Volume 3:

Evaluation of Alternatives

Appendix H:

Evaluation of Alternative Solutions

Criteria	Evaluation of Alternative Solutions						
	Alt. 1 **Expand Clarkson WRRF only (518 MLD / 500MLD); New PS at G.E. Booth WRRF**	**Alt 2A** **Expand Both WRRFs (550MLD / 450MLD); New Outfall at G.E. Booth WRRF**	**Alt 2B** **Expand Both WRRFs (550MLD / 450MLD); New PS at G.E. Booth WRRF and divert 150 MLD peak flows**	**Alt 3** **Expand Both WRRFs (550MLD / 500MLD); New Outfall at G.E. Booth WRRF**	**Alt 4A** **Expand Both WRRFs (600MLD / 400MLD); New Outfall at G.E. Booth WRRF**	**Alt 4B** **Expand Both WRRFs (600MLD / 400MLD); New PS at G.E. Booth WRRF and divert 300 MLD peak flows**	**Alt 5** **Expand Both WRRFs (600MLD / 500MLD); New Outfall at G.E. Booth WRRF**
Natural Environment							
Terrestrial System	The G.E. Booth WRRF has significant woodlot habitats in the northwest and southwest portions of the site, as well as the storage lagoon ponds. Natural features adjacent to the G.E. Booth WRRF site include Applewood Creek, Serson Creek, the Significant Marie Curtis Park Woodlot Complex, and natural habitats being constructed as part of JTLCA. Consequently, alternatives with larger expansion of the G.E. Booth WRRF have more potential to impact terrestrial systems. The Clarkson WRRF has limited significant natural features on and surrounding the site; impacts on terrestrial systems will be minor.						
	7	5	5	5	3	3	3
Aquatic System	Alternatives with the largest capacity expansions at the G.E. Booth WRRF have greater potential to impact the aquatic habitats and species in Applewood Creek, the on-site stormwater wetland, and the wetlands in JTLCA. Alternatives with no new outfall at the G.E. Booth WRRF may have more potential to impact aquatic systems, because the existing outfall extends only about 1.4 km offshore, and as flows through the outfall increase, the size and area of the effluent plume will increase. The plume may impinge on the nearshore, impacting water quality and associated aquatic habitats. The Clarkson WRRF is outside the Lakeside Creek and Lake Ontario floodplain, and its outfall has sufficient capacity under all alternatives and extents over 2 kms into Lake Ontario. There is little risk to aquatic systems on site or in the nearshore of Lake Ontario.						
	3	8	3	8	6	3	6
Lake Ontario Water Quality	Alternatives with no new outfall at the G.E. Booth WRRF may have more potential to impact nearshore water quality, as the effuent plume may impinge on the nearshore as flows increase. The Clarkson WRRF outfall has capacity under all alternatives and extends over 2 km into Lake Ontario. There is little risk of nearshore water quality, water treatment plant intakes, Lakeside Creek, or Lake Ontario floodplains being impacted.						
	5	8	3	8	8	3	8
Groundwater Water Quality and Quantity	All alternatives are not expected to impact groundwater quality or quantity. Measures to mitigate impacts on groundwater quality and quantity during construction will be implemented.						
	7	7	7	7	7	7	7
Air Quality	Alternative solutions will be designed to include emission control and treatment such that emissions meet all air quality standards. However, with the mid-to-high rise residential buildings being planned as part of the Lakeview Development, there may be challenges meeting the incinerator point-of-impingement requirements for the alternatives with higher treatment capacities at the G.E. Booth WRRF.						
	7	6	6	6	4	4	4
Climate Change	All alternatives will include energy recovery and reuse technologies to help reduce greenhouse gas (GHG) emissions. Alternatives with the largest expansions will have less opportunities to reduce GHG emission from WRRF processes. In addition, alternatives that include an effluent pumping station will have less opportunities for energy recovery/reuse given their need for large standby power equipment.						
	6	8	6	8	7	4	5
Total Score (Out of 60)	**35**	**42**	**30**	**42**	**35**	**24**	**33**
Normalized Score (Total 25)	**14.6**	**17.5**	**12.5**	**17.5**	**14.6**	**10.0**	**13.8**
Natural Environmental Preference Rating	**2nd**	**1st**	**4th**	**1st**	**2nd**	**5th**	**3rd**

Criteria	Evaluation of Alternative Solutions						
	Alt. 1 **Expand Clarkson WRRF only (518 MLD / 500MLD); New PS at G.E. Booth WRRF**	**Alt 2A** **Expand Both WRRFs (550MLD / 450MLD); New Outfall at G.E. Booth WRRF**	**Alt 2B** **Expand Both WRRFs (550MLD / 450MLD); New PS at G.E. Booth WRRF and divert 150 MLD peak flows**	**Alt 3** **Expand Both WRRFs (550MLD / 500MLD); New Outfall at G.E. Booth WRRF**	**Alt 4A** **Expand Both WRRFs (600MLD / 400MLD); New Outfall at G.E. Booth WRRF**	**Alt 4B** **Expand Both WRRFs (600MLD / 400MLD); New PS at G.E. Booth WRRF and divert 300 MLD peak flows**	**Alt 5** **Expand Both WRRFs (600MLD / 500MLD); New Outfall at G.E. Booth WRRF**
Social - Cultural							
Odour	Odour control measures are in place at both WRRFs. Although there are no odour complaints associated with the Clarkson WRRF operations, there have been odour concerns with the operation of the G.E. Booth WRRF, due to its proximity to sensitive residential receptors. Odour control measures will continued to be implemented to manage odours from operations for all alternatives, with particular emphasis on controls at the G.E. Booth WRRF. It is expected that alternatives with the largest capacity expansions at G.E. Booth WRRF will required the most odour controls.						
	7	6	6	6	4	4	4
Noise/Vibrations	Noise attenuation measures will be implemented to manage noise from WRRF operation for all alternatives, resulting in a decrease in the risks of off-site noise. However, it is expected that alternatives with larger capacity expansions at G.E. Booth WRRF will have the greatest potential for noise concerns, and require more noise control measures. Vibrations are not expected to be a concern of the WRRF operations.						
	8	7	7	7	5	5	5
Visual Aesthetics	The visual aesthetics of the G.E. Booth WRRF will be a concern of the local community, including the new Lakeview Community development adjacent to the plant site. The larger the expansion of the G.E. Booth WRRF, the more visual aesthetics will be a concern. With the Clarkson WRRF located in an industrial area, visual aesthetics of the facility are not expected to be as much of a concern. Site landscaping and facility design will be part of all alternatives.						
	8	7	7	7	4	4	4
Truck Traffic	Truck traffic during operation will be required at each site to transport treated biosolids to off-site utilization areas, as well as for operational and maintenance purposes. Truck traffic in and out of Clarkson WRRF avoids residential areas; while truck traffic to and from the G.E. Booth WRRF has the potential to impact businesses on Lakeshore and the proposed Lakeview Community Development. The alternatives involve treatment and management of biosolids at each plant separately, therefore the larger the Clarkson WRRF expansion the more potential for truck traffic to utilize biosolids.						
	6	5	5	6	7	7	4
Disruption During Construction	All alternatives will have similar impacts during construction, which will be mitigated. The larger the expansion at G.E. Booth WRRF the more potential for short-term construction related impacts however, given the sensitivity of surrounding areas, landowners and users. The construction of a new outfall at the G.E. Booth WRRF will also have short-term impacts on the newly constructed JTLCA. Alternatives with the highest capacity expansion at G.E. Booth WRRF will have the most disruption during construction, although impacts will be mitigated.						
	6	5	5	5	3	3	3
Property Acquisition and Easement Requirements	There are no property acquisition requirements for any of the alternatives. All expansion can be accommodated on the existing sites. Easements will be required in Lake Ontario for alternatives that include a new outfall.						
	9	8	9	8	8	9	8
Recreational Use and Users	Alternatives with no new outfall at the G.E. Booth WRRF may have more potential to impact water quality, and associated shoreline and nearshore recreational activities, because the existing outfall at the G.E. Booth WRRF extends only about 1.4 km offshore, and as flows through the outfall increase, the size and area of the effluent plume will increase. The plume may impinge on the nearshore, thereby impacting shoreline and water users. The Clarkson WRRF outfall has capacity under all alternatives and extends over 2 km into Lake Ontario. There is little risk of nearshore water quality of water treatment plant intakes being impacted. There is also more residential land users in the vicinity of the G..E. Booth WRRF that may be impacted from odour during operations, with more potential for impacts the larger the expansion.						
	6	8	5	8	8	5	8

Human Health and Well Being	All alternatives will be designed to ensure air emission and effluent quality requirements are met to protect human health and the environment. Alternatives with no new outfall at the G.E. Booth WRRF may have some challenges meeting Lake Ontario Provincial Water Quality Objectives (PWQO) in the nearshore and not interfering with WTP intake protection zones (IPZs) as flows increase.						
	7	9	7	9	9	7	9
Existing and Future Adjacent Land Use Compatibility	The Clarkson WRRF is in an industrial area and is consistent with the existing and planned uses. The G.E. Booth WRRF is located within an urban community, with the new Lakeview Village Development planned adjacent to the WRRF, and is therefore currently not compatible with existing and future land uses. All alternatives allow Peel the opportunity to develop the G.E. Booth WRRF site so that it is more consistent with future land uses through implementation of enhanced odour and noise controls, and visual facility and site improvements. Alternatives with a new outfall also allow Peel to protect nearshore water quality to ensure compatibility with the JTLCA.						
	7	7	6	7	6	4	6
Archaeology & Natural Heritage	The Stage 1 and 2 Archaeological Assessments indicate that the potential for archaeological resources on site is low at both WRRFs. No cultural heritage features in the vicinity of the WRRFs are expected to be impacted.						
	9	9	9	9	9	9	9
Total Score (Out of 100)	**73**	**71**	**59**	**63**	**54**	**50**	**51**
Normalized Score (Total 25)	**18.3**	**17.8**	**14.8**	**15.8**	**13.5**	**12.5**	**12.8**
Social-Cultural Preference Rating	**1st**	**1st**	**3rd**	**2nd**	**4th**	**5th**	**5th**

Criteria	Alt. 1 Expand Clarkson WRRF only (518 MLD / 500MLD); New PS at G.E. Booth WRRF	Alt 2A Expand Both WRRFs (550MLD / 450MLD); New Outfall at G.E. Booth WRRF	Alt 2B Expand Both WRRFs (550MLD / 450MLD); New PS at G.E. Booth WRRF and divert 150 MLD peak flows	Alt 3 Expand Both WRRFs (550MLD / 500MLD); New Outfall at G.E. Booth WRRF	Alt 4A Expand Both WRRFs (600MLD / 400MLD); New Outfall at G.E. Booth WRRF	Alt 4B Expand Both WRRFs (600MLD / 400MLD); New PS at G.E. Booth WRRF and divert 300 MLD peak flows	Alt 5 Expand Both WRRFs (600MLD / 500MLD); New Outfall at G.E. Booth WRRF
Technical							
Effectiveness	The alternatives with a new outfall are the most effective at meeting stated project objectives - wastewater, biosolids, and wet weather flow management (to 2041). There is a risk of the existing outfall not meeting nearshore water quality objectives as flows to the G.E. Booth WRRF increase. There is risk associated with relying on the East-to-West diversion to divert peak flows during wet weather events, given its location in the service area. Wet weather events occurring south of the diversion will not be able to be diverted and could be substantial.						
	6	9	4	9	9	4	9
Long-term Sustainability and Flexibility	Alternatives with the highest capacity expansions at the G.E. Booth WRRF may limit the ability to implement new technologies in the future, as an expansion of this size will extend into the lagoon area taking up much of the available site capacity. Maintaining the G.E. Booth WRRF at its rated capacity may limit treatment flexibility in the future as it limits flow diversion options. Alternatives with peak flow diversion limit treatment flexibility at the Clarkson WRRF by utilizing the additional excess capacity in the Clarkson WRRF outfall.						
	2	7	4	9	6	4	6
Ease of Operation	Alternatives with peak flow diversion may present challenges in operating the east-to-west flow diversion chambers intermittently during wet weather events. In addition, the alternatives with an effluent pumping station have more operational complexity than those with a new outfall.						
	4	8	3	8	8	3	8
Redundancy	All alternatives will be designed to provide treatment redundancy during emergency and maintenance conditions. However, there may be challenges to provide treatment redundancy during wet weather events at both the G.E. Booth WRRF and the Clarkson WRRF that rely on a diversion of peak flows during wet weather flow events.						
	4	8	4	9	8	4	8
Compatibility with Existing Infrastructure System	Alternatives with lower plant capacity expansions at the Clarkson WRRF do not take full advantage of the east-west flow diversion strategy. Likewise, maintaining the G.E. Booth WRRF at its current rated capacity does not take full advantage of the east-west flow diversion strategy.						
	3	8	8	9	3	3	8
Geotechnical and Hydrogeology	The on-site geotechnical and hydrogeological conditions at both the G.E. Booth WRRF and the Clarkson WRRF will not present significant challenges during construction, as site conditions and mitigation measures at both sites are well understood. Alternatives with a new outfall at the G.E. Booth WRRF will present more geotechnical challenges. Additional off-shore geotechnical investigations will be required to confirm construction techniques and mitigation measures before construction of a new outfall.						
	8	6	8	6	6	8	6
Contaminated Soils	All alternatives will have the potential to impact Areas of Potential Environment Concern (APECs) on both the G.E. Booth WRRF and Clarkson WRRF sites. Additional investigations and analysis may be required, and appropriate mitigation and remediation methods implemented. The larger the expansion, the more potential to impact on-site APECs at both WRRF sites.						
	8	7	7	7	5	5	4
Energy use and Recovery	Expansion of both WRRFs will allow for opportunities to further promote energy use and recovery. In particular, opportunities exist to increase energy recovery associated with biosolids generation and treatment at Clarkson WRRF. Alternatives with pumping will be somewhat less energy efficient.						
	6	7	6	8	**6**	**6**	8

Climate Change Adaptability	All alternatives will be designed to be adaptable to change climate change, by minimizing the risk of wet weather flows impacts on treatment processes. Alternatives without no new outfall at the G.E. Booth WRRF may not be as adaptable to raising lake levels as a consequence of climate change.						
	4	8	4	8	8	4	8
Permits and Approvals	Alternatives with peak flow diversion may take longer to approve, as there may be challenges in meeting MECP receiving water quality requirements using the existing outfall at the G.E. Booth WRRF. Alternatives with the greater capacity increases at G.E. Booth WRRF may also face approval challenges given the proximity of the new Lakeview Community development. Receiving approvals for expansion of the Clarkson WRRF are not expected to be as challenging as obtaining approvals for expansion of the G.E. Booth WRRF.						
	3	6	2	6	4	2	4
Total Score (Out of 100)	**48**	**74**	**50**	**79**	**63**	**43**	**69**
Normalized Score (Total 25)	**12.0**	**18.5**	**12.5**	**19.8**	**15.8**	**10.8**	**17.3**
Technical Preference Rating	**6th**	**2nd**	**5th**	**1st**	**4th**	**7th**	**3rd**

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Economic							
Capital Cost	All alternatives involve a significant capital investment, ranging from $850 to $1200 M; Alternatives without the new outfall are at the lower end of the range; while those with the new outfall are at the higher end of the range. Alternative 5, which has an outfall and the largest WRRF expansion has the highest capital costs.						
	5	3	5	3	3	5	1
Operating and Maintenance (O&M) Costs	All alternatives will have comparable O&M costs, with the exception of alternatives with an effluent pumping station. Operating costs of a pumping station are higher than those alternatives that include a new outfall at the G.E. Booth WRRF.						
	4	6	4	6	6	4	6
Cash Flow	All Alternatives have similar construction scheduling periods, with the exception of Alternative 4, which has both plants being constructed during similar time periods. Peel would have large capital expenditures during a shorter time period. Alternatives which include an effluent pumping station at the G.E. Booth WRRF and diversion of peak flows help Peel reduce capital expenditures during the planning period for this study (to 2041). However, an outfall at the G.E. Booth WRRF will still eventually be required to meet future peak flow requirements.						
	4	6	4	6	2	2	6
Total Score (Out of 30)	**13**	**15**	**13**	**15**	**11**	**11**	**13**
Weighted	**25**	**25**	**25**	**25**	**25**	**25**	**25**
Normalized Score (Total 25)	**10.8**	**12.5**	**10.8**	**12.5**	**9.2**	**9.2**	**10.8**
Economic Preference Rating	**2nd**	**1st**	**2nd**	**1st**	**3rd**	**3rd**	**2nd**

Criteria	Evaluation of Alternative Solutions						
	Alt. 1 **Expand Clarkson WRRF only (518 MLD / 500MLD); New PS at G.E. Booth WRRF**	**Alt 2A** **Expand Both WRRFs (550MLD / 450MLD); New Outfall at G.E. Booth WRRF**	**Alt 2B** **Expand Both WRRFs (550MLD / 450MLD); New PS at G.E. Booth WRRF and divert 150 MLD peak flows**	**Alt 3** **Expand Both WRRFs (550MLD / 500MLD); New Outfall at G.E. Booth WRRF**	**Alt 4A** **Expand Both WRRFs (600MLD / 400MLD); New Outfall at G.E. Booth WRRF**	**Alt 4B** **Expand Both WRRFs (600MLD / 400MLD); New PS at G.E. Booth WRRF and divert 300 MLD peak flows**	**Alt 5** **Expand Both WRRFs (600MLD / 500MLD); New Outfall at G.E. Booth WRRF**
Total Scores							
Natural Environment	14.6	17.5	12.5	17.5	14.6	10.0	13.8
Social/Cultural	18.0	17.8	14.8	15.8	13.5	12.5	12.8
Technical	12.0	18.5	12.5	19.8	15.8	10.8	17.3
Economic	10.8	12.5	10.8	12.5	9.2	9.2	10.8
	55%	**66%**	**51%**	**66%**	**53%**	**42%**	**55%**
Alternative Ranking				**Preferred**			

Note: Alternative 3 was selected as the preferred over Alternative 2A as it provides Peel with better long-term sustainability and reliability in wastewater treatment, by providing more capacity at the Clarkson WRRF. Selecting solutions that are sustainable and reliable are key objectives of the Region of Peel.

Appendix I:

Description and Screening of Long List of Wastewater Treatment Technologies

Clarkson Water Resource Recovery Facility
Schedule C Class Environmental Assessment

Technical Memorandum

Description and Screening of Long List of Wastewater Treatment Technologies

3/29/2022

VERIFIED AND APPROVED					
Rev	**Prepared By**	**Date**	**Verified By**	**Date**	**Issue/Revision Description**
1	Maria Bovtenko / Gustavo Arvizu	July 6, 2021	Troy Briggs	July 6, 2021	Final Draft
2	Maria Bovtenko / Gustavo Arvizu	March 2, 2022	Troy Briggs	March 2, 2022	Final

AUTHORIZED AND DISTRIBUTED					
Rev	**Authorized By**	**Date**	**Issued To**	**Date**	**Copies**
1	Troy Briggs	July 6, 2021	Laurie Boyce	July 6, 2021	1
2	Troy Briggs	March 2, 2022	Laurie Boyce	March 2, 2022	1

Final Review QA/QC Review – Rev. 1		
Date	**Name**	**Signature**
Jul 6, 2021	Troy Briggs, P. Eng.	[signature]
Jul 25, 2021	Zhifei Hu, P.Eng.	[signature]
Jul 27, 2021	Laurie Boyce, M.A.	[signature]

Final Review QA/QC Review – Rev. 2		
Date	**Name**	**Signature**
March 2, 2022	Troy Briggs, P. Eng.	[signature]
March 18, 2022	Zhifei Hu, P.Eng.	[signature]
March 29, 2022	Laurie Boyce, M.A.	[signature]

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LIST OF FIGURES

Term or Acronym	Definition
AA	Archaeological Assessment
ACM	Asbestos Containing Material
ANSI	Area of Natural and Scientific Interest
APEC	Area of Potential Environmental Concern
Approx.	Approximately
AST	Above Ground Storage Tank
BBO	Open Beach/Bar
BTEX	Benzene, Toluene, Ethylbenzene, and Xylene
°C	Degrees Celsius
CBOD or CBOD5	Carbonaceous Biochemical Oxygen Demand
CFC	Chlorofluorocarbon
cfu	Colony forming units
CIC	Commercial/Industrial
CO2	Carbon Dioxide
CUH	Cultural Hedgerows
CUM	Cultural Meadow
CTC	Credit Valley-Toronto and Region-Central Lake Ontario Conservation Authorities
CVC	Credit Valley Conservation
d	Flow depth
D	Diameter
dBA	Decibels Adjusted
DEC	District Energy Centre
DMP	Development Master Plan
dT/d	Dry Tonnes per Day
EA	Environmental Assessment
EASR	Environmental Activity and Sector Registry
ECA	Environmental Compliance Approval
E. coli	Escherichia Coli
Elev.	Elevation
ESR	Environmental Study Report
FOD	Deciduous Forest
GAC	Granular Activated Carbon
GGH	Greater Golder Horseshoe
GHG	Greenhouse Gas
GLWQA	Great Lakes Water Quality Agreement
GPa	Gigapascal
ha	Hectare
HCFC	Hydrochlorofluorocarbons
HRT	Hydraulic Retention Time
HVAC	Heating, Ventilation, and Air Conditioning

Term or Acronym	Definition
IPZ	Intake Protection Zone
I/I	Inflow / Infiltration
IPCC	Intergovernmental Panel on Climate Change
JTLCA	Jim Tovey Lakeview Conservation Area
kg/d	Kilogram per Day
km	Kilometre
kPa	Kilopascal
L	Litre
L/s	Litre per second
LWC	Lakeview Waterfront Connection
m	Metre
MCFN	Mississaugas of the Credit First Nation
mg/d	Milligram per Day
ml	Millilitre
mm	Millimetre
MOC	Commercial/Industrial Open Space
MEA	Municipal Engineers Association
MECP	Ministry of the Environment, Conservation and Parks
MLD	Megalitres per Day
MNRF	Ministry of Natural Resources and Forestry
MTO	Ontario Ministry of Transportation
NH	Natural Heritage
OAO	Open Aquatic
OCWA	Ontario Clean Water Agency
ODS	Ozone Depleting Substances
OGS	Ontario Geological Survey
OPS	Ontario Provincial Standard
O&M	Operations and Maintenance
OPG	Ontario Power Generation
ORM	Oak Ridges Moraine
OU	Odour Units
PAH	Polycyclic Aromatic Hydrocarbon
PCB	Polychlorinated Biphenyl
PPS	Provincial Policy Statement 2014
pH	Potential of Hydrogen
PHC	Petroleum Hydrocarbons
PTTW	Permit to Take Water
PWQO	Provincial Water Quality Objectives
QEW	Queen Elizabeth Way
RCP	Representative Concentration Pathway

Term or Acronym	Definition
RSC	Record of Site Condition
RQD	Rock Quality Designation
SAR	Species at Risk
SLS	Servicing Limit State
SWH	Significant Wildlife Habitat
SWM	Stormwater Management
SWRT	Single Well Response Test
TAN	Total Ammonia Nitrogen
T/d	Tonnes per Day
TM	Technical Memorandum
ToR	Terms of Reference
TOX	Thermal Oxidation
TP	Total Phosphorus
TRCA	Toronto and Region Conservation Authority
TSS	Total Suspended Solids
UFFI	Urea Formaldehyde Foam Insulation
UFS	Urban Forest Strategy
UIA	Un-ionized Ammonia
ULS	Ultimate Limit State
UST	Under Ground Storage Tank
VOC	Volatile Organic Compound
WAS	Waste Activated Sludge
WHMIS	Workplace Hazardous Materials Information System
WRRF	Water Resource Recovery Facility
WTP	Water Treatment Plant
WWTP	Wastewater Treatment Plant

1.0 Introduction

1.1 Purpose of this TM

The Regional Municipality of Peel is completing two Schedule C Class Environmental Assessments (EAs) to identify the preferred approach to meeting future wastewater treatment needs within the Region. One Schedule C Class EA is for the G.E. Booth Water Resource Recovery Facility (WRRF) and the other is for the Clarkson WRRF, formerly referred to as Wastewater Treatment Plants (WWTPs). Schedule C Class EAs require completion of Phases 1 to 4 of the Class EA process. Phase 3 of the Class EA process focuses on alternative design concepts to implement the preferred alternative solution at each WRRF. While much of Phase 2 considered both G.E. Booth and Clarkson WRRFs together, Phase 3 activities will focus on each WRRF individually.

This TM documents the first step in the Phase 3 process, which is identification of potential technology alternatives to implement the preferred alternative solution for wastewater management and treatment at the Clarkson WRRF. Namely, alternative technologies to upgrade and expand the Clarkson WRRF from its current rated capacity of 350 MLD to a rated capacity of 500 MLD by the year 2029.

Initially, a long list of technology alternatives is defined which are screened based on "must-have" criteria to develop a short list of wastewater technologies. The short-list of technologies is then combined to develop alternative wastewater treatment design concepts to be evaluated in detail.

This is the second draft of the TM. It has been updated to reflect the inputs and comments of the Value Engineering (VE) Study (January 2022).

1.2 Technical Memorandum Outline

This TM is structured as follows:

1. Section 1 – Introduction: Describes the progress on the Class EAs.
2. Section 2 – Overview of Value Engineering (VE) study and input related to the screening of treatment processes presented in this TM.
3. Section 3 – Design Basis: Presents the design parameters for Clarkson WRRF, the current plant performance, and the expansion design basis.
4. Section 4 – Screening Criteria and Methodology: Introduces the methodology and "must have" criteria that will be used to evaluate the long list of technology alternatives.
5. Section 5 – Wastewater Management and Treatment Alternatives: A discussion and evaluation of the long list of secondary treatment and disinfection technology alternatives.
6. Section 6– Short List of Technology Alternatives: Presents the selected short list of technology alternatives to be carried forward for further evaluation.
7. Section 7 – Summary and Next Steps: Presents a summary of the development of the short list of technology alternatives. The next steps involving developing alternative design concepts are also discussed.

2.0 Value Engineering (VE) Study

To provide expert input into the Class EA process before finalizing the recommended design concept, the Region of Peel undertook a VE study. A VE workshop was held from January 24 to 27, 2022, and a VE Report was prepared. A detailed summary of the comments received, and the Project Team responses, are provided under separate cover. The VE comments related to the screening of wastewater technologies are provided in **Table 2-1**. This **TM C3-2 (Long List of Wastewater Treatment Alternatives)** has been updated to reflect comments provided by the VE team**.**

Table 2-1: VE Team Comments and Project Team Responses

VE Team Comment	Project Team Response
Evaluation should reflect the urgency of having the Clarkson WRRF expansion operational by approximately 2029. It is recommended that an additional screening criterion (schedule) be added to the evaluation to reflect the criticality of the schedule and the need to implement in a short timeframe must be considered.	Agreed. The screening criterion "Ability to Implement within Required Schedule" was added. The purpose being to screen out technologies that would risk the Region's ability to implement the project on schedule.
The VE team suggested that a more rigorous assessment of chlorination/dechlorination vs. UV disinfection be considered at the Clarkson WRRF. The VE team commented that UV disinfection meets the screening criteria and should be carried forward for further evaluation at the Clarkson WRRF.	The Project Team re-evaluated the disinfection alternative screening process and agreed that UV disinfection should be carried forward for detailed evaluation as it would reduce the facility's reliance on chemicals.
Step-feed treatment and potential for side stream BNR. The VE team suggested that step-feed treatment be considered as a separate alternative. A sidestream BNR alternative was also recommended for further consideration.	Step Feed treatment is considered a variation of the Conventional Activated Sludge and Biological Nutrient Removal process options which have been short-listed for further investigation. The same is true for sidestream BNR which is a type of BNR process. It was not deemed necessary to evaluate different design configurations individually as part of the screening process. This review will be carried out as part of the evaluation of short-listed options.

3.0 Design Basis

As part of the work completed in Phase 2 of the Class EA, design parameters were defined as shown in **Table 3-1.** These parameters will be used to evaluate the alternative design concepts. The future effluent limits and objectives were identified based on early discussions with the MECP and will be revised/confirmed through the ongoing Assimilative Capacity Study. For this memorandum, effluent limits were developed as follows:

- BOD_5 and TSS limits consistent with secondary level of treatment.
- Total Ammonia Nitrogen (TAN) limits and objectives are based on achieving a maximum 0.2 mg/L unionized ammonia at the 75th percentile effluent pH and seasonal typical temperatures.
- The phosphorus limit was conservatively selected to maintain existing ECA approved loading limits at 350 kg/d at the expanded plant capacity.

The proposed effluent objectives and limits are achievable through conventional secondary treatment without the need for tertiary filtration.

Table 3-1: Summary of Design Parameters for the Clarkson WRRF Expansion

Parameter	Design Value
Design Year	2041
Service Population	804,604
Design Flows	
Average Day Flow	500 MLD
Maximum Day Flow	850 MLD
Peak Hourly Flow	1,200 MLD
Peak Instantaneous Flow	1,500 MLD
Wastewater Characteristics[1]	
$cBOD_5$	230 mg/L
TSS	305 mg/L
TKN	30 mg/L
TP	4.6 mg/L
Minimum Month Temperature	10.8°C
Alkalinity	233 mg/L
Anticipated Effluent Limits[2]	
$cBOD_5$	25 mg/L
TSS	25 mg/L
TAN	13.0 mg/L (May 1 - May 31) 10.0 mg/L (Jun 1 – Sep 30) 13.0 mg/L (Oct 1 – Oct 31) 24.0 mg/L (Nov 1 - Apr 30)
TP	0.70 mg/L
E. Coli	200 organisms per 100 mL
Anticipated Effluent Objectives[2]	
$cBOD_5$	15 mg/L
TSS	15 mg/L

Parameter	Design Value
TAN	5.0 mg/L (May 1 - Oct 31) 12.0 mg/L (Nov 1 - Apr 30)
TP	0.60 mg/L
E. Coli	150 organisms per 100 mL

Notes:
1. The plant is expected to receive 350 MLD from the West Trunk Sewer and 150 MLD of flow diverted from the East Trunk Sewer (as part of the East-West Diversion Project). The raw wastewater characteristics in this design basis were defined based on weighted averages of the concentrations from each trunk sewer.
2. Effluent limits and objectives require confirmation through Assimilative Capacity Study and MECP.

3.1 Current Capacity Assessment

The existing Clarkson WRRF consists of two (2) parallel conventional activated sludge facilities known as Plant 1 and Plant 2. Together, the two plants have a rated average daily flow capacity of 350 MLD.

A capacity assessment was also completed for the major unit processes at the Clarkson WRRF to evaluate the capacity of the existing facility. The assessment was based on traditional desktop analytical methods, using historical plant operational data, plant design criteria, process train capacities as stated in the ECA and MECP design guidelines. The findings of the capacity assessment were documented in *Phase 2 – Draft Technical Memorandum – Development of Alternative Solutions (December 2020)*.

The capacity of each plant unit process relative to the facility's rated capacity of 350 MLD is shown in **Figure 3-1.** The graphs are colour coded based on the capacity limiting condition for each unit process as follows:

- Unit processes limited by average day flow/loadings are shown in blue.
- Unit processes limited by peak daily flows are shown in green.
- Unit processes limited by peak hourly flows are shown in orange.
- Unit processes limited by peak instantaneous flows are shown in yellow.

As shown, it was determined through the assessment there is a small capacity limitation within the existing secondary clarifiers at design peak hourly flows.

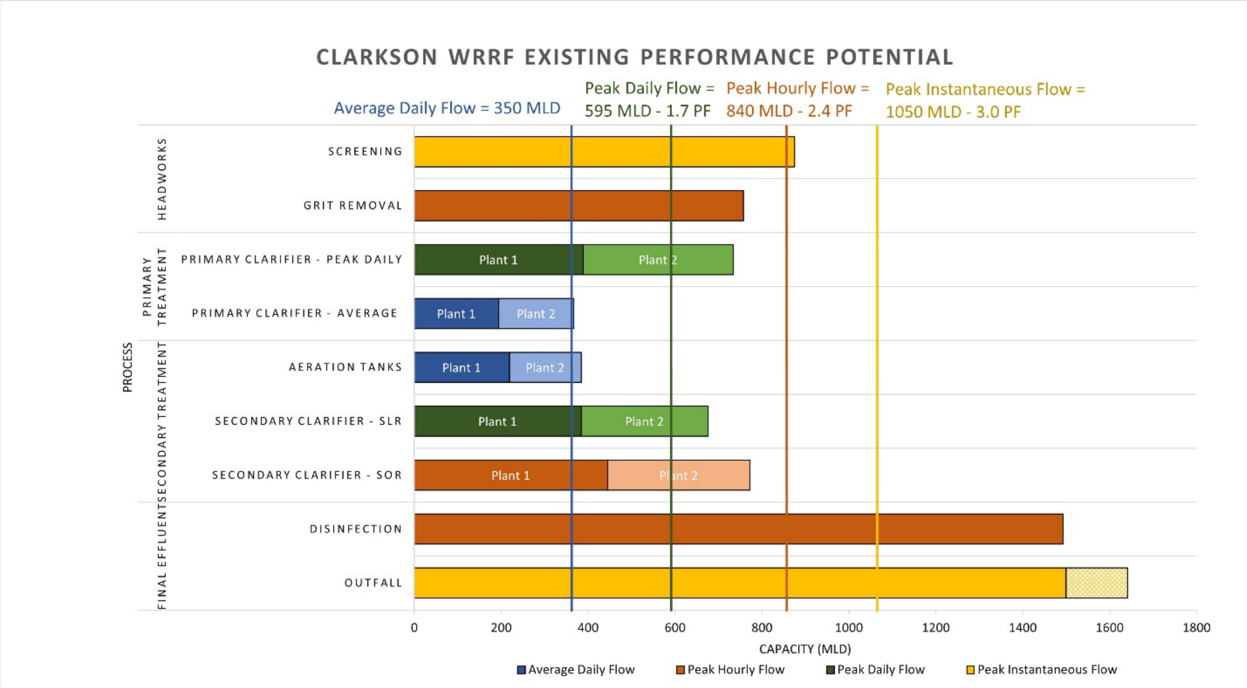

Figure 3-1: Existing Capacity Assessment at Clarkson WRRF

4.0 Screening Criteria and Methodology

The long list of technology alternatives is screened in this report to define a short list to be evaluated further for implementation at Clarkson WRRF.

Table 4-1 below lists the factors/ “must have” descriptors or criteria that will be used for screening of the long list of alternative technologies. The technologies that successfully meet the criteria will be recommended for further consideration.

Table 4-1: Screening Criteria

Screening Criteria	Description
Maturity of Technology	The technology must have been in use for long enough that most of its initial operational issues and inherent problems have been removed or reduced by further development. It must be robust, reliable and have a successful track record.
Proven Application at Large WRRFs	The technology must be able to serve WRRF’s of the size of the G.E. Booth WRRF and the Clarkson WRRF. The technology will have a successful operating history at facilities of equivalent size or larger.
Compatibility with Existing and Future Processes	The technology must be compatible with the existing treatment processes at the WRRF, consider existing infrastructure investments, and be constructible give existing site conditions.
Compatibility with Regional Energy Management and GHG Reduction Goals	Offers opportunities for energy efficiency, reduction in chemical inputs or potential for resource recovery to help support Region Energy Management and GHG Reduction Goals.
Ability to Implement within Required Schedule	Capacity expansion of Clarkson WRRF is required by 2029 to accommodate projected wastewater flows. This criterion assesses the option’s impact on the implementation schedule.

5.0 Wastewater Management and Treatment Alternative Design Concepts

5.1 Overview

This section presents a long list of wastewater management and treatment technologies that could be utilized to expand the Clarkson WRRF.

WRRFs typically include the following unit processes listed in **Table 5-1.**

Table 5-1: Major Unit Processes in WRRFs

Unit Process	Function
Preliminary Treatment	Involves processes such as screening and grit removal to remove large debris and heavy, abrasive, inorganic solids. This process protects downstream equipment from excessive wear and operational issues and reduces solids handling requirements in downstream processes.
Primary Treatment	Removes suspended solids to reduce the organic and solids load on the downstream biological treatment system.
Secondary Treatment	Involves processes to encourage biological activity to remove soluble BOD_5 and suspended and non-settleable colloidal solids, nitrogen, and phosphorus. Secondary treatment processes may be modified to biologically remove nitrogen and phosphorus.
Tertiary Treatment (Optional Depending on Effluent Limits)	Includes processes such as filtration and disinfection. Filtration is typically required for facilities with low effluent TP limits (less than 0.5 mg/L).
Disinfection	Disinfection involves the destruction and/or inactivation of pathogens in the effluent prior to discharge to the receiving water.

Preliminary treatment will be expanded to maintain protection of downstream equipment and processes using similar equipment as those existing at the plant. Primary treatment will be expanded using similar technology to the existing processes since it meets the “must-have” criteria:

- Mature Technology – The existing primary treatment processes are robust, reliable, and have a proven track record.

- Proven Application at Large Plants – The existing processes have been proven to operate effectively at the Clarkson WRRF.
- Compatible with Existing and Future Process – The process is the same as existing and will be compatible in with any other processes selected in the future.
- Compatible with Region's energy management and greenhouse gas (GHG) emission reduction goals as follows:
    - Primary treatment is a low energy process that can significantly reduce energy requirements in secondary treatment.
    - Primary treatment produces raw sludge that is high in energy potential. This enables more gas production in the digestion process and more energy recovery through the on-site Combined Heat and Power (CHP) system.
- Ability to Implement within Required Schedule

Since preliminary and primary treatment processes will be similar to the existing processes, the evaluation of alternative design concepts focuses on screening a long list of secondary treatment and disinfection technologies. As discussed previously, the anticipated effluent limits for the Clarkson WRRF are achievable with secondary treatment and tertiary treatment is not required.

5.2 Screening of Long List of Secondary Treatment Technologies

The purpose of secondary treatment is to reduce the concentration of pollutants in the treated effluent. Secondary treatment processes are typically based on the activated sludge process in which naturally occurring microorganisms utilize dissolved and suspended organic and inorganic compounds contained in the wastewater. They utilize these compounds to produce more microorganisms which can be separated from the wastewater via gravity settling or other physical separation methods.

Secondary treatment processes can generally be classified into two categories: suspended growth and attached growth (film). In suspended growth processes, the microorganisms are suspended in the wastewater. In attached growth processes, the microorganisms are attached to media contained inside the treatment reactors. Secondary treatment processes are supplemented by tertiary treatment which include filtration and disinfection.

The long list of technology alternatives for secondary treatment includes both suspended and attached growth processes, which are considered feasible and applicable to the Clarkson WRRF given existing site conditions and treatment processes. The long list includes:

1) Conventional Activated Sludge (CAS)
2) CAS with Chemically Enhance Primary Treatment (CEPT)
3) CAS with Wet Weather Flow (WWF) Treatment
4) Biological Nutrient Removal (BNR)
5) Ballasted Activated Sludge
6) Membrane Bioreactors (MBR)

7) Membrane Aerated Biofilm Reactors (MABR)

8) Integrated Fixed Film Activated Sludge (IFAS) / Moving Bed Bioreactor (MBBR)

9) Sequencing Batch Reactors (SBR)

10) Aerobic Granular Sludge (AGS)

11) Biological Aerated Filters (BAF)

Descriptions of these technology alternatives as applied to the Clarkson WRRF are presented below.

5.2.1 Technology Alternative 1 – Conventional Activated Sludge (CAS)

5.2.1.1 General Process Description

In this process, wastewater flows into a primary clarifier where suspended solids settle out and primary treated effluent is directed to a bioreactor (aeration tank) where it mixes with activated sludge. Mixed liquor (the combination of primary effluent and activated sludge) in the aeration tank is mixed and aerated to stimulate the conversion of soluble and colloidal organic matter in the wastewater to microorganisms (biomass). The mixed liquor then flows to a secondary clarifier, where solids settle to the bottom of the tank and secondary treated effluent flows to the disinfection process.

A portion of the settled solids are recycled to the head of the aeration tank (return activated sludge) to maintain a consistent mixed liquor suspended solids concentration and the excess (waste activated sludge) is sent to the solids' management process train. The biosolids management facility selected would need to be capable of handling sludge loads from primary and secondary treatment.

The CAS process is shown schematically in **Figure 5-1** below.

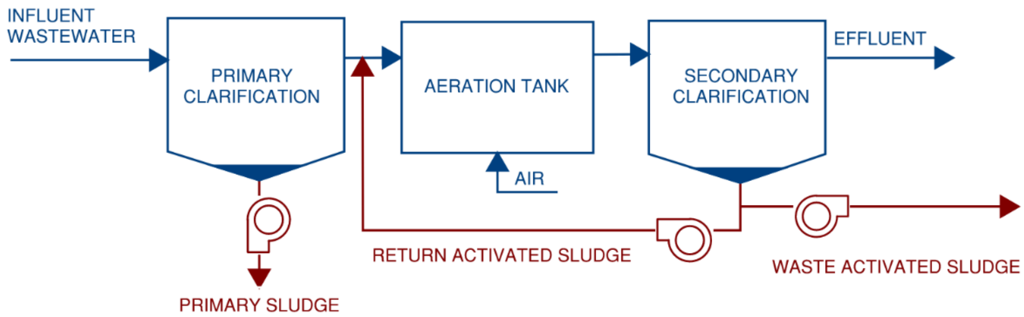

Figure 5-1: Conventional Activated Sludge Process Flow Diagram

Several variations of the CAS process exist including plug-flow, complete-mix, high-rate, contact stabilization, and step-feed systems.

The plug-flow activated sludge process is widely used and is the process currently in place in the Clarkson WRRF. As the wastewater flows through the plug-flow bioreactor, the fluid particles pass through reduced longitudinal mixing before they exit the reactor. Thus, the residence time of the wastewater (and its characteristics) is a function of its position in the aeration tank. The plug flow configuration results in relatively high organic loading at the influent end and reduced loading as wastewater travels over the length of reactor. The high organic loading at the beginning of the aeration tank often improves sludge settling beyond that realized from a completely stirred reactor. Plug flow is well suited for nitrification, denitrification, and enhanced biological phosphorous removal.

5.2.1.2 Maturity of Technology

The CAS process is the most common process for domestic wastewater treatment in the world. The effluent quality achieved by this process is typically below 10 mg/L for BOD and TSS (Metcalf & Eddy, 2014). CAS can be optimized and modified to incorporate other technologies allowing for significant flexibility. In general, flexibility, robustness, and familiarity are key advantages of the process.

5.2.1.3 Proven Application at Large WRRFs

The CAS process is the technology used at the Clarkson WRRF and G.E. Booth WRRF. The majority of large (over 100 MLD) facilities in Canada and the United States also use this process. **Table 5-2** includes some of the North American facilities with capacities similar or greater than Clarkson WRRF which use the CAS process.

Table 5-2: Facilities using CAS Process with Capacities Similar or Greater than the Clarkson WRRF

Name	Location	Rated Capacity (MLD)
Clarkson WRRF[1]	Mississauga, Ontario	350
Humber WWTP[2]	City of Toronto, Ontario	473
GE Booth WRRF[1]	Mississauga, Ontario	518
Duffin Creek WPCP[3]	Pickering, Ontario	630
Ashbridges Bay WWTP[2]	City of Toronto, Ontario	818
Newton Creek WWTP[4]	New York City, NY, USA	2,650
Atotonilco WWTP[5]	Mexico City, Mexico	4,320
Notes: 1. (Region of Peel, n.d.) 2. (City of Toronto, 2020) 3. (Durham Region & York Region, 2017) 4. (NYC Environmental Protection, 2012) 5. (Acciona, n.d.)		

5.2.1.4 Compatibility with Existing and Future Processes

The CAS process is fully compatible with the existing Clarkson WRRF facility and site since it is the process already in operation. There would be no concern with regards to the ability to convey flows by gravity through the process and discharge to the existing outfall. The operation strategy of the expanded facility would be similar to that currently in place.

The CAS process has a large footprint requirement compared to some of the newer technologies outlined in the following sections. However, the Clarkson WRRF has sufficient space to accommodate expansion using the CAS process.

5.2.1.5 Compatibility with Regional Energy Management and GHG Reduction Goals

The CAS process, including its variations, require considerable amounts of energy to satisfy aeration and reactor mixing demands. The aeration energy demand is often 40 to 60 % of the total energy usage for the overall WRRF. There are enhancements that can be integrated to reduce energy including anoxic zones and ammonia-based aeration control (ABAC).

5.2.1.6 Ability to Implement within Required Schedule

The CAS process is a proven technology and is the current technology utilized at Clarkson WRRF. Thus, this technology has simplified MECP approvals and would be easy to implement at the current site meeting the 2029 timeline.

5.2.1.7 Advantages and Disadvantages

Table 5-3 summarizes of the advantages and disadvantages of the CAS process.

Table 5-3: Summary of Advantages and Disadvantages of CAS Technology

Advantages	Disadvantages
• Proven technology – used at facilities across the world including most large facilities in Ontario and North America. • Compatible with existing site and processes – Current technology used in at Clarkson and GE Booth WRRF. • Relatively low operational complexity. • Simplified MECP approvals. • Opportunity for future retrofit with new technologies/variations of CAS. • Can be implemented by 2029.	• Large footprint. • Susceptible to occasional sludge settling problems. • Handling Wet Weather Flow can significantly increase footprint. • Relatively high energy costs.

5.2.2 Technology Alternative 2 – CAS with Chemically Enhanced Primary Treatment (CEPT)

5.2.2.1 General Process Description

The CAS process with CEPT includes the same processes as those described in **Section 5.2.1** with the addition of metal salts and polymer upstream of primary treatment. The addition of chemical coagulants such as ferric chloride or alum, neutralize colloidal particles and other low density suspended solids to facilitate the formation of floc, while polymer increases the size and density of floc (Reardon, 2005). The CEPT process can achieve higher surface overflow rates through the primary clarifiers while maintaining high removal rates of TSS and BOD (EPA, 2007). This improved removal efficiency reduces the organic and solids loading in the primary effluent and reduces the size requirement for aeration tanks. While CEPT optimizes the CAS process, it increases primary sludge production. This requires larger biosolids management facilities but has the added benefit of greater biogas production.

A schematic of the CAS process with CEPT is shown in **Figure 5-2** below.

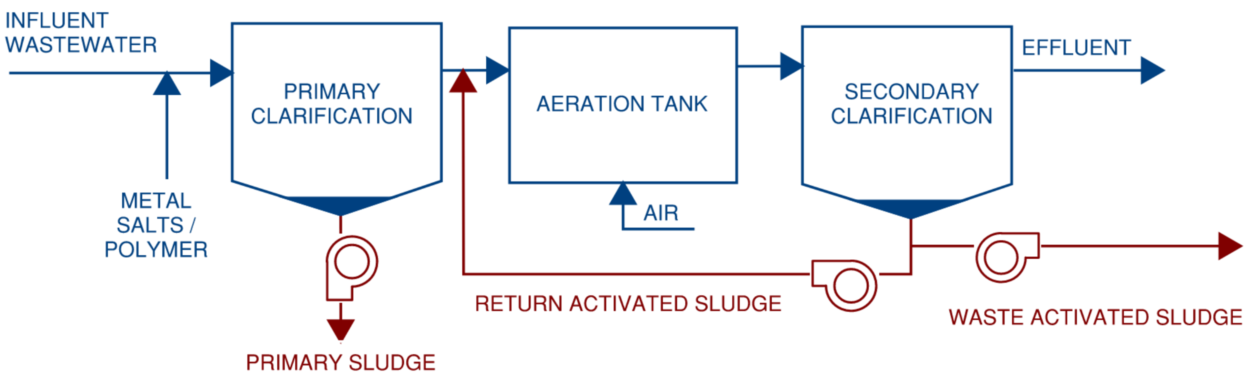

Figure 5-2: CAS Process with CEPT Schematic

5.2.2.2 Maturity of Technology

This technology is a chemical enhancement process that employs coagulation and flocculation within primary treatment. Coagulation and flocculation are very common and widely used treatment methods in water and wastewater treatment. In addition, CEPT is a commonly used method in peak wet weather flow management, since it has the ability to increase removal efficiencies of TSS from the typical range of 55 to 65% up to 85% (EPA, 2007).

5.2.2.3 Proven Application at Large WRRFs

The CAS process with wet weather CEPT is currently utilized at GE Booth WRRF. The Niagara Falls WWTP in Niagara Falls, Ontario employs this process, but the facility has a smaller capacity of 68 MLD (Niagara Region, 2018). There are some other large facilities globally that integrate CEPT into their CAS process as outlined in **Table 5-4.**

Table 5-4: Large Full-Scale Installations of the CAS Process with CEPT

Name	Location	Rated Capacity
GE Booth WRRF[1]	Mississauga, Ontario	518 MLD
Point Loma WWTP[2]	San Diego, California	587 MLD
Stonecutters Island STW[3]	Victoria Harbor, Hong Kong	2,450 MLD
Notes: 1. (Region of Peel, n.d.) 2. (City of San Diego, 2015) 3. (Government of Hong Kong, n.d.)		

5.2.2.4 Compatibility with Existing and Future Processes

Since this technology alternative is a variation of the CAS process at the Clarkson WRRF, there is no concern with compatibility. A polymer storage and dosing system would need to be constructed for the CEPT process. This process would reduce the organic loading to the aeration tanks which would reduce the aeration requirements relative to a traditional CAS process.

5.2.2.5 Compatibility with Region's Energy Management and GHG Reduction Goals

With the use of CEPT, the primary clarifier removal efficiency is increased resulting in decreased aeration requirements and energy consumption. However, with this alternative there are increased chemical costs compared to the traditional CAS process. Depending on the biosolids technology adopted, the increased primary sludge production may increase biogas generation offering benefits for additional energy recovery through combined heat and power (CHP).

5.2.2.6 Ability to Implement within Required Schedule

This process is a modification of CAS and is a proven technology with simplified MECP approvals. Thus, the implementation of this technology would be able to meet the 2029 project timeline.

5.2.2.7 Advantages and Disadvantages

Table 5-5 summarizes the advantages and disadvantages of implementing the CAS process with CEPT.

Table 5-5: Summary of Advantages and Disadvantages of the CAS Process with CEPT

Advantages	Disadvantages
• Proven technology. • Compatible with existing facilities – variation of CAS. • Improves ability to handle wet weather flows. • Increased primary sludge production with increased potential for biogas production at Clarkson WRRF. • Energy savings from reduced aeration requirements. • Simplified MECP approvals. • Can be implemented by 2029.	• Relatively large footprint. • Susceptible to intermittent sludge settling problems. • Increased chemical use and costs. • Increased chemical addition may consume alkalinity and affect nitrification performance. • Production of chemical sludge which may affect biosolids disposal options.

5.2.3 Technology Alternative 3 - CAS with Wet Weather Flow Treatment

5.2.3.1 General Process Description

In this alternative, the CAS process is optimized with the addition of a parallel high-rate treatment facility to handle peak wet weather flows. With this approach, wet weather flow (WWF) in excess of CAS capacity is treated in a separate facility. Thus, the CAS process would be sized for lower peak wet weather flow requiring smaller process tankage. A parallel physical-chemical system is well suited for WWF treatment as it has reduced space requirements, rapid start-up times, and can handle the dilute wastewater concentrations commonly observed during wet weather flows resulting from infiltration and inflow in collection systems (Reardon, 2005).

A schematic of a CAS process with a parallel WWF treatment facility is shown below in **Figure 5-3.**

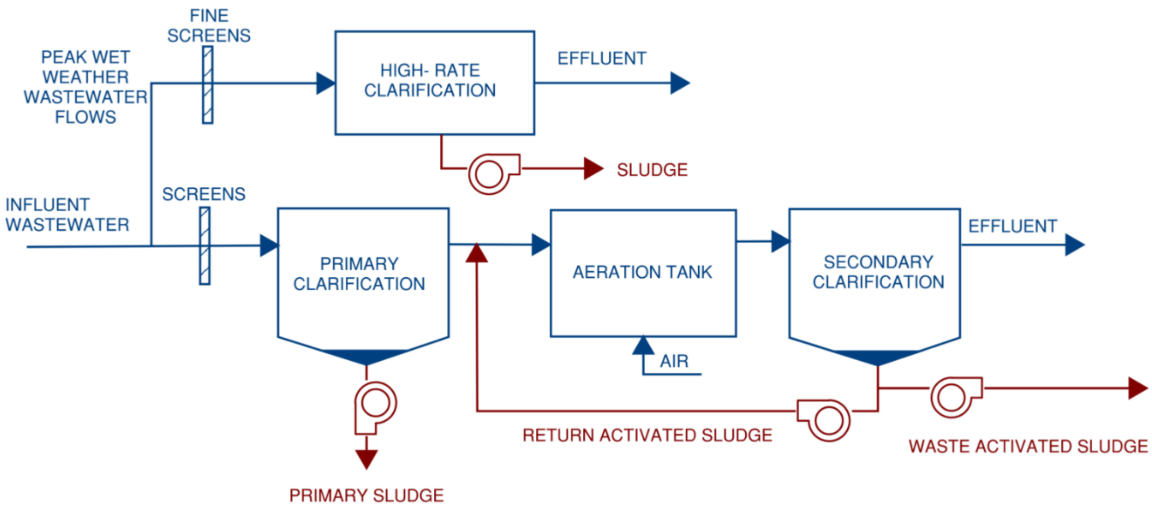

Figure 5-3: CAS Process with WWF Treatment Schematic

There are a few vendors on the market utilizing different technologies for parallel or side stream WWF treatment.

One example is ACTIFLO® which is a ballasted clarification process. Ballasted clarification is a coagulation and flocculation process which utilizes coagulant such as alum or ferric chloride with a microsand flocculent aid (ballast) to form denser, heavier floc for rapid sludge settling. Clarification performance is further improved by the use of lamellae plate settlers. The microsand is separated from the sludge slurry by centrifugal force in a hydrocyclone and reused (Veolia Water Technologies, 2020). This enhanced clarification process is similar to the ballasted activated sludge process discussed below in **Section 5.2.4.**

Another example is AquaStorm® which utilizes cloth media filtration disks for side stream high-rate solids removal for WWF. Although cloth media filtration disks are typically used for tertiary treatment, they can also be used for WWF treatment due to their proven performance. The outside – in flow pattern within the AquaStorm® system is advantageous as it creates three separate zones for solids removal (Aqua-Aerobic Systems Inc., 2019). There is the top “floatable zone” where floatable scum collects on the water surface and is removed regularly by a weir or a floatable valve (Aqua-Aerobic Systems Inc., 2019). The middle “filtration zone” is where solids are captured on the cloth media and form a mat until backwash vacuum shoes remove the solids to waste. The bottom “solids zone” is where heavier solids settle at the bottom of the tank and are removed intermittently.

It should be noted that the WWF high-rate treatment trains cannot remove soluble organics or ammonia in the wastewater as they rely only on physical/chemical solids separation processes.

5.2.3.2 Maturity of Technology

Cloth media filtration disks have been in use for tertiary filtration for over 20 years so the technology itself is mature and proven. Although the technology is mature, its application for parallel WWF treatment is new so it may require pilot testing. Ballasted clarification is a mature technology with many installations mostly in drinking water treatment and some smaller applications in wastewater treatment (Veolia Water Technologies, 2020). Testing of parallel high-rate clarification facilities have been reported to have high removal rates of TSS, BOD_5, TKN, and TP (Reardon, 2005).

5.2.3.3 Proven Application at Large WRRFs

There have been full-scale pilot studies but no permanent installations of cloth media filters for parallel WWF treatment, therefore the MECP approvals may require pilot testing. A summary of existing full-scale installations for parallel ballasted clarification high-rate WWF treatment is shown in **Table 5-6**.

Table 5-6: Full-Scale Applications of the CAS Process with Parallel WWF Treatment

Name	Location	Technology	Rated Capacity (MLD)
P Street WWTP[1]	Fort Smith, Arizona	ACTIFLO®	144
Lawrence WWTP[2]	Lawrence, Kansas	ACTIFLO®	151

Notes:
1. (CDM Smith, 2016)
2. (Veolia Water Technologies, 2020)

5.2.3.4 Compatibility with Existing and Future Processes

Overall, this alternative would be compatible with the existing processes at the plant since it is a variation of CAS. However, the high-rate treatment process may require additional pumping to the outfall.

This alternative would reduce the space required by the CAS process since WWF would be handled by the high-rate facility. However, peak WWF is not a significant concern at the Clarkson WRRF.

5.2.3.5 Compatibility with Region's Energy Management and GHG Reduction Goals

This alternative would slightly reduce the size required for the CAS process and would have minimal impact on aeration energy requirements. The high-rate facility would have additional small intermittent energy demands (during peak WWF only) for backwashing (in the case of a cloth filter process) or for mixing and microsand separation through a hydrocyclone (when using ACTIFLO®). In addition, intermediate pumping may be required due to the high headlosses through the high-rate treatment process.

5.2.3.6 Ability to Implement within Required Schedule

This technology is a variation of CAS. However, there are limited large scale applications in Ontario, which may increase MECP approval timelines. Thus, this option may affect the ability to meet the 2029 project timeline.

5.2.3.7 Advantages and Disadvantages

Table 5-7 summarizes the advantages and disadvantages associated with implementing the CAS process with WWF treatment.

Table 5-7: Summary of Advantages and Disadvantages of the CAS process with WWF Treatment

Advantages	Disadvantages
• Compatible with existing facilities – variation of CAS. • Flexibility in operation. • Wet weather flow treatment – aids in reducing solids washout during peak flows. • Smaller footprint by allowing smaller CAS facility. • High level of performance for TSS, BOD (particulate/colloidal) and TP removal.	• High headloss, may require additional pumping. • Does not remove soluble BOD and NH_3. • Limited applications in Ontario; may increase MECP approvals timelines. • Increased chemical use (in the case of ballasted flocculation). • May affect ability to implement project by 2029.

5.2.4 Technology Alternative 4– Ballasted Activated Sludge Process

5.2.4.1 General Process Description

The ballasted activated sludge process uses an inert carrier media (ballast) to enhance settling of biomass in the activated sludge process. Biomass attaches to the inert carrier media creating a larger and denser floc which settles faster. This allows clarifiers to operate at higher solids loading and surface overflow rates and thus reduces tank size requirements. The carrier media is then recovered and re-circulated back to the inlet of the tanks.

The main drawback of this technology is the risk of media migration into the WAS stream, impacting biosolids treatment.

There are several vendors for this technology. Each utilizes a different media (S:Select® with MIMICS® and BioMag®, BioActiflo®, etc.) and has different media recovery processes. The BioMag® system discussed in this section is an example of the ballasted activated sludge process. BioMag® uses magnetite (fully inert iron ore particulates) as the ballast for the biomass (Evoqua Water Technologies, 2017). The WAS from the clarifier is pumped to an in-line high-speed shear mill where magnetite is separated from the floc (Evoqua Water Technologies, 2017). A magnetic recovery drum is then used to capture the magnetite and release it back into the system for reuse. The remaining WAS is then conveyed to sludge treatment facilities.

This process requires occasional replenishing of the carrier media (although some vendors claim that their process can operate for 20 years without requiring media replenishment, but these claims cannot be validated due to the lack of long-term operation experience).

Figure 5-4 below shows a schematic of the BioMag® ballasted activated sludge process. Other vendors have very similar process schematics but with different media and media recovery technologies.

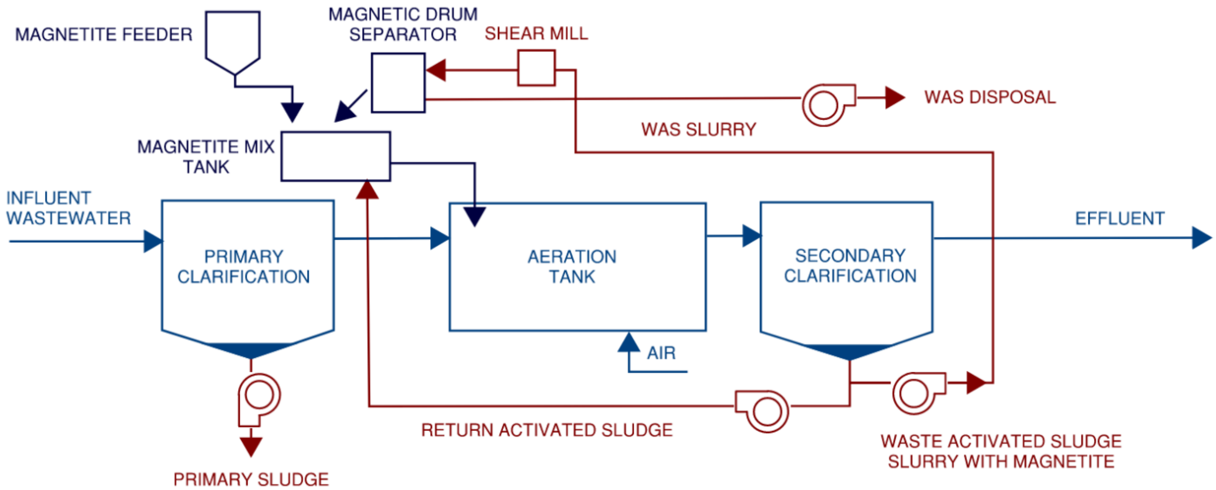

Figure 5-4: BioMag® Ballasted Activated Sludge Process Schematic (Evoqua Water Technologies, 2017)

5.2.4.2 Maturity of Technology

The ballasted activated sludge process is still maturing as most facilities have only tested the technology with few permanent installations worldwide; and none at a large scale of similar capacity to Clarkson WRRF.

5.2.4.3 Proven Application at Large WRRFs

Currently, there are no full-scale installations with capacities at the same scale as Clarkson WRRF. As a result, MECP approval will likely require site specific pilot testing. A pilot study was completed at the Kemptville WPCP in North Grenville, Ontario using BioMag®, but the plant has a small capacity – 4.5 MLD (Municipality of North Grenville, 2013). The first permanent full-scale installation will be installed at the Rugby Sewage Treatment Works in the United Kingdom as part of its expansion to 60 MLD in 2028 (Evoqua Water Technologies, 2019).

5.2.4.4 Compatibility with Existing and Future Processes

The ballasted activated sludge process is a variation of CAS with some additional equipment such as a shear mill or hydrocyclone, feeders and mix tanks. Ballasted activated sludge has a high solids removal rate which would reduce the secondary clarifier footprint requirement in comparison to CAS. The sludge that was sheared from the magnetite slurry may require thickening to increase its solids content (Evoqua Water Technologies, 2017). The existing plant has a limited hydraulic grade line, and this will limit the ability to realize the full capacity potential of this technology.

5.2.4.5 Compatibility with Regional Energy Management and GHG Reduction Goals

There are minimal energy savings opportunities using this technology as it has similar specific energy consumption as the CAS system. Some ballasted activated sludge technologies mimic the operating conditions for aerobic granular sludge (discussed below in **Section 5.2.10**) which should save energy, but these savings are vendor specific and not fully understood at this time.

5.2.4.6 Ability to Implement within Required Schedule

There are currently no full-scale applications of this technology in North America. Since this alternative will likely require site specific pilot testing and long MECP approval timelines, it may not be able to meet the 2029 expansion timeline.

5.2.4.7 Advantages and Disadvantages

Table 5-8 provides a summary of the advantages and disadvantages of the ballasted activated sludge technology.

Table 5-8: Summary of Advantages and Disadvantages of Ballasted Activated Sludge Technology

Advantages	Disadvantages
• High solids removal efficiency reducing footprint of secondary clarifiers relative to CAS.	• No full-scale applications in North America. • Long-term O&M costs not well understood. • Risk of media washout/entrainment in waste solids. • MECP approvals may require site specific pilot testing. • May not be able to meet the 2029 project timeline.

5.2.5 Technology Alternative 5 – Biological Nutrient Removal (BNR) Process

5.2.5.1 General Process Description

This process is also referred to as Enhanced Biological Phosphorus Removal (EBPR), Biological Excess Phosphorus Removal or simply Biological Phosphorus Removal. In this process, the conditions are created for the proliferation of phosphorus accumulating organisms (PAOs) which remove phosphorus by accumulating intracellular polyphosphate reserves. The amount of phosphorus removed by PAOs is almost two orders of magnitude greater than that removed by typical heterotrophic organisms in traditional activated sludge processes (Chen et al, 2020).

The stimulation of PAOs is achieved by having an anaerobic then aerobic (or anoxic) sequence of reactors (Chen et al, 2020). In the absence of oxygen, PAOs consume VFAs and other rapidly biodegradable COD and stored as polyphosphates (PHA). When the biomass enters the aerobic or anoxic reactor, PAOs utilize oxygen or nitrate as an electron acceptor and utilize PHA as a carbon and energy source, for cell growth and regeneration (Chen et al, 2020).

There are different configurations of the BNR process with phosphorus and nitrogen removal, some of which are listed below (Metcalf & Eddy, 2014):

1. Anaerobic-anoxic-aerobic process.
2. Westbank process (anoxic-anaerobic-anoxic-aerobic)
3. Modified Bardenpho process (anaerobic-anoxic-aerobic-anoxic-aerobic).
4. EBPR with Primary Sludge Fermentation

Figure 5-5 shows a schematic of a typical anaerobic-anoxic-aerobic BNR process.

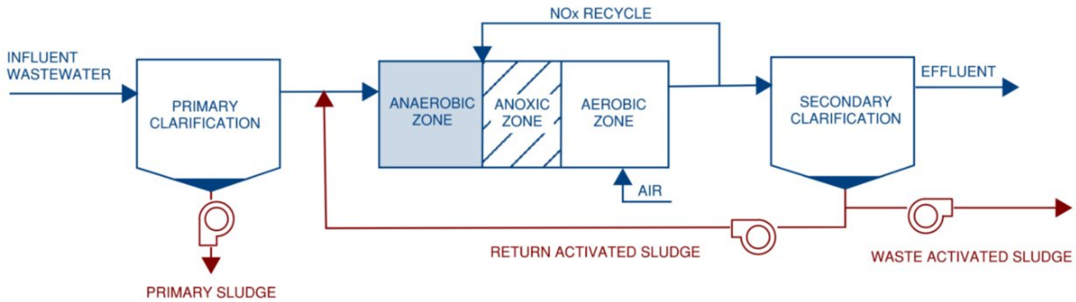

Figure 5-5: Anaerobic-Anoxic-Aerobic BNR Process Schematic (Metcalf & Eddy, 2014)

5.2.5.2 Maturity of Technology

The BNR process is a mature technology and variations of the process for nitrogen and/or phosphorus removal are very well known. There are many different configurations, so it can be modified for a variety of influent wastewater characteristics.

5.2.5.3 Proven Application at Large WRRFs

There are several full-scale applications of the different BNR process configurations, with larger Canadian plants located in Western Canada. In Ontario, there are only a few small BNR facilities including the Sault St. Marie WWTP (Sault Ste. Marie, n.d.) and the Elmira WWTP (CIMA+, 2019). The small number of BNR facilities is Ontario has generally been attributed to the lower cost of metal salts for phosphorus removal compared to the implementation cost of a BNR process. A list of some of the full-scale installations are shown below in **Table 5-9.**

Table 5-9: Full-Scale Applications of the BNR Process

Name	Location	Process	Capacity (MLD)
Pine Creek WWTP[1]	Calgary, Alberta	Westbank	100
COS Plant[1]	Poznan, Poland	Modified Bardenpho	300
Bonnybrook WWTP[1]	Calgary, Alberta	Westbank	500
Notes: 1. (Oleszkiewicz & Barnard, 2007)			

5.2.5.4 Compatibility with Existing and Future Processes

The footprint requirements for the various BNR configurations are larger than CAS due to the addition of tankage for several selector zones. Some configurations incorporate one or more anoxic zones in addition to the anaerobic zone, which increase the aeration tank footprint by 20-30%.

5.2.5.5 Compatibility with Regional Energy Management and GHG Reduction Goals

With the addition of unaerated zones, BNR processes have less aeration energy requirements compared to a conventional activated sludge system. This energy savings is partially offset by unaerated/anoxic zone mixing and recycle flows. BNR offers the advantage of significantly reducing or eliminating chemical addition required for phosphorus precipitation.

5.2.5.6 Ability to Implement within Required Schedule

The BNR process is a variation of CAS and is a proven, mature technology. There are limited installations in Ontario, but the MECP approvals process is not expected to be onerous. Therefore, this technology would be able to meet the 2029 expansion timeline.

5.2.5.7 Advantages and Disadvantages

Table 5-10 provides a summary of the advantages and disadvantages of the BNR technology.

Table 5-10: Summary of Advantages and Disadvantages of BNR Technology

Advantages	Disadvantages
• Proven, mature technology but limited installations in Ontario. • Compatible with existing processes and plug flow tanks– variation of CAS. • Lower chemical use and cost. • Lower aeration costs. • Reduction in sludge production. • Many different configurations available. • Simplified MECP Approvals. • Able to meet 2029 implementation timeline.	• Larger footprint due to additional bioreactor tankage. • Potential for secondary release of phosphorus in solids management. • Higher capital cost associated with larger footprint and additional equipment (mixers, recycle pumps, etc.) • More complex operating requirements.

5.2.6 Technology Alternative 6 – Membrane Bioreactor (MBR) Process

5.2.6.1 General Process Description

The MBR process is a suspended growth activated sludge wastewater treatment process in which physical separation of solids utilizes an ultrafiltration membrane system. Membranes are commonly installed as modules in submerged dedicated tanks. Mixed liquor from the biological reactor is fed to the membrane tanks and clean effluent is drawn through membrane filters by permeate pumps.

MBRs include air scour, back pulse, and clean-in-place systems to maintain membrane permeability (EPA, 2019). During the clean-in-place cycles, membrane tanks are emptied of wastewater and then filled with a cleaning solution. Therefore, implementation of MBRs requires chemical use and additional process redundancy.

The MBR process is not affected by the requirement to produce sludge with good settling characteristics as with other suspended growth technologies. Therefore, an MBR can be operated at considerably higher MLSS concentrations than the CAS process. By operating at a high MLSS (up to 10,000 mg/L) and eliminating the need for secondary clarifiers and tertiary filters, the system footprint is significantly reduced compared to a conventional system. Oxygen requirements are satisfied by a combination of diffused air and an air scouring system.

Excess biological sludge is wasted directly from the aeration tank.

A typical MBR process is capable of reliably achieving very low effluent TP concentrations (<0.1 mg/L) as the ultrafiltration system can remove particles greater than 0.01 µm (Fleischer, et al., 2006).

Figure 5-6 below shows a typical MBR system.

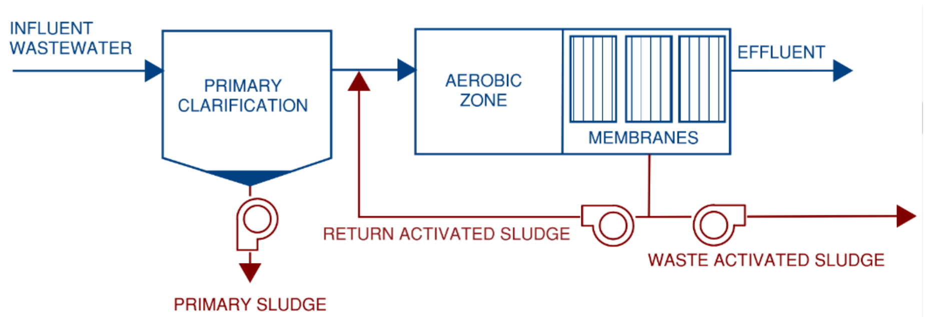

Figure 5-6: MBR Process Schematic (Metcalf & Eddy, 2014)

5.2.6.2 Maturity of Technology

BOD removal performance is similar to that of a CAS process. However, the MBR system also allows the biological process to be operated at extended SRT values, ensuring complete nitrification even under cold weather conditions without the need to increase the footprint of the aeration tank (EPA, 2019). Under these conditions, the sludge yields at extended SRTs are lower than for CAS processes due to endogenous decay of biomass in the reactor.

5.2.6.3 Proven Application at Large WRRFs

With increasingly stringent effluent requirements, MBR has become more widely used across Canada and North America. However, given its operational complexity and high capital and operating costs, MBRs have generally been limited to plants with footprint constraints and/or with total phosphorus effluent limits lower than 0.1 mg/L.

MBRs have been successfully implemented in small municipalities including facilities in Ontario such as the Port McNicoll, Creemore, and Oxford (London, Ontario) facilities.

There is a limited number of large full-scale installations similar in capacity to Clarkson WRRF. The City of Barrie is planning the implementation of MBRs at their wastewater treatment plant with the aim to increase the plant capacity from 76 MLD to 115 MLD within a constrained site and with the requirement to meet very low effluent phosphorus limits (City of Barrie, 2019). A short list of full-scale facilities with capacities over 100 MLD is shown in **Table 5-11** below.

Table 5-11: Full-Scale Applications of the MBR Process

Name	Location	Capacity (MLD)
Canton WWTP[1]	Canton, Ohio	159
F. Wayne Hill WRC[2]	Buford, Georgia	190
Notes: 1. (Ovivo Water, n.d.) 2. (CH2M Hill Canada Ltd., 2008)		

5.2.6.4 Compatibility with Existing and Future Processes

Since MBRs remove the need for secondary and tertiary treatment, this alternative has reduced footprint requirements.

In the case of the Clarkson WRRF, an MBR process could be installed by replacing the secondary clarifiers with membrane tanks. The quantity of membranes is closely related to the peak flows at the plant. Plants with a large peak to average flow ratio will require additional membrane and thus would have higher capital costs. Fine screening is also required upstream to protect the integrity of the membranes. This leads to increased headlosses but can be compensated through the hydraulic grade line by the MBR permeate pumps.

5.2.6.5 Compatibility with Regional Energy Management and GHG Reduction Goals

Given the high MLSS concentrations in the MBR process and air scouring requirements, oxygen demands, and aeration energy costs are greater than those required for a CAS process. In addition, membranes also have additional energy associated with very high flow recycle streams (typically four times average day flow) and permeate pumps. Overall, energy consumption and costs are higher for the MBR process. The MBR process provides very low effluent TP concentrations, but this level of treatment is not required for the Clarkson WRRF.

5.2.6.6 Ability to Implement within Required Schedule

The MBR technology is a proven technology and is used at facilities in Ontario and North America. Thus, the MECP approvals process is not expected to be onerous, so this technology will be able to meet the 2029 expansion timeline.

5.2.6.7 Advantages and Disadvantages

Table 5-12 provides a summary of the advantages and disadvantages of the MBR technology.

Table 5-12: Summary of Advantages and Disadvantages of MBR Technology

Advantages	Disadvantages
• Proven technology – used at facilities in Ontario and North America and around the world. • Ability to achieve very low TP concentrations in the effluent (<0.1 mg/L). • Can operate at high MLSS concentrations, thus reducing size of aeration tanks. • Small footprint – eliminates need for secondary clarifiers and tertiary treatment and reduces size of aeration tanks. • Simplified MECP approvals. • Able to meet 2029 implementation timeline.	• High capital costs. • High energy requirements and cost. • Membranes require periodic replacement (typically every 10 years) increasing life cycle costs. • Upstream fine screening (potential headloss concerns can be addressed with permeate pumps).

5.2.7 Technology Alternative 7 – Membrane Aerated Biofilm Reactor (MABR) Process

5.2.7.1 General Process Description

MABR is an attached growth process in which membranes are located within a bioreactor tank, providing a large-fixed surface area for biomass growth. The membranes in the reactor diffuse oxygen at a molecular level in an inside-out fashion.

Unlike other attached growth processes, in the membrane supported biofilm, oxygen and substrate (ammonia and organics) approach the biofilm from opposite sides (**Figure 5-7**). The oxygen is delivered directly to the biofilm by diffusion from the inside of the membrane and ammonia diffuses into the biofilm from the bulk liquid. Since ammonia is a small molecule, it diffuses into the biofilm much faster than organic carbon molecules. Therefore, the establishment of nitrifying bacteria is favoured over heterotrophic bacteria even in the presence of significant readily biodegradable organics (Suez Water Technologies & Solutions, 2018). As a result, nitrification occurs within the inner portion of the biofilm and denitrification in the outer portion of the biofilm, utilizing influent BOD to reduce the nitrate/nitrite.

This system provides a more efficient delivery of oxygen to the biomass when compared to a traditional fine bubble diffuser system. MABR also achieves denitrification which further reduces aeration requirements.

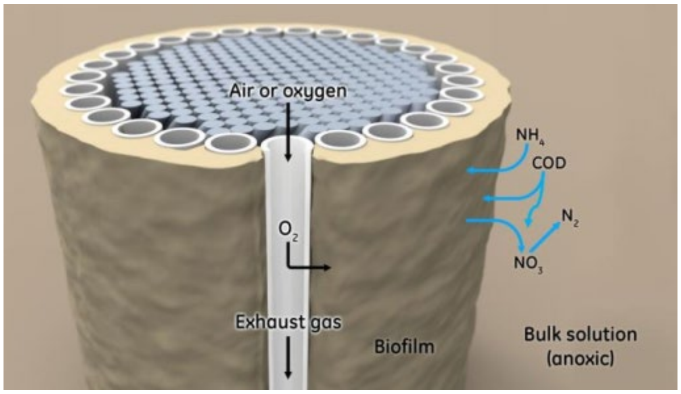

Figure 5-7: MABR Operation Principle (Suez Water Technologies & Solutions, 2018)

The MABR process can be installed in an anoxic tank to increase the secondary treatment capacity by:

- Operating at a lower suspended growth SRT (i.e., lower MLSS concentration) due to the biofilm nitrifier population attached to the membranes.
- Increasing secondary clarifier capacity for plants that are limited by solids loading rate.

An example of the MABR configuration can be seen in **Figure 5-8** below.

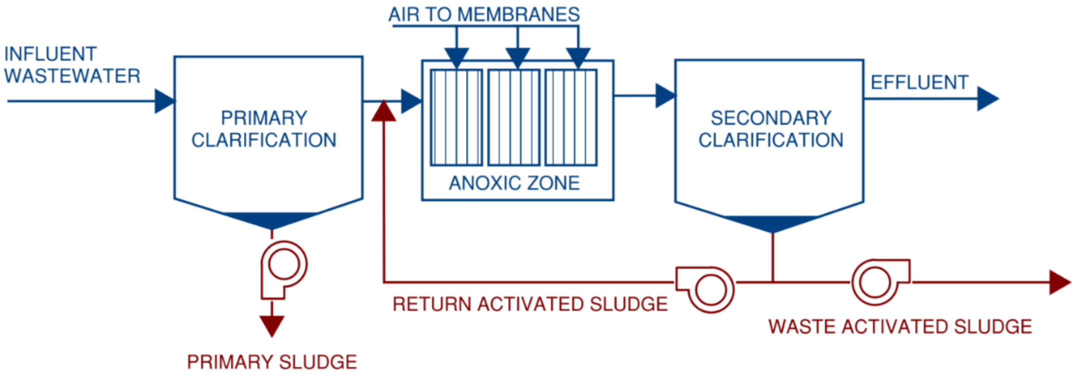

Figure 5-8: MABR Process Schematic (Suez Water Technologies & Solutions, 2018)

5.2.7.2 Maturity of Technology

The MABR process is a maturing technology with limited installations, but it is developing rapidly with many pilot studies.

5.2.7.3 Proven Applications at Large WRRFs

There are currently no full-scale installations in Ontario. The Hespeler WWTP (9.34 MLD) in the Region of Waterloo and the North Toronto Treatment Plant (45 MLD) have been approved by the MECP and are under construction. There is also an 11.7 MLD full scale MABR plant operating since 2017 in Yorkville-Bristol, IL in the USA. A list of the approved or operating full-scale applications of the MABR process are shown in **Table 5-13** below.

Table 5-13: Approved or Operating Full-Scale Applications of the MABR Process in North America

Name	Location	Status	Capacity (MLD)
Hespeler WWTP[1]	Cambridge, Ontario	Approved	9.34
Yorkville-Bristol[2] Sanitary District	Yorkville, Illinois	Operating	13.7
North Toronto TP[3]	East York, Ontario	Approved	45

Notes:
1. (WaterWorld, 2020)
2. (WaterWorld, 2016)
3. MABR will be installed in 2 of 8 aeration tanks for side-by-side comparison to CAS (City of Toronto, 2020)

5.2.7.4 Compatibility with Existing and Future Processes

The MABR process is compatible with the existing Clarkson WRRF as the membrane modules would be installed in anoxic zones created within the first pass of the existing aeration tanks. The footprint requirement would be reduced in comparison to the current facility since an aerobic zone is not required.

5.2.7.5 Compatibility with Regional Energy Management and GHG Reduction Goals

MABR operates at very high oxygen transfer efficiency greatly reducing the amount of electricity used (Suez Water Technologies & Solutions, 2018). Aeration requirements are also reduced as influent BOD supports denitrification.

5.2.7.6 Ability to Implement within Required Schedule

This technology is still developing as there are no large full-scale applications in operation in Ontario. The MECP has approved two full-scale applications which are under construction in Ontario, but for this technology to be implemented at Clarkson WRRF, site specific pilot testing may be required. This may hinder the ability to meet the 2029 expansion timeline.

5.2.7.7 Advantages and Disadvantages

Table 5-14 provides a summary of the advantages and disadvantages of the MABR technology.

Table 5-14: Summary of Advantages and Disadvantages of MABR Technology

Advantages	Disadvantages
• Smaller footprint. • Compatible with existing facility – variation of CAS. • Reduced energy consumption and costs (high oxygen transfer efficiencies).	• Developing technology – no large full-scale applications in Ontario.

Advantages	Disadvantages

• Simultaneous nitrification/denitrification (reduced effluent nitrate).
• MECP has approved two full-scale applications under construction in Ontario.
  ○ North Toronto TP
  ○ Hespeler WWTP
	• Capital and long-term operating and maintenance (O&M) costs not well understood.
	• May not be able to meet 2029 implementation timeline.

5.2.8 Technology Alternative 8–Integrated Fixed Film Activated Sludge (IFAS) / Moving Bed Bioreactor (MBBR) Process

5.2.8.1 General Process Description

The IFAS and MBBR processes are types of attached growth aerobic processes. IFAS is a variation of the CAS process in which inert plastic media (free floating or fixed to a grid) within the aeration tanks provides a large surface area per unit volume for biomass to attach and grow within the bioreactor (Metcalf & Eddy, 2014). This allows a higher inventory of biomass to be maintained per unit tank volume than CAS.

The MBBR process is a submerged attached growth process similar to IFAS with mixed, suspended media, except there is no RAS (Metcalf & Eddy, 2014). Many of the characteristics of IFAS are applicable including the biofilm carrier media, aeration and mixing, and substrate flux into the biofilm (Metcalf & Eddy, 2014). In this process, the biofilm formed on the media allows the removal of BOD in addition to the development of nitrifier microorganisms that oxidize ammonia compounds.

Both the IFAS and MBBR processes can be used to improve the performance of existing WRRF or to increase treatment capacity when the area on site is limited. The process requires the installation of a higher capacity aeration system to meet the oxygen requirements associated with the larger amount of biomass generated in the reactor. Containment grills or screens are also required to prevent the media from escaping from the aeration tank.

This technology allows the gradual expansion of capacity in the plant by simply adding more media and increasing the amount of air sent to the aeration tank.

A typical IFAS process with floating biofilm carrier media is illustrated in **Figure 5-9** below. As noted above, MBBR is similar, but it does not require a return stream.

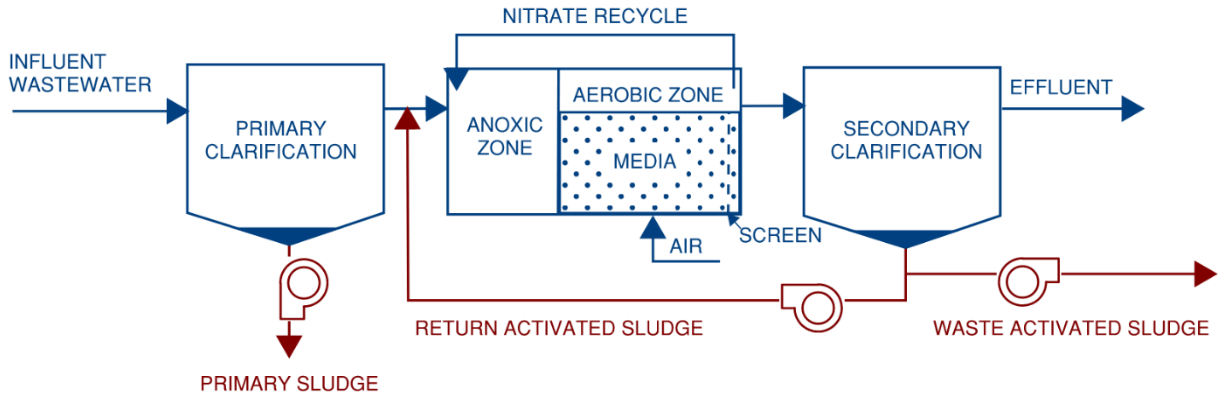

Figure 5-9: Typical IFAS with Floating Biofilm Carriers Process Schematic (Metcalf & Eddy, 2014)

5.2.8.2 Maturity of Technology

The IFAS process is gaining wider interest for cold weather nitrification expansion. IFAS has been shown to significantly increase the rate of nitrifying bacteria growth, which is the rate limiting step in the CAS process. The key advantage of the IFAS process is the increase in plant capacity without the need for additional aeration tanks.

Special care is required when emptying tanks for maintenance to prevent the weight of the media from causing damage to the air distribution system. In addition, there have been instances in which fragments of the media are broken and thus discharged with the effluent of the plant.

5.2.8.3 Proven Applications at Large WRRFs

This technology has been commonly used in Europe in the last 20 years, but most applications are used for treating industrial wastewater. Applications to municipal systems include mostly projects to convert CAS systems for increased treatment capacity. This process is used in Peterborough WWTP (64 MLD), but there are no large full-scale applications in North America with a similar capacity to Clarkson WRRF.

This technology was piloted at GE Booth WRRF in Plant 1B. During the pilot, it was found that the high flow velocities into the aeration tank led to bunching of the media at the retention screens, causing excessive headloss and media loss from the tanks.

5.2.8.4 Compatibility with Existing and Future Processes

Given the experience at G.E. Booth WRRF and the fact that flow velocities into the Clarkson multi-pass plug flow aeration tanks are also high; an IFAS retrofit at the Clarkson WRRF would therefore have the same headloss and media retention issues faced during the G.E. Booth WRRF pilot.

5.2.8.5 Compatibility with Regional Energy Management and GHG Reduction Goals

Given the increased biomass per unit volume in the aeration tanks, IFAS/MBBR results in higher oxygen requirements than the CAS process. Thus, this technology has greater energy consumption and costs.

5.2.8.6 Ability to Implement within Required Schedule

This technology is still maturing, but it is used and has been tested at some facilities in North America. To be implemented at Clarkson WRRF this technology may require site specific pilot testing which may limit this alternative's ability to meet the 2029 expansion timeline.

5.2.8.7 Advantages and Disadvantages

Table 5-15 provides a summary of the advantages and disadvantages of the MBBR and IFAS technology.

Table 5-15: Summary of Advantages and Disadvantages of IFAS and MBBR Technology

Advantages	Disadvantages
• Increased treatment efficiency per unit volume. • Smaller footprint requirements than CAS. • Could be retrofitted into CAS facility.	• Maturing technology – used at some facilities in North America and tested at others. • Greater energy requirements than CAS. • Implementation at existing facilities is limited by hydraulic considerations. • Headloss across media retention screens. • May not be able to meet the 2029 expansion timeline.

5.2.9 Technology Alternative 9 – Sequencing Batch Reactor (SBR) Process

5.2.9.1 General Process Description

The SBR process is a suspended growth process where all steps of the activated sludge process occur in a single reactor. Since mixed liquor remains in the reactor during the whole process, the need for separate secondary settling tanks is eliminated. However, SBRs may require a subsequent equalization process due to high intermittent discharge flows. To control solids retention time, sludge is wasted from the bottom of the SBR.

SBR processes typically involve five steps or stages: fill, react (aeration), settle (sedimentation/clarification), draw (decant), and idle as illustrated in **Figure 5-10** below (Metcalf & Eddy, 2014).

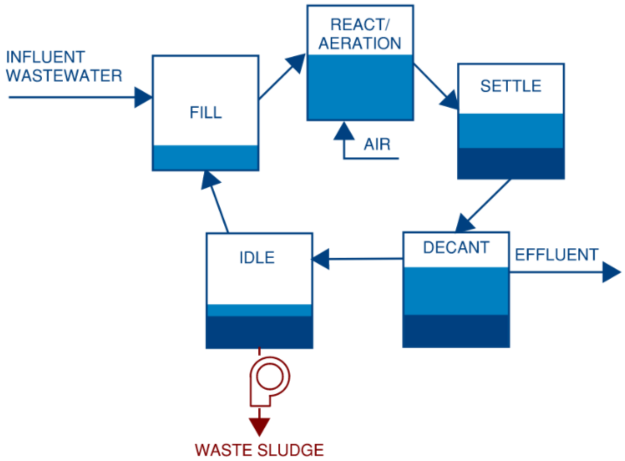

Figure 5-10: SBR Process Steps Schematic (Metcalf & Eddy, 2014)

To accommodate continuous influent wastewater flow, at least two tanks operating in parallel are required so one tank fills while the other tank completes its treatment cycle (Metcalf & Eddy, 2014). The duration of each step is adjusted as a function of influent flow. Decanting is achieved with either a fixed or floating mechanism that draws from the clarified liquid layer in the SBR.

By changing the duration of each of the steps, aerobic, anaerobic, and anoxic conditions can be achieved in the reactor depending on the treatment objectives.

5.2.9.2 Maturity of Technology

This technology is mature and well developed but is mostly used at facilities with small flows. Variations of the process can achieve nitrification and biological nutrient removal by altering the duration of the steps.

5.2.9.3 Proven Applications at Large WRRFs

Very limited large-scale installations of the SBR process exist internationally as listed in **Table 5-16** below. However, this process is typically used in and recommended for plants with rated capacities less than 20 MLD given that process operation complexity can increase considerably for larger plants.

Table 5-16: Large Full-Scale Application of the SBR Process

Name	Location	Capacity (MLD)
Bowling Green WWTP[1]	Bowling Green, Kentucky, USA	45.4
Liverpool WWTW[2]	Kirkdale, Liverpool, United Kingdom	356

Notes:
1. (WaterWorld, 2013)
2. Liverpool WWTW has a cyclic activated sludge system (CASS) SBR (Constantine & Henderson, 2015)

5.2.9.4 Compatibility with Existing and Future Processes

In general, the SBR system is better suited for smaller applications with intermittent flows. At larger SBR plants with larger, continuous flow rates, the system involves multiple reactors in parallel with complex controls to coordinate the duration of each SBR step and the order in which each reactor operates.

Retrofitting of existing tankage to accommodate an SBR process would be challenging. Aeration tanks could be converted to SBRs but there would need to be significant modifications to control influent flows into and out of each tank. Multiple parallel reactors and an equalization tank would be required. Given the hydraulic grade line at the Clarkson WRRF, pumping would be required from the equalization tank to the disinfection facility.

SBR operations are completely automated as the duration of each SBR cycle and each SBR reactor is adjusted as a function of the influent flow. Operation complexity increases as a function of the rated capacity and the required number of SBR reactors in parallel, so it would be complex at a plant the size of Clarkson WRRF.

5.2.9.5 Compatibility with Regional Energy Management and GHG Reduction Goals

Energy costs for aeration would be similar as those required for CAS. However, the need for intermediate pumping from the equalization tank would result in higher energy and operating costs.

5.2.9.6 Ability to Implement within Required Schedule

This technology is mature but is mostly installed at facilities with small flows due to the operation complexity at larger scales. Since there are limited large applications with capacities at the same scale as Clarkson WRRF, the MECP approvals process may be long. Due to uncertainty with approvals and testing, this technology may not be able to meet the level of service expansion timeline.

5.2.9.7 Advantages and Disadvantages

Table 5-17 provides a summary of the advantages and disadvantages of the SBR technology.

Table 5-17: Summary of Advantages and Disadvantages of SBR Technology

Advantages	Disadvantages
• Smaller footprint. • Flexibility in operating conditions and easily modified for biological nutrient removal. • No RAS required.	• Complex operation when more than 2 SBRs operate in parallel. • Limited large plant experience worldwide. • Higher headloss due to decanting – requires equalization and intermediate pumping. • Higher energy costs due to intermediate pumping. • May not be able to meet 2029 implementation timeline.

5.2.10 Technology Alternative 10– Aerobic Granular Sludge (AGS) Process

5.2.10.1 General Process Description

The AGS system is an advanced technology for biological wastewater treatment based on the SBR process which fosters the formation of aerobic granular biomass. These granules include layers of ordinary heterotrophs, nitrifying and denitrifying bacteria which can simultaneously remove carbon, nitrogen and phosphorus from the wastewater (Nancharaiah & Reddy, 2018). The granules also exhibit better settleability characteristics.

To develop the granules, the SBR is operated to achieve anaerobic, anoxic and aerobic conditions (Aqua-Aerobic Systems Inc., 2017). Granules can be considered as a special case of biofilm growth without carrier material (Weber, Ludwig, Schleifer, & Fried, 2007). Therefore, the AGS process is considered an attached growth process with floating media instead of a suspended growth process such as the SBR process (Metcalf & Eddy, 2014). A magnified granule is shown in **Figure 5-11** below.

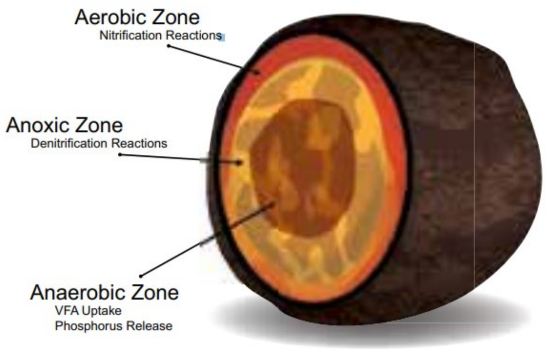

Figure 5-11: Magnified Granule in the AquaNereda® Cycle Process (Aqua-Aerobic Systems Inc., 2017)

AquaNereda® is a commercially available system which utilizes the aerobic granular sludge process. A granular sludge reactor can be operated at higher biomass concentrations, allowing higher loading rates while maintaining a longer solids retention time (SRT). A longer SRT is necessary for stable nitrification and providing anoxic and anaerobic micro-environments in the sludge granules for nutrient removal. To achieve granulation under aerobic process conditions, short settling times are used to introduce a strong selective advantage for well-settling sludge granules. Poor-settling biomass is washed out under these conditions (Pronk, et al., 2015).

There is significant ongoing research to integrate aerobic granular sludge into continuous flow activated sludge systems. In most cases, studies involve modifying aeration tank operating conditions and using hydrocyclones on the sludge stream to preferentially retain a denser biomass in the aeration tanks.

5.2.10.2 Maturity of Technology

This technology is still maturing, and full-scale applications operate in an SBR configuration (Nereda®). A hybrid application can also be considered where a granular sludge SBR plant treats a portion of the flow and generates granules to seed the parallel conventional activated sludge system allowing for higher overall flow capacity.

This process exhibits the same disadvantages as an SBR process as it relies on a complex automatic control system. The formation of granules is very sensitive to changes in wastewater temperature and variations in wastewater pollutant concentration before stabilizing following the long start-up process.

5.2.10.3 Proven Applications at Large WRRFs

This technology has been mostly applied on high strength effluents and leachates. There are currently no full-scale installations of granular sludge technology in Canada, but there are full-scale installations in either construction or operation in other parts of the world.

There are only a few large installations with capacities over 100 MLD such as those listed in **Table 5-18** below.

Table 5-18: Large Full-Scale Applications of the AGS Process

Name	Location	Capacity (MLD)
Jaboatão WWTP[1]	Jaboatão, Recife, Brazil	169
Ringsend WWTP[1]	Dublin, Ireland	600
Notes: 1. (Royal HaskoningDHV, n.d.)		

5.2.10.4 Compatibility with Existing and Future Processes

Typically, full scale applications of this process utilize deep tanks (6 m or deeper) to improve the oxygen transfer within the tanks, ultimately lowering aeration requirements (Pronk, et al., 2015). Retrofitting of existing tankage at the Clarkson WRRF would not be feasible without constructing higher walls and providing intermediate pumping.

5.2.10.5 Compatibility with Regional Energy Management and GHG Reduction Goals

According to recent estimates from research studies, energy consumption for AGS facilities can be up to 30% lower than CAS facilities (Nancharaiah, Sarvagith, & Mohan, 2019). However, the need for intermediate pumping from the equalization tank would off-set most of these savings.

5.2.10.6 Ability to Implement within Required Schedule

The AGS technology is still developing with limited large full-scale installations. This technology has not yet been approved by the MECP. As a result, long term piloting will likely be required for approval, impacting project timelines. As a result, this technology will likely be unable to meet the 2029 expansion timeline.

5.2.10.7 Advantages and Disadvantages

Table 5-19 provides a summary of the advantages and disadvantages of the aerobic granular sludge technology.

Table 5-19: Summary of Advantages and Disadvantages of Aerobic Granular Sludge Technology

Advantages	Disadvantages
• Smaller footprint than CAS. • Simultaneous nitrification/denitrification and organic carbon removal. • No RAS required. • Improved settling performance.	• Developing technology – limited large full-scale cold weather applications. • Capital and long-term O&M costs not well understood. • Not compatible with existing facility – higher headloss; typically use deeper tanks. • Higher headloss require intermediate pumping. • MECP may require pilot testing. • May not be able to meet the 2029 implementation timeline.

5.2.11 Technology Alternative 11– Biological Aerated Filter (BAF) Process

5.2.11.1 General Process Description

BAF is another type of attached growth process in which media such as expanded clay or shale or other inert plastic media are used as a filter medium on the surface from which microorganisms adhere to forming a biofilm.

Wastewater is pumped into the BAF and flows through the filter medium. Air is added to the bioreactor by means of diffusers at the bottom of the tank. Microorganisms attach to the filter media and use up the organic matter contained in the wastewater. As in other attached growth processes, BAF can be operated to maintain anaerobic, anoxic, and aerobic conditions to achieve biological nutrient removal. This process combines biological substrate removal and physical separation of solids into a single structure. Therefore, BAF does not require the use of secondary clarifiers and takes up less space than the CAS process.

Fine screening is required upstream of the BAF process to minimize the risk of distribution and media retention nozzles.

The process requires intermittent backwashing to maintain hydraulic performance and to remove excess solids from the bioreactor. Backwash solids from the BAF have a very low solids concentration, so thickening systems are typically required. For the Clarkson WRRF, pre-gravity thickening prior to the rotary drum thickeners (RDT) will likely be required to avoid hydraulic overloading of the WAS thickening system.

There are upflow or downflow configurations of the BAF process.

Although the space requirements for this system are relatively small, there are limitations regarding economies of scale at larger facilities as unit cost per volume does not reduce with increased size (Metcalf & Eddy, 2014).

Maintenance of the diffuser system and BAF underdrains requires careful consideration as this would require emptying the tank and discarding the media to access the bottom of the BAF tank. This process is fully automated and operator input is minimal requiring only setting the frequency of backwash cycles.

The BAF process is patented and in Ontario systems have been provided by two vendors: Veolia (Biostyr™) and Suez (BioFOR™).

Figure 5-12 depicts a schematic of the BAF process.

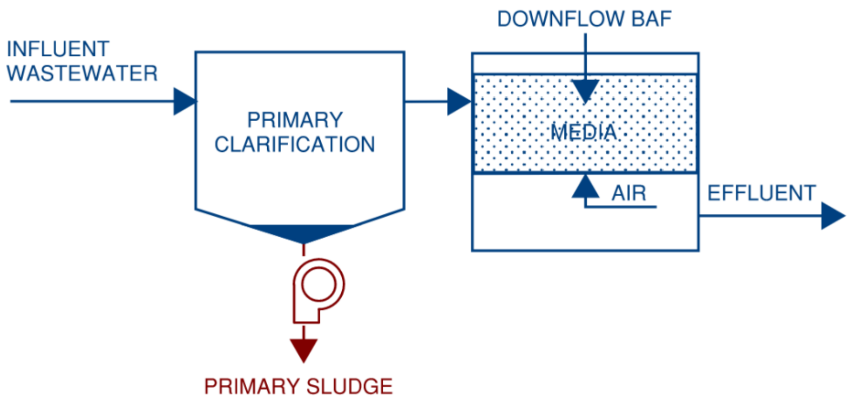

Figure 5-12: Schematic of BAF Process (Metcalf & Eddy, 2014)

5.2.11.2 Maturity of Technology

This process is mature with more than 1,000 installations worldwide (Suez, 2009).

5.2.11.3 Proven Applications at Large WRRFs

There are many applications of this process in the world (particularly in Europe and Asia). In North America, there are more than 20 applications in the United States and less than 10 in Canada. The plants in Windsor, Thunder Bay, Kingston and Owen Sound are the only municipal facilities which utilize BAF in Ontario. The Cataraqui Bay WWTP in Kingston, Ontario and Owen Sound WWTP are both small facilities with capacities of 55 MLD (Utilities Kingston, 2020) and 10 MLD (Municipality of Owen Sound), respectively. Thunder Bay WWTP is a medium sized facility with a capacity of 84.5 MLD (City of Thunder Bay, 2019) and the Lou Romano WRP in Windsor is rated at 218 MLD (Stantec).

Full-scale installations at capacities just below or similar to Clarkson WRRF are shown in **Table 5-20**.

Table 5-20: Full-Scale Applications of the BAF Process

Name	Location	Rated Capacity (MLD)
Joong Ang WWTP[1]	Pusan, South Korea	111

Name	Location	Rated Capacity (MLD)
Lou Romano WRP[2]	Windsor, ON	218
El Segundo WWTP[1]	El Segundo, California	236
Louis-Fargues WWTP[1]	Bordeaux, France	276
Seine Centre STP[3]	Colombes, France	240
Xiamen WWTP[1]	Xiamen, China	300

Notes:
1. (Suez, 2009)
2. (Stantec)
3. (Gasperi, Rocher, Gilbert, & Azimi, 2010)

5.2.11.4 Compatibility with Existing and Future Processes

It would not be possible to retrofit the existing process tanks to accommodate the BAF process. BAF could be implemented for the new expansion facilities. Intermediate pumping and fine screening would be required.

5.2.11.5 Compatibility with Regional Energy Management and GHG Reduction Goals

BAF energy requirements are similar to a conventional activated sludge process. However, there would be additional energy associated with intermediate pumping.

5.2.11.6 Ability to Implement within Required Schedule

This is a mature technology with small to medium sized installations in North America as well as larger installations internationally. The MECP approvals process is not expected to be onerous, so it will likely be able to meet the 2029 expansion timeline.

5.2.11.7 Advantages and Disadvantages

Table 5-21 provides a summary of the advantages and disadvantages of the BAF technology.

Table 5-21: Summary of Advantages and Disadvantages of BAF Technology

Advantages	Disadvantages
• Mature technology with mostly small to medium sized facilities in North America. • Large full-scale applications internationally. • Smaller footprint than CAS. • Simplified MECP Approval. • Able to meet 2029 project implementation timeline.	• Not compatible with existing facility. • Higher energy requirements due to intermediate pumping. • High capital cost. • Difficult access to aeration system for maintenance due to media coverage. • Media needs to be replaced every two to three years. • Low concentration solids in backwash.

5.2.12 Summary of Evaluation of Long List of Secondary Treatment Technologies

The results of the secondary treatment technology screening are presented in **Table 5-22** below. Based on the screening, it is recommended that the following technologies be short-listed and developed into alternative design concepts for a more detailed evaluation:

1. Conventional Activated Sludge (CAS)
2. CAS with Chemically Enhanced Primary Treatment (CEPT)
3. Biological Nutrient Removal (BNR)

Table 5-22: Clarkson WRRF Secondary Treatment Technology Screening

No.	Technology Alternative	Maturity of Technology	Proven Application at Large WWTPs	Compatibility with Existing and Future Processes	Compatibility with Regional Energy Management and GHG Reduction Goals	Ability to Implement within Required Schedule	Consider for Evaluation
1	Conventional Activated Sludge	Mature technology, the most common wastewater treatment process.	Yes, many large installations internationally.	Yes, current process utilized at Clarkson WRRF.	Higher energy requirements with opportunity for energy enhancement.	Yes, widely used and current technology at Clarkson WRRF. Simplified MECP approvals process.	Yes.
2	Conventional Activated Sludge with CEPT	Mature technology, coagulation and flocculation in CEPT is a common wastewater treatment process.	Yes, several large installations internationally. Currently used for wet weather flows at G.E. Booth WRRF.	Yes, variation of CAS process which is currently utilized at Clarkson WRRF.	Yes. Reduces aeration energy consumption and increases biogas production.	Yes, proven technology at large facilities. Simplified MECP approvals process.	Yes.
3	Conventional Activated Sludge with WWF Treatment	Mature technology that has many proven installations.	Application of parallel WWF technology in large facilities is limited.	No. WWF and space constraints are not a significant concern.	Similar to CAS.	Uncertain, may require a longer MECP approvals process.	No.
4	Ballasted Activated Sludge	Limited number of installations.	No applications at large facilities.	Yes, variation of CAS process which is currently utilized at Clarkson WRRF.	Higher energy requirements with limited opportunity for energy enhancement.	No, may require pilot testing.	No.
5	Biological Nutrient Removal	Mature technology with well-established variations of the process.	Yes, several large installations in Western Canada.	Yes, variation of CAS process which is currently utilized at Clarkson WRRF.	Yes, reduces chemical usage.	Yes, mature technology at large facilities. Simplified MECP approvals process.	Yes.
6	Membrane Bioreactor	Mature technology, has become more widely used across North America.	Application at large facilities is limited.	Yes, MBR would be installed in place of secondary treatment.	High energy requirements due to oxygen demand, air scouring, recycle streams and permeate pumps.	Yes, mature technology. Simplified MECP approvals process.	No.
7	Membrane Aerated Biofilm Reactor	Maturing Technology. Several pilot studies completed in Ontario.	No. However, the MECP is actively testing this technology with several pilot studies having been completed in Ontario.	Yes, MABR would be installed within the anoxic zone of aeration tanks.	Significantly reduces energy consumption for aeration.	No, will likely require pilot testing.	No.
8	Integrated Fixed-Film Activated Sludge / Moving Bed Bioreactor	Maturing technology. Limited number of installations in North America.	No. However, full-scale pilot testing has previously been completed at G.E. Booth WRRF.	No. High flows would lead to high headloss and hydraulic constraints from media bunching.	High energy requirements from increased oxygen demand.	No, will likely require pilot testing.	No.
9	Sequencing Batch Reactor	Mature and well-developed technology. Many installations at small facilities.	Application at large facilities is limited.	No. Operation is complex at high, continuous flows. High headloss would require intermediate pumping.	High energy requirements from intermediate pumping.	Uncertain, mature technology but limited large installations. May involve longer MECP approvals process.	No.
10	Aerobic Granular Sludge	Limited number of full-scale municipal wastewater installations.	Application at large facilities is limited.	No. High headloss would require intermediate pumping.	Limited information on energy requirements.	No, will likely require pilot testing.	No.
11	Biological Aerated Filter	Mature technology, many installations internationally. Newer in North America.	Yes, several large installations internationally.	No. BAF requires fine screening and high headloss would require intermediate pumping.	High energy requirements from intermediate pumping.	Yes, proven technology at large installations. Simplified MECP approvals process.	No.

5.3 Long List of Disinfection Technologies

Disinfection is the process of destruction or inactivation of pathogenic microorganisms. This process is applied to wastewater treatment effluents discharging to surface water to reduce the risk of disease on recreational users and to reduce the risk to other nearby water users. The MECP is using *E. Coli* as the indicator parameter to establish wastewater effluent disinfection standards.

The performance of a disinfection system is assessed in terms of its pathogen destruction/inactivation efficiency, the non-toxicity of its residues in the effluent to humans and aquatic flora and fauna, its ease of storage and handling (in the case of chemical disinfectants), and its cost.

The following disinfection technology alternatives were considered for disinfection at the Clarkson WRRF:

1) Chlorination/Dechlorination
2) Ultraviolet (UV) Disinfection
3) Ozone
4) Peracetic Acid (PAA)

Descriptions of these technology alternatives as applied to the Clarkson WRRF are presented below.

5.3.1 Technology Alternative 1 – Chlorination and Dechlorination

5.3.1.1 General Process Description

Chlorine is a strong oxidant that breaks down the cellular component of microorganisms to inactivate both bacteria and viruses (EPA, 1999).

Chlorination involves adding chlorine to the final effluent, then allowing for a sufficient contact time for disinfection. After sufficient contact time is achieved, a dechlorination chemical is injected to ensure chlorine concentrations are below 0.02 mg/L (the threshold for non-toxicity in Canada). Chlorination and dechlorination is the current disinfection process used at the Clarkson WRRF. Sodium hypochlorite is used for chlorination and sodium bisulphite is used for dechlorination.

Chemical disinfection can be expressed in terms of a first order differential equation commonly known as the Chick-Watson model. The model expresses the concentration of pathogenic microorganisms in the water as a function of the reaction time and the disinfectant chemical concentration (Metcalf & Eddy, 2014). As the product of concentration and time (CT) increases, the concentration of microorganisms decreases.

MECP recommends a minimum chlorine residual of 0.5 mg/L at average flow conditions after a 30-minute contact time to meet disinfection requirements. In addition, a contact time of 15 minutes is recommended at the design peak hourly flow (MECP, 2008).

Any facility using chlorination must dechlorinate the effluent before the effluent is discharged to the environment. Dechlorination agents react with the chlorine in solution to produce chloride ions that do not have a toxic impact on aquatic organisms. The dechlorination reaction is very quick and a contact time of less than a few minutes is normally sufficient to reduce a chlorine residual to below the acceptable level (EPA, 2000).

5.3.1.2 Maturity of Technology

Chlorination/dechlorination is a well-established method for disinfection. Most of the large plants discharging to Lake Ontario use this method of disinfection, including the South Peel water resource recovery facilities.

5.3.1.3 Proven Application at Large WRRFs

Chlorination/dechlorination is widely used across North America and the rest of the world.

A list of some of the large full-scale applications similar or greater in size to Clarkson WRRF is shown in **Table 5-23.**

Table 5-23: Full-Scale Applications of Chlorination/Dechlorination

Name	Location	Rated Capacity (MLD)
Highland Creek TP[2]	Scarborough, Ontario	219
Clarkson WRRF	Mississauga, Ontario	350
Humber TP[2]	Etobicoke, Ontario	473
GE Booth WRRF	Mississauga, Ontario	518
Duffin Creek WPCP[1]	Durham, Ontario	520
Notes: 1. (Durham Region & York Region, 2017) 2. (City of Toronto, 2020)		

5.3.1.4 Compatibility with Existing and Future Processes

This is the disinfection method currently in use at Clarkson WRRF.

5.3.1.5 Compatibility with Regional Energy Management and GHG Reduction Goals

Chlorination/dechlorination has a low capital cost and a low energy consumption. However, it requires the purchase and storage of two separate chemicals.

5.3.1.6 Ability to Implement within Required Schedule

This technology is mature and is currently used and established at Clarkson WRRF. This alternative will be able to meet the 2029 expansion timeline.

5.3.1.7 Advantages and Disadvantages

Table 5-24 provides a summary of the advantages and disadvantages of the chlorination/dechlorination.

Table 5-24: Summary of Advantages and Disadvantages of Chlorination/Dechlorination

Advantages	Disadvantages
• Well-established technology. • Many proven large full-scale applications. • Simple operation. • Low capital and energy costs. • Able to meet 2029 implementation timeline.	• Dechlorination is required (more chemical purchase and storage required). • Sodium hypochlorite has a relatively short shelf life, although this is not an issue at a large continuous flow application like the Clarkson WRRF.

5.3.2 Technology Alternative 2 - UV Disinfection

5.3.2.1 General Process Description

UV disinfection consists of irradiating water with radiation waves in the range of 250-270 nm (ideally around 254 nm) to inactivate pathogenic microorganisms and viruses (EPA, 1999). UV irradiation cuts through the genetic components of microorganisms preventing them from reproducing (EPA, 1999). UV light is generated by a mercury (vapour) lamp much like a normal florescent light, which ionizes (excites) mercury inside the lamp when charged by striking an electric arc (EPA, 1999). UV light is emitted as a result of the energy generated by the excitation of the mercury vapour in the lamp. UV disinfection does not require any chemical addition and effluent is non-toxic to aquatic life.

UV dose is a measurement of the UV energy input to the wastewater effluent. To be effective, the dose must exceed a threshold value dependent on the target microorganisms to be inactivated. UV dose is defined as the product of the UV intensity and the UV exposure time. A reactor contact time of only a few seconds is normally adequate to achieve the desired effluent quality.

Since UV disinfection systems require significantly less contact time (20-30 seconds) than chlorine, the footprint required for UV disinfection is much smaller than a chlorine contact tank. However, the Clarkson WRRF uses the outfall for disinfection contact time and eliminates the footprint advantages of UV disinfection. UV disinfection systems require flow control weirs or other flow control structures to maintain a near constant submergence level of the UV lamps. This increases headloss in comparison to chlorine disinfection and may impact system capacity at Clarkson without effluent pumping.

The effectiveness of UV disinfection depends on the characteristics of the wastewater specifically iron and suspended solids which affects UV transmittance and thus the UV dosage required to treat the wastewater. For the Clarkson WRRF which uses iron salts for phosphorus removal, higher UV doses and energy costs would be required to achieve disinfection requirements. Similarly, treatment of bypasses is challenging as the disinfection performance may be affected by the higher solids content.

5.3.2.2 Maturity of Technology

UV is considered a mature technology since it has been widely used in wastewater and drinking water treatment. There are installations at both Arthur P. Kennedy Water Treatment Plant and Lorne Park Water Treatment Plant in the Region. Its use in wastewater disinfection is increasing and in recent years, with many facilities in Ontario using UV disinfection.

5.3.2.3 Proven Application at Large WRRFs

UV disinfection has been proven at large full-scale applications with similar capacities to Clarkson WRRF with installations in Canada. The Ashbridges Bay TP (818 MLD) is currently constructing a UV disinfection system for secondary effluent with chlorination/dechlorination of secondary bypass flows. A list is summarized below in **Table 5-25**.

Table 5-25: Full-Scale Applications of UV Disinfection

Name	Location	Rated Capacity (MLD)
Pine Creek WWTP[1]	Calgary, Alberta	100
South End WPCC[2]	Winnipeg, Manitoba	100
North End WPCC[2]	Winnipeg, Manitoba	380
Bonnybrook WWTP[1]	Calgary, Alberta	500

Notes:
1. (City of Calgary, n.d.)
2. (City of Winnipeg, 2020)

5.3.2.4 Compatibility with Existing and Future Processes

UV disinfection would require construction of a new disinfection building to house UV channels and power equipment. Secondary effluent flows would need to be diverted upstream of the drop shaft to the new disinfection facility. Effluent out of the new disinfection facility would then be diverted back the drop shaft to flow out to the outfall. A more detailed analysis would be required to determine if there is sufficient head to maintain gravity flow hydraulic capacity through the UV channels and the outfall.

5.3.2.5 Compatibility with Regional Energy Management and GHG Reduction Goals

UV disinfection facilities require significant energy and power requirements. This technology, coupled with the risk of effluent pumping to maintain hydraulic capacity, would significantly increase energy use and associated GHG emissions at the Clarkson WRRF relative to the existing chlorination and dechlorination system. However, this option would reduce the need for chemical use at the WRRF, thus reducing Scope 3 emissions associated with the plant operation.

5.3.2.6 Ability to Implement within Required Schedule

UV disinfection is a mature technology and proven at large installations. The MECP approvals process is likely to be simplified and this alternative will be able to meet the 2029 expansion timeline.

5.3.2.7 Advantages and Disadvantages

Table 5-26 provides a summary of the advantages and disadvantages of the UV disinfection.

Table 5-26 Summary of Advantages and Disadvantages of UV Disinfection

Advantages	Disadvantages
• Proven at large full-scale installations. • Well-established technology. • No chemical storage or handling. • No harmful residuals. • Able to meet 2029 implementation timeline.	• Would require a new disinfection facility. • High energy costs. • Greater headloss due to flow control structures. • Higher solids in bypass flows would impact sizing and performance of disinfection system. • High capital cost.

5.3.3 Technology Alternative 3 - Ozone

5.3.3.1 General Process Description

Ozone (O_3) is an unstable gas that is a strong oxidizer used to disinfect water. When dissolved in water, ozone forms hydrogen peroxyl (HO_2) and hydroxyl radicals (OH-) which are stronger oxidizing agents. Inactivation of viruses, bacteria, and cysts by ozone is attributed to the oxidation or destruction of the cell wall (EPA, 1999). The overall system design is similar to chlorine gas disinfection; however, ozone is a stronger disinfectant than chlorine. Therefore, it requires lower concentrations and less contact time (i.e., as little as five minutes, compared to 30 minutes for chlorine).

Ozone is reactive and unstable, so it must be generated on-site (EPA, 1999). For large systems, liquid oxygen is commonly supplied to the site and is then evaporated to a gas and fed into an ozone generator. An electrical current is then applied to the oxygen gas to convert it to ozone (EPA, 1999). The gas is then injected into the water to be disinfected. Any off gas remaining in the headspace of the contact tank is then passed through a catalytic converter to destroy any residual ozone.

Ozone reacts with organics in the water which leads to the formation of organic peroxides, aldehydes, and halogenic compounds (Metcalf & Eddy, 2014).

Although, the footprint required for the contact tank for ozonation is smaller than for chlorine disinfection, ozonation would require greater space for liquid oxygen storage, evaporators, ozone generators, and electrical equipment.

5.3.3.2 Maturity of Technology

Ozone has been used for disinfection of potable water for many years; it is currently being used in the Arthur P. Kennedy WTP in the Region to disinfect raw lake water. Overall, there are relatively few water resource recovery facilities that utilize ozone for disinfection. It gained acceptance for use in municipal wastewater disinfection in the United States in the 1970s and many systems were installed in the 1980s (Loeb, Thompson, Drago, & Takahara, 2012). However, many discontinued the use of ozone and from 2005 to 2010 it was reported that less than 10 facilities still utilize ozone in the United States (Loeb, Thompson, Drago, & Takahara, 2012). Montreal's Jean R. Marcotte (JRM) WWTP is the only facility in Canada to use ozone for disinfection. It is important to note that this plant only provides primary treatment rather than secondary treatment like Clarkson WRRF. Due to the poorer wastewater effluent quality produced at the JRM WWTP, the strong oxidizing potential of ozone can offer advantages.

5.3.3.3 Proven Application at Large WRRFs

There are limited full-scale applications at wastewater facilities. Ozone was previously used at two Indianapolis plants – Belmont WWTP and Southport WWTP (both at 473 MLD) but has since been replaced with chlorination/dechlorination. The City of Montreal uses ozone for disinfection at JRM WWTP. This plant is a primary treatment facility (no secondary treatment), and ozone was selected given the poor water quality effluent produced compared to a secondary treatment facility (Stevenson, 2019). North American facilities with ozonation are listed in **Table 5-27** below.

Table 5-27: Full-Scale Applications of Ozone Disinfection

Name	Location	Status	Rated Capacity (MLD)
Belmont AWTP[1]	Indianapolis, Indiana	Discontinued	473
Southport AWTP[1]	Indianapolis, Indiana	Discontinued	473
Jean-R. Marcotte WWTP[2]	Montreal, Quebec	Operating (primary treatment only)	2,780
Notes: 1. (EPA, 1999) 2. (Stevenson, 2019)			

5.3.3.4 Compatibility with Existing and Future Processes

Ozonation would require construction of new covered contact tanks, a new facility to house liquid oxygen and evaporators, ozone generators, ozone off-gas destructors, and electrical equipment. Secondary effluent flows would need to be diverted upstream of the drop shaft to a new disinfection facility. This facility would include a special ozone diffuser system and an excess ozone capture/destruction system. Effluent out of the disinfection facility would then be diverted back the drop shaft to flow out to the outfall. With a dedicated contact tank, the system could be designed to minimize headloss impacts on the existing plant hydraulics.

5.3.3.5 Compatibility with Regional Energy Management and GHG Reduction Goals

Due to the requirements of generating ozone on-site, destroying off-gas, and injecting gas to the secondary effluent, the energy costs associated with this technology are very high and would contribute to an increased GHG footprint for the Clarkson WRRF.

5.3.3.6 Ability to Implement within Required Schedule

There is currently no large-scale operating wastewater treatment facility in Canada utilizing ozone disinfection. Thus, the MECP approvals process may be long, and this alternative may not be able to meet the 2029 expansion timeline.

5.3.3.7 Advantages and Disadvantages

Table 5-28 provides a summary of the advantages and disadvantages of the ozone disinfection.

Table 5-28: Summary of Advantages and Disadvantages of Ozone Disinfection

Advantages	Disadvantages
• No harmful residuals to remove prior to discharge. • Short contact time requirements relative to chlorination.	• No operating wastewater treatment facilities with ozone disinfection in Canada. • Would require a new disinfection facility to house liquid oxygen storage and ozone generator. Special diffusion systems and excess ozone recovery systems would also be required. • High energy costs • High capital costs. • Ozone is very reactive, corrosive, and hazardous gas (health and safety risks). • Generates harmful off-gas that needs to be destroyed. • More complex operation. • May not be able to meet the 2029 implementation timeline.

5.3.4 Technology Alternative 4 - Peracetic Acid (PAA)

5.3.4.1 General Process Description

Peracetic Acid (PAA) is a strong oxidant and virucide. The free radicals formed when PAA decomposes in water (hydrogen peroxyl and hydroxyl) disinfects the water by oxidizing or destructing the cell wall of pathogenic organisms (EPA, 2012). PAA decomposes into acetic acid, hydrogen peroxide, and water relatively quickly, so the contact time requirements are less than those for chlorine (EPA, 2012).

Studies completed with PAA used for disinfection show very low residuals eliminating the need for neutralization before release. In addition, PAA did not produce any disinfection by-products that are harmful to the environment and human health (Bettenhausen, 2020). However, the decomposition of PAA to dilute acetic acid can generate BOD within the treated effluent, contributing to the biological uptake of oxygen in the receiving water (PeroxyChem, 2016).

The storage and chemical feed system required for PAA would be similar to those for sodium hypochlorite. Capital costs for implementation of a PAA system have been found to be similar to those using sodium hypochlorite (EPA, 2012). However, the operating costs for PAA are currently higher than chlorination/dechlorination as the cost of PAA is approximately $1.40 - $1.70 USD per liter ($5.30 - $6.81 USD per gallon) (Bettenhausen, 2020). A comparison of the unit cost of purchasing PAA to purchasing sodium hypochlorite and sodium bisulphite is shown below in **Table 5-29**.

Table 5-29: Chemical Cost Comparison of PAA to Chlorination/Dechlorination

Chemical	Unit Cost (USD)
Sodium Hypochlorite[1]	$0.86 per gallon
Sodium Bisulphite[1]	$2.03 per gallon
Total Chlorination/Dechlorination	**$2.89 per gallon**
Peracetic Acid[2]	**$5.30 - $6.81 per gallon**
Notes: 1. (City of Lawrence, 2019) 2. (Bettenhausen, 2020)	

5.3.4.2 Maturity of Technology

PAA is a newer technology that has been gaining more interest recently. However, its application at water resource recovery facilities is currently limited. Bulk chemical availability and high chemical costs are significant factors limiting the more widespread use of PAA. These factors are expected to improve as this technology gains more popularity for usage in disinfection. In addition, the decomposition to dilute acetic acid contributes to effluent BOD_5; an important consideration for sensitive receivers with very low effluent limits (PeroxyChem, 2016).

5.3.4.3 Proven Application at Large WRRFs

There are several small municipalities that have either piloted or use PAA for disinfection. However, there is only one facility with a capacity over 100 MLD as listed below in **Table 5-30.** It is currently the largest installation of PAA for wastewater disinfection.

Table 5-30: Large Full-Scale Application of PAA

Name	Location	Rated Capacity (MLD)
Maxon WWTP	Memphis, Tennessee	265

Name	Location	Rated Capacity (MLD)
Notes: 1. (Bettenhausen, 2020)		

5.3.4.4 Compatibility with Existing and Future Processes

PAA disinfection involves a system of chemical storage and dosage similar to that in place at the Clarkson WRRF. The existing chemical storage systems could be repurposed to accommodate PAA.

However, PAA's availability in bulk is limited and would potentially present challenges for a facility the size of Clarkson WRRF. Furthermore, chemical costs would be almost triple those for chlorination/dechlorination.

5.3.4.5 Compatibility with Regional Energy Management and GHG Reduction Goals

PAA has a low capital cost and a low energy consumption. It also does not require an additional chemical for neutralization which reduces chemical purchase and storage.

5.3.4.6 Ability to Implement within Required Schedule

This technology is still maturing and there are limited large installations in wastewater. This alternative may not be able to meet the 2029 expansion timeline.

5.3.4.7 Advantages and Disadvantages

A summary of the advantages and disadvantages of utilizing PAA in disinfection is listed below in **Table 5-31**.

Table 5-31: Summary of Advantages and Disadvantages of PAA

Advantages	Disadvantages
• No harmful residuals to remove prior to discharge. • Does not require the addition of another chemical for neutralization. • Capital costs similar to those for a sodium hypochlorite system. • The existing chemical storage and dosage system could be repurposed. • Low energy costs. • Simple operation.	• Maturing technology. • Limited large full-scale applications in wastewater. • Limited bulk chemical available (for a plant the size of Clarkson WRRF) and high chemical costs. • May not be able to meet 2029 implementation timeline.

5.3.5 Summary of Evaluation of Long List of Disinfection Technologies

The results of the disinfection technology screening are presented in **Table 5-32** below. Based on the screening it is recommended that the chlorination/dechlorination and UV disinfection be short-listed for the development of alternative design concepts for detailed evaluation.

Table 5-32: Clarkson WRRF Disinfection Technology Screening

No.	Technology Alternative	Maturity of Technology	Proven Application at Large WRRFs	Compatibility with Existing and Future Processes	Compatibility with Regional Energy Management and GHG Reduction Goals	Ability to Implement within Required Schedule	Consider for Evaluation
1	Chlorination/ dechlorination	Mature technology. Widely used in North America and internationally.	Yes, many large installations internationally.	Yes, currently integrated into the existing outfall.	Requires purchase and storage of two separate chemicals. Low energy consumption.	Yes, mature technology currently in use at Clarkson WRRF.	Yes.
2	UV Disinfection	Mature technology. Widely used in wastewater and water treatment.	Yes, several large installations in Canada.	Greater headloss due to flow control structures. Might require effluent pumping.	High power requirements from UV lamps. Effluent pumping would also increase energy requirements. However, chemical usage for disinfection would be eliminated.	Yes, mature technology with large scale installations. Simplified MECP approvals process.	Yes.
3	Ozonation	Maturing technology for wastewater treatment. Limited operating installations.	Limited operating large installations. Several facilities have been discontinued.	Requires many new facilities to house liquid oxygen, ozone generation/off gas destruction equipment, and contact tanks.	High energy requirements from ozone generation, off gas destruction, and diffusion of gas into secondary effluent.	Uncertain, no current operational large installations. May involve long MECP approvals process.	No.
4	Peracetic Acid	Newer technology not yet widely used at wastewater facilities.	Applications at large facilities is limited.	Limited bulk chemical availability. Triple the chemical cost of chlorination/ dechlorination.	Requires purchase and storage of one chemical. Low energy consumption.	Uncertain, limited large installations. May involve long MECP approvals process.	No.

6.0 Short List of Technology Alternatives

6.1 Preliminary Treatment

Preliminary treatment will be expanded to maintain protection of downstream equipment and processes using similar equipment as those existing at the plant. The existing preliminary treatment equipment at Clarkson WRRF includes screening and grit removal units.

6.2 Primary Treatment

Primary treatment will be expanded using similar technology to the existing processes since it has been proven to operate effectively at Clarkson WRRF. Primary treatment is a low energy process and can significantly reduce energy requirements in secondary treatment. The raw sludge produced from primary treatment is high in energy potential and can enable more gas production in the digestion process allowing for more energy recovery.

6.3 Secondary Treatment

Based on the assessment presented in **Section 5.2.12**, the secondary treatment technology alternatives short listed for further evaluation are listed in **Table 6-1** below:

Table 6-1: Short Listed Secondary Treatment Technology Alternatives

Alternative	Description
CAS Process	This alternative involves expanding the Clarkson WRRF with new CAS process trains which are consistent with the existing facility and will follow the same operating philosophy. There are opportunities to retrofit CAS tankage in the future to accommodate other newer technologies to optimize aeration and energy efficiency (e.g., MABR).
CAS Process Optimized with CEPT	This alternative involves expanding the Clarkson WRRF with new CAS process trains optimized with CEPT. The addition of metal salts and polymer upstream of the primary clarifiers will aid with solids settling, reducing the organic and solids load to the secondary treatment process. This will reduce the size of the aeration tanks and will reduce the energy consumption required for aeration.
BNR Process	This alternative involves expanding the Clarkson WRRF with new process trains including primary clarification followed by a BNR process to provide biological nitrogen and phosphorus removal. This will reduce chemical use for TP precipitation and reduce energy use and sludge production.

6.4 Disinfection

Based on the assessment presented in **Section 5.3.5**, the disinfection technology alternative short listed for further evaluation is listed in **Table 6-2** below:

Table 6-2: Short Listed Disinfection Technology Alternatives

Alternative	Description
Chlorination/dechlorination	This technology involves expanding the disinfection facilities at Clarkson WRRF using chlorination and dechlorination. This disinfection approach is already integrated into the existing outfall which will continue to service the 500 MLD Clarkson WRRF.
UV Disinfection	This technology involves expanding the disinfection facilities at Clarkson WRRF using UV disinfection to include a new facility to house UV channels and power equipment. The secondary effluent would be diverted to the new UV facility before discharging to the outfall.

6.5 Potential Design Concept Combinations

The above short-listed technologies will be combined to create design concepts that will be further detailed and evaluated in a separate technical memorandum. Each design concept will have screens and grit removal as well as primary clarifiers similar to existing preliminary and primary treatment, respectively. A detailed evaluation of the disinfection technologies will also be undertaken in a separate technical memorandum to short-list a single technology.

6.5.1 Design Concept 1

Design Concept 1 expands Clarkson WRRF using preliminary and primary treatment followed by the CAS process. This is illustrated in **Figure 6-1**.

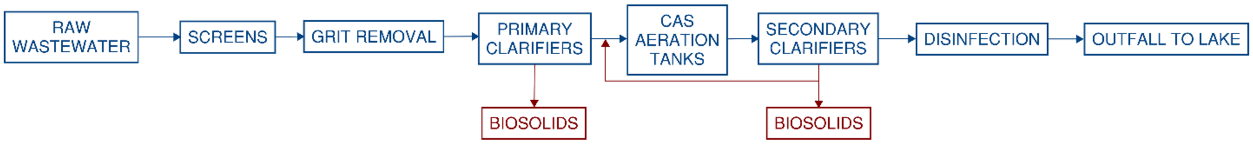

Figure 6-1: Design Concept 1: Expansion of Existing Facility using the CAS Process

6.5.2 Design Concept 2

Design Concept 2 expands Clarkson WRRF using preliminary and primary treatment followed by the CAS process optimized with CEPT. The primary treatment in this alternative is enhanced with additional metal salts/polymer dosing in comparison to traditional CAS. This is illustrated in **Figure 6-2**.

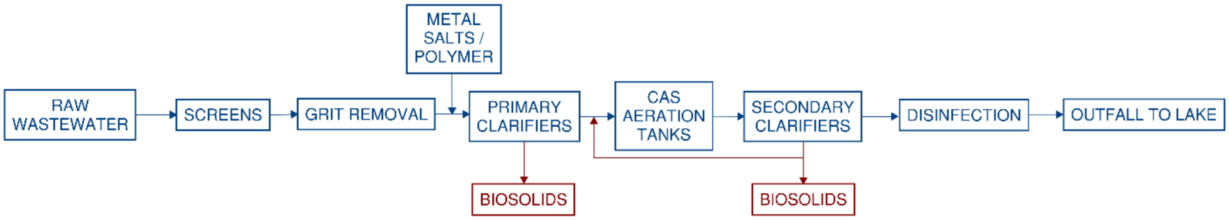

Figure 6-2: Design Concept 2: Expansion of Existing Facility using the CAS Process Optimized with CEPT

6.5.3 Design Concept 3

Design Concept 3 expands Clarkson WRRF using preliminary and primary treatment followed by the BNR process. There are many different configurations of the BNR process, this will be further detailed when developing the details of the design concepts. This is illustrated in **Figure 6-3**.

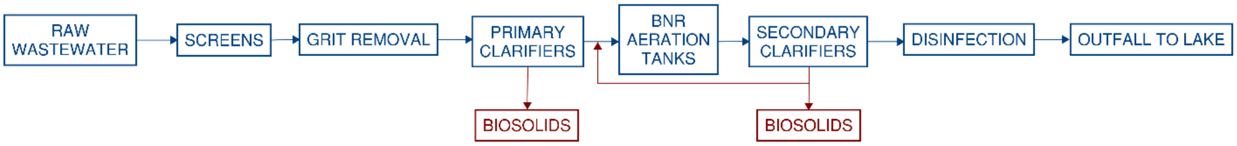

Figure 6-3: Design Concept 3: Expansion of Existing Facility using the BNR Process

7.0 Summary and Next Steps

The purpose of this Technical Memorandum was the review and evaluation of a long list of secondary treatment and disinfection technology alternatives for the expansion of the Clarkson WRRF, and to develop wastewater design concepts to be assessed in detail by combining the short list of technologies. The design of other unit processes and overall site planning depends heavily on the selected secondary treatment process, so the screening of these technologies was imperative. A long list of disinfection technology alternatives was also evaluated. The long lists of both secondary treatment and disinfection technology alternatives were screened based on a set of pass-fail criteria as described in **Section 4.0**, and a short list developed.

A detailed evaluation will be completed for the following two short-listed disinfection technologies to determine the preferred technology to be combined with the design concepts below.

1. Chlorination/Dechlorination.
2. UV Disinfection

The short list was combined to develop the following alternative design concepts:

1. Expansion of the Existing Facility Using Conventional Activated Sludge.
2. Expansion of the Existing Facility Using Conventional Activated Sludge optimized with CEPT.
3. Expansion of the Existing Facility Using Biological Nutrient Removal.

These alternative design concepts for the expansion of the Clarkson WRRF will then be evaluated in detail to select the preferred wastewater design concept to expand the Clarkson WRRF.

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Appendix J:

Evaluation of Wastewater Design Concepts

J1: Disinfection Concepts

Table J1: Evaluation of Disinfection Technology Alternatives

Sub-Criteria	Expansion Using Chlorination/Dechlorination	Expansion Using Ultraviolet (UV) Disinfection
Natural Environment		
Terrestrial System	Expanding the chlorination/dechlorination will have limited impacts on natural environment features as it is integrated into the existing outfall, and no major construction is required. UV disinfection requires the construction of a new facility. While this facility would be located in a disturbed area of the site, with limited natural features, additional mitigation measures will be necessary to reduce risks to surrounding natural features.	
	9	8
Aquatic System	Lakeside Creek, Lake Ontario floodplain, and CVC regulated areas are outside the site boundary. With chlorination/dechlorination there is a risk of disinfection by-product formation and release into Lake Ontario, potentially impacting water quality and aquatic species. The risk is considered to be low.	
	7	9
Surface Water Quality and Source Water Protection	With chlorination/dechlorination there is a risk of disinfection by-product formation and release into Lake Ontario. As a result, chlorination/dechlorination has slightly more potential to impact surface water quality than UV disinfection. The risk is considered to be low.	
	7	9
Groundwater Water Quality and Quantity	Neither alternative is expected to impact groundwater quality and quantity. Mitigation measures would be implemented during construction of the UV facility.	
	9	8
Air Quality	Air emissions at the Clarkson WRRF currently meets MECP requirements. Chlorination / dechlorination will not impact air emissions at the Clarkson WRRF. UV disinfection will require increased standby power requirements, but air emissions from the generators can be controlled to meet air quality standards.	
	9	8
Greenhouse Gas Emissions (GHG)	UV has higher overall Scope 1 & 2 GHG emissions than chlorination/dechlorination which accounts for 75% of the weighting in this evaluation. Chlorination/dechlorination has higher Scope 3 emissions due to chemical use.	
	8	7
Total Score (Out of 60)	49	49
Normalized Score (Total 25)	**20.4**	**20.4**
Social - Cultural Environment		
Odour	Neither alternative would have odour impacts.	
	9	9
Noise/Vibrations	Neither alternative would have noise/vibration impacts. Impacts during construction of the UV facility would be mitigated.	
	9	9
Visual Aesthetics	Concerns related to visual aesthetics are minimal since the site is located within an industrial area.	
	9	9
Truck Traffic	Truck traffic would be greater for chlorination/dechlorination due to regular chemical deliveries. Truck traffic would be increased during construction of the UV facility.	
	7	9
Disruption During Construction	UV disinfection is expected to produce some disruption during construction however mitigation measures would be implemented.	
	9	7

Sub-Criteria	Expansion Using Chlorination/Dechlorination	Expansion Using Ultraviolet (UV) Disinfection
Property Acquisition and Easement	No property acquisition and easements would be required for either alternative.	
	9	9
Recreational Use and Users	Both alternatives would be located within the site boundary with limited recreational uses nearby (Lakeview Park across the street from Clarkson WRRF). UV disinfection construction impacts would be mitigated.	
	9	9
Agricultural Use and Users	Agricultural use and users will not be impacted.	
	9	9
Human Health and Well-Being	Both alternatives would be designed to meet air emission and effluent quality requirements to protect human health.	
	9	9
Existing and Future Adjacent Land Use Compatibility	Both alternatives would be located within the existing site in an industrial area and are consistent with the existing and planned uses.	
	9	9
Archaeology/Natural Heritage & Aboriginal Interest	Both alternatives would be located in the disturbed area of the site. The Stage 1 AA indicated that there is no potential for archaeological resources in the area sited for new UV facilities. Chlorination/dechlorination would require no additional construction on site.	
	9	9
Total Score (Out of 110)	97	97
Normalized Score (Total 25)	**22.0**	**22.0**
Technical Considerations		
Effectiveness	Both alternatives would be designed to effectively treat wastewater to meet effluent objectives and wet weather management needs.	
	9	9
Long Term Sustainability	Both alternatives would be designed to meet current needs, while not compromising the ability to meet future needs.	
	9	9
Ease of Operation	Both alternatives are easy to operate.	
	9	9
Ease of Implementation	The UV disinfection facility would involve construction of a new facility, and diversion of secondary effluent to the new facility before discharging to the outfall. An effluent pumping station may be required to mitigate increased headlosses from the UV channel weirs. Increased standby power capacity would be required.	
	9	6
Resiliency	Both alternatives would be designed to have adequate levels of redundancy.	
	9	9
Compatibility with Existing Infrastructure System	UV disinfection would cause an increase in headloss thereby impacting system capacity which may require the implementation of effluent pumping. Additional standby power capacity would also be required.	
	9	6
Geotechnical and Hydrogeology	The UV system would be designed according to on-site geotechnical and hydrogeological conditions. Chlorination/dechlorination requires no new construction of facilities.	
	9	8

Sub-Criteria	Expansion Using Chlorination/Dechlorination	Expansion Using Ultraviolet (UV) Disinfection
Contaminated Soils	The UV system would be designed according to the on-site environmental/contamination conditions that may be present within the existing site boundary. The Phase 1 Environmental Site Assessment (ESA) indicated that the area designated for a new UV facility is not in an Area of Potential Environmental Concern (APEC).	
	9	8
Energy Use and Recovery	The UV disinfection option has the highest energy requirements due to the power draw from the UV lamps. The power draw of the UV system at peak flows is approximately 900 kilowatts, which would have a significant impact on the electrical system at maximum flows. Furthermore, installation of the UV system may require expansion to the standby power system to ensure emergency power is available to achieve disinfection compliance at all flows. The chlorination/dechlorination requires minimal energy to dose chemical to the outfall, so the energy consumed is negligible in comparison.	
	9	6
Climate Change Adaptability	Impacts to system capacity caused by headloss from the UV system could reduce the facility's climate change resiliency. However, UV disinfection would make the facility less reliant on external chemical deliveries which might make it less vulnerable to supply chain disruptions due to climate change.	
	9	8
Permits and Approvals	UV disinfection is a well-established technology which would be readily approved by the MECP. However, a change in process may require more detail and time to gain approval than continuing with the existing process.	
	9	8
Total Score (Out of 110)	99	86
Normalized Score (Total 25)	**22.5**	**19.5**
Economic Considerations		
Capital Cost	Negligible	$79 M
	9	3
Operating and Maintenance (O&M) Costs	$3.1 M	$2.5 M
	6	7
Life Cycle Costs (30-year NPV life cycle cost estimate)	$67 M	$118 M
	7	4
Total Score (Out of 30)	22	14
Normalized Score (Total 25)	**18.3**	**11.7**
Total Score	**83.2%**	**73.6%**

Appendix J:

Evaluation of Wastewater Design Concepts

J2: Wastewater Design Concepts

Table J2: Detailed Evaluation of Wastewater Design Concepts

Sub-Criteria	Design Concept 1: Expansion Using CAS	Design Concept 2: Expansion Using CAS with CEPT	Design Concept 3: Expansion Using BNR
Natural Environment			
Terrestrial System	The footprint for all alternatives will be located within the existing site boundary primarily to the northeast of the existing secondary treatment facilities, on disturbed lands. The additional primary tanks will be constructed to avoid the area classified as Mineral Cultural Meadow, with has scattered occurrences of young to mid-age trees as well as shrub species. If tree removal is required, a tree removal plan will be developed with trees replaced at the front of the site. No significant habitats or species at risk are expected to be impacted. Given the characteristics of the area and the ability to mitigate impacts, all alternatives are rated as having minor impacts.		
	7	7	7
Aquatic System	Lakeside Creek, Lake Ontario floodplain, and CVC regulated areas are outside the site boundary. The Mineral Cultural Meadow, a non-provincially significant wetland, is not expected to be impacted by the construction of facilities. Measures will be implemented to mitigate and avoid impacts.		
	8	8	8
Surface Water Quality and Source Water Protection	The Receiving Water Impact Assessment (RWIA) indicated that the impacts of the expanded Clarkson WRRF (under all alternative design concepts) would have no to very low impacts on water quality in terms of meeting PWQOs and GLWQA requirements. The IPZs of the Peel Lorne Park and A.P. Kennedy Water WTPs and the Toronto R.L Clark WTP are not impacted.		
	8	8	8
Groundwater Water Quality and Quantity	None of the alternatives are expected to significantly impact groundwater quality and quantity, given the soil and hydrogeological conditions on site. The site conditions are well known meaning fewer challenges with dewatering. Impacts on groundwater quantity and quality are therefore rated as low. Shoring and dewatering plans will be developed during detailed design to protect groundwater resources.		
	8	8	8
Air Quality	Air emissions at the Clarkson WRRF meet MECP requirements, and any expansion of the WRRF will include controls to limit air emissions such that the WRRF continues to meet MECP requirements. All alternatives would be designed to include emission control and treatment to ensure air quality standards are met and impacts are mitigated.		
	8	8	8
Greenhouse Gas Emissions (GHG)	All alternatives have similar direct GHG emissions (Scope 1). The CAS process produces the most Scope 2 GHG emissions due to its increased aeration requirements. The CEPT process produces the most Scope 3 emissions due to increased chemical use and the shipment of these chemicals to the site on a regular basis. Overall, the BNR alternative produces the lowest GHG emissions with reduced aeration energy (Scope 2) and chemical use (Scope 3).		
	6	7	8
Total Score (Out of 60)	45	46	47
Normalized Score (Total 25)	**18.8**	**19.2**	**19.6**
Social - Cultural Environment			
Odour	All three alternatives would be designed to include odour control and treatment such that all air quality standards are met, and impacts mitigated.		
	8	8	8
Noise/Vibrations	The three alternatives would be designed to mitigate noise/vibrations to meet requirements at the nearest receptors.		
	8	8	8
Visual Aesthetics	The facilities are located to the northwest and northeast of existing facilities, closer to adjacent to industrial uses, with buffers planned between the site and Lakeshore Road. Concerns related to visual aesthetics of the expanded site are assumed to be minimal. Plant designs and landscaping will be such that visual aesthetics of the site will be similar or improved from present.		
	9	9	9

Sub-Criteria	Design Concept 1: Expansion Using CAS	Design Concept 2: Expansion Using CAS with CEPT	Design Concept 3: Expansion Using BNR
Truck Traffic	There would be increased truck traffic to deliver chemicals for the CAS and CEPT design concepts compared to BNR. Truck traffic would be greatest for CEPT over its lifecycle due to additional chemical deliveries (two types of iron and polymer) and increased sludge production. In addition, the BNR process produces less biosolids meaning less trucks for haulage off-site.		
	8	6	9
Disruption During Construction	All three alternatives would produce some disruption during construction, but the duration and magnitude will be similar for all alternatives and will be mitigated. As these are short-term impacts and they can be mitigated, the impacts are relatively low for all alternatives.		
	7	7	7
Property Acquisition and Easement	Property acquisition and easements would not be required.		
	9	9	9
Recreational Use and Users	All three alternatives would be located within the site boundary with limited recreational uses nearby. Near shore water quality would not be impacted.		
	8	8	8
Agricultural Use and Users	The alternatives will have no impact on agricultural use and users.		
	9	9	9
Human Health and Well-Being	All alternatives would be designed to meet air emission and effluent quality requirements to protect human health.		
	8	8	8
Existing and Future Adjacent Land Use Compatibility	The majority of the surrounding areas is identified as commercial/industrial (CIC) and there are no plans in Peel or Mississauga's Official Plans to change these land use designations within the planning period. All three alternatives would be located within the existing site in an industrial area and the expanded facilities will be located at the northwest side of the site, furthest from Lakeshore Road. The alternatives are compatible with existing and future land uses in the area.		
	9	9	9
Archaeology/Natural Heritage & Aboriginal Interest	The Stage 1 AA indicated that there is no potential for archaeological resources in the area designated for expansion.		
	8	8	8
Total Score (Out of 110)	91	89	92
Normalized Score (Total 25)	**20.7**	**20.2**	**20.9**
Technical Considerations			
Effectiveness	All three alternatives would be designed to effectively treat wastewater to meet effluent objectives and wet weather management needs.		
	9	9	9
Long Term Sustainability	All three alternatives would be designed to meet current needs, while not compromising the ability to meet future needs. Although not currently an effluent requirement, BNR is more effective at removing total nitrogen (TN). In addition, BNR offers more flexibility in treatment as it allows operation as either a BNR facility or a CAS facility with no additional capital cost.		
	8	8	9
Ease of Operation	The BNR process involves a different operating philosophy but does not require significant operator intervention. There is limited operating experience with this process internationally. This process will be piloted at the Ashbridges Bay Treatment Plant in the City of Toronto. CEPT involves management of polymer and two types of iron on site.		
	9	6	8
Ease of Implementation	The implementation requirements of all alternatives would be similar. The new facilities would be constructed in open areas within the site. Staging would be required to tie-in to existing plant processes.		
	8	8	8

Sub-Criteria	Design Concept 1: Expansion Using CAS	Design Concept 2: Expansion Using CAS with CEPT	Design Concept 3: Expansion Using BNR
Resiliency	All three alternatives would be designed to have adequate levels of redundancy, providing one additional spare train.		
	8	8	8
Compatibility with Existing Infrastructure System	The BNR process is the least compatible with the existing CAS process since it involves a different treatment process.		
	9	8	7
Geotechnical and Hydrogeology	All three alternatives would be designed according to on-site geotechnical and hydrogeological conditions.		
	8	8	8
Contaminated Soils	All three alternatives would be designed according to on-site environmental/contamination conditions that may be present within the existing site boundary. The Phase 1 ESA indicated the area of construction is in an Area of Potential Environmental Concern (APEC). BNR would result in slightly increased excess soil management requirements due to its larger footprint.		
	7	8	7
Energy Use and Recovery	The CEPT design concept produces the most primary sludge which can be used for energy recovery, and it has low energy requirements.		
	7	9	7
Climate Change Adaptability	CAS and CEPT would be more resilient to changes in flow and temperature resulting from climate change. BNR would be slightly less resilient to variations in wastewater flow/load.		
	8	8	7
Permits and Approvals	The BNR variation proposed (S2EBPR) is relatively new and there is limited operating experience with this process internationally. This process will be piloted at the Ashbridges Bay Treatment Plant in the City of Toronto. Approvals should be similar to a CAS due to the inherent flexibility to operate as a CAS process.		
	9	9	8
Total Score (Out of 110)	90	89	86
Normalized Score (Total 25)	**20.5**	**20.2**	**19.5**
Economic Considerations			
Capital Cost	$341 M	$307 M	$359 M
	6	7	6
Operating and Maintenance (O&M) Costs	$8.1 M	$9.0 M	$7.5 M
	6	5	7
30-Year NPV life cycle costs	$532 M	$518 M	$536 M
	7	7	7
Total Score (Out of 30)	19	19	20
Normalized Score (Total 25)	15.8	15.8	16.7
Total Score	**75.8%**	**75.4%**	**76.7%**

There is no significant difference among the total scores of the alternative design concepts. Consequently, another level of assessment was completed comparing each alternative design concept's ability to meet the Region's key objectives. Based on this review, **Design Concept 3: Expansion Using BNR** was selected as the preferred. It is preferred in terms of long term sustainability (i.e., offers the flexibility to operate with reduced chemicals and can also be considered to operate as a CAS facility. BNR also has the potential for greater nitrogen removal through integrated nitrification and denitrification), community acceptability (i.e., less truck traffic), energy efficiency, lower GHG emissions, and the lowest operating costs.

Appendix K:

Biosolids Product Market Assessment

Clarkson Water Resource Recovery Facility
Schedule C Class Environmental Assessment

Technical Memorandum:

Biosolids Product Market Assessment

10/3/2022

BLACK & VEATCH

VERIFIED AND APPROVED					
Rev	**Prepared By**	**Date**	**Verified By**	**Date**	**Revision Description**
1	Mark Lang/ Emma Cabrera-Aragon	Dec 1, 2020	Zhifei Hu	Dec 2, 2020	Draft
2	Mark Lang	March 29, 2022	Zhifei Hu	March 29, 2022	Final Draft
3	Mark Lang	October 3, 2022	Zhifei Hu	October 3, 2022	Final

AUTHORIZED AND DISTRIBUTED					
Rev No	**Authorized By**	**Date**	**Issued To**	**Date**	**Copies**
1	Zhifei Hu	Dec 2, 2020	Laurie Boyce	Dec 2, 2020	1
2	Zhifei Hu	March 29, 2022	Laurie Boyce	March 29, 2022	1
3	Zhifei Hu	October 3, 2022	Laurie Boyce	October 3, 2022	1

QA/QC REVIEW – REV.1		
Date	**Name**	**Signature**
Dec 2, 2020	Zhifei Hu, P.Eng.	
Dec 7, 2020	Troy Briggs, P.Eng.	
Dec 10, 2020	Laurie Boyce, M.A.	

QA/QC REVIEW - REV.2		
Date	**Name**	**Signature**
March 29, 2022	Zhifei Hu, P.Eng.	
March 29, 2022	Troy Briggs, P.Eng.	
March 29, 2022	Laurie Boyce, M.A.	

QA/QC REVIEW – REV.3		
Date	**Name**	**Signature**
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October 3, 2022	Troy Briggs, P.Eng.	
October 3, 2022	Laurie Boyce, M.A.	

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Term or Acronym	Definition
%	Percent
°C	Degrees Celsius
°F	Degrees Fahrenheit
µg	Microgram
µg/l	Microgram per Litre
6:2 FTS	6:2 fluorotelomer sulfonate
6:2 FTS	6:2 fluorotelomer sulfonate
8:2 FTS	8:2 fluorotelomer sulfonate
ABTP	Ashbridges Bay Treatment Plant
As	Arsenic
B&V	Black & Veatch
BMC	Biosolids Management Centre
BNQ	Bureau de normalization du Quebec
BTG	Biosolids Task Group
Ca(OH)2	Calcium Hydroxide
CaO	Calcium Oxide
CCME	Canadian Council of Ministers of the Environment
Cd	Cadmium
CEPA	Canadian Environmental Protection Act
CFIA	Canadian Food Inspection Agency
CFU	Colony Forming Units
CFU/g	Colony Forming Unit per Gram
CM1	NASM metal category 1 based on metal content
CM2	NASM metal category 2 based on metal content
Co	Cobalt
CP1	NASM pathogen category 1 based on pathogen level
CP2	NASM pathogen category 2 based on pathogen level
Cr	Chromium

Term or Acronym	Definition
Cu	Copper
DT	Dry Tonnes
DT/ha	Dry Tonnes per Hectare
DT/ha-yr	Dry Tonnes per Hectare per Year
DT/yr	Dry Tonnes per Year
EA	Environmental Assessment
EASR	Environmental Activity and Sector Registry
ECCC	Environment and Climate Change Canada
EPA	Environmental Protection Act
FzA	Fertilizers Act
FzR	Fertilizers Regulations
g	Gram
ha	Hectare
Hg	Mercury
kg	Kilogram
kg/ha	Kilogram per Hectare
KOH	Potassium Hydroxide
l	Litre
m3	Cubic Metre
MAC	Maximum Acceptable Concentration
MAD	Mesophilic Anaerobic Digester
MECP	Ministry of the Environment, Conservation and Parks
mg	Milligram
mg/kg	Milligram per Kilogram
mg/kg-day	Milligram per Kilogram per Day
mg/L	Milligram per Litre
mm	Millimetre
Mo	Molybdenum

Term or Acronym	Definition
MPN	Most Probably Number
MTO	Ministry of Transportation Ontario
N	Nitrogen
Na	Sodium
NaOH	Sodium Hydroxide
NASM	Non-Agricultural Source Material
ng	Nanograms
Ni	Nickel
NMA	Nutrient Management Act
NMP	Nutrient Management Plan
NPRI	National Pollutant Release Inventory
OC1	NASM odour category 1 based on odour detection threshold
OC2	NASM odour category 2 based on odour detection threshold
OC3	NASM odour category 3 based on odour detection threshold
OMAFRA	Ontario Ministry of Agriculture, Food and Rural Affairs
OPS	Ontario Provincial Standards for Roads and Public Works
ou	Odour Units
OWRA	Ontario Water Resources Act
Pb	Lead
PCB	Polychlorinated Biphenyl
PCDD	Polychlorinated Dibenzo-p-dioxins
PFAS	Per- and Polyfluoroalkyl Substances
PFBA	Perfluorobutanoate
PFBS	Perfluorobutane sulfonate
PFCA	Perfluorocarboxylic Acid
PFHpA	Perfluoroheptanoate
PFHxA	Perfluorohexanoate
PFHxS	Perfluorohexane sulfonate

Term or Acronym	Definition
PFNA	Perfluorononanoate
PFOA	Perfluorooctanoic acid
PFOS + PFOA	Perfluorooctane sulfonate + Perfluorooctanoic acid
PFOS	Perfluorooctane sulfonate
PFPeA	Perfluoropentanoate
PIWMF	Peel Integrated Waste Management Facility
Region	Region of Peel or Regional Municipality of Peel
Se	Selenium
SRM	Specified Risk Materials
SSO	Separated Source Organics
SSV	Soil Screening Values
TEQ	Toxic Equivalents
THP	Thermal Hydrolysis Process
TI	Thallium
TM	Technical Memorandum
ton	Imperial Ton
tonne	Metric Tonne
TPAD	Temperature Phased Anaerobic Digestion
TS	Total Solids
V	Vanadium
VSr	Volatile Solids Reduction
WPCP	Water Pollution Control Plant
WRRF	Water Resource Recovery Facility
WWTP	Wastewater Treatment Plant
yr	Year
Z	Zinc

1.0 Introduction

1.1 Background

The Region of Peel (Region) has retained the GM BluePlan, CIMA, and Black & Veatch (B&V) Team to complete two Schedule C Class Environmental Assessments (EAs); one each for the G.E. Booth and Clarkson Water Resource Recovery Facilities (WRRFs); formerly referred to as Wastewater Treatment Plants (WWTPs). The purpose of the Schedule C Class EAs is to identify a preferred solution for meeting future capacity requirements at both the G.E. Booth and Clarkson WRRFs. Enhanced conceptual designs for each facility will be developed that not only provide details on the expansion work required to meet 2041 demands, but a long-term comprehensive, sustainable vision for future plant designs beyond 2041.

Both WRRFs are conventional activated sludge facilities and biosolids generated at both facilities are incinerated at the G.E. Booth WRRF. The digested sludge generated at Clarkson WRRF is transferred to G.E. Booth for incineration. The residual ash slurry from the incineration process is transferred to two on-site settling lagoons which are dredged regularly and stored on-site in an ash pond.

Design Basis TMs established design basis wastewater flows, and loadings along with biosolids quantities and characteristics for each WRRF. The current and future biosolids production at the G.E. Booth and the Clarkson WRRFs were used to conduct the biosolids product market assessment.

1.2 Purpose of Biosolids Market Assessment Technical Memorandum

This technical memorandum (TM) documents the biosolids product market assessment conducted for G.E. Booth and Clarkson WRRFs. This TM summarizes the regulatory framework for the management of biosolids in Ontario, defines the different biosolids products and their characteristics, identifies target markets/outlets available and provides an overview of estimated demand and market potential. The TM provides recommendations and market considerations for the biosolids products and outlets with the most market potential. The information presented herein is being used to develop biosolids management alternatives for each WRRF.

2.0 Regulatory Framework

2.1 Biosolids Regulations

2.1.1 Federal

At the national level, Environment Canada administers the Canadian Environmental Protection Act to protect the environment and human health. The Canadian Food Inspection Agency (CFIA) regulates the sale and import of biosolids intended for use as a fertilizer or supplement.

2.1.1.1 The Canadian Environmental Protection Act (CEPA)

The Canadian Environmental Protection Act (CEPA) was enacted in September of 1999 and provides the Canadian government the power to protect the environment and human health while contributing to sustainable development. The CEPA does not directly address biosolids products. It may, however, address new substances found in biosolids through the National Pollutant Release Inventory (NPRI). The NPRI is a program that requires the reporting of the release of 323 substances listed on the inventory based on an annual threshold. From a regulatory perspective, Environment Canada currently considers biosolids to be a waste product. As a result, biosolids may be impacted in the future if the substances on the inventory or the threshold quantities change.

2.1.1.2 The Canadian Food inspection Agency (CFIA) Fertilizers Act (FzA) and Fertilizers Regulations (FzR)

The Canadian Food inspection Agency (CFIA) administers several Acts and Regulations including the *Fertilizers Act (FzA*) and *Fertilizers Regulations (FzR)*. These have been designed to protect the food supply along with animals and plants. As a result, they enhance Canada's environment, economy, and the well-being of its citizens.

The Fertilizers Act and Regulations require that regulated fertilizers and soils supplements are safe for humans, animals, plants, and the environment. The regulations require that the items are labeled for safety and their proper use. The products regulated include:

- Farm fertilizers
- Micronutrients
- Lawn and Garden products
- Supplements, including:
  - Water holding polymers
  - Microbial inoculants
  - Abiotic stress protectants
  - Liming materials
  - Waste derived material such as composts and municipal biosolids.

While CFIA regulates the fertilizers and supplements that are sold and imported into Canada, the manufacturer of the product, their use and disposal are controlled by provincial and municipal regulations. The CFIA performs pre-market assessments and label verification on fertilizer products. For supplements such as biosolids products and compost they provide marketplace monitoring to verify their compliance with prescribed standards which include pathogens, metals, and pesticide residue along with dioxins and furans.

The Fertilizer Trade Memoranda provides product specific information and requirements for fertilizers and supplements regulated under the *Fertilizers Act* Section T-4-93. The safety standards for fertilizers and supplements, provide a series of metals concentrations that are acceptable in a fertilizer product. As noted on **Table 2-1**, the maximum acceptable product metal concentration (in milligrams per kilogram (mg/kg)) on a dry weight basis) is calculated based on an anticipated 45-year cumulative loading (in kg per hectare (kg/ha)).

Table 2-1 CFIA Fertilizer and Supplements Metals Standards

METAL	MAXIMUM ACCEPTABLE CUMULATIVE METALS ADDITION TO SOIL OVER 45 YEARS (KG/HA)	EXAMPLES OF MAXIMUM ACCEPTABLE PRODUCT METAL CONCENTRATION BASED ON ANNUAL APPLICATION RATES (MG/KG) 4,400 KG/HA-YR	EXAMPLES OF MAXIMUM ACCEPTABLE PRODUCT METAL CCONCENTRATION BASED ON ANNUAL APPLICATION RATES (MG/KG) 2,000 KG/HA-YR	EXAMPLES OF MAXIMUM ACCEPTABLE PRODUCT METAL CONCENTRATION BASED ON ANNUAL APPLICATION RATES (MG/KG) 500 KG/HA-YR
Arsenic (As)	15	75	166	666
Cadmium (Cd)	4	20	44	177
Chromium (Cr)	210	1,060	2,333	9,333
Cobalt (Co)	30	151	333	1,333
Copper (Cu)	150	757	1,666	6,666
Mercury (Hg)	1	5	11	44
Molybdenum (MO)	4	20	44	177
Nickel (Ni)	36	181	400	1,600
Lead (Pb)	100	505	1,111	4,444
Selenium (SE)	2.8	14	31	124
Thallium (TI) (1)	1	5	11	44
Vanadium (V) (1)	130	656	1,444	5,777
Zinc (Z)	370	1,868	4,111	16,444

Note (1) Not all products require analysis for Thallium and Vanadium. Results may be requested on a case-by-case basis based on the type of product or material.

The number of samples to be collected is dependent on the number of “batches” or “lots” produced within the last three-year period. If greater than 26, the number of samples will be determined in conjunction with CFIA.

The maximum acceptable cumulative addition to soils of polychlorinated dibenzo-p-dioxins (dioxins; PCDD) and polychlorinated dibenzofurans concentrations and the 45-year cumulative application product concentrations for dioxins and furans to soil is 5.355 toxic equivalents per hectare (TEQ/ha). In addition, a maximum concentration of 100 nanograms (ng) TEQ/kg is being considered to protect workers.

Table 2-2 CFIA Fertilizer and Supplements Dioxin and Furan Standards

	MAXIMUM ACCEPTABLE CUMULATIVE PCDD/FS ADDITION TO SOIL OVER 45 YEARS (MG TEQ/HA)	EXAMPLE OF MAXIMUM ACCEPTABLE PCDD/FS CONCENTRATION BASED ON ANNUAL APPLICATION RATES (NG TEQ/HA) 4,400 KG/HA-YR	EXAMPLE OF MAXIMUM ACCEPTABLE PCDD/FS CONCENTRATION BASED ON ANNUAL APPLICATION RATES (NG TEQ/HA) 2,000 KG/HA-YR
PCDD/ Fs	5.355	27	59.5

Section T-4-93 of the *Fertilizers Act* also addresses pathogen reduction in biosolids using Salmonella and Faecal Coliforms as indicators. The section mentions that this approach is closely aligned with the US EPA’s 40 Part 503 Regulations. The maximum level of these organisms in fertilizers and supplements is presented in **Table 2-3**. It further includes information regarding the acceptable tolerances for fertilizers that guarantee certain concentrations of micronutrients in their product.

Table 2-3 CFIA Indicator Organisms in Fertilizers and Supplements

INDICATOR ORGANISM	LEVEL	MINIMUM DETECTION LIMIT
Salmonella	Not Detectable	Less than 1 Colony Forming Unit (CFU) / 25 grams
Faecal Coliforms	1000 Most Probable Number (MPN) / gram	Less than 2 CFU / gram

The Fertilizer Trade Memoranda provides information on the requirements for compost under the *Fertilizers Act*. Section T-4-120, Regulation of Compost under the Fertilizers Act and Regulations, describes the safety and labelling requirements that must be met to sell compost in Canada. This Section is also intended to assist compost producers and facility operators in meeting the regulations administered by the CFIA.

Compost is classified as a supplement and is defined in schedule II of FzR. Compost products are exempt from registration and do not require a market reassessment by CFIA. The product must still meet all the standards and requirements outlined in the FzR. The requirements include:

Labelling requirements

- Nutrient information if guaranteed on the product labelling
- Net material weight
- Producer information
- Organic matter and moisture content
- Lot number (all supplements must include a lot number on the product label)
- Directions for use
- Cautionary Statements
- Product pH and sodium (Na) content are recommended but not required.
- Labels can be printed in English or in French. If printed in both, each language must contain the full level of detail as the other.

Safety standards

- Physical contaminants
- Chemical contaminants which include most of the metals outlined in **Table 3-1**.
- Biological contaminants which include the indicator organism information outlined in **Table 3-3**.
- Maturity. The sale of compost is restricted to mature product. It is the producer's responsibility to demonstrate the maturity using scientifically valid methods.
- Prohibited materials including Specified Risk Materials (SRM)

The requirements for compost products also include recall procedures, record keeping requirements and sampling procedures

Safety standards for fertilizers and supplements, provides a series of metals concentrations that can be contacted as a fertilizer product.

2.1.1.3 2.1.1.3 Canadian Council of Ministers of the Environment (CCME) Guidance Document for the Beneficial Use of Municipal Biosolids, Municipal Sludge and Treated Septage

The Guidance Document for the Beneficial Use of Municipal Biosolids, Municipal Sludge and Treated Septage was developed by the CCME Biosolids Task Group (BTG) and published in 2012. It was developed in support of a Canada-wide approach to the management of biosolids. The guidance supports the beneficial use of biosolids and the sound management of biosolids, wastewater treatment sludge and treated septage. The guidance "contains information to assist Canadian regulators and generators to manage these three categories of wastewater residuals in an environmentally beneficial and sustainable manner" (Canadian Council of Ministers of the Environment, 2012).

2.1.1.4 CCME Guidelines for Compost Quality

In the early 1990s the CCME, to support the composting industry in Canada, established a committee to develop quality guidelines for compost products. The CCME, the Bureau de normalization du Quebec (BNQ) and the CFIA agreed to coordinate and develop compost standards to provide consistency. This effort resulted in the first edition of the CCME Compost Quality Guidelines which were published in 1996. The growth in the composting industry since 1996 and the advances in science and technologies resulted in the need to update the guidelines. The revised guidelines published in 2005 are based on four criteria to ensure product safety and quality (Canadian Council of Ministers of the Environment, 2005):

- Foreign matter
- Maturity
- Pathogens and
- Trace Elements

The Guidelines established two grades of material:

- Category A – Unrestricted use and
- Category B – Restricted use

The Guidelines for Compost Quality are referenced in the CCME Guidance Document for the Beneficial Use of Municipal Biosolids, Municipal Sludge and Treated Septage.

2.1.2 Provincial

2.1.2.1 Environmental Protection Act (EPA), Ontario Water Resources Act (OWRA) and Nutrient Management Act (NMA)

Ontario regulates the maintenance and operation of wastewater treatment and biosolids processing facilities through the Ontario Water Resources Act (OWRA) and the Environmental Protection Act (EPA). Application of municipal biosolids on agricultural land, as well as any form of commercial fertilizer, is regulated under the Nutrient Management Act 2002 (NMA), Ontario Regulation (O. Reg. 267/03). Application on other lands in Canada is regulated under the EPA.

The NMA was developed by the Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA), and the Ministry of the Environment, Conservation and Parks (MECP). OMAFRA is responsible for the approvals, training, certification and education activities required for the safe application of non-agricultural source material (NASM). They will also notify the local municipality (lower or single tier) when any NASM Plan within its jurisdiction is approved. MECP is responsible for enforcing compliance with the O. Reg. 267/03 of the NMA. They will also carry out proactive inspections and respond to complaints of NASM land application activities to ensure compliance with the regulatory standards and protection of the environment.

Regulation 347 under the EPA provides details on the regulation of organic soil conditioning sites and the standards applied, such as distance from watercourses, points of access to water, and distance from residences. Environmental quality, food safety, and human health issues and concerns are addressed in both Regulations and supporting land application publications of the OMAFRA and the MECP.

The NMA regulates biosolids as NASM intended for application to agricultural land as nutrients. NASM categories include yard waste, fruit and vegetable peels, food processing waste, pulp and paper biosolids and municipal sewage biosolids. O. Reg. 267/03 under the NMA prohibits application of these materials to land that is unsuitably close to adjacent surface waters and sensitive areas; sets out criteria regarding heavy metal concentrations and suitable soil types and topography; and outlines the amount, method and timing of application. Before being approved for application on farmland, biosolids must be tested for pH, available nitrogen, potassium and phosphorus, pathogens, 11 regulated heavy metals, and meet sampling requirements set out in the regulation.

NASM is categorized into three categories (1, 2, and 3) under the NMA, based on material quality. These categories set requirements for material and soil testing and level of approval. Biosolids are a Category 3 NASM. In addition, materials are further sub-categorized into pathogen (CP1 and CP2), odour (OC1, OC2, and OC3), and metal (CM 1 and CM2) categories. Metal and pathogen categories determine setbacks from wells, surface water, groundwater and bedrock. Setback distances to residential, commercial, community or institutional properties are determined by odour category. The standards for biosolids under each of these categories are described as follows:

- Pathogen Category: Biosolids that meet the CP1 standard must meet levels of E.coli ≤1,000 colony forming units (CFU)/g dry weight or 100ml, Salmonella < 3 CFU or Most Probable Number (MPN)/4g or 100 ml, and Viable Helminth Ova & total culturable Enteric Virus < 1 organism per 4g or 100 ml. Sewage biosolids categorized as CP2 must meet the E.coli < $2x10^6$ CFU/g of total solids dry weight standard.

- Odour Category: Biosolids must have an odour detection threshold of less than 500 odour units (ou) per cubic metre (m^3) to be categorized as OC1. OC2 biosolids are between 500-1,500 ou/m^3 and OC3 biosolids are between 1,500 and 4,500 ou/m^3. O.Reg 267/03 does not allow NASM materials to be applied to agricultural land if they exceed 4,500 ou/m^3.

- Metal Category: Biosolids are classified as CM1 if they do not exceed the metal concentrations laid out in the middle column of **Table 2-4** and CM2 if they fall between CM1 concentrations and the right-most column.

Table 2-4 Biosolids Categories CM1 and CM2 Metal Concentrations (O. Reg 267/03 (2002))

REGULATED METAL	CM1 CONCENTRATION IN NON-AQUEOUS MATERIAL (CONTAINING 1% OR MORE TOTAL SOLIDS, WET WEIGHT), EXPRESSED AS MG PER KG OF TOTAL SOLIDS, DRY WEIGHT	CM2 CONCENTRATION IN NON-AQUEOUS MATERIAL (CONTAINING 1% OR MORE TOTAL SOLIDS, WET WEIGHT), EXPRESSED AS MG PER KG OF TOTAL SOLIDS, DRY WEIGHT
Arsenic	13	170
Cadmium	3	34
Cobalt	34	340
Chromium	210	2,800
Copper	100	1,700
Lead	150	1,100
Mercury	0.8	11
Molybdenum	5	94
Nickel	62	420
Selenium	2	34
Zinc	500	4,200

Updates to the NMA were published in July 2021. Part IX, Sampling, Analysis, and Quality Standards and Application Rates, Category 3, Sections 98.0.7, 98.0.8 and 98.0.9 set the criteria for determining the maximum biosolids application rates based on crop Nitrogen and Phosphorus requirements. In addition to these nutrient restrictions, new approvals for land application (NASM Plans) must meet beneficial use criteria (demonstrate beneficial use for either organic matter content, nutrients, increase soil pH or irrigation) as well as regulated metals and dry matter.

Plant available nitrogen applied cannot exceed crop requirement or nitrogen removed by crop harvesting and must be less than 200 kg/ha in any 12-month period.   Plant available phosphate over a five-year period cannot exceed the phosphate removed by crop harvesting plus 390 kg/ha.

The maximum application rates of regulated metals are presented in **Table 2-5**. The application of regulated metals through biosolids application must be limited to the listed amounts per hectare (ha) over a five-year period. The MECP must be satisfied that the application of CM2 materials will not result in a measurable increase in soils whose concentrations exceed those listed in the third column of **Table 2-5**.

Table 2-5 Maximum Application Rates of Regulated Metals

O. Reg 267/03 (2002)

REGULATED METAL	MAXIMUM ADDITION TO SOIL (IN KILOGRAMS OF REGULATED METAL PER HECTARE/PER FIVE YEARS)	MAXIMUM CONCENTRATION IN SOIL (IN MILLIGRAMS PER KILOGRAM OF SOIL, DRY WEIGHT)
Arsenic	1.4	14
Cadmium	0.27	1.6
Cobalt	2.7	20
Chromium	23.3	120
Copper	13.6	100
Lead	9	60
Mercury	0.09	0.5
Molybdenum	0.8	4
Nickel	3.56	32
Selenium	0.27	1.6
Zinc	33	220

Category 3 NASM must also meet the application limits listed in **Table 2-6** for sodium and fats, oils, and greases for each soil hydrologic group. Soil hydrologic groups are defined and described in the Drainage Guide for Ontario, Publication 29, published by the OMAFRA (2007).

Table 2-6 Maximum Application Limits for Sodium, Fats, Oils and Greases

O.Reg 267/03 (2002)

HYDROLOGIC SOIL GROUP	MAXIMUM ADDITION TO SOIL (IN KILOGRAMS OF SODIUM PER HECTARE/YEAR)	MAXIMUM ADDITION TO SOIL (IN KILOGRAMS OF FATS, OILS AND GREASE PER HECTARE/YEAR)
A	200	5,000
B	200	5,000
C	500	2,500
D	500	2,500

Ontario also has land application requirements that specify waiting periods for harvesting tree fruits and grapes, vegetables, hay and haulage, and sod as well as grazing horses, cattle, swine, sheep and goats.

A NASM Plan is like a Nutrient Management Plan (NMP) but deals only with the area where NASM is applied and not the whole farm. The NASM must be prepared by a certified individual. Under the NMA, for land application of material, copies of the NASM Plan, annual update and summary, site characterization, and records of the NASM application area, quantity applied, source of material, dates on which it was applied, and sampling and analysis results must be kept for two (2) years.

Haulers need to have a System Environmental Compliance Approval (ECA) issued by the MECP or register their operations to the Environmental Activity and Sector Registry, where eligible, but it must be revised to allow the transport of NASM to sites operating under a NASM Plan. Land Appliers need to have a Prescribed Materials Application Business License and the person applying the NASM must be trained and have a license.

For application on non-agricultural land the ECA sets out the maximum acceptable metal limits in the biosolids and soil of the receiving site on a case-by-case basis. There are no regulations on the inclusion of biosolids in topsoil and manufactured soil blends. If the blends are applied to agricultural land, a NASM plan under O.Reg. 267/03 is required; if the blends are applied on non-agricultural land, then an ECA under EPA is required.

O. Reg. 267/03 sets out storage capacity requirements for biosolids to be applied to agricultural land. NASM, including biosolids, cannot be land applied during the period beginning on December 1 of one year and ending on March 31 of the following year or at any other time when the soil is snow-covered or frozen. The Design Guidelines for Sewage Works, published by the MECP, indicate that a minimum 240 days of storage should be provided for biosolids unless a different period is justified based on site-specific conditions. The Design Guidelines note that the 240 days storage requirements under O. Reg. 267/03 can be a combination of a “permanent biosolids nutrient storage facility, a temporary field nutrient storage site (dewatered municipal sewage biosolids only) or a combination of such facilities and sites that is capable of storing generated sewage biosolids during a period of at least 240 days.”

2.1.2.2 Quality Standards and Guidelines for the Production of Compost (2012)

In 2012, Ontario updated its quality standards and guidelines for the production of compost, to encourage the composting of more materials, while protecting the environment and human health (Ontario Ministry of the Environment, Waste Management Policy Branch, 2012). The new standards include three categories of compost (AA, A, and B), which provide additional options for the management of biosolids. Category AA is unrestricted use that allows compost to be given away and used by the public freely. Under the Ontario compost regulation, a compost that contains biosolids cannot be classified as AA Category. These standards set quality criteria for metals, pathogens, maturity and foreign matter for each category of finished compost.

The maximum metals concentration for compost categories A and B are detailed in **Table 2-7**, as well as the maximum metals concentration in compost feedstock (biosolids in this case).

Table 2-7 Maximum Metals Concentration

METAL	CATEGORY A COMPOST (MG/KG DRY WEIGHT)	CATEGORY B COMPOST (MG/KG DRY WEIGHT)	FEEDSTOCK FOR CATEGORIES A & B COMPOST (MG/KG DRY WEIGHT)
Arsenic	13	75	170
Cadmium	3	20	34
Chromium	210	1060	2800
Cobalt	34	150	340
Copper	400	760	1700
Lead	150	500	1100
Mercury	0.8	5	11
Molybdenum	5	20	94
Nickel	62	180	420
Selenium	2	14	34
Zinc	700	1850	4200

Compost Category A and B must not exceed the following pathogen reduction requirements: 1,000 CFU or MPN E. coli/gram total solids and 3 MPN Salmonella/4 grams total solids. Both categories must be cured for 21 days at a set respiration rate to achieve required standard maturity. Compost product must be maintained at a moisture concentration of no more than 40%.

For Category A foreign matter >3 mm cannot exceed 1%, calculated on a dry weight basis and will contain no sharp matter. For Category B foreign matter >3mm cannot exceed 2%, dry weight, and must contain no more than 3 sharp pieces per 50 ml, no greater than 12.5 mm. For both categories, plastic cannot exceed 0.5%, dry weight, and foreign matter cannot exceed 25 mm.

Category A material must be labelled with:

- A statement that the product contains municipal sewage biosolids, if biosolids included in feedstock
- Recommended application rate
- A statement that failure to comply with recommended application rate could result in accumulation of metals in soil
- A statement that product should not be used on soils with elevated copper or zinc concentrations

Categories A and B allow municipal wastewater biosolids to be used as feedstocks up to 25%, allowing for the beneficial use of these resources. Category A compost is exempt from the need for approvals if it meets the new standards, including labelling, while Category B, falls under the same requirements as a

NASM, will continue to require government approval for use and transportation, including an ECA or Environmental Activity and Sector Registry (EASR) registration for transport and ECA for use off-farm or approved NASM Plan for on-farm use. The new standards also align Ontario more closely with those set out in 2005 by the CCME.

2.2 Landfill Regulation

2.2.1 Federal

In Canada federal, provincial, territorial, and municipal governments share the responsibility for managing wastes. Municipal governments manage the collection, recycling, composting and disposal of household wastes and provincial authorities approve and monitor waste management facilities and operations. The federal government complements the activities of municipal and provincial authorities by controlling international and interprovincial movements of hazardous waste and identifying best practices to reduce pollution from the management of this waste.

Hazardous wastes are managed under CEPA, by regulations such as the Export and Import of Hazardous Waste and Hazardous Recyclable Material Regulations and the Polychlorinated Biphenyl (PCB) Waste Export Regulations. Incinerator ash and digested dewatered cake, currently produced at G.E. Booth and Clarkson WRRFs, respectively, do not qualify as hazardous wastes. Landfilling of these biosolids products is regulated under provincial regulations.

2.2.2 Provincial

In Ontario, landfilling sites and other waste management activities are regulated by the EPA and the regulations made under the Act. Regulatory requirements for the design and operation of waste disposal sites are included in O. Reg 347. For new or expanding landfilling sites, these regulatory requirements are superseded by O. Reg 232/98, under the EPA.

Under O. Reg 347 waste is considered non-hazardous if produced from the operation of a wastewater treatment plant which is subject to OWRA, where the works are owned by a municipality. Likewise, incinerator ash resulting from the incineration of waste that is not a hazardous waste and is therefore considered non-hazardous. Non-hazardous waste is called “municipal” waste under O. Reg 347. Landfill standards in Regulation 232/98 only apply to sites accepting “municipal” waste.

An ECA must be obtained for the establishment, operation, alteration, or enlargement of a landfilling site. Prior to approval a detailed assessment, per O. Reg 232/98, is required to identify any potential effects on the environment and how these effects will be addressed. Each site’s ECA defines the size of the landfill site, the types of waste to be accepted, and any necessary conditions for design and operation.

Wastewater solids, such as the undigested and digested dewatered cake produced at G.E. Booth and Clarkson WRRFs, respectively, can be disposed of in approved municipal sanitary landfills. The required solids concentration of sludges to be landfilled are specified by the individual landfill authorities. Per the MECP's Design Guidelines for Sewage Works, "with small quantities of sludge for co-disposal landfilling with municipal solid waste, liquid sludge at solids concentrations as low as 3 percent Total Solids (TS) may be acceptable." For landfills that are sludge-only a minimum 18 percent (TS) concentration is required, or a slump of 150 mm or less. O. Reg 347 includes the "Test Method for Determination of Liquid Waste (Slump Test)" (MECP, 2008).

2.3 Potential Regulatory Trends and Changes

Regulations developed to protect human health and the environment are extremely important. The regulations are reviewed on a regular basis and are amended, when necessary, based on new findings within the scientific community. There are a number of chemicals and materials being found in wastewater that may impact the future regulation of biosolids. These include:

- Per- and polyfluoroalkyl substances (PFAS), and
- Microplastics

This section provides an overview of these trends.

2.3.1 Per- and polyfluoroalkyl substances (PFAS)

PFAS are a group of chemicals that have been widely used for 50 years in consumer products, fire-fighting foams, and manufacturing. PFAS are characterized by a carbon molecule bonded to a fluoride molecule, one of the strongest chemical bonds in nature. Additionally, they are hydrophobic and repel fats in humans and animals, some of these compounds (especially the longer-chain versions) tend to bind to proteins and are found in blood serum and the liver. Some PFAS type compounds have half-lives of four or more years in humans.

The primary concern with PFAS in biosolids is related to its potential to leach to water supplies after being applied to soils, or runoff to the surface waters used for drinking water. There is less regulatory concern regarding inhalation, ingestion, dermal contact, or other possible organic residuals-related routes of exposure.

A 2010 CCME report titled Emerging Substances of Concern in Biosolids: Concentrations and Effects of Treatment Processes looked at a select group of pharmaceuticals, fragrance and alkylphenolic compounds. Due to budgetary limitations, it did not look at other emerging substances of concern, such as other pharmaceutical compounds, natural and synthetic human hormones, industrial chemicals (e.g. phthalate esters, polybrominated diphenyl ethers and other flame retardants, perfluorinated organic substances, alkylphenol ethoxylates, quaternary ammonium compounds), and personal care products (insect repellents, sunscreens, parabens, organic siloxanes, fabric softeners, fluorescent whitening agents, etc.) (Canadian Council of Ministers of the Environment, 2010).

At the Federal level perfluorooctanoic acid (PFOA), perfluorocarboxylic acid (long-chain PFCAs) and perfluorooctane sulfonate (PFOS) are listed as substances subject to Prohibition of Certain Toxic

Substances Regulations (2012), as regulated by Environment and Climate Change Canada (ECCC). The regulations prohibit the manufacture, use, sale, offer for sale or import of the toxic substances listed below, and products containing them, with a limited number of exemptions. In 2018, Health Canada introduced drinking water quality and screening values for PFOS, PFOA and other PFAS (see **Table 2-8** and **Table 2-9** below), following by soil screening values in 2019 (see **Table 2-10**) (Government of Canada, 2019; Health Canada, 2019; Health Canada, 2016).

Table 2-8 Canadian drinking water quality - MACs for PFOS and PFOA

PFAS NAME	ACRONYM	MAXIMUM ACCEPTABLE CONCENTRATION (MAC) (MILLIGRAMS/LITRE) (MG/L)	MAXIMUM ACCEPTABLE CONCENTRATION(MAC) (MICROGRAMS/LITRE) (µG/L)
perfluorooctanoic acid	PFOA	0.0002	0.2
perfluorooctane sulfonate	PFOS	0.0006	0.6

Table 2-9 Health Canada drinking water screening values - other PFAS

PFAS NAME	ACRONYM	DRINKING WATER SCREENING VALUE (MILLIGRAMS/LITRE) (MG/L)	DRINKING WATER SCREENING VALUE (MICROGRAMS/LITRE) (µG/L)
perfluorobutanoate	PFBA	0.03	30
perfluorobutane sulfonate	PFBS	0.015	15
perfluorohexanesulfonate	PFHxS	0.0006	0.6
perfluoropentanoate	PFPeA	0.0002	0.2
perfluorohexanoate	PFHxA	0.0002	0.2
perfluoroheptanoate	PFHpA	0.0002	0.2
perfluorononanoate	PFNA	0.00002	0.02
6:2 fluorotelomer sulfonate	6:2 FTS	0.0002	0.2
8:2 fluorotelomer sulfonate	8:2 FTS	0.0002	0.2

Table 2-10 Health Canada Soil Screening Values

PFAS NAME	PFAS ACRONYM	SOIL SCREENING VALUES (SSVS) (MG/KG)		
		AGRICULTURAL/ RESIDENTIAL PARKLAND LAND USE	COMMERCIAL LAND USE	INDUSTRIAL (COMMERCIAL WITHOUT TODDLER) LAND USE
Perfluorooctane sulfonate	PFOS	2.1	3.2	30.5
Perfluorooctanoic acid	PFOA	0.70	1.05	9.94
Perfluorooctane sulfonate + Perfluorooctanoic acid	PFOS + PFOA	$\frac{[PFOS]}{SSV_{PFOS}} + \frac{[PFOA]}{SSV_{PFOA}} \leq 1$		
Perfluorobutanoate	PFBA	114	173	1630
Perfluorobutane sulfonate	PFBS	61	92	872
Perfluoropentanoate[b]	PFPeA	0.80	1.21	11.41
Perfluorohexane sulfonate[a]	PFHxS	2.3	3.5	33
Perfluorohexanoate[b]	PFHxA	0.80	1.21	11.41
Perfluoroheptanoate[b]	PFHpA	0.80	1.21	11.41
Perfluorononanoate	PFNA	0.08	0.13	1.2
6:2 fluorotelomer sulfonate[b]	6:2 FTS	0.80	1.21	11.41
8:2 fluorotelomer sulfonate[b]	8:2 FTS	0.80	1.21	11.41

a) SSV is based on PFOS toxicity and an estimated daily intake from other sources assumed to be 0 mg/kg-day
b) SSV is based on PFOA toxicity and an estimated daily intake from other sources assumed to be 0 mg/kg-day

To date, there have been no impacts to biosolids programs in Ontario resulting from the implemented limits at the Federal level. A 2018 paper titled *Land Application of Municipal Biosolids: Managing the Fate and Transport of Contaminants of Emerging Concern*, produced by Agriculture and Agri-Food Canada, summarized a suite of studies conducted in Ontario and found that “although a considerable

PBDE and PFAA, Perfluoroalkyl Acids, load was applied at time of biosolids application … detection of PBDEs and PFAAs in subsurface drainage, groundwater, and soil indicated that atmospheric deposition was likely an important source of these compounds. In addition, post-application levels of PBDEs and PFAAs in the soil remained largely within background soil levels derived from the literature" (Agricultural and Agri-Food Canada, 2018).

The USEPA published "PFAS Strategic Roadmap: Commitments to Action 2021 – 2024", in October 2021. The document outlines their proposed steps to "Research, Restrict, and Remediate" PFAS compounds in the environment. One of the most significant activities outlined in the document is the completion of a risk assessment for PFOA and PFOS in Biosolids. The risk assessment, which will consider highly exposed individuals under a variety of exposure pathways, will result in actual concentrations and loading rates of PFAS compounds. A case study was performed in Arizona in response to the land application ban that was a result of public opposition. The case study lead by the University of Arizona on behalf of the Pima County Regional Wastewater Reclamation Department sampled and analyzed the land that has had biosolids irrigation used in their agricultural programs, as well as the land that did not have biosolids applied. The study demonstrated that the use of biosolids and irrigation had limited PFAS concentrations at various depths from one to nine feet below the ground surface. The study resulted in the County lifting the ban on land application. The University of Arizona is working with several Biosolids Associations to conduct similar case studies throughout North America.

Conventional wastewater treatment will not remove PFAS compounds. The compounds can be removed from the liquid stream using Granular Activated Carbon (GAC). The State of Michigan in the United States is monitoring the success of GAC pretreatment from industrial sources that use the compounds in production. The GAC process will reduce the concentration in the wastewater collection systems but not eliminate it; in States with limited industrial influence, such as Vermont, the highest concentrations of PFAS compounds in the collection systems were found in residential areas.

Some high temperature biosolids treatment processes, including gasification and pyrolysis, are being tested as various levels of pilot scales to reduce the PFAS concentrations in biosolids. These processes which begin a dried biosolids product have not yet been operated consistently at full scale. To eliminate PFAS from our environment, including wastewater and biosolids, we must end the use of the compounds in our daily lives. The concentrations of two long chain PFAS compounds in human blood samples, PFOA and PFOS, have dropped substantially since they were banned in the United States in 2010.

2.3.2 Microplastics

Microplastics are defined as plastic material that are ≤ 5 mm in size. Microplastics are produced from the breakdown of plastic materials and can include fragments (from litter or plastic molding), line and fiber (from rope, netting or cigarette butts), foam (from food containers and packaging) and film (from plastic bags and wrappers), microbeads (from toiletry products) as well as production pellets (from the manufacture of plastic products). Microplastics can enter domestic wastewater through sources such as household dust, water from washing machines and erosion of paints.

Researchers recently (Mahon, et al., 2017) investigated the fate of these particles through different biosolids stabilization processes at seven wastewater treatment facilities in Ireland. The researchers found that lime stabilization and thermal drying produce the most microplastics (up to 13,675 particles per kg of dry matter), whereas anaerobic digestion produced up to 4,000 particles per kg of dry matter. The researchers postulated that the higher content in lime stabilized biosolids was due to shredding and flaking, while melting and blistering were potential contributors in thermal drying.

At the Federal level, Canada enacted a ban prohibiting the manufacture, import and sale of toiletry products that contain microbeads in 2018, extending the ban to include microbeads in natural health products and non-prescription drugs in 2019. A 2020 paper analyzed biosolids from two suppliers and the soils of three agricultural fields to which they were applied in Ontario (Crossman, Hurley, Futter, & Nizzetto, 2020). The study found that all fields receiving biosolids had higher soil pre-treatment microplastics concentrations than the control. The study findings suggested that biosolids applications at all sites likely result in microplastics export to surrounding aquatic systems from the terrestrial environment where biosolids were applied. The study noted that the recent ban on microbeads in cosmetics and personal care products would likely lead to a reduced load of microplastics in biosolids.

While there is limited scientific research documenting the effects of microplastics on soil (Nizzetto, Futter, & Langaas, 2016; Abel de Souza Machado, et al., 2018; Crossman, Hurley, Futter, & Nizzetto, 2020), studies indicate that there are no adverse effects from the presence of microplastics in land applied biosolids. The benefits of organic matter and nutrients from biosolids improving the soil's microbial health are believed to outweigh the possible concerns of effects from microplastics.

3.0 Biosolid Products and Their Characteristics

3.1 Existing Sludge Characteristics

The Clarkson WRRF currently produces anaerobically digested and dewatered biosolids cake. The G.E. Booth WRRF produces dewatered cake that has not been stabilized. Design basis assessments of the G.E. Booth and Clarkson WRRFs were carried out to establish existing conditions. It is estimated that that the G.E. Booth WRRF currently produces approximately 40,000 dry tonnes (DT)/yr of dewatered cake and the Clarkson WRRF produces approximately 13,000 DT/yr of digested, dewatered cake.

Biosolids sampling data for Clarkson WRRF for 2020 to-date is presented and compared to regulatory values in Appendix A, **Table A-1**. The data indicates that biosolids meet CFIA maximum acceptable cumulative metals limits, Category 3 NASM CM2 metals concentration limits and metals limits for feedstock for categories A & B of Ontario compost quality standards.

Due to the level of stabilization performed, the biosolids generated at the Clarkson WRRF currently do not meet CFIA fecal coliform limit of <1000 MPN/g or Category 3 NASM's CP1 E.coli limit of <1000 MPN or CFU/g of dry weight, falling under CP2 E.coli limit of $<2x10^6$ CFU/g dry weight (average recorded value of 5,945 CFU/g).

Since the solids generated at the G.E. Booth WRRF are not stabilized, they also do not meet these pathogen reduction requirements. The biosolids generated at both facilities could meet the CFIA pathogen limits with further stabilization. Solids processing alternatives and the resulting biosolids products are discussed in the following sections.

3.2 Biosolid Products

To understand potential markets for various biosolids products, it is important to understand both how biosolids products differ and how those characteristics impact their use. This section addresses both needs and "sets the stage" both for the identification of target markets and potential market size evaluations.

Biosolids products can be placed into the following general categories:

- Anaerobically digested dewatered cake
- Advanced digested dewatered cake
- Incinerator ash
- Thermal-dried products
- Compost product
- Alkaline stabilized products
- Thermal-Alkaline hydrolyzed products
- Manufactured soils

Each of these products can be applied to land to add nutrients and organics to soil and are generally referred to as “soil amendments”. While the products are markedly different, they share the benefits listed in **Table 3-1**.

Table 3-1 Biosolids Benefits

BENEFIT	EXPLANATION
Improved soil structure	Biosolids can enhance the physical structure of soil, reducing its erosion potential
Improved drought resistance	Increased organic matter provided through biosolids can increase water retention, improving drought resistance and promoting more efficient water utilization
Increased CEC	An increased CEC improves a plant’s ability to utilize nutrients more effectively, reducing nutrient loss by leaching
Enhanced soil biota	The activity of soil organisms is essential in productive soils and for healthy plants. Their activity is largely based on the presence of organic matter, which can be provided through biosolids applications.
Slow-release nitrogen (N)	The N in biosolids is predominantly organic N and must be converted to inorganic N by soil microbes to become available to plants. This process is generally slow, and consequently the N in biosolids is referred to as “slow release.” Slow-release N products can better match the N uptake of growing plants, minimizing the “burning” sometimes associated with inorganic N products and the potential for excess N leaching as well
Carbon sequestration	The organic matter in land applied biosolids sequesters carbon in the soil, reduces greenhouse gas emissions and energy consumption as compared to the production of fossil fuel based inorganic fertilizer
Fertilizer replacement	The nutrients in biosolids can reduce the greenhouse gas emissions from fossil-fuel based fertilizer production

Specific characteristics and uses for each product assessed are discussed in the sections below.

3.3 Anaerobically Digested and Dewatered Biosolids Cake

As mentioned, the Clarkson WRRF uses anaerobic digestion and centrifuges to stabilize and dewater biosolids prior to transport to the G.E. Booth WRRF for incineration and ash disposal. If the solids from both facilities were to be used in a land application program all of the solids would require stabilization. Anaerobic digestion is a popular process at the scale of these WRRFs to meet the CP2 limits class. If anaerobic digestion was also employed at the G.E. Booth WRRF the dewatered cake could be used as part of a land application program.

Anaerobically digested and dewatered biosolids cake typically have a TS concentration between 25 and 30 % and are clay-like in appearance and consistency. These can be land applied with certain management practice requirements to meet agricultural crop nutrient requirements.

The application of digested and dewatered cake to agricultural land is regulated under the NMA, as described in Section 2.1.2. Application of biosolids to non-agricultural land requires an ECA. Application rates vary based on crop needs, and are limited by the nitrogen, phosphate, metals, and sodium content of the biosolids products. Typical application rates range from 2 dry tonnes per hectare (DT/ha) to 4 DT/ha.

3.4 Advanced Digested Dewatered Biosolid Cake

Some agencies elect to employ an advanced digestion process which allows them to meet the CP1 criteria, Category A CCME Guidance, and with certain biosolids characteristics of the CFIA requirements. The following advanced digestion processes can be considered:

- **Thermal Hydrolysis**: The thermal hydrolysis process (THP) is a high-pressure, high temperature, pretreatment process used prior to anaerobic digestion. Dewatered solids entering the process are heated and pressurized. When the pressure is quickly released the cell walls of the microorganisms within the wastewater solids rupture increasing the bioavailability of the material entering the anaerobic digestion system. Because the THP process is performed on dewatered solids, the concentration in the downstream anaerobic digesters is much higher than in conventional mesophilic anaerobic digesters (MAD), 8 % TS or higher, which reduces the required digester volume. The THP process typically achieves a volatile solids reduction (VSr) of approximately 60 percent or more. This results in increased biogas production while reducing total solids production. As with any process that increases VSr, the nutrient loads in the dewatering sidestream will increase with THP. The process improves the dewaterability of the digested solids, resulting in dewatered cake solids concentrations of 28 percent or higher, regardless of dewatering technology. The heating step in the THP process can meet Class A Pathogen reduction requirements.

- **Thermophilic Anaerobic Digestion**: Thermophilic anaerobic digestion includes one or more stages that are operated at thermophilic temperatures, ranging from 50 to 60°C (122 to 140°F). Thermophilic digestion typically results in increased VSr and pathogen reduction. Depending on the configuration, thermophilic digestion can meet Class A criteria and most thermophilic digestion systems are designed to generate a Class A biosolids product. Existing mesophilic digestion can be converted to a thermophilic process. The conversion typically requires the addition of new heat exchangers along with system pumping and piping modifications, tank insulation, batch tanks, and modification to the existing biogas system. Thermophilic digestion processes have a higher odour potential and often reduced dewaterability when compared to mesophilic digestion.

- **Temperature Phased Anaerobic Digestion**: Temperature phased anaerobic digestion (TPAD) process uses a combination of thermophilic and mesophilic stages to optimize digester performance. Batch thermophilic tanks used in the systems allow the process to meet the Class A pathogen reduction criteria. The TPAD process requires similar modifications to as existing MAD system as outlined above with the Thermophilic anaerobic digestion process. The TPAD systems also face challenges with odour potential and reduce dewaterability.

While the biosolids that have undergone advanced digestion can meet the CP1 criteria, Category A CCME Guidance, and with certain biosolids characteristics of the CFIA requirements, their physical characteristics, totals solids concentration and clay like handling, primarily limit their use to bulk agriculture or silviculture applications.

3.5 Incinerator Ash

Incineration is a unit process which evaporates the water and burns the organic matter in dewatered cake using high temperature chemical oxidation reactions. The solids generated at both the G.E. Booth and the Clarkson WRRFs are currently incinerated at the Fluidized Bed Incinerator at the G.E. Booth facility.

The main advantages of incineration are the reduction in weight and volume of dewatered solids. Another advantage is the potential for energy recovery. The disadvantage is that emissions from the incinerator may impact surrounding air quality. These impacts are mitigated by using air pollution control systems including a quenching device, wet scrubber and mercury scrubber, like those operated at the G.E. Booth facility.

The ash generated during the incineration process can be disposed of at a landfill or beneficially used. The ash, which has a bulk density higher than fly ash but lower than Portland cement can be used in the production of concrete. The ash has also been used in the production of asphalt, bricks, light weight blocks and tile. The Region is currently conducting a separate study to investigate these and other potential beneficial uses for ash, which will be considered in the Class EAs.

3.6 Thermal Dried Products

Thermal drying is the process of evaporating the water in the dewatered cake by the addition of heat. Complete drying typically results in a product with 5 to 10 percent moisture content, and results in an approximate 30-fold volume reduction as compared with digested biosolids. Except for incineration, the moisture content of thermally dried biosolids is the lowest of the process alternatives considered. Heat is one of the most effective pathogen destructors. Thermal drying results in a product that meets the requirements of CFIA indicator organisms and the Category A CCME Guidance. The dried product can be used as a fertilizer or soil conditioner on acidic or alkaline soils. The dried biosolids (often termed pellets or granules) can also be used as a biofuel. The quality of the granules produced, drying system used, and local economic factors are likely to determine the end use of the dried biosolids.

During drying, biosolids undergo several structural changes as the moisture content decreases. The most critical stage is called the plastic stage when the moisture content is between 40 to 60% TS. In this stage, the dried product becomes sticky and difficult to manipulate. The power input required to move the product through this phase to higher concentrations is significant. It is essential to minimize dust production or accumulation during the drying process due to the increased probability of fire or explosions, which have occurred in this process. Dust collection systems are used in multiple locations throughout the process to reduce the potential of fire or explosion.

The benefits of thermal dried products include:

- Storage of dried sludge requires less volume and is easier to handle.
- Transportation costs are reduced.
- Dried solids have a higher fuel value and can be used as a fuel source or incinerated.

The process is energy intensive. Safety is a key factor during design start up and operation. It is recommended that all biosolids that are thermally dried be anaerobically digested prior to dewatering to ensure product quality.

A summary of selected thermal drying facilities in Canada is presented in **Table 3-2**. All the facilities identified have used a direct drying technology.

Table 3-2 Selected Thermal Drying Facilities in Canada

FACILITY LOCATION	COMMISSION DATE
City of Windsor (operated by Synagro Technologies Inc.)	1999
City of Toronto (operated by a Veolia)	2000
Smiths Falls (operated by Smiths Falls)	1992
Gatineau (operated by Synagro Technologies Inc.)	1992
Hamilton (operated by Synagro Technologies Inc.)	2020

As noted in **Table 3-2** Veolia operates the drying facility on behalf of the City of Toronto. They currently produce approximately 22,000 tonnes of thermally dried product at the Ashbridges Bay WRRF annually.

Veolia representatives explained to B&V that the product, Nutri-Pel, is certified as a CFIA fertilizer product and is successfully marketed to the agriculture market. The Veolia representatives explained that they manage the material through the entire drying and product sales market stages. In the Ontario market, Veolia works with approximately 250 farmers. They work with the farmers to determine their fertilizer needs, transport the material to the farms and apply the product on the farmers' behalf. The program that Veolia has developed allows them to successfully manage all of the dried product generated at the Ashbridges Bay WRRF. In addition to the agricultural market, the City of Toronto's thermally dried product is used in the City's parks in turf grass and horticultural applications.

3.7 Compost Products

Composting is a biological process in which organic material undergoes biological degradation to a stable product. This technology can be applied for stabilization of dewatered wastewater solids (between 14% and 30% solids), supplied in undigested, digested or chemically stabilized forms. This self-heating aerobic process can attain temperatures in the pasteurization range of 50 ˚C to 70 ˚C. These temperatures destroy pathogens and can result in the production of well-stabilized compost product that can be stored indefinitely with minimal odour. Drying during the composting process can produce total solids concentrations from 55% to 65%.

The high-quality product can be used as a soil conditioner or organic fertilizer supplement for the horticultural and agricultural industry. Composting requires a relatively large footprint when compared to digestion, incineration or thermal drying. Based on the characteristics of the solids generated at the G.E. Booth and Clarkson WRRFs, it is anticipated that the Region could generate a Class A Compost product. Composting, if not properly managed, can be an odour intensive process. There is a benefit to digesting the biosolids prior to initiating the composting process. Even with digested biosolids entering the process and careful operation, there will be periods of odour. It is recommended that a composting facility be sited with sufficient buffer from homes and institutions. Maintenance of a minimum temperature of 55˚C for at least three days is required to inactivate the pathogens within an aerated static pile system. Some fungi however, including Aspergillus fumigatus, can survive the composting process because they are thermotolerant organisms. Compost product must meet the Ontario quality standards and restrictions on use outlined in Section 2.2.1. In addition, compost products sold in the Canadian marketplace must meet the safety, microbial quality, efficacy, and labelling requirements in the federal FzA and FzR administered by the CFIA. See Section 2.1.2.2 for additional information.

As mentioned previously, compost product is easily handled and is often used for small- and large-scale landscaping, turf farming, soil blending, golf course construction, and nursery applications. The market for the composted biosolids includes home and garden use as well as commercial and institutional fertilizer uses.

Category B compost can also be used as daily and intermediate cover at a landfill that permits the use of Category B compost. This, however, is not considered to be a significant market for compost product.

The primary markets for compost product include use in landscaping, nursery and garden centers, golf course and park maintenance. The Region currently operates a composting program, converting organics (food and yard waste) collected from residents. Regional compost sells for approximately 3.5¢ per kg or $35 per tonne.

The main disadvantage of composting the large quantity of other organic material needed to produce Class A compost, the subsequent material handling requirements and the large footprint required. To be exempt from NMA and EPA regulations biosolids can only be a maximum of 25% of feedstock. This results in a larger footprint for composting and product storage when compared to some other alternatives. While unlikely, if biosolids are composted and metal standards for Category A are not met, the compost can only be applied to land with NMA or EPA approval.

3.8 Alkaline Stabilized Product

Alkaline stabilization is a reliable physical chemical process used to stabilize wastewater solids. In the process, an alkaline material such as lime is mixed with biosolids to raise the pH to greater than 12.0 standard units. The elevated pH reduces pathogens. This process yields a product that can be land applied in support of agriculture. The most common alkaline compounds used to raise the pH are either hydrated lime ($Ca(OH)_2$), also known as calcium hydroxide or slaked lime, or quicklime (CaO).

To further stabilize the biosolids additional materials such as sodium hydroxide (NaOH), potassium hydroxide (KOH), cement kiln or lime kiln dust, Portland cement or fly ash, can be added to the mixture and/or ancillary heat can be applied. These additional materials or processes further reduce the pathogens in the product.

Proprietary alkaline systems and processes are provided by suppliers such as Walker Industries (formerly N-Viro Systems Canada) and RDP Technologies, Inc. Walker Industries employs an advanced alkaline stabilization with accelerated drying. RDP Technologies offers a lime stabilization system and a pasteurization system which incorporates lime stabilization and ancillary heating to further reduce pathogens. Walker industries currently processes approximately 60,000 DT/yr of biosolids in Southern Ontario.

A list of alkaline stabilization facilities in Canada is presented in **Table 3-3**.

Table 3-3 Alkaline Stabilization Facilities for Municipal Biosolids in Canada

FACILITY LOCATION	SUPPLIER	COMMISSIONING YEAR
Leamington, Ontario	Walker	1996
Sarnia, Ontario	Walker	2001
Stellarton, Nova Scotia	RDP Technologies	2005
Region of Niagara, Ontario	Walker	2005
Halifax Regional Municipality, Nova Scotia	Walker	2006
Summerside, Prince Edward Island	Walker	2008

Walker Industries has registered their product as a fertilizer under the CFIA regulations. This allows them to distribute the product through agriculture marketing groups. Walker Industries explained to B&V that in addition to organics and nutrients contained in their product, the elevated pH and liming characteristics of the material are a benefit to agricultural customers. Walker Industries is currently working with enough agricultural property in southern Ontario to manage over 60,000 tonnes per year. They have had demand for all the product that they can deliver.

3.9 Thermal-Alkaline Hydrolysis

Lystek International has a proprietary technology that uses a low temperature, low pressure thermal-alkaline hydrolysis process to stabilize biosolids. The process mixes biosolids and Alkali material, operates at 70 degrees Celsius (°C), at atmospheric pressure and a pH of 9.5 to 10.0 to create a product with a TS concentration of approximately 15 percent. The product has been registered as fertilizer by the CFIA under the *FzR*. There are several Lystek International facilities operating in Ontario. One of these is the Southgate Organic Materials Recovery Centre, which can accept up to 150,000 DT/yr of wastewater solids.

The thermal-alkaline hydrolysis facilities located in Ontario are presented in **Table 3-4**.

Table 3-4 Thermal-Alkaline Hydrolysis Facilities in Ontario.

FACILITY LOCATION	SUPPLIER	COMMISSION DATE
Guelph, Ontario	Lystek International	2002
Southgate Organic Materials Recovery Centre, Dundalk, Ontario*	Lystek International	2013
City of Peterborough, Ontario	Lystek International	2010
Third High Farms, Iroquois, Ontario	Lystek International	2013
Township of Center Wellington, Ontario	Lystek International	2014

**Standalone facility owned and operated by Lystek*

Lystek representatives explained to B&V that in 2020 they anticipate processing 130,000 tonnes at the Southgate facility, including approximately 20,000 tons that they receive from the City of Toronto. Lystek supports the operation of eleven stabilization facilities in North America. They manage the product marketing and distribution for all but one of those facilities. All of the fertilizer produced at Southgate is used within a 90-minute radius of the facility.

3.10 Manufactured Soils

There is no standard specification for “manufactured soils,” “soil blends,” “engineered soils,” or “imported soils”. These blended products vary depending on the materials available. When biosolids are used in manufactured soil production, the biosolids are typically dewatered cake following an advanced digestion process. The process serves to further reduce pathogen content but often leave the dewatered product “wet” 20% to 30% TS and clay like in consistency. Mixing this material with a dryer material such as sand, sandy loam soil or sawdust results in a product that in much more marketable. Some facilities have been able to establish a market for this product in bulk and in bags at retail facilities.

As noted in Section 2.1.2.1 there are no regulations on the inclusion of biosolids in topsoil and manufactured soil blends. If the blends are applied to agricultural land, a NASM plan under O.Reg. 267/03 would be required. If the blended products are applied on non-agricultural land, then an ECA under EPA would be required.

4.0 Target Markets & Market Availability Assessment

4.1 Biosolids Market End Users

The biosolids products described in Section 3 can be managed in a number of manners including beneficial use, thermal reduction, landfilling and co-management with municipal solid waste. Each management option yields different potential end users, as outlined in **Table 4-1**.

Certain products, such as dewatered biosolids cake or compost products can be managed in more than one way, depending on the intended end use. The availability of end users listed in **Table 4-1**, and the markets they represent, in and around the Region are described in the following sections.

Table 4-1 Management Options and End Users for Biosolids Products

MANAGEMENT OPTIONS	BIOSOLID PROCESS AND PRODUCTS	MARKET END USERS
Beneficial Use	▪ Digested biosolids (liquid) ▪ Digested biosolids (dewatered cake) ▪ Manufactured soil material ▪ Advanced digested biosolids; liquid or cake ▪ Thermal-dried biosolids ▪ Alkaline stabilized biosolids ▪ Thermal-alkaline hydrolysis biosolids ▪ Composted biosolids products	▪ Agricultural land application ▪ Silviculture (tree farming) ▪ Horticultural market ▪ Golf courses, parks and recreation ▪ Landscaping ▪ Land rehabilitation
Thermal Reduction	▪ Incinerator residual ash disposal ▪ Incinerator residual ash use	▪ Municipal waste landfill ▪ Incorporation into cement ▪ Other ash reuse options
Landfilling	▪ Unstabilized dewatered cake ▪ Stabilized dewatered cake ▪ Compost products ▪ Thermally dried product	▪ Municipal landfill and landfill cover ▪ Monofill (dedicated landfill)
Co-management with municipal solid waste	▪ Compost products ▪ Biosolids cake (dewatered)	▪ Management with source separated organics

4.2 Agriculture, Silviculture and Horticulture

4.2.1 Market Availability

As summarized in the Region's 2016 Census of Agriculture Farm and Food Operator Data, livestock is the Region's largest agricultural sector, accounting for 43% of Peel's farms (Region of Peel, 2017). Oilseed, grain, and hay farms represent 32% of the Region's farms. Farms, woodlots and greenhouses producing flowers, maple syrup, honey, fruits, and vegetables represent another 24% of the Region's farms. The amount of land in agriculture decreased by 7% between the 2011 and 2016 census, with a total of 34,265 hectares of agricultural land owned, rented, leased or crop-shared in the Region in 2016. Of that agricultural land 27,000 hectares is dedicated to cropland and 2,800 hectares to pasture.

Christmas trees, the principal product of silviculture in the Region, are grown on only 9 hectares of land in Peel Region. In the horticultural market, farms growing nursery products represented 90 hectares of land. Neither represents a significant market when compared to overall agricultural cropland in Peel Region (OMAFRA, 2017).

The Golden Horseshoe of Ontario, comprised of the Regions of Durham, Halton, Niagara, Peel, York and the Cities of Hamilton and Toronto, is a rich agricultural area and represents a significant end user market for biosolid products. The Region of Peel is located at the center of the Golden Horseshoe, allowing easy access to agricultural end users to the east and west in the Golden Horseshoe (Figure 4-1). Currently the Golden Horseshoe has 296,000 hectares dedicated to cropland and 29,000 hectares dedicated to pasture (OMAFRA, 2017).

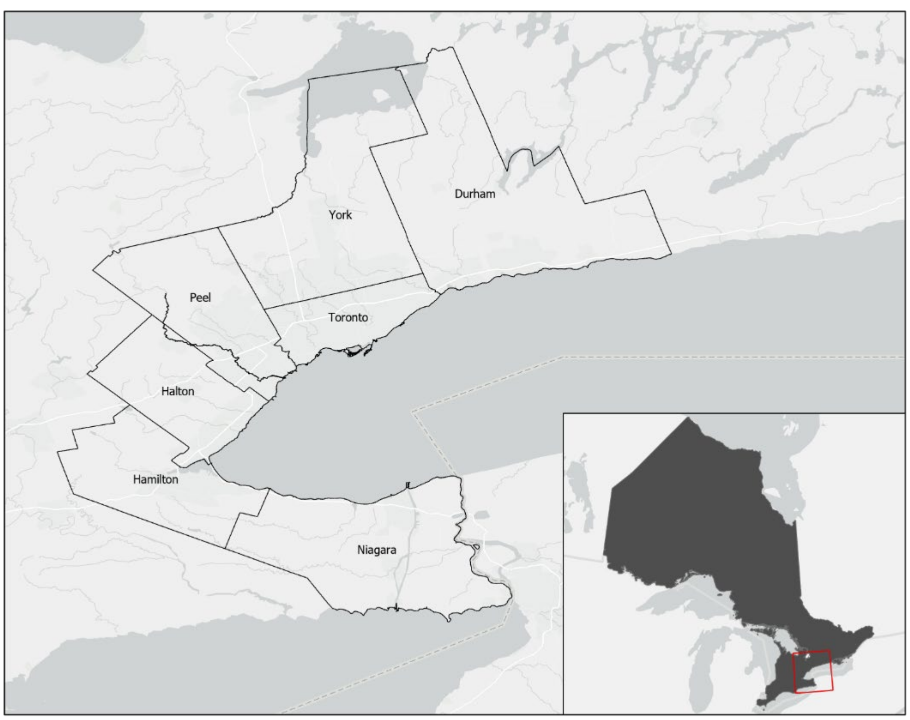

Figure 4-1 Peel Region and Surrounding Golden Horseshoe

4.2.2 Demand Assessment

Using the lower application rate of 2 DT/ha-yr, the 27,000 hectares of cropland in the Region could represent an annual demand of 54,000 DT of biosolids product. Cropland in the Golden Horseshoe, anticipating the same application rate, could represent an annual demand of 600,000 DT. Both numbers exceed the amount of biosolids produced at the Clarkson and G.E. Booth WRRFs combined, which is currently approximately 53,000 DT/yr (refer to Section 3.1). If the solids generated at the G.E. Booth WRRF were to be used in agriculture, they would need to first be stabilized, resulting in a reduction in the amount of solids to be applied.

As discussed, Veolia, Lystek and Walker Industries representatives, in conversation with B&V, all indicated that the agricultural market in southern Ontario would be able to absorb some or all biosolids produced at the two facilities. Veolia indicated that during the high season, from August to October, their agricultural market could absorb two to three times the amount of biosolids currently produced at their Toronto facility (22,000 DT/yr). Walker Industries indicated that a new facility could accommodate 10,000 - 15,000 DT/yr of solids generated at the Clarkson or G.E. Booth WRRFs. Lystek indicated that their standalone Southgate Organic Materials Recovery Centre could potentially accommodate up to an additional 80,000 DT/yr, more than are currently generated at the two WRRFs.

Although the actual demand is likely lower than the maximum demand, as a number of end users already land apply biosolids, the market should be able to accommodate some or all biosolids produced at the Clarkson and G.E. Booth WRRFs, given the volume of potential demand versus volume of biosolids produced.

4.3 Parks and Recreation Departments

4.3.1 Market Availability

In addition to agricultural use, as a result of the additional stabilization, advanced digested products, thermally dried products, and compost products could be used to supplement fertilization programs and as soil amendments to maintain outdoor recreational fields and parks in the Region. The application of any product other than Category A compost, however, would require an ECA. Parks maintained by lower-tier municipalities within the Region cover approximately 2,600 hectares of land (City of Mississauga, 2019; City of Brampton, 2017; Town of Caledon, 2010).

4.3.2 Demand Assessment

As mentioned above based on an application rate of 2 DT/ha-yr, the 2,600 hectares of parks and recreational fields in the Region could represent a maximum annual demand of 5,200 DT of product. This represents approximately 10 percent of the biosolids produced at Clarkson and G.E. Booth WRRFs combined (refer to Section 3.1), although stabilization of solids generated at the G.E. Booth WRRF would result in a reduction of solids to be applied. Exploration of parks and recreational fields as an outlet for the Region's biosolids would require further investigation and communication with the three lower-tier municipalities listed above.

4.4 Ministry of Transportation Ontario (MTO)

4.4.1 Market Availability

The Ontario Provincial Standards for Roads and Public Works (OPS) organization produces a comprehensive set of standards for use by road and public works departments, contractors, and consultants in Ontario. The Ministry of Transportation Ontario (MTO) manages the publishing and electronic distribution of the OPS standards. The use of OPS standards by MTO and other infrastructure owners is not mandatory, however they do serve as a guideline and are often considered by municipalities when developing their design standards and specifications. The use of compost or biosolids in blended soils is not restricted by these standards. OPS construction specification for topsoil (OPSS.MUNI 802) requires only that topsoil shall not contain material greater than 25 mm in size, such as stones and clods, shall not have contaminants that adversely affect plant growth and will have organic content between 7-11% by weight and a pH between 6 to 8 (Ministry of Transportation Ontario, 2019).

4.4.2 Demand Assessment

The Region owns and maintains 1,555 lane-kilometers (number of lanes, multiplied by their length) of road (The Region of Peel Public Works Department, Transportation Division). Over the 8-year period captured in the Region's Transportation Fact Sheet, the road network grew by only 100 lane-kilometers, with yearly growth varying from 0 to 31 lane-kilometers. Given the variability of network growth and maintenance and the relatively low demand of biosolids as feedstock for compost or blended soils, this is considered a limited market.

4.5 Landscape Contractors

4.5.1 Market Availability

Soil amendments and composts are often sold, used, or distributed by landscapers but the volumes handled vary considerably. As an ECA would be required for application of biosolids products not regulated as a fertilizer by the CFIA or classified as a Category A Compost, this is considered to be a limited market.

4.5.2 Demand Assessment

As stated above, this is considered a limited market. Veolia, Lystek and Walker Industries, who produce biosolids products meeting CFIA standards, indicated that the principal demand and market share for these products is in the agricultural market.

4.6 Golf Courses

4.6.1 Market Availability

Both thermally dried biosolids and compost are used at golf courses, with dried product used as an organic fertilizer and compost used as a top dressing that supplies nutrients to the turfgrass. Biosolids products, other than Category A compost, would require an ECA for the golf course operator to be able to apply solids to their land. Although this would add additional cost and effort to fertilization programs at Regional golf courses, it would need to be weighed against potential savings in commercial fertilizer costs. Some golf courses in neighbouring York Region use ECAs to allow beneficial reuse of reclaimed water, WRRF effluent, on golf courses.

An online search was used to identify golf courses in Peel Region, which are presented in **Table 4-2** below. Courses are both public or private and have 9 holes, 18 holes or 27 holes. On average, 27-hole courses have 135 acres of greenway, 18-hole courses have 90 acres of greenway and 9-hole courses typically have 45 acres of greenway. Altogether, 16 courses were identified within Peel Region, representing 1,400 acres or 570 hectares of greenway.

4.6.2 Demand Assessment

Using an application rate of 4 DT/ha-yr, the 570 hectares of golf courses in the Region could represent a maximum annual demand of 2,300 DT of biosolids product. This represents approximately 4 percent of the biosolids produced at Clarkson and G.E. Booth WRRFs combined (refer to Section 3.1), although stabilization of solids generated at the G.E. Booth WRRF would result in a reduction of solids to be applied. Exploration of parks and recreational fields as an outlet for the Region's biosolids would require further investigation and communication with private golf course owner or the lower tier municipalities (Mississauga and Brampton) which own and operate golf courses in the Region. Compared to the potential demand from the agricultural market, this is considered a limited market.

Table 4-2 Golf Courses in Peel Region

GOLF COURSE	SIZE	AREA (ACRES)
Glen Eagle Golf Club	27-Hole	135
Mayfield Golf Course/Club	18-Hole	90
Caledon Country Club	27-Hole	135
Turnberry Golf Club	18-Hole	90
Parkshore Golf Club	9-Hole	45
Peel Village Golf Couse (owned/operated by Brampton)	9-Hole	45
Brampton Golf Club	18-Hole	90
Lionhead Golf Club & Conference Centre	18-Hole	90
Streetsville Glen Golf Club	18-Hole	90
Derrydale Golf Course	12-Hole	68
BraeBen Golf Course (owned/operated by Mississauga)	18-Hole	90
Grand Highland Golf Club	9-Hole	45
Centennial Park Golf Centre	27-Hole	135
Markland Wood Golf Club	18-Hole	90
Lakeview Golf Course (owned/operated by Mississauga)	18-Hole	90
Credit Valley Golf and Country Club	18-Hole	90

4.7 Land Rehabilitation

4.7.1 Market Availability

Biosolids products can be applied to rehabilitate or reclaim land. Biosolids products have been used in the reclamation of mine tailing sites, re-vegetation of remediated environmentally contaminated sites, and in the establishment of vegetation around construction sites. From 2014 to 2018, a project at Vale Canada's Copper Cliff operation in Sudbury, Ontario, reclaimed approximately 150 hectares of Vale's tailings with 25,000 DT of biosolids (Terrapure). Under an ECA permit, biosolids were used to provide organic matter and nutrients to vegetation and to stabilize the pH of the tailings.

4.7.2 Demand Assessment

Although there are a number of mines and contaminated sites in Ontario, their number within and adjacent to the Region indicate that this a limited market. The number of active federal contaminated sites in and around the Region can be seen in Figure 4-2, with fewer than 5 sites in the Region itself (Treasury Board of Canada Secretriat, 2020). There are 40 mines in Ontario, but they are all at a distance that would make hauling biosolids to tailings sites an impractical solution (refer to Figure 4-3).

Figure 4-2 Federal Contaminated Sites in and Around the Region of Peel

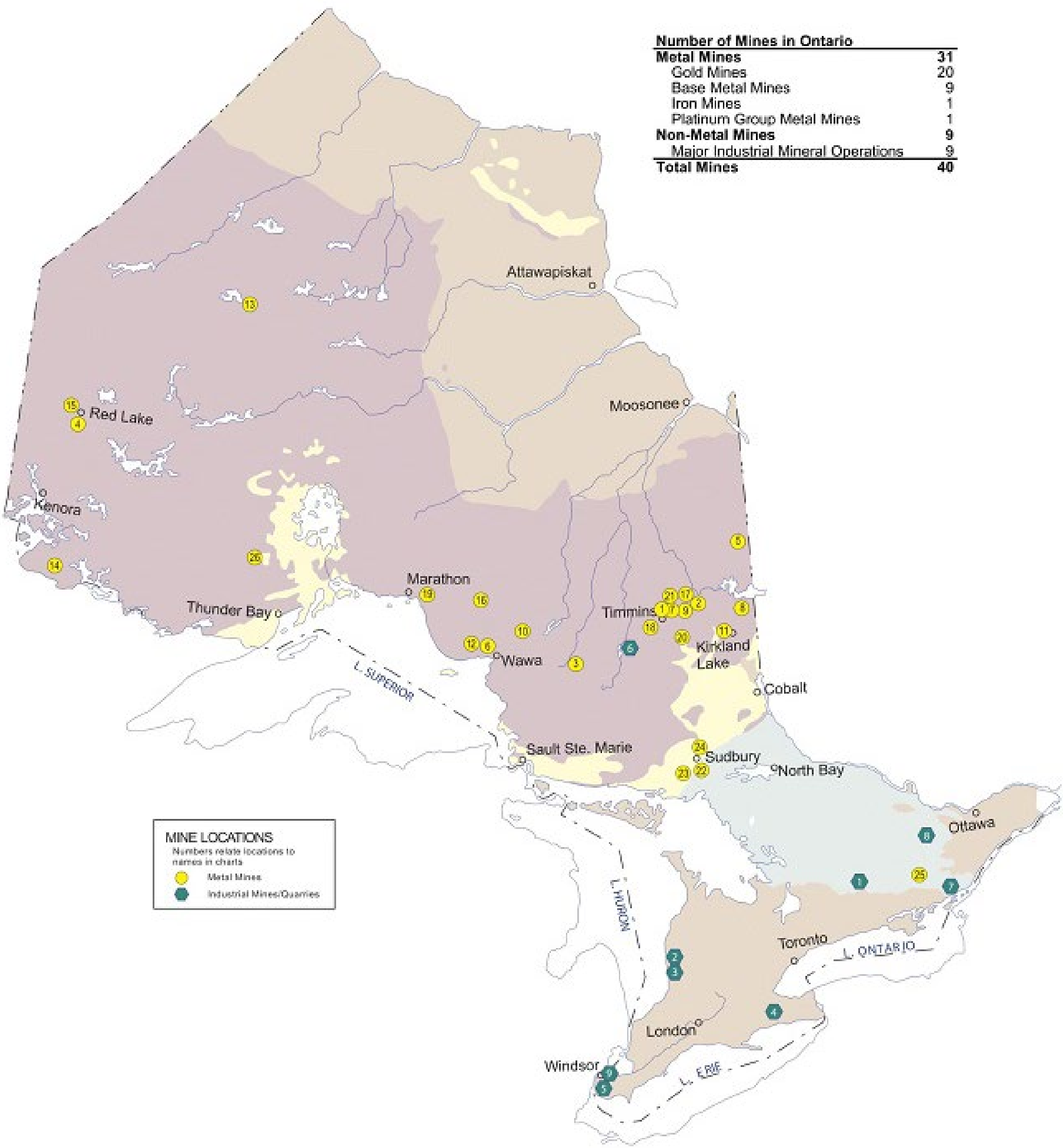

Figure 4-3 Ontario Mining Operations 2020

4.8 Landfill Sites

4.8.1 Market Availability

Currently ash produced at G.E. Booth WRRF, and dewatered biosolids cake produced at Clarkson WRRF not hauled to G.E. Booth for incineration, is transferred to landfill for disposal. Clarkson WRRF biosolids hauled to landfill from 2017-2019 totaled approximately 5,800 tonnes. Ash produced by the incinerators could be diverted for beneficial use (as discussed in Section 3.5, this is the subject of a separate, ongoing study) or continue to be landfilled. Landfills can be monofil (dedicated to only biosolids products), or co-disposal (accepting both biosolids products and municipal solid waste). Biosolids products such as compost products and their feedstock biosolids could be beneficially reused for landfill cover. As discussed in Section 3.7, Category B compost can be used as daily, intermediate cover at a landfill, as permitted by an ECA.

4.8.2 Demand Assessment

The Ontario Waste Management Association's 2018 Landfill Report estimated that Ontario's 805 most active public and private sector landfill sites had a remaining capacity of 122 million tonnes, which could be depleted by 2032 (Ontario Waste Management Association, 2018). Landfills received 8.1 million tonnes of waste in 2017, an increase of 5% over 2016. Based on the current landfill capacity depletion rate, Ontario's available landfill capacity is expected to be exhausted in 12 years, by the year 2032. If the United States were to prohibit Ontario's waste from crossing the border, Ontario's landfill capacity could be exhausted by 2028.

Based on reporting from 2012, Peel contracts with Waste Management Corporation to haul municipal waste to a landfill site in Warwick, Ontario (Brampton Guardian, 2012). The Twin Creeks Landfill underwent an Environmental Screening Process in order to amend to the ECA for the landfill in 2017. The project proposed by Waste Management Corporation increases the maximum annual fill rate to 1,400,000 tonnes, from 750,000 tonnes. The increase was proposed to allow the Twin Creeks Landfill to receive wastes historically directed to the Petrolia Landfill, scheduled to close in 2017, in addition to retaining and servicing a growing customer base (Waste Management of Canada Corporation, 2020).

The Roadmap to a Circular Economy in the Region of Peel aims to divert 75% of waste generated in the Region from landfill (Region of Peel, n.d.). This aligns with the provincial framework for waste management as set out in the Waste-Free Ontario Act, 2016 and the Strategy for a Waste-Free Ontario, 2017. Although there is capacity for landfilling of biosolids, decreasing capacity and the Region's goal to move away from landfilling as a solution, make this a less favourable outlet than the beneficial uses outlined in the above sections.

4.9 Co-Management with Source Separated Organics (SSO)

4.9.1 Market Availability

As discussed in Section 3.7, the Region currently operates a composting program, converting organics (food and yard waste) collected from residents. Peel Region has two existing composting facilities, the Peel Integrated Waste Management Facility (PIWMF) in Brampton and a smaller facility in Caledon. Both have been used to treat Source Separated Organics (SSO) - PIWMF since 2007, and Caledon since 1995. Together the facilities process approximately 80,000 tonnes of SSO annually, roughly half food and half yard waste (Canadian Biogas Association). Regional compost is sold for 3.5¢ per kg or $35 per tonne and has been successfully marketed to residents, farmers, soil blenders, Filtrex applications, and nurseries.

As part of the Region's Roadmap to a Circular Economy in the Region of Peel an Anaerobic Digestion Facility is planned, with the ability to process 120,000 tonnes of organic material per year, with the possibility for expansion. The facility will allow the Region to add disposal of diapers and pet waste to its green bin (SSO) program and increase diversion by 5% (The Regional Municipality of Peel, 2019).

4.9.2 Demand Assessment

As detailed in Section 3.7, compost Categories A and B allow municipal wastewater biosolids to be used as feedstocks up to 25%. Category A compost is exempt from the need for approvals, provided that it meets quality standards, while Category B compost can be land applied as a NASM (agricultural land) or through an ECA (non-agricultural land). In the case of the planned Anaerobic Digestion Facility, products would not be covered under Ontario's compost quality standards and guidelines, as they only apply to compost produced by aerobic composting of organic materials. Products of the facility could meet CFIA requirement to be sold as fertilizer.

Neither the existing composting facilities, nor the planned Anaerobic Digestion Facility, were, or are, being designed to accommodate biosolids from G.E. Booth and Clarkson WRRFs. Although it is technically feasible to co-manage biosolids with SSO through composting and/or anaerobic digestion, these facilities would not have the capacity to absorb biosolids from the two WRRFs.

4.10 Summary and Recommendation

Of the target markets discussed in the sections above, application of biosolids products to agricultural land represents the greatest potential market. Within the Region, agricultural land accounts for over ten times the area associated with parks and recreational facilities, and almost fifty times the area available on golf courses (see **Table 4-3**). Given that other target markets discussed in the sections above offer a limited market, impractical solutions, or insufficient ability to meet demand, the recommended market to explore, going forward, is the agricultural market for biosolids products in and around the Region.

Table 4-3 Biosolid Products Target Markets in Peel and Golden Horseshoe

OUTLET	PEEL REGION		GOLDEN HORSESHOE	
	LAND AREA (HECTARES)	ANNUAL MAXIMUM POTENTIAL DEMAND (DT/YR)	LAND AREA (HECTARES)	ANNUAL MAXIMUM POTENTIAL DEMAND (DT/YR)
Agriculture	27,000	54,000	296,000	600,000
Parks & Rec. Dept.	2,600	5,200		
Golf Courses	570	1,100		
TOTAL	**30,170**	**60,300**	**296,000**	**600,000**

5.0 Market Considerations for Peel

5.1 Recommended Target Markets/Outlets

As summarized in Section 4.10, the greatest potential market for biosolids products in and around the Region is the agricultural market. Biosolids products can serve to fertilize soils, increase soil organic matter, and amend soil pH, in the case of biosolids products such as alkaline stabilized and thermal-alkaline hydrolyzed products. Outlets for biosolids products in the agricultural market include land application of biosolids as a Category 3 NASM or as a biosolids product meeting CFIA fertilizer requirements (refer to Sections 2.1.2.1 and 2.1.1.2, respectively). Beneficial use options for incinerator ash are also being explored, with landfill being considered only if beneficial use options are not available.

In summary, the three potential target markets/outlets for biosolids products recommended for consideration under the Schedule ‘C’ Class EAs of the South Peel WRRFs are:

- Land application of dewatered, anaerobically digested biosolids.
- Soil amendment with fertilizers (biosolids products) meeting CFIA requirements.
- Beneficial use of ash and, or landfilling, based on the results of the study being conducted concurrently with this TM (see Section 3.5).

Further considerations for each market/outlet are outlined in Sections 5.2 to 5.5 below.

5.2 Product Distribution

Biosolids producers can access available target markets in three different ways: direct sales, third-party sales and third-party processing and sales.

Direct sale of biosolids products to end users would require the greatest level of time and effort on the Region’s part. Regional staff would be responsible for biosolids processing, permitting and approvals, building a customer base, branding, and marketing of biosolids products, delivery and transport of biosolids, communications and outreach to end users and the public, financial management of biosolids sales program and management of ongoing relationships with end users.

Third-party sales, whereby the Region would be responsible for processing biosolids to be marketed and sold by a third party, would reduce some of the burden on the Region. The third party would be responsible for branding and marketing of biosolids products, managing the customer base, sales program and delivery and transport of biosolids products. Product storage under the third-party sales option could be the Region’s responsibility, the third party’s responsibility or some combination of the two. A concern of third-party sales is the quality of the biosolids product. The agreement would likely include required characteristics of the product. If those characteristics are not complied with, the third party may have difficulty marketing the product and the Region may have some risk.

Under a third-party processing and sales scenario, a third-party would except responsibility for creating the biosolids product and be responsible for branding and marketing of the product, managing the customer base, sales program, and delivery of the product. Under this scenario, the entity managing the biosolids is also responsible for its marketing and sales. This greatly reduces the risk to be managed by the Region. Companies such as Veolia, Walker and Lystek, can operate as either a third-party sales or third-party processing and sales partner to the Region.

A third-party could operate a biosolids processing facility off-site, or on-site at a Regional WRRF. An example of an off-site facility is the Lystek Southgate Organic Materials Recovery Centre, which processes biosolids from neighbouring municipalities. Lystek explained during a conversation with B&V, that they have the ability to accommodate a portion of the biosolids generated by the Region. An example of an on-site facility would be Veolia's operation of the thermal drying facility at the Ashbridges Bay Treatment Plant (ABTP) for the City of Toronto. In both cases the third-party operates the biosolids process facility under contract with the municipality producing the biosolids, and is responsible for marketing, sales, transport, and storage of biosolids products as well as management of the customer base.

5.3 Market Competition

A biosolids product that is produced at Clarkson and/or G.E. Booth WRRF would need to compete with other fertilizing and liming products in the marketplace, including other biosolids products and commercial fertilizers used in and around the Region.

A survey of the other municipalities in the Golden Horseshoe indicated that biosolids products generated, including those generated by the Region of Peel, will likely not exceed the current agricultural demand in the area. Biosolids products generated in the Golden Horseshoe and their associated outlets are summarized below.

- In **York and Durham Regions,** the majority of biosolids produced by the wastewater treatment facilities are transferred to Duffin Creek Water Pollution Control Plant (WPCP) for incineration (Durham Region, 2018; Durham Region, 2019; York Region, 2014). The ash from the incineration process is beneficially used to create cement products (Durham Region, 2019). In 2019 only two WPCPs in the Regions produced biosolids for land application to agricultural fields. Corbett Creek WPCP produced 37,514 m^3 of anaerobically digested sludge which was transferred to a holding facility for storage, before being land applied to agricultural fields (Durham Region, 2019). The Courtice WPCP produced 33,342 m^3 of anaerobically digested sludge which was also transferred to a holding facility for storage before being land applied to agricultural fields (Durham Region, 2019).
- **Halton Region's** seven wastewater treatment facilities (WWTF) produce over 35,000 wet tonnes of biosolids per year. Solids are anaerobically digested and dewatered. A Biosolids Management Centre (BMC) provides storage for liquid biosolids prior to land application (Halton Region, 2020). The Halton Region's Biosolids Master Plan indicated that Halton's biosolids are increasingly being land applied outside of the Region as the land available to receive biosolids within Halton Region declines. It estimated that by 2021 Halton's WWTFs will produce 278,546 m^3 of anaerobically digested liquid biosolids and 32,937 wet tonnes of anaerobically digested, dewatered biosolids per year. The Master Plan recommended investigation of other outlets including composting to enhance Halton's land application program and incineration (XCG Consultants Ltd, 2012; Halton Region, 2016).The Region of Halton is currently investigating potential sites for a composting facility.

- Approximately half of **Niagara Region's** biosolids are land applied to local agricultural fields as a liquid (Niagara Region, n.d.). The remaining biosolids are dewatered and transported to Walker Industries' N-Viro Biosolids Facility, in Thorold, Niagara Region, for processing (Niagara Region, n.d.; Gun, 2015). In 2015 the facility was producing approximately 33,000 wet tons (30,000 wet tonnes) of alkaline stabilized biosolids product per day. They were able to market the material for $10/ton. The facility was receiving between 100 and 165 tons every weekday of which approximately 85 percent was from Niagara Region and the balance from the City of Toronto (Gun, 2015; Houle, 2015).
- The **City of Hamilton's** new Biosolids Management Process began operations in May 2020. It can process up to 60,000 wet tonnes of wastewater biosolids annually and produces a thermal-dried biosolids product meeting the requirements of the CFIA (City of Hamilton, 2020). Currently Hamilton's wastewater treatment produces approximately 43,000 wet tonnes of anaerobically digested and dewatered biosolids per year. It is estimated that thermal drying will reduce the volume of the biosolids product by approximately 75 percent (Moro, 2020).
- The **City of Toronto** thermal dries about half of all biosolids produced, land applies about a quarter of biosolids produced and alkaline stabilizes or thermal-alkaline stabilizes the remaining quarter (City of Toronto, n.d.). In 2019 28,641 wet tonnes of the biosolids produced at the ABTP were land-applied and 7,731 wet tonnes were used at mine reclamation sites. A total of 34,494 wet tonnes were transported off-site, for alkaline stabilization and thermal-alkaline stabilization. (Toronto Water, 2020). As discussed in Section 3.6, Veolia operates a thermal drying facility at ABTP, producing approximately 22,000 DT/yr of thermal dried product; in 2019 83,970 wet tonnes of biosolids were processed by the thermal drying facility (Toronto Water, 2020). All the wastewater solids generated at Humber WRRF and North Toronto WRRF are transferred to ABTP for processing, making up part of the biosolids produced (Toronto Water, 2020; Toronto Water). Dewatered biosolids produced at Highland Creek WRRF are incinerated at the plant, producing an ash that is stored in two ash lagoons. When a lagoon is full, ash is removed and hauled to landfill for final disposal (Toronto Water, 2020).

The different units (m^3, DT, wet tonnes, tonnes) used to report generated biosolids products across different municipalities make it difficult to calculate the exact number of biosolid products being land-applied or used to amend agricultural land in the Golden Horseshoe. To produce a high-level estimate of biosolids produced and applied to agricultural land in the Golden Horseshoe, the following assumptions were made:

Anaerobically digested biosolids produced at Corbett, Courtice Creek WPCPs and Halton's wastewater treatment facilities are assumed to have a density of approximately 1000 kg/m^3 and 3% TS concentration.

Anaerobically digested and dewatered biosolids produced at Halton Region, Niagara Region, Hamilton and Toronto's wastewater treatment facilities were assumed to have a 20-25 % TS concentration. TS concentration of 25 %was used to produce a high-level estimate. The biosolids processed at Walker Industries' Niagara facility, reported as tons or tonnes, were anticipated to be wet tonnes, confirmed during a conversation with Walker Industries'. Walker Industries' processes approximately 30,000 wet tonnes per year at its facility, of which 85%, or 25,500 wet tonnes, are sourced from Niagara Region and 15%, or 4,500 wet tonnes, are sourced from Toronto. By this estimate, an additional 25,500 wet tonnes of Niagara Region biosolids are liquid land applied, as the biosolids processed at Walker's facility represent half of Niagara Region's biosolids.

The resulting biosolids quantities and outlets to which they are directed are summarized in **Table 5-1**.

Table 5-1 Biosolids Products and Outlets in the Golden Horseshoe

MUNICIPALITIES IN GOLDEN HORSESHOE	BIOSOLIDS PRODUCTS GENERATED APPROXIMATE (DT/YR)	BIOSOLIDS PRODUCT	OUTLET
Durham Region	2,126	Anaerobically Digested	Land applied (liquid)
Halton Region	8,356	Anaerobically Digested	Land applied (liquid)
	8,234	Anaerobically Digested and Dewatered	Land applied (cake)
Niagara Region	6,375	Anaerobically Digested	Land applied (liquid)
	6,375	Alkaline Stabilized	Soil amendment (fertilizer)
City of Hamilton	10,750	Thermal Dried	Soil amendment (fertilizer)
City of Toronto	7,160	Anaerobically Digested and Dewatered	Land applied (cake)
	1,933	Anaerobically Digested and Dewatered	Land rehabilitation (mine site)
	8,624	Alkaline Stabilized or Thermal-Alkaline Stabilized	Soil amendment (fertilizer)
	20,993	Thermal Dried	Soil amendment (fertilizer)
Total	**80,925**		

The high-level estimate in **Table 5-1** indicates that approximately 81,000 DT/yr of biosolids products with potential for land application or use as soil amendment are currently produced in the Golden Horseshoe. This figure is significantly less than the estimated 600,000 DT/yr potential demand for biosolids products from the agriculture community within the Golden Horseshoe as described in Section 4.2.2. The fertilizer demand that is not met with biosolids is met using commercial fertilizers and application of other NASM, such as manure. According to the 2016 Census figures, commercial fertilizer was used on 56 percent of all agricultural land (total agricultural land was 380,000 ha, including 296,000 ha of cropland), lime was used on 3.5% of all agricultural land and solid or composted manure was used on 2.4% of all agricultural land in the Golden Horseshoe (OMAFRA, 2017). Anticipating that these products reduce the potential demand by approximately 50 percent, the remaining demand (592,000 DT/yr) still exceeds biosolids production in the Golden Horseshoe. This aligns with Veolia, Lystek and Walker Industries' indication in Section 4.2.2, that the agricultural market in southern Ontario would be able to use all biosolids produced at the G.E. Booth and Clarkson WRRFs, even with existing market competition taken into account.

5.4 Seasonality and Storage

Per Section 2.1.2.1, NASM, including biosolids, cannot be land applied from December 1st to March 31st and require a minimum of 240 days of available storage. Although biosolids products that meet the requirements for CFIA regulated fertilizers, such as those produced by Veolia, Lystek and Walker, do not need to meet the same requirements, they are also affected by Southern Ontario's limited growing season. A typical growing season for farmers in Ontario lasts from May to October, with the greatest demand for biosolids between August and October. This means that biosolids products can be applied to agricultural land, at best, for five months of the year.

On-site and off-site storage, such as that employed at the Southgate Organic Materials Recovery Centre, can help to mitigate the impacts of the limited growing season. Certain third-party vendors such as Veolia partner with the end user, to provide bagged storage at the end user locale. Veolia produces a product by thermal drying, which can be stored in bags for an extended time. The bags should be plastic, preferably wrapped on pallets, and stored in a covered or enclosed building.

To encourage sales outside of the growing season, another strategy is to reduce the price of biosolids products when not in high demand. Veolia has employed this strategy to increase sales, and to free up storage, when the sold biosolids can be stored at end user's site rather than at their facility.

Given the space constraints at G.E. Booth WRRF there would exist limited opportunities for storage of biosolids products on site, apart from the existing storage for incinerator ash. There may be some opportunity to store biosolids at the less space constrained Clarkson WRRF.

5.5 Transportation

The cost of transporting biosolids products varies and is dependent on solids concentration of the product being transported, the transportation mode and hauling distance. Fuel, labour and permitting costs would be the direct responsibility of either the Region or the third-party vendor depending on the product distribution model adapted. Per Section 2.1.2.1 hauling biosolids products may require an ECA or EASR registration. Third-party biosolids processors and vendors indicated that in Ontario, due to market demand, biosolids products are typically not transported more than two to three hours from their point of origin. To maintain cost effectiveness, it is assumed biosolids products generated in the Region would likely adhere to the same constraints.

6.0 Summary

The biosolids currently produced at the Clarkson WRRF meet CFIA, NASM Category 3 CM1 and Category A & B feedstock metals limits. With anaerobic digestion, the Clarkson WRRF biosolids meet CP2 limits for faecal coliform and could meet the CP1 and CFIA limits with further processing. It is anticipated that the biosolids characteristics are similar at G.E. Booth WRRF. There appears to be no regulatory issues that would prevent biosolids products from either WRRF entering the target markets discussed in this TM.

The greatest target market availability is found in agricultural cropland. It is anticipated that this market represents a biosolid demand much higher than the biosolids quantity currently produced at Clarkson and G.E. Booth WRRFs combined. Conversations with third-party operators and vendors indicate that the biosolids market in Southern Ontario would be able to absorb some, if not all, biosolids produced at the two WRRFs.

The information presented in this TM will be used to establish biosolids management alternatives at each of the WRRFs. As a next step, alternatives for processing and utilizing biosolids will be further assessed, taking into considered product markets, distribution, storage, and transportation.

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Region of Peel

Appendix A

Biosolids Characteristics

Table A-1 Biosolids and Sludge Analysis Values

			CFIA				NASM			Ontario Compost				Sludge Analysis Values 2020						
Parameter	Maximum acceptable cumulative metals addition to soil over 45 years (kg/ha)	Examples of maximum acceptable product metal concentration based on annual application rates (mg/kg) 4,400 kg/ha-yr	Examples of maximum acceptable product metal concentration based on annual application rates (mg/kg) 2.000 kg/ha-yr	Examples of maximum acceptable product metal concentration based on annual application rates (mg/kg) 500 kg/ha-yr	Pathogen Level	Pathogen Minimum detection limit	CM1 Concentration in non-aqueous material (containing 1% or more total solids, wet weight), expressed as mg per kg of total solids, dry weight / CP1 Standards	CM2 Concentration in non-aqueous material (containing 1% or more total solids, wet weight), expressed as mg per kg of total solids, dry weight / CP2 Standards	Maximum addition to soil (in kilograms of regulated metal per hectare/per five years)	Maximum concentration in soil (in milligrams per kilogram of soil, dry weight)	Plant Available Nitrogen (12 Month Period) KG/HA	Plant Available Phosphate (5 Year Period + Phosphorus Removed by Crop Harvesting) KG/HA	Category A Compost (mg/kg dry weight)	Category B Compost (mg/kg dry weight)	Feed for Categories A & B Compost (mg/kg dry weight)	Clarkson Average 2020 Sludge Cake NASM Analysis Values (mg/kg)	GE Booth Average 2020 Sludge Cake Analysis Values (mg/kg)	Clarkson assuming an application rate of 4 DT/ha/yr Over 12 Months (kg/ha)	Clarkson assuming an application rate of 4 DT/ha/yr Over 5 Years (kg/ha)	Clarkson assuming an application rate of 4 DT/ha/yr Over 45 Years (kg/ha)
Arsenic (As)	15	75	166	666			13	170	1.4	14			13	75	170	0.30		0.0012	0.006	0.05
Cadmium (Cd)	4	20	44	177			3	34	0.27	1.6			3	20	34	0.04		0.0002	0.0009	0.008
Chromium (Cr)	210	1,060	2,333	9,333			210	2,800	23.3	120			210	1060	2800	3.4		0.014	0.069	0.62
Cobalt (Co)	30	151	333	1,333			34	340	2.7	20			34	150	340	0.2		0.0006	0.0032	0.03
Copper (Cu)	150	757	1,666	6,666			100	1,700	13.6	100			400	760	1700	31		0.12	0.62	5.5
Mercury (Hg)	1	5	11	44			0.8	11	0.09	0.5			0.8	5	11	0.1	0.1	0.00022	0.0011	0.01
Molybdenum (Mo)	4	20	44	177			5	94	0.8	4			5	20	94	0.4		0.0017	0.0087	0.08
Nickel (Ni)	36	181	400	1,600			62	420	3.56	32			62	180	420	1.1		0.0042	0.021	0.19
Lead (Pb)	100	505	1,111	4,444			150	1,100	9	60			150	500	1100	0.8		0.0031	0.0154	0.14
Selenium (Se)	2.8	14	31	124			2	34	0.27	1.6			2	14	34	0.1		0.0006	0.0028	0.03
Thallium (Tl)	1	5	11	44														-	-	-
Vanadium (V)	130	656	1,444	5,777														-	-	-
Zinc (Z)	370	1,868	4,111	16,444			500	4,200	33	220			700	1850	38	25		0.10	0.50	4.52
Salmonella					Not Detectable	< 1 CFU / 25 grams	< 3 CFU or MPN/4g						3 MPN /4 g total solids	3 MPN /4 g total solids						
Faecal Coliforms					<1000 MPN / gram	< 2 CFU / gram	E. coli ≤1,000 CFU/g dry weight	E.coli < $2x10^6$ CFU/g dry weight					1,000 CFU or MPN E.coli/g total solids	1,000 CFU or MPN E.coli/g total solids		5945 CFU/g				
Nitrogen											200					3308	(Total Kjeldahl Nitrogen)	13	66	595
Phosphorus												390				1527	(Total Phosphorus)	6.1	31	275

Appendix L:

Description and Screening of Long List of Solids Treatment Technologies

Clarkson Water Resource Recovery Facility
Schedule C Class Environmental Assessment

Technical Memorandum:

Description and Screening of Solids Treatment Technologies

3/29/2022

VERIFIED AND APPROVED					
Rev	**Prepared By**	**Date**	**Verified By**	**Date**	**Issue/Revision Description**
1	Maryam Shahab / Mark Lang	May 4, 2021	Zhifei Hu	May 4, 2021	Final Draft
2	Mark Lang	March 29, 2022	Zhifei Hu	March 29, 2022	Final

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Term or Acronym	Definition
AA	Average Annual
ATAD	Auto Thermophilic Aerobic Digestion
CO	Carbon Monoxide
CFIA	Canadian Food Inspection Agency
DT/d	Dry Tonnes per Day
FBI	Fluidized Bed Incinerator
FzA	Fertilizers Act
HSW	High Strength Waste
KG H_2O/H	Kilograms water evaporated per hour
LB H_2O/H	Pounds water evaporated per hour
MACT	Maximum Achievable Control Technology
MHI	Multiple Hearth Incinerator
mm	Millimeters
MM	Maximum Month
NASM	Non-Agricultural Source Material
NMA	Nutrient Management Act
O&M	Operating and maintenance
PPH	Pounds of Water Evaporated per Hour
RTO	Regenerative Thermal Oxidizer
SRT	Solids Retention Time
SSI	Sewage Sludge Incineration
THP	Thermal Hydrolysis Process
TPAD	Temperature-Phased Anaerobic Digestion
US EPA	United States Environmental Protection Agency
VSR	Volatile Solids Reduction
WAS	Waste Activated Sludge
WRC	Water Resource Center
WRF	Water Reclamation Facility
WRRF	Water Resource Recovery Facility
WTTP	Wastewater Treatment Plant

1.0 Introduction

1.1 Background

The Region of Peel is undertaking two Schedule C Environmental Assessments (EAs) to identify and develop preferred design concepts for meeting future wastewater treatment needs at each of their Water Resource Recovery Facilities (WRRFs), formerly known as Wastewater Treatment Plants (WWTPs). The preferred solution identified in Phase 2 of the Class EA is to expand the G.E. Booth WRRF from its current rated capacity of 518 MLD to 550 MLD, and to expand the Clarkson WRRF from its current rated capacity of 350 MLD to 500 MLD.

The treatment of additional wastewater will result in the production of additional wastewater solids. As part of Phase 2 of the Class EAs, biosolids management strategies were also considered, and the preferred solution is for each WRRF to treat the solids they generate at their respective facilities. The expanded WRRFs are expected to generate the following quantities of solids (monthly maximum):

- G.E. Booth WRRF; dewatered cake solids generation for incineration: 229 dry tonnes (dt)/day (d)
- Clarkson WRRF; thickened primary and waste activated solids for digestion: 198 dt/d

These future quantities exceed the capacity of the solids handling systems at each WRRF. As a result, the Region is considering biosolids management alternatives to meet their future needs. Prior to selecting alternatives to develop and evaluate, the Region has reviewed and screened potential technologies that could be used to manage their solids. This Technical Memorandum (TM) summarizes the process used to identify and screen solids processing technologies available to process and treat wastewater solids at the Clarkson WRRF and recommends the alternative design concepts to be evaluated. The results of the market capacity assessment for biosolids products in the Region presented in the Biosolids Market Product Assessment Technical Memorandum were also considered in the development of the recommended alternative design concepts. The alternative design concepts selected will be evaluated using detailed evaluation criteria, and an overall method for managing biosolids, including treatment processes, and end-use markets will be identified and developed.

1.2 Purpose

The purpose of this Technical Memorandum (TM) is to identify and screen technologies available to process and treat wastewater solids at the Clarkson WRRF and to identify alternatives for managing the biosolids based on the shortlist of technologies. The alternative management methods will then be evaluated using detailed evaluation criteria, and an overall method for managing biosolids, including treatment processes and end-use markets will be identified and developed. The initial phase included the assessment of the market capacity for biosolids products in the Region to determine the size of the market available for the types of biosolids products that Region may produce, and the results will be considered in the assessment of biosolids management alternatives and the development of the preferred alternative. The overall goal is to provide the Region with a biosolids management strategy that will provide a dependable and cost-effective means to manage the wastewater solids generated at each facility in the future.

2.0 Value Engineering (VE) Study

To provide expert input into the Class EA process before finalizing the recommended design concept, the Region of Peel undertook a VE study. A VE workshop was held from January 24 to 27, 2022, and a VE Report was prepared. A detailed summary of the comments received, and the Project Team responses, are provided under separate cover. The VE comments related to the screening of wastewater technologies are provided in **Table 2-1**. This **Clarkson Phase 3 TM C3-4** has been updated to reflect comments provided by the VE team**.**

Table 2-1: VE Team Comments and Project Team Responses

VE Team Comment	Project Team Response
Evaluation should reflect the urgency of having the Clarkson WRRF expansion operational by approximately 2029 It is recommended that an additional screening criteria (schedule) be added to the evaluation to reflect the criticality of the schedule and the need to implement in a short timeframe must be considered.	Agreed. The screening criterion "Ability to Implement within Required Schedule" was added. The purpose being to screen out technologies that would risk the Region's ability to implement the project on schedule.
The VE team suggested that composting of biosolids is a viable option and should be considered as part of Peel's overall biosolids management program. It was suggested that the biosolids could be co-managed at the planned Halton Compost Facility or Peel owned facility.	The Project Team recognizes the benefits of composting including: • Produces high-quality, saleable product suitable for agricultural use. • Produces a product that meets CP1 pathogen criteria. • Relatively simple process that can also be used with a variety of amendments including yard waste and other carbonaceous wastes. • Compatible with anaerobic digestion; digestion helps to reduce overall odour potential from the process. • Generally, acceptable to the public as a "green" technology. In addition, the team is aware that composting is part of the Region of Halton's overall plan for managing their biosolids in the future. The Region of Halton has recently initiated a Class EA to site and develop the facility.

VE Team Comment	Project Team Response
	Although composting may be a viable alternative in the long-term, it would be a challenge to implement within the critical timeframe (i.e., additional wastewater and biosolids management capacity is required at Clarkson WRRF by 2029). Even with the Halton Composting Facility on-line by that date, Halton's priority is to process Halton biosolids at the facility, and agreements to process other municipal biosolids at the facility would take time and not be guaranteed. In addition, the biosolids from the Clarkson WRRF would likely be equal or more than the biosolids produced at the Region of Halton. This makes co-management of Clarkson biosolids at the Region of Halton a challenge to implement. As part of the Region of Peel's long-term biosolids implementation strategy, Peel will continue to keep up to date on biosolids treatment technologies and markets and their applicability to Peel Region.
As a general comment, the VE team suggested that technologies for Direct Thermal Drying (i.e., Drum Dryer, Belt Dryer, Fluidized Bed Dryer) should not be screened out at this stage.	The Project Team did not screen out the drying technologies. In developing the biosolids alternative design concepts, for EA costing purpose only, it was assumed that rotary drum dryers would be used for concept development. During the design stage, different technologies will be assessed.

3.0 Long List of Solids Treatment Technologies

There are numerous biosolids management practices and technologies, along with combinations of practices and technologies, available to agencies for consideration. This technology screening process has been conducted to allow the Region of Peel to identify technologies which can provide reliable long-term solutions for the management of the Region's biosolids in the future. These technologies and combination of technologies, once selected, will be developed into alternatives for a planning level evaluation and analysis.

This section provides an overview of technologies which could be considered for use at the Clarkson WRRF. These technologies were then screened using four broad criteria:

- Maturity of Technology
- Compatibility with existing and future processes and biosolids end use markets
- Proven application at large WRRFs
- Compatible with Regional Energy Management and GHG Reduction Goals
- Ability to Implement within Required Schedule

Technologies which meet these criteria were recommended to the Region to be developed and evaluated.

The following technologies include biological, chemical, and thermal processes that can stabilize wastewater solids and change their characteristics. These technologies are used together to comprise a treatment alternative. As a result, a relatively small number of technologies can be used in different configurations to develop a much larger number of alternatives. As an example, anaerobic digestion can be used as a stand-alone stabilization technology prior to land application. It can also be used following a hydrolysis process to yield a product that can be used more widely than just in agriculture or upstream from a thermal process to enhance the characteristics of a dried product or to reduce the mass and volume of solids entering an incineration process.

3.1 Biological Digestion Technologies

3.1.1 Conventional Anaerobic Digestion

Anaerobic digestion involves the conversion of volatile fraction of wastewater solids in a controlled environment in the absence of oxygen. Most anaerobic digesters are operated as high-rate digesters in the mesophilic temperature range. These digesters operate in the 32-38°C (90-100°F) range using methanogenic (methane forming) bacteria. These digesters are equipped with mixers and external heating to allow for shorter detention times (15-20 days) and more stable conditions than previously popular low-rate digesters, which do not include mixing. Anaerobic digestion systems stabilize the biosolids and reduces the mass of volatile solids by 40-60 percent. The process generates methane containing biogas which can be used as a fuel source.

The digested biosolids are suitable for use in bulk application to agricultural land as a fertilizer. The anaerobic digestion process can consistently meet the CP2 Pathogen Reduction Criteria as required by the Nutrient Management Act (NMA), Ontario Regulation O.Reg.267/03, for non-agricultural source material (NASM).

A general schematic showing a typical configuration for the anaerobic digestion process is provided in **Figure 3-1**.

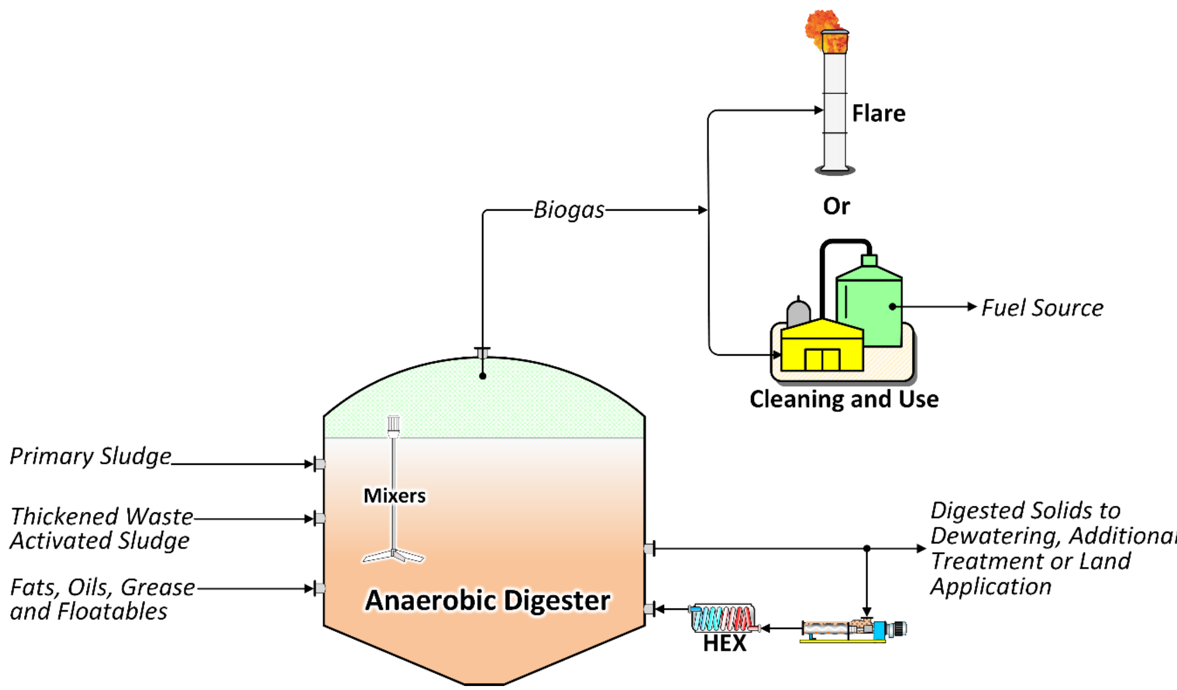

Figure 3-1 Anaerobic Digestion General Schematic

The advantages and challenges associated with Anaerobic Digestion are summarized in **Table 3-1**.

Table 3-1 Advantages and Challenges of the Anaerobic Digestion process

ADVANTAGES	CHALLENGES
• Anaerobic digestion is a well proven technology. • Anaerobic digestion process is currently used by the Region of Peel. • Relatively straight forward operation. • Ability to stabilize solids is a benefit to all the technologies that are under consideration. • Biogas produced in the process can be available for beneficial use.	• Additional digester capacity would be required at the Clarkson WRRF. • Minimal product volume reduction compared to other technologies. • Challenges associated with managing a land application program, permitting, transportation of product, winter storage and so on. • Requires additional processing to meet CP1 criteria.

3.1.2 Temperature-Phased Anaerobic Digestion

Temperature-phased anaerobic digestion (TPAD) involves the use of thermophilic digesters operated in a batch mode upstream of conventional mesophilic digesters. By including a batch thermophilic digestion step, with a typical Solids Retention Time (SRT) of 6-8 days, prior to the mesophilic digesters, the process has the potential to meet the CP1 pathogen reduction requirements.

The thermophilic digestion step in the process also reduces the SRT requirement in the down-stream mesophilic digestion step. The downstream mesophilic digesters are usually operated in a flow through configuration, with a typical SRT of 8 days, approximately half of the conventional high-rate mesophilic digesters. While the process can generate a CP1 product, the digested solids leave the process at a low total solids concentration and require dewatering to create a dewatered cake at approximately 20 percent Total Solids (TS). Based on the consistency of the dewatered material a TPAD cake is often used in bulk land application programs.

A general schematic showing a typical configuration for the TPAD process is provided in **Figure 3-2**.

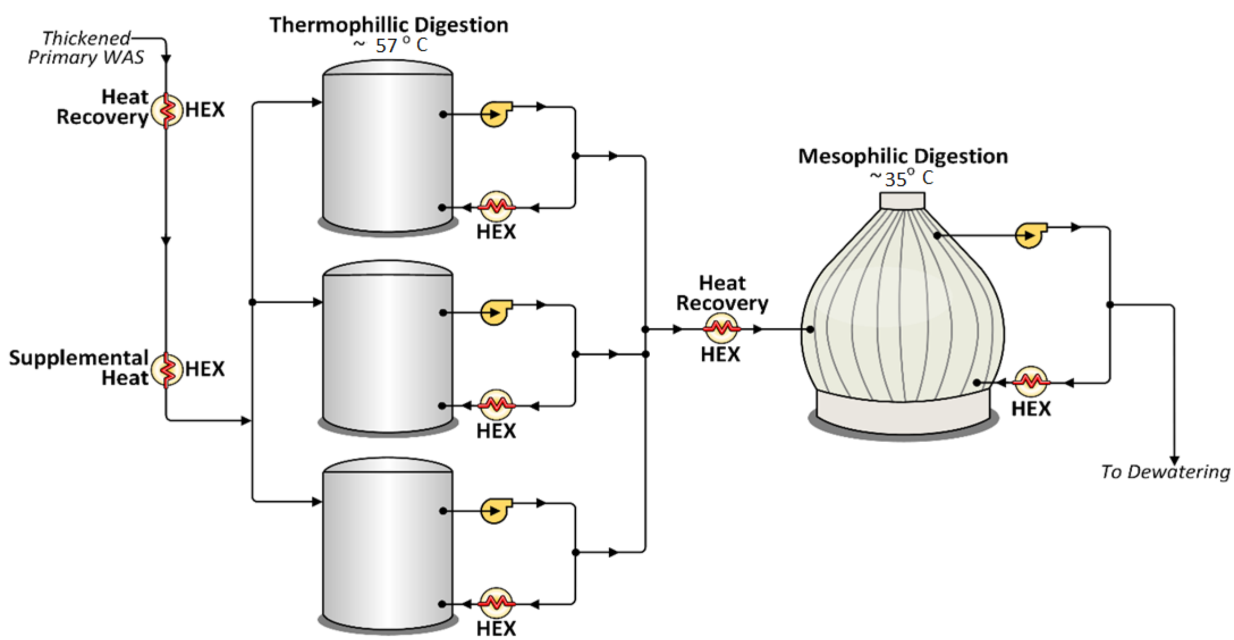

Figure 3-2 TPAD General Schematic

The advantages and challenges associated with TPAD are summarized in **Table 3-2**.

Table 3-2 Advantages and Challenges of Temperature Phased Anaerobic Digestion (TPAD)

ADVANTAGES	CHALLENGES
• TPAD is a proven technology. • Can produce a CP1 Product • The system is energy efficient and would be a net energy producer. • There would be the potential for biogas to be converted to electricity or renewable natural gas.	• Significant investment required for the thermophilic digestion systems. • The digestion system would be more complex than current digestion at Clarkson WRRF. • Production of a dewatered cake rather than a dried or composted product would provide less flexibility in product end use and more risk of not finding a market for the product. • There have been some fecal coliform re-growth concerns with TPAD systems using centrifuge dewatering.

3.1.3 Acid-Gas Phased Anerobic Digestion

Acid-gas digestion anaerobic digestion provides separate tanks for the acidogenic and methanogenic bacteria, which may improve the overall performance of digestion process. The acid phase can be operated at thermophilic or mesophilic temperatures with a short SRT of 1.5 to 2 days, during which the substrates are hydrolyzed to produce VFAs, which are used by methanogens to produce CH4 and CO2 in the second phase. Acid-gas digestion is also expected to reduce foaming potential; however, this benefit has not been definitively proven.

Enzymic hydrolysis is a proprietary acid-gas digestion technology developed by Monsal. The system consists of multiple stage serial flow reactors, which provide the acid phase of the digestion process. The total SRT for the multiple reactors is 2 days or less. Several of the small reactors can be operated at thermophilic temperatures, which have been shown to meet Class A pathogen requirements. If thermophilic stages are included, the process becomes enhanced enzymic hydrolysis. The enhanced enzymic hydrolysis process claims to be more effective than conventional digestion in pathogen inactivation, which may be a function of the staged digestion process and reduced short circuiting. A general schematic showing a typical configuration for the Acid – Gas anaerobic digestion process is provided in **Figure 3-3**.

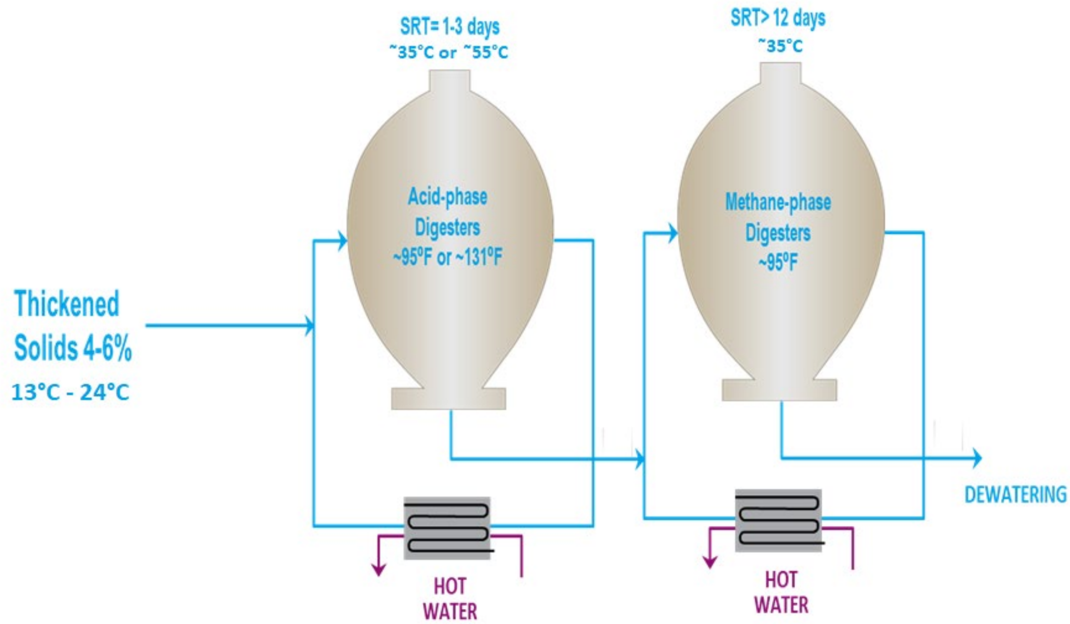

Figure 3-3 General Schematic of Acid – Gas Phase Anaerobic Digestion

The advantages and challenges associated with acid-gas anaerobic digestion are summarized in **Table 3-3**.

Table 3-3 Advantages and Challenges of Acid-Gas Anaerobic Digestion

ADVANTAGES	CHALLENGES
• Produces a CP1 product. • Separating acid and methane phases increases digestion efficiency. • Total Hydraulic Retention Time (HRT) is reduced compared to mesophilic anaerobic digestion.	• Investment required for the additional digesters in the acid gas system. • The digestion system would be more complex than current digestion at Clarkson WRRF. • Production of a dewatered cake rather than a dried or composted product would provide less flexibility in product end use and more risk of not finding a market for the product.

3.1.4 Thermal Hydrolysis Process (THP)

The thermal hydrolysis process (THP) is often used to condition solids prior to anaerobic digestion. The process consists of a high-temperature, high-pressure steam, solids pre-treatment process that is installed upstream of mesophilic anaerobic digestion. The process hydrolyzes the feed solids, making them easier to digest. Hydrolyzing the solids and the resulting changes in the material's viscosity allows the anaerobic digesters downstream of THP processes to be fed at loading rates that are significantly higher than conventional high-rate digesters. The process requires pre-screening and pre-hydrolysis dewatering upstream of THP to minimize the amount of debris fed to the pressure vessels and to feed the system at ideal solids concentrations for optimum performance.

Cambi is a leader in the THP technology. They have more installations than any other manufacturer in North America. Cambi is credited with developing the original hydrolysis process prior to anaerobic digestion. Veolia has the second largest portfolio of hydrolysis systems. Other manufacturers also offer the THP technology including Haarslev, Eliquo Stulz and DMT Environmental.

The benefits of THP conditioning compared to conventional digestion include a higher loading rates to the anaerobic digestion system following hydrolysis, greater product stability, measured as Volatile Solids Reduction (VSR) through the process, improved dewaterability, which results in the reduction of the mass and volume of cake requiring transportation and a Class A product with no demonstrated regrowth of fecal coliform. THP can meet the US EPA Class A pathogen and Vector attraction reduction requirements based on the following factors:

- Solids are heated in a batch mode in the THP reactors to 165°C (329°F) and held for more than 20 minutes. This provides enhanced pathogen reduction
- Digestion with THP typically achieves VSR of 55% or higher.

As an alternative to being installed upstream of digestion, THP can also be used in an intermediate configuration (between two phases of digestion) or downstream of digestion with COD rich dewatering filtrate returned to the digesters for treatment. Intermediate THP, however, requires significant digester capacity. These configurations were not considered viable for the Region of Peel.

Figure 3-4 shows the THP system installed at the Davyhulme treatment facility in Manchester, UK.

Figure 3-4 THP system at Davyhulme, UK

A schematic showing a typical configuration for a THP and anaerobic digestion system is provided in **Figure 3-5**. A key requirement of the system is steam supply for the THP unit. Steam can be generated directly by burning biogas (or natural gas), or by utilizing waste heat from an engine generator.

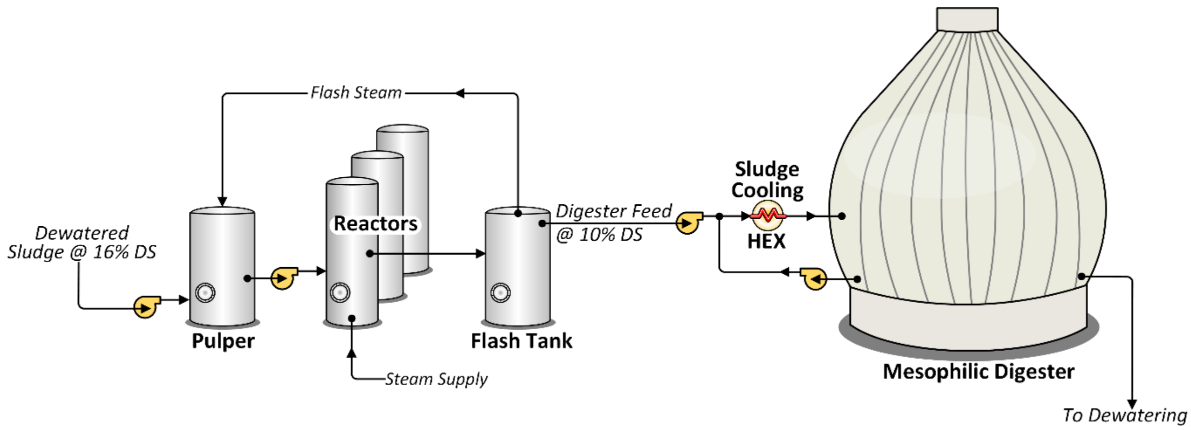

Figure 3-5 Typical Configuration with THP Upstream of Anaerobic Digestion

The advantages and challenges associated with Thermal Hydrolysis are summarized in **Table 3-4**.

Table 3-4 Advantages and Challenges of the Thermal Hydrolysis Process

ADVANTAGES	CHALLENGES
• Meet CP1 pathogen criteria. • Proven technology. • Allows higher loading of downstream anaerobic digesters. • Increase Volatile Solids Reduction (VSR) (55-60%). • Improved dewaterability (~28-32%) depending on operating SRT in the digesters. • Reduced wet mass for hauling (circa 30% saving vs. conventional digestion). • Minimal regrowth potential.	• Additional mechanical equipment (screening, pre-dewatering, cake bin, THP). • Steam boiler operation (vs water boiler). • Increased side stream N & P loading including recalcitrant components (even more so with cake imports from other WRRFs). • Reactors operate at high temperature / pressure requiring annual inspection and suitable O&M procedures to ensure safe operation.

3.1.5 Thermal/Alkaline Hydrolysis Process

In the thermal/alkaline hydrolysis process, sodium hydroxide (NaOH) and heated water 60 to 72 degrees C (140 to 160 degrees F) are used to hydrolyze cell walls and solubilize contents which, similar to other hydrolysis processes, results in increased VSR and biogas production in the subsequent anaerobic digestion process.

Centrisys CNP markets a technology, Pondus, which hydrolyzes thickened WAS using sodium hydroxide and low-grade heat. As shown in **Figure 3-6**, effluent from Thermochemical Hydrolysis Process (TCHP) process is typically blended with raw primary sludge so there is no need for cooling heat exchangers. Since primary sludge is not treated through TCHP process, the final digested biosolids product is not Class A/AA. However, this would not be a concern at Northside WRF because there are no primary clarifiers. CNP has a single installation in the US at Kenosha, WI.

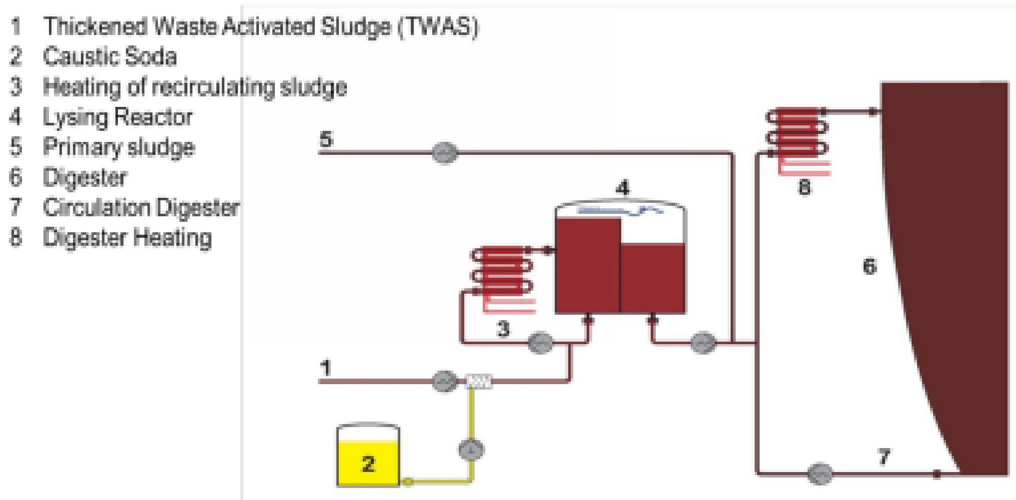

Figure 3-6 Pondus Process Configuration Upstream of Anaerobic Digestion (courtesy of CNP)

The advantages and challenges associated with Thermal / Alkaline Hydrolysis are summarized in **Table 3-5**.

Table 3-5 Advantages and Challenges of Thermal / Alkaline Hydrolysis Process

ADVANTAGES	CHALLENGES
• When combined with Anaerobic Digestion produces biosolids that meets the CP1 pathogen criteria. • Operates at atmospheric pressure. • Allows higher loading of downstream anaerobic digesters. • Increases biogas production. • Increase Volatile Solids Reduction (VSR).	• Technology process WAS only. • Additional mechanical equipment required. • Requires chemical handling and addition. • Increased side stream N & P loading. • Limited systems operating at full scale.

3.1.6 Conventional Aerobic Digestion

An aerobic digester operates on the same principle as the activated sludge process. As food is depleted from the dissolved phase of the wastewater, the microbes enter the endogenous phase where the organisms eat one another, ultimately oxidizing most of the cells to CO2, H2O, NH3, NO2, and NO3. Up to 80 percent of the cell may be oxidized in this manner; the remaining fraction contains inert and non-biodegradable materials. Factors to be considered during design of the process are characteristics and origin of the sludge, hydraulic residence time, solids loading criteria, energy requirement for mixing, environmental conditions, and process operation.

Oxygenation and mixing requirements of aerobic digestion systems are provided by diffused air, mechanical surface aeration, mechanical submerged turbines, jet aeration, and combined systems. A substantial amount of energy is required to provide the oxygen required by the digestion system. To meet CP2 pathogen criteria requires significant solids retention times,

The advantages and challenges associated with aerobic digestion processes are summarized in **Table 3-6**.

Table 3-6 Advantages and Challenges of Aerobic Digestion Processes

ADVANTAGES	CHALLENGES
• Equipment and operation similar to activated sludge process. • Relatively simple tank design. • Proven technology.	• Best suited to smaller facilities. • Difficult to meet VAR requirements in cold weather. • Meets CP2 pathogen criteria and will need to land applied or provided additional stabilization. • High energy requirement for aeration. • Low volume reduction. • Dewatering of digested biosolids can be difficult. • Odour potential.

3.1.7 Autothermal Thermophilic Aerobic Digestion

Autothermal thermophilic aerobic digestion (ATAD) operates under thermophilic temperatures in the 45-70°C (113-158°F) range. In this process, heat is generated by thermophilic bacteria decomposing organic compounds. The digesters are insulated to limit heat losses and do not require external supplemental heat, except at start-up. When the reactor's temperature is maintained at or above 55°C (131°F), ATAD can meet CP1 pathogen criteria.

With early ATAD systems, odour and poor dewatering characteristics were substantial problems. Improvements in the process, which include extended aerated storage, have improved the dewaterability and reduced odour. As a general consideration, aerobic digestion, and consequently the ATAD process, tend not to be cost-effective solutions on larger facilities, due to the energy consumption associated with aerating the reactors.

The advantages and challenges associated with ATAD are summarized in **Table 3-7**.

Table 3-7 Advantages and Challenges Associated with ATAD Processes

ADVANTAGES	CHALLENGES
• Meets the CP1 pathogen criteria. • Proven technology.	• Generally best suited to smaller facilities. • High energy requirement for aeration. • Low volume reduction. • Dewatering of digested biosolids can be difficult. • Odour potential. • Foam control for oxygen transfer.

3.2 THERMAL DRYING TECHNOLOGIES

Thermal (heat) drying involves the use of heat to evaporate moisture from wastewater solids, improving the handling characteristics of the solids and reducing their mass for final use. Drying systems can be operated to remove a portion of the moisture remaining in the dewatered cake or to further dry the cake to resulting in a product that can be marketed a fertilizer under the Canadian Food Inspection Agency's (CFIA) requirements under the Fertilizers Act (FzA).

Dried biosolids products that meet CFIA, FzA requirements are suitable for beneficial use as fertilizer, soil conditioner, or fuel. The energy required for heat drying is typically furnished by combusting fossil fuels such as natural gas or fuel oil, or biogas generated during anaerobic digestion.

Drying technologies used in North America can be grouped in two categories: direct and indirect systems.

- **Direct Drying Systems**. With direct systems, also called convection dryers, the solids are heated by direct contact with the drying medium, which can be heated air from gas fired burners or hot flue gases from other processes. The exhaust gas volume from direct dryers tends to be higher than with indirect systems, thus in some cases the amount of emissions is comparable.

- **Indirect Drying Systems**. With indirect dryers, also called conduction dryers, there is no physical contact between the heat carrier and the solids. Indirect systems use steam or hot oil to heat metal plates, disks, or paddles that transfer the heat by conduction to the biosolids. These systems have typically lower volumes of exhaust gases for treatment.

Table 3-8 provides an overview of drying technologies currently available in the municipal market. Both categories offer advantages and disadvantages. Typically, indirect systems operate at lower temperatures when compared to larger rotary drum direct dryers. Indirect dryers operating temperatures generally range from 200°C-232°C (390°F-450°F). The dryers generate significantly less exhaust air to treat and require a smaller footprint than direct systems with similar capacity. The disadvantages associated with indirect dryers include the potential to produce an irregularly shaped product with a relatively high concentration of fine material, dust. This is the case with several paddle dryers.

Direct dryer systems operate at a wide range of temperatures, between 150°C- 535°C (300°F-1,000°F). Direct dryers that include back mixing can produce uniform granules with lower dust concentrations when compared to indirect dryers.

Table 3-8 Overview of Drying Technologies

TYPE	COMMENTS
DIRECT CONTACT (CONVECTION)	
Rotary Drum	Most widely used technology in the municipal wastewater market with more than 25 installations in North America. Well suited for larger facilities (typically greater than 20 dry tons per day (dtpd)). Produces a pelletized product using back mixing with recycled product. Screening is typically used to improve pellet quality.
Belt Dryer	Relatively new technology with growing interest. Currently there are at least 10 belt dryers operating with several more under construction. The belt dryer is an established technology in Europe with approximately 10 to 15 years-experience in full-scale applications. Product characteristics vary depending on the supplier due to different solids feed systems and handling. The technology is best suited for small to mid-sized facilities, typically less than 20 dtpd.
Fluidized Bed	Limited experience in U.S. with only one installation. Produces a pelletized product using back mixing with recycled product. The technology is fairly well established in Europe with multiple installations.
INDIRECT CONTACT (CONDUCTION)	
Paddle/Disc	This technology has been widely used in North America. The systems work well for small to medium-sized facilities, below 20 dtpd. Some systems do not recycle or screen product, while others have incorporated recycling to improve product quality. The product is irregular shaped. The concentration of fines is dependent on screening and recycling.

3.2.1 Dryer Safety

While heat drying biosolids provides substantial benefits, there are safety considerations associated with this processing technology that must be considered. Dried biosolids are a combustible material, and in the presence of oxygen and an ignition source, the dried product will burn. As a result, common fire safety hazards associated with combustible materials are present with dried biosolids. In addition to the typical hazards associated with combustible materials, heat drying of biosolids can create some unique hazards, including production of explosive combustible dust as well as fires resulting from reheating of the dried material.

Combustible dust is produced as part of the material handling process of the dried product. Dust accumulation can occur if the solids that are too dry or if there is inadequate removal of dust from equipment as part of maintenance operations. Combustible dust can be an explosion hazard if it is suspended in the air in sufficient concentration when an ignition source is present.

Dried biosolids contain chemical and biological constituents that can undergo reheating if rewetted from condensation in storage bins and silos or if too much moisture remains in the product after the drying process. The moisture can restart exothermic chemical and biological degradation. The reheating process generates heat, which, if not dissipated, can result in smoldering combustion that can lead to a fire. In addition to the hazards associated with the fire itself, the fire can provide an ignition source for explosion of nearby combustible dust. Smoldering material can produce carbon monoxide, which is a combustible gas--although opinion are divided as to whether explosive levels would ever be reached in a drying system.

3.2.2 Rotary Drum Dryers

Rotary drum dryers are widely used throughout North America and Europe, with over 100 installations worldwide. The first system was installed in the United States, and possibly North America was installed Milwaukee in the 1920s. Currently, rotary drum dryers operate at more than 25 large and midsized wastewater treatment facilities in the North America, including those serving Toronto, ON, Milwaukee, WI, New York, NY, Baltimore, MD, Boston, MA, Louisville KY, Nashville, TN, Jacksonville, FL and Carlsbad, CA. The Irvine Ranch Water District in California is currently constructing a new rotary drum drying facility. The primary manufacturers of systems operating in the U.S., include Andritz-Ruthner (Andritz) and Baker Rullman, which is typically used by New England Fertilizer Company (NEFCO). Other dryer manufacturers with units in North America include Sernagiotto and Vomm.

Rotary drum dryers have the highest throughput among drying systems and are rated in terms of pounds of water evaporated per hour (pph), with an evaporation rate in the 4,400-24,000 pph range. This corresponds to a solids throughput of approximately 10-55 dry tons per day (dtpd) per unit, based on 20 percent cake solids and a 5 day per week operating schedule. These systems produce a high-quality pelletized product that is suitable for diverse outlets.

Rotary drum drying systems include the rotary drum with direct gas heating and recycle feed system. A process flow diagram for a typical system supplied by Andritz is shown in **Figure 3-7**.

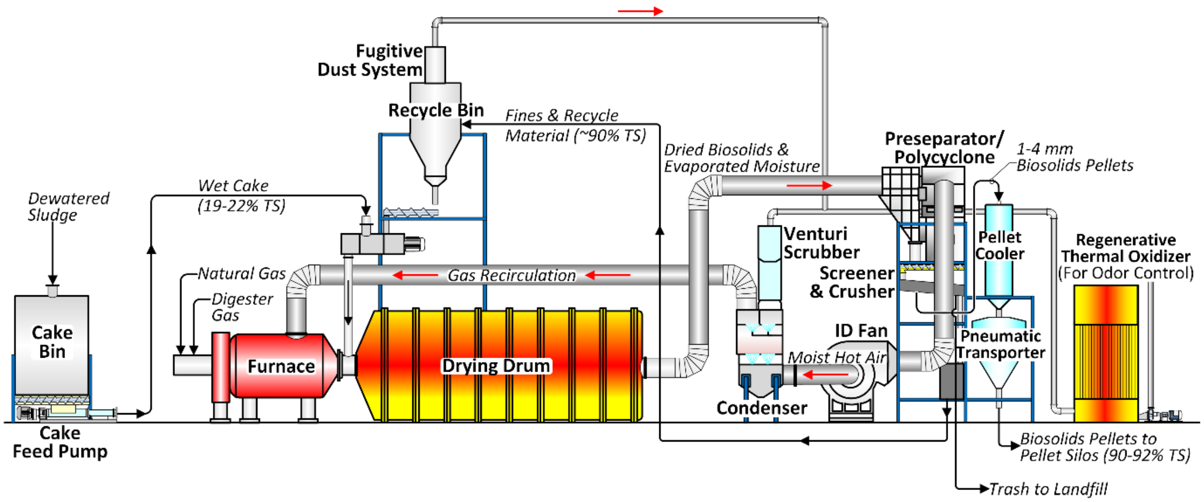

Figure 3-7 Rotary Drum Dryer Process Flow Diagram

The dried recycled product is coated with dewatered cake in a mixer before entering the rotary drum dryer. Heated process gas flows through the drum, heating the pellets and absorbing evaporated moisture while the rotation of the drum keeps the material in motion. At the exit of the drum, the dried product becomes entrained in the process gas flow and is carried to a pre-separator and cyclone, where the pellets are separated and conveyed to a screen. In the screen, oversized material and undersized material are separated from the desired size pellets. The oversized material is crushed and returned to the mixer, along with fines and a portion of the pellets may be crushed and returned as needed. The recycled material is recoated with dewatered cake and sent back through the dryer. A portion of the separated pellets downstream of the screen are cooled in a product cooler and conveyed to storage as finished product.

Downstream of the cyclone, the process gas flows through a wet scrubber condenser for removal of particulates and moisture. A large percentage of the gas is then returned to the furnace to repeat the cycle. A portion of the process gas stream is removed and directed to a high efficiency wet Venturi scrubber to remove fine particulates. This blow-down gas is then treated through a regenerative thermal oxidizer (RTO) for odour control.

Rotary drum dryers are equipped with extensive temperature and carbon monoxide (CO) monitoring systems, and oxygen levels throughout the dryer system are maintained at a concentration below six percent to prevent fires and explosions. The product is typically stored in silos, which are also typically monitored for temperature and CO, prior to discharge into trucks. Nitrogen inserting capability is recommended for silo storage systems in the event a smoldering fire is detected. An oil conditioning system can be used at loadout to agglomerate fines and reduce dust.

The advantages and challenges associated with rotary drum dyers are summarized in **Table 3-9**.

Table 3-9 Advantages and Challenges of Rotary Drum Dryers

ADVANTAGES	CHALLENGES
• Meets CP1 Pathogen criteria • High quality and uniformity of the end-product. • The finished granules resemble manufactured chemical fertilizers. • The product size can be varied to meet demand, but typically falls in the 2-4 millimeters (mm) in diameter size. • High throughput capacity. • Limited dust formation during product handling due to the hardness of the granules and use of a screening process. Oils can also be used to control dusting during product loadout.	• Complex system with high maintenance requirements. • System needs to operate continuously for extended periods. Continuous presence of operations staff is required to monitor the system. • Variability in the feed solids concentration can affect operations. • Safety must be a focus to minimize the potential for fire and explosions. • Requires natural gas or biogas.

3.2.3 Belt Dryer

Belt drying technology in municipal applications was first introduced in Europe in the mid-1990's with relatively widespread acceptance. Recently the use of this technology in North America has been increasing. When compared to rotary drum dryers, belt dryers are mechanically simpler. Manufactures of belt dryers with operating facilities in North America include Veolia/Kruger, Andritz, Suez, Huber, Siemens, and Gryphon.

A belt dryer is a direct (convective) drying system that uses heated gas 127-165°C (260-330°F) in direct contact with the dewatered solids to evaporate water. The specific configuration differs based on the manufacturer. The dryer consists of one or two porous belts with a gas circulation system. Belts may be steel mesh or synthetic material similar to that used with belt filter presses. Dewatered cake is introduced onto the belt with a pumped extrusion system or is mixed with recycled dried material (back-mixing) and deposited on the belt as pre-formed granules. The feed material then is slowly conveyed by the belt while heated gas is brought in contact with the solids. The product is dry by the time it reaches the end of the belt(s).

For recirculating gas systems, hot gas is drawn or blown through the product on the belt with a fan and is then passed through a heat exchanger to recover energy. A belt dryer can use a gas-fired furnace (biogas or natural gas) for the energy source, or alternative energy sources. For example, hot water from cogeneration engines can be used in water-to-air heat exchangers to transfer the heat to the drying gas. A large percentage of the drying gas is recycled to improve thermal efficiency, but enough must be exhausted to remove the evaporated water collected in the gas during the drying process. The exhaust is typically treated through a condenser system, with the resulting condensate being returned to the liquid treatment process. The non-condensable exhaust is conveyed to an odour control system.

The odour control technology varies depending on the system supplier, although biofilters and wet scrubbers are predominantly used. RTOs are generally not considered with these systems due to the large volume of gas would make the system very expensive to operate.

The end product from the belt dryers is irregular in shape and size, containing fines and particles up to 6 mm in diameter. The size and density of the product varies, depending on the methods of pre-processing and feeding the cake to the dryer used by the various manufacturers. Product screening is typically not used with these systems to reduce the materials handling complexity and cost. An oil conditioning system can be used at loadout to agglomerate fines and reduce dust. At least one manufacturer has added downstream processing to create a more uniform and denser pellet.

For safety, the operating temperatures are maintained below ignition levels, and monitoring systems are provided to identify safety problems and reduce the risk of fires and explosions. Some of the monitoring systems may include temperature and CO detection. Product storage should also be monitored for temperature and CO levels. Nitrogen purging capability is recommended for silo storage systems in the event a smoldering fire is detected. Due to the sizes of the drying systems' components belt dryers are best suited for small to medium sized drying applications.

A schematic showing the basic configuration of an Andritz belt dryer system is provided in **Figure 3-8**.

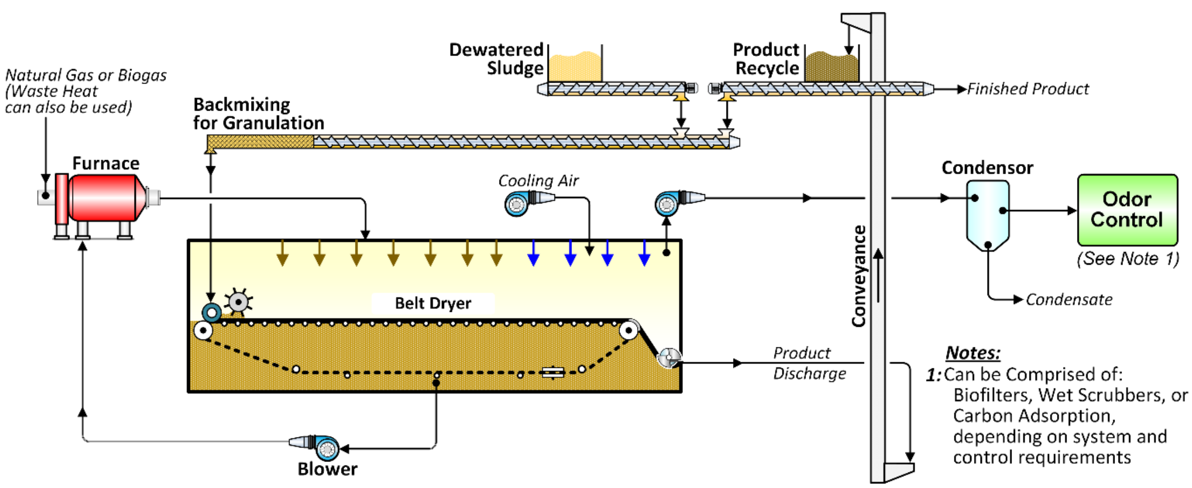

Figure 3-8 Belt Dryer Schematic

The advantages and challenges associated with belt dyers are summarized in **Table 3-10**.

Table 3-10 Advantages and Challenges of Belt Dryers

ADVANTAGES	DISADVANTAGES
• Maximizes volume reduction. • Relatively low mechanical complexity. Belt dryers generally involve less materials handling equipment, especially in comparison to rotary drum dryers.	• Because the drying gas is at a low. temperature, a large quantity of gas is needed to achieve the required evaporation, which in turn requires large equipment with a significant footprint.

ADVANTAGES	DISADVANTAGES
• Ability to use alternative energy sources (such as waste heat) to power belt dryers, which operate at low drying temperatures (below the ignition point of the dried solids). • Intrinsic safety associated to low drying temperatures. • Potential to operate the dryer unattended during night shifts. Shutdowns can be automated if problems arise that cannot be corrected remotely. • Less potential for dust due to low velocity of the belt moving along the length of the dryer.	• Depending on the manufacturer, the volume of exhaust gas for odour control can be significant. Some manufacturers recycle the exhaust gases, resulting in a relatively low volume of exhaust gas requiring odour control. • The product is irregularly shaped, and the concentration of fines varies depending on the manufacturer and feed characteristics. • For some manufacturers, the product has a low bulk density. • For systems using extrusion nozzles, these can get clogged, requiring periodic cleaning. • Dust builds up that does occur may require operators of some systems to access the dryer and manually remove deposits.

3.2.4 Fluidized Bed Dryer

Fluidized bed dryers have seen limited use in North America with biosolids. The Emerald Coast Utilities Authority (ECUA, Pensacola, Florida) developed a system in the 1990's to replace an existing incinerator. When hurricane damage resulted in a relocation of the Water Reclamation Facility in 2004, the City implemented a paddle drying system. In 2014 ECUA stopped all drying and shifted to production of compost. In the early-2000's, the North Shore Sanitation District developed a "Minergy Glass Pack" system that used a combination of a fluidized bed dryer and a high temperature furnace to "melt" the dewatered solids and create a glass aggregate that could be used as construction fill material. The furnace proved difficult to maintain, but the fluidized bed dryer remains in operation and is operating as a regional dryer. Worldwide, there are approximately 40 fluidized bed dryer installations processing biosolids.

In North America fluidized bed dryers are available through Andritz and Schwing/Bioset. Capacities are similar to those for a rotary drum dryer, but the largest units installed are approximately 75 percent of the capacity of the largest rotary drum dryer systems installed. A schematic of a fluidized bed dryer is shown in **Figure 3-9**.

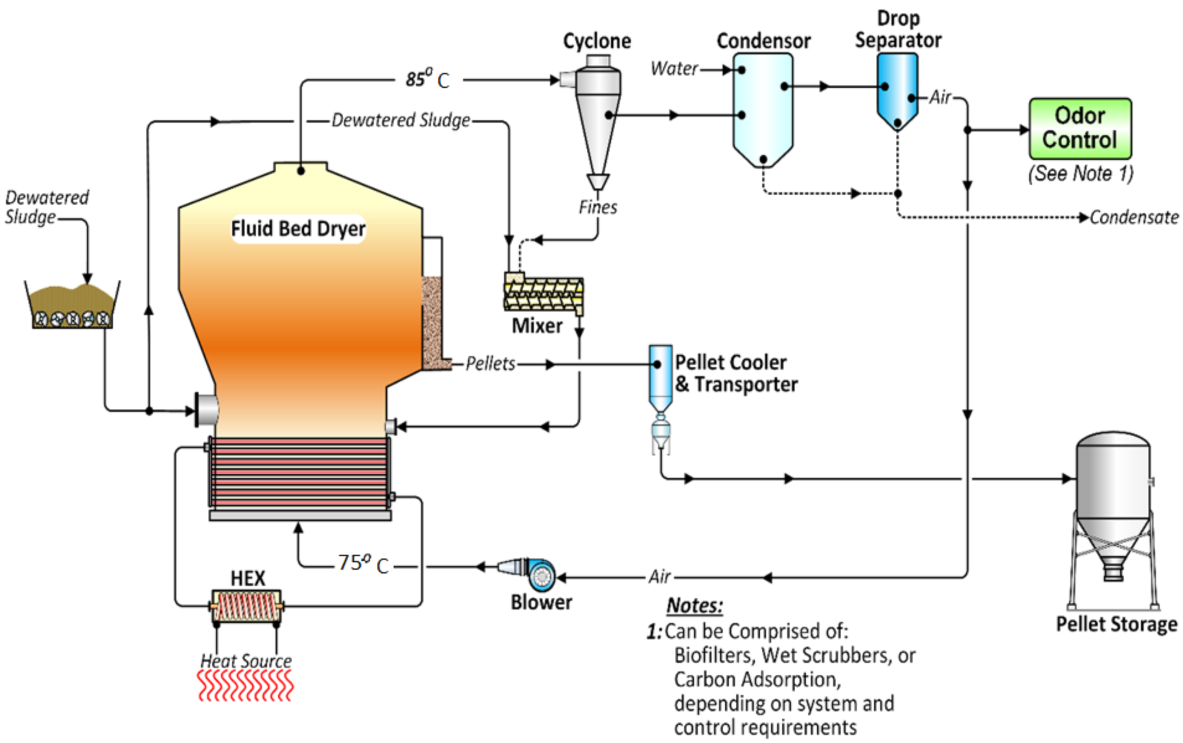

Figure 3-9 Fluidized Bed Dryer Schematic

The fluidized bed dryer is a combination of a direct and indirect system. Dewatered cake is injected into the dryer shell, where spinning cutters create small pieces of solids that drop into the fluidized mass of solids. Heat is transferred to the fluidized mass of solids from an internal heat exchanger. Fluidizing air (process gas) is recirculated through the dryer to fluidize the particles, help with heat transfer to the particles, and to remove the evaporated moisture. Steam or hot oil is used to provide heat through the heat exchange system.

The fluidized bed operates much like a fluidized bed incinerator, except the dried biosolids act as the fluidized sand in the system. The fluidizing motion in the bed produces a granular product that is relatively dust-free, but less uniform in size than the material from a rotary drum. Product size typically ranges from 1-5 mm. As the material dries, its density is reduced such that it rises to the overflow weir in the dryer and exits the dryer. The process gas is treated using a cyclone to capture fine particulates in the gas. These fine particles are recycled to drying by mixing with a side stream of dewatered cake.

Downstream of the cyclone, the process gas flows through a wet scrubber condenser for removal of particulates and moisture. A large percentage of the gas is then returned through the heat exchange system and through the dryer. A small portion of the process gas stream is removed and directed to a demister and is then sent to odour control. The exhaust can be treated with a biofilter or an RTO.

Fluidized bed dryers are equipped with temperature and oxygen monitoring systems. The oxygen concentration levels throughout the dryer system are maintained below six percent to prevent fires and explosions. The end product is typically stored in silos, which are monitored for temperature and Carbon Monoxide. Nitrogen inerting capability is recommended for silo storage systems in the event a smoldering fire is detected. An oil conditioning system can be used at loadout to agglomerate fines and reduce dust.

The advantages and challenges associated with Fluidized Bed Dryers are summarized in **Table 3-11**.

Table 3-11 Advantages and Challenges of Fluidized Bed Dryers

ADVANTAGES	CHALLENGES
• Maximizes volume reduction. • Relatively uniform quality pellet. • Lower temperature drying. • Vertical system resulting in a slightly smaller footprint than rotary drum. • System can adjust to varying cake concentrations.	• Complex system with high maintenance requirements. • System needs to operate continuously for extended periods. Note, some European systems operate continuously with only yearly shutdowns (similar to incineration) and operate with minimal staffing or unattended overnight. • Safety must be a focus to minimize the potential for fire and explosions. • Requires natural gas or biogas.

3.2.5 Paddle Dryer

Paddle dryers and disc dyers use an indirect (conductive) system, with biosolids encountering a heated surface. Paddle dryers consists of two counter rotating agitator shafts with paddles or flights and a jacketed housing. Oil or steam is circulated through the paddles/flights and the housing to heat the dewatered cake and drive off moisture. Dewatered cake is introduced to one end of the dryer. The rotation of the agitators conveys the material through the dryer to the discharge end. Evaporated moisture and non-condensable gases are pulled from the top of the unit and conveyed to a condenser. Non-condensable gas is then discharged to an odour control system.

Komline-Sanderson (Komline) and Andritz supply similar paddle dryers in North America. Both designs are based on the NARA drying technology, which originated in Japan and has been licensed to both manufacturers. Until recently, all the paddle dryers operating in the U.S. were supplied by Komline. Andritz acquired the license through the acquisition of Royal GMF-Gouda and is actively marketing the NARA paddle dryer in North America. There are manufacturers of disc dryers, which are similar to paddle systems. Some of the systems available have questionable track records and are best suited for small facilities. A schematic of a paddle dryer is shown in **Figure 3-10**.

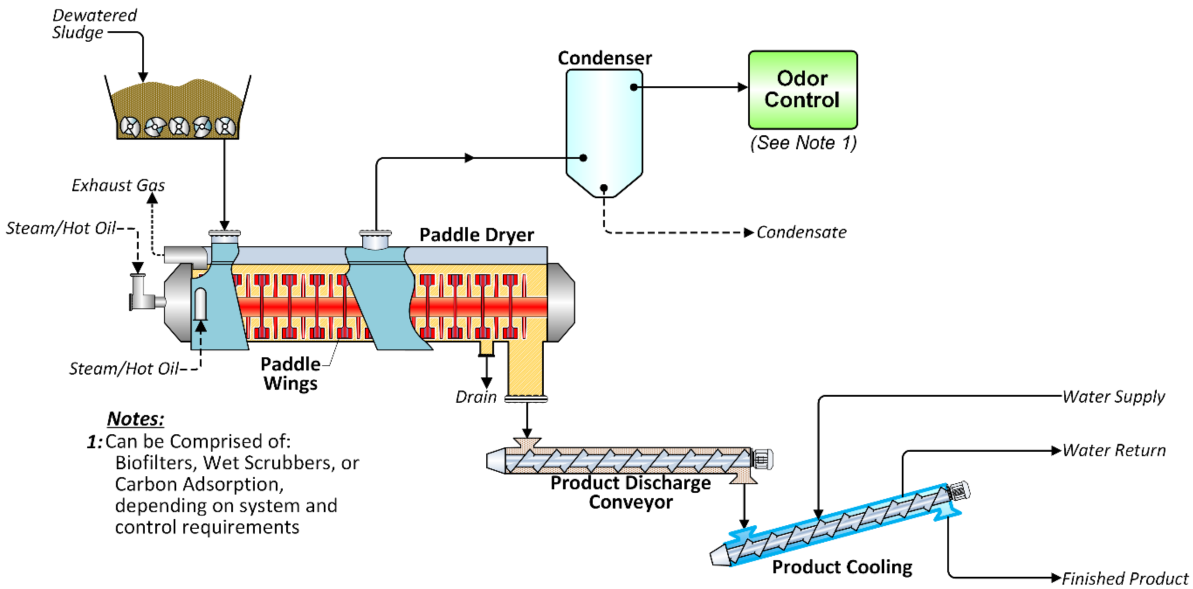

Figure 3-10 Paddle Dryer Schematic

The advantages and challenges associated with Paddle Dryers are summarized in **Table 3-12**.

Table 3-12 Advantages and Challenges of Paddle Dryers

ADVANTAGES	CHALLENGES
• Maximizes volume reduction. • Relatively small footprint. • Low volume of exhaust gas, limiting emissions and odour control requirements.	• Relatively long start-up and shut down period in comparison to belt dryers. • Potential wear of the surface of the paddles, which come in direct contact with the sludge. • The dried product is irregularly shaped, and the concentration of fines varies depending on the manufacturer. • Safety must be a focus to minimize the potential for fire and explosions.

3.2.6 Solar Drying

The use of the sun to dry biosolids is process that has been used for many decades. Over time the process has evolved, and recently solar drying system have included greenhouse enclosures, along with automated feed, material turning and discharge systems. The material turning systems till the biosolids that have placed in a relatively thin layer, less than 6 cm in depth. The mixing equipment mix the solids being dried and bring the moist material to the surface to accelerate the drying process.

Some solar drying systems use sensors to monitor drying conditions, and control air louvers and ventilation fans. The ventilation systems provide circulating air movement and remove the moisture-laden air. A number of facilities with mechanical ventilation contain the air leaving the greenhouses and treat any odour using biofilters or wet scrubbers.

The dried biosolids product from a solar drying facility have a Total Solids (TS) concentration of approximately 70% or greater. In the United States, the US EPA does not consider solar drying to be "Process to Further Reduce Pathogens" (PFRPs) under US EPA 40 CFR Part 503 regulations due to the "weather-dependence" of the process. However, site-specific permitting is available for facilities that demonstrate production Class A pathogen reduction by testing for fecal coliform and by product TS concentration to meet Vector Attraction Reduction requirements, > 70 % TS if the solids have been stabilized and > 90% TS if the solids have not been stabilized prior to drying. To comply with the CP1 pathogen criteria for NASM the dried product will need to test for E. coli.

Drying costs and energy consumption are lower for solar drying than thermal drying processes. However, the land area requirement is larger for solar drying than for other thermal drying technologies.

A solar dryer installation is shown in **Figure 3-11**.

Figure 3-11 A Solar Drying Facility

The advantages and challenges associated with solar drying are summarized in **Table 3-13**.

Table 3-13 Advantages and Challenges of Solar Drying Processes

ADVANTAGES	CHALLENGES
• Maximizes volume reduction. • Marketable product with high degree of diversity in use. • Can be combined with other processes like digestion. • Simple process. • Low risk for explosions. • No natural gas or biogas required for drying.	• Large area required. • Remote facility would be required along with associated transportation of dewatered cake. • Additional storage required or supplemental heat required in colder climates as a result of reduced winter drying performance. • Increased risk of odour. Off-gas requires treatment.

3.3 Alkaline Stabilization

3.3.1 Alkaline Stabilization

Alkaline stabilization uses alkaline materials, such as quicklime, to treat biosolids. The chemical reaction of the dewatered biosolids with the alkaline agent generates heat and elevates the pH. This allows the resulting product to meet both pathogen reduction requirements and VAR criteria. The product typically has a lower nutrient content than digested biosolids due to the dilution effect of adding the alkaline material and the resulting loss of ammonia from volatilization.

Biosolids require approximately one pound of lime per pound of dry solids to produce a material that can meet the CP1 pathogen criteria. The lime requirements are reduced to 0.2 to 0.3 pounds of lime per dry pound of wastewater solids to comply with the CP2 pathogen criteria.

Lime is typically added to dewatered cake rather than thickened solids. This reduces the loading to the dewatering equipment and reduces damage to the equipment that can take place when dewatering a mixture with an elevated pH.

A lime stabilization process can be implemented for a comparatively low capital cost. The operating costs, however, can be significant due to the volume of alkaline material that is required to increase the pH. The process results in an increase in the mass of solids produced due to the alkaline material added to increase the pH. There have also been odour issues associated with product. The odours have been experienced at the processing site as well as at the land application sites. A photograph of an alkaline stabilization facility is presented in **Figure 3-12**.

The product resulting from alkaline stabilization typically has a higher pH than digested biosolids and is usually managed as a liming agent. Consequently, land application requirements will differ from those used for anaerobically digested Class A biosolids.

Figure 3-12 Lime Stabilization System

3.3.2 Alkaline Stabilization with Supplemental Heat or Acid

While many alkaline stabilization systems are based solely on lime addition, there are proprietary alkaline stabilization processes available to meet CP1 pathogen criteria by combining alkaline material, with supplemental heat or an acid to reduce the quantity of lime required and to improve the dewatered cake characteristics. These include EnVessel pasteurization by RDP and Bioset Process by Schwing. A schematic diagram of a Bioset Alkaline Stabilization process is presented in **Figure 3-13**.

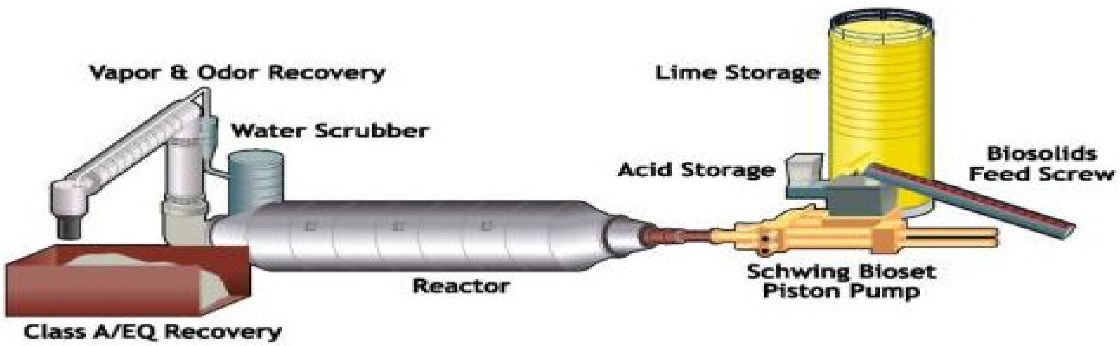

Figure 3-13 Bioset Process Schematic (Courtesy of Schwing)

3.3.3 Alkaline Stabilization with Heat and High-Speed Mixing

The Lystek® process is applied to dewatered cake and uses a combination of heat, the addition of alkaline material, and high shear mixing to generate conditions for pathogen reduction. The process can be designed to meet CP1 pathogen criteria. The process heats dewatered solids to 75°C (167°F) with steam, applies high speed mixing (max. 1,000 rpm) and increases the pH of the material to 9.5-10.0 using alkali to facilitate hydrolysis. The solids are treated through a batch or semi-batch process. The end-product is a pumpable liquid, with a high-solids concentration. The product can be anaerobically digested, or land applied as a liquid product. Lystek® reports to be able to operate at concentrations as high as 35 percent total solids. A schematic of the Lystek® process is shown in **Figure 3-14**.

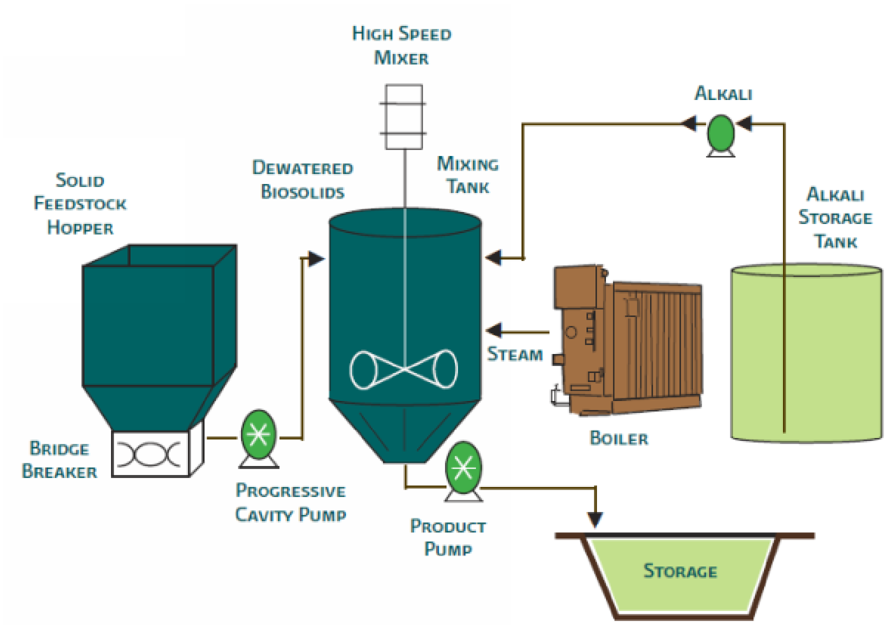

Figure 3-14 Lystek® Process Schematic (Courtesy of Lystek®)

There are currently eleven Lystek® facilities operating in the North America. Eight of the facilities, are in Canada. As mentioned above while the Lystek® process can be used to treat undigested wastewater solids, it can also be installed downstream of anaerobic digestion, which reduces the required capacity of the Lystek® system and has the benefit of generating biogas for energy recovery.

The advantages and challenges associated with alkaline stabilization processes are summarized in **Table 3-14**.

Table 3-14 Advantages and Challenges of Alkaline Stabilization Processes

ADVANTAGES	CHALLENGES
• Relatively low capital cost. • Addition of heat, chemicals and mixing can produce a material that meets the CP1 pathogen criteria. • Relatively simple process and operation. • Capable of handling a wide range of sludges. • The end product can be used as fertilizer and is potentially marketable if farmers need to supplement soil alkalinity.	• Different processes require various amount of lime of other alkaline material. • Addition of alkaline material increases the volume of stabilized biosolids product to be managed. • The high pH precipitates various metals in the stabilized solids and reduces their solubility. • The high pH also results in the release of ammonia from the biosolids which can create odour and a corrosive environment. • The process and product can generate dust that is also corrosive and can create a poor work environment. • The decrease in pH over time that is associated with alkaline stabilization can result in bacterial regrowth which can result in product odour generation and issues with beneficial use.

3.4 Composting

Composting is a natural process in which aerobic organisms break down organic matter and generate heat (exothermic). The temperatures reached during composting are high enough to kill pathogenic organisms; consequently, the compost product can meet CP1 pathogen criteria. The elevated temperature along with aeration and/or mixing help to drive off moisture and increase the Total Solids of the compost product.

The composting process involves blending of dewatered biosolids with a carbonaceous amendment, typically ground wood wastes, to provide the appropriate amount of carbon to achieve a proper carbon to nitrogen ratio for biological degradation. Composting can be employed in several different configurations to produce a stabilized biosolids soil amendment and low-grade fertilizer. With proper operation composting processes can meet the requirements for Class A biosolids.

The first large scale composting program in North America began in the early 1970’s at the City of Los Angeles. The City implemented a conventional, non-aerated windrow composting system that was open to the atmosphere. Other methods of composting, such as the aerated static pile process, soon followed. Most of the early systems were open air systems.

In the mid-1980’s, several proprietary “in-vessel” systems were marketed to municipalities. These systems were enclosed, offering better control of odour and the process, but were more capital intensive and mechanically complex.

Compost system development peaked in the late 1980’s. By this time, there was enough experience with the systems that utilities were able to fully evaluate the suitability of the process for their application.

The compost product can be easily stored in the open and is an excellent organic amendment for soil. The product has been used for landscaping, turf farming, soil blending, golf course construction, and nursery applications.

Composting is a relatively simple process and does not require specialized skills for the operators. It also provides an opportunity for using other waste products, such as yard waste, as an amendment to the process. The primary disadvantage of the composting process is the quantity of amendment that is required by the process. To reach an initial mixture total solids concentration of 40 percent Total Solids and a Carbon to Nitrogen Ration of 30:1 requires a significant volume of amendment which results in a large volume of compost product. Typically, amendment is a woody material such as, wood chips, sawdust or as mentioned above processed yard waste. The volume of these amendments can be as much as three times the volume of the biosolids entering the process. These materials need to be transported to the composting site. This increases the truck traffic into the site. The volume of the biosolids product that must be removed from the site impacts the vehicle traffic into and out of the composting site.

Photographs of an aerated static pile composting process and a horizontal agitated bin In-vessel composting process are presented in **Figure 3-15** and **Figure 3-16**.

Figure 3-15 Denton, Aerated Static Pile, Composting Facility at Columbus, OH

Figure 3-16 In-Vessel, Horizontal Agitated Bin, Composting Facility

The advantages and challenges associated with composting technologies are summarized in **Table 3-15**.

Table 3-15 Advantages and Challenges of Composting

ADVANTAGES	CHALLENEGES
• High-quality, saleable product suitable for agricultural use. • Produces a product that meets CP1 pathogen criteria. • Relatively simple process that can also be used with a variety of amendments including yard waste and other carbonaceous wastes. • Compatible with anaerobic digestion; digestion helps to reduce overall odour potential from the process.	• Requires an amendment, which increases materials handling and truck traffic. • Requires significant land area. • Would need to be located at a new site remote from the Clarkson WRRF. • Requires either forced air and / or turning. • Relatively high operational cost; labour intensive.

Of note is that Peel's neighbouring municipality Halton Region has identified composting as part of their long-term biosolids management plan. They have recently initiated a Class B EA to identify a site and conceptual design. Although the facility would be located relatively close to Peel Region and the Clarkson WRRF, the challenges associated with composting Peel's biosolids at the Halton Facility include that the facility will likely not be operational in time to meet Peel's biosolids management needs prior to 2030. The Region of Halton's priority is to process Halton biosolids at the facility, and agreements to process other municipal biosolids at the facility would take time and are not guaranteed. The addition of Clarkson's biosolids would require a significantly larger facility to compost the solids generated from both Regions, which would have to be incorporated into site selection. This would significantly delay the Halton compositing facility EA project. Another issue is the impact of the vehicle traffic that would be required to transport the Clarkson WRRF's biosolids to Region of Halton's composting facility.

3.5 Thermal Conversion

Thermal conversion technologies for biosolids include Incineration, gasification, and pyrolysis. The processes differ in the amount of air, oxygen, used in the process and if the systems are currently used on a commercial scale or pilot scale. Incineration uses excess air in the process, gasification uses partial air and pyrolysis does not use air.

Incineration is a well-established, commercially available thermal conversion technology for biosolids. Most incineration facilities are serving water reclamation facilities that produce of 50 dry tons of solids daily.

Gasification and pyrolysis are becoming more viable as technologies for energy recovery. These technologies are currently considered as emerging with respect to their application with biosolids and are not sufficiently advanced to provide a realistic full-scale option for biosolids processing within the timeframe required for the Region of Peel.

3.5.1 Incineration

Incineration achieves complete combustion of the volatile component of wastewater solids in the presence of excess air. The process results in the destruction of pathogens, the evaporation of moisture and production of a non-odorous ash consisting of inert solids that can be landfilled or further processed for a beneficial use

Two types of incinerators have been widely employed worldwide: multiple hearth incinerators (MHIs) and fluidized bed incinerators (FBIs). MHIs are less efficient than FBIs, leading to their gradual phase out. The MHI furnace consists of a cylindrical steel shell surrounding several solid refractory hearths, and a central rotating shaft to which rabble arms are attached. In FBI units, the reactor is a closed cylindrical vessel with refractory walls. Fluidizing and combustion air enter the unit and keeps silica sand particles in suspension for optimum contact of the cake with the combustion air. The sand bed retains the organic particles until they are reduced to ash.

A schematic showing a typical arrangement for a fluidized bed incinerator is provided in **Figure 3-17**.

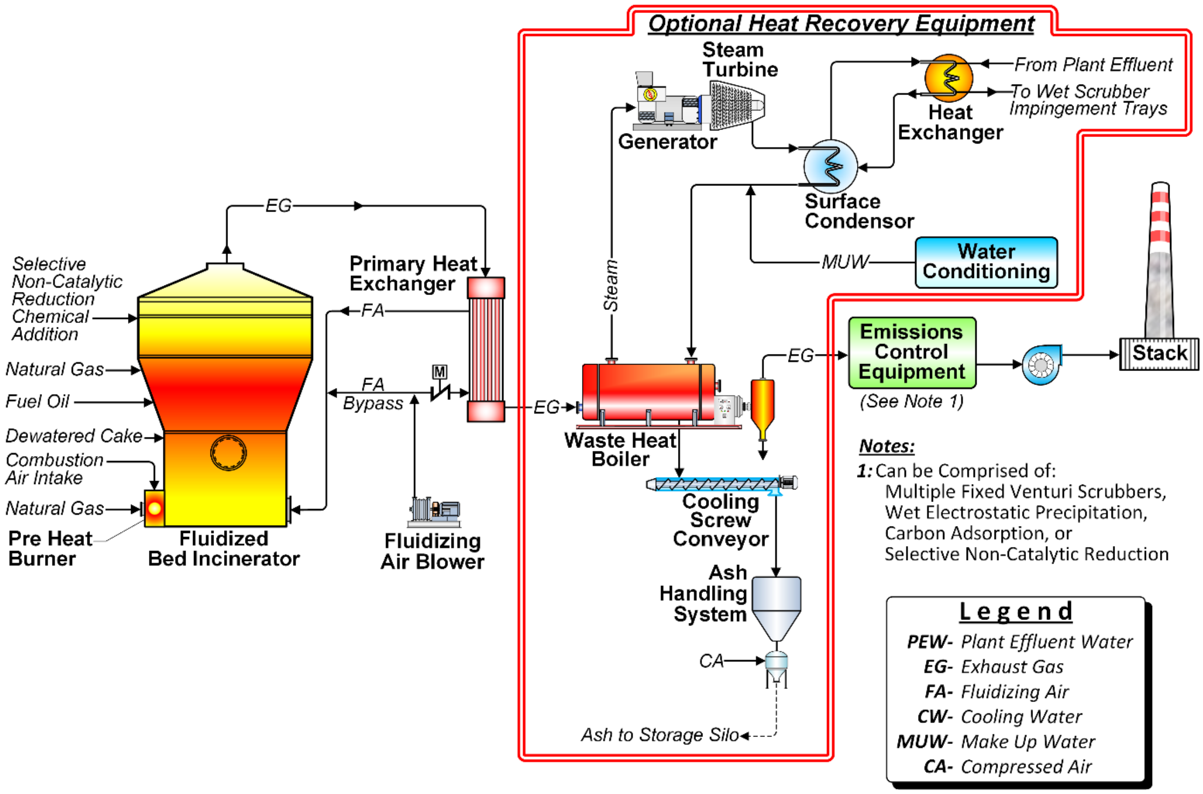

Figure 3-17 Fluidized Bed Incinerator Schematic

The advantages and challenges associated with incineration technologies are summarized in **Table 3-16**.

Table 3-16 Advantages and Challenges of Incineration

ADVANTAGES	CHALLENGES
• Proven Technology • Achieves the maximum reduction in the mass of final product for disposal (produces an inert ash). • Complete pathogen destruction. • Potential for energy recovery. • Produces inert Ash	• Relatively complex process from a mechanical and control perspective. • An auxiliary source of fuel is required for start-up, and possibly for normal operation depending on the characteristics of the solids entering the process. • Public perception can be a problem for incineration facilities. • Permitting of new or expanded facilities is challenging. • Exhaust gas treatment is often required to meet discharge requirements. • The process has a long start-up time to reach operating temperature and needs to be operated continuously for extended time periods. • The process requires a relatively uniform dewatered solids feed.

3.5.2 Gasification

Gasification involves the thermal conversion of the biosolids with a limited oxygen supply. The process involves a chemical reaction of carbon in the solids with oxygen, steam, and carbon dioxide at temperatures between 260 and 760°C (500 and 1,400°F). The amount of air, oxygen, added to the process is limited to that required to support the chemical reactions. The process produces heat which can be used and synthetic natural gas (syngas). Depending on the operating temperatures, the feed characteristics and pressure of the process the energy within the syngas can range from 10 to over 90 percent of that in natural gas. The biosolids entering the gasification process are often thermally dried to achieve an optimum feed solids concentration.

3.5.3 Pyrolysis

Pyrolysis uses high temperature and pressure in the absence of oxygen to convert the organic material in wastewater solids into bio-oil, syngas, and biochar. The biochar is a combustible material. There are slow pyrolysis and fast pyrolysis processes. The slow process does not produce the bio-oil, while the fast pyrolysis does. The operating temperature of pyrolysis is lower than gasification, ranging between 450 and 750°C (900 and 1,100°F). Markets for the biochar produced are being explored and include soil amendment, including carbon offsets, livestock feed, carbon electrodes, fuel cells, and building materials. Currently there are no large-scale pyrolysis systems operating in North America.

3.5.4 Wet Oxidation

Wet air oxidation is a high temperature, high pressure reaction of oxidizable material in water with oxygen. The oxidation is a chain type radical reaction which typically takes place in a vertical bubble column reactor. The oxidation reactions occur at a temperature between 150 and 320°C and a pressure of 10 bar to 220 bar. The history of wet air oxidation technology includes the Zimpro process which has had systems in operation for over 50 years.

3.5.5 Hydrothermal Liquification

Hydrothermal liquification is a process to produce a biocrude oil which can be upgraded at an existing petroleum refinery to reduce the use of traditional crude oil. In the process wastewater solids and the water are pumped and heated to reactor conditions of approximately 3,000 psia and 339°C (622°F). The product leaving the reactor is a biocrude, a separate aqueous phase, solids, and gases. The solids are removed by filtration. The solids can be sold as a fertilizer with confirmation of meeting regulatory requirements or disposed of in a landfill. The gas generated in the hydrothermal liquification process is removed as part of the cooling process. The biocrude is transported to a petroleum refinery for processing to upgrade the product, the aqueous phase is treated using hydrothermal gasification. The resulting off gas can be used for process heat. Additional heat is required to support the hydrothermal liquification process and the catalytic hydrothermal gasification process.

The advantages and challenges associated with Gasification, Pyrolysis, Wet Oxidation and Hydrothermal Liquification are summarized in **Table 3-17**.

Table 3-17 Advantages and Challenges of High Temperature High Pressure Processes; Gasification, Pyrolysis, Wet Oxidation and Hydrothermal Liquification

ADVANTAGES	CHALLENGES
• The processes produce useable products including synthetic natural gas, biocrude, carbon products and biochar. • High temperature processes are reported to destroy PFAS Compounds. • Potential for energy recovery from the processes.	• Relatively complex process from a mechanical and control perspective. • These processes have not yet been implemented at full scale. Certainly not at the scale required by the Region of Peel. • Several processes require upstream thermal drying to achieve optimum process feed characteristics.

4.0 Biosolids Technology Screening

The technologies were screened to identify which ones should be developed into alternatives and evaluated for use to manage the wastewater solids generated at the Clarkson WRRF. Four screening criteria were used to screen the technologies. Those technologies that successfully met the criteria were recommended for consideration. The criteria used to screen the technologies are summarized in **Table 4-1**.

Table 4-1 Screening Criteria

SCREENING CRITERIA	DESCRIPTION
Maturity of Technology	The technology must have been in use for long enough that most of its initial operational issues and inherent problems have been removed or reduced by further development. It must be robust, reliable, and have a successful track record.
Compatibility with existing and future processes and biosolids end use markets.	The technology must be compatible with the liquid stream wastewater treatment process, consider existing infrastructure investments, and be constructible give existing site conditions. It must also compliment the end use alternatives and markets that have been identified for the Region of Peel.
Proven application at large WRRFs	The technology must be able to serve WRRF's of the size of the G.E. Booth and Clarkson WRRFs. The size of the technology's components must be large enough to process the solids generated at the current and the anticipated loading rates. The technology will have a successful operating history at facilities of equivalent size or larger.
Compatibility with Regional Energy Management and GHG Reduction Goals	Offers opportunities for energy efficiency, reduction in chemical inputs or potential for resource recovery to help support Region Energy Management and GHG Reduction Goals
Ability to Implement within Required Schedule	Capacity expansion of Clarkson WRRF is required by 2029 to accommodate projected wastewater flows. This criterion assesses the option's impact on the implementation schedule.

The results of the technology screening are presented in **Table 4-2**. Based on the screening it is recommended that the following technologies be developed into alternatives and evaluated using detailed evaluation criteria, reflecting natural, social/cultural, technical, and economic factors:

- Conventional Mesophilic Anaerobic Digestion.
- Thermal Hydrolysis followed by Mesophilic Anaerobic Digestion.
- Direct Thermal Drying.
- Advanced Alkaline Stabilization with Supplemental Heat or Acid.
- Advanced Alkaline Stabilization with Supplemental Heat and High-Speed Mixing.

Table 4-2 Region of Peel, Clarkson WRRF, Technology Screening

NO.	TECHNOLOGY	MATURITY OF TECHNOLOGY	COMPATIBILITY WITH EXISTING AND FUTURE PROCESSES AND BIOSOLIDS END USE MARKETS	PROVEN APPLICATION AT LARGE WRRFS	COMPATIBILITY WITH REGIONAL ENERGY MANAGEMENT AND GHG REDUCTION GOALS	ABILITY TO IMPLEMENT WITHIN REQUIRED SCHEDULE	CONSIDER FOR FURTHER EVALUATION
1	**ANAEROBIC DIGESTION**						
1a	**Conventional Mesophilic Anaerobic Digestion**	Mature Technology	Yes	Yes	Diversification of Peel's biosolids management program would reduce reliance on incineration and allow biosolids beneficial use on land, thereby helping to support the Region's Energy Management and GHG Reduction Goals. The additional biogas generated could reduce the need for purchased electrical energy and natural gas.	Yes	Yes – Expansion of the existing digestion system at the Clarkson WRRF is a viable alternative and should be carried forward to develop design concepts for biosolids management at the Clarkson WRRF.
1b	**Temperature-Phased Anaerobic Digestion (TPAD)**	Uncommon when compared to mesophilic anaerobic digestion	Yes	Yes	Diversification of Peel's biosolids management program would reduce reliance on incineration and allow biosolids beneficial use on land, thereby helping to support the Region's Energy Management and GHG Reduction Goals. The additional biogas generated could reduce the need for purchased electrical energy and natural gas.	Yes	No - More complex operation for additional pathogen reduction. The THP Process has more large-scale experience to achieve the same outcome.
1c	**Acid/Gas Phased Anaerobic Digestion**	Limited number of installations.	Yes	Yes	Diversification of Peel's biosolids management program would reduce reliance on incineration and allow biosolids beneficial use on land, thereby helping to support the Region's Energy Management and GHG Reduction Goals. The additional biogas generated could reduce the need for purchased electrical energy and natural gas.	Yes	No - More complex operation for additional pathogen reduction. The THP Process has more large-scale experience to achieve the same outcome.
2	**ANAEROBIC DIGESTION WITH HYDROLYSIS PRETREATMENT**						
2a	**Thermal Hydrolysis Pretreatment (THP)**	Maturing technology becoming popular	Yes	Yes	Diversification of Peel's biosolids management program would reduce reliance on incineration and allow biosolids beneficial use on land, thereby helping to support the Region's Energy Management and GHG Reduction Goals. The additional biogas generated could reduce the need for purchased electrical energy and natural gas.	Yes	Yes - THP for use at the Clarkson WRRF prior to the anaerobic digestion system is viable and should be carried forward to develop design concepts for biosolids management at the Clarkson WRRF.

NO.	TECHNOLOGY	MATURITY OF TECHNOLOGY	COMPATIBILITY WITH EXISTING AND FUTURE PROCESSES AND BIOSOLIDS END USE MARKETS	PROVEN APPLICATION AT LARGE WRRFS	COMPATIBILITY WITH REGIONAL ENERGY MANAGEMENT AND GHG REDUCTION GOALS	ABILITY TO IMPLEMENT WITHIN REQUIRED SCHEDULE	CONSIDER FOR FURTHER EVALUATION
2b	**Thermo / alkaline Hydrolysis Pretreatment**	Limited number of installations.	Yes	Limited: Does not currently have the full-scale operating experience of the process.	Diversification of Peel's biosolids management program would reduce reliance on incineration and allow biosolids beneficial use on land, thereby helping to support Region Energy Management and GHG Reduction Goals. The additional biogas generated could reduce the need for purchased electrical energy and natural gas.	Yes	No
3	**AEROBIC DIGESTIONs**						
3a	**Conventional Aerobic Digestion**	Mature Technology	Not compatible with primary solids. Would require a separate stabilization process for primary solids.	No	Diversification of Peel's biosolids management program would reduce reliance on incineration and allow biosolids beneficial use on land. However, aerobic digestion will consume energy for aeration and will not generate biogas.	Yes	No
3b	**Autothermal Thermophilic Aerobic Digestion (ATAD)**	Maturing Technology Second Generation	Not compatible with primary solids. Would require a separate stabilization process for primary solids.	No	Diversification of Peel's biosolids management program would reduce reliance on incineration and allow biosolids beneficial use on land. However, it will consume additional energy and will not generate biogas.	Yes	No
4	**DRYING**						
4a	**Direct Thermal Dryer (Drum Dryer, Belt Dryer, Fluidized Bed Dryer)**	Mature Technology	Yes	Yes	Diversification of Peel's biosolids management program would reduce reliance on incineration and allow biosolids beneficial use on land, thereby helping to support the Region's Energy Management and GHG Reduction Goals. The process will require additional energy (such as natural gas or biogas) to remove water from the dewatered biosolids cake.	Yes	Yes – Direct Thermal Drying following the anaerobic digestion system is a viable option at the Clarkson WRRF and should be carried forward to develop design concepts for biosolids management at the Clarkson WRRF.
4b	**Indirect Thermal Dryer (Paddle Dryer, Disc Dryer)**	Mature Technology	Yes	Limited experience in North America	Diversification of Peel's biosolids management program would reduce reliance on incineration and allow biosolids beneficial use on land, thereby helping to support the Region's Energy Management and GHG Reduction Goals. The process will require energy to remove water from the dewatered biosolids cake.	Yes	No

NO.	TECHNOLOGY	MATURITY OF TECHNOLOGY	COMPATIBILITY WITH EXISTING AND FUTURE PROCESSES AND BIOSOLIDS END USE MARKETS	PROVEN APPLICATION AT LARGE WRRFS	COMPATIBILITY WITH REGIONAL ENERGY MANAGEMENT AND GHG REDUCTION GOALS	ABILITY TO IMPLEMENT WITHIN REQUIRED SCHEDULE	CONSIDER FOR FURTHER EVALUATION
4c	**Solar Dryer**	Newer, successful technology becoming popular but still not a mature technology for large WRRFs.	Yes	Limited	Diversification of Peel's biosolids management program would reduce reliance on incineration and allow biosolids beneficial use on land, thereby helping to support the Region's Energy Management and GHG Reduction Goals	No It would be difficult for the Region to obtain the approvals required to implement a solar drying facility on a remote site in time to provide wastewater solids management capacity by 2029. If a solar drying facility with adequate capacity to process a portion, or all, of the solids generated at the Clarkson WRRF were to become available, the Region may wish to consider an agreement with a third party to process their solids as well	No
5	**CHEMICAL STABILIZATION**						
5a	**Alkaline Stabilization**	Mature Technology	No – Alkaline stabilization without advanced processing (as provide in 5b and 5c) would result in large volume of product. Does not compliment the end use alternatives and markets that have been identified for the Region of Peel. There is also significant odour potential.	Large systems in operation	Diversification of Peel's biosolids management program would reduce reliance on incineration and allow biosolids beneficial use on land, thereby helping to support the Region's Energy Management and GHG Reduction Goals.	Yes Alkaline Stabilization could be available at facilities operated by third party vendors to manage the solids generated at the Clarkson WRRF by 2029	No
5b	**Alkaline Stabilization with Supplemental Heat or Acid**	Mature Technology	Yes	Large systems in operation	Diversification of Peel's biosolids management program would reduce reliance on incineration and allow biosolids beneficial use on land, thereby helping to support the Region's Energy Management and GHG Reduction Goals	Yes Advanced Alkaline Stabilization processes are currently operated by third party vendors and could be available to manage the solids generated at the Clarkson WRRF by 2029	Yes - Consider an agreement with an advanced alkaline stabilization processing firm to transport, manage, and market the biosolids.
5c	**Alkaline Stabilization with Supplemental Heat and High-Speed Mixing**	Maturing technology	Yes	Large systems in operation	Diversification of Peel's biosolids management program would reduce reliance on incineration and allow biosolids beneficial use on land, thereby helping to support the Region's Energy Management and GHG Reduction Goals	Yes Advanced Alkaline Stabilization processes are currently operated by third party vendors and could be available to manage the solids generated at the Clarkson WRRF by 2029.	Yes - Consider an agreement with an advanced alkaline stabilization processing firm to transport, manage, and market the biosolids.

NO.	TECHNOLOGY	MATURITY OF TECHNOLOGY	COMPATIBILITY WITH EXISTING AND FUTURE PROCESSES AND BIOSOLIDS END USE MARKETS	PROVEN APPLICATION AT LARGE WRRFS	COMPATIBILITY WITH REGIONAL ENERGY MANAGEMENT AND GHG REDUCTION GOALS	ABILITY TO IMPLEMENT WITHIN REQUIRED SCHEDULE	CONSIDER FOR FURTHER EVALUATION
6	**COMPOSTING**						
6	**Composting (Open Technologies Aerated Static Pile and Windrow Composting) or co-composting with Region of Halton**	Mature Technology	No - Large volume of amendment material would be required, resulting in large volume of product. Does not compliment the end use alternatives and markets that have been identified for the Region of Peel.	Yes	Diversification of Peel's biosolids management program would reduce reliance on incineration and allow biosolids beneficial use on land, thereby helping to support the Region's Energy Management and GHG Reduction Goals	No- difficult to obtain the approvals required to implement a composting facility on a remote site in time to provide wastewater solids management capacity by 2029. If a composting facility with adequate capacity to process a portion, or all, of the solids generated at the Clarkson WRRF were available, the Region may wish to consider an agreement with a third party to process their solids as well	No
7	**THERMAL CONVERSION**						
7a	**Incineration**	Mature Technology	Yes	Yes	Incineration of biosolids at both the G.E Booth and Clarkson WRRF is not compatible with Region Energy Management and GHG Reduction Goals	Yes	No
7b	**Gasification**	Currently unproven technology at full scale. May destroy PFAS	Yes	Currently not operating at a commercial sale	Thermal conversion of biosolids at both the G.E Booth and Clarkson WRRF is not compatible with Region Energy Management and GHG Reduction Goals	No It is not anticipated that the gasification technology will be operating at a commercial scale in time to provide wastewater solids management capacity by 2029	No
7c	**Pyrolysis**	Currently unproven technology at full scale. May destroy PFAS	Yes	Currently not operating at a commercial sale	Thermal conversion of biosolids at both the G.E Booth and Clarkson WRRF is not compatible with Region Energy Management and GHG Reduction Goals	No It is not anticipated that the pyrolysis technology will be operating at a large commercial scale in time to provide wastewater solids management capacity by 2029	No
7d	**Wet Oxidation**	Process has been used for years. New technologies are being developing for use with biosolids	Yes	Currently not operating at a commercial sale	Thermal conversion of biosolids at both the G.E Booth and Clarkson WRRF is not compatible with Region Energy Management and GHG Reduction Goals	No It is not anticipated that the wet oxidation technology will be operating at a commercial scale in time to provide wastewater solids management capacity by 2029	No
7e	**Hydrothermal Liquification**	Developing technology for use with biosolids	Yes	Currently not operating at a commercial sale	Thermal conversion of biosolids at both the G.E Booth and Clarkson WRRF is not compatible with Region Energy Management and GHG Reduction Goals	No It is not anticipated that the hydrothermal liquification technology will be operating at a commercial scale in time to provide wastewater solids management capacity by 2029	No

5.0 Shortlisted Biosolids Management Alternatives

As presented above, the technologies carried forward and developed into alternatives include:

- Conventional Mesophilic Anaerobic Digestion.
- Thermal Hydrolysis Process (THP) followed by Mesophilic Anaerobic Digestion.
- Direct Thermal Drying.
- Advanced Alkaline Stabilization with Supplemental Heat or Acid.
- Advanced Alkaline Stabilization with Supplemental Heat and High-Speed Mixing.

As presented in the Biosolids Product Market Assessment Technical Memorandum (October 2022), the target markets for the Clarkson WRRF biosolids include agricultural land application, soil amendment as fertilizer, and land reclamation.

Considering the above, three combinations of technologies/markets alternatives were identified. The alternatives incorporate the use of conventional mesophilic anaerobic digestion, thermal hydrolysis prior to anaerobic digestion and direct thermal drying at the Clarkson WRRF. In addition, two advanced alkaline stabilization technologies could be implemented by third party biosolids management firms following two of the three alternatives summarized below:

Alternative 1: Anaerobic digestion and dewatering prior to beneficial use by third party biosolids management vendors. This alternative considers the expansion of the anaerobic digestion system that currently serves the Clarkson WRRF. The stabilized biosolids can be used in a beneficial use program. The alternative includes dewatering all stabilized sludge to reduce the volume and mass of the material that will be transported from the Clarkson WRRF. The responsibility of the biosolids management firms will begin when the digested and dewatered cake is discharged into their vehicles for transport. The third party biosolids management firms can land apply the biosolids or provide further processing, such as composition or alkaline stabilization, to produce higher quality products (such as fertilizers) or use dewatered biosolids as part of a land reclamation program.

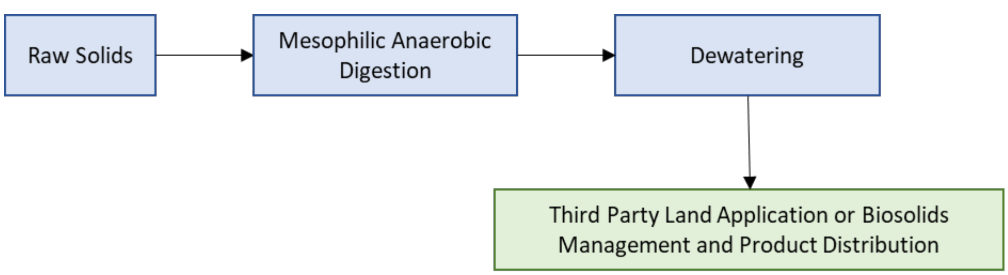

Figure 5-1. Alt. 1 Process Flow Diagram

Alternative 2: Thermal hydrolysis process (THP) followed by anaerobic digestion and dewatering prior to beneficial use by third party biosolids management firms. This alternative considers the addition of a thermal hydrolysis process prior to the mesophilic anaerobic digestion system that currently serves the Clarkson WRRF. Thermal hydrolyses allows for a shorter hydraulic retention time and thicker sludge in the anaerobic digesters, which reduces the required mesophilic digestion volume when compared to Alternative 1. In addition, the THP followed by the anaerobic digestion process, kills more pathogens than anaerobic digestion alone and can result in a fertilizer quality product that meets the CFIA registration requirements. The CFIA registration provides greater flexibility in biosolids product markets. Similar to Alternative 1, third party biosolids management firms will transport the biosolids from the Clarkson WRRF for beneficial use, such as land application, soil amendment as fertilizer, or land reclamation. Due to the physical characteristics, total solids and clay like texture of the biosolids cake product, which is very similar to those of Alternative 1's product, the third party biosolids management firms may elect to further process the biosolids cake before marketing the material.

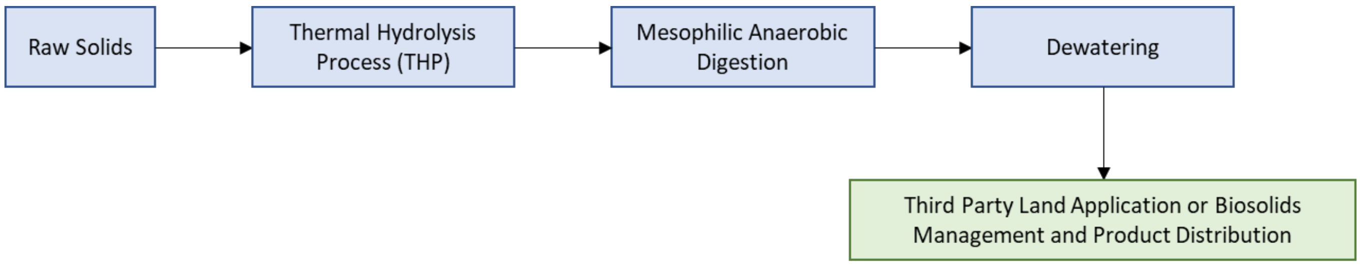

Figure 5-2. Alt. 2 Process Flow Diagram

Alternative 3: Anaerobic digestion and dewatering, prior to direct thermal drying and fertilizer product distribution by third party biosolids management firms. This alternative considers direct thermal drying of the anaerobically digested and dewatered biosolids generated at the Clarkson WRRF. The dried material can be certified as a fertilizer in Ontario and sold in the bulk and retail markets.

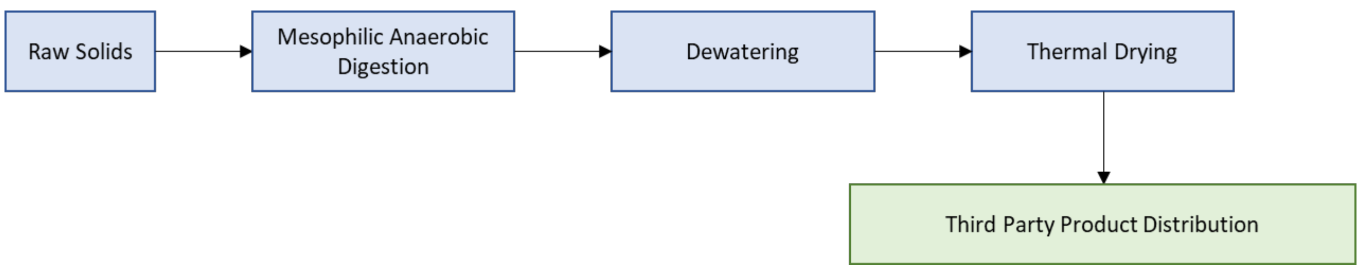

Figure 5-3. Alt. 3 Process Flow Diagram

6.0 Next Steps

The biosolids management alternatives described in Section 5 will be developed in detail including descriptions of unit processes, capacities, and site layouts. The biosolids management alternatives will then be evaluated in detail based on natural environment, social/cultural environment, technical, and financial considerations. A preferred biosolids management design concept will then be developed for the Clarkson WRRF.

Appendix M:

Evaluation of Biosolids Design Concepts

Table M1 – Detailed Evaluation of Biosolids Management Design Concepts

<table>
<tr><th>Criteria</th><th>Scoring</th><th>Design Concept 1: Expansion of the Anaerobic Digestion System and Third-Party Beneficial Use</th><th>Design Concept 2: THP and expansion of the Anaerobic Digestion System and Third-Party Beneficial Use of CP1 Biosolids or a Fertilizer Product</th><th>Design Concept 3: Expansion of the Anaerobic Digestion system and Direct Thermal Drying and Third-Party Beneficial Use of a Fertilizer Product</th></tr>
<tr><td colspan="5">Natural Environmental</td></tr>
<tr><td rowspan="2">Terrestrial System</td><td rowspan="2">10</td><td colspan="3">The expansion area for the biosolids facilities is in the northwest corner of the site, adjacent to the existing anaerobic digesters. The area in the northwest corner of the site is classified SWD2-2 (Green Ash Deciduous Forest), with potential for breeding birds and species at risk (SAR). This area is avoided with all design concepts. However, design Concepts will encroach on the area classified as MAM2 (Mineral Meadow Marsh), a non-provincially significant wetland. Design Concepts 1 and 3 have the largest footprints, so will impact this area more so than Design Concept 2. Impacts to these natural features must be controlled though proper mitigation techniques throughout construction, as well as compensation for the loss of the Mineral Meadow Marsh area elsewhere on the site (area exists at the southwest of the site for additional Mineral Meadow Marsh area).</td></tr>
<tr><td>5</td><td>6</td><td>5</td></tr>
<tr><td rowspan="2">Aquatic System</td><td rowspan="2">10</td><td colspan="3">Lakeside Creek, Lake Ontario floodplain, and CVC regulated areas are outside the site boundary, so impacts on aquatic systems are expected to be low and will be mitigated.</td></tr>
<tr><td>8</td><td>8</td><td>8</td></tr>
<tr><td rowspan="2">Groundwater Water Quality and Quantity</td><td rowspan="2">10</td><td colspan="3">All design concepts are not expected to impact groundwater quality or quantity. Measures to mitigate impacts on groundwater quality and quantity during construction will be implemented.</td></tr>
<tr><td>8</td><td>8</td><td>8</td></tr>
<tr><td rowspan="2">Source Water Quality and Source Water Protection</td><td rowspan="2">10</td><td colspan="3">All design concepts will not impact surface water quality. A stormwater management plan will be developed to control runoff and erosion during and after construction.</td></tr>
<tr><td>9</td><td>9</td><td>9</td></tr>
<tr><td rowspan="2">Air Quality</td><td rowspan="2">10</td><td colspan="3">All design concepts would be designed to include emission control and treatment such that all air quality standards are met and impacts mitigated. Design Concept 3 includes direct thermal drying which would require more stringent emission controls. This requirement would be somewhat offset by the lower number of vehicles required to transport the dried biosolids from the site.</td></tr>
<tr><td>7</td><td>6</td><td>6</td></tr>
<tr><td>Greenhouse Gas Emissions (GHG)</td><td>10</td><td colspan="3">The results of the GHG Emissions estimates indicate that Design Concepts 1 and 2 have very similar GHG emissions that are reported by the Region; however, Design Concept 3 has the higher GHG emissions that are reported by the Region because all design concepts include biosolids beneficial use on land, resulting in significant credit from carbon sequestration and synthetic fertilizer replacement. However, Design Concept 3 has the least amount of dried biosolids products for trucking, resulting in less GHG emission associated with transportation.</td></tr>
<tr><td>Region’s GHG Reporting Emission Sources</td><td>75%</td><td>8</td><td>8</td><td>6</td></tr>
<tr><td>Total Scope 1, 2, & 3 Emissions</td><td>25%</td><td>6</td><td>8</td><td>9</td></tr>
<tr><td></td><td></td><td>7.5</td><td>8.0</td><td>6.8</td></tr>
<tr><td>Total Score (Out of 60)</td><td></td><td>44.5</td><td>45.0</td><td>42.8</td></tr>
<tr><td>Weight</td><td></td><td>25</td><td>25</td><td>25</td></tr>
<tr><td>Normalized Score (Total 25)</td><td></td><td>18.5</td><td>18.8</td><td>17.8</td></tr>
</table>

Criteria	Scoring	Design Concept 1: Expansion of the Anaerobic Digestion System and Third-Party Beneficial Use	Design Concept 2: THP and expansion of the Anaerobic Digestion System and Third-Party Beneficial Use of CP1 Biosolids or a Fertilizer Product	Design Concept 3: Expansion of the Anaerobic Digestion system and Direct Thermal Drying and Third-Party Beneficial Use of a Fertilizer Product
Social - Cultural				
Odour	10	All design concepts would be designed to include odour control and treatment such that all air quality standards are met and impacts mitigated. Design Concept 1 could have the highest volume of material and product odour. Design Concept 3 would have the highest degree of process odour control and the least volume of product to be transported from the WRRF and lowest product odour generation potential.		
		6	7	8
Noise/Vibrations	10	All design concepts would be designed to mitigate noise/vibration to meet requirements at nearest receptors.		
		8	8	8
Visual Aesthetics	10	The facilities are located to the northwest of existing facilities, closer to adjacent industrial uses, with buffers planned between the site and Lakeshore Road. Concerns related to visual aesthetics of the expanded site are assumed to be minimal. Plant designs and landscaping will ensure that visual aesthetics of the site will be similar or improved from current conditions.		
		8	8	8
Truck Traffic/Transportation Network	10	All design concepts would require some level of truck traffic to transport biosolids products; Design Concept 3 would have significantly lower vehicle traffic to transport the dried product.		
		5	6	9
Disruption During Construction	10	All three design concepts would produce some disruption during construction, but the duration and magnitude will be similar for all design concepts and will be mitigated. As these are short-term impacts and they can be mitigated, the impacts are considered to be relatively low for all design concepts.		
		7	7	7
Property Acquisition and Easement	10	No additional property would be required.		
		9	9	9
Recreational Use and Users	10	Treatment facility requirements for all design concepts would be located within the site boundary to the northwest of the site, furthest from the recreation areas south of Lakeshore Road. Odour and noise will be controlled. Impacts on recreational uses are therefore expected to be minimal.		
		8	8	8
Agricultural Use and Users	10	Biosolids products improve the characteristics and productivity of agricultural soil. Design Concepts 2 and 3 produce the highest quality biosolids product which meets fertilizer standards.		
		8	9	9
Human Health and Well-Being	10	All design concepts would be designed to meet air emission and effluent quality requirements to protect human health and the environment. In addition, biosolids products will meet all beneficial use guidelines. Design Concept 3 will produce the lowest volume high-quality product.		
		8	8	8
Existing and Future Adjacent Land Use Compatibility	10	The majority of the surrounding areas is identified as commercial/industrial (CIC) and there are no plans in Peel or Mississauga's Official Plans to change these land use designations within the planning period. All three design concepts would be located within the existing site in an industrial area and the expanded facilities will be located at the northwest side of the site, furthest from Lakeshore Road. The design concepts are considered to be compatible with existing and future land uses in the area.		
		9	9	9
Archaeology/Natural Heritage & Aboriginal Interest	10	The Stage 1 AA indicated that there is potential for archaeological resources in the northwestern corner of the site where the biosolids facilities are to be located. The Stage 2 AA cleared the area of archaeological potential. Consequently, impacts to unknown archaeological resources of all design concepts are minimal.		
		9	9	9
Total Score (Out of 110)		85	88	92
Weight		25	25	25
Normalized Score (Total 25)		**19.3**	**20.0**	**20.9**

Criteria	Scoring	Design Concept 1: Expansion of the Anaerobic Digestion System and Third-Party Beneficial Use	Design Concept 2: THP and expansion of the Anaerobic Digestion System and Third-Party Beneficial Use of CP1 Biosolids or a Fertilizer Product	Design Concept 3: Expansion of the Anaerobic Digestion system and Direct Thermal Drying and Third-Party Beneficial Use of a Fertilizer Product
Technical				
Effectiveness	10	All design concepts would be designed to effectively treat and manage biosolids. All design concepts provide opportunities for beneficial use of biosolids products.		
		9	9	9
Long term Sustainability	10	All design concepts would offer beneficial end use with some degree of reliability. Design Concepts 2 and 3 generate a near pathogen free product, offer additional market outlets to reduce risk and increase reliability. Design Concept 2 could produce registered fertilizer; however, there are currently no operating THP facilities in Canada. It will take time to obtain CFIA registration. Design Concept 3 products can be registered as fertilizers as there are several drying facilities in Ontario that currently produce registered fertilizer products.		
		6	7	8
Ease of Operation	10	While all design concepts would add some complexity to operation, Design Concept 1 would be the simplest. Design Concept 2 with THP would be more complex, requiring specially trained operators (stationary engineers) in addition to wastewater operators.		
		8	5	6
Ease of Implementation	10	Design Concept 1 would be the easiest to implement. Design Concept 2 would require digestion expansion and THP construction completed at the same time to provide the required stabilization capacity. Design Concept 3 could allow the Region to defer the construction of the drying facility once the digestion expansion is completed, resulting in more flexibility in capital project implementation to ease cash flow and the coordination of construction contracts.		
		8	6	7
Resiliency	10	All design concepts would be designed to have adequate levels of redundancy.		
		8	8	8
Compatibility with Existing Infrastructure System	10	While all design concepts would be compatible with the existing wastewater treatment infrastructure, Design Concept 2 (which includes THP) could require side stream treatment to minimize impact on liquid stream treatment processes.		
		8	7	8
Geotechnical and Hydrogeology	10	All design concepts would be designed according to the on-site geotechnical and hydrogeological conditions.		
		8	8	8
Contaminated Soils	10	All design concepts would be designed according to the on-site conditions, which may be present in the proposed expansion area on the existing Clarkson WWTP site.		
		6	6	6
Energy Use and Recovery	10	Energy Consumption: anaerobic digestion only, Design Concept 1 would use the least energy. Drying for Design Concept 3 would use the most energy onsite. Energy Recovery: anaerobic digestion only, Design Concept 1, and direct thermal drying following anaerobic digestion, Design Concept 3, would have similar biogas production. However, Design Concept 1 would have less energy demand by treatment processes, resulting in higher energy recovery potential. Design Concept 2, THP followed by anaerobic digestion would generate more biogas. However, some of the additional biogas would be used for the THP and sludge digestion process. The THP process could produce return side stream with increased ammonia loading, which would result in increased energy use in the liquid stream treatment process.		
		8	7	6
Climate Change Adaptability	10	Climate change is not expected to have a significant impact on any of the design concepts. However, Design Concept 3 may be slightly more adaptable to climate changes as it offers more beneficial end uses options for its product.		
		7	8	9
Permits and Approvals	10	Design Concept 1 would require greater permitting and approvals to allow for land application of digested biosolids. Design Concepts 2 and 3 would generate a marketable fertilizer product. The physical characteristics of the THP anaerobic digested dewatered product (Design Concept 2) has a clay like consistency and 26 percent solids, 74 percent water, and as a result is currently not as marketable as the dried product (92 percent solids and small pellet shape).		
		7	8	9
Total Score (Out of 110)		83	79	84
Weight		25	25	25
Normalized Score (Total 25)		**18.9**	**18.0**	**19.1**

Criteria	Scoring	Design Concept 1: Expansion of the Anaerobic Digestion System and Third-Party Beneficial Use	Design Concept 2: THP and expansion of the Anaerobic Digestion System and Third-Party Beneficial Use of CP1 Biosolids or a Fertilizer Product	Design Concept 3: Expansion of the Anaerobic Digestion system and Direct Thermal Drying and Third-Party Beneficial Use of a Fertilizer Product
Economic				
Capital Cost ($ M)	10	$150 M	$179 M	$236 M
		7	6	5
Annual Operating and Maintenance (O&M) Costs ($ M)	10	$9.7 M	$9.5 M	$5.3 M
		5	5	7
Net Present Value (NPV) 30-Year Life Cycle Cost ($M)	10	$360 M	$390 M	$360 M
		6	5	6
Total Score (Out of 30)		18	16	18
Weight		25	25	25
Normalized Score (Total 25)		**15.0**	**13.3**	**15.0**
Total Score		**71.7**	**70.1**	**72.8**

There is no significant difference among the total scores of the alternative design concepts. Consequently, another level of assessment was completed comparing each design concept's ability to meet the Region's key objectives. Based on consideration of the Region's objectives, **Design Concept 3 (Direct Thermal Drying of Anaerobically Digested Biosolids and Third-Party Distribution)** and **Design Concept 1 (Anaerobic Digestion and Dewatering and Third-Party Distribution)** best aligned with Region's objectives. These concepts were selected together as they provide a diversified biosolid management program to increase flexibility and strengthen resiliency to market change, fluctuations in utility costs, and new regulations.