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To: Suzanne Corser Esqrs.
Planner, Halifax County Municipality
From: S. M. Mandaville, Co-Ordinator
Date: 27 January 1995
Subject: Dts. 1 & 3 MPS public hearing on 23 January 1995 -and- our telephone conversation of 26 January 1995----*SYNOPSIS- LAKE CARRYING CAPACITIES*

In order that the MPS is not delayed unduly, the following strategy may serve to be quite effective:

[I] A planning policy statement to the effect that Council will initiate a secondary planning strategy ASAP (with perhaps a time limit) to address the important focus on "water quality" will be a compromise. In the case of District 3, the significant system is the Woodens (or Hosier) river system. There is also interest in the East River system and I am not at the present quite sure what portion of the watershed is within Dt. 1.

[II] While inland "water quality" is generally considered as a provincial responsibility, nevertheless it has now been widely accepted by the scientific and related communities that land development (municipal responsibility), stewardship practices and other related activities of the human species can have long term deleterious effects.

(a) With respect to onsite systems, it has been reported in extensive literature that even properly functioning systems do contribute phosphorus (the limiting nutrient) to the watercourses, generally within 300m on a reasonable time scale. The effective methodology to prevent undue pollution is to implement density controls (#s of onsite systems) with the concern on **`cultural eutrophication'** in mind.

(b) This approach is recognized and used by the Ontario Ministry of Environment and Energy, and by some municipalities in Ontario such as the District Municipality of Muskoka and its constituent local municipalities, townships surrounding Upper Rideau Lake, Big Rideau Lake and Lower Rideau Lake and the Township of Chandos. In the District of Muskoka this was accomplished by first setting **maximum average summer Chlorophyll*a* levels** and then translating same to result in larger lots (i.e. density controls) or in extreme cases, further lakeshore development has been prohibited. Most of the development in Muskoka (recreational lakes) has been allegedly along the lakeshores, hence the focus on same. Kings County, N.S. is considering similar controls around lakes Aylesford, George and Loon. Whereas, in the suburban areas of Halifax County development does extend into so-called backlands. Though in some instances, controls may not be necessary depending on future "water quality" desired.

(l) The Dorset Research Centre under the able leadership of Dr. P.J. Dillon has communicated to us that the 300m zone is considered as the area which is the most susceptible over the near to mid-future time scales. It is believed that phosphorus would reach the lake through ground water as a result of the following phenomenon (but not limited to); water logging during spring, macropores (thru decaying roots) in subsurface, and fractures in bedrock. Under ideal conditions (laboratory conditions do not exist in the real world), the intervening soil complexes dictate the rate of progression of the phosphorus plume (several cm in clay soils to metres in sandy soils).

[III] An important part of the problem relates to the manner in which the subdivisions review process is undertaken, i.e., in bits and pieces. What should be taken into account is the cumulative effects of all other plans of subdivision that preceded an application, some of which might not occur for many years to come.

There are two aspects in the Lake Carrying Capacities, the Shoreland Development Capability (not restrictive and sometimes being implemented by Public Health engineers indirectly) and the Lake Trophic state (not presently considered by any agency, which can be quite restrictive) depending on the water quality objectives of the community and the degree of change in the water quality that the community wishes to permit.

[IV] EUTROPHICATION is, ofcourse, only one aspect of water quality, which is generally defined as the sum of all detectable properties of water, including bacterial conditions, smell, appearance, toxicity, and the nature and extent of aquatic plant and animal communities. Although localized bacterial and human health problems do occur from time to time, these are generally not widespread in recreational lakes. As well, toxic contamination is not a significant problem in most inland recreational lakes (with rare exceptions). Therefore, EUTROPHICATION is generally the prime water quality concern on recreational lakes, and lake trophic state is considered to be the prime indicator of recreational lake health.

[V] Lake managers prefer summertime or ice-free conc. of Ch-a (Chlorophyll-a), rather than TP (Total Phosphorus) conc. and SD (Secchi Disk) depths as the prime indicators of lake trophic state because:

(a) i) While an excellent mathematical relationship exists between TP and Ch-a, TP is not visible to the naked eye and has no direct impact on shoreline residents or lake users.

ii) In contrast Ch-a is readily apparent, and its direct impact is one of the key concerns expressed by members of the public about their lakes.

iii) Though a mathematical relationship between Ch-a and SD depths also exists, SD measurements are often substantially influenced by factors other than Ch-a, such as natural colour, suspended sediment, waves. As well, SD depths are recorded by individuals in the field, and there can be considerable variations between the depths recorded by different surveyors under the same conditions.

(b) In general, average ice-free Ch-a conc. up to about 2 μg/l indicate low algal densities and an unproductive or nutrient-poor lake. Average conc. between 2 and 5 μg/l, although moderately high, are acceptable for swimming and other water contact recreation. However, lakes in this intermediate range can experience short term pulses of up to 10 μg/l to 12 μg/l in warm, calm periods in midsummer, producing algal blooms. Average ice-free conc. exceeding 5 μg/l are high; at these levels, water quality for swimming and other water contact recreation frequently deteriorates, and aesthetic quality declines.

[VI] <u>For predictive purposes, TP conc. and variations are utilized</u>.

(a) Although predictive models are not perfect, neither are measurements. Actual biological conditions in a lake vary from year to year, as a result of climatic and other environmental variations. Field sampling and (in the case of TP and Ch*a*) laboratory analysis are not exact processes and involve a degree of error. For these reasons, when used as a basis for lake management decisions, measured data should represent the means of large numbers of samples over long periods of time; therefore the estimates generated by a well calibrated model based on current use and development conditions can be taken as representing the long term means around which measurements, if available, would vary. This is ofcourse an ideal world, and in the real world of large and complex lake systems, this claim of accuracy cannot be made in all cases. Even if there is a significant gap between the predicted and measured trophic state indicators for a particular lake, and some doubt surrounds the absolute value of the predicted indicators, the model will still indicate the relative change in trophic state that would result from a given change in conditions.

(b) The value of 0.8 kg TP/capita years/year originates from a survey of phosphorus conc. in inflows of domestic sewage in a number of urban STPs in North America and Europe. A similar value was empirically determined from studies of underdrained tile field systems at the Ontario Hospital in Orillia. This estimate is accurate ± 0.2 kg/capita years/year, depending on locale and food intake, and accounts for inputs associated with storm drainage.

(g) **Phosphorus** may enter a water body through the inflows, precipitation, dry fallout and from the sediments, and it may be removed by sedimentation and through the outflow. **Nitrogen** has a more complex pathway. In addition to the inputs and outputs described for phosphorus, nitrogen can enter and leave a water body in the form of free nitrogen gas (N_2_) through atmospheric exchange. Carbon has been shown to diffuse into the water column at rates sufficient to meet the needs of photosynthesizing cells. Phosphorus, on the other hand, cycles between living and nonliving particulate forms and the dissolved form. The different pathways of phosphorus, nitrogen and carbon in lake metabolism make phosphorus the obvious choice for **eutrophication control.** A certain reduction of phosphorus input will generally result in a greater reduction in algal biomass compared with the same reduction of nitrogen. Furthermore, the reduction of nitrogen input without a proportional reduction in phosphorus, creates low N/P ratio which favors nitrogen fixing nuisance algae, without any reduction in algal biomass.

Total Phosphorus and not other phosphorus species, is considered the key variable for practical rather than theoretical reasons. Total phosphorus includes some or all of the following fractions: crystalline, occluded, absorbed, particulate organic, soluble organic and soluble inorganic phosphorus. Out of these fractions, the three biologically available phosphorus fractions listed in order of *decreasing availability* are soluble reactive phosphorus (a mixture of dissolved inorganic and organic species), soluble unreactive phosphorus (some include dissolved phosphorus fed by persulfate oxidation, and is available for phytoplankton by enzymatic hydralisation which frees organically bound fractions), and "labile" phosphorus (associated with soil particles).

[VII] `**Ecosystem'** is the unit of natural organization in which all living organisms interact collectively with the physical chemical environment as one physical system. **Lakes** are living ecosystems. `Trophy' refers to the rate of supply of organic matter. Lake ecosystems are complex, involving *both terrestrial and aquatic photosynthesis*, external and internal nutrients, grazer and detrital food webs, and aerobic and anaerobic metabolism. Lake ecosystem consists of two major components: the "aquatic" component which is the waterbody itself, and the "paralimnetic" component which consists of the drainage basin or watershed. The paralimnetic component could be divided into a variety of land-use fractions (urban, agricultural, and wooded/wetland), soil groupings, slope classes, or other categories. Likewise, the aquatic component could be divided into littoral zone; pelagic zone; benthic (profundal zone) boundary layer; sediments; and during summer stratification into epilimnion, metalimnion, and hypolimnion.

Most energy enters a small lake through terrestrial photosynthesis in the watershed (paralimnion). About one half of the incident PAR (photosynthetically active radiation) is reflected and refracted at the lake surface, and much of the rest may be absorbed by lake water and organic matter dissolved in it. Terrestrial organic material affects physical/chemical properties and processes of lakes, combines with products of aquatic photosynthesis to support lake food webs, and accumulates in lake sediments. Autochthonous production by aquatic macrophytes (littoral zone photosynthesis) and phytoplankton (pelagic photosynthesis) is grazed by littoral invertebrates and pelagic zooplankton, then by forage fish preying on zooplankton, and finally by predatory fish (piscivores) on forage fish. This trophic dynamic structure prevails in the littoral zone and trophogenic pelagic zone of mesotrophic and eutrophic lakes.

[VIII] **Trophic classification** (for numerical values refer to our Synopsis # 2 titled Prediction of Lake Capacity/Lake Use): Lakes in which most of the organic matter is from autochthonous sources are referred to as autotrophic, whereas those dominated by the input of paralimnetic particulate organic matter (POM) and dissolved organic matter (DOM) are termed allotrophic. Rodhe's scheme included Oligotrophic (low in both auto- and allotrophic organic sources), eutrophic (dominated by autotrophy), dystrophic (dominated by allotrophy, brown coloured water), and mixotrophy (high in both auto- and allotrophic organic sources).

Trophic classification is most commonly performed using parameters which reflect pelagic phytoplanktonic autotrophy (total phosphorus [TP], chlorophyll, Secchi). As commonly used, trophic state indices (TSIs) refer to the level of planktonic autotrophy. In lakes dominated by paralimnetic or littoral organic sources, the TSI will be low because autochthonous (pelagic, phytoplanktonic) production is low, e.g., dystrophic lakes.

Oligo-Eutro classification scheme: Oligotrophic lakes are poorly supplied with plant nutrients and support little plant growth. As a result, biological productivity is generally low, the waters are clear, and the deepest layers are well supplied with oxygen throughout the year. Mesotrophic lakes are intermediate in characteristics. They are moderately well supplied with plant nutrients and support moderate plant growth. Eutrophic lakes are richly supplied with plant nutrients and support heavy plant growths. As a result, biological productivity is generally high, the waters are turbid because of dense growths of phytoplankton, or contain an abundance of rooted aquatic plants; deepest waters exhibit reduced concentrations of dissolved oxygen during periods of restricted circulation. The boundary categories of the above are ultraoligotrophy and hypereutrophy. Eutrophic and the extreme condition of eutrophy, hypereutrophic lakes are not desired by most citizens. It will be appropriate to point out here that the oxygen depletion in the bottom waters could occur even in lakes lesser productive than eutrophic lakes (e.g. oligo/meso) with small hypolimniums.

[IX] Lake Restoration (`after the fact'): The first and most obvious step toward protection and restoration of a lake or reservoir is to divert or treat excessive nutrient, organic, and silt loads. **Even this expensive process, while necessary, may be insufficient** to produce immediate and long-lasting effects, due to internal recycling of nutrients and the associated production of algae and macrophytes. Several authors have identified feedback loops in eutrophic systems that can maintain the eutrophic state for some period after loading is curtailed. These include macrophyte growth-death-decay cycles, nutrient release under aerobic and anaerobic conditions, and bioturbation. In these lakes and reservoirs a second step, a technique to manipulate or alter an internal chemical, biological, or physical process, may be needed to promptly restore the water body.

The problem is more complicated because most lakes and many reservoirs are small or shallow, with extensive littoral zones, macrophyte development, and high ratios of bottom sediment to lake volume. We now know that lakes and reservoirs contain interacting food webs and dynamic stores of nutrients in their bottom sediments that interact with the water column. They are not simply reaction vessels containing nutrients and algae. Managing and restoring lakes and reservoirs must include a recognition of the significance of littoral zones and macrophyte development, as well as the roles of biological interactions and feedback processes, which might combine to maintain high nutrient concentrations and plant biomass long after nutrient diversion.

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Ecosystems can be viewed as arbitrary subdivisions of The Biosphere in which living organisms and their environments interact, adaptively. For example, an ecosystem can be an aquarium, a tropical rain forest, a lake, ocean, city, or family farm.

....................The difference between the concepts of environment and ecosystem is comparable to that between *house* and *home.* A house is external and detached. In contrast, a home is something that we are in, and see ourselves in even when we are not there.

.... *`Johnny Biosphere'*
(Dr. J.R. Vallentyne, Former Co-Chairman, Great Lakes Science Advisory Board, Member, SWCS)

<u>The Challenge of Change</u>

Man often becomes what he believes himself to be. If I keep on saying to myself that I cannot do certain things, it is possible that I may end by really becoming incapable of doing it. On the contrary, if I shall have the belief that I can do it, I shall surely acquire the capacity to do it, even if I may not have it at the beginning.

.... Mahatma Gandhi (quoted in "Our Province, Our Future, Our Choice", A Consultation Paper for A Nova Scotia Economic Strategy, Voluntary Planning, March 1991)