DISCUSSION PAPER

Capital Regional District
Core Area Wastewater Management Program

Macaulay/McLoughlin Point Wastewater Treatment Plant

Discussion Paper – Liquid Process Alternatives Evaluation
034-DP-1

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1 Objective

The Core Area Wastewater Management Program consists of four key elements: source control, distributed wastewater treatment, water reuse and resource recovery, and wet weather flow management. Distributed wastewater treatment will include a secondary wastewater treatment plant at Macaulay/McLoughlin Point, two or more decentralized water reclamation plants within the wastewater collection system, and a wet weather flow management strategy that will see surplus wet weather flows managed on a more local basis.

Macaulay/McLoughlin Point is the site of the largest proposed wastewater treatment facility. In addition to the two or more distributed water reclamation plants, wet weather facility is proposed at Clover Point. The Path Forward (CRD, 2007) proposed liquid treatment alternatives for the wastewater treatment facility at Macaulay/McLoughlin Point. The objective of this discussion paper is to further evaluate those liquid process alternatives and develop a conceptual liquid-stream footprint requirement. A representative alternative will provide information to determine site development needs and can be refined at a later date with a more detailed analysis of the distributed wastewater treatment strategy.

2 Design Flows and Loads

Ultimate flows and loads for the Year 2065 were used to size and evaluate the alternative liquid treatment unit processes. Preliminary and primary treatment would be provided for the 2065 peak wet weather flow (PWWF) of 364 ML/d, assuming a contributing population equivalent (PE) of 400,000. Secondary treatment capacity would be two times the ultimate average dry weather flow (ADWF), including dry weather wastewater flow from the Clover Point sewerage area, for up to 220 ML/d. Flows above 2*ADWF would receive preliminary and primary treatment only.

In addition to treating wastewater for an equivalent population of 400,000, the Macaulay/McLoughlin Point WWTP will treat sludge generated from a number of distributed plants. It is assumed these distributed WWTPs would collectively serve 207,000 PE in the CRD core area and send their primary and waste activated sludge to the Macaulay/McLoughlin Point WWTP. A typical domestic per capita loading for biological oxygen demand (BOD) of 70 g/PE/d was assumed for all plants. The influent total suspended solids (TSS) load was assumed to be 63 g/PE/d. It was assumed that the maximum month design influent loads would be 15 percent higher than average dry weather loads. Table 2-1 lists the design flows and loads for the Macaulay/McLoughlin Point WWTP used for this alternative development.

Table 2-1
Design Flows and Loads

Source	Parameter	Value
Macaulay Catchment		
	ADWF, ML/d	110
	PWWF, ML/d	364
	Secondary Treatment Capacity, ML/d	220
	ADWF BOD (mg/L)	255
	ADWF TSS (mg/L)	230
	ADWF BOD (kg/d)	28,000
	ADWF TSS (kg/d)	25,200
Distributed WWTPs		
	ADWF BOD (kg/d)	14,500
	ADWF TSS (kg/d)	13,000

For the purpose of this analysis, it was assumed that the flows from the solids streams of the distributed WWTPs and the Clover Point wet weather treatment facility were negligible compared to the flow from the Macaulay Catchment. Further, it was assumed that the solids loading from the Clover Point facility, estimated to add an equivalent TSS concentration between 90 and 150 mg/L to the raw wastewater for the duration of the wet weather events for a ballasted flocculation process, would be intermittent and would not affect the liquid stream unit process sizing at the Macaulay/McLoughlin WWTP.

3 Description of Alternatives

Based on a previous evaluation documented in The Path Forward (CRD, 2007), multiple alternatives for primary and secondary treatment at the Macaulay/McLoughlin facility were selected for further consideration. This section reviews these treatment alternatives and those selected for conceptual design development.

3.1 Primary Treatment

The primary treatment technologies evaluated were conventional primary clarifiers, Lamella clarifiers, and Actiflo®.

- **Conventional Primary Clarifiers:** Conventional primary clarification is a settling process that is carried out in a relatively quiescent basin. It removes solids through gravitational settling and incorporation into a sludge blanket for solids/liquids separation in the basin. BOD removal is achieved through removal of organic matter associated with the solids. Oil, grease, and other floatable materials are removed by scum skimming mechanisms. This process does not require any chemical addition and the sludge produced is readily stabilized and biodegradable. Peak surface overflow rates are in the order of 125 $m^3/m^2/d$ when external primary sludge thickening is used. Typical process performance is 25 to 35 percent BOD removal and 40 to 60 percent TSS removal. Conventional primary clarification is a well-established technology commonly used in wastewater treatment plants throughout Canada and the world.

- **Lamella Clarifiers:** Lamella plate settlers, also known as inclined plate settlers, are used to decrease the footprint required to facilitate settling and solids removal in primary clarification. Lamella clarifiers consist of inclined parallel plates in rectangular sedimentation tanks. Inclined settling is typically accomplished using plastic or stainless-steel plates in a tank where the wastewater flow is counter-current, co-current, or cross-current to produce a clarified effluent. Plate settlers are designed to be vertically inclined, which allows settled solids to slide down the inclined surface and drop into the basin below. The distance between plates is designed to provide an upflow velocity lower than the settling velocity of the particles, thereby allowing particles to settle to the plate surface. Increased surface loading rates up to 240 $m^3/m^2/d$, can be used to achieve proper settling. This allows the unit process size to be substantially reduced. Typical process performance is 25 to 35 percent BOD removal and 40 to 60 percent TSS removal. Plate settlers are a proven and robust high-rate clarification process.

- **Actiflo:** Actiflo® is a proprietary ballasted-floc high-rate clarification system that uses microsand-enhanced flocculation and lamella tube settling to produce a clarified primary effluent. Adding chemicals to flocculate colloidal material in the influent wastewater enhances settling properties of primary solids and increases BOD and TSS removal in primary clarifiers. Seeding the influent with ballast to speed up the formation of floc structures further enhances primary clarification. Introducing sand particles to the influent provides the ballast that acts as a seeding agent. Chemicals are added to the influent with rapid mixing and then sand is added along with polymer. Floc maturation occurs under slow mixing conditions before settling occurs in shallow inclined tubes. The whole process occurs in less than 15 minutes. Settled sludge is removed from the bottom of the clarifier and a portion is recycled. The recycled sludge stream is first passed through a hydrocyclone to recover the sand. The sand ballast provides particles with the highest settling velocity, and the footprint is generally less than 50 percent of conventional primary clarifiers. However, grit removal is required to ensure the sand particle distribution size is not compromised. Approximately 1 to 3 percent sand loss occurs and the large amounts of chemical addition required can increase sludge production by more than 50 percent. Typical process performance is 35 to 70 percent BOD removal and 60 to 85 percent TSS removal.

3.1.1 Primary Treatment Process Evaluation

The advantages and disadvantages of the above three primary treatment processes are summarized in Table 3-1.

Table 3-1
Primary Treatment Options

Process	Advantages	Disadvantage
Conventional Primary Clarifiers	• Many installations • Low maintenance • Low capital cost • Can thicken sludge within tanks (although at lower overflow rates)	• Only achieves 40 to 60 percent solids removal
Lamella Clarifiers	• Less space required than conventional clarifiers • Less civil construction	• Plate settlers are prone to fouling problems • High horizontal velocities limit primary sludge solids concentration • Standby units are required to facilitate Lamella cleaning • Higher cost
Actiflo®	• Higher TSS/BOD removals achieved • Less space required than Lamella clarifiers • Less civil construction	• More operator attention required • High chemical use • Sand loss • Greater sludge volumes • Proprietary process

The Macaulay/McLoughlin site is very small, and the number of conventional primary clarifiers required would be impractical for the limited space available. Therefore, conventional primary clarification was not advanced for further development. Both Lamella clarifiers and Actiflo® are proven, viable primary treatment processes which provide a more compact footprint than conventional primary clarifiers. Lamella clarifiers typically require more land than an Actiflo® process. Hence a Lamella clarifier layout was selected as a reasonable representative primary treatment technology for the Macaulay/McLoughlin Point WWTP. A Lamella clarifier layout accommodates both technologies and does not limit the process selection in the detailed analysis phase.

3.2 Secondary Treatment

The secondary treatment alternatives considered were conventional activated sludge (CAS), biological aerated filters (BAF), and membrane bioreactor (MBR).

- **CAS:** CAS is a well proven suspended growth process. Raw wastewater or primary effluent is directed to a bioreactor where it mixes with return activated sludge. The resulting mixed liquor is aerated until BOD removal has occurred and then transferred to a secondary clarifier. In large systems, oxygen is normally supplied via high efficiency, fine bubble aeration diffusers. Treated effluent is separated from the solids by gravity in the secondary clarifier and most of the settled sludge is returned to the bioreactor to maintain the desired inventory of microbial mass. A portion of the sludge is wasted to offset microbial growth so that the desired solids retention time is maintained. CAS may be modified to be high-rate or low-rate depending upon the effluent quality requirements. For example, the process can be modified to facilitate nitrification and denitrification for ammonia and/or nitrogen removal. CAS is a very reliable process which can satisfy a wide range of influent conditions. One disadvantage for application of CAS at Macaulay/McLoughlin Point is the large footprint required to accommodate the bioreactors and secondary clarifiers.

- **BAF:** BAF is an attached growth process that consists of a submerged, aerated reactor in which a biofilm is maintained on the surface of a bed of expanded clay or synthetic granules. The granules are made from proprietary materials that differ according to the vendor. Primary effluent is passed upwards through the media bed. The media bed filters suspended solids efficiently, thus producing effluents with low TSS concentrations, precluding the need for secondary clarification. Aeration of the biofilm is achieved by passing air through a grid located at the base of the media bed. The presence of treated water on the surface of the media mitigates odour emissions. Biomass growth on the media results in an increase in head loss across the bed. When this exceeds a target value, the bed is backwashed by supplementing the process air with a flow of scour air through a second aeration grid and fluidizing the bed by passing a temporary high flow of treated effluent through the bed. Because of its modular approach, the BAF process is easily modified to accommodate biological nitrogen removal by adding aerobic modules to achieve high levels of nitrification, and non-aerated modules to achieve denitrification. BAF is a reliable process with an approximately 50 percent lower footprint requirement than CAS.

- **MBR:** The membrane bioreactor is a suspended growth activated sludge process in which the final liquid/solids separation is done using micro- or ultra-filtration. Raw wastewater or primary effluent is directed to a bioreactor where it mixes with return activated sludge. The resulting mixed liquor is aerated until BOD removal occurs. The MBR differs from CAS in that treated effluent is separated from the mixed liquor using membranes instead of secondary clarifiers. Membranes with pore size 0.1-0.4 micron are submerged in mixed liquor and permeate passes through the membrane by gravity, or is withdrawn under a slight vacuum. Most of the settled sludge is returned to the bioreactor to maintain the desired level of microbial mass. A portion of the sludge is wasted to offset microbial growth so that the desired solids retention time is maintained. Membranes may be located in separate tanks from the bioreactors to provide flexibility and optimize energy consumption. MBR processes are normally designed for nitrification, and the process design can be modified to incorporate denitrification. The absence of secondary clarifiers and the increased MLSS concentrations result in about 50 percent space savings over CAS. However, the need to facilitate membrane cleaning uses some of these footprint savings.

3.2.1 Secondary Treatment Process Evaluation

The advantages and disadvantages of the above secondary treatment processes are summarized in Table 3-2.

Table 3-2
Secondary Treatment Options

Process	Advantages	Disadvantage
CAS	• Well proven, commonly applied process • Flexible, can adapt to minor pH, organic loading and temperature changes • Moderate energy costs • Can be upgraded to meet more stringent effluent quality standards	• Large footprint • Process performance is dependent on maintaining good sludge settling properties
BAF	• Eliminates the need for secondary clarification • Low footprint • Can be upgraded to meet more stringent effluent quality standards	• Complex operation • High energy cost • Mechanically complex • High visual impact • Better suited to dilute wastewaters • High backwash flow generated

Process	Advantages	Disadvantage
MBR	• Low footprint • Compact liquid/solids separation • Low effluent BOD and TSS concentrations • Low effluent NH_4 concentrations can be achieved if specifically designed for this purpose • Reduces need for effluent disinfection • Increased MLSS concentration	• Limited peak wet weather flow capacity • High energy cost • Mechanically complex • Membranes required frequent cleaning • Limited membrane life

CAS is used successfully at many large WWTPs, but requires a large footprint. Both BAF and MBR are reliable processes that are more compact secondary treatment technologies than CAS. For the purposes of being conservative in the context of the land area requirements for wastewater treatment, it is assumed that both the BAF and MBR processes would be sized to provide ammonia removal though nitrification. This is in anticipation of possible future regulatory changes that may require either ammonia removal and/or the removal of contaminants of concern (endocrine disrupting compounds, pharmaceutical and personal care products, etc.). Initial indications are that biological processes designed for nitrification appear to have enhanced microconstituent removal capability when compared with conventional secondary treatment processes. However, it should noted that wastewater in the CRD area is generally low in natural alkalinity, so supplemental alkalinity may have to be added to the wastewater to maintain stable nitrification in the secondary treatment process.

Both the BAF and MBR processes have enhanced treatment capability in a smaller footprint than CAS, and are therefore more applicable for the Macaulay/McLoughlin Point WWTP. It should be noted that the BAF process is better suited to low strength incoming wastewaters, which may present a challenge for a facility that also receives significant quantities of sludge from distributed wastewater treatment plants in its incoming wastewater. The potential impact of the solids from the distributed plants on a BAF process can be evaluated in more detail once the distributed treatment strategy is finalized. For these reasons, the MBR process was selected as a representative technology in this liquid alternative evaluation.

4 Alternative Design Development

The representative liquid process alternative developed for the proposed Macaulay/McLoughlin Point WWTP is lamella primary clarifiers with MBRs. Unit process sizing and other design criteria were developed for this process train.

4.1 Representative Alternative – Lamella Primary Clarifiers with MBR

Figure 4-1 and Table 4-1 show the process flow diagram and conceptual design criteria for the representative liquid process alternative. This alternative would have lamella clarifiers for primary treatment and an MBR process for secondary treatment. An influent pump station would convey raw wastewater to a distribution channel, from where it would flow by gravity through influent bar screens with 25 mm openings and vortex grit removal units. Flow would continue by gravity through one of 3 duty lamella clarifiers. Each unit would have an area of 600 m^2 and a side water depth of 4 m. The total volume of the clarifiers would be 9,600 m^3, including a fourth, standby unit.

After the lamella clarifiers, primary effluent flows up to 220 ML/d would flow through fine screens (2 mm openings) to protect the membranes from excessive fouling. Wastewater would then flow through the bioreactors which would have an anoxic zone followed by a larger aerobic zone with fine bubble diffusers. A weir would separate the anoxic and aerobic zones. There would be 4 bioreactors, with a total volume of approximately 40,000 m^3. Following the bioreactors, membrane feed pumps would convey mixed liquor to the membrane tanks. There would be 8 duty membrane tanks with a total approximate volume of 10,000 m^3. The MBR bioreactor has been conservatively sized to operate at a solids retention time of 14 days to ensure stable ammonia and contaminant of concern removal. As the process design is refined, it may be possible to reduce the MBR process volume and footprint to facilitate a higher rate process.

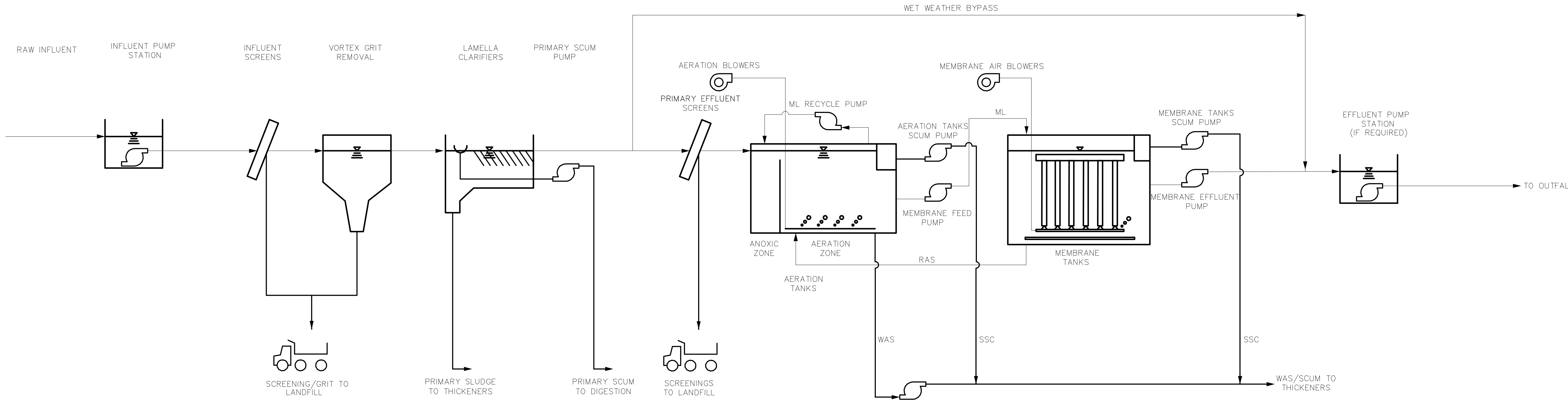
The membranes would operate under a slight vacuum, with effluent pumps withdrawing permeate through the membranes. The membrane effluent would then be pumped to the effluent collection box prior to entering the effluent pump station wet well, if an effluent pump station is required. Primary effluent flows above 220 ML/d would bypass the MBR process and be combined with the secondary effluent in the effluent collection box.

Table 4-1
Representative Alternative Design Criteria

Process	Parameter	Description
Lamella Primary Clarifiers	Hydraulic Loading Rate (peak)	240 m^3/m^2 d
	No. of Units	3 duty; 1 standby
	Length	50 m
	Width	12 m
	Side Water Depth	4 m
Bioreactors	SRT (total for secondary treatment)	14 d
	MLSS (max)	8,000 mg/L
	No. of Units	4
	Length	60 m
	Width	28 m
	Side Water Depth	6 m
Membrane Tanks	Net Peak Flux	19.7 $L/m^2/h$
	Total Membrane Area Required	465,000 m^2
	No. of Membrane Cells	32 duty; 4 standby
	No. of Membrane Tanks	8 duty; 1 standby
	Length	31 m
	Width	10 m
	Side Water Depth	4 m

5 Summary

Based on the information presented in the previous sections, a representative liquid treatment alternative of lamella primary clarifiers followed by membrane bioreactors (MBR) was selected to provide information that will be used to develop a preliminary plant layout for the proposed Macaulay/McLoughlin Point wastewater treatment plant. The representative alternative will not preclude the other viable processes (e.g. Actiflo®, BAF) from being selected in a more detailed analysis to be performed in the future since the land requirements of the representative technologies selected are greater than or approximately equal to the other processes. This approach provides a robust alternative for the plant siting analysis.



DESIGN FLOWS

ADWF	110 ML/d
MMF	125 ML/d
PWWF	364 ML/d
STC	220 ML/d

VORTEX GRIT REMOVAL

- 3 UNITS
- 6 m DIAMETER
- 1.5 m^3/s

LAMELLA CLARIFIERS

- 4 UNITS (3 DUTY/ 1 STANDBY)
- 50 m LONG
- 12 m WIDE
- 4.0 SWD
- OFR, PWWF: 240 m^3/m^2 d

AERATION TANKS

- 4 TANKS
- 60 m LONG
- 28 m WIDE
- 6.0 m SWD

MEMBRANE TANKS

- DESIGN FLOW, PWWF: 220 ML/d
- DESIGN NET PEAK FLUX: 19.7 L/m^2H
- TOTAL MEMBRANE AREA 465,000 m^2
- 9 TANKS
- 31 m LONG
- 10 m WIDE
- 4.0 m SWD

ABBREVIATIONS

ML	MIXED LIQUOR
RAS	RETURN ACTIVATED SLUDGE
SSC	SECONDARY SCUM
WAS	WASTE ACTIVATED SLUDGE
EPS	EFFLUENT PUMP STATION
IPS	INFLUENT PUMP STATION
ADWF	AVERAGE DRY WEATHER FLOW
MMF	MAX MONTH FLOW
PWWF	PEAK WET WEATHER FLOW
STC	SECONDARY TREATMENT CAPACITY

ADWF DESIGN LOADS

	MACAULAY	DISTRIBUTED WWTPS
BOD kg/d	28,000	14,500
TSS kg/d	25,200	13,000

FIGURE 4–1

MCLAUGHLIN POINT
LIQUIDS PROCESS FLOW DIAGRAM

LAMELLA–MBR

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