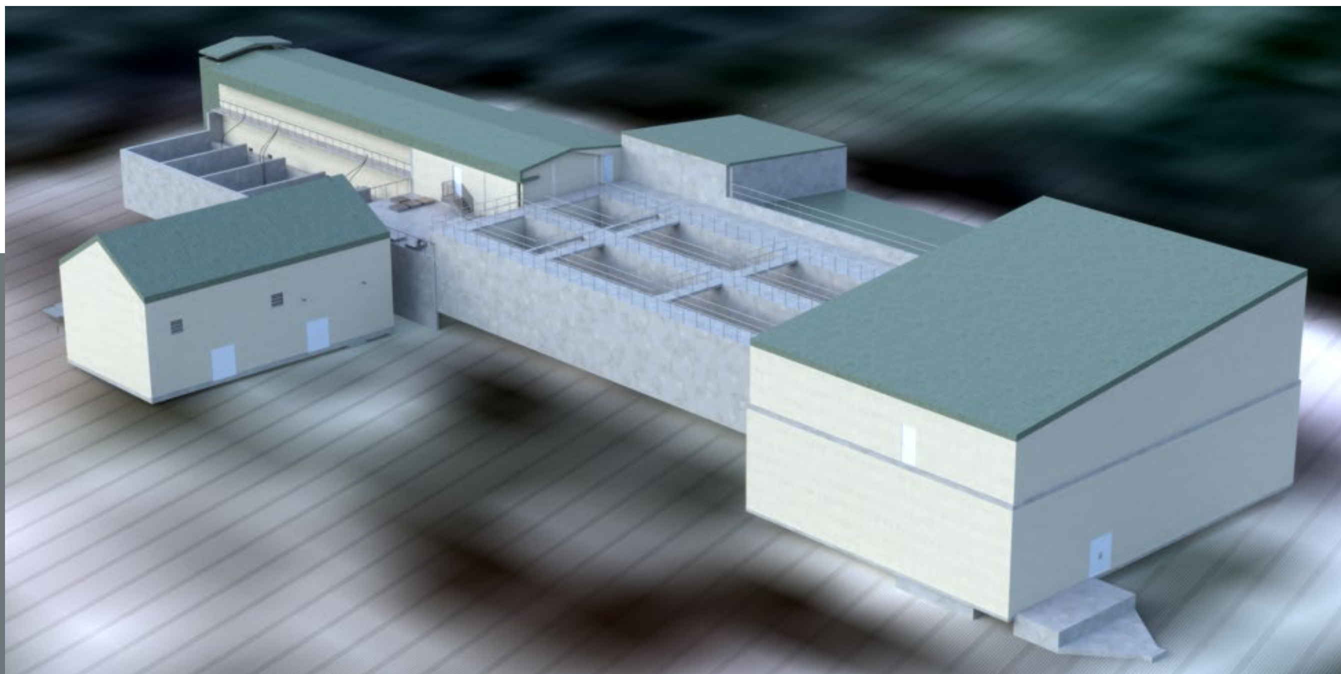
Town of Canmore

Wastewater Treatment Plant Technology Assessment



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Bradley Young

Digitally signed by Bradley Young
DN: E=Bradley.Young@cima.ca, CN=Bradley Young, OU=Usagers, OU=57, OU=C13, OU=Cima, DC=cima, DC=plus
Date: 2023.04.11 13:44:49-04'00'

Prepared by:

Pavel Manchinskiy, P.Eng.

Bradley Young, P.Eng.

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Date April 11 2023

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The Association of Professional
Engineers and Geoscientists of Alberta

Executive Summary

The existing Canmore Wastewater Treatment Plant (WWTP) is a two stage Biological Activated Filtration (BAF) plant for BOD removal and Nitrification.

Upgrades Need and Treatment Requirements

The Town of Canmore retained CIMA+ to complete a Capacity Evaluation of the Town's Wastewater Treatment Plant (WWTP) in 2022, to determine the plant's ability to support growth within Canmore until the year 2047. The Capacity Evaluation report (April 5, 2023) identified that the treatment process units do not have the capacity necessary to support the anticipated growth of the Town for the next 25 years. Several plant upgrades are required and were identified in the Capacity Evaluation report to accommodate life-cycle projects, along with the anticipated growth.

Additionally, the Water Quality Based Effluent Limits Study (WQBEL) has been completed and identified the effluent limits that will come into effect c. 2031. The new limits are more stringent with the inclusion of a Total Nitrogen (TN) limit. The existing facility will not be able to achieve these limits without a significant upgrade and potentially a change in secondary treatment technology.

The existing and proposed effluent limits are summarized in the table below.

Table E1. Current and Future Effluent Limits

Parameter	Current Effluent Limit	Future Effluent Limit
$cBOD_5$	≤ 20 mg/L (1)	≤ 10 mg/L (1)
TSS	≤ 20 mg/L (1)	≤ 10 mg/L (1)
TAN	≤ 5 mg/L (1) (Jul – Sep) ≤ 10 mg/L (1) (Oct – Jun)	≤ 5 mg/L (1) (Jul – Sep) ≤ 10 mg/L (1) (Oct – Jun)
TN	N/A	**15 mg/L(1)**
TP	≤ 1.0 mg/L (1)	**≤ 0.5 mg/L (1)**
Faecal Coliform	≤ 200 CFU per 100 mL(2)	≤ 200 CFU per 100 mL(2)

Notes:

(1) Monthly arithmetic means of daily composite samples

(2) Monthly geometric mean of daily grab samples

The current report reviews potential scenarios of a Canmore WWTP upgrade, identifies the preferred alternatives for achieving the new limits, provides conceptual level capital and operational expenses of the upgrade.

All proposed scenarios assume that a significant portion of the existing Canmore WWTP will continue to serve as part of the upgraded treatment process. Specifically, the headworks, sludge treatment, Dissolved Air Flotation (DAF), Ultraviolet Disinfection (UV), some electrical components (e.g. newer Motor Control Centers, Generator), administrative section, and existing concrete tankage.

Evaluation Framework

Achieving the new effluent limits will require modification or replacement of the existing secondary treatment process (BAF). It may also require the addition of a tertiary treatment (e.g. filtration).

The technologies potentially available in the market have been reviewed using a two staged approach. The long list of treatment technologies suitable to provide the required treatment has been developed and assessed based on the overall feasibility as well as suitability for the existing WWTP upgrade. The long-list technologies review is provided in Appendix A "Treatment Technologies Evaluation Framework and Preliminary Screening Results".

Based on the results of the preliminary screening the following scenarios have been identified.

+ Replacement of existing BAF system with the treatment process based on Aerobic Granular Sludge (AGS) complemented with the tertiary disc filtration.
+ Replacement of existing BAF system with Membrane Biological Reactor (MBR).
+ Expansion of existing BAF system complemented with the biological denitrification process and tertiary disc filtration.

The proposed scenarios have been evaluated based on the set of non-price related factors describing Technical, Operational, Social and Environmental factors. The detailed scoring is provided in Appendix B "Technology Assessment Scoring Matrix".

Following the evaluation of non-price related factors, the capital costs as well as Operation and Maintenance (O&M) costs were evaluated and a Net Present Value (NPV) of the alternatives have been assessed.

Analysis Results

Five options have been developed to assess the overall score. The options' description is shown in the table below.

Table E2. Treatment Upgrade Options, Costs and Options Ranking

	Option 1	Option 2	Option 3	Option 4	Option 5
	AGS Based Treatment		MBR Based Treatment		Existing BAF Based Treatment
Description	PC, AGS, DF	AGS, DF	PC, FS, MBR	FS, MBR	PC, BAF, MBBR, DF
Non-price Related Rating	2	1	4	3	5
Capital Cost	$78,000,000	$68,000,000	$81,000,000	$71,000,000	$87,700,000
Annual O&M Costs	$981,300	$1,050,500	$1,451,000	$1,520,600	$1,661,600
Life-Cycle Cost (20-year NPV)	$95,150,000	$86,360,000	$109,700,000	$100,880,000	$116,730,000
LCC Ranking	2	1	4	3	5
PC – Addition of 3d Primary Clarifier AGS – Aerobic Granular Sludge process DF – Disc Filtration FS – Fine Screening			MBR – Membrane Biological Reactor BAF – Biological Activated Filter MBBR – Moving Bed Bioreactor		
The costs provided are for the full build out flows and loads (c. 2047)					
Additional $12,000,000 will also be required to be invested between now and 2031. This is lifecycle components replacement needed to maintain the existing WWTP					

Primary Clarifier Options

Both AGS and MBR based scenarios are divided into two options. The main difference is Option 1 and Option 3 include the new third Primary Clarifier (PC) in addition to the existing two clarifiers while Options 2 and 4 do not include the PC.

AGS and MBR processes do not require primary clarification to achieve treatment results. However, the clarifier installed upstream of AGS will reduce the energy requirements for the AGS biological processes. This can be seen in “Annual O&M Costs” line of the table above, the O&M costs for Option 2 are higher than the corresponding O&M cost for Option 1. The clarifier also slightly reduces the energy consumption of the MBR system; however, the savings are less pronounced as significant power consumption in MBR process is due to the return activated sludge and permeate pumping.

The existing Primary Clarifiers will remain in place in any scenario. They will reduce the load to the downstream processes and will serve as an equalizing volume.

The need for the third clarifier should be investigated based on the following criteria.

- O&M energy consumption due to the additional clarifier should be compared with the capital costs of the third clarifier. Since the clarifier probable cost is $10mln and the annual savings for the AGS option are approximately $100k, the addition of the third clarifier may not be warranted.
- In the Capacity Evaluation report it has been identified that based on the observed performance and BioWin testing, the existing clarifiers are approaching their capacity limit and may not be able to provide sufficient clarification in the next 5 – 10 years (before the 2031 upgrade). It is recommended to complete a stress testing of the existing system to confirm the actual limitations of the primary clarification system and solids loading to the BAF. Depending on the results of this testing a decision should be made regarding the addition of the third clarifier prior to the secondary treatment upgrade. If the third clarifier is to be added to the existing system, it will continue to serve as part of the upgraded treatment (post 2031) and will provide the noted energy savings.

Capital and Operational Costs

Both the AGS and MBR treatment trains are essentially equivalent on capital costs (BAF expansion being slightly more costly) with annual operating costs being the main differentiator for the life-cycle cost analysis. AGS-based alternatives have considerably lower operating costs versus other technologies due to reduced aeration requirements, no return activated sludge / backwash pumping and reduced chemical use.

Overall, the evaluation results reflect the fact that the AGS process with discfilters is less resource intensive and provides a more sustainable solution that will meet the current and proposed wastewater servicing needs for the Town of Canmore. The technology recommendation between AGS and MBR shall be made following consultation with EPA and existing primary clarifiers stress testing to identify if a third primary clarifier needs to be constructed between now and 2031.

Project Planning and Staging

Implementation of the additional treatment processes for the expected 2031 timeline will require extensive design efforts and large capital investment. A high level schedule of the principal engineering and construction activities is provided in the table below. A liaison with the regulators (Environment and Protected Areas, Crown administration, etc.) and with the other stakeholders should be established at the earliest stage of the project to ensure their support and understanding of the required efforts and schedule.

Table E3. Principal Project Activities and Milestones

Year	Activities (Engineering)	Activities (Construction)
2024	Conceptual Report Define the preferable technology Confirm if Piloting is required	
2025	Preliminary Design Set the parameters for the detailed design	
2026	Preliminary Design Pilot (if required)	
2027	Detailed Design Refine Population Projections (Utility Master Plan)	Pilot (if required)
2028	Detailed Design	
2029	Tender Construction Admin	Civil, Concrete, Buildings Equipment Ordering
2030	Construction Admin	Architectural, HVAC, Process, Electrical, Control

2031	Construction Admin	Commissioning
2032	SCADA Programming Close Outs	Commissioning, As builts, existing equipment repurposing

Capital Costs and Project Staging

The base capital costs noted in Table E2 are for the WWTP upgrade for the full build out scenario is based on the population and loading projections expected for the year 2047. The costs ($80 – 90 mln) represent a large capital investment for the Town. It should be noted that the full build out construction completed around 2032 will likely create some treatment capacity that will be initially underutilized because it is sized to accommodate the future flows.

Construction staging should be considered to reduce the initial capital expenses and to optimize the WWTP operation. The initial phase of the project (that will be completed in 2031) can be designed to accommodate the approximately 15-year population growth (c. 2037). Preliminary estimate shows that this would allow the reduction of the initial capital costs by approximately 20%.

After the construction is completed (c. 2032) and the WWTP is commissioned, further evaluation of the Town growth and actual needs will be undertaken, and future expansion can be planned at that time.

Sufficient room and process integration should be allocated on site to accommodate further WWTP expansion.

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1 Introduction

The Town of Canmore retained CIMA+ to complete a Capacity Evaluation of the Town's Wastewater Treatment Plant (WWTP) in 2022 to determine the plant's ability to support growth within Canmore until the year 2047. The Capacity Evaluation identified that the treatment process units do not have the capacity necessary to support the anticipated growth of the Town for the next 25 years. Several plant upgrades are required and were identified in the Capacity Evaluation report to accommodate life-cycle projects, along with the anticipated growth.

In parallel, the Town, EPCOR and Environment and Protected Areas (EPA) Alberta have been discussing effluent limits required to accommodate the receiving effluent water quality.

The proposed effluent limits are more stringent than current, Table 1-1. Irrespective of growth, the existing WWTP will require additional process units to achieve the effluent quality.

Table 1-1: Current and Anticipated Effluent Limits

Parameter	Current Effluent Limit	Anticipated Effluent Limit
$cBOD_5$	≤ 20 mg/L (1)	≤ 10 mg/L (1)
TSS	≤ 20 mg/L (1)	≤ 10 mg/L (1)
TAN	≤ 5 mg/L (1) (Jul – Sep) ≤ 10 mg/L (1) (Oct – Jun)	≤ 5 mg/L (1) (Jul – Sep) ≤ 10 mg/L (1) (Oct – Jun)
TN	N/A	15 mg/L(1)
TP	≤ 1.0 mg/L (1)	≤ 0.5 mg/L (1)
Faecal Coliform	≤ 200 per 100 mL(2)	≤ 200 per 100 mL(2)

Notes:

(3) Monthly arithmetic means of daily composite samples

(4) Monthly geometric mean of daily grab samples

CIMA+ has since been retained by the Town to complete a technology assessment for the proposed Canmore WWTP upgrades. This report, "WWTP Technology Assessment", will evaluate the technologies retained through preliminary screening with the evaluation methodology identified in Appendix A: "Treatment Technologies Evaluation Framework and Preliminary Screening Results". The report will recommend the preferred technologies for the Canmore WWTP upgrade.

The purpose of this report is to:

- Review the evaluation methodology.
- Develop the retained alternatives to a feasibility level.
- Perform a detailed comparative evaluation of each alternative with and including:
    - Qualitative technical benefit evaluation and scoring
    - Detailed cost evaluation
    - Cost-benefit analysis
- Recommend a preferred alternative.

2 Project Goals and Evaluation Framework

2.1 Project Goals and Status

Project goals/objectives for the preferred design concept are outlined below:

- The preferred technologies proposed for the Canmore WWTP upgrade will be able to provide adequate and reliable treatment of Canmore's wastewater that meets the proposed effluent objectives for the plant in a financially and technically responsible manner.
- Construction and implementation of the preferred technologies will allow the Town to provide wastewater treatment capacity at the projected future flows and loads. Construction must also occur within the stipulated timeframe and minimize interference with the current operation of the existing Canmore WWTP.
- The preferred technologies will allow the Town / Operating Authority to operate the new facility in a manner that is consistent with the availability of staff resources, and in a way that is simple and financially responsible considering the complete life-cycle costs.
- The preferred technologies will address, in a responsible and practical manner, issues and concerns identified by the project team and different stakeholder groups.

2.2 Evaluation Framework

The figure below outlines the general evaluation framework for this project. The first three steps Figure 2-1 represent the preliminary screening of technologies available in the market. The technologies screening is provided in Appendix A “Treatment Technologies Evaluation Framework and Preliminary Screening Results”. The last two steps are discussed in detail in the body of the current report.

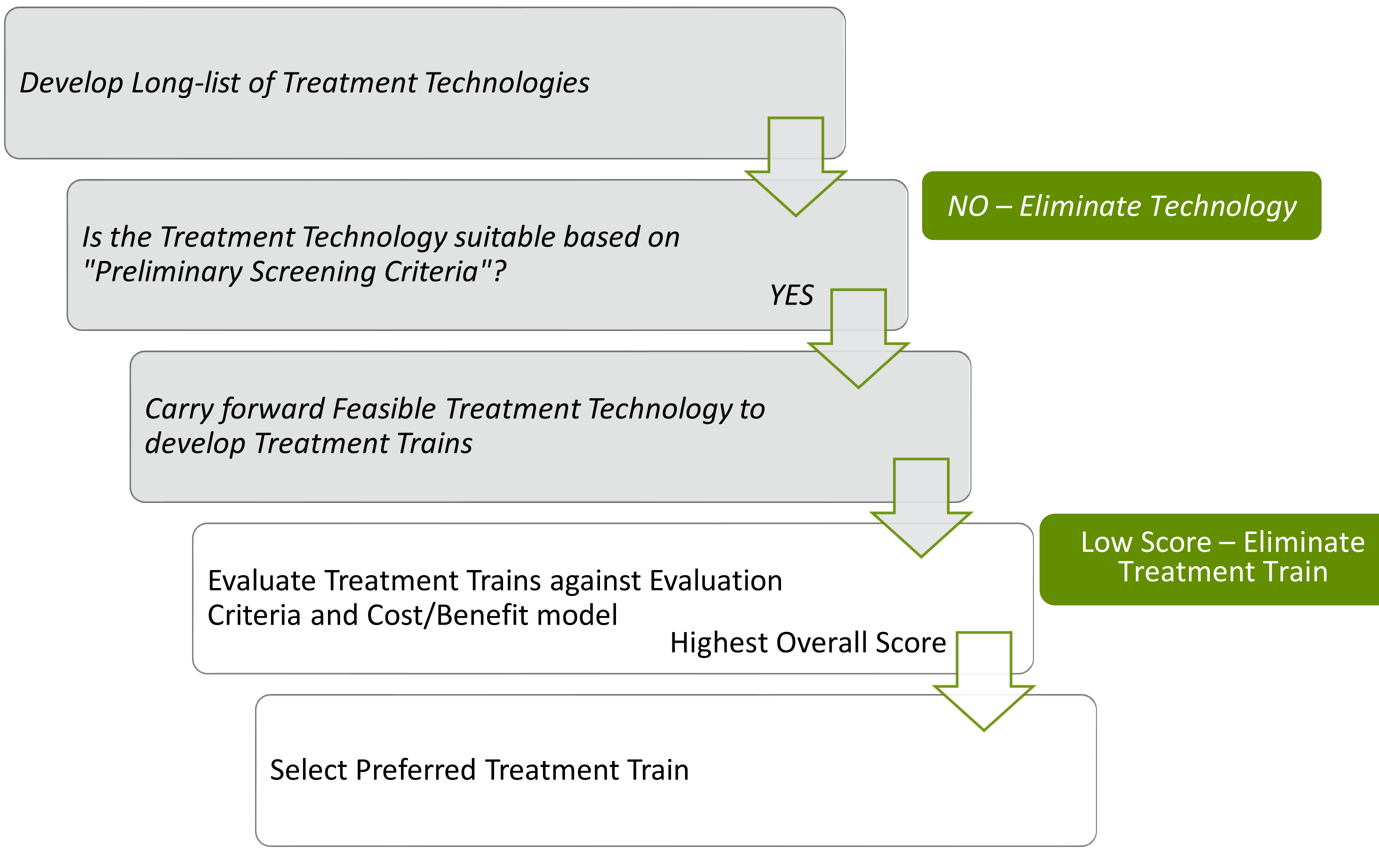

Figure 2-1: Evaluation Framework Schematic

2.3 Detailed Comparative Evaluation

Appendix A retained a list of technologies meeting all minimum criteria through preliminary screening. These technologies have been carried forward to the detailed comparative evaluation in this report. The detailed comparative evaluation involves the development of the alternative design concepts to a feasibility level, followed by a comparative evaluation, cost analysis, and scoring of each alternative.

The detailed comparative evaluation and decision model will use a weighting and ranking system to compare the alternative technologies (Appendix B). This approach will result in a systematic, rational, and reproducible comparison of alternative treatment trains and a straightforward identification of the preferred alternative.

For the purposes of this report, the technologies considered were developed based on the buildout design basis defined in Appendix A. Concept-level site layouts and sizing were prepared in support of the technical benefit scoring and life-cycle cost evaluations.

2.3.1 Decision-Making Model

To strike a balance between cost and non-cost factors, the methodology to determine the preferred alternative was followed:

1) A decision model was constructed including consideration of all factors or criteria not related to cost. Each of these factors/criteria are expressed in a positive way, so that each option is rated against the model. The model effectively measures a relative benefit offered by that option. In other words, decision modeling will be used to rate the “Benefits” offered by each option.
2) Conceptual level capital, Appendix C, and O&M costs, Appendix D, were generated for each option, to develop the lifecycle costs for each alternative.
3) The technical benefit scoring obtained for each option was divided by the lifecycle costs (in $ millions) to produce a “Benefit-to-Cost Ratio”. As a result, the alternative scoring the highest benefit-to-cost ratio is preferred.
4) Lastly, a sensitivity analysis is performed on the technical benefit scoring to evaluate how the decision model is impacted with slight changes to the technical benefit scoring weighting. This effectively confirmed that the decisions made using the decision model are robust and defensible.

2.3.2 Scoring Approach and Detailed Evaluation Criteria

For each alternative, applicable treatment technologies have been evaluated against the set of criteria and respective weight factors identified in Appendix A.

The four primary criteria for this project are presented below, Table 2-1.

Table 2-1: Evaluation Criteria and Weights

Primary Criteria	Weight
Technical	**35**
Operational	**30**
Social	**15**
Natural Environmental	**20**

The technical benefit scoring methodology compares the benefits of each treatment technology relative to each other, and their ability to perform under each evaluation criterion. To facilitate fair comparisons between similar technologies, the alternatives were grouped into and evaluated according to liquid treatment train options.

This approach facilitates consistent technical benefit scoring between alternatives and consistent cost-benefit analysis between alternatives. It simplifies the decision model by achieving defined evaluation results based on comparable benefits and similar cost magnitudes.

Each treatment train was firstly assessed for each sub-criteria on a scale from 0 to 10. The sub-criteria scoring was then weighted per the primary criteria weights to achieve a total technical benefit scoring out of 100 points. As such, the option with the highest score has the greatest benefit.

2.3.3 Cost Analysis Methodology

Capital costs for each alternative was estimated on a Class D basis with 30% contingencies. O&M costs were estimated using $ 0.2/kWh for electricity and 300$/hr (3 operators on site) for labour costs, along with past project experience and vendor inputs for other maintenance items and chemical costs.

Only capital, operation and maintenance cost components were considered for this analysis, excluding the salvage value. The salvage value component was instead evaluated qualitatively in the technical benefit scoring to simplify the quantitative cost evaluation and obtain more tangible results for the scope of this exercise.

The life-cycle cost analysis for each alternative was based on a net present value analysis over a 20-year period with a 6% interest rate, and 4% inflation rate. Capital costs for ancillary components for the WWTP upgrade (siteworks, MBR fine screening and administration section costs) are included in the capital costs for the liquid treatment train technologies. A detailed breakdown of the costing evaluation and assumptions used is included in Appendix C and Appendix D.

3 Summary of Retained Technologies

3.1 Overview

The list of suitable technologies retained following the preliminary screening process is presented below, Table 3-1.

Table 3-1: Liquid Treatment Train Options

Treatment Train	Primary Treatment Technologies	Secondary Treatment Technologies	Tertiary Treatment Technologies
Option 1	Primary Clarification	Aerobic Granular Sludge	Discfilters
Option 2	No Treatment	Aerobic Granular Sludge	Discfilters
Option 3	Primary Clarification	1-2 mm Screen and MBR	
Option 4	No Treatment	1-2 mm Screen and MBR	
Option 5	Primary Clarification	BAF Expansion and MBBR Denitrification	Discfilters

This section serves to provide an overview and describe each alternative that was developed as part of this report. Concept-level process flow diagrams (PFD) and site layouts were elaborated for each alternative. Rationale for the technical benefit scoring and the development of costs are in part based on these layouts.

3.2 Common Components

For the purposes of this evaluation, all alternatives included plant siteworks, a headworks facility, and an administration section. To minimize costs re-use of tankage from the existing WWTP is considered wherever possible.

3.2.1 Headworks Facility

The headworks facility will be common to each of the alternative designs. The existing headworks building will be upgraded such that it can meet the influent pumping and screening requirements for the future flows anticipated at the Canmore WWTP. The existing aerated grit removal is anticipated to have sufficient capacity to meet future flow requirements, therefore, no upgrade is required.

Costs related to stricter pre-treatment requirements for the MBR alternative has been priced in as an additional secondary treatment cost.

3.2.2 Administration Section

The administration section of the Canmore WWTP currently resides between the headworks and disinfection building. During the upgrade to the liquid treatment train, no plans are in place to upgrade the administration section of the plant at this time. This portion of the existing plant serves its purpose well, and the Town has not made a request to expand this section.

3.2.3 Re-use of Existing Tankage

3.2.3.1 Primary Clarifiers

The primary clarifiers at the Canmore WWTP are an integral part of the current operations of the BAF technology. The primary clarifiers provide the benefit of reducing load as well as co-thickening excess backwash, thus extending BAF filter run times and treatment performance. The proposed options with AGS or MBR are projected to be hydraulically limited and are not reliant on primary clarifiers to achieve the treatment objectives.

The capacity assessment identified the existing primary clarifiers are projected to need an expansion prior to the 2031 expansion project. The Capacity Assessment report developed a conceptual cost estimate for the primary clarifier expansion that will be utilized in this report.

It is important to note, if the current plant can operate without adding an additional clarifier prior to the expansion and an AGS or MBR shows favorable there is significant capital savings to be realized. The existing primary clarifiers could continue to be used with peak flows passively bypassed directly to secondary treatment. This approach would utilize the existing infrastructure and mitigate the additional OPEX of treating the full BOD and TSS Load.

We *recommend a stress test to confirm the capacity of the clarifiers* and develop a needs assessment for the third clarifier upstream of the proposed expansion.

3.2.3.2 BAF Cells

The BAF could be reused for ancillary tankage for the AGS or MBR options depending on detailed design and future site constraints. The BAF expansion option would re-use the existing cells as is. In all cases, the BAF cells would remain online during the construction period to allow for continuity of operations.

3.3 Description of Alternatives

3.3.1 Liquid Treatment Train

3.3.1.1 Aerated Granular Sludge & Disc filtration (Options 1 / 2)

The Aerobic Granular Sludge alternatives have been sized based on the buildout design basis. With the proposed peak flows and loadings, the AGS technology is limited by hydraulics through the system and not mass loading. The technology can be operated with primary clarifiers (Option 1) or without primary clarification (Option 2) within the same biological volume.

This alternative consists of the following components for construction and installation works:

- Optional construction of a 3rd Primary Clarifier,
- Intermediate pumping station upstream of the AGS reactors and related equipment
- Construction of 3 AGS reactor tanks and equipment,
- Re-use of existing WWTP tankage, BAF cells, for intermediate tankage (sludge buffer and water level correction tanks),
- Reuse of existing DAF for WAS thickening
- Construction of air and piping galleries,
- Construction of Blower and Discfilter Building
- Supply and install of Discfilter and related equipment
- All electrical, mechanical, and civil works

An overview configuration of a WWTP for this alternative and its components is presented in a PFD, Figure 3-1, and a preliminary site layout with both primary clarification and without primary clarification is presented in Figure 3-2 and Figure 3-3.

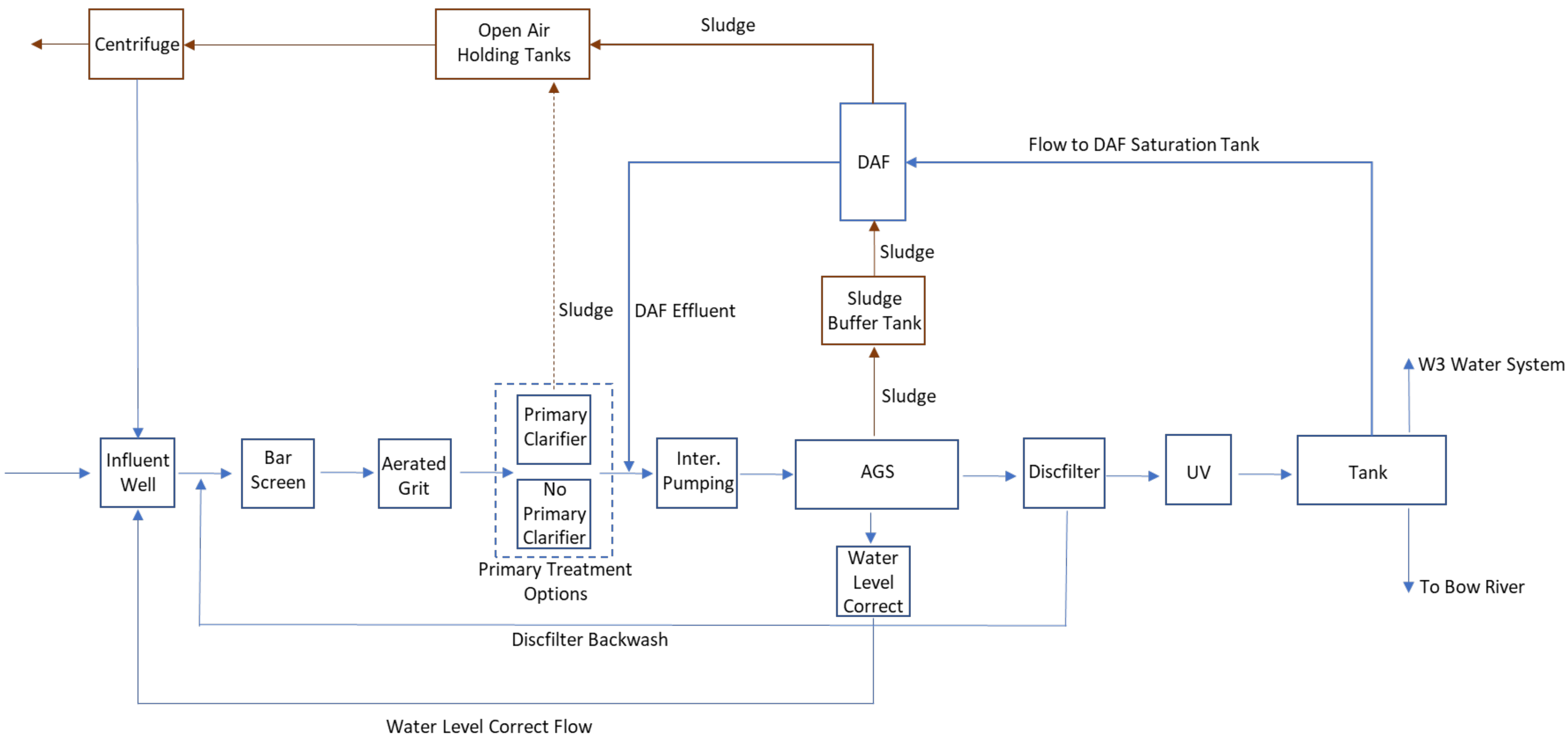

Figure 3-1: Process Flow Diagram of Options 1 and 2

Figure 3-2: Preliminary Site layout of Option 1 (Primary Clarification Included)

Figure 3-3: Preliminary Site Layout of Option 2 (Without Primary Clarification)

The AGS and Discfilter technology approach fits within the existing site constraints for the buildout scenario. Both technologies can be partially built and phased in if necessary. This presents opportunities to stage the process upgrades, which would allow part of the capital expenses to be postponed until demand requires the expansion (i.e. additional AGS tank, additional Discfilter unit).

The main advantage of this technology is the enhanced biological process with reduced resource intensity. These advantages lead to a low operational cost and low footprint, both of which are relevant advantages for the Canmore WWTP.

A technical summary of the technology can be found in Appendix E.

3.3.1.2 Membrane Bioreactor (Options 3 / 4)

The Membrane Bioreactor alternative has been sized based on configurations proposed by the technology supplier, with redundancy to handle 100% peak day flow (PDF) with one train out of service.

This alternative consists of the following components for construction and installation works:

- Optional construction of a 3rd Primary Clarifier,
- Construction of a fine screen and chemical building,
- Construction of parallel bioreactors,
- Supply and installation of membrane tank
- Construction of membrane equipment (incl. permeate pumping, cleaning components, etc.) and blower building
- Reuse of existing DAF for WAS thickening
- Supply and install of all supporting equipment (aeration, pumping, instrumentation),
- All electrical, mechanical, and civil works

An overview configuration of the WWTP for this alternative and its components is presented in a PFD, Figure 3-4, and in preliminary site layouts, Figure 3-5 and Figure 3-6.

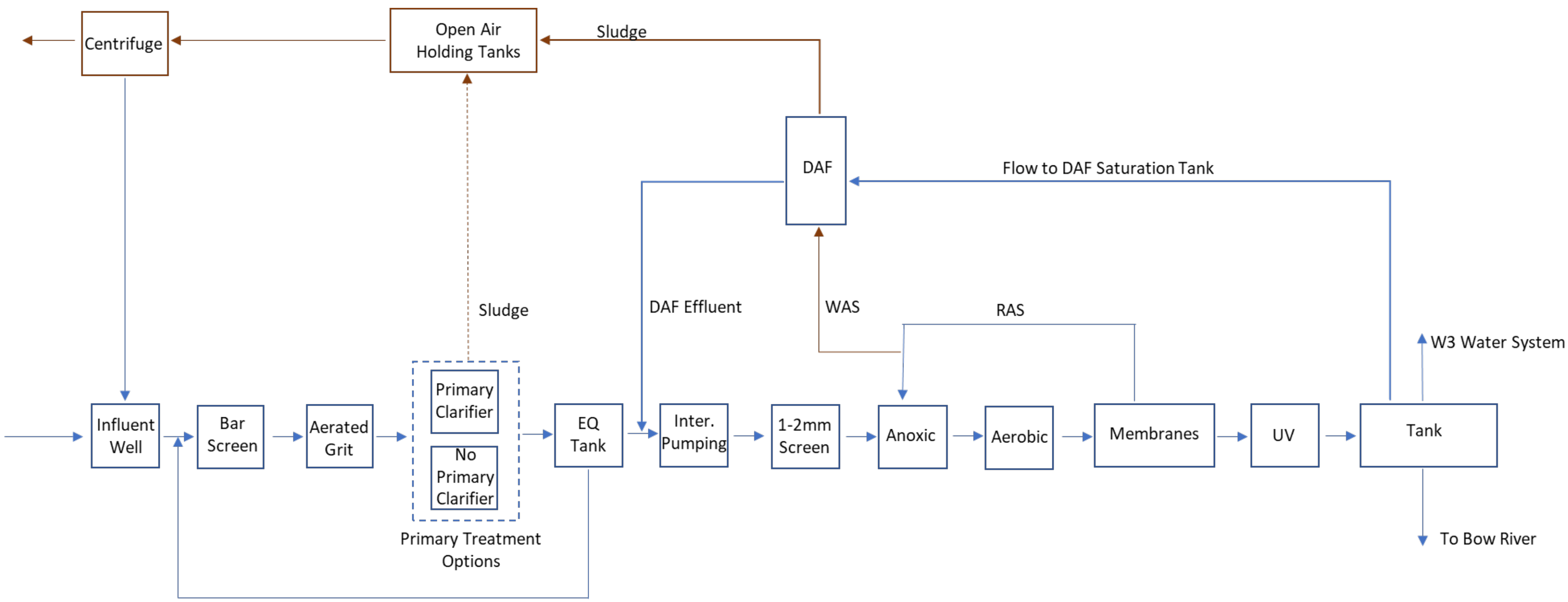

Figure 3-4: Process Flow Diagram of Option 3 and 4

Figure 3-5: Preliminary Site Layout, with Primary Clarifiers, for Option 3

Figure 3-6: Preliminary Site Layout, without Primary Clarifiers, for Option 4

The MBR option fits within the existing site constraints for the buildout scenario. The bioreactors can be built in phases; however, it is likely more economical to have two parallel trains. The membrane tanks and supply are modular and can be phased in according to proposed development and corresponding influent flowrates.

The main advantage of this technology is the MBR's ability to produce high quality effluent. This technology produces effluent that can meet lower requirements than the proposed 2031 effluent requirements, Table 1-1. Equalization is recommended to manage the peak flows experienced at Canmore as all water must pass through the membranes.

A technical summary of the technology can be found in Appendix F.

3.3.1.3 Biological Aerated Filter Expansion / Moving Bed-Bioreactor & Discfilter (Option 5)

The BAF expansion alternative would allow the WWTP to keep the existing technology of the plant, minimizing operator training once the upgrade has been performed. An MBBR would be added after the N-side BAFs for denitrification, while disc filtration would be used to further polish the wastewater, such that the quality would be able to meet the anticipated effluent regulation update.

This alternative consists of the following components for construction and installation works:

- Addition of a 3rd Primary Clarifier,
- Construction of both C-side and N-side BAF cells with galleries and building
- Construction of an MBBR and required re-ox tankage,
- Construction of additional blowers,
- Construction of a building to house the Discfilters,
- Supply and installation of Discfilter equipment and supporting components,
- All electrical, mechanical, and civil works

The process streams for this alternative technology is presented in a simple PFD, Figure 3-7, and a partial site layout showing the technology footprint is presented in Figure 3-8.

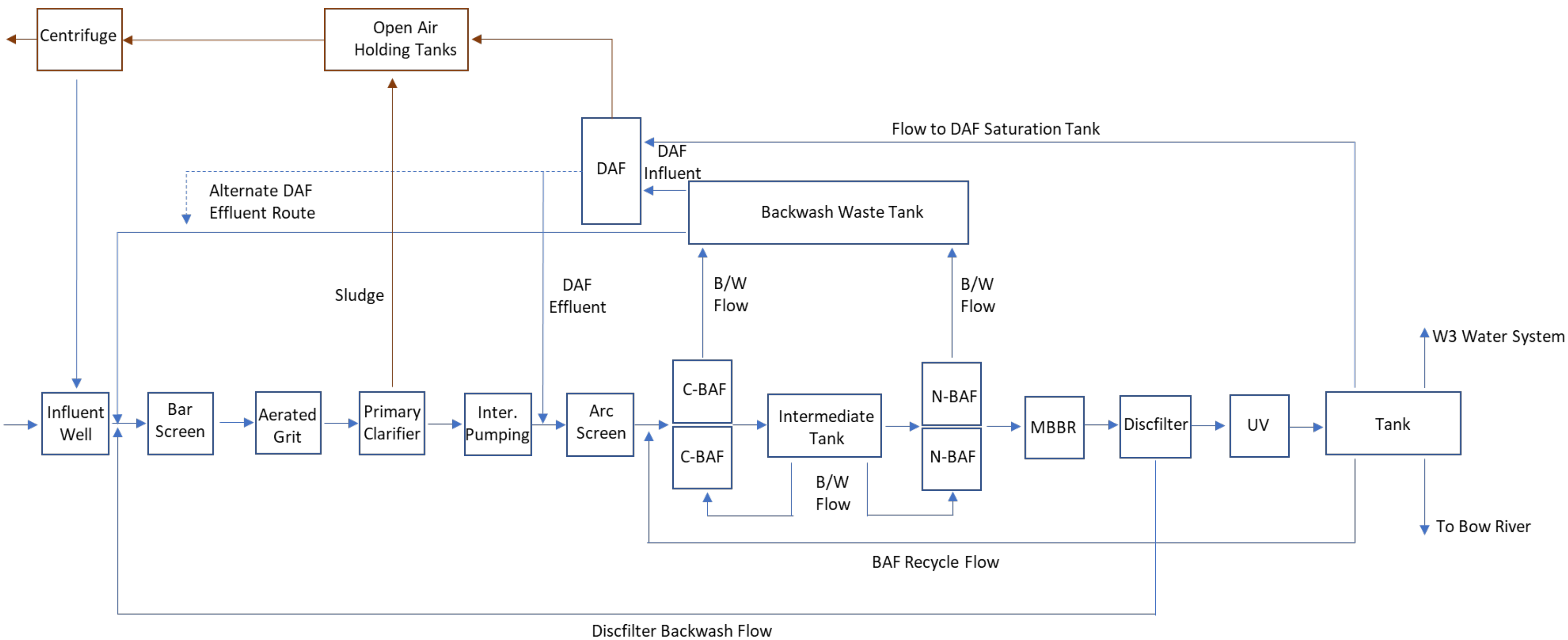

Figure 3-7: Process Flow Diagram of Option 5

Figure 3-8: Preliminary Site Layout for Option 5

At a high level, the BAF expansion can fit within the site constraints, however the flow split, and operation will be challenging. The main disadvantage of the BAF technology is that it requires a large amount of energy to effectively operate as the existing units are not intended to provide total nitrogen removal. Thus, by expanding the BAFs, operating costs will significantly increase relative to the other alternatives. The BAF technology also generates high volumes of backwash and requires a significant number of cells to allow the technology to have the necessary hydraulic capacity.

4 Evaluation Results

4.1 Liquid Treatment Train Technologies

4.1.1 Technical Benefit Scoring

The Technical Benefit Scoring results and rankings for the liquid treatment train alternatives are presented in the table below, Table 4-1. The detailed evaluation matrix for all options is presented in Appendix B.

Table 4-1: Scoring Results of the Evaluation Matrix

Parameters	Weight	Option 1	Option 2	Option 3	Option 4	Option 5
Description		PC, AGS, DF	AGS, DF	PC, FS, MBR	FS, MBR	PC, BAF, MBBR, DF
Technical	/35	27.8	28.6	28.6	29.4	25.8
Operational	/30	25.5	25.0	23.9	23.8	15.2
Social	/15	11.8	12.1	11.8	12.1	10.6
Natural Environmental	/20	17.0	16.4	15.0	15.0	14.2
Overall Scores	/100	82.0	82.1	79.3	80.3	65.7
Scoring Rank		**2**	**1**	**4**	**3**	**5**
Overall Scores – Inverted Bias	/100	82.1	81.8	78.0	78.9	68.0
Scoring Rank – Inverted Bias		1	2	4	3	5
Notes						

Alternatives with AGS and Discfilter (Option 1 and 2) are the two highest-scored; while the MBR approach is close behind. In general, the AGS is favorable for less operational complexity and lower energy usage and the MBR is favorable for the higher quality of effluent. The BAF expansion was significantly less favorable than the other options.

4.1.2 Life-cycle cost analysis

A summary of the life-cycle cost analysis and resulting rankings is presented in the table below, Table 4-2.

Option 2, no Primary Clarifiers and Aerobic Granular Sludge with Discfilters, has the lowest life-cycle cost over a 20-year project lifetime. As mentioned in Section 3.2.3, this option is only available if the existing plant can operate until 2031 without a third primary clarifier. A stress test is recommended to properly plan as the existing clarifiers are approaching the identified capacity.

Table 4-2: Alternative Life-Cycle Cost Analysis

Parameters	Option 1	Option 2	Option 3	Option 4	Option 5
Description	PC, AGS, DF	AGS, DF	PC, FS, MBR	FS, MBR	PC, BAF, MBBR, DF
Capital Cost	$78,000,000	$68,000,000	$81,000,000	$71,000,000	$87,700,000
Annual O&M Cost	$981,300	$1,050,500	$1,451,000	$1,520,600	$1,661,600
Life-cycle Cost (20-year NPV)	$95,200,000	$86,400,000	$109,700,000(1)	$100,900,000(1)	$116,800,000
LCC Ranking	**2**	**1**	**4**	**3**	**5**

Notes

(1) The LCC for both MBR options only considered a membrane replacement at Year 10, a second membrane replacement will be required in Year 21

(2) LCC Costs are rounded

4.1.3 Decision model results

Benefit-to-Cost ratios for the alternative technologies are presented below, Table 4-3, based on the results from technical benefit scoring and life-cycle cost analysis.

Based on this evaluation, the preliminary preferred alternative for the liquid treatment train is Option 2 – Aerobic Granular Sludge with Discfilters, as it had the highest Benefit-to-Cost ratio of 0.95. Option 1 – Primary Clarifier, Aerobic Granular Sludge, and Discfilter is the runner up with a Benefit-to-Cost ratio of 0.86.

Table 4-3: Alternative Benefit to Cost Ratios

Parameters	Option 1	Option 2	Option 3	Option 4	Option 5
Description	PC, AGS, DF	AGS, DF	PC, FS, MBR	FS, MBR	PC, BAF, MBBR, DF
Overall Scores	82	82.1	79.3	80.3	65.7
Capital Costs	$78,000,000	$68,000,000	$81,000,000	$71,000,000	$87,700,000

Life-cycle Cost (20-year NPV) ($ millions)	95.200	86.400	109.700	100.900	116.800
B:C ratio	0.86	0.95	0.72	0.80	0.56
Ranking	**2**	**1**	**4**	**3**	**5**
Notes					

4.1.4 Main Differentiators and Key Advantages

In summary, AGS-based alternatives outranked alternatives based on Membrane Bioreactors and BAF expansion because of increased future expansion ability, lower footprint, and reduced O&M costs. The Membrane Bioreactors fell short during evaluation due to the high annual O&M costs, largely related to their energy consumption and membrane replacement approximately every 10 years. The BAF expansion was unable to compete as the technology requires a high energy consumption, substantial initial capital cost, and larger footprint.

Both the AGS and MBR treatment trains are essentially equivalent on capital costs (BAF expansion being slightly more costly) with annual operating costs being the main differentiator for the life-cycle cost analysis. AGS-based alternatives have considerably lower operating costs versus other technologies due to reduced aeration requirements, no return activated sludge and reduced chemical use.

For tertiary treatment components, Discfilters were chosen due to their smaller footprint, compatibility with existing site conditions, their increased flexibility on the proposed HGL, and their improved flexibility for expansion. Discfilters also require little excavation with intermediate pumping upstream of the biological system, limiting capital expenditure and allowing for flexibility due to the high groundwater table (also refer the comments in Section 5.5) at the Canmore WWTP.

Overall, the evaluation results reflect the fact that the AGS process with Discfilters is less resource intensive and provides a more sustainable solution that will meet the current and proposed wastewater servicing needs for the Town of Canmore. The technology recommendation between AGS and MBR shall be made following consultation with EPA and stress testing to identify if a third primary clarifier needs to be constructed between now and 2031.

4.1.5 Baseline Minimal Growth Scenario

It has also been reviewed an option to upgrade the existing WWTP to meet the upcoming EPA effluent limits without increasing the capacity of the existing WWTP. Such upgrade will include the addition of processes for Total Nitrogen and Phosphorous removal.

The capital costs for this option are $31,200,000. In addition to the direct capital costs, another $12,000,000 will be required between now and 2031 for lifecycle replacement projects (similar to the other options).

The cost estimate for this scenario is provided in Appendix C, table labeled “Option 0”. This option has not been tested in a cost/benefit analysis due to the low probability of a no growth scenario. This option simply provided as a baseline to compare the capital needed to update the existing treatment to meet the upcoming limits with the capital costs required due to the Town’s growth.

5 Additional Project Requirements

5.1 Land Availability

The existing Canmore WWTP is located in the Bow River valley approximately 50 m from the Bow River. The land belongs to the Crown. The Town has leased the existing WWTP parcel (DML940030). The leased area has an irregular shape as shown on the drawing in Appendix G. The west area of the leased parcel is occupied by the Town Recycle plant and thus not available. The central area is occupied by the existing WWTP buildings. It has a few smaller available spots to house some auxiliary equipment but does not have enough space for the larger plant upgrade. The East portion of the leased land with an approximate size of 100 x 60m could potentially be used for the WWTP expansion. The lands surrounding the existing DML940030 disposition are leased to other individuals and are not directly available.

Based on the preliminary projections, the East area of the existing lease will likely be sufficient for the AGS or MBR equipment placement. The space size requirements should be finalized during the conceptual design stage. If more land is required to accommodate the expansion, a land agent should be engaged to commence the negotiations with the lease holders of the surrounding parcels.

If the size of available land is sufficient, a temporary field authorization (TFA) should be obtained prior to the construction commencement. The Crown administrator (EPA) may request to conduct additional studies and stakeholders engagement prior to granting the TFA. Environmental studies of the site may be required. Additionally, First Nation Consultation (FNC) may be required.

5.2 Environmental Requirements

The East section of the existing DML940030 is covered by trees. Most likely, a biophysical study and wetland study (desktop and onsite) be required to ascertain the environmental risks and site limitations. Other studies or onsite investigations may be recommended depending on the results of the biophysical study.

Environment and Protected Areas (EPA) should be consulted at the very inception of the project. EPA should be informed on the conceptual report results, especially the type of treatment technology the Town would be proceeding the upgrade.

Should the Town decide to select an emerging technology (e.g. AGS), the EPA and the Town's consultant should agree on the need to conduct a pilot test of the technology or simply rely on the technology performance results collected in another site.

The EPEA approval 483-04-00 will be reissued by the EPA after reviewing and accepting the WQBEL study and the treatment proposal (Section 3.2.4 of the Approval). The updated approval will likely stipulate the upgrade requirements with the probable implementation date of 2031.

It does not appear that the Department of Fisheries and Oceans should be consulted. E.g. no changes or modifications to the existing effluent is anticipated. This, however, should be confirmed during the conceptual design.

5.3 Piloting

Projects with the environmental and societal magnitude similar to Canmore WWTP upgrade often conduct piloting of a small-scale model of the treatment system prior to proceeding with the detailed design. Project piloting confirms the suitability of a new technology. More often, however, it is conducted for a relatively known technologies to fine tune the theoretical sizing of the equipment, improve the design quality and simplify the equipment commissioning.

The current report considered both MBR or AGS technologies to achieve the required level of the effluent treatment.

MBR technology is well known in North America and has numerous successfully operating installations. Since the technology is widely accepted and the operation results may be obtained from a very similar plants (e.g. Evan Thomas in Kananaskis), the value of the MBR piloting would be limited to the equipment fine tuning for the site. Therefore, the MBR piloting may potentially be reduced or even eliminated all together.

AGS process is known in Europe and currently is gaining acceptance in North America. Several new plants using AGS are operational including White Fish, Montana, USA (northern climate), several are currently under construction, and at the time of the detailed design more real data could be available from the recently commissioned plants built in Canada and the US.

The need for the selected technology piloting should be assessed during the conceptual design. If the project team opts not to conduct the piloting, this would slightly reduce the costs of the project.

5.4 Existing WWTP Drawings Digitalization

The existing Canmore WWTP has been built around 1995 with some larger processes added in 2009 (BAF 9,10), 2017 (DAF), 2020 (Dewatering). Numerous other upgrades have been completed over the years. The existing as built drawings are of variable detailing and quality and completed in different CAD based systems.

The initial stage of WWTP existing process drawings digitalization has been completed. Most of the process and some structural drawings are currently available in a Revit model. Additionally, a complete 3D building scan has been completed in 2020

However, the HVAC and plumbing, other structural and architectural drawings still require completion.

The as built digitalization should be best prepared prior to commencing the detailed design of the WWTP upgrade. The 3D version of the existing drawings will allow inclusion of the upcoming upgrade to the same model. At the end, the Town will be supplied with a complete version of the as built drawings that would include existing and new facilities.

The electrical drawings are currently CAD based. It would make sense to keep the schematic based drawings in CAD and only to bring to a 3D model the larger electrical equipment (e.g. generator, MCCs, main conduits). The overhaul of the electrical and control drawings should probably be completed as part of the as built drawings completion after the upgrade is done.

5.5 Ground Water

The existing WWTP site is located at the lower Bow River valley. A geotechnical consultant should be engaged during the preliminary design stage to assess the soil conditions for the expected WWTP tanks and buildings construction.

The WWTP site elevation is less than 3 m above the Bow River level. The expected soils on site may consist of gravels with a potential for a high ground water presence. This should be taken into consideration during the preliminary and detailed design. Consideration should be given to place the tankage above ground or at shallow (less than 3 m) installations or consider the construction methods that do not require dewatering.

6 Recommendations

A summary of the preliminary preferred treatment train for the Canmore WWTP upgrade is provided in Table 6-1 below.

Table 6-1: Preliminary Preferred Treatment Train

Parameters	Preferred Alternative (1)
Liquid Treatment Train	Aerobic Granular Sludge + Discfilters
Overall Scores	82.1/ 100
Life-cycle Cost (20-year NPV) ($ millions)	$ 86.40 M
B:C ratio	0.95
Treatment Plant Expansion Strategy	Addition of process units
Notes: (1) Pending official go-ahead from EPA	

Considering all process units selected, the upgraded WWTP will have an estimated life-cycle cost of $ 86.40 million over its 20-year lifetime. Beyond its initial life cycle, it is anticipated that the facility remains in use and be expanded through addition of process units.

The evaluation process identified Aerobic Granular Sludge with Discfilters as the preferred secondary technology given its benefits of reduced operating costs, reduced footprint, and its improved robustness through the wide range of flows and loads seen from start-up to buildout.

However, Aerobic Granular Sludge remains an emerging technology in wastewater treatment plants in Canada. It is recommended that Canmore staff have a discussion with, and possibly visit, an existing facility using the AGS technology, to confirm suitability of this technology for the Canmore WWTP upgrade.

7 Project to Implementation Planning

The new effluent limits for the Canmore WWTP are likely to come into effect in 2031, thus the upgrade to the plant must be completed by this date. The upgrade to the plant must be operational as of 2031, and close out of the project can take place afterwards, running through 2031 and into 2032, if necessary.

Below is a table, Table 7-1, that outlines a high-level project schedule, along with capital needs during that timeframe. Note that the budgets, timing, and schedule presented in

Table 7-1 are subject to change as many factors affect these parameters, and not all of them can be accounted for at the time of writing this report.

Table 7-1 shows the timeline and costs for a full build out scenario (i.e. the entire WWTP capacity will be constructed by 2031). However, the full build out construction completed around 2031 will likely create some treatment capacity that will be initially underutilized because it is sized to accommodate the future flows.

Construction staging should be considered to reduce the initial capital expenses and to optimize the WWTP operation. The initial phase of the project (that will be completed in 2031) can be designed to accommodate the approximately 15-year population growth (c. 2037). The design and construction schedule will be similar to the full build out plant. Preliminary estimate shows that the initial capital expenses will be reduced by approximately 20%. This scenario is shown in Table 7-2: .

After the construction is completed (c. 2031) and the WWTP is commissioned, further evaluation of the Town growth and actual needs will be undertaken, and future expansion can be planned at that time.

Sufficient room should be allocated on site to accommodate further WWTP expansion.

Table 7-1: High Level Project Schedule and Capital Needs (Full Build Out, c.2047)

AGS or MBR Upgrade	2024	2025	2026	2027	2028	2029	2030	2031	2032	Total
Annual Construction Budget Secondary & Tertiary Treatment Upgrade				**500,000**		**21,500,000**	**19,800,000**	**17,500,000**	**5,000,000**	**64,300,000**
Pilot Test				500,000						
Civil, Concrete, Buildings						14,500,000				
Equipment Ordering						7,000,000				
Architectural, HVAC							5,000,000	5,000,000		
Process, Electrical, Control							7,000,000	7,500,000		
Equipment Installation							7,800,000	5,000,000		
Commissioning									3,000,000	
BAF Repurposing									1,000,000	
Close Outs (O&M, As-builts, site clean out, etc.)									1,000,000	
Annual Engineering Budget	**600,000**	**600,000**	**850,000**	**850,000**	**800,000**	**850,000**	**750,000**	**900,000**	**500,000**	**6,700,000**
Conceptual Design Options Review Report	300,000									
Environmental and Admin Crown Land, EPA, FN Consult, Landowners Consent	100,000	200,000	150,000	150,000	150,000	150,000	150,000	100,000	50,000	
As Built Drawings (Digitalization)	200,000								50,000	
Preliminary Design Upgrade report, Costs		400,000	400,000							
Pilot Administration			100,000	50,000						
Detailed Design			100,000	650,000	650,000					

AGS or MBR Upgrade	2024	2025	2026	2027	2028	2029	2030	2031	2032	Total
Tender						100,000				
Construction Admin						500,000	500,000	250,000		
Geotech. Env. Consult			100,000			100,000	100,000	50,000		
SCADA Programming								350,000		
Commissioning								150,000	250,000	
Close Outs BAF Decommissioning									150,000	
AGS or MBR Subtotal										**71,000,000**
Project Existing WWTP Upgrades**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**	
Annual Budget	**2,900,000**		**2,260,000**	**5,270,000**	**10,200,000**	**500,000**			**1,170,000**	**22,300,000**
Odor Control	2,000,000									
Inlet Screen	900,000									
Inlet Lift Station Pumps, Expansion				4,100,000						
Influent Piping				1,170,000						
Misc. Sludge Trtm Upgrades: Scum piping, Grit Separator, Grit separator Fan, Headworks Isolation Valves			2,260,000							
3d Primary Clarifier					10,200,000					
UV 3						500,000				
Septage Receiving Station									1,170,000	
Grand Total										**93,300,000**

**Existing WWTP Upgrades budget includes both construction and engineering costs. Engineering should be completed in the year prior to the year of construction.

Table 7-2: High Level Project Schedule and Capital Needs (Partial Upgrade, c.2037)

AGS or MBR Upgrade	2024	2025	2026	2027	2028	2029	2030	2031	2032	Total
Annual Construction Budget Secondary & Tertiary Treatment Upgrade				**400,000**		**17,200,000**	**15,840,000**	**14,000,000**	**4,000,000**	**51,440,000**
Pilot Test				400,000						
Civil, Concrete, Buildings						11,600,000				
Equipment Ordering						5,600,000				
Architectural, HVAC							4,000,000	4,000,000		
Process, Electrical, Control							5,600,000	6,000,000		
Equipment Installation							6,240,000	4,000,000		
Commissioning									2,400,000	
BAF Repurposing									800,000	
Close Outs (O&M, As-builts, site clean out, etc.)									800,000	
Annual Engineering Budget	**480,000**	**480,000**	**680,000**	**680,000**	**640,000**	**680,000**	**600,000**	**720,000**	**400,000**	**5,360,000**
Conceptual Design Options Review Report	240,000									
Environmental and Admin Crown Land, EPA, FN Consult, Landowners Consent	80,000	160,000	120,000	120,000	120,000	120,000	120,000	80,000	40,000	
As Built Drawings (Digitalization)	160,000								40,000	
Preliminary Design Upgrade report, Costs		320,000	320,000							
Pilot Administration			80,000	40,000						

AGS or MBR Upgrade	2024	2025	2026	2027	2028	2029	2030	2031	2032	Total
Detailed Design			80,000	520,000	520,000					
Tender						80,000				
Construction Admin						400,000	400,000	200,000		
Geotech. Env. Consult			80,000			80,000	80,000	40,000		
SCADA Programming								280,000		
Commissioning								120,000	200,000	
Close Outs BAF Decommissioning									120,000	
AGS or MBR Subtotal										**56,800,000**
Project Existing WWTP Upgrades**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**	
Annual Budget	**2,900,000**		**2,260,000**	**5,270,000**	**10,200,000**	**500,000**			**1,170,000**	**22,300,000**
Odor Control	2,000,000									
Inlet Screen	900,000									
Inlet Lift Station Pumps, Expansion				4,100,000						
Influent Piping				1,170,000						
Misc. Sludge Trtm Upgrades: Scum piping, Grit Separator, Grit separator Fan, Headworks Isolation Valves			2,260,000							
3d Primary Clarifier					10,200,000					
UV 3						500,000				
Septage Receiving Station									1,170,000	
Grand Total										**79,100,000**

**Existing WWTP Upgrades budget includes both construction and engineering costs. Engineering should be completed in the year prior to the year of construction

8 Conclusion

In conclusion, three viable secondary treatment technologies have been short listed for the Canmore WWTP upgrade. Each of the technologies will be able to provide the Town with sufficient effluent quality to meet the updated regulations, Table 1-1.

High level capital budget and planning was created to facilitate the planning of the plant upgrade in Table 7-1. Both the AGS and MBR technologies can be staged appropriately to accommodate the needs of the plant, while staging of the BAF technology is more challenging. AGS is an innovative solution that reduces O&M costs through the technology's lifetime, however, MBR is a common technology in Canada that produces higher quality effluent but requires larger capital and O&M costs. If the chosen technology to proceed with for the upgrade is the innovative AGS solution, pilot testing may be needed, but the necessity of the pilot testing will be determined at a later stage.

A

Appendix A: Treatment Technologies Evaluation Framework and Preliminary Screening Results

CIMA+

Town of Canmore

Wastewater Treatment Plant – Technology Assessment

Technical Memorandum
Evaluation Framework and Preliminary Screening Results

Wednesday, February 22, 2023

C04-00496

CIMA+

6815-8 St NE
Calgary, AB T2E 7H7
T 403 775 0100 **F** 403 775 0102
cima.ca

Contact

Pavel Manchinskiy
Pavel.manchinskiy@cima.ca
T 403 988 3256

Engineering for **people**

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1 Introduction

The Town of Canmore retained CIMA+ to complete Capacity Evaluation of the Town's Wastewater Treatment Plant (WWTP) in 2022 and to determine the plant's ability to support growth within the Town of Canmore until the year 2047. The Capacity Evaluation identified that the treatment process units does not have the capacity necessary to support the anticipated growth of the Town for the next 25 years. Several plant upgrades are required and were identified in the Capacity Evaluation report to accommodate the anticipated growth as well as life-cycle projects.

In parallel, the Town, EPCOR and Environment and Protected Areas (EPA) Alberta have been discussing effluent limits required to accommodate the receiving effluent water quality. The new limits will likely be imposed during the time of the existing EPEA Approval renewal in 2031. The proposed effluent limits are more stringent than current (Table 1). Irrespective of growth, the existing WWTP will require additional process units to achieve the effluent quality.

Table 1: Current Effluent Limits

Parameter	Effluent Limit
$cBOD_5$	≤ 20 mg/L (1)
TSS	≤ 20 mg/L (1)
TAN	≤ 5 mg/L (1) (Jul – Sep) ≤ 10 mg/L (1) (Oct – Jun)
TP	≤ 1.0 mg/L (1)
Faecal Coliform	≤ 200 per 100 mL(2)

Notes:

(1) Monthly arithmetic mean of daily composite samples

(2) Monthly geometric mean of daily grab samples

The purpose of this TM is to:

- Define the evaluation framework to be used to evaluate alternative design concepts and select the preferred design concept

- Identify and develop a long list of treatment technology alternatives for the liquid train
- Provide screening of long list alternatives to produce a short list of technology alternatives for further evaluation

2 Project Goals and Design Basis

2.1 Project Goals

Project goals/objectives have been developed to represent the driving factors behind the technology assessment as well as those elements to be highly influential in the decision-making process. The success of the evaluation framework can be measured by the extent to which the outcome of the evaluation process is able to achieve these goals/objectives at the end of the process. The following project goals have been developed:

- The preferred design concept proposed for the Canmore WWTP upgrade will be able to provide adequate and reliable treatment of Canmore's wastewater that meets the proposed effluent objectives for the plant in a financially and technically responsible manner.
- Construction and implementation of the preferred design concept will allow the Town to provide wastewater treatment capacity at the projected flows and loads. Construction must also occur within the stipulated timeframe and minimize interference with the current operation of the existing Canmore WWTP.
- The preferred design concept will allow the Town / Operating Authority to manage the new facility in a manner that is consistent with the availability of staff resources, and in a way that is simple and financially responsible considering the complete life-cycle costs.
- The preferred design concept will address in a responsible and practical manner issues and concerns identified by the project team and stakeholder groups.

2.2 Design Basis

2.2.1 Influent Flows and Loads

The historical data, and proposed design basis for the Canmore WWTP upgrade were reviewed in the Capacity Evaluation report and are summarized in Table 2 and Table 3.

Table 2: Hydraulic Design Basis for the Proposed Canmore WWTP Upgrade

Flow	2047
Average Day (m^3/d)	19,200
Peak Day (m^3/d)	48,070
Peak Hour (m^3/d)	69,530

Table 3: Design Influent Wastewater Loadings

Design Parameter	2047
Average Loadings (kg/d)	
BOD_5	3,993
TSS	3,688
TP	79
TAN	374
Peak Month Loadings (kg/d)	
BOD_5	4,855
TSS	4,852
TP	100
TAN	450

2.2.2 Effluent Criteria

Wastewater effluent quality objectives for the Canmore WWTP have been finalized. The effluent limits have been established by EPA and accepted by the Town. It is anticipated that the new regulations will come into effect as of 2031 after the existing Approval is renewed. The technology assessment is using the proposed effluent regulation limits (Table 4). The proposed effluent limits will be used to establish the minimum requirements against which to measure each treatment strategy developed and evaluated in this technology assessment.

Table 4: Proposed Future Effluent Regulation Limits

Parameter	Effluent Limit
$cBOD_5$	≤ 10 mg/L (1)
TSS	≤ 10 mg/L (1)
TAN	≤ 5 mg/L (1) (Jul – Sep) ≤ 10 mg/L (1) (Oct – Jun)
TN	15 mg/L (1)
TP	≤ 0.5 mg/L (1)

Faecal Coliform	≤ 200 per 100 mL(2)
Notes: (1) Monthly arithmetic mean of daily composite samples (2) Monthly geometric mean of daily grab samples	

2.3 Proposed Evaluation Framework

The proposed evaluation framework will consist of two steps: preliminary screening of individual treatment technologies, and a detailed comparative evaluation on all retained solutions for the Canmore WWTP upgrade.

A general schematic of the proposed evaluation model for the selection of the main treatment process train is shown below (Figure 1).

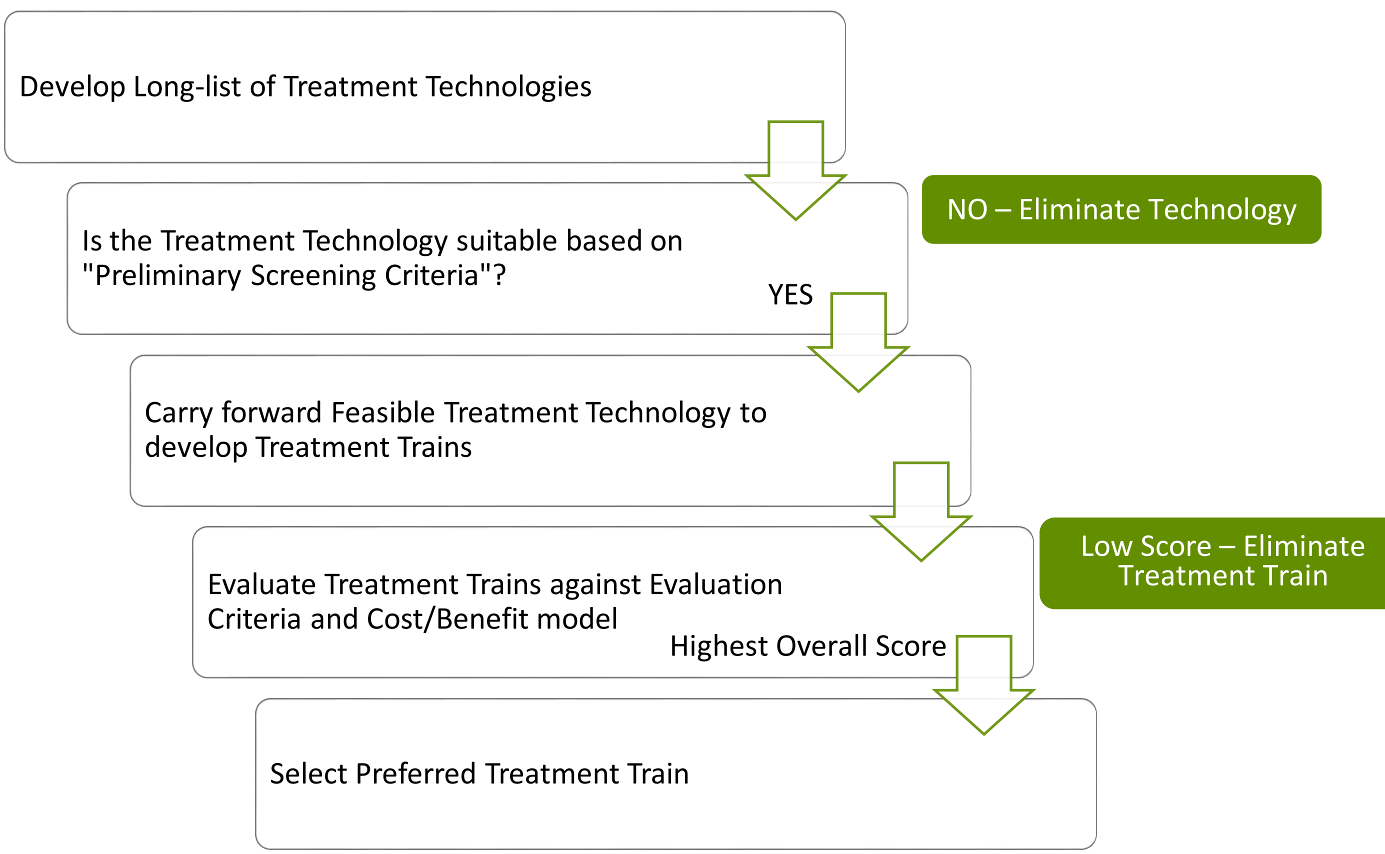


Figure 1: Evaluation Framework Schematic

2.4 Preliminary Screening

Preliminary screening will be used to screen for treatment technologies considered "feasible" and eliminate those that are not, given the project's character and nature, as identified in the Project Goals. This first step simplifies the evaluation process by eliminating options that are not viable for implementation at the Canmore WWTP upgrade.

The preliminary screening criteria listed below (Table 5) will be applied to a comprehensive list of treatment technologies for evaluation.

Table 5: Preliminary Screening Criteria

Screening Criteria	Description
Technical Feasibility	The technology must be able to meet the required design criteria (i.e., effluent criteria and objectives for the design capacity), given the raw wastewater quality.
Operational Feasibility	Is the technology compatible with existing operational practices, operating risk, maintenance, and monitoring requirements? Can the technology be implemented without interruption of the existing Canmore WWTP during construction?
Site Conditions Compatibility	Suitability of technology given the site-specific constraints (i.e., hydraulic grade line, site limits for current expansion, footprint requirements for future expansion, compatibility for phasing).

2.5 Detailed Comparative Evaluation

Treatment technologies that are considered suitable based on the preliminary screening will be carried forward to the detailed comparative evaluation. This step involves the development of the alternative design concepts, comparative evaluation, costing and scoring.

The detailed comparative evaluation will use a weighting and ranking system to compare the alternative design concepts. This will result in a systematic, rational, and reproducible comparison of alternative treatment trains and a straightforward identification of the preferred design concept.

2.5.1 Decision-Making Model

As the selection of the preferred design concept will need to strike a balance between cost and non-cost factors, the proposed methodology for the detailed comparative evaluation step is as follows:

1) A decision model will be constructed including consideration of all factors or criteria not related to cost. Each of these factors/criteria will be expressed in a positive way, so that when each option is rated against this model, if an option rates well against that factor, it effectively measures a relative benefit offered by that option compared to others. In other words, decision modeling will be used to rate the "Benefits" offered by each option.
2) In parallel, conceptual level capital and O&M costs will be generated for each option, which in turn will be used to develop Life Cycle Costs for each option.
3) The Benefits Score obtained for each option will be divided by the Life Cycle Costs, to produce a "Benefit-to-Cost Ratio". It is recommended that the option scoring the highest benefit-to-cost ratio will be the preferred design concept.

2.5.2 Scoring Approach and Detailed Evaluation Criteria

For each unit process, applicable treatment technologies will be evaluated against a set of criteria that represent all aspects or factors of importance to identify the preferred design concept. The evaluation methodology is used as a basis to compare the benefits of each treatment technology, relative to each other, and their ability to perform under each evaluation criterion.

The criteria to be used during the detailed evaluation of treatment technologies train are subdivided in two categories: primary and secondary criteria. The primary criteria capture global issues that need to be addressed, and the secondary criteria further breaks down the primary criteria, so that specific issues can be easily evaluated.

The primary and secondary criteria are assigned weight factors based on their degrees of importance, with the secondary criteria weight factors being related to the weight factor assigned to the primary criteria. Factors are assigned so that the higher the significance of the criterion, the higher the weighting.

Each treatment process will be assessed for each of the evaluation criteria in the model and assigned a total score out of 100. Each score will represent how well the specific alternative treatment technology meets the criterion; therefore, the options will be rated such that the higher the ability to perform or meet the criterion, the higher the score to be assigned (e.g., score of 100 for best performing option, score of 0 to worst performing option).

For this project, four (4) primary criteria have been established:

- Technical Considerations

- Operational Considerations
- Social Considerations
- Natural & Environmental Considerations

The primary criteria, secondary criteria and weight factors are presented in Table 6.

Table 6: Evaluation Criteria and Weights

Primary Criteria	Weight	Sub-Criteria	Relative Weight
Technical	**35**	Meets Effluent Quality Criteria	20
		Treatment beyond effluent quality requirements	3
		Flexibility to respond to variable raw wastewater quality and low initial loads	20
		Compatibility with existing infrastructure, headworks, PC, available site area	15
		Compatibility with Hydraulic Grade Line Requirements	5
		Constructability	15
		Proven Technology with strong track record; pilot testing, start-up needs, ease of approvals AEP	10
		Pre-treatment requirements	5
		Ability to maximize ultimate site capacity & Flexibility for expansion (future phases)	7
		Maximum Sub-total Score – Technical =	**100**
Operational	**35**	Flexibility for staging of capacity up to buildout	25
		Flexibility for expansion beyond buildout capacity	15
		Process complexity (including chemical systems)	10
		Process robustness (likelihood of process upsets) and redundancy.	20
		Biosolids Volume Handling (Dewatering Requirements)	5

Primary Criteria	Weight	Sub-Criteria	Relative Weight
		Operation and Maintenance Requirements	20
		Training Requirements	5
		Maximum Sub-total Score – Operational =	**100**
Social	**15**	Minimize footprint and site impacts	25
		Minimize truck traffic (during construction & operation)	10
		Minimize noise (during operation)	10
		Minimize odour (during operation)	30
		Minimize impacts on neighboring properties	25
		Maximum Sub-total Score – Social =	**100**
Natural Environmental	**15**	Minimize air/solids emissions	20
		Minimize impacts on species at risk	15
		Source Water Protection	15
		Minimize impacts on and of Climate Change (greenhouse gas emissions & carbon footprint – Climate Lens)[1]	25
		Minimize impacts on and of Climate Change (resiliency in face of climate change – Climate Lens)[1]	25
		Maximum Sub-total Score – Natural Environmental =	**100**

Notes:

1. Climate Lens assessment is currently a requirement for any federal funding that may be or become available for the project

2.5.3 Selection of Preferred Design Concept

Treatment technologies will be assessed relative to each other and evaluated against all criteria shown in Table 6. As mentioned previously, the performance of each treatment train against the various sub-criteria will be scored on a 0-100 basis, with higher scores given to better performing options.

The treatment train that scores the highest is considered the option that provides the most "Benefits" to this project. To identify the recommended preferred design concept for the Canmore WWTP upgrade, an assessment of the value associated with each design concept will be carried out. The overall benefit score for each option will be divided by each concept's estimated life cycle cost, resulting in a "benefit-to-cost" ratio. The concept with the highest "benefit-to-cost" ratio would offer the greatest value and thus, would be selected as the preferred design concept.

3 Long List of Treatment Technologies

3.1 Overview

This section presents the following:

- Identification of a long list of technology alternatives for the principal unit processes that could be implemented for the proposed Canmore WWTP upgrade.
- Development of the preliminary screening results and "short list" of proposed technology alternatives for the Canmore WWTP upgrade for further evaluation with the comprehensive detailed assessment.

3.2 Unit Processes for Evaluation

To streamline the evaluation process, specific unit processes will be prioritized for evaluation based on the capacity assessment report and proposed effluent limits, notably: **Primary Treatment, Secondary Treatment**, and **Tertiary Treatment**

These components have the most sway in terms of impacts to the overall plant design and most other treatment processes are dependent on requirements for the secondary treatment unit process.

Screening and Grit Removal process selection will be deferred to detailed design as most technologies will be common for most options. Any differences in requirements and their impact on the selected alternatives will be captured in the evaluation of secondary treatment technologies. The Canmore WWTP has aerated grit removal existing, and this was shown to have enough capacity until 2047, therefore, it is unlikely that the grit removal would need upgrading.

WAS Thickening process selection is dependent on the existing technology at the current Canmore WWTP. The plant is currently equipped with a dissolved air floatation (DAF) unit to thicken the sludge prior to sludge holding. It is anticipated this unit will remain in use for the future upgrade.

Disinfection at the existing Canmore WWTP already exists and is performed through UV disinfection. The plant is currently upgrading its disinfection capacity and the upgraded UV shall be retained through the 2047 horizon.

3.3 Long List of Technologies

The long list of technologies for preliminary screening was selected based on the needs identified in Section 3.2. Table 7 provides a long list of wastewater treatment technologies identified for the liquid train of the Canmore WWTP.

Table 7: Summary of Long List Treatment Technologies

Unit Process	Function	Long List Technologies	Evaluation Status
Screening	*Protects the downstream equipment by removing large debris, assists in maximizing the associated treatment efficiency, and minimizes downstream operational and maintenance issues.*	*Mechanically Cleaned Screens (6 mm)* *Mechanically Cleaned Screens (1-3 mm)*	*Deferred to Detailed Design*
Grit Removal	*Physically removes heavy, abrasive, inorganic solids from screened wastewater, to protect the downstream equipment from excessive wear, reduce deposit formation in pipes and basins, and reduce solids handling.*	*Aerated Grit Removal* *Vortex Grit Removal*	*Selected: Pre-existing at the plant*
Primary Treatment	*Primary treatment reduces the load on the downstream biological treatment system by removing TSS and BOD5 and reduce energy consumption.*	No Treatment Primary Clarifiers	To be Evaluated

Unit Process	Function	Long List Technologies	Evaluation Status
Secondary Treatment	Removes BOD_5, TSS, nitrogen and phosphorous from the wastewater.	Conventional Activated Sludge (CAS) Sequencing Batch Reactor (SBR) Biological Aerated Filter (BAF) Biological Nutrient Removal (BNR) Moving Bed Biofilm Reactor (MBBR) Integrated Fixed-Film Activated Sludge (IFAS) Membrane Aerated Biofilm Reactor (MABR) Aerobic Granular Sludge (AGS) Membrane Bioreactor (MBR)	To be Evaluated
Tertiary Treatment	Polishes secondary effluent to improved water quality; may be used as single line of treatment in case of bypass during High Peak flows.	Sand Filters Discfilters Ballasted Flocculation	To be Evaluated
Disinfection	Protects public safety by killing and inactivating pathogens in treated water. Selection of disinfection technologies must also consider impacts on disinfection by-products (DBPs) formation.	UV Disinfection Chlorination / Dechlorination Ozone	*Selected: Pre-existing at the plant*
WAS Thickening	*Reduce sludge volume prior to stabilization and/or dewatering, and final disposal.*	*Dissolved Air Flotation* *Rotary Drum Thickener (RDT)* *Membrane Thickener* *Gravity Thickener*	*Selected: Pre-existing at the plant*
Digestion	*Reduce volume and stabalize sludge prior to disposal*	*Open Air Holding Tank* *Aerobic Digestion* *Anaerobic Digestion*	*Selected: Open Air Holding Tank existing at the plant and*

Unit Process	Function	Long List Technologies	Evaluation Status
			disposal by compost
Dewatering	*Reduce volume for disposal hauling*	*Centrifuge* *Belt Press*	*Selected: Pre-existing at the plant*

3.4 Primary Treatment Technologies

The following technology alternatives were considered for primary treatment at the Canmore WWTP upgrade:

- No Treatment
- Primary Clarification

3.4.1 No Treatment

The existing Canmore WWTP has primary clarification, however, some of the proposed secondary treatment technologies function with or without primary treatment. The current BAF technology requires primary clarification to operate efficiently, however, as an integrated process several of the secondary treatment technologies do not require primary clarification to operate.

Without primary clarifiers, raw primary sludge that would typically be diverted to digestion is removed within the biological process. The Canmore WWTP does not utilize anaerobic digestion or other means to capture biogas, hence the primary clarifier’s core benefit are to protect the BAF units. In future processes, primary clarifiers may not be required to protect the secondary process and operation without primary clarifiers shall be carried forward where applicable in the integrated process train. It’s important to note, without primary clarifiers the loading to the biological process and aeration demands will increase. This shall be captured in the life cycle cost analysis of alternatives.

The following table, Table 8, illustrates the rationale and results of the preliminary screening.

Table 8: No Treatment - Preliminary Screening Results

Primary Treatment	Preliminary Screening Observations and Comments
No Treatment	**Technical Feasibility:** - Primary treatment is not required by all secondary treatment options and is technically viable with certain secondary processes. Sludge management system compatible with WAS only. **Operational Feasibility:** - No primary treatment would decrease the level of operational complexity of the Canmore WWTP, as it would be one less treatment process in operation. - The facility would experience increased aeration demands. - WAS only will reduce the potential for odours in the open air sludge holding tank **Site Conditions Compatibility:** - The secondary treatment process may become larger due to higher loadings. The increase in size is unlikely to be significant and shall be evaluated as an integrated process as needed. **Summary** - Removing primary treatment is viable with select secondary processes. The increase in secondary treatment size is unlikely to be significant, hence the lifecycle cost of an additional primary clarifier with O&M compared to increased energy consumption shall be investigated where appropriate. - **Carry forward for further consideration: YES**

3.4.2 Primary Clarifiers

Primary clarifiers remove carbon, organics, and solids from the wastewater prior to secondary treatment. This removal is done through sedimentation, as the clarifiers have a long HRT, allowing the solids within the wastewater to settle to the bottom of the tank, and be removed as sludge. This sludge can then be sent to a digester or holding tank, where further treatment must be performed to render the sludge a useful resource.

As noted, the existing Canmore WWTP has primary clarifiers, and these clarifiers have been useful in diverting carbon and organics from the existing secondary treatment technology. Many of the secondary treatment technologies require primary clarification to function properly. The existing clarifiers do not have capacity for the future flows and loadings, and a recommendation to add a 3rd clarifier was established in the Capacity Evaluation Report.

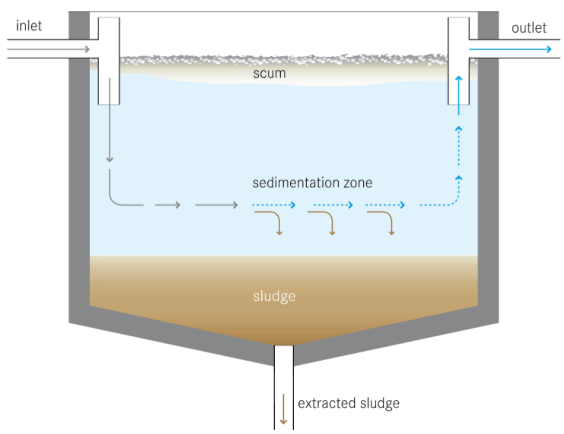


Figure 2: Primary Clarifier

Table 9 represents the preliminary screening results of including primary clarifiers as apart of the liquid train at the Canmore WWTP

Table 9: Primary Clarifiers - Preliminary Screening Results

Primary Treatment	Preliminary Screening Observations and Comments
Primary Clarifiers	**Technical Feasibility:** - Primary treatment is already implemented at the Canmore WWTP in the form of primary clarifiers. Upgrading these clarifiers to meet the future capacity requirements could allow the plant to consider a broader scope of secondary treatment technologies. **Operational Feasibility:** - This technology would transition well between the existing plant and the upgraded plant, as the operators are already aware of how to effectively run this technology. - The diverted carbon reduces the aeration demand in the secondary process. - Primary sludge in the open-air holding tank is a potential source for odours **Site Conditions Compatibility:** - Upgrading the clarifiers is feasible within the existing footprint. **Summary** - The operators at the Canmore WWTP are familiar and comfortable operating primary treatment technologies; furthermore, primary treatment allows for a broader scope of secondary technologies to be considered. - **Carry forward for further consideration: YES**

3.5 Secondary Treatment Technologies

The following technology alternatives were considered for secondary treatment for the Canmore WWTP upgrade:

- Conventional Activated Sludge (CAS)
- Sequencing Batch Reactor (SBR)
- Biological Aerated Filter (BAF)
- Biological Nutrient Removal (BNR)
- Moving Bed Biofilm Reactor (MBBR)
- Integrated Fixed-Film Activated Sludge (IFAS)
- Membrane Aerated Biofilm Reactor (MABR)
- Aerobic Granular Sludge (AGS)
- Membrane Bioreactor (MBR)

3.5.1 Conventional Activated Sludge

Conventional activated sludge (CAS) process is the basic mechanized secondary treatment process found in WWTPs. It consists of primary clarifiers, aeration tanks followed by secondary clarifiers. Microorganisms in the aeration tanks are maintained in suspension by aeration and mixed for effective contact with the influent (i.e., substrate) and dissolved oxygen (DO). Air is typically used as the oxygen source and is commonly supplied to the aeration tanks by blowers and diffusers, although other aeration systems can be used.

Effluent from the aeration tank passes to the secondary clarifier where solids and microorganisms are settled out and returned to the aeration basin. Excess sludge is wasted from the system and generally further processed on-site. The returned sludge is sent back to the head of the aeration basin to maintain the microbial concentration. This step decouples the solids retention time (SRT) and the hydraulic retention time (HRT); which allows more efficient use of the biomass to reduce reactor volume requirements. The basic process is vulnerable to washout under peak flows, and nitrification performance suffers with cold influent conditions. The CAS process has been widely used in the wastewater treatment facilities in Canada and around the world. It is the most common wastewater treatment technology.

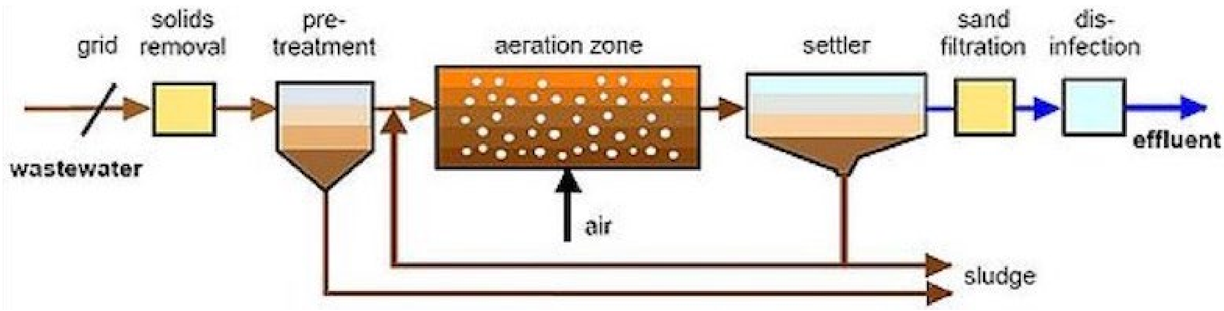


Figure 3: Conventional Activated Sludge Process

The following table, Table 10, highlights the technical feasibility, operational feasibility, and site conditions compatibility for CAS at the Canmore WWTP upgrade.

Table 10: Conventional Activated Sludge - Preliminary Screening Results

Secondary Treatment	Preliminary Screening Observations and Comments
Conventional Activated Sludge	**Technical Feasibility:** - The conventional activated sludge technology has a proven record as a robust treatment process with a long history of application in similar climates. **Operational Feasibility:** - This technology requires more supporting unit processes (primary treatment, secondary clarifiers) and has a medium operational complexity due to the greater number of components to operate and maintain. - The CAS process has been widely used in the wastewater treatment facilities in Canada and around the world. It is the most common wastewater treatment technology and is highly familiar to operators in Alberta. **Site Conditions Compatibility:** - Conventional activated sludge has a relatively large footprint in part due to the secondary clarifiers, relatively low MLSS concentration in the biomass and ancillary equipment required. The footprint at the Canmore WWTP is not sufficient. **Summary** - Conventional Activated sludge can meet the preliminary screening criteria in terms of Technical and Operational Feasibility. However, this technology does not meet the Site Conditions Compatibility requirement due to the requirements for secondary treatment. - **Carry forward for further consideration: NO**

3.5.2 Sequencing Batch Reactor

This SBR technology is an activated sludge process that is configured for batch operation. The multiple batch reactors are operated in sequence with consecutive cycles of Fill, React, Settle and Decant (Figure 4).

The fill cycle introduces raw influent to the basin in either a non-aerated or aerated condition. Once the basin has achieved the max operating water level, the influent wastewater is either equalized or directed to an idle SBR. This allows the process to enter the react phase. In react, aeration is provided to oxidize the carbon and nitrogen for a set period of time. Once this time is completed, the aeration is stopped, and the biomass is allowed to settle to the bottom of the tank. After settling, a decanter supernates (upper portion) the treated effluent of the water column to a specified bottom water level. After decanting, the SBR is idle and ready to receive raw influent.

The SBR configuration reduces the tankage requirement by combining the aeration tank and settling tank in the same vessel. The main challenge of the process is the reliance on the settling of suspended biomass and a decreasing water level towards the sludge blanket. Depending on the sludge settleability, biomass quality and cycle times, there is risk of solids exiting the reactor during the lower levels of the decant phase.

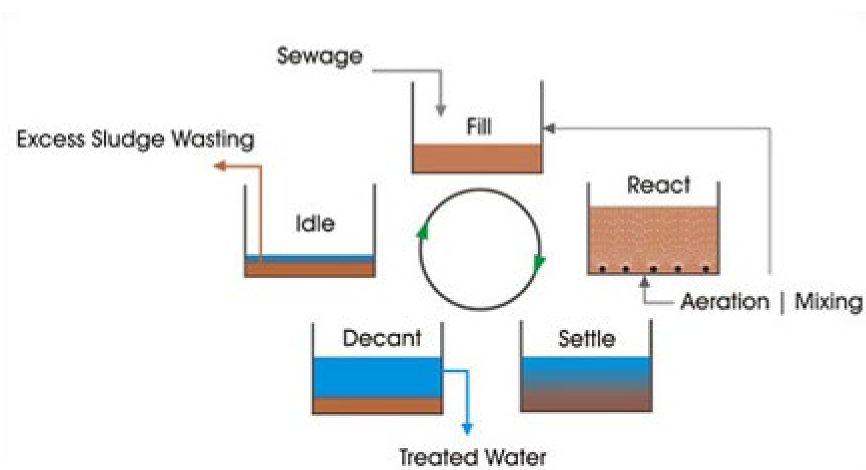


Figure 4: SBR Operating Cycle

The following table, Table 11, illustrates the rationale and results of the preliminary screening.

Table 11: Sequencing Batch Reactor - Preliminary Screening Results

Secondary Treatment	Preliminary Screening Observations and Comments
Sequencing Batch Reactor	**Technical Feasibility:** - Sequencing Batch Reactors are best suited to smaller WWTPs with good and reliable effluent quality for BOD removal and Nitrification. **Operational Feasibility:** - Compared to other activated sludge processes, sequencing batch reactors benefit from simplified operation due to the single tank design and reduction of sludge return pumping efforts. Its operation can be automated, but maintenance requirements on some components is typically higher (i.e.: decanter mechanism maintenance). - The process robustness can be limited by sludge settling issues and variability. **Site Conditions Compatibility:** - This technology benefits from a lower footprint than typical activated sludge processes through the single tank design. However, this technology can have potentially large tank volumes to accommodate high peak flows. **Summary** - Sequencing Batch Reactors can meet the preliminary screening criteria in terms of Technical Feasibility and Operational Feasibility. However, from a Site Conditions Compatibility perspective, the SBR's requirement for large tanks to deal with high peak flows and potentially poor sludge settling characteristics does not align itself with the limited footprint of the Canmore WWTP. - **Carry forward for further consideration: NO**

3.5.3 Biological Aerated Filter

The biological aerated filter (BAF) is an attached growth technology that simultaneously biologically treats the wastewater and removes suspended solids in a single unit reactor. There are three (3) different variations of the technology: downflow with sunken media, upflow with sunken media (Figure 5), and upflow with floating media. All three (3) of these variations are effective at growing biomass within the media while also filtering out the suspended solids. Due to biomass accumulation and filtering of solids, BAFs require frequent backwashing such that the media does not clog and increase the head loss experienced through them.

The BAF technology can either be designed for BOD removal only, combined BOD removal and nitrification, combined nitrification and denitrification, or tertiary nitrification and tertiary denitrification. The Canmore WWTP currently has the BAF technology with upflow and sunken media that is implemented in two stages. The first stage of BAFs are responsible for carbon (BOD) removal, and the second stage is responsible for ammonia removal (nitrification).

The BAF process has operator familiarity as it is currently used as the secondary treatment process at the existing Canmore WWTP. Hence, this approach will have the least impacts on the Town's operational practices; however, the technology also requires a large footprint due to the number of BAF cells required and supplemental treatment will be required for total nitrogen removal.

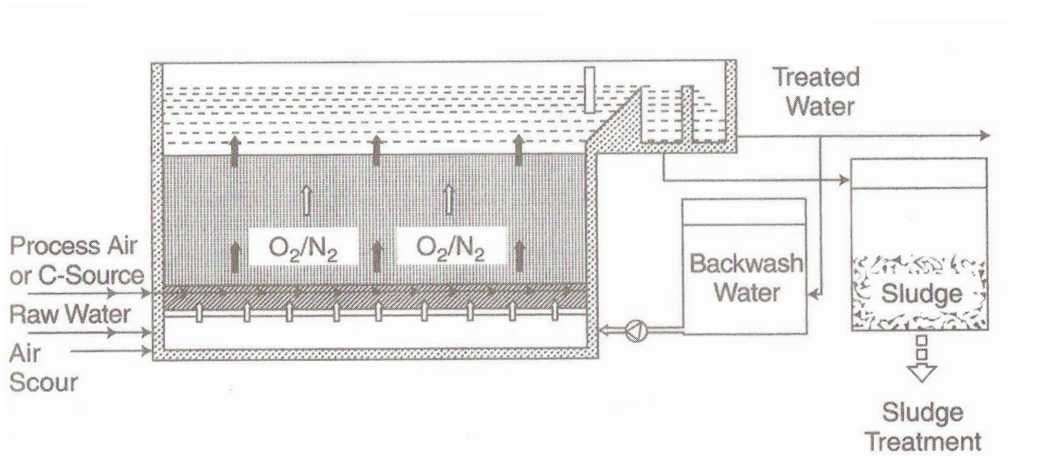


Figure 5: Upflow with Sunken Media BAF

Table 12 represents the preliminary screening results of including BAFs within the liquid train of the Canmore WWTP after the upgrade.

Table 12: Biological Aerated Filter - Preliminary Screening Results

Secondary Treatment	Preliminary Screening Observations and Comments
Biological Aerated Filter	**Technical Feasibility:** - Biological aerated filter is an effective technology for achieving reliable and good effluent quality, for BOD removal and Nitrification. Primary treatment is required for the treatment process and a downstream process for total nitrogen removal will be required. **Operational Feasibility:** - This technology is currently in place at the existing Canmore WWTP. The downstream process unit can employ a Moving Bed Biofilm Reactor (MBBR), which utilizes similar biofilm principles and is a flow through process for simple operation and maintenance. This alternative will have the least impacts on the Town's operational practices. **Site Conditions Compatibility:** - This technology requires numerous reactor tanks to provide sufficient treatment to larger flowrates. Despite the technology currently being in place at the plant, this technology would limit flexibility for future upgrades of the Canmore WWTP and require a large footprint for anticipated future flows. **Summary** - Biological aerated filters can meet all preliminary screening criteria, the site conditions may be constrained, however, as it is the existing technology at the plant, it should be site compatible. - **Carry forward for further consideration: YES**

3.5.4 Moving-Bed Biofilm Reactor

The moving bed biofilm reactor (MBBR) is an attached growth technology that use an inert carrier media for biofilm attachment and growth. The carriers are maintained in suspension by mixers or an aeration system (depending on process) and are retained in the reactors with sieves (Figure 6).

The biomass is self regulating and fixed to the carrier surface. In general, the mass of biofilm within the reactor increases and decreases naturally to changing loads. As the biomass is fixed to the surface, the performance is not dependent on recycle flows and is not susceptible to washout.

The MBBR carriers can occupy approximately 25 to 60% of the reactor volume. As more carriers are introduced, the available surface for biological growth increases hence increasing the capacity of the process. The process is most efficient with the target removal occurring in stages (i.e., BOD removal stage, nitrification stage). The biofilm nature and inherently long SRTs (due to attached growth) allow for robust nitrification at low temperatures and provides some resiliency to inhibitory compounds that may unintentionally enter the facility.

The MBBR provide flexibility for process phasing and overall high-rate biological system. Without recycle, the effluent solids are not flocculated and in general do not gravity settle well. Typically, more advanced high-rate clarification technologies are integrated to maximize the benefit of the system.

Figure 6: MBBR reactor basin showing internal components, sieves for media retention and MBBR media with dimensions approximately 25 mm diameter x 4 mm thickness (not to scale) (Courtesy of Veolia)

The following table, Table 13, highlights the preliminary screening results of the MBBR for the Canmore WWTP upgrade

Table 13: Moving-Bed Biological Reactor - Preliminary Screening Results

Secondary Treatment	Preliminary Screening Observations and Comments
Moving-Bed Biofilm Reactor	**Technical Feasibility:** - Moving-Bed Biofilm Reactors are resilient processes for high-rate BOD removal, Nitrification and or Denitrification, with increased robustness under extreme winter climate and toxicity events. Its biological process is not dependent on recycle flows and is not susceptible to washout. - MBBR would be used for denitrification at the Canmore WWTP succeeding the BAF cells. **Operational Feasibility:** - Introduction of MBBR for denitrification would increase operational complexity. - Supplemental Carbon dosing will be required for Total Nitrogen Removal. **Site Conditions Compatibility:** - MBBRs typically have a low footprint requirement due to the long SRT and short HRTs that they can produce. They a good solution for plants that are tight on space. **Summary** - Moving-Bed Biofilm Reactors can meet all preliminary screening criteria. They are effective at denitrification, slightly increase operational complexity, and require a small footprint to be used. This technology is proposed to be used downstream of the BAF for TN removal. - **Carry forward for further consideration: YES**

3.5.5 Integrated Fixed-Film Activated Sludge

Integrated Fixed-Film Activated Sludge (IFAS) is a hybrid process that combines the attached growth and activated sludge (suspended growth) processes. The aeration tank is configured to include biofilm carrier media and return activated sludge in the bioreactor.

The primary advantage of the IFAS process is to improve nitrification. When designed properly, the nitrifying biomass preferentially attaches to the fixed media allowing for the suspended growth system to operate at lower SRTs without risk of critical nitrifier washout. Operating at lower SRTs reduces the overall site footprint and allows existing facilities to increase nitrification capacity without additional bioreactor volumes.

The biofilm can be introduced with moving media, which effectively creates an MBBR zone in an activated sludge system, or a fixed media.

An emerging IFAS technology with fixed media uses membrane aerated biofilm reactor (MABR) modules. The MABR process employs gas transfer membranes to supply a gas transfer membrane to deliver oxygen to a biofilm that grows on the surface of a membrane (Figure 7). This delivery of oxygen to the biofilm is significantly more efficient than fine bubble aeration as the air has direct contact to the biomass. The technology is typically installed in the Anoxic zone of the bioreactor to maximize efficiency and provide simultaneous nitrification/denitrification. The efficiency gain has reported benefits of reducing energy consumption required for aeration by up to 30%. The MABR technology has successfully been piloted in Ontario and is currently being installed at full-scale.

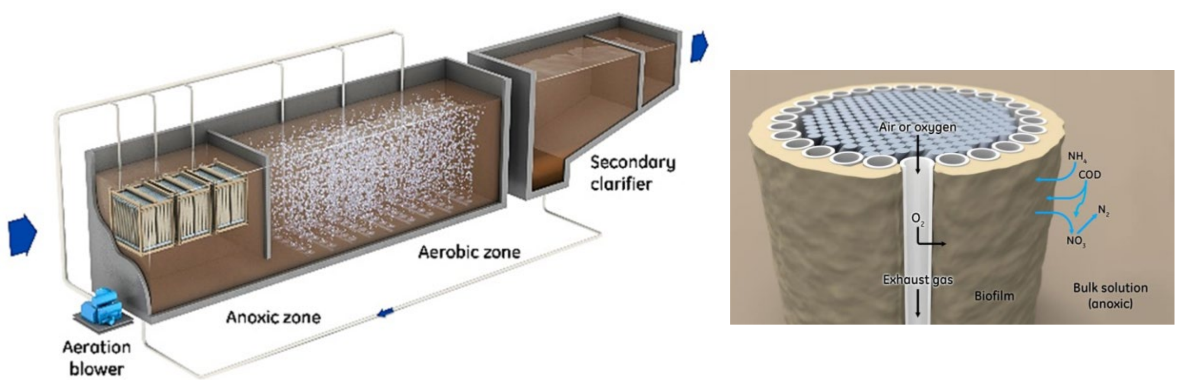


Figure 7: Typical MABR configuration and membrane (Courtesy of Suez)

The following table, Table 14, highlights the technical feasibility, operational feasibility, and site conditions compatibility for IFAS at the Canmore WWTP upgrade.

Table 14: Integrated Fixed-Film Activated Sludge - Preliminary Screening Results

Secondary Treatment	Preliminary Screening Observations and Comments
Integrated Fixed-Film Activated Sludge	**Technical Feasibility:** - These technologies are often used as a retrofit option for existing CAS plants, providing higher resiliency to washouts, and increased effective treatment capacity with limited increased solids loading to the clarifiers, by adding attached growth biomass to the process. Some of these benefits are less impactful with construction of new facilities. - MABRs specifically are a resilient process for nitrification in cold weather and provide some level of simultaneous TN removal with the standard process for BOD removal and Nitrification. - The MABR technology is still considered an emerging technology with limited full-scale applications and may require site-specific pilot testing to support AEP approvals. **Operational Feasibility:** - IFAS systems are often energy intensive, in similar ways to MBBRs. MABR technology however offers potential energy consumption savings for aeration by up to 30% compared to the conventional treatment process (CAS). The significant energy savings for MABRs result from the delivery of oxygen at an efficiency up to four times greater than fine bubble aeration. This is achieved by the very efficient, lower pressure oxygen transfer across the biofilm carrying membranes. - The MABRs capital and long-term operating and maintenance (O&M) costs are not as well understood as IFAS or other more proven technologies. - The Town of Canmore is unfamiliar with this technology, greatly enhancing the operational complexity of the technology. **Site Conditions Compatibility:** - The benefits of IFAS or MABR are most realized when retrofitting a CAS plant, otherwise they require a large footprint due to the requirement for secondary clarifiers and ancillary equipment. **Summary**

	- IFAS and MABR technologies can meet the preliminary screening criteria in terms of Technical Feasibility. However, from an Operational Feasibility and Site Conditions perspective the requirement for activated sludge does not align with the Canmore WWTP footprint restriction. - **Carry forward for further consideration: NO**

3.5.6 Aerobic Granular Sludge

The aerobic granular sludge (AGS) system is a biofilm process that uses a modified sequencing batch reactor to form granules. The granules have a high density with fast settling properties with an SVI of 20 to 60 mL/g after 5 minutes. The process is natural and does not require any external ballast, does not require return pumps, provides partial biological phosphorus and total nitrogen removal without internal mixed liquor recycle and does not require a secondary clarifier (Figure 8). The effluent is discharged through a static weir at the top of the reactor during the fill phase, which provides a more continuous flow and reduced mechanical components.

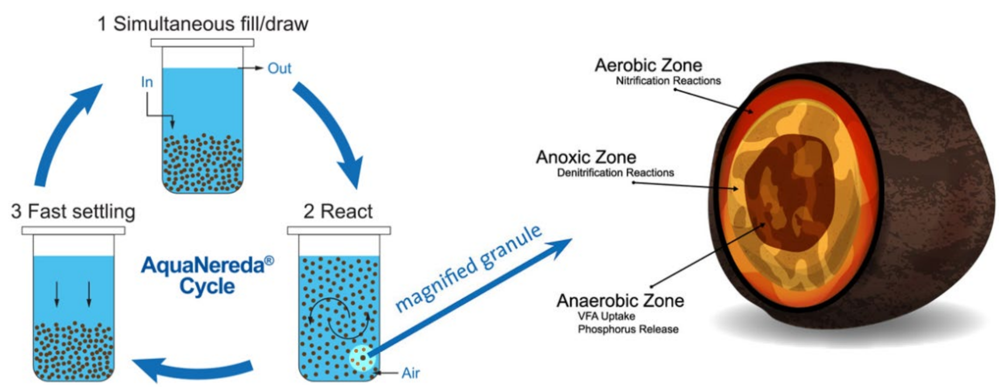


Figure 8: AGS Operating Philosophy (Courtesy of Aqua Aerobics)

Once seeded with activated sludge biomass (from any operating facility), the process modulates reactor conditions (anaerobic, anoxic, and aerobic conditions) to favour the formation of dense and fast settling sludge granules. Once the process achieves granulation, the technology provides treatment comparable to a BNR facility with Total Nitrogen removal and Total Phosphorus removal. In typical municipal wastewater, the process is able to reduce Total Phosphorus down to 1 mg/L without chemical addition. The granules are self contained biofilm and are hence resilient to process upsets and are less affected by temperatures. Conceptually, this provides equivalent treatment of approximately 8,000 mg MLSS/L with the benefits of small footprint, reduced energy (up to 50%) and provides significant chemical savings.

Primary clarifiers are not required with the AGS technology. Due to the large max month flow (MMF) experienced by the Canmore WWTP during the snow melt season, the hydraulics of the primary clarifiers will likely drive their design and sizing. This would add costs to the plant upgrade, for minimal benefits if AGS is selected, as the clarifiers mainly divert carbon and organics from the secondary process, which is not required if AGS is selected.

The aerobic granular sludge technology is still considered an emerging technology in Canada, however there are currently over 50 full-scale installations in operation or construction in other parts of world, ranging from 0.265 MLD to 625 MLD. Pilot testing has been undertaken in Canada, and the first facilities are currently undergoing design and construction.

Table 15 illustrates the preliminary screening results of AGS to determine if this technology should be carried forward for further consideration.

Table 15: Aerobic Granular Sludge - Preliminary Screening Results

Secondary Treatment	Preliminary Screening Observations and Comments
Aerobic Granular Sludge	**Technical Feasibility:** - Aerobic Granular Sludge can achieve simultaneous BOD removal, nitrification/denitrification, and TP removal through its granulated biomass. This process can achieve the combined benefits of the BNR processes such as (Denitrification, TP removal through PAOs) and attached growth processes (biomass resiliency to process upsets and low temperature nitrification) without the use of plastic or other fixed media. In addition, granular sludge has better settleability characteristics than sludge generated by attached growth processes or activated sludge. - The AGS technology is considered an emerging technology with the first facilities undergoing design and construction in Canada. The technology is emerging in North America but has seen widespread use at several WWTPs worldwide including the Norther USA. This technology may require pilot testing to support AEP approvals. **Operational Feasibility:** - This technology benefits from much lower operating and energy costs due to the reduced mechanical complexity of the process as well as the reduced chemical requirements due to biological phosphorus removal integral to the biology of this process. AGS operations (cycling and operating regimes) are controlled automatically and function closer to a continuous flow system than a conventional SBR – simplifying operations. **Site Conditions Compatibility:** - AGS technology offers very compact design, due to the high settling rate of the granulated biomass compared to other attached or suspended growth processes and relatively deep tanks. This is compatible with the constrained site conditions. With the proposed site of the Canmore WWTP upgrade, this technology also provides flexibility for future upgrades of the WWTP beyond the current design basis. **Summary**

	- Aerobic Granular Sludge can meet all of the preliminary screening criteria and would provide the most anticipated benefits to the Town's operational practices and O&M requirements. - **Carry forward for further consideration: YES**

3.5.7 Membrane Bioreactor

The Membrane Bioreactor (MBR) process is an advanced treatment technology that uses activated sludge and ultrafiltration membrane modules for clarification in lieu of secondary clarifiers (Figure 9). The MBR bioreactors use conventional suspended growth biomass. The biomass is recycled from the membrane tank to the bioreactor and a portion is wasted. The MLSS concentration in the bioreactors has a significant impact on membrane performance and fouling. When the MLSS is in the typical range for extended aeration (3,000 to 5,000 mg/L) the biomass is liable to release biopolymers that increase membrane fouling. To avoid this risk, MBRs are typically operated at MLSS concentrations of 6,000 to 10,000 mg/L. The reactors are capable of operating at higher MLSS concentrations; however, the flux will decrease with increasing MLSS concentrations.

The membranes need to be protected from abrasive debris that can damage the membrane and reduce their integrity. The membranes also need to be protected from fibrous material that can clog and be trapped in the modules. The fibrous material is difficult to remove even with the integrated air scouring mechanism. To manage the risk, the maximum allowable screen openings is 2 mm with 1 mm preferred when the plant is operated without primary clarifiers. At the Canmore WWTP, this would require a new head works building and an additional fine screen before the MBR to ensure no abrasive debris enters the membrane. Conceptually, grit removal is high efficiency vortex type to eliminate the inert material.

The MBR technology is proven in Alberta. In general, the capital cost and operating costs of the technology are higher with the benefits mostly realized where footprint requirements are strict or when the effluent quality criteria are very stringent (i.e., Total Phosphorus 0.05 to 0.1 mgP/L).

Figure 9: MBR Process Flow (Courtesy of Suez)

The preliminary screening results for the MBR technology are described in Table 16.

Table 16: Membrane Bioreactor - Preliminary Screening Results

Secondary Treatment	Preliminary Screening Observations and Comments
Membrane Bioreactor	**Technical Feasibility:** - Membrane bioreactors are a proven technology that produce effluent that can meet stringent quality criteria for TSS, BOD removal, nitrification as well as low phosphorus limits (<0.05 to 0.1 mg/L). - Membrane bioreactors provide solids separation within the aeration tanks themselves, thereby eliminating the need for secondary clarifiers. This technology's benefits are mostly realised where footprint requirements are strict; or when the effluent quality criteria are stringent. **Operational Feasibility:** - The membrane filtration component of the MBR requires periodic maintenance, more complicated and costly automation due to many mechanical pieces of equipment for cleaning of membranes and replacement parts. - The O&M of the process requires high operating costs due to energy consumption as well as general membrane maintenance and replacement. - The overall complexity of operations, although different, is not more than the existing process train. **Site Conditions Compatibility:** - Membrane Bioreactors have a small footprint and are compatible with the constrained site conditions of the Canmore WWTP site. **Summary** - Membrane bioreactors can meet all of the preliminary screening criteria. This technology offers proven, and effective, TP removal to low concentrations with a small footprint. - **Carry forward for further consideration: YES**

3.6 Tertiary Treatment Technologies

The following technology alternatives were considered for tertiary treatment for the Canmore WWTP upgrade:

- Sand filters
- Discfilters
- Ballasted Flocculation
- Membranes

3.6.1 Sand Filters

The deep-bed sand filter technology is an upflow, deep bed, granular media filter with continuous or intermittent backwash. Raw water enters near the bottom of the tank and organic and inorganic impurities are captured by the sand as the raw water flows up through the media bed, shown schematically in (Figure 10). As the filtrate reaches the top of the filter, it passes over the effluent weir and is discharged. The filter media is cleaned by a simple internal washing system that does not require backwash pumps or storage tanks.

Sand filters can be implemented in single or two stages. Single stage polishes TSS and removes phosphorus reliably down to 0.15 mg TP/L, while Two stage filtration can achieve 0.05 mg TP/L.

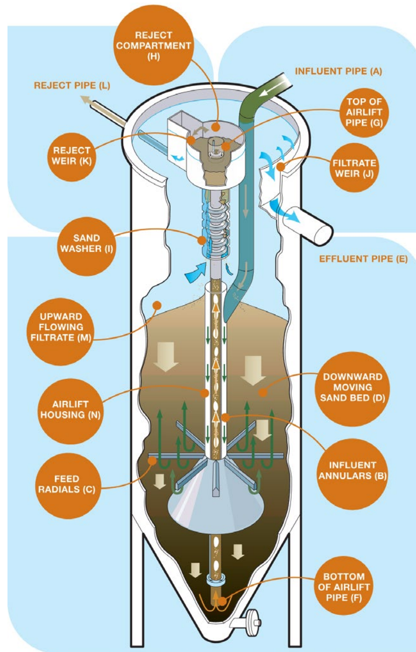


Figure 10: Schematic of continuous backwash sand filter (Courtesy of Parkson)

Sand filters are a widely used technology for tertiary treatment in Canada. The technology requires deep tanks and has large HGL requirements to overcome the head loss through the filtration process.

The following table, Table 17, highlights the technical feasibility, operational feasibility, and site conditions compatibility for Sand Filtration at the Canmore WWTP post upgrade.

Table 17: Sand Filter - Preliminary Screening Results

Tertiary Treatment	Preliminary Screening Observations and Comments
Sand Filter	**Technical Feasibility:** - Sand Filters are a widely used technology in potable water and wastewater treatment with proven capabilities to remove TSS and TP when combined with coagulation and flocculation. There are several variations of sand filter technologies, with continuous backwashing filters able to achieve TP limits down to approximately 0.05 mg/L (site specific). - The technology has large HGL requirements to overcome head loss through the filtration process, which will impact construction cost of the overall plant. - Sand filters have limited hydraulic flexibility and need larger units to achieve similar peak flow treatment capacity. **Operational Feasibility:** - Sand filters are a simple technology with well-understood maintenance requirements. **Site Conditions Compatibility:** - This technology has a large footprint to provide the required hydraulic flexibility to treat peak flows, when compared to other tertiary treatment technologies. - Sand Filters must be very deep to adequately treat large peak flows, and due to the ground water level at the Canmore WWTP, this would not be feasible. **Summary** Sand Filters can meet all of the preliminary screening criteria except for site conditions due to their large footprint requirements and large depth required. - **Carry forward for further consideration: NO**

3.6.2 Discfilters

Disc filters are used in various municipal and industrial treatment applications and utilize a range of filter cloth mesh sizes. The technology consists of fine-woven media mounted on filter panels. The panels are held in frames, with frames arranged in pairs to form a disc with a hollow centre and fibre cloth on each side. There are various approaches to vendor Discfilter design (Figure 11) with the core difference in flow path and backwashing methodology.

For example, one approach the influent water enters into the centre of the drum, then flows by gravity into the filter discs through openings in the drum. Water is filtered in inside-out mode, passing through the filter cloth, which retains suspended solids on the inside of the hollow disc. Filtered effluent is collected in a basin and exits over a weir. A second approach, the influent water is routed to a filter basin and water passes through the media via an outside-in flow path. In operation a portion of the particulates are removed and stored within the depth of the pile cloth media while others are deposited on the pile cloth media surface.

Different vendors offer different backwash strategies including backwash while the filter operates by liquid suction or backwash by a rotating backwash system with effluent water.

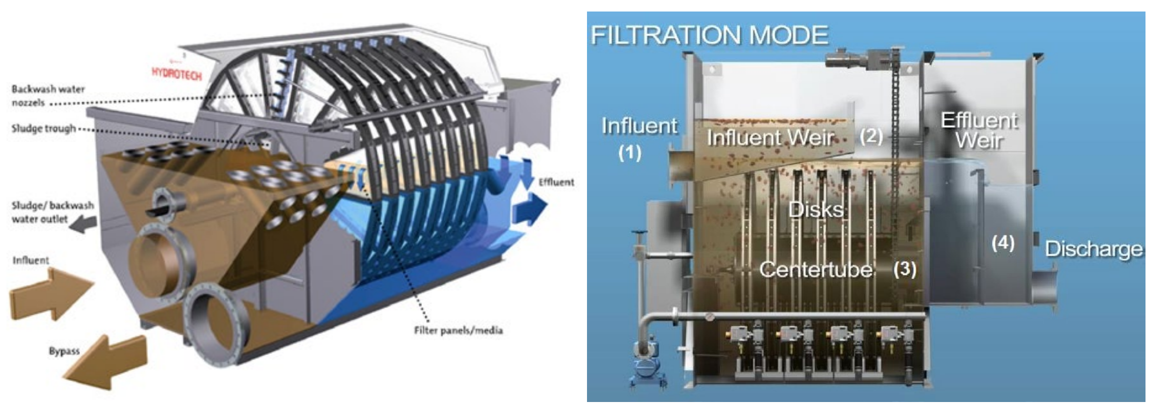


Figure 11: Schematic of rotating Discfilter (Courtesy of Veolia) left and non-rotating Discfilter (Courtesy of Aqua-Aerobics)

The Discfilter technology can be used in combination with coagulant and/or polymer flocculant to achieve low TP objectives. In tertiary application with chemical addition the suspended solids are polished, and the technology can reliably achieve an effluent TP concentration down to 0.15 mg P/L with lower objectives possible.

The following table, Table 18, illustrates the preliminary screening results of the discfilter, and whether it should be carried forward for further consideration.

Table 18: Discfilter - Preliminary Screening Results

Tertiary Treatment	Preliminary Screening Observations and Comments
Discfilter	**Technical Feasibility:** - Discfilters provide reliable BOD and TSS removal, in tertiary treatment applications with chemical addition they can achieve an effluent TP concentration down to a range of 0.10 to 0.15 mg P/L. These units lower head loss and can operate at a wide range of flows. **Operational Feasibility:** - Discfilters benefit from simple operation. This technology has been widely used in Ontario with successful installations from several vendors. Its O&M requirements are well understood, and compatible with the Town's operational practices. - Discfilter units are highly modular and can be upgraded as the wastewater treatment needs increase over the life of the upgraded WWTP. **Site Conditions Compatibility:** - This technology offers minimal footprint and lower HGL requirements which provides additional flexibility for the Hydraulic Grade Line. **Summary** Discfilters can meet all of the preliminary screening criteria and offer good TP removal performance with a smaller footprint and lower energy requirement than other tertiary treatment technologies that will be competitive against other tertiary treatment technologies. - **Carry forward for further consideration: YES**

3.6.3 Ballasted Flocculation

Ballasted flocculation is a high rate settling process combining chemical conditioning and an inert ballast. The most common tertiary ballasted flocculation technology used uses micro-sand as the ballast (Figure 12). The influent wastewater is combined with coagulant, polymer and microsand upstream of a maturation tank. The micro sand is bound to the solids providing a particulate with high density for rapid settling. The sand and solids particles collect at the bottom of the settling tank and are discharged by pump. The discharged material passes through a hydrocyclone where the higher density sand is separated and returned to the process while the sludge is wasted.

This technology has a small footprint, and can provide TP removal down to approximately 0.07 mg/L. However, this technology has relatively higher O&M costs driven by its high coagulant use. When used in WWTPs this technology can also be used to treat plant bypasses when large peak flows are encountered.

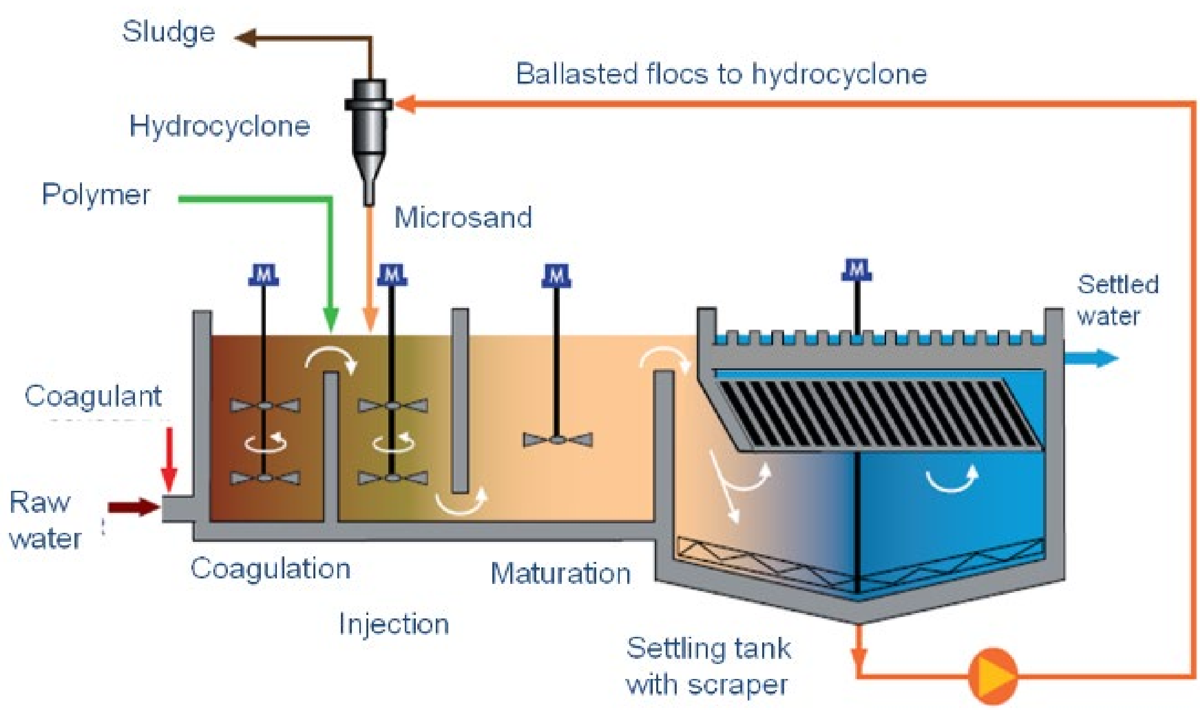


Figure 12: Schematic of sand ballasted flocculation ACTIFLO® process (Courtesy of Veolia)

Table 19 illustrates the preliminary screening results for the ballasted flocculation technology.

Table 19: Ballasted Flocculation - Preliminary Screening Results

Tertiary Treatment	Preliminary Screening Observations and Comments
Ballasted Flocculation	**Technical Feasibility:** - Ballasted Flocculation can provide reliable tertiary TSS and BOD removal and can reliably provide TP removal down to the range of 0.05 to 0.07 mg/L, treated in-unit. This technology has high hydraulic flexibility with the ability to treat bypass flows in peak conditions. With the design of an upgraded facility for the Canmore WWTP, this advantage is unlikely to be required. **Operational Feasibility:** - This technology has relatively higher O&M costs driven by chemical use and additional clarifier equipment. This increased O&M requirement is not compatible with the Town's operational practices. **Site Conditions Compatibility:** - This technology has a small footprint and would fit on site. **Summary** - Ballasted Flocculation can meet the preliminary screening criteria in terms of Technical Feasibility and Site Conditions Compatibility. However, from an Operational Feasibility perspective and due to its chemical use and related O&M requirements, the technology is not expected to be competitive with other technologies under consideration for tertiary treatment – providing little added benefit for its additional costs. It is therefore not compatible with the Town's operational practices. - **Carry forward for further consideration: NO**

4 Preliminary Screening of Long list Technologies

This section presents the results of the preliminary screening step under which all treatment process technologies described in Section 3 were evaluated. The treatment process technologies that met the preliminary screening criteria will be considered "feasible" and recommended to be short listed for further consideration in the development of alternative treatment trains, which constitutes the next key step in the technology assessment.

Preliminary screening of available treatment process technologies has been accomplished by assessment of the technologies from a technical and operational feasibility as well as on compatibility with site conditions, as described in Section 2.4, and Table 5 of this technical memorandum.

The results of the preliminary screening for Primary Treatment, Secondary Treatment, and Tertiary Treatment are documented in Table 20.

Table 20: Short List of Technologies to Carry Forward

Technology Alternative	Carry Forward: YES or NO
Primary Treatment	
No Treatment	**YES**
Primary Clarifiers	**YES**
Secondary Treatment	
Conventional Activated Sludge	NO
Sequencing Batch Reactor	NO
Biological Aerated Filter	**YES**
Moving-Bed Biofilm Reactor	**YES**
Integrated Fixed-Film Activated Sludge	NO
Aerobic Granular Sludge	**YES**

Membrane Bioreactor	**YES**
Tertiary Treatment	
Sand Filters	NO
Discfilters	**YES**
Ballasted Flocculation	NO

5 Next Steps

The next step in the technology assessment comprises of the development of the short listed alternatives, their detailed evaluation, and the selection of the preferred design concept. Table 21 summarises the list of treatment trains to be carried forward for detailed evaluation.

Table 21: Liquid Treatment Train Options

Treatment Train	Primary Treatment Technologies	Secondary Treatment Technologies	Tertiary Treatment Technologies
Option 1	Primary Clarification	Aerobic Granular Sludge	Discfilters
Option 2	No Treatment	Aerobic Granular Sludge	Discfilters
Option 3	Primary Clarification	1-2 mm Screen and MBR	
Option 4	No Treatment	1-2 mm Screen and MBR	
Option 5	Primary Clarification	BAF Expansion and MBBR Denitrification	Discfilters

B

Appendix B: Technology Assessment Scoring Matrix

Town of Canmore
Canmore WWTP Technology Assessment
Evaluation Matrix and Scoring
Date: 21-Feb-23

Primary Criteria	Weight	Sub-Criteria	Relative Weight	Option 1 - PC, AGS, Discfilter	Scoring Rationale	Option 2 - AGS, Discfilter	Scoring Rationale	Option 3 - PC, 1-2 mm Screen, MBR	Scoring Rationale	Option 4 - 1-2 mm Screen, MBR	Scoring Rationale	Option 5 - BAF Expansion, MBBR Denit, Discfilter	Scoring Rationale
Technical	35	Meets Effluent Quality Criteria	20	10	This alternative can fully meet the effluent criteria.	10	This alternative can fully meet the effluent criteria.	10	This alternative can fully meet the effluent criteria.	10	This alternative can fully meet the effluent criteria.	10	This alternative can fully meet the effluent criteria.
		Treatment beyond effluent quality requirements	3	8	This alternative can provide enhanced effluent quality since it can perform biological phosphorus removal (without chemical addition) and it can perform some level of denitrification (removal of soluble nitrogen species).	8	This alternative can provide enhanced effluent quality since it can perform biological phosphorus removal (without chemical addition) and it can perform some level of denitrification (removal of soluble nitrogen species).	9	This alternative can provide enhanced effluent quality with very low effluent solids concentrations and enhanced chemical phosphorus removal.	9	This alternative can provide enhanced effluent quality with very low effluent solids concentrations and enhanced chemical phosphorus removal.	7	This alternative incorporates MBBR denitrification which effectively removes Nitrates from the water. The use of disc fitration can provide enhanced TP removal to 0.15 mg/L.
		Flexibility to respond to variable raw wastewater quality and low initial loads	20	9	This alternative can be staged to accommodate the increase in received wastewater load over the lifetime of the WWTP. Influent equalisation tanks can be incorporated in the design to facilitate staging early on. This alternative also benefits from the continuous flow - sequencing batch reactor configuration of the Aerobic Granualr Sludge technology.	9	This alternative can be staged to accommodate the increase in received wastewater load over the lifetime of the WWTP. Influent equalisation tanks can be incorporated in the design to facilitate staging early on. This alternative also benefits from the continuous flow - sequencing batch reactor configuration of the Aerobic Granualr Sludge technology.	8	This technology can be staged through the use of casettes, allowing some flexibiliy to respond to low initial loads. Through the use of an equalisation tank, the technology can deal with variable wastewater flow.	8	This technology can be staged through the use of casettes, allowing some flexibiliy to respond to low initial loads. Through the use of an equalisation tank, the technology can deal with variable wastewater flow.	7	This alterniative has some ability to adapted with varibale wastewater and low initial loads, as BAF cells can be taken on and offline. The MBBR deals with varibale wastewater well.
		Compatibility with existing infrastructure, headworks, PC, available site area	15	7	This alternative has a relatively compact footprint, due to the minimal tankage required for the technology. The exisiting BAF cells could be repurposed for water level correction and sludge buffer capacity. An additional primary clarifier would be required. The reduced tertiary buidling footprint requirement for the discfilters provides additional benefits.	8	This alternative has a relatively compact footprint, due to the minimal tankage required for the technology. The exisiting BAF cells could be repurposed for water level correction and sludge buffer capacity. The reduced tertiary buidling footprint requirement for the discfilters provides additional benefits.	7	This technology has a small volume of required tankage. An additonal primary clarifier would be required. This technology eliminates the need for a tertiary treatment building, but a fine screening and chemical building would be required.	8	This technology has a small volume of required tankage. This technology eliminates the need for a tertiary treatment building, but a fine screening and chemical building would be required.	8	This alterniative requires expansion of the BAF cells. Operating familiarity with the BAF technology would help post upgrade. The MBBR and discfilter require limited footprints which provides additonal benefits.
		Compatibility with Hydraulic Grade Line Requirements	5	5	This alternative would require intermediate pumping.	5	This alternative would require intermediate pumping.	5	This alternative would require intermediate pumping.	5	This alternative would require intermediate pumping.	5	This alternative would require intermediate pumping.
		Constructability	15	7	This alternative requires less tankage than other alternatives, and has a reduced construction scope compared to alternatives, such as BAF expansion. An additonal primary clarifier would be required. There is also reduced construction scope for the tertiary treatment buidling. Unknown geotechnical conditions in expansion area.	8	This alternative requires less tankage than other alternatives, and has a reduced construction scope compared to alternatives based on BAF expansion. There is also reduced construction scope for the tertiary treatment buidling. Unknown geotechnical conditions in expansion area.	7	This alternative requires less tankage than other alternatives, but does require an additional primary clarifier. An MBR does require fine screening/chemical building, but does not require the construction of a tertiary treatment building. Unknown geotechnical conditions in expansion area.	8	This alternative requires less tankage than other alternatives. An MBR does require fine screening/chemical building, but does not require the construction of a tertiary treatment building. Unknown geotechnical conditions in expansion area.	7	This alternative requires the construction of a 3rd primary clarifier, along with additional BAF cells, an MBBR, and a disfilter building. Overall requires large amounts of tankage. Unknown geotechnical conditions in expansion area.
		Proven Technology with strong track record; pilot testing, start-up needs, ease of approvals AEP	10	5	Specific to Aerobic Granular Sludge component, this technology is considered an emerging technology in wastewater treatment. It has seen widespread use around the world and is currently seeing growing use in the United-States. A pilot study may be required to confirm approvals by the AEP.	5	Specific to Aerobic Granular Sludge component, this technology is considered an emerging technology in wastewater treatment. It has seen widespread use around the world and is currently seeing growing use in the United-States. A pilot study may be required to confirm approvals by the AEP.	10	This alternative is a standard wastewater treatment technology, and is widely used in Canada.	10	This alternative is a standard wastewater treatment technology, and is widely used in Canada.	8	The BAF cells are exisiting at the Canmore WWTP and have proven they work. MBBR and discfilters are a common technology widely used acrossed North America.
		Pre-treatment requirements	5	8.5	This alternative requires 6mm screen. No additional technical impacts are anticipated.	8.5	This alternative requires 6mm screen. No additional technical impacts are anticipated.	6.5	This alternative requries 1-3mm screening..	6.5	This alternative requries 1-3mm screening..	6.5	This alternative requires standard headworks processes to support it. No additional technical impacts are anticipated. Additional ultra fine screening required.
		Ability to maximize ultimate site capacity & Flexibility for expansion (future phases)	7	9	Regarding the Aerobic Granular Sludge component, this alternative can be expanded in the future with the addition of clarifiers and reactors, maximizing use of the site. Expansion of the discfilter component would require the addition of discs or other units, which is achievable given the site layout.	8	Regarding the Aerobic Granular Sludge component, this alternative can be expanded in the future with the addition of reactors. Expansion of the discfilter component would require the addition of discs or other units.which is achievable given the site layout.	9	This alternative can be expanded in the future with the addition of clarifiers, aeration tanks and membrane modules, maximizing use of the site.	8	This alternative can be expanded in the future, through aeration tanks and membrane modules.	2	This alternative cannot be expanded easily as addiitonal BAF cells require a large footprint for the projected large peak flows.
		Sub-total Score – Technical =	**100**	**79.5**		**81.8**		**81.8**		**84.1**		**73.8**	
		Sub-total Score – Technical =	**35**	**27.8**		**28.6**		**28.6**		**29.4**		**25.8**	

Primary Criteria	Weight	Sub-Criteria	Relative Weight	Option 1 - PC, AGS, Discfilter	Scoring Rationale	Option 2 - AGS, Discfilter	Scoring Rationale	Option 3 - PC, 1-2 mm Screen, MBR	Scoring Rationale	Option 4 - 1-2 mm Screen, MBR	Scoring Rationale	Option 5 - BAF Expansion, MBBR Denit, Discfilter	Scoring Rationale
Operational	**30**	Flexibility for staging of capacity up to buildout	10	9	This alternative provides flexibility for staging of capacity up to buildout.	9	This alternative provides flexibility for staging of capacity up to buildout.	9	This technology can be staged easily throughout its design life without encountering operational issues. Staging could increase the frequency of membrane replacement.	9	This technology can be staged easily throughout its design life without encountering operational issues. Staging could increase the frequency of membrane replacement.	5	This alternative cannot be staged throughout its design life easily, due to the footprint requirements fo the BAF technology to cope with large peak flows.
		Flexibility for expansion beyond buildout capacity	20	9	This alternative can be expanded beyond its buildout capacity.	9	This alternative can be expanded beyond its buildout capacity.	9	This alternative can be expanded beyond its buildout capacity.	9	This alternative can be expanded beyond its buildout capacity.	3	This alternative can be expanded beyond its buildout capacity, but comes with challenges related to footprint.
		Process complexity (including chemical systems)	10	8.5	This alternative's main process is more complex than other conventional technologies due to its varying operating conditions and batch process timing; however, the technology's operation is largely automated and controlled via process logic. Scoring reflects the mitigated impact of the process complexity.	9	This alternative's main process is more complex than other conventional technologies due to its varying operating conditions and batch process timing; however, the technology's operation is largely automated and controlled via process logic. Scoring reflects the mitigated impact of the process complexity.	7	Operation of this alternative is more complex than conventional systems since membrane trains require periodic cleaning, and are susceptible to leaks and fouling. This complexity results in increased maintenance hours compared to other wastewater treatment technologies.	7.5	Operation of this alternative is more complex than conventional systems since membrane trains require periodic cleaning, are susceptible to leaks and fouling. This complexity results in increased maintenance hours compared to other wastewater treatment technologies.	5.5	This alternative's process complexity is considered standard, since the BAF technology is used in the existing WWTP, therefore, the wastewater operators are familiar with the technology. Training will be required for both the MBBR and the discfilter.
		Process robustness (likelihood of process upsets) and redundancy.	25	9	This alternative has great robustness and is less susceptible to process upsets due to an additional clarifier vs. other conventional technologies. Its main advantage is an improved ability to recover biomass, and process performance recovery following a process upset (ie. hydrocarbon contamination).	8	This alternative has good robustness and is less susceptible to process upsets vs. other conventional technologies. Its main advantage is an improved ability to recover biomass, and process performance recovery following a process upset (ie. hydrocarbon contamination).	8.5	This alternative is greatly robust due to the addiitonal primary clarifier and the equalization tank used to regualte flow to the MBR.	8	This alternative is robust due to the equalization tank used to regualte flow to the MBR.	6	This alternative is fairly robust as cells can be taken on and offline, but can experience process upsets due if large unexpected flows are sent to the plant
		Biosolids Volume Handling (Dewatering Requirements)	5	7	Biosolids handling for this alternative is comparable with all other technologies considered, except primary sludge removed prior to bioreactors, reducing load on the WAS thickening DAF.	5	Biosolids handling for this alternative is comparable with all other technologies considered.	7	Biosolids handling for this alternative is comparable with all other technologies considered, except primary sludge removed prior to bioreactors, reducing load on the WAS thickening DAF.	5	Biosolids handling for this alternative is comparable with all other technologies considered.	5	Biosolids handling for this alternative is comparable with all other technologies considered.
		Operation and Maintenance Requirements	25	8	This alternative reduces operation and maintenance requirements due to the reduced energy, chemical, labour and general maintenance requirements. Discfilters offers some additional benefit in this regard.	8.5	This alternative reduces operation and maintenance requirements due to the reduced energy, chemical, labour and general maintenance requirements, as no primary clarifiers are required. Discfilters offers some additional benefit in this required.	7	This alternative has the highest operation and maintenance costs due to the increased energy use, and membrane maintenance requirements. An additional clarifier is also required.	7.5	This alternative has high operation and maintenance costs due to the increased energy use, and membrane maintenance requirements.	5	Operation and maintenance requirements for this alternative are considered standard and on par with the current status quo.
		Training Requirements	5	7	This alternative requries increased training requirements since aerobic granular sludge is not a conventional technology and is not as widely known to operators in Alberta, or in Canada.	7	This alternative requries increased training requirements since aerobic granular sludge is not a conventional technology and is not as widely known to operators in Alberta, or in Canada.	7	This process requires some training mostly attributed to the membrane maintenance components.	7	This process requires some training mostly attributed to the membrane maintenance components.	8	Training requirements with this technology are minimal, since the process remains comparable to what is used in the exisiting facility. Training would be required to operate the MBBR and discfilter effectively.
		Sub-total Score – Operational =	**100**	**85.0**		**83.3**		**79.8**		**79.3**		**50.5**	
		Sub-total Score – Operational =	**30**	**25.5**		**25.0**		**23.9**		**23.8**		**15.2**	

Primary Criteria	Weight	Sub-Criteria	Relative Weight	Option 1 - PC, AGS, Discfilter	Scoring Rationale	Option 2 - AGS, Discfilter	Scoring Rationale	Option 3 - PC, 1-2 mm Screen, MBR	Scoring Rationale	Option 4 - 1-2 mm Screen, MBR	Scoring Rationale	Option 5 - BAF Expansion, MBBR Denit, Discfilter	Scoring Rationale
Social	15	Minimize footprint and site impacts	20	8	This alternative has a low impact on the site, due mostly because of the reduced footprint it provides. The discfilter alternative provides some additional benefit.	8.5	This alternative has a low impact on the site, due mostly because of the reduced footprint it provides, especially without the need for an additional clarifier. The discfilter alternative provides some additional benefit.	8	This alternative has a low impact on the site, due mostly because of the reduced footprint it provides.	8.5	This alternative has a low impact on the site, due mostly because of the reduced footprint it provides, along with no additional primary clarifier.	5	This alternative has the largest fotoprint of all alternatives due to the number of BAF cells required to cope with the anticipated future flows.
		Minimize truck traffic (during construction & operation)	15	7.5	During construction, less traffic is anticipated compared to other technologies due to the reduced scope. This alternative requires less truck traffic during operations since fewer chemicals deliveries are requried. The requirements for the hauling of biosolids remains comparative to other technologies–all other aspects remaining equal.	7.5	During construction, less traffic is anticipated compared to other technologies due to the reduced scope. This alternative requires less truck traffic during operations since fewer chemicals deliveries are requried. The requirements for the hauling of biosolids remains comparative to other technologies–all other aspects remaining equal.	7.5	Truck traffic is not negatively impacted by the alternative beyond the status quo for this technology.	7.5	Truck traffic is not negatively impacted by the alternative beyond the status quo for this technology.	7	Truck traffic is not negatively impacted by the alternative beyond the status quo for this technology..
		Minimize noise (during operation)	15	7.5	Noise during operations is not anticipated to exceed conventional levels. There remains some noise during operations of the facility.	7.5	Noise during operations is not anticipated to exceed conventional levels. There remains some noise during operations of the facility.	7.5	Noise during operations is not anticipated to exceed conventional levels. There remains some noise during operations of the facility.	7.5	Noise during operations is not anticipated to exceed conventional levels. There remains some noise during operations of the facility.	7.5	Noise during operations is not anticipated to exceed conventional levels. There remains some noise during operations of the facility.
		Minimize odour (during operation)	25	7.5	Odours produced during operations is not anticipated to exceed conventional levels for a wastewater treatment facility. There remains some odour production potential during operations of the facility.	8	Odours produced during operations is not anticipated to exceed conventional levels for a wastewater treatment facility. There remains some odour production potential during operations of the facility. Odor levels will be minimzed due to less primary sludge production.	7.5	Odours produced during operations is not anticipated to exceed conventional levels for a wastewater treatment facility. There remains some odour production potential during operations of the facility.	8	Odours produced during operations is not anticipated to exceed conventional levels for a wastewater treatment facility. There remains some odour production potential during operations of the facility. Odor levels will be minimzed due to less primary sludge production.	7.5	Odours produced during operations is not anticipated to exceed conventional levels for a wastewater treatment facility. There remains some odour production potential during operations of the facility.
		Minimize impacts on neighboring properties	25	8.5	This alternative has lesser impacts on neighbouring propreties, due to its smaller footprint compared to BAF expansion as a secondary treatment technology. The reduced tertiary treatment building size with the discfilter components provides some benefit. The setback to neghboring propreties for this alternative is equivalent to all others.	8.5	This alternative has lesser impacts on neighbouring propreties, due to its smaller footprint compared to BAF expansion as a secondary treatment technology. The reduced tertiary treatment building size with the discfilter components provides some benefit. The setback to neghboring propreties for this alternative is equivalent to all others.	8.5	This alternative has lesser impacts on neighbouring propreties, due to its smaller footprint compared to BAF expansion as a secondary treatment technology. The reduced tertiary treatment building size with the discfilter components provides some benefit. The setback to neghboring propreties for this alternative is equivalent to all others.	8.5	This alternative has lesser impacts on neighbouring propreties, due to its smaller footprint compared to BAF expansion as a secondary treatment technology. The reduced tertiary treatment building size with the discfilter components provides some benefit. The setback to neghboring propreties for this alternative is equivalent to all others.	8	This alternative would have the most impact on neighboring properties as it has the largest footprint of all alternatives. The reduced tertiary treatment building size with the discfilter components provides some benefit.
		Sub-total Score – Social =	**100**	**78.5**		**80.8**		**78.5**		**80.8**		**70.5**	
		Sub-total Score – Social =	**15**	**11.8**		**12.1**		**11.8**		**12.1**		**10.6**	

Primary Criteria	Weight	Sub-Criteria	Relative Weight	Option 1 - PC, AGS, Discfilter	Scoring Rationale	Option 2 - AGS, Discfilter	Scoring Rationale	Option 3 - PC, 1-2 mm Screen, MBR	Scoring Rationale	Option 4 - 1-2 mm Screen, MBR	Scoring Rationale	Option 5 - BAF Expansion, MBBR Denit, Discfilter	Scoring Rationale
Natural Environmental	**20**	Minimize air/solids emissions	20	8.5	This alternative provides some indirect reduction in air emissions largely due to its reduced energy and chemical use, as well as its reduced use of concrete.	9	This alternative provides some indirect reduction in air emissions largely due to its reduced energy (no additional clarifier) and chemical use, as well as its reduced use of concrete.	8.5	This alternative provides some indirect reduction in air emissions largely due to its reduced use of concrete, however remains the most energy and resource intensive.	9	This alternative provides some indirect reduction in air emissions largely due to its reduced use of concrete, however remains the most energy and resource intensive. But without primary clarifiers, this technology becomes less energy intensive	9	This alternative provides provides minimal reduction in air emissions as this alternative is energy intensive and requries the largest footprint of all the alternatives.
		Minimize impacts on species at risk	15	8	Species at risk are not anticipated to be impacted by this alternative. Impacts from all alternatives do not deviate beyond the status quo.	8	Species at risk are not anticipated to be impacted by this alternative. Impacts from all alternatives do not deviate beyond the status quo.	8	Species at risk are not anticipated to be impacted by this alternative. Impacts from all alternatives do not deviate beyond the status quo.	8	Species at risk are not anticipated to be impacted by this alternative. Impacts from all alternatives do not deviate beyond the status quo.	8	Species at risk are not anticipated to be impacted by this alternative. Impacts from all alternatives do not deviate beyond the status quo.
		Source Water Protection	15	8	This alternative's wastewater effluent quality or its construction are not anticipated to impact source water quantity or quality.	8	This alternative's wastewater effluent quality or its construction are not anticipated to impact source water quantity or quality.	9	This alternative's wastewater effluent quality or its construction are not anticipated to impact source water quantity or quality.	9	This alternative's wastewater effluent quality or its construction are not anticipated to impact source water quantity or quality.	8	This alternative's wastewater effluent quality or its construction are not anticipated to impact source water quantity or quality.
		Minimize impacts on and of Climate Change (greenhouse gas emissions & carbon footprint – Climate Lens)	25	9	This alternative is less energy and resource intensive alternative when considering secondary treatment, as the additional primary clarifer leads to less energy in the reactor being used. The use of discfilters for tertiary treatment provides some additional benefit.	7.5	This alternative is less energy and resource intensive compared to other secondary treatment options. The use of discfilters for tertiary treatment provides some additional benefit.	5.5	This alternative is highly energy and resource intensive, however the use of the primary clarifiers reduces the amount of energy used for treatment.	5	This alternative is the most energy and resource intensive of all considered.	5.5	This alternative is energy and resource intensive. The BAF component uses more electricity to supply blowers, and the primary clarifiers require considerable chemical use to treat phosphorus to the required levels.
		Minimize impacts on and of Climate Change (resiliency in face of climate change – Climate Lens)	25	8.5	This alternative requires some clear cutting of the trees around the exisiting WWTP, however with the reduced footprint of both the secdondary treatment technology and discfilters, this is minimized.	8.5	This alternative requires some clear cutting of the trees around the exisiting WWTP, however with the reduced footprint of both the secdondary treatment technology and discfilters, this is minimized.	7.5	This alternative requires some clear cutting of the trees around the exisiting WWTP, however with the reduced footprint of the treatment train, this is minimized as much as possible.	7.5	This alternative requires some clear cutting of the trees around the exisiting WWTP, however with the reduced footprint of the treatment train, this is minimized as much as possible.	6	This alternative requires the most clear cutting of the trees around the exisiting WWTP, limiting the resiliency of the surroudnign environemt to combat climate change.
		Sub-total Score – Natural Environmental =	**100**	**84.8**		**82.0**		**75.0**		**74.8**		**70.8**	
		Sub-total Score – Natural Environmental =	**20**	**17.0**		**16.4**		**15.0**		**15.0**		**14.2**	
		Overall Scores	**100**	**82.0**		**82.1**		**79.3**		**80.3**		**65.7**	
		Overall Scores - Inverted Technical vs. Social 65%/35%	**100**	**82.1**		**81.8**		**78.0**		**78.9**		**68.0**	

C

Appendix C: Capital Costs Summary

Canmore Wastewater Treatment Plant Upgrade
Conceptual Design Cost Estimates
C04-00496

Drafted by PB 21-Feb-23

Component Description	Quantity	Unit	Unit Cost	Material Cost	Installation		Total Cost
					% of Matl	Cost	
Option 1 & 2: PC, AGS, Discfilter (Full Build Out, 2047)							
Site Works & Structural / Architectual							**$ 8,800,000**
General Civil Work	1	LS	$ 1,000,000	$ 1,000,000	incl.	$ -	$ 1,000,000
Discfilter Building	600	m2	$ 3,000	$ 1,800,000	incl.	$ -	$ 1,800,000
AGS Tank (includes mud slab and backfill)	1,916	m3	$ 2,000	$ 3,832,000	incl.	$ -	$ 3,832,000
AGS excavation/Bakcfill/Disposal	8,615	m3	$ 200	$ 1,723,000	incl.	$ -	$ 1,723,000
Tree Clear Cutting	82,222	ft2	$ 4.50	$ 369,999	incl.	$ -	$ 369,999
Miscellaneous	1	LS	$ 125,000	$ 125,000	incl.	$ -	$ 125,000
Process & Equipment							**$ 21,000,000.00**
AGS Reactors and included Equipment	1	LS	$ 8,235,000	$ 8,235,000	55%	$ 4,529,250	$ 12,764,250
AGS Filtration System	1	LS	$ 1,890,000	$ 1,890,000	55%	$ 1,039,500	$ 2,929,500
Intermediate Pump Station	1	LS	$ 1,500,000	$ 1,500,000	30%	$ 450,000	$ 1,950,000
Piping	750	m	$ 450	$ 337,500	incl.	$ -	$ 337,500
Valving	1	LS	$ 500,000	$ 500,000	incl.	$ -	$ 500,000
Chemical Dosing System	1	LS	$ 1,000,000	$ 1,000,000	incl.	$ -	$ 1,000,000
BAF Abandonment	1	LS	$ 500,000	$ 500,000	incl.	$ -	$ 500,000
BAF Retrofit (Sludge Buffer and water Correct)	1	LS	$ 1,000,000	$ 1,000,000	incl.	$ -	$ 1,000,000
Environmental Compliance	0	LS	$ 500,000	$ -	incl.	$ -	$ -
Pilot Test	0	LS	$ 500,000	$ -	incl.	$ -	$ -
HVAC & Plumbing	1	LS	15%	$ 8,800,000	incl.	$ -	$ 1,320,000
Instrumentation and Controls	1	LS	15%	$ 21,000,000	incl.	$ -	$ 3,150,000
Electrical	1	LS	30%	$ 21,000,000	incl.	$ -	$ 6,300,000
Sub-Total MBR							**$ 40,600,000**
Sub-Total Costs (A)							**$ 40,600,000**
General Contractor's Overhead & Profit, Mob., bond		% of A	15.0%				$ 6,090,000
Sub-Total Costs (B)							**$ 46,700,000**
Construction Contingency		% of B	30.0%				$ 14,010,000
Engineering		% of B	15.0%				$ 7,005,000
Total Estimated Construction Costs (C) - Excluding Escalation, GST & Engineering							**$ 68,000,000**

Component Description	Quantity	Unit	Unit Cost	Material Cost	Installation		Total Cost
					% of Matl	Cost	
Option 3 & 4; PC, 1-2mm Screen, MBR (Full Build Out, 2047)							
Site Works & Structural / Architectual							**$ 11,700,000**
General Civil Work	1	LS	$ 1,000,000	$ 1,000,000	incl.	$ -	$ 1,000,000
Building for Membrane Equipment	600	m2	$ 3,000	$ 1,800,000	incl.	$ -	$ 1,800,000
Building for Fine Screens	600	m2	$ 3,000	$ 1,800,000	incl.	$ -	$ 1,800,000
Bioreactor Tank (includes mud slab and backfill)	1,555	m3	$ 2,000	$ 3,110,000	incl.	$ -	$ 3,110,000
Bioreactor Excavation/Bakcfill/Disposal	6,336	m3	$ 200	$ 1,267,200	incl.	$ -	$ 1,267,200
Construction of EQ Tank	756	m3	$ 2,000.00	$ 1,512,000	incl.	$ -	$ 1,512,000
EQ Tank Excavation	3,637	m3	$ 200.00	$ 727,400	incl.	$ -	$ 727,400
Tree Clear Cutting	82,222	ft2	$ 4.50	$ 369,999	incl.	$ -	$ 369,999
Miscellaneous	1	LS	$ 125,000	$ 125,000	incl.	$ -	$ 125,000
Process & Equipment							**$ 20,300,000.00**
MBR and Related Equipment	1	LS	$ 8,850,600	$ 8,850,600	55%	$ 4,867,830.00	$ 13,700,000.00
MBR Biological Equipment	1	LS	$ 307,900	$ 307,900	55%	$ 169,345.00	$ 500,000.00
EQ Tank Equipment	1	LS	$ 1,500,000	$ 1,500,000	incl.	$ -	$ 1,500,000.00
1-2mm Pre-treatment fine screens	2	LS	$ 250,000	$ 500,000	55%	$ 275,000.00	$ 800,000.00
Intermediate Pump Station	1	LS	$ 1,500,000	$ 1,500,000	30%	$ 450,000	$ 1,950,000
WAS Pumping	1	LS	$ 500,000	$ 500,000	incl.	$ -	$ 500,000
Piping	700	LS	$ 450	$ 315,000	incl.	$ -	$ 315,000
Valving	1	LS	$ 500,000	$ 500,000	incl.	$ -	$ 500,000
BAF Abandonment	1	LS	$ 500,000	$ 500,000	incl.	$ -	$ 500,000
HVAC & Plumbing	1	LS	15%	$ 11,700,000	incl.	$ -	$ 1,755,000
Instrumentation and Controls	1	LS	15%	$ 20,300,000	incl.	$ -	$ 3,045,000
Electrical	1	LS	30%	$ 20,300,000	incl.	$ -	$ 6,090,000
Sub-Total MBR							**$ 42,900,000**
Sub-Total Costs (A)							**$ 42,900,000**
General Contractor's Overhead & Profit, Mob., bond		% of A	15.0%				$ 6,435,000
Sub-Total Costs (B)							**$ 49,300,000**
Construction Contingency		% of B	30.0%				$ 14,790,000
Engineering		% of B	15.0%				$ 7,395,000
Total Estimated Construction Costs (C) - Excluding Escalation, GST & Engineering							**$ 71,000,000**

Component Description	Quantity	Unit	Unit Cost	Material Cost	Installation		Total Cost
					% of Matl	Cost	
Option 5: PC, BAF Expansion, MBBR & DiscFilter (Full Build Out, 2047)							
Site Works & Structural / Architectual							**$ 8,010,000**
MBBR Tank (includes mud slab and backfill)	660	m3	$ 2,000	$ 1,320,000	incl	$ -	$ 1,320,000
Discfilter Building	600	m2	$ 3,000	$ 1,800,000	incl.	$ -	$ 1,800,000
Excavation/Bakcfill/Disposal	2646	m3	$ 200	$ 529,200	incl.	$ -	$ 530,000
Construction of BAF Cells	753	m3	$ 2,000	$ 1,506,000	incl.	$ -	$ 1,506,000
BAF Expansion Excavation	2,807	m3	$ 200	$ 561,400	incl.	$ -	$ 561,400
BAF Building Expansion	600	m3	$ 3,000	$ 1,800,000	incl.	$ -	$ 1,800,000
Tree Clear Cutting	82222	ft2	$ 4.50	$ 369,999	incl.	$ -	$ 370,000
Miscellaneous	1	LS	$ 125,000	$ 125,000	incl.	$ -	$ 125,000
Process & Equipment							**$ 25,800,000**
MBBR Supply (Media, mixers, sieves, aeration grid, re-ox blowers)	1	LS	$ 2,750,000	$ 2,750,000	55%	$ 1,512,500	$ 4,260,000
Equipment to operate additional BAF Cells	1	LS	$ 10,000,000	$ 10,000,000	55%	$ 5,500,000	$ 15,500,000.00
Intermediate Pump Station	1	LS	$ 1,500,000	$ 1,500,000	30%	$ 450,000	$ 1,950,000
Disfilter and Related Equipment	1	LS	$ 1,050,000	$ 1,050,000	55%	$ 577,500	$ 1,630,000
Environmental Compliance	1	LS	$ 250,000	$ 250,000	incl.	$ -	$ 250,000
Piping	1000	m	$ 450	$ 450,000	incl.	$ -	$ 450,000
Valving	1	LS	$ 750,000	$ 750,000	incl.	$ -	$ 750,000
Chemical Dosing System	1	LS	$ 500,000	$ 500,000	incl.	$ -	$ 500,000
Miscellaneous	1	LS	$ 500,000	$ 500,000	incl.	$ -	$ 500,000
HVAC & Plumbing	1	LS	15%	$ 8,010,000	incl.	$ -	$ 1,201,500
Instrumentation and Controls	1	LS	15%	$ 25,800,000	incl.	$ -	$ 3,870,000
Electrical	1	LS	30%	$ 25,800,000	incl.	$ -	$ 7,740,000
Sub-Total MBBR & Discfilter							**$ 46,600,000**
Sub-Total Costs (A)							**$ 46,600,000**
General Contractor's Overhead & Profit, Mob., bond		% of A	15.0%				$ 6,990,000
Sub-Total Costs (B)							**$ 53,600,000**
Construction Contingency		% of B	30.0%				$ 16,080,000
Engineering		% of B	15.0%				$ 8,040,000
Total Estimated Construction Costs (C) - Excluding Escalation, GST & Engineering							**$ 77,700,000**

D

Appendix D: Operation and Maintenance Costs Summary

Canmore Wastewater Treatment Plant Upgrade
Conceptual O&M Costs
C04-00496

Drafted by PB
Date 21-Feb-23

Parameter	Value	Unit	Value	Unit	Yearly Expense	
Intermediate Pump Station						
Pump Operation	1253	kwh/d	$ 0.20	$/kwh	$ 91,453	$/yr
AGS - Including Primary Clarification						
Water level Correct Pump Power Consumption	81	kwh/d	$ 0.20	$/kwh	$ 5,913	$/yr
Average Aeration Power Consumption	2339	kwh/d	$ 0.20	$/kwh	$ 170,747	$/yr
Sludge Buffer Avg Power Consumption	49	kwh/d	$ 0.20	$/kwh	$ 3,577	$/yr
AGS - Without Primary Clarification						
Water level Correct Pump Power Consumption	81.8	kwh/d	$ 0.20	$/kwh	$ 5,971	$/yr
Average Aeration Power Consumption	3283	kwh/d	$ 0.20	$/kwh	$ 239,659	$/yr
Sludge Buffer Avg Power Consumption	52	kwh/d	$ 0.20	$/kwh	$ 3,796	$/yr
MBR						
Permeate Pumping	1611	kwh/d	$ 0.20	$/kwh	$ 117,582	$/yr
Chemicals cost	0.02	$/m3	6978800	m3/y	$ 139,576	$/yr
Membrane Replacements	$ 4,000,000	$/RP	1	REP/10YR	$ 4,000,000	$/10YR
Bioreactor blowers	3951	kwh/d	$ 0.20	$/kwh	$ 288,423	$/yr
Bioreactor mixers	45	kwh/d	$ 0.20	$/kwh	$ 3,285	$/yr
RAS Pumping	2148	kwh/d	$ 0.20	$/kwh	$ 156,776	$/yr
WAS Pumping	49	kwh/d	$ 0.20	$/kwh	$ 3,577	$/yr
BAF Expansion						
Aeration Requirements (10 blowers)	4488	kwh/d	$ 0.20	$/kwh	$ 327,624	$/yr
Backwash Pumps (3 pumps)	936	kwh/d	$ 0.20	$/kwh	$ 68,328	$/yr
Intermediate Pumps (2 pumps)	456	kwh/d	$ 0.20	$/kwh	$ 33,288	$/yr
Backwash waste pumps (3 pumps)	540	kwh/d	$ 0.20	$/kwh	$ 39,420	$/yr
Backwash blower (3 blowers)	3240	kwh/d	$ 0.20	$/kwh	$ 236,520	$/yr
Replacement Parts	$ 100,000	$/yr	1	REP/yr	$ 100,000	$/yr
MBBR						
Mixer for Denitrification	1080	kwh/d	$ 0.20	$/kwh	$ 78,840	$/yr
Discfilter						
Drum motor	20	kwh/d	$ 0.20	$/kwh	$ 1,445	$/yr
Backwash motor (20 hp)	358	kwh/d	$ 0.20	$/kwh	$ 26,129	$/yr
Chemicals						
MBR Coagulant	0.191	Ton/d	$ 880	$/ton	$ 61,349	$/yr
Discfilter Coagulant	0.073	Ton/d	$ 880	$/ton	$ 23,448	$/yr
Manpower						
Labour	$ 300	$/h	37.5	h/wk	$ 585,000	Plant Operation
UV						
Power Consumption from the 168 Lamps	1008	kwh/d	$ 0.20	$/kwh	$ 73,584	$/yr

E

Appendix E: Activated Granular Sludge Technical Summary

AquaNereda®

Aerobic Granular Sludge Technology

AQUA-AEROBIC SYSTEMS, INC.
A Metawater Company

AquaNereda®

Aerobic Granular Sludge Technology

The AquaNereda® Aerobic Granular Sludge Technology is an innovative biological wastewater treatment system that provides advanced treatment using the unique features of aerobic granular biomass.

The aerobic granular biomass is comprised of compact granules which consist of layered microbial communities and provides superior settling compared to conventional activated sludge. Within a single tank, the process creates proper conditions to develop and reliably maintain a stable granule population without the need for a supplemental carrier. The layered aerobic and anaerobic zones within the granule allow for simultaneous processes to take place in the granular biomass, including enhanced biological phosphorus reduction and simultaneous nitrification and denitrification.

The unique process features of the AquaNereda technology translate into a flexible and compact process that offers energy efficiency and significantly lower chemical consumption culminating in a low life-cycle cost.

System Features and Advantages

- Optimal biological treatment is accomplished in one effective aeration step
- Settling properties at SVI values of 30-50 mL/g allow MLSS concentrations of 8,000 mg/l or greater
- 25% of the footprint compared to conventional activated sludge systems
- Energy savings up to 50% compared to activated sludge processes
- No secondary clarifiers, selectors, separate compartments, or return sludge pumping stations
- Proven enhanced nutrient removal (ENR)
- Robust structure of granule withstands fluctuations in chemical spikes, load, salt, pH and toxic shocks
- Significant reduction of chemicals for nutrient removal due to the layered structure and biopolymer backbone of the granule
- Ease of operation with fully automated controls
- Lowest life-cycle cost

Typical Applications

- Retrofit of existing tanks to increase treatment capacity
- Upgrade of existing treatment systems to meet BNR requirements
- New construction plants
- Municipal and industrial

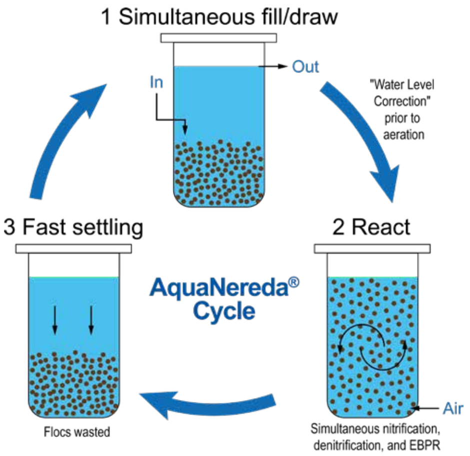
SVI_5 comparison of aerobic granular sludge (left) and conventional activated sludge (right)

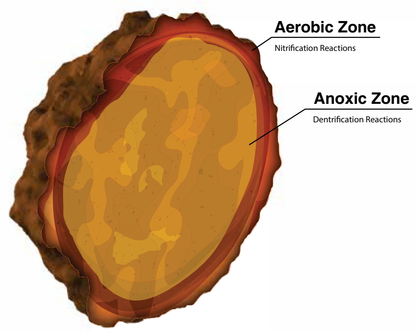
Three AquaNereda® reactors show compact design, typically 50% of a conventional plant.

Granule sample following sieve testing at the AquaNereda® demonstration facility, Rockford, IL

AquaNereda®
Batch Cycle Structure

Based on the unique characteristics of granular biomass, the AquaNereda® Aerobic Granular Sludge System uses an optimized batch cycle structure. There are three main phases of the cycle to meet advanced wastewater treatment objectives. The duration of the phases will be based upon the specific waste characteristics, the flow and the effluent objectives.





Plant Profile: Riviera Utilities Wastewater Treatment Plant at Wolf Creek - Foley, AL

The AquaNereda® Aerobic Granular Sludge System represents a step-change in the wastewater treatment industry. The new system at the Riviera Utilities Wastewater Treatment Plant at Wolf Creek consists of three aerobic granular sludge reactors operating similar to a continuous flow system with a Fill/Draw phase that alternates between reactors. Downstream polishing is performed by AquaDisk® Pile Cloth Media Filters to produce Class B reuse-quality water. Although not currently required by permit to achieve Total Nitrogen (TN) limit, the inherent BNR properties of Aerobic Granular Sludge provide TN removal now and for future permit limits. Since start-up in January 2020, the plant has consistently produced remarkable effluent quality which far surpasses current permit requirements, and in fact, already meets future anticipated TN and TP limits.

Compared to the previous conventional treatment process, AquaNereda achieves:

- Overall power cost reduction of 40%
- Zero chemical usage
- 30% of footprint
- 75% increase in treatment capacity
- Elimination of secondary clarifiers and RAS pumping
- Increased process resilience during peak wet weather
- Events and influent load variations
- Exceeds anticipated future nutrient removal requirements

Riviera Utilities WWTP Upgrade Received Distinction for Wastewater Project of the Year at the 2021 Global Water Awards

GLOBAL WATER AWARDS

Phases of Operation

1 Fill/Draw Phase

- Influent flow, substrate and readily available carbon source enter the reactor
- Anoxic and anaerobic conditions are present
- Biomass conditioning phase
- Phosphorus release to promote enhanced bio-P removal
- Treated water is discharged

2 React Phase

- Influent flow is terminated
- The biomass is subjected to aerobic and anoxic conditions
- Simultaneous nitrification/denitrification occurs
- Nitrate is transported by diffusion between outer aerated and inner anoxic layers of the granule, eliminating the need for pumping large recycle flows in the plant
- Luxury uptake of phosphorus is promoted
- Automated control of the process allows energy savings and process optimization

3 Settle Phase

- Influent flow does not enter the reactor
- Granular biomass is separated from the treated water during a very short settling phase
- Excess sludge is wasted in order to maintain the desired amount of biomass
- The system is ready for a new cycle

Since 1969, Aqua-Aerobic Systems, Inc. has led the industry by providing advanced solutions in water and wastewater treatment. As an applied engineering company serving both municipal and industrial customers, we work collaboratively with consulting engineers, owners, plant managers, and operators to design and manufacture the best treatment solution with the lowest lifecycle cost.

Providing TOTAL Water Management Solutions

- Aeration & Mixing
- Biological Processes
- Filtration
- Oxidation & Disinfection
- Membranes
- Controls & Monitoring Systems
- Aftermarket Products and Services

The Development of Nereda®

A public-private research partnership in the Netherlands between the world-renowned Delft University of Technology, research institutes, water authorities and Royal HaskoningDHV led to the invention of the first technology applying aerobic granular sludge for the treatment of wastewater.

Since its development, Royal HaskoningDHV has transferred the process into an internationally applied, sustainable and cost-effective wastewater treatment technology. After 20 years of research and development, this innovative biological solution is now proving to be one of the most sought–after, progressive wastewater treatment technologies.

In 2016, Aqua-Aerobic Systems partnered with Royal HaskoningDHV to expand aerobic granular sludge into North America and is the exclusive provider of this technology in the United States and Canada.

AquaNereda®

Aerobic Granular Sludge Technology

Visit our website at www.aqua-aerobic.com to learn more about the AquaNereda® Aerobic Granular Sludge Technology and our complete line of products and services.

AQUA-AEROBIC SYSTEMS, INC.
A Metawater Company

www.aqua-aerobic.com
6306 N. Alpine Road, Loves Park, IL 61111-7655
p 815.654.2501 | f 815.654.2508 | solutions@aqua-aerobic.com

Bulletin #991A 4/22

F

Appendix F: Membrane Biological Reactor Technical Summary

LEAPmbr*

Taking ZeeWeed* MBR technology to the next level

WATER TECHNOLOGIES

Addressing Our Customer's Challenges

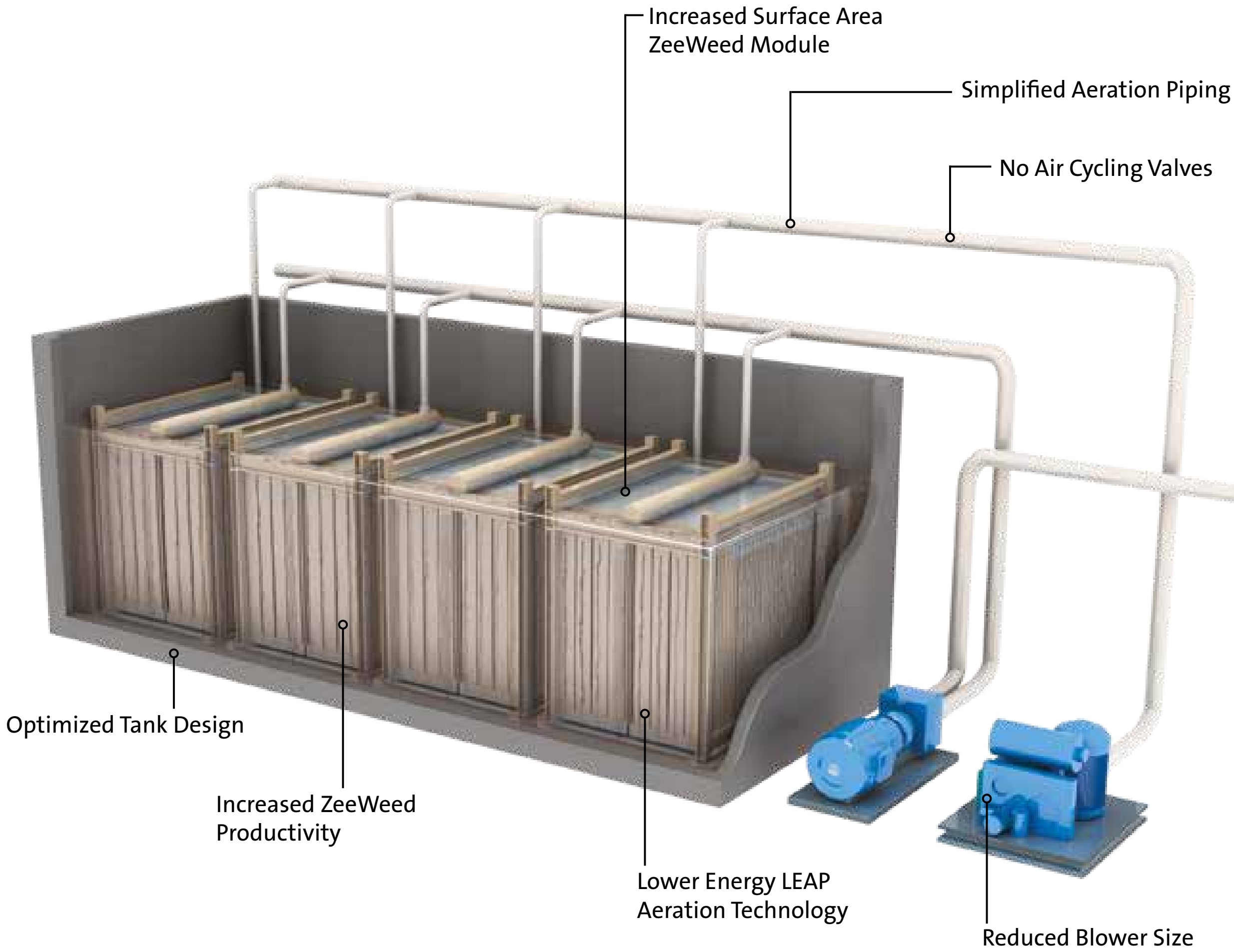
Veolia has always strived to help our customers create sustainable water supplies to alleviate scarcity issues, provide cleaner water bodies, meet the needs of growing populations and industries, and meet or exceed the world's highest standards for water reuse. As the global membrane bioreactor leader, with over 5,000,000 m^3/d (1.32 BGD) of ZeeWeed MBR capacity, our MBR systems have continued to combine proven ultrafiltration technology with biological treatment for municipal, commercial and industrial wastewater treatment and water reuse applications.

With over 25 years of proven MBR experience, Veolia continues to set the industry standards for research & development, membrane manufacturing, system design and customer support. When our customers challenged us to find a solution to their biggest challenges: productivity, footprint, operation simplicity and energy costs, we answered. Building on two decades of ZeeWeed MBR product innovation, Veolia now introduces the new LEAPmbr to address our customers key wastewater treatment challenges and provide the low energy and advanced performance solution demanded by the global wastewater treatment and reuse market.

At Veolia, we manufacture our membranes utilizing the most advanced mass production methods, while delivering the most reliable MBR membrane product in the world, living up to our reputation as quality leaders. With LEAPmbr, we continue this tradition with the release of our most robust, highest performing ZeeWeed 500 series product to date, delivering the lowest installed and operating costs in the history of our ZeeWeed products. The design of an MBR plant is a balance between flexibility and simplicity, both in design and operation. Veolia's approach is to incorporate maximum flexibility into our plant designs to give operators a complete toolbox to manage all events; Veolia achieves this by providing automation that simplifies operator touch. With the new LEAPmbr, we have achieved a new level of simplicity, while not compromising on flexibility.

What Is LEAPmbr?

Our new level of Zeeweed MBR technology was developed to address our customers' challenges of productivity, footprint, simplicity and energy savings. LEAPmbr builds on our 25 years of MBR experience to deliver the most advanced Zeeweed MBR solution to date. At its core, LEAPmbr uses the industry's most trusted leading ZeeWeed membrane while incorporating significant innovations that take MBR to the next level. The figure below represents the product innovations.



Increased Productivity

- Boost your productivity 15% with our latest ZeeWeed membrane.

Energy Savings

- Reduce your operating costs with a 30% energy savings.

Smaller Footprint

- Save on construction costs with a flexible design that reduces your MBR footprint by 20%.

Guaranteed Reliability

- Have the confidence of the strongest, most reliable membrane in the industry.

Simplified Design

- Simplify your design by reducing membrane aeration equipment and controls by 50%.

Case Studies

Marco Island Florida, USA

During the winter months, the population of Marco Island, Florida can double due to tourism, which places an increased demand on the wastewater treatment facility. In 2007, the existing conventional treatment facility was expanded to a membrane bioreactor (MBR) since it required an increased treatment capacity but lacked space to expand plant footprint.

The effluent produced at Marco Island exceeds the discharge requirement and provides high quality reuse water which is a continuous and reliable supply of irrigation water for golf courses and residential properties.

Marco Island was selected for testing of the LEAPmbr technology beginning in May 2010. Process testing was done compared to previous aeration and performance standards. The results of over a year of testing have demonstrated significant energy savings and productivity improvements.

Facility in Southern Ontario, Canada

The population of Southern Ontario continues to steadily grow, and several membrane bioreactors facilities with Veolia ZeeWeed membranes have been installed to treat the increased capacity demand and address tighter regulatory requirements. An existing MBR facility in Southern Ontario utilizing ZW500d membrane modules was retrofitted with LEAPmbr technology in early 2011.

Process testing was done to verify product performance at various operating conditions.

Test results showed considerable increased system performance at reduced aeration flow rates compared to previous aeration methods. Not only that, but LEAPmbr also eliminated foaming issues that had previously existed at the wastewater facility.

Increased performance, lower energy levels and simplified operation were successfully demonstrated for LEAPmbr in this full scale application.

Resourcing the world

Veolia Water Technologies
Please contact us via:
www.veoliawatertechnologies.com

G

Appendix G: WWTP Land Use Site Plan

LEGEND

PROPERTY LINE
EXISTING DISPOSITION

No.	Date	Issue Description	By
A	YYYY-MM	FOR PRELIMINARY APPROVAL	PB

STAMPS:

PROFESSIONAL ENGINEER
PAVEL MANCHINSKIY
ALBERTA
2023-04-10

PERMIT TO PRACTICE
CIMA CANADA INC.
Signature
Date April 11 2023
PERMIT NUMBER: P 8204
The Association of Professional Engineers and Geoscientists of Alberta

ENGINEER:

CIMA+

T 403 775-0100, F 403 775-0102
300, 6815 - 8 Street NE
Calgary, AB T2E 7H7 CANADA

DRAWING DISCLAIMER :
This drawing does not show all existing structures and underground utilities. The existence, location and elevation of structures and underground utilities shown are approximate and are not guaranteed. It is the Contractor's responsibility to locate and protect all works including pipelines and to make satisfactory arrangements for the work with Owners or Authorities.

CLIENT:

Town of CANMORE

PROJECT NAME:

CANMORE WWTP UPGRADE
CANMORE, ALBERTA

SHEET TITLE:

CONCEPTUAL SITE PLAN

SCALE: 1:1000 (0 4 10 20 30m)

DRAFTED: MLC	DESIGNED: PM
APPROVED: SD	APPROVED:
PROJECT No: C017|C04-00496	DRAWING No: C-001
REVISION No: 0	