THE EFFECTS OF LAND USE CHANGES ON WATER QUALITY OF URBAN LAKES IN THE HALIFAX/DARTMOUTH REGION

BY

PAUL R. MANDELL

SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE

AT

DALHOUSIE UNIVERSITY

HALIFAX, NOVA SCOTIA

MARCH, 1994

ABSTRACT

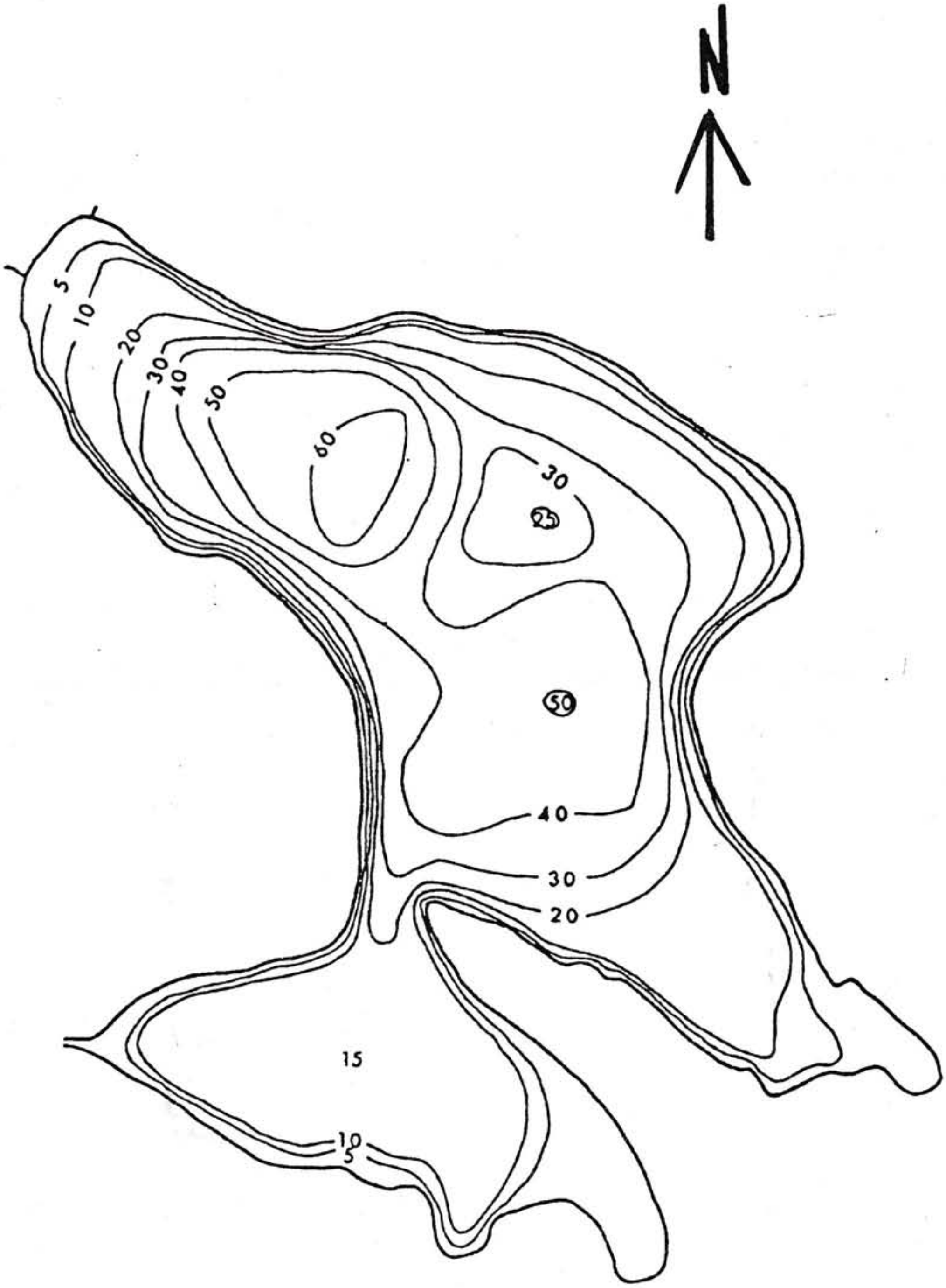
Land use changes as sources of anthropogenic stress can cause changes in urban lake water quality. In order to examine and delineate effects of land use changes, the following 3 research questions were asked: as a result of anthropogenic stress (1) what is the current water quality of Halifax/Dartmouth Lakes, (2) have there been changes in urban lake water quality over time, and (3) if there have been changes in urban lake water quality over time, can these changes be related to changes in land use?

The underlying theoretical basis of the study was the idea of urban lake water quality under anthropogenic stress. Six anthropogenic stressors and indicators for each were chosen to assess water quality of urban lakes.

Thirty four urban lakes in the Metro region were chosen for extensive study. These extensively studied lakes were sampled 4 times from November, 1991to November, 1992. Two of the extensive lakes, Bell and Settle, were chosen for intensive study. Each of the intensive lakes was sampled 30 times from May 13-Nov 29, 1992. Bell Lake had undergone sustainable development, while Settle Lake had been unsustainably developed. Examination of the indicators of anthropogenic stress demonstrated (1) Settle Lake water quality was being stressed by physical disturbance, eutrophication, bacterial contamination, road salt contamination, and oxygen deficit, while Bell Lake water quality was stressed by physical distrubance, (2) the delineated indicators of anthropogenic stress were efficacious and accurate in assessing urban lake water quality under stress. Stress assesments were then completed on the remaining 32 urban lakes. 20.6% of the urban lakes were being stressed by acidification, 47.1% were being stressed by eutrophication, 67.7% were being stressed by bacteriological contamination, 70.6% were being stressed by physical disturbance, and 88.2% were being stressed by roadsalt contamination.

In order to investigate the possibility that urban lake water quality had changed over time as a result of anthropogenic stress, 1991-92 stress assessments were compared with 1971 stress assesments. The entire suite of 6 stressors could not be used as the 1971 data was only comparable to the 1992 data on stress by acidification, eutrophication, and road salt contamination. Even using 3 stressors, the analysis indicated an increase from 1971-92 of 24.1% in the number of urban lakes' stressed by eutrophication, an increase of 17.2% in stress by acidification, and an increase in 48.3% stressed by road salt contamination. The per cent decrease in urban lakes whose water quality was unstressed by any of the 3 comparable stressors was 55.2%. Having demonstrated changes in urban lake water quality over time due to anthropogenic stress, the relationship between land use changes and changes in urban lake water were explored. Watersheds of the extensive lakes were digitized. Land use categories as per cent of the watershed were obtained for each watershed for 1967 and 1986. Land use changes, expressed as changes in per cent land use for each category were computed for each watershed for 1967 and 1986. Special attention was paid to urban land use. Initially, it was hypothesized there would be a strong correlation between the magnitude of urban land use change and resultant anthropogenic stress to urban lakes. On closer examination, it was found that the specific change in land use(road building etc.) was responsible for the resultant anthropogenic stress to urban lakes. For the majority of lakes, resultant stressors and cause due to specific change in land use were elucidated. The importance of anthropogenic stress assessment as a tool to identify stressors of urban lake water quality was demonstrated by comparing Vollenweider-Kerekes trophic categories to anthropogenic stress assessment for Governor Lake. According to Vollenweider-Kerekes, Governor Lake is oligotrophic, suggesting its water quality is unstressed. The use of anthropogenic stress assessment reveals Governor Lake water quality to be stressed by the entire suite of stressors. Anthropogenic stress assessment is a rigorous ecological tool for the determination of urban water quality. By analysing anthropogenic stressors of urban lake water quality, it may also be possible to attenuate their effects.

MAP 25 **SANDY LAKE**



1"=675'(app.)

44°44'00"N 63°42'10"W

18. Sandy Lake (Reference lake type 1)

The average pH of Sandy Lake is 5.35 (range 5.10-5.9). The average alkalinity is 0.44 mg/l $CaCO_3$. The average pH and alkalinity are values to be expected in a lake in Halifax geology with some Aspotogan soil type (Farmer *et al.*, 1982). The average conductivity value is 111 µsiemens/cm which indicates contamination by road salt. High average sodium (15.3 mg/l) and chloride (26.9 mg/l) values support this conclusion. Average faecal count is 24/100ml sample, (range 0-92) which is high. The low average chlorophyll-*a* value of 0.99 mg/m3 (range 0.71-1.25 mg/m3) in spite of a high total phosphorus concentration of 0.009 mg/l and a low average total nitrogen concentration of 0.17 (range 0.07-.29 mg/l) indicate no input of excess nutrients. The colour is elevated at a value of 26. The average turbidity value of 1.8 JTUs is also high. The assessment of Sandy Lake water quality in terms of indicators of anthropogenic stress would therefore be:

Indicators of Acidification A moderately high average pH of 5.35, combined with an average alkalinity of 0.44 even in the presence of a high average sulphate concentration of 12.36 mg/l, indicate Sandy Lake water quality is not being stressed by acidification.

Indicators of Physical Disturbance An average turbidity of 1.8 JTUs indicates Sandy Lake is being stressed by physical disturbance.

Indicators of Eutrophication A low average chlorophyll-*a* value of 0.99 mg/m3 combined with high average total phosphorus concentration of 0.009 mg/l, and low average nitrogen concentration of 0.17 mg/l, indicate Sandy Lake water quality is not being stressed by eutrophication.

Indicators of Contamination by Sewage Pathogens A high average faecal coliform count of 24/100 ml sample indicates Sandy Lake is being stressed by sewage pathogens.

Indicators of Road Salt Contamination A high conductivity value, coupled with high sodium and chloride values, indicate the water quality of Sandy Lake is being stressed by road salt contamination.

Conclusion Sandy Lake is being stressed by physical disturbance, contamination by sewage pathogens and road salt.

19. Oathill Lake (Reference lake type 2)

Oathill Lake is underlain by the Halifax Formation. The presence of a drumlin on the eastern side suggests upwellings of groundwater (Stea *et al.*, 1992.). The average pH of 7.38

highly eutrophied waterbody, due to inputs of excess nutrients originating from massive amounts of fertiliser used on the trees and plants in the Pond in the Public Gardens. It is also highly contaminated by road salt due to road runoff which is channeled into the pond. It is also highly contaminated by sewage pathogens originating from a large population of resident and seasonal ducks.

Conclusion The pond in the Public Gardens is being stressed by eutrophication, faecal contamination, road salt and physical disturbance, due to excessive amounts of chemical fertilisers entering the pond.

17. SANDY LAKE 1967 GIS evaluation of land use in the Sandy Lake watershed indicates 0% urban and 100% woods. Ogden (1971) does not report a pH for Sandy Lake in his water quality assessment of 30th August, 1971. A federal department of Fisheries and Oceans lake survey in July, 1971 reported a pH value of 6.00. Ogden (1971) reports an alkalinity of 10 mg/l $CaCO_3$. This alkalinity is consistent with DFO's pH of 6.00, and also consistent with Halifax Geology, and Halifax/Aspotogan soil types. The sulphate value is 8.0 mg/l which is low. Both federal department of Fisheries and Oceans (1971) and Ogden (1971) report conductivities of 37 µsiemens/cm. This value is low, indicating no contamination by road salt, Ogden (1971) reports low sodium (2.3 mg/l) and low chloride (7.5 mg/l), confirming the non-contamination conclusion. Although COD at surface is high, soluble phosphate reading is 0.013 which is low, indicating no excess input of nutrients. Sandy Lake water quality was unstressed in 1967.

GIS land use evaluation for 1986 indicates an increase of +21.09% urban use, and concomitant -21.09% decrease in woods. Conductivity has increased from the 1971 value of 37 to an average 1991-92 value of 111µsiemens/cm, indicating contamination by road salt. Sodium values have increased from 2.3-15.9 mg/l and chloride values have increased from 7.5 to 26.9 mg/l, confirming the contamination conclusion. The pH of Sandy Lake has decreased from 1971 value of 6.00 to an average 1991-92 value of 5.35. Sulphate value has increased from a 1971 value of 8 mg/l to an average 1991-92 value of 12.36 mg/l. 1991-92 stress assessment on stressors comparable to Ogden's 1971 data indicates Sandy water quality is being stressed by road salt contamination.

Conclusion Sandy Lake water quality has changed from unstressed in 1971 to being stressed by road salt contamination due to an increase of 21.09% urbanisation of its watershed.

18. OATHILL LAKE1967 GIS land use evaluation of the Oathill Lake watershed indicates 100% urban land use. Ogden (1971) estimated " 33% of the watershed of this small lake is

Indicators of stress Eutrophication and road salt contamination.

land use changes Conversion of woods to intensive floriculture, construction of asphalted paths.

18. SANDY LAKE GIS indicates an increase in urban land use of 21.09% in the Sandy Lake watershed.

Indicators of stress Road salt contamination.

land use changes Highway construction.

19. OATHILL LAKE GIS evaluation indicates 0% change is urban land use from 1967 to 1986. This is because the Oathill Lake watershed was 100% urbanised in 1967. Urbanisation included extensive storm drains to remove excess water created by deforestation of the watershed. When asked if the storm drains were necessary, an engineering technician commented to the author that "80% of the drainage was for aesthetic purposes. People don't like puddles on their streets."

Indicators of stress Eutrophication, contamination by road salt.

land use changes Road and housing construction, input of stormwater drainage system.

20. SULLIVANS POND GIS indicates a decrease of -17.86 urban land use. This is probably incorrect. There are storm drains entering Sullivans Pond.

Indicators of stress Eutrophication and road salt contamination.

land use changes Housing and road construction, culverts draining roads,

21. LOON LAKE GIS indicates a 6.41% increase in urban land use of the Loon Lake watershed. Even though there are a lot of houses on the eastern side of Loon Lake, care was taken to place the septic tanks as far away from the lake as possible, given the lot size. Loon Lake receives inputs from Cranberry Lake, which is eutrophied. However the quantity of water entering does not seem to contribute excess amounts of nutrients.

Indicators of stress Road salt contamination.

land use changes Stormwater drains, minimal housing and road construction.

22. PENHORN LAKE GIS indicates 0% change in urban land use of the Penhorn Lake watershed. Urban land use in 1967 was 100%. Penhorn lake receives stormwater drainage from a major highway and shopping mall.