Muskoka Lakes Association Water Quality Initiatve:

2004 Annual Report

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Executive Summary

The Muskoka Lakes Association's pilot project in water quality research and monitoring was completed in 2003. The 2004 programme therefore represents the MLA's long-term commitment on behalf of the community to monitoring, protecting and enhancing the environmental resources of the Muskoka Lakes area. For the most part, the 2004 programme closely resembles how the programme is likely to look like into the foreseeable future.

Scientific protocols and analytical procedures will continue to evolve slowly, but were developed to a substantial degree of proficiency through the pilot project. Only one small change to sampling protocol was made in 2004 – the removal of the 80 micron filter from phosphorus sample collection.

Research focused again on the effects of residential development on nearshore water quality (specifically total phosphorus concentration) as recommended following the 2003 programme. Data collected more strongly suggested a difference between nearshore and offshore water quality than did data from 2003 however statistical significance could not be established. After two years of non-statistically significant data, it is concluded that the effects of residential development on nearshore water quality, while suggested by the data collected, are too small to be thoroughly analyzed. The research programme in 2005 will therefore focus on the effects of golf courses and resort development on nearshore water quality.

Popularity of the programme continued to grow through 2004, as three new partner associations were added; the North Lake Joseph Association, the Friends of Long Lake and the Silver Lake Association. Monitoring efforts grew to 136 sites monitored by an all-time high number of volunteers. Results of the monitoring programme are once again available online at http://www.mla.on.ca.

Several recommendations are made for consideration in 2005 including a continuation of the public education campaign associated with the water quality initiative, embracing the Muskoka Watershed Council's protocol for benthic community monitoring and the use of volunteers to analyze bacteria samples. Technical recommendations include a detailed study of mid-lake sites (coinciding with traditional District of Muskoka annual monitoring) and the establishment of a manual to aid in the transition between programme co-ordinators.

TABLE OF CONTENTS

List of Tables

List of Figures

1.0 Introduction

The Muskoka Lakes Association (MLA) is a non-profit group that represents the interests of lakefront residents in the Muskoka Lakes area of Central Ontario. While the MLA has always recognized the urgency of protecting and enhancing the local environment, a formal scientifically based ecological monitoring and research program interested in lake water quality was introduced in 2001. The pilot water quality initiative spanned the 2001 to 2003 seasons and was overseen by Dr. Neil Hutchinson of Gartner Lee Ltd. The 2004 program represents the first year of ongoing commitment by the MLA Board of Directors to the initiative; a response to the program's scientific and social significance.

The 2004 season marks the maturation of the initiative to a sustainable monitoring and research program that will be financially and logistically feasible as long as the MLA membership is interested in maintaining it. Funded entirely by internal revenue streams and successful only with the hard work of MLA volunteers, the initiative is advised by Logan Environmental Consulting. Mike Bidwell, a fourth year Environmental Engineering student from the University of Waterloo was also retained by the MLA to coordinate the day to day operation of the 2004 initiative.

The 3-year pilot project established that there are two main functions of the MLA's Water Quality Initiative: monitoring and research. These functions reflect how the results of the program are reported and used; they do not substantially affect data collection or project cost. The scientific details of the 2004 program and the results of the research function of the program are presented here.

1.1 Monitoring Function Report

For simplicity and data access considerations, the detailed results of the monitoring function of the MLA program have been published online. This allows the average reader to easily access the monitoring results they are looking for, without being bogged down by hundreds of pages of less-interesting results and scientific detail. These online

results can be viewed at the MLA's website (http://www.mla.on.ca), where easy-to-read instructions for accessing the data are also published. MLA members can also obtain a copy of the *Summary Report of 2004 Monitoring Programme including instructions for accessing data via the Internet* from the MLA office. This report should be widely distributed among MLA members.

2.0 Background

With over 250,000 lakes in Ontario (Globe and Mail, 2004), Provincial and Local government resources are insufficient to protect and thoroughly monitor the state of all of Ontario's aquatic ecosystems. The traditional approach to planning for lakeside development in Ontario is embodied in mathematical models that try to simplify the process. They do this by representing lake health with total phosphorus concentration, and predicting the phosphorus concentration in each lake based on empirical observation and records of development around the lake. These models were developed in part by the District of Muskoka (DMM), and to keep them appropriately calibrated, DMM monitors spring turnover total phosphorus (TP_{so}) in approximately 150 lakes within the district on a rotational basis (Planning and Economic Development Department, 2003). While this rational approach has been generally successful in predicting lakeshore capacity and limiting development, it inevitably cannot provide a "correct" solution to the management of sustainable landscape change. Environmental planning and resource management must instead be responsive to public opinion while integrating dynamic scientific knowledge (Logan, 2003).

The provincial Ministry of the Environment also monitors lakes in several ways. The Lake Partner Program is an attempt to engage the public in the collection of scientific information and therefore in environmental management. The goal of this program is to "protect the quality of Ontario's inland lakes by involving citizens in a volunteer-based water quality monitoring program" (MOE, 2004). Volunteers involved in this program collect TP_{so} samples and make monthly water clarity observations on their lakes. This information is intended to facilitate the "early detection of changes in the nutrient status

of the lake due to the impacts of shoreline development, climate change and other stresses." (MOE, 2004) Lake Partner Program samples are collected infrequently (thus requiring several years' data for a useful scientific tool) and volunteers mail the samples into a central analysis location. While the usefulness of volunteer efforts to the government ministry is apparent, meaningful engagement of the public and human capacity-building in protecting and enhancing the local environment is somewhat less obvious.

Responding to MLA member interest, the Association began to thoroughly and systematically study water quality in both the offshore and nearshore zones in 2001. Since then, the initiative has grown spatially (even to include several lakes outside of the MLA's traditional scope of interest) and evolved into a marquis program of the MLA.

2.1 Long-term Objectives

The long-term objectives originally set out by Gartner Lee Limited's *Innovative Methods for the Determination of Water Quality in the Lakes Muskoka, Joseph and Rosseau* are as follows (GLL, 2001):

a) **Review of existing information** on water quality in Lakes Muskoka, Joseph and Rosseau;
b) **An opinion on the water quality stresses of most significance** to the Muskoka Lakes and the MLA and rationale for that opinion, with particular emphasis on acid rain, nutrient enrichment and bacterial contamination;
c) **Development of a research and monitoring program** to document conditions of nutrient runoff, bacterial contamination and algal growth in the near-shore waters as they are influenced by bottom substrate, development density and shoreline vegetation;
d) **Liaison with other management initiatives** (District of Muskoka, MOE, non-governmental organizations (NGOs)
e) **Advise on future stewardship initiatives** for the MLA.

As the water quality initiative matures and evolves from year to year new objectives have been and will be identified. In addition to the original objectives outlined above, the 2003 initiative identified additional long-term goals:

f) Build on relationships and **work more closely with the Muskoka Watershed Council** to adopt protocols that already used for various water quality indicators;
g) Attain **external funding** for the program, now that the initiative has a positive track record;
h) **Expand the monitoring function** as much as financial and human resources allow in order to acquire the most complete record of water quality possible;
i) **Build human-capacity** by utilizing volunteers to analyze bacteria samples using ColiPlates and incubators;

2.2 Technical Objectives

Several technical recommendations that will develop the scientific reputation of the initiative were also identified in 2003:

a) 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;
b) Compare bacteria duplicate variability with data from the Muskoka-Parry Sound Health Unit's public beaches program to determine natural ranges of within site bacterial variability. If possible, shadow Health Unit staff and compare CoilPlate results with official results;
c) Purchase new caps for bacteria bottles at the beginning of each year;
d) Experiment with standardized mixing of turbidity samples.

2.3 Achievements

Over the past three years all of the initial long-term objectives (A through E) have been achieved. Objectives A and B were accomplished in the inaugural year (2001) and are detailed in Gartner Lee Limited, 2001. Objectives C, D, and E were the focus of the 2002 and 2003 seasons and once again are detailed in Hutchinson, 2003 and Logan , 2004. Significant achievements have also been made in 2004. These successes, both related to program objectives and those that have developed in an ad hoc fashion, are outlined in the following sections.

2.3.1 Partnerships

During the 2004 season there were no new partnerships created with any level or government or other decision-making agencies. However, community groups on lakes in the vicinity of Lakes Muskoka, Joseph, and Rosseau have been very interested in the MLA's water quality initiative and the credibility that potential partnerships with the MLA could provide to their own water quality monitoring efforts. Three additional community groups joined the MLA on the water quality initiative for the 2004 season: Friends of Long Lake (Bala) and Silver Lake (Port Carling) initiated monitoring programmes on their lakes, and the North Lake Joseph Association financially helped the MLA expand the initiative in north Lake Joseph. The East Leonard Lake Association did not participate in the initiative due to financial constraints. As a result the MLA had a total of seven community groups in partnership with the MLA's Water Quality Initiative for 2004 season:

- Brandy Lake Association
- Friends of Long Lake
- Gull and Silver Lakes Residents' Association (Gravenhurst)
- North Lake Joseph Association
- Silver Lake Association (Port Carling)
- South Muskoka Lake Community Association
- Sucker Lake Cottagers' Association

Local media coverage, scientific credibility of the initiative, and a presentation on the initiative at the 2004 MLA annual general meeting has sparked interest from community groups near Lakes Muskoka, Joseph, and Rosseau. Five more nearby community groups have already expressed serious interest in becoming involved with the program in 2005. They are the Clear Lake Association (Torrence), the Skeleton Lake Association (Rosseau), the Bass Lake Association (Foot's Bay) the Nine Mile Lake Association (Torrence) and the Moon River Property Owner's Association (Bala). The MLA should begin now to develop relationships with the executive of each of these associations.

2.3.2 External Funding

During the early part of the 2004 season an application was put forth to the Ontario Trillium Foudation for funding to support the MLA's water quality initiative. The funding would have provided the financial support to expand the monitoring function of the program and explore other interests of the research function. Unfortunately, the MLA's request for funding was not approved by the Trillium Foundation for undisclosed reasons. In the future, other sources of funding such as Environment Canada's EcoAction program should be explored. A substantial financial contribution by the membership of the MLA should remain despite any other sources of funding, as this demonstrates the importance of the program to the Association.

2.3.3 Monitoring Function Expansion

Increased awareness and support from MLA members facilitated the addition of three areas to the water quality initiative. Gordon Bay and Stanley Bay were added on Lake Joseph and the Willow Beach area was added on Lake Muskoka. The expansion was a result of a combination of new volunteer support and financial donations made to the initiative. This expansion will help to build a more complete record of our water quality on a larger spatial scale.

3.0 Methods

3.1 Volunteers

During the 2004 season over 65 volunteers participated in the water quality initiative. The volunteers were divided into 28 teams that sampled each area across 9 lakes in Muskoka. Each team consisted of between 1 and 4 volunteers. This year a record number of volunteers worked on the initiative; increased numbers per team proved successful in providing flexibility and reliable support to ensure that there was always someone to do the required sampling on each sampling day. Below is a list of the 28 teams responsible for sampling 136 sites every two weeks:

Lake Joseph

Hamer Bay
Terry Johnson

Cox Bay
Gord Ross

Joseph River
Heather Wilson Irons

Little Lake Joseph
Dirk Soutendijk
Mark Johnstone

Foot's Bay
John Maas

Stanley Bay
Bob Hunter
Fred & Mary Sims

Gordon Bay
Tony Taylor

Lake Rosseau

Rosseau/Shadow River
Linda White

Windermere
John Duncan
Bev Manchee

Minnett
Bill Boughner
Keith Shantz

Royal Muskoka Island
Doug Applegath
John Curran

Indian River
Inglis MacDonald

Brackenrig Bay
Ian Wallace

Lake Muskoka

North Bay
Doug Wilson
Jack Fenn
David Barker

Bala
Bill Sloan
Len Wait
Arch Nordstrum
Ian Baker

Muskoka River
John Wood

Beaumaris
Louise Cragg
Lori Morrisey

East Bay
Ron Manto

Eilean Gowan Island
Joe Moher
John Carr
Doug & Sandy Turner

Walker's Point
Diane Faught
Peter Wiley
Alex Tilley

Muskoka Sands
Anne Stanway
Ted Smith
Ted Greig

Willow Beach
Liz Denyar

Muskoka Bay
Paul & Gayle Aggett

Partner Associations

Sucker Lake	*Long Lake*	*Brandy Lake*
Gail & Jack Hepworth	Cheryl Watt	Jim Cormack
Marion Heintzman	Ellen	
	Jim White	

Silver Lake (Port Carling)	*Gull & Silver Lakes*
Perry Bowker	Jim Davis
	Gordon Lee

3.2 Sites

The 2003 Annual Report (Logan, 2004) reported that results of the research program focused on the effects of residential development on nearshore water quality were inconclusive, and recommended that the program be repeated in 2004. Research program sites therefore remained unchanged from those described in Section 3.2.1 and Table 3.2 (Logan, 2004)

As previously mentioned, the monitoring program did expand as recommended (Logan, 2004). 136 sites (an increase from 114 in 2003) were monitored biweekly throughout the summer (24 May 2004 to 6 September 2004). All sites were analysed for temperature and turbidity and 121 sites were analysed for bacterial contamination. Total phosphorus was also measured at sixty-one sites.

As in previous years, the 136 sampling sites were divided into two groups to facilitate a reasonable load of sample analysis and volunteer management. This way approximately half of the sites (the northern-most sites) were sampled on one week and then the other half (the southern-most sites) were sampled the following week. Table 3.1 shows when each sample was taken. Table 3.2 shows which parameters were analysed for each site.

Table 3.1 - Sampling Groups

Sample Number	Group 1	Group 2
	Lake Joseph, Lake Rosseau, Brandy Lake, Silver Lake (Port Carling), Sucker Lake	Lake Muskoka, Long Lake, Gull & Silver Lakes,
1	May 24, 2004	May 31, 2004
2	June 7, 2004	June 14, 2004
3	June 21, 2004	June 28, 2004
4	July 5, 2004	July 12, 2004
5	July 19, 2004	July 26, 2004
6	August 2, 2004	August 9, 2004
7	August 16, 2004	August 23, 2004
8	August 30, 2004	September 6, 2004

Table 3.2 - Monitoring programme sites (▲ indicates measurement of parameter)

Location	Code	Land Use	Bacteria	Phosphorus	Turbidity
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	▲		▲
Stanley Bay	STN-0	Offshore	▲	▲	▲
	STN-1	Residential	▲		▲
	STN-2	Residential	▲		▲
	STN-3	Residential	▲		▲
Gordon Bay	GNB-0	Offshore	▲	▲	▲
	GNB-1	Marina/Highway	▲		▲
	GNB-2	Residential	▲		▲
	GNB-3	Residential	▲		▲
	GNB-4	Residential	▲		▲
Foot's Bay	FTB-0	Offshore	▲		▲
	STI-0	Offshore		▲	▲
	STI-2	Golf Course (Still's Bay)		▲	▲
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	▲		▲

Table 3.2 - Monitoring programme sites (▲ indicates measurement of parameter) (cont'd)

Location	Code	Land Use	bacteria	phosphorus	turbidity
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	▲	▲	▲
	RMI-4	Residential		▲	▲
	RMI-5	Residential		▲	▲
Brackenrig Bay	BRA-0	Offshore	▲	▲	▲
	BRA-1	Residential	▲	▲	▲
	BRA-2	Residential		▲	▲
	BRA-3	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)	▲		▲
Indian River	IND-0	Offshore	▲	▲	▲
	IND-1	Residential	▲	▲	▲
	IND-2	Town (Port Carling)	▲		▲
	IND-3	Trailer Park	▲		▲
	IND-5	Residential		▲	▲
	IND-6	Residential		▲	▲
Joseph River	JRV-1	Residential	▲		▲
	JRV-2	Residential	▲		▲
	JRV-3	Residential	▲		▲
	JRV-4	Residential	▲		▲
Brandy Lake	BDY-0	Offshore	▲	▲	▲
	BDY-1	Wetland	▲	▲	▲
	BDY-2	Residential	▲		▲
	BDY-3	Residential	▲	▲	▲
	BDY-5	Residential	▲		▲
Silver Lake (Port Carling)	SPC-0	Offshore	▲	▲	▲
	SPC-1	Residential	▲		▲
	SPC-2	Residential	▲		▲
	SPC-3	Residential	▲		▲
North Bay	NRT-0	Offshore	▲		▲
	NRT-1	Residential	▲		▲
	NRT-2	Transfer Station	▲		▲
	NRT-3	Transfer Station	▲		▲

Table 3.2 - Monitoring programme sites (▲ indicates measurement of parameter) (cont'd)

Location	Code	Land Use	bacteria	phosphorus	turbidity
Bala	BAL-0	Offshore	▲	▲	▲
	BAL-1	Residential		▲	▲
	BAL-2	Town Site	▲	▲	▲
	BAL-3	Residential		▲	▲
	BAL-4	Residential	▲		▲
	BAL-5	Residential	▲		▲
	BAL-6	Residential	▲		▲
East Bay	EAS-0	Offshore	▲	▲	▲
	EAS-1	Undeveloped	▲	▲	▲
	EAS-2	Undeveloped	▲		▲
	EAS-3	Undeveloped	▲		▲
Beaumaris	BMR-0	Offshore	▲	▲	▲
	BMR-1	Undeveloped	▲		▲
	BMR-2	Golf Course (Beaumaris)	▲	▲	▲
	BMR-3	Town (Beaumaris)	▲		▲
	BMR-4	Golf Course	▲	▲	▲
Eilean Gowan	ELG-0	Offshore	▲		▲
	ELG-1	Residential	▲		▲
	ELG-2	Residential	▲		▲
	ELG-3	Residential	▲		▲
Willow Beach	WLB-0	Offshore	▲	▲	▲
	WLB-1	Resort	▲		▲
	WLB-2	Resort	▲		▲
	WLB-3	Golf Course (Kirie Glen)	▲		▲
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-3	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		▲	▲
	MBA-7	Residential		▲	▲
	MBA-8	Residential		▲	▲

Table 3.2 - Monitoring programme sites (▲ indicates measurement of parameter) (cont'd)

Location	Code	Land Use	bacteria	phosphorus	turbidity
Long Lake	LOL-0	Offshore	▲	▲	▲
	LOL-1	Residential	▲		▲
	LOL-2	Residential	▲		▲
	LOL-3	Residential	▲		▲
	LOL-4	Residential	▲		▲
	LOL-5	Residential	▲		▲
Gull Lake	GUL-0	Offshore	▲	▲	▲
	GUL-1	Hoc Roc	▲	▲	▲
	GUL-2	Residential	▲		▲
	GUL-3	Residential	▲		▲
	GUL-4	Park	▲	▲	▲
Silver Lake (Gravenhurst)	SVR-0	Offshore	▲	▲	▲
	SVR-1	Residential	▲		▲
	SVR-2	Jevins Lake	▲		▲

3.3 Phosphorus

Total phosphorus (TP) was measured at sites indicated in Table 3.2. As recommended in Section 3.3 of the 2003 Annual Report (Logan, 2004), the use of 80 micron filters supplied in 2003 by the MOE in TP sample collection was discontinued. Digest tubes were filled directly from surface water and analyzed by the Trent University Environmental Science Centre in Dorset as described in Section 3.7 of the 2002 Annual Report (Hutchinson, 2003).

3.4 Total Coliforms

Bacteria samples were again collected and analyzed at each site as noted in Table 3.2. Protocols have remained unchanged since 2002 (Hutchinson, 2003; Logan, 2004). Following the change of pigments used in the manufacture of the ColiPlates (Logan, 2004) counting of blue cells (positive for coliform presence) has been more accurate. Readings from the 2004 program can therefore be directly compared with those from 2003.

It is prudent to note once again that the detection limits of the ColiPlate technology was handled by assigning all readings of "less than three" counts of coliform/100mL sample

as an absolute value of 1 count/100mL. This is a conservative estimate that reminds the reader that no untreated surface water is free from bacterial contamination.

3.5 Escherichia Coli

Sampling and analytical procedure for E.Coli remained unchanged from 2002 and 2003. A detailed explanation of protocols is found in the 2002 Annual Report (Hutchinson, 2003).

3.6 Turbidity

As recommended following the 2003 season, the MLA considered the possibility of purchasing a turbidimeter to measure water clarity. The result of brief research was that the one-time investment in the turbidimeter would be far less costly than lab costs for turbidity analysis. A HACH 2100P Turbidimeter was purchased and used in the 2004 program as a result. This equipment is now available for the long term, and represents considerable cost savings.

The manual for the HACH 2100P Turbidimeter mentions that samples should be gently, but thoroughly, mixed for every sample before analysis is performed (Hach Company, 2003). As a result of this information supplied from Hach the procedure for the 2004 season consisted of doing one inversion of the original sample bottle before taking an aliquot for analysis.

3.7 Temperature

Temperature readings are collected for general interest and are useful in determining aesthetic quality of the water. Samplers place a pool thermometer into the surface water when first arriving at each site. After all of the other protocols were completed, the sampler then read the thermometer and recorded the reading. This procedure is easy for

volunteers to follow and allows the pool thermometer to stabilize, giving an accurate reading.

3.8 Duplicates and Blanks

Sound scientific procedures give the knowledge generated by the MLA water quality initiative its credibility. This credibility is particularly important since the program is volunteer-based. As in 2002 and 2003, random duplicate measures and blank samples were used throughout the 2004 season. Sampling protocols are detailed in the 2002 Annual Report (Hutchinson, 2003). Five percent of phosphorus samples were duplicated and analyzed by Trent University, five percent of bacteria samples were duplicated and analyzed internally and a further five percent of bacteria samples were duplicated and analyzed 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 analyzed for bacterial contamination internally. Turbidity was measured for all of the duplicate and field blank samples analyzed internally.

4.0 Results

The two functions of the MLA water quality initiative – research and monitoring – have been well-defined over the past two sampling seasons. The following results focus on the results of the research programme as well as the quality control and quality assurance measures necessary to maintain scientific credibility. A summary of the monitoring results and instructions for using the interactive online database that displays all monitoring results is available separately.

4.1 Duplicates and Blanks

No scientific programme of study can claim to use or produce information that is absolutely 'correct.' Instead, scientific information helps people to understand how the

world works (in this case, how the lake ecosystem works) by collecting information through procedures that can be replicated. When analyzed and shared appropriately, this information is transformed into knowledge that helps people to interact with their physical environment and the world (Logan, 2003). There is usually great variability in information, especially when environmental parameters are being measured in the field. Nevertheless, it is the goal of programmes like the MLA's to reduce environmental variables as much as possible in order to create knowledge through scientific procedures that are both generally sound and replicable.

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 protocols that aim to identify procedural error is of utmost importance in the MLA programme.

4.1.1 Bacteria Blanks

Bacteria blanks are important to the MLA's water quality initiative as they provide an indication of bacteriological contamination in the samples. Possible sources of contamination include improper sterilization of collection bottles, the breaking of seals on the bottles after sterilization and contamination of the samples by volunteers. While it was recommended in 2003 that new bottle caps be purchased for 2004, a sufficient number of caps were not available from the manufacturer until after the sampling season concluded. This possible source of contamination was still significant throughout the season.

Table 3.4 shows the results of bacteria blanks, sorted by sampling date. Note that as previously mentioned that all samples analyzed using the ColiPlate technology and recorded as being contaminated with 1 bacteria count/100mL actually had a result of <3 bacteria counts/100mL (the detection limit of the technology). A reading of one count therefore does not necessarily represent contamination in the blank sample, but is a

conservative estimate of an uncontaminated reading. Three of 35 blank samples (8.5%) therefore showed contamination. Two positive bacteria readings occurred during samples 7 and 8 (at the end of the season), and may be due to the deterioration of bottle caps (Logan, 2004). It is significant to note that two of the three contaminated samples were taken by the same volunteer (Taylor). Section 4.1.2 shows that turbidity blanks for both of these samples (GNB-0-4 and GNB-4-7) also show contamination. In all likelihood, these samples actually contained lake water rather than previously treated "blank" water. Before further sample collecting, blank sample protocols should be reviewed with Mr. Taylor to avoid any further error.

Table 4.1 - Bacteria blank results

Site	Sample Number	TC Blank	EC Blank	Sampler
MBA-2	2	1	1	Aggett
BAL-2	4	1	1	Wait
BMR-1	4	1	1	Morrisey & Cragg
COX-0	4	1	1	Ross
EAS-1	4	1	1	Manto
ELG-1	4	1	1	Carr
GNB-0	4	3	1	Taylor
HMB-0	4	1	1	Johnson
NRT-1	4	1	1	Barker
RSH-1	4	1	1	White
STN-0	4	1	1	Clegg
WAK-1	4	1	1	Faught
COX-2	5	1	1	Ross
GNB-2	5	1	1	Taylor
HMB-2	5	1	1	Johnson
RSH-1	5	1	1	White
STN-2	5	1	1	Clegg
BAL-5	6	1	1	Baker
BMR-3	6	1	1	Morrisey & Cragg
EAS-3	6	1	1	Manto
ELG-3	6	1	1	Turner
NRT-3	6	1	1	Barker
COX-4	7	1	1	Ross
GNB-4	7	8	1	Taylor
HMB-4	7	1	1	Johnson
LLJ-3	7	1	1	Soutendijk
RSH-3	7	1	1	White
STN-3	7	1	1	Clegg
GUL-4	8	1	1	Lee
IND-4	8	1	1	MacDonald
LOL-4	8	1	1	Watt & Edwards
MBA-5	8	1	1	Aggett
MRV-4	8	1	1	Wood
MSN-3	8	1	1	Stanway
WLB-3	8	3	1	Denyar

4.1.2 Turbidity Blanks

Turbidity blanks were tested from the same sample used for the bacteria blanks. Theoretically the turbidity should be identical with a narrow range of variability due to the high standard of the commercially produced Aquafina bottled water used for blanks. Varying turbidity would suggest either a contaminated treated water supply, or problems with the turbidimeter. Turbidity blank results are shown in Table 3.5.

Table 4.2 - Turbidity Blanks

Site	Sample Number	Turb Blank
BAL-2	4	0.15
BMR-1	4	0.24
COX-0	4	0.16
EAS-1	4	0.27
ELG-1	4	0.34
GNB-0	4	0.59
HMB-0	4	0.15
NRT-1	4	0.39
RSH-1	4	0.22
STN-0	4	0.20
WAK-1	4	0.15
COX-2	5	0.22
GNB-2	5	0.15
HMB-2	5	0.19
RSH-1	5	0.22
STN-2	5	0.13
BAL-5	6	0.23
BMR-3	6	0.18
EAS-3	6	0.15
ELG-3	6	0.30
NRT-3	6	0.25
COX-4	7	0.12
GNB-4	7	0.69
HMB-4	7	0.15
LLJ-3	7	0.47
RSH-3	7	0.24
STN-3	7	0.16
GUL-4	8	0.21
LOL-4	8	0.22
MBA-5	8	0.11
MRV-4	8	0.22
MSN-3	8	0.23
WLB-3	8	0.27

The results showed that the turbidity of two samples exceeded twice the standard deviation above the average of all readings. Both of these blank samples also featured bacterialogical contamination, as described in Section 4.1.1. As suggested in Section 4.1.1, it is likely that these samples actually contained lake water rather than previously treated "blank" water. Before further sample collecting, blank sample protocols should be reviewed with Mr. Taylor to avoid any further error. Blank results were otherwise satisfactory and suggest that there was no significant contamination of treated water or any problems with the turbidimeter throughout the season.

4.1.3 Bacteria ColiPlate Duplicates

Five percent of bacteria samples were duplicated and analysed with ColiPlates as described in Section 3.9. Figure 4.1 shows the results of a comparison between duplicate total coliform measures. An r^2 value of 0.9766 suggests the ColiPlates very consistently report total coliform contamination.

Total coliform data for all duplicated samples analysed internally using ColiPlates is shown in Table A.1 in Appendix A. There is one duplicate (MIN-8-8) that not graphed as its result was outside of the ColiPlate's detection limit.

Similarly, E.Coli duplicate results are shown in Figure 4.2, and data in Table A.2 in Appendix A. Due to the clustered nature of bacteria some variability is expected at the extreme low end of the ColiPlate detection limit. This explains why E.Coli duplicate results are less closely correlated than the total coliform duplicate results (r^2 value of 0.439 for E.Coli compared to 0.977 for total coliforms). None the less, the E.Coli duplicate results showed reasonable conformity and no systematic bias.

4.1.4 Bacteria Lab Duplicates

As in previous years, a further five percent of bacteria samples were duplicated and analyzed by an accredited laboratory (Central Ontario Analytical Laboratory, in Orillia). Tables A.3 and A.4 in Appendix A show total coliform and E.Coli lab duplicate data respectively. Six of the bacteria samples could not be used for QA/QC analysis as the

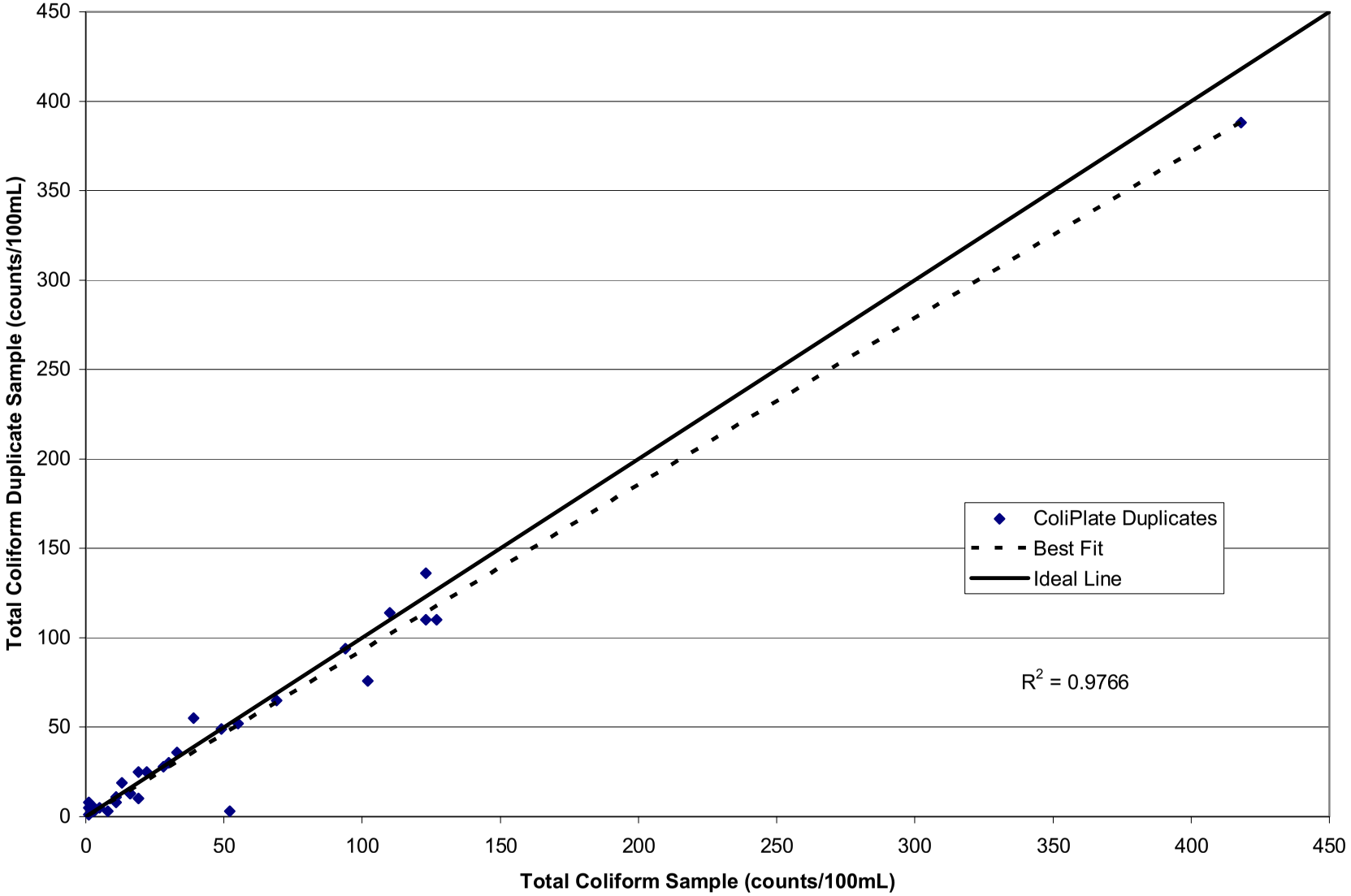

Figure 4.1 - Total coliform duplicates compared using ColiPlate technology

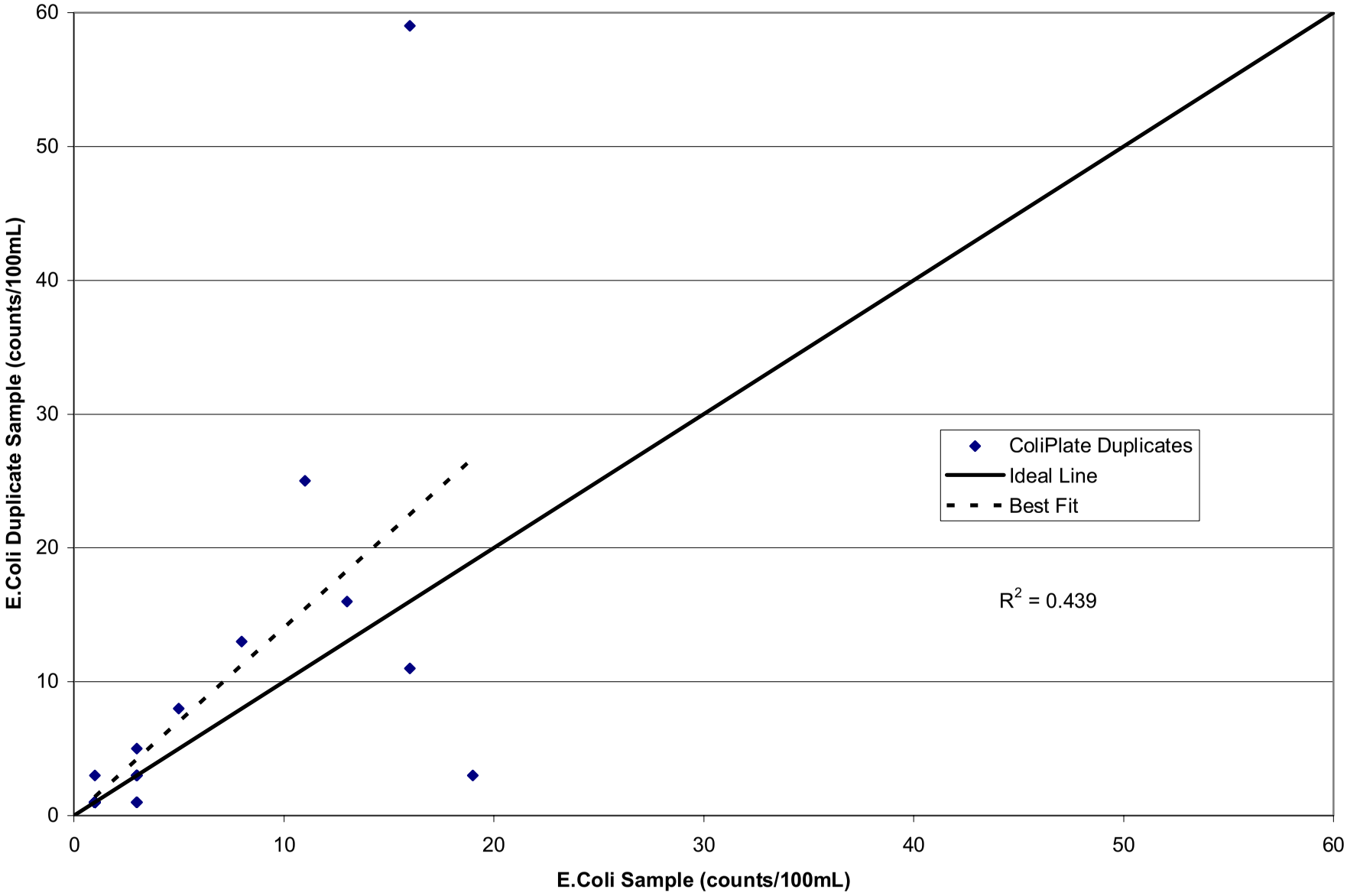

Figure 4.2 – E.Coli duplicates compared using ColiPlate technology

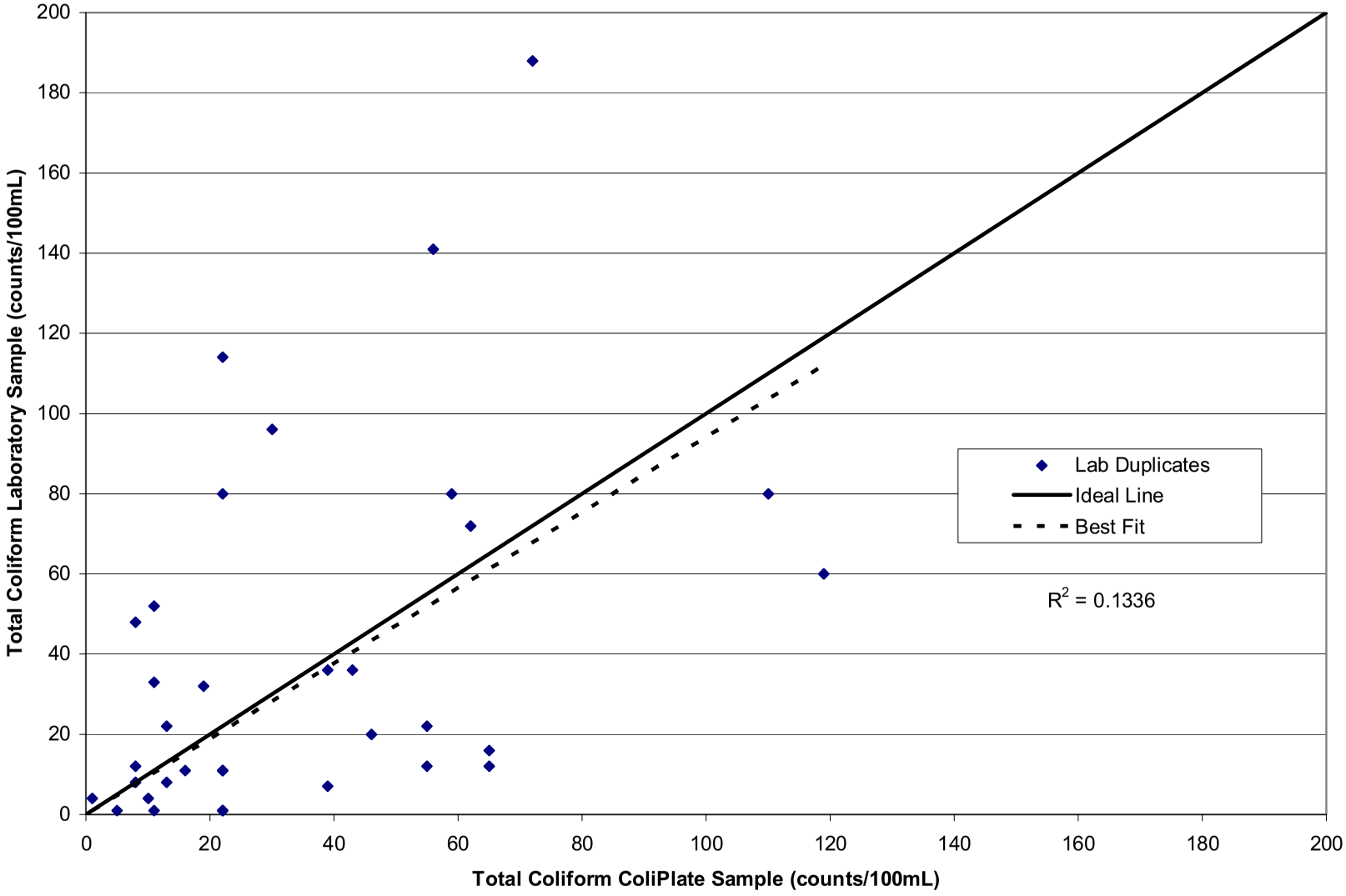

Figure 4.3 - Total coliform duplicates compared using Central Ontario Analytical Laboratory

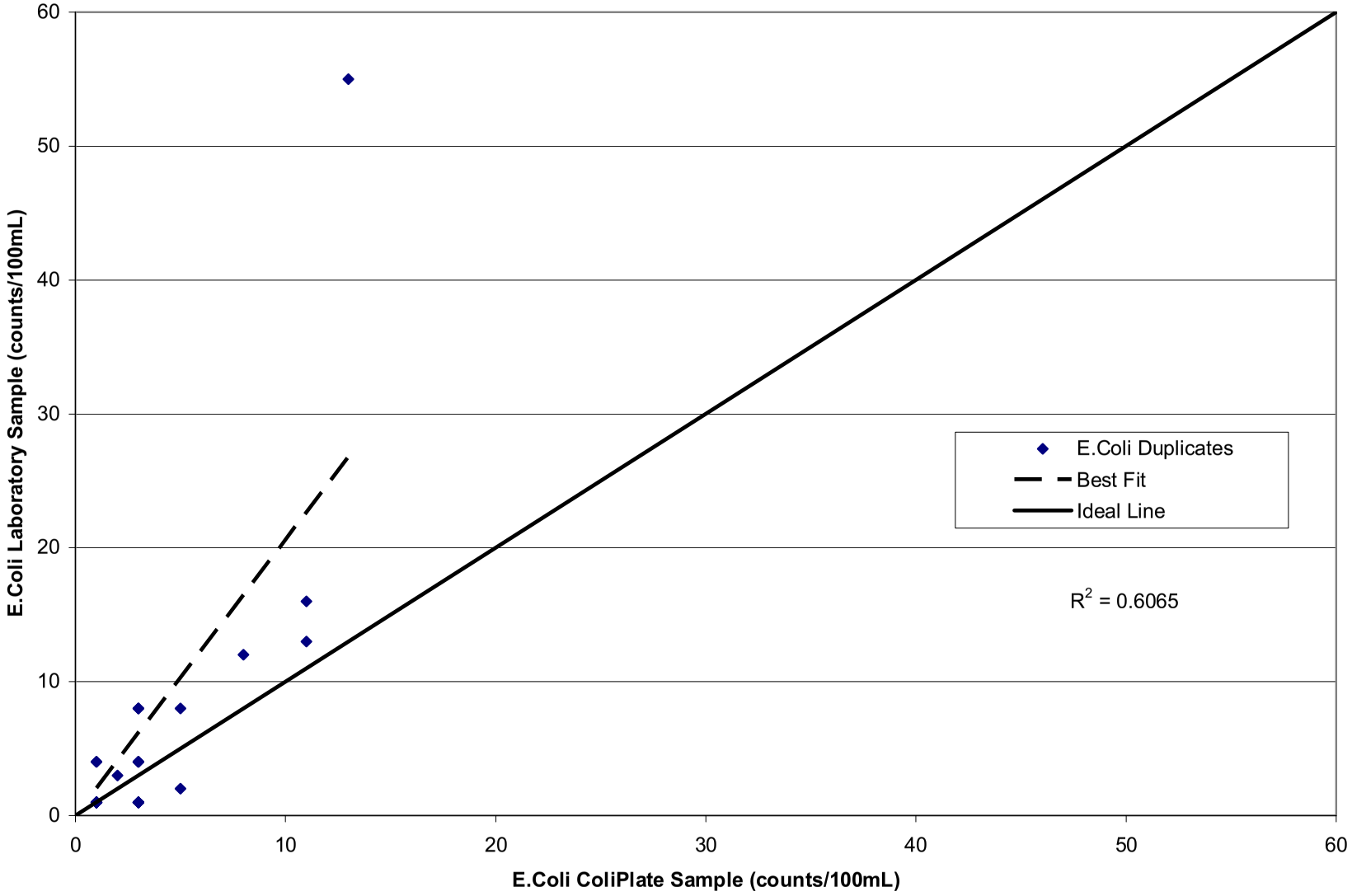

Figure 4.4 – E.Coli duplicates compared using Central Ontario Analytical Laboratory

samples were not delivered to the lab until after the acceptable preservation time had expired. Figure 4.3 shows the correlation between ColiPlate results and lab results (r^2 value of 0.1336). Figure 4.4 similarly shows results for the E.Coli duplicates (r^2 value of 0.6065).

Both total coliform and E.Coli lab duplicates varied more significantly from ColiPlate results than did duplicate ColiPlate results. This variance is consistent with results from 2002 and 2003. The increased variance may be due to the time that passes between internal analysis and lab analysis. Moreover, the r^2 value for total coliform results was quite low (indicating that correspondence between the two datasets is poor), however no bias is observed, as both the ideal linear relationship and best fit line are nearly coincident in Figure 4.3.

Figure 4.4 shows that the ColiPlates typically underestimated E.Coli contamination. This result differs from 2003 results (when the ColiPlates were judged to overestimate E.Coli contamination) but consistent with 2002 results. From this three-year analysis, lab duplicates suggest that there is no consistent bias in the ColiPlate results; neither an overestimation nor an underestimation.

4.1.5 Phosphorus Duplicates

Five percent of all phosphorus samples were duplicated and analysed by Trent University's lab at the 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 was observed between original and duplicate samples during the 2002 programme. To avoid particulate matter in the samples, water was filtered through an 80 micron filter during the 2003 season, and average difference in duplicates was significantly reduced. Use of these filters was nevertheless discontinued in 2004 as recommended after 2003.

Duplicate data is shown in Table A.5 of Appendix A and in Figure 4.5. Difference between duplicate samples averaged 3.4µg/L. This difference is much higher than the

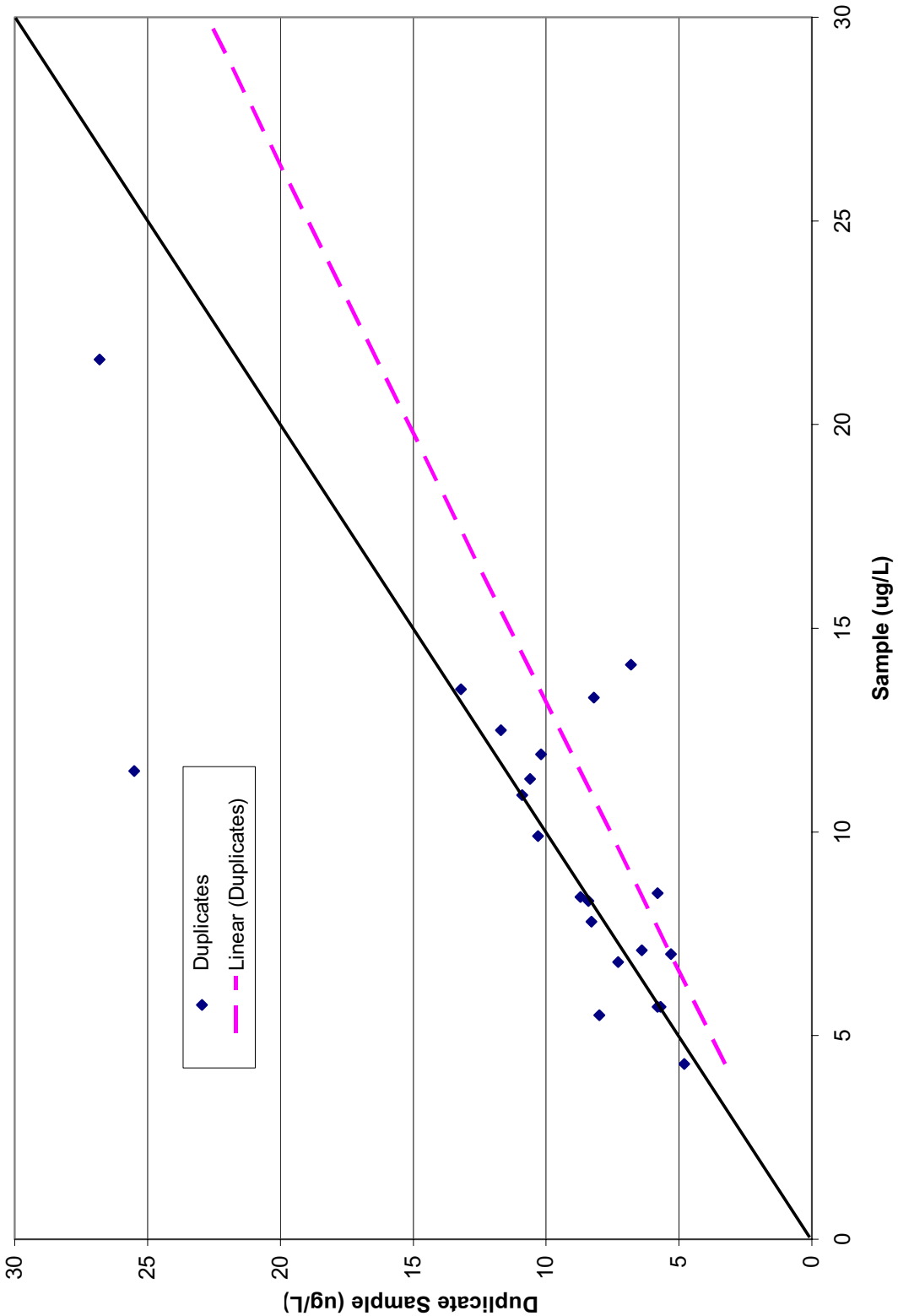

Figure 4.5 – Comparison of Phosphorus concentration duplicates

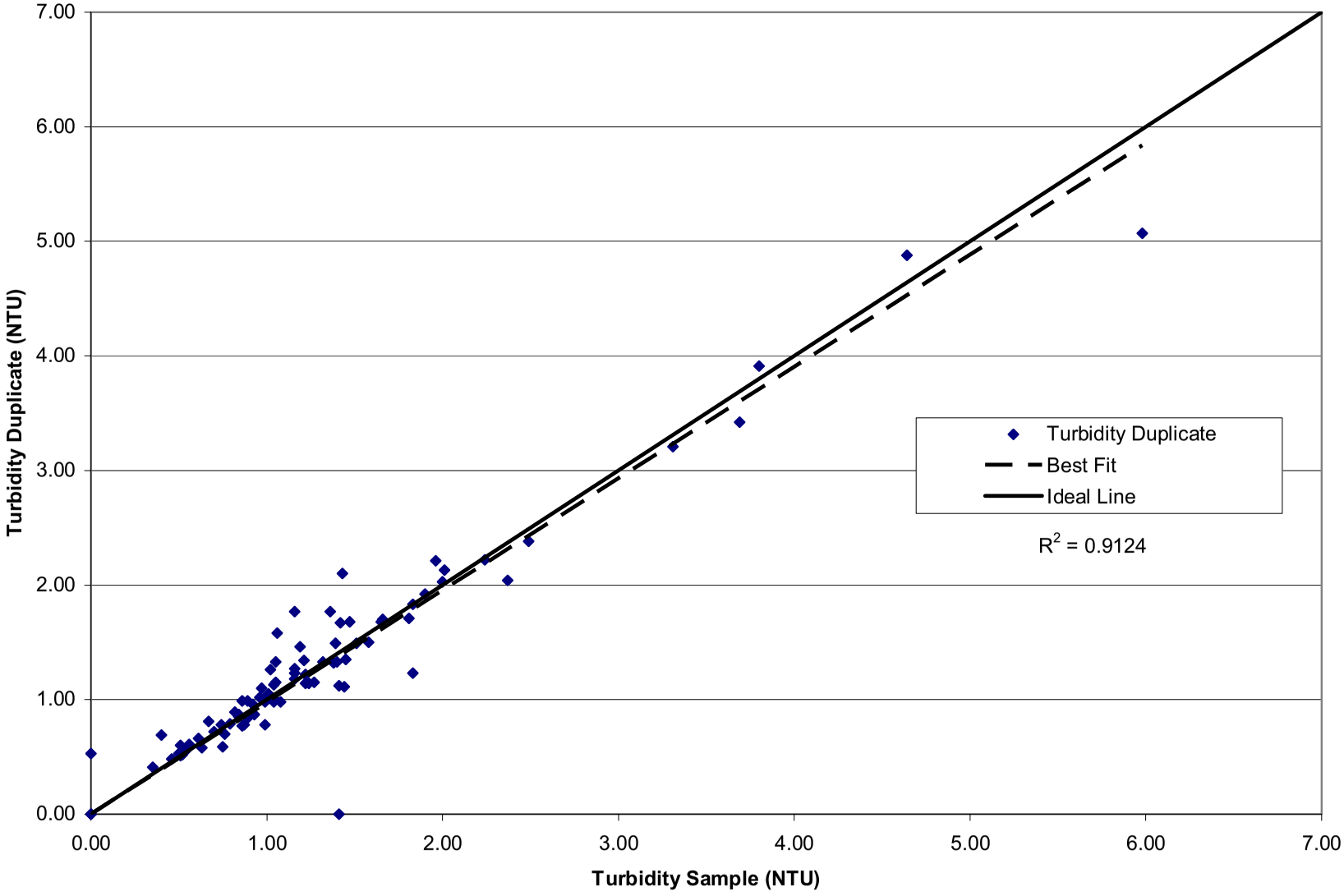

Figure 4.6 - Turbidity duplicates comparison

difference observed in 2003, on comparable to the difference observed in 2002. It may therefore, represent a real variability of nearshore phosphorus concentration that was filtered out by the 80 micron filter in 2003 (see Section 4.2.1 for an explanation of variability in nearshore total phosphorus concentration). Given the consistency of results in multiple years and the fact that there is no significant bias in the results, the range of TP concentration observed in the TP duplicate experiment should be considered normal.

4.1.6 Turbidity Duplicates

Bacteria duplicates analyzed internally using ColiPlates were also analyzed for turbidity. Turbidity duplicate data is shown in Table A.6 in Appendix A. Figure 4.6 compares the initial turbidity measurement and its corresponding duplicate measurement. As in previous years, the results show a high degree of correlation, suggesting that measurements recorded by the turbidimeter are consistent.

4.1.7 QA/QC Conclusion

Several methods of quality control and quality assurance are employed in the MLA water quality initiative. Results suggest that contaminantion of samples does occur from time to time, but generally there is no consistent bias in the analysis. While it would be ideal to eliminate all sources of contamination and error, the three-year volunteer program has produced consistently acceptable and useable data, indicating that the current level of management and training is sufficient.

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, and in turn quality of life (Logan, 2003).

The 2003 Final Report gave the results of a detailed research program designed to quantify the effects of residential development on the nearshore waters of the Muskoka Lakes. 29 research sites were selected for this analysis based on physical characteristics. The data collected in 2003 was inconclusive, as the difference between nearshore and offshore water quality that had been observed previously was not apparent.

Recommendations from 2003 suggested that the research program be repeated in 2004 with a slight change in TP collection protocol (as discussed in Section 3.3) in order to determine whether or not there is a significant difference between nearshore and offshore water quality. Data was again collected at 27 of the same 29 research sites, and results are now examined in detail.

4.2.1 Hypothesis Formation

Section 4.2.1 of the 2003 annual report defined three hypotheses to be statistically tested using data collected from the 27 research sites. These hypotheses would in turn form the basis for lakefront planning policy. The hypotheses are:

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 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).

4.2.2 Analysis

Hypotheses 1 and 2 were evaluated the same way they were in 2003. 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. Table 4.3 summarizes which hypotheses were confirmed for the 27 research sites considered in 2004 and compares the information with which hypotheses were confirmed for the 29 sites considered in 2003. 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)	
	2003	2004	2003	2004	2003	2004	2003	2004
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	▲	▲			▲	▲		▲

(greyed cells indicate that samples were not taken at these locations)

The '▲' symbol indicates that the hypothesis was confirmed for the given site. As in 2003, 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 (hypothesis 1 was true at 70% of sites and hypothesis 2 at 75% of sites). Statistical significance was even less common (10% for hypothesis one and 35% for hypothesis two).

While these results offer more support for hypotheses 1 and 2 than the completely unexpected results observed in 2003, they remain inconclusive. In 2003 the hypotheses typically both held true for all sites in some groups and no sites in other groups, but both hypotheses held true for at least one site in each group in 2004.

4.2.3 Research Conclusion

Two consecutive years of monitoring total phosphorus at residential sites around the Muskoka Lakes suggests that nearshore water is often higher in TP than offshore water as expected. Likewise, the variance observed in nearshore TP concentration is usually greater than offshore water quality. These differences are not generally statistically significant however, so observations remain anecdotal. The land-based influences of residential development suggested by observation are simply too small to detect with the MLA's current sampling protocols.

It is possible that differences between nearshore and offshore water quality would appear statistically significant with greater frequency of sampling however this is not the best use of MLA resources. It is recommended that the focus of the research program shift in 2005 to focus on another land use as identified by the MLA Environment Portfolio and/or membership at large. Possible foci are golf courses, resort developments and town-sites.

5.0 Recommendations

Several changes are recommended to increase the efficacy of the 2005 MLA water quality initiative.

The MLA should work towards a closer relationship with the Muskoka Watershed Council. The Watershed Council could help the MLA to adopt protocols that they already use for various water quality indicators. A significant opportunity for cooperation is a shared information dissemination tool, such as the interactive mapping system being suggested by the University of Waterloo's Computer Systems Group (CSG).

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 is imperative. In addition to the proposed CSG mapping tool, biweekly or monthly updates on the program could easily be sent to all MLA members through new electronic newsletters and website updates.

Section 5.0 of the 2003 Annual Report details several suggestions relating to the acquisition of external funding, including ways in which to use any external funding acquired. The MLA should continue to search out external funding sources, but should also recognize in kind support from research groups such as Universities and other non-governmental organizations.

The MLA should also support the work of the Muskoka Watershed Council in benthic community monitoring as discussed in Section 5.0 of the 2003 Annual Report. This would be an excellent way to cooperate with the Muskoka Watershed Council, and it would also give more MLA members the opportunity to participate in the initiative. Mapping and reporting functionality proposed for the redesigned MLA website could also help to advance the science of benthic community monitoring, thus creating a truly cooperative relationship.

5.1 Research Function

The research function of the programme is the cornerstone of the initiative. Even though there have been no definitive conclusions come out of the 2003 or 2004 programme, the MLA must not lose focus from the deliberate research that sets the Association's water quality initiative apart from other volunteer-based programmes. 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 human capacity and knowledge about the local environment and ecosystem be developed and used to help make our community better in the future.

Further study of nearshore areas adjacent to residential development is not warranted at this time. A focus on phosphorus concentration in nearshore areas surrounding golf courses and resorts would be prudent, as it would build on the preceding three years' data, and results would be analyzed in a manner similar to the analysis of residential impacts 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 analyze 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.

During 2004, several local residents groups approached the MLA about becoming partners in the water quality initiative. As a result, a decision was made by the MLA Directors to disengage from sponsoring other associations to participate in the program (due to the greater management and financial responsibilities associated with so many partner associations). The programme will instead be managed by Logan Environmental Consulting. All practical aspects of the initiative will remain unchanged, and the Directors of the MLA will remain closely involved with the initiative's work on the Muskoka Lakes. Leaders from the other participating groups will also be closely involved with management of the initiative in their own communities.

The MLA should strive to build and maintain relationships with other residents groups in the area that are involved in the programme. A social event and meeting to specifically discuss programme results and achievements would be very beneficial and it would be an appropriate way for the MLA to offer a good will gesture.

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.
- Produce a co-ordinator's manual in order to pass on expertise from one year to the next

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10 December 2004

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Appendix A

Table A.1 - Total coliform duplicates using ColiPlate technology

Site	Sample Number	TC (counts/100mL)	TC ColiPlate Duplicate (counts/100mL)	Remarks
BAL-0	3	8	3	
BMR-0	3	19	10	
ELG-0	3	11	11	
MRV-1	3	123	110	
WAK-0	3	1	5	
WLB-0	3	3	3	
RSH-0	4	13	19	
WIN-0	4	11	8	
BAL-4	5	30	30	
LOL-1	5	127	110	
MRV-2	5	123	136	
NRT-2	5	3	5	
SVR-0	5	110	114	
LLJ-2	6	16	13	
MIN-1	6	19	25	
RMI-1	6	22	25	
RSH-2	6	39	55	
WIN-1	6	69	65	
LOL-2	7	16	13	
MBA-3	7	55	52	
MRV-3	7	102	76	
SVR-1	7	49	49	
WLB-2	7	418	388	
BDY-0	8	94	94	
IND-4	8	1	1	
JOR-3	8	1	8	
MIN-2	8	1696	2424	Omit due to out of range sample
MIN-4	8	28	28	
SUC-0	8	5	5	
SUC-2	8	33	36	
WIN-2	8	52	3	

Table A.2 - E.Coli duplicates using ColiPlate technology

Site	Sample Number	EC Sample (counts/100mL)	EC ColiPlate Duplicate Sample (counts/100mL)	Remarks
MBA-2	2	1	1	
BAL-0	3	1	1	
BMR-0	3	1	1	
ELG-0	3	1	1	
MRV-1	3	8	13	
WAK-0	3	1	1	
WLB-0	3	1	1	
RSH-0	4	3	3	
WIN-0	4	3	1	
BAL-4	5	16	11	
LOL-1	5	3	3	
MRV-2	5	19	3	
NRT-2	5	1	1	
SVR-0	5	1	1	
LLJ-2	6	1	1	
MIN-1	6	1	1	
RMI-1	6	5	8	
RSH-2	6	1	1	
WIN-1	6	13	16	
LOL-2	7	1	1	
MBA-3	7	3	1	
MRV-3	7	11	25	
SVR-1	7	1	1	
WLB-2	7	16	59	
BDY-0	8	3	1	
IND-4	8	1	1	
JOR-3	8	1	1	
MIN-2	8	3	5	
MIN-4	8	1	1	
SUC-0	8	1	3	
SUC-2	8	3	3	
WIN-2	8	3	3	

Table A.3 - Total coliform duplicates using Central Ontario Analytical Laboratories

Site	Sample Number	TC (counts/100mL)	TC Lab Duplicate (counts/100mL)	Remarks
RSH-0	1	10	4	
RSH-2	1	22	80	
RSH-5	1	39	7	
WIN-0	1	11	1	
WIN-1	1	59	80	
WIN-2	1	1	4	
WIN-3	1	110	80	
WIN-4	1	65	12	
EAS-0	3	8	12	
GUL-0	3	19	32	
LOL-0	3	30	96	
MBA-0	3	11	52	
MSN-0	3	13	8	
NRT-0	3	8	48	
BMR-2	5	5	1	
EAS-2	5	22	1	
GUL-1	5	22	114	
MBA-1	5	22	1	
MSN-1	5	62	72	
WAK-2	5	39	36	
BRA-1	6	22	11	
COX-3	6	55	22	
GNB-3	6	13	22	
HMB-3	6	11	33	
IND-1	6	22	11	
JOR-1	6	8	8	
STN-3	6	16	11	
BAL-6	7	65	16	
GUL-2	7	119	60	
GUL-3	7	43	36	
LOL-3	7	56	141	
MBA-4	7	72	188	
MSN-2	7	55	12	
SVR-2	7	46	20	
IND-2	8	2424	3800	Omit: Data arrived late at lab
IND-4	8	1	1	Omit: Data arrived late at lab
RSH-4	8	16	24	Omit: Data arrived late at lab
RSH-5	8	3	56	Omit: Data arrived late at lab
SPC-0	8	19	22	Omit: Data arrived late at lab
SPC-1	8	94	92	Omit: Data arrived late at lab

Table A.4 - E.Coli duplicates using Central Ontario Analytical Laboratories

Site	Sample	EC	EC Lab Duplicate	Remarks
	Number	(counts/100mL)	(counts/100mL)	
RSH-0	1	2	3	
RSH-2	1	5	60	Omit due to improper testing at lab
RSH-5	1	5	2	
WIN-0	1	1	1	
WIN-1	1	13	55	
WIN-2	1	1	4	
WIN-3	1	22	60	Omit due to improper testing at lab
WIN-4	1	8	12	
EAS-0	3	1	1	
GUL-0	3	1	1	
LOL-0	3	3	8	
MBA-0	3	1	1	
MSN-0	3	1	4	
NRT-0	3	1	1	
BMR-2	5	1	1	
EAS-2	5	1	1	
GUL-1	5	3	4	
MBA-1	5	3	1	
MSN-1	5	5	8	
WAK-2	5	3	4	
BRA-1	6	3	1	
COX-3	6	1	1	
GNB-3	6	1	1	
HMB-3	6	1	1	
IND-1	6	3	1	
JOR-1	6	1	1	
STN-3	6	1	1	
BAL-6	7	3	4	
GUL-2	7	3	1	
GUL-3	7	11	13	
LOL-3	7	11	16	
MBA-4	7	3	8	
MSN-2	7	1	1	
SVR-2	7	3	1	
IND-2	8	469	2800	Omit: Data arrived late at lab
IND-4	8	1	1	Omit: Data arrived late at lab
RSH-4	8	3	8	Omit: Data arrived late at lab
RSH-5	8	1	24	Omit: Data arrived late at lab
SPC-0	8	1	11	Omit: Data arrived late at lab
SPC-1	8	1	1	Omit: Data arrived late at lab

Table A.5 – Total Phosphorus duplicates

Site	Sample Number	TP (ug/L)	TP duplicate (ug/L)
MSN-0	1	7.8	8.3
MSN-2	1	13.5	13.2
MSN-4	1	21.6	26.8
WIN-0	1	6.8	7.3
WIN-3	1	31.3	24.7
BRA-0	4	9.9	10.3
MBA-0	4	10.9	10.9
MSN-0	4	11.3	10.6
RMI-0	4	13.3	8.2
STI-0	4	7	5.3
STI-2	4	5.7	5.7
BRA-1	5	12.5	11.7
MIN-0	5	5.7	5.8
WIN-3	5	14.1	6.8
MBA-4	6	32.1	4.2
MSN-2	6	8.4	8.7
WLB-0	6	8.3	8.4
RMI-4	7	5.5	8
STI-0	7	4.3	4.8
STI-2	7	8.5	5.8
BAL-3	8	7.1	6.4
MBA-8	8	11.5	25.5
WAK-3	8	11.9	10.2

Table A.6 - Turbidity duplicates

Site	Sample Number	Turbidity Sample (NTU)	Turbidity Duplicate Sample (NTU)
BDY-3	2	1.90	1.92
BRA-2	2	1.40	1.33
COX-2	2	0.51	0.60
FTB-0	2	0.00	0.53
GNB-0	2	0.40	0.69
GNB-1	2	0.50	0.53
GNB-2	2	0.46	0.48
GNB-3	2	0.50	0.53
HMB-4	2	0.35	0.41
IND-2	2	0.76	0.70
LLJ-1	2	0.63	0.58
LLJ-2	2	0.86	0.77
LLJ-3	2	0.61	0.66
MBA-2	2	0.00	0.00
MIN-4	2	1.38	1.32
RMI-0	2	0.54	0.57
RMI-1	2	0.52	0.52
RSH-1	2	4.64	4.88
SPC-1	2	0.79	0.79
STN-1	2	0.55	0.57
STN-2	2	0.51	0.51
STN-3	2	0.56	0.61
SUC-4	2	0.97	1.10
WIN-2	2	0.84	0.85
BAL-0	3	0.86	0.99
BMR-0	3	1.05	1.33
EAS-0	3	1.21	1.34
ELG-0	3	0.82	0.89
GUL-0	3	1.42	1.67
LOL-0	3	1.47	1.68
MBA-0	3	1.16	1.77
MRV-1	3	1.65	1.68
MSN-0	3	1.16	1.18
NRT-0	3	1.04	1.13
WAK-0	3	0.84	0.87
WLB-0	3	0.89	0.84
RSH-0	4	0.99	0.98
WIN-0	4	0.99	0.78
BAL-4	5	1.04	1.01
BMR-2	5	1.43	2.10
EAS-2	5	2.24	2.22
GUL-1	5	1.06	1.58
LOL-1	5	0.87	0.78
MBA-1	5	3.69	3.42
MRV-2	5	1.22	1.14
MSN-1	5	1.44	1.11

Table A.6 - Turbidity duplicates (cont'd)

Site	Sample Number	Turbidity Sample (NTU)	Turbidity Duplicate Sample (NTU)
NRT-2	5	1.19	1.46
SVR-0	5	1.39	1.49
WAK-2	5	1.05	1.15
BAL-4	6	1.41	0
BRA-1	6	3.31	3.21
COX-3	6	1.51	1.49
GNB-3	6	0.75	0.59
HMB-3	6	0.67	0.81
IND-1	6	1.66	1.7
JOR-1	6	1.16	1.27
LLJ-2	6	1.04	0.98
MIN-1	6	1.22	1.22
RMI-1	6	1.58	1.5
RSH-2	6	1.96	2.21
STN-3	6	0.74	0.78
WIN-1	6	1.81	1.71
BAL-6	7	0.89	0.99
GUL-2	7	2.01	2.13
GUL-3	7	2.49	2.38
LOL-2	7	0.7	0.72
LOL-3	7	0.96	1.02
MBA-3	7	1.27	1.15
MBA-4	7	1.45	1.35
MRV-3	7	1.08	0.98
MSN-2	7	2.37	2.04
SVR-1	7	0.92	0.96
SVR-2	7	1.41	1.12
WLB-2	7	1.83	1.23
BDY-0	8	5.98	5.07
IND-2	8	1.36	1.77
IND-4	8	0	0
JOR-3	8	1.83	1.83
MIN-2	8	1.02	1.26
MIN-4	8	0.93	0.87
RSH-4	8	1.16	1.23
RSH-5	8	1.24	1.14
SPC-0	8	2	2.03
SPC-1	8	3.8	3.91
SUC-0	8	1.01	1.05
SUC-2	8	1.01	1.05
WIN-2	8	1.32	1.33