BROCKVILLE

CITY OF THE 1000 ISLANDS

BROCKVILLE WATER POLLUTION CONTROL CENTRE UPGRADE

CLASS ENVIRONMENTAL
ASSESSMENT REPORT

Technical Memorandum No. 3
Evaluation of Short Listed Secondary Treatment Process Options

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1. Introduction

The City of Brockville is proceeding to complete a Class Environmental Assessment to assess alternative solutions for a proposed Brockville Water Pollution Control Plant (WPCC) Upgrade.

The upgrade works, as a minimum, are to provide the current "normal" level of treatment prescribed by the Ministry of Environment (MOE), which is considered as being secondary treatment or equal and consistent with the Provincial Guideline F-5.

This Technical Memorandum (TM#3) has been prepared to further evaluate the short listed secondary treatment process options, including a review of economical, performance and other factors impacting the selection decision. The evaluation process includes the development and application of a project specific evaluation matrix. The evaluations weighted scoring attempts to best reflect decision factors associated with selecting the preferred secondary processes for the Brockville WPCC Upgrade.

2. Short Listed Secondary Treatment Options

2.1 Process Options

Although all secondary treatment processes outlined in Technical Memorandum No. 2 (TM#2) could be implemented at the Brockville plant, some processes may be better suited than others. TM#2 provided a summarized initial review of a long list of secondary treatment process options. Key considerations identified for the initial review and general comparison included:

- Ability to meet effluent criteria/discharge requirements
- Degree of system/operational complexity
- Ability to treat and accommodate peak flows and loadings, and shock loadings
- Capital and operational costs
- Reliability/operation experience in municipal application
- Solids and biosolids management

The review of process options for the upgrade evaluated priorities and issues unique to the WPCC, and identified a short list of treatment options considered most appropriate for further evaluation. Based on the initial review, the short listed secondary treatment processes considered most appropriate for further evaluation for the Brockville WPCC Upgrade include:

- Activated Sludge Process (ASP)
- Sequencing Batch Reactors (SBR)
- Rotating Biological Contactor (RBC)
- Biological Aerated Filter (BAF)
- Hybrid Fixed Film Process (e.g. Moving Bed Biofilm Reactors (MBBR)

2.2 Summary of Advantages and Disadvantages

This section provides a general discussion of the specific benefits and limitations of each secondary treatment process. A comparison of the advantages and potential limitations for the listed secondary treatment technologies are summarized in **Table 1**.

TABLE 1:
Advantages and Disadvantages of Short Listed Secondary Treatment Process

Process	Advantages	Potential Limitations
Suspended Growth: Activated Sludge (ASP)	➢ Common process ➢ Flexible process ➢ Upgrading potential ➢ BNR possible	➢ Sludge settleability can be a concern ➢ Foaming can be a concern ➢ High energy needs for aeration
Suspended Growth: Sequencing Batch Reactor (SBR)	➢ Aeration and clarification is combined in a single tank ➢ Very flexible for nutrient removal (i.e., BNR) ➢ High degree of automated control	➢ Less common at larger scale ➢ More complex mechanical/electrical ➢ Discontinuous discharges
Fixed Film: Rotating Biological Contactor (RBC)	➢ Simple process to operate and maintain ➢ High process stability ➢ Modular process ➢ Low energy needs	➢ Generally poor effluent aesthetics ➢ Limited degree of process control ➢ Mechanical concerns
Fixed Film: Biological Aerated Filter (BAF)	➢ High loading rate; small footprint ➢ No final clarifiers required ➢ Modular process; upgrading potential ➢ Enhanced effluent quality; but relies on primary clarifiers for chemical enhanced P removal ➢ High degree of automated control	➢ Complex mechanical/electrical and control systems ➢ Upstream fine screening, oil and grease removal ➢ Potential loss of media ➢ Limited degree of process control ➢ Less common process ➢ Requires backwashing
Fixed Film: Moving Bed Biofilm Reactor (MBBR)	➢ Simple designs ➢ Retrofit of existing tankage, no primary clarifiers required ➢ Smaller footprint than ASP ➢ Low headloss; no backwashing	➢ Upstream fine screening ➢ Medium/Coarse bubble aeration ➢ Media retention screen assemblies ➢ Limited degree of process control ➢ Less common process

2.3 Process Loadings

Process loadings vary for each process and even within a process depending on the process design and influent concentrations. **Table 2** provides a summary of the typical process loadings for each unit process.

TABLE 2:
Summary of Typical Process Loadings

Process	Loading (units)	Value
Modified ASP	Aeration HRT (hr) Clarifier SOR peak ($m^3/m^2.d$)	3 - 15 29.4
SBR	Reactor HRT (h)	10
RBC	TOL (g $BOD_5/m^2.d$) Clarifier SOR peak ($m^3/m^2.d$)	3.5 40 - 70
BAF	TOL (kg $BOD_5/m^3.d$) Clean Water/Backwash Wells	1.05 10% each of cell volume
MBBR	Reactor HRT (hr) Clarifier SOR peak ($m^3/m^2.d$)	2 - 4 40

Notes:
1. Abbreviations: hydraulic retention time (HRT), surface overflow rate (SOR), and total organic loading (TOL)

3. Related Items and Considerations

Prior to focusing on the short listed secondary treatment option descriptions and evaluations that follow, this section first discusses various process treatment related items and considerations.

3.1 Extended Aeration (Activated Sludge Variation) Option

In addition to the short-listed secondary treatment options, a variant of the activated sludge process is to provide extended aeration with low rate continuous wasting. This option would have no primary clarification, and offer a reduced overall footprint requirement. Extended aeration is designed with longer aeration system retention times and generally higher solids retention times (SRT). **Table 3** provides a comparison of a conventional activated sludge system with primary clarifiers and an extended aeration system. The aeration volume would be greater for an extended aeration process for Brockville, however the primary clarifiers would not be required and could conceptually be converted to provide aeration basin capacity. The four primary clarifiers have a total volume of approximately 4,200 m^3, therefore the extended aeration process would require an additional 9,425 m^3, which is still greater than the conventional activated sludge option. Process loadings are within typical levels based on MOE design guidelines. Aeration tank MLSS concentrations are based on typical values and to provide adequate process loadings (i.e. F/M ratio) and are based on a MLSS concentration of 1,500 and 2,500 mg/L, respectively for the conventional and extended aeration processes. Process modeling using GPS-X™ indicated that a lower MLSS for the conventional ASP would be adequate (or less aeration). Modeling of the extended aeration process resulted in a higher MLSS concentration than 2,500 mg/L partially due to the chemical sludge generated.

Solids generation was determined using the assumed SRT and MLSS concentration and from modeling each process. The results indicate similar solids generation from each process. Air requirements for each treatment process were estimated, and are higher for the extended aeration process. The air requirements are higher for both oxygen demand (higher influent BOD_5 concentration) and mixing requirements for the extended aeration process relative to the conventional activated sludge based on MOE design guideline values. Furthermore, sludge co-thickening would not be an option for the extended aeration process as the primary clarifiers would be removed.

Based on the above evaluation there is no indicated advantage to proceeding with an extended aeration option relative to the conventional activated sludge option.

TABLE 3:
Comparisons of Conventional and Extended Aeration Processes for Brockville

Parameter	Conventional Activated Sludge with Primary Clarifiers	Extended Aeration without Primary Clarifiers
Design Average Flow (m^3/d)	21,800	21,800
Influent Concentrations (mg/L) • $CBOD_5$ • NH_3-N	 51 12.3	 108 12.3
Typical Sizing • HRT (h) • SRT (d)	 6 8	 15 15
Aeration Volume (m^3)	5,450	13,625
Calculated Loadings • F/M Ratio (d^{-1}) • Organic Loading (kg/m^3.d)	 0.14 (0.05-0.25)[1] 0.2 (0.31-0.72)[1]	 0.07 (0.05-0.15)[1] 0.17 (0.17-0.24)[1]
Sludge Generation (kg/d) • Primary Sludge • Secondary Sludge • Chemical Sludge • Total	 2,345 (prorated from current) 320-1,020 0 (included in primary) 2,665-3,365	 0 2,270-3,160 620 2,890-3,780
Aeration Requirements (m^3/d) • Oxygen Demand (fine bubble aeration , SOTE=20%, alpha of 0.7 and no DO residual) • Aeration Mixing	 66,770 63,830	 101,840 159,580
Notes: 1. Typical MOE design guidelines		

3.2 Sequencing Batch Reactors and Primary Clarification

Similar to extended aeration, SBRs are often considered without primary clarifiers. Again, co-thickening of the waste activated sludge (WAS) would not be possible without primary clarifiers. Therefore, the WAS solids would likely be mechanically thickened.

Another potential disadvantage with operating an activated sludge process with no primaries is the increased loading to the aeration tank and the potentially longer hydraulic retention time required, as indicated above in the extended aeration comparisons. The plant currently adds coagulant to the total flow at the plant and obtains enhanced removals in the primaries. A new facility with no primaries would need to have additional aeration capacity, similar to an extended aeration activated sludge process to handle the increased loading and coagulant would have to be separately added to the SBR aeration/settling tank.

Based on the above, there is no indicated advantage to consider the conceptual SBR treatment option operating without use of the existing primary clarifiers.

3.2 Waste Activated Sludge and Waste Solids Handling Options

Options for WAS thickening include gravity belt thickeners (GBT), internal feed rotating drums, dissolved air flotation, centrifuge and co-thickening in the primary clarifiers. Mechanically thickened options need to consider life-cycle cost issues and odour. The GBT option is cost effective option compared to centrifuges due in part to the lower electrical costs. The rotating drum thickener or screen is also a low energy user, but is also enclosed like a centrifuge, an advantage that should be evaluated. Mechanical thickening system can be utilized for all secondary processes presented, except for the Biological Aerated Filter (BAF) unless first concentrated. The BAF washwater solids will be of low concentration, estimated to be between 300 and 600 mg/L as suspended solids. This washwater stream will also have a high volume, estimated as being up to 15% of the treated flow. Therefore, this stream would probably utilize some form of gravity thickening either co-thickening in the primary clarifiers or separate gravity thickening prior to any mechanical thickening. The BAF suppliers' base scope of supply assumes washwater is returned to the primary clarifiers.

Waste activated sludge and waste solids handling options are considered in a separate Technical Memorandum.

3.3 Biosolids Stabilization Options

Biosolids stabilization options will also need to consider the additional biological sludge generated due to the secondary treatment process. Both the volume and characteristics of the biosolids will need to be considered. If waste activated sludge is co-thickened the concentration of the raw (feed) sludge pumped to digestion can be expected to be reduced, as the combined WAS and raw sludge does not generally compact as well as raw or primary sludge alone. In addition the final usage for biosolids needs to be considered prior to any expansion or modification of the existing digestion and dewatering processes and facilities.

Biosolids stabilization options are considered in a separate Technical Memorandum.

3.4 Septage Receiving Implications

Septage from domestic sources can be handled in a variety of different ways. Historically, septage solids were either discharged to the headworks of a WPCP or applied directly to land. The new Nutrient Management Act will phase out the practise of land application prior to additional treatment or stabilization. Two main septage handling options include co-treatment at a municipal wastewater treatment facility (WWTF) having a biological treatment process, or separate independent treatment at a private/commercial facility. Co-treatment at a WWTF could include addition to the liquid stream, sludge stream (i.e. digesters) or both. Independent treatment could include stabilization lagoons, conventional biological treatment, digestion (aerobic or anaerobic), lime stabilization or other processes.

Co-treatment at a WWTF is an attractive option as the plant is already designed to treat wastewater, is staffed by trained personnel, and septage (although stronger) is similar to domestic wastewater. All of the secondary treatment options being considered provide a form of biological secondary treatment that is suitable to co-treat a septage of typical characteristics. Depending on the nature and volume of received septage, the design basis of options may require some adjustment to properly accommodate the projected septage hydraulic and organic loadings. Septage receiving is considered in a separate Technical Memorandum.

3.5 Disinfection Options

There are several disinfection options for the plant, but to provide a non-toxic effluent with respect to lethality testing procedures 1) chlorination followed by dechlorination, and 2) Ultraviolet (UV) disinfection are the two most common options. The Brockville WPCC presently chlorinates its primary effluent with sodium hypochlorite. A secondary effluent will be easier to effectively chlorinate, and will require subsequent dechlorination to be non-toxic. Consideration of UV disinfection will be impacted by the secondary processes chosen. Disinfection options are considered in a separate Technical Memorandum.

4. Descriptions and Conceptual Layouts of Secondary Process Alternatives

Descriptions and conceptual layouts for each short listed process are developed in this section and are used as the basis for budget costing of each process alternative. Schematic layouts for each secondary treatment process are attached at the end of this section and are referenced as **Figures 1** to **5**.

4.1 Activated Sludge Process (ASP)

As discussed in section 3.1, the conventional activated sludge process with primary clarification seems to be the most appropriate ASP configuration for the Brockville WPCC. Based on the process evaluation and modeling of the process an aeration tank hydraulic retention time (HRT) of 4 hours is sufficient for the current enhanced primary effluent to provide organic removal and nitrification. Generally an activated sludge process with an aeration tank HRT of 4 hours is considered a high-rate ASP. The corresponding process needs, for a high-rate process with a 4 hour HRT, include:

- Aeration tank volume – 3,640 m^3
- Aeration Requirements – 94,000 m^3/d firm capacity (based on fine pore aeration, 20% SOTE, 0.7 average alpha and DO residual of 2 mg/L)
- Clarifier surface area – 1,854 m^2
- RAS pump capacity – 21,800 m^3/d firm capacity (i.e. 100% recycle)

See **Figure 1** for a conceptual layout of a representative activated sludge process.

4.2 Sequencing Batch Reactor (SBR)

Sequencing Batch Reactors use a modification of the activated sludge process, and provide sequential treatment in a single reactor. Both the aeration or biological reactions and settling occur in a single reactor based on a timed cycle. Multiple tanks are generally used so one SBR is filling, another aerating and perhaps a third settling. This allows for continuous inflow and feed, and sequential SBR decanting and discharge. The SBR processes tend to utilize proprietary equipment and therefore a number of suppliers were contacted to obtain sizing and equipment costs for an SBR process for Brockville. **Table 4** provides a summary of three SBR options and sizing, and an approximate equipment cost. Typically the supplier scope includes SBR process equipment only, and excludes all tankage, channels, piping and valves, and electrical, control and instrumentation.

See **Figure 2** for a conceptual layout of a representative SBR process.

TABLE 4:
Summary of Representative SBR Options

Item	Supplier		
	H2Flow/Fluidyne	Napier-Reid	ECO Process
Design basis	Raw influent	Primary effluent	Primary effluent
Tankage	4 tanks, each with a volume of 4,672 m^3, total volume of 18,689 m^3	2 train, 2 basins/train, basins are 15.5 x 39 x 5.5m deep, total volume of 13,300 m^3	4 basins, each 37.5 x 18 x 4.84m deep, total volume of 13,070 m^3
Nominal HRT (h)	20.6	14.6	14.4
Approx. Equipment Cost	Value of $1.0 M used in evaluation		

4.3 Rotating Biological Contactor (RBC)

The RBC process uses a fixed film that is alternatively rotated through the primary effluent and into the air. The more standard RBC configuration is to submerge the media approximately 40%, with the liquid level below the rotating support shaft. One option for this process is to submerge the RBC nearly completely and provide process air through aeration, this process is referred to as a submerged biological contactor. Preliminary designs from suppliers have been obtained for both RBCs (2) and an S-RBC (Submerged RBC) system. These systems include the RBC media, shaft and bearings, covers and drive motors or air header system. If units are air driven (S-RBC only in this case) the aeration blowers are not included. **Table 5** provides a summary of the three RBC options and sizing, and an approximate equipment cost. Typically the supplier scope includes RBC process equipment only, and excludes all tankage, channels, piping and valves, and electrical, control and instrumentation.

See **Figure 3** for a conceptual layout of a representative RBC process.

TABLE 5:
Summary of Representative RBC Options

Item	Supplier		
	John Meunier/Walker Process Equipment – RBC	US Filter - RBC	US Filter - Submerged RBC
Design basis	Primary effluent	Primary effluent	Primary effluent
Trains and Media	6 parallel trains, 55,472 m^2 on first stage, 334,451 m^2 total	5 parallel trains, 112,877 m^2 on first stage, 282,193 m^2 total	2 parallel trains, 115,200 m^2 on first stage, 287,999 m^2 total
RBC Loading (kg/m^2.d) • First stage • Overall	 15.4 (31.3)[1] 2.6 (5.2)[1]	 15.4 6.2	 15.1 6.1
Approx. Equipment Cost	Value of \$3.0 M used in evaluation		

Note:
1. Loading in brackets based on influent $sBOD_5$ of 80 mg/L, rather than 40 mg/L assumed in the supplier quote. Overall media area appears sufficient.

4.4 Biological Aerated Filter (BAF)

The BAF process provides a compact design and potential for enhanced effluent quality. These processes tend to utilize proprietary equipment and therefore a number of suppliers were contacted to obtain sizing and equipment costs for a BAF process for Brockville. Both systems are upflow, co-current BAF processes for combined organic removal and nitrification. One system, the BIOFOR™, provides an expanded shale media that sits on a false floor, though which effluent and air are introduced through a nozzle system. The other system, the BIOSYTR™, uses a styrene media that floats against a raised floor through which effluent passes through a nozzle system. Both systems include some mechanical items, including blowers, pumps, media, etc., and typically the supplier scope includes BAF process equipment only, and excludes all civil works, tankage, channels, major piping, sluice gates, valves, and electrical and control and instrumentation. **Table 6** provides a summary of two BAF options and sizing, and an approximate equipment cost**.**

See **Figure 4** for a conceptual layout of a representative BAF process. A new primary clarifier is shown in the conceptual layout to accommodate the return of BAF washwater volumes to the primary clarifiers.

TABLE 6:
Summary of Representative BAF Options

Item	Supplier	
	Degremont	John Meunier
Design basis	Primary effluent	Primary effluent
Process Name	BIOFOR	BIOSTYR
Cells and Sizes	6 Biofor C filters, each with a surface area of 40 m^2, total surface area of 240 m^2, media depth of 3.9 m	11 cells, each 43 m^2, total surface area of 473 m^2, media depth of 3 m
BAF Loading ($kg/m^2.d$)		
• Organic (BOD_5)	2.24	1.47
• TKN	0.38	0.27
• Hydraulic (m/h)	3.8	1.9
Backwash Volume (m^3/d)	3,000	3,500
Approx. Equipment Cost	Value of $ 3.7 M used in evaluation	

Note:
1. Fine screening (6 mm) for BAF influent recommended.
2. Final clarification or settling is not indicated as a requirement; primary clarifiers to provide chemically enhanced phosphorus removal.

4.5 Hybrid Fixed Film (example MBBR)

Hybrid fixed film systems can be designed to provide organic removal and nitrification. These systems can be operated on their own or in conjunction with a suspended growth system. The proposed MBBR system can be operated in either mode, but for this application the supplier has selected the system as fixed film only with no return of biomass to the reactor – that is a once flow through system similar to a RBC. **Table 7** provides a summary of the MBBR system option and sizing, and an approximate equipment cost. This system only includes requirements for the bioreactor in terms of media, retention system, aeration diffuser and in tank piping. Typically the supplier scope includes MBBR process equipment only, but does not include the process air blower, civil works (i.e. aeration tank), final clarifier, channels, piping and valves, and electrical, instrumentation and control.

The MBBR system has been proposed without primary clarifiers and therefore the existing primary clarifiers would be retrofitted and re-used as four individual 3-stage bioreactors. This system will also require very fine screening (3 mm) for removal of particulate matter, and this is additional to the quoted equipment cost.

See **Figure 5** for a conceptual layout of a representative MBBR process. The represented secondary clarifier surface area is based on a peak SOR of 40 $m^3/m^2.d$.

TABLE 7:
Summary of Representative MBBR Option

Item	Supplier
	AnoxKaldnes
Design basis	Raw influent
Process Name	Kaldnes media
Cells and Sizes	Retrofit existing primaries into 3 cells, 2 for organic removal one for nitrification, 45% media with surface area of 956,000 m^2
MBBR Loadings • HRT (hr)	4.6 avg. 1.85 peak
Approx. Equipment Cost	Value of $1.8 M used in evaluation

Note:
1. Very fine screening (3 mm) for MBBR influent recommended.
2. Approximate equipment cost using exchange rate 0.8.
3. With higher organic loadings, or if owner preference, supplier offers to provide MBBR-only process in separate basins following primary clarifiers, or combination of MBBR with activated sludge process.

5. Preliminary Costing of Secondary Processes

Preliminary costing of each secondary treatment process has been undertaken using a standard approach and is presented as an opinion of probable costs. Costing has been based on preliminary estimates from CapdetWorks™ (a cost estimating software package) and has been updated to reflect manufacturers' supplied costs. Operating and maintenance costs have also been developed in CapdetWorks and adjusted for the various processes. Each process capital cost includes the secondary process only, and does not include for other works or modifications to existing facilities (e.g. preliminary treatment, primary clarifiers, chemical addition, disinfection, digestion and dewatering). The operating and maintenance costs include a preliminary estimate, and adjusted allowances for coagulation, and solids digestion, management and disposal operating costs for the respective treatment processes.

5.1 Capital Costs

Capital cost estimates have been generated and modified to reflect supplier preliminary quotations. The particular approximate equipment cost used for each treatment process is outlined in the previous section, and the base line activated sludge process is based directly from CapdetWorks. The capital costs are summarized in **Table 8**.

TABLE 8:
Summary of Secondary Treatment Process Capital Cost Estimates

Secondary Process	Capital Cost ($ million)	Comments
ASP	16.3	Rectangular tanks used for aeration and final clarifiers
RBC	16.0	RBC cost taken from supplier, tankage cost and final clarifiers added
SBR	17.1	SBR cost taken from supplier, tankage cost added
BAF	17.2	BAF cost taken from supplier, tankage cost added, plus dirty water backwash tank, primary clarifier and finer screen added
MBBR	14.1	MBBR cost taken from supplier, tankage cost added, allowance for primary retrofit, very fine screening system, and final clarifiers added
Note: 1. Common markups used for engineering, contingency, contractor profit, yard piping etc.		

5.2 Estimated O&M

Operating and maintenance (O&M) cost estimates have been generated and modified for each process. The ASP, RBC and SBR processes are based directly from CapdetWorks, however, the SBR cost was slightly modified to address sludge pumping requirements. The BAF and MBBR processes have been estimated from those determined by CapdetWorks, and include additional screening processes recommended. The O&M costs are summarized in **Table 9**. O&M costs are based on energy (i.e. $0.08/kWhr), labour (i.e. $22/hr), a coagulant chemical cost allowance for phosphorus removal, and solids digestion, handling and disposal cost allowance for each process.

TABLE 9:
Summary of Secondary Treatment Process Operating and Maintenance Cost Estimates

Secondary Process	O&M Cost ($ million)	Comments
ASP	1.11	Directly from CapdetWorks with additional allowances.
RBC	0.90	Directly from CapdetWorks, with air purge, media replacement, and other additional allowances
SBR	1.10	Directly from CapdetWorks with reduced sludge pumping, and additional allowances
BAF	1.12	Similar O&M to RBC expected, plus aeration/pumping for process and cleaning, also additional screening operation, media replacement

		and other additional allowances
MBBR	1.14	Lower O&M than RBC, but aeration required, also additional very fine screening operation, media replacement and other additional allowances
Notes: 1. Above O&M costs are estimated for secondary treatment processes, at Average Day Flow and maximum month design basis conditions, for relative comparison purposes. Above O&M cost estimates do not represent total treatment facility operating and maintenance costs. 2. RBC, BAF and MBBR O&M cost estimates include annual allowance towards full media replacement at year 20.		

5.3 Life Cycle Costing

Life cycle costing is based on the capital and O&M costs estimated in the previous sections, and is based on a 20-year period, 2.5% inflation and 6.0% interest rate. **Table 10** summarizes the results.

TABLE 10:
Summary of Secondary Treatment Plant Costs

Secondary Process	In millions of $			
	Capital Cost	O&M Cost	NPV of O&M	Net Present Value
ASP	$ 16.3	$ 1.11	$ 15.9	$ 32.2
RBC	$ 16.0	$ 0.90	$ 12.9	$ 28.9
SBR	$ 17.1	$ 1.10	$ 15.8	$ 32.8
BAF	$ 17.2	$ 1.12	$ 16.0	$ 33.3
MBBR	$ 14.1	$ 1.14	$ 16.3	$ 30.5

Capital costs are relatively close, approximately within +/- 10% for most processes, with the MBBR having the lowest estimated capital cost. The MBBR capital cost is approximately 12% less than the 2nd low secondary process capital cost. The net present value of the combined capital cost and 20-yr O&M cost are also relatively close for all processes (<+/- 10% of the average NPV value), with the RBC process having the lowest estimated NPV. The relative O&M cost for the fixed film processes (RBC, BAF, MBBR) will reduce if the service life of the media extends beyond a 20-year period.

Table 11 provides a summary table of the various options including loadings, expected performance, sludge generation, air requirements, and costs (capital, O&M and life-cycle).

TABLE 11:
Summary of Process Options

Parameter	Process Options				
	ASP	RBC	SBR	BAF	MBBR
Design Basis • **Flow (ML/d)** • **Raw Influent Concentrations (mg/L)** ○ **$CBOD_5$** ○ **TSS** ○ **TP** ○ **TKN**	21.8 average, 54.5 peak 120 average, 160 maximum month 160 average, 200 maximum month 4 average, 4 maximum month 15 average, 18 maximum month				
Expected Effluent Performance • **Concentrations (mg/L)** ○ **$CBOD_5$** ○ **TSS** ○ **TP** ○ **TKN**	15 15 0.5 2-3	15 15 0.5 2-4	15 15 0.5 2-3	8 10 < 0.5 2-3	15 15 0.5 2-4
Peak Flow Handling and Process Stability	Good/Good	Very Good/Good	Good/Good	Good/Good	Good/Good
Process Space Requirements (approx.) m^2	2,720	2,420	2,700	530 (w/ storage)	1,420 (finals only)
Process Air Requirements (m^3/hr)	5,730	0[1]	6,540	3,600	8,300 - 11,900
Total Estimated Sludge Production (kg/d)	5,120	4,670	4,440	4,550	4,700 – 5,150
Costs (millions of $) ○ **Capital** ○ **O&M** ○ **Life Cycle**	16.3 1.11 32.2	16.0 0.90 28.9	17.1 1.10 32.8	17.2 1.12 33.3	14.1 1.14 30.6

Notes:
1. Motor driven – no process air requirement. Media purge air included for RBC first stage shafts.
2. “Total Estimated Sludge Production” is forecast process treatment (inclusive of primary and/or secondary sedimentation basin) waste solids or waste sludge as mass/day.

6. Ranking/Rating of Secondary Treatment Options

6.1 Ranking/Rating Schedule

To evaluate each of the selected secondary options, a factor evaluation matrix has been developed. The matrix identifies the criteria to evaluate each option (e.g. capital cost) and a score assigned to each criterion (e.g. 3 – capital cost is comparatively low). In addition to a score, each criterion has been assigned a weighting factor of either 1, 3, 5 or higher. The higher the factor weight assigned to the factor, the more important or critical it is considered to the evaluation. The product of the weight and score was calculated for each factor and the sum over all the factors was used to determine the score for the alternative being evaluated. The factor evaluation matrix is shown in **Table 12**.

TABLE 12:
Evaluation Matrix for the Brockville WPCC Secondary Treatment Process Upgrade

Factor	Weight (1,2,3)	Relative Score			Factor Score (Weight Score)
		1	2	3	
Ability to meet anticipated effluent requirements					60
BOD_5	5	Difficult	Modest	Easy	
SS	5	Difficult	Modest	Easy	
TP	5	Difficult	Modest	Easy	
NH_3-N	5	Difficult	Modest	Easy	
Ability to meet potentially more stringent future effluent criteria	5	Lower	Modest	Higher	15
On-site process expansion capability	5	Lower	Modest	Higher	15
Ability to treat peak:					30
Flows	5	Difficult	Modest	Easy	
Loading (incl. shock)	5	Difficult	Modest	Easy	
Capital cost	15	High	Medium	Low	45
Ongoing Expenses					45
Maintenance	5	High	Medium	Low	
Staff requirements/costs	5	High	Medium	Low	
Operations (excl. staff)	5	High	Medium	Low	
Impact on existing/not upgraded unit processes	5	Excessive	Some Impact	Minimal	15
Sludge/Biosolids Management					30
Volume of sludge generated	5	High	Medium	Low	
Ability of digesters to handle biosolids	5	Difficult	Possible	Easy	
Common / Proven application and experience of technology	3	Not Common	Modest	Common	9
System complexity	3	High	Modest	Low	9
System flexibility	3	Low	Modest	High	9
Ability to achieve consistent non-toxic effluent	3	Lower	Medium	Higher	9
Maintained compatibility with surroundings - mitigation efforts required	3	Higher	Modest	Low	9
Operator Expertise Requirements	1	High	Medium	Low	3
Modular design/expansion potential	1	Poor	Medium	Excellent	3
TOTAL SCORE FOR ALTERNATIVE					306 (100%)

6.2 Evaluation

Using the evaluation matrix outlined in **Table 12**, scores for each factor have been determined and are presented in **Table 13**. The factor scores attempt to reflect the economics, performance and other decision factors associated with determining the preferred secondary processes for the Brockville WPCC Upgrade.

TABLE 13:
Scoring of Secondary Process Options for Brockville

Factor	Score				
	ASP	RBC	SBR	BAF	MBBR
Ability to meet anticipated effluent requirements					
BOD_5	3	3	3	3	3
SS	2	1	2	3	2
TP	2	2	2	3	2
NH_3-N	3	3	3	3	3
Ability to meet potentially more stringent future effluent criteria	2	2	2	3	2
Process expansion capability on-site	2	2	2	3	3
Ability to treat peak:					
Flows	2	3	2	2	2
Loading (incl. shock)	3	3	3	2	2
Capital cost	2	2	1	1	3
Ongoing Expenses					
Maintenance	2	2	2	2	2
Staff requirements/costs	2	3	2	2	3
Operations (excl. staff)	3	2	3	2	2
Impact on existing/not upgraded unit processes	3	2	3	1	2
Sludge/Biosolids Management					
Volume of solids generated	2	3	3	3	3
Quality of sludge for treatment	3	2	3	2	2
Common / Proven application and experience of technology	3	2	2	2	1
System complexity	2	3	1	1	2
System flexibility	2	1	3	2	1
Concern of ability to achieve consistent non-toxic effluent	3	3	3	3	3
Potential negative neighbour impact (e.g. odour emissions during upset)	2	2	2	3	2
Operator knowledge requirements	2	3	2	2	3
Modular design/expansion potential	2	3	3	3	3

Each factor was assessed for each process to determine the scoring from 1 to 3. General observations for each factor are presented below.

Effluent Requirements

All processes can meet the effluent requirements identified; however, some processes have additional potential for enhanced effluent and/or consistent effluent. All systems can consistently meet the BOD limit, fixed film systems (i.e. RBC and MBBR) often produce a more turbid effluent that may impact the solids in the effluent and associated particulate phosphorus. The BAF provides some filtration and will consistently provide lower solids concentrations than the other processes.

Ability to Handle Peaks

It is expected that all of the treatment systems can be designed to satisfactorily handle the peak flows at the plant; the RBC scored higher as this process has the lowest potential for process and/or hydraulic limitations at peak flows. Shock loadings should be able to be handled by most processes; the BAF and MBBR scored lower because both these processes are high rate systems with short retention times.

Ongoing Expenses

The processes have varying types and different aspects of maintenance, (e.g. SBR has decanter, MBBR has screens in aeration process, etc.), but were scored similarly. Staff requirements were scored highest for the RBC and MBBR systems since these processes are of relatively low process control design and have less equipment systems requiring staff monitoring relative to the other processes.

Impact on Existing Processes

Again all the processes have varying aspects of potential impact on the existing processes, but were scored similarly. The ASP processes (ASP and SBR) systems could retain existing pretreatment and could be controlled with co-thickening the biosolids with the primary sludge. The RBC and MBBR sludges may have different characteristics and require different handling (e.g. thickening), and the MBBR requires a very fine screen. The BAF process will provide the most dilute waste solids and the largest volume (i.e. approximately 15% of the treated flow).

Sludge/Biosolids Management

The Activated Sludge process (ASP) scored lower has it had the highest total estimated sludge production. All waste sludges generated can be stabilized with anaerobic digestion, however in terms of the quality of solids/sludges for further treatment, the fixed film systems will tend to have more dilute solids and therefore these systems have been rated lower than the suspended growth systems.

System complexity and flexibility

The BAF and SBR processes operate on a cyclic basis and therefore involve sequenced control systems and are inherently more complex. The RBC and MBBR are less controllable and therefore are less complex, but consequently also less flexible.

The RBC and MBBR processes have few or no points of operator intervention in terms of controls to account for excess or undesirable biomass. The RBC process is provided with an air scouring system to assist in controlling excess growth, but no other control methods are available to select desirable biomass such as selector zones, controlling returns, chlorinating returns etc. The proposed 3-stage flow through MBBR process also has no return or selector zone controls (although they can be introduced in an optional process configuration). However with no biomass control, this also means that these processes are simpler as they do not have internal recycles to be considered.

Other Factors

All systems can meet toxicity targets; with the recognition that RBC and BAF effluent may have reduced ability to be disinfected with UV due to lower transmittance (RBC) or type of solids generated (BAF). All biological processes have the potential for odour generation on occasion. The BAF influent is directed through the bottom of the filter and the aerated media is relatively contained, therefore the potential for odour release with the BAF process is reduced. Secondary processes require additional knowledge to assist with the control these biological processes, in this case the RBC and MBBR processes have been scored higher since these processes are relatively simpler in design and operation, and have neither periodic cyclic operations or biological recycle. The RBC, BAF and MBBR have the easiest ability to be modularly designed and can be expanded in comparatively small steps. The SBR is also well suited to modular design and expandability, relative to the ASP processes, just not in as small steps as the RBC, BAF, and MBBR.

Based on the scoring shown in **Table 13** and the weighting in **Table 12** the overall results for each process are summarized in **Table 14** out of a total score of 306. The weighted scores for each process are relatively close, all are within a +/- 5% band of the average score of 231. The top three processes, ASP, BAF and MBBR had a very close total weighted score, and the RBC and SBR scored comparatively lower.

TABLE 14:
Summary of Weighted Scoring

Process	Total Weighted Score
Activated Sludge (ASP)	235
Rotating Biological Contactor (RBC)	229
Sequential Batch Reactor (SBR)	223
Biological Aerated Filter (BAF)	233
Moving Bed Bioreactor (MBBR)	233

8. Overall Assessment Results

Overall any of the secondary processes short-listed as alternatives for the Brockville WPCC upgrade could meet the limits for the effluent. Each could be a viable process and each provides advantages and disadvantages. Costing was undertaken for each process using a standardized approach (i.e. CapdetWorks) and these costs were updated to reflect supplier costs for the equipment particular to each process, and other treatment process requirements. Based on this evaluation the capital cost for the MBBR was lowest, then the RBC and ASP process, and then by the SBR and BAF which had a similar but higher estimated secondary treatment process capital cost. Estimated O&M costs, including associated allowances, are relatively similar for each process, and therefore the trend for the present value or life cycle evaluation is similar to the capital cost numbers.

Based on the established evaluation criteria and weighting, the ASP scored the best, followed closely by the BAF and MBBR processes. The RBC and SBR processes received marginally lower application specific total weighted scores. Overall the three processes of high rate ASP, BAF and MBBR effectively scored the same. It is recommended that these three secondary processes be considered as preferred alternatives for the Brockville WPCC secondary treatment upgrade, and that further evaluation be undertaken as a component of the preliminary design activities.