Memo To: Paul Allore
Memo From: Martin T. Auer
Date April 30, 2015
Subject: York Region Technical Memorandum – Actiflo – March 11, 2015
cc: Jennifer Danahy

This memo constitutes a review of the Technical Memorandum entitled, "Conceptual Design of Actiflo Process for Tertiary Treatment at the Duffin Creek Water Pollution Control Plant (Duffin Creek WPCP). The memorandum consists of a *Conceptual Design of Actiflo® Process* (hereafter, *Conceptual Design*) for implementation of the technology prepared by CH2M Hill for the Regions of York and Durham, accompanied by a *Letter of Transmittal* co-authored by the Regions' Project Managers.

The *Conceptual Design* draws upon information from ballasted flocculation installations at wastewater treatment plants in Syracuse, NY and Winnipeg, Manitoba and clearly documents the design process and constituent assumptions and supporting information. As such, the *Conceptual Design* is amenable to analysis by others seeking to compare the design and cost analysis to existing facilities.

The *Letter of Transmittal* opens by noting that a partial or pilot installation would not facilitate an accurate assessment of the efficacy of ballasted flocculation technology in controlling beach fouling by *Cladophora* in the Pickering-Ajax-Whitby waterfront. I would support this conclusion. The purpose of a pilot installation would be to confirm that the Duffin Creek WPCP can achieve the removal efficiencies attained at other plants utilizing ballasted flocculation (e.g. the Metropolitan Syracuse WWTP, Metro, and the Ithaca Area WWTP, IAWWTP) and to verify estimates of operating costs prepared through the *Conceptual Design*. Assessment of the efficacy of implementation of ballasted flocculation at the Duffin Creek WPCP in remediating nuisance algal conditions in the Pickering-Ajax-Whitby waterfront requires application of a linked hydrodynamic-phosphorus-*Cladophora* model.

In developing the *Conceptual Design*, CH2M Hill has clearly laid out their approach, characterized inputs to their calculations and presented the result in a manner readily accessible for subsequent evaluation. To my mind, the critical shortfall in the process lies with the apparent terms of reference provided to CH2M Hill and the perspective adopted by the Regions in interpreting and presenting the results. *Specifically, the design basis for CH2M Hill's work is established in a manner that maximizes the economic burden on the Regions and the analysis of CH2M Hill's work serves to minimize the environmental and economic benefit.* Finally, valuation of the potential for ballasted flocculation to remediate conditions of nuisance algal growth proceeds from the Regions' position that the Duffin Creek WPCP plays no role in the water quality degradation presently experienced in the Pickering-Ajax-Whitby nearshore. Further details relating to these issues are provided below.

1. The *Letter of Transmittal* asserts that beach fouling by *Cladophora* in the vicinity of the Duffin Creek WPCP discharge is due to 'other factors'.

The Duffin Creek WPCP contributes an annual total phosphorus (TP) load of 133 kgP/day to the Ajax nearshore, operating at a flow of 342 ML/d (Duffin Creek WPCP 2014 Annual Performance Report). The requested increase in discharge volume (to 630 ML/d) would increase that load to between 244 and 311 kgP/d, the former at the present day effluent TP concentration, the latter at the MOE-approved loading limit (ESR, p. ES-1). No improvement in the level of phosphorus removal is proposed by the Class EA, despite a projected doubling (factor of 1.8-2.3) in the phosphorus load. Such a path would be indefensible in a water quality management context unless it could be shown that both the present and future loads have no negative impacts in the nearshore.

The subject ESR takes the position that the discharge from the Duffin Creek WPCP plays no role in the beach fouling and water quality degradation presently occurring in the Pickering-Ajax-Whitby waterfront. *In this Technical Memorandum, the significance of the Duffin Creek WPCP, the second largest point source of phosphorus in the GTA, is again dismissed.* The Regions' position on this point stands in direct opposition to the findings of Auer et al. (2014; *Phosphorus Provenance and Cladophora Growth in Lake Ontario* 2014) which identify the Duffin Creek WPCP discharge as the primary source of phosphorus. The Regions' 'no effect' position becomes embedded in all efforts to resolve the existing beach fouling problem.

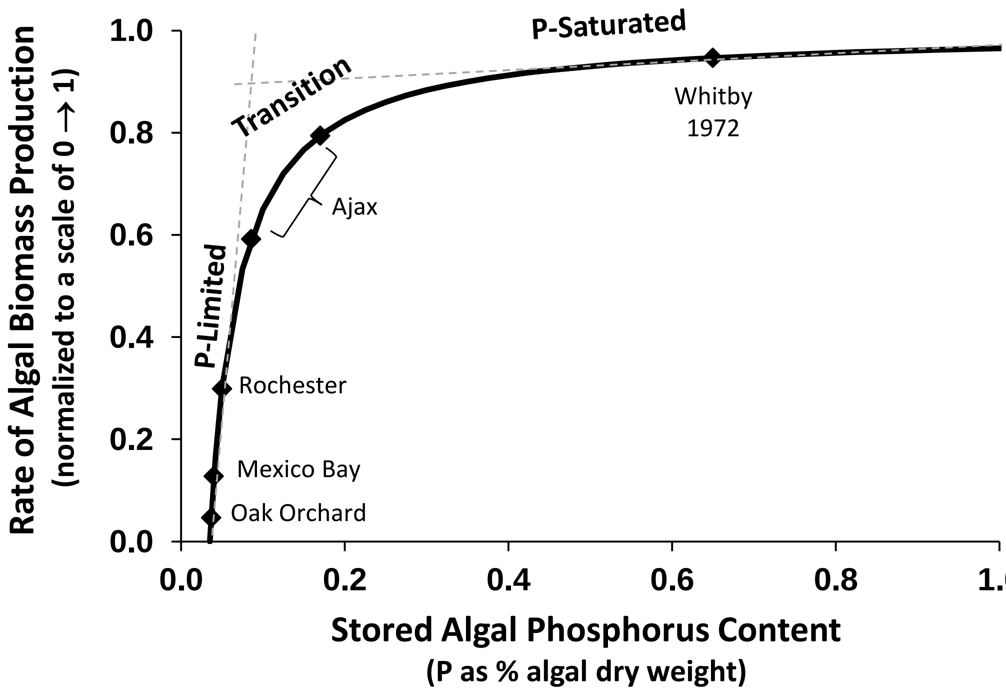
2. The *Letter of Transmittal* develops a position that implementation of ballasted flocculation at the Duffin Creek WPCP would not offer significant benefit compared with costs incurred.

Here, the Regions take the position that implementation of ballasted flocculation would offer only a modest improvement in phosphorus removal efficiency (reducing the TP load by 99% from 94%, an increment of 5%) and this achieved at a significant cost. This line of reasoning is not well-founded, as it fails to recognize two key aspects of the *Cladophora* – phosphorus dynamic.

a) *Non-linearity of the response curve* - it is incorrect to assume that the relationship between phosphorus discharges and the production of *Cladophora* biomass is linear. This relationship has, in fact, been demonstrated to be decidedly non-linear (Tomlinson et al. 2010). Hyperbolic relationships between phosphorus nutrition and *Cladophora* production demonstrates that significant levels of P removal may be achieved before the receiving water reaches a condition of P-limitation. This is clearly demonstrated by measurements of stored P content for *Cladophora* from Lake Ontario (Figure 1) where samples collected at Whitby, ON in 1972 (Painter and Kamaitis 1987) are P-saturated and samples representing contemporary conditions on the south shore of Lake Ontario are P-limited (Higgins et al. 2012). Stored P content at Ajax presently lies at the point of transition from P-saturated to P-limited conditions (Higgins et al. 2012; Auer et al.

2014). For this reason *Cladophora* nutrition along the Pickering-Ajax-Whitby nearshore would be expected to be sensitive to reductions in P loads.

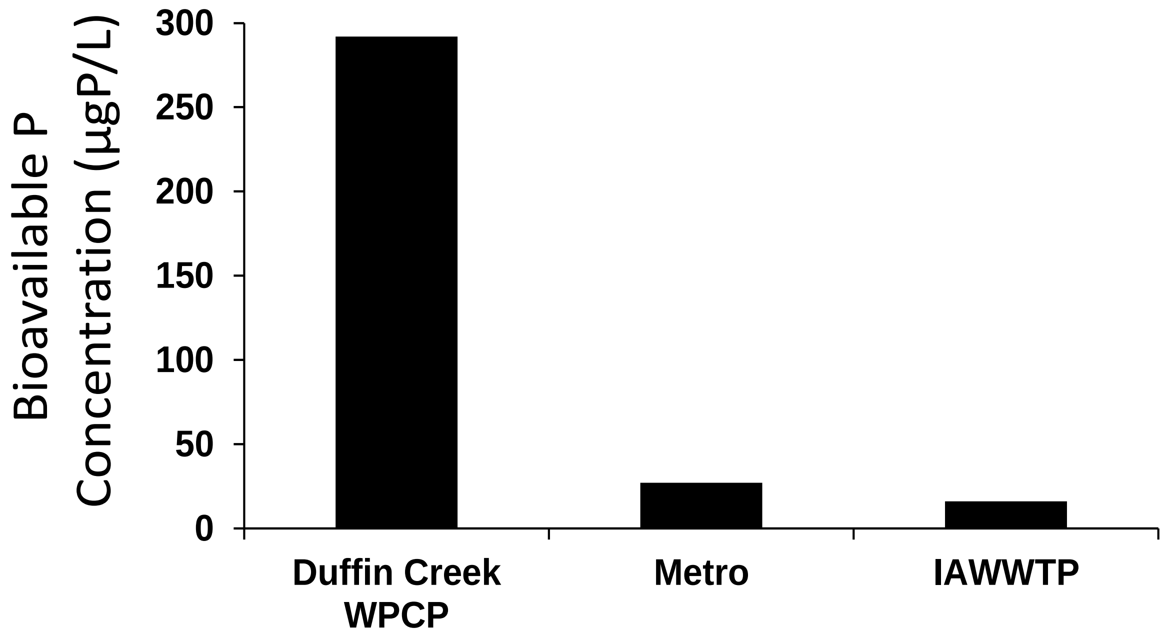
Figure 1. Stored phosphorus content of *Cladophora* at Whitby, ON in 1972 compared with contemporary measurements at other sites on Lake Ontario. *Cladophora* nutrient status at Ajax, ON presently lies in the transition region between P-saturation and P-limitation.



b) *Bioavailable phosphorus removal* - soluble reactive phosphorus (SRP) is the form of phosphorus freely and directly available to support algal growth. Levels of SRP in the water include that directly discharged as SRP plus a portion of the phosphorus discharged as dissolved organic (DOP) and particulate (PP) P that is transformed to SRP following discharge through mineralization. The sum of the SRP discharged and that later made available through mineralization is termed bioavailable phosphorus.

The Great Lakes Water Quality Protocol of 2012 has called for consideration of phosphorus bioavailability in managing loads. Implementation of ballasted flocculation offers benefits in mitigating nuisance algal growth beyond those that may be expressed in terms of the percent reduction in TP load. Ballasted flocculation treatment technology achieves an exceptionally high removal of bioavailable phosphorus by incorporating iron-phosphorus flocs within a sand matrix (ballast) which is efficiently captured through gravitational settling. The Duffin Creek WPCP, which practices conventional chemical removal of phosphorus, discharges an effluent with a bioavailable P concentration of 292 µgP/L (Auer et al. 2015a). Metro (Lambert et al. 2015) and the IAWWTP (Auer et al. 2015b), both utilizing ballasted flocculation, achieve effluent bioavailable P concentrations of 27 and 16 µgP/L, respectively (Figure 2).

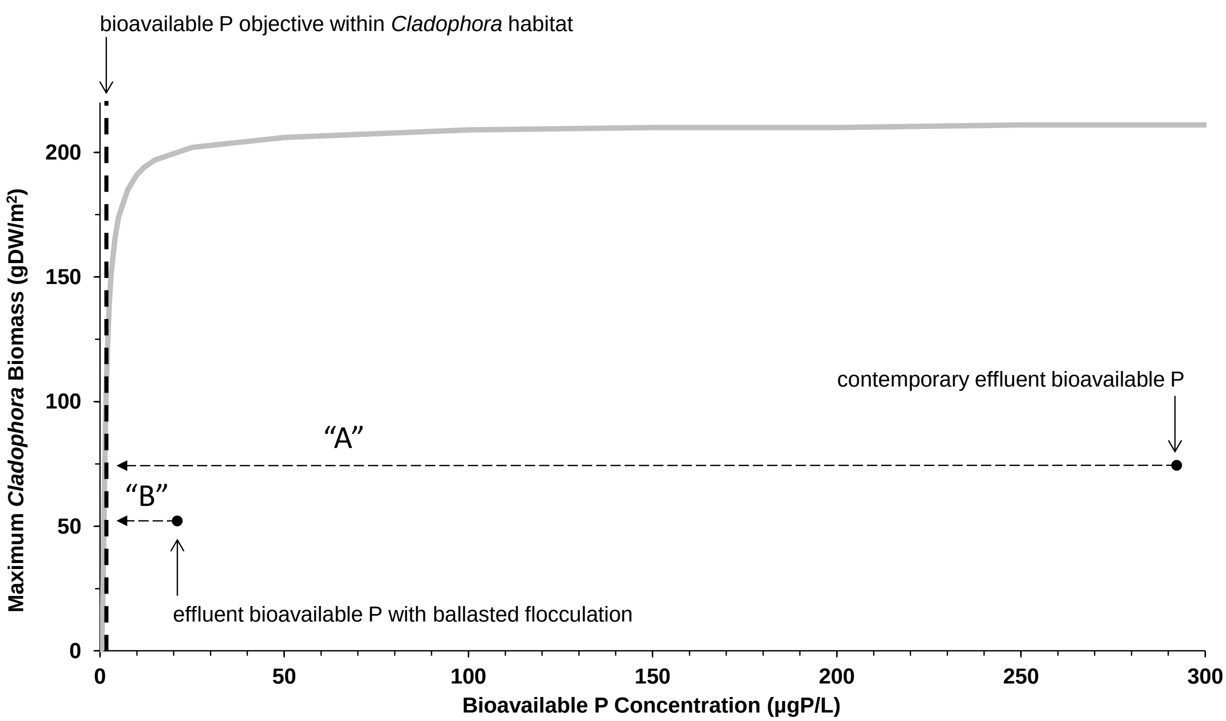
Figure 2. Comparison of bioavailable phosphorus concentrations in the effluents of the Duffin Creek WPCP (conventional P removal, sampled in 2014) and Metro and the IAWWTP (ballasted flocculation, sampled in 2012 and 2013, respectively).



The objective in controlling nuisance growth of *Cladophora* is to maintain bioavailable phosphorus (i.e. fully realized SRP) levels within the linear, P-limited region of the phosphorus response curve (Figures 1 and 3). On a stored P level, this would be <0.1 P as %DW (Figure 1); for SRP, this would be a concentration ~1 µgP/L (Figure3). At present, the bioavailable P concentration of the Duffin Creek WPCP effluent is 292 µgP/L (Auer et al. 2015a). *In order to meet the management objective, the WPCP effluent bioavailable phosphorus concentration must be reduced from 292 µgP/L at its point of discharge to ~1 µgP/L at the point that the plume encounters and impacts Cladophora habitat (A in Figure 3).* For the Duffin Creek WPCP outfall, this reduction is sought through dilution with lake water, i.e. maintenance of a mixing zone. The dimensions of the mixing zone necessary to accomplish the required dilution are determined by the degree of mixing and the difference between the objective concentration and the effluent concentration (A in Figure 3). *At present, the SRP mixing zone for the Duffin Creek WPCP extends over ~8 km of the Pickering-Ajax-Whitby nearshore, encountering and* *impacting Cladophora habitat (Auer et al. 2014). Separation of the Duffin Creek WPCP discharge from the area supporting Cladophora growth requires either a lakeward extension of the discharge point, reductions in the effluent bioavailable phosphorus concentration or combinations of the two.*

Based on the performance achieved at other facilities (Metro, Lambert et al. 2015 and the IAWWTP, Auer et al. 2015b), implementation of ballasted flocculation at the Duffin Creek WPCP would reduce the bioavailable P concentration of the effluent to 16-26 µgP/L. This would markedly reduce the amount of dilution required to bring the effluent bioavailable P down to the concentration objective (B in Figure 3). *The result would be that a smaller area of Cladophora habitat would be impacted by the effluent plume and a lesser degree of pipe extension would be required.*

Figure 3. Post-discharge mixing and dilution required following conventional and ballasted flocculation treatment for bioavailable phosphorus at the Duffin Creek WPCP (M.T. Auer, unpublished).



In their *Technical Memorandum*, the Regions note that they presently remove 94% of the Total Phosphorus received as influent, reducing the TP concentration from 5600 to 390 µgP/L (93%, Duffin Creek WPCP 2014 Annual Performance Report). This level of removal is not sufficient to prevent the WPCP's effluent plume from making contact with *Cladophora* habitat at a bioavailable phosphorus concentration that would lead to nuisance conditions of algal growth.

Unless additional treatment is provided (e.g. ballasted flocculation), the only way to reduce nuisance conditions of algal growth is to extend the WPCP outfall further into the lake.

Our analysis examined the potential impact of ballasted flocculation in terms of bioavailable phosphorus (not simply TP), as recommended by the 2012 Protocol (Figure 3). The 94% removal efficiency for TP presently attained at the Duffin Creek WPCP results in an effluent bioavailable phosphorus concentration of 292 µgP/L ("A" in figure 3). Using the WPCP's present treatment technology, dilution of the effluent's bioavailable phosphorus concentration to the 1 µgP/L standard creates a mixing zone extending ~8 km along the Pickering-Ajax-Whitby waterfront. Within that mixing zone, concentrations exceeding the objective are encountered and impact broad areas supporting *Cladophora* growth on the lakebed. *Again, barring improved treatment in the Duffin Creek WPCP, the only solution is to further extend the point of discharge.*

Based on performance at other sewage treatment facilities (e.g. Metro and IAWWTP), the implementation of ballasted flocculation at the Duffin Creek WPCP would lower its effluent bioavailable phosphorus concentration to 16-26 µgP/L ("B" in Figure 3), a reduction of 91-95% BEYOND that presently achieved at the WPCP <u>and</u> a 99^{+}% reduction from the concentration entering this WPCP. We note that this extraordinarily effective level of treatment is presently being achieved at WPCPs in several locations.

The reduction in the size of the Duffin Creek WPCP mixing zone attending implementation of ballasted flocculation would be expected to significantly reduce the role of the discharge in stimulating nuisance growth of Cladophora. With less algal biomass generated, there would be fewer occurrences of the beach fouling <u>and</u> less generation of the odours accompanying the decomposition of algae. Lost beneficial uses, including contact recreation in the Pickering-Ajax-Whitby nearshore, could be restored and the potential for fouling at industrial (Pickering Nuclear Generating Plant) and municipal (Durham Region's Ajax Water Supply Plant) water intakes reduced. *These benefits are not recognized in interpreting the results of the CH2M Hill Conceptual Design and, as a result, the potential benefits associated with implementation of ballasted flocculation are minimized.*

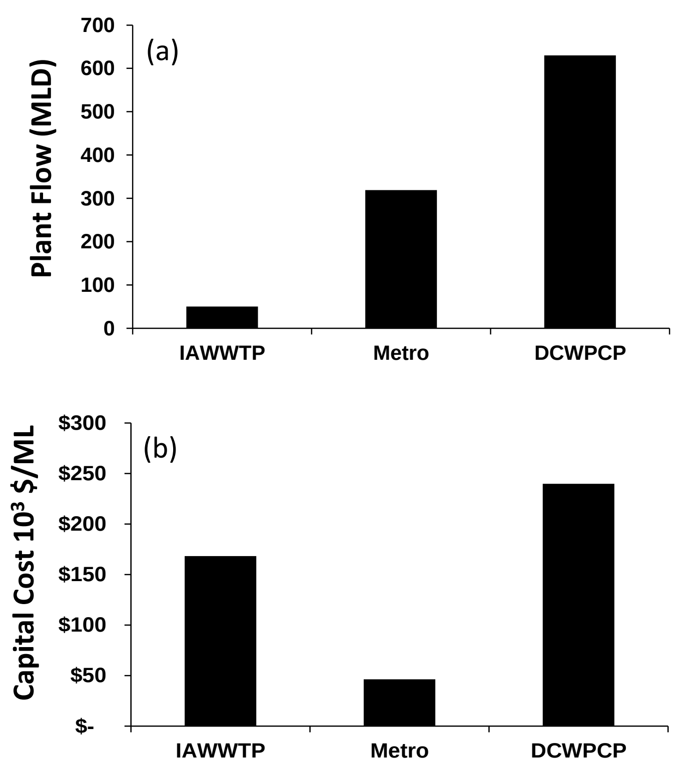
3. The *Letter of Transmittal* develops a position that implementation of ballasted flocculation at the Duffin Creek WPCP would incur costs well in excess of the benefits received.

It would appear that the terms of reference under which CH2M Hill's *Conceptual Design* was formed serve to maximize the economic burden of implementing ballasted flocculation by limiting the analysis to a case where the maximum design capacity of the plant is realized and then adding a 1.5 multiplier to the peak flow requiring treatment. While this may represent an appropriate long term scenario, *other alternatives would reduce the economic burden significantly while providing immediate relief from the nuisance growth of Cladophora presently* *experienced. Such alternatives were either not considered or were not fully developed in framing the Conceptual Design*.

A thorough review of the results embodied in the *Conceptual Design* is beyond the scope of this review; however, a cursory examination of the cost estimates and framing of the document raises some points of interest to stakeholders:

a) *Capital cost comparisons* – the *Conceptual Design* used in deriving a cost estimate of $151 million for implementation of ballasted flocculation is based on application of the technology at Metro, yet no side-by-side cost comparison to that facility or others using the technology is presented. Lambert et al. (In Review) report that capital costs at Metro were $14.8 million (2015 dollars) to treat 319 MLD and $8.4 million (2015 dollars) at IAWWTP to treat 50 MLD (M.T. Auer, unpublished). *It is recommended that the capital costs estimated for implementation at the Duffin Creek WPCP be compared with the actual capital costs incurred at Metro and the IAWWTP, appropriately scaled to plant size and infrastructure requirements (Figure 4).*

Figure 4. Comparison of (a) *Conceptual Design* flow for the Duffin Creek WPCP at proposed 630 million litres/day (630 MLD) capacity compared with contemporary operating flows for Metro and the IAWWTP and (b) *Conceptual Design*-based capital costs for the Duffin Creek WPCP at proposed 630 MLD capacity compared with actual capital costs at Metro and the IAWWTP (all 2015 dollars).



b) *Staged implementation – the Region's design yielding a capital cost of $151 million is based on a discharge of 945 MLD (the Duffin Creek WPCP's maximum rated average daily capacity*, 630 MLD, plus a peaking factor of 1.5 to eliminate the need for high flow bypass of the ballasted flocculation process). The Regions have projected that the maximum rated capacity will be reached in ~16 years (2031; ESR, p. 3-3). Of course, that time to maximum capacity is an estimate that remains to be corroborated by the actual growth of the service area. It would seem that a staged approach is warranted here, i.e. adding process trains and pumping stations at intervals commensurate with the realized service area growth. This may serve to markedly reduce the economic burden of implementation, while offering immediate relief from environmental degradation of the Pickering-Ajax-Whitby nearshore.

c) *Redundant process train* – the ability to transfer flows among process trains to facilitate maintenance represents a significant component of the overall cost. The environmental impact of reductions in residence time to accommodate short-term maintenance needs without depending on a redundant process train has not been quantified. Further, if a staged implementation approach were selected to ease the economic burden, redundant capacity would be available by design throughout the implementation period requiring installation of a redundant process train only as part of the final step.

d) *Peaking factor* – the *Conceptual Design* includes a peaking factor of 1.5 to avoid bypass of the ballasted flocculation process during wet weather flows. This peaking factor requires accommodation of an additional 315 MLD, almost equal to the present volume treated. A peaking factor was <u>not</u> included in the Regions' consideration of tertiary treatment options presented in the *Class Environmental Assessment* (ESR, p. 9- 12). This departure from the Regions' established design approach serves to maximize the economic burden for implementation of ballasted flocculation at the Duffin Creek WPCP. Several additional factors relating to the peaking factor merit consideration.

- a plant operating with a wet weather bypass typically discharges an effluent that receives primary treatment (at a shorter residence time) and disinfection. The DCWPCP has chosen to design for a plant that does not have a wet weather bypass for its contemporary and future operation;
- wet weather bypass of the ballasted flocculation process would yield an effluent comparable to that of contemporary operation, i.e. primary and secondary treatment plus conventional chemical treatment. Such an effluent would have a substantially higher quality than would exist in effluent that bypasses its contemporary operations;
- permitting a wet weather bypass of the ballasted flocculation process during the 8-month interval outside of the *Cladophora* growing season, e.g. Sep-Apr would

not exacerbate algal growth in the nearshore. Wet weather events are typically experienced in spring at the Duffin Creek WPCP, during a period largely outside of the *Cladophora* growing season; and

- finally, the environmental impact of bypassing the ballasted flocculation process for wet weather during the *Cladophora* growing season has not been quantified.

Given the high cost of adding a peaking factor of 1.5, it would seem that due diligence in evaluating the value of that capability should be further exercised.

e) *Operational costs* – as for capital costs, a comparison to operating and management costs at presently active ballasted flocculation facilities (e.g. Metro and the IAWWTP) seems appropriate. Here, expression of O&M costs on a 'per volume' basis would facilitate the comparison. Further, the *Conceptual Design* calculates O&M costs to be $6.9 million annually. Mass transport calculations made for the Pickering-Ajax-Whitby nearshore (M.T. Auer, unpublished) indicate that ballasted flocculation would be required only 4-5 months annually, i.e. the duration of the *Cladophora* growing season. For the balance of the year, the effluent could be discharged using only the existing conventional chemical treatment, reducing the economic burden to ~$2.5 million annually. As currently framed, the *Conceptual Design* minimizes the benefits of seasonal operation and justifies doing so by pointing to increased staff attention required at startup/shutdown and ongoing monitoring of the process even when not in operation. However, even assuming full labor costs for the entire year, the economic burden of O&M would be reduced from $6.9 million to $2.4-3.0 million, a significant annual savings.

Summary

This Technical Memorandum consists of a *Letter of Transmittal* and a *Conceptual Design* offering the Regions' perspective on the cost and attendant benefit of implementing tertiary treatment with ballasted flocculation at the Duffin Creek WPCP. The *Conceptual Design*, prepared by CH2M Hill provides a transparent and well documented treatment of the design and cost analysis amenable to review by other parties. However, the terms of agreement used to frame the design process and the interpretation of the resulting Conceptual Design serve to maximize the apparent costs and minimize the apparent benefits of implementation of this technology as a means for managing the *Cladophora*-phosphorus dynamic in the Pickering-Ajax-Whitby nearshore. In this response, we have identified opportunities to amend the *Conceptual Design* to more fairly consider costs and benefits as a means of providing relief from the ongoing water quality degradation associated with the WPCP discharge.

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