

Meeting the Challenges of Nutrient Removal for a Small Remote Community – The Story of Thompson WWTP

Saibal Basu^{1*}, Jamie Brewster¹, Rob De Koninck¹, Harkamaljeet Singh Gill²

¹Stantec Consulting Ltd., Winnipeg, Manitoba, Canada

² Manager of Infrastructure, City of Thompson, Manitoba, Canada

* Email: saibal.basu@stantec.com

ABSTRACT

The City of Thompson (City) plans to replace its aging wastewater treatment infrastructure. Located approximately 740 km north of Winnipeg, the City currently operates two wastewater treatment facilities which function independent of each other. A mechanical WWTP provides primary treatment only for approximately 70% of the City's total wastewater flows while a single cell continuous discharge aerated lagoon treats the remaining 30% of the flows. Both systems are unable to meet the current Manitoba Water Quality Standards, Objectives, and Guidelines. Based on review of alternative processes and life cycle cost analysis during the preliminary design, a centralized wastewater treatment facility utilizing a SBR technology was selected to service a projected population of 15,000 people. The system is designed for biological nutrient removal (BNR) to meet a TP limit of $\leq 1\text{mg/L}$ and TN of $\leq 15\text{ mg/L}$. The existing infrastructure will be decommissioned. Construction is ongoing with a scheduled commissioning and plant start-up in Spring of 2019. The paper addresses the planning, technical challenges, design innovations and construction of the proposed facility.

KEYWORDS: Sequencing Batch Reactor (SBR), Nitrogen removal, Phosphorus removal, Cold Weather Design

INTRODUCTION

The City of Thompson (City) is located approximately 740 km north of Winnipeg. The community was formally established with the discovery of nickel following several years of mining exploration in the region. The City currently serves as a major hub for Northern Manitoba and plays a key role as the region's service and trade centre. Vale Ltd. operations continue to be the largest employer in the area.

The City has two existing wastewater treatment facilities which function independent of each other. The mechanical WWTP provides primary treatment only for approximately 70% of the City's total wastewater flows. The second facility is a single cell continuous discharge aerated lagoon and it provides secondary treatment and treats the remaining 30% of the wastewater flow from the south and south-western catchment of the City.

The City has created a new water and sewer utility to maintain its aging water and sewer infrastructure. This utility model allows the City to generate revenue through utility rates rather than property tax assessment. Both existing wastewater treatment systems are dated and are unable to meet the latest Manitoba Water Quality Standards, Objectives, and Guidelines with respect cBOD₅ and TSS limits of ≤ 25 mg/L (on a daily never to exceed basis), Total Nitrogen of ≤ 15 mg/L and Total Phosphorus of ≤ 1 mg/L (on a 30-day rolling average).

DESIGN APPROACH AND PROCESS SELECTION

As a part of the preliminary design, the following approach was adopted to identify the appropriate solution for the City:

- Establish design criteria (population projections, flows, loads, effluent criteria)
- Assess the aerated lagoon for nutrient reduction requirements and develop cost effective options for upgrade/expansion.
- Assess existing WWTP and review potential for re-use.
- Develop two (2) options to address the long-term treatment of wastewater generated by the City.
 - **Option 1:** Upgrade/expand existing treatment systems to meet the target effluent criteria. This involves an upgraded/expanded aerated lagoon along with an upgraded/expanded mechanical WWTP. In this option, both the upgraded WWTP and lagoon will be operated independently as per current practice.
 - Three (3) alternative wastewater treatment processes were reviewed for the mechanical WWTP upgrade/expansion option and the SBR technology was selected based on technical factors and life cycle cost analysis.
 - **Option 2:** Decommission the existing aerated lagoon and construct a single centralized wastewater treatment facility (WWTF) to handle projected flows and loads from the City treating wastewater from both the existing WWTP and lagoon catchment areas. The treatment process was also based on a SBR technology as per analysis undertaken under Option 1.
- Technical and economic analysis of Options 1 and 2 were undertaken to recommend the best overall wastewater treatment upgrade solution for the City.

Based on the above approach and subsequent analysis, **Option 2** which requires the construction of a single centralized WWTP was recommended to the City based on the following rationale:

- Option 2 involves operating and maintenance of a single centralized facility compared to Option 1.
- A single facility will be more cost effective to operate in the long run although costs were comparable.
- It is unlikely that the Province will issue two (2) separate licences for the City required under Option 1.

- The City's operating resources are better utilized by having to maintain a single facility (Option 2) over two separate facilities (Option 1).

The information developed in the preliminary design was utilized to advance the design concepts of the proposed centralized WWTP and prepare a Functional Design Report. The primary purpose of the functional design was to further define and size the key components of the proposed WWTP including establishing the design basis for structural, architectural, building mechanical, electrical, instrumentation and controls and site services components of the project. The Functional Design report was presented to the community residents via a Public Open House and was the basis for obtaining an Environment Act Licence for the proposed facility.

On May 15, 2015, the City was successful in receiving funding assistance from the New Building Canada Fund's Provincial-Territorial Infrastructure Component-National and Regional Projects including support from the Government of Manitoba (Manitoba Water Services Board). Subsequently, the detailed design process was initiated in late 2015.

To address the challenges associated with high groundwater table and poor soil conditions, all the process tanks (SBR, post equalization, aerobic digesters) were designed with common walls and shallow foundation. A compact plant layout was developed allowing all process tanks to be covered while meeting the functional requirements for plant operation utilizing three (3) operating levels. For tank covers, pre-cast slabs were selected for lower costs (compared to cast-in-place concrete) and quick installation. This compact design resulted in minimizing the use of the existing site footprint, optimized energy use and retained space for future plant expansion and upgrades.

To meet the design flows, loadings and effluent requirements, a Sequencing Batch Reactor (SBR) based on the "continuous feed – intermittent decant" type operation was selected for the secondary process. The overall secondary process design was optimized using a *BioWin*TM simulation. The odorous air from the headspace of the digesters, influent channels in the headworks area and dewatered sludge storage bin room will be directed to the biofilters prior to being released to the atmosphere.

DESIGN CRITERIA

The design population was based on a 20-year projection while factoring the uncertainty with future mining operations but provides a conservative estimate for the community on a long-term basis. The proposed design flow includes an allowance for truck hauled wastewater from holding tanks from the nearby cottage areas. A summary of the design criteria showing the design population, flows, influent characteristics, and effluent criteria is presented in **Table 1**.

Table 1. Design Population, Flows, Influent Characteristics and Effluent Criteria

Parameter	Unit	Value
Design Population		
Population	Person	15,000
Design Flows		
Annual Average Flow	m ³ /d	6,500
Maximum Month Flow	m ³ /d	8,100
Maximum Day Flow	m ³ /d	13,700
Peak Hourly Flow	m ³ /h	1,260
Influent Characteristics (at Maximum Month Condition)		
BOD ₅	mg/L	170
TSS		270
TKN		50
TP		7.5
Effluent Criteria		
cBOD ₅	mg/L	≤ 25 (daily not to exceed basis)
TSS	mg/L	≤ 25 (daily not to exceed basis)
TP	mg/L	≤ 1 (30-d rolling average)
TN	mg/L	≤ 15 mg/L (30-d rolling average)
Fecal Coliforms	MPN ¹ /100 mL	≤ 200 (monthly geometric mean)
Total Coliforms		< 1500 (monthly geometric mean)

¹MPN: Most Probable Number

KEY PLANT COMPONENTS

The plant includes the following key components for the liquid stream:

- Trucked wastewater receiving station
- 6 mm mechanically screened bar screens
- High efficiency grit removal
- Secondary treatment system utilizing a SBR system
- Effluent equalization and pumping
- UV disinfection
- Odor Control

The solids processing train is based on the characteristics of sludge anticipated from the SBR treatment process. There will be no primary sludge generated in the WWTP. The key unit processes proposed for the solids stream is follows:

- Aerobic Stabilization of waste activated sludge (WAS)
- Sludge dewatering (Centrifuge)

- Final disposal/beneficial reuse of dewatered biosolids

Prior to undertaking the detailed design, key process equipment was pre-selected through a competitive bidding process. This included the bar screen, SBR, UV disinfection, centrifuge, and odor control equipment. A summary of the process design for the key unit processes is provided as follows.

Trucked Wastewater Receiving Station. The City currently receives truck hauled wastewater from holding tanks from the surrounding areas that are not served by the collection system. To handle increased truck hauled wastewater from nearby cottages, a new truck haul receiving station was designed. The system includes the following:

- Automatic swipe card system
- Cam-lock connection
- Electrically actuated discharge isolation valve
- Equalization tank
- Hydrocarbon detector
- Cast-in-place single chamber concrete equalization storage tank
- Level controls
- Submersible hauled wastewater transfer pumps
- Magnetic flow meter

The equalization tank will also serve to equalize and blend the return streams from plant processes such as grit dewatering, digester supernatant and centrate (from sludge dewatering) before they are pumped back to the inlet to the screening channel. The design is based on handling two 1500 US gallons (5.7 m³) septic truck successively i.e., 11.4 m³ plus return flows from the grit dewatering, digester supernatant and centrate from sludge dewatering operations for a total active volume of 70 m³.

Screening. The screening system consist of a 6 mm Automatic Multiple Rake Bar screen capable of handling the 20-year PWWF plus hauled wastewater and plant return streams. A summary of the key design parameters are as follows:

- | | |
|-------------------------|-----------------------------------|
| • Design capacity: | 325 L/s |
| • Size of openings: | 6 mm Automatic Multiple Rake Bars |
| • Angle of inclination: | 60 degrees |
| • Channel dimensions: | 1200 mm wide by 1500 mm deep |
| • Maximum headloss: | 85 mm |

Grit Removal. The grit removal system is based on a proprietary Multi-Tray Vortex, high efficiency grit removal system. The system is comprised of a single 3.7 m diameter grit concentrator unit, a self-standing 600 mm stainless steel grit classifier and stainless steel grit washing dewatering unit. A summary of the key design parameters are as follows:

- | | |
|--------------------|---------|
| • Design capacity: | 325 L/s |
|--------------------|---------|

- Diameter of trays: 3.7 m
- Number of trays: 5
- System efficiency: Removal of 95% of all grit ≥ 75 microns
- Maximum headloss: 300 mm

SBR Process. The secondary biological treatment is based on the continuous inflow – discontinuous decant type SBR utilizing the proprietary Xylem ICEAS™ process. The design details are as follows:

- Number of SBR basins: 2
- Volume of each basin (at max W.L.): 4,001 m³
- Top water level: 5.50 m
- Bottom water: 3.89 m
- Basin width: 15.0 m
- Basin length: 48.5 m
- F/M Ratio: 0.035 kg BOD₅/kg MLSS/day
- SVI: 150 mL/g
- MLSS at Bottom Water Level: 5,130 mg/L
- Sludge depth: 3.32 m
- Decanter drawdown: 1.73 m
- Normal decant rate: 1,500 m³/h
- Peak decant rate: 2,400 m³/h
- HRT at Design Flows 1.23 days
- Design Flow: 6.6 h
- Sludge Age (SRT): 30.7 days
- Number of blowers: 1 duty + 1 stand-by with VFD
- Drive Motor: 100 HP

Effluent Equalization and pumping. The SBR basins decants treated effluent by gravity to an Effluent Equalization (EQ) chamber on an intermittent basis. As the SBR is a batch process, this decant rate is significantly higher than influent flow to the SBR basin. The EQ chamber therefore provides a more uniform flow to the downstream UV disinfection system. The EQ chamber design basis is as follows:

- Number of EQ tanks: 1
- Operating Volume: 920 m³
- Maximum water level: 2.7 m
- Normal pumping rate: 1,500 m³/h
- Peak pumping rate: 2,400 m³/h

Ultraviolet Disinfection (UV). The system is based on a high efficiency low pressure high output lamp utilizing a unique staggered, inclined array design incorporating a fully automatic chemical/mechanical cleaning system. The UV system is physically located on top of the EQ tank. The summary of the UV disinfection system design are as follows:

- Average design flow: 360 m³/h
- Peak design flow: 576 m³/h
- Peak hydraulic flow: 810 m³/h
- Design % transmissivity: 60% (minimum)
- Maximum TSS: 25 mg/L
- Type of UV lamps: High efficiency low-pressure high output lamps, 1000 W each
- No. of channels: 1
- No. of banks: 2 (in series)
- No. of lamps/bank: 8
- Total no. of lamps: 16
- Type of cleaning: Automatic (chemical/mechanical)
- Number of UV Sensors: 1 per bank
- Number of Power Distribution Centers: 1
- Number of System Control Centers: 1
- Number of level controllers: 1

Odor Control System. The odor control is based on a biofiltration system that is designed in a forced draft, up-flow configuration. Foul air is first humidified in a counter-flow packed tower with continuous water flow. Following humidification stage the foul air enters the base of the packed biofilter bed and then passes through the specially selected media. This high porosity media provides an ideal environment for the establishment of the bacterial colonies. As the foul air comes in contact with the biofilm, odorous compounds are solubilized into the moisture layer and subsequently oxidized by the microbes. The media and biofilm are kept adequately moistened by way of intermittent irrigation with water. Key design includes:

- Air flow rate: 3,800 m³/h
- Average inlet H₂S: 15 ppm
- Average inlet total reduced sulphide: 1 ppm
- Configuration: 1 cylindrical humidification vessel followed by 2 cylindrical biofilter vessels
- Empty bed contact time (EBCT): 45 seconds

Sludge Stabilization. WAS is stabilized via aerobic digestion. Two 50% digesters with a total volume of 2,228 m³ are proposed that will handle the design maximum month sludge production of 200 m³/d. The digesters will receive WAS directly from the SBRs. Aeration will be provided by fine bubble diffusers and two positive displacement blowers capable of maintaining 1 ppm of dissolved oxygen in the liquid.

Sludge Dewatering. Digested sludge is dewatered utilizing a decanter centrifuge. Dewatered sludge cake is transferred to a trailer and the centrate is returned to the process via the truck haul wastewater receiving station wet well. Part of the dewatered sludge will be used by the local mine for the tailing pond rehabilitation while the rest will be landfilled. A summary of the design is provided as follows:

- Number of Units: 1
- Design Solids Loading: 260 kg/h
- Design Hydraulic Loading: 20 m³/h
- Operating cycle: 7 h/d x 5 d/week
- Average feed sludge concentration: 1.1% to 1.3% TS
- Solids Capture: >95%
- Minimum Cake Solids Conc.: 18% solids (dry-weight basis)

PROJECT IMPLEMENTATION

Following pre-qualification of general contractors, contractor selection via tendering and award, the WWTP construction started in July 2017. The project is scheduled for completion in Spring of 2019. An aerial view of the current site is shown in **Figure 1**.



Figure 1. Aerial View of Thompson WWTP Construction

CONCLUSIONS

The Thompson WWTP project estimated at \$ 35 Million will provide a significant improvement to the overall water quality in the receiving stream through the elimination of partially treated wastewater discharges, nitrogen and phosphorus reduction and the implementation of the UV disinfection process. The new complex is being constructed adjacent to the old primary plant. A new lift station will transfer flows currently handled by the aerated lagoon to the proposed centralized plant by a dedicated forcemain.

The WWTP complex is a unique design that keeps the site (facilities) compact. The compact footprint also optimizes energy usage and retains space for future expansion. Furthermore, it will result in significant cost savings over a conventional plant design spread over a larger area. The

plant employs several sustainable design and energy efficient features, including high efficiency motors; blowers/pumps equipped with variable frequency drives; independent mixing and aeration, and maximizing the use of natural light. There is also a heat recovery ventilation system capable of capturing reject heat from the blowers and providing supplemental heat to other process areas of the plant. The rendering of the WWTP is shown in **Figure 2.0**.



Figure 2. Thompson WWTP – 3D Rendering

REFERENCES

1. Stantec Consulting Ltd. (2014) City of Thompson WWTP Upgrade/Expansion – Functional Design Report.