Hutchinson
Environmental Sciences Ltd.

Georgian Bay Forever
Causation Study Synthesis
Final Report

Prepared By: **Hutchinson Environmental Sciences Ltd.**
Prepared For: **Georgian Bay Forever**

Project #: J110014
Date: May 2014

1 May 2014

Mr. David Sweetnam
Executive Director – Georgian Bay Forever
48 Lesmill Road
Toronto ON
M3B 2T5

Dear David:

Re: HESL J110014 – Georgian Bay Forever Causation Study Synthesis

We are pleased to provide our final report to on the 20112 Causation Study and Synthesis to Georgian Bay Forever (GBF). Hutchinson Environmental Sciences Ltd. (HESL) was retained by GBF in 2011 to review available information on the current state of water quality in several coastal areas of Georgian Bay. The review was guided by anecdotal observations of proliferation of algae and rooted aquatic plants by members of the GBF and concerns that remediation was warranted. These concerns and the need for a synthesis of information were discussed at a meeting in Port Severn on February 11, 2011, the minutes of which are presented in Appendix A. This report was provided in draft form in October of 2011. In August of 2013 SSEA provided some comments on the draft report. These did not materially change our conclusions and I have responded to them in a separate letter to you.

An examination of the existing data makes it clear that the nutrient and oxygen status of North Bay and South Bay have been well described. What is not known is how far the various ecosystem metrics have departed from natural or background conditions and this represents the largest uncertainty. Monitoring by the Severn Sound Environmental Association (SSEA) has shown that there are no significant trends within the timeframe of their monitoring record, but it is uncertain whether or not changes have occurred in the past.

The observed recent ecosystem shifts that have concerned GBF members do not have their present conditions well described or quantified and any changes that have occurred are based on observation. These types of shifts will require further work before the underlying processes can be understood and it would be premature to link these observations to specific stressors such as development pressure. Aquatic plant and periphyton proliferation are regional phenomena that have been linked to external stressors such as climate change or to the presence of invading species. The current data do not allow insight into these problems.

Although it is a bit of a platitude for scientists to ask for more data, this is essentially what is required to develop cause and effect for ecosystem shifts, to characterize the current nutrient and oxygen conditions relative to background and thus assess the need for and means of remediation. We have provided some recommendations on how to proceed in this regard.

This report was prepared using information current to early 2011. Since that time, GBF has competed additional monitoring under its coastal program, the SSEA has competed additional detailed studies, HESL completed a paleolimnological assessment of several embayments for GBF and GBF sponsored investigations into the causes of cyanobacterial blooms in Georgian Bay embayments by Dr. Lewis Molot. These studies, and possibly others, may have addressed many of the outstanding concerns identified in this report. We therefore recommend that GBF update this synthesis report using the currently available materials and recent studies.

Yours very truly,
Hutchinson Environmental Sciences Ltd.

Neil J. Hutchinson, Ph.D.
President and Principal Scientist

Signatures

Report prepared by:
Bev Clark
Senior Aquatic Scientist (now retired).

Reviewed by:
Neil J. Hutchinson, Ph.D.
Principal Scientist

Executive Summary

There have been recent anecdotal observations by members of GBF, that there are changes in water quality and the aquatic ecosystem occurring in North Bay, South Bay and at other locations in the Honey Harbour area including Church Bay. These observations include:

- North Bay, in which the growth of rooted aquatic plants (of unknown identification) has proliferated over the past 10-15 years. The Severn Sound Environmental Association (SSEA) also reports "subtle shifts" in the open water phytoplankton community of North Bay between 1998 and 2010.
- South Bay, in which there is visible degradation of water clarity over the 2.5 km between the inflow from Baxter Lake and the outlet towards Georgian Bay and accumulations of periphyton are observed on the rocky shoreline, especially in late summer. The Severn Sound Environmental Association (SSEA) reports "subtle shifts" in the open water phytoplankton community of South Bay between 1998 and 2010.
- Honey Harbour, which has many of the highest observed bacteria counts in the Coastal Monitoring area as observed by the volunteer monitoring program. (We note that these values are ~50 cfu/100 ml, and are therefore within the Ontario Ministry of the Environment's (MOE) Provincial Water Quality Objective of 100 cfu/100 ml for body contact recreation.)
- The Church Bay area of Honey Harbour, in which water quality appears degraded and aquatic plants and phytoplankton are proliferating. Historic reports by Ron Griffiths, (then with the University of Guelph, 2003) showed degraded benthic invertebrate communities.

Members have suggested that these changes are related to shoreline development. These are generally difficult changes to quantify and they are even more difficult to assess within the framework of cause and effects. Hutchinson Environmental Sciences Ltd. (HESL) was retained by GBF to review available information on the current state of water quality in coastal areas of Georgian Bay in which anecdotal observations of changes had been made. HESL reviewed what is known about the aquatic environment in these areas by completing a synthesis of all information that is available from various sources. We have summarized this to identify problems and causes and made recommendations with respect to science and management activities that should follow.

The detailed work that has been done by the Severn Sound Environmental Association (SSEA) suggests that water quality conditions are not changing, at least within recent years, and that these conditions (as indicated by average open water values of normal monitoring parameters such as total phosphorus, dissolved oxygen, water clarity) are not at a state where they should cause alarm. This is not to say, however, that these areas are not without problems, only that the average conditions measured for large areas are not problematic.

Recommendation 1 – That the accumulated state in the Areas of Concern has been well described such that no additional monitoring programs are required other than those currently being conducted by the SSEA. With respect to gaps and overlaps the following program-related recommendations are offered:

1. **That the more intensive SSEA program conduct the monitoring in the areas of concern with no requirement for coastal monitoring program data collection in those areas covered by SSEA ,**
2. **Sites should be standardized and maintained in the program.**

Nevertheless, there are anecdotal reports of algal and rooted plant proliferation. If these are not explained by existing data then additional research is warranted to clearly define what the reported problems are in North Bay, South Bay and Church Bay and go forward from there to identify causes and then solutions.

Recommendation 2 - For each perceived problem there must be a method devised to confirm whether the problem exists and if so, outline the extent of the problem, and identify the driver or drivers responsible for the problem.

Once the set of potential problems have been identified there will be a need to map the extent of the problem and link this to causes that may involve a set of multiple stressors. In this case, there may be a need to coordinate science initiatives with volunteer efforts to collect the kinds of data that will be required to describe the problem and demonstrate its responses to system drivers.

Recommendation 3 - Programs should be coordinated to achieve maximum benefit from volunteer efforts and the expenditure of science program dollars.

Finally, anoxic hypolimnia and internal phosphorus loading have been documented for the GBF embayments (Bluewater Bioscience, 2009) and these can result in cyanobacterial blooms and algal proliferation. These conditions do not exist exclusively in the bays near Honey Harbour but have also been documented in Twelve Mile Bay and have resulted in cyanobacterial blooms in Sturgeon Bay. If these conditions are natural, then they do not represent “bad” water quality per se, but rather water quality that when exacerbated by other external stressors may create conditions that are seen as undesirable (i.e., algal blooms). Paleolimnological techniques are well suited to reconstructing past water quality to establish the history of cyanobacterial blooms in lakes. There are also proven management actions available to control internal loading, either through sediment inactivation or aeration technologies.

Recommendation 4 - Projects should be initiated that can assess the degree to which the accumulated state (which has been well described) has departed from the historic background conditions. This information will be critical to determine the nature of the problem or if remediation is required at some point in the future. This would include information about past nutrient concentrations, past oxygen climate conditions in bottom waters and past distribution of periphyton and aquatic plants. Many conditions are in place that predispose the areas of concern to algal blooms. Paleolimnological surveys, especially in the areas of concern (South Bay and North Bay) are recommended to establish the past history of water quality and incidence of algal blooms.

2014 Update

This report was competed and submitted to GBF in draft form in October of 2011. Since that time, ongoing monitoring by GBF and SSEA and several initiatives that have been undertaken by GBF may address some of the recommendations and needs addressed herein. These include:

- A GBF-supported study to Identify Cyanobacteria Bloom Formation Risk in Georgian Bay Embayments by Prof. Lewis Molot and colleagues in 2012-2013,
- A GBF-supported study: “Historical Water Quality Trends in Georgian Bay Embayments – A Paleolimnological Study” carried out by HESL for GBF in 2012-2013.
- Ongoing detailed monitoring of selected areas by the SSEA
- Ongoing routine monitoring by GBF as part of their Coastal Monitoring Program.

Recommendation 5 - Results of these studies should now be available and should be reviewed against the findings and recommendations of this report to determine a) if any conditions have changed and b) what factors are better understood as a result of those studies and c) how these relate to the concerns expressed by the Georgian Bay residents that informed this report.

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Appendices

1. Background

There have been recent concerns expressed, based on anecdotal observations by members of GBF, that there are ecosystem changes occurring in North Bay, South Bay and at other locations in the Honey Harbour area including Church Bay. Additional observations based on past monitoring in these areas also suggest deteriorated water quality conditions. Members have suggested that these changes are related to shoreline development. These concerns were summarized at two meetings; first with the District Municipality of Muskoka on January 20, 2011, and then with the Georgian Bay Forever Foundation on February 11, 2011 (Minutes in Appendix A). These observations include:

- North Bay, in which the growth of rooted aquatic plants (of unknown identification) has proliferated over the past 10-15 years. The Severn Sound Environmental Association (SSEA) also reports "subtle shifts" in the open water phytoplankton community of North Bay between 1998 and 2010.
- South Bay, in which there is visible degradation of water clarity over the 2.5 km between the inflow from Baxter Lake and the outlet towards Georgian Bay and accumulations of periphyton are observed on the rocky shoreline, especially in late summer. The Severn Sound Environmental Association (SSEA) reports "subtle shifts" in the open water phytoplankton community of South Bay between 1998 and 2010.
- Honey Harbour, which has many of the highest observed bacteria counts in the Coastal Monitoring area as observed by the volunteer monitoring program. (We note that these values are ~50 cfu/100 ml, and are therefore within the Ontario Ministry of the Environment's (MOE) Provincial Water Quality Objective of 100 cfu/100 ml for body contact recreation.)
- The Church Bay area of Honey Harbour, in which water quality appears degraded and aquatic plants and phytoplankton are proliferating. Historic reports by Ron Griffiths, (then with the University of Guelph, 2003) showed degraded benthic invertebrate communities.

These are generally difficult changes to quantify and they are even more difficult to assess within the framework of cause and effects. Although elevated nutrient concentrations could explain many of these observations they may not be the sole cause, and may interact with other factors to produce the observed changes. The effects of external stressors such as climate change, water levels or invasive species confound our ability to interpret small or fractured datasets. The proliferation of chrysophyte (yellow algae) blooms, the increase in circumpolar blue green algae (cyanobacteria) blooms, the increase in number of ice free days, and the translocation of nutrients to nearshore areas by zebra and quagga mussels have all been reported in various parts of Ontario in recent years and represent complex responses of, and stressors on, aquatic ecosystems. It is only through combined efforts to collect comprehensive data sets that there can be a clear understanding of these observations and how they relate to external (regional) or local anthropogenic influences. Such understanding is necessary to determine if remediation is warranted, if it can be effective, what the remedial target should be and what management actions are necessary.

Hutchinson Environmental Sciences Ltd. (HESL) was retained by GBF to review available information on the current state of water quality in coastal areas of Georgian Bay in which anecdotal observations of changes had been made. HESL reviewed what is known about the aquatic environment in these areas by completing a synthesis of all information that is available from various sources. We have summarized this to identify problems and causes (where it is possible to do so) and made recommendations with respect to science and management activities that should follow.

2. Elements of an Ideal Monitoring Study

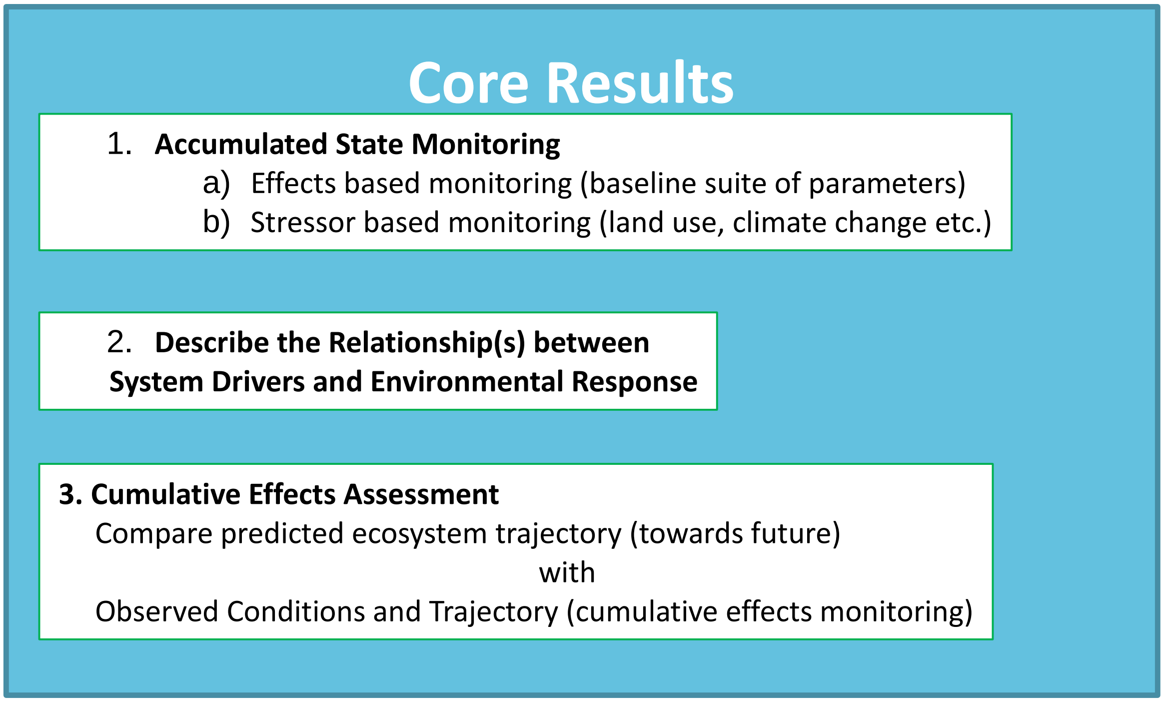
Any investigation of changes and cause should proceed from a clear understanding of what is required to a) document the changes and b) determine their origins or cause. This is true whether one is investigating localized concerns or large regional concerns. In March 2011, Environment Canada published "The Lower Athabasca Water Quality Monitoring Plan (LAWQMP)" as the framework for an ideal monitoring program design for Alberta's oil sands region. While HESL recognizes the difference in scope and magnitude of stressors and impacted area between the oil sands and Georgian Bay, the three key concepts provided in the LAWQMP are sound and can be readily applied to Georgian Bay. A sound monitoring and remedial program should include:

- description of the baseline conditions and the accumulated or current state ("environmental state"),
- description of the relationship between the system stressors ("drivers") and the environmental state, and
- Comparison of the expected and the observed trajectory of the environmental state that would result from the cumulative system stressors.

Ideally, if the concepts described by the monitoring program design described by LAWQMP (Figure 1) are met there should be baseline monitoring, stressor based monitoring, identification of relationships between stressors and environmental responses and an attempt to compare predicted responses to the actual changes that are occurring in the environment.

There are few monitoring programs other than those designed to intensively study a wide variety of watershed interactions over the long term that are adequate to accomplish all of the outcomes described by the LAWQMP design. The LAWQMP, however, provides an excellent framework upon which to evaluate monitoring programs and identify information or data gaps. HESL adopted this framework for guidance in this report and will refer to this monitoring design concept in later sections of this synthesis.

Figure 1. Key elements of monitoring programs as described by LAWQMP.



3. Causation Study Synthesis

The main areas of concern that are examined in this causation study synthesis are in the Honey Harbour area of Georgian Bay namely; North Bay, South Bay and Church Bay (Figure 2). These areas are sampled as part of several monitoring programs that cover larger geographic areas. The Bays are sampled as part of the GBF's Coastal Monitoring Program, which samples enclosed embayments from Honey Harbour in the south to Twelve Mile Bay further north. They are also sampled as part of the Severn Sound Environmental Association's (SSEA) monitoring program which samples additional locations in open water areas of Georgian Bay. Neither of these programs has a water quality monitoring station in Church Bay. The following synthesis is therefore primarily based on HESL`s review of the findings provided by the following two reports:

1. ***Water Quality Monitoring Report Summary 2001 to 2009 Township of Georgian Bay – December 2009,*** Bluewater Biosciences Inc. (Dr. Karl Schiefer), December 2009. We will refer to this program as the Coastal Monitoring Program (CMP),
2. ***Report on Water Quality in the Honey Harbour Area of Georgian Bay*** (Draft), Severn Sound Environmental Association, June 2010 plus a brief overview of proposed 2011 SSEA activities. We will refer to this program as the SSEA.

In addition, we have included relevant information from additional program materials that have been collected in the area of concern including:

- water quality for North and South Bay from the District of Muskoka Lake System Health program, referenced as from the DMM,

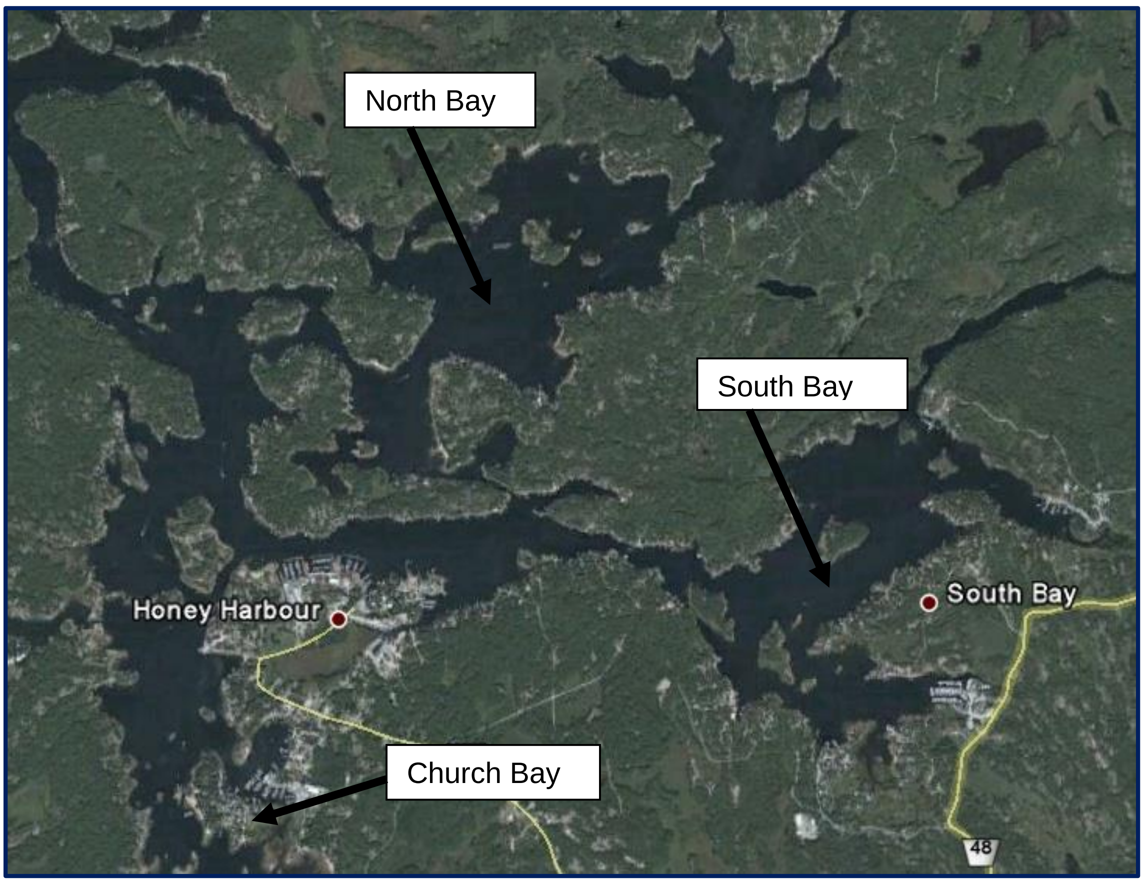
- MOE Lake Partner Program (2010) from all relevant locations, referenced as LPP data. (*http://www.ene.gov.on.ca/stdprodconsume/groups/lr/@ene/@local/@lakepartner/documents/nativedocs/stdprod_082417.pdf*), and
- invertebrate data for Church Bay (Griffiths, 2003).

HESL`s synthesis of the available data and findings was conducted with a focus on evaluating:

- the degree to which the monitored areas have been characterized (accumulated state),
- the findings that indicate ecosystem stress or trends towards undesirable conditions,
- the identification of cause or of uncertainty around cause, and
- the identification of further required science or management steps.

In addition, the summary sections of the reports were compared to determine whether there was consensus between monitoring programs with respect to the problems and their causes. HESL was interested in describing both how well any identified problems had been documented and whether or not their causes had been identified.

Figure 2. Areas of concern in the Honey Harbour area.



3.1 Characterization of the Accumulated State

With respect to water quality and the characterization of nutrient status, all programs that were summarized describe conditions that are similar throughout the area of concern. Table 1 summarizes physical attributes, mean phosphorus concentrations and dissolved oxygen (DO) conditions in stratified portions of the individual study areas. Data were summarized from the Coastal Monitoring Program (CMP), the Severn Sound Environmental Association (SSEA), the Ministry of the Environment Lake Partner Program (LPP) and the District Municipality of Muskoka Lake System Health Program (DMM).

The areas that are the focus of the Causation Study, with the exception of Church Bay, share similar limnological characteristics. They span the range of depths which are marginally deep enough to stratify (9 m) to moderate depths of 19 m. No areas are typical of deep, cold, well-oxygenated, lake trout habitat. Late summer anoxia and demonstrated internal phosphorus loads are pervasive in the hypolimnia of all areas that stratify. These bays also share similar nutrient climates. All have mixed layer chemistry that is generally in the lower half of the mesotrophic range (total phosphorus (TP) concentrations of 10-15 µg/L) and there is not a large degree of seasonal or between year variation in the data. These conditions are similar in the other isolated bays that are monitored by the CMP. Nutrient status has been well documented in both the CMP and in the SSEA datasets and these findings are supported by additional data collected by other programs such as the Lake Partner Program and the District of Muskoka Lake System Health Program. The data are both consistent and reliable enough to establish the accumulated state with respect to TP and DO.

Table 1. Characteristics of the areas of concern for the causation study.

Parameter	Source	North Bay	South Bay	Honey Harbour	Church Bay	Open Water
Area *(ha)*	CMP	220	200			na
Max Depth *(m)*	CMP	22	11	8.5		na
Water Exchange	CMP	Poorly flushed	Flushed by Severn River	Exchange with Bay	Exchange with Bay	na
TP *(µg/L)*	Late summer mean (CMP)	10.4	10.1	13.6		
	(SSEA) 1982-2009 mean	13.4	14.2	9.8		P4 shows trend from ~16 - ~8.5 M5 = 10.5 (2003-09)
	LPP (2-yr mean)	12.4	10.3			8.1
	DMM (spring)	13.5	14.3 (LSH) 12.5 (2002-10)			
Hypolimnetic DO	CMP SSEA	anoxic	anoxic	Mixed? may temporarily stratify	Mixed?	oxic

Notes: na – not applicable

The SSEA monitoring data have, in addition, characterized North Bay, South Bay, Honey Harbour and open water areas for other water quality parameters (Secchi depth, Chlorophyll a, and nitrogen) and have collected both phytoplankton and zooplankton data in recent years. It is HESL's opinion that the accumulated state has been well described by these programs (part 1A of the core results described in Figure 1). There is little else that needs to be done to describe the current conditions.

With respect to part 1B of the core results (stressor based monitoring) the monitoring programs summarized here are focused on observing the parameters of concern with no direct monitoring of land use changes, climate variables or deposition and export quantities for phosphorus. These and many other stressor variables that may be driving the results collected by the monitoring program may however be currently collected through other agencies in areas that are regionally similar.

HESL recommends that all existing data that pertain to land use, invading species or climate that may describe relevant external stressors should be gathered and examined to understand the range of stresses that could influence water quality in the nearshore areas of Georgian Bay.

Aspects of climate and land use have also changed in recent years and arrived at their own accumulated state which may be significantly different than the conditions observed even a few decades ago. In Lake of the Woods for example, the number of ice free days has increased by 28 days since 1964 (Rühland et al. 2010). This shift has changed lake dynamics in Lake of the Woods in significant ways, leading to increased frequency and intensity of cyanobacteria blooms. An accurate description of the accumulated state is therefore more meaningful if there are clues to describe the vectors that brought the system to the current conditions and which might change the current state to a further degree.

3.2 The Relationship between System Drivers and Environmental Response

It is critical to understand the processes that have an effect on the aquatic environment (system drivers) and the degree to which they have changed the environment (environmental response). Without this information it is not possible to determine the causes of any observed ecosystem deterioration or to assess the usefulness of remediation techniques if they become necessary.

The monitoring programs reviewed here focus on the tracking of nutrient status indicators. It is a normal response to suspect elevated nutrient conditions in areas that are heavily developed and as a result there are many references to degraded conditions in these reports that are assumed to be the result of development. It is not unreasonable to assume that shoreline development is having an effect on the nutrient status of the enclosed bays since there are well developed relationships between shoreline development and phosphorus concentrations in lakes (Paterson et al., 2006).

There are also many external climate-related system drivers that are becoming better understood only in recent years. These are more difficult to quantify and the clear understanding of effects is confounded by interactions between multiple stressors. Climate change, for example, is manifest as changes in the length of ice cover, changes in the period of lake stratification, warmer surface water temperatures, changes in annual precipitation volumes, more intense storms, longer periods of drought and changes in lake levels (Gunn et al., 2003, Schindler, 2009, Muskoka Watershed Council, 2010). These are the types of system drivers that may cause shifts in aquatic plants, periphyton and phytoplankton communities with possible cascade effects to secondary producers and on up the food chain to fish and even to larger animals. This will be discussed further in Section 3.3.3.

3.3 Observations that Indicate Ecosystem Stress

Cumulative effects assessment (Part 3 of LAWQMP) involves comparison of the results of the cumulative effects monitoring and the predicted ecosystem trajectory towards a future value. In the reports reviewed here, no predictions have been made about the current state that should exist in the areas of concern or the direction that various environmental variables will take in the future. The Severn Sound Remedial Action Plan (SSRAP) was the only formal process whereby conditions were assessed as undesirable and targets for improvement set. The SSRAP worked to lower phosphorus concentrations in the general Severn Sound area, but it is unclear how much these changes affected the GBF areas of concern. Aside from this, measured environmental vectors over the period of study do not indicate large changes.

It should be noted that phosphorus reductions have been documented for lakes throughout Ontario that are not linked to reductions in anthropogenic inputs (e.g., Eimers et al., 2009). While mechanisms for the phosphorus decline are not fully understood, they are thought to be linked to aspects of regional scale acidification and drought. It is therefore possible to predict that there may be reductions in phosphorus concentrations in the area of concern, as there have been elsewhere, if no other variables change. The impact of development however would predict increases in phosphorus that may have occurred before the study period covered by these reports. Effects that drive systems in opposite directions such as these make it difficult to assess the impact that the multiple stressors are having on the results shown by the monitoring programs.

For data records such as these, which are too short to detect long term trends, there are other ways that the data can be used to assess ecosystem stress. The first is to demonstrate conditions that are outside of jurisdictional guidelines or are on a trajectory that will eventually see the guideline exceeded. The second is to demonstrate a condition that is not covered by a guideline, but indicates an ecosystem shift to a condition that is undesirable or has been demonstrated to have a detrimental effect in other areas.

In the GBF areas of concern that are the focus of this Causation Study there are both areas that are below certain guidelines and areas where there is possible evidence of ecosystem shifts. It is important to note that although these conditions have been identified, long term trends cannot be verified in most cases and where sufficient data exist, there are no trends. For example, we cannot tell whether or not bottom waters (in areas that stratify) have historically been anoxic and we cannot demonstrate that conditions are getting worse with existing data. With respect to ecosystem shifts there are many observations that may indicate shifts but in no case can we show measurements that indicate a trend or clearly link any changes to a specific cause with existing information. A summary of the observations and opinions relating to ecosystem stress from various sources is shown in Table 2, along with our opinion on whether or not the stress has been demonstrably linked to a cause. Our evaluation finds that while there are several observations that suggest ecosystem stress, in all cases but one, these have not been linked to a cause, or causes have been speculated without direct assessment.

Table 2. Summary of observed conditions that are perceived as being deteriorated or unacceptable. Water Quality Monitoring Summary Report 2001 to 2009 indicated by WQMSR and Report on Water Quality in the Honey Harbour Area of Georgian Bay indicated by WQHH.

Area	Source	Observation/Opinion	Linked to Cause
All	WQMSR	1. Water quality addressed as the number 1 concern in opinion surveys.	na
HH,NB,SB, GHB,TMB	WQMSR (section 3.8)	2. Lakeshore development has caused TP levels characteristic of more advanced eutrophication.	no
SB	WQMSR (section 3.8, 4.24)	3. Filamentous algal growth on nearshore rocks as a result of eutrophication.	no
HH	WQMSR (section 3.8)	4. Water clarity declines from 8 m in Geo Bay to 3 m in Honey Harbour.	no

NB,SB, TMB,CL	WQMSR	5. Dissolved oxygen depletion as symptom of eutrophication (levels severe in NB,SB due to eutrophication).	no
NB,SB	WQMSR	6. Cold water fish scarce in areas with degraded water quality. Habitat suitability described but cause not identified.	yes/no
ALL	WQMSR (section 3.8)	7. Low water levels are aggravating water quality conditions.	no
Severn River	WQMSR	8. Higher TP at Port Severn due to lakeshore development in Little Lake and Port Severn.	no
Port Severn	WQMSR	9. Increased aquatic plant growth due to higher nutrient loadings.	no
TMB	WQMSR	10. Higher TP levels in east indicative of development. 11. Declines in clarity from mouth to east end.	no
CL	WQMSR	12. P sediment release in Cognashene linked to many decades of lakeshore development.	no
HH (south)	WQMSR	13. High bacteria counts due to human activity.	no
Church Bay	Griffiths	14. Indications of degraded water quality by invertebrate community structure in some area including Church Bay. Abundant aquatic vegetation and periphyton indicated with rapid accumulation of material.	yes
All	SSEA*	15. These areas should be considered sensitive to significant inputs of phosphorus.	no
HH	SSEA (pg. 25)	16. Declines in water clarity in recent years – no explanation provided.	no
LL	SSEA	17. Phytoplankton shift to dominance by chrysophytes with an increase in diversity between 1998 and 2008.	no

* Brief summary of 2011 activities

3.3.1 Conditions that do not meet guidelines

Phosphorus

Any assessment of cause must consider not only the present day conditions, and whether they exceed guidelines, but also whether or not the baseline conditions, in the absence of human inputs, would exceed the guidelines. There are sources of guidance to consider, the first is the MOE's Provincial Water Quality Objectives (PWQO, MOE 1994) and the second is the Lake System Health Program of the DMM.

Open water areas of Georgian Bay and Severn Sound are now generally below the MOE's Provincial Water Quality Objective (PWQO) of 10 µg/L for a high level of protection against aesthetic deterioration[1] (MOE, 1994; Table 1). Many inner bays in the Coastal Monitoring Program also have measured phosphorus concentrations below 10 µg/L (Table 3). South Bay concentrations are in the range of 10 to 15 µg/L, which do not meet the PWQO. North Bay concentrations are also above 10 µg/L but background (natural) concentrations in North Bay are naturally over 10 µg/L, as modeled by the Lake System Health Program (13.5 µg/L, Gartner Lee Ltd., 2005). All mean concentrations in the area of concern are below the PWQO of 20 µg/L, for protection against nuisance algal growth.

[1] The MOE actually recommends an interim guideline value for total phosphorus: Current scientific evidence is insufficient to develop a firm Objective at this time. Accordingly, the following phosphorus concentrations should be considered as general guidelines which should be supplemented by site-specific studies:

> To avoid nuisance concentrations of algae in lakes, average total phosphorus concentrations for the ice-free period should not exceed 20 ug/L;
> A high level of protection against aesthetic deterioration will be provided by a total phosphorus concentration for the ice-free period of 10 ug/L or less. This should apply to all lakes naturally below this value.

Phosphorus concentrations in the mixed surface layer, however, are not fully descriptive of water quality conditions. Bluewater Bioscience (2009) reported high concentration of phosphorus (66-2173 µg/L) in the deep waters of North Bay and South Bay, coincident with anoxia. These represent internal loading of phosphorus from the sediments and this internal load can play a major role in algal growth, as has been documented in Sturgeon Bay of Georgian Bay (Gartner Lee Ltd. 2008).

The District Municipality of Muskoka has modeled some of the inland lakes and bays to determine background concentrations relative to both measured and target (background + 50%) concentrations. The background + 50% value is used in the DMM Lake System Health program as a target value – if modeled estimates of current conditions and measured phosphorus concentrations are more than 50% above the modeled estimate of natural conditions, then the lake is considered to be "over threshold" and investigation of causes and potential remedial actions are warranted. The DMM results are shown in Table 3. North Bay has a high natural concentration of phosphorus (13.5 µg/L). The current measured concentrations of 13.5 µg/L (Table 1) are the same as the modeled background value, suggesting that North Bay is not impacted by human phosphorus sources. The modeled present-day concentrations were 16.4 µg/L, which is less than the target value of 20 µg/L. The remainder of the bays in Table 3 are naturally oligotrophic (<10 µg/L) and should be managed to background +50% targets. South Bay is indicated as being over threshold.

The key observations in these results are:

- North Bay has relatively high background TP concentration, but is not over threshold, and
- South Bay is naturally oligotrophic and over threshold for total phosphorus concentration.

Table 3. Summary of DMM modeled and measured total phosphorus (TP) concentrations for selected inland bays shown with estimates for South and North bays. Units are µg/L.

Area	Background TP	Background TP +50%	Modeled Present TP	Measured TP
South Bay	8.43	12.65	12.78	14.3 (n=4) 12.4 (02-10)
North Bay	13.5	20.2	16.4	13.5 (n=4)

Mr. Keith Sherman (SSEA, pers. comm. 2011) notes that there are declines over time for TP concentrations in most areas and that all SSEA sites met the Severn Sound Remedial Action Plan phosphorus delisting objective of 15 µg/L by 2003. It is not clear whether general declines in phosphorus concentrations are occurring throughout the areas of concern but these patterns have been noticed in adjacent Shield areas (Eimers et al., 2009) such that concentrations in the major inflows to these areas from Shield portions of the watershed may also be declining.

To summarize, South Bay is the only area where phosphorus is indicated to be above guidelines although recent years of data have shown a shift to lower concentrations (DMM). We caution however, that nuisance cyanobacterial blooms have occurred in Sturgeon Bay where cyanobacteria can take advantage of internally high concentrations of internally loaded phosphorus, although surface water concentrations are within guidelines.

Dissolved Oxygen

All areas in the inner bays that stratify have mean, volume-weighted hypolimnetic DO concentrations below the recommended concentration of 7 mg/L to support lake trout populations and below MOE's PWQO of 6 mg/L of dissolved oxygen for cold water species at 10°C. Although the main portion of Georgian Bay supports lake trout it is unclear whether the guidelines that relate to their habitat requirements should extend into the isolated Bays and so the PWQO is also appropriate for consideration. Dissolved oxygen concentrations near the bottom in all areas that stratify tend to reach anoxia by late summer. This equates to a loss of habitat for all fish and creates suitable conditions for the development of internal phosphorus loading. Internal phosphorus loading due to anoxia and consequent nutrient-rich water near the mixed layer may contribute to the development of late summer cyanobacteria blooms as was determined for Sturgeon Bay of Lake Huron (Gartner Lee Ltd., 2008). It is not clear whether the development of anoxia in the areas of concern is natural (as a result of bathymetry) or the result of human activity in the watershed, but this represents a loss of cold water fish habitat and the potential to support cyanobacteria blooms.

3.3.2 Trajectories towards conditions that will not meet guidelines.

There are no documented trends through time to indicate that water quality is deteriorating in the areas of concern. This is not to say that conditions have not deteriorated at some point in the past to produce the current conditions, only that the existing data do not show any trends. It is possible that phosphorus concentrations have increased, or dissolved oxygen has decreased relative to historic levels in response to development in the watershed or along the shoreline, but conditions have not worsened over the period covered by this study.

In general, decreasing phosphorus concentrations have been documented in Ontario surface waters over the past twenty years, and the efforts of the Severn Sound Remedial Action Plan (SSRAP) were successful in reducing phosphorus loads to Severn Sound (Environment Canada, 2010). Phosphorus concentrations in South Bay and Honey Harbour may be influenced by the SSRAP remedial activities or changes in export from inland areas that are the result of acidification of soils or drought. It is unclear whether changes in water levels have played a role. It is possible that phosphorus concentrations were originally elevated from background levels in these areas during the early years of shoreline development and have now stabilized.

It is important to note that declines in TP concentrations have been noticed in many Shield lakes throughout Ontario, some of which are undeveloped. This may be linked to acidification of the watersheds or to drought as a consequence of climate change. It is therefore possible that effects of development in the watershed that would increase phosphorus loads are being offset by other environmental processes that are reducing export to the bay and inland water bodies. **If either acidification or drought are reversed there may be a return to higher export from watersheds which may lead to higher concentrations in the areas of concern.**

To summarize there is no evidence that water quality is deteriorating over the period of monitoring. Phosphorus and dissolved oxygen concentrations appear stable over the last several decades. The low dissolved oxygen status of the bays is strongly influenced by their bathymetry, as their shallow depth limits the hypolimnetic volume available for assimilation of production. We cannot, however, exclude the possibility that current conditions represent a change from historic (pre-development) conditions, only that changes have not been measured over the period of monitoring.

3.3.3 Documented ecosystem shifts that indicate external stressors

A summary of ecosystem stress indicators that are listed in report summaries are shown in Table 4, together with potential external stressors that may have had an influence on the monitoring results. In each case, the column labeled “uncertainty” provides our opinion on the strength and evidence supporting the mechanistic link of stressor to response. Most observed ecosystem shifts that are reported for the areas of concern in the Causation Study area have potential to be driven by external stressors such as climate change or the introduction of invasive species. Ecosystem shifts include the proliferation of aquatic plants, periphyton growth in nearshore areas, changes in phytoplankton community assemblages and changes in water clarity. These represent ecosystem interactions that are difficult to measure and which respond to multiple stressors.

With some of these shifts it is easy to demonstrate cause and effect. Increases in water clarity following zebra mussel invasions for example, are easy to demonstrate and are the result of a mechanism that is intuitively straightforward. Algal blooms in response to hypolimnetic anoxia are also well understood and can be reliably managed. The proliferation of aquatic plants or periphyton, on the other hand, are both difficult to explain and to remediate because these shifts are likely responses to multiple stressors. While nutrients are part of the explanation, other factors must be considered. For example, increased water clarity allows deeper areas to be colonized by aquatic plants, changes in sedimentation may provide more soft surfaces for colonization, changes in climate may allow different species to proliferate and changes in crayfish or snail populations will alter grazing pressures. Some management activities can address local stressors such as land use, while others (invading species) require management throughout the Great Lakes basin and others (climate change) require a global solution. Understanding the stressors is therefore an important stage in the process of managing water quality.

Table 4. Summary of stress indicators and potential drivers with references.

Stress Indicator	Driver	Reference	Uncertainty
TP concentrations	• Shoreline development including commercial development	Paterson et al., 2006	low
	• Climate effects – drought and acidification reduce P inputs	Schindler et al., 1996	med
	• Internal load (represents pool of P that is influenced by other external drivers)	Sorano et al., 1997	low
	• *Dreissenid* nearshore shunt	Hecky et al., 2004	med
Hypolimnetic DO	• P concentrations and morphometry	Molot et al., 1992 Clark et al., 2002	low
	• Duration of stratification (climate)	Schindler, 2009	low
Phytoplankton shift to Chrysophytes	• Climate	Paterson et al., 2004	med
Changes in water clarity	• Invasive species	MacIsaac, 1996	low
	• Trophic cascades	Brett and Goldman, 1996	high
	• Changes in DOC concentration	Gunn et al., 2001	high
Shifts in Zooplankton community	• Trophic cascades	Brett and Goldman, 1996	high
	• Climate	Gyllstrom et al., 2005	high
	• Invading species	Yan et al., 2001	low
Periphyton growth	• Climate	Baulch et al., 2005	high
	• Changes in grazer density	Hillebrand and Kahlert, 2001	high
	• Nutrient shunt	Hecky et al., 2004	med
Rooted aquatic plant growth	• Climate	Lacoul and Freedman, 2006	high
	• Water clarity shifts		low
	• Water levels		low

3.4 Outlining Uncertainty

3.4.1 What are the background conditions?

The largest single uncertainty lies with the fact that we do not know a great deal about how these water bodies behaved in the past or what the water quality conditions were prior to implementation of reliable monitoring programs. The MOE's Lakeshore Capacity Model (Paterson et al., 2006) can estimate background phosphorus concentration as the total phosphorus concentration minus that portion that is contributed by current human activities such as wastewater discharges, shoreline development or urban runoff in the watershed. The background, however, includes current phosphorus deposition in precipitation and incorporates any human-related changes in phosphorus runoff from natural areas (i.e., by acidification). This is not the same as predicting what the concentrations were before colonization and the accuracy of the background estimate depends on the accuracy of the values that populate the model. The estimate does not tell us anything about what the water bodies were like in the past.

In North Bay, the modeled background conditions are not that different than the current measured conditions, while in South Bay, measurements and modeled results suggest some degree of present enrichment compared to the natural background (Table 3). Some studies (i.e., Clerk et al., 1998) provide evidence that Muskoka area lakes were more nutrient rich before colonization than they are today, based on paleolimnological records of algal remains preserved in lake sediments. Many other influences that have occurred on these landscapes such as logging or forest fires will also have an impact that may show up in paleolimnological records. Cyanobacterial pigments from blue green algae are also preserved in lake sediments and so it is possible determine whether or not blue green algal blooms have occurred in the past, based on lake sediment records. Such information is valuable to determine if blooms are natural or not, to assess causation, and determine whether or not remediation can be successful in cases where blooms begin to occur.

Our assessment concludes that conditions in the GBF areas of concern favour the potential formation of cyanobacteria blooms. This is due to the physical nature of the bays and the internal phosphorus loads that are generated in a shallow hypolimnion. If blooms were to occur, the first question would be "are we correct in assuming that the blooms are a result of recent anthropogenic changes such as nutrient enrichment?" If the current conditions are shown to be close to background conditions for nutrients then we can speculate that the blooms may be caused by other factors such as those created by climate change. These cause and effect relationships whereby blooms are increasing in frequency as a result of climate-related changes have been shown for other areas of Ontario, including Sturgeon Bay of Lake Huron (Cumming et al., 2006; Gartner Lee Ltd., 2008, see section 3.5) and most recently, for Lake of the Woods in northwestern Ontario (Rühland, 2010).

3.4.2 Why have there not been cyanobacteria blooms?

New science led by Dr. Lewis Molot at York University has shown that one reason why cyanobacteria proliferate in the fall is directly linked to their ability to derive iron from anoxic, iron rich bottom waters. It is the iron that controls their growth and this control is secondary to phosphorus. These results (Molot et al, 2010) mean that cyanobacteria blooms should not occur in areas where the algae do not have access to iron. In areas with limited hypolimnetic volume (such as the GBF areas of concern), there is limited assimilation volume such that even moderate or natural nutrient levels induce anoxia in bottom waters which in turn releases iron to the hypolimnion. Although cyanobacteria are photosynthetic and require light, they can alter their buoyancy and forage for nutrients in the deeper oxygen free zone where internal loading produces very high phosphorus concentrations and ferrous (reduced) iron, which they can utilize. This provides a great competitive advantage to cyanobacteria over other forms of algae which are less able to control their buoyancy and which require oxidized (ferric) iron. As a result, cyanobacteria can proliferate in areas with anoxic hypolimnia and internal phosphorus loading. Increased TP concentrations may help increase the magnitude of the bloom but are not essential since the cyanobacteria can also compete at low TP concentrations. These findings are compelling and the dynamics around these processes should be further studied to assess their relevance to the GBF areas of concern. **The key consideration is that the bays monitored by the Coastal Monitoring Program should all be considered as having the potential to support cyanobacteria blooms.**

3.4.3 What are the external stressors and what is their impact?

There is good evidence that climate change has affected aquatic ecosystems in Canada and potential mechanisms of climate change impact to surface waters are becoming increasingly well understood (Schindler 2009, Ruhland et al., 2010). The barrier to understanding exact cause and effects lies in the fact that there are often multiple stressors acting on the system. In some cases more than one of these may be the result of climate change. For example, the system may be impacted to the greatest degree by a change in the number of ice free days and by changing water levels and these two stressors may both be a result of climate change. Algal blooms may be occurring in a certain location as a result of overdevelopment and then become more frequent due to favourable conditions caused by climate change. In this case the climate change can act as a stress multiplier.

With respect to the areas of concern for this synthesis there are many stressors that could have an impact on the aquatic ecosystem. These include:

- Warmer temperatures and longer ice free seasons
- Water level fluctuations
- Increased development including increased boat traffic
- Invasive species
- Changes in trophic status or changes in land use practices

At present, the GBF has documented anecdotal changes in water quality and several opinions as to the causes (Appendix 1: Bluewater Biosciences, 2009) and this report has identified additional stressors and how they may act. Additional focused investigation is required, however to a) confirm what changes have occurred and when they occurred, and b) to identify the stressor that is most likely responsible for the changes, before the need for, and approach to any management actions is determined.

3.5 Steps to Reduce Uncertainty

Application of the MOE's Lakeshore Capacity Model would allow estimation of background and current conditions and inform predictions of the response of water quality to various development or management scenarios that altered phosphorus supply in the future. The problem is that the model provides information only for phosphorus concentrations and does not provide information about historical conditions or about other external forces that may be acting on the trophic status. Neither is it well calibrated to model two-directional exchange of water between a modeled embayment (e.g., South Bay) and a larger water body (i,e., Georgian Bay). The model can be updated to include different runoff coefficients or other weather related inputs if these changes can be quantified. A more detailed examination of the DMM modeled results for North and South Bay is warranted possibly with an attempt to correct the results with exchange between the bays and Georgian Bay at different water levels. These results may indicate that more detailed nutrient budgets are required or may, at the least allow estimates of what sources of phosphorus are most important in determining responses.

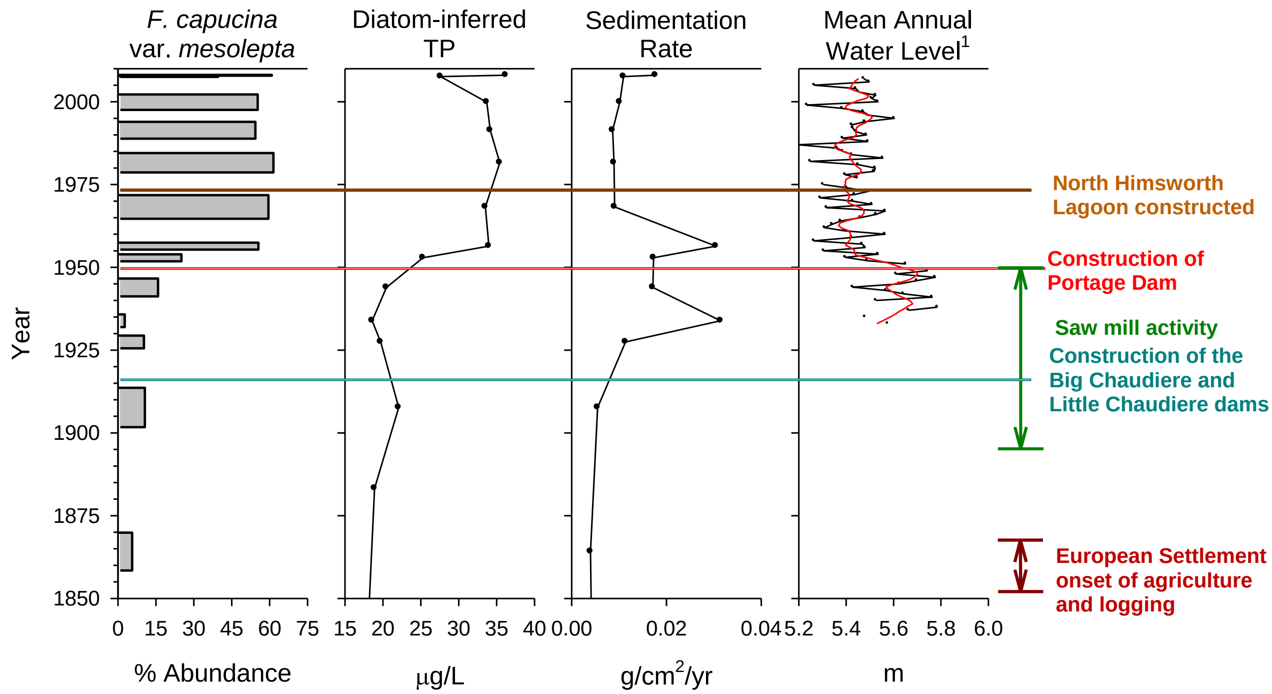
Examination of climate related influences if available would be a valuable exercise. For example it would be useful to have records of days of ice cover or other indications of changes effects that would influence the planktonic or aquatic plant communities. Water level data or land use data would also be useful. These types of data can be used to explain community shifts at specific points in time and are very useful to help with the interpretation of paleolimnological data.

Paleolimnology is the study of the past history of lakes using information preserved in lake sediments such as the fossil remains of algae (e.g., diatom cell walls, pigments) and animals (e.g., head capsules of larval midges). A core of sediment is retrieved from the bottom of the lake and thin sections of the core that correspond to different dates in the past history of the lake are examined for the indicator of choice, which is used to make inferences about past lake and environmental conditions. Water chemistry, anoxia, planktonic community composition, proliferation of rooted aquatic plants and the pervasiveness of blue green algal blooms can all be inferred over a long historical record using this technique. This helps to identify the system drivers, the timing and frequency of water quality changes and conclusions about the need for, and likely success of, remediation. The following three case studies illustrate how paleolimnology has helped to address specific lake management issues in Ontario lakes.

1. Callander Bay (AECOM, 2009)

Recent, extensive blooms of toxin-producing bluegreen algae (cyanobacteria) in Callander Bay of Lake Nipissing not only threaten the quality of the bay as a drinking water source for Callander, ON, but have impaired residential, commercial and recreational uses. While phosphorus concentrations often control algal production, other factors can also play a role in promoting cyanobacterial blooms (e.g., physical habitat conditions, competition, nitrogen limitation, weather patterns, and climate change). A thorough understanding of previous bloom formation and factors controlling those blooms is essential for the development of effective management strategies to reduce the risk of bloom formation. A diatom-based paleolimnological analysis was undertaken to identify the time course and relative magnitude of changes in nutrient status in the bay over the past ~400 years to guide assessment of the problem. Results indicated that Callander Bay became slightly more eutrophic following European settlement with land use changes related to logging, sawmill activity and agriculture. At ~1950, a significant increase in phosphorus concentrations, inferred from the diatom assemblages, occurred coincident with the construction of the Portage Dam in 1949-1950 at the outlet of Lake Nipissing (Figure 3). Operation of the dam resulted in an overall decrease in water levels in Lake Nipissing, particularly during the spring melt period, which would have reduced the available volume of water for assimilation of phosphorus loads thereby causing increased phosphorus concentrations. Operation of the dam may have also resulted in a combination of physical changes to Callander Bay including an altered mixing regime, changes in flushing rates and mixing with waters in the main basin of Lake Nipissing, exposure of productive low lying areas, decrease in hypolimnetic volume and increased size of the shallow littoral zone, all of which could contribute to increased phosphorus concentrations. Phosphorus concentrations have remained relatively stable in the past 50 years despite land use changes over that time frame that would be expected to increase phosphorus loads to the bay. This study demonstrated that large scale changes in water levels may be as important as local watershed factors in governing trophic status and informs management planning initiatives to reduce the formation of cyanobacterial blooms through nutrient abatement. In particular, the study indicates that while nutrient abatement initiatives in the watershed are unlikely to change the basic eutrophic nature of the Bay, they may be able to reduce the potential for formation of bluegreen algal blooms. The Callander Bay paleolimnology study was completed by HESL staff while employed at AECOM.

Figure 3. Figure showing inferred TP increases concurrent with the construction of the Portage Dam.



2. Sturgeon Bay (Cumming et al., 2006; Gartner Lee Ltd., 2008)

Since at least 1999, extensive algal blooms have developed most years in Sturgeon Bay of Georgian Bay, beginning in late summer (Figure 4). Some long-time residents of the bay recalled seeing periodic algal blooms over the past ~50 years, particularly in the mid-1960s. These earlier blooms, however, were apparently less extensive than those observed in recent years. Due to concern over the apparent increase in algal bloom activity, the Township of The Archipelago retained Gartner Lee Limited (GLL) to develop an appropriate remediation strategy to control algal production. This strategy was to be guided by an understanding of all factors contributing to increased algal biomass (e.g., nutrient or water levels, habitat availability) so that a holistic management plan could be developed to focus efforts in the right areas to achieve a cost effective and long-term management solution. Key to the strategy developed by GLL was information provided by a paleolimnology study performed by Cumming et al. (2006). In 2005, a 56-cm long sediment core was retrieved from Sturgeon Bay representing approximately 300 years of sediment accumulation. The core was analyzed for diatom algae and algal pigments, and total phosphorus concentrations were reconstructed using diatom-based statistical tools. Results indicated that Sturgeon Bay was naturally productive, with relatively high total phosphorus concentrations over the past ~300 years ranging from 19 to 35 µg/L. Beginning ~1940, however, increases in the concentrations of several major pigments suggested increased algal productivity in the absence of increasing total phosphorus concentrations. The increase in algal production was coincident with increases in diatoms that that prefer stable, thermally-stratified conditions suggesting a strong climate influence that increased thermal stability of the water column promoting algal production. This increased thermal stability combined with lower water levels in the bay likely contributed to greater oxygen depletion in bottom waters resulting in enhanced anoxia and internal phosphorus loading from the sediments. Based on this evidence, along with results of monitoring studies, phosphorus loading estimates and phosphorus modeling, it was determined that mitigation efforts to control internal phosphorus loading from sediments would be most effective to control algal blooms in Sturgeon Bay.

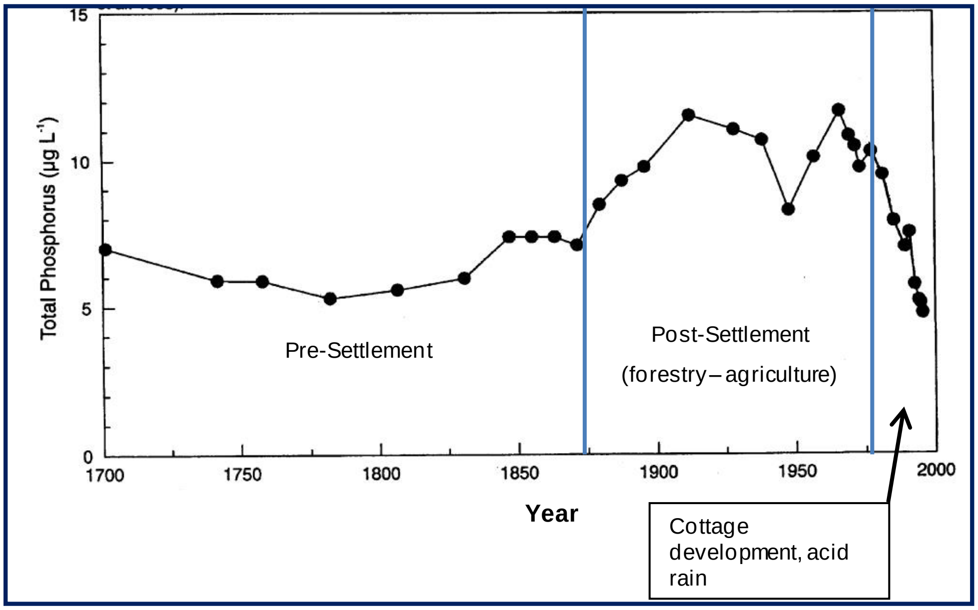
Figure 4. Algal Bloom in the north end of Sturgeon Bay, 28-Sep-2007 (source: Parry Sound North Star)

This paleolimnological analysis was performed by Cumming et al. (2006) at Queen's University and was this approach was recommended, reviewed and used by HESL staff while employed at Gartner Lee Limited to inform recommendations to control algal biomass in Sturgeon Bay.

3. Peninsula Lake (Clerk et al. 1998)

Peninsula Lake, a small (853 ha) Precambrian Shield lake in Ontario, Canada, has been subjected to moderate cultural disturbances (forest clearance, cottage and resort development). Impacts of forest clearance and human land use on water quality were assessed by comparing deep water oxygen conditions reconstructed from fossil midges (chironomids) and total phosphorus concentrations reconstructed from fossil diatoms to changes in terrestrial pollen and historical data. Pre-disturbance chironomid assemblages were indicative of stable, oxygen-rich deepwater conditions, while diatoms indicated low total phosphorus concentration (5-7 μg/L). Chironomids characteristic of lower oxygen availability increased following land-clearance, road construction, establishment of a grist mill and lakeshore development beginning ca. 1870. Similarly, changes in the diatoms at that time indicated eutrophication and diatom-inferred total phosphorus concentration doubled (~ 6-12 μg/L). This evidence indicated that naturally-oligotrophic Precambrian Shield lakes were extremely sensitive to initial land-clearance activities following European settlement. Since ~1960, however, the chironomids and diatoms indicate improved lake conditions with greater oxygen availability and lower total phosphorus concentrations. These recent water-quality improvements, possibly in response to enhanced nutrient removal from detergents and sewage, climate-related reductions in external phosphorus loads, and catchment (but not lake) acidification and reforestation, suggest that habitat for commercially-valuable cold-water fishes has improved in recent decades despite greater recreational lake-use. Diatom inferences of [TP] and chironomid inferences both suggest that Peninsula Lake was historically oligotrophic, became oligo-mesotrophic after European settlement, and returned to oligotrophy in recent years (Figure 5).

Figure 5. Changes in Diatom-Inferred Total Phosphorus Concentrations in Peninsula Lake (modified from Clerk et al., 1998)



The above case studies illustrate the versatility of paleolimnology to reconstruct past lake conditions in a variety of settings and to assess 'cause and effect' relationships where monitoring data are lacking. **We suggest that a well-designed paleolimnological study would be useful to assess the potential stressors identified in the Georgian Bay areas of concern and to confirm anecdotal evidence of change. Importantly, this approach would provide a means to address important questions about the relative influence of human disturbance, climate and natural variability on the system upon which to base sound management decisions.**

3.6 Identification of Gaps and Overlaps

An initial review of the proposed SSEA activities in North Bay, South Bay, Honey Harbour and Church Bay indicate that the 2011 monitoring will represent a concentrated science initiative in the GBF areas of concern and a potential overlap with the data collected by the GBF Coastal Water Quality Monitoring Program. The monitoring proposed by the SSEA is more temporally intense such that there is little merit in maintaining the coastal "one observation per year" monitoring at these locations while SSEA is doing the same. HESL had conversations with Keith Sherman prior to the 2011 Coastal Monitoring field season and he suggested that the 2011 Coastal Monitoring Program would likely be suspended for these areas in 2011. With respect to gaps and overlaps the following program-related recommendations are offered:

1. That the more intensive SSEA program conduct the monitoring in the areas of concern with no requirement for coastal monitoring program data collection,
2. Sites should be standardized and maintained throughout both programs,
3. Volunteers should be utilized for more detailed sampling or observations to augment the SSEA program or any future GBF causation studies.

A more detailed review and summary of recommendations is provided in HESL (2011).

3.7 Data Required to Derive Nutrient Budgets for North and South Bays

An examination of the existing data indicates that there will not likely be a compelling need to develop detailed nutrient budgets for North and South Bays. In North Bay, the measured TP concentrations are close to estimated background concentrations. These findings suggest that the model may need to be recast for North Bay to determine the reasons for the background and measured values being similar. In South Bay the measured values are close to the modeled background + 50% concentrations, which indicates that the Bay is currently near its development capacity.

The use of the Lakeshore Capacity Model represents a simple way to tell us what the phosphorus concentrations in the water would look like without human impacts, what they would look like under present conditions and finally it can estimate the conditions that would be in place under future development scenarios. When the numbers agree, and when there are no problems, there is usually no need to assemble a more detailed nutrient budget.

There are however, situations where a more detailed nutrient budget is required. These usually arise when water quality problems develop that require remediation. Normally, if there are multiple phosphorus inputs and the problem at hand is linked to phosphorus, then a budget is required to assess the relative inputs from different sources which will then allow an estimate of potential reductions that could be realized by controlling the different sources to the system. In the case of the North and South Bays it would be necessary to estimate the nature of water exchange with the main bay, and the contribution of phosphorus from internal loads, large inflows and septic systems.

It is important to note that nutrient budgets would only be undertaken in cases where there was direct evidence that phosphorus concentrations were involved with the identified problem. Algal blooms for example might be linked to internal loads which would justify efforts to quantify internal loads relative to loads from elsewhere (a more detailed nutrient budget).

The principle elements of a nutrient budget (which include natural and human sources in the immediate and upstream watersheds) were completed for North and South Bays as part of the 2005 Lake System Health Program of the District of Muskoka (Gartner Lee Ltd., 2005). North and South Bays were modeled as "anoxic", but explicit internal loads were not calculated as model inputs. HESL are currently retained by the DMM to undertake a review of the model and the Lake System Health program and the work plan includes reassessment of embayments along Georgian Bay and elsewhere. Some results will be available in 2014 and may inform future management plans of GBF.

The known sources of information that can be used as elements of a detailed nutrient budget are given in Table 5.

Table 5. Summary of inputs to nutrient models for North and South Bays.

Input	North Bay	South Bay
P in precipitation	MOE Dorset measured regional data	MOE Dorset measured regional data
Export from wetlands	MOE Dorset regional wetland equation	MOE Dorset regional wetland equation

Export from forested catchments	MOE Lakeshore Capacity Model export coefficients	MOE Lakeshore Capacity Model export coefficients
Load from development	DMM recent development counts May need to be updated	DMM recent development counts May need to be updated
Load from Sediment	Use anoxic settling velocity or calculate explicit estimate of internal load	Use anoxic settling velocity or calculate explicit estimate of internal load
Load from major inflows	Not applicable	DMM modelled export from Baxter Lake
Runoff depth	Lakeshore Capacity Model coefficients	Lakeshore Capacity Model coefficients
Septic retention	Undetermined	Undetermined

4. Recommendations and Conclusions

The detailed work that has been done by SSEA suggests that water quality conditions are not changing, at least within recent years, and that these conditions (as indicated by average open water values of normal monitoring parameters such as total phosphorus, dissolved oxygen, water clarity) are not at a state where they should cause alarm. Our review concludes that conditions are not deteriorating in recent years and that conditions do not indicate that remediation is required. The same conclusions can be drawn through the examination of the bacteria data that has been collected (see HESL 2011). This is not to say, however, that these areas are not without problems, only that the average conditions measured for large areas are not problematic.

Recommendation 1 – That the accumulated state in the Areas of Concern has been well described such that no additional monitoring programs are required other than those currently being conducted by the SSEA. With respect to gaps and overlaps the following program-related recommendations are offered:

3. **That the more intensive SSEA program conduct the monitoring in the areas of concern with no requirement for coastal monitoring program data collection in those areas covered by SSEA ,**
4. **Sites should be standardized and maintained in the program.**

Nevertheless, there are anecdotal reports of algal and rooted plant proliferation. If these are not explained by existing data then additional research is warranted to confirm and quantify the problems and link them to causes. The important next step is to identify those changes among all that have been noticed (aquatic plants, periphyton, water clarity, community shifts) that represent problems that require local attention to avoid conditions deteriorating to an unacceptable state. If aquatic plants and periphyton are proliferating in all similar systems throughout Ontario due to certain links to climate change, for example, then these cannot be labelled as problems that require local attention. The solution is to organise a scientific approach to identifying the extent and causes of each perceived problem. It would be a waste of resources to first conclude that a problem exists and then assume that it is linked to a local activity and go forward to examine the local activity to establish cause and effect. These are natural but ill conceived directions. The proper approach however is often more difficult and consumptive of resources. To identify the extent and causes of ecosystem shifts in the face of multiple stressors is a difficult task which can challenge the capabilities of accomplished and well endowed research institutions. The next step that should be taken is to clearly define what the problems are in North Bay, South Bay and Church Bay and go forward from there to identify causes and then solutions.

Recommendation 2 - For each perceived problem there must be a method devised to confirm whether the problem exists and if so, outline the extent of the problem, and identify the driver or drivers responsible for the problem.

Once the set of potential problems have been identified there will be a need to map the extent of the problem and link this to causes that in all likelihood will involve a set of multiple stressors. In this case, there may be a need to coordinate science initiatives with volunteer efforts to collect the kinds of data that will be required to describe the problem and demonstrate its responses to system drivers.

Recommendation 3 - Programs should be coordinated to achieve maximum benefit from volunteer efforts and the expenditure of science program dollars.

Finally, anoxic hypolimnia and internal phosphorus loading have been documented for the GBF embayments (Bluewater Bioscience, 2009) and these can result in cyanobacterial blooms and algal proliferation. These conditions do not exist exclusively in the bays near Honey Harbour but have also been documented in Twelve Mile Bay and have resulted in cyanobacterial blooms in Sturgeon Bay. The conditions (anoxic bottom waters) in these areas which could fuel cyanobacteria blooms may be natural. If so, then management of existing phosphorus sources may not eliminate the problem, though reduced phosphorus loading may reduce its severity in the long term. It is therefore important to assess whether or not these conditions existed since before the shorelines were developed. If these conditions are natural, then they do not represent “bad” water quality per se, but rather water quality that when exacerbated by other external stressors may create conditions that are seen as undesirable (i.e., algal blooms). Paleolimnological techniques are well suited to reconstructing past water quality to establish the history of cyanobacterial blooms in lakes. There are also proven management actions available to control internal loading, either through sediment inactivation or aeration technologies.

Recommendation 4 - Projects should be initiated that can assess the degree to which the accumulated state (which has been well described) has departed from the historic background conditions. This information will be critical to determine the nature of the problem or if remediation is required at some point in the future. This would include information about past nutrient concentrations, past oxygen climate conditions in bottom waters and past distribution of periphyton and aquatic plants. Many conditions are in place that predispose the areas of concern to algal blooms. Paleolimnological surveys, especially in the areas of concern (South Bay and North Bay) are recommended to establish the past history of water quality and incidence of algal blooms.

2014 Update

This report was competed and submitted to GBF in draft form in October of 2011. Since that time, ongoing monitoring by GBF and SSEA and several initiatives that have been undertaken by GBF may address some of the recommendations and needs addressed herein. These include:

- A GBF-supported study to Identify Cyanobacteria Bloom Formation Risk in Georgian Bay Embayments by Prof. Lewis Molot and colleagues in 2012-2013,
- A GBF-supported study: “Historical Water Quality Trends in Georgian Bay Embayments – A Paleolimnological Study” carried out by HESL for GBF in 2012-2013.
- Ongoing detailed monitoring of selected areas by the SSEA
- Ongoing routine monitoring by GBF as part of their Coastal Monitoring Program.

Results of these studies should now be available and should be reviewed against the findings and recommendations of this report to determine a) if any conditions have changed and b) what factors are better understood as a result of those studies and c) how these relate to the concerns expressed by the Georgian Bay residents that informed this report.

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APPENDIX A. Meeting Minutes from February 11, 2011 Workplan Development Meeting

Meeting Action List

Activity	Date		Start Time
Workplan Development Meeting	11/02/2011		10:08
Location			Finish Time
Port Severn Town Office			14:00

Attendees:	Regrets:	Purpose	Keywords
Al Hazelton(Phone) Paul Wianko Neil Hutchinson Bev Clark Pat Chow-Fraser(Phone) Paul Percheson Bob Duncanson(phone) Keith Sherman Patsy Cross David Sweetnam (also acted as secretary)	Karl Schiefer Jan McDonnell Tom Bain (Judi Brouse was consulted about the meeting and its intent and will be copied on the circulation of these notes.)	To discuss the possible statement of work for a remedial action or research plan in the North Bay and South Bay areas of Honey Harbour to address anecdotal observations of prolific and unusual aquatic vegetation growth over the last decade.	Planning Meeting, Honey Harbour, North Bay, South Bay, remedial, Township of Georgian Bay

Notes:
The meeting started at 10:08 am in the meeting room at the Township of Georgian Bay offices in Port Severn. There were four attendees on the phone.

Honey Harbour Association
David Sweetnam opened the meeting with a statement of purpose that there has been an evolving idea beyond the annual water quality monitoring programs, that there should also be some focussed effort to resolve some water quality concerns in several specific areas. The Township of Georgian Bay has expressed an interest in reviewing such a plan and will consider providing funding.

Community Observations

David then invited Al Hazelton to share his observations about the massive “weed” growth occurring on the bottom of North Bay and the observed algae growth on the rocks along the shore. Al noted that in South Bay area, Baxter Lake (upstream) is not experiencing this problem, but as the water flows down from this lake and into South Bay, there is increasing algae growing on the shoreline exposed rock within a few kilometers. The suspicion stated by Al was that possibly the marina operations and boaters were causing this increased loading.

David Sweetnam suggested that at this point we limit assigning causal agents and simply discuss the observations and formulate the study design questions needed to provide an understanding of what is happening in these areas.

It was also noted that Church Bay (the bay off the town docks) area of Honey Harbour is also experiencing weed and algae growth. Low water levels are causing reduced water exchange in this area and it was suggested that each area may have different driving factors and any study design should consider this.

Al Hazelton shared that the locals observe discoloured foul runoff during high rains in the vicinity of the marina that uses are communal tile field. South Bay Cove Marina offers pump-out at dockside for all boats. He noted that early water quality testing in the area was developed to determine the impact of boaters. There was a report produced by U of T and Queens in the early ‘90s on this testing. Al thought that Tom Bain would likely have a copy. Pat Seyfried (sp?) published a sediment pathogenic bacterial report looking at boating bays and sampled in Frying Pan bay.

Also, MOE?/MNR? Produced a white paper in 1991 on Grey Water discharge restrictions. (Beck & McLaren).

Study Considerations

Neil Hutchinson suggested that a paleo-limnological study could reconstruct cyanobacterial concentrations from a core sample analysis. (U of W). He noted that the core study would also include macrophytes and attached or suspended diatom characterization to determine if prolific plant growth had also been occurring in the past. He also noted that the district of Muskoka will be adding deep water phosphorus to select sites in their program testing this fall.

Pat Chow-Fraser questioned if the growth noted was in pondweed or milfoil and shared the reported possibility that hybridization between native and Eurasian Milfoil may have occurred and be resulting in these prolific growths. She also suggested that either cladophera or fresh water sponge could be what is being observed on the shoreline. She thought that light penetration is likely causing the increased plant growth. It would be important to conduct a reference plant study and also look at sediment nutrients to determine what species are present and overgrowing.

Bev Clark noted that this is a province wide phenomenon and is likely a regional effect. He also observed that at depths of 9-11m the main drivers are typically internal loading and nutrient recycling.

Pat noted that Tadenac Bay has been a reference site and with depths of 8-10m they are note experiencing any similar problems. The species mix in this area is predominately nutrient limited. Once nutrient loads increase, then canopy species begin to move in and take over.

Keith Sherman shared that Severn Sound Environmental Association (SSEA) has data from North and South Bays for the past several years (as does GBF) starting late April / early May. They assay for surface composites, deep water phosphorus and metals, algae, phytoplankton and zooplankton following MOE protocols. Shifting communities are being noted and this will be available in a report to be released in March 2011. Keith also

Keith noted that in ’96-’97 the Geological Survey of Canada completed a seismic survey using North Bay as a reference site and that core samples were taken and Keith will determine their status and if they are available for comparison or baseline study. SSEA would be interested in the diatom core study and would be willing to contribute some support for this work.

Keith observed that South Bay has the backdoor in the form of inflows from Baxter Lake that increases the flushing term of the equation while North Bay doesn’t. He also noted that there are many flat profile areas of approximately 6m in depth that may be where much of the plant growth is occurring. Church Bay was studied in 2002 with the MOE for chemistry and near-shore water quality (no algae was sampled).

Other factors to consider:

- Phosphorus levels haven't been changing so does that mean it is in the plants?
- Rooted plant take nutrients from the soil while rootless get phosphorus from the water column.
- Lower water levels mean higher concentrations.
- Church Bay and South Bay have changed in terms of boat lengths.
- Twelve Mile bay has a new water treatment facility at Moose Deer Point being run by the federal government to Provincial standards.
- Non-jurisdictional exchange of training.

He also noted that the sediment quality has been augmented due to the presence of historic septage lagoons (decommissioned in the '80s). Officially these areas are no longer in operation. Locals believe that septage haulers are still using these areas.
It was also noted that boats can re-suspend sediments so source determinations of detrimental water quality loads are important to characterize accurately.
Keith agreed to build a literature list as a summer project this year and also informed that the Severn Sound Remedial Action document is available online at www.severnsound.ca.
Neil shared that the District of Muskoka is looking for lake loading model data input.
Paul Wianko noted that the Township plan to remediate the Honey Harbour Church Bay area is not around swimming but rather a higher quality visual experience.

Suggested for Study
Baxter Lake – characterize trophic status
Paleo-limnological assessment of North Bay
Sediment Samples – North, South and Church Bays
Reference Plant Study – North and South Bays
Macrophyte index – Keith will provide the parameters.
Church Bay – algae sampling
Adopt-A-Wetland Stewardship program in North Bay to raise public awareness.
Gap analysis and Literature sysnthesis

It was suggested that Church Bay be considered separately for the purposed of the development of this terms of reference and that it be started in mid to late April. SSEA will add this work to its budget request.
David thanked all of the participants for their valuable insights into the development discussion and the Honey Harbour Remedial Pilot meeting was terminated.
Termination
The meeting was terminated at 1200.

Action List

	Delivery Date	Deliverable	Action
1	ASAP	Preliminary Study Proposal	Neil Hutchinson to prepare and forward to David Sweetnam
2	ASAP	Budget for Summer Programs	David Sweetnam to assemble and provide to Paul Wianko
3	ASAP	Bathymetry data to Pat Chow-Fraser on North Bay and South Bay	David Sweetnam to provide
4	September 2011	Literature reference list	Keith Sherman to initiate a summer program to complete

5	ASAP	Church Bay project	Keith Sherman to update the Severn Sound Environmental Association budget proposal to council to incorporate the Church Bay study.
6	TBD	Next Meeting	Based on the discussions following receipt of the suggestions from Neil Hutchinson and the determination of the available budget from the Town and Georgian Bay Forever it will be determined when the next meeting should occur and who should be asked to participate.
7	ASAP	Sediment Sampling	Pat to provide budget estimates for this work
8	ASAP	Reference Plant Study	Pat to provide budget estimates for this work
9	ASAP	Water Quality instrumentation	Bev Clark to provide David Sweetnam with estimates for capital acquisition or alternatives