COMMUNITY OF CRANE RIVER

Arnason Industries
Community of Crane River
Water Treatment Plant Upgrade
Design Brief
FINAL REPORT
Project No. 12-2436-002
April 2013

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KGS GROUP
CONSULTING ENGINEERS

TABLE OF CONTENTS

PAGE

TABLES

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1.0 INTRODUCTION

1.1 BACKGROUND AND REVIEW

The community of Crane River has 130 residences based on Statistic Canada for 2011 located on the west shore at the north end of Lake Manitoba. The Community utilizes Lake Manitoba as raw water source. Currently the water treatment solely consists of chlorination, filtration, storage and re-chlorination. The treated water is then pumped to the distribution system.

Crane River raw water has high total organic carbon (TOC) and moderately high total dissolved solids (TDS). The TDS in the raw water is slightly higher than the Aesthetic Objective of 500 mg/L as set by *the Guidelines for Canadian Drinking Water Quality (GCDWQ).* As TDS is primarily an aesthetic issue reducing TDS is considered optional. On the other hand, TOC reduction is mandatory due to health issues related to the formation of trihalomethanes (THMs), which are disinfection by-products, in the treated water. The maximum acceptable concentration (MAC) for THMs in drinking water is 0.100 mg/L (100 µg/L) based on an annual average.

1.1.1 BACKGROUND REVIEW

The following documents were reviewed by KGS Group for this project:

- Treated Water quality reports for the year of 2009 and 2011.
- Raw Water quality reports for the year of 2009 and 2011.

In addition historical engineering work was discussed with Manitoba Aboriginal and Northern Affairs representative Morley Nagle and a site visit was conducted on October 30, 2012.

1.1.2 SCOPE OF WORK

To address the drinking water quality, the provisions of upgraded water treatment and storage capacity for the community is required. The purpose of this design brief is to provide a complete description of the project.

The scope of the study is to include reviews and discussion of key items such as:

- Water demands and use.
- Water quality study.
- Water supply status and availability.
- Treatment process – Slow Sand Filtration followed by Nanofiltration.

The format of the report generally follows the above noted sequence.

2.0 DESIGN CRITERIA REVIEW

2.1 FUTURE POPULATION AND WATER PLANT CAPACITY

The community of Crane River had a population of 232 persons in 1991. Since that time, the community has experienced a decreasing trend and according to Statistic Canada, the population of the community was 178 people in 1996 and 130 people in 2011.

To ensure adequate treated water supplies can be provided for the design life of the facility an increasing population growth of 1.0% is assumed. Based on the assumed population growth the future population is estimated to be 175 people in 2030.

The water treatment plant production capacity is designed on the basis of the maximum day demand of the design year. For Crane River the maximum day demand was estimated utilizing the future population at 110 m^3/day. Utilizing this value, the estimated future maximum day consumption is 628 L/cap•d.

The following design criteria will be used for water treatment equipment sizing:

- Population: 175
- Average day demand: 40 m^3/d (7.3 USGPM)
- Maximum day demand: 110 m^3/d (20.2 USGPM)
- Peak hourly demand: 7.5 m^3/hr, 125 L/min (33 USGPM)

3.0 WATER SUPPLY AND QUALITY

3.1 RAW WATER SUPPLY CHARACTERISTICS

Currently, Crane River Water Treatment Plant, obtains raw water from Lake Manitoba. Raw water is pumped to two off-site storage water ponds at opportune times in the year. A gravity raw water line from the ponds supplies a wet well. The wet well is equipped with two submersible pumps required to supply the treatment plant. Raw and treated water quality data are shown in Table 3.1.

The data show raw water total dissolved solids (TDS) levels exceed the limits of the Guidelines for Canadian Drinking Water Quality (GCDWQ).

Total Dissolved Solids

Total Dissolved Solids (TDS) for the raw water is in the range of 656 mg/L based on raw water analysis in August 18, 2012 which is greater than the aesthetic objective of 500 mg/L. An elevated TDS concentration is not considered as a health concern, but does contribute to the acceptability and palatability of the treated water. Aesthetic objectives may have impacts on facility operation and downstream processes, but are generally dependant on consumer acceptability of the treated water supply.

TDS is difficult to remove using most conventional methods. Treatment to remove TDS typically consists of, electrodialysis or reverses osmosis. Discussions with MANA representative Morley Nagle confirmed that while TDS reduction is encouraged for this facility long term, the primary drivers for this design is organics reduction. If flexibility can be provided in the design to either add or upgrade filtration components to ensure TDS reduction then that would also be preferred.

Total Organic Carbon

The presence of colour and total organic carbon (TOC) can provide an indication of the presence of humic substances and natural organic matter in the treated water. Organics, when subjected to chlorine disinfectants, can potentially cause the formation of THM within the treated water storage and distribution. The historical colour values for Crane River are in the range of 10-15 TCU and the TOC 17-18 mg/L. Guidelines for Canadian Drinking Water Quality (GCDWQ), the aesthetic objectives for colour should be less than or equal to 15 true colour units (TCU).

Colour and TOC provides and indication of trihalomethane formation during disinfection with chlorine due to a reaction between organic substances and chlorine. Colour and TOC removal in the treatment process is therefore essential for removal of disinfection byproduct precursors to minimize THM formation and for the aesthetic quality of the treated water supply. In order to safely ensure trihalomethanes are not produced above regulated limits finished total organic carbon levels (TOC) should be below 4.0 mg/L.

3.2 TREATED WATER SUPPLY CHARACTERISTICS

During our October 30th, 2012 inspection, the following was noted;

- Existing facility has a small foot print
- Existing facility consists of prechlorination, filtration, post chlorination, storage and distribution. Not entirely sure why there is no coagulation step presently.
- Two large ponds presently exist outside of the facility, with a gravity line to a pump well located close to the plant.
- Raw water UVT 56.3
- Treated water UVT 61.3
- Historical finished turbidities have ranged from 1.0 to 5.0 NTU
- Present backwash water is kicked out to the river, which eventually feds into Lake Manitoba.

Treated water quality provided by the community of Crane River is shown in table 3.1.

The treated water quality analysis indicates that the treated water have similar inorganic characteristics of the raw water quality with less colour and turbidity. Confirmation of the reasoning was provided during the site inspection, as no coagulant is presently being utilized.

THMs are formed when chlorine, which is used for disinfection, reacts with naturally occurring organic compounds present in the water. Surface water typically has higher levels of these natural organic compounds. The trihalomethanes most commonly found in drinking water are chloroform, bromodichloromethane (BDCM), dibromochloromethane (DBCM) and bromoform.

There are several factors that help to increase the formation and/or formation rate in the water such as high temperatures, high pH values, high organics concentrations, high free chlorine residuals and high bromide and iodide concentrations. Health Canada has established a guideline for THMs of 100 micrograms per liter (0.1 mg/L). THMs concentration in the treated water is in the range of 0.176 to 0.316 mg/L.

THMs can be reduced in drinking water in by one of three approaches:

1) removing trihalomethanes precursors (organics) through the treatment regime
2) removing trihalomethanes after their formation, or
3) by utilizing alternative disinfectants.

The result from ALS Laboratory Group indicates that the Crane River distribution system water has THMs as follow:

Bromodichloromethane	0.0381 mg/L	
Bromoform	<0.0005 mg/L	-
Chloroform	0.13 mg/L	-
Chlorodibromomethane	0.0081 mg/L	-
Total THM	0.176 mg/L	0.1 mg/L (MAC)

As emphasized earlier, following discussions with MANA the primary goal of the upgraded facility is to provide a well disinfected safe water with disinfection by products below regulated limits. In order to accomplish that the following finished treatment targets are provided:

- total organic carbon < 4.0 mg/L
- turbidity levels that ensure effective disinfection.

3.3 WATER SUPPLY SYSTEM

Currently, the Crane River obtains raw water from Lake Manitoba. Raw water is pumped from the lake to two water ponds at periods of time that provides the best opportunity for reduced turbidity. The raw water gravity line from the ponds supplies a wet well. The wet well is located 4 feet west of the treatment plant and is equipped with two submersible pumps to supply the treatment plant. The intention is for the existing pumps to be replaced in the upgraded facility.

A multi barrier approach to organics reduction provides the best opportunity for long term operational flexibility. Organics control at the offsite storage facility could come in the form of aeration, and consistent vegetation control.

4.0 WATER TREATMENT PROCESS

4.1 EXISTING FACILITIES

The existing treatment was designed to consist of direct filtration, sodium hypochlorite addition for disinfection and pumped distribution. The treatment plant has a truck fill option for non-connected customers.

4.2 PROPOSED WATER TREATMENT SYSTEM

The proposed maximum day water plant capacity, based on 24-hour operating period, was determined to be 110 m^3 (1.3 L/s). It should be noted that an extensive review of water use values was not conducted, but rather the provided filtration rate was reviewed and appears to be adequate

- Raw water characteristics including **turbidity, TOC** and **TDS**, are higher than *Guidelines for Canadian Drinking Water Quality (GCDWQ)*,
- **Turbidity** can be reduced using slow sand or pressure sand filters.
- **TDS** can only be removed using an Reverse Osmosis membrane system
- Slow sand can reduce **TOC**, theoretically between 25 and 50%.
- Finished **TOC level should be under 4 mg/L** in order for THM"s not to be produced above 100 ug/L
- Traditional slow sand alone will not reduce **TOC levels** to under 4 mg/L in the case of Crane River's raw water.
- An additional organics reduction mechanism is required; either activated carbon, biological carbon, or Nano filtration membranes.
- TDS reduction in this facility is not considered mandatory for this design, TOC reduction is mandatory to ensure THM's are not above regulatory levels,
- Elevated TOC levels will impact Reverse Osmosis filtration membranes.
- Conclusion - TOC levels will need to be treated by Nanofiltration.

Based on the predesign report (2012), three options were presented and slow sand filtration followed by Nanofiltration membrane system option was selected.

Slow Sand Filtration System followed by Nanofiltration

The slow sand process percolates untreated water slowly through a bed of porous sand, with the influent water introduced over the surface of the filter, and then drained from the bottom.

Slow sand filters operate at low filtration rates and rely on the development of a schumutzdeke layer on the surface of the filter for particulate straining. As this schumutzdeke develops during the filtration cycle, it plays the dominant role in filtration rather than the granular media.

In traditional slow sand filter cleaning occurs when fine sand becomes clogged, which is measured by the head loss. Traditional cleaning is done by scraping off the top layer of the filter bed. The source water quality must have low turbidity for slow sand filter to produce acceptable treated water. No chemicals are added to aid the filtration process.

Slow sand filter relatively inexpensive to operate and has been found effective for removal of Giardia from low-turbidity water. Monitoring of turbidity and head loss for the sand filter is an important process control factor for maintaining optimum filter performance.

The SSF system is consisted of two tanks each tank is 2 m x 4 m with a surface area of 8 m2 for each filter and 2 high. The tanks are made of stainless steel and underdrain pipes made of PVC. The water height in the filters can be adjusted accordingly.

The SSF is equipped with backwash capability. The SSF filters operate like a traditional slow sand filter or a backwashed slow sand filter. When the backwash is used the filter does not require scraping and resanding but may still require the ripening period similar to traditional slow sand filters. The backwash loading rate is 7.2 m/hr. For the 2 m x 4 m filter with a surface area of 8 m2 the required flow rate is 16 L/s of filtered and unchlorinated water with a head between 3 m to 4 m. Based on low backwash rate the effect of the backwashing will be minimal on the schumutzdeke layer established. Water from the transfer tanks with a backwash pump will be used for backwashing. Crane River raw water is generally very good and backwash may not be used at all. The slow sand filter system with UV system should easily provide 3-Log removal credits for Cryptosporidium and Giardia. Online turbidity will be also installed to continuously monitoring effluent turbidity.

The SSF is equipped with filter to waste after the backwash.

Design criteria for the slow sand filter sizing was based on the following:

- Maximum day flow: 110 m^3 per day
- Maximum filters capacity: 160 m^3 per day
- Maximum filtration rate: 0.42 m/hr (10 m/day)
- Surface area required 2 (for redundancy) 16 m^2

Traditional slow sand is effective in reducing turbidity and particles however slow sand may reduce TOC level by 25-35% at maximum. Nanofiltration membrane system will be introduced to reduce the TOC to less than 4 mg/L.

An Online turbidity meter will be installed after the slow sand filters. The online turbidity meter will have the capability of data logger and can record 1500 data point with selected intervals and can be downloaded by a computer.

Nanofiltration membrane system (NF)

Nanofiltration membrane technologies are physical separation methods that rely on pressurizing the feed solution to a hydraulic pressure that is greater than the osmotic pressure of the solution. The osmotic pressure in nanofiltration is a function of the concentration and temperature of the solution and typically increases with increasing concentration. Nanofiltration has the capacity to remove bacteria, viruses, larger colloids organics, divalent ions, larger monovalent ions and colour. Nanofiltration membranes are also used for the removal of natural organic matter from water, especially tastes, odours and colours, and in the removal of trace herbicides from raw water. NF can reduce the level of calcium, magnesium ions, TOC and THMs through the removal of disinfection by-product precursors. It is documented that nanofiltration system with low turbidity surface water had an average of 90% dissolved organic carbon (DOC).

The nanofiltration membranes have the ability to selectively reject different dissolved salts, and have high rejection of organic compounds. Nanofiltration membranes are mainly used to partially soften potable water, allowing some minerals to pass into the product water and thus increase the stability of the water and prevent it from being aggressive to distribution piping material. However NF membrane removes bicarbonate and alkalinity and the product water can be corrosive. A post treatment for pH and alkalinity adjustment may be required. Sodium hydroxide or sodium carbonate will be added as a post treatment if required.

Design criteria for this option were based on the following:

- Membrane system: 140 m^3/day (Raw water)
- Membrane system: 110 m^3/day (Treated water)
- Membrane system: 30 m^3/day (Reject water)
- System recovery: 75%-80%

The design will be equipped with NF system bypass which will be used during maintenance and emergency only. A pipe spool or lock-out valve will be provided to prevent operational errors. The slow sand, UV systems and with chlorination system should provide sufficient multiple barrier protection. The NF system should be in operation at all the times due to high TOC and the potential of THMs formation in the treated water.

4.3 DISINFECTION

Primary Disinfection - UV System

Primary disinfection will be achieved through ultraviolet disinfection at a wavelength of 254.7 nm with 40 mJ/cm^2 at the end of lamp life. Two inline, ultraviolet reactors will be installed downstream after the membrane systems and will be sized to accommodate the maximum day flow through the process. The reactors will be outfitted with automatic cleaning mechanisms. The applied UV dose will be monitored on a continuous basis with suitable alarm system to indicate lamp failure or insufficient dose.

The UV system specified will be rated so that the 4-log inactivation of Cryptosporidium and Giardia can be achieved. Virus inactivation will be achieved through chlorine disinfection.

The combination of SSF and NF would achieve product water with higher than 75% UVT. The UV system is designed with 75% UVT to obtain the necessary log credits needed for approval.

The UV system will be equipped with 4-20 mA unit allows for both UV intensity and UV transmittance (UVT) signal to be provided. The 4-20 mA unit provides two analog signals that can be used with any device that requires a 4-20 mA signal for logging purposes and process control. The unit will have water quality alarm set points for UV intensity and UVT if drop below the set points.

Secondary - Disinfection- Chlorination

Disinfection will be provided by addition of 12% sodium hypochlorite. Hypochlorite feed will be interconnected with the operation of the treatment system in an on/off configuration.

Two, chlorine feed pumps will be provided in a duplex duty/standby configuration. Alarms will provide notification to operations personnel of a pump failure. Feed pumps will also be interlocked with the raw water feed pumps to shut down production in the event of a failure of both chlorine feed pumps.

A public water supplier using surface water or groundwater under the direct influence of surface water (GUDI) has to ensure that all water entering the water distribution system meets the following Drinking Water Quality Standards Regulation of 99.9 % reduction of *Giardia* lamblia cysts and 99.99% reduction for viruses.

In order to determine if the plant meets the above reduction requirements, Concentration Time (CT) factors were calculated. In general, the CT factor is the concentration of the disinfectant (in mg/L) multiplied by the contact time. A disinfection profile was developed from the water treatment plant consumption data and the KGS Group calculations performed.

As the raw water is surface water source, *Giardia* inactivation requirements are the limiting constraint for surface and GUDI raw water sources. CT calculations for slow sand system were based on a peak hourly flow of 125 L/min, a free chlorine concentration of 0.5, a pH of 8.7, a temperature of 5.0ºC, and an assumed baffle factor of 0.3 for the storage tanks. Based on these assumptions chlorine disinfection should be capable of providing an estimated 0.5–log inactivation for *Giardia* and 24-log inactivation for viruses. Free chlorine of 1.1 mg/L is sufficient to provide an estimated of 0.5–log inactivation for *Giardia* and 12.0-log inactivation for viruses with half full tank.

5.0 WATER STORAGE

The treatment plant will be equipped with three fibreglass treated water storage tanks. The storage tanks will have total of 40 m3 with indoor installation. Each tank has 2.438 m diameter and 3.438 m height.

The new storage tanks pipes will be as follow: the filtered and chlorinated water will be discharged into the one tank. An equalization pipe between the tanks will be installed and the treated water will pumped to the distribution system from the third last tank. New pipe connections will be installed to isolate and clean each tank individually.

This configuration will prevent the short circuiting and provides the requirement chlorine contact time. Based on Ten states standards the minimum storage capacity for a system not providing fire protection is equal to the average day demand.

6.0 BUILDING

The building size and geometry depends on the size of process equipment, storages and pumping system. The preliminary footprints for the treatment plant are estimated of 260 m^2 and the interior heights would be approximately 3.5 m.

7.0 DISCUSSION

The primary benefits of utilizing the slow sand are operational flexibility and ease of understanding on the front end of the treatment train. In the event that the membrane systems do go down the facility utilizing the slow sand front end approach on its own will still be able to provide treated water that meets all regulatory standards except for Trihalomethanes, which is an chronic concern rather than an acute one. In addition, is also understood that this is the primary driver for the slow sand direction recommended by MANA.

Given the additional requirement for organics reduction, the slow sand will essentially run sole as a polisher for the nanofiltration system. However it will provide an ability to run on its own at short periods of time, given that UV disinfection will be added at the back end of the slow sand process. It must be noted that UV transmittance must be greater than 75% to obtain the necessary log credits needed for approval however with the slow sand and NF running a higher UV transmittance is expected.

TABLES

Table 3.1: Raw and Treated Water Quality Data.

Sample		Raw	Treated	MAC/AO*	Units
Aesthetic Criteria					
Conventional Parameters		18/08/2011	18/08/2011		
Total Dissolved Solids		656	672	500*	mg/L
Dissolved Chloride	Cl	237	242	250*	mg/L
Dissolved Sulphate	SO_4	58.8	56.9	500*	mg/L
Conventional Parameters					
pH, Lab		8.75	8.71	6.5-8.5*	pH unit
Total Alkalinity	$CaCO_3$	167	169	-	mg/L
Bicarbonate Alkalinity	HCO_3	178	182	-	mg/L
Carbonate Alkalinity	CO_3	11.8	10.7	-	mg/L
Hydroxide Alkalinity	OH	<0.4	<0.4	-	mg/L
Ammonia as N	NH_3-N	0.018	0.031		
Cation-Anion Balance	%	102	105		
Metal Analysis					
Copper	Cu	0.00217	0.00288	1*	mg/L
Iron	Fe	<0.1	<0.1	0.3*	mg/L
Manganese	Mn	0.00769	0.0056	0.05*	mg/L
Sodium	Na	150	163	200*	mg/L
Zinc	Zn	<0.005	0.005	5*	mg/L
Health Criteria					
Hardness (Total)	$CaCO_3$	233	232	-	mg/L
Dissolved Fluoride	F	0.107	0.092	1.5	mg/L
Nitrate and Nitrite	N	<0.05	<0.05	10	mg/L
Dissolved Sulphate	SO_4	58.8	56.9	-	mg/L
Ammonia Nitrogen	N	0.018	0.031	-	mg/L
Conductivity		1090	1120	-	µS/cm
Metal Analysis					
Aluminum	Al	0.0083	<0.005	-	mg/L
Antimony	Sb	<0.0002	<0.0002	0.006	mg/L
Arsenic	As	0.00191	0.00203	0.01	mg/L
Barium	Ba	0.0251	0.0252	1	mg/L
Boron	B	0.083	0.088	5	mg/L
Cadmium	Cd	<0.00001	<0.00001	0.005	mg/L
Calcium	Ca	32	32.1	-	mg/L
Chromium	Cr	<0.001	<0.001	0.05	mg/L
Lead	Pb	0.00079	0.000245	0.01	mg/L
Magnesium	Mg	37.1	36.9	-	mg/L
Potassium	K	8.75	9.39	-	mg/L
Selenium	Se	<0.001	<0.001	0.01	mg/L
Silver	Ag	<0.0001	<0.0001	-	mg/L
Uranium	U	0.00074	0.00075	0.02	mg/L
Organic/Inorganic Carbon					
Total Organic Carbon	C	17	16.9		mg/L
Total Inorganic Carbon	C	37	37		mg/L
Total Carbon	C	53.9	53.9		mg/L

Total Metels Analysis					
Beryllium	Be	<0.0002	<0.0002		mg/L
Bismoth	Bi	<0.0002	<0.0002		mg/L
Cesium	Cs	<0.0001	<0.0001		mg/L
Cobalt	Co	<0.0002	<0.0002		mg/L
Lithium	Li	0.0287	0.0288		mg/L
Molybdenum	Mo	0.00072	0.00071		mg/L
Nickel	Ni	<0.002	<0.002		mg/L
Phosphorus	P	<0.2	<0.2		mg/L
Rubidium	Rh	0.00315	0.00323		mg/L
Silicon	Si	1.4	1.47		mg/L
Strontium	Sr	0.229	0.23		mg/L
Tellurium	Te	<0.0002	<0.0002		mg/L
Thallium	Tl	<0.0001	<0.0001		mg/L
Thorium	Th	<0.0001	<0.0001		mg/L
Tin	Sn	<0.0002	<0.0002		mg/L
Titanium	Ti	0.00089	0.00081		mg/L
Vanadium	V	0.0006	0.00064		mg/L
Zirconium	Zr	<0.0004	<0.0004		mg/L
Conventional Parameters					
True Color		12.2	<5.0	15	CU
Turbidity		0.88	0.62		NTU
Langelier Saturation Index in Water					
Langelier indx	4C	0.74	0.71		
Langelier indx	60C	1.5	1.5		

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