Muskoka Lakes Association Water Quality Initiative:

2003 Annual Report

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Executive Summary

2003 marked the end of the Muskoka Lakes Association's pilot project in nearshore water quality. Over the three year pilot project, the Association has realized great successes both technically and socially.

Building on results of the 2002 programme, two distinct functions of the water quality programme developed in 2003. A research function focused attention on nearshore measurements of total phosphorus, and how different intensities of residential development affected those levels. Periphyton growth was used as a diagnostic tool to further determine quality of nearshore water. The main body of this report is dedicated to the statistical and scientific analysis of this research. A monitoring function also emerged. Results of bacteria, phosphorus, water clarity and temperature are available on the MLA website at http://www.mla.on.ca. Website users are able to compare the quality of water in one location with provincial water quality objectives, other areas tested and with previous years' results. Using this online interface, community members are able to see changes in their water quality and when it might be appropriate to take mitigative action.

Two hypotheses that form the basis of results analysis are that a) mean nearshore total phosphorus levels are higher than mean offshore total phosphorus levels as b) nearshore total phosphorus measurements are more varied than offshore total phosphorus measurements. Research showed that offshore total phosphorus levels increased in 2003 over levels observed in 2002, whereas nearshore levels remained approximately equal. Due to this change, the two hypotheses did not generally hold true as they had in 2002.

Even though a definite cause of this important change in observations was not apparent, it is strongly suggested that sampling continue through 2004 with only slight changes to protocol as outlined in Section 6. This would act to confirm either the results observed in 2002 or those observed in 2003. Another focus of the research programme, such as resorts, golf courses or townsites may be chosen since these land uses may be associated with more explicit affects to nearshore water quality and may therefore be more easily documented.

Long term knowledge generation and community sustainability is dependent on the research function of the programme, but the monitoring function is very important to community members in the short term. Several interested parties, including those from lakes other than Muskoka, Joseph and Rosseau have expressed a desire to participate in the programme. With the help of funding from external sources such as the Ontario Trillium Foundation, it is recommended that the monitoring function of the programme be expanded to engage more volunteers, sample water from more areas and involve more communities.

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1.0 Introduction

The 2003 Muskoka Lakes Association (MLA) water quality initiative builds on two previous years of study into water chemistry and bacteriological qualities of surface water in the vicinity of Lakes Muskoka, Rosseau and Joseph in Central Ontario. The MLA has successfully used the programme to engage its membership and build relationships with local governments and other local residents' associations.

The original initiative designed to formulate sampling protocols and research factors affecting nearshore water quality has developed into the research function of the current initiative. Previous years' data suggests that there is some correlation between the intensity of residential development and nearshore phosphorus concentration. The 2003 research programme focussed on the affects of different characteristics of residential landscapes.

Two further reports concerning the 2003 programme are available. A graphical interface organizing the numerical results can be found online at http://www.mla.on.ca. A secondary textual analysis of the programme's periphyton results is also available.

2.0 Background

Local governments in Muskoka and certain Ontario Provincial Government agencies have been involved in the testing and monitoring of water quality for many years, and are still considered to be world leaders in basing land-use decisions on water quality. Tools such as the Ontario Lakeshore Capacity Simulation Model (and its local adaptations) and projects like the Lake Partners Programme have been used extensively and are widely recognised for their efficacy. The Muskoka Lakes Association feels that they can further help to protect and enhance the local environment and quality of life through engaging in a water quality research and monitoring initiative with specific local goals.

A water quality programme was started in 2001 as a three-year pilot project of the MLA with the help of Dr. Neil Hutchinson of Gartner Lee Limited. Since that time, the programme has expanded to encompass much broader issues including planning, development and community building.

2.1 Long-term Objectives

Long term objectives of the Water Quality Initiative were originally captured in five tasks:

1. **Review existing information** on water quality in Lakes Muskoka, Joseph and Rosseau;
2. **Give an opinion on the water quality stresses of most significance** to the Muskoka Lakes and the MLA, along with rationale for that opinion, with particular emphasis on acid rain, nutrient enrichment and bacterial contamination;
3. **Develop a research and monitoring programme** to document conditions of nutrient runoff, bacterial contamination and algal growth in the nearshore waters as they are influenced by bottom substrate, development density and shoreline vegetation;
4. **Liaise with other management initiatives** (District of Muskoka, Ministry of Environment, non-governmental organisations (NGOs)); and
5. **Advise on future stewardship initiatives** for the MLA.

2.2 Achievements

Through its third year, the MLA water quality initiative has accomplished all five of the pilot programme's original objectives. Objectives 1 and 2 were detailed in Gartner Lee's report on the 2001 programme entitled *Innovative Methods for the Determination of Water Quality in the Lakes Muskoka, Joseph and Rosseau* (GLL, 2001). In 2002, the MLA acted on Gartner Lee's recommendations to develop expertise and 'champions' internal to the association. As a result, the 2002 report (GLL, 2003) focussed on objectives 3, 4 and 5.

2.2.1 Research & Monitoring Programme

Two distinct functions of the water quality initiative explicitly emerged in the 2003 programme. These two functions were research and monitoring.

The research programme aims to further the effectiveness of the land use decision-making process that is currently based on water quality protection. Phosphorus concentration (trophic status) is the parameter traditionally considered in land use decision-making and is most representative of overall ecosystem health, so the research programme relies on nearshore phosphorus concentration measurements. The 2003 research programme follows directly from previous results which showed that collection of nearshore phosphorus data by volunteers is possible and nearshore phosphorus concentration is different from offshore phosphorus concentration. Further research by Logan (Logan, 2003) suggested that a specific, deliberative research question could make information collected most useful. Logan also suggested that changing peoples' behaviour (the way land is developed and used) could be the most effective way to protect and enhance water and environmental quality in the long term. Regulations such as local Official Plans and Zoning By-laws are still important tools available for environmental protection in the short term and can in fact be influenced by behaviour.

The monitoring function of the water quality initiative grew out of the newly developed capacity of the Muskoka Lakes Association in water quality measurement, and the involvement of volunteers in the programme. Expertise in testing protocols, information sharing and scientific credibility of the programme's results allowed an effective bacteriological monitoring programme designed to ensure safety of recreational waters in the Muskoka Lakes.

2.2.2 Partnerships

Through 2002, the MLA had seen limited success at building partnerships with other decision-making agencies and community groups. Several groups and governments were aware of the programme. In addition, the MLA was represented with a position on the District of Muskoka's Muskoka Watershed Council, and another on the Ministry of Natural Resources' Muskoka River Water Strategy. Both the Brandy Lake Property Owners Association and South Muskoka Lakes Community Association did partner with the MLA in extending the initiative to Brandy Lake and the area around the Muskoka

Sands resort. However, there were several opportunities for further cooperation with governments and other community groups.

Many factors including scientifically credible results, local media coverage and social acceptance helped to develop and extend many partnerships in 2003. The Gull and Silver Lakes Association, East Leonard Lake Association and Sucker Lake Cottagers' Association all partnered with the MLA in addition to the Brandy Lake Association and South Muskoka Lake Community Association. Presentations of results were also made to town councils in Seguin, Muskoka Lakes and Bracebridge, ensuring elected officials were aware of the programme in addition to government staff.

The Township of Muskoka Lakes' ad hoc Committee considering Waterfront Density is also a good opportunity for further cooperation between the local government and the MLA. The Township's committee has reviewed various aspects of development intensity from a social and aesthetic perspective in order to make recommendations for Official Plan amendments. The 2003 MLA research programme was developed in order to consider similar factors from the perspective of water quality. During public consultation during the fall and winter of 2003, it is hoped that results from both initiatives will be used by the public and decision-makers to determine appropriate amendments to the Township's Official Plan.

Even though relationships with local governments and community groups continued to develop and flourish, partnerships with the District of Muskoka and the Watershed Council have unfortunately been more stagnant.

2.2.3 Stewardship

Through its pilot project phase, the MLA programme has enjoyed three years of credible data and knowledge generation. At the conclusion of this pilot project, the monitoring branch of the programme is the most important stewardship initiative that has come directly from the programme. A public education campaign carried on through the pages of the quarterly newsletter *The Burgee* has also come to fruition. The MLA is also in a very good position to acquire external funding to implement various lessons learned through the programme, thanks to credible scientific knowledge and partnerships with local governments. It is recommended that further public education sessions be held during the summer of 2004, and that funding acquired be used to implement lessons learned during the 2003 programme.

3.0 Methods

Several recommendations were made following the 2001 programme. These included involving volunteers and the hiring of a coordinator for the programme. All of these recommendations were implemented during the 2002 season. Recommendations following the 2002 programme were relatively minor in comparison, since another years' experience proved to 'work out some of the bugs' from the programme. However, several further changes to methods were suggested by Gartner Lee Ltd. (2003).

Most recommendations were implemented during the 2003 programme, including many changes that allowed the programme to more efficiently use financial resources. These included a strict budgeting procedure, considering the cost of each type of parameter measurement. Knowledge gained from the MLA's association with Gartner Lee allowed the MLA to reduce reliance on Gartner Lee in 2003, freeing up more money for investment in sample collection and analysis costs such as lab time and equipment.

Restrictions on time and resources did not allow the programme to compare results with the Muskoka-Parry Sound Health Unit, or measure water quality in the large basins of the largest Muskoka Lakes, as was recommended. It should be the goal of the programme coordinator to implement these recommendations during the 2004 programme.

3.1 Volunteers

Volunteers were used to collect most of the samples during the 2003 programme as in 2002. Many other water quality programmes in Ontario also use volunteers to collect samples, but the MLA initiative further develops the use of volunteers to include sample analysis and public education.

The use of volunteers keeps costs extremely low. With the help of volunteers, the MLA was able to collect and analyse 2259 water samples during 2003, for a cost of approximately $35 000, including all administration and expert input. Many comparisons could be made with programmes that are much more costly and are much less thorough in sampling than the MLA programme.

Volunteers also help to internalise the expertise developed by the programme within the MLA (Logan, 2003). The local community is more likely to be aware of the programme and to have a sense of ownership of the knowledge developed through the programme because community members are a part of it. This is illustrated by the vast amount of local media coverage the programme continues to enjoy as well as multiple requests for presentation of results. Examples from 2003 include the Federation of Ontario Cottagers' Association, the South Muskoka Probus Club and the Town of Bracebridge Council. In addition to the local media, the MLA programme was also featured in a story published by the Globe and Mail newspaper in August of 2003 (Hunter, 2003).

3.2 Site selection

Three terms are used in this report to describe different water samples and locations: group, site and sample. A site is a specific location on the lakes where water is sampled on a bi-weekly basis. A series of sites including an offshore site and several nearshore sites are chosen to study a particular land use. These series are called groups. Every other week, a sample is taken from each site.

Efficiency in use of resources was illustrated by the fact that the MLA was able to consider water quality at 114 sites (up from 70 sites) with a smaller budget than 2002. Testing began at Windermere, Bala Bay, the Muskoka River, Sucker Lake, Gull Lake, Silver Lake (Gravenhurst) and Leonard Lake, and was discontinued at Arthuerlie Bay and Arundel Lodge as recommended by GLL (2003). Offshore sites were included with every group of nearshore sites and some nearshore sites were added to existing groups.

Several sites were added to the programme that focussed on different levels of residential intensity however details of site selection remained unchanged from 2002. Once again, nearshore sites were chosen in areas felt to be representative of various land uses and land-based activities. These nearshore sites were complemented by a local offshore site.

3.2.1 Residential Intensity

A particular emphasis was placed on sites representing different characteristics of residential intensity. These characteristics included:

- Impervious surface cover (ISC)
- Building envelope size
- Setback from lake
- Vegetated buffer zone
- Shoreline structures

The definition of residential intensity, for the purpose of this report, is a level of landscape alteration. This measurement is distinct from residential density, which implies a particular number of developments on a unit of landscape. It is also distinct from usage intensity, which implies how much a development is used or how many people use a piece of property.

The intention of choosing these sites was to be able to correlate these characteristics with water quality data, thus attributing specific residential landscapes with effect on water quality. Residential intensity was chosen as the research question to be considered in 2003 as per recommendations from Logan (2003). Residential intensity is most closely related with members of the MLA, since each resident owns (and therefore has control over) a parcel of residential land. Behaviour change brought about by increased knowledge about the environment will therefore have the greatest affect in residential areas. Focus on residential areas also shows individuals that their own behaviour indeed affects nearshore water quality, rather than focussing attention on resort or golf course owners who could otherwise become convenient scapegoats for water quality concerns.

The research programme considered phosphorus concentration as its parameter of primary concern. Phosphorus was therefore measured at each of the 29 sites chosen for analysis of residential intensity characteristics. Research sites are listed in Table 3.1 and shown in Appendix A. Results of the research programme are outlined in Chapter 4.

Table 3.2 - Sites chosen to research residential intensity factors (phosphorus concentration)

Location	Site
Royal Muskoka Island	RMI-0 RMI-1 RMI-4 RMI-5
Brackenrig Bay	BRA-0 BRA-1 BRA-2 BRA-3
Indian River	IND-0 IND-1 IND-5 IND-6
Bala	BAL-0 BAL-1 BAL-2 BAL-3
East Bay	EAS-0 EAS-1 EAS-2 EAS-3
Walker's Point	WAK-0 WAK-1 WAK-2 WAK-3 WAK-4
Muskoka Bay	MBA-0 MBA-6 MBA-7 MBA-8

Table 3.3 - Monitoring programme sites (▲ indicates measurement of parameter)

Location	Code	Land Use	bacteria	phosphorus	turbidity	algae
Hamer Bay	HMB-0	Offshore	▲	▲	▲	
	HMB-1	Golf Course (Rocky Crest)	▲	▲	▲	▲
	HMB-2	Resort (Rocky Crest)	▲	▲	▲	
	HMB-3	Resort (Rocky Crest)	▲	▲	▲	▲
	HMB-4	Residential	▲	▲	▲	▲
Little Lake Joe	LLJ-0	Offshore	▲		▲	
	LLJ-1	Residential	▲		▲	
	LLJ-2	Residential	▲		▲	
	LLJ-3	Residential	▲		▲	
Foot's Bay	FTB-0	Offshore	▲		▲	
	STI-0	Offshore		▲	▲	
	FTB-1	Residential	▲		▲	
	STI-2	Golf Course (Still's Bay)		▲	▲	
	FTB-3	Residential	▲		▲	
	FTB-4	Residential	▲		▲	
Cox Bay	COX-0	Offshore	▲	▲	▲	
	COX-1	Golf Course (Lake Joe)	▲	▲	▲	
	COX-2	Golf Course (Lake Joe)	▲	▲	▲	
	COX-3	Town (Port Sandfield)	▲		▲	
	COX-4	Resort (Pinelands)	▲		▲	
Sucker Lake	SUC-0	Offshore	▲		▲	
	SUC-1	Residential	▲		▲	
	SUC-2	Residential	▲		▲	
	SUC-3	Residential	▲		▲	
Rosseau/Shadow River	RSH-0	Offshore	▲		▲	
	RSH-1	Wetland	▲		▲	
	RSH-2	Wetland	▲		▲	
	RSH-3	Town (Rosseau)	▲		▲	
	RSH-4	Town (Rosseau)	▲		▲	
	RSH-5	Camp (Muskoka Woods)	▲		▲	
Royal Muskoka Island	RMI-0	Offshore	▲	▲	▲	
	RMI-1	Residential	▲	▲	▲	
Brackenrig Bay	BRA-0	Offshore	▲	▲	▲	
	BRA-1	Residential	▲	▲	▲	▲
	BRA-2	Residential		▲	▲	▲
Minett	MIN-0	Offshore	▲	▲	▲	
	MIN-1	Resort (Cleveland's House)	▲		▲	
	MIN-2	Resort (Cleveland's House)	▲		▲	
	MIN-4	Golf Course (LRBR)	▲	▲	▲	
Windermere	WIN-0	Offshore	▲	▲	▲	
	WIN-1	Dee River	▲		▲	
	WIN-2	Residential	▲		▲	
	WIN-3	Golf Course (Windermere)	▲	▲	▲	▲
	WIN-4	Resort (Windermere House)			▲	

Table 4.2 continued

Location	Code	Land Use	bacteria	phosphorus	turbidity	algae
Indian River	IND-0	Offshore	▲	▲	▲	
	IND-1	Residential	▲	▲	▲	▲
	IND-2	Town (Port Carling)	▲		▲	
	IND-3	Trailer Park	▲		▲	
	IND-5	Residential		▲	▲	▲
Brandy Lake	BDY-0	Offshore	▲		▲	
	BDY-1	Wetland	▲		▲	
	BDY-2	Residential	▲		▲	
	BDY-3	Residential	▲		▲	
	BDY-4	Residential	▲		▲	
	BDY-5	Residential	▲		▲	
North Bay	NRT-0	Offshore	▲		▲	
	NRT-1	Residential	▲		▲	
	NRT-2	Transfer Station	▲		▲	
	NRT-3	Transfer Station	▲		▲	
Bala	BAL-0	Offshore	▲	▲	▲	
	BAL-2	Town Site	▲	▲	▲	
East Bay	EAS-0	Offshore	▲	▲	▲	
	EAS-1	Undeveloped	▲	▲	▲	
Beaumaris	BMR-0	Offshore	▲	▲	▲	
	BMR-1	Undeveloped	▲		▲	
	BMR-2	Golf Course (Beaumaris)	▲	▲	▲	
	BMR-3	Town (Beaumaris)	▲		▲	
Eilean Gowan	ELG-0	Offshore	▲		▲	
	ELG-1	Residential	▲		▲	
	ELG-2	Residential	▲		▲	
	ELG-3	Residential	▲		▲	
Muskoka River	MRV-1	Mouth	▲		▲	
	MRV-2	Santa's Village	▲		▲	
	MRV-3	South Branch	▲		▲	
	MRV-4	North Branch	▲		▲	
Walker's Point	WAK-0	Offshore	▲	▲	▲	
	WAK-1	Residential	▲	▲	▲	▲
	WAK-2	Residential	▲	▲	▲	
	WAK-4	Residential		▲	▲	▲
Muskoka Sands	MSN-0	Offshore	▲	▲	▲	
	MSN-1	Resort (Muskoka Sands)	▲		▲	
	MSN-2	Golf Course (Taboo)	▲	▲	▲	
	MSN-3	Residential	▲		▲	
	MSN-4	Golf Course (Taboo)	▲	▲	▲	
Muskoka Bay	MBA-0	Offshore	▲	▲	▲	
	MBA-1	Wetland	▲		▲	
	MBA-3	Residential	▲		▲	
	MBA-4	Town (Gravenhurst)	▲	▲	▲	
	MBA-5	Town (Gravenhurst)	▲	▲	▲	
	MBA-6	Residential		▲	▲	▲

Table 3.2 continued

Location	Code	Land Use	bacteria	phosphorus	turbidity	algae
Leonard Lake	LEO-0	Offshore	▲		▲	
	LEO-1	Residential	▲		▲	
	LEO-2	Residential	▲		▲	
	LEO-3	Residential	▲		▲	
	LEO-4	Residential	▲		▲	
Gull Lake	GUL-0	Offshore	▲	▲	▲	
	GUL-1	Hoc Roc	▲	▲	▲	
	GUL-2	Residential	▲		▲	
	GUL-3	Residential	▲	▲	▲	
	GUL-4	Park	▲	▲	▲	
Silver Lake	SVR-0	Offshore	▲		▲	
	SVR-1	Residential	▲		▲	
	SVR-2	Jevins Lake	▲		▲	

3.2.2 Monitoring

Bacteria and turbidity were measured at all sites chosen for monitoring purposes. Phosphorus concentration and periphyton growth were also measured at some sites. Moreover, some 'research' sites were also 'monitoring' sites. Essentially, bacteria were measured at some 'research' sites for the sake of completeness in monitoring. Financial constraints unfortunately made it impossible to measure bacteria at all 'research' sites. Sites included in the monitoring programme are listed in Table 3.2. Maps showing the location of each site are available on the MLA website at http://www.mla.on.ca. Sampling dates are shown in Table 3.3.

Table 3.3 - Sample Dates

Sample Number	Date	
	Lake Joseph, Lake Rosseau, Indian River, Sucker Lake, Brandy Lake	**Lake Muskoka, Muskoka River, Hoc Roc River, Leonard Lake, Gull Lake, Silver Lake**
1	26 May 2003	2 June 2003
2	9 June 2003	16 June 2003
3	23 June 2003	30 June 2003
4	7 July 2003	14 July 2003
5	21 July 2003	28 July 2003
6	4 August 2003	11 August 2003
7	18 August 2003	25 August 2003
8	1 September 2003	8 September 2003

3.3 Phosphorus

Total phosphorus (TP) was measured by the MLA in 2003 at sites as described in Section 3.2. Samples were analysed by the Trent University Laboratory at the Ministry of the Environment's (MOE) Environmental Science Centre in Dorset as they were in 2002 (GLL, 2003).

The sampling procedure used by volunteers for TP did change slightly as per MOE recommendations. Instead of filling the digest tubes directly from surface water, volunteers scooped water into a plastic jar and filtered water through a 80 micron filter supplied by the MOE into the tubes. These filters were meant to separate any zooplankton from sample water since these organisms can severely skew TP results. MOE staff suggests that variability in TP concentration reduced by 33% on average throughout the province (Clark, 2003). It is recommended that the MLA programme discontinue the use of these filters for several reasons.

The MLA sampling protocol is meant to measure TP concentration in the nearshore and offshore zones of the lakes. Acute influences on nearshore TP concentration originating on land such as erosion and runoff following rain events are therefore expected. Use of filters could in fact filter out particulate matter that is important in determining actual nearshore phosphorus concentration (the same influences are not expected in offshore zones which MOE protocols are designed for). Consistency in data collection between the MLA initiative and the MOE Lake Partner Programme is not a concern either, since the MOE collects spring turnover phosphorus data (TP_{so}) where the MLA initiative measures a seasonal average. In addition, it is unclear whether or not all MLA volunteers used the filters properly. In a few instances, MLA volunteers used the filters when sampling for bacteria or turbidity. The use of these filters clearly complicate the sampling protocol from the viewpoint of the volunteers and may even corrupt the MLA initiative's TP collection protocol.

3.4 Total Coliforms

Volunteers collected samples for coliform tests using sterilized 300mL juice bottles, as they had done in 2002 (GLL, 2003). These bottles were obtained from a bottler, and are identical to bottles conventionally used to hold fruit juices.

Towards the end of the 2003 season, it became more difficult to seal the bottles after sterilization. This is due to the fact that most of the bottles and caps had been used many times over, and caps began to rust or otherwise deteriorate (interior rubber coating). It is recommended that new caps be purchased for all bottles in 2004, and new caps be purchased at the beginning of each subsequent year to avoid this situation.

The rest of the sampling and analysis procedure remained unchanged from 2002, and is described in detail by Gartner Lee Ltd., 2003, however convention used in the counting of positive blue cells did change slightly. It was noted by GLL, 2003 that a convention concerning a certain shade or 'darkness' of blue that a cell must be in order to be counted was applied during the 2002 programme. Part way through the year, Dr. Karl Schiefer of Environmental Biodetection Products Incorporated indicated that in fact any cell that could be considered any shade of blue or green should be counted. At the time, it was decided that analysis should use the established convention. New ColiPlates in 2003 were designed with different pigments that made it much easier to identify positive blue cells. Therefore, all cells considered to be any shade of blue were counted. For this reason, total coliform levels on average are higher in 2003 than they were in 2002.

It is also important to consider the detection limits of the ColiPlate technology. If a ColiPlate has no blue cells, the number of bacteria cells per 100mL is less than three. For the sake of simplicity, any reading of "<3" bacteria per 100mL were assigned a value of 1.

3.5 *Escherichia coli*

Sampling and analytical procedure for E.Coli remained unchanged from 2002. Detailed explanation is found in Gartner Lee Ltd., 2003.

3.6 Turbidity

Water clarity was measured in terms of turbidity and recorded in Nephelometric Turbidity Units (NTU) as described by Gartner Lee Ltd., 2003. Turbidity for sample 4 was not recorded, because the turbidimeter was being used by Gartner Lee staff for another project and it was not possible to process MLA samples in a timely manner.

The MLA should continue to use turbidity in its water quality initiative since it is an economical and easy way to measure water clarity. However, a one-time investment should be made to purchase a dedicated machine for measuring turbidity to reduce reliance on Gartner Lee.

In order to standardize the protocol, MLA personnel should also experiment with different methods of mixing samples prior to analysis. By consistently shaking samples prior to analysis, elapsed time between sampling and analysis should become less important (this factor becomes more important as analysis of bacteria samples is further internalized to volunteers throughout the region). On the other hand, there is a possibility that standardized mixing of the samples could change the analysis in a way that in situ suspended solids (found in the natural water column) will be consistently mixed regardless of elapsed time between sample collection and analysis.

3.7 Algae

Taxanometric analysis of periphyton growth was measured throughout the season as described by Gartner Lee Ltd., 2003. Neither algal biomass nor chlorophyll a was measured because it was felt that results from 2002 did not justify the human and financial resources used in this aspect of the initiative. That is, variable field conditions caused biomass measurements to be less useful than taxonomy.

3.8 Duplicates and Blanks

A volunteer-based research programme like the MLA initiative achieves recognition by the lake management community only through the use of sound scientific methods. In order to ensure integrity or results, several steps were taken. These included duplicate samples and field blanks as quality control and quality assurance measures.

The 2003 initiative used the same protocols for quality control and quality assurance measures as were used in 2002. These are described by Gartner Lee Ltd., 2003. Five percent of phosphorus samples were duplicated and analysed by Trent University, five percent of bacteria samples were duplicated and analysed internally and a further five percent of bacteria samples were duplicated and analysed by a laboratory accredited by the Ontario government (Central Ontario Analytical Laboratory). Field blank measurements using commercially available purified drinking water were also taken alongside of five percent of bacteria samples and analysed for bacterial contamination internally. Turbidity was measured for all of the duplicate and field blank samples analysed internally.

4.0 Results

Chapter 2 described the two functions of the 2003 MLA water quality initiative – research and monitoring. This report focuses on the results of the research programme as well as the quality control and quality assurance measures necessary to maintain the credibility of the entire programme. Detailed results of the monitoring programme are presented in the form of an online interactive database available for viewing at the Muskoka Lakes Association website (http://www.mla.on.ca). The website allows MLA members to click on an imagemap of the Muskoka Lakes to select an area for which to view monitoring programme results. Bacteria and turbidity can be compared to other locations monitored by the MLA or to results of previous years at the same area.

Section 4.1 presents results of the QA/QC programme. Section 4.2 details the analysis of the research programme designed to correlate characteristics of residential landscapes with nearshore water quality.

4.1 Duplicates and blanks

No scientific programme of study can claim to use information that is always 'correct.' Variability in information is even greater when environmental parameters are being measured in the field. Simply put, there are too many natural variables to be individually considered. Nevertheless, it is the goal of programmes like the MLA's to reduce environmental variables as much as possible in order to understand those that are isolated.

Using volunteers who are not professionally trained in field protocol nor who receive any sort of compensation for efforts further complicates a scientific research programme. Volunteers may not understand or bother to follow all protocols thus increasing variability in information collected. For this reason, quality control and quality assurance is of utmost importance in the MLA programme, in order to minimize sources of variance.

4.1.1 Bacteria Blanks

There are several possible sources of contamination to bacteria samples. These include insufficient sterilization, volunteers contaminating sample bottles in the field after they are opened and broken seals after sterilization.

Results of blank tests are shown in Table 4.1. Note that as discussed in Section 3.4, all samples recorded as 1 bacteria/100mL actually had a result of <3 bacteria/100mL, and therefore do not necessarily represent contamination. Samples are sorted by sampling date. Five of 36 samples (13.5%) showed contamination. One of the contaminated

Table 4.1 - Bacteria blank results

Site	Sample Number	TC Blank	EC Blank	Sampler
BMR-0	1	1	1	Logan
ELG-0	1	1	1	Logan
MIN-0	1	1	1	Mitchell
RSH-0	1	1	1	Taylor
WIN-0	1	1	1	Logan
GUL-0	2	1	1	Lee
LEO-0	2	1	1	G. Roberts
RMI-0	2	8	1	Logan
BAL-0	3	1	1	Nordstrum
EAS-0	3	1	1	Morrisey
HMB-0	3	1	1	Johnson
IND-0	3	1	1	MacDonald
LLJ-0	3	1	1	Johnstone
BMR-1	4	1	1	Marine Patrol
MIN-1	4	1	1	Boughner/Shantz
NRT-0	4	1	1	Barker
RSH-1	4	1	1	Taylor
WIN-1	4	1	1	Manchee
BDY-0	5	1	1	Cormack
BRA-0	5	1	1	Wallace
ELG-1	5	1	1	Moher
MRV-1	5	1	1	Wood
MSN-0	5	1	1	Marine Patrol
BRA-1	6	1	1	Wallace
GUL-2	6	5	1	Lee
HMB-1	6	13	1	Johnson
IND-1	6	1	1	MacDonald
LLJ-1	6	1	1	Soutendijk
SUC-3	6	1	1	Hepworth
BMR-2	7	1	1	M. Logan
ELG-2	7	1	1	Carr
MRV-2	7	1	1	Wood
NRT-2	7	1	1	Barker
SUC-2	7	1	1	Hepworth
FTB-0	8	11	1	Sillcox
HMB-2	8	1	1	Johnson
LLJ-2	8	1	1	Soutendijk
MBA-0	8	3	1	West

samples occurred at the beginning of the season (in week two) while the other four contaminated samples were observed near the end of the season (in weeks six and eight). The later contaminated samples might have been due to the fact that bottles were difficult to sterilize near the end of the season as discussed in Section 3.4. No two contaminated samples were collected by the same volunteer. This suggests that no volunteers are guilty of consistently contaminating the sample bottles in the field, and that all bacteria results did not suffer from consistent contamination.

In future years, new caps should be purchased for bacteria sampling bottles to ensure sterilization.

4.1.2 Turbidity Blanks

Field blanks were tested for turbidity in the same manner as normal samples. Since the blank samples had been mechanically and chemically treated to a high standard, turbidity should be consistent for all blank samples. Varying turbidity would suggest either a contaminated treated water supply, or problems with the turbidimeter.

Turbidity results for the field blanks are shown in Figure 4.2. Turbidity in three of 38 samples exceeded two times the standard deviation above the mean for the sample set. These three results are highlighted in Table 4.2. Sample FTB-0-8 also registered bacterial contamination. Clearly this sample actually contained lake water rather than distilled water, and represents volunteer error in sampling protocol rather than sample contamination.

Table 4.2 - Turbidity blank results.

Site	Sample Number	Turbidity (NTU)
BMR-0	1	0.3
MIN-0	1	0.31
RSH-0	1	0.29
WIN-0	1	0.28
GUL-0	2	0.26
LEO-0	2	0.38
RMI-0	2	0.28
SUC-0	2	0.27
BAL-0	3	0.32
EAS-0	3	0.29
HMB-0	3	0.27
IND-0	3	0.45
LLJ-0	3	0.35
BDY-0	5	0.34
BRA-0	5	0.37
ELG-1	5	0.35
MRV-1	5	0.63
MSN-0	5	0.3
BRA-1	6	0.31
GUL-2	6	0.25
HMB-1	6	0.32
IND-1	6	0.33
LLJ-1	6	0.31
SUC-3	6	0.31
BMR-2	7	0.27
ELG-2	7	0.57
MRV-2	7	0.35
NRT-2	7	0.41
SUC-2	7	0.31
ELG-0	8	0.3
FTB-0	8	0.72
HMB-2	8	0.37
LLJ-2	8	0.36
MBA-0	8	0.28

4.1.3 ColiPlate Duplicates

Five percent of bacteria samples were duplicated and analysed with ColiPlates as described in Section 3.8. Results of total coliform duplicates are shown in Figure 4.1, and results of E.Coli duplicates are shown in Figure 4.2.

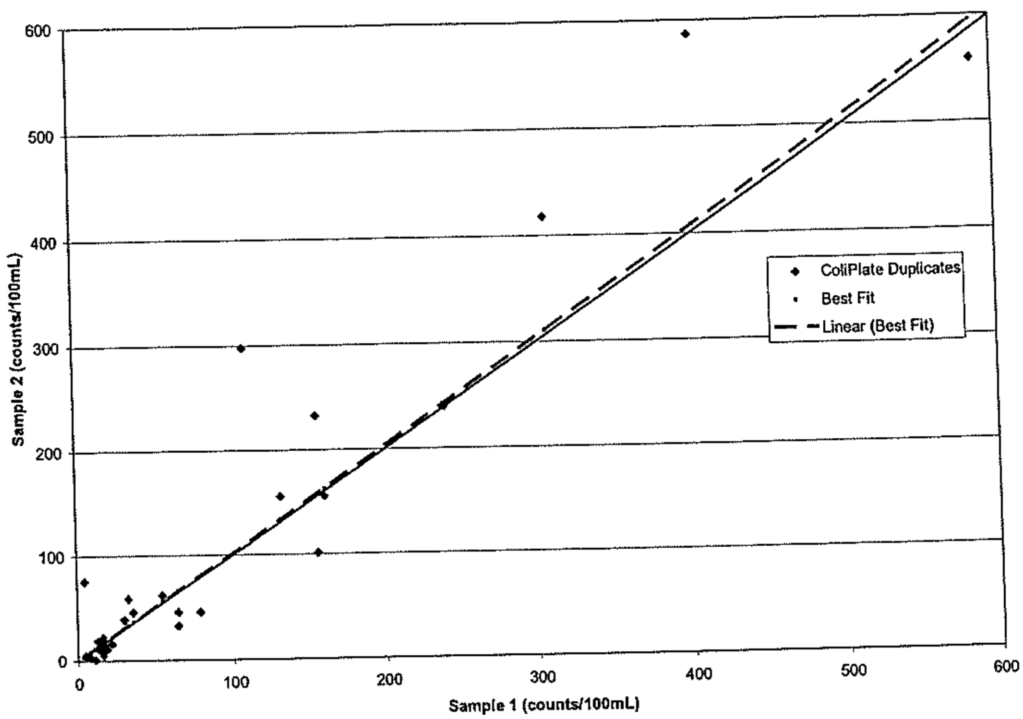

Figure 4.1 - Total coliform duplicates compared using ColiPlate technology.

Some variation between original samples and duplicates can be expected since bacteria organisms tend to occur in agglomerations and adsorb to suspended particles in the water column. It is therefore important to interpret variations observed appropriately.

Figure 4.1 shows that total coliform duplicates do not feature a bias. Linear regression was performed on the data set to find the curve best fit to the data. This curve is shown in Figure 4.1 as the dashed line. The figure clearly indicates that the best fit curve is nealy coincident with a direct correlation between samples and their duplicates (represented by the solid line). One sample did feature a very large difference between total coliforms in the original and duplicate. BRA-0-3 had a difference of 1420% (5 counts/100mL vs. 76 counts/100mL). It is most likely that this one sample was taken improperly by the volunteer or was otherwise contaminated.

E.Coli duplicate results are shown in Figure 4.2. The figure shows, on average, a greater relative variance than existed in total coliform duplicate results (204% as opposed to -1.5%). This large relative difference is due to the small numbers associated with E.Coli levels. The average absolute difference between original and duplicate E.Coli samples was only 1.5 organisms per 100mL. Since the ColiPlates have a margin or error of approximately 2.5 counts/100mL (most probable number calculation only accurate to within two or three counts), an average absolute difference of 1.5 counts per 100mL is acceptable. 1.5 counts per 100mL represents such a large relative difference (204%) because E.Coli levels are generally very low.

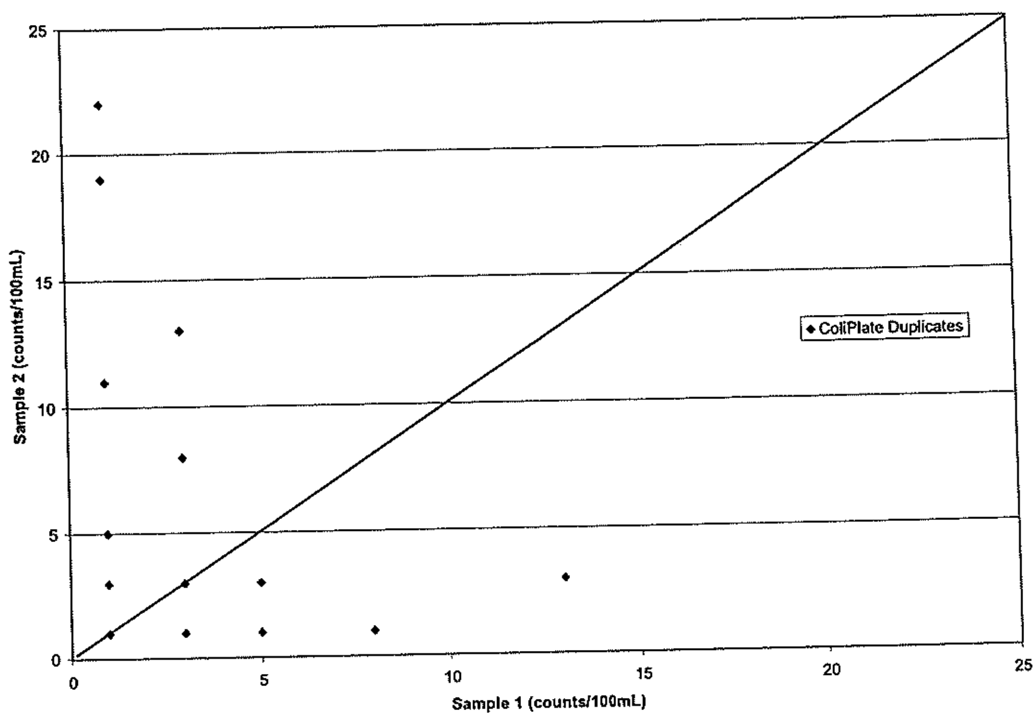

Figure 4.2 - E.Coli duplicates compared using ColiPlate technology

4.1.4 Lab Duplicates

In addition to the duplicates described in Section 4.1.3, five percent of bacteria samples were duplicated and sent to an accredited laboratory (Central Ontario Analytical

Laboratory, Orillia). A comparison between COAL results and ColiPlate results are given in Figures 4.3 and 4.4.

Figure 4.3 clearly suggests a strong positive bias indicating that ColiPlate total coliform results were higher than results on the same samples undertaken at the accredited laboratory. Linear regression was performed on the data set. The best fit curve given by regression is shown as the dashed line on Figure 4.3. This relationship suggests that the ColiPlates overestimate total coliforms by more than four-fold on average. An approximate three-fold overestimation can be seen in the 2002 data set. An increase in overestimation can be attributed to the change in analysis convention described in Section 3.4. ColiPlate total coliform results are considered to be conservative. Since total

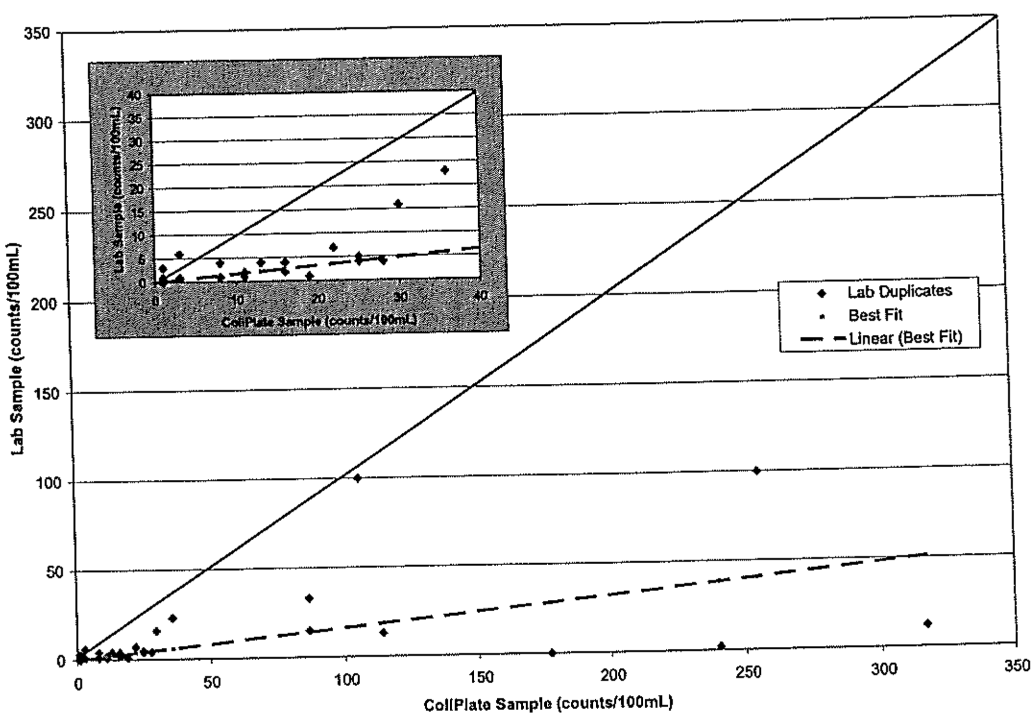

Figure 4.3 - Comparison between Laboratory and ColiPlate total coliform results.

coliforms have little bearing on public health concerns, there is little risk of this conservative estimation causing undue anxiety amongst communities (as might be the case if E.Coli were being grossly overestimated.) However, the interpretation of total coliform information should consider this overestimation.

Figure 4.4 also shows an overestimation in E.Coli counts by the ColiPlates, but the overestimation is less than two-fold. Such comparison is also affected by the fact that the levels of E.Coli are close to the detection limit of the ColiPlates. Most ColiPlate results were less than three counts per 100mL, which were assigned values of "1" to make statistical analysis possible. Since laboratory results are more exact, these corresponding lab measurements could have been 0, 1 or 2 and still have been an 'exact match.' However, a zero result would imply that the ColiPlates had overestimated the E.Coli contamination.

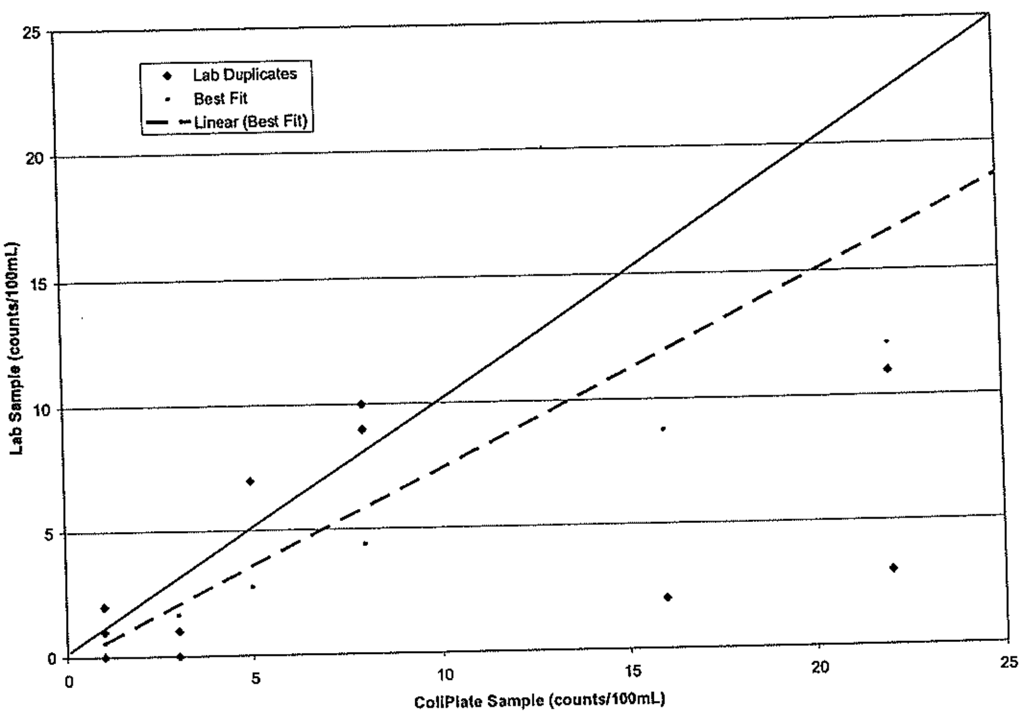

Figure 4.4 - Comparison between Laboratory and ColiPlate E.Coli results.

In general, it is important to note that E.Coli measurements appear to be slightly overestimated by the ColiPlates. This means that ColiPlate results are a conservative estimate of bacterial contamination, but results are not gross overestimates that might cause undue anxiety amongst the public.

4.1.5 Phosphorus Duplicates

Five percent of all phosphorus samples were duplicated and analysed by Trent University's lab at the MOE's Environmental Science Centre in Dorset as described in Section 3.3. Possible sources of variation include lab error and particulate matter within the samples when collected. GLL, 2003 notes that a relatively large average difference of 27% was seen between original and duplicate samples. To avoid particulate matter in the samples, water was filtered through an 80 micron filter as described in Section 3.3. Comparison between original and duplicate samples is shown in Figure 4.5.

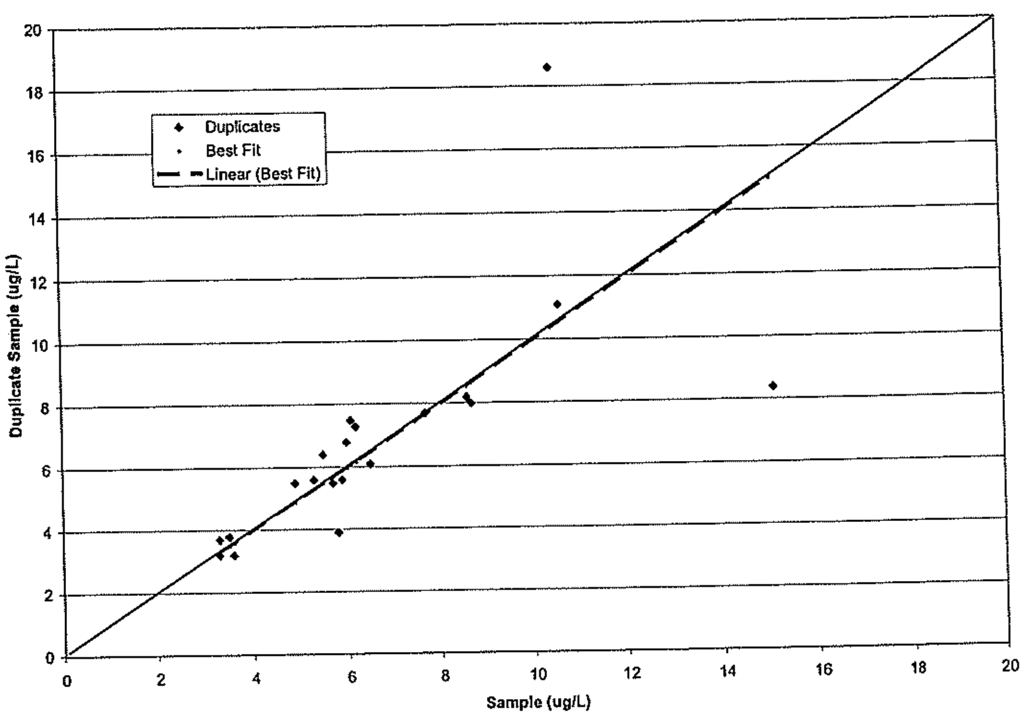

Figure 4.5 - Comparison of phosphorus concentration duplicates

The dashed line on the figure shows the best fit curve as calculated by linear regression on the data set. Clearly, the curve of best fit indicates a very close correlation between original and duplicate samples. Difference between the original and duplicate samples was 0.16 µg/L on average (3.6%). These statistics show a much closer correlation than did the 2002 MLA programme (GLL, 2003). This result may be due to the use of the 80 micron filter, or a decrease in laboratory error. Overall, the variation observed in the phosphorus concentration data set is an acceptable level.

4.1.6 Turbidity Duplicates

Turbidity of each sample was measured according to the protocol outlined in Section 3.6. Turbidity was also recorded for all bacteria duplicates analysed internally using ColiPlates. A comparison between turbidity of original and duplicate samples is shown in Figure 4.6. The dashed line if Figure 4.6 represents the best fit curve calculated by linear regression on the data set. The average variation is only -0.03 NTU, which is insignificant compared with the degree of uncertainty in using the turbidimeter (GLL, 2003). Overall, there is a strong correlation between the original and duplicate samples.

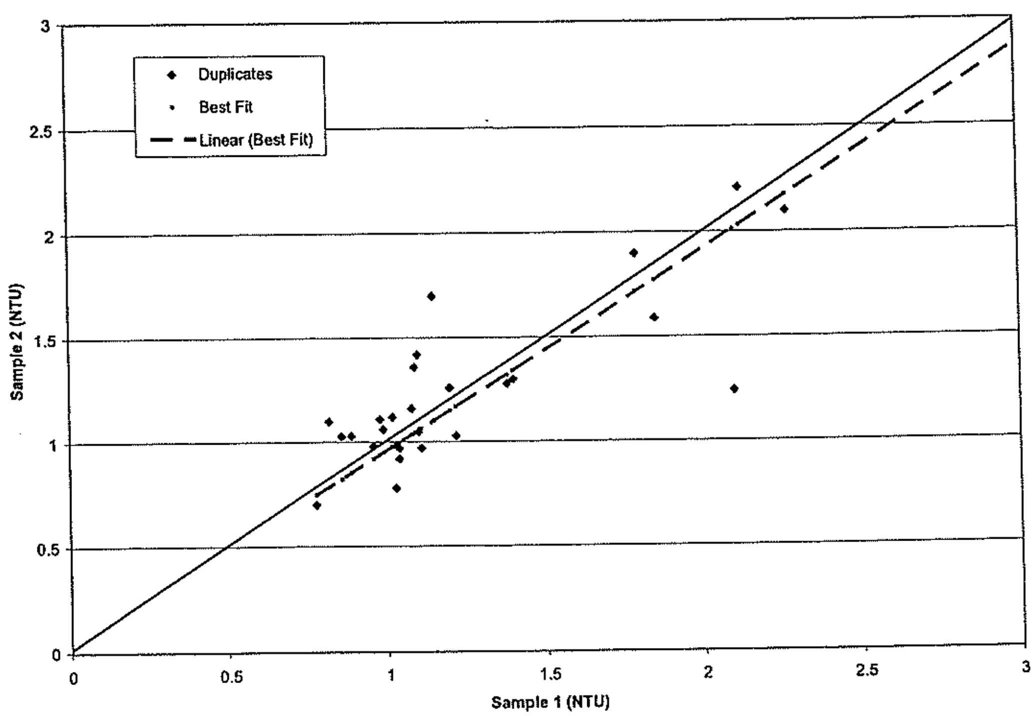

Figure 4.6 - Comparison of Turbidity Duplicates

4.1.7 QA/QC Conclusion

Several methods of quality control and quality assurance are employed by the MLA water quality initiative. Results show that contaminantion of samples does occur from time to time, but generally there is no consistent bias in the analysis. The exception to this is in bacteria results given by the ColiPlate technology. Total coliforms seem to be conservatively estimated by a factor of four. Likewise, E.Coli are overestimated by a small margin (less than a factor of two.) These results are acceptable since they represent conservative estimates of bacterial contamination. E.Coli, which are important in terms of public health are only slightly overestimated, so undue concern brought about by conservative estimates is unlikely.

4.2 Research Programme Results

The long-term goal of the MLA water quality initiative is to protect and enhance environmental quality by changing the way development occurs on Muskoka's lakes. The MLA hopes to do this by objectively determining what style of development is most appropriate. This style of development can be implemented in the shorter term through regulations and restrictions outlined in local Official Plans and other planning policy. In the longer term, appropriate development must become part of the local culture. Both the shorter and longer term success of this programme hinges on building knowledge about how development affects environmental quality (Logan, 2003).

The first step to building apposite knowledge is identifying a natural phenomenon and creating a hypothesis to explain it (Logan, 2003). Useful data must then be collected to support or refute the hypothesis. The data in turn, must be scientifically accurate and replicable, and must be easily transferred and shared throughout the community (Logan, 2003). Section 4.1 outlines the results of several quality assurance and quality control measures taken to ensure the accuracy and replicability of the data. Knowledge is also likely to be shared throughout the community since the community was involved in developing the knowledge, and knowledge is becoming more and more accessible (eg. interactive online database).

The research function of the water quality initiative directly aims to build knowledge about how development affects the local environmental quality. Data collected at the 29 research sites will now be examined in detail.

4.2.1 Hypothesis Formation

The MLA water quality initiative has been research-driven since its inception in 2001. At the time, the hypothesis being tested stated that nearshore water quality was different than offshore water quality, and these differences could be attributed to land uses land-based activities. This hypothesis was very general. The MLA considered several parameters and several different land uses. The first year's programme focussed on developing protocols for the collection of replicable data. In 2002, the focus changed to determining whether nearshore and offshore water quality differed.

By 2003, the programme had shown that it was possible to collect replicable data (GLL, 2001) and that water quality did differ between the nearshore and offshore (GLL, 2003). It was then appropriate to narrow the research focus in order to build knowledge about how the mechanisms attributable to specific land uses and land-based activities affect water quality in the nearshore zone.

Residential land use was chosen as the research focus for three important reasons. First, data collected in 2002 suggested an intuitive correlation between level of development (characterised by impervious surface cover, vegetative buffer zones, building envelope size etc) and water quality. A depiction of this intuitive correlation is given in Appendix B. Secondly, if long term goals of the MLA programme are to change people's behaviour and make appropriate development styles culturally expected, residential development is most important since most community members have control over development of their own private land (as opposed to resorts or town sites). Finally, the MLA hoped to work with the Township of Muskoka Lakes' ad hoc committee currently studying possibilities for changing to the township's waterfront designation in the Official Plan and By-law.

The three 2003 hypotheses state

1) Phosphorus is more concentrated in the nearshore zone than in the offshore zone (due to acute land-based influences)
2) Variance in phosphorus concentration is higher in the nearshore zone than in the offshore zone (acute land-based influences are more uniformly distributed by the time they assimilate into deep water)
3) Land-based influences can be attributed to characteristics of the residential landscape

Hypotheses one and two came directly from results of the 2002 programme (GLL, 2003; Logan, 2003). Hypothesis three was developed using previous knowledge and inference. Extensive field work was undertaken during the 2003 season to document these characteristics of the residential landscape.

4.2.2 Analysis of the Dataset

Hypotheses one and two must be accepted before hypothesis three can be considered. The initial hypotheses are physically corollaries, since they attempt to predict two effects of the same phenomenon (land-based sources of phosphorus that acutely affect the nearshore zone due to its proximity to land). That is, phosphorus concentration is both higher and more varied in the nearshore zone because sources of phosphorus are land-based (and potentially attributable to specific characteristics of the residential landscape).

To evaluate these hypotheses, results of the eight phosphorus samples taken at each location were used to calculate the annual average phosphorus concentration as well as the standard deviation of each eight-point dataset. The annual average phosphorus concentration and standard deviation for each nearshore site was then compared with its corresponding offshore site. Phosphorus concentration data collected is shown in Table A1 in Appendix A, and calculated values (annual average and standard deviation) are shown in Table A2 in Appendix A. Table 4.3 summarizes which hypotheses were confirmed for the 29 research sites considered. Statistical significance was only calculated for sites where hypotheses were confirmed.

Table 4.3 - Summary of hypothesis tests

	Hypothesis 1	Statistical Significance (H1)	Hypothesis 2	Statistical Significance (H2)
BAL-1	▲		▲	▲
BAL-2	▲		▲	▲
BAL-3	▲	▲	▲	
BRA-1				
BRA-2				
BRA-3				
EAS-1				
EAS-2	▲		▲	
EAS-3	▲		▲	
IND-1	▲		▲	
IND-5	▲	▲	▲	
IND-6	▲	▲	▲	
MBA-6	▲		▲	
MBA-7				
MBA-8				
RMI-1				
RMI-4				
RMI-5				
WAK-1	▲		▲	
WAK-2	▲	▲	▲	
WAK-3	▲		▲	▲
WAK-4	▲		▲	

The '▲' symbol indicates that the hypothesis was confirmed for the given site. Statistical significance between mean of offshore and nearshore data was determined using a one-tailed paired Student's T-test with α=0.05. Statistical significance between variance of offshore and nearshore data was calculated using a one-tailed F-test with α=0.05. Table 4.3 clearly shows that the hypotheses do not hold true in all situations (both hypotheses true at 59% of sites). Statistical significance was even less common (18% for hypothesis one and 14% for hypothesis two). The hypotheses typically both hold true for all sites in some groups and no sites in other groups. More specifically, all sites at Bala, the Indian River and Walker's Point support both hypotheses, but sites at Brackenrig Bay, Muskoka Bay and Royal Muskoka Island do not support either hypothesis. Sites at East Bay were not necessarily expected to support the hypotheses since it is an undeveloped area, but all other sites were expected to support both hypotheses. In fact, all but one group of sites (Cox Bay) supported both hypotheses in 2002.

Since sampling typically supported both hypotheses in 2002, but not in 2003, it is appropriate to determine how the two datasets are different. Several sites measured in 2003 are dissimilar to sites measured in 2002. Furthermore, interannual variation may confuse a year-to-year comparison. Comparison will therefore focus on the variance (standard deviation) in each eight-point dataset (hypothesis two). Theoretically, the variance observed should be similar from one year to the next.

Table 4.4 - Comparison between average variance (standard deviation)

	2002	**2003**
Offshore average	2.02 μg/L	3.42 μg/L
Nearshore average	4.91 μg/L	3.10 μg/L

Table 4.4 compares the average variance, measured as standard deviation, of each eight-point dataset. On average, the offshore datasets were much less varied than nearshore datasets in 2002, but were more varied than nearshore datasets in 2003.

Table 4.5 directly compares the variance observed in sites that were sampled both in 2002 and in 2003. The upper portion of the table represents offshore datasets (with a '0' in the site code) and the lower portion represents nearshore datasets. The table shows that variance increased by an average of 23% in the offshore datasets while variance in nearshore datasets decreased by an average of 13%.

The correlation between variance (range) and average (mean) must also be considered. If the increased variance of offshore datasets shown in Table 4.5 is simply a reflection of the larger range associated with higher mean, it would be ill advised to read any more into the analysis. This does not appear to be the case, however. Even though variance in nearshore datasets decreased by 13% (1.9 μg/L), the mean of these datasets actually increased by 17% (0.3 µg/L). In this case, phosphorus concentrations were consistently higher, whereas in offshore datasets, mean phosphorus concentration increased at the same time as its variance (or uncertainty). In spite of advice to the contrary (Clark, 2003), the decrease in nearshore variance might be explained by the fact that 80 micron filters which could have eliminated suspended particulate matter were used to filter phosphorus samples (Section 3.3), but the increase in offshore variance cannot be explained so easily.

Table 4.5 - Comparison between variance in sites common to both datasets

Site	Standard Deviation 2002 (µg/L)	2003 (µg/L)	Difference (µg/L)	Percent Difference
BMR-0	3.10	0.82	-2.28	-73.46%
COX-0	2.42	1.51	-0.90	-37.41%
EAS-0	1.22	2.49	1.27	103.93%
HMB-0	1.72	3.10	1.38	79.99%
IND-0	1.24	1.16	-0.09	-6.88%
MBA-0	2.52	4.39	1.87	74.07%
WAK-0	1.78	2.13	0.35	19.80%
Average	**2.00**	**2.23**	**0.23**	**22.86%**
COX-1	1.25	1.52	0.27	21.80%
EAS-1	1.92	2.06	0.14	7.32%
HMB-1	7.00	3.62	-3.38	-48.25%
IND-1	1.31	1.73	0.42	32.04%
WAK-1	16.13	2.55	-13.58	-84.20%
BMR-2	2.84	1.49	-1.35	-47.50%
COX-2	1.37	1.59	0.22	15.84%
EAS-2	2.84	2.67	-0.17	-5.85%
HMB-2	2.43	1.93	-0.50	-20.74%
WAK-2	5.81	4.72	-1.09	-18.78%
MSN-2	2.52	5.13	2.61	103.68%
EAS-3	9.24	2.43	-6.80	-73.65%
HMB-3	4.13	1.97	-2.16	-52.24%
WAK-3	6.31	6.38	0.07	1.11%
HMB-4	1.83	2.01	0.18	9.82%
MBA-4	4.11	3.83	-0.28	-6.88%
WAK-4	4.74	4.49	-0.25	-5.20%
MBA-5	12.16	4.42	-7.74	-63.62%
Average	**4.89**	**3.03**	**-1.86**	**-13.07%**

Table 4.6 - Variance observed in 2003 offshore datasets

Site	Standard Deviation (μg/L)
RMI-0	7.10
BRA-0	16.66
IND-0	1.16
BAL-0	1.81
EAS-0	2.49
WAK-0	2.13
MBA-0	4.39

Table 4.6 further illustrates the effect that an increased variance in offshore datasets has on hypotheses one and two. The table shows standard deviation of each offshore dataset sampled in 2003. Shaded rows are associated with the groups of nearshore sites that did not generally support either hypothesis. East Bay is darkly shaded since it was not expected to support either hypothesis due to its lack of land-based influences.

It is apparent that the groups of sites that supported both hypotheses had offshore datasets with low variance (less than 2.25), while groups of sites that did not support either hypothesis had offshore datasets with large variance (greater than 4). Therefore, whether or not nearshore phosphorus concentration is higher than offshore phosphorus concentration appears to be dependent on the variance observed in the offshore dataset.

Considering that variance is not directly proportional to mean (as shown by a comparison between variance observed in 2002 and 2003), there is no physical explanation for increased variance in offshore datasets. The problem of large variance might be solved in the future by collecting more robust datasets or by eliminating outliers. Elimination of outliers is not an ideal solution, because all datasets would need to be treated similarly even though there is a physical explanation for outliers in nearshore datasets (acute land-based influences).

4.2.3 Nearshore vs. Offshore Comparison

Further analysis of sites that support both hypotheses may reveal what unique characteristics of each site affect nearshore water quality. The first step in the analysis is to plot the actual difference between nearshore and offshore concentration. Figure 4.7 shows this difference for each site at Bala, the Indian River and Walker's Point.

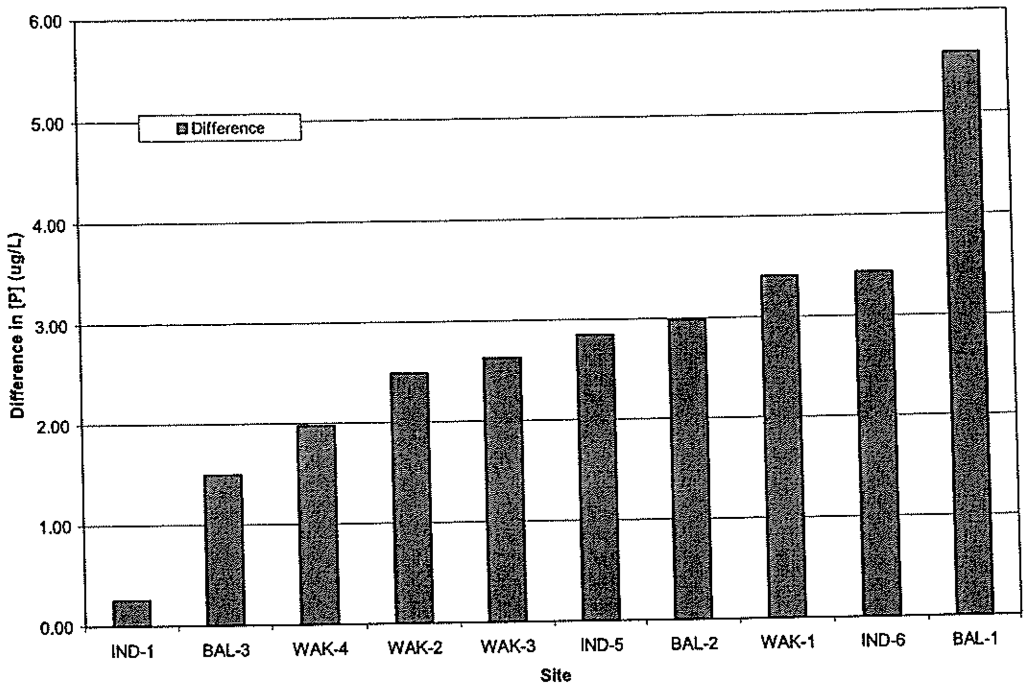

Figure 4.7 - Difference between offshore and nearshore phosphorus concentration

The height of each bar in Figure 4.7 represents the difference between phosphorus concentration at that site and its corresponding offshore site measured in μg/L. For four of these sites (BAL-3, IND-5, IND-6 and WAK-2, as shown in Table 4.3) water in the nearshore and offshore is significantly different in terms of phosphorus concentration. The other six sites have α values in one-tailed paired Student's T-tests ranging from 0.08 to 0.21. These relative low α values suggest with some likelihood that the difference between phosphorus levels at nearshore sites offshore sites is due to a real physical mechanism rather than chance. More samples during a year or more years of data may lead to statistically significant differences.

If nearshore sites support physically different sources of phosphorus, the nearshore datasets would also potentially be significantly different from each other. When a twotailed paired Student's T-test is used to compare each nearshore dataset within a group, only two pairings are in fact significantly different. These are IND-1/IND-5, and IND-1/IND-6. α values are substantially higher than when comparing nearshore and offshore datasets, meaning there is a higher probability that results came from the same dataset (i.e. there is no real difference between water at different locations). Results of this test are shown in Table 4.7. Statistically significant results are shaded.

Table 4.7 - Results of Student's T-test on nearshore datasets

Sites Compared		α
IND-1	IND-5	0.01
IND-1	IND-6	0.01
IND-5	IND-6	0.32
BAL-1	BAL-2	0.62
BAL-1	BAL-3	0.34
BAL-2	BAL-3	0.34
WAK-1	WAK-2	0.58
WAK-1	WAK-3	0.30
WAK-1	WAK-4	0.23
WAK-2	WAK-3	0.56
WAK-2	WAK-4	0.71
WAK-3	WAK-4	0.71

The results shown in Table 4.7 suggest that nearshore datasets are more similar to each other than they are to offshore datasets. In order to determine which characteristics of the residential landscape have which affects on nearshore water quality, many samples are therefore needed (the smaller the difference in datasets, the larger the dataset must be to show significance).

Even though it is not possible to draw scientifically defendable conclusions from the water quality data that was collected during the 2003 MLA water quality initiative, it is instructive to attempt to categorize the sites appearing in Figure 4.7 in terms of landscape characteristics. Through this categorization, patterns may emerge that may explain the information shown in Figure 4.7.

4.2.4 Landscape Characteristics

Five broad characteristics that define residential landscapes are considered. These are level of impervious surface cover, building envelope size, building envelope setback, vegetated buffer zone and shoreline structures. Current land use regulations (Official Plan and By-law) used in Muskoka typically restrict residential development based primarily on 'lot coverage' which uses building envelope size as its parameter, and building setbacks. Suggested changes to by-laws suggest that vegetated buffer zones be required and that decks be included in lot coverage regulations.

A comparison between these five features that characterize residential landscapes may help to determine which are most important (and therefore should be considered in Official Plans and By-laws). In the future, the details of such regulations (such as how large setbacks should be or what maximum building envelopes size should be) may also be objectively determined by the MLA's water quality research.

For the purposes of this study, three categories will be defined for each characteristic. Sites will then be classified based on these characteristics, and the resulting classification will be compared with Figure 4.7 in an attempt to identify trends and patterns. Approximately 25m on either side of the water sampling site will be considered in this analysis of landscape characteristics.

4.2.4.1 Impervious Surface Cover

Impervious surface cover (ISC) is defined as the area that is impervious to rainwater or overland runoff. ISC is important because it changes hydrology of a piece of property (in Muskoka's case, on the waterfront). When rainwater and overland runoff cannot penetrate the earth's surface both the volume and intensity of runoff increases. This leads to erosion of the shoreline and more dramatically carries any sources of phosphorus on the land's surface into the lake.

Any area of land that is covered by structures or pavement (such as asphalt or concrete) is included in ISC. Areas covered by gravel or wood chips are not considered to be impervious. Decking is semi-pervious, but is common in Muskoka and changes local hydrology in other ways not explicitly considered (removal of vegetation) and therefore will be included as ISC.

Categories:

- **Less than 10% of shoreline area (40m from shore)**
- **10% - 20%**
- **More than 20%**

4.2.4.2 Building Envelope Size

Building envelope size measures the area of land covered by a structure. Building envelope size can have a similar effect on hydrology as ISC. A comparison between the effects of building envelope size and ISC might suggest which is more important in terms of nearshore water quality, and therefore help land use decision-makers to accurately restrict development based on the 'lot coverage' parameter of most importance. Building envelope is normally considered to be the area of the roof of a structure, but this study will include decking in building envelope size as well.

Categories:

- **Less than $100m^2$ (40m from shore)**
- **100 - $250m^2$**
- **More than $250m^2$**

4.2.4.3 Building Envelope Setback

Building envelope setback is a linear measurement between the shoreline and the closest part of the building envelope. This measurement has traditionally been used to regulate development based on social considerations (crowding, noise pollution etc.) Setback also affects water quality through a hydrologic process. Effects of ISC or building envelope can be mitigated by larger setbacks from the lake as rain and overland runoff is able to infiltrate the ground between the development and the water's edge.

Categories:

- **More than 20m**
- **10 - 20m**
- **Less than 10m**

4.2.4.4 Vegetated Buffer Zone

Official Plans currently suggest that land owners maintain an undisturbed vegetated buffer zone between their development and the water's edge. This zone is defined by a particular density of trees. In concert with setbacks, the buffer zone works to mitigate hydrologic effects of development.

Categories:

- **Natural vegetation**
- **Some vegetation**
- **No vegetation**

These categories are subjectively defined, as it is difficult to accurately measure vegetation density without intensive field research. Figures 4.8a through 4.8c are generally indicative of the types of vegetation cover suggested by the above-mentioned categories.

4.2.4.5 Shoreline Structures

Muskoka's traditional shoreline structures include docks and boathouses. However, any type of hardened or otherwise altered shoreline has a similar effect on nearshore water quality. Destroying or altering natural riparian ecosystems changes the way that phosphorus and other nearshore contaminants behave once they reach the lake. Hardening a shoreline with docks or concrete walls means that plants that are vital to cleansing the water can't grow.

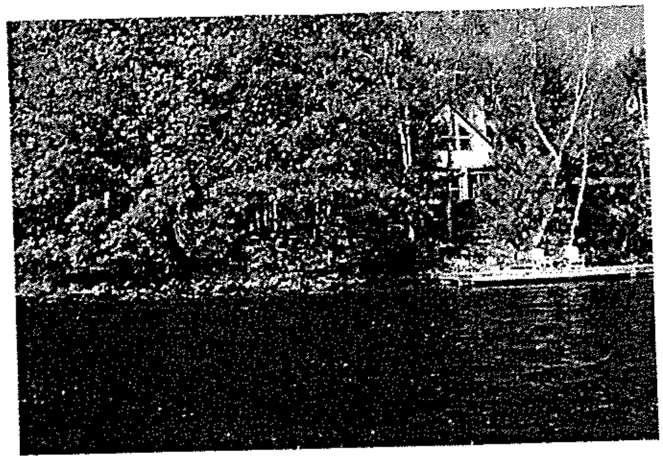

Figure 4.8a - Example of natural vegetation

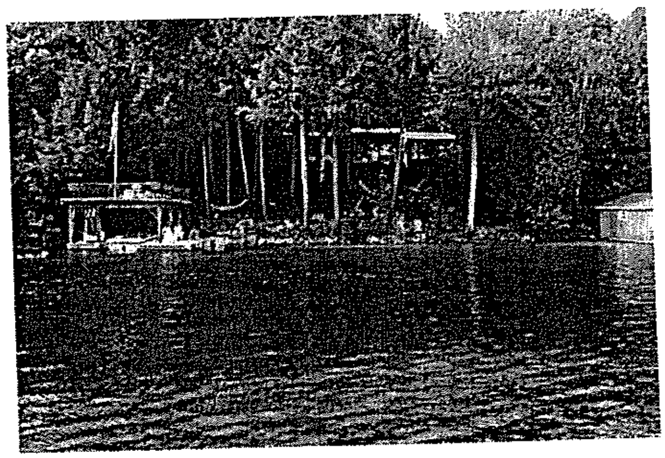

Figure 4.8b - Example of some vegetation

Figure 4.8c - Example of no vegetation

Categories:

- **Less than 25%**
- **25 – 50%**
- **More than 50%**

4.2.5 Categorization of Sites

Photos of shorelines surrounding each of the sites shown in Figure 4.7 can be found in Appendix C. Each site is categorized according to each of the five characteristics outlined in Section 4.2.4. Field notes on site conditions are not included in this report in order to protect the identities of owners of each property considered. A summary of classification is shown in Table 4.8.

Table 4.8 - Classification of site characteristics listed according to magnitude of difference between nearshore and offshore phosphorus concentration

Site	ISC	Building Size	Setback	Buffer	Shoreline Structures
IND-1	1	2	2	1	2
BAL-3	2	3	3	2	2
WAK-4	1	1	2	2	1
WAK-2	3	3	3	2	3
WAK-3	1	2	1	2	2
IND-5	1	1	1	2	3
BAL-2	3	3	3	3	3
WAK-1	2	3	2	3	3
IND-6	2	3	2	2	3
BAL-1	1	3	3	2	3

Of the ten sites listed in Table 4.8 that satisfy both hypotheses, there are no apparent patterns in landscape characteristics that might explain the affects on nearshore water quality. The characteristics of all sites are relatively similar. For example, six of the ten sites were more than 50% covered by shoreline structures, whereas only one site was less than 25% covered. Since only ten sites met the requirements of both hypotheses (due to changes in offshore water chemistry results, as demonstrated in Section 4.2) only a limited scope of sites could be considered in Table 4.8. Ideally, sites very similar in all characteristics except one should be compared in order to attribute affects on water quality to specific landscape characteristics.

Such a research programme would be very difficult to undertake, since sites with common land use are typically similar but not identical. That is, residential sites do not all have the same orientation, groundcover or vegetated buffer zone, but differences tend to be minor in comparison to sites with golf courses or resorts.

Even though the 2002 programme results suggested a strong correlation between intensity of residential land use and nearshore phosphorus concentration, further years of study are required in order to determine whether or not nearshore phosphorus concentration is an appropriate indicator of affects due to these limited differences in the landscape. Another indicator such as benthic community assessment may be more effective. Alternatively, it may be impossible to detect the affects of such specific changes to the landscape.

The 2004 research programme should refocus to detecting appreciable differences between nearshore and offshore phosphorus concentration at sites associated with a variety of land uses and land-based activities. In order to accomplish this task, the nearshore phosphorus programme should be extended to as many sites as financial and human resources allow. In addition, the MLA should consider adopting protocols for and testing some other indicators of water quality such as benthic community or sediment coring that may give a more accurate suggestion of long-term anthropogenic affects to the ecosystem.

4.3 Periphyton Results

Analysis of periphyton (algae) test data is available in the report *2003 MLA Water Quality Initiative: Periphyton Analysis* by Gartner Lee Ltd., 2004.

5.0 Recommendations

Several changes are recommended to make the 2004 MLA water quality initiative more effective.

The MLA should also explore possibilities of working more closely with the Muskoka Watershed Council. The Watershed Council could help the MLA to adopt protocols that they already use for various water quality indicators.

The public education campaign started by the MLA should be continued in the future. In addition to quarterly articles in *The Burgee*, the MLA should consider holding seminars for community members throughout the summer season. Use of the redeveloped MLA website should also be thoroughly considered. Biweekly or monthly updates could easily be sent to all MLA members through new electronic newsletters and website updates.

The three-year track record of the MLA water quality initiative proves that the programme is effective and supported by a diverse cross-section of the community. In this light, it would be very prudent for the MLA to seek government funding to help expand the initiative in coming years. Typically, funding agencies will only match investment supplied by the community group or local government. Three important funding sources that should be explored are the Ontario Trillium Foundation, Environment Canada's EcoAction programme and the Canadian Water Network. Trillium would be most likely to provide funding to offset costs of personnel and equipment, whereas the EcoAction programme is designed to support all aspects of community-based environmental initiatives including public education and scientific research. The Canadian Water Network may be more difficult to access, since most funding is supplied through a series of researchers and institutions across Canada. The MLA's recent association with the University of Waterloo may provide this needed connection.

Several recommendations are made for the use of newly acquired grants or funds. Funds could effectively be used to extend and expand existing testing and analysis. Demonstrated partnerships between the MLA and other local NGOs may make an application for funding stronger and would also allow partner associations to expand the programme on their own lakes. An interest in boat gas pollution has been made very apparent over the last three years. The concern is greatest in high traffic areas and in areas around resorts and marinas. Testing for indicators of hydrocarbon contamination such as MtBE, benzene or toluene would be appropriate as part of a research programme focusing on the effects of urban or resort development on nearshore water quality. It would also be very helpful for the coordinator of the programme to have the use of a boat similar to those used by the Marine Patrol. The use of a personal craft is risky for the coordinator in terms of repair costs, but it would also serve as good public relations to have a dedicated vessel on the water. Funding grants could be made available for the purchase of a boat, if the current arrangement with Gordon Bay Marine cannot be extended to include a third vessel.

The Muskoka Watershed Council has suggested the inclusion of their benthic community protocols in the MLA programme. Where the usefulness of these protocols seems to be minimal and essentially irrelevant to the purpose of the MLA programme, their limited use should be considered. The protocols may be appealing to some residents of the lake who wanted to get involved with the programme in a way that is less time consuming than other volunteer positions. The protocols may be particularly intriguing for children, and consequently serve as a good way for the MLA to engage the community's youth. In the longer term, results of the benthic community assessments may become more scientifically relevant, in which case it would be useful to have baseline results from the Muskoka Lakes. Finally, the use of these protocols may aid in strengthening the relationship between the MLA and Watershed Council. It is recommended for these reasons that the benthic community assessment protocols used by the Muskoka Watershed Council be promoted by the MLA water quality initiative and monitoring facilitated by the MLA.

5.1 Research Function

The research function of the programme is the cornerstone of the initiative as demonstrated by the opportunities that the MLA has to work with the Township of Muskoka Lakes on Official Plan and By-law amendments. Even though there were no definitive conclusions coming out of the 2003 programme, it must be remembered that this is not uncommon in scientific research. Research should build year after year, keeping in mind that the long term goal of the MLA is to protect and enhance the Muskoka Lakes community and area. Only through careful, systematic research can knowledge about the local environment and ecosystem be developed and used to help make our community better in the future.

MLA Directors and membership should be involved in choosing the research focus for 2004. Further study on residential intensity may be useful, but it may be too difficult to obtain statistically significant conclusions from the programme data. In this light, the MLA may wish to explore other research questions such as the affect of golf courses, urban areas or resorts on nearshore water quality.

5.2 Monitoring Function

The monitoring function of the programme should be expanded as much as financial and human resources allow in order to acquire the most complete record of water quality possible. A more complete record would make it easier to evaluate unexpected results like those encountered in the offshore areas during the 2003 programme. A more complete record would also make it easier to statistically analyse results.

In order to expand human capacity, volunteers should be used to analyse bacteria samples using ColiPlates and incubators. Partner associations in particular should be given the responsibility of analysing samples and maintaining the dataset for their own area. This would not only relieve some responsibility from the programme coordinator, but would also give ownership of the programme to the most local community.

Further expansion of the MLA initiative to partner associations should take place. In addition to the five associations already partnered with the MLA on the water quality initiative, residents at the following locations should be approached during the early spring with the intent of involving them in the programme:

- Clear Lake (Muskoka Lakes)
- Silver Lake (Port Carling)
- Long Lake
- 3 Mile Lake
- Bruce Lake
- Skeleton Lake

5.3 *Technical Recommendations*

- Include offshore sites representative of the whole lake. These sites should coincide with District Municipality of Muskoka sampling sites, but follow protocols established by the MLA.
- Compare bacteria duplicate variability with data from the Muskoka-Parry Sound Health Unit's public beaches programme to determine natural ranges of within site bacterial variability. If possible, shadow Health Unit staff and compare ColiPlate results with official results.
- Purchase new caps for bacteria bottles at the beginning of each year.
- Experiment with standardized mixing of turbidity samples.

Report Prepared by:

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Principal

References

Clark, Bev, 2003. Coordinator, Lake Partners Programme, Ontario Ministry of the Environment. Personal Communication. Monday, 22 September 2003, 3:00pm.

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Logan, Michael, 2003. *"Science, Community Empowerment and Planning: The Environment of a Resort Community"* Faculty of Engineering, Dalhousie University. Halifax, Nova Scotia. 21

Appendix A

Table A1 – 2003 Phosphorus concentration data collected

Site	Samples Taken							
	Sample 1 µg/L	Sample 2 µg/L	Sample 3 µg/L	Sample 4 µg/L	Sample 5 µg/L	Sample 6 µg/L	Sample 7 µg/L	Sample 8 µg/L
HMB-0	4.0	4.7	8.5	3.5	11.2	6.8	3.1	2.1
HMB-1	11.7	13.0	5.2	4.3	5.4	6.9	4.0	3.5
HMB-2	8.9	8.6	4.8	5.3	4.5	6.3	5.0	3.6
HMB-3	9.7	5.6	6.3	4.0	5.2	4.2	4.0	3.8
HMB-4	7.3	7.3	3.7	3.8	6.3	4.4	3.3	1.8
STI-0	5.7		3.6	5.9	4.9	5.8	3.0	1.9
STI-2	8.2		4.9	5.6	5.0	6.8	3.4	3.1
COX-0	7.2	4.0	5.5	6.1	6.5	3.7	3.5	3.4
COX-1	5.6	5.2	6.7	7.4	5.5	8.7	4.5	4.2
COX-2	5.6	5.8	5.3	4.9	5.2	8.6	3.3	3.8
RMI-0	6.5	7.3	4.2	5.7	4.8	24.6	3.5	2.8
RMI-1	6.1	8.3	8.6	7.6	4.6	10.5	4.2	2.8
RMI-4	7.1	5.5	4.0	7.2	6.4	5.2	3.2	2.1
RMI-5	6.3	6.1	3.8	5.0	4.1	4.8	3.8	2.1
WIN-0	6.0	5.4	4.4	5.1	5.7	3.8	3.0	9.1
WIN-3	8.0	7.0	5.6	13.8	5.4	5.7	6.9	8.5
MIN-0	5.6	5.2	5.8	5.5	5.3	6.0	4.3	2.4
MIN-4	6.2	6.0	4.5	4.7	6.2	7.5	4.1	2.8
BRA-0	8.7	9.2	12.2	13.7	15.7	11.9	10.6	58.4
BRA-1	8.1	12.8	14.3	15.7	13.6	13.5	10.6	10.6
BRA-2	22.6	11.3	12.0	12.6	13.3	8.5	11.6	8.5
BRA-3	11.0	9.5	10.1	13.7	13.1	11.7	10.2	6.9
IND-0	6.3	5.5	5.4	5.1	6.6	4.2	3.2	6.3
IND-1	9.2	6.8	5.9	5.2	6.0	4.6	3.6	4.5
IND-5	8.1	8.0	9.2	6.7	8.2	7.2	5.5	6.3
IND-6	8.3	12.0	7.6	7.3	8.9	7.3	5.6	6.9
BAL-0	7.1	6.2	7.5	6.2	8.6	3.6	3.9	4.4
BAL-1	7.1	8.0	6.3	6.5	13.8	39.8	4.9	5.8
BAL-2	6.3	7.7	6.1	6.1	10.2	7.3	3.2	24.5
BAL-3	10.9	6.9	7.7	6.2	7.9	8.6	3.9	7.4
BMR-0	6.1	6.4	5.7	7.2	7.0		6.5	8.2
BMR-2	6.4	5.5	7.2	7.7	6.0		3.5	4.4
EAS-0	12.0	7.7	5.4	5.8	7.7	9.7	4.4	6.3
EAS-1	6.8	7.0	8.9	8.1	6.8	4.9	3.5	3.3
EAS-2	6.7	11.9	7.7	6.7	9.3	4.6	4.1	4.6
EAS-3	7.1	9.2	6.0	5.3	9.0	3.3	3.0	3.9
WAK-0	6.3	6.9	6.0	9.2	7.6	8.6	3.9	3.1
WAK-1	7.9	9.3	7.6	9.3	8.4	4.2	3.7	3.3
WAK-2	7.1	7.2	5.8	18.5	7.9	5.8	3.8	3.6
WAK-3	5.9	22.0	5.6	6.0	5.8	7.3	16.8	5.4
WAK-4	6.4	11.4		6.5	17.2	5.5	4.2	9.6
MSN-0	15.1	14.3	8.1	6.9	7.8	5.3	8.1	3.7
MSN-2	17.5	18.5	10.0	6.4	9.8	4.7	9.8	6.1
MSN-4	29.5	26.5	24.7	25.1	8.6	19.5	14.8	9.2

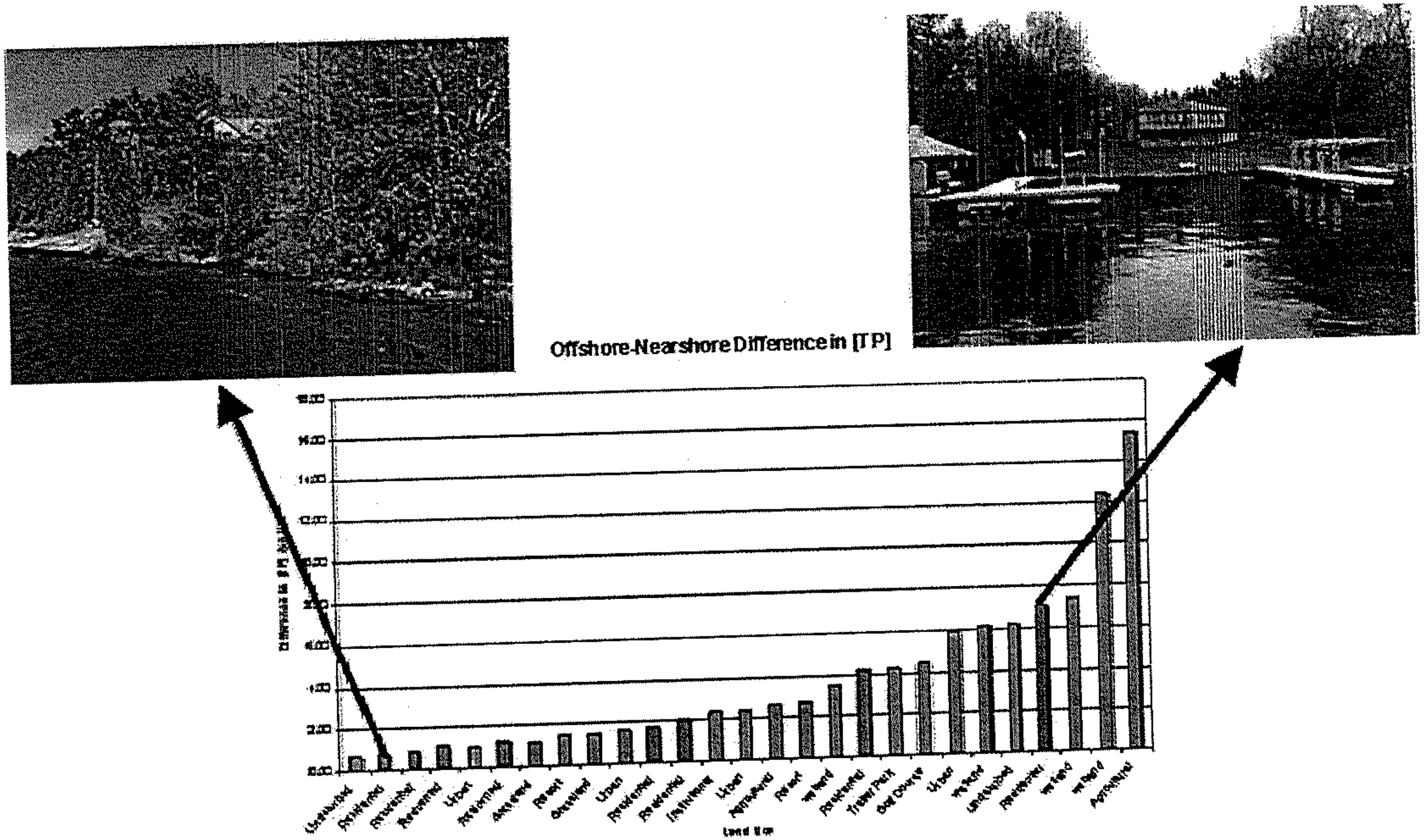
Table A1 – 2003 Phosphorus concentration data collected

Site	Samples Taken							
	Sample 1 µg/L	Sample 2 µg/L	Sample 3 µg/L	Sample 4 µg/L	Sample 5 µg/L	Sample 6 µg/L	Sample 7 µg/L	Sample 8 µg/L
MBA-0	17.9	9.2	7.7	7.9	10.2	5.8	4.7	4.0
MBA-4	12.3	11.2	12.6	15.4	9.8	6.1	5.0	5.5
MBA-5	12.7	12.7	18.4	10.8	11.5	5.5	5.9	6.3
MBA-6	10.7	8.0	9.2	8.2	8.6	19.0	4.9	4.5
MBA-7	10.0	9.9	8.9	9.4	8.9	6.7	5.6	4.7
MBA-8	9.3	9.6	7.9	10.2	8.0	4.2	6.0	7.2
GUL-0	5.8	5.9	7.7	10.4	8.8	4.2	5.5	7.6
GUL-1	7.0	7.7	8.1	6.3	7.3	6.3	5.0	4.4
GUL-3	5.4	8.7	5.4	8.6	8.6	4.5	5.3	4.8
GUL-4	5.9	5.4	8.0	10.0	9.0	4.5	5.4	4.5
SVR-0	10.9	10.0	8.4	9.9	9.1	5.5	4.8	2.7

Table A2 - Calculated means and standard deviations for 2003 phosphorus concentration data

Site	Annual Average (µg/L)	Standard Deviation	Site	Annual Average (µg/L)	Standard Deviation
HMB-0	5.49	3.10	BMR-0	6.73	0.82
HMB-1	6.75	3.62	BMR-2	5.81	1.49
HMB-2	5.88	1.93	EAS-0	7.38	2.49
HMB-3	5.35	1.97	EAS-1	6.16	2.06
HMB-4	4.74	2.01	EAS-2	6.95	2.67
STI-0	4.40	1.58	EAS-3	5.85	2.43
STI-2	5.29	1.80	WAK-0	6.45	2.13
COX-0	4.99	1.51	WAK-1	6.71	2.55
COX-1	5.98	1.52	WAK-2	7.46	4.72
COX-2	5.31	1.59	WAK-3	9.35	6.38
RMI-0	7.43	7.10	WAK-4	8.69	4.49
RMI-1	6.59	2.61	MSN-0	8.66	4.03
RMI-4	5.09	1.86	MSN-2	10.35	5.13
RMI-5	4.50	1.36	MSN-4	19.74	8.05
WIN-0	5.31	1.83	MBA-0	8.43	4.39
WIN-3	7.61	2.74	MBA-4	9.74	3.83
MIN-0	5.01	1.17	MBA-5	10.48	4.42
MIN-4	5.25	1.49	MBA-6	9.14	4.50
BRA-0	17.55	16.66	MBA-7	8.01	2.05
BRA-1	12.40	2.46	MBA-8	7.80	1.99
BRA-2	12.55	4.43	GUL-0	6.99	2.01
BRA-3	10.78	2.15	GUL-1	6.51	1.29
IND-0	5.33	1.16	GUL-3	6.41	1.87
IND-1	5.73	1.73	GUL-4	6.59	2.12
IND-5	7.40	1.20	SVR-0	7.66	2.95
IND-6	7.99	1.89			
BAL-0	5.94	1.81			
BAL-1	11.53	11.75			
BAL-2	8.93	6.59			
BAL-3	7.44	2.00			

Appendix B


Offshore-Nearshore Difference in [TP]

Appendix C

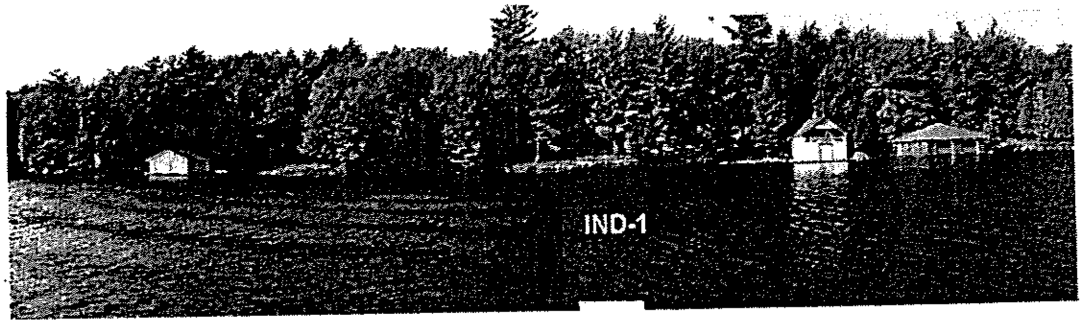


Figure C1 - Site IND-1

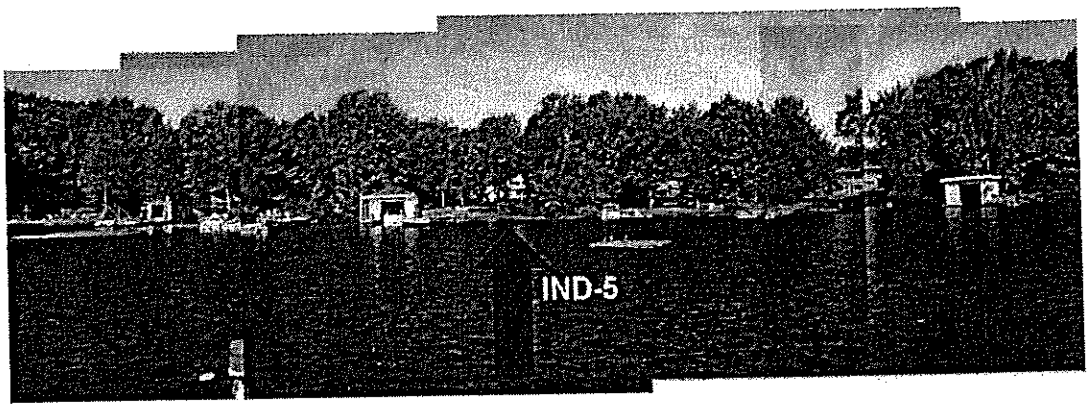


Figure C2 - Site IND-5

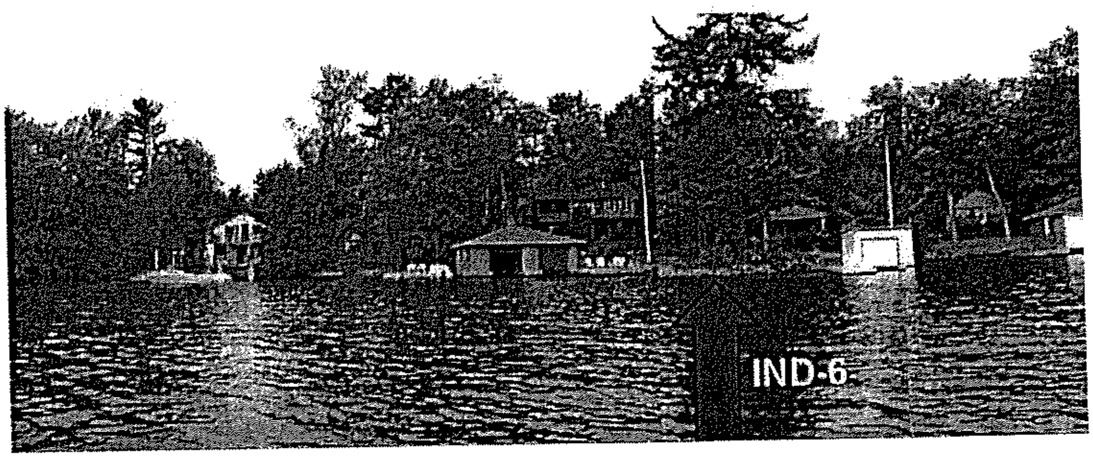


Figure C3 - Site IND-6

Figure C4 - Site BAL-1

Figure C5 - Site BAL-2

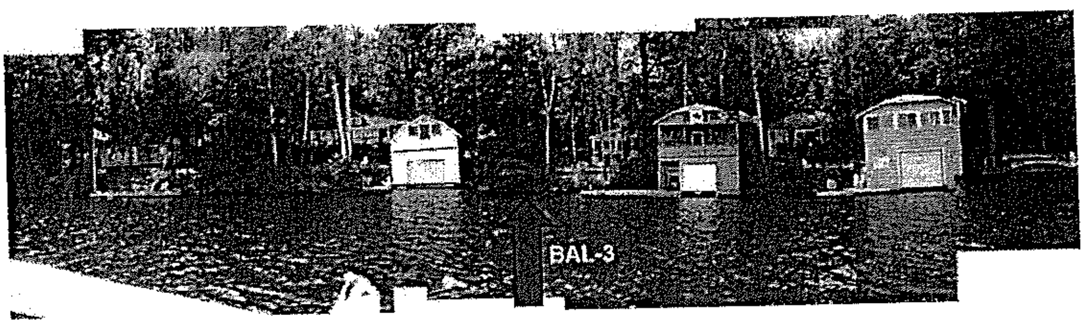


Figure C6 - Site BAL-3

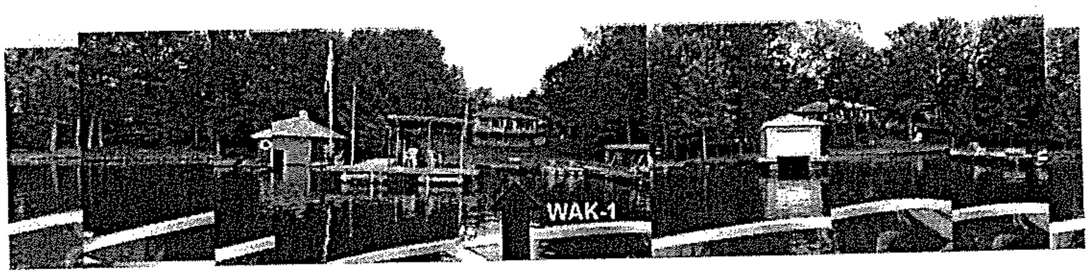


Figure C7 - Site WAK-1

Figure C8 - Site WAK-2

Figure C9 - Site WAK-3

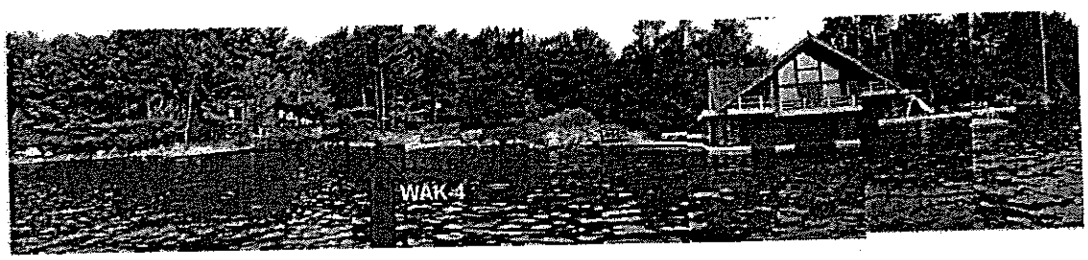


Figure C10 - Site WAK-4