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Ref.:	Governor_Lake_Timberlea2013 (7 pages)
To:	**Chair & Members, Halifax and West Community Council (HWCC), HRM**
From:	S. M. Mandaville Post-Grad Dip., Professional Lake Manage. Chairman and Scientific Director
Date:	September 06, 2013
Subject:	GOVERNOR LAKE, Timberlea:- Significant cautionary signs apparent in the HRM's chlorophyll*a* data of 2006-2011 in comparison with historical data

Please feel free to ask me any questions, and I will endeavour my level best to respond either via emails and/or in person at one of your meetings, if invited to do so. Written informally, hence may have typos.

Restoration parameters for consideration by the HWCC are suggested on page-3.

I have provided a synopsis of the data from various known sources referenced appropriately (see page-5).

Of specific interest are the Ch*a* (chlorophyll*a*) values which are representative of the `algal production'. HRM's Ch*a* data ranged 0.61–20.78 µg/l during the years 2006 to 2011 (analyzed at private labs). Compare that with Paul Mandell's grad thesis data of 1991-92 which ranged 0.76–8.43 µg/l (lab work at the QEII labs), and BIO's data of 1991 and 2000 which ranged 0.622-2.376 µg/l (lab work at federal government labs).

With the exception of HRM's year-2010 results, the TP (total phosphorus) data since 1980 has been in the same general range.

The fact that the sampling events are limited per year may have some (scientific) weight but it should raise red flags to the dedicated parties.

I also include the predictive phosphorus modelling conducted by my team some years back (results updated in page-5, and the original pictorial model in page-7). The prime purpose of predictive modeling is to anticipate nutrient enrichment even before it occurs so that regulatory agencies can take the `precautionary approach' and protect the lake, hopefully in perpetuity.

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Environment Canada (2004) published a table which was derived from the 18-country OECD peer consensus (http://lakes.chebucto.org/TPMODELS/OECD/oecd.html) which I reproduce below:-

Table 4.1 Trophic classifications of lakes, with their corresponding phosphorus and chlorophyll concentrations and transparency (Secchi depth) (sources: Wetzel 2001; Vollenweider and Kerekes 1982).

Trophic level	Total Phosphorus ($\mu g \cdot L^{-1}$)		Chlorophyll *a* ($\mu g \cdot L^{-1}$)		Secchi depth (m)	
	Wetzel (2001)	Vollenweider and Kerekes (1982)	Vollenweider and Kerekes (1982)		Vollenweider and Kerekes (1982)	
			Mean	Max	Mean	Min.
Ultra-oligotrophic	< 5	< 4	< 1	< 2.5	> 12	> 6
Oligo-mesotrophic	5-10	4-10	< 2.5	< 8	> 6	> 3
Meso-eutrophic	10-30	10-35	2.5-8	8-25	6-3	3-1.5
Eutrophic	30-100	35-100	8-25	25-75	3-1.5	1.5-0.7
Hypereutrophic	> 100	> 100	> 25	> 75	< 1.5	< 0.7

To further understand the relevance of Ch*a* values, kindly note that the Kings County of Nova Scotia set maximum objective <u>Ch*a* values in the low range of 2.5 µg/l</u> for 18 lakes. I herewith insert a scan of their policy from my archives:-

Kings County adopted water quality objectives for 18 lakes in the county, through amendment of MPS and LUB. The maximum objective value of chlorophyll-a for most of these lakes is 2.5 µgm/L. Seven of the lakes' objectives were set below the level of 2.5. Based on predictive modelling, the estimated maximum number of dwellings that could be added to the contributing area without exceeding the threshold value was established. This number of dwellings was set as a limit for development in the LUB. Policy in the MPS enables application for a permit with a development having "near-zero impact" through site standards or performance standards. Primarily this condition is expected to be met with septic field fill with a 20 year phosphorus input retention and a requirement to replace the fill every 20 years. A condition in adopting these limits was implementation of an annual monitoring program for a minimum of six years. The sampling required was to be completed by volunteers.

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We have not studied the zoobenthos, i.e., the preferred indicator organisms within the sediments (or sometimes known as the `canary in the coal mines') there yet unlike select other metro lakes since we have numerous other scientific priorities right now.

Suggested restoration consideration by the HWCC:

(i) Methods to restore the lake to its recent historical data of the 1990's based on chlorophyll*a* (Ch*a*) values; mean of means=1.48 µg/l (range=0.2-8.43 µg/l).

(ii) As a reminder, HRM's Ch*a* data of 2006-2011; mean of means=6.08 µg/l (range=0.61-20.78 µg/l).

(iii) It may not be practical to restore the lake to its pre-cultural phosphorus value of 6.2 µg/l, or even to the pre-industrial value of 11.5 µg/l expressed as total phosphorus (TP).

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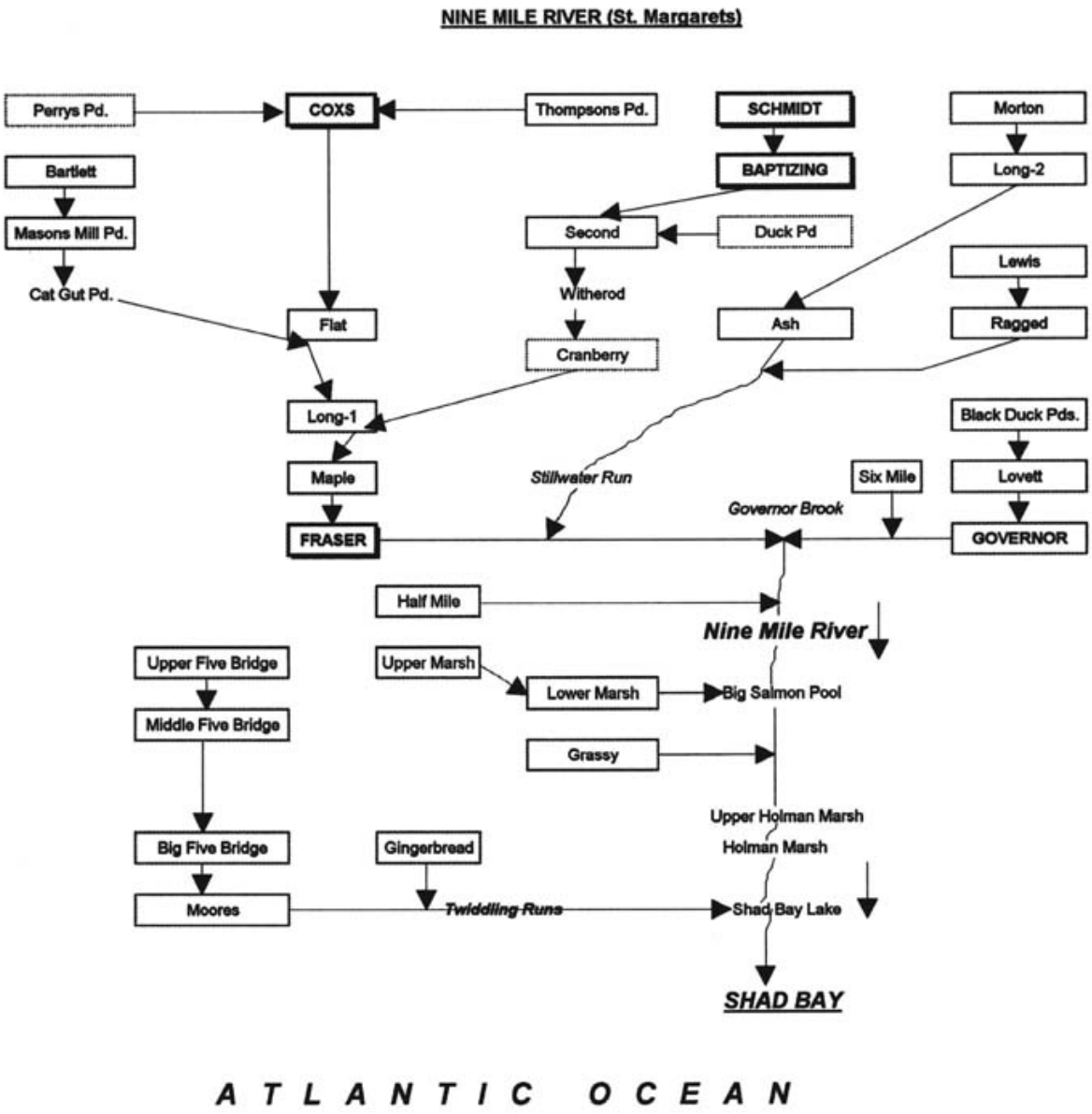
The Nine Mile River flow chart developed by us



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Data archives

Source of field data	Date(s) of sampling	#s of sampling events and type of sampling	TP (µg/l)		Ch*a* (µg/l)	
		Deep stn.	mean	range	mean	range
BIO	Apr. 1980	1# (surf.)	29	-	-	-
NS Lands & Forests	Aug. 1983	1# (surf.)	11	-	-	-
BIO	Apr. 1991	East basin-1# (surf.)	28	-	0.622	-
		West basin-1# (surf.)	29	-	2.376	-
SWCSMH	Oct. 1992	1# (vol. wtd.)	32	-	0.2	-
SWCSMH's Predictive Modelling (also see graph on page 6)		Pre-cultural	6.2	-	-	-
		1988, Serv. Res. @ 0.52 kg/ha	11.1	-	-	-
		1988, Serv. Res. @ 1.1 kg/ha	17.8	-	-	-
Mandell	1991-92	4#s (surf.)	8	5 – 10	3.09	0.76 – 8.43
BIO	March, 2000	2#s (surf.)	14	-	1.132	-
HRM	2006	2#s (1 m.)	6.5	2 – 11	1.83	1.44 – 2.2
HRM	2007	3#s (1 m.)	7.7	5 – 10	3.95	0.61 – 7.06
HRM	2008	3#s (1 m.)	15.3	13 – 18	5.92	1.06 – 12.29
HRM	2009	3#s (1 m.)	14.3	11 – 19	5.33	1.49 – 10.53
HRM	2010	3#s (1 m.)	31.3	17 – 56	8.33	4.62 – 15.14
HRM	2011	3#s (1 m.)	15.3	4 – 28	11.10	2.40 – 20.78
Thiyake's Paleo Inference Model	1850's (i.e., pre-industrial)	Queen's University Diatom Inference Model	11.5	-	-	-
	2005-2006		4.68	-	-	-

Acronyms & brief explanation on next page

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Acronyms & brief explanation of the aforesaid table (all sampling @ deep stn.)

arms depth.= sampling at arms depth
surf.= surface samples
1 m.= 1 metre depth sampling

BIO- Bedford Institute of Oceanography
SWCSMH- Soil & Water Conservation Society of Metro Halifax's research
SWCSMH's predictive modelling- Computer modelling carried out by the Soil & Water Conservation Society of Metro Halifax
Mandell- Paul Mandell's MSc thesis (1994) at Dalhousie University
HRM- Halifax Regional Municipality (2006 to 2011; the Ch*a* values are means of the 2 methodologies reported)
Thiyake- Thiyake Rajaratnam's MSc thesis (2009) at the Queen's University in Kingston, Ontario under a major NSEC grant. The grant was for the first ever paleolimnology conducted on lakes across Nova Scotia (I calculated the antilog values from her reported log values based on the diatom inference model)

Basic Morphometric and Hydrologic data
(computed by us from bathymetric maps supplied by the Provincial Fisheries Dept.)

- Shoreline length= 4.591 km
- Surface area= 37.8 ha
- maximum depth= 14.0 m; mean depth= 4.6 m
- volume= 1.86×10^6 cu.m.
- watershed (local)= 402.5 ha; watershed (total)= 621.9 ha
- Flushing rate= 3.2 times/yr (approx.)
- In-lake TP retention= 0.31

- Zr , Relative depth= 2.0 % ……. (for most lakes, Zr < 2%. Deep lakes with small surface areas exhibit greater resistance to mixing and usually have Zr > 4%).
- DL, Shoreline dev.= 2.1 ……. (DL is important because it reflects the potential for development of littoral communities which are usually of high biological productivity).
- Dv, Deve. of volume= 1.0 …….. (For the majority of lakes, Dv will be greater than 1 (i.e. a conical depression).
- Index of Basin Permanence (IBP)=0.42 $\times 10^6$ cu.m/km …… (The IBP is a morphometric index that reflects the littoral effect on basin volume. Lakes within the Atlantic National Parks (IBP < 0.1) are dominated by rooted aquatic plants and indicate senescence (excessive shallowness, high water color and high TP).

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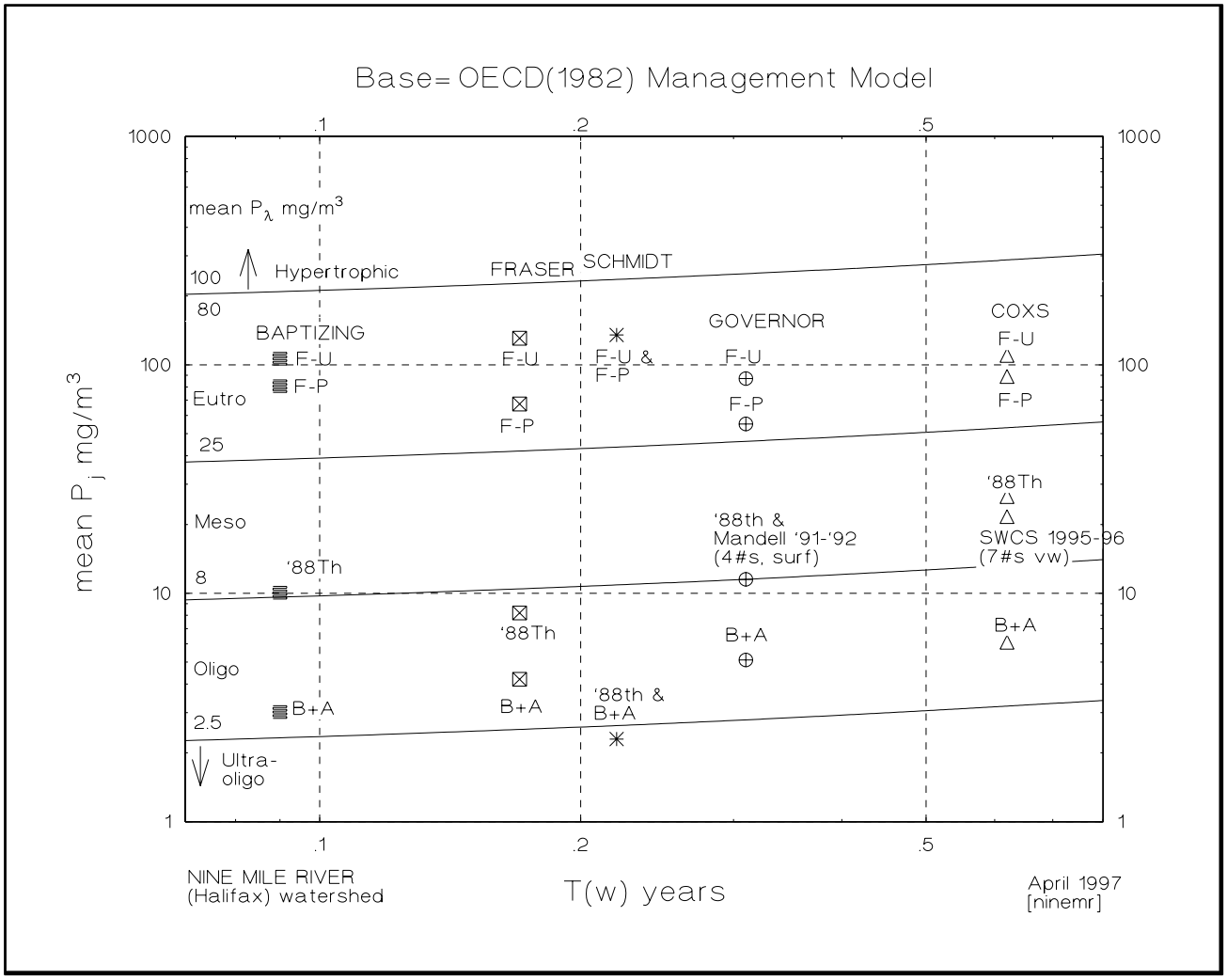
Our predictive model utilizing the 18-country OECD (Organization for Economic Co-Operation and Development) peer consensus base models



Notes for the log-log graph above:-

The X-axis is the water retention time. The Y-axis is the inflow TP concentration. The pelagic (i.e., open water) phosphorus concentrations are shown as curved lines with values of 2.5, 8, 25, 80, and 100 µg/l expressed as total phosphorus (TP) delineating the OECD management model categories of nutrient enrichment. Chlorophyll*a* values have not been plotted though they can be with some more work.

B+A= Background+Aereal
`88= Based on 1988 land use stats
F-P= Future-Probable
F-U= Future-Ultimate