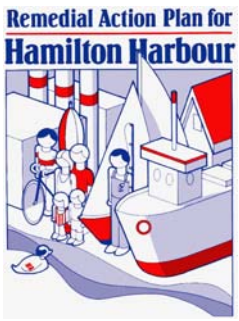
Hamilton Harbour RAP
Water Quality Goals and Targets Review

Part 1: Response to the City of Hamilton's Proposed Wastewater System Upgrades

SUMMARY REPORT

July 2007



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Executive Summary

Background

Hamilton Harbour was identified as an Area of Concern (AOC) by the International Joint Commission (IJC) in 1985. Since that time, local stakeholders have joined together to prepare and implement a Remedial Action Plan (RAP). The 1989 Stage 1 Report evaluated environmental conditions and defined the problems facing the Harbour; whereas the 1992 Stage 2 Report developed goals, targets and recommendations to remediate the Harbour. Initial and final water quality goals and/or loading targets were set for a number of parameters, including total suspended solids (TSS), total phosphorus (TP), ammonia, and dissolved oxygen. The 1992 Stage 2 Report and its 2002 Update identified the need to re-visit Harbour water quality goals and loading targets after evaluation of the Harbour's response to initial remedial actions. An updated understanding of Harbour processes was used to predict future outcomes to wastewater treatment system enhancements and watershed improvements. With the development of a master plan for the City of Hamilton's wastewater treatment system the Hamilton Harbour RAP Technical Team initiated this review of RAP final water quality goals and loading targets.

The water quality goals and loading targets reviewed by the RAP Technical Team will be completed in two parts. Part 1, this report, focuses on a response to the City of Hamilton's proposed wastewater system upgrades. Part 2 will focus on recommendations posed by the Bay Area Implementation Team (BAIT) in their 2006-2011 Workplan, including confirmation or adjustment of the final water quality goals and targets. Any changes to final targets will be made to match current stakeholder visions for the Harbour, and will be based on a greater understanding of how the Harbour responds to loading reductions, in addition to what loading reductions are achievable. This includes addressing uncertainty associated with natural variability in the Harbour system, by exploring the move from a single point based target to ranges. The RAP Technical Team will also proceed with a re-evaluation of the dissolved oxygen final target to determine what is biologically meaningful and achievable considering both the Harbour's historical conditions, and the present urban nature of the watershed.

This Summary Report includes: a short background, the scope and context of the report, the present state of the Harbour, a brief outline of the City of Hamilton's proposed wastewater system upgrades, a summary of a preliminary re-evaluation of key water quality parameters, and a clear response with recommendations from the RAP Technical Team to the City of Hamilton. An important part of this report is the Technical Appendix (under separate cover). Up to this time, a clear documentation of the analysis completed by the original RAP scientific writing teams in the Stage 1 and 2 reports has never been consolidated. The Technical Appendix attempts to rectify this through a detailed review of past reports.

It is important to note that several members of Hamilton Harbour RAP Technical Team including Murray Charlton (RAP Technical Team Chair) and John Hall (RAP Coordinator), have participated in both the City of Hamilton's Phase 1 and 2 development of the proposed wastewater system management strategy and the Hamilton Harbour RAP Technical Team review. This cross-over highlights the strong partnership between various RAP stakeholders and the commitment of all stakeholders to work together to achieve delisting in 2015.

Technical Analysis

The RAP Technical Team reviewed the loading targets identified in the *Summary Report on Woodward Avenue WWTP Wastewater Treatment and Combined Sewer Overflow (CSO) Management Strategy* with respect to anticipated effects on the water quality for the Harbour; specifically, the loading design objectives for suspended solids, phosphorus, and ammonia were reviewed.

Suspended Solids: The RAP Stage 1 & 2 Reports identified suspended solids/sediments as issues germane to the Cootes Paradise Marsh and the streams entering the Harbour. The major sediment sources to these areas are from the watershed, including urban runoff. Decreased water clarity in the Harbour is principally the result of algae and not suspended solids. It was noted that the decrease in suspended solids at the Woodward WWTP is directly related to measures taken to reduce phosphorus loading. It is the opinion of the RAP Technical Team that the reduction in suspended solids that will occur as a result of tertiary treatment for phosphorus is an acceptable target. The cost effective and most beneficial focus for additional suspended solids reductions should come from watershed and urban runoff best management practices.

Phosphorus: Reducing total phosphorus loading to the Harbour is the single most important means to reduce algae and increase water clarity. This in turn provides the single greatest benefit to the fish, wildlife and benthic communities. The City of Hamilton is proposing a high standard of conventional tertiary treatment for its Woodward WWTP. It is anticipated that the magnitude of phosphorus reduction to be achieved will result in Harbour phosphorus concentrations on par with that presently identified as the final target for the Harbour.

Ammonia: Ammonia is a concern due to potential toxic effects on the fish community. The City of Hamilton is proposing a final effluent concentration at the provincial water quality objective for ammonia and this is expected to prevent toxic effects downstream in the mixed environment of the Harbour.

The proposed design objectives for the Woodward Wastewater Treatment Plant (WWTP) effluent loadings and the estimated combined sewer overflow (CSO) loadings are consistent with meeting the final RAP loading targets.

	Current Loading (kg/d)	Proposed Loading (kg/d) (% reduction from current)		RAP Final Loading (kg/d) (% reduction from current)		Difference Between Proposed and Final Reductions
Woodward WWTP						
Ammonia	2971	1000	(66%)	530	(82%)	**16 %**
Total Phosphorus	207	74	(64%)	60	(71%)	**7 %**
Total Suspended Solids	6918	1488	(78 %)	900	(87%)	**9 %**
CSO System						
Ammonia	117	48	(59%)	20	(83%)	**24 %**
Total Phosphorus	46	8	(83%)	5	(89%)	**6 %**
Total Suspended Solids	2396	329	(86%)	200	(92%)	**6 %**

Conclusions

The Hamilton Harbour RAP Technical Team has reviewed the loadings proposed by the City of Hamilton regarding upgrades to the Woodward WWTP and CSO system. It is the RAP Technical Team's opinion that the loadings proposed will allow for the remediation of Hamilton Harbour to the environmental conditions sought by the Remedial Action Plan. Therefore, the Hamilton Harbour RAP Technical Team gives its support to the City of Hamilton's proposed wastewater system upgrades – a vital component to achieving delisting in 2015.

In particular, for the Woodward WWTP and the CSO system, the RAP Technical Team supports the following:

	Total Suspended Solids	**Total Phosphorus**	**Ammonia**
Woodward WWTP Proposed Design Objective Loadings	1488 kg/d	74 kg/d	1000 kg/d
CSO Estimated Loadings	329 kg/d	8 kg/d	48 kg/d

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Acronyms

AOC	Area of Concern
BAIT	Bay Area Implementation Team
CSO	Combined sewer overflow
DO	Dissolved oxygen
EA	Environmental Assessment
GLWQA	Great Lakes Water Quality Agreement
GRIDS	Growth Related Integrated Development Strategy
ha	hectare
HHRAP	Hamilton Harbour Remedial Action Plan
HHWSP	Hamilton – Halton Watershed Stewardship Program
IJC	International Joint Commission
ML/d	Megalitres per day
µg	microgram
mg/L	milligram per Litre
N	Nitrogen
NH_3	Ammonia
OECD	Organization for Economic Cooperation and Development
P	Phosphorus
ppm	parts per million – same as mg/L
RAP	Remedial Action Plan
STP	Sewage Treatment Plant – preferred term is now Wastewater Treatment Plant
TP	Total phosphorus
TSS	Total suspended solids
WWTP	Wastewater treatment plant

1. Background

1.1 Areas of Concern

The International Joint Commission (IJC) is an independent, binational organization created in 1909 to oversee and advise on boundary water use and quality issues between Canada and the United Sates (IJC 2004). Between 1985 and 1989 the IJC identified 43 degraded water bodies on the Great Lakes as Areas of Concern (AOC). These were geographic sites that failed to meet the 14 beneficial uses listed in Annex 2 of the 1987 Great Lakes Water Quality Agreement (IJC 1987, p.24). Each AOC was to locally develop and implement a Remedial Action Plan (RAP) divided into three stages:

Stage 1: Environmental Conditions and Problem Definition (What's Wrong?)
Stage 2: Goals, Options and Recommendations (What Is Going To Be Done About It?)
Stage 3: Evaluation of Remedial Measures and Confirmation of Restoration of Uses (Proof Things Have Changed).

1.2 Hamilton Harbour Remedial Action Plan

Hamilton Harbour is a 2,150 hectare (ha) embayment of Lake Ontario connected to the lake by a single ship canal across the sandbar that forms the bay. The conditions in the Harbour reflect natural inputs, human activities, land uses and drainage from the watershed of 49,400 ha. The watershed is drained by three main tributaries: Grindstone Creek, Red Hill Creek, and Spencer Creek. There are four wastewater treatment plants (WWTPs) that currently discharge to the Harbour: Skyway WWTP (Region of Halton), Woodward WWTP (City of Hamilton), Dundas WWTP (City of Hamilton), and Waterdown WWTP (City of Hamilton).

The IJC identified Hamilton Harbour as an AOC in 1985 (IJC Board 1985, p. 204). Issues such as poor water quality, beach closures, toxic sediment, fish health, fish edibility, fish population stress and loss of habitat were listed as concerns. The Ontario Ministry of the Environment (OMOE) released a report in August 1985 detailing the results of previous studies and setting out a number of options for future remedial actions for Hamilton Harbour, entitled *Hamilton Harbour Technical Summary and General Management Options*. In April 1986 the OMOE announced that a public consultation process would be used in Hamilton Harbour's restoration (Land Use 1986, p.5). In July 1986, the Federal Department of the Environment and the OMOE sponsored a meeting of 45 stakeholders – principal organizations, industries and groups from around the watershed. They were asked to develop a set of recommendations for water quality and desired uses to provide input into the Hamilton Harbour Remedial Action Plan (Land Use 1986, pp. 3-4).

A scientific writing team released the *Hamilton Harbour RAP Stage 1 Report* in 1989 with an update completed in 1992 (HHRAP 1989, 1992a). The *Hamilton Harbour RAP Stage 2 Report* was released in 1992 with a set of 50 recommendations to guide remediation efforts (HHRAP 1992b). The stakeholders were brought together again and produced the *Hamilton Harbour RAP Stage 2 Update 2002*, this time with a set of 57 recommendations and 159 associated tasks with timelines and responsible agencies (HHRAP 2003). In 2006, the Bay Area Implementation Team (BAIT) prepared a 2006-2011 Workplan which expanded on the 2002

Stage 2 Update by adding a further 183 tasks with timelines and responsible agencies, including identifying the lead agency (BAIT 2006).

The stakeholder's vision for Hamilton Harbour is as follows:

> People living in the Harbour's watershed have a vision of Hamilton Harbour as a vibrant centrepiece in their community's life. They look towards a time when the environment will be balanced, friendly, accessible, clean and humming with diversity. They see the pleasure of recreation mixed with prosperity from use of the Harbour as an essential marine transportation link. They hope that what is a vision for them will be reality for generations to come. (HHRAP 2002, p. 19)

The RAP Stakeholders set out three primary principles for the RAP: ecosystem approach, zero discharge of inputs of persistent toxic substances, and sustainable communities. An ecosystem approach refers to "a holistic, (emphasizing the organic or functional relation between part and wholes) basin wide approach to planning, research and management" (Land Use 1986, p. 8). It is intended to integrate social, economic and environmental matters. As an example, with the goal to create a warm-water fishery in Hamilton, everything connected to this needs to be addressed in the clean up including: water quality, fish habitat (aquatic vegetation), food chain links (benthos, phytoplankton, zooplankton), and fish health. If even one piece of the puzzle is overlooked then it may not be possible to fully achieve the goal.

From the beginning, it has been firmly held by RAP stakeholders that moving wastewater discharge to Lake Ontario would only be considered as a last resort. It was recommended in 1986 that "the proposal to re-direct sewage treatment plant effluent to Lake Ontario be rejected due to its impact on Lake Ontario, and it being, at best, a short-term, "band-aid" solution to Harbour water quality" (Land Use 1986, p. 13). Recommendation # 50 in the *1992 Stage 2 Report* states "that diversion of STP effluent to Lake Ontario be considered only after all other technically feasible and practical options have been implemented" (HHRAP 1992b, p.153).

Delisting Hamilton Harbour as an Area of Concern will have many benefits. The stigma associated with being a "dirty place" has an economic cost to the community such as not being able to attract the best and the brightest to live and work. A marked reduction in "eutrophication aspects are important for the plan to restore aesthetics, recreational uses, hypolimnion oxygen, and plant/fish habitat" (Charlton 2001, p. 4069). A decrease in nutrient input to the Harbour will allow the community to enjoy benefits ranging from fewer algal blooms (some of which are smelly, unattractive, and potentially toxic), to the simple act of being able to see their feet when they swim at the beaches. The Hamilton Harbour RAP is on target to delist as an AOC in 2015.

2. Report Scope and Context

2.1 Scope of Report

The 1992 Stage 2 Report recognized that there would be a need to review the reaction of the Harbour conditions to initial remedial actions so that "…[confidence] in our ability to predict changes be improved by analysis of these data and by development of more comprehensive models" (HHRAP 1992b, pp. 144-145). Further in the Stage 2 Report this idea was again reiterated with specific reference to upgrades at the wastewater treatment plants:

> …it seems prudent to carefully monitor the changes in the Harbour as the sewage treatment plants install each phase of their remedial program. Given the precision of current predictions, the observed conditions will be a better gauge of the effectiveness of the strategy and the first phases will sharpen the precision of our predictive capability for the generally more costly final stages. (HHRAP 1992b, p. 164).

The Water Quality Task Group working on the 2002 Stage 2 Update reaffirmed this need to revaluate by recommending that "…the final loading targets be reviewed once the initial targets have been met and some analysis of corresponding conditions can be completed" (HHRAP 2003, p. 37). The task group also included a long term target, WQ – 1b.2, stating: "Final targets as listed in Table WQ – 1b are to be met by 2015. Subject to a full assessment by BARC and BAIT of the utility and cost of measures required to reach these final targets" (HHRAP 2003, p. 37).

The Hamilton Harbour RAP has been designed to more effectively implement remedial actions by utilizing research and monitoring to: track trends, promote adaptive management, develop interdisciplinary integration, and increase public accountability. Using trend data generated over time, it is possible to track water quality improvements in the centre of the Harbour and link them to major upgrades when they have occurred at the two large WWTPs, Skyway and Woodward. Adaptive management is important to the RAP process as it ensures that the best possible solutions are being used for the restoration of the Harbour based on existing data. The stakeholder process of the RAP promotes interdisciplinary integration through committees such as the RAP Technical Team to collaborate on the monitoring and modification of remedial actions. Finally, a continued focus on research and monitoring increases accountability to the public by helping to justify the cost and time expenditures required to carry out remedial actions. (Hall 2006, pp. 235-239)

As initial water quality goals for the Harbour are now generally being met, the time has come for the re-evaluation of final water quality goals and targets. This re-evaluation of water quality goals and loading targets will be completed in two parts:

- Part 1: A response to the City of Hamilton's wastewater system upgrade plan to determine if their proposal will accomplish the necessary loading reductions to meet RAP final water quality goals. This will be done in a summary report and a technical appendix.
- Part 2: A response to the water quality review recommendations posed by the BAIT 2006-2011 Workplan, including the finalization of water quality goal (i.e. dissolved oxygen) and loading target changes. This will include a determination of what

long term assessment, monitoring, and/or modelling will be necessary to delist the beneficial use impairment associated with eutrophication.

2.2 Context of Report

2.2.1 Quantitative vs. Qualitative

The framework for a RAP is a two part process – qualitative objectives are selected by a wide group of stakeholders, then scientists translate these to quantitative targets. Zarull (2000a) phrased it in this way:

> The objectives will, in narrative form, describe desirable conditions and will reflect social values and long-term visions for the ecosystem state. The process is, therefore, a social-political one, rather than technical, although technical input is essential to ensure that the vision has a foundation in the realm of ecological possibilities and scales… The selection of indicators and numerical targets is a technical process that requires expert input based on both historic and current knowledge of ecosystem structure, function and performance. (Zarull 2000a, p. 2346)

An example of a qualitative objective set by stakeholders is to improve water quality to move away from a eutrophic system by achieving improved aesthetics, water clarity, and warm-water fishery. The corresponding quantitative targets set by scientists are the water quality goals and loading targets outlined in the Stage 2 Report for phosphorus, ammonia, total suspended solids, Secchi depth, chlorophyll a, and aquatic plant habitat area (HHRAP 2003, pp. 26-27).

2.2.2 Historical Explanations of Choices

The Appendix A to this report is a Technical Appendix (RAP Tech Team 2007) that re-examines the original decisions made by the scientific writing teams of the Stage 1 and Stage 2 reports. Up to this time, a clear documentation of this process has been considered lacking and the technical support document attempts to rectify this. In some cases finding the exact model, estimate, or data used to select these goals and loading targets was not a straightforward process. Likely pathways have been established, but unfortunately the original participants who were contacted for this review have been unable to recall some details needed for certainty. In no case has it been shown that the goals and loadings previously set were unreasonable, except perhaps the final dissolved oxygen goal of > 4 ppm and this has been a concern for scientists long before this review.

2.2.3 Uncertainties

One criticism of the RAP water quality goals and loadings has been the omission of uncertainty. Biological ecosystems and the weather are intrinsically variable and can affect the response to restoration efforts in Hamilton Harbour. In addition to normal season weather patterns, Lake Ontario water levels have been artificially controlled by the IJC to meet a variety of purposes. The effect of the introduction of invasive species such as zebra mussels have not been examined yet. Climate change (e.g. global warming) is an emerging environmental concern

which affects the Hamilton Harbour system; however, managing the pace of climate change is much bigger than can be addressed by any one AOC. The models and regression equations used towards determining RAP goals, targets and environmental outcomes have uncertainty associated with them; however, this uncertainty is not currently acknowledged with ranges or error bars. There is some uncertainty associated with the quality of historical data. As monitoring methods have improved over time, so has the quality of the data (e.g. a change in sampling location at Woodward WWTP in 2000 better represents effluent loadings, which had previously been underestimated).

The RAP Technical Team will be exploring the possibility of moving from point based goals and targets to ranges. Ranges would take into account inherent system variability and the uncertainty associated with methods used to determine a single point. This discussion will occur in the preparation of Part 2 of this report series.

2.2.4 Point sources vs. Non-point sources

Historically, the Hamilton Harbour RAP has been focused on the control of point source loadings to the system. Point sources such as the WWTPs, combined sewer overflows (CSOs), and industry have been understood to represent a large proportion of the loading contributions to the Harbour, is the easiest to quantify, and, to a certain extent, to control. Furthermore, there is a higher confidence in the results that can be achieved as a result of remedial actions on point sources as demonstrated through the work of Charlton (1997). Plotting the combined Hamilton and Burlington WWTP effluent phosphorus loads versus the measured phosphorus concentration in Hamilton Harbour, Charlton (1997) found that "initial and final goals of the RAP for ambient phosphorus concentrations in the harbour can be approached largely by phosphorus load reductions at the Hamilton and Burlington [WWTPs]" (Charlton 1997, p. 415). This is due to the dominance of these sources to Harbour phosphorus loads.

As control on point sources have been put into place, the balance has been shifting to non-point sources representing a growing portion of the total contribution. The challenge in this is non-point sources are inherently variable, as they are dominated by unpredictable rainfall/runoff events; therefore, even with the best controls in place, non-point sources will continue to vary from event-to-event and year-to-year.

Despite the focus on point sources, controls on non-point sources of nutrients to Hamilton Harbour are important in reducing the total Harbour load. These controls are being pursued through a number of initiatives including: source water protection led by the Conservation Authorities, stormwater master plans led by the municipalities, and the Hamilton-Halton Watershed Stewardship Program (HHWSP). The HHWSP works with land owners to achieve voluntary agreements to practice sustainable activities on environmentally significant areas of their property.

2.2.5 Focus on Phosphorus

Addressing eutrophication in Hamilton Harbour has focused on phosphorus loadings. A reduction in phosphorus will have a positive impact on chlorophyll *a* concentrations and Secchi

disc depths. The importance of phosphorus loads to Harbour water quality was reiterated by Charlton (1997) in that a "full reduction of phosphorus loading to RAP final phosphorus load goals at the Hamilton and Burlington [WWTPs] will be needed to achieve RAP water quality goals" (Charlton 1997, p. 419). Field data from 1997 strengthened the connection between chlorophyll *a* and water clarity with a period of "…Secchi depths of over 5 m…This unprecedented period of clear water [during a time of zooplankton abundance] shows that there are no unusual causes of turbidity in the harbour; algae cause the problem" (Charlton 2001, p. 4070). Phosphorus is a well established predictor of algae growth which is measured through chlorophyll *a*.

Scientists generally have chosen to measure total phosphorus (TP) in Hamilton Harbour instead of the more biologically available soluble reactive phosphorus, because TP is the more reliable and routinely measured form of phosphorus.

2.2.6 Annual Loadings and Monthly Concentrations

The operation of biological wastewater treatment plants is complex. They are not only subject to very wide ranges in the quantity and quality of incoming wastewaters, but these variations occur on an hourly, daily and seasonal basis. It is easy to be distracted by relatively small upsets into the Harbour system; however even though one-half of the water flowing into the Harbour is treated wastewater with concentrations 10–20 times greater than ambient water, this is partly assimilated by processes in the Harbour and some dilution by inflowing streams (Charlton 1997, p. 411). An upset would need to be continued over a period of days or weeks, not hours, for there to be any noticeable response in ambient Harbour waters (Charlton personal communication 2007). The models used to determine the RAP water quality goals and corresponding loading targets utilize annual averages. They are not capable of representing the certainty necessary to use instantaneous measurements. Thus it is important to keep the larger picture in mind when in the midst of an isolated event.

The seasonal variation in flow makes it impractical to set a loading target for a WWTP with a short averaging time frame for such as weekly or monthly averages. The RAP Technical Team believes that an annual average loading is sufficient. To keep closer tabs on WWTP performance, a monthly average concentration target could be set; this will be discussed in Part 2 of this report series.

2.2.7 Water Quality Expectations

If ten people were surveyed about what they felt water quality would look like after successful implementation of the Hamilton Harbour RAP, it is likely ten different answers would be heard. Successful restoration of AOCs does not mean a return to pre-settlement conditions. Even the IJC "recognize[s] that the AOCs will not be restored to pristine conditions, but rehabilitated to a 'desired future state'" (Zarull 2000b, p. 2349).

It is certain Hamilton Harbour cannot become an oligotrophic system like Lake Superior. Using the Organization for Economic Cooperation and Development (OECD) study of eutrophication from 1970s, Charlton compared Hamilton Harbour with other lakes worldwide to

show RAP final goals will achieve between a trophic level between mesotrophic (for phosphorus and chlorophyll goals) and eutrophic (for Secchi depth) (HHRAP 2003, p.36). This work helps to reassure that the aspirations set by the original RAP stakeholders are realistic and such their achievement would be a satisfying and visibly worthwhile improvement.

Education of the public and politicians should not be limited to what caused the problems and what can be done; the discussions need to include a realistic picture of what a remediated Harbour will or should look like.

3. Present State of the Harbour

3.1 Water Quality Goals and WWTP Loading Trends

This section is a reproduction, with permission, of: Charlton, M. and Milne, J. 2007. "Water Quality Update 2006". Hamilton Harbour Remedial Action Plan Research and Monitoring Report: 2006 Season.

Since the late 1980s [the National Water Research Institute of Environment Canada has] measured water quality parameters at a station in the center of Hamilton Harbour. Traditional samplers were used for chemistry and chlorophyll and electronic profilers were used for temperature, pH, and, dissolved oxygen. Several water samples were taken at various depths but only surface data are shown here. A simple suite of parameters has been chosen to relate most directly to decisions about nutrient control.

Figure 1 shows Total Phosphorus (TP) data. Considerable seasonal variation often results in lower concentrations in Spring and Fall and higher values in summer. This may be due to differential mixing and lake exchange depending on seasonal variation in relative density of wastewater inflows. To avoid premature de-listing due to averaging out deleterious summer data the summer was chosen as the criterion period. Some higher peaks in the earlier data which fell outside the criterion period may have been due to CSO events which are now largely corrected [in the Cootes Paradise area, with some more work to do to Harbour CSOs]. Figure 2 shows the data in the summer HHRAP criterion period of June, July, and, August. Although, since the late 1990s, there have been more TP values below the initial goal of 34 µg/L, particularly in 2004, none of the years had data consistently below the initial goal.

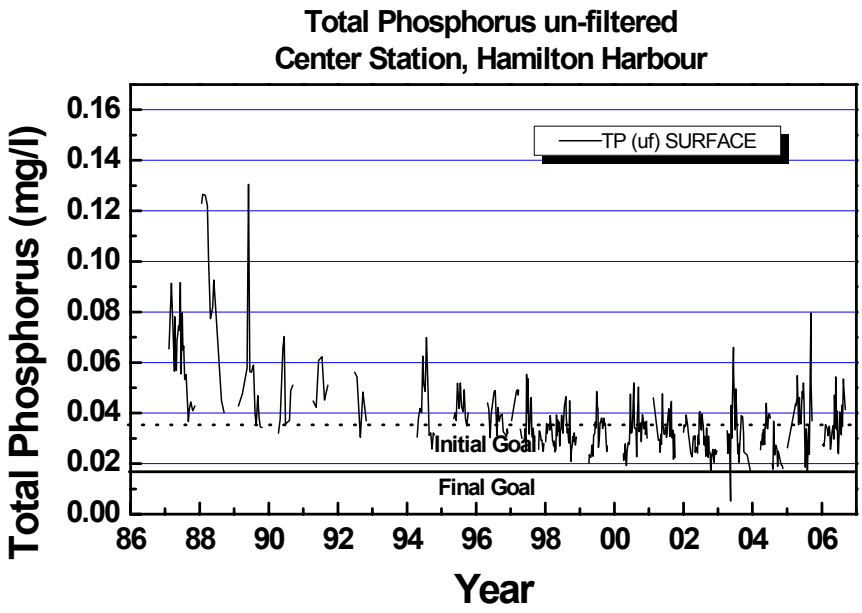


Figure 1. Total Phosphorus Concentrations (1987-2006)

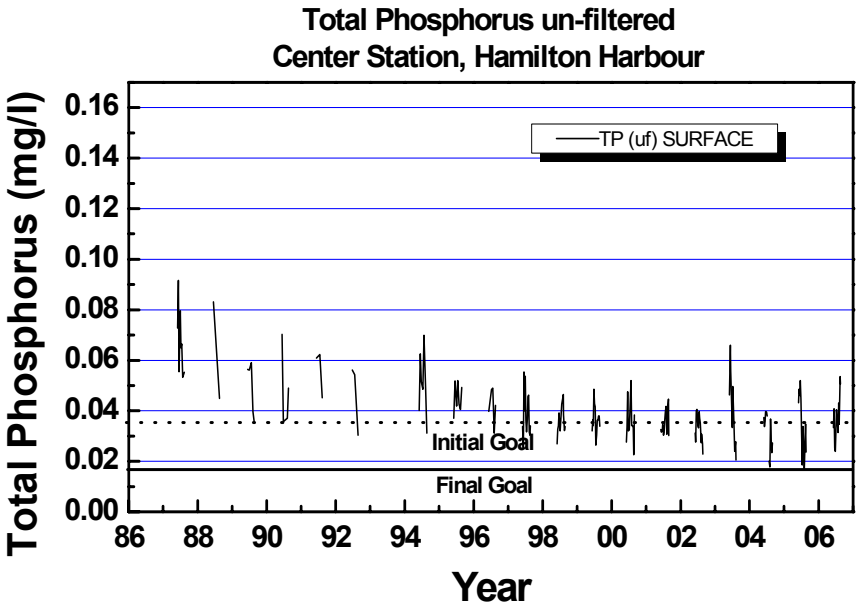


Figure 2. Total Phosphorus Concentrations - June July August (1987-2006)

Similar, to TP, Chlorophyll concentrations often peak in summer. Figure 3 shows the concentrations in the criterion period are more often below the initial goal and into the final goal range. These better concentrations are however counterbalanced by peaks that tend to be caused by blue-green algae blooms. In 2006 a blue-green bloom began in mid-July and persisted until the end of September.

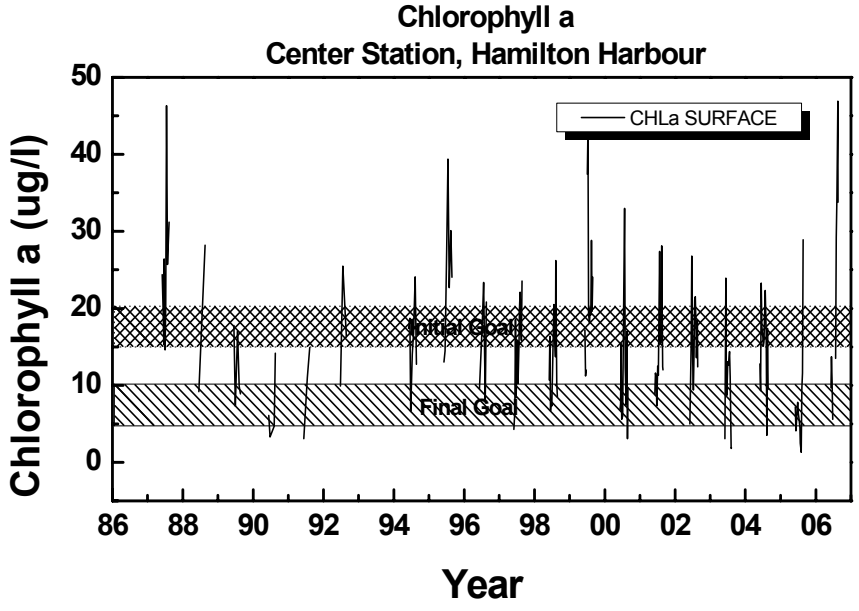


Figure 3. Chlorophyll *a* Concentrations (1987-2006)

Figure 4 shows that water transparency as measured by Secchi [disc depth] has increased in the summer period since the late 1990s. Extremely high readings in 1997 were caused by an unusually high zooplankton population; this indicates that much of the turbidity is algal. The

blue-green algae blooms do not always cause low Secchi disk readings because the algal colonies are large enough to present less of an impediment to light penetration than more diffuse smaller particles. In 2006, a smaller colonial form of blue-green bloom corresponded with less transparency.

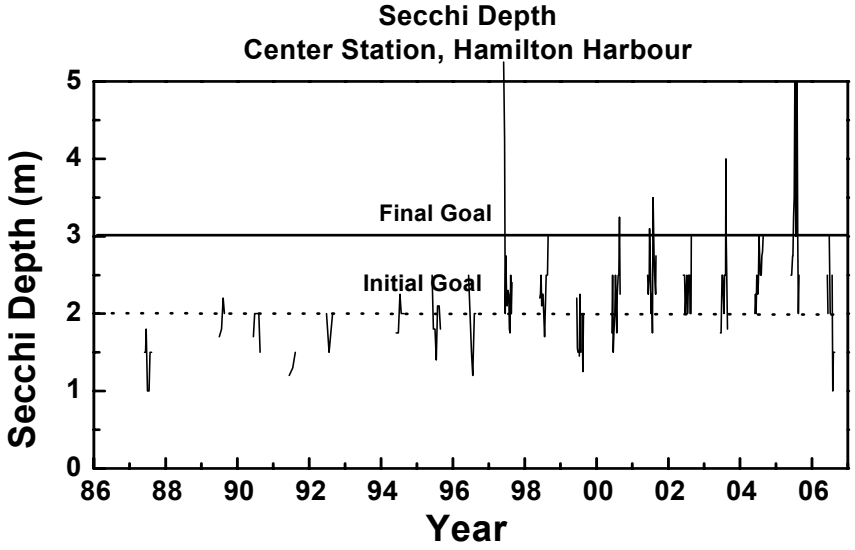


Figure 4. Secchi Depth (1987-2006)

Figure 5 shows that unionized ammonia still tends to briefly exceed the goal. These data do not pertain to the summer period but rather to all the data we have been able to produce. The peak corresponds with a late decline in total ammonia offset by increasing temperatures and pH which force the equilibrium between ammonia forms toward the [more toxic] unionized. Ammonia loads come mainly from waste water treatment plants.

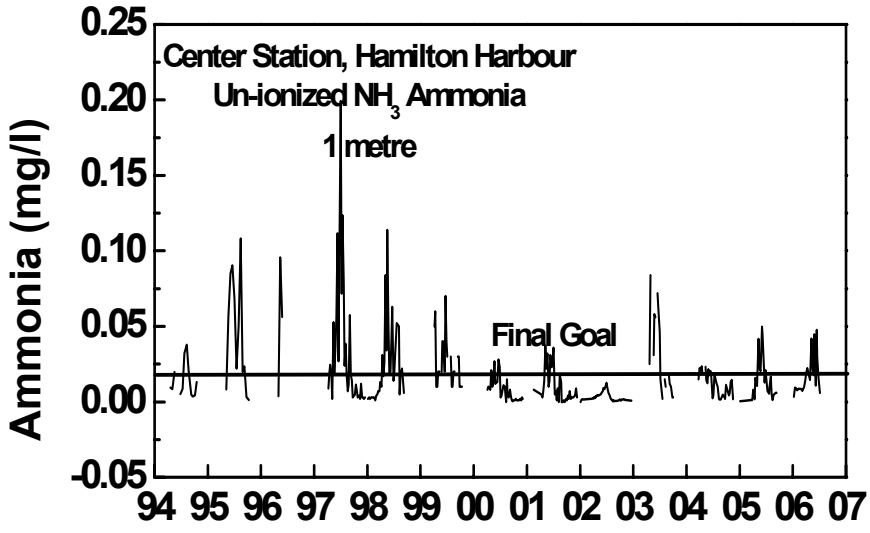


Figure 5. Un-ionized NH_3 Ammonia (1994-2006)

Figure 6 shows that there has been a tendency for a decreased period of deleterious low oxygen conditions in the cool lower water layer (hypolimnion). This is expectable due to

decreased nutrient loads and decreased algal populations. However, there must be a considerable background oxygen depletion naturally plus influences of urban effects such as unavoidable runoff that will exacerbate oxygen depletion so that the goal of a hypolimion hospitable to fish year round may be unattainable.

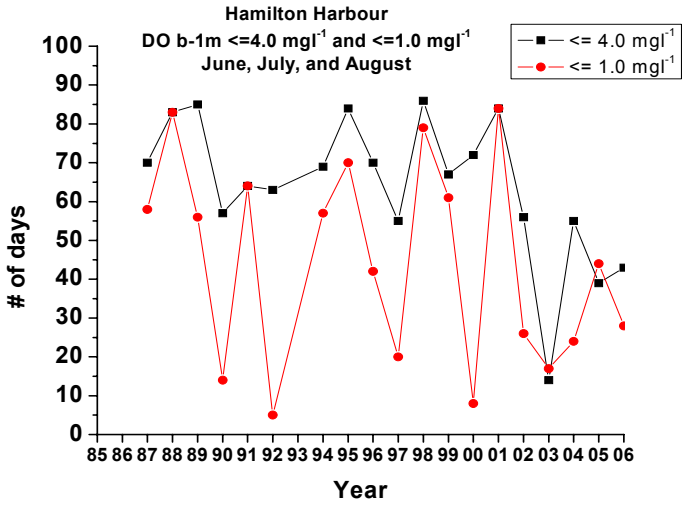
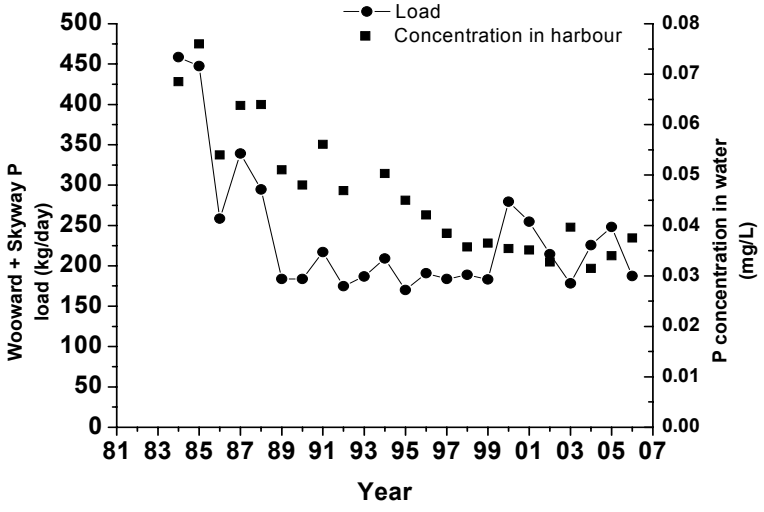


Figure 6. Dissolved Oxygen Levels - June July and August (1987-2006)

Figure 7 shows the combined load from the Woodward and Skyway wastewater treatment plants compared to summer mean phosphorus concentrations. Water concentrations responded strongly to load reductions. There is a lag in Harbour water response to load reduction that may be caused by the time required to decompose recently formed organic matter such algae that contain phosphorus.



[Notes: In 2000, Woodward relocated their sampling location to correct an underestimation. In 2004 and 2005, Woodward experienced upset conditions.]

Figure 7. Phosphorus Load from Woodward and Skyway with Summer Water Phosphorus Concentration in the Harbour (1984-2006)

4. City of Hamilton's Proposed Plan

The City of Hamilton has been developing strategic policies to deal with future growth scenarios, mainly through GRIDS – Growth Related Integrated Development Strategy. The Water and Wastewater Master Plan "is a critical component in the integrated GRIDS process and provides the framework and vision for the water and wastewater servicing needs for the City" for the 2031 planning period (KMK 2007, p. 1). Phases 1 and 2 of the Class Environmental Assessment (EA) Process have been accomplished with this Master Plan. The City is moving forward with Phases 3 and 4 of the Class EA planning study for the Woodward WWTP upgrades and expansion as well as the CSO management strategy.

The City of Hamilton used a "Triple Bottom Line" approach to select a preferred option for upgrades at Woodward WWTP and the CSO system. This provides the City with a way to find an optimum balance between environmental, social and economical criteria (KMK 2007, p. 1). At some point, further gains in environmental performance become economically impractical in a cost-benefit analysis.

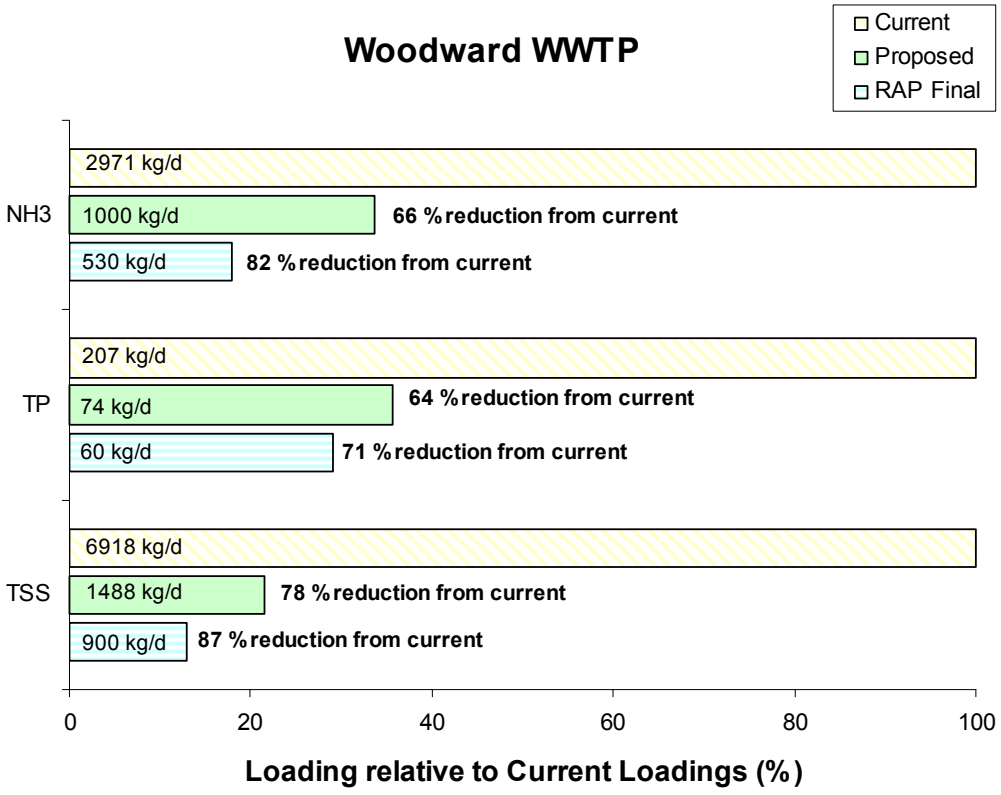
The proposed design objectives of the upgraded and expanded Woodward WWTP are presented in Table 1 with concentrations and loadings at an average daily design flow of 500 ML/d shown in comparison to RAP final targets. The City purposefully used the RAP final loading targets when developing their design objectives.

Table 1: Proposed Woodward WWTP Effluent Design Objectives

Parameter	Proposed Design Objectives		RAP Final Loading Targets	
	Design Objective	Corresponding Loadings at 500 ML/d	Final Loading Target	Corresponding Effluent Concentration at 500 ML/d
Total Suspended Solids	3 mg/L	1,488 kg/d	900 kg/d	1.8 mg/L
Total Phosphorus	0.15 mg/L	74 kg/d	60 kg/d	0.12 mg/L
Ammonia-N	2 mg/L (May to November)	1,000 kg/d	530 kg/d	1.0 mg/L

Source: KMK 2007, pp. 10-11

As demonstrated in Figure 8, the proposed total suspended solids (TSS) loading target for Woodward WWTP represents a 78% reduction from current loadings, a difference of 9% from RAP final target reductions. The proposed total phosphorus (TP) loading target for Woodward WWTP represents a 64% reduction from current loadings, a difference of 7% from RAP final target reductions. The proposed ammonia (NH_3) loading target for Woodward WWTP represents a 66% reduction from current loadings, a difference of 16% from RAP final target reductions. All of the proposed loading reductions for Woodward WWTP and the CSOs will be substantial improvements from current conditions.



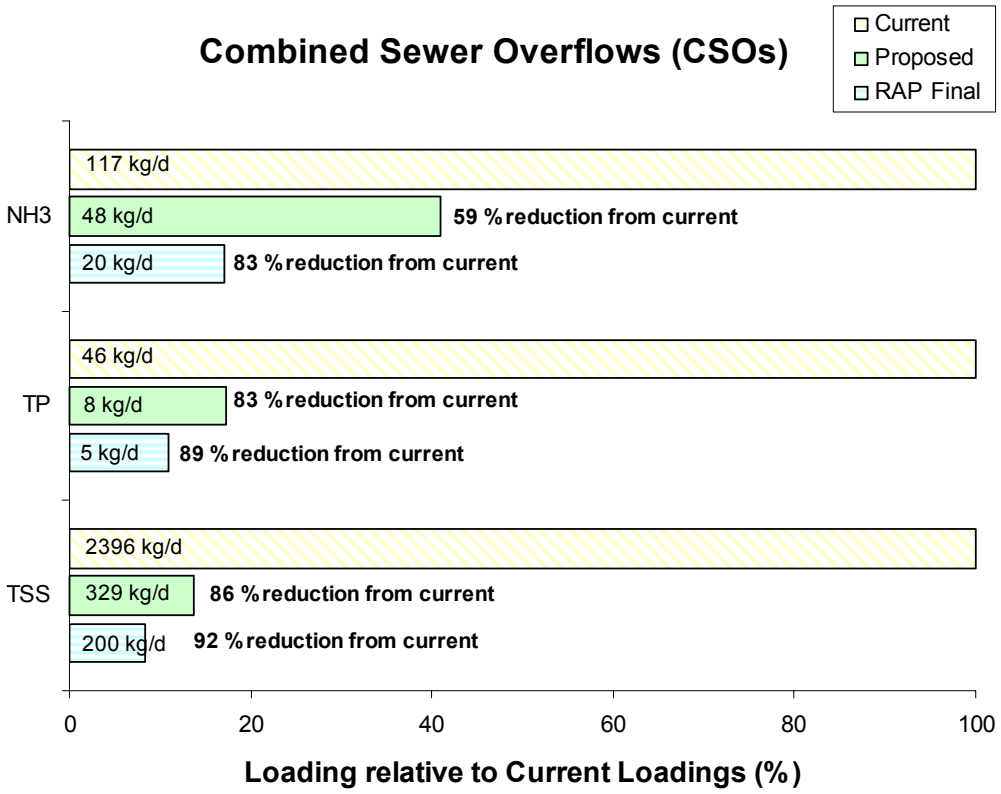


Figure 8: Proposed Woodward WWTP and CSO Loadings Relative to Current

5. Hamilton Harbour RAP Goals and Loadings Reviewed

An in depth technical review of the original development of the Hamilton Harbour RAP concentration goals and loading targets was prepared in conjunction with this summary report. Details on each of the water quality parameters (suspended solids, phosphorus, ammonia, and dissolved oxygen) can be found in Appendix A - Technical Appendix. This section only provides conclusions of the review and the opinions provided regarding the City of Hamilton proposal. Several representatives from the Hamilton Harbour RAP and Environment Canada had been part of the City of Hamilton's Phase 1 and 2 processes and did not alert the Technical Team to any concerns. Therefore, during this review the RAP Technical Team has taken the work of KMK Consultants Limited at face value and has not been evaluated. It is assumed the work is valid and represents a best effort for the City of Hamilton to move forward.

Although the following water quality parameters relate to one another, for the purpose of clarity, it was necessary to present them as separate issues in this report. Part 2 of this report series will attempt to integrate the water quality parameters by looking at additive effects such as the impact of ammonia and phosphorus on hypolimnetic dissolved oxygen.

5.1 Suspended Solids

Table 2: Suspended Solids – Final Goals, Targets, and Proposed Effluent

Harbour Final Goal		RAP Final Target	RAP Final Target (Concentration at 500 ML/d)	Proposed Concentration	Proposed (WWTP at 500 ML/d) or Projected (CSO) Loading
n/a	Woodward	900 kg/d	1.8 mg/L	3 mg/L	1,488 kg/d
	CSO	200 kg/d			309-329 kg/d

Source: KMK 2007, pp. 10-11, 13

The RAP final loading target (900 kg/d) for Woodward WWTP would translate into a final effluent concentration requirement of approximately 1.8 mg/L at 500 ML/d flow; however the City is proposing a final effluent concentration of 3 mg/L or loading of 1,488 kg/d (Table 2). Going beyond current proposed effluent objective (3 mg/L) to meet RAP final loading targets (~1.8 mg/L) would significantly increase WWTP capital and operating costs for benefits which are not clearly linked to receiving water quality conditions in the harbour. Although it is likely that through meeting the RAP loading targets for phosphorus, WWTP effluent will also see a net reduction in suspended solids loading, any reduction in phosphorus loadings is, and should remain, a nutrient loading issue linked to the nutrient status of the harbour.

The substantial suspended solids reduction proposed by the City of Hamilton from 6918 kg/d to 1488 kg/d is supported by the RAP Technical Team. It is recommended that the RAP suspended solids final loading targets for the Harbour from WWTPs and CSOs be addressed indirectly though measures specifically developed for phosphorus removal and best available technology as presently proposed by the City of Hamilton.

5.2 Phosphorus

Table 3: Phosphorus – Final Goals, Targets, and Proposed Effluent

Harbour Final Goal		RAP Final Target	RAP Final Target (Concentration at 500 ML/d)	Proposed Concentration	Proposed (WWTP at 500 ML/d) or Projected (CSO) Loading
17 µg/L	Woodward	60 kg/d	0.12 mg/L	0.15 mg/L	74 kg/d
	CSO	5 kg/d			8 kg/d

Source: KMK 2007, pp. 10-11, 13

The Technical Appendix (Appendix A) presents a detailed discussion on the background of the total phosphorus water quality goals. Further work is required in Part 2 of this series to quantify the uncertainties associated with a single point goal and potentially explore replacing this with a range. This exercise will help demonstrate that the current final water quality target of 17 µg/L will encourage substantial water quality improvements while realizing that results approximating this level can achieve RAP goals. It should be noted the provincial water quality objective for total phosphorus is 20 µg/L.

The City of Hamilton is proposing an effluent design objective of 0.15 mg/L for total phosphorus, which equates to 74 kg/d at a flow of 500 ML/d. This is above the RAP final loading targets of 60 kg/d (equates to 0.12 mg/L at 500 ML/d), but a substantial improvement over current loadings of 207 kg/d. The design objective of 0.15 mg/L is contingent on efficiency of suspended solids removal, which has been recommended as 3 mg/L TSS as a design criterion (KMK 2007). The TP loading from the Woodward WWTP is proposed at a level approximately an order of magnitude lower than current values. It is significant that the City of Hamilton is using best available technology for their proposed upgrades and reaching effluent TP concentrations (~0.15 mg/L) that were expected during the early development of the RAP (i.e. TP concentrations are on par with that obtained through the installation of sand filters/dual point injection).

The RAP Technical Team supports the total phosphorus loading proposed by the City of Hamilton. The load reductions are expected to improve conditions in Hamilton Harbour to a level consistent with the intended RAP goals addressing the water clarity beneficial use impairment (BUI).

5.3 Ammonia

Table 4: Ammonia – Final Goals, Targets, and Proposed Effluent

Harbour Final Goal		RAP Final Target	RAP Final Target (Concentration at 500 ML/d)	Proposed Concentration	Proposed (WWTP at 500 ML/d) or Projected (CSO) Loading
< 0.02 mg/L un-ionized	Woodward	530 kg/d	1.0 mg/L	2 mg/L (May to November)	1,000 kg/d
	CSO	20 kg/d			48 kg/d

Source: KMK 2007, pp. 10-11, 13

The provincial water quality objective (PWQO) for un-ionized ammonia is 0.02 mg/L, which was a concentration set to be "protective of all forms of aquatic life and all aspects of the aquatic life cycle during indefinite exposure to the water" (MOE, 1994). While the PWQO is protective of chronic (long-term) toxicity effects, un-ionized ammonia is generally a concern when addressing acute toxicity, or the severe, short-term effects that can be had on the resident fish populations (e.g. fish kills). The un-ionized ammonia concentration at which acute toxicity is of concern, is well above (i.e. approximately 5-10 times) the PWQO. Concentrations of un-ionized ammonia in water bodies are generally compared against the PWQO rather than the acute toxicity limit because the PWQO is the desired upper limit according to provincial policy (MOE, 1994) and because this method is more protective of aquatic life.

In Hamilton Harbour there are still periods when un-ionized ammonia concentrations exceed the PWQO. It should be noted that the un-ionized ammonia data are based on a few instantaneous measurements, and therefore may not reflect the long-term trends in the harbour. The peaks in the data were generally measured during the April – August period, with June having the greatest frequency of measured peaks, indicating that this is likely the most difficult time of year to eliminate ammonia toxicity impacts.

The Technical Appendix (Appendix A) reports that finding a clear relationship between ammonia loads and harbour concentrations is complex. One cannot control overall harbour processes (i.e. temperature and pH impacts) and/or ammonia internal loading from the sediment (i.e. historical sources). Regarding toxicity concerns, if point source ammonia concentrations meet or come close to the PWQO (chronic guideline), then clearly this will address acute toxicity concerns at the point of discharge. An ammonia loading target requiring an effluent capable of meeting the PWQO from the Woodward WWTP does not appear to be required from a RAP or regulatory perspective.

A complication for RAP Tech Team efforts to confirm a total ammonia loading target is the natural variability in the harbour (pH, temperature, etc.) which can result in a range of peak un-ionized ammonia concentrations as a function of one particular annual ammonia loading value. The Woodward WWTP is proposing a final effluent total ammonia concentration of 2 mg/L from May – November (KMK 2007, p. 18).

Of note is the time period on which the Woodward WWTP design objective was based, as May to November corresponds to the period of concern to the RAP due to the greatest frequency peaks measured in summer. As seen in Table 5 for temperature and pH values common in Hamilton Harbour, the un-ionized ammonia concentration corresponding to a total ammonia concentration of 2 mg/L during the criterion period, will meet the PWQO much of the time. This means that the proposed ammonia effluent concentration from Woodward WWTP will generally meet a more stringent chronic guideline intended to be applied to lakes, not effluent. This point and the large proposed reduction in ammonia loading to the Harbour are significant, positive accomplishments.

Table 5: Concentration of un-ionized ammonia (mg/L) at a total ammonia concentration of 2 mg/L

Temp (C)	pH 7	pH 8
0	0.00166	0.0164
5	0.0026	0.024
10	0.0038	0.036
15	0.0054	0.054
20	0.008	0.076
25	0.0114	0.108
30	0.016	0.15

Source: MOE 1994

Note: Shaded cells indicate an exceedance of PWQO (0.02 mg/L)

The RAP Technical Team supports the City of Hamilton's proposed ammonia concentration as a positive move towards reducing periods of toxicity. However, due to the relationship between ammonia and dissolved oxygen, it was not possible for the RAP Technical Team to reach a conclusion regarding final ammonia loading targets. The final ammonia concentration target was set lower than the PWQO to improve the complex dissolved oxygen situation in the Harbour; a situation described in the next subsection. This relationship between ammonia and dissolved oxygen will be explored in greater detail by the RAP Technical Team in Part 2 of this report series.

5.4 Dissolved Oxygen

Table 6: Dissolved Oxygen – Initial and Final Goals

Harbour Initial Goal	Harbour Final Goal
> 1 ppm	> 4 ppm

Source: HHRAP 2003, p. 35

Based on the review of the literature that evaluated the historical nature of hypolimnetic dissolved oxygen (DO) depletion in Hamilton Harbour, as well as some updates to reflect the current state of the Harbour, it is not likely the goal of the entire harbour water column to always be above 4 mg/L DO will be met, regardless of WWTP

actions (RAP Tech Team 2007). As such, the RAP recognizes the strides and improvements in effluent loads/concentrations proposed by the City of Hamilton, and therefore give support to the City of Hamilton Wastewater Master Plan from a DO perspective.

In Part 2 of this series of reports, the RAP Technical Team will be proceeding with a re-evaluation of the DO target to determine what goal is biologically meaningful and achievable considering both the natural state of the harbour and inputs anticipated from the watershed and wastewater treatment system. This may include setting temporal and/or spatial goals in regard to DO concentration in Hamilton Harbour. This re-evaluation will be aimed at determining what is a realistic DO goal and what needs to be done to set the updated goal (e.g. modelling).

6. RAP Technical Team Response to City of Hamilton's Proposed Wastewater System Upgrades

The Hamilton Harbour RAP Technical Team has reviewed the loadings proposed by the City of Hamilton regarding upgrades to the Woodward WWTP and CSO system. It is the RAP Technical Team's opinion that the loadings proposed will allow for the remediation of Hamilton Harbour to the environmental conditions sought by the Remedial Action Plan. Therefore, the Hamilton Harbour RAP Technical Team gives its support to the City of Hamilton's proposed wastewater system upgrades – a vital component to achieving delisting in 2015. In particular, for the Woodward WWTP and the CSO system, the RAP Technical Team supports the following:

	Total Suspended Solids	**Total Phosphorus**	**Ammonia**
Woodward WWTP Proposed Design Objective Loadings	1488 kg/d	74 kg/d	1000 kg/d
CSO Estimated Loadings	329 kg/d	8 kg/d	48 kg/d

The Hamilton Harbour RAP Technical Team recommends that the City of Hamilton continue to involve the RAP Technical Team as they proceed with Phases 3 and 4 of the Class EA planning study for the Woodward WWTP upgrades and expansion as well as the CSO management strategy. It also recommends the City of Hamilton continue to participate in the RAP Technical Team to benefit from the team's efforts to: track trends, promote adaptive management, develop interdisciplinary integration, and increase public accountability.

References

Bay Area Implementation Team (BAIT). 2006. *BAIT 2006-2011 Workplan*. June 2006. 58 pp. (Internal Publication)

Charlton, M. and Milne, J. 2007. "Water Quality Update 2006". *Hamilton Harbour Remedial Action Plan Research and Monitoring Report: 2006 Season*. (Not yet published)

Charlton, M.N. 2001. "The Hamilton Harbour remedial action plan: eutrophication." *Verh. Internat. Verein. Limnol.* 27: 4069-4072.

Charlton, M. N. 1997. "The Sewage Issue in Hamilton Harbour: Implications of Population Growth for the Remedial Action Plan." *Water Qual. Res. J. Canada.* 32 (2): 407-420.

Charlton, M.N. 1996. *The Burlington Sewage Treatment Plant Issue: Implications of Expansion for the Hamilton Harbour Remedial Action Plan.* Prepared as advice to the Bay Area Implementation Team and the Bay Area Restoration Council of the Hamilton Harbour Remedial Action Plan. 17 pp.

Charlton, M. Undated. *Hamilton Harbour RAP Goals Compared With Other Lakes*. (Internal communication)

Hall, J.D., O'Connor, K., and Ranieri, J. 2006. "Progress Toward Delisting a Great Lakes Area of Concern: The Role of Integrated Research and Monitoring in the Hamilton Harbour Remedial Action Plan". *Environmental Monitoring and Assessment.* 113: 227-243.

Hamilton Harbour RAP (HHRAP). 2003. *Remedial Action Plan for Hamilton Harbour. Stage 2 Update 2002*. June 2003.

Hamilton Harbour RAP (HHRAP). 1992a. *Remedial Action Plan for Hamilton Harbour: Environmental Conditions and Problem Definition. Second Edition of the Stage 1 Report.* 247 pp.

Hamilton Harbour RAP (HHRAP). 1992b. *Remedial Action Plan for Hamilton Harbour: Goals, Options and Recommendations. Stage 2 Report, Volume 2 – Main Report.* November 1992. 328 pp.

Hamilton Harbour RAP (HHRAP). 1989. *Remedial Action Plan for Hamilton Harbour. Stage 1 Report: Environmental Conditions and Problem Definitions.* March 1989. 162 pp.

International Joint Commission, Great Lakes Water Quality Board (IJC Board). 1985. *1985 Report on Great Lakes Water Quality.* 212 pp.

International Joint Commission United States and Canada (IJC). 2007. *Who We Are.* Accessed May 1, 2007 at http://www.ijc.org/en/background/biogr_commiss.htm

International Joint Commission United States and Canada (IJC). 1987. *Revised Great Lakes Water Quality Agreement of 1978: Agreement, with Annexes and Terms of Reference, Between the United States of America and Canada.* November 1987. 64 pp.

KMK Consultants Limited. 2007. *City of Hamilton. Summary Report on Woodward Avenue WWTP Wastewater Treatment and Combined Sewer Overflow (CSO) Management Strategy. Water and Wastewater Master Plan.* February 2007. 16 pp.

Land Use Research Assoicates. 1986. *Interim Report. Hamilton Harbour's Water Quality: The Stakeholders's Proposals*. September 1986. 31 pp.

RAP Technical Team (RAP Tech Team). 2007. *Hamilton Harbour RAP Water Quality Goals and Targets Review. Part 1: Response to City of Hamilton's Proposed Wastewater System Upgrades. Appendix A: Technical Appendix.* May 2007.

Zarull, M. A. and Hartig, J. H. 2000a. "Quantifying aquatic ecosystem health targets." *Verh. Internat. Verein. Limnol.* 27: 2346-2348.

Zarull, M. A. and Hartig, J. H. 2000b. "Aquatic ecosystem response to rehabilitative measures taken in the Great Lakes Areas of Concern." *Verh. Internat. Verein. Limnol.* 27: 2349-2352.

Appendix A: Technical Appendix

Available under separate cover.