection, which can increase the formation of disinfection byproducts. While membrane filtration is able to treat more, it comes with greater complexity and higher chemical demands. Greensand filtration, on the other hand, is simpler to operate and has reduced chemical requirements. Both options effectively address the iron and manganese concerns in the raw water supply.

Another category was Constructability and Expandability, greensand received the highest total score for this category with 15. Greensand expansion is easily integrated into the existing infrastructure, it offers the least amount of down time for plant operation to change over and improve capacity and water quality without major modifications. Membranes score well for ease of staging and future expansion, indicating they can adapt to increasing water quality or capacity demands with relatively straightforward system additions. However, staging in the existing building space would not be viable and would require a building expansion. In all scenarios a building expansion is necessary, but the size of the building is considered to increase with Membrane having the largest required footprint.

With regards to Operability and Maintainability, greensand achieves a high score for reliability, ease of operation, lowering operating training requirements compared to the other options. Membrane requires more chemical and operator training, increasing the complexity of the care for the system.

Option 1, which includes UV, does not provide n+1 redundancy for maximum day demands, due to the significant seasonal variations in projected flow rates (i.e., winter versus summer) however with additional UV units n+ 1 redundancy can be achieved. The same consideration applies to Option 3. Additionally, the required building expansion to fit the addition of redundancy would increase substantially. The need for redundancy will be further evaluated during preliminary design.

Based on the technical analysis of the three options, the results, ranked from highest to lowest, were as follows:

1. Option 1 - Greensand filtration with UV for primary disinfection.
2. Option 2 - Greensand filtration followed by chlorine gas for primary disinfection.
3. Option 3 - Membrane filtration addition.

9 EQUIPMENT COST

Estimated equipment cost were previously completed by BCL Engineering Ltd. in 2022. These cost estimates, in 2025 dollars, are summarized in **Table 9-1** below. The 2025 estimated equipment costs have been calculated using an 8.5% escalation factor based on Government of Canada Builder's *Construction Price Index and Bank of Canada Inflation* rate.

Table 9-1 Probable Equipment Cost

Option	Description	Probable Cost Range ($)
1	Greensand process expansion followed by UV disinfection	700,000 to 850,000
2	Greensand process expansion followed by chlorine gas	600,000 to 710,000
3	Greensand process expansion followed membrane filtration	1,800,000 to 2,700,000

Cost estimates in the above table are for equipment only and do not account for the estimated additional building footprint, electrical and associated requirements. If n+1 redundancy is necessary for maximum day demands for Option 1 and Option 3, the estimated equipment costs will increase.

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Appendix A