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Ref.:	BissettLake2013 (9 pages)
To:	Harbour East - Marine Drive Community Council (HEMDCC), HRM
From:	S. M. Mandaville Post-Grad Dip., Professional Lake Manage. Chairman and Scientific Director
Date:	October 30, 2013
Subject:	BISSETT LAKE, Cole Harbour:- very enriched, comparison with HRM's data of 2006-2011, and suggested restoration parameters

(*cf.* http://lakes.chebucto.org/WATERSHEDS/COWBAYR/BISSETT/bissett.html)

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.

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

I have provided a synopsis of the relevant data from various known sources referenced appropriately (see page-5). These are all deep station values (shallow zone values may differ considerably). A summary of the historical phytoplankton has been noted in page-8, and an excerpt from a 3rd party university study of macrophytes in pages- 8 & 9. We hope to carry out further research in biological limnology of this long enriched (i.e., degraded) lake when opportunity arises.

Of specific interest here are the Ch*a* (chlorophyll*a*) values which are representative of the `algal production'. HRM's Ch*a* data ranged 0.15–27.90 µg/l during the years 2006 to 2011 (analyzed at private labs) which is alarming. Compare that with our 1992-1993 data of 1.1-13.7 µg/l (lab work at the Environment Canada lab in Moncton), and Paul Mandell's grad thesis 1991-92 data of 0.55–6.61 µg/l (lab work at the provincial QEII labs).

The TP (total phosphorus) values which are usually the `limiting nutrients':- HRM's TP data ranged 11–145 µg/l during the years 2006 to 2011 (analyzed at private labs) is quite shocking. Compare that with our 1992-1993 data of 12-35 µg/l (lab work at an Environment Canada lab in NB), and Paul Mandell's grad thesis 1991-92 data of 12-19 µg/l (lab work at the Province's QE II labs). Our modelled pre-cultural hindcast (+0.173 kg/ha.yr precipitation) value is 3.7 µg/, and the Queen's University pre-industrial (i.e., pre-1850's) diatom inference value is 5.13 µg/l.

I also include the predictive phosphorus modelling conducted by my team some years back (results updated in page-5, and the pictorial model in page-7).

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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	~~Max~~ 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	27-75	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 a maximum objective <u>Ch*a* values in the low range of 2.5 µg/l</u> for 18 lakes. I herewith insert a scan from their policy in 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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Suggested deliberation for restoration by the community council (CCME):

(i) See the CCME's fact sheet (2004) for the phosphorus guidance framework (http://documents.ccme.ca/download/en/205/).

(ii) The CCME's framework recommends a maximum enrichment of 50% increase over the hindcast value of TP, and to not exceed the trigger range. The hindcast cultural (+0.173 kg/ha.yr precipitation) value is 3.7 µg/l, hence 50% increase results in a conc. of 5.6 µg/l, but the relevant trigger range is the stringent <4 µg/l. As an exception, 6.0 µg/l can be a compromise which is also very stringent for this lake.

(iii) Further compromise:- The pre-industrial (pre-1850's) TP value is 5.13 µg/l; 50% increase would be 7.70 µg/l which would fall within the trigger range of 4-10 µg/l. Hence, the max. acceptable value would be 8 µg/l to round it off. Even this could be impractical, but one can try if one is seriously interested in `restoring' the lake! Lake restoration results from elsewhere have been widely published in the scientific handbooks and published papers.

Total phosphorus (TP) trigger ranges for Canadian lakes and rivers (CCME, 2004)

Trophic status	TP (µg/l)
Ultra-oligotrophic	< 4
Oligotrophic	4-10
Mesotrophic	10-20
Meso-eutrophic	20-35
Eutrophic	35-100
Hyper-eutrophic	> 10

Per the CCME (2004), the framework offers a tiered approach where phosphorus concentrations should not (i) exceed predefined 'trigger ranges'; and (ii) increase more than 50% over the baseline (reference) levels. The trigger ranges are based on the range of phosphorus concentrations in water that define the reference trophic status for a site (i.e., hindcast values). If the upper limit of the range is exceeded, or is likely to be exceeded, further assessment is required. When assessment suggests the likelihood of undesired change in the system, a management decision must be made.

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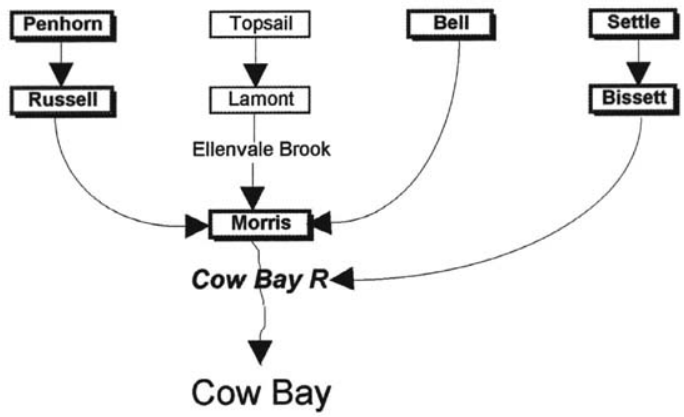
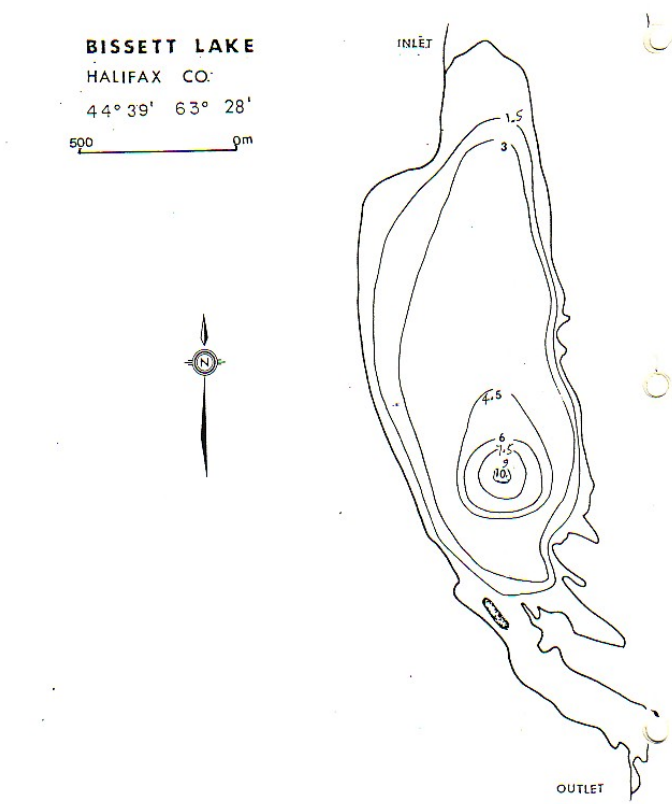
The flow chart developed by us



Lake bathymetry (as supplied by the NS. Dept. of Fisheries)



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Deep station data archives (shallow area data can vary significantly)

Source of field data	Date(s) of sampling	#s of sampling events and type of sampling	TP (µg/l)		Cha (µg/l)	
		Deep stn.	mean	range	mean	range
BIO	Apr. 1980	1# (surf.)	7.0	-	-	-
SWCSMH	June-Oct. 1990	3#s (arms depth)	24.1	20.1 – 27.6	5.28	2.20 – 9.25
BIO	Apr. 1991	1# (surf.)	3.0	-	15.044	-
SWCSMH's Predictive Modelling (also see graph on page-7)		Pre-cultural (+0.173 kg/ha.yr precipitation)	3.7	-	-	-
		1993 Serv. Res. @ 0.52 kg/ha.yr	25.3	-	-	-
		1993 Serv. Res. @ 1.1 kg/ha.yr	45.3	-	-	-
Mandell	1991-92	4#s (surf.)	15	12 – 19	3.97	0.55 – 6.61
SWCSMH	1992-93	11#s (vol. wtd.)	21	12 – 35	4.8	1.1 – 13.7
Sherwood	Aug. 1994	1# (surf.)	12.8	-	3.5	-
BIO	March, 2000	2 stns (surf.)	22	-	11.678	-
Jordon & Owen	Aug. 2002	1# (surf.)	7	-	5.7	-
Thiyake's Paleo Inference Model	Pre-1850's (Bottom layer of core)	Queen's University Diatom Inference Model	5.13	-	-	-
	Early 2000's (Top layer of core)		15.85	-	-	-
HRM	2006	1# (1 m.)	8.0	-	2.65	-
HRM	2007	3#s (1 m.)	13.7	11 – 15	7.00	0.15 – 12.34
HRM	2008	3#s (1 m.)	27.7	11 – 40	6.30	0.45 – 14.96
HRM	2009	3#s (1 m.)	17.7	15 – 20	10.44	4.89 – 21.14
HRM	2010	3#s (1 m.)	27.3	12 - 49	3.62	2.32 – 4.80
HRM	2011	3#s (1 m.)	62.3	17 – 145	19.23	3.63 – 27.90

(Acronyms & brief explanation on next page)

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Acronyms & brief explanation of the aforesaid table

vol. wtd.= volume weighted discrete depth sampling
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
Sherwood- Alison Sherwood, former Dalhousie Univ. student
Jordan & Owen- Bob Jordon & Rochelle Owen, former Dalhousie Univ. students
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 NSERC 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= 7.979 km
- Surface area= 88.8 ha
- maximum depth= 9 m; mean depth= 3.2 m
- volume= $2.79x10^6$ cu.m.
- watershed (local)= 776 ha; watershed (total)=812.4 ha
- Flushing rate= 3.1 times/yr (approx.)
- In-lake TP retention= 0.56

- Zr , Relative depth= 0.8 % ………. (for most lakes, Zr < 2%. Deep lakes with small surface areas exhibit greater resistance to mixing and usually have Zr > 4%).
- DL, Shoreline dev.= 2.4 …………. (DL is important because it reflects the potential for development of littoral communities which are usually of high biological productivity).
- Dv, Deve. of volume= 1.1 ………….. (For the majority of lakes, Dv will be greater than 1 (i.e. a conical depression).
- Index of Basin Permanence (IBP)=0.35 $x10^6$ 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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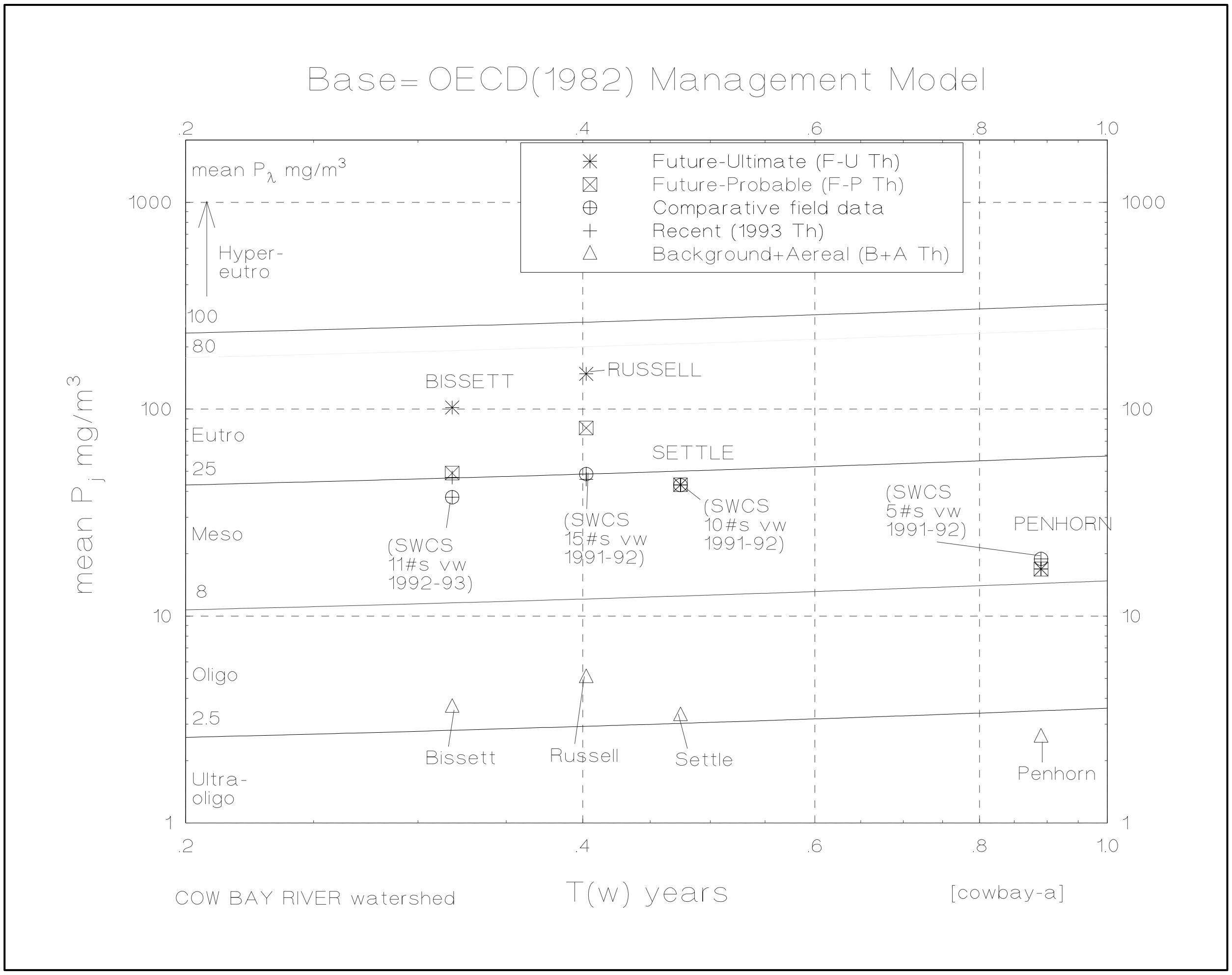
<u>Our predictive model utilizing the 18-country OECD (Organization for Economic Co-Operation and Development) peer consensus base models</u>



<u>Notes for the log-log graph above</u>:-

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. We have also not updated the model with the latter field data of various sources inclusive of HRM's from the Table since it will get cluttered.

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Summary only of select phytoplankton analyses (does not include all yet)

(*cf.* SWCSMH, 1993. 120p. Refer to that report for the detailed listing of species.)

The late summer sampling at this lake presented large numbers of Myxophycean plankton, notably tangled mats of *Anabaena* and *Lyngbya* species. This was one of the few lakes where *Anabaena* and other blue-green species were present to any considerable extent. Upon sampling in autumn, the overall population density had decreased substantially, and the previously high proportion of *Anabaena* and *Lyngbya* declined to a few scattered filaments. A shift in species makeup resulted in fewer Myxophycean representatives, and greater numbers of *Scenedesmus* species and unicellular Chlorophyta. Diatom populations remained fairly consistent.

(*cf.* Sherwood, 1994. 49 leaves. Refer to that report for the detailed listing of species.)

The dominant epiphytic diatoms of Bissett Lake were identified as *Cymbella minuta*#1, *Synedra acus*, *Synedravar. oxyrhynchus*, *Fragilaria virescens*, *Fragilaria vaucheria*, *Gomphonema angustatum* var. *citera*, and *Fragilaria capucina*.

Macrophytes:- Excerpts from the lab report of Jordan & Owen, Dalhousie University, August, 2002 (rec'd a high mark of 19.5 out of 20)

The macrophyte cover was found to be quite dense, particularly in Bisset Lake, and included characteristic species of eutrophic *and* oligotrophic lakes including: *Typha latifolia* (cat-tail), *Pontederia cordata* (pickerel weed), *Nuphar lutea* and *Nymphaea odorata* (yellow and white water-lilies), *Equisetum fluviatile* (horse's tail), and *Juncus militaris* (soldier rush). Of these species, *latifolia* and *fluviatile* are characteristic of eutrophic lakes; *odorata* are found in mesotrophic lakes; and *militaris* are found in oligotrophic lakes (*cordata* are found in lakes of all these trophic states) (Srivastava, D.S., Staicer, C.A., Freedman, B., 1995). (Please see Appendix G for photos of these and other species taken at Russell Lake)

The macrophyte cover, in both lakes was substantial and as with every other factor involved, pointed to a slightly more eutrophic state at Bisset Lake compared to Russell Lake. This remains true when the numbers are combined with the CA (Chlorophyll a) results to yield a value representing primary productivity.

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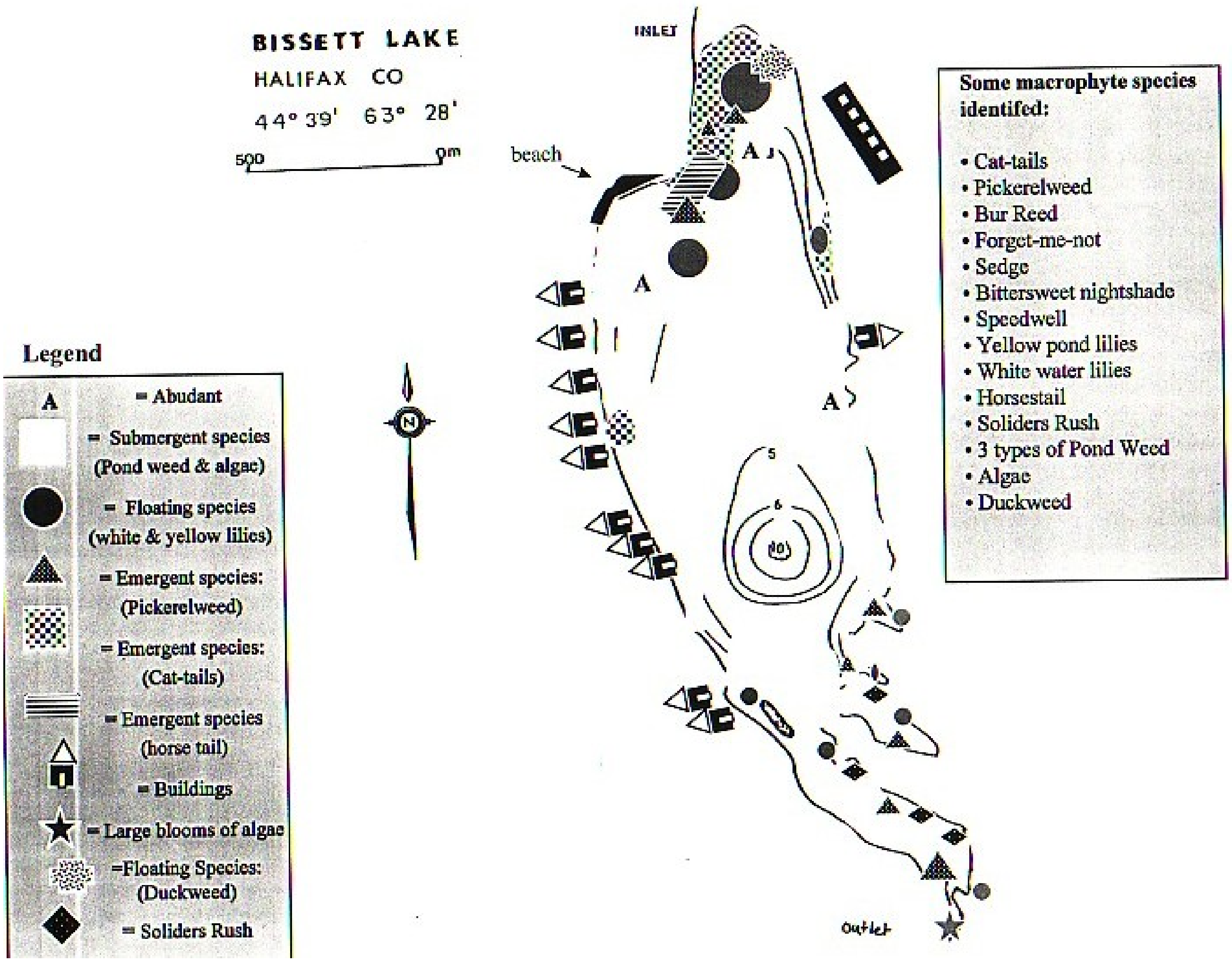
(contd. Jordan & Owen report)



(see our web page on their report,
http://lakes.chebucto.org/WATERSHEDS/COWBAYR/holt.html)