DATA BOOK OF WORLD LAKE ENVIRONMENTS

—A SURVEY OF THE STATE OF WORLD LAKES—

(1991 Report)

edited by

Lake Biwa Research Institute

and

International Lake Environment Committee

International Lake Environment Committee

United Nations Environment Programme

Otsu 1991

Foreword to the 1991 Report

This is the fourth report from the Joint ILEC/UNEP project "Survey of the State of World Lakes" (FP/5201-87-02 and FP/5201-89-01), compiling geographical, limnological, socio-economic and environmental data on 38 lakes and reservoirs from Mongolia, Russia, eastern and southern Europe, USA, Canada, South America and Africa, which are newly added to 145 natural and man-made lakes of the world dealt with in the preceding three reports (1988-1990). Since the publication of the last report (1990), the Centre for International Projects (CIP) of the former USSR has joined ILEC and UNEP in the project.

The greater part of this report consists of data from Canadian and Russian lakes, supplied by the National Water Research Institute of Canada and the USSR State Committee for Environmental Protection (through CIP), respectively. Representing the Internaitonal Lake Environment Committee Foundation (ILEC) and Lake Biwa Research Institute (LBRI), which have been responsible for the editorial work since the start of the project in 1987, I would like to express the editorial committee's heartfelt thanks for the cooperation of these two organizations as well as by those who kindly contributed relevant information to this report from other parts of the world.

The importance of lakes/reservoirs as sources of freshwater is everincreasing. Rivers and aquifer, which used to be the main source of freshwater for human communities, are now rarely capable of meeting water demands from big cities and industrial centers due to either the unstableness or the shortage of their supplying capacity, and tend to be replaced by natural or man-made lakes. However, lake systems with their stagnant water, limited size and more or less complete isolation from other water bodies are very fragile and liable to environmental degradation. The amount and quality of water resources in lakes are progressively threatened by various kinds of environmental problems all over the world, including accelerated siltation due to the mis-use of lands in their catchments declining water level caused by over-use of water, toxic contamination, acidification and eutrophication. Besides, lake biota, which contains the more diverse endemic species the longer the history of the lakes' isolation, are concurrently being degenerated or exterminated to the irreversible loss of biological diversity from aquatic ecosystems.

We earnestly hope that the data compiled in these reports, including various cases of lake environment deterioration, responsible factors concerned and examples of both success and failure of countermeasures taken, will help decision-makers and technical experts in their unending efforts toward the sustainable management of lake resources and environments.

December 1991, at Otsu

Tatuo Kira
Chief Editor
Chairperson, Scientific Committee of ILEC
and Director, LBRI

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QUESTIONNAIRE SHEETS

FOR THE COMPILATION OF

DATA BOOK OF WORLD LAKE ENVIRONMENT

INSTRUCTIONS

GENERAL

1) Please fill in the following blank tables and answer the questions as far as relevant data and information are available.

2) If you do not have access to necessary data, please suggest the names of appropriate persons or organizations together with their mailing address so that we may be able to establish contact for requesting their assistance.

3) Part of the data or answers may be substituted by attaching publications or their photocopies containing required information.

4) Please supply data as numerical tables as far as possible, unless otherwise stated. To save publishing costs, graphic representation should preferably be limited to a minimum number of cases in which quantitative data are not available.

5) Drawings provided ought to be clear and concise. They need not be camera-ready, however, because they will be redrawn by a specialist in the editorial office.

6) Short supplementary comments may be provided to help explain the numerical data or to compensate the lack of quantitative data.

7) Please mention clearly the sources of data referred to so that editorial committee can obtain the necessary permission for citation.

PHYSIOGRAPHIC AND BIOLOGICAL DATA

8) Average values over the latest 3-5 years are preferable. However, the data for a latest available year may be used if longer term data are not available.

9) As far as physico-chemical properties of lake water are concerned, the data observed at or near the lake center are preferred. If the lake concerned is large and consists of sub-basins or parts having different water qualities, data at more than one station may be given, respectively, in separate tables.

SOCIO-ECONOMIC DATA

10) Data for the latest available year are requested.

11) If the data are based on only parts of the lake's catchment area or on administrative boundaries which do not overlap with the catchment exactly, specify the area to which the data pertains(if necessary, on a map).

EXAMPLES

12) For your reference, two examples of data set are attached; one for a lake with fairly abundant information and the other for a lake with relatively limited data.

PHOTOGRAPH

13) A copy of colored photo, a slide or a print(larger than about 12.5cm x 9cm in size), is requested. An aerial view of the lake is most preferred. If this is not available, please supply one that illustrates a typical landscape, either natural or cultural.

LAKE NAME ____________________

A. LOCATION

*Administrative district(county or state, country)

____

____

*Approximate latitude and longitude(ranges for large lakes)

° '- ° 'N or S ° '- ° 'E or W

*Altitude __________ m above sea-level

B. INTRODUCTORY DESCRIPTION OF THE LAKE

[Note] Please prepare a brief description of the lake (about 500 words), including the lake's geological origin, characteristic features if any(topographical, geographical, biological, etc.), social values as resources, natural landscape, scientific monuments and the likes, history of relations with human activities, recent environmental issues, etc. In case of man-made lakes, add the purpose, the incurred costs of project development and construction, and the responsible body in charge of construction, and the year of completion.

C. PHYSICAL DIMENSIONS

*Surface area ______________________________ km^2

*Volume ______________________________ m^3

*Maximum depth ______________________________ m

*Mean depth ______________________________ m

*Normal range of annual water level fluctuation ______________ m

Is the lake's water level artificially controlled? Yes [ ] No [ ]

*Length of shoreline ______________________ km

*Residence time __________________________ yr

*Catchment area[1] ________________________ km^2

[Note][1]The total sum of the catchment areas of rivers directly flowing into the lake. Not including the lake area.

D. PHYSIOGRAPHIC FEATURES

D_1 GEOGRAPHICAL

*Bathymetric map(attach as a separate sheet, if available. Mark the locations of meteorological station and observation points in the lake for cross referencing with the following tables or figures).

*Names and areas of main islands on the lake___________________

____

*Number and names of outflowing rivers and channels

Number ________ Name(s) ______________________________________

D_2 CLIMATIC[1]

*Climatic data pertaining to a representative spot on or near the lake shore

Place name ______________________________

Period of observation __________________

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean temp.[°C]													
Precipitation [mm]													

*Number of hours of bright sunshine per year ______________ hr yr^{-1}

*Average solar radiation ______________ MJ $m^{-2}day^{-1}$

*Water temperature [°C]
Station name(if necessary) ______________

Period of observation ______________

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Surface (m)												

*Freezing period(lake) From ______________ to ______________

*Mixing type(please mark appropriate word)

Meromictic Dimictic Monomictic Polymictic Others( )

*Notes on water mixing and thermocline formation(if necessary)

____

____

[Note][1]In the case of large lakes which extend over different climatic regions, please give data at more than one spots.

E. LAKE WATER QUALITY

E_1 TRANSPARENCY[m]

Station name ______________ Period of observation ______________

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec

E_2 pH

Station name ______________ Period of observation ______________

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec

E_3 SS[mg l^{-1}]

Station name ______________ Period of observation ______________

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec

E_4 DO[mg l^{-1}]

Station name ______________ Period of observation ______________

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec

E_5 COD[mg l^{-1}]

Station name ______________ Period of observation ______________

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec

*Please mark the method used.

$KMnO_4$-method $K_2Cr_2O_7$-method

E_6 CHLOROPHYLL CONCENTRATION [$\mu g\ l^{-1}$]

Station name ______________ Period of observation ______________

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec

E_7 TOTAL-N CONCENTRATION[1] [$mg\ l^{-1}$]

Station name ______________ Period of observation ______________

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec

[Note] [1] If not available, substitute NO_3-N and/or NH_4-N data.

E_8 Total-P CONCENTRATION[2] [mg l^{1}]

Station name ______________ Period of observation ____________

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec

[Note] [2]If not available, substitute PO_4-P data.

E_9 CHLORINE ION CONCENTRATION [mg l^{-1} or ‰](saline and brackish lakes only)

Station name ______________ Period of observation ____________

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec

E_{10} PAST TRENDS OF THE ABOVE-MENTIONED WATER QUALITY VARIABLES (tabular or graphical data), IF AVAILABLE

F. BIOLOGICAL FEATURES

Station name and the year of observation
(if necessary, especially in large lakes)______________________

F_1 FLORA(mention the names of dominant or remarkable species)

*Emerged macrophytes ____

____

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*Floating macrophytes ____

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*Submerged macrophytes ____

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*Phytoplankton(for different seasons, if necessary) _____________

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F_2 FAUNA

*Zooplankton(for different seasons, if necessary) _______________

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*Benthos(for different depths, if necessary) ____________________

____

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*Fish(mark economically important species with asterisks) ______

*Supplementary notes on the biota(endeminsm, distribution in the lake, etc., if necessary) ______

F_3 PRIMARY PRODUCTION RATE[1]

Station name ______ Period of observation ______

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual total
Net production													
Dark respiration													
Gross production													

[Note] [1]Use units of the amount of carbon or dry matter produced, or oxygen released, per unit water surface area and time.

F_4 BIOMASS

Biomass data for the above taxa in units of dry matter per unit water or bottom area or plankton dry matter per unit volume of water; monthly and/or annual mean values.

F_5 FISHERY PRODUCTS

*Annual fish catch[metric tons]________________________ (in 19   )

*Fishery products other than fish(shrimp, shellfish,etc., if any)

____

F_6 PAST TRENDS OF PRIMARY PRODUCTIVITY, BIOMASS AND FISHERY PRODUCTION(tabular or graphical data, if available)

F_7 NOTES ON THE REMARKABLE CHANGES OF BIOTA IN THE LAKE(if any, in recent years)

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G. SOCIO-ECONOMIC CONDITIONS

G_1 LAND USE IN THE CATCHMENT AREA(in 19)[1]

	Area(km^2 or ha) [%]
Natural landscape	
Woody vegetation	
Herbaceous vegetation	
Swamp	
Others	
Agricultural land	
Crop field	
Pasture land	
Settlement area	
Others	
Total	

[Note] [1]If the data are based on an area not exactly the same with the catchment area, please describe the area concerned.

____

*Types of important forest or scrub vegetation(please mention only those which occupy large land areas)______________________

____

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*Types of important herbaceous vegetation(do.)______________________

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*Types of the other important vegetation(do.)______________________

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*Main kinds of crops and/or cropping systems ______________________

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*Levels of fertilizer application on crop fields(please mark appropriate word)

Heavy   Moderate   Light   None

*Trends of change in land use in recent years, if any ________

____

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G_2 INDUSTRIES IN THE CATCHEMENT AREA AND THE LAKE(in 19)

	Gross product Per year[2] (=US$1.00)	No. of persons engaged	No. of establishments	Main products or major industries
Primary industry				
Crop production				
Animal husbandry				
Fisheries[3]				
Others				
Secondary industry				
Tertiary industry				

[Note] [2]On monetary basis(provide the current conversation rate to US dollars)
[3]Fisheries on the lake concerned.

*Numbers of domestic animals in the catchment area

Cattle________ Sheep________ Swine________

Poultry________ Others________, ________, ________

G_3 POPULATION IN THE CATCHMENT AREA(in 19)

	Population	Mean population density [no km^{-2}]	Names of major cities
Urban[4]			
Rural			
Total			

[Note] [4]Urban area defined here includes all the cities of which the population is greater than 30,000.

H. LAKE UTILIZATION

H_1 LAKE UTILIZATION(mark the appropriate boxes)

- [ ] Source of water(see below)
- [ ] Navigation and transportation
  *Tonnage(metric)of cargo per year(in 19   ) ____________
- [ ] Sightseeing and tourism
  *Number of visitors per year(in 19   ) ________________
- [ ] Recreation
  - [ ] Swimming   [ ] Sport-fishing   [ ] Yachting
- [ ] Fisheries
- [ ] Others(please specify) ______________________________

H_2 THE LAKE AS WATER RESOURCE(in 19   )

	Use rate[1]
Domestic water	
Irrigation	
Industrial water	
Power plant	
Others(please specify)	
____________	
____________	

[Note] [1]In units of m^3sec^{-1}, m^3day^{-1}, kw hr^{-1}, etc.

I. DETERIORATION OF LAKE ENVIRONMENTS AND HAZARDS

I_1 ENHANCED SILTATION

*Extent of damage(mark the appropriate box)

[ ] Serious   [ ] Not serious   [ ] None

*Supplementary notes,(rates of sedimentation and/or washout inflow, kinds of damage, recent history, local differences, etc. if necessary)

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I_2 TOXIC CONTAMINATION

*Present status of toxic contamination(mark the appropriate box)

☐ Serious ☐ Detected but not serious

☐ None ☐ No information

*Main contaminants, their concentrations(year of determination) and sources

Station name(s) ______________________________

Name of contaminants	Range of concentrations[ppm] in [1]						Main Sources[2]
	Water	Bottom mud	Fish [3]	Other organisms [4]			
	(19)	(19)	(19)	(19)	(19)	(19)	
	( )	( )	( )	( )	( )	( )	
	( )	( )	( )	( )	( )	( )	
	( )	( )	( )	( )	( )	( )	
	( )	( )	( )	( )	( )	( )	
	( )	( )	( )	( )	( )	( )	
	( )	( )	( )	( )	( )	( )	

[Note] [1] Please specify the basis of representation; volume basis, dry weight basis, wet weight basis, etc.

[2] Industrial, pesticide, airborne, waste dumps, etc.

[3] Species names and kinds of tissue ______________________________

[4]Species names and kinds of tissue ____________________

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*Environmental quality standards for contaminants in the lake, if any ____________________

____

*Food safety standards or tolerance limits for toxic contaminant residue (national or local), if any

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*Past trends of the above concentrations(tabular or graphical data, if available)

*Supplementary notes(recent history and spacial distribution of contamination, countermeasures, etc., if necessary)

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I_3 EUTROPHICATION

*Nuisance caused by eutrophication(mark the appropriate boxes)

- [ ] Unusual algal bloom
  Dominant species of algae ______________________
  ____
- [ ] Disturbed filtration in cleaning beds
- [ ] Foul odour of tap water
- [ ] Harms to fishery products
  Kinds of products damaged ______________________
- [ ] Others(Please describe) ______________________

*Nitrogen and phosphorus loadings to the lake(in 19)[5]

Sources	Industrial	Domestic	Agricultural	Natural	Total
T-N					
T-P					

[Note] [5] Rates of loading on a whole lake basis or per unit lake surface area; e.g. kg day^{-1} , t yr^{-1}, kg m^{-2} day^{-1}, etc

*Supplementary notes on the recent history of eutrophication and countermeasures implemented

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I_4 ACIDIFICATION

*Extent of damage(mark the appropriate box)

- [ ] Serious
- [ ] Detected but not serious
- [ ] None
- [ ] No information

*Kinds of damage(please describe) ______________________
____

*Past trends in hydrogen ion concentration in lake water, and, if available, rain/stream water(tabular or graphical data)

*Supplementary notes on the recent history of acidification and countermeasures implemented

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I_5 OTHER HAZARDS(Please describe shortly, if any)

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J. WASTEWATER TREATMENTS

J_1 GENERATION OF POLLUTANTS IN THE CATCHMENT AREA

Please mark the appropriate boxes.

*a. No major human settlements or activities producing significant pollution(pristine lake environments) ☐

*b. Location of pollution-generating human settlements or activities being restricted along the inflowing river basins or the coastal region of the lake, resulting in no major pollution of the lake(e.g. lake reserves) ☐

*c. Sporadic development of the catchment area with some provision for on-site wastewater treatment, municipal and/or industrial wastewater treatment, or agricultural runoff control, resulting in some discharge of pollution load into the lake ☐

*d. Significant development of the catchment area with some provision for municipal and/or industrial wastewater treatment or agricultural runoff control, resulting in measurable discharge of pollution load into the lake ☐

*e. Extensive development or exploitation of the catchment area with little or no provision for municipal and/or industrial wastewater treatment or agricultural runoff control, resulting in severe pollution of the lake ☐

*f. Other cases(please describe) ☐

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____

____

J_2 APPROXIMATE PERCENTAGE DISTRIBUTION OF POLLUTANT LOADS

	Percentage
Non-point sources (agricultural, natural and dispersed settlements)	
Point sources	
Municipal	
Industrial	
Others(please specify)	
__________	
__________	
__________	
Total	100%

J_3 SANITARY FACILITIES AND SEWERAGE

*Percentage of municipal population in the catchment area provided with adequate sanitary facilities(on-site treatment systems) or public sewerage ☐

*Percentage of rural(sparsely settled community) population with adequate sanitary facilities(on-site treatment systems) ☐

*Municipal wastewater treatment systems

No. of tertiary treatment systems(specify typical systems adopted) ☐

____

No. of secondary treatment systems(do.) ☐

____

No. of primary treatment systems(do.) ☐

____

No. of other types(specify, e. g., nightsoil treatment, etc.) ☐

____

*Industrial wastewater treatment systems
How many? (specify typical system(s) adopted) ☐

____

K. IMPROVEMENT WORKS IN THE LAKE(please mark the appropriate box and provide supplementary notes, if possible)

K_1 RESTORATION

☐ Notes ______________________

____

____

K_2 AERATION

☐ Notes ______________________

____

____

K_3 OTHERS

☐ Notes ______________________

____

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____

L. DEVELOPMENT PLANS

Please describe the development plans in the lake and catchment area which have already been completed in recent years, or are now going on, or are being drawn up(period of operation, responsible body, purpose, cost, etc.)

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M. LEGISLATIVE AND INSTITUTIONAL MEASURES FOR UPGRADING LAKE ENVIRONMENTS

M_1 NATIONAL AND LOCAL LAWS CONCERNED

Please specify the names of laws dealing directly with control and restoration of lake environments and provide, in respective order, the information requested regarding each law.

*Names of the laws(the year of legislation)

(1) ______

(2) ______

(3) ______

(4) ______

(5) ______

*Responsible authorities

(1) ______

(2) ______

(3) ______

(4) ______

(5) ______

*Main items of control

(1) ______

(2) ______

(3) ______

(4) ______

(5) ______

*Supplementary notes, if necessary ______

M_2 INSTITUTIONAL MEASURES

Please mention the names, locations and year of establishment of public organizations responsible for monitoring, control and restoration of lake environments, with supplementary notes, if necessary.

(1) ______________________________

____

____

(2) ______________________________

____

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(3) ______________________________

____

____

M_3 RESEARCH INSTITUTE ENGAGED IN THE LAKE ENVIRONMENT STUDIES

The same as above.

(1) ______________________________

____

(2) ______________________________

____

(3) ______________________________

____

(4) ______________________________

____

Supplementary notes, if necessary ______________________________

____

____

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____

N. SOURCES OF DATA

Please give the reference numbers in square brackets [ ] to tables, figures, etc. in the order of pages, and list the references below under corresponding nunmbers.

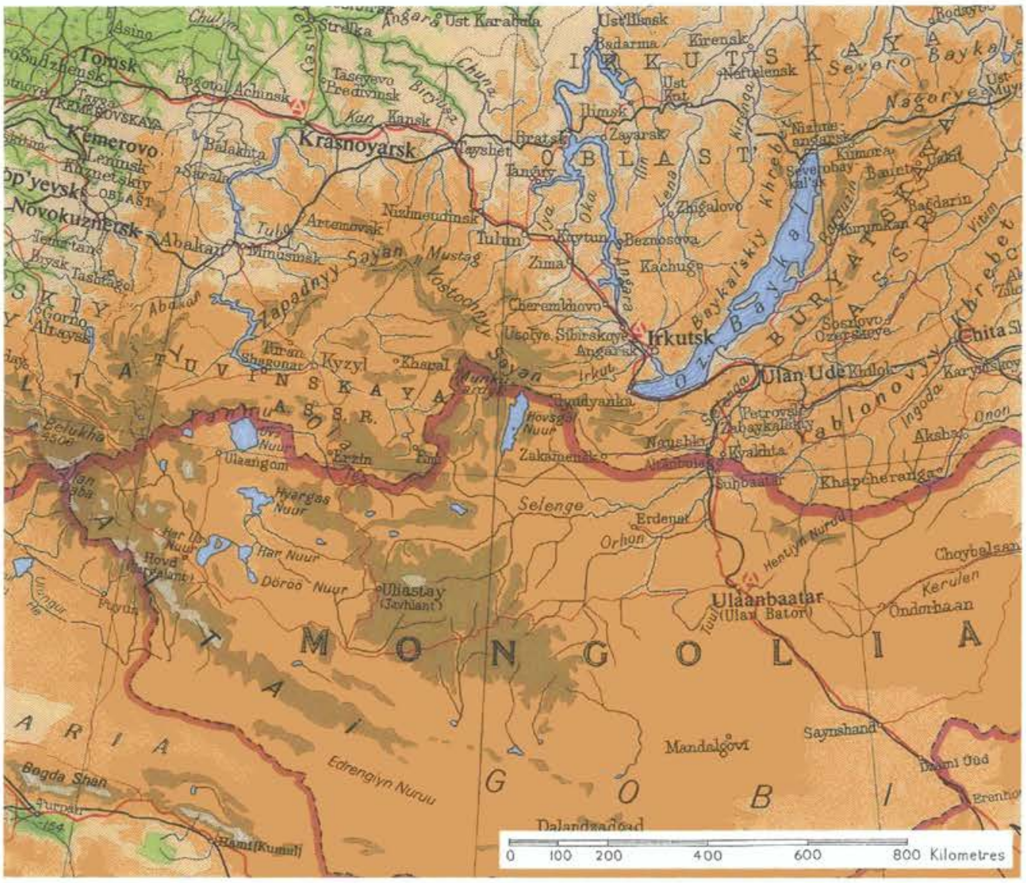
N. SOURCES OF INFORMATION

*Please identify the sources of data and information(reference documents, literature, etc.) in sequential numerical order in brackets, [ ], immediately following subject headings or subheadings for tables and figures, and list the details of these reference materials in corresponding order in the following space.

LAKE HUBSUGUL

A view on the lakeshore

Photo: P. Nyamjav



A. LOCATION

§ Hubsugul Aimag, Mongolia.
§ 50°27′-51°37′N, 100°51′-101°47′E ; 1,645 m above sea level.

B. DESCRIPTION

Lake Hubsugul is the largest freshwater lake in Central Asia. The landscape complex around the lake is unique and inimitable in its beauty. The lake basin consists largely of highlands, where underground permafrost layers, sometimes as deep as 100-200 m, are widespread.

The climate is severely continental with 300-430 mm of mean annual precipitation. Between the lake shore and the top of high mountains reaching 3,491 m in altitude, there is a series of alternating vegetation zones from steppe, through forest-steppe, forest and forest-tundra, to alpine tundra zone. Forests of larch, cedar, pine and birch predominate on permafrost, together with tundra. The lake basin supports 60 species of mammals including 32 game animals and 800 species of plants of which more than 50 % are grasses and herbs.

The lake has three tributaries, while a single river, the Egyn-gol flows out toward Lake Baikal. There are petroleum fields in Hatafal and Hanh on the north and the south side of the lake. More than 30 phosphorite beds have also been exploited.

It is of prime importance for this lake as a natural treasure how to maintain its crystal-clean water against the impact from industrial developments. The exploitation of phosphorite beds may disrupt surrounding environments, Lake Hubsugul, and eventually Lake Baikal via the Egyn. Local authorities are making efforts to cope with the problem, but the processes and extent of industrial influence on the environment still remain unknown because of the lack of comprehensive ecological research on the complex system of the lake, its surroundings, rivers and springs (Q1).

C. PHYSICAL DIMENSIONS (Q1, 2)

Surface area [km^2]	2,770
Volume [10^{6}m^3]	381
Maximum depth [m]	267
Mean depth [m]	138
Normal range of annual water level fluctuation (unregulated) [m]	0.5-2.0
Length of shoreline [km]	414
Catchment area [km^2]	4,940

D. PHYSIOGRAPHIC FEATURES (Q1)

D1 GEOGRAPHICAL

§ Bathymetric map (Fig. ASI-51-1).
§ Main islands (number and names) : 2 (Modon Khui, Khadan Khui).
§ The outflowing and rivers and channels (number and names) : 1 (Egyn-gol).

D2 CLIMATIC

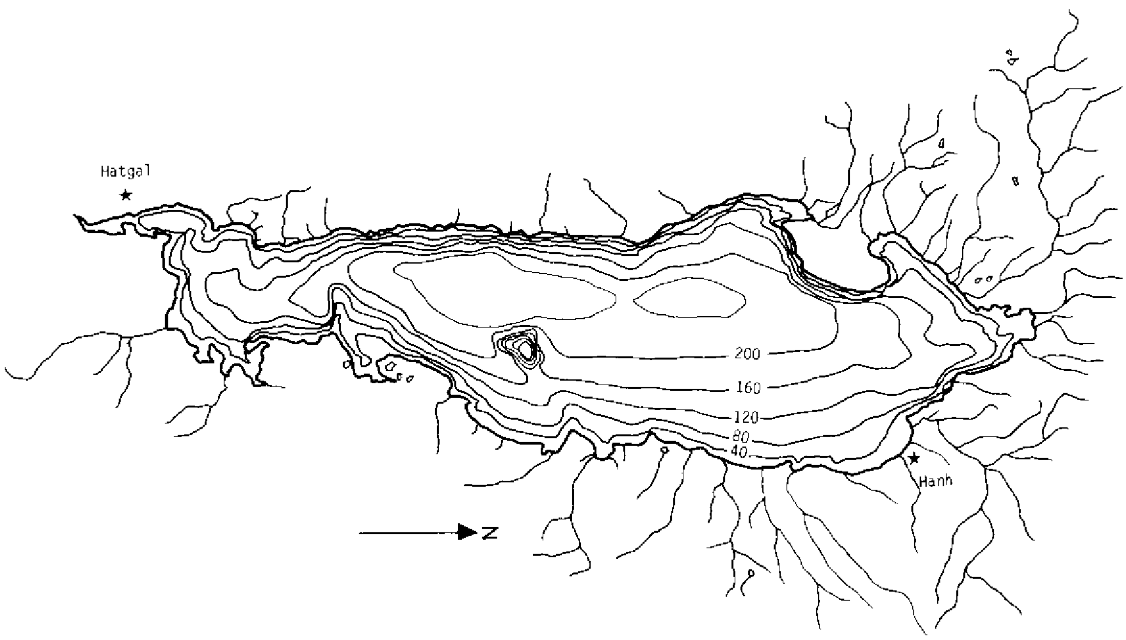
§ Climatic data at Hatgal, 1980-1989

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean temp. [°C]*	-22.7	-21.2	-13.1	-2.5	5.5	9.2	11.4	10.4	4.6	-3.8	-14.2	-20.4	-4.8
Precipitation [mm]**	0.8	0.3	2	8	17	77	90	71	31	11	10	0.4	319

* 1980-1989.
** 1980-1986.

§ Number of hours of bright sunshine : 2,773 hr yr l^{-1}.

Fig. ASI-51-1 Bathymetric map [m] (Q1).



§ Water teprature [°C]

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.5	–	–	–	–	5.1	9.9	13.4	13.6	9.5	3.8	–	–

§ Freezing period : From Jun. 15 to Oct. 25, approximately.

E. LAKE WATER QUALITY (Q1)

E1 TRANSPARENCY [m]

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
30	30	–	–	–	–	19	13	24	–	30	30

E2 pH

Station 1, Hatgal and Station 2, Hanh, 1986-1990

Depth [m]		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
St. 1	0.5	7.9	7.6	7.8	7.4	6.9	7.9	7.9	7.9	8.0	7.8	8.0	7.6
St. 2	0.5	7.9	7.9	8.0	7.5	7.6	8.2	7.4	7.9	7.7	7.5	8.1	7.8

E4 DO [mg l^{-1}]

Hanh, 1986

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.5	7.7	7.7	10.3	10.9	8.4	7.0	9.0	8.3	9.4	–	–	–

E5 COD [mg l^{-1}]

K_2MnO_4 method.
Station 1 and 2, 1986-1990

Depth [m]		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
St. 1	0.5	1.1	2.7	2.3	2.1	0.9	2.1	1.8	3.1	1.9	2.7	2.4	1.5
St. 2	0.5	1.4	2.0	3.2	1.8	1.5	3.7	2.2	1.5	3.3	1.4	2.2	2.6

E6 CHLOROPHYLL CONCENTRATION

The content of chlorophyll *a* of the lake water is very low, being 0.35 mg m^{-3} in average for the layer of 0-100 m.

E7 NITROGEN CONCENTRATION

§ NO_3-N [mg l^{-1}]

Station 1 and 2, 1986-1990

Depth [m]		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
St. 1	0.5	0.05	0.19	0.17	0.32	0.12	0.19	0.20	0.22	0.08	0.11	0.06	0.02
St. 2	0.5	0.18	0.20	0.27	0.10	0.11	0.19	0.67	0.10	0.10	0.21	0.05	0.02

§ NH_4-N

Station 1 and 2, 1986-1990

Depth [m]		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
St. 1	0.5	0.14	0.16	0.14	0.21	0.16	0.05	0.18	0.30	0.15	0.04	0.10	0.11
St. 2	0.5	0.11	0.14	0.18	0.13	0.28	0.19	0.24	0.14	0.14	0.04	0.08	0.08

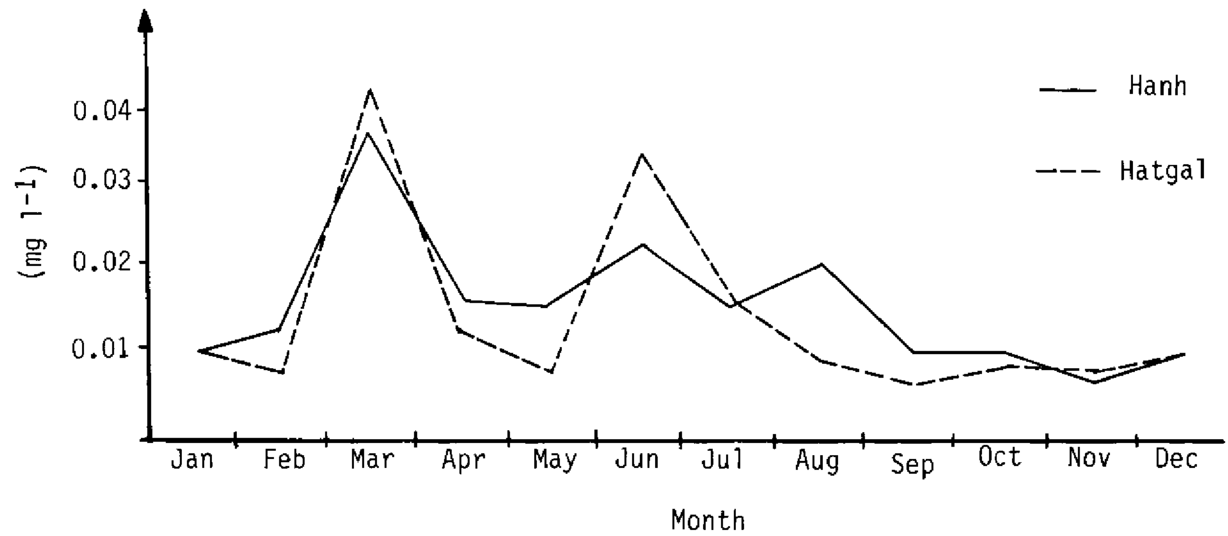
E8 PHOSPHORUS CONCENTRATION

§ Total-P [μg l^{-1}]

Station 1 and 2, 1986-1990

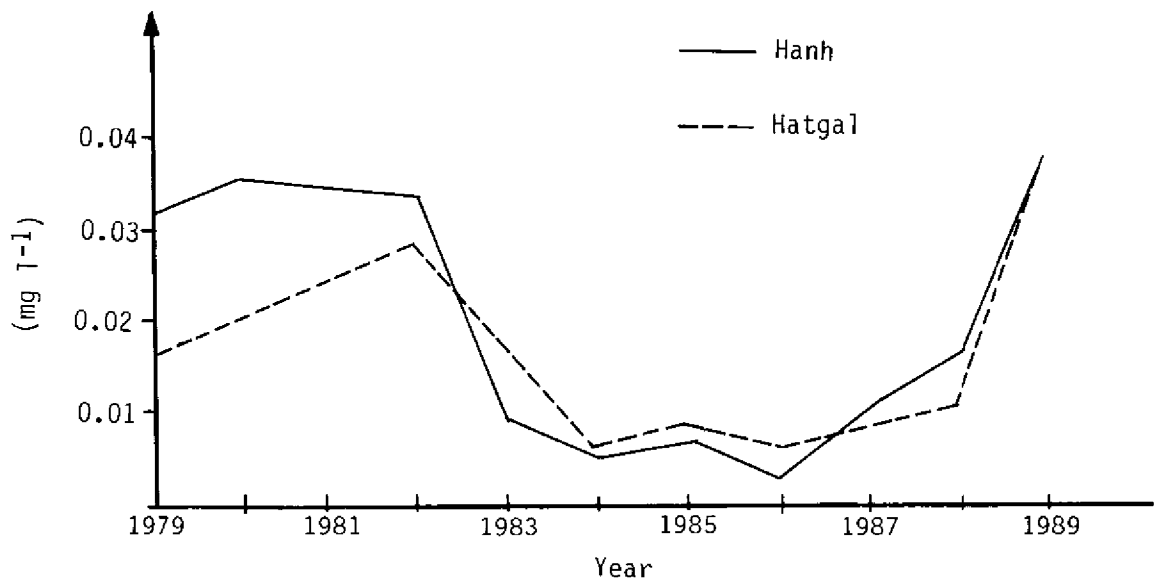
Depth [m]		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
St. 1	0.5	46	12	14	4	8	5	7	13	20	15	8	7
St. 2	0.5	14	2	9	9	6	18	18	4	16	11	23	9

Fig. ASI-51-2 Seasonal change of PO_4-P concentration [mg l^{-1}] of surface water (Q1).



E.10 PAST TRENDS

Fig. ASI-51-3 Long time fluctuation of PO_4-P concentration [mg l^{-1}] of surface water (Q1).



F. BIOLOGICAL FEATURES

F1 FLORA

There are 55 species of floating aquatic plant, 33 species of submerged macrophyte, 2 species of moss and about 10 species of phytoplankton in the lake (6).

§ Emerged macrophytes : Poaceae, Asteraceae, Cyperaceae (Q2).

§ Phytoplankton

Cyclotella ocellata, Gymnodinium fuscum, Oocystis sobitaria, O. mongolica, Dictyosphaerium pulchellum, Chroomonas sp., *Crucigenia quadrata, Glenodinium* sp. (Q2).

F2 FAUNA

§ Zooplankton

Mixodiaptomus incrassatus, Cyclops abyssorum, Daphnia longispina hyalina, Kellicottia longispina, Filinia longiseta, Conochilus unicornis (total 69 species) (Q2, 6).

§ Benthos

Hydra, Phabdococcida, Planaridae, Nematoda, Oligochaeta, Ostracoda, Gammaridae (total 170 species) (Q2, 6).

§ Fish

Brachymystax lenok, *Coregonus autumnalis migratorius*, *Thymallus arcticus*, *T. nigrescens*, *Rutilus lacustris*, *Lota vulgaris*, *Lota lota*, *Perca fluviatilis* (total 9 species) (Q2, 6).

F4 BIOMASS

§ Phytoplankton

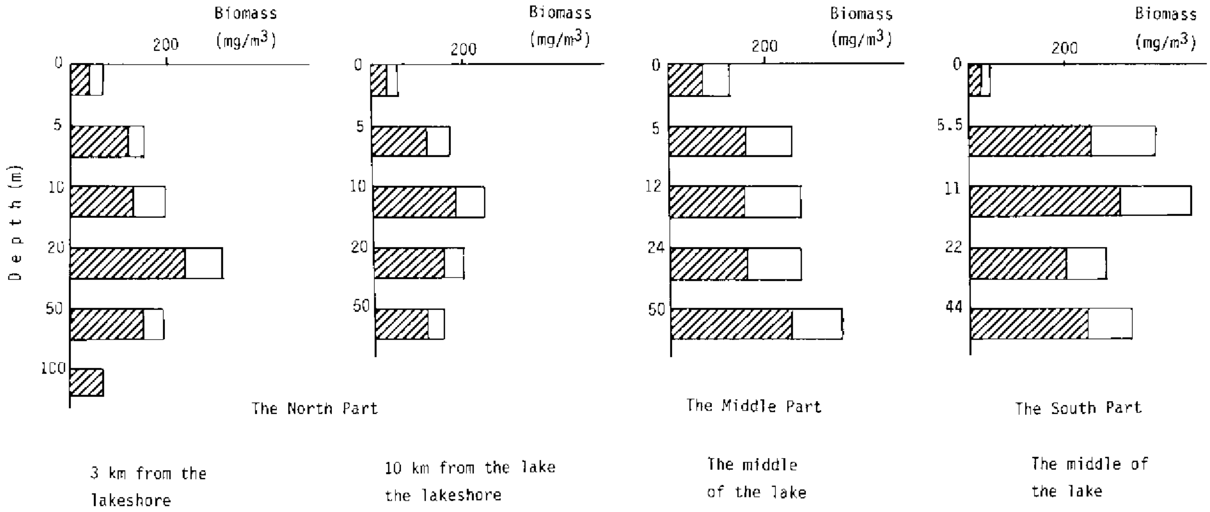
Whole lake survey (8)

	No. of samples	Number [10^3 l^{-1}] Mean (range)	Biomass [mg m^{-3}] Mean (range)
Jun. -Aug., 1972	50	812(355-1,650)	166(64-301)
Mar., 1973	21	1,399(99-2,806)	212(22-453)

Pelagic water, Hanh region (Q1)

Date		Biomass [mg m^{-3}]		
		Cyclotella ocellata	*Dictyosphaerium pulchellum*	Total
1976	Jun. 16	17	61	113
	Jul. 8	30	58	135
	Jul. 20	46	31	179
	Jul. 29	57	28	140
	Aug. 9	92	33	172
	Aug. 20	96	34	204
	Sep. 18	67	2	95
	Sep. 25	104	2	140
	Oct. 21	37	7	81
	Dec. 22	160	25	226
1977	Feb. 28	36	25	85
	Mar. 21	36	57	137
	Mar. 27	50	73	173
	May. 13	22	78	144
Average		61	37	145

Fig. ASI-51-4 Vertical and horizontal distribution of phytoplankton biomass in pelagic water, March 1973 (Q1).



§ Zooplankton (9)
Whole lake survey

Date	No. of samples	Mean number (range) [10^3 l^{-1}]			
		Copepoda	Cladocera	Rotatoria	Total
Jun. -Aug., 1978	18	9.2 (1.7-21.6)	0.66 (0.1-2.4)	0.32 (0.1-0.9)	10.1 (1.9-22.4)
Jul., 1979	9	8.3 (5.1-10.1)	0.44 (0.1-0.7)	0.54 (0.1-1.1)	9.3 (5.8-11.4)
Date	**No. of samples**	**Mean biomass (range) [mg m^{-3}]**			
		Copepoda	Cladocera	Rotatoria	Total
Jun. -Aug., 1978	18	158.2 (11.4-362.0)	11.0 (0.3-34.6)	0.31 (0.1-1.0)	168.4 (11.8-373.4)
Jul., 1979	9	183.6 (78.0-283.0)	8.0 (3.0-16.0)	0.69 (0.1-1.0)	192.2 (82.0-299.2)

§ Zoobenthos (8)
Whole lake survey

Zone (depth)	Mean number [m^{-2}]	Mean biomass [g m^{-2}]
Open water		
Littoral (0–20 m)	4,304	4.8
Sublittoral (20-50 m)	4,267	5.4
Upper abyssal (50-90 m)	1,322	0.8
Lower abyssal (>90 m)	303	0.2
Bays		
Alagasair	7,190	4.5
Turugsky	5,350	6.5
Khankhinsky	10,862	3.8
Mongorinsky	5,903	10.3

Hanh region

Date	No. of samples	Number [m^{-2}]	Biomass [g m^{-2}]
Aug. 1971	6	2,399	1.8
Jun. 1972	15	7,570	3.8
Jul. 1976	2	9,570	5.7
Aug. 1976	8	8,053	2.7
Sep. 1976	4	5,252	1.8

§ Total biomass of the whole lake system (8)

Zone		[g m^{-3}]	[g m^{-2}]	[10^3 t/zone]
Littoral & sublittoral	Phytobenthos	—	0.6-3.5	
(15 % of total lake area)	Zoobenthos	—	5.0	2,070
Abyssal (85 %)	Zoobenthos	—	0.5	1,173
Whole water column	Bacterio-plankton	0.03	3.48	9,605
Photic zone	Phytoplankton	0.17	19.72	54,427
(mean depth 16 m)	Zooplankton	0.10	11.60	32,016

F5 FISHERY PRODUCTS

§ Annual fish catch in 1990 : 300 [metric tons] (6).

G. SOCIO-ECONOMIC CONDITIONS

G1 LAND USE IN THE CATCHMENT AREA (Q1, Q2)

	Area [km^2]*	[%]**
Natural landscape		
Woody vegetation	—	30-60
Herbaceous vegetation	—	20-30
Swamp	—	5-10
Others	—	5-10
Agricutural land		
Crop field	(9.2)*	
Pasture land	2.7	25 30
Settlement area	6.5	
Total	4,920	100

* Q1, ** Q2.

§ Types of important forest vegetation : *Larix sibirica* and *Betula platyphylla*, with *Lonicera altaica*, *Ledum palustre*, *Vaccinium vitis-idaea*, *Calamagrostis obtusata*, *Aconitum septentrionale*, *Hylocomium proliferum*, etc. (Q1, Q2).

§ Types of other important vegetation : High mountain lichen-moss tundra (*Cladonia alpestris*, *Cetraria cuculata*) (Q1, Q2).

§ Main kinds of crops : No crop field.

G2 INDUSTRIES IN THE CATCHMENT AREA AND THE LAKE

§ Numbers of domestic animals in the catchment area : Cattle, 8,466, sheep 6,650, others 1,434 (Q2).

G3 POPULATION IN THE CATCHMENT AREA (1990) (Q1)

	Population	Population density [km^{-2}]	Main cities
Urban	5,473		
Rural	1,163		Hatgal
Total	6,636	1.3	

H. LAKE UTILIZATION

H1 LAKE UTILIZATION (Q1)

Source of water, navigation and transportation (20,000-30,000 tons of cargo per year during 1953-1990 ; it will be stopped in the second half of 1991), sightseeing and recreation.

H2 THE LAKE AS WATER RESOURCE (Q1)

Use rate of domestic water : 45.0 m^3 yr^{-1}.

I. DETERIORATION OF LAKE ENVIRONMENTS AND HAZARDS (Q2)

I1 ENHANCED SILTATION : None.

I2 TOXIC CONTAMINATION

§ Present status : None.

I4 ACIDIFICATION

§ Extent of damage : None.

J. WASTEWATER TREATMENT (Q2)

J1 GENERATION OF POLLUTANTS IN THE CATCHMENT AREA : (b) No sources of significant pollution.

M. LEGISLATIVE AND INSTITUTIONAL MEASURES FOR UPGRADING LAKE ENVIRONMENTS (Q1)

M1 NATIONAL AND LOCAL LAWS CONCERNED

The Government had closed the wool-washing factory from July 1988, and also has decided to remove the petroleum reserve to Muren town within 1991.

M2 INSTITUTIONAL MEASURES

(1) Hubsugul Lake Protection Foundation

M3 RESEARCH INSTITUTES ENGAGED IN THE LAKE ENVIRONMENT STUDIES

(1) The administration for the Hubsugul Lake protection
(2) Soviet Union and Mongol joint expeditions for the Hubsugul Lake study.

N. SOURCES OF DATA

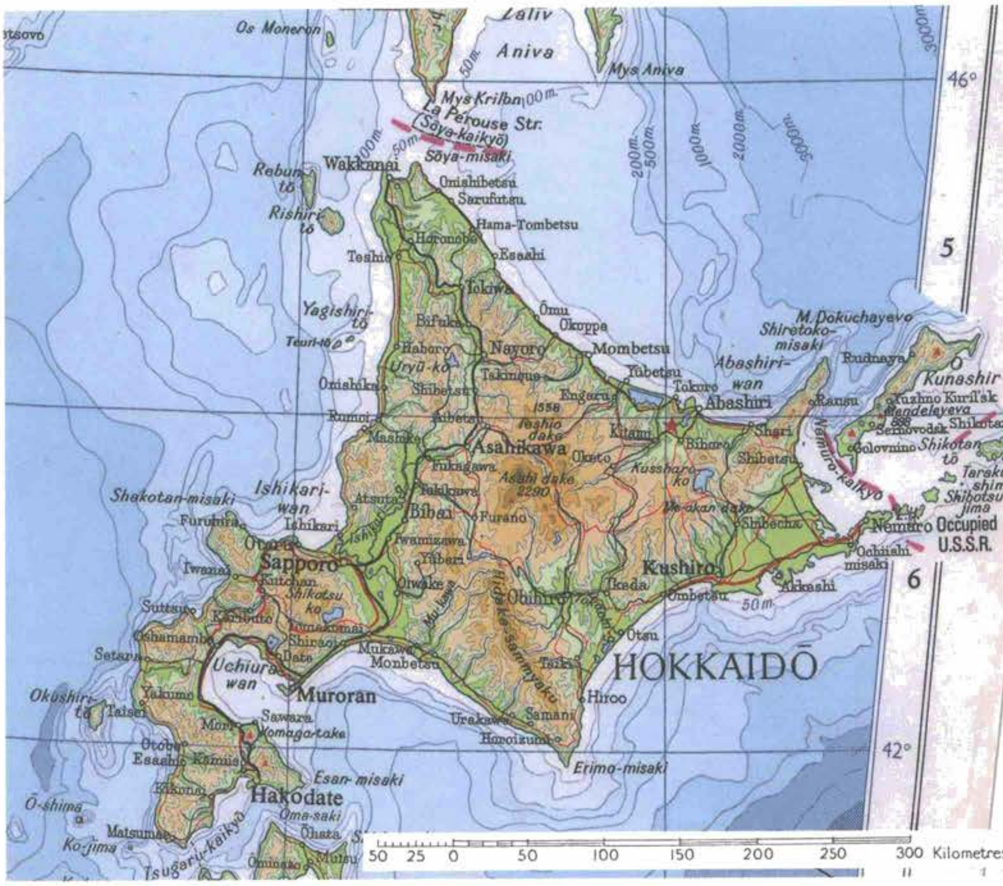
(Q1) Questionnaire filled by Dr. P. Nyamjav, Head, Surface Water Resource Sector, State Committee for Environmental Control Institute of Water Problems, Ulaanbaatar, Mongolia.
(Q2) Questionnaire filled by Mr. Ts. Baldorj, Newspaper of the MPR Government (UNEN), Ulaanbaatar, Mongolia.
(1) Tserensodnom, J. (1970) Lakes of Mongolia. Ulaanbaatar.
(2) Dulmaa, A. (1985) Life in the Lake. Ulaanbaatar.
(3) Gira, E. (1985) Climatic Reference Book of the MPR. Vol. 1, Solar Energy Cadastre. Ulaanbaatar.

(4) Erbaev, E. A. & Kojova, O. M. (1990) The problems of zoobenthos study of the Hubsugul Lake. Natural condition and resources of some regions of the MPR. Theses of the talks and conferences, XVII International Scientific Conference on the Results of the Mongolian and the Soviet Union Complex Expedition Work of the Hubsugul Lake.
(5) Dulmaa, A. & Tserensambuu, S. (1990) General Estimation of Primary Productivity of the MPR's Lakes. Ulaanbaartar.
(6) —— & —— (1990) The Hubsugul Lake monitoring. "Problems of Nature and Environmental Protection of the Hubsugul Lake and the Selenge River Basins." Ulaanbaatar.
(7) Kojova, O. M. & Zagorencko, G. F. (1976) Winter phytoplankton of the Hubsugul Lake. "Natural Condition and Resources of Prikhubsugul, Proceedings of the USSR and MPR Complex Expedition of the Hubsugul", Issue 3-4. Irkutsk-Ulaanbaatar.
(8) Kojova, O. M., Zagorencko, G. E., Pomazkova, G. I., Putyatina, T. N., Erbaev, E. A. & Izmesteva, L. R. (1978) Hydrological regime of the Hubsugul Lake. "Hydrobiological and Ichtiological Studies in the East Siberia." Irkutsk.
(9) Pomazkova, G. I. & Shyagina, E. V. (1982) Distribution of zooplankton in the Hubsugul Lake in summer, 1978-1979. "Natural Condition and Resources of Prikhubsugul, The Proceedings of the Research Talks, ISU, MSU."
(10) Tsengel, T. (1990) The principal characteristics of the Hubsugul Lake. "Problems of Nature and Environment Protection of the Hubsugul Lake and the Selenge River Basins, The Proceedings of the Research Conference." Ulaanbaatar.

ABASHIRI-KO (LAKE ABASHIRI)

An aerial view of the whole lake

Photo: A. Kurata



A. LOCATION

§ Hokkaidô, Japan.
§ 43°58′-44°00′N, 144°08′-144°14′E ; 0.4 m above sea level.

B. DESCRIPTION

Lake Abashiri is situated in the northeast part of coastal area of Hokkaidô along the Sea of Okhotsk, with 32.5 km^2 of surface area, 42 km of shoreline, 16.1 m of maximum depth, 7.2 m of mean depth and 0.4 m of altitude. The lake is covered completely with approximately 1 m thick of ice from the midst of December to the midst of April of the next year.

Abashiri River which flow down from the most southern part of catchment area flows into the lake and flows out again from the northeast end of the lake. The river flows into finally the Sea of Okhotsk with 7 km long of flowing down course from the lake. During winter dry season, very high salinity concentration of saline flows backward from the sea very often to Abashiri River and a part of it flows into the lake. Owing to this phenomenon, a very stable hypolimnion is formed in deeper than 10 m layer with approximately 10,000 ppm chlorine concentration of saline.

Judging from the bottom core samples obtained by boring work at the deepest point of the lake, it is considered that a prototype of lake basin was formed at the last Glacial epoch, approximately 20,000 years ago and then present feature of lake was appeared by long corrosion force of Abashiri River at the Holocene epoch, approximately 6,000 years ago. Many remains of Jômon period (an archaeological term designating the Japanese neolithic cultural period extending from about 8,000 B.C. or earlier to about 200 B.C.) are found in the shallow region of estuary of Memanbetsu River.

Recently, replanning of agricultural land has been practiced in the upstream region of Abashiri River and most of rivers and streams were straighten consequently in the catchment area for the development of paddy fields and the repair work of rivers. Since then, however, siltation becomes serious in the estuary. Lowland crop fields along lakeshore were suffered heavy damage from flood in May, 1975. Hereafter, such damage to the wetland of Abashiri Quasi-national Park and camping site of lakeshore is anxious seriously.

Smelt and trout are most important fish in the lake for sport-fishing throughout the season. Eutrophication, however, has progressed recently by the nutrient loading from mainly agricultural land and forest (1, 3, 8).

C. PHYSICAL DIMENSIONS

Surface area [km^2]	32.5
Volume [10^6m^3]	232.7
Maximum depth [m]	16.1
Mean depth [m]	7.2
Normal range of annual mater level fluctuation [m]	Unregulated
Length of shoreline [km]	44
Residence time [yr]	0.43
Catchment area [km^2]	1,380

D. PHYSIOGRAPHIC FEATURES

D1 GEOGRAPHICAL

§ Sketch map (Fig. ASI-52-1).
§ Bathymetric map (Fig. ASI-52-2).
§ Main islands (name and area): None.
§ Outflowing rivers and channels (number and names): 1 (Abashiri R.).

D2 CLIMATIC

§ Climatic data at Nemuro, 1931-1960 (2)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean temp. [°C]	-4.8	-5.6	-2.2	2.8	6.8	10.0	14.3	17.5	15.5	10.8	4.7	-1.3	5.7
Precipitation [mm]	49	40	77	77	99	97	104	106	152	124	92	63	1,080

§ Number of hours of bright sunshine : 1,952.5 hr yr^{-1}.

Fig. ASI-52-1 Sketch map of Lake Abashiri and its drainage basin (3).

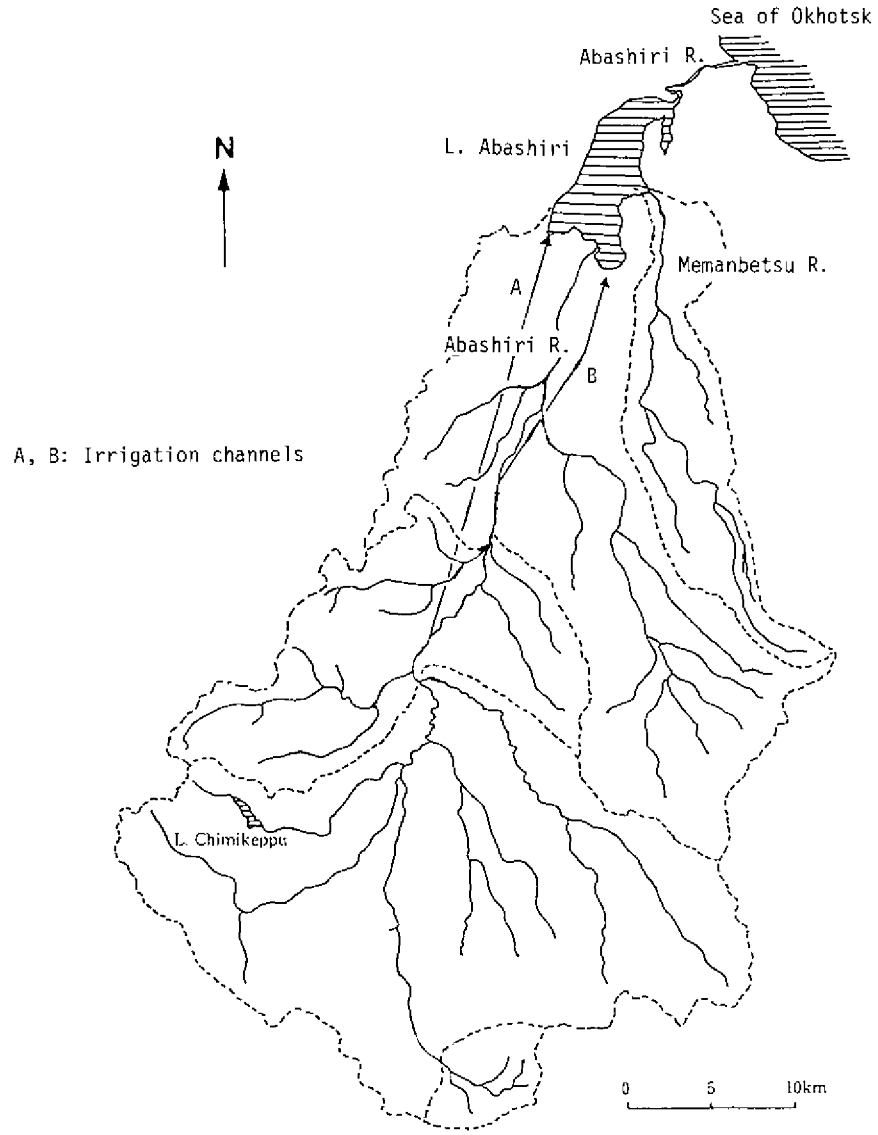
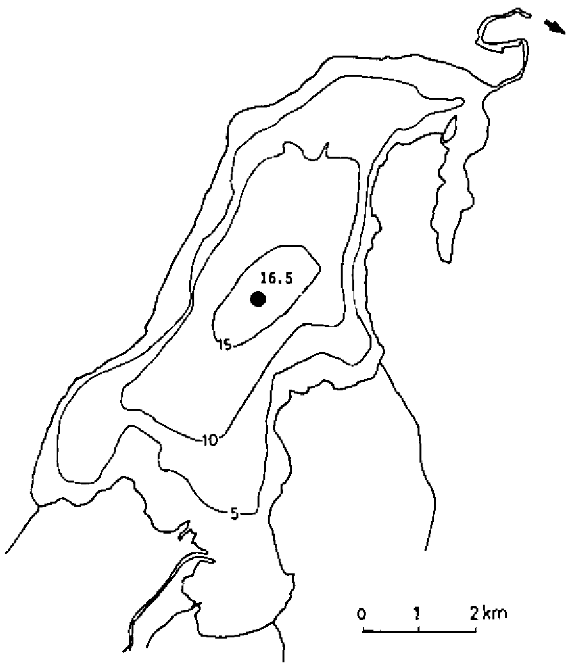
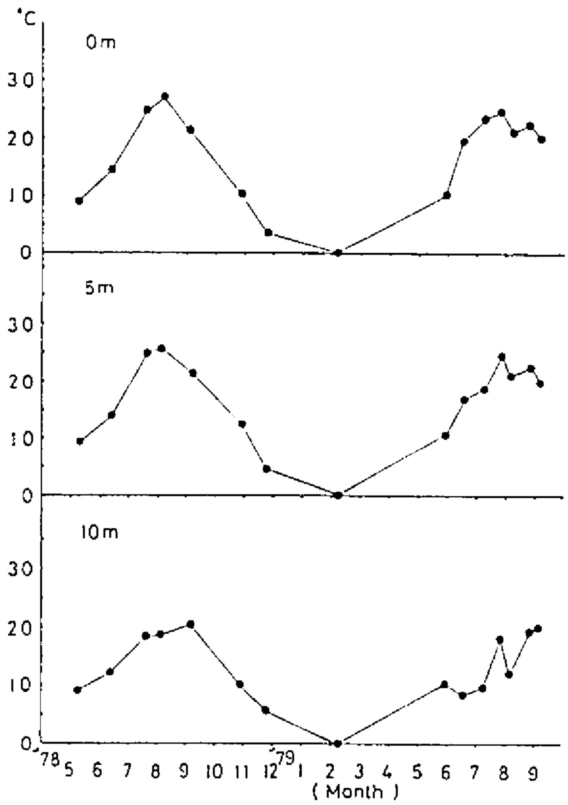


Fig. ASI-52-2 Bathymetric map [m] (4).
● : Sampling point.



§ Water temperature

Fig. ASI-52-3 Seasonal variation of water temperature [°C] at lake center (4).



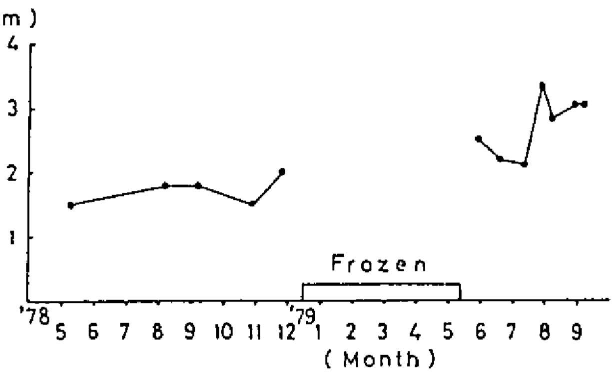
§ Freezing period : From the midst of Dec. to the early or midst of Apr.
§ Mixing type : Dimictic.
§ Notes on water mixing and thermocline formation

A very high chloride concentration and reduced condition of layer is formed usually under 10.5 m deep layer because of the invasion of seawater from adjacent Sea of Okhotsk to the lake.

E. LAKE WATER QUALITY

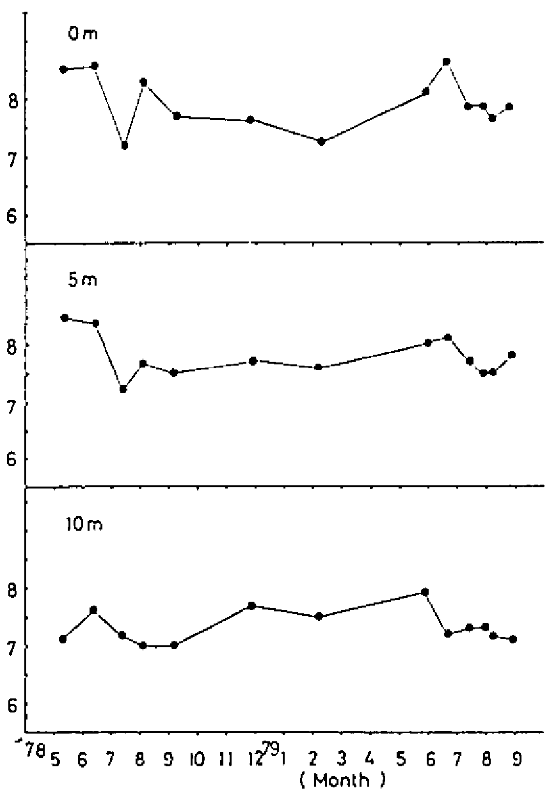
E1 TRANSPARENCY

Fig. ASI-52-4 Seasonal variation of transparency [m] at lake center (4).



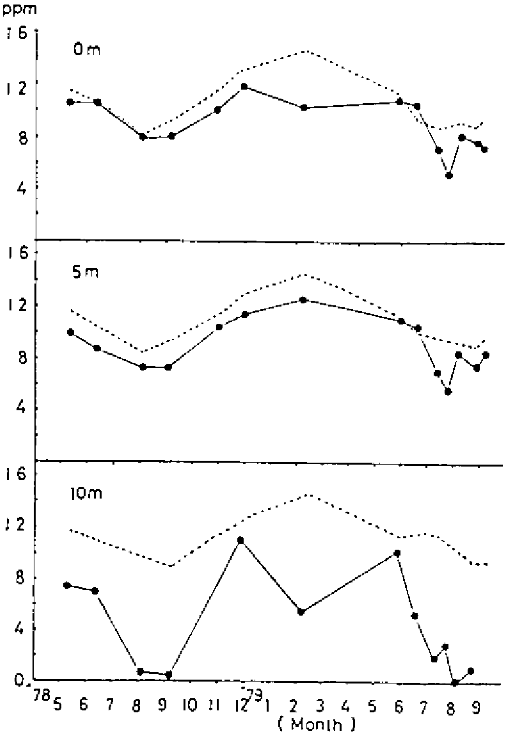
E2 pH

Fig. ASI-52-5 Seasonal variation of pH value at lake center (4).



E4 DO [mg l⁻¹]

Fig. ASI-52-6 Seasonal variation of DO concentration at lake center (4).
Solid line : Measured values.
Dotted line : Theoretical saturation values.



E6 CHLOROPHYLL CONCENTRATION [μg l⁻¹]

Fig. ASI-52-7 Vertical distribution of chlorophyll *a*, PON and DON concentrations at lake center, 1983 (5).

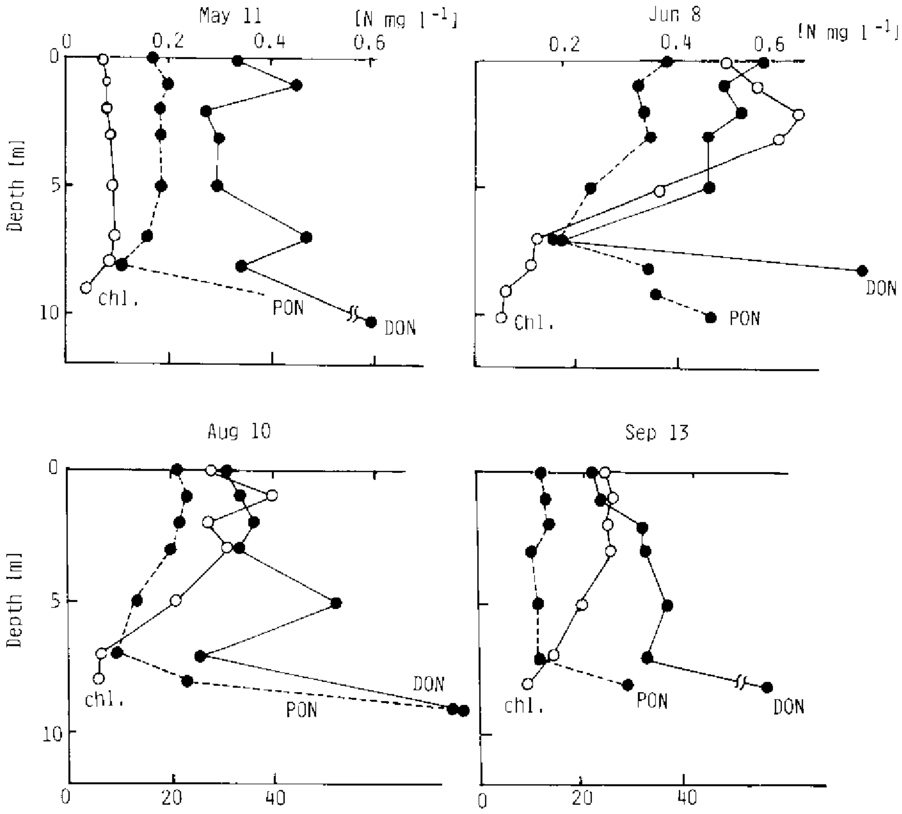
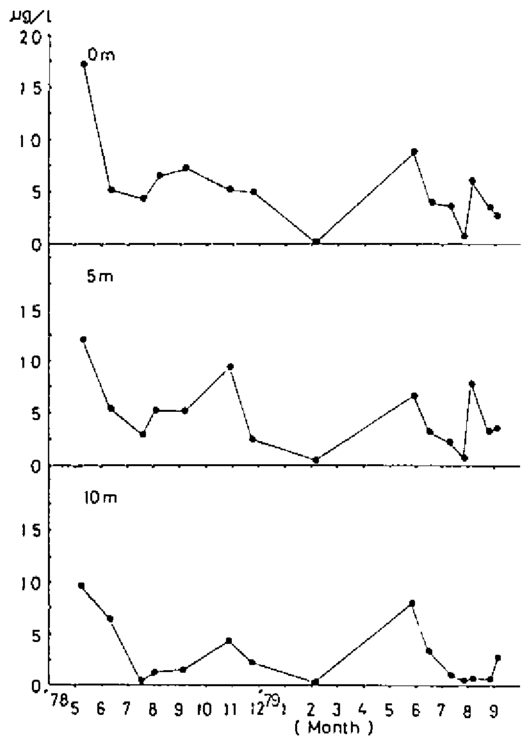
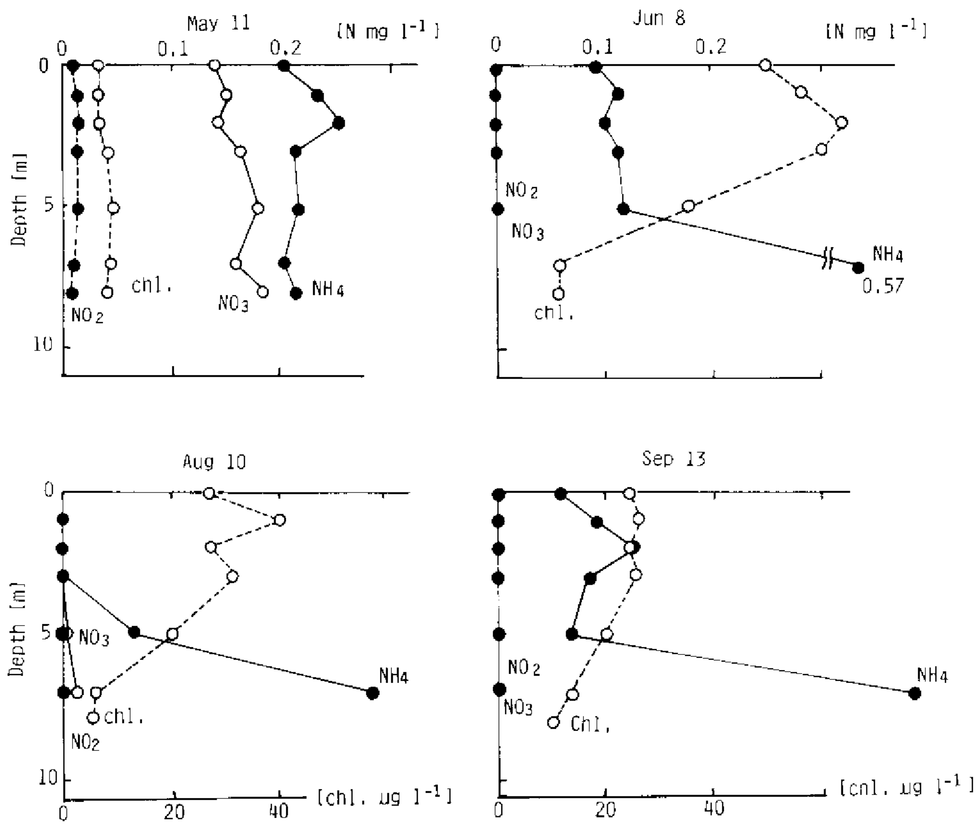


Fig. ASI-52-8 Seasonal variation of chlorophyll *a* concentration at lake center (4).



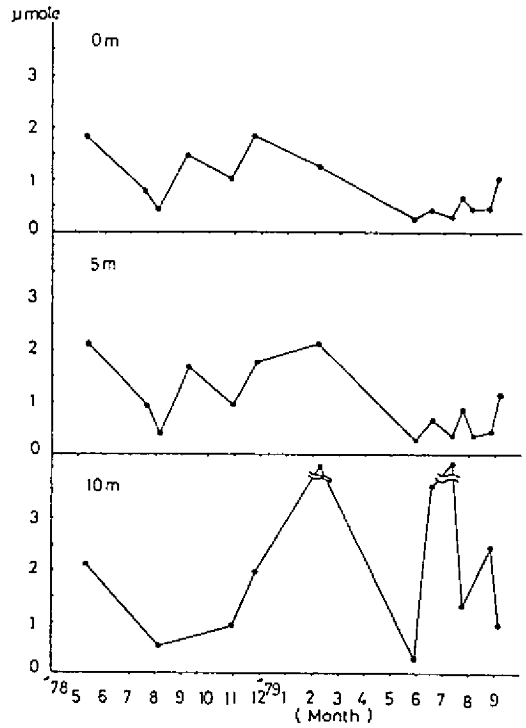
E7 NITROGEN CONCENTRATION

Fig. ASI-52-9 Vertical distribution of NH_4-N, NO_2-N, NO_3-N and chlorophyll *a* concentrations at lake center, 1983 (5).



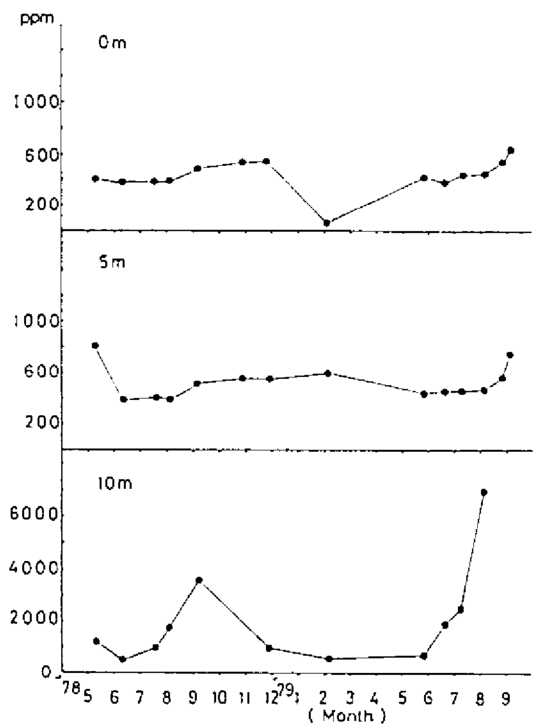
E8 PHOSPHORUS CONCENTRATION

Fig. ASI-52-10 Seasonal variation of PO_4-P concentration [$\mu g\ l^{-1}$] at lake center (4).



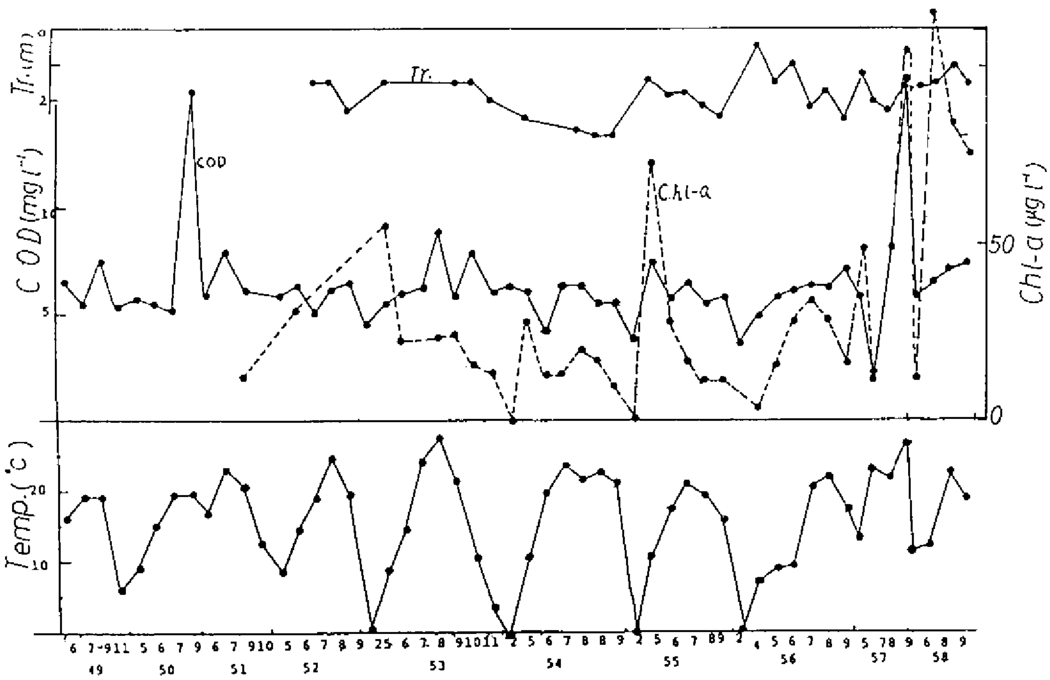
E9 CHLORINE ION CONCENTRATION

Fig. ASI-52-11 Seasonal variation of chlorine ion concentration [ppm] at lake center (4).



E10 PAST TREND

Fig. ASI-52-12 Annual change of water temperature [°C], transparency [m], chlorophyll *a* concentration [μg l^{-1}] and COD value [mg l^{-1}] (5).



F. BIOLOGICAL FEATURES

F1 FLORA

§ Phytoplankton

Cyanophyceae (*Dactylococcopsis acicularis*, *Merismopedia tenuissima*, *Anabaena flos-aquae* var. *treleasi*, *A. scheremetievi*), Bacillariophyceae (*Melosira varians*, *M. undulata*, *M. granulata*, *M. italica*, *Cyclotella meneghiniana*, *C. glomerata*, *Coscinodiscus lacustris*, *C. marginatus*, *C. astromphalus*, *Stephanodiscus hantzschii*, *Actynoptychus senarius*, *Actynocyclus ehrenbergi*, *Terpsinoe americana*, *Tabellaria flocculosa*, *Diatoma vulgare*, *D. hiemale* var. *mesodon*, *D. elongatum*, *Fragilaria construens*, *F. japonica*, *F. vaucheriae*, *Ceratoneis arcus* var. *amphioxys*, *Asterionella gracillima*, *Synedra ulna*, *S. ulna* var. *oxyrhnchus*, *S. acus*, *Eunnotia pectinalis* var. *minor*, *Cocconeis placentula*, *C. scutellum*, *Achnanthes lanceolata*, *A. lanceolata* var. *elliptica*, *A. lanceolata* var. *rosterata*, *Rhoicosphenia curvata*, *Diploneis interrapta*, *D. smithii*, *Navicula scutiformis*, *N. alpha* var. *longistris*, *N. gregaria*, *Pinnularia appendiculata*, *Amphiprora paludosa*, *Amphora ovalis*, *A. coffeiformis*, *Gyrosigma acuminatum*, *Cymbella amphicephara*, *C. ehrenbergii*, *C. ventricosa*, *Gomphonema acuminatum*, *G. olivaceum*, *Epithmia turgida*, *E. sorex*, *Rhopalodia gibba*, *Bacillaria paradoxa*, *Nitzschia trybionella*, *N. trybionella* var. *levidensis*, *N. littoralis*, *Surirella linearis*, *Stenopterobia intermedia*, *Chaetoceros didymus*), Crysophyceae (*Dinobryon cylindrica*), Chlorophyceae (*Eudorina elegans*, *Planctonema lauterbornii*, *Dictyosphaerium ehrenbergianum*, *Westella botryoides*, *Closteriopsis longissima*, *Pediastrum duplex*, *P. boryanum*, *Scenedesmus acuminatus*, *S. quadricauda*) (4).

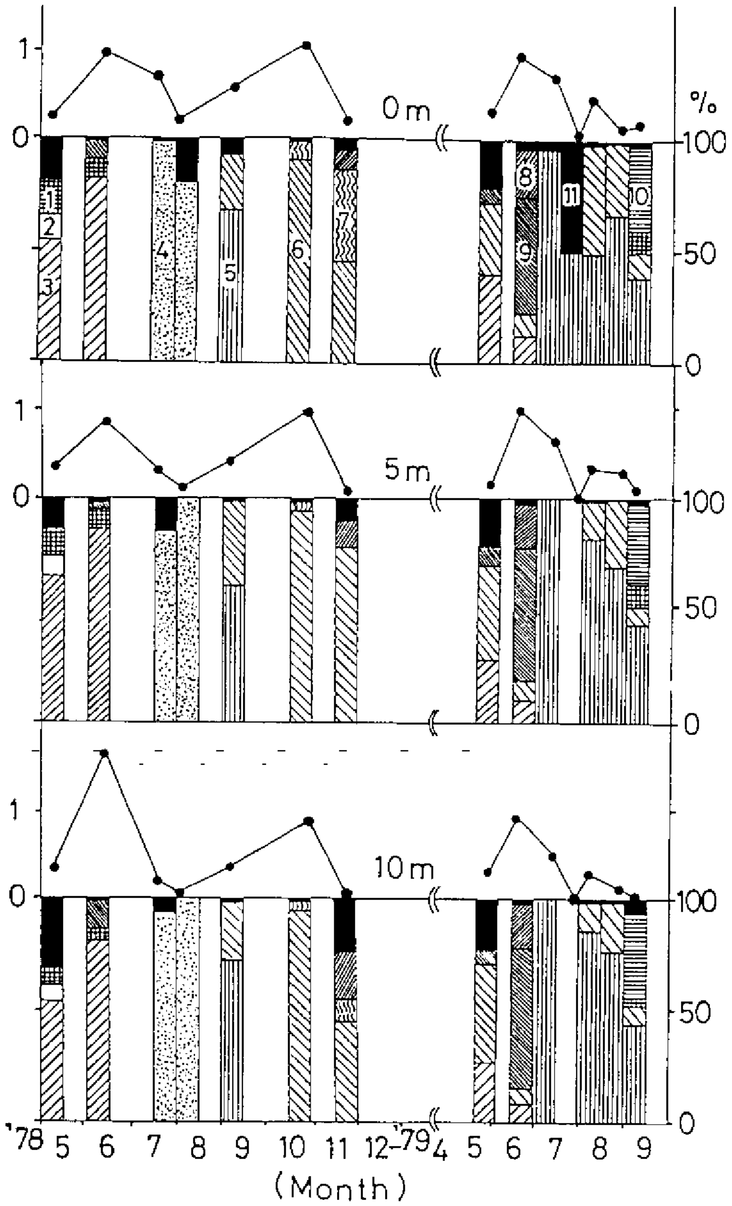
F2 FAUNA

§ Zooplankton : *Bosmina coregoni* (4).
§ Benthos : *Corbicula japonica* (6).
§ Fish

Salmo keta, *S. masou*, *Hypomesus transpacificus**, *Leucopsarion petersi* (*economically important) (6).

F4 BIOMASS

Fig. ASI-52-13 Seasonal variation of population density [$\times 10^5$ cells l^{-1}], composition and rate of appearance [%] of phytoplankton (4).



1. Melosira distans var. alpigena, 2. Nitzschia capitellata, 3. Diatoma elongatum, 4. Anabaena flos-aquae var. intermedia f. spiroides, 5. Cyclotella glomerata, 6. Melosira granulata, 7. Chaetoceros sp., 8. Synedra ulna, 9. Synedra acus, 10. Merismopedia tenuissima, 11. Other species.

F5 FISHERY PRODUCTS

§ Annual fish catch in 1980 : 605 [metric tons] (6).

G. SOCIO-ECONOMIC CONDITIONS

G1 LAND USE IN THE CATCHMENT AREA (1990) (6)

	Area [km²]	[%]
Natural landscape		
Forest	1,014.3	73.5
Agricultural land		
Crop field	219.4	15.9
Settlement area	23.5	1.7
Others	122.8	8.9
Total	1,380	100

§ Main types of woody vegetation : Deciduous forest (*Betula ermanii*, *Quercus mongolica*, *Acer ukurunduense*, *Cornus controversa*) and larch (*Larix kaempferi*) plantation.

§ Main kinds of crops : Rice, potato, hay, sugar beet, kidney bean, onion.

§ Levels of fertilizer application on crop fields : Moderate.

G3 POPULATION IN THE CATCHMENT AREA (7)

	Population	Population density [km^{-2}]	Main cities
Rural	17,300	12.5	None
Total	17,300		

H. LAKE UTILIZATION (3)

H1 LAKE UTILIZATION

Source of water, fisheries, sightseeing and tourism, recreation (sport-fishing).

H2 THE LAKE AS WATER RESOURCE (1990)

	Use rate [$t\ day^{-1}$]*
Irrigation	604,800

* From May 1 to Aug. 31.

I. DETERIORATION OF LAKE ENVIRONMENTS AND HAZARDS (3)

I1 ENHANCED SILTATION

§ Extent of damage : Serious.

I2 TOXIC CONTAMINATION

§ Present status : None.

I3 EUTROPHICATION

§ Nuisance caused by eutrophication : Unusual algal blooms of blue-green algae.

§ Nitrogen and phosphorus loadings

Sources	Total [$t\ day^{-1}$]	
	Fine day	Rainy day
T-N	0.66	3.01
T-P	0.01	0.45

I4 ACIDIFICATION

§ Extent of damage : None.

J. WASTEWATER TREATMENTS

J1 GENERATION OF POLLUTANTS IN THE CATCHMENT AREA : (d) Measurable pollution with limited wastewater treatment.

L. DEVELOPMENT PLANS

None (6).

M. LEGISLATIVE AND INSTITUTIONAL MEASURES FOR UPGRADING LAKE ENVIRONMENTS

M1 NATIONAL AND LOCAL LAWS CONCERNED

For national laws see "Biwa-ko"

N. SOURCES OF DATA

* Printed in Japanese. The titles are tentatively translated into English with the original titles in romanized Japanese in parentheses.

(1) Hirai, Y. (1991) Lake Abashiri (Abashiri-ko). "Bird-eye view of Japanese Lakes (Sorakara miru Nippon no koshô)" (ed. Okuda, S., Kurata, A., Nagaoka, M. & Sawamura, K.), pp. 18-20, Maruzen Co. Ltd., Tokyo.*

(2) Arakawa, H. & Taga, S. (1969) Climate of Japan. "World Survey of Climatology, Volume 8, Climates of Northern and Eastern Asia" (ed. Arakawa, H.), pp. 119-158. Elsevier Publishing Company, Amsterdam-London-New York.

(3) Fukuyama, R., Sakata, K. & Murata, K. (1990) Annual Report of Hokkaidô Public Pollution Prevention Institute (Hokkaidô Kôgai Bôshi Kenkyûsho hô), 17, 29-41.*

(4) Nakamura, Y., Aoi, T. & Kurogi, M. (1980) Journal of Environmental Science of Hokkaidô University (Kankyô kagaku, Hokkaidô Daigaku), 3 (1), 35-45.*

(5) Sakata, K., Aoi, T., Murata, K., Kondô, H., Hino, S. & Konishi, K. (1984) Annual Report of Hokkaidô Public Pollution Prevention Institute (Hokkaidô Kôgai Bôshi Kenkyûsho hô), 11, 52-65.*

(6) All Japan Promotion Committee for Conservation of Lake Environments (Zenkoku koshô kankyô hozen taisaku suishin kyôgi kai) (1989) Data Book of Japanese Lake Environments (Zenkoku koshô shiryô shû). pp. 4-5.*

(7) Japanese Geographical Institute (Nihon Chishi Kenkyû sho) (1981) Geography of Japan (Nihon chishi), 2, p. 116, Ninomiya shoten, Tokyo.*

(8) The editor's observation.

LAKE ONEGO

A view on the lakeshore

Photo: M. I. Fedorov

A. LOCATION

§ Karelian ASSR, Leningrad and Vologda regions of RSTSR, USSR.
§ 60°55′-62°55′N ; 34°14′-36°30′E ; 35 m above sea level.
 * Place names are not updated.

B. DESCRIPTION

Lake Onego is the second largest lake in Europe next to Lake Ladoga. The lake basin is situated on two contrasting parts of the earth crust with different geological histories, Baltic shield and Russian plate. The boundary runs approximately along the line connecting the mouths of the Vodla River and the Shuja River. To the north of the boundary, the shoreline is extremely jagged, and the greater part of islands and numerosus fjord-type bays are found. The northern basin is surrounded by hills and cliffs consisting of crystalline rocks. There, land relief forms are oriented from northwest to southeast, following the direction of ice flow during glacial periods. Deep hollows (90-100 m deep) are interspersed with ridges only 1-2 m below the water surface. The southern basin is relatively shallow with a mean depth of 30 m and more or less flat bottom. Shorelines are less jagged, and are frequently covered by marsh.

Tectonic processes in the pre-glacial period, combined with glacial erosion and transport, formed the specific hydrographical network. The history of Lake Onega experienced several glacial periods, when its flora and fauna were exterminated. The last glaciation ended 11,000-12,000 years ago. The lakeshore became inhabited some 9,000 years ago. Some 800 rock drawings or so-called petrogliffs, which were made from the end of the third to the beginning of the second millenium B. C., are invaluable heritage in the history human culture. On the lake shore, there are also a number of wood architectures of 17-18th centuries including world-famous Kizhi-ensemble.

Lake Onego is now the source of freshwater of high quality (total mineral concentration 34-36 mg l^{-1}). It also forms part of the major waterborne transport system in the USSR, and serves as a reservoir for hydroelectric power generation and an important fishing ground.

C. PHYSICAL DIMENSIONS (Q)

Surface area [km^2]	9,890
Volume [$10^9 m^3$]	280
Maximum depth [m]	120
Mean depth [m]	30
Normal range of annual water level fluctuation (regulated) [m]	0.5
Residence time [yr]	12
Catchment area [km^2]	51,540

D. PHYSIOGRAPHIC FEATURES

D1 GEOGRAPHICAL (Q)

§ Sketch map of the lake (Fig. EUR-36-1).

§ Main islands (name and area): Klimenetskiy (148 km^2), Lelikovskiy (21 km^2) and Suisari (19.3 km^2).

§ Outflowing rivers and channels (number and names): 1 (Svir R.).

D2 CLIMATIC

§ Climatic data (1870-1950)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean temp. [°C]*	-9.8	-10.1	-6.1	1.3	1.3	19.0	16.3	14.3	9.4	3.4	-2.1	-6.6	2.5
Precipitation [mm]**	35	29	29	34	42	50	65	69	66	62	43	43	567

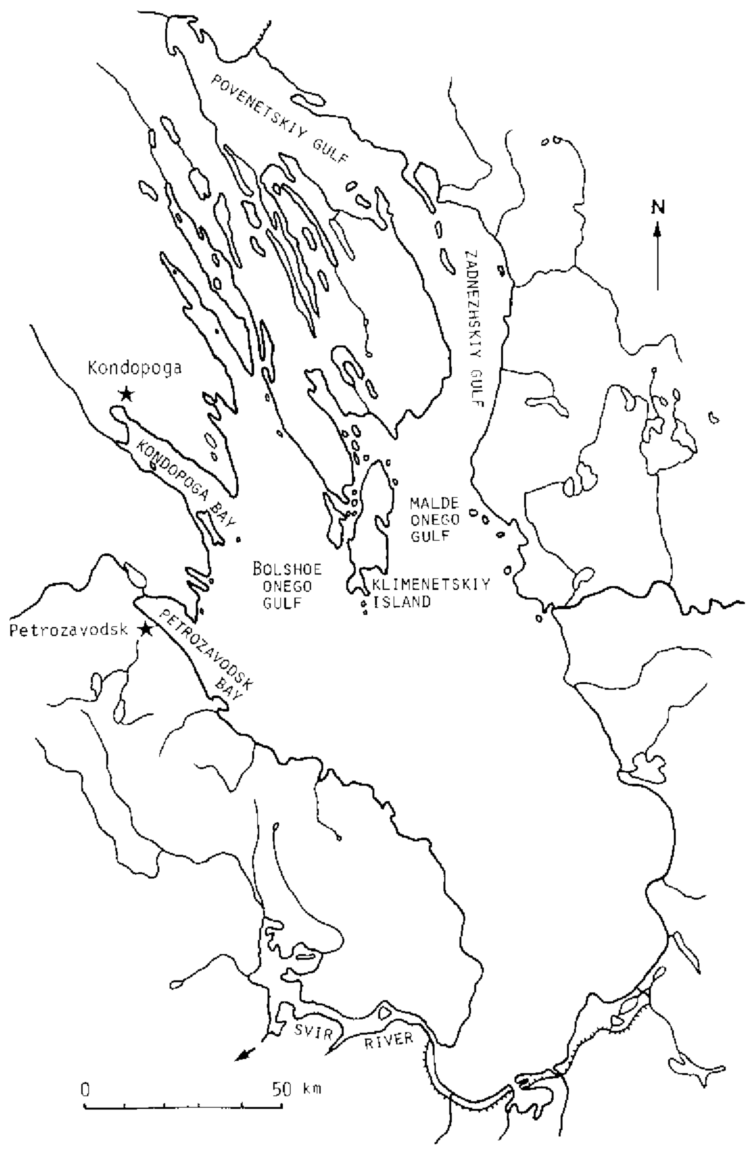
* Petrozavodsk.

** Shvets P. D.

§ Number of hours of bright sunshine at Petrozavodsk: 1,719 hr yr^{-1}.

§ Average solar radiation: 4.21 MJ $m^{-2}day^{-1}$.

Fig. EUR-36-1 Sketch map of the lake (Q).

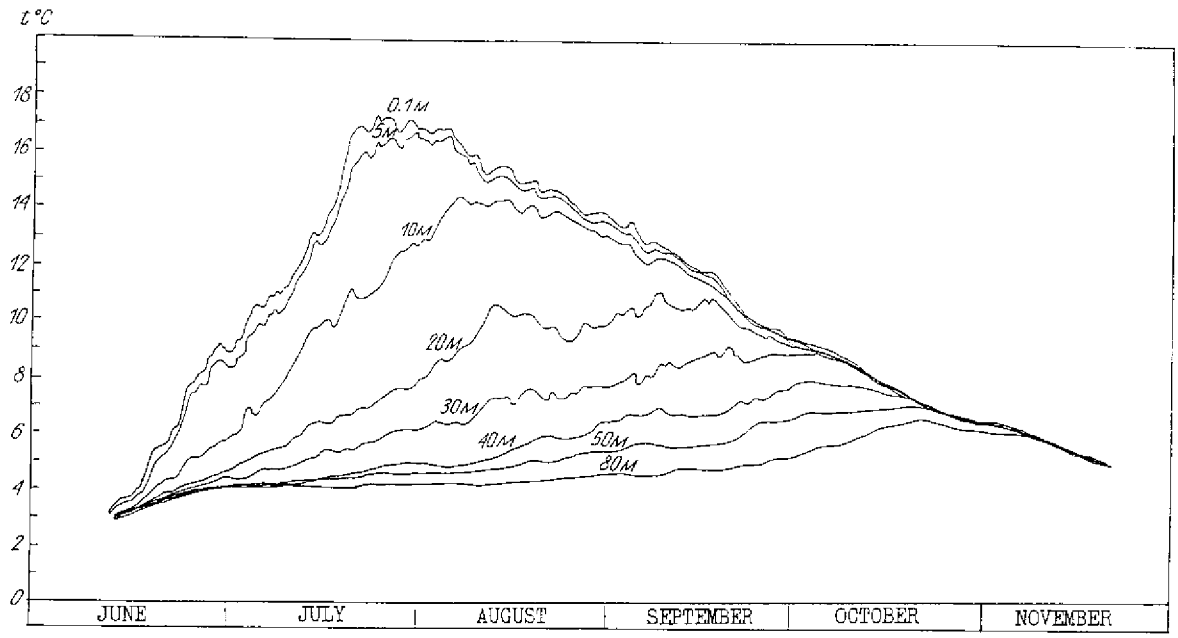


§ Water temperature [°C] (1972-1984)

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.5		—— ice cover ——			2.7	8.9	15.2	12.5	11.5	7.2	3.5	0.8

§ Freezing period at Tichomirov (1948-1967) : From Jan. 18 to May 18.
§ Mixing type : Dimictic.
§ Notes on water mixing and thermocline formation : Thermal bar disappears at the end of June. Hydrological summer is 65-70 days. Maximum heating in August. Epilimnion about 20-30 m deep. Temperature in metalimnion is around 10°C, hypolimnion 4-5°C. Autumn thermal bar is observed in November.

Fig. EUR-36-2 Seasonal change of water temperature, 1956-1988 (Q).



E. LAKE WATER QUALITY (Q)

E1 TRANSPARENCY [m]

Lake center, 1989

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	—— ice cover ——			3.5	3.7	3.5	3.5	3.5	3.5	3.5	3.7

E2 pH

Lake center, 1989

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Surface	—	—	—	—	7.4	7.4	7.8	7.7	7.5	7.5	—	—
5.0	—	—	—	—	7.4	7.4	7.8	7.8	7.6	7.5	—	—
10.0	—	—	—	—	7.4	7.4	7.7	7.6	7.5	7.5	—	—
20.0	—	—	—	—	7.4	7.4	7.4	7.4	7.4	7.4	—	—
40.0	—	—	—	—	7.4	7.4	7.4	7.4	7.4	7.4	—	—
80.0	—	—	—	—	7.4	7.4	7.4	7.4	7.4	7.4	—	—
Bottom	—	—	—	—	7.4	7.4	7.4	7.4	7.3	7.3	—	—

E3 SS [mg l^{-1}]
Annual mean, 1966-1987 : 0.2.

E4 DO [mg l^{-1}]
Lake center, 1989

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Surface	—	—	—	—	13.1	13.1	10.8	9.4	10.5	—	—	—
5.0	—	—	—	—	13.1	13.2	10.5	9.3	10.4	—	—	—
10.0	—	—	—	—	13.0	13.0	10.7	9.2	10.3	—	—	—
20.0	—	—	—	—	13.2	12.5	11.8	9.2	11.0	—	—	—
40.0	—	—	—	—	13.2	12.8	12.2	12.5	11.4	—	—	—
80.0	—	—	—	—	13.1	13.1	12.0	12.6	11.6	—	—	—
Bottom	—	—	—	—	13.2	12.9	12.0	12.8	12.0	—	—	—

E5 COD [mg l^{-1}]
Annual means, 1970-1988 : 7.1 (Mn), 14.7 (Cr).

E6 CHLOROPHYLL CONCENTRATION [μg l^{-1}]
Lake center, 1989

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Surface	—	—	—	—	0.8	1.4	5.8	5.2	—	—	—	—
5.0	—	—	—	—	—	1.2	3.8	4.5	—	—	—	—
10.0	—	—	—	—	—	1.0	3.2	2.6	—	—	—	—

E7 NITROGEN CONCENTRATION
§ Total-N [mg l^{-1}]
Lake center, 1989

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Surface	—	—	—	—	0.45	0.60	0.85	0.49	0.45	—	—	—
5.0	—	—	—	—	0.41	0.62	0.66	0.51	0.58	—	—	—
10.0	—	—	—	—	0.45	0.60	0.50	0.49	0.54	—	—	—
20.0	—	—	—	—	0.44	0.70	0.50	0.49	0.65	—	—	—
40.0	—	—	—	—	0.48	0.76	0.50	0.56	0.68	—	—	—
80.0	—	—	—	—	0.36	0.80	0.70	0.51	0.65	—	—	—
Bottom	—	—	—	—	0.31	0.64	0.50	0.51	0.60	—	—	—

E8 PHOSPHORUS CONCENTRATION
§ Total-P [μg l^{-1}]
Lake center, 1989

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Surface	—	—	—	—	8	6	7	10	7	—	—	—
5.0	—	—	—	—	9	7	7	10	6	—	—	—
10.0	—	—	—	—	9	7	7	7	5	—	—	—
20.0	—	—	—	—	10	7	6	5	6	—	—	—
40.0	—	—	—	—	5	6	8	6	6	—	—	—
80.0	—	—	—	—	5	6	8	6	6	—	—	—
Bottom	—	—	—	—	14	11	9	8	6	—	—	—

F. BIOLOGICAL FEATURES (Q)

F1 FLORA

§ Emerged macrophytes : *Phragmites australis*, *Scirpus lacustris*, *Equisetum fluviatile.*

§ Floating macrophytes : *Nuphar lutea*, *Polygonum amphibium.*

§ Submerged macrophytes

Potamogeton perfoliatus, *P. luceus*, *P. praelongus*, *Batrachium eradicatum*, *B. gilibertii.*

§ Phytoplankton

Spring ; *Melosira islandica* subsp. *helvetica*, *M. italica*, *M. distans* var. *alpigena*, *Asterionella formosa*, *Tabellaria fenestrata.*

Summer ; *Dinobryon divergens*, *D. bavaricum*, *Coelosphaerium kuettzingianum*, *Oscillatoria tenuis*, *Sphaerocystis schroeteri.*

F2 FAUNA

§ Zooplankton

Spring ; *Strombidium viride*, *Lembadion lucens*, *Limnocalanus macrurus*, *Cyclops abissorum*, *Eudiaptomus gracilis*, *Kellicottia longispina.*

Summer ; *Vorticella anabaena*, *Tintinnopsis cratera*, *Limnocalanus macrurus*, *Cyclops abissorum*, *Diaptomus gracilis*, *Mesocyclops oithonoids*, *Daphnia cristata*, *Bosmina obtusirostris*, *Kellicottia longispina*, *Asplanchna priodonta.*

§ Benthos

Pontoporeia affinis, *Pallasea quadrispinosa*, *Lampodrilus isoporus*, *Stylodrilus heringianus*, *Spirosperma ferax*, *Procladius* sp., *Trissocladius paratatricus*, *Protanypus* sp., *Prodiamesa bathyla*, *Neopisidium conventus.*

§ Fish : *Coregonus albula*, *C. lavaretus*, *Osmerus eperlanus*, *Lucioperca lucioperca.*

§ Supplementary notes on the biota

There are noteworthy relict species such as *Pontoporeia affinis*, *Pallasea quadrispinosa*, *Mysis oculata* var. *relicta*, *Gammarocanthus lacustris* and *Lampodrilus isoporus.*

F3 PRIMARY PRODUCTION RATE [mg C $m^{-2}day^{-1}$]

Lake center, 1989

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Gross production	—	—	—	—	—	17.6	40.3	52.8	79.9	—	—	—	7.6

F4 BIOMASS

§ Macrophytes [g m^{-2}] (1989)

Phragmites	220
Scirpus	187
Equisetum fluviatile	100
Potamogeton natans	142
P. perfoliatus	32
Polygonum amphibium	77

§ Phytoplankton [g fresh weight m^{-2}] (1989)

Regions	Jun	Jul	Aug	Sep
Bolshoje Onego Gulf	34.7	12.5	5.7	4.7
Petrozavodsk Bay	42.0	4.0	12.0	4.5
Kondopoga Bay	114.8	8.9	4.3	22.3

§ Bacterioplankton [g fresh weight m^{-2}] (1989)

Regions	Jun	Jul	Aug	Sep
Bolshoje Onego Gulf	65.8	61.2	60.2	106.7
Petrozavodsk Bay	28.2	29.5	33.1	52.8
Kondopoga Bay	61.5	91.4	52.1	119.4

§ Protozoa [g fresh weight m^{-2}] (1989)

Regions of the lake	Jun	Jul	Aug	Sep	Oct
Bolshoje Onego Gulf	0.2	1.0	0.7	2.9	2.9
Petrozavodsk Bay	0.4	4.7	1.1	0.2	2.7
Kondopoga Bay	1.4	3.1	0.2	0.5	1.4

§ Zooplankton [g fresh weight m^{-2}] (1989)

Regions of the lake	Jun	Jul	Aug	Sep	Oct
Bolshoje Onego Gulf	3.2	6.5	12.2	5.6	4.0
Petrozavodsk Bay	4.2	5.9	8.3	6.0	1.6
Kondopoga Bay	5.2	13.0	19.3	5.5	6.2

F5 FISHERY PRODUCTS

§ Annual fish catch in 1990 : 2,100 [metric tons].

G. SOCIO-ECONOMIC CONDITIONS (Q)

G1 LAND USE IN THE CATCHMENT AREA (1988)

	Approximate area [10^3 km^2]	[%]
Natural landscape	(50.7)	(98.6)
Woody vegetation	36.8	71.6
Herbaceous vegetation	0.4	0.8
Swamp	9.8	19.1
Others	3.7	7.2
Agricultural land	(0.5)	(1.0)
Crop field	0.3	0.6
Pasture land	0.2	0.4
Settlement area	0.2	0.4
Total	51.4	100.0

§ Types of important forest : Spruce, pine, birch, aspen.
§ Main kinds of crops : Potato, cabbage, carrot, perennial, herbs.
§ Levels of fertilizar application on crop fields : Moderate.
§ Trends of change in land use in recent years : Expansion of agricultural lands ; reduction of forest felling.

G2 INDUSTRIES IN THE CATCHMENT AREA AND THE LAKE (1989)

	Gross Production during the year [US $]	Number of persons engaged	Number of establishments
Primary industry		8,982	1,371
Crop production	13,632		
Animal husbandry	61,792		
Secondary and tertiary industry			
Timber and wood-working	132,236	21,915	2,698
Cellulose and paper	127,418	5,281	713
Building materials	67,607	9,054	1,382
Machine production	180,817	20,352	4,981

§ Number of domestic animals in the catchment area : Cattle 68,000, sheep 34,000, swine 54,000, poultry 1,908,000, goat 1,700, horse 900, mink 102,000, polar fox 3,400, fox 1,000.

G3 POPULATION IN THE CATCHMENT AREA (1989)

	Population	Population density [km^{-2}]	Main cities
Urban	305,000		Petrozavodsk, Kondopoga
Rural	194,000		
Total	499,000	9.7	

H. LAKE UTILIZATION (Q)

H1 LAKE UTILIZATION

Source of water, navigation and transportation (tonnage of cargo yr^{-1}, 1989 ; 10 million tons), sightseeing and tourism (number of visitors yr^{-1} ; 300,000), recreation (sport-fishing, yachting) and fisheries.

H2 THE LAKE AS WATER RESOURCE (1988)

	Use rate [10^6 m^3 yr^{-1}]
Domestic water	26.9
Industrial water	27.0
Agriculture	0.2
Total	54.1

I. DETERIORATION OF LAKE ENVIRONMENTS AND HAZARDS (Q)

I3 EUTROPHICATION

§ Nitrogen and phosphorus loadings to the lake (1989)

	Total [t yr^{-1}]
T-N	17,800
T-P	1,040

I4 ACIDIFICATION

§ Extent of damage : Detected but not serious.

J. WASTEWATER TREATMENTS (Q)

J1 GENERATION OF POLLUTANTS IN THE CATCHMENT AREA : (c) Limited pollution with wastewater treatment.

J2 APPROXIMATE PERCENTAGE DISTRIBUTION OF NUTRIENT LOADS

	[%]
Non-point sources	10
Point sources	
Municipal	10
Industrial	80
Fish farming	0
Total	100

J3 SANITARY FACILITIES AND SEWERAGE

§ Percentage of municipal population in the catchment area provided with adequate sanitary facilities (on-site treatment systems) or public sewerage : 100 %.

§ Percentage of rural population with adequate sanitary facilities : 60 %.

§ Municipal wastewater treatment systems

No. of secondary treatment systems : 6.
No. of primary treatment systems : 0.
No. of other types : 0.

§ Industrial wastewater treatment systems : 11.

K. IMPROVEMENT WORKS IN THE LAKE

None (Q).

M. LEGISLATIVE AND INSTITUTIONAL MEASURES FOR UPGRADING LAKE ENVIRONMENTS (Q)

M1 NATIONAL AND LOCAL LAWS CONCERNED

§ Names of the laws (the year of legislation)

(1) Principles of Water Laws for the USSR (1971)
(2) RSFSR Water Code (1980)
(3) "Measures on ensuring of protection and rational utilization of water and other natural resources in the Basin of Lakes Ladoga, Onego and Ilmen", Council of Ministers of the USSR Decision (1984)

§ Responsible authorities

(1) Local authorities
(2) State sanitary inspection
(3) State fish inspection
(4) State Committee of Environmental Protection
(5) State Committee of Hydrometeorology

§ Main items of control

(1) Discharge of industrial and municipal sewage
(2) Non-point sources of contamination control

M2 RESEARCH INSTITUTES ENGAGED IN THE LAKE ENVIRONMENT STUDIES

(1) Karelian Centre of the Academy of Science of the USSR, Petrozavodsk
(2) Northern State Research Institute for Fish Industry, Petrozavodsk

N. SOURCES OF DATA

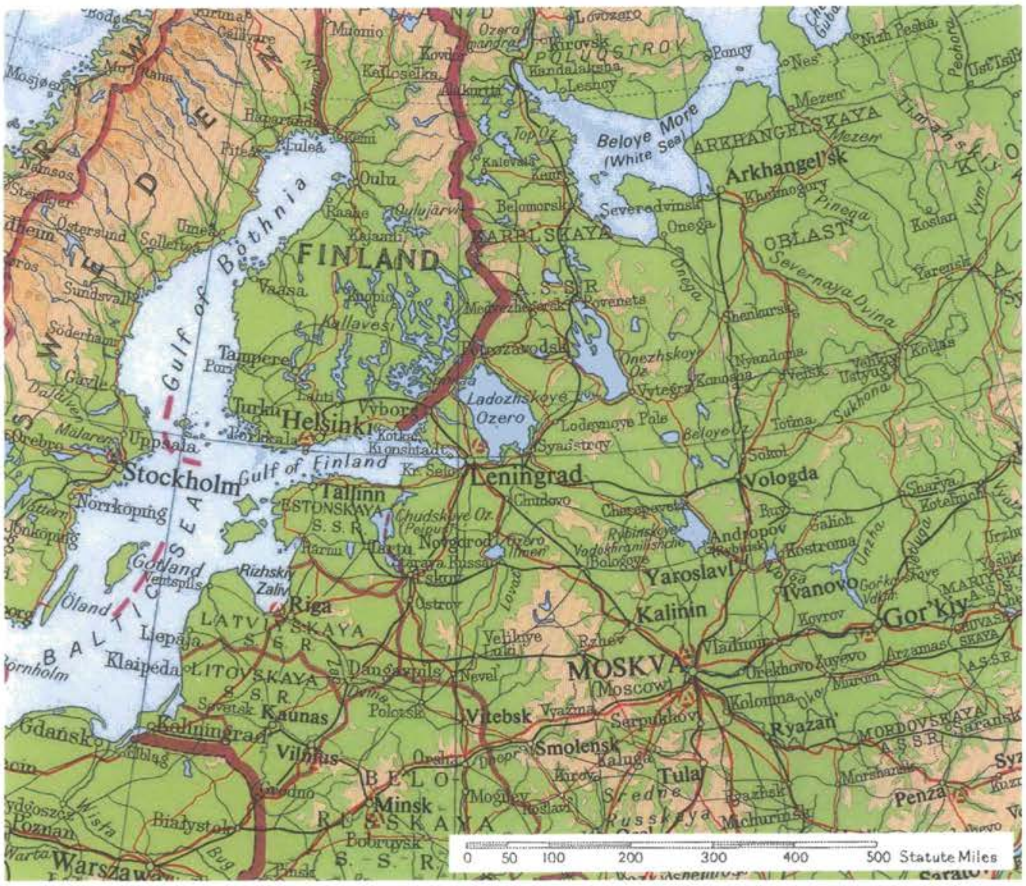
(Q) Questionnaire filled by Dr. N. N. Filatov, Water Problem Department, Karelian Centre of the Academy of Science of the USSR, Petrozavodsk, based on the following sources.

Kauffman, Z. S. (ed.) (1990) The Ecosystem of the Onego Lake and the Trends of Its Changes (in Russian). 263pp. Publ. House "Nauka", Leningrad.

LAKE LADOGA

A view on the lakeshore

Photo: I. M. Raspopov



A. LOCATION

§ Leningrad District, Karelia, USSR.*
§ 59°54′-61°47′N, 29°47′-32°58′E ; 4.8 m above sea level.
* Place names are not updated.

B. DESCRIPTION

Lake Ladoga is the largest freshwater body in Europe with a surface area of 18,135 km² including the islands area of 460 km². The volume of the lake is 908 km³, its average and maximum depths being 51 and 230 m, respectively. The shallowest southern part has a mean depth of 13 m (the lake is divided into four zones taking depth distribution into account).

Lake Ladoga is situated on the borderline between the crystalline Baltic shield and Great Russian Plain, and the geological history of its drainage basin (250,600 km²) is very complicated (1). Differences in the geological structure of the watershed are reflected in the structure of both shores and depressions of the lake. Seven types of bottom sediments were distinguished (2) ; blocks, boulders, pebbles and gravel, sand of various grain size, coarse-grained aleurite silt, fine-grained aleurite silt, and clayey silt. Clayey silt accumulates in the deepest areas of the lake. The other types of bottom sediments are characteristic of littoral and declinate zones.

The principal components of water balance are inflow and outflow, accounting for 86 and 92 % of the total inputs and outputs, respectively. Since 1981 the annual inflow has varied between 77.8 and 89.0 km³ (3). Lake thermic regime is characterized by the existence of thermal bar in periods of spring warming and autumn cooling. Thermal bar divides the lake into two regions — thermoactive and thermoinert, whose water masses differ one from another by physicochemical characteristics (4). Lake Ladoga is influenced by wind waves. The maximal measured wave height amounts to 5.8 m and the maximal length to 60 m (3).

Ladoga water is poorly mineralized average value of mineralization is 62 mg l^{-1}. Once favorable oxygen regime is now getting worse under the influence of anthropogenic eutrophication during the last 10 years. Great attention is being paid to the preservation of water quality in Lake Ladoga. In 1984 the Council of Ministers of USSR adopted a resolution on protecting measures for Lake Ladoga and its basin. Implementing this resolution, a large pulp and paper plant in Priozersk was closed. The governmental program "Ladoga" has been elaborated and is being carried out by cooperation of several different institutions (Q).

C. PHYSICAL DIMENSIONS (3)

Surface area [km²]	18,135
Volume [10⁹m³]	908
Maximum depth [m]	230
Mean depth [m]	51
Normal range of annual water level fluctuation [m] (unregulated)	0.69
Length of shoreline [km]	1,570 (excluding islands)
Residence time [yr]	12.3
Catchment area* [km²]	70,120

* Not including the catchments of upstream lakes (cf. Fig. EUR-37-2).

D. PHYSIOGRAPHIC FEATURES

D1 GEOGRAPHICAL

§ Bathymetric map (Fig. EUR-37-1).
§ Sketch map of the whole Ladoga Lake basin (Fig. EUR-37-2).
§ Physiographic zoning map (Fig. EUR-37-3).
§ Main islands (name and area): Riekkalansaari (55.3 km^2), Mantsinsaari (39.4 km^2), Valaam (27.8 km^2).
§ Outflowing rivers and channels (number and names): 1 (Neva R.).

D2 CLIMATIC (5, 6)

§ Climatic data at Sucho Island, 1881-1960

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean temp. [°C]	-7.8	-8.8	-5.9	-0.3	5.5	11.8	16.3	15.6	11.1	5.2	0.1	-4.7	3.2
Precipitation [mm]	26	24	24	29	43	46	54	55	58	49	39	28	475

§ Number of hours of bright sunshine: 1,784 hr yr^{-1}.

Fig. EUR-37-1 Bathymetric map [m] (Q).

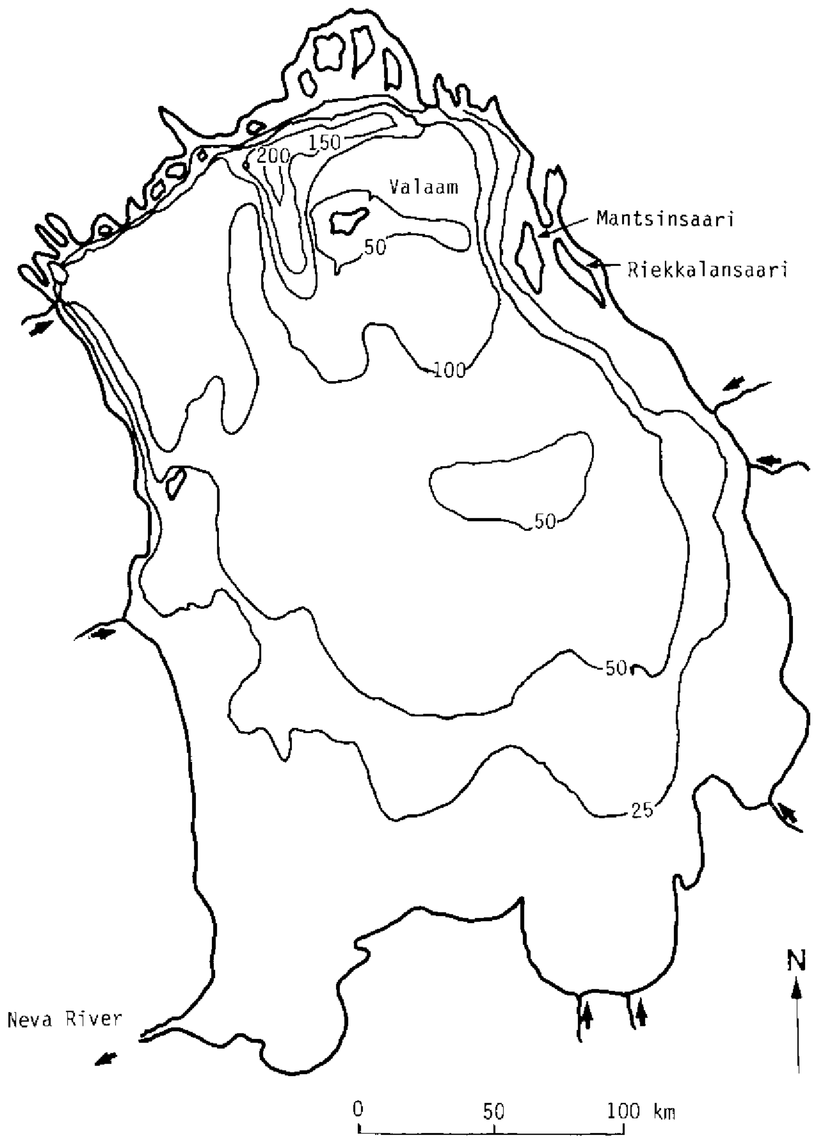


Fig. EUR-37-2 Sketch map of the whole Ladoga Lake basin (Q).

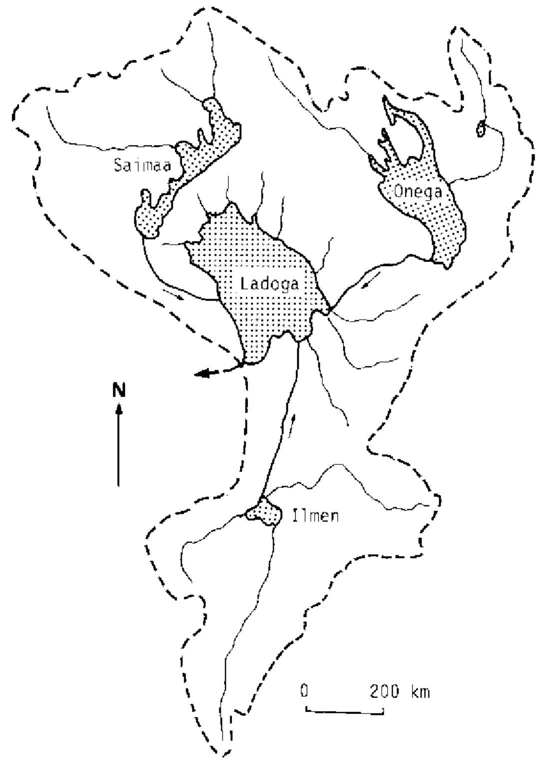
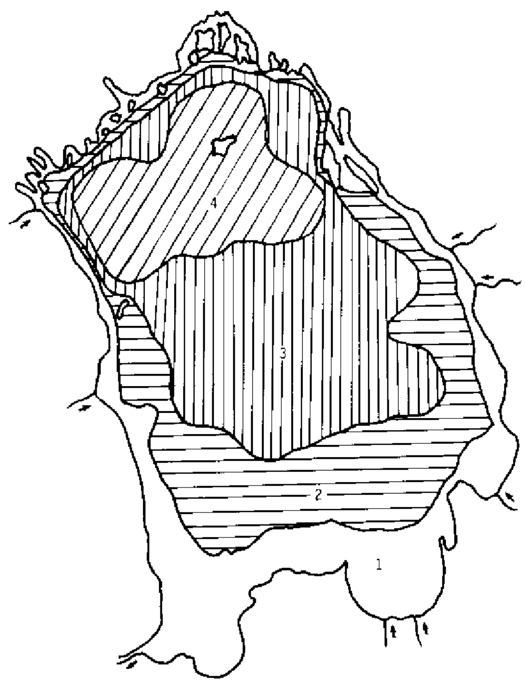


Fig. EUR-37-3 Physiographic zoning of the lake. 1) coastal zone, 2) declinate zone, 3) profundal zone, 4) ultra-profundal zone.



§ Average solar radiation : 9.2 MJ $m^{-2}day^{-1}$.

§ Water temperature [°C]

Average for the northern part of the lake, 1959-1988

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.1	0.8	0.0	–	–	0.4	7.6	13.4	15.7	11.9	7.8	4.0	1.8

§ Freezing period : From Feb. to May.

§ Mixing type : Dimictic.

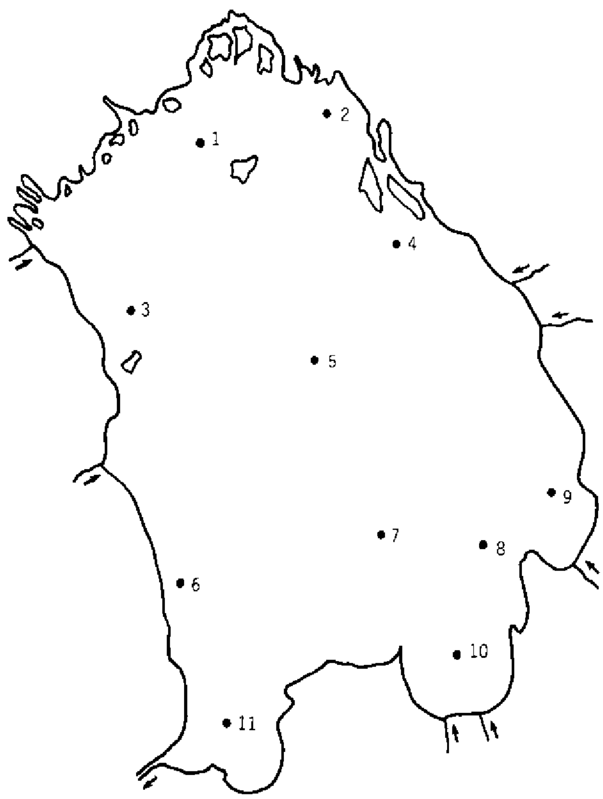
E. LAKE WATER QUALITY (Q)

E1 TRANSPARENCY [m]

Station 1 to 11, 1990

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	–	–	–	–	3.6	–	3.4	–	–	4.4	–	–
2	–	–	–	–	4.0	–	3.3	–	–	3.7	–	–
3	–	–	–	–	3.5	–	3.1	–	–	–	–	–
4	–	–	–	–	3.5	–	3.5	–	–	–	–	–
5	–	–	–	–	5.0	–	3.3	–	–	3.3	–	–
6	–	–	–	–	1.8	–	3.1	–	–	3.1	–	–
7	–	–	–	–	3.7	–	3.0	–	–	3.3	–	–
8	–	–	–	–	3.6	–	2.5	–	–	3.2	–	–
9	–	–	–	–	1.5	–	2.7	–	–	2.7	–	–
10	–	–	–	–	2.8	–	2.7	–	–	1.9	–	–
11	–	–	–	–	1.8	–	2.4	–	–	–	–	–

Fig. EUR-37-4 Observation stations where the transparency was measured (Q).



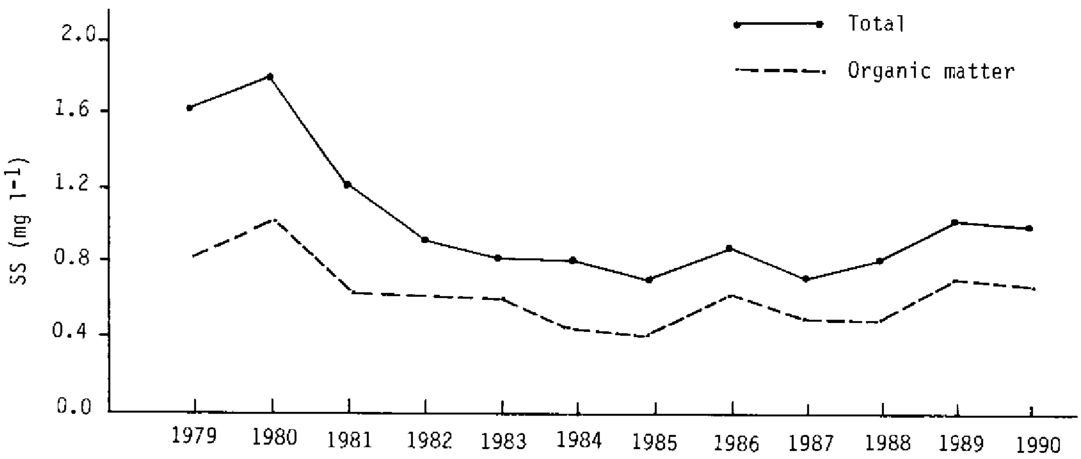
E2 pH

1981-1982

Season	Surface level	Bottom level
Spring	7.40-8.90	7.30-8.75
Summer	7.25-9.50	7.10-8.45
Autumn	7.25-7.65	7.25-7.60

E3 SS

Fig. EUR-37-5 Mean concentration of SS in the ultra-profundal zone, 1979-1990 [mg l^{-1}] (Q).



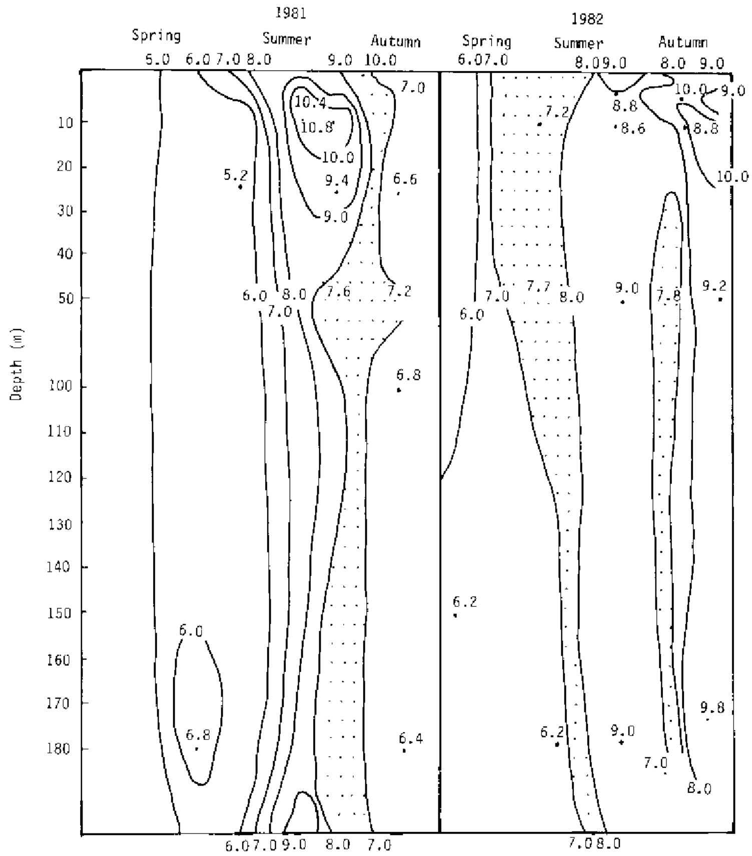
E4 DO [mg l^{-1}/%]

Ultra-profundal zone, 1987-1988

Depth [m]	1987 Jun	1987 Jul	1988 Jun	1988 Jul	1988 Aug
0	12.8 / 96	11.0 / 105	11.8 / 89	10.6 / 105	10.0 / 105
10	12.8 / 95	11.3 / 102	12.8 / 96	11.62 / 117	9.41 / 98
25	12.8 / 95	11.8 / 95	12.8 / 97	11.87 / 94	12.47 / 100
50	–	12.0 / 95	12.7 / 95	11.28 / 97	12.1 / 95
100	12.2 / 91	12.0 / 95	12.8 / 96	12.31 / 97	12.6 / 98
120	11.8 / 89	12.0 / 94	11.9 / 89	11.9 / 93	11.9 / 93

E5 COD

Fig. EUR-37-6 Seasonal and vertical distribution of organic carbon [mg C l^{-1}] in the ultra-profundal zone (Q).



E6 CHLOROPHYLL CONCENTRATION

Fig. EUR-37-7 Distribution of spring chlorophyll *a* concentration [$\mu g\ l^{-1}$], May 1981 (Q).

Fig. EUR-37-8 Distribution of summer chlorophyll a concentration [$\mu g\ l^{-1}$], averages for Aug., 1980-1982 (Q).

E7 NITROGEN CONCENTRATION

§ Total-N [mg l^{-1}]

Mean (range), 1986

Spring (May-Jun)	Summer (Jul-Aug)	Autumn (Sep-Oct)
0.61(0.45-0.90)	0.60(0.39-0.90)	0.55(0.42-0.91)

E8 PHOSPHORUS CONCENTRATION

§ Total-P [$\mu g\ l^{-1}$]

Mean (range), 1988-1989

Lake zone	1988			1989		
	Spring	Summer	Autumn	Spring	Summer	Autumn
Coastal	24 / 14-59	25 / 16-70	–	26 / 16-40	22 / 15-26	18 / 16-18
Declinate	25 / 16-27	20 / 12-36	–	24 / 18-40	2 / 14-27	18 / 16-26
Profundal	19 / 15-21	19 / 12-28	–	23 / 18-32	19 / 15-30	18 / 15-22
Ultraprofundal	19 / 17-20	19 / 14-30	–	21 / 20-24	18 / 13-24	18 / 15-20
Whole lake	20 / 14-59	19 / 12-70	–	22 / 16-40	19 / 13-30	18 / 15-26

E10 PAST TRENDS

§ Trend of DO

Profundal zone [mg l^{-1} (% saturation)]

Depth		May	Jun	Jul	Aug	Sep	Oct
10 m	1982	–	12.9 (97)	10.7 (84)	10.9 (92)	8.8 (81)	–
	1983	8.9 (68)	–	11.9 (105)	–	–	–
	1984	11.9 (89)	–	10.5 (84)	–	–	11.0 (98)
	1985	11.6 (109)	–	11.8 (97)	11.6 (97)	–	–
	1986	12.6 (94)	–	–	11.0 (101)	–	–
	1987	–	12.8 (95)	11.3 (102)	–	–	–
	1988	12.8 (96)	11.6 (117)	–	9.4 (98)	–	–
50 m	1981	–	–	–	12.9 (99)	–	10.9 (96)
	1982	–	12.6 (95)	8.9 (70)	11.6 (92)	10.2 (81)	–
	1983	9.5 (72)	–	13.0 (102)	–	–	–
	1984	13.1 (99)	–	–	–	–	–
	1985	12.3 (97)	–	12.3 (97)	12.5 (99)	–	–
	1986	12.3 (91)	–	–	12.0 (94)	–	–
	1987	–	–	12.0 (95)	–	–	–
	1988	–	12.8 (96)	12.3 (97)	12.6 (98)	–	–
120 m	1981	12.7 (94)	–	–	12.4 (97)	–	12.1 (95)
	1982	–	12.2 (92)	10.8 (85)	10.6 (83)	10.9 (86)	–
	1983	8.0 (61)	–	13.0 (102)	–	–	–
	1984	13.2 (99)	–	12.6 (99)	12.5 (98)	–	12.5 (99)
	1985	12.6 (99)	–	12.4 (97)	12.5 (98)	–	–
	1986	11.8 (89)	–	–	11.9 (94)	–	–
	1987	–	11.8 (89)	12.0 (94)	–	–	–
	1988	–	11.9 (89)	11.9 (93)	11.9 (93)	–	–

§ Trend of chlorophyll *a*

Mean-suspended (MS) and maximum (Max) concentrations of chlorophyll a in surface water in different seasons [$\mu g\ l^{-1}$]

Year	Spring (May-Jun)		Summer (Jul-Aug)		Autumn (Sep-Oct)	
	MS	Max	MS	Max	MS	Max
1976	2.5	7.8	2.1	6.4	–	–
1977	1.6	7.0	2.3	8.2	0.7	1.5
1978	2.9	5.9	3.7	38.9	5.0	5.3
1979	1.6	1.8	3.3	25.0	0.4	1.3
1980	2.8	10.0	1.8	7.0	1.9	5.3
1981	2.5	12.6	3.6	47.0	1.2	6.0
1982	2.4	15.0	2.4	21.5	0.8	6.5
1983	1.8	8.5	2.5	35.6	0.7	1.8
1984	1.7	5.3	0.7	3.2	0.4	1.2
1985	–	–	2.0	14.5	0.4	1.3
1986	2.9	13.5	2.1	7.0	0.6	1.7
1987	4.2	17.2	1.7	4.2	–	–
1988	1.7	5.1	1.3	14.3	1.6	4.1
1989	2.1	6.3	2.9	6.4	3.0	13.0(66.5)

§ Trend of nitrogen concentration

Mean (range) [mg l^{-1}]

	Spring (May-Jun)	Summer (Jul-Aug)	Autumn (Sep-Oct)
1981	0.73 (0.60-1.20)	0.74 (0.50-1.42)	0.66 (0.50-0.97)
1982	0.59 (0.45-0.95)	0.59 (0.43-0.99)	0.55 (0.50-0.87)
1983	0.83 (0.71-1.44)	0.69 (0.61-1.26)	—
1984	0.77 (0.52-1.12)	0.53 (0.42-0.86)	0.66 (0.55-1.12)
1986	0.61 (0.45-0.90)	0.60 (0.39-0.90)	0.55 (0.42-0.91)

§ Trend of phosphorus concentration

Total-P [$\mu g\ l^{-1}$]

Zone		Spring	Summer	Autumn
Coastal	1981	42	37	49
	1982	35	37	44
	1983	30	36	23
	1984	33	35	38
	1986	30	40	34
	1987	39	50	—
	1988	24	25	—
	1989	26	22	18
Ultraprofundal	1981	21	29	21
	1982	23	20	19
	1983	24	20	—
	1984	24	24	24
	1986	17	22	26
	1987	21	22	—
	1988	19	19	—
Whole lake	1981	24	28	21
	1982	24	23	22
	1983	24	24	21
	1984	24	24	23
	1986	18	24	27
	1987	21	24	—
	1988	20	19	—
	1989	22	19	18

F. BIOLOGICAL FEATURES

F1 FLORA (7, 9)

§ Emerged macrophytes

Phragmites australis, *Scolochloa festucacea*, *Glyceria maxima*, *Scirpus lacustris*, *Eleocharis palustris*, *Equisetum fluviatile*.

§ Floating macrophytes

Nuphar lutea, *Polygonum amphibium*, *Potamogeton natans*, *Hydrocharis morsus-ranae*, *Stratiotes aloides*, *Sparganium emersum*.

§ Submerged macrophytes

Potamogeton perfoliatus, *P. gramineus*, *Elodea canadensis*, *Myriophyllum spicatum*.

§ Phytoperiphyton

Spring (*Tabellaria fenestrata*, *Fragilaria crotonensis*), summer (*Oedogonium* sp., *Cladophora glomerata*, *Ulothrix zonata*).

§ Phytoplankton

Spring (*Aulacosira islandica, Asterionella formosa, Diatoma elongatum*), summer (*A. formosa, Fragilaria crotonensis, Tribonema affine, Oscillateria tenuis, O. planctonica, Aphanizomenon flos-aque*), autumn (*Woronichinia naegeliana, Aulacosira islandica, Tribonema depauperatum, Aphanizomenon flos-aque*).

F2 FAUNA (8, 10, 11)

§ Zooplankton

Spring (*Cyclops abyssorum, Limnocalanus macrurus, Eudiaptomus gracilis, Keratella quadrata, Kellicotia longispina*), summer (*Asplanchna priodonta, Limnocalanus macrurus, Cyclops abyssorum, Mesocyclops olthonoides, Bosmina obtusirostris, Daphnia cristata*).

§ Benthos

Pontoporeia affinis, Lamprodrilus isoporus, Peloscolex ferox, Procladius, Cryptochironomus, Isochaetides newaensis, Trissocladius paratatricus, Prodiamesa bathyphila, Polypedilum, Stylodrilus heringianus, Potamothrix hammoniensis, Pallasea quadrispinosa.

§ Fish

46 species ; *Coregonus lavaretus, C. abula, Osmerus eperlanus, Stizostedion luciperca, Perca fluviatilis, Lota lota, Salmo salar.*

§ Supplementary notes on the biota

Relict species: *Pontoporeia affinis, Pallasea quadrispinosa, Mysis oculata* var. *relicta, Mesidothea entomon.*

F3 PRIMARY PRODUCTION RATE (Q)

Mean daily rates of phytoplankton production, 1989 [μg C m^{-2}]

Season	Lake zone				Whole lake mean
	Coastal	Declinate	Profundal	Ultra-profundal	
Spring	160	732	537	164	454
Summer	1,026	805	943	1,605	1,031
Autumn	623	119	252	168	275

Production rates of basic seasonal complexes of phytoplankton ; mean value (range)

Complex	Chlorophyll *a* content [μg l^{-1}]	Daily production [μg C l^{-1}]
Spring		
Aulacosira (thermo-active area)	2.7 (0.4-7.2)	324 (19-1,183)
Aulacosira (thermoinert area)	0.2 (0.02-2.6)	13 (3-36)
Aulacosira-Asterionella (thermoactive area)	1.7 (0.9-3.5)	171 (65-315)
Aulacosira-Diatoma (thermoninert area)	2.1 (1.9-4.9)	391 (109-1,050)
Summer		
Asterionella	1.4 (0.5-11.7)	45 (13-210)
Asterionella-Diatoma	3.5 (1.7-8.2)	273 (68-492)
Asterionella-Tribonema	2.4 (2.3-2.5)	123 (74-452)
Trinonema	1.6 (0.6-3.3)	180 (49-173)
Tribonema-Peridinea	1.4 (0.2-3.5)	109 (42-294)
Fragilaria	1.4 (0.9-1.5)	127 (78-177)
Oscillatoria	1.6 (0.2-2.4)	270 (120-387)
Aphanizomenon	2.3 (0.2-21.3)	117 (14-1,390)
Microcystis	3.0 (0.2-6.3)	237 (7-4,220)
Autumn		
Woronichinia	0.6 (0.2-1.0)	69 (42-96)
Aulacosira-Tribonema	1.1 (0.3-1.6)	27 (2-97)

F4 BIOMASS (Q)

§ Macrophytes

Average biomass per water surface : 3.1 [g (dry wt) m^{-2}].
Biomass of *Phragmites* : 529-1,820, average 929 [g m^{-2}].
Biomass of *Scirpus* : 280-660 [g m^{-2}].
Biomass of *Potamogeton perfoliatus* : 105-340 [g m^{-2}].

§ Phytoperiphyton

Biomass of *Ulothrix zonata* : 200-400 [mg cm^{-2}] on substrata at 0.0-0.5 m depth.
Biomass of diatoms : ca. 1 [mg cm^{-2}] at depths more than 0.5 m in the northern part of the lake.
Periphyton biomass : ca. 2.0 [mg cm^{-2}] in the southern part of the lake.

§ Zoobenthos

Average biomass : 2.5 [g m^{-2}] (wet wt.).

F5 FISHERY PRODUCTS

§ Annual fish catch in 1986 : 5,527 (total 8,000 including angling) [metric tons] (Q).

F6 PAST TRENDS (Q)

§ Trend of phytoplankton production [μg C m^{-2}]

Season	Year	Lake zone				Whole lake mean
		Coastal	Declinate	Profundal	Ultra-profundal	
Spring	1976	87	46	22	5	40
	1977	351	568	205	53	276
	1978	615	1,090	388	100	511
	1981	526	711	85	16	232
	1982	262	728	51	34	210
	1983	1,515	784	152	121	696
	1984	198	135	52	23	102
	1985	319	240	172	32	199
	1986	439	345	291	40	296
	1987	273	559	24	4	232
	1988	480	585	131	60	327
	1989	160	732	537	164	454
Summer	1976	71	470	111	230	147
	1977	391	479	375	554	435
	1978	640	1,852	1,527	224	946
	1981	387	902	414	475	434
	1982	310	497	391	576	360
	1983	346	144	67	135	158
	1984	158	227	200	329	221
	1985	2,442	1,809	2,480	3,726	2,482
	1986	554	1,328	1,029	1,575	1,111
	1987	248	250	375	252	291
	1988	751	332	465	251	449
	1989	1,026	805	943	1,605	1,031
Autumn	1977	55	20	72	7	52
	1981	235	115	85	117	135
	1982	142	89	199	240	174
	1983	14	44	40	40	34
	1984	124	10	9	12	34
	1985	254	216	125	84	172
	1986	90	75	82	48	76
	1987	114	68	84	62	82
	1988	480	220	432	47	314
	1989	623	119	252	168	275

Annual production, whole lake average [g C m^{-2}]

Year	Production	Year	Production
1976	14.7	1984	20.6
1977	46.4	1985	139.5
1978	88.1	1986	75.8
1979	48.1	1987	38.1
1982	44.9	1988	65.3
1983	54.5	1989	96.5

§ Trend of the average number of bacterioplankton in summer [10^6 cells ml^{-1}]

Year	Lake zone	Total number of bacterioplankton	
		Epilimnion	Hypolimnion
1980	Coastal	0.84	–
	Declinate	0.70	0.41
	Profundal	0.61	0.14
	Ultra-profundal	0.42	0.12
	Whole lake	0.67	0.24
1981	Coastal	0.80	–
	Declinate	1.00	0.39
	Profundal	1.00	0.29
	Ultra-profundal	1.20	0.23
	Whole lake	1.00	0.30
1982	Coastal	1.00	–
	Declinate	0.85	0.49
	Profundal	0.91	0.36
	Ultra-profundal	0.85	0.34
	Whole lake	0.90	0.40
1983	Coastal	0.84	–
	Declinate	0.75	–
	Profundal	0.70	–
	Ultra-profundal	0.40	–
	Whole lake	0.72	–
1984	Coastal	0.50	–
	Declinate	0.70	0.51
	Profundal	0.90	0.43
	Ultra-profundal	0.70	0.47
	Whole lake	0.72	0.47
1985	Coastal	0.70	–
	Declinate	0.90	0.63
	Profundal	0.90	0.41
	Ultra-profundal	0.90	0.54
	Whole lake	0.86	0.52

§ Trend of fishery production [t yr^{-1}]

Year	Catch
1981	6,915
1982	6,770
1983	5,540
1984	6,461
1985	5,091
1986	5,527

Fig. EUR-37-9 Zooplankton biomass [g m^{-2}] at 0-10 m depth in Jul.-Aug., 1983 (Q).
1) <10, 2) 10-30, 3) >30.

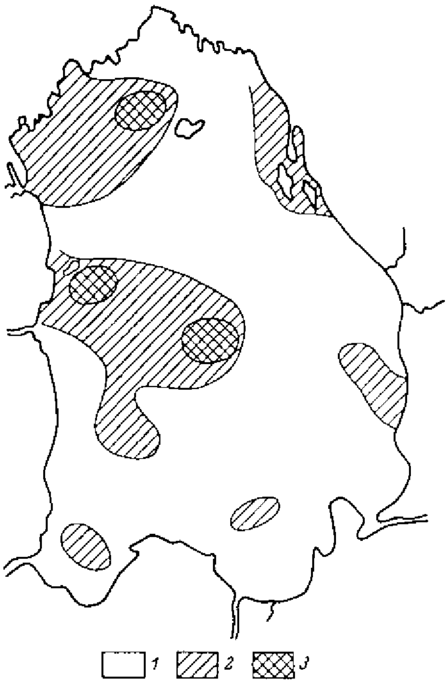


Fig. EUR-37-10 Biomass of Oligochaeta [mg (fresh wt) m^{-2}] (Q).
1) <20, 2) 21-50, 3) 51-100, 4) 101-200,
5) 201-400, 6) 401-800, 7) >800.

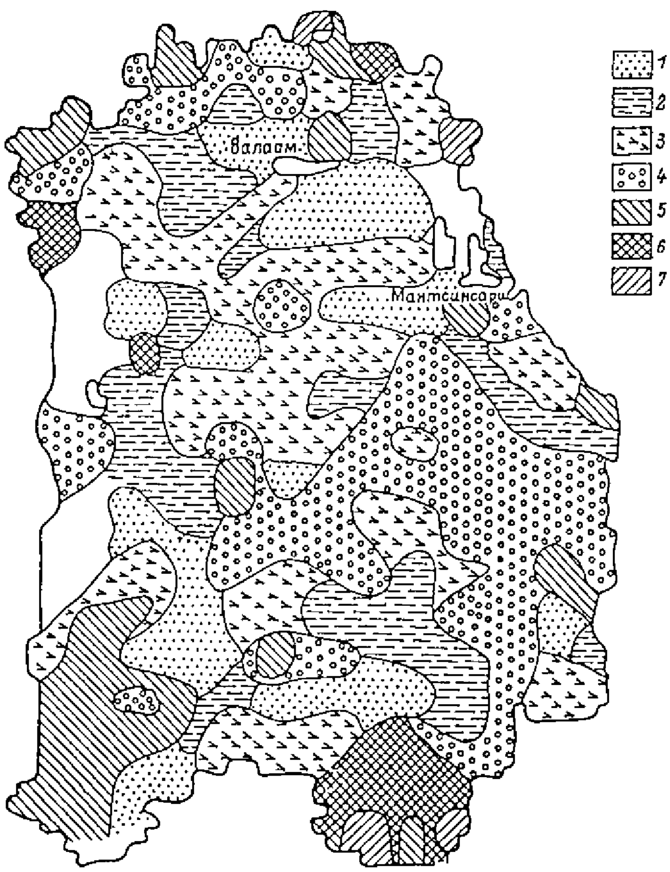


Fig. EUR-37-11 Biomass of Amphipoda [mg (fresh wt) m^{-2}] (Q). For legends see Fig. EUR-37-10.

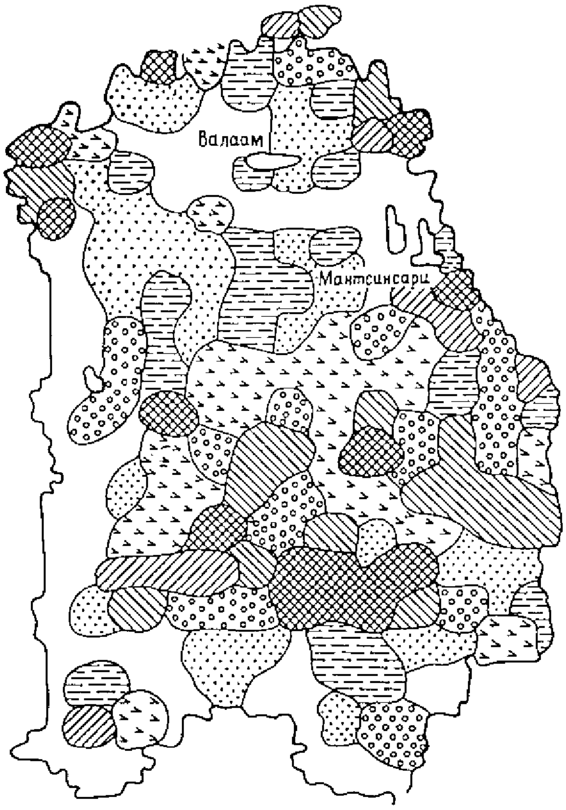


Fig. EUR-37-12 Biomass of Mollusca [mg (fresh wt) m^{-2}] (Q). For legends see Fig. EUR-37-10.

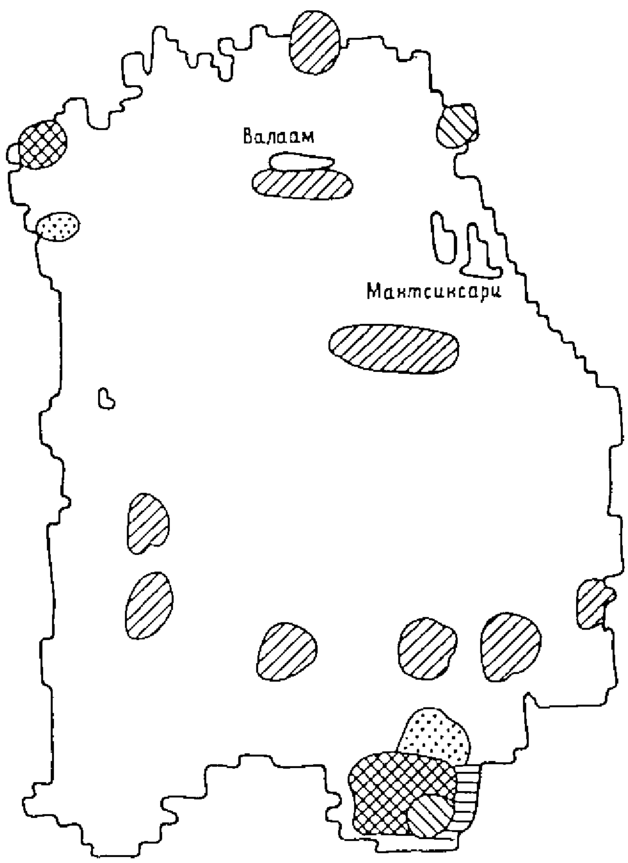


Fig. EUR-37-13 Biomass of Chironomidae [mg (fresh wt) m^{-2}] (Q).
1) <10, 2) 10-20, 3) 21-40, 4) 41-80,
5) 81-160, 6) 161-320, 7) 320-640.

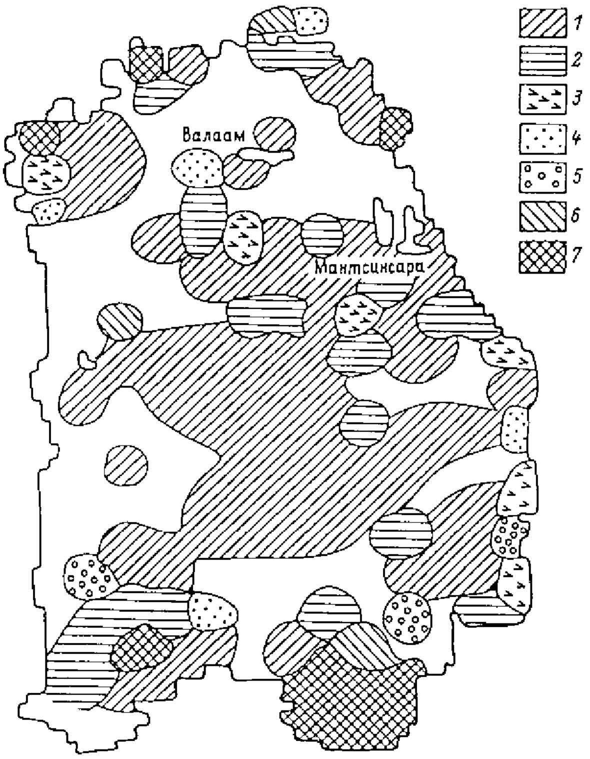
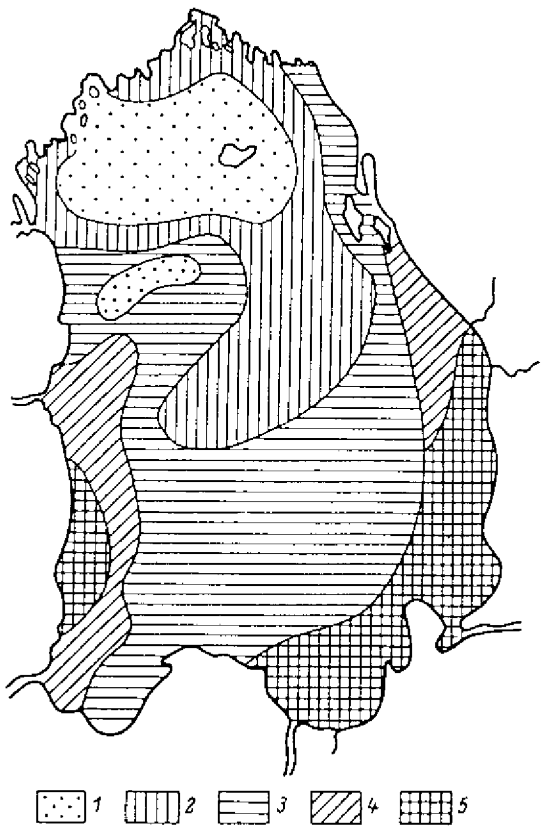


Fig. EUR-37-14 Biomass of meiobenthos [mg m^{-2}] (Q).
1) <150, 2) 150-300, 3) 301-600, 4) 601-1,200, 5) >1,200.



G. SOCIO-ECONOMIC CONDITIONS (Q)

G1 LAND USE IN THE CATCHMENT AREA (1987)

	Area [km^2]	[%]
Natural landscape		
Woody vegetation	51,180	73.0
Swamp	7,250	10.3
Others	2,460	3.5
Agricultural land		
Crop field	2,140	3.1
Pasture land	960	1.4
Settlement area	1,420	2.0
Others	4,710	6.7
Total	70,120	100.0

§ Types of important forest vegetation : Pine and fir.
§ Types of the other important vegetation : Peat-bogs.
§ Main kinds of crops and/or cropping system : Vegetable-growing.
§ Levels of fertilizer application on crop fields : Moderate.

G3 POPULATION IN THE CATCHMENT AREA (1987)

	Population	Population density [km^{-2}]	Main cities
Urban	688,000	9.8	Nowgorod, Tikhvin,
Rural	216,000	3.1	Kirishi, Volkhov,
			Pikalevo, Lodeynoye Pole
Total	904,000	12.9	

H. LAKE UTILIZATION (Q)

H1 LAKE UTILIZATION (1990)

Source of water, navigation and transportation, sightseeing and tourism, recreation (swimming, sport-fishing, yachting) and fisheries.

H2 THE LAKE AS WATER RESOURCE*

	Use rate [m^{3}sec^{-1}]
Domestic water	26.3
Industrial water	28.2
Power plant	–
Agricultural	1.5
Others	1.4
Total	57.4

* With calculation by Leningrad water-supply.

I. DETERIORATION OF LAKE ENVIRONMENTS AND HAZARDS (Q, 1, 2, 8, 9, 16)

I1 ENHANCED SILTATION

§ Extent of damage : Not serious.

I2 TOXIC CONTAMINATION

§ Present status : Detected but not serious.

§ Metal concentration

Mean/range [$\mu g\ l^{-1}$], 1982-1986

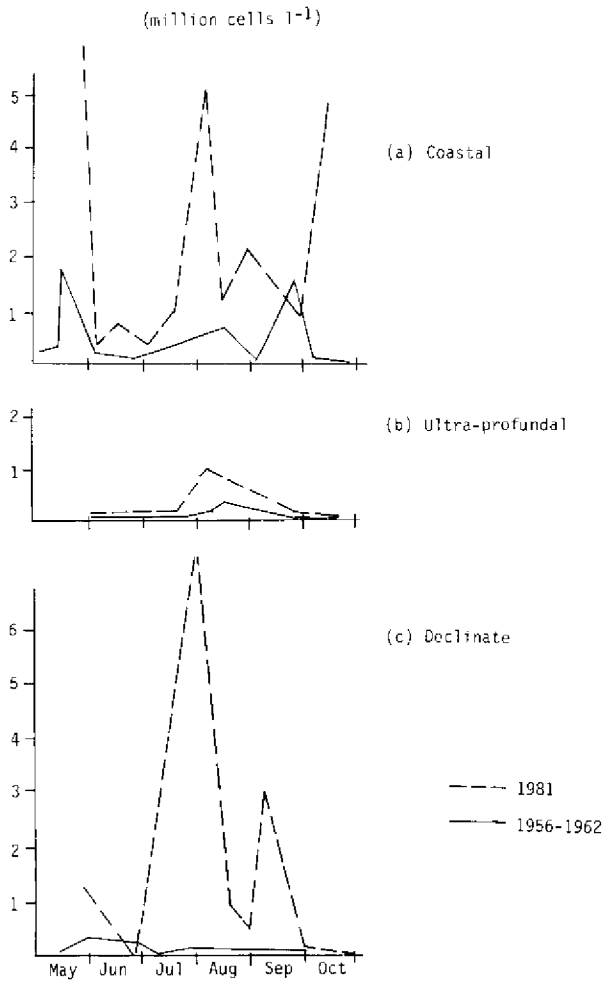
Ion/Lake zone	Coastal	Declinate	Profundal	Ultra-profundal	Whole lake
Fe	225 / 45-1,150	160 / 45-1,730	118 / 33-890	91 / 15-250	148 / 15-1,730
Al	88 / 12-420	63 / 19-240	51 / 12-210	40 / 10-150	60 / 10-420
Mn	17.0 / 1.8-100	9.0 / 1.2-135.0	5.2 / 1.0-80.0	2.2 / 0.5-7.0	8.4 / 0.5-135.0
Cu	6.7 / 1.0-22.0	6.7 / 1.0-24.5	5.8 / 1.4-15.5	5.7 / 0.5-18.9	6.0 / 0.5-24.5
Pb	1.5 / 0.5-4.0	1.6 / 0.5-5.5	1.5 / 0.5-6.0	1.6 / 0.5-4.5	1.6 / 0.5-6.0

I3 EUTROPHICATION

§ Nuisance caused by eutrophication

Unusual algal bloom (*Aulacosira islandica, Diatoma elongatum, Microcystis aeruginosa, Aphanizomenon flos-aque, Woronichinia naegeliana, Tribonema affine*), disturbed filtration in cleaning beds.

Fig. EUR-37-15 Changes in the seasonal dynamics of phytoplankton population during the process of anthropogenic eutrophication (Q).



§ Nitrogen and phosphorus loadings to the lake [t yr^{-1}] (1987)

Sources	Industrial	Domestic	Agricultural	Aerial	Natural	Total
T-N	–	–	–	–	–	81,200
T-P	2,500	700	1,400	400	1,200	6,200

I4 ACIDIFICATION

§ Extent of damage: Detected but not serious (due to atmospheric transport).

J. WASTEWATER TREATMENTS (Q)

J1 GENERATION OF POLLUTANTS IN THE CATCHMENT AREA: (d) Measurable pollution with limited wastewater treatment.

J2 APPROXIMATE PERCENTAGE DISTRIBUTION OF POLLUTANT LOADS

	Percentage of Total-P [%]
Point sources	
Municipal (domestic wastewater)	11
Industrial wastewater	40
Non-point sources	
Agricultural runoff	23
Aerial precipitation	6
Natural sources	20
Total	100

L. DEVELOPMENT PLANS (Q)

Project "Ladoga".

M. LEGISLATIVE AND INSTITUTIONAL MEASURES FOR UPGRADING LAKE ENVIRONMENTS (Q)

M1 NATIONAL AND LOCAL LAWS CONCERNED

§ Names of the laws (the year of legislation)

(1) Principles of Water Laws for USSR and Soviet Republics, Suprime Council of the USSR (1970)

(2) About Measures on Protection Intensification of Baltic Sea from Pollution, Council of Ministers of USSR (1976)

(3) RSFSR Water Code, Suprime Council of RSFSR (1980)

(4) About Additional Measures on Ensuring of Protection and Rational Use of Water and Other Natural Resources in Lakes Ladoga, Onega and Ilmen, Council of Ministers of USSR (1984)

§ Responsible authorities

(1) State Sanitary Inspection

(2) State Fish Inspection

(3) North-Western Administration of State Committee of Hydrometeorology

(4) USSR State Committee for Environment Protection, Leningrad Branch

§ Main items of control

(1) Toxic substances (ions of heavy metals and others)

(2) Phenols, oil, pollutants of industrial, domestic and agricultural origin

M3 RESEARCH INSTITUTES ENGAGED IN THE LAKE ENVIRONMENT STUDIES

(1) Institute of Limnology, Academy of Science of USSR, Leningrad

(2) State Research Institute for Fish Industry (GosNIORCH), Leningrad

N. SOURCES OF INFORMATION

(Q) Questionnaire filled by Dr. I. M. Raspopov, Institute of Limnology, Academy of Science of USSR, Leningrad.

(1) Arkhangelsky, A. D. (1947, 1948) Geological Structure and Geological History of the USSR. 415 pp. (I) and 372 pp. (II). Publ. House Ac. Sci. USSR, Moscow (In Russian).

(2) Semenovich, N. I. (1966) Bottom Sediments of Lake Ladoga. Publ. House Ac. Sci. USSR. 124 pp. Moscow and Leningrad (In Russian).

(3) Malinina, T. I. (ed.) (1966) Hydrological Regime and Balance of Lake Ladoga. 324 pp. Publ. House Ac. Sci. USSR, Leningrad (In Russian).

(4) Tikhomirov, A. I. (1982) Thermal Structure of Large Lakes. 232 pp. Publ. House Nauka, Leningrad (In Russian).

(5) Climate of USSR Reference Book (1974) Publ. House Hydrometeoizdat, Leningrad, 284 pp. (In Russian).

(6) Long Standing Data of Conditions and Resources of Inland Surface Waters, 1 (5) (1986) Publ. House Hydrometeoizdat, Leningrad, 688 pp. (In Russian).

(7) Petrova, N. A. (ed.) (1982) Anthropogenic Eutrophication of Lake Ladoga. 304 pp. Publ. House Nauka, Leningrad (In Russian).

(8) Petrova, N. A. & Raspletina, G. F. (eds.) (1987) Natural State of the Lake Ladoga Ecosystem. 213 pp. Publ. House Nauka, Leningrad (In Russian).

(9) Raspopov, I. M. (1985) Higher Auqatic Vegetation of Large Lakes in the Northwestern Area of the USSR. 200 pp. Publ. House Nauka, Leningrad (In Russian).

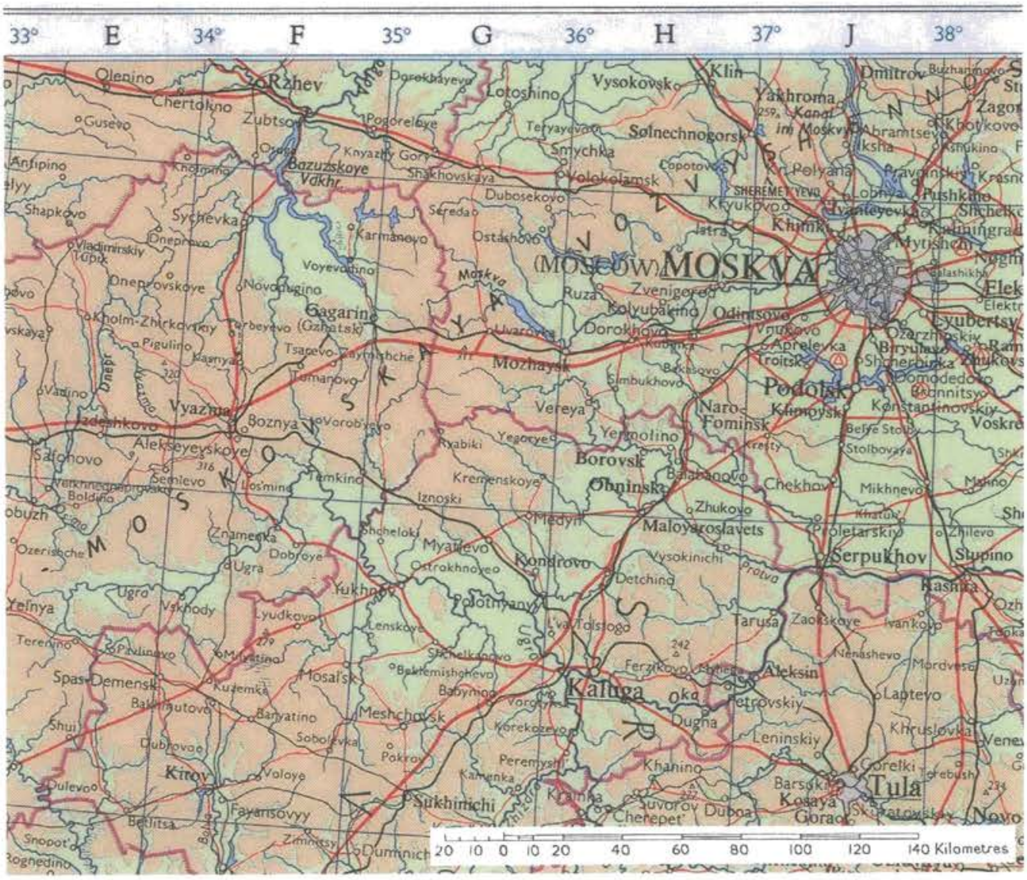
(10) Menshutkin, V. V., Slepukhina, T. D., Menshutkina, M. V. & Suvorova, T. P. (1986) Distribution of bottom invertebrates, eatable for fish in Lake Ladoga. In : Biological Characteristics of Trade Fish in Lake Ladoga and Finnish Gulf and Their Economical Use, pp. 76-89, Leningrad (In Russian).

(11) Fedorova, G. V. (1987) Fish catch from Lake Ladoga and causes of its fluctuations. Trudy GosNIORCH, Leningrad, 266, pp. 3-10 (In Russian).

MOZHAYSK RESERVOIR

A view on the lakeshore

Photo: S. G. Tushinsky



A. LOCATION

§ Mozhaysk District, Moscow Region*.
§ 55°30′N-35°50′E ; 183 m above sea level.
* Place names are not up-dated.

B. DESCRIPTION

Mozhaysk Reservoir was formed by the construction of Mozhaysk Dam (1955-1960) in the upper reaches of the Moskva River 94 km downstream from its source, within the framework of the Hydroproject Scheme commanded by the Water Supply and Sewerage Board of Moscow Municipality Executive Committee. After its completion in 1961, this small reservoir forms, together with similar three reservoirs (Rouza, Ozerna and Istra Lake), the Moskva River System which provides about 50 % of water for municipal and industrial uses by more than nine million inhabitants of the capital city Moscow.

The reservoir stores runoff water from the Moskva River and its two tributaries, the Koloch and the Lousyanka River. The Koloch is dammed at its mouth to protect the old field of Borodino Battle (1812) from submergence, the river water being pumped up to the Mozhaysk Reservoir. Another tributary, the Bodnya, is also dammed to reduce flooded areas and its flow is diverted into an adjacent basin by a canal.

According to the morphogenetic classification of man-made lakes, Mozhaysk Reservoir is referred to as the morphologically simple reservoirs of flood plain/valley type. Its bed is part of a very old (formed more than 100 million years ago) valley filled up by glacial deposits 30-50 m in thickness, in which a narrow (2 km wide) and deep (up to 25 m) trench was dug by the Moskva River. The mean gradient of the valley bed is 6 m km^{-1}.

The water quality of the reservoir satisfies the requirements of USSR state standards for potable water. Water is discharged through the surface and bottom outlets at a mean rate of 9.4 m^3 sec^{-1} (range from 1.5 to 350-400 m^3 sec^{-1}). The rate of water exchange is not large, being larger in spring than in summer.

The catchment extends over the southwestern slopes of Smolensk-Moscow Hills and is characterized by gentle hilly relief with a miximum height of 310 m above sea level. The catchment area is covered by podsols under mixed spruce-birch forests, meadows and arable lands. There are neither cities nor towns and the construction of industrial plants is prohibited. Thanks to these conditions, the water quality of tributaries remains more or less stable, though nutrient loads from arable lands and livestock farms have increased during the last ten years.

The Mozhaysk Reservoir is intensively used for recreational activities of Moscovites and local residents. Within the catchment of the reservoir, sport fishing is popular and there are a lot of hunting bases, sanatoriums, holioday homes, children's summer camps and country cottages. For the protection of water resources, it is of prime importance to control eutrophication, recreational load, fish fauna composition and fishing activities (Q, 1-6, 9).

C. PHYSICAL DIMENSIONS (2)

Surface area [km^2]	30.7
Volume [$10^6 m^3$]	235
Maximum depth [m]	22.6
Mean depth [m]	7.7
Normal range of annual water level fluctuation [m] (regulated)	4.8 (range 2.7-6.6) (1961-1988)
Length of shoreline [km]	119
Residence time [yr]	0.54 (range 0.36-1.03) (1961-1987)
Catchment area [km^2]	1,335

D. PHYSIOGRAPHIC FEATURES

D1 GEOGRAPHICAL

§ Bathymetric map (Fig. EUR-38-1).
§ Main islands (name and area): Myshkin (0.05 km^2), Goroshkov (0.03 km^2).
§ Outflowing rivers and channels (number and names): 1 (Moskva R.).

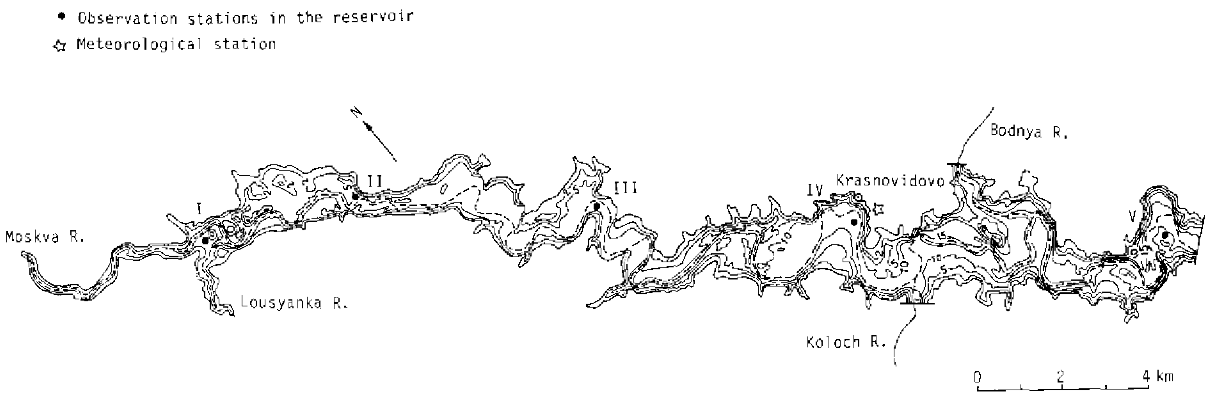
D2 CLIMATIC

§ Climatic data at Krasnovidovo, 1987-1989

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean temp. [°C]	-10.2	-5.3	-3.1	3.9	12.4	17.7	17.9	15.0	9.8	3.8	-4.1	-7.3	4.2
Precipitation [mm]	22	31	40	29	50	91	71	73	41	32	41	56	577

§ Number of hours of bright sunshine at Moscow (1958-1987): 1,739 hr yr^{-1}.
§ Average solar radiation at Moscow (1958-1987): 10.1 MJ $m^{-2}day^{-1}$.
§ Average solar radiation, reaching the reservoir surface during ice free period (1961-1969): 11.1 MJ m^{-2} day^{-1} (1).
§ Average depth of maximum snow accumulation [cm] (Krasnovidovo, 1987-1989): 44 in the forest, 40 in the field, 21 on the surface of the reservoir.

Fig. EUR-38-1 Bathymetric map [m] (Q).



§ Water temperature [°C] (Q)
Station IV, 1983-1986

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.5	0.4	0.3	0.4	3.1	15.1	17.7	19.5	19.4	14.8	7.8	3.4	0.6
1	0.7	0.6	0.8	2.6	14.8	17.5	19.4	19.3	14.8	7.8	3.4	0.8
3	1.1	1.1	1.4	2.4	13.4	16.9	18.8	19.0	14.8	7.8	3.5	1.0
5	1.2	1.3	1.7	2.7	11.5	15.9	17.9	18.8	14.8	7.8	3.5	1.4
7	1.5	1.6	1.5	2.3	9.3	14.2	17.0	18.4	14.8	7.7	3.5	2.1
9	2.0	1.7	1.5	2.4	7.7	12.9	16.2	17.9	14.7	7.7	3.6	2.7
11	2.2	2.0	1.8	2.5	7.3	11.6	15.3	17.1	14.6	7.7	3.7	2.8
13	2.6	–	–	2.7	7.1	11.2	14.6	16.5	14.6	7.7	3.7	3.4
15	–	–	–	2.7	7.1	11.2	13.6	15.1	14.6	7.7	–	–

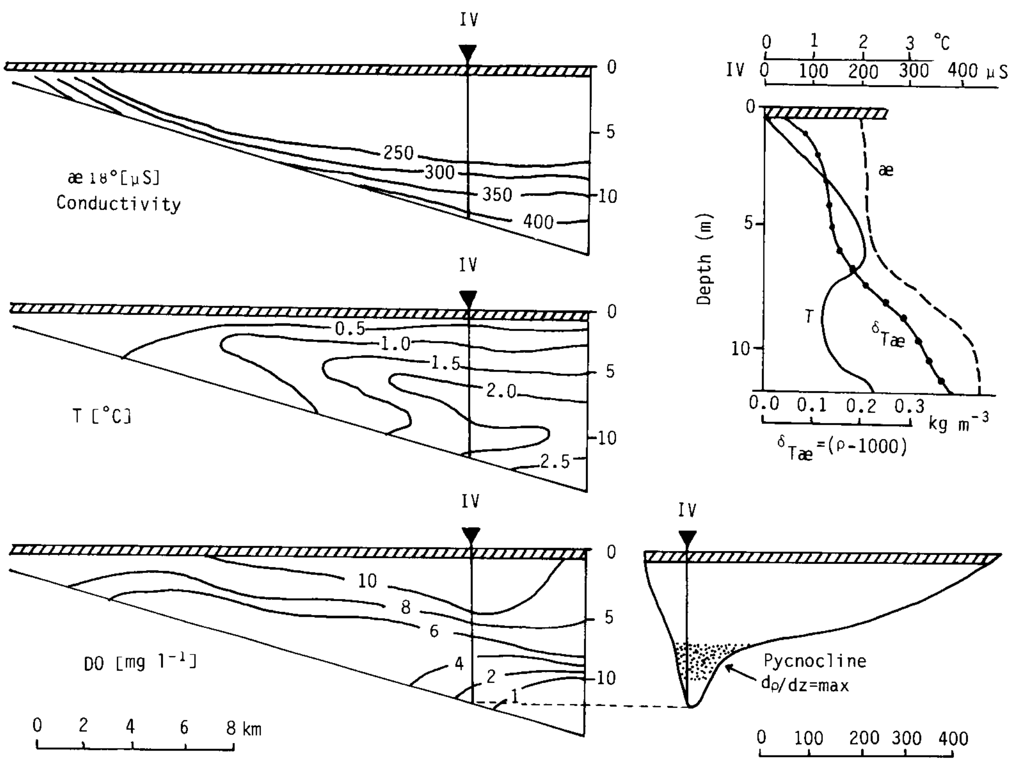
§ Freezing period (mean of 1961-1989) : From Nov. 19 to Apr. (130-170 days) ; ice thickness up to 85 cm.

§ Mixing type : Dimictic.

§ Notes on water mixing and thermocline formation

The thermocline is usually formed in May. By July in upper and middle parts of the reservoir the thermocline submerges to the bottom of inundated flood plain, and remains until September only in the river-bed and in the Weir reach. The maximum thermal gradients in thermocline reach 6°C m^{-1} (1). The thermocline with thermal gradient up to 2°C m^{-1} appears on the upper boundary of density current during icebound period (Fig. EUR-38-2). Annually this current takes place in the river-bed owing to moving of cooler and more mineralized waters of the Moskva and Lousyanka River in winter (density is 1,000.23 kg m^{-3}), flowing under less dense (1,000.15 kg m^{-3}) water of the reservoir. The rate of the river water movement from the upper reaches to the Mazhaysk Dam is about 1 cm sec^{-1}. The density gradient reaches 0.135 kg m^{-3} in the upper layer of the density current (7). Similar density currents occur in three other reservoirs of the Moskva River System (2).

Fig. EUR-38-2 Water mixing and thermocline formation in winter (Q).



E. LAKE WATER QUALITY (Q)

E1 TRANSPARENCY [m]

Station IV, 1983-1986

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
–	–	–	1.0	1.0	2.6	1.9	1.1	1.3	1.7	1.6	–

E2 pH

Station IV, 1990

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.5	7.8	8.2	7.7	8.0	8.8	8.7	8.8	8.3	8.0	8.1	7.8	–
15	7.8	8.0	7.7	7.8	8.0	7.8	8.0	8.1	8.0	7.3	7.8	–

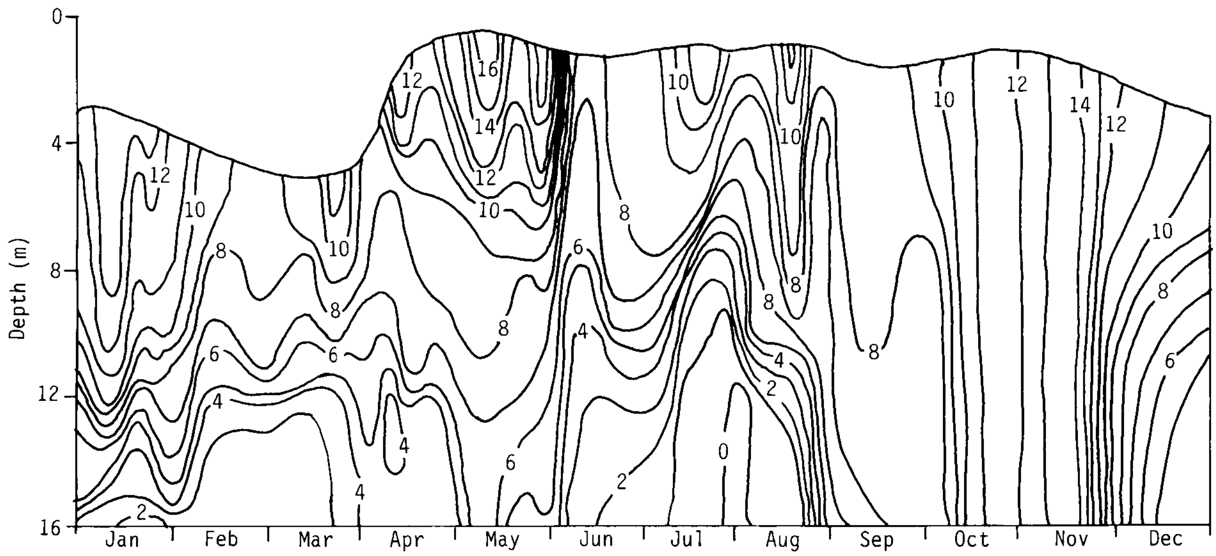
E3 SS [mg l^{-1}]

Station IV, 1990

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.5	1.5	1.2	2.5	3.0	6.0	4.0	5.6	5.8	4.2	5.1	6.8	–
6	–	–	–	–	5.9	2.5	4.3	3.8	–	4.8	–	–
15	1.9	1.2	3.0	3.0	15.3	5.5	9.0	5.7	4.7	5.4	6.0	–

E4 DO

Fig. EUR-38-3 Seasonal change of DO [mg l^{-1}] profile, Station IV, 1984 (Q).



§ Supplementary notes

During the period of intensive phytoplankton growth, DO values at 0.3 m depth may reach 19.6 mg l^{-1} (220 % of saturation) with its horizontal gradient up to 2.8 mg l^{-1} per 100 m, indicating irregular distribution of DO in the surface layer (9).

E5 COD [mg l^{-1}]

Determined by $K_2Cr_2O_7$ method.

Station I, 1984

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	11.7	–	12.2	17.2	22.7	12.3	41.9	27.7	–	23.7	16.2	10.8
3	11.5	–	14.0	15.2	20.5	14.0	19.4	22.4	–	21.8	15.6	10.3
5	–	–	16.2	16.3	20.1	11.7	24.1	21.1	–	22.7	17.0	8.6

Station II, 1984

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	8.7	–	13.2	19.3	19.0	13.7	34.6	24.2	–	19.0	17.2	31.8
3	12.1	–	11.4	18.6	20.4	13.8	36.6	25.1	–	16.9	19.2	18.3
5	–	–	12.0	18.4	20.6	12.0	33.0	24.5	–	22.6	16.9	10.0
7	–	–	–	17.5	20.6	12.1	31.3	25.0	–	16.6	17.0	11.7
9	–	–	–	18.2	21.2	13.2	30.7	–	–	–	–	–

Station III, 1984

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	20.7	–	18.0	14.0	20.1	14.3	60.2	21.4	–	17.9	16.3	17.3
3	15.7	–	16.8	15.8	20.0	13.2	36.4	21.9	–	16.2	16.2	16.8
5	13.2	–	40.8	15.6	20.1	14.0	25.0	21.3	–	17.9	18.6	16.2
7	14.4	–	9.9	14.4	21.7	10.9	27.0	16.5	–	20.2	15.2	20.1
9	–	–	–	14.3	19.8	11.8	21.7	17.0	–	29.8	16.8	14.6
11	–	–	–	14.7	18.0	13.1	28.2	18.9	–	20.2	–	–

Station IV, 1984

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	17.1	–	17.1	13.2	17.4	13.7	48.8	20.5	–	13.6	15.1	18.0
3	14.7	–	17.4	13.7	19.3	12.8	20.4	28.3	–	15.2	14.5	20.0
5	18.4	–	18.1	13.7	17.6	11.2	28.9	31.7	–	15.4	15.8	19.9
7	15.3	–	17.4	15.3	16.3	12.0	20.7	21.4	–	19.0	14.9	17.3
9	15.3	–	11.3	13.7	16.1	13.1	28.0	16.6	–	21.6	13.9	21.7
11	14.7	–	11.4	13.7	17.3	14.3	18.6	15.4	–	20.5	16.2	15.4
13	16.0	–	–	13.5	15.7	12.6	21.5	16.0	–	19.3	14.6	15.6
15	–	–	–	14.4	20.9	10.6	27.2	19.6	–	19.1	15.2	–

Station V, 1984

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	15.8	–	20.1	21.5	21.5	10.6	41.6	39.2	–	13.6	14.8	15.4
3	–	–	16.2	14.1	34.8	8.1	46.2	38.2	–	12.4	14.9	16.6
5	15.1	–	15.6	11.0	20.8	11.8	39.5	30.1	–	15.2	15.6	16.3
7	–	–	15.9	11.8	17.4	11.7	31.5	15.7	–	15.2	11.4	17.9
9	16.5	–	14.9	11.9	18.0	10.0	16.7	16.5	–	16.5	13.2	21.8
11	–	–	14.8	13.7	18.3	11.5	13.2	16.2	–	16.2	13.5	19.8
13	13.5	–	12.6	11.8	15.4	11.4	12.1	16.2	–	14.6	14.6	19.3
15	–	–	15.4	10.4	14.8	11.2	13.1	17.9	–	13.2	13.5	19.9
17	15.9	–	–	11.2	17.0	10.3	14.1	17.6	–	17.1	13.5	17.3
19	–	–	–	9.7	15.1	9.4	14.9	18.4	–	15.7	15.6	–

E6 CHLOROPHYLL CONCENTRATION [$\mu g\ l^{-1}$]

Mean concentration at 0.5 m depth for 1971, 1983, 1986, 1987

	May	Jun	Jul	Aug	Sep
Station I	4	2	22	28	32
Station III	15	32	25	67	13
Station IV	28	16	13	50	16
Station V	22	17	16	65	5

E7 NITROGEN CONCENTRATION

§ NH_4-N [mg l^{-1}]

Station I, 1984

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	0.34	–	0.05	0.11	0.13	0.13	0.21	0.22	–	0.47	–	–
3	0.32	–	–	0.09	0.23	0.09	0.22	0.12	–	0.41	–	–
5	–	–	–	0.15	0.25	0.10	0.33	0.17	–	0.44	–	–

Station II, 1984

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	0.39	–	0.07	0.21	0.19	0.17	0.17	0.27	–	0.23	0.14	0.20
3	0.82	–	0.00	0.13	0.17	0.14	0.21	0.24	–	0.22	0.14	0.08
5	–	–	0.37	0.22	0.20	0.27	0.39	0.25	–	0.14	0.14	0.09
7	–	–	–	0.17	0.50	0.64	0.94	0.20	–	–	–	–
9	–	–	–	0.17	0.62	0.68	0.99	–	–	–	–	–

Station III, 1984

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	0.57	–	0.05	0.08	0.18	0.47	0.05	0.12	–	0.24	0.12	0.12
3	0.54	–	0.06	0.13	0.20	0.27	0.12	0.12	–	0.16	0.12	0.14
5	0.42	–	0.05	0.27	0.34	0.30	0.10	0.08	–	0.22	0.12	0.12
7	0.23	–	0.14	0.10	0.36	0.45	0.19	0.03	–	0.12	0.10	0.07
9	–	–	–	0.18	0.40	0.72	0.64	0.09	–	0.08	0.14	0.15
11	–	–	–	0.05	0.45	0.78	0.91	0.50	–	0.14	–	–

Station IV, 1984

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	0.31	–	0.02	0.22	0.22	0.13	0.06	0.14	–	0.32	0.11	0.11
3	0.33	–	0.06	0.22	0.22	0.16	0.00	0.11	–	0.24	0.10	0.12
5	0.34	–	0.01	0.08	0.25	0.12	0.00	0.24	–	0.29	0.11	0.15
7	0.40	–	0.14	0.25	0.19	0.13	0.02	0.02	–	0.25	0.11	0.14
9	0.39	–	0.28	0.33	0.23	0.31	0.01	0.07	–	0.28	0.12	0.15
11	0.61	–	0.23	0.37	0.29	0.58	0.54	0.49	–	0.29	0.12	0.21
13	0.99	–	–	0.22	0.31	0.58	0.88	0.68	–	0.24	0.07	0.22
15	–	–	–	0.20	0.22	0.57	1.11	1.30	–	0.26	0.07	–

Station V, 1984

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	0.22	–	0.06	0.29	0.16	0.07	0.01	0.19	–	0.35	0.06	0.07
3	–	–	0.04	0.28	0.16	0.03	0.01	0.27	–	0.41	0.07	0.08
5	0.18	–	0.06	0.29	0.08	0.08	0.02	0.36	–	0.40	0.07	0.06
7	–	–	0.05	0.01	0.12	0.08	0.03	0.16	–	0.33	0.08	0.08
9	0.22	–	0.04	0.08	0.06	0.09	0.06	0.17	–	0.45	0.07	0.07
11	–	–	0.64	0.13	0.06	0.13	0.04	0.23	–	0.47	0.07	0.13
13	0.45	–	0.27	0.01	0.07	0.09	0.00	0.31	–	0.55	0.07	0.15
15	–	–	0.20	0.40	0.08	0.10	0.54	1.00	–	0.44	0.07	0.17
17	0.61	–	–	0.00	0.08	0.10	0.48	0.90	–	0.29	0.08	0.19
19	–	–	–	0.59	0.06	0.15	0.41	0.88	–	0.15	0.09	–

§ NO_3-N [mg l^{-1}]

Station I, 1984

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	1.06	–	0.24	0.33	0.03	0.01	0.00	0.01	–	0.19	1.06	1.56
3	0.85	–	–	0.30	0.03	0.02	0.06	0.04	–	0.19	0.83	1.63
5	–	–	–	0.32	0.04	0.02	0.28	0.12	–	0.17	1.08	1.39

Station II, 1984

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	0.92	–	0.21	0.35	0.15	0.02	0.00	0.00	–	0.24	0.96	0.86
3	0.42	–	0.19	0.33	0.10	0.02	0.00	0.00	–	0.22	0.95	0.92
5	–	–	0.24	0.39	0.14	0.10	0.02	0.00	–	0.23	0.90	1.37
7	–	–	–	0.35	0.10	0.18	0.01	0.01	–	0.30	0.86	1.25
9	–	–	–	0.32	0.11	0.29	0.00	-	–	–	–	–

Station III, 1984

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	1.06	–	0.21	0.40	0.30	0.14	0.00	0.01	–	0.08	0.43	0.51
3	1.18	–	0.26	0.31	0.30	0.13	0.00	0.01	–	0.07	0.51	0.49
5	0.56	–	0.20	0.35	0.31	0.42	0.04	0.01	–	0.08	0.68	0.67
7	0.55	–	0.21	0.31	0.32	0.44	0.06	0.01	–	0.02	0.51	0.97
9	–	–	–	0.35	0.34	0.42	0.01	0.01	–	0.08	0.43	0.98
11	–	–	–	0.26	0.36	0.43	0.02	0.01	–	0.09	–	–

Station IV, 1984

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	0.64	–	0.24	0.30	0.33	0.49	0.00	0.01	–	0.08	0.48	0.54
3	0.57	–	0.24	0.31	0.33	0.47	0.00	0.00	–	0.08	0.70	0.49
5	0.11	–	0.22	0.32	0.27	0.46	0.01	0.00	–	0.07	0.65	0.53
7	0.07	–	0.21	0.34	0.23	0.53	0.14	0.02	–	0.12	0.45	0.50
9	0.49	–	0.16	0.40	0.28	0.50	0.14	0.02	–	0.10	0.56	0.76
11	0.50	–	0.23	0.40	0.32	0.49	0.05	0.02	–	0.12	0.48	0.90
13	0.35	–	–	0.30	0.32	0.47	0.01	0.01	–	0.17	0.58	0.85
15	–	–	–	0.30	0.32	0.46	0.02	0.01	–	0.13	0.52	–

Station V, 1984

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	0.57	–	0.22	0.31	0.32	0.45	0.00	0.00	–	0.08	0.85	0.49
3	–	–	0.26	0.38	0.32	0.46	0.00	0.02	–	0.12	0.53	0.58
5	0.85	–	0.22	0.34	0.26	0.55	0.00	0.01	–	0.08	0.68	0.53
7	–	–	0.31	0.36	0.29	0.48	0.20	0.01	–	0.09	0.77	0.46
9	0.05	–	0.14	0.32	0.29	0.49	0.30	0.02		0.08	0.65	0.50
11	–	–	0.21	0.34	0.28	0.51	0.36	0.02	–	0.07	0.62	0.57
13	0.84	–	0.20	0.31	0.28	0.46	0.41	0.01	–	0.07	0.63	0.51
15	–	–	0.15	0.36	0.25	0.46	0.19	0.01	–	0.09	0.59	0.48
17	0.70	–	–	0.31	0.27	0.45	0.28	0.01	–	0.10	0.59	0.50
19	–	–	–	0.33	0.27	0.45	0.26	0.03	–	0.14	0.58	–

§ Total-N [mg l^{-1}]
Station I, 1984

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	2.03	–	3.15	2.75	2.56	1.73	1.65	2.57	–	2.53	3.92	3.32
3	2.32	–	–	3.21	2.54	1.73	2.01	2.35	–	3.46	3.05	3.18
5	–	–	–	2.56	2.20	1.82	2.29	2.33	–	3.88	3.25	2.88

Station II, 1984

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	1.67	–	3.37	2.28	2.38	1.90	2.21	2.06	–	2.44	2.95	3.66
3	1.60	–	3.88	2.56	2.06	1.44	2.12	2.91	–	2.18	3.35	3.12
5	–	–	2.26	2.49	1.81	2.00	0.62	2.53	–	3.04	3.00	3.25
7	–	–	–	3.68	2.17	2.30	2.11	1.91	–	2.76	2.75	3.35
9	–	–	–	2.57	2.53	1.15	1.75	–	–	–	–	–

Station III, 1984

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	2.68	–	2.73	3.16	2.41	1.94	2.45	1.77	–	2.03	2.62	2.70
3	2.78	–	4.44	2.83	0.64	1.61	2.42	1.77	–	2.64	2.25	1.98
5	2.10	–	3.25	3.50	2.42	2.44	2.81	2.34	–	2.06	2.20	2.59
7	2.90	–	5.68	2.81	2.24	1.85	2.43	1.96	–	2.54	2.08	2.92
9	–	–	–	3.40	3.21	2.20	1.33	2.00	–	1.99	2.25	3.12
11	–	–	–	3.08	2.62	2.08	1.62	2.49	–	2.66	–	–

Station IV, 1984

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	2.25	–	8.50	3.03	2.94	2.65	1.29	2.98	–	3.12	2.62	2.15
3	1.67	–	2.90	3.70	8.33	2.09	1.59	2.70	–	2.39	2.38	2.84
5	2.10	–	3.12	3.58	3.18	2.46	2.33	2.18	–	2.54	3.02	2.31
7	1.96	–	5.17	3.99	2.78	2.29	2.23	3.09	–	2.42	2.50	2.22
9	1.31	–	3.40	3.35	2.58	2.04	2.06	1.71	–	2.01	3.02	2.48
11	2.54	–	4.02	4.60	8.47	1.98	2.04	2.45	–	2.86	2.20	2.75
13	2.54	–	–	3.59	4.62	2.37	2.75	2.22	–	2.84	2.38	2.58
15	–	–	–	4.04	3.32	2.06	1.95	3.12	–	2.17	2.62	–

Station V, 1984

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	2.54	–	2.26	3.47	2.42	3.87	1.94	3.71	–	2.83	2.38	2.06
3	–	–	1.70	2.75	2.54	2.81	1.88	3.48	–	2.27	2.28	3.00
5	2.03	–	1.91	4.20	2.61	3.36	2.55	2.46	–	2.26	2.30	2.70
7	–	–	2.89	2.64	2.82	2.37	2.11	2.54	–	4.12	2.28	2.40
9	2.83	–	3.20	3.03	2.80	2.06	0.06	2.48	–	2.20	2.32	2.88
11	–	–	2.48	3.00	2.54	2.00	1.69	1.66	–	2.46	2.50	2.42
13	2.61	–	2.29	2.72	3.08	2.59	2.78	2.34	–	2.95	2.50	2.56
15	–	–	2.43	2.51	2.76	2.08	1.89	3.06	–	2.04	2.62	2.75
17	2.32	–	–	3.06	3.59	2.57	2.44	2.89	–	2.74	2.88	3.00
19	–	–	–	3.66	3.27	2.08	2.56	2.73	–	3.18	1.95	–

E8 PHOSPHORUS CONCENTRATION

§ PO_4-P [$\mu g\ l^{-1}$]

Station I, 1984

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	43	–	51	37	71	80	54	51	–	191	84	66
3	45	–	–	43	70	52	83	65	–	186	55	75
5	–	–	–	35	54	70	125	78	–	206	69	56

Station II, 1984

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	45	–	34	80	21	106	40	49	–	89	44	45
3	41	–	27	56	20	105	51	51	–	85	55	88
5	–	–	26	45	20	82	120	48	–	90	49	94
7	–	–	–	47	100	85	170	48	–	106	58	101
9	–	–	–	39	108	141	133	–	–	–	–	–

Station III, 1984

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	113	–	36	67	27	65	20	32	–	60	30	50
3	100	–	44	48	28	16	25	28	–	60	36	50
5	30	–	15	77	28	26	16	28	–	63	52	76
7	55	–	34	66	24	24	60	33	–	49	42	85
9	–	–	–	71	40	100	185	44	–	45	8	88
11	–	–	–	70	41	110	48	63	–	56	–	–

Station IV, 1984

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	49	–	41	93	37	38	20	36	–	63	26	59
3	50	–	30	90	30	18	20	41	–	32	14	63
5	43	–	27	93	33	14	20	33	–	54	19	58
7	51	–	46	91	31	8	20	40	–	60	17	74
9	31	–	21	113	29	23	20	29	–	73	4	89
11	27	–	25	101	25	65	104	59	–	75	2	88
13	11	–	–	101	32	40	191	148	–	55	10	88
15	–	–	–	93	30	95	203	226	–	44	21	–

Station V, 1984

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	39	–	31	110	20	10	29	67	–	63	19	66
3	–	–	45	104	35	10	29	48	–	56	1	65
5	46	–	35	115	25	10	30	58	–	68	17	71
7	–	–	51	94	23	20	41	23	–	65	19	71
9	49	–	29	103	18	20	24	20	–	70	16	68
11	–	–	17	100	17	8	0	32	–	73	27	66
13	34	–	17	66	30	10	0	62	–	71	21	63
15	–	–	24	54	42	23	145	233	–	81	12	81
17	31	–	–	30	46	30	126	291	–	73	9	84
19	–	–	–	40	48	22	158	263	–	90	31	–

§ Total-P [$\mu g\ l^{-1}$]

Station I, 1984

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	60	–	94	45	77	90	120	156	–	390	88	94
3	59	–	–	50	91	76	118	99	–	248	57	87
5	–	–	–	45	104	75	161	132	–	245	73	76

Station II, 1984

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	59	–	39	95	53	129	81	88	–	103	68	135
3	56	–	45	62	19	15	80	88	–	93	76	110
5	–	–	33	60	44	84	209	90	–	125	78	100
7	–	–	–	59	134	88	175	94	–	125	76	104
9	–	–	–	53	143	177	154	–	–	–	–	–

Station III, 1984

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	126	–	56	80	54	106	118	84	–	65	55	65
3	127	–	68	68	38	41	70	59	–	63	81	74
5	33	–	35	84	30	40	41	76	–	70	60	91
7	59	–	60	74	35	42	90	56	–	70	60	90
9	–	–	–	80	54	135	198	50	–	55	50	93
11	–	–	–	76	49	128	93	86	–	63	–	–

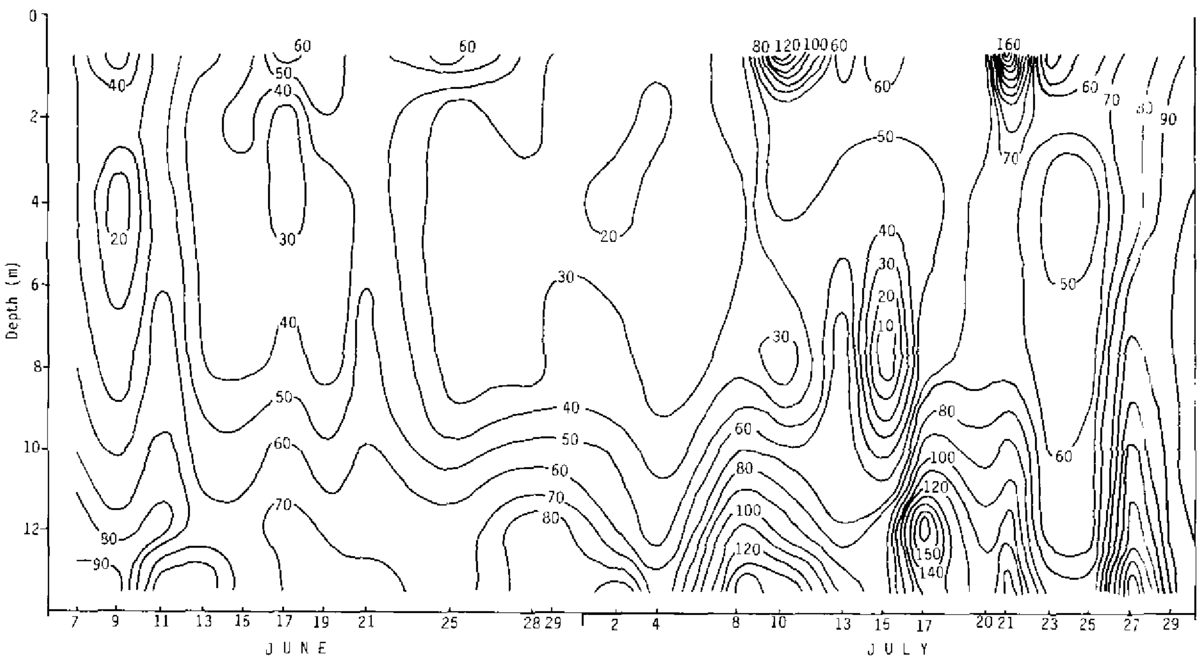
Station IV, 1984

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	54	–	76	105	48	50	198	49	–	110	73	65
3	54	–	55	106	40	49	74	48	–	85	39	71
5	54	–	45	119	37	48	46	81	–	74	38	77
7	54	–	59	105	55	25	53	100	–	73	25	78
9	33	–	60	117	33	43	33	88	–	75	27	94
11	41	–	35	113	33	98	116	88	–	76	29	108
13	27	–	–	110	55	70	200	166	–	64	61	94
15	–	–	–	107	35	120	254	343	–	54	41	–

Station V, 1984

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	55	–	64	123	35	33	62	248	–	99	44	80
3	–	–	61	119	35	35	65	185	–	91	16	73
5	56	–	56	125	33	34	53	173	–	95	40	75
7	2	–	57	116	28	33	46	51	–	95	37	75
9	54	–	55	115	23	34	25	90	–	100	34	74
11	–	–	36	118	24	20	11	64	–	99	35	88
13	48	–	30	76	37	30	19	73	–	93	41	68
15	–	–	71	55	49	66	150	246	–	98	31	87
17	45	–	–	31	60	50	145	321	–	101	37	87
19	–	–	–	45	57	51	176	286	–	110	31	–

Fig. EUR-38-4 Vertical distribution of Total-P concentration [$\mu g\ l^{-1}$], Station IV, 1990 (Q).



F. BIOLOGICAL FEATURES

F1 FLORA (2, 10)

§ Emerged macrophytes : *Sparganium erectum, Scirpus lacustris, Eleocharis palustris.*

§ Floating macrophytes : *Potamogenton natans, Nuphar lutea, Polygonum amphibium.*

§ Submerged macrophytes

Potamogeton lucens, P. perfoliatus, P. crispus, P. pectinatus, Ceratophyllum demersum, Myriophyllum spicatum.

§ Phytoplankton

Ceratium hirundinella, Stephanodiscus hantzshill, S. astrea, Melosira granulata, M. italica, Aphanizomenon flos-aquae, Anabaena flos-aquae, A. scheremetievii, Microcystis aeruginosa.

F2 FAUNA

§ Zooplankton (2)

Coleps hirtus, Halteria grandinella, Tintinnopsis cratera, Strombidium viride, Keratella cochlearis, Pompholyx sulcata, Conochilus unicornis, Asplanchna priodonta, Daphnia galeata, D. cucullata, Leptodora kindti, Cyclops kolensis, Mesocyclops leuckarti, Eudiaptomus gracilis. E. graciloides.

§ Benthos (1)

Littoral zone (*Cladotanytarsus mancus, Chironomus muratensis, Stictochironomus rosensholdi, Peloscolex ferox*), Littoral/profound zone (*Polypedilum nubeculosum, Procladius ferrugineus, Chironomus plumosus*), Profound zone (*Chironomus plumosus, C. balatonicus. C. authracinus, Limnodrilus hoffmeisteri, Tubifex tubifex).*

§ Fish (1, 11)

Rutilus rutilus, Abramis brama, Blicca bjoerkna, Stizostedion lucioperca, Perca fluviatilis, Gimnocephalus cernuus, Anguilla anguilla** (* : introduced species).

F3 PRIMARY PRODUCTION RATE (12)

Gross production rate [g C $m^{-2}yr^{-1}$]

	1969	1976	1984
Station IV	300	140	400

F4 BIOMASS (Q)

§ Biomass of phytoplankton [mg l^{-1}, wet wt] (1981-1984)

	May	Jun	Jul	Aug	Sep	Oct
Station II	1.4	1.6	1.1	2.9	1.7	0.4
Station IV	0.7	0.8	9.1	11.2	3.4	0.2
Station V	1.0	2.9	15.0	20.5	6.3	0.1

§ Biomass of Ciliata [mg l^{-1}, wet wt] (1976-1980)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
13	11	12	13	46	171	204	161	84	66	25	12

§ Biomass of zooplankton [mg l^{-1}, wet wt]

1981-1990	May	Jun	Jul	Aug	Sep	Oct
Station IV	3.1	4.4	2.8	2.7	2.7	3.4

1984	May	Jun	Jul	Aug	Sep	Oct
Station II	5.0	7.5	6.5	2.9	5.3	2.3
Station IV	4.5	4.7	1.4	2.2	2.7	2.8
Station V	2.9	2.8	1.5	2.0	5.1	1.3

§ Biomass of benthos [g m^{-2}, wet wt] (1985-1988)

	May	Jun	Jul	Aug	Sep	Oct
Station IV	4.8	4.9	3.8	3.1	3.4	5.8

F5 FISHERY PRODUCTS (Q)

§ Annual fish catch in 1986 : 36.2 [metric tons] (except sport-fishing ca. 20 %).

F6 PAST TRENDS

§ Trend of phytoplankton biomass [mg l^{-1} wet wt], Station IV

	1968	1972	1976	1981	1983	1984
Biomass	2.8	1.6	0.9	5.0	4.8	4.2
Cyanophyta [%]	87	35	66	5	14	10
Pyrrophyta [%]	–	–	–	86	75	83

§ Trend of zooplankton biomass [mg l^{-1} wet wt], Station IV

1961	1967	1969	1972	1975	1981	1983	1984
1.4	2.1	3.7	2.9	0.9	3.2	3.0	3.2

§ Trend of benthos biomass [g m^{-2} wet wt], Station IV

1961	1966	1973	1977	1982	1984	1988	1989
13.8	5.7	7.5	3.1	4.8	4.3	4.0	4.3

§ Trend of fish catch [t yr^{-1}]

1975	1978	1979	1980	1981	1982	1983	1984	1985	1986
17.8	11.5	7.2	7.7	12.9	14.0	30.9	31.9	60.2	36.2

F7 NOTES ON THE REMARKABLE CHANGES OF BIOTA IN THE LAKE IN RECENT YEARS

Changes in planktonic community was noted in the 1970's. The dominance of Cyanophyta was replaced by that of Pyrrophyta. By the beginning of the 1980's the phytoplankton biomass increased twice (up to 4-5 g m^{-2}), while the number of species was reduced by half (13). An increase of the total amount of benthic organisms has also been noted. The share of Tubificidae biomass increased, and *Cladotanytarsus mancus* increased sharply in the littoral zone.

G. SOCIO-ECONOMIC CONDITIONS (Q)

G1 LAND USE IN THE CATCHMENT AREA

	Area [km^2]	[%]
Natural landscape		
Forest	651.0	48.8
Scrub	4.9	0.3
Swamp	4.6	0.3
Agricultural land		
Crop field	399.9	30.0
Pasture land	99.8	7.5
Meadows	64.4	4.8
Settlement area and others	110.4	8.3
Total	1,335.0	100.0

§ Species of the wide-spread forest and scrub vegetation : *Picea abies, Pinus sylvestris, Betula pendula, Alnus incana, Populus tremula, Salix cinerea, Trangula alnus, Rubus idaeus, Viburnum opulus.*

§ Main species of grass vegetation : *Poa nemoralis, Milium effusum, Carex silvatica, Aegopodium podograria, Dactylis glomerata.*

§ Main species of agricultural crops : Wheat, barley, maize, potato, root-crops, clover, flax.

§ Levels of fertilizer application on crop fields : Moderate.

§ Trend of agricultural land use in recent years

During the last 20 years, the use of chemical fertilizers increased by 2.5 times, with associated decrease in organic fertilizer application. Cattle population also increased by 1.4 times. Land reclamation work by drainage has been carried out.

G2 INDUSTRY IN THE CATCHMENT AREA

§ Mining : One sand-pit with a mining-concentration mill for construction materials.

§ Number of domestic animals : Cattle 692,000, swine 10,000.

G3 POPULATION IN THE CATCHMENT AREA (1989)

	Population	Population density [km^{-2}]	Main cities
Rural	25,000		None
Total	25,000	18	

H. LAKE UTILIZATION (Q)

H1 LAKE UTILIZATION (1990)

Source of water, tourism (number of tourists in 1988 ; 3060), recreation (bathing, sport-fishing, sailing), and power generation.

H2 THE LAKE AS WATER RESOURCE

	Use rate [$m^3 sec^{-1}$]
Drinking water	7
Power plant	9 [10^6 KW hr^{-1}]

I. DETERIORATION OF LAKE ENVIRONMENTS AND HAZARDS

I1 ENHANCED SILTATION

§ Extent of damage : Not serious ; mean siltation rate was 0.48 cm yr^{-1} for 1961-1972 (1).

I2 TOXIC CONTAMINATION

§ Present status : Detected but not serious.

§ Mean concentration of some contaminants [$\mu g\ l^{-1}$, $\mu g\ g^{-1}$] (2)

Name of contaminants	Water	Bottom mud	Aquatic plants	Plankton
As	–	0.7	–	–
Ba	130	450	960	76
Br	0.4	1.4	100	–
Co	0.4	9	47	1.6
Cr	10	40	150	12
Cs	0.01	2.8	2.2	0.38
Cu	6.0	110	–	–
Hg	0.27	0.45	0.40	0.05
Li	1.4	1.7	2.7	–
Pb	1.0	26	15	4.0
Sb	0.5	1.2	7.3	0.4
Sc	0.04	12	57.0	1.0
Se	0.57	0.75	–	–
Sr	100	22	440	–
Te	0.32	0.9	–	–
Th	0.03	11	17	–
V	1.5	3.2	–	–
Zn	67	50	310	

§ Supplementary notes : There are some effects of radioactive pollution from Chernobyl.

§ Environmental standards for contaminants in the reservoir water [mg l^{-1}]

As	0.05
Ba	0.1
Br	0.2
Co	0.1
Cr	0.1
Cu	1.0
F	1.5
Hg	0.0001
Li	0.03
Pb	0.03
Sb	0.05
Se	0.001
Sr	7.0
Te	0.01
Zn	1.0

I3 EUTROPHICATION (Q)

§ Nuisance caused by eutrophication

Unusual algal bloom (blue-greens and *Ceratium hinrundinella).*

§ Nitrogen and phosphorus loadings to the reservoir [g $m^{-2}yr^{-1}$] (1984)

Sources	Industrial	Domestic	Agricultural	Natural	Total
T-N	–	–	–	–	34.8
T-P	–	–	0.2	1.1	1.3

§ Supplementary notes

Countermeasures taken include damming of the shallow creek in the Bodnya mouth, planting of protective forest-belts along woodless coastal strips 20 m in width (spruce, pine, birch, acacia), etc.

I4 ACIDIFICATION

§ Extent of damage: None.

J. WASTEWATER TREATMENTS (Q)

J3 SANITARY FACILITIES AND SEWERAGE

§ Percentage of the population in the catchment area provided with adequate sanitary facilities: 20 %.

K. IMPROVEMENT WORKS IN THE LAKE

None (Q).

M. LEGISLATIVE AND INSTITUTIONAL MEASURES FOR UPGRADING RESERVOIR ENVIRONMENTS

M1 NATIONAL AND LOCAL LAWS CONCERNED

§ Names of the laws (the year of legislation)

(1) The resolution of the Council of Ministers of RSFSR "On the assertion of the regulations of water protection zones of rivers, lakes and reservoirs" (1989)

(2) The resolution of the Council of Ministers of RSFSR "On the placing of Moscow water supply reservoirs at the exclusive disposal of the Water-Supply and Sewerage Board of Moscow Municipality" (1984)

(3) The resolution of the Mozhaysk Municipality "On the establishment of boundaries of

water protection zones of the Mozhaysk Reservoir and the Moskva River within the Mozhaysk District" (1984)

§ Responsible authorities

(1) Mosvodocanal Board of Moscow Municipality Executive Committee
(2) Nature Protection Committee of Mozhaysk Municipality
(3) Mozhaysk Inter-district Fish Protection Inspection
(4) Moskva River System Hunter and Fisherman Society

§ Main items of control

(1) Purification systems of settlements within the catchment
(2) Purification systems of livestock farms

M2 INSTITUTIONAL MEASURES

(1) United Protection Board of the Mozhaysk and Rouza Dams
(2) Krasnogorsk Goskomgidromet of USSR Hydrometeo-station
(3) Mozhaysk Medical-Epidemiologic Station

M3 RESEARCH INSTITUTES ENGAGED IN THE RESERVOIR ENVIRONMENT STUDIES

(1) Moscow State University, Faculty of Geography ; Department of Hydrology and Reservoir Laboratory in Krasnovidovo.
(2) Moscow State University, Faculty of Biology ; Departments of Hydrobiology, Invertebrate Zoology and Ichthyology, and Scientific Station in Ilyinskoe.

N. SOURCES OF DATA

(Q) Questionnaire filled by Profs. K. K. Edelstein, G. N. Golubev & V. S. Docenko, Faculty of Geography, Dept. of Hydrology, Moscow State University.

(1) Mozhaysk Reservoir (1979). Multidisciplinary Studies of the Reservoirs Vol. III. Moscow University Press. 400pp. (in Russian).

(2) The Reservoirs of the Moskva-river Supply System (1985) Multidisciplinary Studies of the Reservoirs, Vol. VI. Moscow University Press. 266pp. (in Russian).

(3) Ershova, M. G. (1971) On Mozhaysk Reservoir water masses dynamics in the freezing Period. Multidisciplinary Studies of the Reservoirs, Vol. I-Moscow, pp. 65-76. Moscow University Press (in Russian).

(4) Edelstein, K. K. (1978) The research of Mozhaysk Reservoir water discharges. Multidisciplinary Studies of the Reservoirs, Vol. IV, pp. 160-169. Moscow Univ. Press, (in Russian).

(5) —— (1977) Morphological classification of the reservoirs. Vestnik of Moscow Univ., Geography, pp. 96-104 (in Russian).

(6) Spiridonov, A. Y. (1935) Geomorphological essay of the Moskva River basin to North-West from Moscow. Geography, Vol. 37, iss. 2 (in Russian).

(7) Edelstein, K. K. (1971) Hydrological regime of the Mozhaysk reservoir in winter. Multidisciplinary Studies of the Reservoirs, Vol. I, pp. 51-64. Moscow Univ. Press (in Russian).

(8) An Estimation of the Resources and Quality of Surface Waters (On Example of Moscow Region) (1989). 197pp. Moscow Univ. Press.

(9) Malutin, A. N. & Edelstein, K. K. (1980) Spatial heterogenety of hydrological characteristics in the reservoir. Multidisciplinary Studies of the Reservoirs, Vol. V, pp. 56-68. Moscow Univ. Press (in Russian).

(10) Levshina, N. A. (1973) Phytoplankton of the Mozhaysk Reservoir. Multidisciplinary Studies of the Reservoirs, Vol. II. pp. 50-55. Moscow Univ. Press (in Russian).

(11) Fish of the reservoirs near Moscow (1988) 143pp. Scien., Moscow (in Russian).

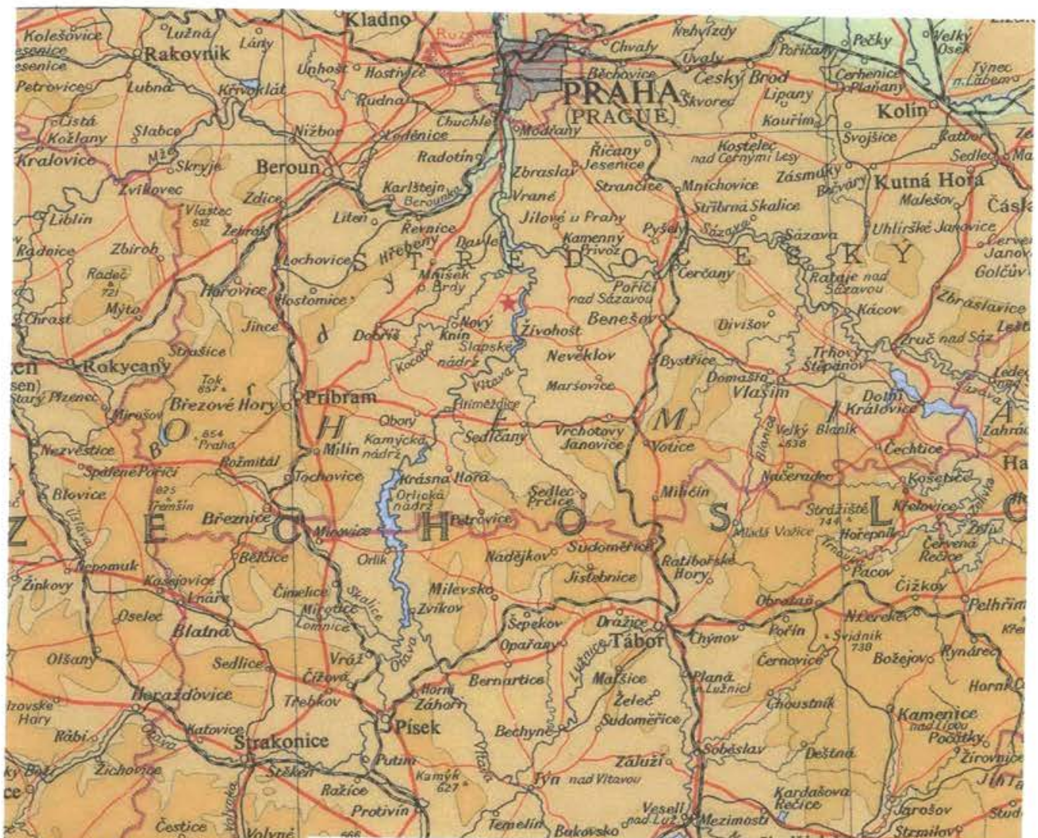
(12) Maltzman, T. S., Kozlova, E. Y. & Shirokova, E. L. (1980) Biotic balance of the pelagial ecosystem of the Mozhaysk reservoir. Trophyic Relations of the Freshwater Invertebrates, pp. 89-94. Leningrad (in Russian).

(13) Sokolova, N. Ju. & Sakharova, M. Y. (1990) Biological investigation of the Upper Volga Mozhaysk drinking water reservoir. Verh. Internat. Verein. Limnol., 25 : 294-295.

LAKE SLAPY

A view from the damside hill

Photo: M. Straškraba



A. LOCATION

§ Bohemia, Czechoslovakia.
§ 49°37′N, 14°20′E ; 271 m above sea level.

B. DESCRIPTION

Lake Slapy is a multipurpose reservoir built on the Vltava River about 40 km south of Praha, the capital of Czechoslovakia. It represents the third major step of the Vlatava Cascade of Reservoirs (Lipno, Orlík and Slapy) built primarily for power generation. Orlík Reservoir (volume $722\times10^6 m^3$, 75 km long, 70 m deep, completed in 1960) with its re-regulation step (volume $13\times10^6 m^3$) is located immediately upstream of Slapy. After its completion in 1954, the Slapy area became recreational and, because of the lack of natural lakes in the country, is heavily visited during summer.

The underlying geological formation is a plutonic massif, the bed being formed by granodiorite from the younger Paleozoic with the inclusion of Algonkian paleo-volcanites. The reservoir is riverine in its shape, with an average width of about 300 m and a length of 44.5 km, and is rather through-flowing. Due to the peak power generation at both Slapy and Orlík reservoirs, the water level fluctuates daily in addition to the seasonal variation with winter minima. Characteristic is the brown water color resulting from the paper mill industry in the upper reaches of the Vltava (some 200 km upstream from Slapy) and also from natural fulvic acids supplied by bogs in the Black Forest Mountains. Other sources of pollution are municipal sewage containing wastewater from food industry and agricultural non-point runoff.

During its history the reservoir water quality has changed several times : due to "reservoir aging" in 1954–58 when heavy water blooms of blue-greens were observed, in 1960 due to construction of Orlík Reservoir immediately upstream, and in 1966 due to stopping the operation of old paper mills in the upper reaches which reduced the load of resistant organic matter and decreased the brown water colour. Also, the use of motor boats and houseboats has been prohibited since 1970. Most profound effects were due to the construction of the upstream reservoir, which resulted in lowering the load of phosphorus due to its retention by Orlík Reservoir and resultant shifting of the blooms to that reservoir. Also, the stratification structure in Slapy changed : until the construction of Orlík, Slapy were fed by a river with a natural temperature regime, whereas afterwards the inflow is mainly hypolimnic water of Orlík. A continuous water quality trend is related to the development of agriculture in the watershed (about 50 % of the watershed is agricultural land). During the last thirty years the amount of fertilizers applied to the drainage area has been gradually increasing and field meliorations were carried on in the upper reaches of the river. This is mainly reflected in the concentration of nitrogen compounds (annual mean values up to 5 mg l^{-1} N), but also of chlorides and sulphates. Concerning limnological research Slapy Reservoir is, on a long term basis, one of the most intensively studied reservoirs (Q).

C. PHYSICAL DIMENSIONS (Q)

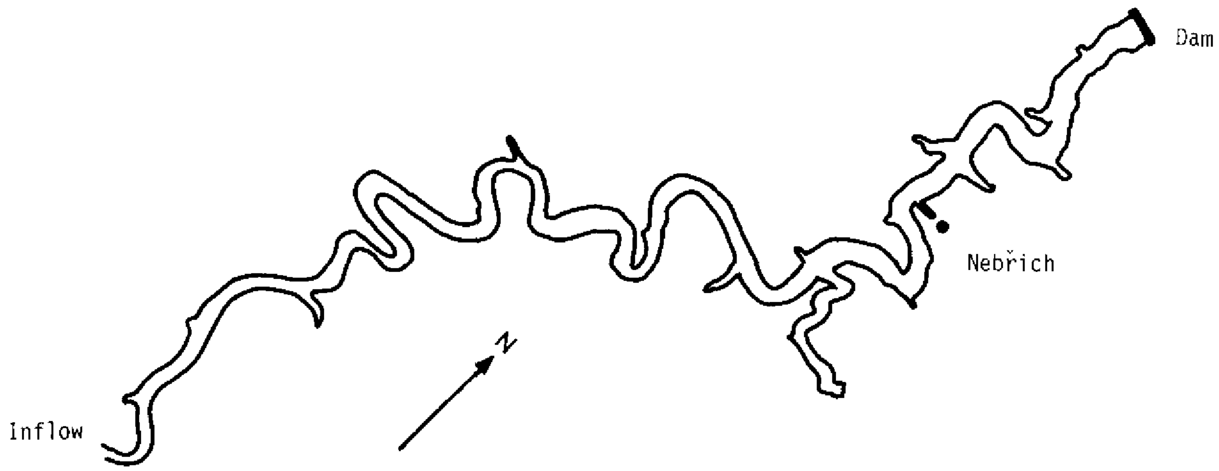
Surface area [km^2]	13.1
Volume [$10^6 m^3$]	270
Maximum depth [m]	53
Mean depth [m]	20.7
Normal range of annual water level fluctuation [m] (regulated)	5~25 (exceptional)
Length of shoreline [km]	150
Residence time [yr]	0.105
Catchment area [km^2]	12,900

D. PHYSIOGRAPHIC FEATURES

D1 GEOGRAPHICAL

§ Sketch map (Fig. EUR-39-1).
§ Main islands: None.
§ Outflowing rivers and channels (number and names): 1 (Vltava R.).

Fig. EUR-39-1 Sketch map (Q).



D2 CLIMATIC (1)

§ Climatic data at Solenice (temperature, 1958-1967) and at Slapy (precipitation, 1967-1974)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean temp. [°C]	-2.5	-0.3	2.2	8.1	12.3	16.0	16.9	16.2	12.9	8.1	3.5	-0.8	7.7
Precipitation [mm]	23	30	30	39	81	88	56	66	46	34	39	27	559

§ Number of hours of bright sunshine: 1,489 hr yr^{-1}.
§ Solar radiation: 10.4 MJ $m^{-2}day^{-1}$.
§ Water temperature [°C] (2, 3, 4)
Nebřich, 1960-1970

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
Surface	3.0	1.8	2.5	6.8	13.6	18.7	21.1	19.7	17.6	14.6	11.1	7.3	11.9
5	3.3	2.0	2.6	5.1	10.1	14.5	17.3	18.0	17.0	14.6	11.1	7.3	10.5
10	3.4	2.2	2.6	4.9	8.6	11.5	14.2	16.0	16.3	14,6	11.1	7.3	9.5
15	3.5	2.3	2.6	4.7	8.1	10.9	13.6	15.9	15.6	14.6	11.1	7.3	9.2
20	3.6	2.5	2.6	4.6	7.4	10.2	13.1	14.7	15.3	14.5	11.1	7.3	8.9
30	3.7	2.9	2.8	4.3	6.8	9.4	12.4	13.8	14.8	14.0	10.6	7.1	8.6
Bottom	3.8	3.1	2.9	4.2	6.1	8.5	10.6	11.5	12.5	12.4	10.4	6.8	7.9

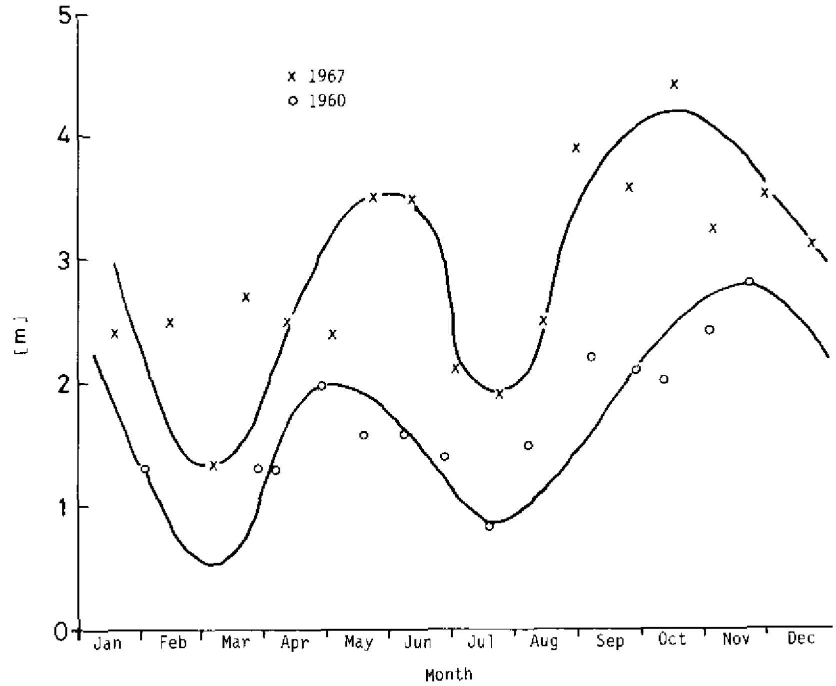
§ Freezing period: Jan.-Mar.
§ Mixing type: Dimictic.
§ Notes on water mixing and thermocline formation

All measures of stratification and mixing intensity such as the degree of stratification, surface and bottom temperature, thermocline depth, coefficient of turbulent diffusion and heat budget are strongly related to theoretical retention time.

E. LAKE WATER QUALITY

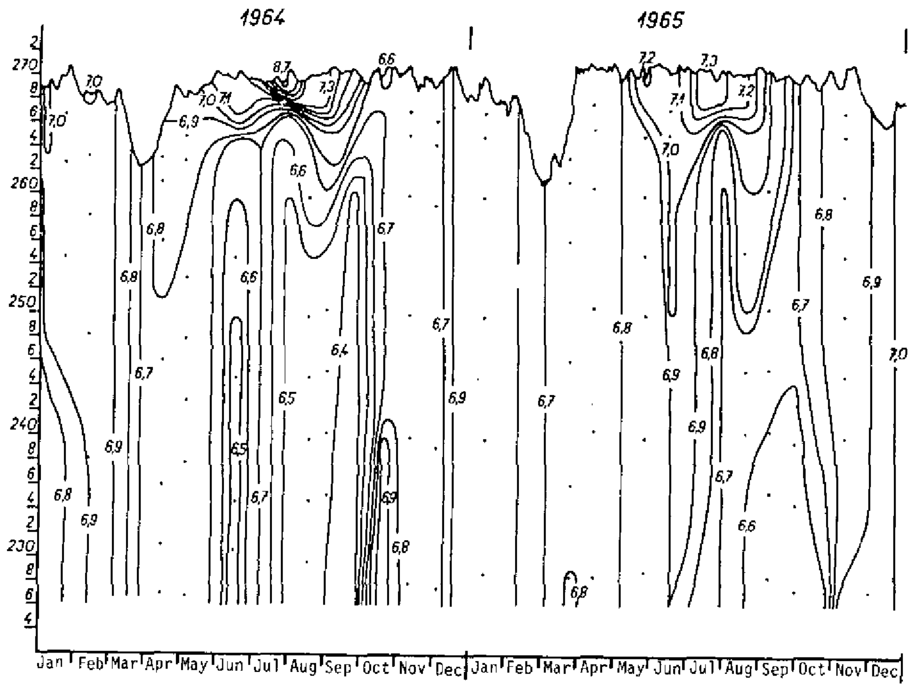
E1 TRANSPARENCY

Fig. EUR-39-2 Seasonal changes of transparency [m] before (1960) and after (1967) the construction of the upstream Orlík Reservoir.



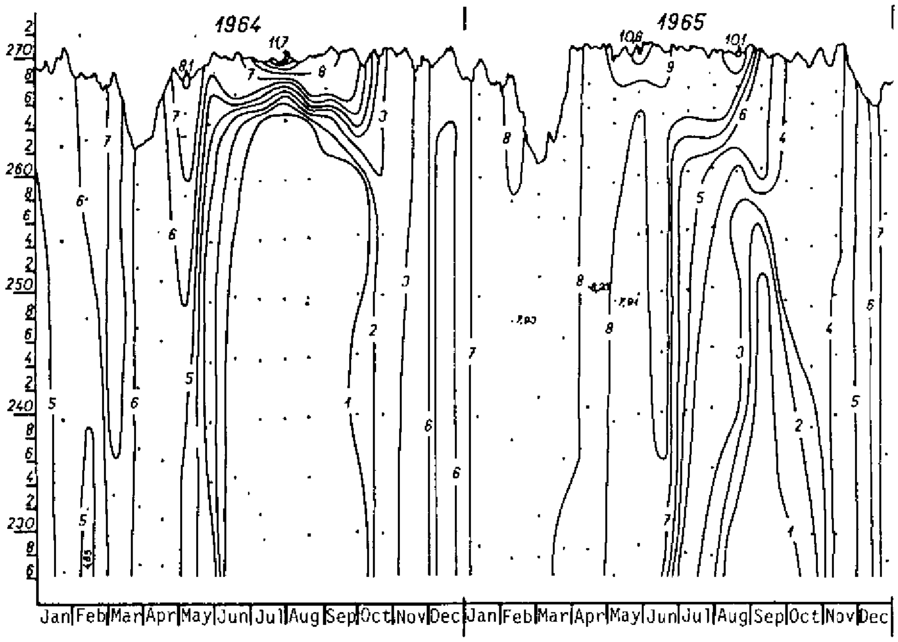
E2 pH

Fig. EUR-39-3 Depth-time changes of pH in a dry year (1964) and a wet (through-flowing) year (1965) at Nebřich.



E4 DO

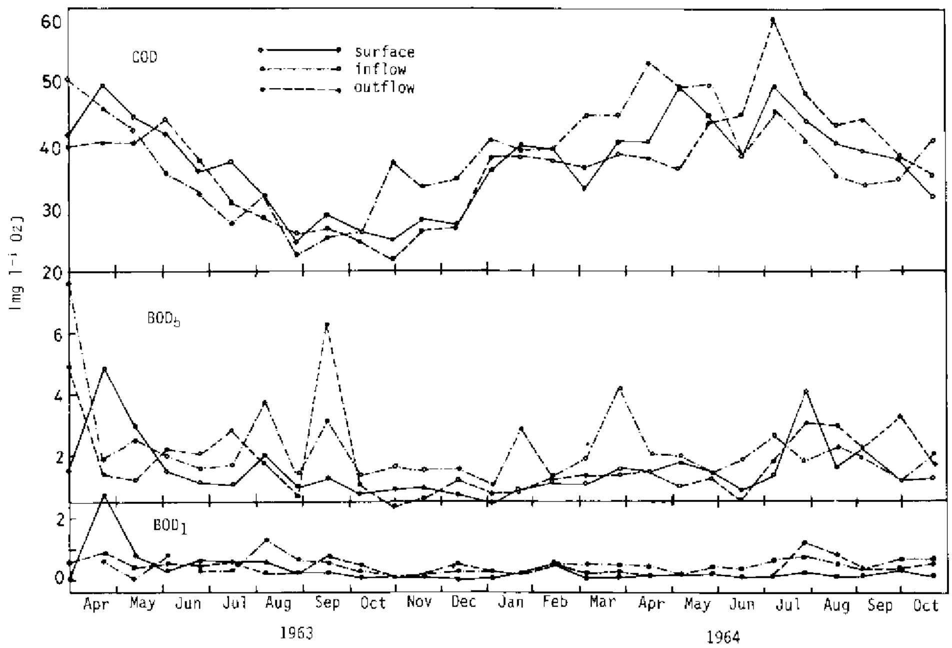
Fig. EUR-39-4 Depth-time changes of DO [mg l^{-1}] in a dry year (1964) and a wet (through-flowing) year (1965) at Nebřich.



E5 COD

Determined by $K_2Cr_2O_4$ method.

Fig. EUR-39-5 Seasonal changes of COD [mg l^{-1}], 1963-1964.



E6 CHLOROPHYLL CONCENTRATION [μg l^{-1}]

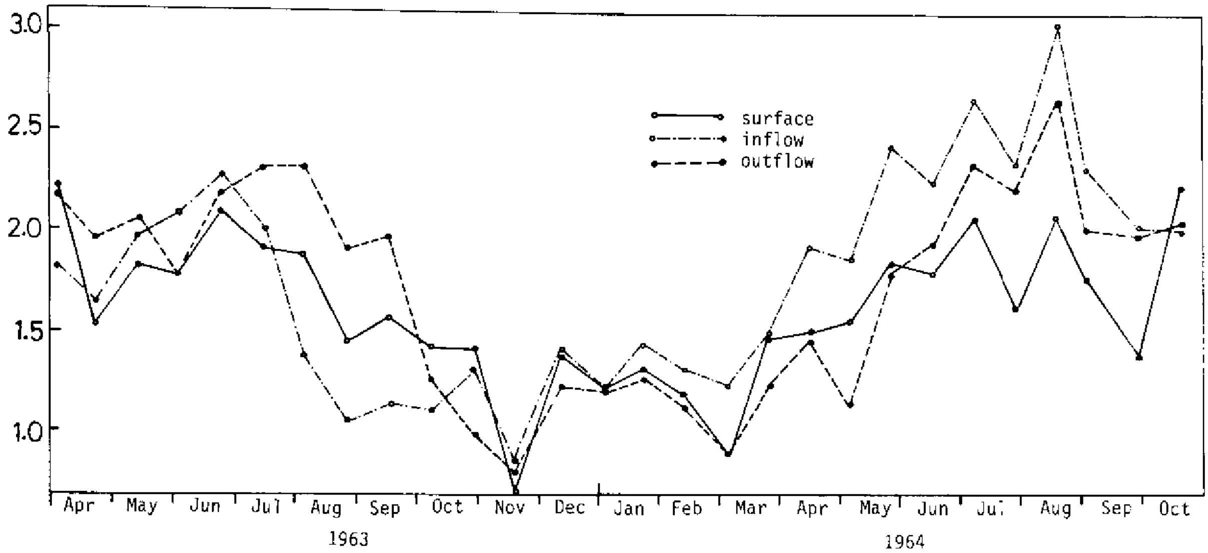
Nebřich, 1964-1975

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0-4	0.7	1.2	0.8	13.3	17.5	7.3	16.6	14.9	7.9	1 4	0.8	0.7

E7 NITROGEN CONCENTRATION

§ Total-N

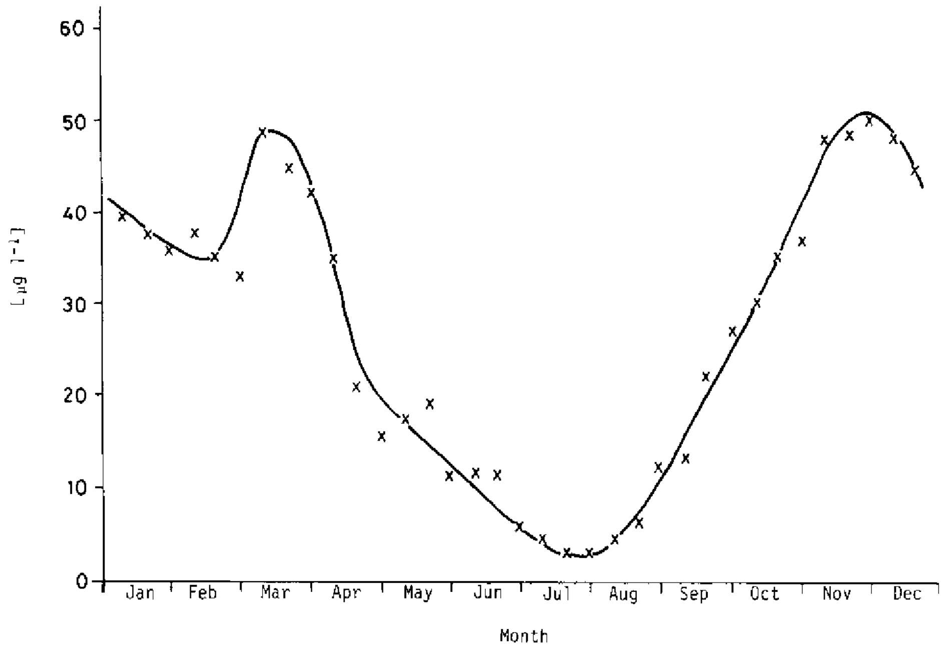
Fig. EUR-39-6 Seasonal changes of total nitrogen [mg l^{-1}], 1963-1964.



E8 PHOSPHORUS CONCENTRATION

§ PO_4-P

Fig. EUR-39-7 Average seasonal changes of PO_4-P concentration [$\mu g\ l^{-1}$] (Nebřich 1961 -1968).

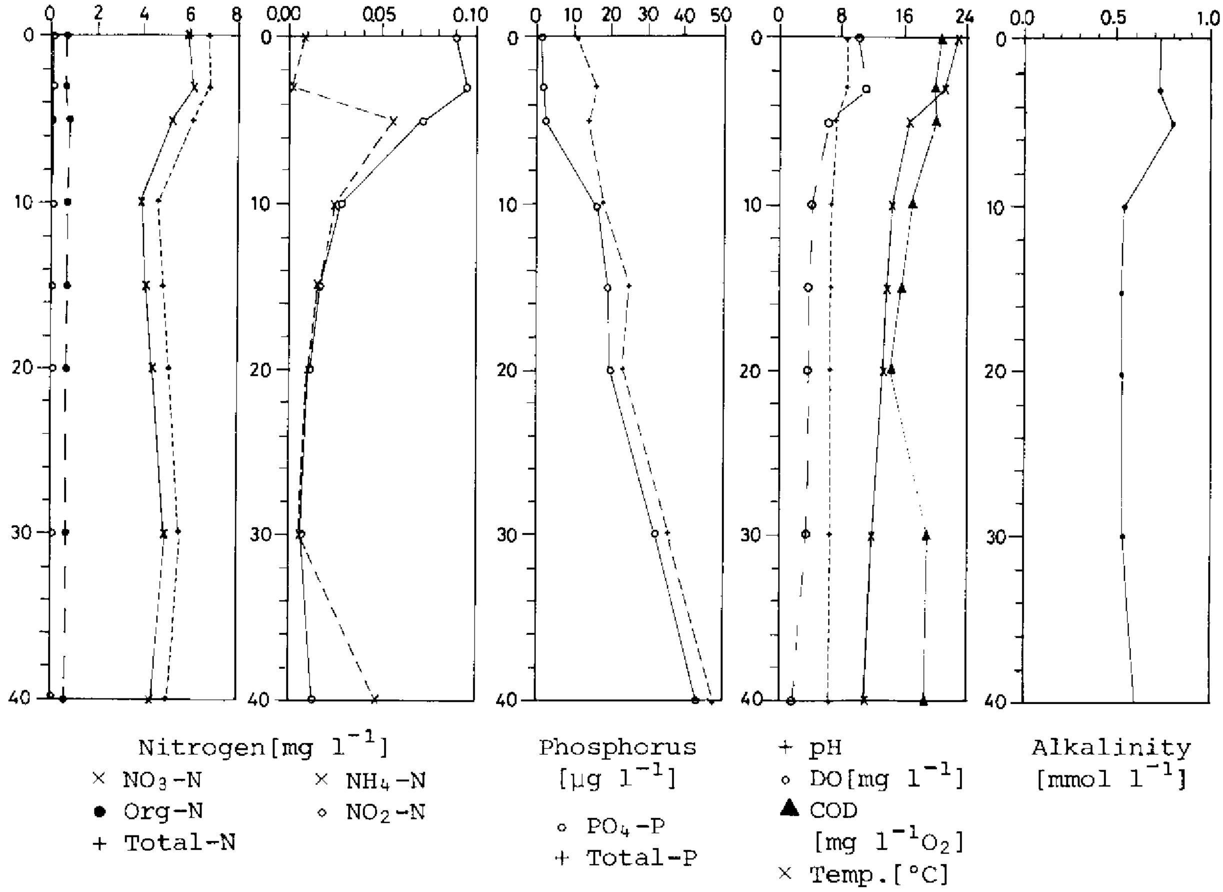


E9 CHLORIDE ION CONCENTRATION [mg l^{-1}]

Slapy, 1978-1986

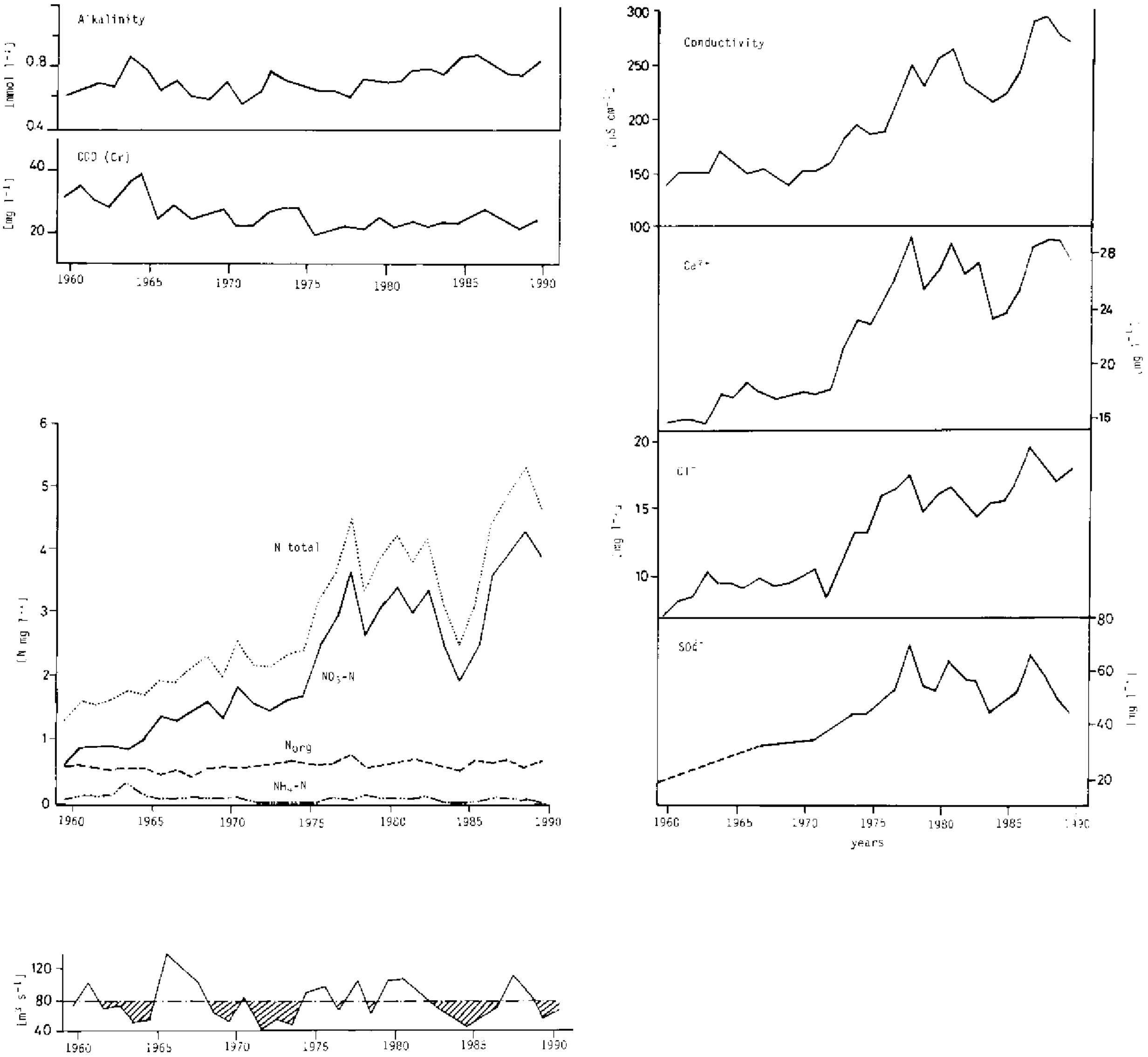
Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	11.0	15.1	15.5	16.2	17.7	18.6	17.7	17.1	16.1	15.1	14.6	15.0

Fig. EUR-39-8 An example of summer chemical stratification (Jul. 1988).



E10 PAST TRENDS

Fig. EUR-39-9 Past trends of chemical variables (Nebřich annual average, n = 17) and corresponding average flow rates.



F. BIOLOGICAL FEATURES

F1 FLORA

§ Emerged macrophytes

Due to large water-level fluctuations there are no macrophytes in the lake.

§ Phytoplankton

Altogether 200 species were found. Dominant species differ according to the season. However, the species composition of different periods also shifts with time. Spring peak: *Rhodomonas lacustris*, *Cryptomonas marssonii*, *C. reflexa*, *C. curvata*, *Chrysococcus* spp., *Stephanodiscus hantzschii*, *Cyclotella comta*, *Aulacoseira granulata*, *Asterionella formosa*, *Nitschia acicularis*, *Peridinium* spp., *Chrysococcus biporus*, *Ch. rufescens*. Lake spring minimum: *Rhodomonas lacustris*, *Cryptomonas marssonii*, *C. reflexa*, *C. curvata*, *Chlamydomonas* spp., Chlorococcales gen. div., *Anabaena circinalis*. Summer peak: *Cryptomonas marssonii*, *C. reflexa*, *Ceratium hirundinella*, *Aulacoseira granulata*, *Melosira italica*, *Asterionella formosa*, *Fragilaria crotonensis*, *Microcystis aeruginosa*, *Aphanizomenon flos-aquae*, *Anabaena circinalis*, *A. flos-aquae*, *Oscillatoria limnetica*, *Pandorina morum*, *Coelastrum*, *Crucigeniella apiculata*, *Monoraphidium* spp., *Pediastrum* spp., *Scenedesmus* spp., *Sphaerocystis*. Fall: *Chrysococcus biporus*, *Ch. rubescens*, *Asterionella formosa*, *Fragilaria crotonensis*, *Rhodomonas lacustris*. Other occasionally common species: *Trachelomonas volvacina*, *Synedra acus*, *Staurastrum* sp., *Aulacoseira* sp., *Gymnodinium* spp., *Closterium polymorphum*, *Cl. limneticum* (2, 3, 4, 7).

F2 FAUNA

§ Zooplankton

Abundant species of Ciliata: *Cyclidium* sp., *Glaucoma* spp., *Halteria grandinella*, *Strombilidium* spp., *Vorticella natans*. Abundant species of Rotatoria: *Keratella guadrata*, *K. cochlearis*, *Asplanchna priodonta*, *Brachionus calyciflorus*, *B. angularis*, *B. quadridentatus*, *B. urceolaris*, *Polyarthra major*, *Synchaeta* spp., *Pedalia mira*, *Filinia longiseta*, *Kellicottia longiseta*, *Conochilus unicornis*. Altogether more than 30 species of Rotatoria were found. Abundant Cladocera: *Leptodora kindtii*, *Polyphemus pediculus*, *Limnosida frontosa*, *Daphnia galeata*, *D. cucullata*, *Bosmina longirostris*, *B. coregoni*, *Diaphanosoma brachyurum*, *Ceriodaphnia quadrangula*. Abundant Copepoda: *Mesocyclops leuckarti*, *Cyclops vicinus*, *Thermocyclops hyalinus*, *Th. crassus*, *Acanthocyclops* cf. *americanus*, *Megacyclops viridis*, *Diacyclops bicuspidatus*, *Eudiaptomus gracilis*. Together 22 species of Crustacea were recorded (2, 3, 4, 8).

§ Benthos

Together 33 benthic animal taxa were recorded. Most common are Turbellaria, Oligochaeta (genera *Tubifex* and *Limnodrilus*), Hirudinea (*Helobdella stagnalis*), Chironomidae (*Chironomus* fl. *plumosus* and fl. *semireductus*, *Glyptotendipes* gr. *gripekoveni*, *Polypedillum* gr. *nubeculosum*, *Procladius*, *Tanytarsus*), Sphaeriidae (*Asellus aquaticus*) (3).

§ Fish

The ichthyocoenosis consisted in 1982-1987 of 26 fish species belonging to 7 families (Salmonidae, Esocidae, Thymallidae, Cyprinidae, Siluridae, Anguillidae and Percidae). *Rutilus rutilus* and *Perca fluviatilis* were the dominant species, also *Abramis brama*. *Gymnocephalus cernuus* and *Alburnus alburnus* abundant; *Cyprinus carpio* was the most important angled fish. Dominant predators were *Esox lucius*, *Stizostedion lucioperca* and *Silurus glanis* (9).

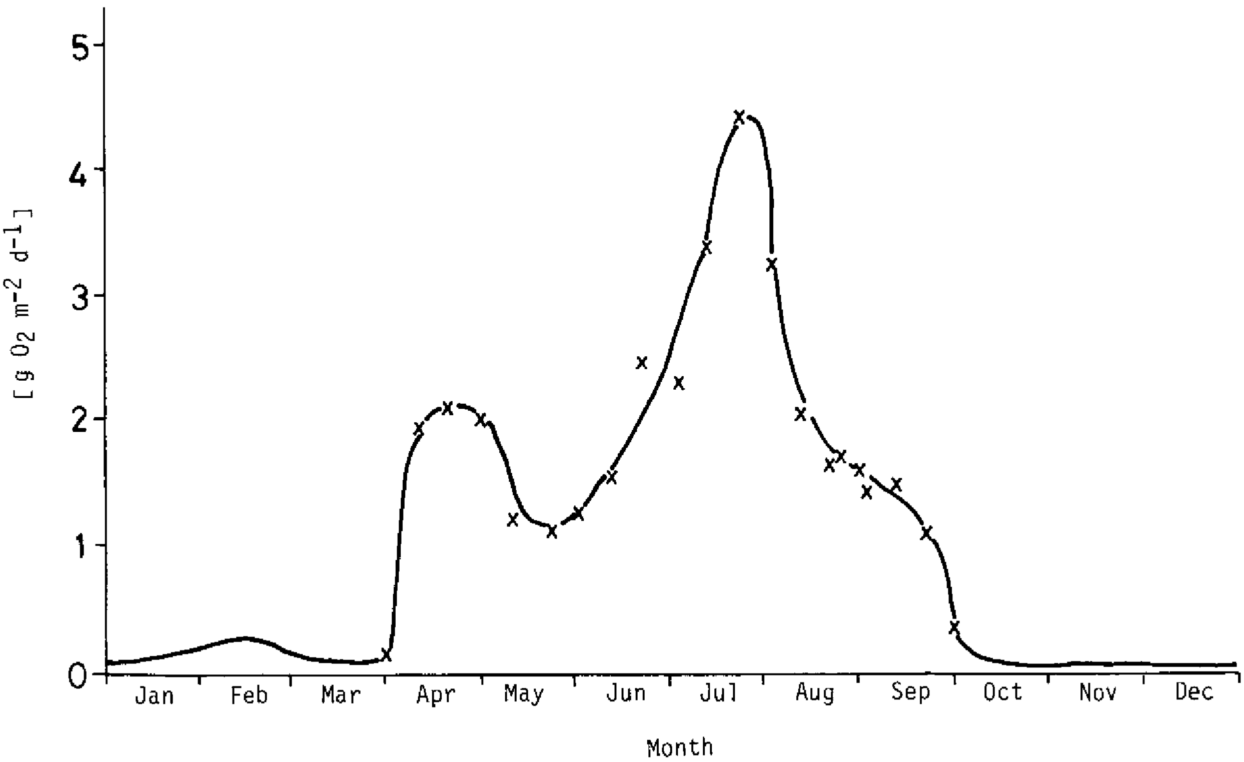
F3 PRIMARY PRODUCTION RATE

§ Gross primary production rate for phytoplankton (3, 4)

Annual gross production, Nebřich Station, 1962-1969: average 6. 12 (range 0.90-3.02) [g $m^{-2}day^{-1}$].

By light and dark bottle/oxygen method. Composite value based on the measurements at 0, 0.5, 1, 2, ······, 6 m depths and recalculated from half-day exposures.

Fig. EUR-39-10 Average seasonal changes of gross primary production rate, Nebřich, 1961-1968.



F4 BIOMASS

§ Phytoplankton biomass

The long term annual average is about 1.9 mg l^{-1} fresh weight. The annual development is characterized by a two-peak curve (spring and summer peaks) reaching maxima between 2.6 and 11.5 mg l^{-1} fresh weight in different years. Winter values are extremely low (0.2-3 μg l^{-1} fresh weight) (3, 4, 7).

§ Zooplankton biomass

The average value for the period 1959-1969 was for the top 5 m 0.195 g m^{-2} protein N, which is equivalent to about 23 g m^{-2} fresh weight. Cladocera accounted for about 50 % of the total biomass (2, 4, 8).

§ Biomass of benthos

At depths 30 m and 40 m at the sampling station Nebřich, the biomass was 62-96 g m^{-2} fresh weight in 1960 and dropped to 51-56 g m^{-2} in 1961 after the construction of Orlík Reservoir. Oligochaeta amounted to 91-99 % in both years. At a station near the river entrance the biomass was between 197 and 346 g m^{-2} in 1960, but dropped to just 5-8 g m^{-2} in 1961 (3).

§ Fish biomass

Rutilus rutilus and *Perca fluviatilis* comprised in average 75 % of the biomass of all fish species caught by nets. *Esox lucius* and *Stizostedion lucioperca* formed 8 % of the biomass (9).

F5 FISHERY PRODUCTS

§ Annual fish catch in 1958-1963 : 21.0 by anglers and 23.5 by nets [metric tons].

§ Fishery products other than fish : None.

F6 PAST TRENDS

§ Past trends of phytoplankton community

Before Orlík Reservoir construction (samples from 1960-1961) the average biomass in the top 3 m was 4.13 mg l^{-1} fresh weight, with maxima formed mainly (97-100 %) by heavy blooms of *Aphanizomenon flos-aquae* and *Microcystis aeruginosa* reaching 24.9 mg l^{-1}. Since then, the biomass in fresh weight has remained nearly constant. However, chlorophyll-*a* concentrations almost doubled within the last 30 years (average for 1963-1969, 6.89 mg l^{-1}, for 1982-1989, 11.42 mg l^{-1}). This is due to the replacement of larger species with low chlorophyll content (*Ceratium hirundinella*, *Peridinium* spp., diatoms) by smaller Cryptophycae, Volvocales and Chlorococcales with higher chlorophyll content. Recently also minute colonial Chlorococcales of the genera *Aphanothece* and *Aphanocapsa* have started to appear. In the seasonal changes the domination of summer peaks was replaced within the last 30 years by spring peaks which now represent the annual maxima (2, 3, 4, 7).

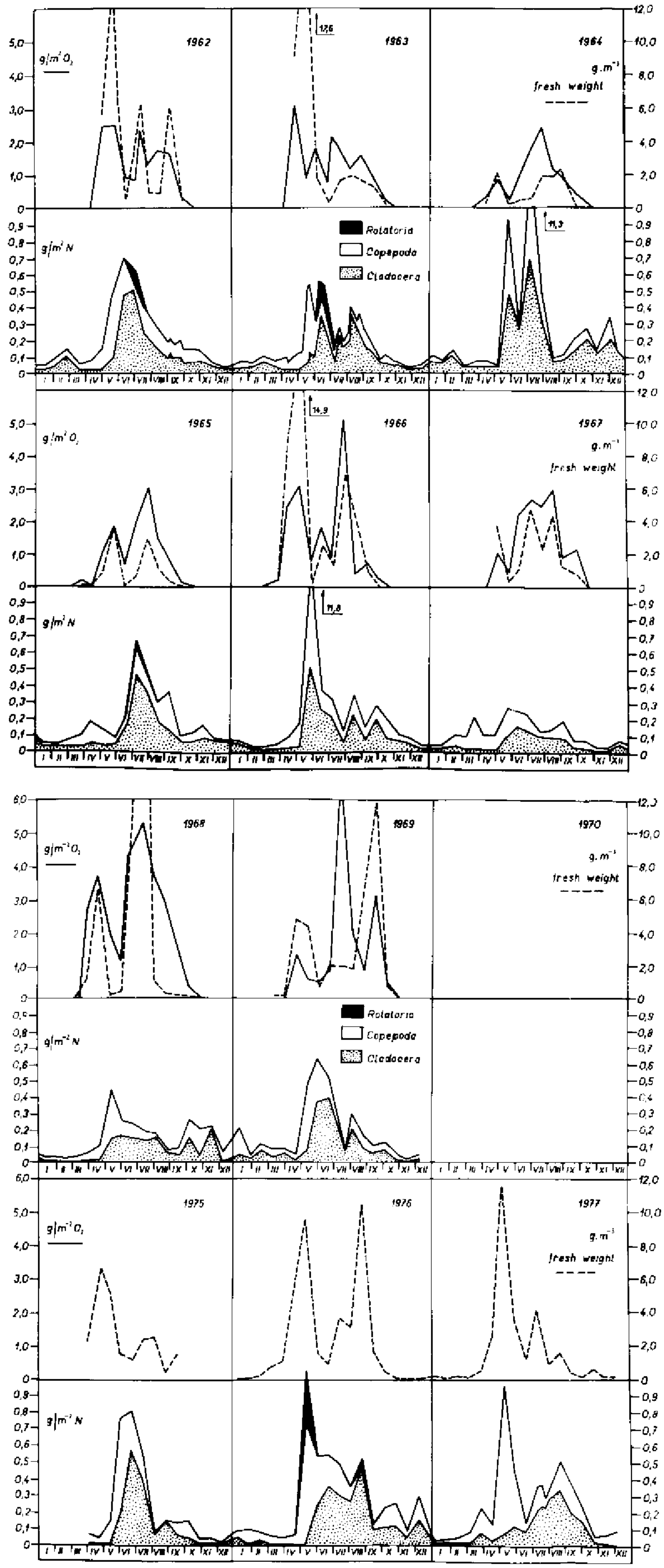
Phytoplankton biomass and productivity (4)

Period	1960-1961	1963-1969	1975-1983	1984-1989
Gross production rate [g $m^{-2}day^{-1}$]	2.37	1.62	—	—
Biomass [mg l^{-1} fresh weight]	4.13	1.76	1.92	—
Chlorophyll *a* [μg l^{-1}]	—	6.86	10.02	11.52

§ Past trends of zooplankton community

Biomass was lower during 1959-1960 (the pre-Orlík period) with heavy blooms of blue-greens: 0.101-0.149 g m^{-2} protein N (2, 4, 8).

Fig. EUR-39-11 Changes in phytoplankton biomass (-----), gross primary production (——), and zooplankton biomass (Rotatoria, Copepoda and Cladocera).



§ Past trends of fish community

Evident changes in the relative abundance of some species are observed when the two periods 1959-1963 and 1985-1987 are compared. The relative abundance of *Abramis brama* decreased from 57 % to 3 %, while the relative biomass of *Rutilus rutilus* and *Perca fluviatilis* increased from 43 % to 75 % (9).

§ Past trends of benthos

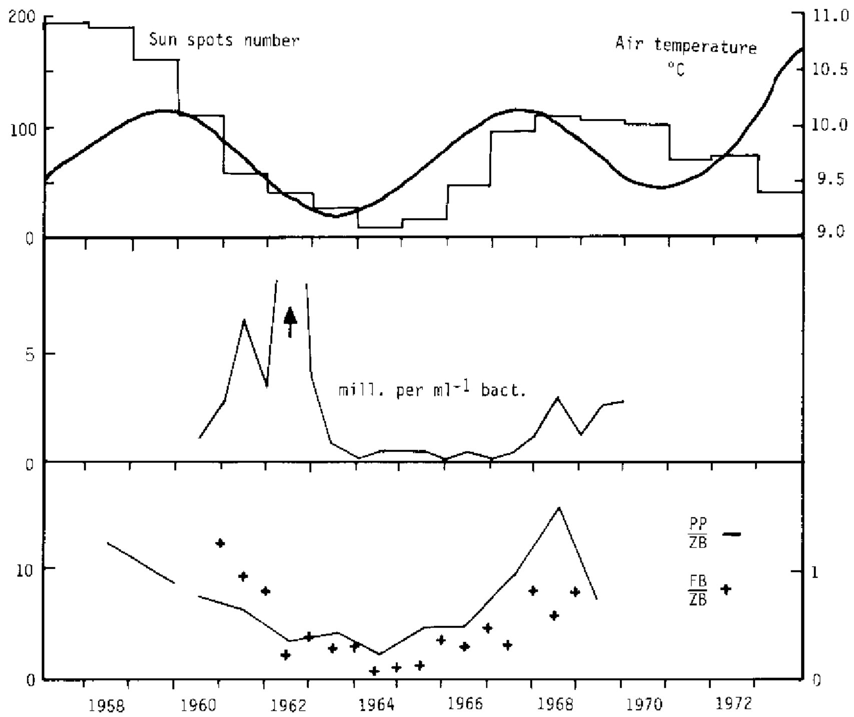
In the pre-Orlík period the biomass of benthos in the inflow part of the reservoir was by two orders of magnitude larger than afterwards (annual average 150 g m^{-2} in 1960 and 4.9 and 1.2 g m^{-2} in 1961 and 1963, respectively). In the lower part near the dam the changes were less conspicuous (44 g m^{-2} in 1961 versus 34 and 22 g m^{-2} in 1961 and 1963, respectively).

F7 NOTES ON THE REMARKABLE CHANGES OF BIOTA IN THE LAKE

Cyclic changes between years with alternating high and low bacteria numbers were observed, and possible causative factors such as secular changes of sun spots number, associated hydrometeorological changes and the relations between phyto- and zooplankton were investigated (Fig. EUR-39-12). In 1970-1975 some submerged objects were heavily overgrown by a freshwater bryozoan *Pectinatella magnifica*. The appearance of a fresh water medusa *Craspedacusta sowerbyi* in 1989 was also peculiar (4).

The changes associated with the construction of upstream Orlík Reservoir in 1960: disappearance of heavy blooms of *Aphanizomenon flos-aquae* and *Microcystis aeruginosa*. Light blooms of *Microcystis* started to reappear in the late 1980's.

Fig. EUR-39-12 Cyclic changes of bacteria numbers and possible causative factors. PP: phytoplankton production. PB: phytoplankton biomass. ZB: zooplankton biomass.



G. SOCIO-ECONOMIC CONDITIONS

G1 LAND USE IN THE CATCHMENT AREA (1988) (11)

	[km²]	Area [%]
Natural landscape	3,870	30
Agricultural land	6,579	51
Crop field	6,192	(48)
Pasture land	387	(3)
Others	2,451	19
Total	12,900	100

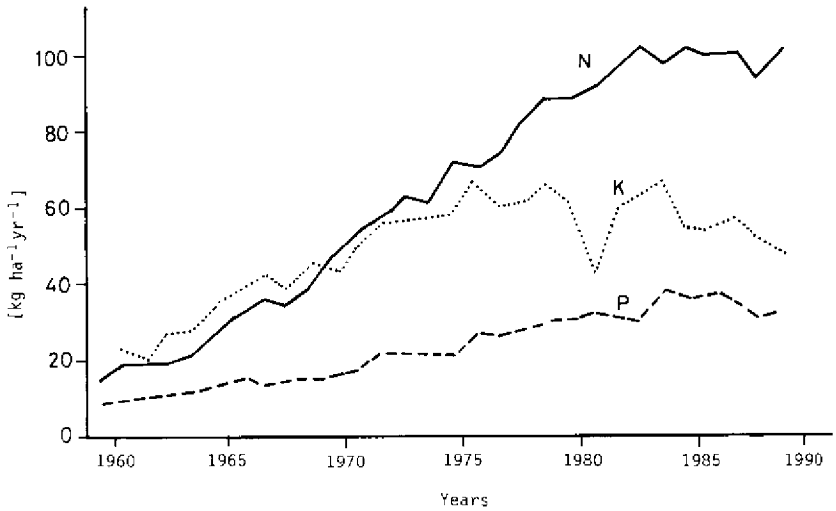
§ Types of important forest or scrub vegetation : Coniferous forests (*Picea, Pinus, Abies*) ; percentage of broadleaf deciduous forests (dominantly *Fagus*) is low.

§ Main kinds of crops : Wheat, barley, oat, potato, maize.

§ Levels of fertilizer application on crop fields : Heavy.

Between 1959-1982 a significant increasing trend in fertilizer application was noted (relative increase for N 7 times, for P 4 times, for K 3 times. After 1982 the levels fluctuate around 100 kg for N, 30 kg for P and 60 kg $ha^{-1}yr^{-1}$ for K (4, 6, 8, 12).

Fig. EUR-39-13 Past trends in the amount of fertilizer application.



G2 INDUSTRIES IN THE CATCHMENT AREA AND THE LAKE (11)

The watershed is dominated by primary industry, about 10 % of population are engaged in agriculture in about 200 establishments (state or collective agricultural units). Secondary industry — mainly paper mills and power plant, and partly food processing and some machinery and textile factories.

§ Number of domestic animals in the catchment area : Cattle 490,000, sheep 36,000, swine 578,000, poultry 3,227,000, others 3,000.

G3 POPULATION IN THE CATCHMENT AREA (1988) (11)

	Population	Population density [km^{-2}]	Main cities
Urban	162,438	92	Č. Budějovice, Písek, Tábor
Rural	534,778	47	
Total	697,216	62	

H. LAKE UTILIZATION

H1 LAKE UTILIZATION

Source of water, sightseeing and tourism, recreation (swimming, sport-fishing, yachting), fisheries and power generation.

H2 THE LAKE AS WATER RESOURCE

	Use rate [GWh yr^{-1}]
Domestic water	Local use
Power plant	300

I. DETERIORATION OF LAKE ENVIRONMENTS AND HAZARDS (Q, 1, 2, 8, 9, 16)

I1 ENHANCED SILTATION

§ Extent of damage : Not serious.

§ Supplementary notes

Before the construction of upstream Orlík Reservoir, siltation was important, with effects on water quality of the inflowing river stretch. After 1960 there is nearly no siltation, all sediments being retained in Orlík Reservoir.

I2 TOXIC CONTAMINATION

§ Present status : Detected but not serious.

§ Main contaminants, their concentrations and sources

Dam, 1976-1980

Name of contaminants	Range of concentrations [$\mu g\ l^{-1}$] in water	Main sources
Zn	10-650	Industrial
Cu	10-80	
Pb	3-8	
Hg	max 0.7	
Cd	2	

§ Past trends

Pesicides concentrations determined in 1976-1977 ; pp' DDT 3 $\mu g\ l^{-1}$, δ-HCH 0.5 $\mu g\ l^{-1}$, aldrin 1 $\mu g\ l^{-1}$, endrin 0.1 $\mu g\ l^{-1}$, heptachlor 0.5 $\mu g\ l^{-1}$ (13).

I3 EUTROPHICATION

§ Nuisance caused by eutrophication : Unusual algal bloom (*Aphanizomenon flos-aquae, Microcystis aeruginosa*) and nuisance to swimming (prior to 1960).

§ Nitrogen and phosphorus loadings to the lake (1987)

Sources	Domestic	Agricultural	Total
T-N		75 %	1.4 [kg $m^{-2}yr^{-1}$]
T-P	$\underbrace{\qquad\qquad}_{90\ \%}$		19 [g $m^{-2}yr^{-1}$]

§ Supplementary notes

Nitrogen loadings to the lake are continuously increasing from 1959 (0.23 kg $m^{-2}yr^{-1}$) till present (1987 : 1.4 kg $m^{-2}yr^{-1}$). The source is dominantly agriculture. Phosphorus loadings before the construction of Orlík Reservoir (1959-1960) amounted to 15-25 g $m^{-2}yr^{-1}$, but thereafter dropped to 5-20 g $m^{-2}yr^{-1}$.

I4 ACIDIFICATION

§ Extent of damage : None.

Due to large natural buffering capacity and high nutrient and mineral contents due to fertilizer runoff, no signs of acidification have appeared in the lake.

§ Past trends in hydrogen ion concentration

Rain water is highly acid, with a mean pH value (volume-weighted average for the last 10 years) of 4.25. The following bulk precipitation loads [kg $ha^{-1}yr^{-1}$] were observed in the last 10 years (1979-1987) (14).

T-N	NO_3-N	NH_4-N	Org-N	T-P	Org-C	SO_4-S	Na	K	Ca	Mg
11.5	4.4	4.3	2.8	0.16	16	18	1.6	1.3	5.1	0.62

I5 OTHER HAZARDS

There are several sources of radioactivity in the watershed. Since 1962 a potential source is the treatment plant for uranium ore at Mydlovary. In 1982 uranium concentrations up to 0.37 mg l^{-1} corresponding to about 22 Bq. l^{-1} were recorded in the Vltava River above Slapy. Recent examination (1990) did not show any significant hazards.

J. WASTEWATER TREATMENTS

J1 GENERATION OF POLLUTANTS IN THE CATCHMENT AREA : (d) Measurable pollution with limited wastewater treatment.

J2 APPROXIMATE PERCENTAGE DISTRIBUTION OF POLLUTANT LOADS

	Percentage
Non-point sources (agricultural, natural and dispersed settlements)	50
Point sources	
Industrial (paper mill wastes)	50
Total	100

J3 SANITARY FACILITIES AND SEWERAGE

§ Percentage of municipal population in the catchment area provided with adequate sanitary facilities (on-site treatment systems) or public sewerage : 78.1 %.

§ Percentage of rural population with adequate sanitary facilities : None.

§ Municipal wastewater treatment systems

Number of tertiary treatment systems : None.

Number of secondary treatment systems : 125.

§ Number of industrial wastewater treatment systems : 51.1 % (total industrial sewage is treated ; for paper mill industry a combined paper-mill/municipal sewage treatment system and an evaporation unit are under construction.)

L. DEVELOPMENT PLANS

Drinking water supply for Prague from or below Slapy Reservoir — being planned for the year 2000.

Significant extension of the paper-mill industrial wastewater treatment — under construction.

A nuclear power plant — in the process of construction at Temelin, some 8 km above the inflow to Orlík and 90 km above Slapy. The operation of the first two blocks of 1,000 MW each is expected to start in 1993 ; the construction of two other blocks is under debate. The expected concentration of tritium will be much below the WHO safety limit. Phosphorus and sulphate concentrations may be more harmful.

M. LEGISLATIVE AND INSTITUTIONAL MEASURES FOR UPGRADING LAKE ENVIRONMENTS

M1 NATIONAL AND LOCAL LAWS CONCERNED

§ Names of the laws (the year of legislation)
(1) 25/75 (1975)
(2) 28/75 (1975)
(3) 3/77 (1977)
(4) 83 0603 Czechoslovak State Norm
(5) 83 0611 Czechoslovak State Norm

§ Responsible authorities
(1) Government of Czech Socialistic Republic
(2) Czech Ministry of Forestry and Water Management
(3) Czech Ministry of Forestry and Water Management

§ Main items of control
(1) Determination of permissible degrees of the parameters of water pollution
(2) Identification of streams for water supply and their watersheds and listing streams significant for water management
(3) Protection of the quality of surface and ground waters
(4) Monitoring of the quality of surface waters
(5) Drinking water

§ Supplementary notes

Additional Czechoslovak State Norms: Instruction by Czech Ministry of Forestry and Water Management and Czech Ministry of Health and Nutrition on improvement of the quality of water in selected water supply reservoirs by specialized fish management. 83 0612 Operational monitoring of the quality of drinking water in water management; 83 0520 Physical-chemical analysis of drinking water; 83 0532 Biological analysis of surface water.

M2 INSTITUTIONAL MEASURES

(1) Povodí Vltavy (Vltava River Board)

M3 RESEARCH INSTITUTES ENGAGED IN THE LAKE ENVIRONMENT STUDIES

(1) Water Research Institute at Prague (15)
(2) Slapy Field Station of the Hydrobiological Laboratory (now Hydrobiological Institute), Czechoslovak Academy of Sciences

§ Supplementary notes

Long-term scientific investigations (since 1958 till present) of the Slapy Reservoir ecosystem from the physical, chemical, bacteriological and biological points of view. The following items are studied particularly; automatic monitoring of several parameters during summer months of several years; development of new chemical, bacteriological and biological methods; mathematical modelling of water quality; comparison between reservoirs of the effect of retention time on reservoir limnology; eutrophication studies; interrelations between bacteria, phytoplankton, zooplankton and fish (2, 3, 4, 6, 7, 8, 10, 13, 14).

N. SOURCES OF DATA

(Q) Questionnaire filled by Dr. M. Straškraba, Hydrobiological Laboratory, Czechoslvak Academy of Sciences.
(1) Data by the Hydrometeorogical Institute, Praha.
(2) Hrbáček, J. (ed.) (1966) Hydrobiological Studies, vol. 1. 408 pp. Academia, Praha.
(3) Hrbáček, J. & Straškraba, M. (eds.) (1973) Hydrobiological Studies, vol. 2. 348 pp. Academia, Praha.
(4) Data by the staff of Hydrobiological Laboratory, Czechoslovak Academy of Sciences. See also Annual Reports vols. 1-28, Hydrobiological Laboratory CAS, Praha and Č. Budějovice.
(5) Straškraba, M. (1971) Limnological basis for modelling reservoir ecosystems. "Man-made Lakes: Their Problems and Environmental Effects (Geophysical Monograph Series 17)" (ed. Ackerman, W. C., White, G. F. & Worthington, E. B.), pp. 517-535.

(6) Procházková, C. & Blažka, P. (1986) Long-term trends in water chemistry of the Vltava River (Czechoslovakia). Limnologica (Berlin) 17 : 263-271. See also — (1989) Ionic composition of reservoir water in Bohemia : long-term trends and relationships. Arch. Hydrobiol., 33 : 323 -330.
(7) Desortová, B. (1980) Phytoplankton of Slapy Reservoir. Sborník Vlastivědných prací z podblanicka, 21 : 33-50 (in Czech).
— (1980) Seasonal development of phytoplankton in Slapy Reservoir with special attention to the spring algal phase. Arch. Hydrobiol. Beih., Ergebn. Limnol., 33 : 409-417.
(8) Hrbáček, J. (1984) Ecosystems of European man-made lakes. "Lakes and Reservoirs" (ed. Taub, F.), pp. 267-290. Elsevier, Amsterdam.
(9) Hanel, L. (Klandruby), personal communication.
(10) Straškrabová, V. (in print) : Periodic interannual oscillations in bacterial number and activity related to meteorological cycles. Verh. Internat. Verein Limnol.
(11) Statistical Yearbook of Czechoslovakia (in Czech). SNTL, Praha.
(12) Straškraba, M., et al. (1981) Estimation of further development of water quality in the lower part of the Vltava Cascade. Final Reports, Section of Hydrobiology, Inst. Landscape Ecology CAS, Praha (in Czech).
(13) Procházková, L. & Bcažka, P. (1984) Summery of Papers and Reports Considering the Vltava River as Water-supply Source of the City of Prague and Its Surroundings. 15 pp. Report, Inst. Landscape Ecol., Section of Hydrobiology (in Czech).
(14) Blažka, P. & Procházková, L. (1987) Relationship of sulphate and nitrate concentrations and pH of precipitations. "Proc. Internat. Workshop on Geochemistry and Monitoring in Representative Basins" (ed. Moldan, B. and Pačes, T.), pp. 26-28. GEOMON, Czechoslovakia.
(15) Brádka, J. (1965) The Resulting Effect of Reservoirs of the Vltava Cascade on Water Quality. Final Report, Water Research Institute, Praha (in Czech).

LAKE VOLVI

A view from the southern shore

Photo: A. Kurata

A. LOCATION

§ Macedonia, Greece.
§ 40°37′-40°41′N ; 23°21′-23°36′E ; 37 m above sea level.

B. DESCRIPTION

Lake Volvi is one of the numerous Macedonian lakes in northern Greece, and is located about 40 km northeast from the city of Thessaloniki. The catchment is mostly barren, mainly used for grazing except a small portion under cultivation, and without any urban or industrial development. Some dry rivers drain the catchment area, while a small stream is the only outflow. There are times when the lake receives water from a neighboring lake, Koronia.

The Lake Volvi area is characterized by a mild Mediterranean climate with rainy warm winters and dry hot summers. The lake never freezes over in winter. The precipitation is the largest in November — December and the least in August. High floods may sometimes occur by unusual heavy rainfall, in contrast to severe droughts when minimum inflow reaches the lake.

Lake Volvi is a warm monomictic lake with thermal and chemical stratification established in May. During the stratification period, the epilimnion is about 11 m thick and microstratifications develop within it. By September, the overturn is initiated and isothermal conditions prevail in winter and early spring. The maximum surface water temperature is measured in August and the minimum in February. The concentration of oxygen in the epilimnion ranges approximately from 8 to 10 mg l^{-1} and the maximum concentration is recorded during the isothermal conditions. During the stratification period the hypolimnion is devoid of oxygen.

Recently, blue-green algal blooms have been observed in early summer after a very dry period when the external input of nutrients decreases significantly. Therefore, it is concluded that the nitrogen fixation by N_2-fixing cyanophytes and the release of ammonia nitrogen, phosphorus and silica from the anoxic sediment may be the most important sources of nutrient supply in this lake during the dry, warm period when the highest phytoplankton biomass is developed (1, 2).

C. PHYSICAL DIMENSIONS

Surface area [km^2]	68.6
Maximum depth [m]	23
Mean depth [m]	13.5
Normal range of annual water level fluctuation [m]	Unregulated
Catchment area [km^2]	1,247

D. PHYSIOGRAPHIC FEATURES

D1 GEOGRAPHICAL

§ Bathymetric map (Fig. EUR-40-1).
§ Main islands : None.
§ Outflowing rivers and channels (number and names) : 1 (unknown).

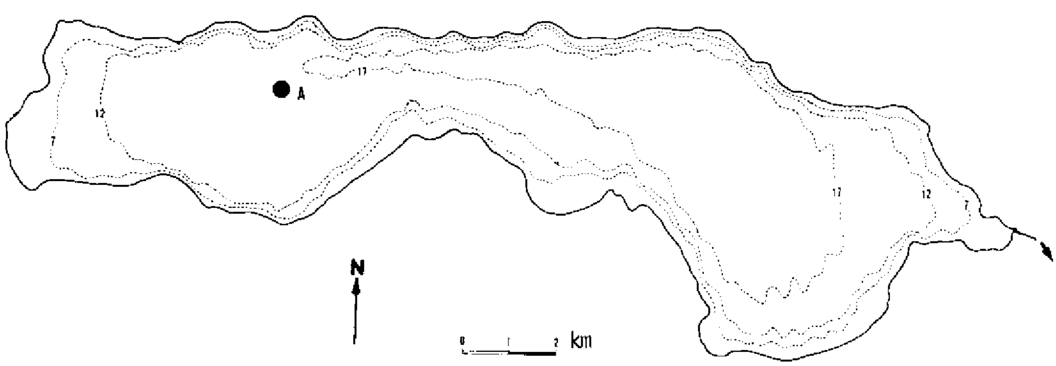
D2 CLIMATIC

§ Climatic data at Thessaloniki, 1931-1960

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean temp. [°C]	5.5	7.1	9.6	14.5	19.6	24.7	27.3	26.8	22.5	17.1	12.0	7.5	16.1
Precipitation [mm]	44	34	35	36	40	33	20	14	28	55	56	54	449

§ Number of hours of bright sunshine (Athens) : 2,655 hr yr^{-1}.

Fig. EUR-40-1 Bathymetric map [m] (1).



§ Water temperature [°C]

Station A, Apr. 1985-Mar. 1986 (1)

	Min.	Max.	Annual mean
Surface	6.9	27.0	17.5
Bottom	6.7	22.0	14.8

§ Freezing period : None.
§ Mixing type : Monomictic.

E. LAKE WATER QUALITY

E1 TRANSPARENCY [m]

Station A, Apr. 1985-Mar. 1986 (1)

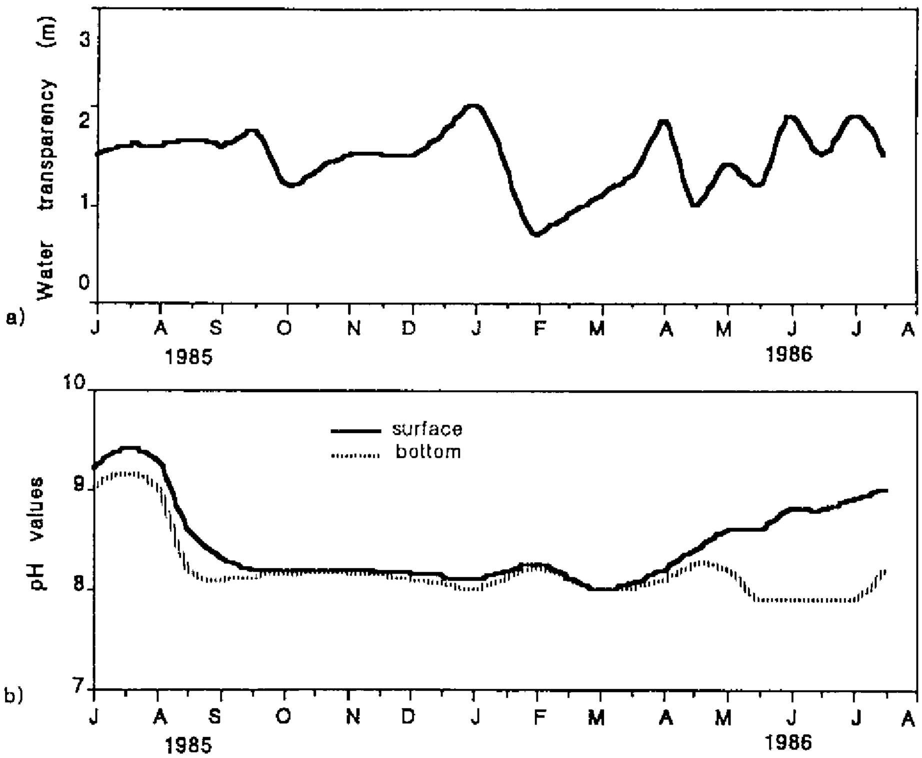
Min.	Max.	Annual mean
0.7	2.4	1.6

E2 pH

Station A, whole water column, Apr. 1985-Mar. 1986 (1)

Min.	Max.	Annual mean
8.0	9.3	8.5

Fig. EUR-40-2 Seasonal variation of transparency (a) and pH (b) (2).



E4 DO [mg l^{-1}]

Station A, whole water column, Apr. 1985-Mar. 1986 (1)

	Min.	Max.	Annual mean
Surface	8.4	11.7	9.6
Bottom	0.0	11.2	5.5

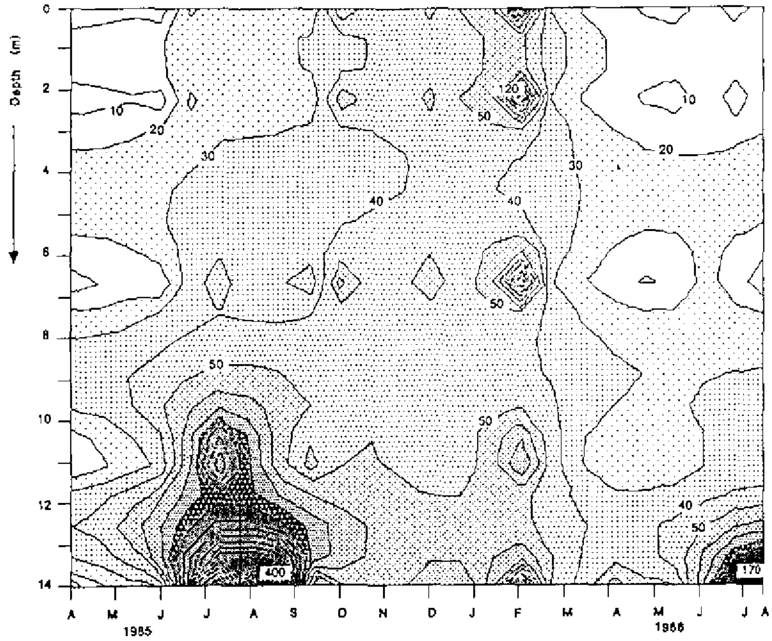
E7 NITROGEN CONCENTRATION

§ NH_4-N [mg l^{-1}]

Station A, whole water column, Apr. 1985-Mar. 1986 (1)

Min.	Max.	Annual mean
0.003	0.109	0.448

Fig. EUR-40-3 Vertical and seasonal distribution of NH_4-N concentration [$\mu g\ l^{-1}$] (2).



§ NO_2-N [mg l^{-1}]

Station A, whole water column, Apr. 1985-Mar. 1986 (1)

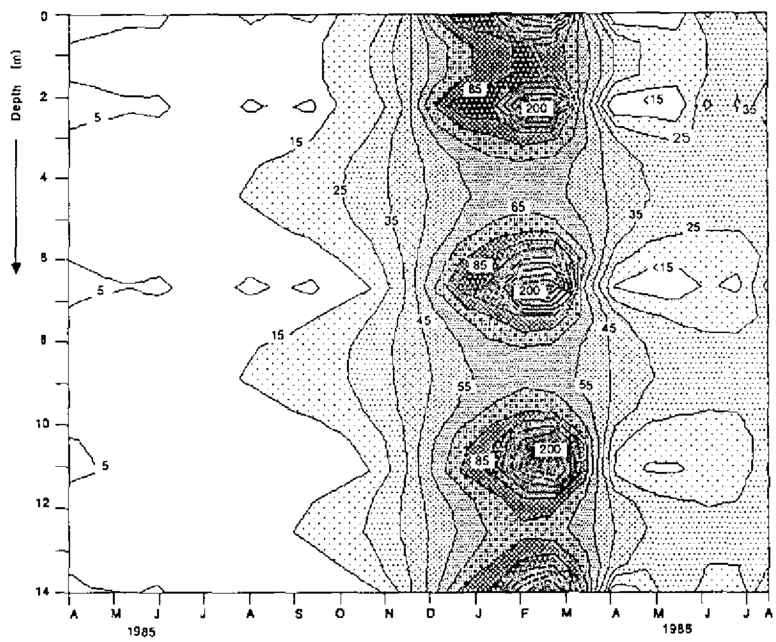
Min.	Max.	Annual mean
0.0	0.057	0.006

§ NO_3-N [mg l^{-1}]

Station A, whole water column, Apr. 1985-Mar. 1986 (1)

Min.	Max.	Annual mean
0.001	0.197	0.045

Fig. EUR-40-4 Vertical and seasonal distribution of NO_3-N concentration [$\mu g\ l^{-1}$] (2).



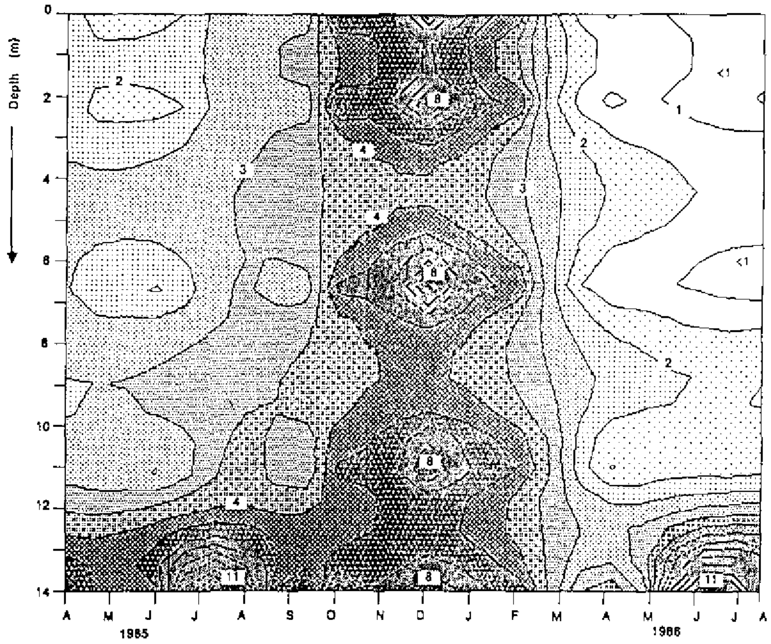
E8 PHOSPHORUS CONCENTRATION

§ PO_4-P [mg l^{-1}]

Station A, whole water column, Apr. 1985-Mar. 1986 (1)

Min.	Max.	Annual mean
0.002	0.008	0.004

Fig. EUR-40-5 Vertical and seasonal distribution of PO_4-P concentration [μg l^{-1}] (2).



F. BIOLOGICAL FEATURES

F1 FLORA (1)

§ Phytoplankton

Cyanophyta (*Anabaena aphanizomenoides, A. circinalis, A. flos-aquae, Anabaenopsis circularis, Aphanocapsa delicatissima, Aphanothece clathrata, Chroococcus limneticus, Coelosphaerium kuetzingianum, C. minutissimum, Cyanocatena planctonica, Cyanogranis ferruginea, Cylindrospermopsis raciborskii, Lyngbya circumcreta, L. limnetica, Merismopedia punctata, M. tenuissima, Microcystis aeruginosa, M. incerta, Oscillatoria limnetica, O. subtilissima, Pseudanabaena limnetica, Radiocystis geminata*), Chlorophyta (*Actinastrum hantzschii, Coelastrum astroideum, C. microporum, Coenococcus polycoccus, Coronastrum lunatum, Crucigenia tetrapedia, Crucigeniella apiculata, Dichotomococcus curvatus, Dictyosphaerium pulchellum, D. tetrachotomum, Didymocystis planctonica, Didymogenes palatina, Elakatothrix genevensis, Franceia ovalis, Kirchneriella lunaris, Koliella longiseta, K. planctonica, Lagerheimia ciliata, L. genevensis, Micractinium pusillum, Monoraphidium arcuatum, M. contortum, M. griffithii, Nephrochlamys willeana, Nephrocytium lunatum, Oocystis lacustris, O. marssonii, Pediastrum boryanum, P. duplex, P. simplex, P. tetras, Planktosphaeria gelatinosa, Quadricoccus ellipticus, Scenedesmus acuminatus, S. alternans, S. ecornis, S. intermedius, S. opoliensis, Tetraedron caudatum, T. minimum, Tetrastrum heteracanthum, Closterium aciculare, C. acutum, Cosmarium depressum*), Euglenophyta (*Euglena* sp.), Chrysophyta (*Cyclotella* sp., *Melosira granulata, Rhizosolenia longiseta, Stephanodiscus hantzschii, S. rotula, Nitzschia acicularis, Synedra acus, S. ulna, Mallomonas* sp.), Dinophyta (*Ceratium hirundinella, Gymnodinium* spp.), Cryptophyta (*Rhodomonas minuta*), Haptophyta (*Chrysochromulina* cf. *parva*).

F2 FAUNA (2)

§ Zooplankton : *Daphnia cucullata*, *Bosmina longirostris*, *Polyarthra* sp., *Keratella* sp.

Fig. EUR-40-6 Changes in the number of species belonging to the most numerous algal classes (a) and the total number of phytoplankton species (b) (2).

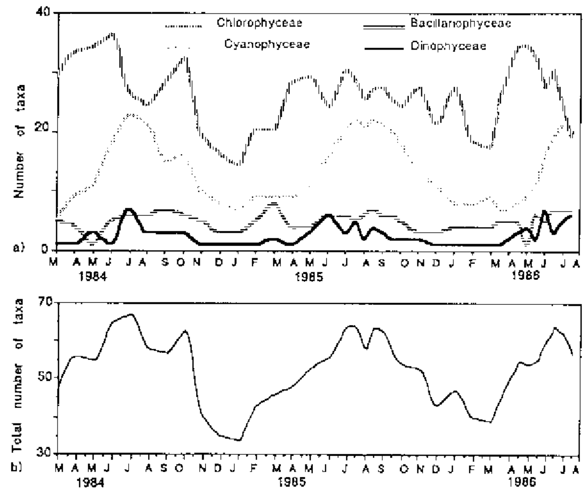
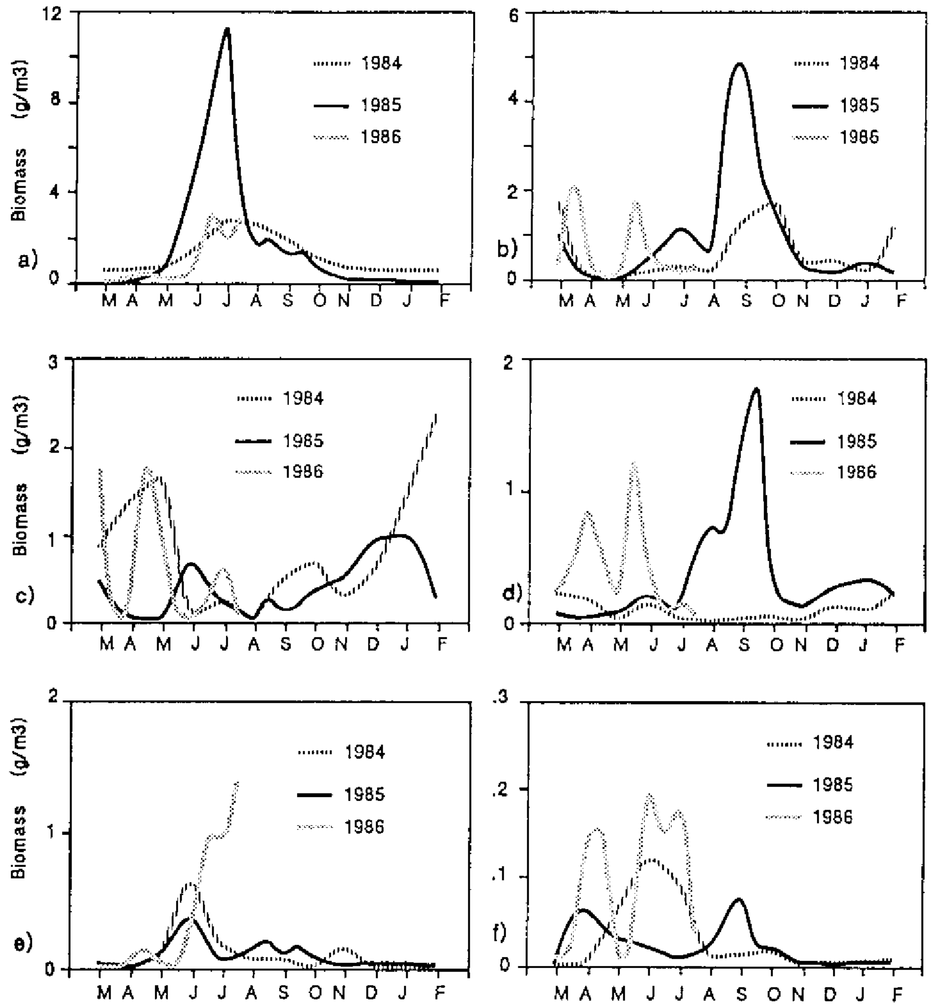


Fig. EUR-40-7 Annual cycles of cyanophytes (a), diatoms (b), cryptophytes (c), chlorophytes (d), dinoflagellates (e) and haptophytes (f) in the lake (2).



F4 BIOMASS

§ Monthly averages of phytoplankton biomass [mg m^{-3}], 1985-1986 (1)

	Bac	Cryp	Cyan	Din	Chl	Hapt	Chr	Total biomass
Mar	1,580	581	2	0	164	0	33	2,360
Apr	261	977	0	0	133	0	29	1,400
May	0	833	45	55	10	30	53	1,026
Jun	45	19	689	248	112	68	0	1,181
Jul	258	249	1,606	160	5	51	0	2,329
Aug	127	31	1,943	59	0	7	0	2,167
Sep	1,201	355	1,200	59	21	7	0	2,843
Oct	1,738	389	466	0	35	15	0	2,643
Nov	331	267	106	136	0	0	0	840
Dec	359	556	0	0	88	2	0	1,005
Jan	162	884	1	0	73	0	3	1,123
Feb	1,096	1,254	1	13	134	3	10	2,511
Mar	622	306	5	24	47	0	3	1,007

Fig. EUR-40-8 Seasonal variation of phytoplankton biomass (1).

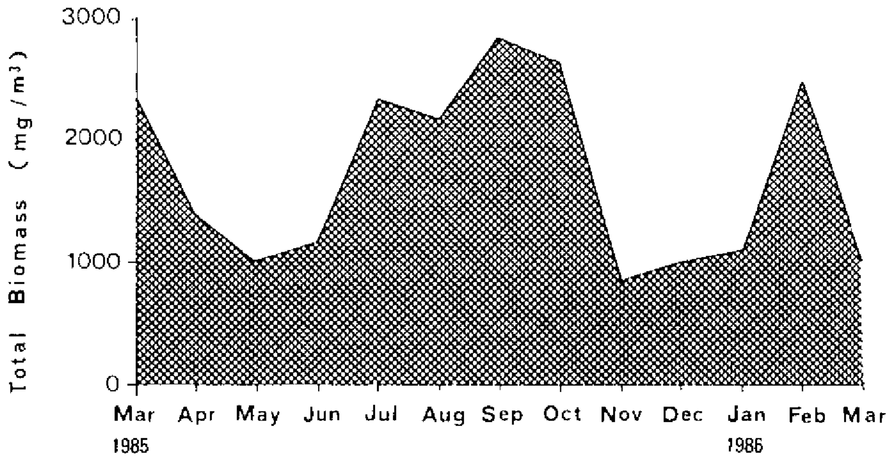
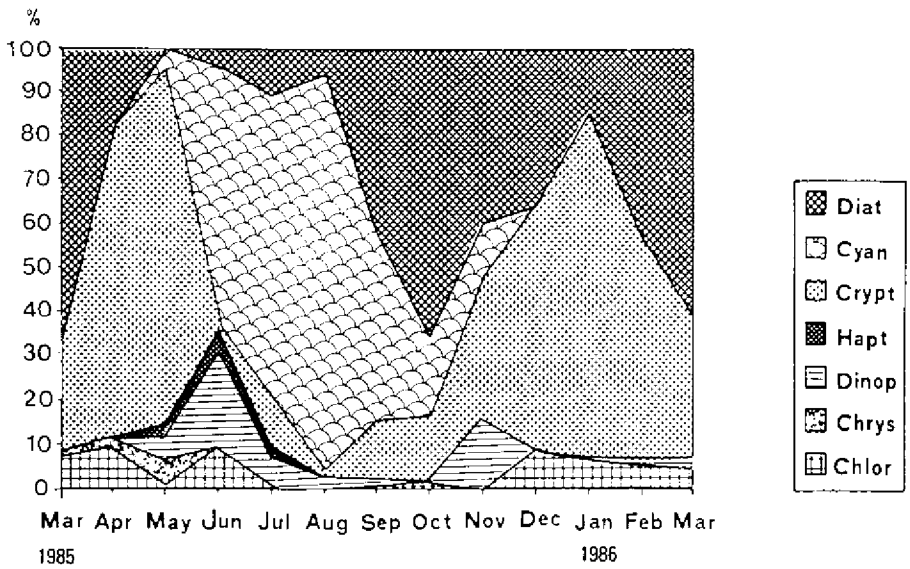


Fig. EUR-40-9 Percentage contribution of the different algal groups to the total phytoplankton biomass (1).



G. SOCIO-ECONOMIC CONDITIONS (1, 3)

G1 LAND USE IN THE CATCHMENT AREA (1988)

Mostly barren area used for grazing, only a small portion is cultivated.

§ Main types of woody vegetation : Oak, fruit gardens.
§ Main kinds of crops : Wheat, maize, barley.
§ Levels of fertilizer application on crop fields : Moderate.

G2 INDUSTRIES IN THE CATCHMENT AREA AND THE LAKE (1988)

None.

H. LAKE UTILIZATION (1, 3)

H1 LAKE UTILIZATION

Sight-seeing and tourism, and recreation.

I. DETERIORATION OF LAKE ENVIRONMENTS AND HAZARDS

I1 ENHANCED SILTATION (1, 3)

§ Extent of damage : None.

I2 TOXIC CONTAMINATION (1)

§ Present status : None.

I3 EUTROPHICATION (1)

§ Nuisance caused by eutrophication : Slight algal bloom.

I4 ACIDIFICATION (1)

§ Extent of damage : None.

J. WASTEWATER TREATMENTS (1, 3)

J1 GENERATION OF POLLUTANTS IN THE CATCHMENT AREA : (b) No sources of significant pollution.

J3 SANITARY FACILITIES AND SEWERAGE

None.

K. IMPROVEMENT WORKS IN THE LAKE

None (1, 2).

L. DEVELOPMENT PLANS

None (1, 2).

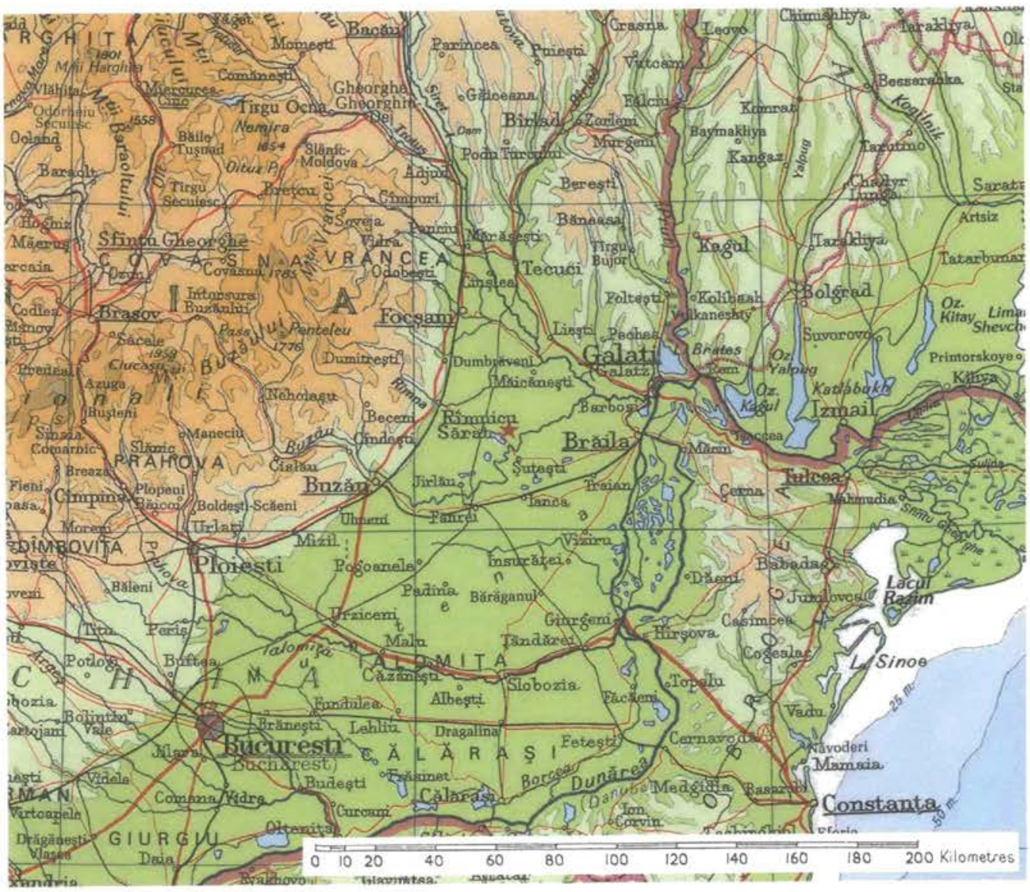
N. SOURCES OF DATA

(1) Moustaka-Gouni, M. T. (1988) Arch. Hydrobiol., 112 : 251-264.
(2) —— & Tsekos, I. (1989) Arch. Hydrobiol., 115 : 575-588.
(3) The editor's observation.

LAKE BALTA ALBĂ

A view on the lakeshore

Photo:V.-A.C. Bulgăreanu



A. LOCATION

§ Buzău and Brăila Districts, Romania.
§ 45°17′N, 27°20′E ; 22.66 m above sea level (1983).

B. DESCRIPTION

The Lake Balta Albă is located in the Râmnic Plain just south of the highway between the cities of Râmnicu-Sărat and Brăila. The southern lake shore — loessial bluff up to 24 m in height — contrasts sharply with the almost flat surrounding landscape. Seen from the bluff top, the lake displays a rich-coloured palette : the yellow of loessial bluff, the white of saline efflorescences on the beach, different shades of green belonging to reed, algae and aquatic weeds dominating the lake water mass in summer, ……

From the limnogenetic standpoint, the lake is a fluviatile "liman" formed by the alluvial damming up of an old Râmnic river bed at its confluence with the Buzău River, as a consequence of Holocene neotectonic subsidence. After the freshwater accumulation, the setting and abrasion of loess-like deposits (Upper Pleistocene — Lower Holocene) modelled the existing lake basin. The present lake, brackish, shallow, dimictic, eutrophic, and pelogenous (=with unctuous, rich-organic, therapeutical muds) is strongly influenced by freshwater inputs from precipitation and Boldu Brook, in connection with the fluctuations of steppe climate. It has only one tributary, Boldu Brook, and no outlet stream.

The sapropelic mud therapy dates back to as early as 1840, the year of the beginning of such treatments in Romania. Recent multidisciplinary researches characterized the lake as one of the important Romanian sources of therapeutical sapropelic mud, which is recommended for the treatment of some rheumatic, articular and dermatological diseases. The therapy uses the mud itself (either by outdoor application in the camping "la Plaja" or by indoor treatments in Balta Alba Spa located ca. 2 km west of the lake) or the "Pell-Amar" extract (=saline interstitial) solution obtained by squeezing the mud (Q, 2, 3, 16).

C. PHYSICAL DIMENSIONS

Surface area [km^2]	10.5
Volume [10^{6}m^3]	11.8
Maximum depth [m]	2
Mean depth [m]	1.1
Normal range of annual water level fluctuation [m] (unregulated)	0.4–0.7
Length of shoreline [km]	17.5
Residence time [yr]	1.1 (1955–1974)
Catchment area [km^2]	91.6

D. PHYSIOGRAPHIC FEATURES (Q, 3, 5, 7, 11)

D1 GEOGRAPHICAL

§ Bathymetric map (Fig. EUR-41-1).
§ Main islands : None.
§ Outflowing rivers and channels : None.

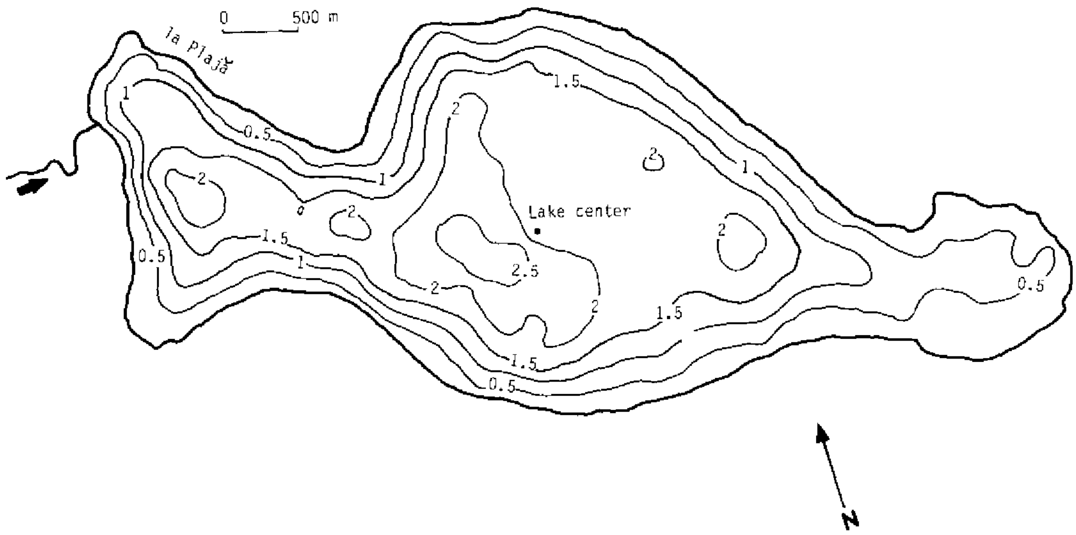
D2 CLIMATIC

§ Climatic data at Făurei (Brăila district), 1896-1965

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean temp. [°C]	-3.0	-1.1	3.9	10.5	16.2	20.1	22.5	21.7	17.0	10.9	4.8	-0.3	10.8
Precipitation [mm]	25	22	29	35	45	62	49	40	36	31	25	30	429

§ Number of hours of bright sunshine : ca. 2,100 hr yr^{-1}.

Fig. EUR-41-1 Bathymetric map [m] (Q).



§ Water temperature [°C]
Lake center

Depth [m]	Jan-Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Surface	–	20.8	24.0	27.0	26.0	19.6	13.0	6.0	–

§ Freezing period : From Dec. to Feb. (60 to 75 days).
§ Mixing type : Dimictic.

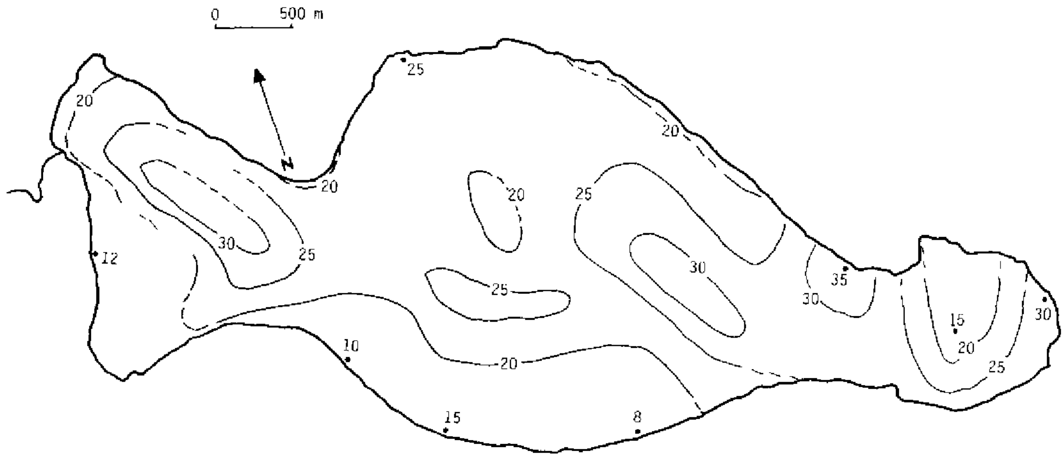
E. LAKE WATER QUALITY (Q, 2, 3, 5, 10)

E1 TRANSPARENCY [cm]

Lake center, 1983-1987

Jan-Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
–	25	–	30	29	32	33	30	–

Fig. EUR-41-2 Secchi disc transparency isopleths [cm], Aug.-Sep., 1983 (Q)

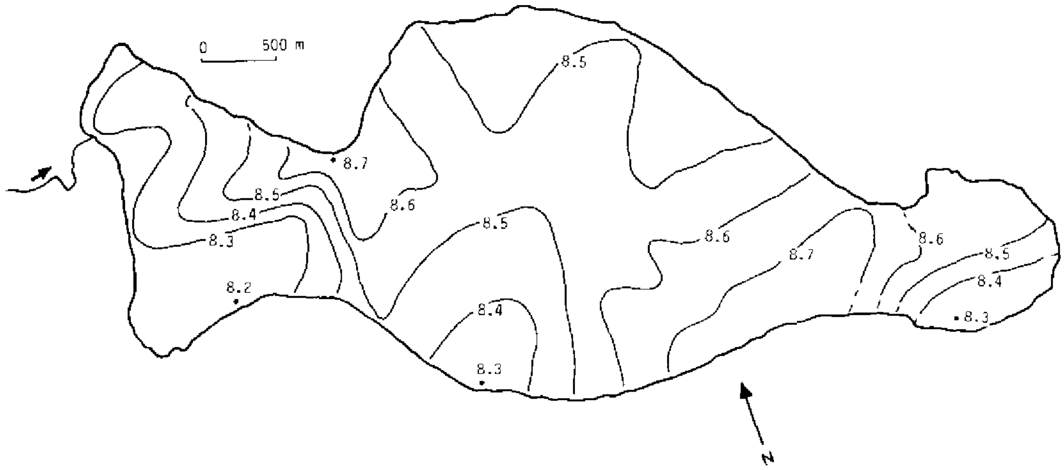


E2 pH

Lake center, 1983-1987

Depth [m]	Jan-Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Surface	—	8.65	8.60	8.00	8.36	8.73	8.27	8.30	—

Fig. EUR-41-3 Lake water pH isopleths, Aug.-Sep., 1983.



E3 SS [mg l^{-1}]

Lake center, 1983-1987

Depth [m]	Jan-Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Surface	—	35.8	—	47.1	—	28.9	29.9	—	—

E5 COD [mg l^{-1}]

Determined by K_2MnO_4 method.
Lake center, 1983-1987

Depth [m]	Jan-Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Surface	—	19.2	—	21.3	—	21.2	16.8	—	—

E7 NITROGEN CONCENTRATION

§ Total-N [mg l^{-1}]*

Lake center, 1983-1987

Depth [m]	Jan-Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Surface	—	0	—	0.03	—	0.42	0.39	—	—

* $(NO_2+NO_3+NH_4)$-N

E8 PHOSPHORUS CONCENTRATION

§ PO_4-P [mg l^{-1}]

Lake center, 1983-1987

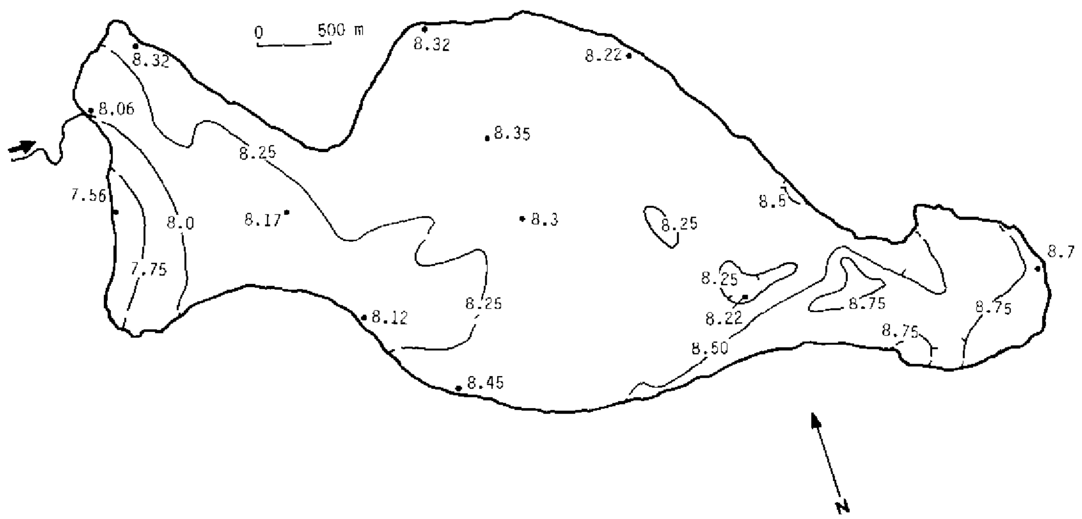
Depth [m]	Jan-Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Surface	—	0.03	—	0.10	—	0.06	0.01	—	—

E9 CHLORINE ION CONCENTRATION [mg l^{-1}]

Lake center, surface, 1983-1987

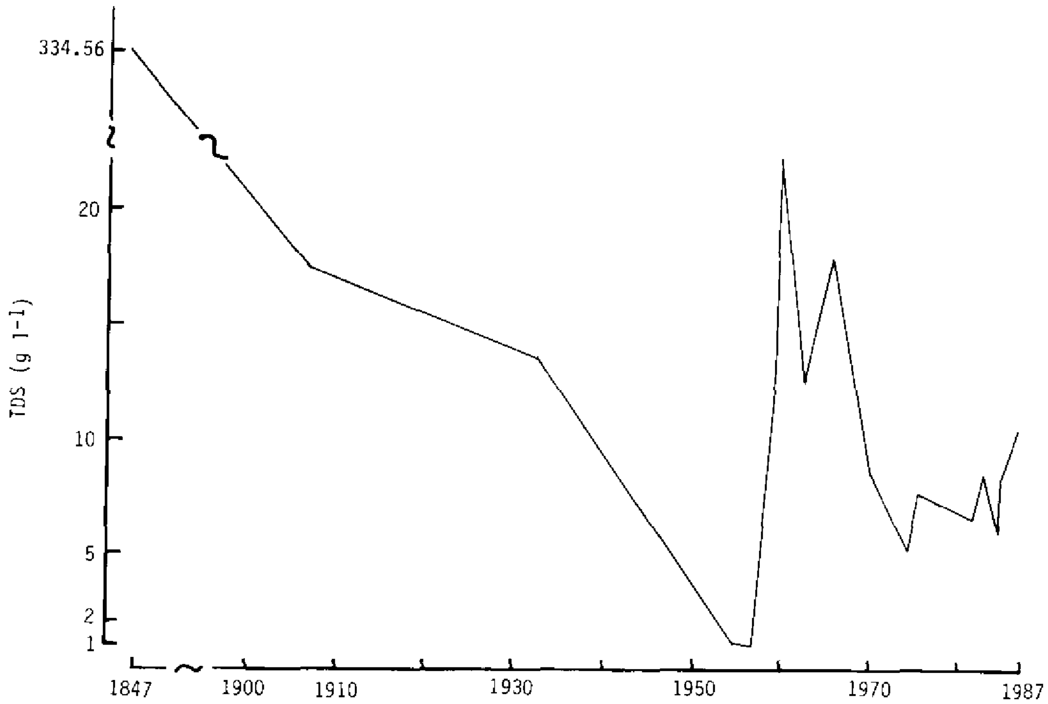
	Na	K	Mg	Ca	Cl	SO_4	HCO_3	Total dissolved solids
May	2,825	32.8	204	22.8	3,582	1,238	946	8,240
Jul	2,710	27.8	177	38.5	3,452	1,038	956	7,970
Sep	3,578	35.5	198	44.3	6,625	1,546	1,140	8,840
Oct	3,110	32.3	196	64.1	3,735	1,273	695	9.120

Fig. EUR-41-4 Isopleths of total dissolved solids [g l^{-1}], Aug.-Sep., 1983 (Q).



E10 PAST TREND OF TOTAL DISSOLVED SOLIDS CONCENTRATION

Fig. EUR-41-5 Past trend of total dissolved solids concentration [g l^{-1}]
Lake center, 1847-1987 (Q).



F. BIOLOGICAL FEATURES (Q, 1, 3)

F1 FLORA

§ Emerged macrophytes

Phragmites australis var. *communis* & *flavescens*, *Schoenoplectus lacustris.*

§ Submerged macrophytes : *Potamogeton pectinatus.*

§ Attached and benthic algae

Cladophora fracta, *Rhizoclonium hieroglyphicum*, *Enteromorpha intestinalis*, *Oscillatoria tenuis*, *O. brevis*, *O. limosa*, *Gyrosigma acuminatum*, *G. attenuatum*, *Synedra spatulata*, *Coloneis amphisbaena.*

§ Phytoplankton

Microcystis aeruginosa, *Chlamydomonas* sp., *Chlorella vulgaris*, *Gyrosigma acuminatum*, *G. attenuatum*, *Melosira varians*, *Navicula rhynchocephala*, *Synechococcus aeruginosus*, *Scenedesmus quadricauda*, *Achnanthes lanceolata.*

F2 FAUNA (Insecta)

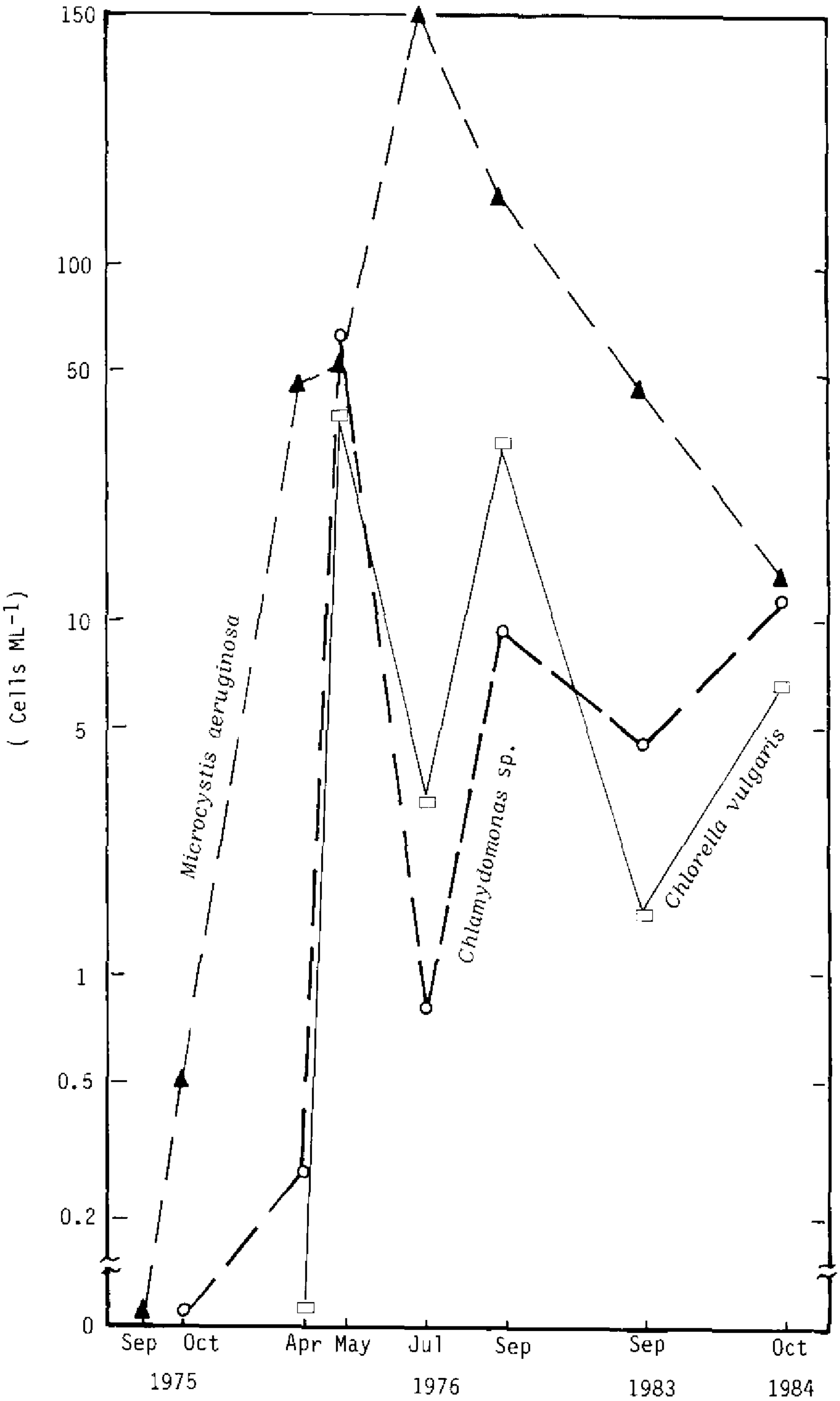
§ Zooplankton : *Arctodiaptomus salinus*, *Eucyclops serrulatus*, *Daphnia magna.*

§ Benthos : *Tanytarsus lauterborni*, *Crytochironomus fridmanae*, *Culicoides* sp.

§ Fish : *Cyprinus carpio**, *Carassus auratus gibelio** (*economically important).

F6 PAST TRENDS

Fig. EUR-41-6 Past trend of phytoplankton population density for whole lake, surface water (Q).



F7 NOTES ON THE REMARKABLE CHANGES OF BIOTA IN THE LAKE IN RECENT YEARS

The extention of the reed (*Pharagmites australis*) area ; yearly invasion of the *Potamogeton pectinatus*/*Cladophora fracta* association ; the fish species number decreased from 9 (1975-1976) to only 2 (1983-1984).

G. SOCIO-ECONOMIC CONDITIONS (Q, 11, 14, 16)

G1 LAND USE IN THE CATCHMENT AREA (1967)

§ Main species of forest or scrub vegetation : *Amygdalus nana*, *Cerasus fruticosa*, *Prunus spinosa*.

§ Main species of herbaceous vegetation : *Amaranthus albus*, *A. retroflexus*, *Artemisia maritima*, *Brassica campestris*, *Chenopodium album*, *Cynodon dactylon*, *Festuca valesiaca*, *Koeleria gracilis*, *Obione pedunculata*, *Puccinellia distans*, *Salicornia herbacea*, *Salsola ruthenica*, *S. soda*. *Stipa capillata*.

§ Main kinds of crops : Maize, wheat, sunflower, sugar beet, potato, vegetables, vine, etc. (in decreasing order).

G2 INDUSTRIES IN THE CATCHMENT AREA AND THE LAKE (1990)

Main products and industry
Primary industry
Crop production
Fisheries (especially in the Boldu village area)
Secondary industry
"Pell-Amar" plant (production of peloid-extract squeezed from lake muds)

G3 POPULATION IN THE CATCHMENT AREA (1971)

	Population	Mean population density [km^{-2}]	Main cities
Rural	9,000	51-100	None

H. LAKE UTILIZATION (Q)

H1 LAKE UTILIZATION (1990)

Indoor and outdoor balneotherapy (by use of lake saline waters and muds, "Pell-Amar" peloid-extract production, sightseeing and tourism, sport-fishing and seasonal seine-fishing.

I. DETERIORATION OF LAKE ENVIRONMENTS AND HAZARDS (Q, 1, 2, 8, 9, 16)

I1 ENHANCED SILTATION

§ Extent of damage : Not serious.

§ Supplementary notes

Silts originate primarily from the erosion of cliffs (since 1984 greatly reduced owing to the lowering of lake water level) and secondarily from the sediment influx via the Boldu Brook.

I2 TOXIC CONTAMINATION

§ Present status of toxic contamination : No data.

I3 EUTROPHICATION

§ Nuisance caused by eutrophication : Unusual algal bloom (*Microcystis aeruginosa*) ; summer overgrowth of the submerged macrophyte *Potamogeton pectinatus* and the floating algae *Cladophora fracta* and *Spirogyra* sp. ; Death of fish (carp and "silver" crucian).

§ Supplementary notes

The lake eutrophication has been acclerated since 1975. Taking into account that aquatic plants and algae (especially *Cladophora fracta* and *Spirogyra* sp.) contribute to the formation of therapeutical muds, the use of algicides (or other chemical agents) is strictly forbidden. For the same reason, water aeration or weed harvesting is not necessary.

I4 ACIDIFICATION

§ Extent of damage : None.

I5 OTHER HAZARDS

There are possibilities of degradation of theraputical sediments by the following processes.

a) Addition of pollutants by the Boldu Brook water, though self-purification processes are detected.

b) Enrichment of sandy material due to the erosion of southern shore cliffs. The rate of shore regression was up to 6.4 m yr^{-1} at higher lake water levels (e. g. before 1984).

c) The seasonal use of seine for fishing, which sweeps lake bottom, may disturb the mud formation located within a few centimeters of sediment surface.

d) Increase of plankton-consuming fish species invading the lake via the Boldu Brook.

J. WASTEWATER TREATMENTS (Q, 16)

J1 GENERATION OF POLLUTANTS IN THE CATCHMENT AREA : (d) Measurable pollution with limited wastewater treatment.

The main source includes the Boldu brook water periodically polluted with the discharge of Boldu village fish ponds, domestic litter disposed by Băile village near the lakeshore, and temporary-settled sheepfolds close to the lake.

J3 SANITARY FACILITIES AND SEWERAGE

§ Percentage of rural population provided with adequate sanitary facilities : Probably 30 %.

§ Supplementary notes

The balneal spa Balta Alba is fully provided with sanitary facilities.

L. DEVELOPMENT PLANS (Q, 16)

In order to separate the fishing and the therapeutical mud exploitation areas, the Geological & Mining Inspectorate (Ministry of Geology) proposed in 1984 the construction of an earth dam with a length of ca. 3,700 m ; the northern section will be about 2/3 of the central basin and for balneotherapeutic exploitation only, the southern section will be utilized for fishing activities.

M. LEGISLATIVE AND INSTITUTIONAL MEASURES FOR UPGRADING LAKE ENVIRONMENTS (Q, 12, 15, 17)

M1 NATIONAL AND LOCAL LAWS CONCERNED

§ Names of the laws (the year of legislation)

(1) Sanitary Law No. 3 (1987)

(2) Official Norms for Protection of Mineral Therapeutic Resources (1982)

§ Responsible authorities

(1) & (2) Ministry of Geology, Ministry of Health, Ministry of Tourism

§ Main items of control

(1) To supervise all the activities concerning the lake protection and exploitation within the so-called "hydrogeological and sanitary-protected perimeter" ; this last perimeter is a major portion of the catchment area, having the strongest influence upon the whole lake

(2) To advice all multidisciplinary studies concerning the lake area

(3) To approve measures for upgrading lake environments and to reject inadequate works or activities within the hydrogeological and sanitary-protected perimeter

M2 INSTITUTIONAL MEASURES

The monitoring, control and restoration in the lake area is carried out by the Geological and Mining Inspection (Ministry of Geology) and the Buzău County Tourism Office (Ministry of Tourism).

M3 RESEARCH INSTITUTES ENGAGED IN THE LAKE ENVIRONMENT STUDIES

(1) Enterprise for Geological and Geophysical Prospections (I. P. G. G.), Bucharest

(2) Faculties of Biology, University of Bucharest and University of Cluj

(3) Institute of Physical Medicine, Balneoclimatology and Medical Recovery (I. M. F B. R. M.), Bucharest

§ Supplementary notes

Since 1983, most intensive studies on the lake area have been carried out by I. P. G G. in collaboration with the biologists of the Bucharest and Cluj Universities.

N. SOURCES OF DATA

* In Romanian with English/French summary.

(Q) Questionnaire filled by Geol. Eng. Valentin-Alex. C. Bulgăreanu, Enterprise for Geological and Geophysical Prospections, Bucharest, based on the data obtained from the following sources.

(1) Bulgăreanu, V.-A. C. & Teculescu V. (1979) Über die limnologischen Bedingungen die die invasionsartige Ausbreitung des *Potamogeton pectinatus* L. in einigen pelogenen Seen der Östlichen Rumänischen Ebene begünstingen. Bulgarische Akad. Wiss., Sofia, XIX, Jubiläumstagung Donauforschung, Sep.-Oct. 1976, pp. 503-511.

(2) Bulgăreanu, V.-A. C, Olariu, C., Enache, Gh. & Urcan, T. (1986) New data regarding the limnogeology of the brackish lake Balta Albă (Buzău and Brăila districts). Rev. Roum. Géol., Géophys., Géogr., GÉOLOGIE, 30 : 89-96.

(3) Bulgăeanu V.-A. C., Ionescu, V., Năstăsescu, M. & Ioaniţescu, E. (in prep.) Characteristics and dynamics of the peloidogenesis processes in saline lake Balta Albă (Buzău and Brăila districts, Romania). Rev. Roum. Géol., Géophys., Géogr., GÉOLOGIE.

(4) Ciumpileac, Gh. (1972) Oscillations de niveaux des limans fluviatiles de la valleé du Buzău et de la Ialomitza. Analele Univ. Bucureşti, Geogr., 21 : 183-193.*

(5) Găştescu, P. (1963) The Lakes in P. R. of Romania ; Genesis and Hydrologic Régime. 293pp. P. R. of Romania Acad. Publ. House, Bucharest.*

(6) Găştescu, P. & Tatiana, N. (1980) Aspects concerning the water balance of the lakes in the north-east Romanian Plain. St. cerc. geol., geofiz., geogr., GÉOGRAFIE, 27 (2) : 233-242.*

(7) Găştescu, P. & Gruescu, I. S. (1975) Brăila District. 134pp. R. S. of Romania Acad. Publ. House, Bucharest (in Rom.).

(8) Ionescu-Ţeculescu Venera, Bulgăreanu, V.-A. C. (1977) The macrophytes of pelogenous lake Balta Albă (Buzău) and their physico-chemical characteristics of the habit. St. cerc. bio., ser. Biol. veget., 29 (2) : 87-92.*

(9) Ionescu-Ţeculeasu Venera, Bulgăreanu V.-A. C. (1978) The development of algal flora of lake Balta Albă (Buzău) in relation with some physico-chemical factors. St. cerc. biol., ser. Biol. veget., 30 (1) : 27-34.*

(10) Liteanu, E. & Ghenea, C. (1962) Hydrogeological and hydrochemical relations between the groundwaters and lake water in Oriental Romanian Plain. St. cerc. geol., geofiz., geogr., ser. Geol., 7 (2).*

(11) Posea, Gr. & Ielenicz, M. (1971) Buzău District. 134pp. R. S. of Romania Acad. Publ. House, Bucharest (in Rom.).

(12) Pricăjan, A. (1985) The Therapeutical Mineral Resources of Romania. 435pp. Scient. Encyclop. Publ. House, Bucharest (in Rom.).

(13) Strauss, H. (1980) Hygiene. 394pp. Didact. Pedag. Publ. House, Bucharest (in Rom.).

(14) Geobotanical data. Soil Map of Romania. Geological Inst. (ed.), Sheets no. 30 and 37 (in Rom.).

(15) Official Norms for Protection of Mineral Resources. Bul. Official RSR., part I, no. 28/16, March 1982, Bucharest (in Rom.).

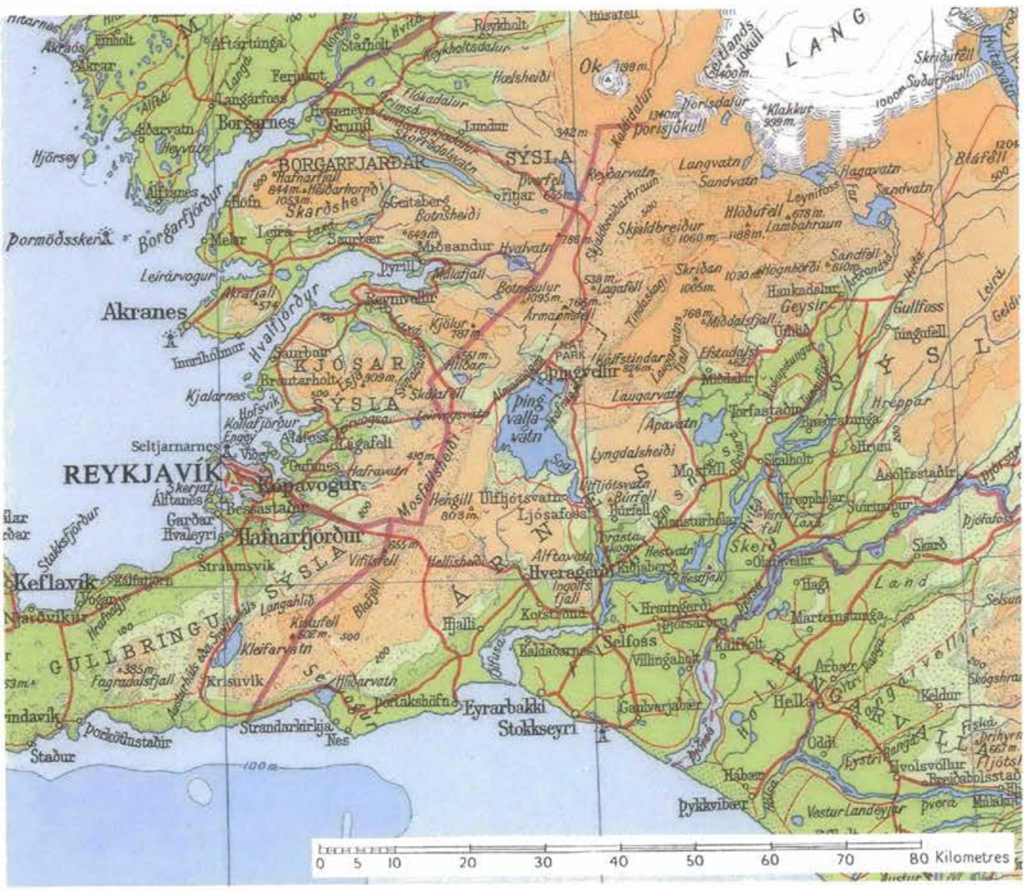
(16) Balta Albă contains therapeutical mud accumulations ; how do we protect them? In : "Flacăra", no. 39 (1476)/30, p. 6., Sep. 1983, Bucharest (in Rom.).

(17) Bălan, St. & Mihăilescu, M. St. (1985) History of Science and Technology in Romania, Chronological Data. 488pp. Romanian Academy Publ. House, Bucharest (in Rom.).

LAKE THINGVALLA

A view from the western shore

Photo: A. Kurata



A. LOCATION

§ Arnes, Sysla, Iceland.
§ 64°15′N, 21°07′W ; 102.5 m above sea level.

B. DESCRIPTION

Lake Thingvalla is the largest lake in Iceland with an area of 83.7 km^2, a maximum depth of 114 m and an average depth of 34.1 m. The lake is located about 30 km east from Reykjavik in a geologically active zone and is almost entirely tectonic in its origin. In fact, a fault zone traverses Iceland and cuts through the landscape of Thingvalla, actually the lake basin itself.

The yearly cycle of the lake is affected partly by the origin of the lake, and partly by its position in the middle of the Atlantic ocean. Weather is wet and windy throughout the year. The yearly temperature amplitude of the lake is 12 °C. Yearly precipitation ranges from 1,226 mm at the northern to 1,436 mm at the southern end (mean 1975-1980).

The mean discharge rate from the lake is about 110 m^{3}sec^{-1}, and the retention time is about 300 days, i. e. almost one year. Water mainly flows into the lake via an underground spring system within the porous volcanic lava surrounding the lake on its north and east sides. However, water entering the lake can be divided into two categories on the basis of ionic composition and temperature. In the northwestern part water of glacial origin percolates the lava basement during some 30-70 years before entering the lake, mostly through subterraneous conduits. Water from this direction has the same ionic composition as the lake water. Water coming from geothermically active areas at the southwestern end is slightly warmer and with higher chloride and silicon content than the lake water in general.

The inflows are very stable throughout the year. Although natural in origin, Lake Thingvalla serves as a natural reservoir for an electric power plant with water intake via a tunnel through the mountain barrier embracing the south end. The water level is slightly regulated and fluctuates around 0.5 m. Both the lake and its surroundings are oligotrophic.

A slightly pronounced stratification usually occurs between 10 and 25 m depth in most years. The temperature difference within this layer is 4-4.5 °C. The stratification increases during spring and summer until late August. Cooling of the lake in September starts a gradual, complete mixing of the lake. Recently, symptoms of eutrophication have been observed in the littoral zone of the lake and investigations have been made by responsible authorities (Q, 2, 3, 4).

C. PHYSICAL DIMENSIONS

Surface area [km^2]	83.7
Maximum depth [m]	114
Mean depth [m]	34.1
Normal range of annual water level fluctuation (regulated) [m]	0.5
Residence time [yr]	ca. 1 (300 days)

D. PHYSIOGRAPHIC FEATURES

D1 GEOGRAPHICAL

§ Bathymetric map (Fig. EUR-42-1).

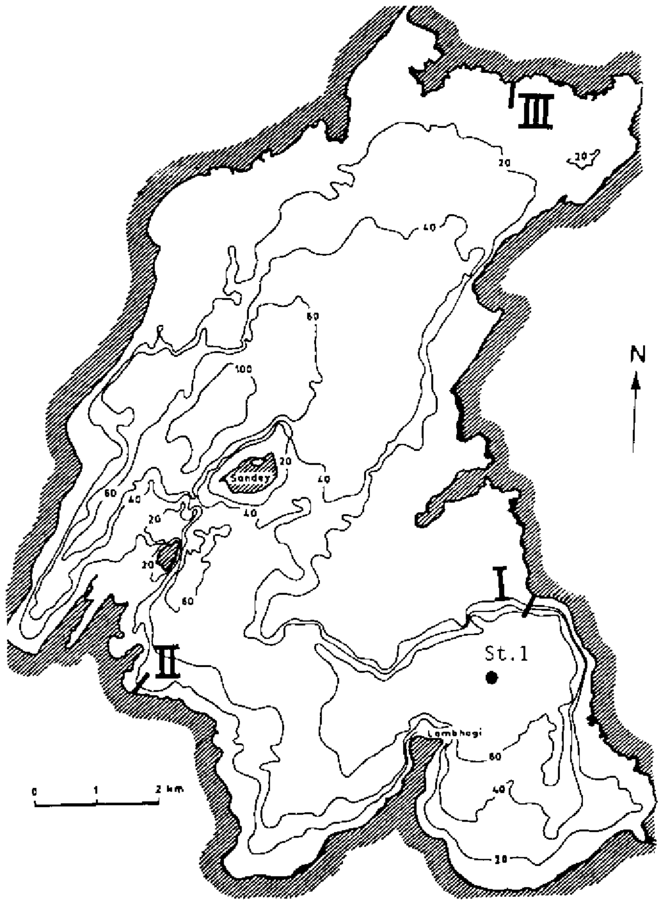
§ Outflowing rivers and channels (number and names) : 1 (river name unknown).

D2 CLIMATIC

§ Climatic data at Reykjavik, 1983 (1)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean temp. [°C]	-0.4	-0.1	1.5	3.1	6.9	9.5	11.2	10.8	8.6	4.9	2.6	0.9	5.0
Precipitation [mm]	90	65	65	53	42	41	48	66	72	97	85	81	805

Fig. EUR-42-1 Bathymetric map [m] (2, 3).
St. 1 is the sampling station for water. Midfell (I), Thorsteinsvik (II) and Vatnskot (III) are transect sampling stations for epilithic periphyton.

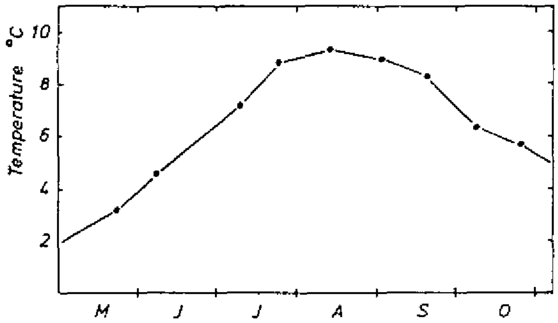


§ Water temperature [°C]

Station 1, May-Sep. 1975 (2)

Depth [m]	Min.	Max.	Average
0	2.7	8.8	6.7
20	2.7	8.5	6.4
50	0.9	8.2	5.1
70	1.2	8.2	5.7

Fig. EUR-42-2 Seasonal variation of water temperature [°C] in the lake (2).



§ Freezing period : Jan.-late Apr. or early May.
§ Mixing type : Monomictic.
§ Notes on water mixing and thermocline formation : Thermocline usually occurs between 10 and 25 m depth in most years. The stratification develops during spring and summer until late August.

E. LAKE WATER QUALITY

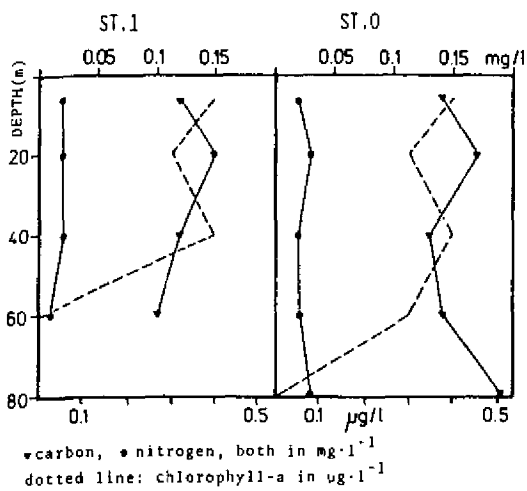
E2 pH

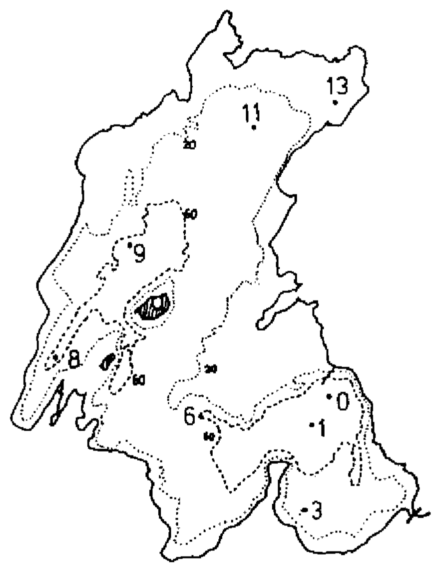
Station 1, May-Sep. 1975 (2)

Depth [m]	Min.	Max.	Average
0	7.0	7.6	7.3
20	7.0	7.6	7.3
50	7.0	7.6	7.3
70	7.0	7.6	7.2

E3 SS

Fig. EUR-42-3 Vertical variation of SS concentration [mg l^{-1}] at Station 0 (depth 80 m) and Station 1 (depth 75 m), Aug. 23, 1979. Location of sampling stations are shown in the right (2).





Horizontal variation of SS concentration at the depth of 6 m (2).
DM : dry matter, C : carbon, N : nitrogen, CHA : chlorophyll *a*.
The carbon proportion of the dry matter was calculated to be 0.25 (25.9 %).
Sampling stations are shown in Fig. EUR-42-3.

Date	St. no.	DM [mg l^{-1}]	C [mg l^{-1}]	N [mg l^{-1}]	CHA [μg l^{-1}]
24 Aug	8	0.538	0.136	0.024	0.6
	9	0.513	0.139	0.022	0.5
	11	0.430	0.126	0.020	0.5
	13	0.505	0.111	0.015	0.7
25 Aug	3	0.945	0.145	0.022	0.5
	6	0.485	0.055	0.011	0.5
29 Aug	0	0.407	0.108	0.015	0.5
30 Aug	1	0.479	0.107	0.018	0.4
	1	0.450	0.118	0.019	0.4
	3	0.432	0.091	0.015	0.5
	3	0.407	0.085	0.013	0.5
	8	0.330	0.100	0.014	—
	8	0.373	0.124	—	0.4
	9	0.405	0.139	0.019	—
	9	0.471	0.151	0.023	0.3
	9	0.413	0.099	0.015	—
	11	0.332	0.118	0.016	0.4
	13	0.343	0.098	0.014	0.5
Averages		0.459	0.114	0.016	0.5

Trap experiments for SS, 1979
DM : dry matter, C : carbon, N : nitrogen, P : phosphorus. In percentage of DM (2).

Depth [m]	DM [mg $m^{-2}d^{-1}$]	C %	N %	P %
Series 1 - 22 Aug to 6 Sep - 15 days				
20	62	7.0	1.0	—
40	16	8.7	1.4	—
60	155	9.4	1.2	—
80	465	6.9	1.1	—
Series 2 - 6 to 28 Sep - 22 days				
20	—	5.9	0.8	0.19
40	—	4.6	0.7	0.19
60	—	4.9	0.8	0.25
80	—	5.0	0.8	0.27
Series 3 - 28 Sep to 9 Nov - 42 days				
20	857	3.4	0.5	0.18
40	2012	3.6	0.5	0.17
60	3230	3.5	0.5	0.18
80	3365	3.5	0.5	0.19

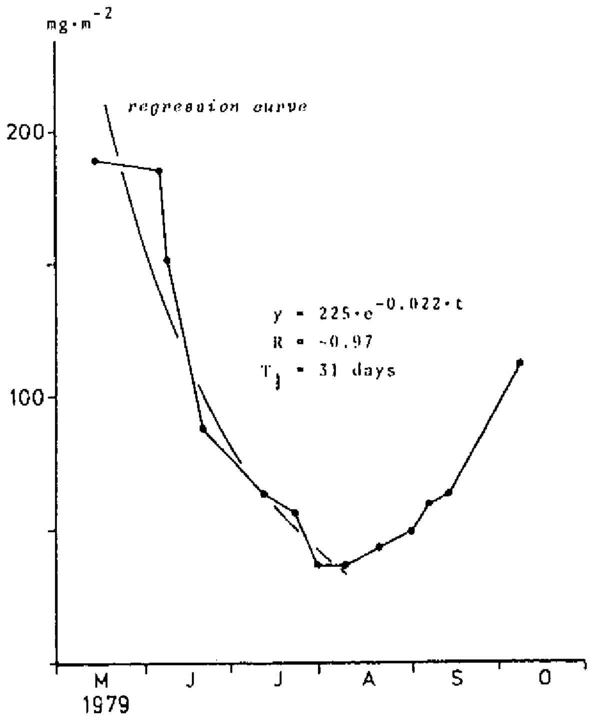
E4 DO [mg l^{-1}]

Station 1, May-Sep. 1975 (2)

Depth [m]	Min.	Max.	Average
0	7.77	9.94	8.66
20	7.83	9.73	8.65
50	8.18	9.66	8.88
70	7.72	9.69	8.47

E6 CHLOROPHYLL CONCENTRATION

Fig. EUR-42-4 Seasonal variation of chlorophyll *a* concentration at Station 1 (2). See also Fig. EUR-42-3.



E7 NITROGEN CONCENTRATION

§ NH_4-N [μg l^{-1}]

Station 1, Sep.-Nov. 1979 (2)

Depth [m]	Min.	Max.	Average
6	4.2	8.4	5.6
20	2.8	35.0	14.0
40	1.4	32.2	11.6
70	2.8	33.6	14.4

§ NO_3-N [μg l^{-1}]

Station 1, Mar. 1975-Nov. 1979 (2)

Depth [m]	Min.	Max.	Average
0	0.0	12.6	3.9
6	1.4	28.0	10.7
20	0.0	8.4	2.3
40	1.4	11.2	4.6
50	0.0	7.0	1.7
70	0.0	4.2	2.2

§ Total-N [μg l^{-1}]

Station 1, Mar.-Sep. 1975 (2)

Depth [m]	Min.	Max.	Average
0	44.8	74.2	59.9
20	43.4	77.0	61.3
50	51.8	78.4	64.7
70	57.4	156.8	91.8

E8 PHOSPHORUS CONCENTRATION

§ PO_4-P [μg l^{-1}]

Station 1, Mar. 1975-Nov. 1979 (2)

Depth [m]	Min.	Max.	Average
0	8.4	15.8	11.0
6	9.6	14.6	11.9
20	8.7	17.1	10.8
40	8.7	12.4	10.1
50	10.5	15.2	13.1
70	8.1	23.9	12.3

E9 CHLORINE ION CONCENTRATION [mg l^{-1}]

Station 1, Mar.-Sep. 1975 (2)

Depth [m]	Min.	Max.	Average
0	6.04	8.42	6.81
20	6.04	6.54	6.34
50	6.13	6.73	6.40
70	6.08	6.56	6.35

F. BIOLOGICAL FEATURES

F1 FLORA

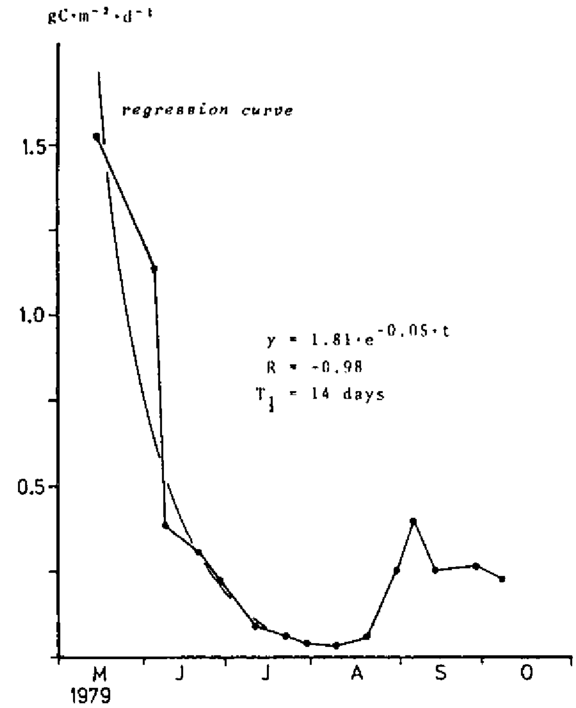
§ Emerged macrophytes : None (4).

§ Floating macrophytes : None (4).

§ Phytoplankton : *Ulothrix zonata*, *U. tenuissima*, *Cymbella cistula*, *Synedra ulna*, *Fragilaria vauheriae*, *Nitzschia dissipata*, *Anabaena inaequalis*, *Tolypathrix distorta*, *Calothrix braunii*, *Nostoc* sp., *Gomphonema clevei*, *Epithemia turgida*, *Rhoicosphenia curvata*, *Achanthes lancedata*, *Amphora ovalis* var. *pediculus*, *Cocconeis placentula* var. *lineata*, *Cladophora glomerata*, *C. aegagropila* (3).

F3 PRIMARY PRODUCTION

Fig. EUR-42-5 Gross production at Station 1 (3).



F4 BIOMASS

Fig. EUR-42-6 Vertical distribution of periphyton standing crop [mg total chlorophyll *a* per m² of the stone surface covered with algae] in the 3 transects in 1977 (Fig. EUR-42-1) and the Midfell transect in 1978 and 1982. The results shown are summer mean and standard deviation (3).

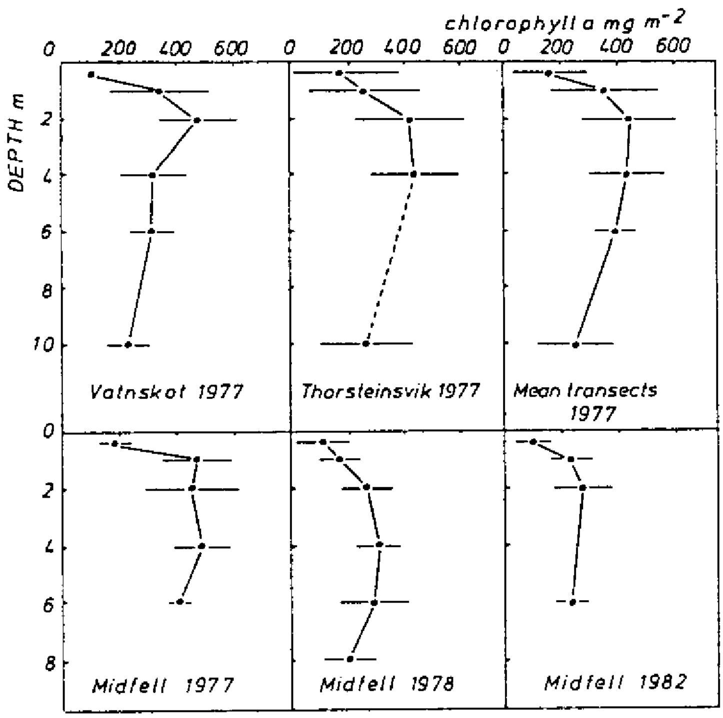
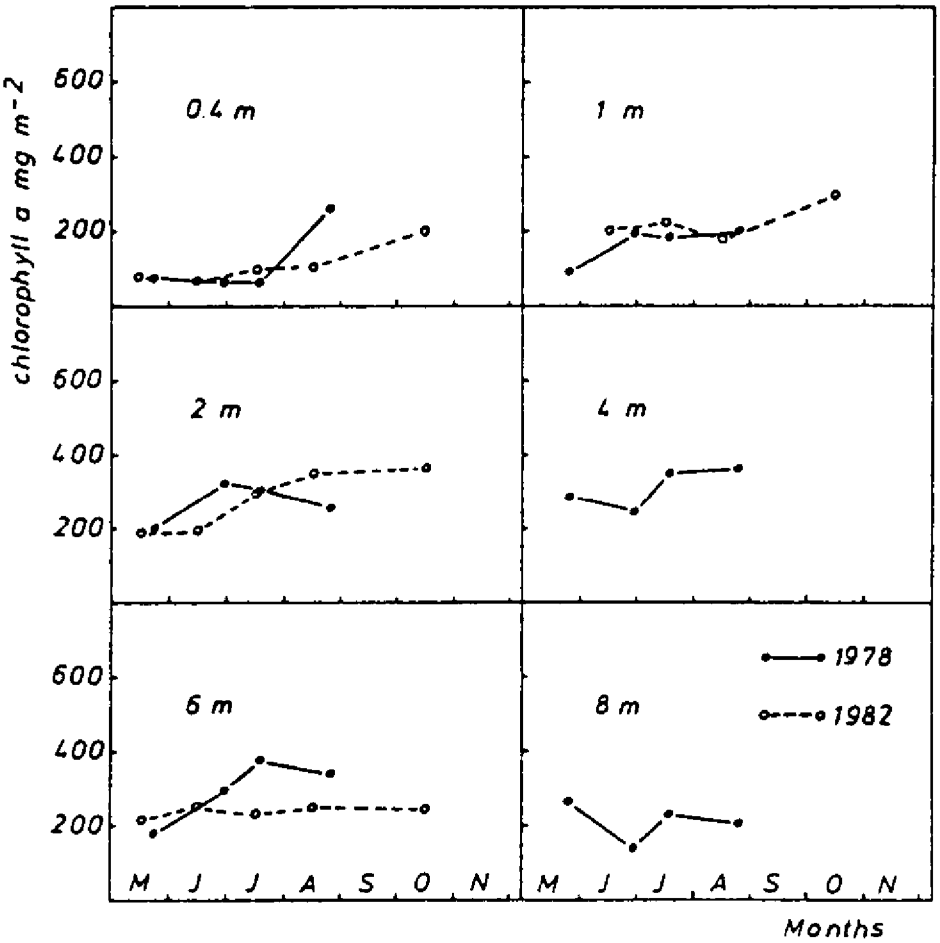


Fig. EUR-42-7 Standing crop of periphyton [total chlorophyll *a* mg per m^2 of the stone surface covered with algae] at various depths during the summer in 1978 and 1981 (3).



G. SOCIO-ECONOMIC CONDITIONS (Q, 4)

G1 LAND USE IN THE CATCHMENT AREA (1990)
Mostly rocky barren area and moss-covered grazing fields; no forests nor crop fields.

G2 INDUSTRIES IN THE CATCHMENT AREA AND THE LAKE (1990)
None.

G3 POPULATION IN THE CATCHMENT AREA (1990)
Very scarce.

H. LAKE UTILIZATION (Q, 3, 4)

H1 LAKE UTILIZATION
Source of water, sight-seeing and tourism.

H2 THE LAKE AS WATER RESOURCE
For power plant and domestic water.

I. DETERIORATION OF LAKE ENVIRONMENTS AND HAZARDS (Q, 3, 4)

I1 ENHANCED SILTATION
§ Extent of damage : Slight.

I2 TOXIC CONTAMINATION
§ Present status : None.

I3 EUTROPHICATION
§ Nuisance caused by eutrophication : None.

I4 ACIDIFICATION
§ Extent of damage : None.

J. WASTEWATER TREATMENTS (Q, 3, 4)

J1 GENERATION OF POLLUTANTS IN THE CATCHMENT AREA : (b) No sources of significant pollution.

J3 SANITARY FACILITIES AND SEWERAGE
None.

K. IMPROVEMENT WORKS IN THE LAKE

Investigations have been done on the trend of eutrophication by responsible authorities and improvement works are being planned (Q, 4).

D. DEVELOPMENT PLANS

None (Q, 4).

M. LEGISLATIVE AND INSTITUTIONAL MEASURES FOR UPGRADING LAKE ENVIRONMENTS

M3 RESEARCH INSTITUTES ENGAGED IN THE LAKE ENVIRONMENT STUDIES (3)
(1) University of Iceland, Marine Research Institute
(2) The National Energy Authority
(3) The Thingvalla Commission
(4) The Power Plant Landsvirkjun

N. SOURCES OF DATA

* Printed in Japanese. The title is tentatively translated into English with the original title in romanized Japanese in parentheses.
(Q) Questionnaire filled by the editors with the support of Dr. G. S. Jônsson, National Center for Hygiene, Food Control and Environmental Protection, Reykjavik, Iceland, based on the following sources.
(1) Tôkyô Shoseki (1983) A Latest Economical Survey of World Countries (Saishin Sekai Kakkoku Yôran, 1983 nendo-ban). 399 pp. Tôkyô Shoseki, Tôkyô.*
(2) Lastein, E. (1983) Oikos, 40 : 103-112.
(3) Jônsson, G. S. (1987) Arch. Hydrobiol., 108 : 531-547.
(4) The editor's observation.

LAKE PAANAJARVI

A view on the lakeshore

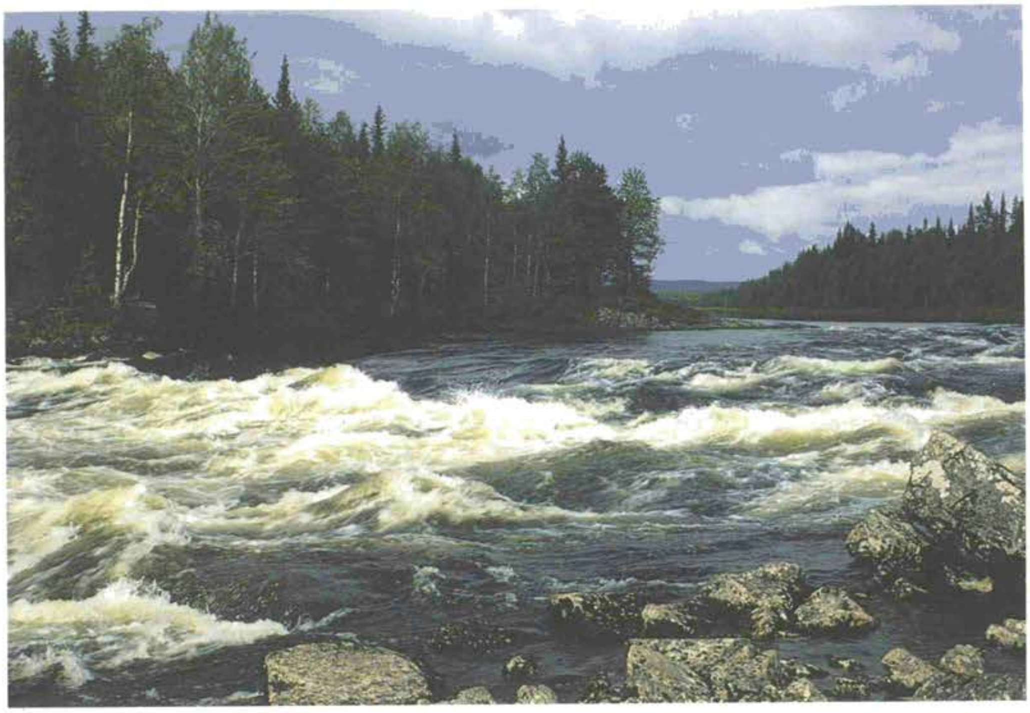
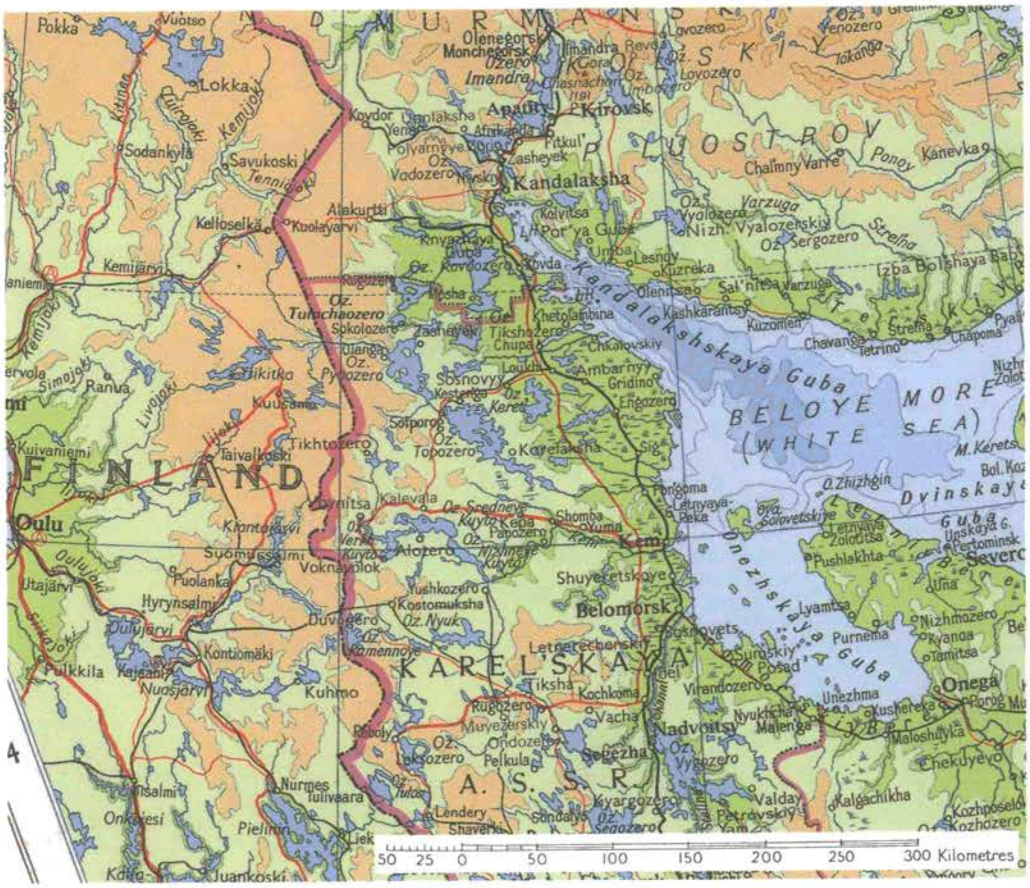


Photo: A. Freindling



A. LOCATION

§ Karelian ASSR, USSR.
§ 66°15′-66°17′N ; 29°48′-30°20′E ; 135 m above sea level.
* Place names are not updated.

B. DESCRIPTION

Sharp broken forms of tectonic relief with large breaks and vertical displacements dominate in the Lake Paanajarvi region. A lot of picturesque lakes connected by swiftly flowing rivers and brooks with waterfalls and rapids are distributed among relatively high mountains.

The lake basin is situated in large tectonic break which were not exposed to the influence of geological remarking or exogenous processes. The lake is surrounded by rocks, boulders or boulder-pebbles ; sometimes banks are sandy. The lake is latitudely orientated ; this feature with specific coast forms define original wind conditions and microclimate in the lake region.

The flora of Paanajarvi region is notable for its richness and variety. There is plenty of rare plant species which require national protection. A number of species are on the area boundary.

Lake Paanajarvi is one of the rare regions in Soviet Karelia where ecological systems of exceptional importance are still remaining in natural conditions. The creation of a national park with domestic and international tourism development may be the best perspective for Lake Paanajarvi (Q).

C. PHYSICAL DIMENSIONS (Q)

Surface area [km^2]	23.6
Volume [$10^6 m^3$]	890
Maximum depth [m]	128
Mean depth [m]	37.8
Normal range of annual water level fluctuation (unregulated)	2.5
Length of shoreline [m]	50.5
Residence time [yr]	0.4
Catchment area [km^2]	5,295

D. PHYSIOGRAPHIC FEATURES

D1 GEOGRAPHICAL

§ Outflowing rivers and channels (number and names): 1 (Olanga R.) (Q).

D2 CLIMATIC (1)

§ Climatic data at Sodankylä (67°22′N, 26°39′E), 1951-1960

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean Temp. [°C]	-13.5	-13.0	-9.0	-2.1	4.9	11.3	14.7	12.0	6.2	-0.5	-5.8	-9.8	-0.4
Precipitation [mm]	27	26	20	31	31	56	74	71	57	43	39	31	508

§ Number of hours of bright sunshine (Sodankylä, 1951-1960): 1,533.7 hr yr^{-1}.
§ Average depth of maximum snow accumulation [cm]: 47.
§ Water temperature [°C] (Q)
Central station, 1988

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Surface	–	–	– Ice cover –			7.1	–	–	–	–	–	–
5	–	–	–	0.4	–	6.5	–	–	–	–	–	–
10	–	–	–	1.2	–	5.8	–	–	–	–	–	–
15	–	–	–	2.3	–	5.6	–	–	–	–	–	–
20	–	–	–	2.8	–	5.4	–	–	–	–	–	–
30	–	–	–	3.3	–	5.1	–	–	–	–	–	–
40	–	–	–	3.6	–	4.7	–	–	–	–	–	–
60	–	–	–	3.64	–	4.3	–	–	–	–	–	–
80	–	–	–	3.68	–	4.2	–	–	–	–	–	–
100	–	–	–	3.71	–	4.1	–	–	–	–	–	–

§ Freezing period: From Nov. 15-May 20.
§ Mixing type: Dimictic.

E. LAKE WATER QUALITY (Q)

E1 TRANSPARENCY [m]

Central station, June 1988: 3.5-4.0.

E2 pH

Central station, 1988

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.5	–	–	–	–	–	7.0	–	7.2	–	–	–	–
5	–	–	–	7.0	–	7.0	–	7.0	–	–	–	–
15	–	–	–	7.0	–	6.8	–	7.1	–	–	–	–
25	–	–	–	7.0	–	6.8	–	6.8	–	–	–	–
45	–	–	–	7.0	–	6.8	–	6.8	–	–	–	–
75	–	–	–	6.8	–	6.8	–	6.7	–	–	–	–
105	–	–	–	6.4	–	6.8	–	6.8	–	–	–	–

E3 SS [mg l^{-1}]
Central station, 1988

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.5	—	—	—	—	—	2.2	—	0.4	—	—	—	—
5	—	—	—	0.8	—	1.6	—	0.4	—	—	—	—
15	—	—	—	2.3	—	2.0	—	0.0	—	—	—	—
25	—	—	—	1.2	—	2.1	—	1.0	—	—	—	—
45	—	—	—	1.1	—	2.0	—	0.9	—	—	—	—
75	—	—	—	0.8	—	2.6	—	0.5	—	—	—	—
105	—	—	—	1.7	—	2.0	—	0.0	—	—	—	—

E4 DO [mg l^{-1}]
Central station, 1988

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.5	—	—	—	—	—	11.2	—	9.6	—	—	—	—
5	—	—	—	10.2	—	10.7	—	9.2	—	—	—	—
15	—	—	—	13.0	—	10.8	—	9.0	—	—	—	—
25	—	—	—	11.2	—	10.6	—	8.9	—	—	—	—
45	—	—	—	10.6	—	10.6	—	8.9	—	—	—	—
75	—	—	—	9.1	—	10.6	—	8.8	—	—	—	—
105	—	—	—	8.6	—	10.0	—	9.1	—	—	—	—

E5 COD [mg l^{-1}]
Cr-method.
Central station, 1988

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.5	—	—	—	—	—	—	—	8.1		—	—	—
5	—	—	—	18.5	—	—	—	12.5	—	—	—	—
15	—	—	—	14.7	—	—	—	11.0	—	—	—	—
25	—	—	—	10.0	—	—	—	6.6	—	—	—	—
45	—	—	—	12.0	—	—	—	7.8	—	—	—	—
75	—	—	—	17.8	—	—	—	10.5	—	—	—	—
105	—	—	—	13.0	—	—	—	9.1		—	—	—

Mn-method.
Central station, 1988

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.5	—	—	—	—	—	6.7	—	5.6	—	—	—	—
5	—	—	—	4.4	—	6.7	—	5.4	—	—	—	—
15	—	—	—	5.1	—	6.5	—	6.0	—	—	—	—
25	—	—	—	6.3	—	6.1	—	6.0	—	—	—	—
45	—	—	—	6.2	—	6.0	—	5.8	—	—	—	—
75	—	—	—	6.2	—	6.7	—	5.6	—	—	—	—
105	—	—	—	5.4	—	6.5	—	5.7	—	—	—	—

E7 NITROGEN CONCENTRATION

§ Total-N [mg l^{-1}]

Central station, 1988

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.5	—	—	—	—	—	1.05	—	1.15	—	—	—	—
5	—	—	—	1.78	—	0.98	—	1.27	—	—	—	—
15	—	—	—	1.88	—	0.98	—	0.95	—	—	—	—
25	—	—	—	2.46	—	0.94	—	1.15	—	—	—	—
45	—	—	—	2.14	—	0.59	—	1.06	—	—	—	—
75	—	—	—	1.82	—	0.63	—	0.64	—	—	—	—
105	—	—	—	1.53	—	0.68	—	0.61	—	—	—	—

E8 PHOSPHORUS CONCENTRATION

§ Total-P [μg l^{-1}]

Central station, 1988

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.5	—	—	—	—	—	5	—	4	—	—	—	—
5	—	—	—	8	—	5	—	2	—	—	—	—
15	—	—	—	7	—	11	—	7	—	—	—	—
25	—	—	—	6	—	5	—	2	—	—	—	—
45	—	—	—	5	—	7	—	6	—	—	—	—
75	—	—	—	7	—	14	—	2	—	—	—	—
105	—	—	—	7	—	10	—	5	—	—	—	—

F. BIOLOGICAL FEATURES (Q)

F1 FLORA

§ Emerged macrophytes : *Phragmites australis*, *Equisetum*.

§ Floating macrophytes : *Nuphar luteum*, *Polygonum amphibium*, *Sparganium friesii*.

§ Submerged macrophytes : *Potamogeton perfoliatus*, *Myriophyllum alterniflorum*.

§ Phytoplankton : *Cyclotella* sp., *Melosira* sp., *Tabellaria* sp.

F2 FAUNA

§ Zooplankton

Daphnia cristata, *Bosmina kessleri*, *Eudiaptomus graciloides*, *Cyclops scutifer*, *Euritemora lacustris*.

§ Benthos

Littoral zone (Naididae sp., Chironomidae sp., *Pontoporeia affinis*) ; profound zone (Oligochaeta, *Pontoporeia affinis*, *Triocladius parataricus*, *Procladius* sp.).

§ Fish

Salmo trutta, *Salvelinus lepechini*, *Coregonus lavaretus*, *C. albula*, *Esox lucius*, *Perca fluviatilis*, *Thymallus thymallus*.

F4 BIOMASS

§ Phytoplankton

Average biomass in summer : 0.2-0.4 [g m^{-3}].
Average number in summer : 300,000 [m^{-3}].

§ Zooplankton

Average biomass in summer : 0.18 [g m^{-3}].
in winter : 0.02-0.06 [g m^{-3}].
Average number in summer : 5,600 [m^{-3}].
in winter : 400-700 [m^{-3}].

§ Benthos

Littoral zone (0-6 m); Average biomass: 4.0 [g m^{-2}].
Average number: 7,240 [m^{-2}].

Profound zone (6-128 m); Average biomass: 0.30 [g m^{-2}].
Average number: 340 [m^{-2}].

§ Macrophytes [g dry weight m^{-2}]

Phragmites	77-98, average 85.
Equisetum	5-46, average 21.
Polygonum amphibium	18-20, average 19.
Potamogeton perfoliatus	4-13, average 7.

G. SOCIO-ECONOMIC CONDITIONS (Q)

G1 LAND USE IN THE CATCHMENT AREA
N. A.

G2 INDUSTRIES IN THE CATCHMENT AREA AND THE LAKE
None.

G3 POPULATION IN THE CATCHMENT AREA
N. A.

H. LAKE UTILIZATION

N. A. (Q).

I. DETERIORATION OF LAKE ENVIRONMENTS AND HAZARDS (Q)

I1 ENHANCED SILTATION
§ Extent of damage: Not serious.

I2 TOXIC CONTAMINATION
None.

I3 EUTROPHICATION
None.

I4 ACIDIFICATION
None.

J. WASTEWATER TREATMENTS (Q)

J1 GENERATION OF POLLUTANTS IN THE CATCHMENT AREA: (a) Pristine lake environments.

J2 APPROXIMATE PERCENTAGE DISTRIBUTION OF POLLUTANT LOADS
N. A.

J3 SANITARY FACILITIES AND SEWERAGE
None.

L. DEVELOPMENT PLANS

None (Q)

M. LEGISLATIVE AND INSTITUTIONAL MEASURES FOR UPGRADING LAKE ENVIRONMENTS

M1 NATIONAL AND LOCAL LAWS CONCERNED (Q)

§ Names of the laws (the year of legislation)

(1) Principles of Water Laws for the USSR (1971)
(2) RSFSR Water Code (1980)

§ Responsible authorities

(1) Local authorities
(2) State fish inspection
(3) State Committee of Environmental Protection

M2 RESEARCH INSTITUTES ENGAGED IN THE LAKE ENVIRONMENT STUDIES (Q)

(1) Karelian Centre of the Academy of Science of the USSR, Petrozavodsk
(2) Northern State Research Institute for Fish Industry, Petrozavodsk

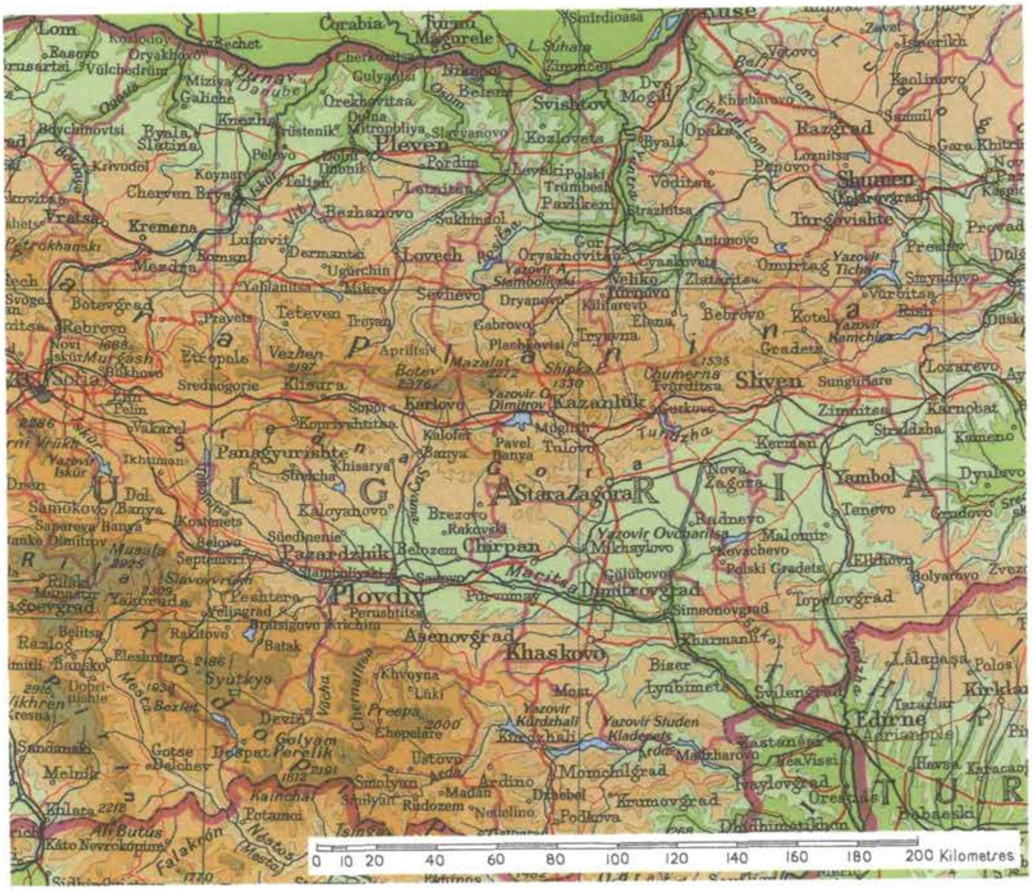
N. SOURCES OF DATA

(Q) Questionnaire filled by Dr. A. Freindling, Water Problem Department, Karelian Centre of the Academy of Science of the USSR, Petrozavodsk.
(1) Johannessen, T. W. (1970) The Climate of Scandinavia. "World Survey of Climatology, Volume 5, Climates of Northern and Western Europe" (ed. Wallen, C. C.), p. 65. Elsevier Scientific Publishing Company, Amsterdam-London-New York.

LAKE G. DIMITROV

Eastern end of the lake

Photo: A. Kurata



A. LOCATION

§ Kazanlak, Bulgaria.
§ 42°36′N ; 25°19′E ; ca. 800 m above sea level.

B. DESCRIPTION

The man-made lake "G. Dimitrov" has been built 7 km upstream from the town of Kazanlak on the Tundja River in the Rosa Valley, which separates the Balkan mountain chain from the Sredna Gora mountains. The rock-filled dam is provided with thick concrete cover on the lake side and a road on its crest. The construction was completed in 1954 and the lake is managed by the office of "Lake and Cascades" Kazanlak Branch.

The watershed covers an area of 861 km^2, and has an average altitude of ca. 800 m and a mean river gradient of 31.4 %. The area is built of granite and granite-gneiss, old Tertiary sediments, diluvial and alluvial deposits. One may find traces of tectonic activities — fissured rocks, dislocation zones with sources of hot spring, etc. Its northern part includes the highest peak of Balkan Mountains, where thick and prolonged snow cover is characteristic. Steep slopes favor surface erosion development.

The lake is about 11 km^2 in its surface area and the maximum depth reaches 40 m. It is located in a rich rural region that needs much clean water, and serves to regulate the seasonal turnoff of water supply according to the requirements of consumers — irrigation for fertile fields of both Kazanlak and Stara Zagora, chemical industry in the town of St. Zagora, and hydroelectric power plant.

Lake Dimitrov is also a great local center for recreation and hot-spring cure because it is surrounded by a number of settlements and dense network of roads. There are good water-sport facilities including a paddle sport base on its northern bank (Q).

C. PHYSICAL DIMENSIONS (Q)

Surface area [km^2]	11
Volume (maximum) [10^6m^3]	140
Maximum depth [m]	40
Mean depth [m]	12.7
Normal range of annual water level fluctuation (regulated) [m]	24
Length of shoreline [km]	26.3
Residence time [yr]	0.6
Catchment area [km^2]	861.4

D. PHYSIOGRAPHIC FEATURES

D1 GEOGRAPHICAL

§ Sketch map (Fig. EUR-44-1).
§ Main islands : None.
§ Outflowing rivers and channels (number and names) : 3 (Tundja R., 2 irrigation channels).

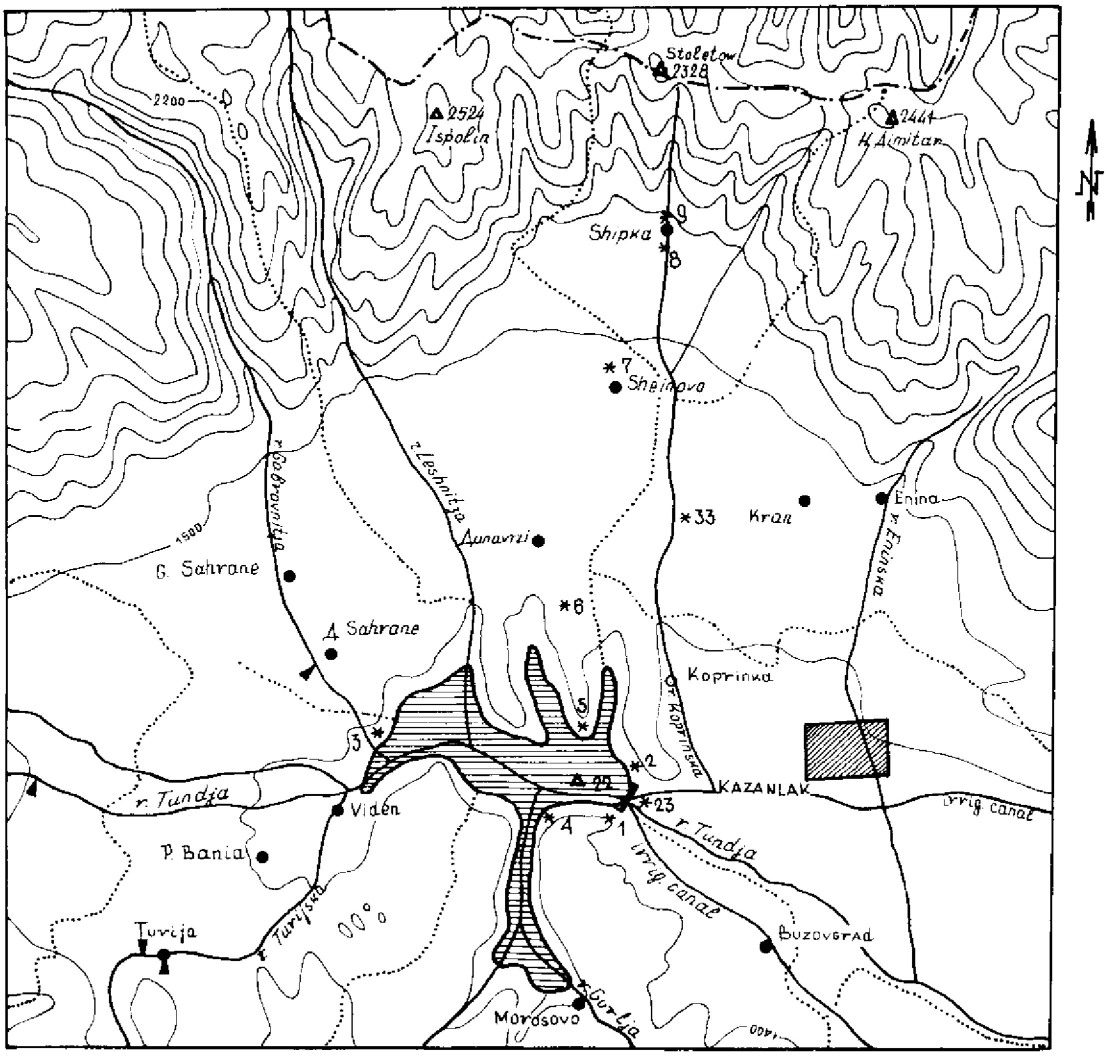
D2 CLIMATIC

§ Climatic data at Kazanlak, 1931-1985

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean temp. [°C]	-0.7	1.3	4.8	10.6	15.3	18.9	31.4	21.0	16.8	11.2	6.4	1.6	11.6
Precipitation [mm]	41	33	31	46	75	76	65	48	34	45	49	45	588

§ Number of hours of bright sunshine : 2,168 hr yr^{-1}.
§ Solar radiation : 13 MJ $m^{-2}day^{-1}$.

Fig. EUR-44-1 Sketch map of the lake and its river network (Q).

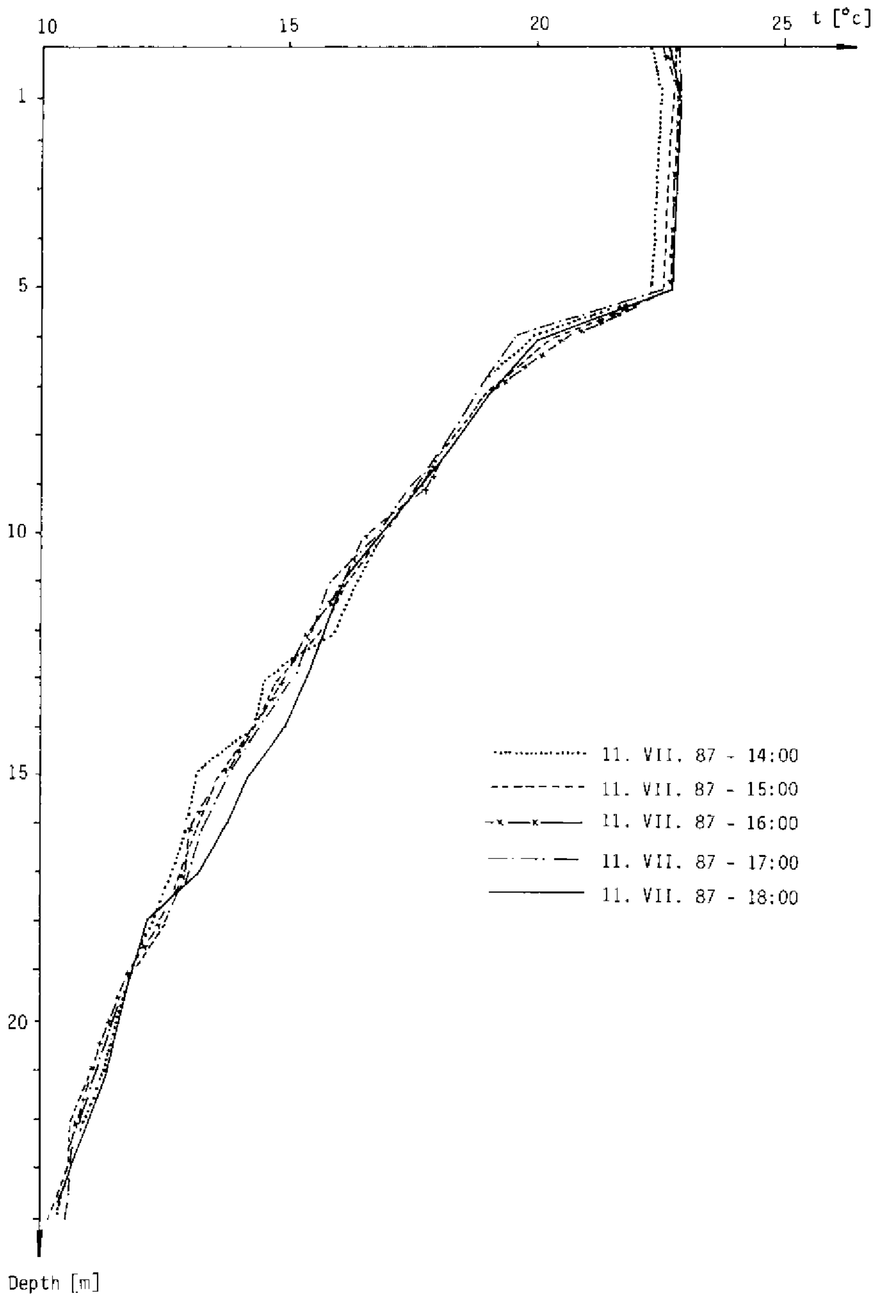


§ Water temperature [°C]
Floating plot, 1954-1964

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.5	3.2	2.8	6.0	11.3	18.2	22.5	24.8	25.0	21.2	16.8	10.6	5.6
5	3.4	2.8	5.3	9.8	15.1	18.8	21.5	22.8	19.7	14.8	10.3	6.0
10	3.7	2.7	5.1	8.6	13.0	16.2	18.9	21.4	19.1	14.8	10.2	5.9
20	3.7	3.0	4.9	7.8	11.4	14.2	16.9	19.5	18.5	14.9	10.7	6.2
Bottom	3.8	3.0	5.0	7.9	10.4	13.2	15.6	18.4	18.0	14.3	10.0	6.0

§ Mixing type : Monomictic.
§ Note on water mixing and thermocline formation : After its formation the thermocline sinks downward due to both the heating of surface water layer and the intensive outflow.

Fig. EUR-44-2 The vertical water temperature distribution at the floating plot on Aug., 11, 1987.



E. LAKE WATER QUALITY (Q)

E1 TRANSPARENCY [m]

Floating plot, 1986-1988

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
–	–	–	2.4	2.1	1.6	1.2	–	1.2	1.2	–	–

E2 pH

Floating plot, 1971-1988

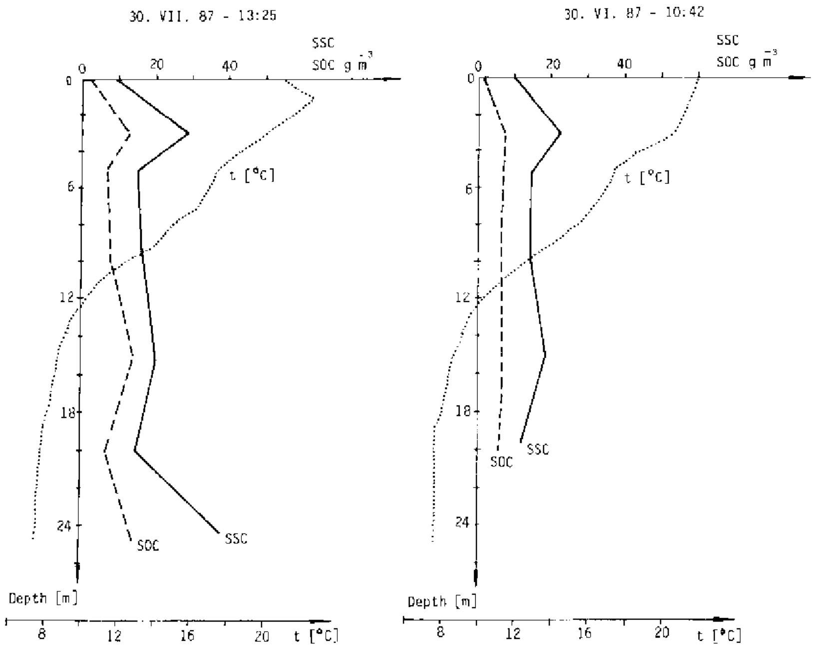
Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Surface	–	7.1	6.6	6.8	6.5	6.7	6.6	6.9	6.9	7.6	6.8	6.4
20	–	–	–	–	–	–	–	6.5	–	–	6.5	–
30	–	–	–	6.0	6.0	–	–	–	–	–	–	–
Bottom	–	6.5	6.5	7.0	6.5	6.5	7.0	6.7	7.0	7.5	6.8	6.8

E3 SS [mg l^{-1}]

Floating plot, 1986-1988

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	–	–	–	–	10	–	–	–	46	–	–	–
1	–	–	–	–	–	–	–	–	53	–	–	–
3	–	–	–	–	45	–	–	–	54	–	–	–
5	–	–	–	–	3	–	–	–	58	–	–	–
8	–	–	–	–	–	–	–	–	71	–	–	–
10	–	–	–	–	6	–	–	–	–	–	–	–
15	–	–	–	–	5	–	–	–	–	–	–	–
20	–	–	–	–	11	–	–	–	–	–	–	–
25	–	–	–	–	11	–	–	–	–	–	–	–
27-Bottom	–	–	–	–	115	–	–	–	–	–	–	–

Fig. EUR-44-3 Vertcal distribution of water temperature [°C], suspended solid concentration (SSC) and suspended organic matter concentration (SOC) at the floating plot on June 30, 1987 (Q).



E4 DO [mg l^{-1}]
Floating plot, 1986-1988

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	—	—	—	—	10.5	—	—	—	—	—	—	—
3	—	—	—	—	10.2	—	—	—	—	—	—	—
5	—	—	—	—	10.8	—	—	—	—	—	—	—
10	—	—	—	—	10.0	—	—	—	—	—	—	—
15	—	—	—	—	10.5	—	—	—	—	—	—	—
20	—	—	—	—	9.3	—	—	—	—	—	—	—
23	—	—	—	—	10.3	—	—	—	—	—	—	—

E6 CHLOROPHYLL CONCENTRATION [$\mu g\ l^{-1}$]
Floating plot, 1988

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.25	—	—	—	—	4.26	—	—	—	—	—	—	—
1	—	—	—	—	4.49	—	—	—	—	—	—	—
3	—	—	—	—	4.86	—	—	—	—	—	—	—
5	—	—	—	—	3.24	—	—	—	—	—	—	—
7	—	—	—	—	2.22	—	—	—	—	—	—	—

E7 NITROGEN CONCENTRATION
§ NO_3-N [mg l^{-1}]
Floating plot, 1986-1988

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	—	—	—	—	3.4	—	—	—	0.8	—	—	—
1	—	—	—	—	—	—	—	—	1.4	—	—	—
3	—	—	—	—	—	—	—	—	1.6	—	—	—
5	—	—	—	—	—	—	—	—	3.8	—	—	—
10	—	—	—	—	4.65	—	—	—	—	—	—	—
20	—	—	—	—	3.00	—	—	—	—	—	—	—
30	—	—	—	—	0.90	—	—	—	—	—	—	—

§ NH_4-N [mg l^{-1}]
Floating plot, 1986-1988

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	—	—	—	—	0.24	—	—	—	0.08	—	—	—
1	—	—	—	—	—	—	—	—	0.10	—	—	—
3	—	—	—	—	—	—	—	—	0.10	—	—	—
5	—	—	—	—	—	—	—	—	0.12	—	—	—
10	—	—	—	—	0.80	—	—	—	—	—	—	—
20	—	—	—	—	1.00	—	—	—	—	—	—	—
30	—	—	—	—	1.98	—	—	—	—	—	—	—

E8 PHOSPHORUS CONCENTRATION

§ PO_4-P [mg l^{-1}]

Floating plot, 1988

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	–	–	–	–	0.03	–	–	–	–	–	–	–
10	–	–	–	–	0.04	–	–	–	–	–	–	–
20	–	–	–	–	0.04	–	–	–	–	–	–	–
30	–	–	–	–	0.03	–	–	–	–	–	–	–

E9 CHLORINE ION CONCENTRATION [mg l^{-1}]

Floating plot, 1986–1988

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	–	–	–	–	14.2	–	–	–	22.2	–	–	–
1	–	–	–	–	–	–	–	–	26.9	–	–	–
3	–	–	–	–	–	–	–	–	22.8	–	–	–
5	–	–	–	–	–	–	–	–	25.1	–	–	–
10	–	–	–	–	14.2	–	–	–	–	–	–	–
20	–	–	–	–	12.8	–	–	–	–	–	–	–
30	–	–	–	–	14.8	–	–	–	–	–	–	–

F. BIOLOGICAL FEATURES (Q)

F1 FLORA

Floating plot, May 1988

§ Phytoplankton

Pyrrophyta (*Cryptomonas* sp.), Bacillariophyta (*Cyclotella* sp.), Cyanophyta, Chlorophyta.

F2 FAUNA

§ Zooplankton

Cyclops strenuus, *Daphnia pulex*, *D. longispina*, *Monia recrostris*, *Bosmina longirostris*, *Ceriodaphia setosa*, *Chydorus* sp., *Leydigia* sp., *Brachionus pala*, *B. angularis*.

§ Benthos

Chironomus plumosus, *C. semireductus*, *Cryptochironomus* ex. gr. *conjugens*, *C.* gr. *camptolabis*, *Polypedilum* ex. gr. *nebuculosum*, *Polypedilum* sp., *Paratendipes* gr. *albimanus*.

§ Supplementary notes on the biota

An '88 search showed a fair uniformity in the biological parameters throughout the lake due to the continuous water outflow that produces a permanent water current going downstream and temporary upstream currents. They both mix up the water.

F3 PRIMARY PRODUCTION RATE

Floating plot, May 1988

	[g O_2 m^{-2}]
0.0 m	0.69
0.5 m	0.80
1.0 m	0.43
3.0 m	0.28
5.0 m	0.14
7.0 m	1.00

F5 FISHERY PRODUCTS

§ Annual fish catch (1954-1964) : 30 [metric tons].
§ Fishery products other than fish : None.

G. SOCIO-ECONOMIC CONDITIONS (Q)

G1 LAND USE IN THE CATCHMENT AREA (1985)

	Area [km²]	[%]
Natural landscape		(64)
Woody vegetation	448	52
Herbaceous vegetation	103	12
Agricultural land		(32)
Crop field	241	28
Pasture land	34	4
Settlement area	34	4
Total	861	100

§ Types of important woody vegetation : Low-stemmed forest (beech, oak), pine forest.
§ Main kinds of crops and/or cropping systems : Rose and lavender (for perfume oil), wheat and maize.
§ Levels of fertilizer application on crop fields : Moderate.
§ Trends of changes in land use in recent years : None.

G2 INDUSTRIES IN THE CATCHMENT AREA AND THE LAKE

	No. of persons engaged [%]	Main products and major industries
Primary industry	40	Mash & tool production,
Crop production	24	timber industry
Others	9	
Secondary industry	12	Energy production, textile, food industry
Tertiary industry	15	

G3 POPULATION IN THE CATCHMENT AREA (1986)

	Population	Population density [km⁻²]	Main cities
Urban	35,000		
Rural	60,000		None
Total	95,000	110	

H. LAKE UTILIZATION (Q)

H1 LAKE UTILIZATION

Source of water, sightseeing and tourism, recreation (swimming, sport-fishing, yachting) and fisheries.

H2 THE LAKE AS WATER RESOURCE (1985)

	Use rate [m^3yr^{-1}]
Domestic water	None
Irrigation	118×10^6
Industrial water	44×10^6
Power plant	100 MWhr

I. DETERIORATION OF LAKE ENVIRONMENTS AND HAZARDS (Q)

I1 ENHANCED SILTATION

§ Extent of damage : Not serious.

§ Supplementary notes

The sedimentation rate is still larger than the target rate decreasing rather slowly.

I2 TOXIC CONTAMINATION

§ Main contaminants and their concentrations

Floating plot, May, 1988

Names of contaminants	Concentration [ppm]	
	Water	Sediments
Mn	0.021	0.088
Cu	0.008	0.0044
Pb	0.001	0.0067
Zn	0.0285	0.0161
Fe	0.132	3.30
Cd	0.0	0.0004

§ Environmental quality standards for contaminants in the lake : Present.

§ Food safety standards or tolerance limits for toxic contaminants in the lake : Present.

I3 EUTROPHICATION

§ Nuisance caused by eutrophication

Unusual algal bloom (Cyanophyta, Chlorophyta, *Chlamydomonas*, Bacillariophyta).

§ Phosphorus loadings to the lake [$g\ l^{-1}$] (1988)

Sources	Industrial	Agricultural	Natural
T-P	10.64	28.02	4.29

I4 ACIDIFICATION

§ Extent of damage : Detected but not serious.

§ Past trends in hydrogen ion concentration in lake water : Since 1976 pH changed from 7.5-7.8 to 6.2-6.4.

I5 OTHER HAZARDS

None.

J. WASTEWATER TREATMENTS

J1 GENERATION OF POLLUTANTS IN THE CATCHMENT AREA : (c) Limited pollution with wastewater treatment (Q).

J3 SANITARY FACILITIES AND SEWERAGE

§ Percentage of municipal population in the catchment area provided with adequate sanitary facilities (on-site treatment systems) or public sewerage: 92 %.

§ Municipal wastewater treatment systems

No. of tertiary treatment systems: 2.
No. of secondary treatment systems: 2.
No. of primary treatment systems: 2.

K. IMPROVEMENT WORKS IN THE LAKE

K1 RESTORATION (Q)

River bed dredging at the mouth for the dam safety.

L. DEVELOPMENT PLANS (Q)

Since 1970 — Recreation development.

M. LEGISLATIVE AND INSTITUTIONAL MEASURES FOR UPGRADING LAKE ENVIRONMENTS (Q)

M1 NATIONAL AND LOCAL LAWS CONCERNED

§ Names of the laws (the year of legislation)

(1) The law for water, air and soil protection (1963)
(2) The law for environment protection (1967)
(3) The law for water (1969)

§ Responsible authorities

(1) Local authority
(2) Ministry of Energetics
(3) Ministry of Agriculture and Forestry

§ Main items of control

(1) Quality and quantity of water inflow
(2) Quality of water outflow
(3) Rate of lake sedimentation

M2 INSTITUTIONAL MEASURES

(1) State Committee for Environment Protection
(2) Local authority
(3) Ministry of Health
(4) Bulgarian Academy of Sciences

M3 RESEARCH INSTITUTES ENGAGED IN THE LAKE ENVIRONMENT STUDIES

(1) Institute for Hydrology and Meteorology, Sofia
(2) Institute for Water Management, Sofia
(3) Environment Protection Research Center, Sofia

N. SOURCES OF DATA

(Q) Questionnaire filled by Dr. G. Gergov, Institute for Hydrology and Meterology, Sofia, Bulgaria.
(1) Handbook of the Bulgarian Rivers, vol. I (1957), II (1958), XVI (1964). Science and Art, Sofia.
(2) Results from both the Economy and Technical Exploitation of the Bulgarian Large Man-made Lakes (1965). Technica, Sofia.
(3) Statistical Yearbook for Bulgaria (1986). Sofia.
(4) The data from field measurements on the man-made lake "G. Dimitrov" supported by a grant of the Ministry of Culture, Science & Education, No. 747/87.

NORTHWOOD LAKE

A view on the lake

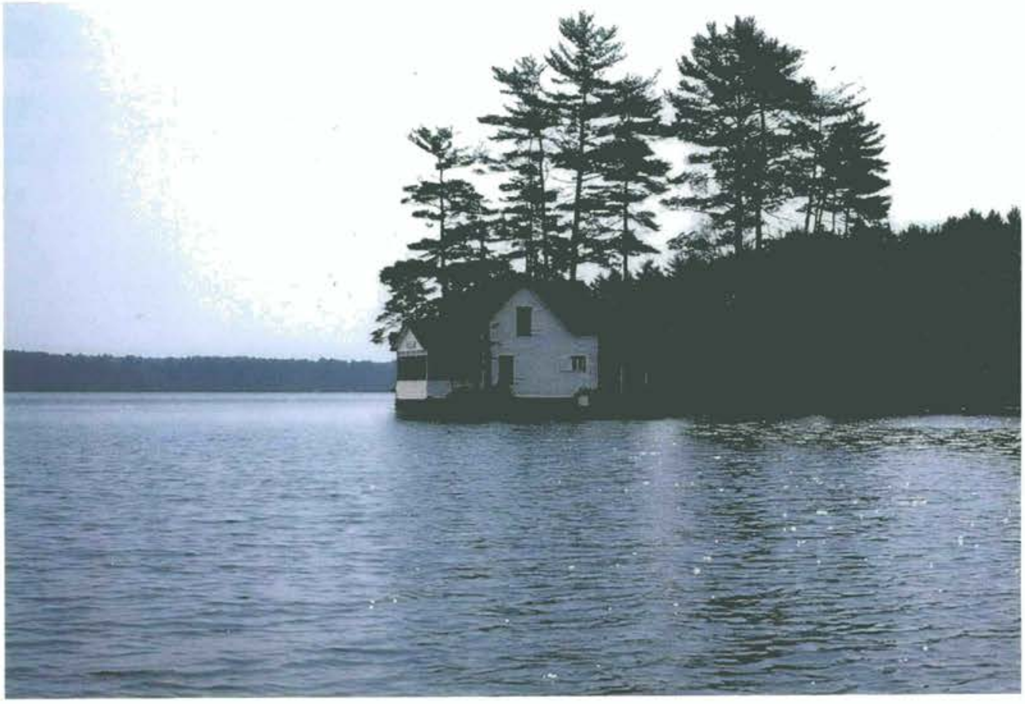
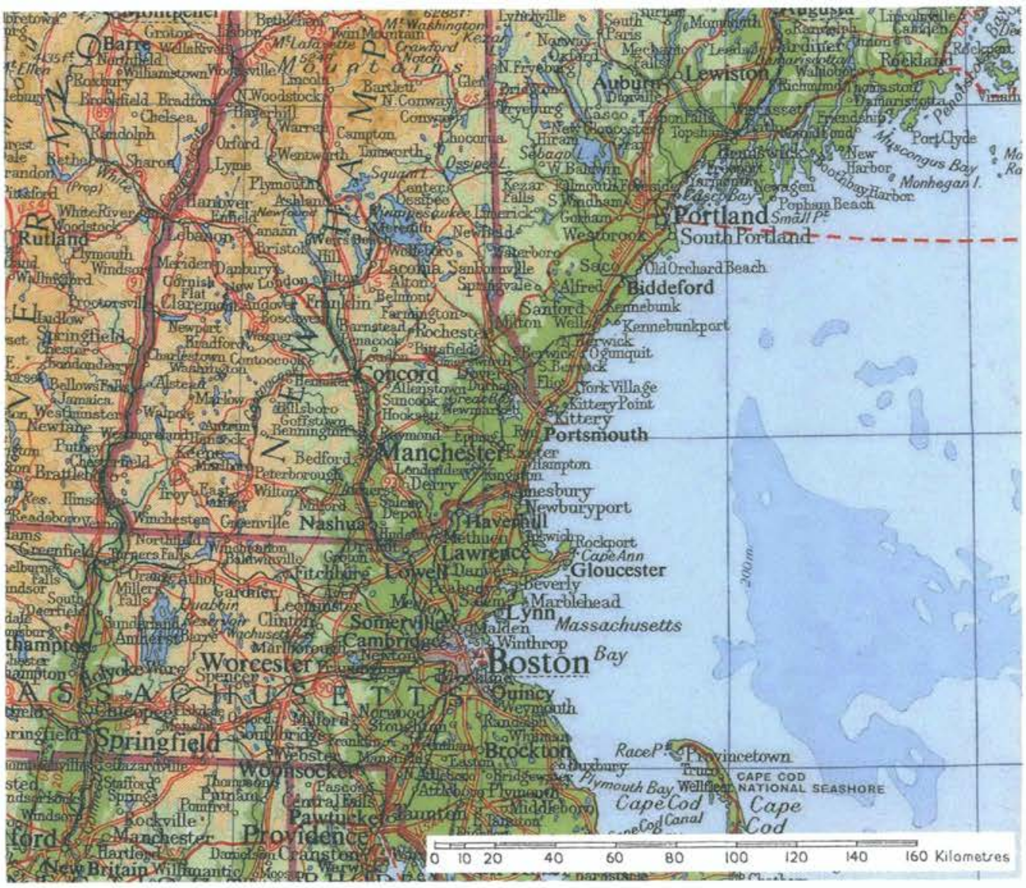


Photo: M. Martin



A. LOCATION

§ New Hampshire, U. S. A.
§ 43°13'N-71°15'W ; 158 m above sea level.

B. DESCRIPTION

Northwood Lake is a long, narrow, shallow lake located in southeastern New Hampshire, in the town of Northwood, Rockingham County. It is situated approximately 18 miles from Concord, and has 3 miles of shoreline along Route 4, the major east-west highway between the capital city area and the state university, the seashore, and the state of Maine. It is a natural lake raised by damming, having an area of 278 hectares, a mean depth of 2.8 meters, and a maximum depth of 7.3 meters.

The lake functions as the final settling basin for several lakes in its 6,226 hectares watershed, prior to its discharge forming the Little Suncook River. The watershed is primarily rural forested and agricutural lands. A large dairy farm and associated corn fields lie along its major tributary Narrows Brook.

Northwood Lake has a free and unencumbered boat launch, a commercial marine, a town beach that is available to non-residents, and a Boy Scout camp. Most of the lake's shoreline is developed, consisting primarily of single family camps and homes. A restaurant and several businesses are located near the lake along Route 4 and a trailer park exists on the shoreline at Northwood Narrows (Q, 3).

C. PHYSICAL DIMENSIONS (1)

Surface area [km^2]	2.6
Volume [$10^6 m^3$]	9.7
Maximum depth [m]	7.6
Mean depth [m]	3.7
Normal range of annual water level fluctuation (regulated) [m]	1.5
Residence time [yr]	0.25
Catchment area [km^2]	41

D. PHYSIOGRAPHIC FEATURES

D1 GEOGRAPHICAL (1)

§ Bathymetric map (Fig. NAM-36-1).

§ Outflowing rivers and channels (number and names) : 1 (Northwood Lake Outlet).

D2 CLIMATIC (1)

§ Climatic data at Concord, Jun. 1980–May 1981

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean temp. [°C]	-11	-1	1	8	14	19	21	19	15	7	-2	-7	6.9
Precipitation [mm]	Average yearly precipitation approximately 1,000												

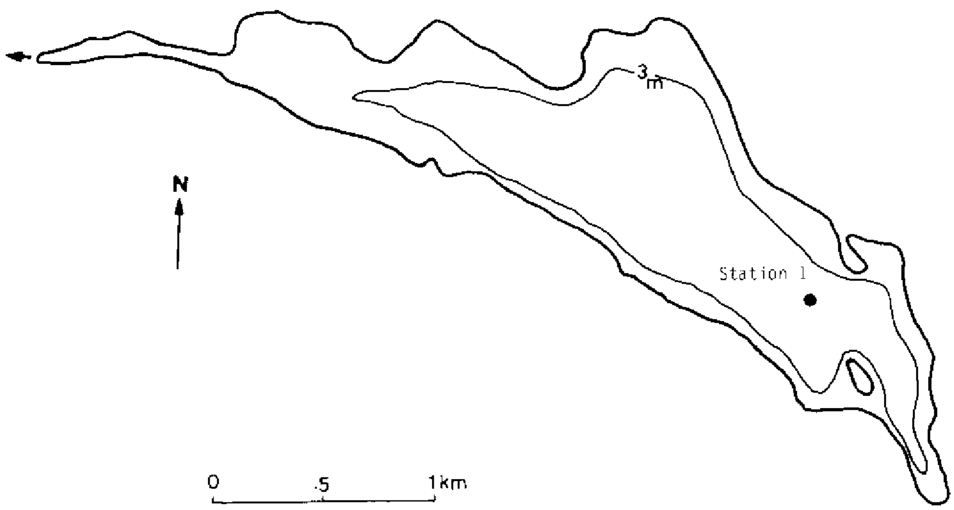
§ Average solar radiation in Concord* : 32.5 MJ $m^{-2}day^{-1}$.

Possible Sunshine in Concord*

Year	[%]
1979	53
1980	59
1981	58
1982	58

* Data from NOAA.

Fig. NAM-36-1 Bathymetric map (2).



§ Water temperature [°C]

Station 1 (Deep Hole), Jun. 1980–May 1981

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	—	—	—	11.2	14.2	22.0	26.0	19.8	18.8	13.5	4.0	—
1	—	—	—	11.1	14.2	22.0	26.0	19.8	18.8	13.5	4.0	—
2	—	—	—	11.1	14.2	20.5	26.0	19.8	18.5	13.4	4.0	—
3	—	—	—	11.0	14.2	19.5	25.9	19.8	18.2	13.3	4.0	—
4	—	—	—	11.0	14.2	17.5	24.2	19.7	17.9	13.3	4.0	—
5	—	—	—	11.0	14.2	17.5	22.2	19.6	17.5	13.2	4.0	—
6	—	—	—	10.9	14.2	—	—	—	17.1	13.2	4.0	—
6.5	—	—	—	—	14.2	—	—	—	—	13.1	4.0	—

§ Freezing period : Dec. to Mar.
§ Mixing type : Dimictic.
§ Note on water mixing and thermocline formation : No stratification observed.

E. LAKE WATER QUALITY (1)

E1 TRANSPARENCY [m]

Station 1 (Deep Hole), Jun. 1980-May 1981

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
–	2.0	–	3.0	2.5	3.0	4.8	3.6	2.9	4.3	2.9	2.2

E2 pH

Station 1, Jun. 1980-May 1981

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0-1	6.2	6.4	–	6.2	6.2	6.6	6.6	–	2.9	6.2	6.6	5.8
2-3	6.0	6.2	–	6.0	6.1	6.6	6.0	4.1	6.3	6.3	6.4	5.8
4-5	5.9	6.0	–	6.0	6.1	6.4	6.3	6.3	6.2	6.3	6.4	5.7
Bottom	–	–	–	6.0	6.1	–	–	6.3	6.3	6.4	–	–

E3 RESIDUE [mg l⁻¹]

Pleasant Lake Brook, Jun. 1980-May 1981

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	21	45	35	31	49	62	67	30	95	2	25	51

E4 DO [mg l⁻¹]

Station 1 (Deep Hole), Jun. 1980-May 1981

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	–	–	–	11.0	9.9	8.7	8.2	8.0	8.9	8.9	11.7	–
1	–	–	–	10.9	9.8	8.6	8.2	8.0	8.9	8.9	11.7	–
2	–	–	–	10.9	9.8	8.7	8.2	8.0	8.9	8.9	11.7	–
3	–	–	–	10.9	9.8	8.4	8.2	8.0	8.9	8.9	11.7	–
4	–	–	–	10.9	9.8	8.2	7.4	8.0	8.7	8.8	11.7	–
5	–	–	–	10.8	9.8	7.6	6.4	7.9	8.4	8.8	11.7	–
6	–	–	–	10.6	9.8	–	–	7.9	8.2	8.8	11.7	–
6.5	–	–	–	–	9.8	–	–	–	–	–	–	–

E6 CHLOROPHYLL CONCENTRATION [μg l⁻¹]

Station 1 (Deep Hole), Jun. 1980-May 1981

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	1.71	0.28	–	2.33	5.32	5.14	2.54	3.42	3.71	2.82	2.21	1.90

E7 NITROGEN CONCENTRATION

§ Total-N [mg l^{-1}]

Station 1 (Deep Hole), Jun. 1980-May 1981

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0-1	0.33	0.66	—	0.36	0.35	0.50	0.27	—	0.33	0.43	—	0.36
2-3	0.37	0.48	—	0.36	0.40	0.42	0.32	0.25	0.74	0.35	—	0.42
3-4	0.53	0.48	—	0.35	0.34	0.48	0.27	0.31	0.39	0.28	—	0.40
Bottom	—	—	—	0.34	0.31	—	—	0.25	0.40	0.36	—	—

E8 PHOSPHORUS CONCENTRATION

§ Total-P [mg l^{-1}]

Station 1 (Deep Hole), Jun. 1980-May 1981

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0-1	.010	.028	—	.016	.015	.024	.014	—	.010	.009	.015	.014
2-3	.009	.020	—	.016	.020	.024	.013	.013	.010	.009	.013	.019
4-5	.022	.032		.018	.019	.030	.013	.009	.008	.009	.023	.024
Bottom	—	—	—	.029	.018	—	—	.004	.009	.011	—	—

F. BIOLOGICAL FEATURES

F1 FLORA (1)

§ Emerged macrophytes

Cephalanthus occidentalis Sagittaria latifolia, Cyperaceae, *Sparganium*, *Typha*, *Carex*, *Eriocaulon septangulare*, *Dulichium arundinaceum*, *Pontederia cordata*, *Eleocharis*, *Phragmites communis*, *Scirpus*.

§ Floating macrophytes : *Nuphar*, *Nymphaea*, *Brasenia schreberi*.

§ Submerged macrophytes

Potamogeton, *Vallisneria americana*, *Myriophyllum humile*, *Utricularia*, *Nitella*.

§ Phytoplankton

Asterionella, *Tabellaria*, *Anabaena*, *Lyngbya*, *Chrysochromulina breviturrita*, *Mallomonas*, *Dinobryon*, *Synura*.

F2 FAUNA

§ Zooplankton

Rotifers (*Kellicottia*, *Keratella*, *Polyarthra*), Crustaceans (*Daphnia*), Calanoid copepods, Cyclopoid copepods, Nauplius larvae, Cilliates (*Tintinnidium*) (1).

§ Fish

Stocked with *Morone americana* (white perch), *Ictalurus natalis* (horned pout), *Micropterus dolomieui* (small mouth bass), *Perca flavescens* (yellow perch), *Notemigonus chrysoleucas* (golden shiner), Astacidae, crayfish, *Esox niger* (eastern chain pickerell), also present *Micropterus salmoides* (large mouth bass), minnows, suckers, sunfish (4, 5).

G. SOCIO-ECONOMIC CONDITIONS

G1 LAND USE IN THE CATCHMENT AREA (1982) (1)

	Area [km^2]	[%]
Forested	ca. 26	63
Wetland/waterbody	ca. 7	16
Open land		<0.5
Agricultural	ca. 6	14
Rural/residential	ca. 2	6
Commercial		<0.5
Total	41	100

G2 INDUSTRIES IN THE CATCHMENT AREA AND THE LAKE (Q)

§ Numbers of domestic animals in the catchment area: Cattle <100, horses <25, sheep <10, poultry <10.

G3 POPULATION IN THE CATCHMENT AREA (1980) (Q)

Total population	Population density [km^{-2}]	Main cities
2,175	53.0	None

H. LAKE UTILIZATION

H1 LAKE UTILIZATION (Q)

Sightseeing and tourism (number of visitors in 1982, approximately 2,200) and recreation (swimming, yachting, sport-fishing).

I. DETERIORATION OF LAKE ENVIRONMENTS AND HAZARDS (Q)

I1 ENHANCED SILTATION

§ Extent of damage: Not serious.

I2 TOXIC CONTAMINATION

§ Present status: None.

§ Environmental quality standards for contamination in the lake: Toxic concentrations and combinations are evaluated in accordance with EPA's published water quality criteria for 64 toxic substances dated November 1980.

I3 EUTROPHICATION

§ Nuisance caused by eutrophication

Unusual algal bloom (*Chrysochromulina breviturrita*) with rotten odor of lake.

§ Phosphorus loadings to the lake (1981) [kg P yr^{-1}]

Sources	Industrial	Domestic	Agricultural	Natural	Total
T-P	–	162.1	244.1	613	1,018.2

I4 ACIDIFICATION

§ Extent of damage: Detected but not serious.

J. WASTEWATER TREATMENTS (1)

J1 GENERATION OF POLLUTANTS IN THE CATCHMENT AREA: (d) Measurable pollution with limited wastewater treatment.

§ Supplementary notes

In June, 1978, Northwood Lake developed into an extremely offensive rotten-cabbage. Samples of lake water revealed an abundance of a small, bi-flagellated organism, later determined to be *Chrysochromulina breviturrita*. This was a brand new species of algae, not described in the literature until 1978 (Nicolls, 1978). During the investigations of this algal problem, high phosphorus levels (up to 50 mg l^{-1}) were found in runoff from a nearby dairy farm.

Prior to this algal bloom, the Water Supply and Pollution Control Commission (WSPCC) had received no other complaints concerning nuisance plant growths in Northwood Lake. However, the following year a shortlived, isolated, *Anabaena* (blue-green algae) bloom was observed in the Lynn Grove — Pine Point area. A general biological survey of the lake, conducted during the summer of 1979, revealed a shallow mesotrophic lake, with relatively low levels of phosphorus and algae.

It appeared that although the lake was still in good shape, subtle changes were occurring in the watershed to cause sporadic algal blooms. Because of the rarity of the *Chrysochromulina* organism, and because of the many unanswered questions concerning the high runoff phosphorus levels and sporadic algal bloom, the State/EPA Agreement for FY 1980 called for a diagnostic/feasibility study of Northwood Lake, to be conducted by the WSPCC and funded partly by the Clean Lakes Program.

J3 SANITARY FACILITIES AND SEWERAGE

§ Percentage of municipal population in the catchment area provided with adequate sanitary facilities (on-site treatment systems) or public sewerage: 100 septic systems for lake shore communities (90 % adequate).

§ Municipal wastewater treatment systems: None.

K. IMPROVEMENT WORKS IN THE LAKE

K1 RESTORATION (Q)

Two applications of copper sulfate in 1978 to reduce the bloom of *C. breviturrita*.

L. DEVELOPMENT PLANS (Q)

Much of the south side is still available for development and will probably be developed within the next few years.

M. LEGISLATIVE AND INSTITUTIONAL MEASURES FOR UPGRADING LAKE ENVIRONMENTS (Q)

M1 NATIONAL AND LOCAL LAWS CONCERNED

§ Names of the laws

(1) Federal Water Pollution Control Act

§ Main items of control

(1) Algae & other aquatic nuisances
(2) Exotic aquatic weeds
(3) Illegal dumping & other violations

M3 RESEARCH INSTITUTES ENGAGED IN THE LAKE ENVIRONMENT STUDIES

(1) Department of Environmental Services, Water Supply and Pollution Control Commission, Biology Bureau

N. SOURCES OF DATA

(Q) Questionnaire filled by New Hampshire Water Supply and Pollution Control Commission., Concord, New Hampshire.

(1) Towne, R. E. & Estabrook, R. H. (1982) Northwood Lake Diagostic/Feasibility Study. New Hampshire Water Supply and Pollution Control Commission, Staff Report No. 131.

(2) Classification and Priority Listing of N. H. Lakes, Rockingham and Strafford Counties, Volume 2, Part 6. New Hampshire Water Supply and Pollution Control Commission, Staff Report No. 121. March, 1981.

(3) Towne, R. E. & Estabrook, R. H. (1979) A Trophic Study of Northwood Lake, Northwood, N. H. New Hampshire Water Supply and Pollution Control Commission.

(4) Newell, A. E. (1970) Biological Survey of the Lakes and Ponds in Cheshire, Hillsborough and Rockingham Counties. State of New Hampshire Fish and Game Department, Survey Report No. 8C.

(5) Scarola, J. F. (1973) Freshwater Fishes of New Hampshire. New Hampshire Fish and Game Department, Division of Inland and Marine Fisheries.

SMITH MOUNTAIN LAKE

An aerial view of the lake

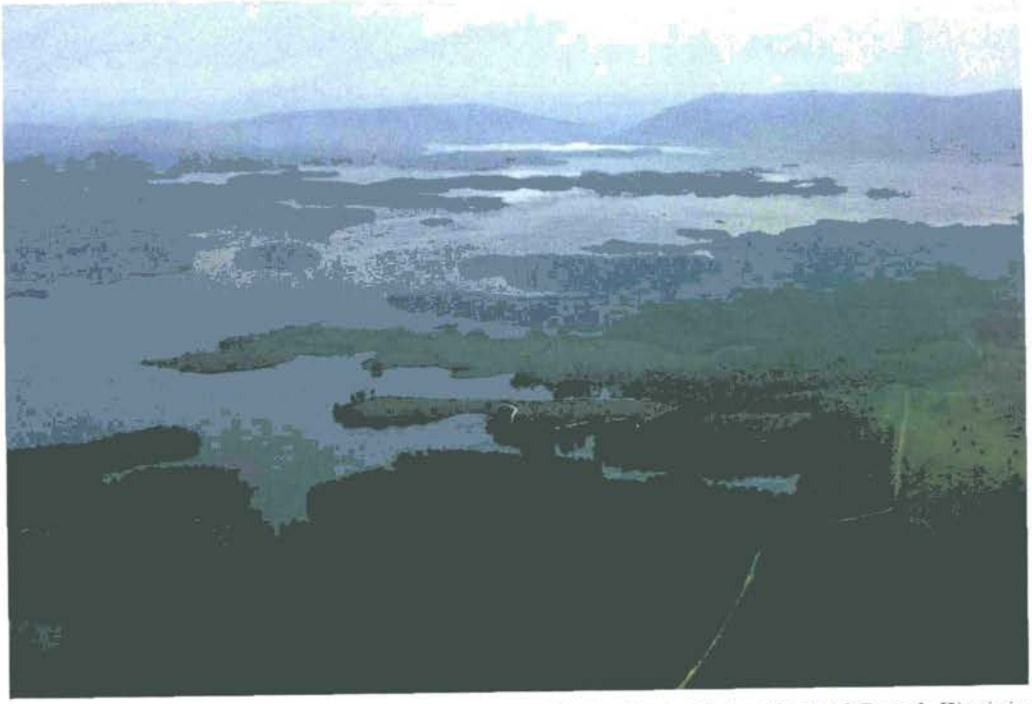
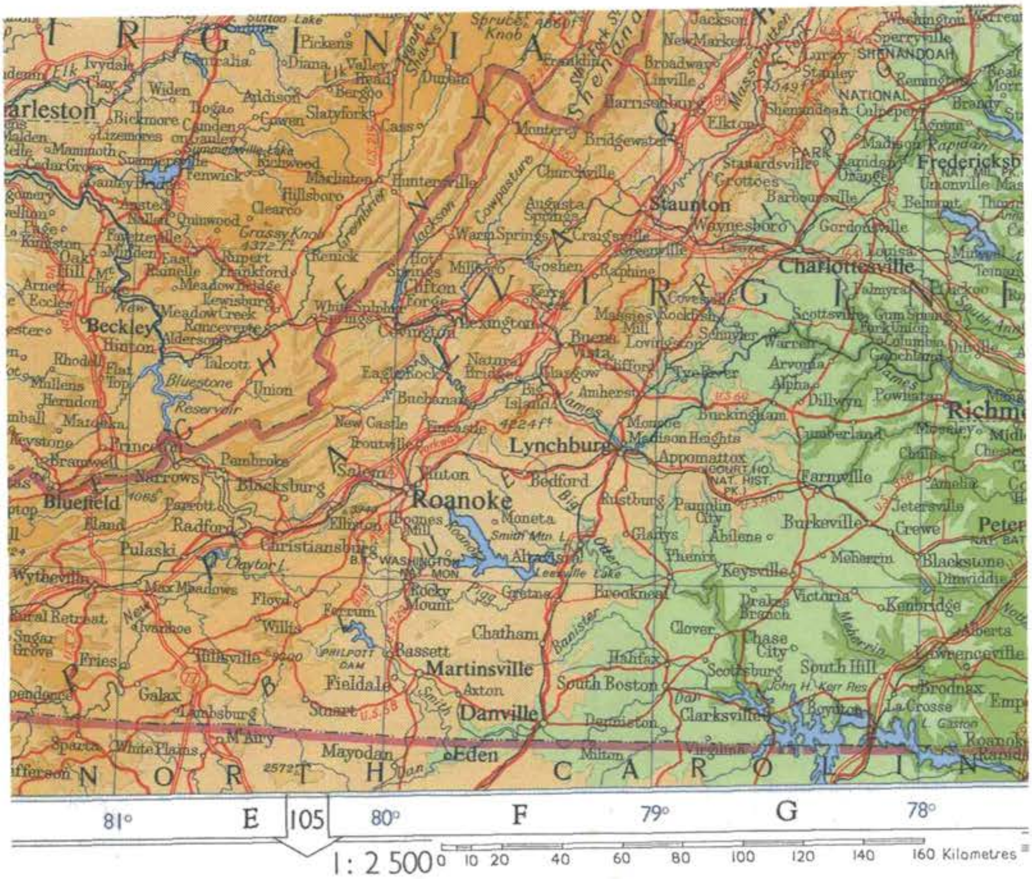


Photo: State Water Control Board, Virginia



A. LOCATION

§ Virginia, U. S. A.
§ 37°02′-37°11′N ; 79°32′-79°45′W ; 238 m above sea level.

B. DESCRIPTION

Since the mid-1960's, when Smith Mountain Lake was first filled, the lake has been a very popular and important multipurpose resource. An important function of Smith Mountain Lake, and the primary reason for its creation, is to provide hydroelectric power. Appalachian Power Company owns and operates Smith Mountain Dam as well as the dam on Leesville Lake just downstream from Smith Mountain. The two lakes together make it possible to operate Smith Mountain Dam as a "pumped storage" operation. In this arrangement water can be pumped from Leesvile Lake back into Smith Mountain Lake during periods of low power usage. AP Co. can thus be prepared for peak periods of power demand because the "power pool" in Smith Mountain Lake has been maintained at a high level.

Smith Mountain Lake is also a very popular recreation site, serving people from throughout the western part of Virginia. Thousands enjoy boating, swimming, fishing and other activities on the lake every year. Many resort homes, condominiums and year-round residences are located on the shores of this reservoir. A significant economic impact on localities around the lake results from recreational businesses, construction of homes and resorts, and the addition of new residents to the communities growing around the shoreline.

Smith Mountain Lake is presently used as a public water supply. The water and shoreline of the lake provide habitat for many aquatic plants and animals, as well as birds and other terrestrial wildlife. The protection of aquatic life and other uses already mentioned for this lake is the goal of lake management activities.

Two rivers, the Blackwater and the Roanoke, are the main tributaries to Smith Mountain Lake. The Roanoke River is the larger of the two tributaries and drains a watershed that includes the Roanoke Metropolitan area. The Blackwater River's drainage is mostly rural and agricultural. A 1980 study indicated 72 % of the phosphorus loading to Smith Mountain Lake came from the Roanoke River, and that at least 90 % of this load was non-point source in origin. Recommendations were made and some of these were implemented. The Blackwater River arm of the lake was also found to have a relatively high eutrophication rate in its upper reach, a result attributed largely to non-point source. Agriculture was the biggest contributor of nutrients from runoff, with dairy farms yielding the highest loads per acre. Progress has been made in controlling some agricultural sources of nutrients through the State Water Control Board agricultural no-discharge permit program. In recent years, a number of these permits, which require approved methods for storage and disposal of liquid animal wastes, have been issued in the Blackwater River drainage area (Q).

C. PHYSICAL DIMENSIONS

Surface area [km^2]	80.9
Volume [10^{6}m^3]	2.8
Maximum depth [m]	61.0
Mean depth [m]	35.1
Normal range of water level fluctuation	Regulated
Length of shoreline [km]	805
Residence time [yr]	3.2-3.5
Catchment area [km^2]	2,570

D. PHYSIOGRAPHIC FEATURES

D1 GEOGRAPHICAL

§ Sketch map (Fig. NAM-37-1).

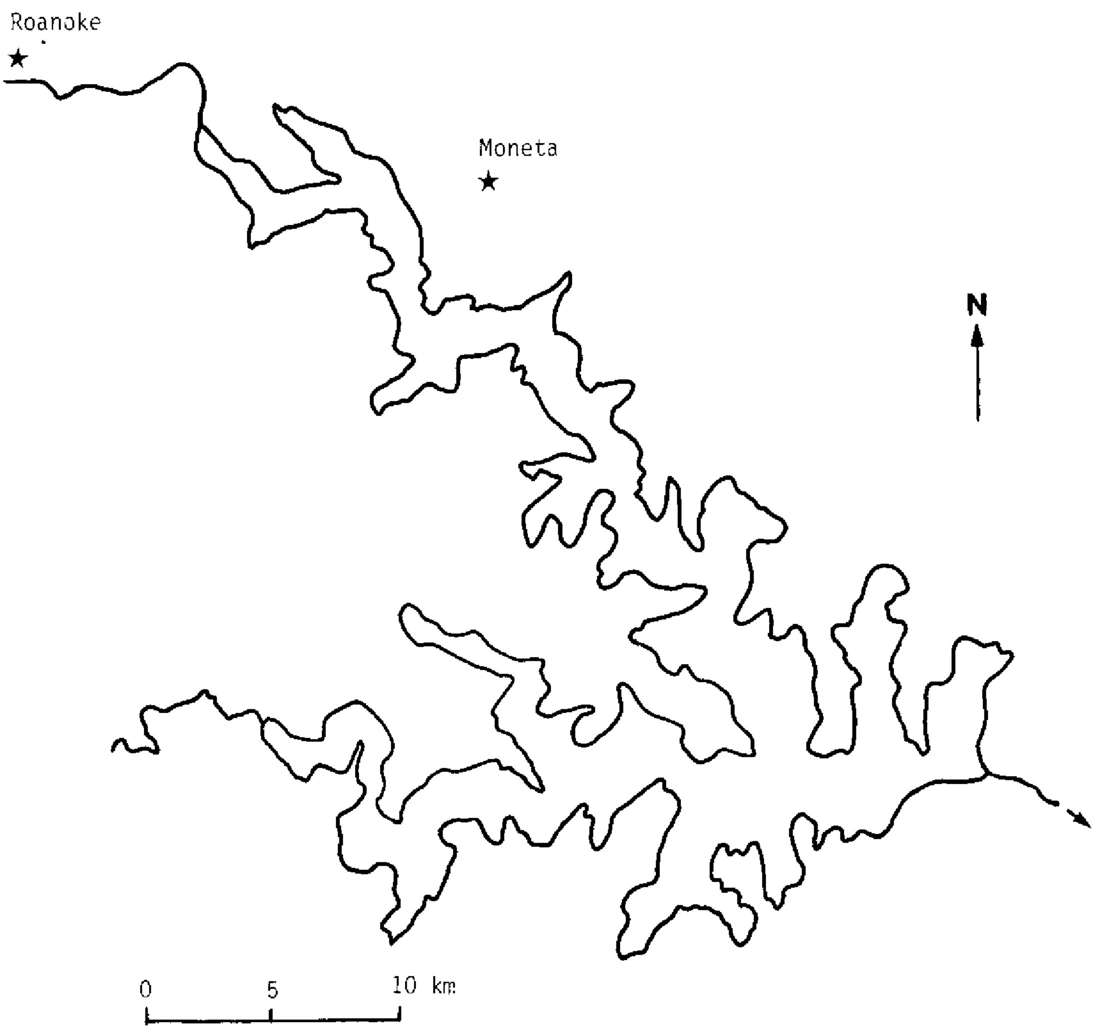
§ Outflowing rivers and channels (number and names) : 1 (Roanoke R.)

D2 CLIMATIC

§ Climatic data at Richmond

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean temp. [°C]	3.7	4.4	8.2	13.9	19.2	23.7	25.6	24.7	21.2	15.1	9.2	4.3	14.4
Precipitation [mm]	88	74	87	80	94	95	142	141	93	76	77	75	1,122

Fig. NAM-37-1 Sketch map of the lake.



§ Water temperature [°C]
Dam station, 1987

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	–	–	–	13	–	26	–	28	–	17	–	–
10	–	–	–	13	–	13	–	16	–	17	–	–
20	–	–	–	9	–	11	–	14	–	16	–	–
30	–	–	–	7	–	9	–	13	–	14	–	–
40	–	–	–	6	–	7	–	12	–	13	–	–
50	–	–	–	6	–	6	–	–	–	12	–	–
60	–	–	–	5	–	–	–	–	–	12	–	–

§ Freezing period: None.

§ Notes on water mixing and thermocline formation: Occasional thermocline, but pumped-storage system causes lake to be vertically homogeneous.

E. LAKE WATER QUALITY (Q)

E1 TRANSPARENCY [m]

Dam station, 1987

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
–	–	–	1.3	–	3.0	–	2.6	–	2.9	–	–

E2 pH

Dam station, 1987

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.3	–	–	–	8.2	–	8.7	–	8.3	–	7.6	–	–
30.0	–	–	–	7.8	–	7.7	–	6.6	–	7.4	–	–
60.0	–	–	–	7.7	–	7.7	–	6.8	–	7.4	–	–

E4 DO [mg l^{-1}], (temp. [°C])

Dam station, 1987

Depth [m]	Apr	Jun	Aug	Oct
1	11 (13)	9 (26)	9 (28)	6 (17)
10	10 (13)	8 (13)	4 (16)	6 (17)
20	10 (9)	8 (11)	3.5 (14)	3 (15)
30	9 (7)	8 (9)	3 (13)	2 (14)
40	9 (6)	7 (7)	1.5 (12)	0 (13)
50	9 (6)	6 (6)	N. D.	0 (12)
55	–	6 (6)	0.4 (10)	0 (12)
60	8 (5)	N. D.	N. D.	0 (12)

E6 CHLOROPHYLL CONCENTRATION [$\mu g\ l^{-1}$]

Dam station, 1987

Depth [m]	Apr	Jun	Aug	Oct
0.3	0.31	0.60	1.5	N. D.

15 stations in August, 1987 : 8.65±7.54.

E7 NITROGEN CONCENTRATION

§ Total Kjeldahl-N [mg l^{-1}]

Dam station, 1985-1987

Depth [m]	1985 Apr	Jun	Aug	Oct	1986 Apr	Jun	Aug	Oct	1987 Apr	Jun	Aug	Oct
0.3	0.3	0.3	0.2	0.3	0.3	0.5	0.3	0.2	0.3	0.3	0.2	0.2

E8 PHOSPHORUS CONCENTRATION

§ Total-P [mg l^{-1}]

Dam station, 1985-1987

Depth [m]	1985 Apr	Jun	Aug	Oct	1986 Apr	Jun	Aug	Oct	1987 Apr	Jun	Aug	Oct
0.3	0.01	0.01	0.01	0.01	0.02	0.01	0.01	0.03	0.02	0.01	0.01	<0.01

F. BIOLOGICAL FEATURES (Q)

F1 FLORA

§ Phytoplankton

Dam station, 1973

Sampling date	Dominant genera	Cells [ml^{-1}]	Chlorophyll a [μg l^{-1}]
Apr. 4, 1973	*Stephanodiscus*	4,329	4.3
	Flagellates	2,029	
	Melosira	433	
	Ankistrodesmus	352	
	Synedra	189	
	Others	163	
	Total	7,495	
Jul. 16, 1973	*Lyngbya*	7,994	3.9
	Chroococcus	2,858	
	Raphidiopsis	2,501	
	Flagellates	1,474	
	Synedra	1,279	
	Other	2,679	
	Total	18,801	
Sep. 26, 1973	Flagellates	1,325	3.7
	Raphidiopsis	564	
	Merismopedia	536	
	Dactylococcopis	479	
	Stephanodiscus	423	
	Other	722	
	Total	4,094	

F2 FAUNA

§ Fish

Stripped bass (*Mofone saxatillis*)*, large mouth bass (*Micropterus salmoides*), small mouth bass (*Micropterus dolomieui*), shad (*Dorosoma alosa*) (* economically important).

F3 PRIMARY PRODUCTION RATE [mg C m^3 day^{-1}]

Dam station, 1966-1967

Depth [m]	1966 May	Jul	Aug	Nov	1967 Aug
Surface	9.8	24.3	38.8	19.5	13.9
1	19.7	42.9	34.6	20.2	10.8
2	17.6	26.7	41.4	18.0	21.2
5	17.1	44.9	28.4	2.1	14.0
8	5.0	6.0	1.8	0.0	19.8
10	0.7	1.0	0.0	0.0	3.0
12	0.0	0.0	0.0	0.0	0.0

G. SOCIO-ECONOMIC CONDITIONS (Q)

G1 LAND USE IN THE STUDY AREA*(1980)

	Area [ha]	[%]	Smith Mountain Lake Basin Water Supply Plan [%]
Natural landscape	405,048	57.2	
Forest			60.7
Agricultural land			
Orchard, etc.	27,828	3.9	
Crop field	195,455	27.6	8.4
Pasture land			18.6
Settlement area	30,680	4.3	
Urban			10.7
Uncategorized	4,177	0.6	
Water	44,756	6.3	1.7
Total	707,944	100	

* Study area : 41 % of Smith Mountain Lake drainage area.

§ Types of important forest vegetation : Pine, mixed hardwood forests (most forestland has been harvested at least one time and is in a continual regrowth cycle).
§ Main kinds of crops : Pasture, orchards, corn, tobacco, hay, alphalfa, fallow/inactive.
§ Levels of fertilizer application on crop fields : Moderate.
§ Trends of change in land use : Development of shoreline for residential/recreational use and continuing urbanization of Roanoke area.

G2 INDUSTRIES IN THE CATCHMENT AREA AND THE LAKE

	Number of establishment	Main products and major industries
Primary industry		Wood product, tobacco, fruits
Dairy farms	60-70	
Secondary industry		Plastics, petroleum
Tertiary industry		Recreational

§ Number of domestic animals in the catchment area : Cattle 55,000.

G3 POPULATION IN THE CATCHMENT AREA (1984)

	Population	Population density [km^{-2}]	Main cities
Urban	225,000		Roanoke, Salem, Bedford
Rural	15,209		
Total	240,209	93.5	

H. LAKE UTILIZATION (Q)

H1 LAKE UTILIZATION

Source of water and recreation (swimming, sport-fishing and yachting).

H2 THE LAKE AS WATER RESOURCE (1988)

Domestic water, irrigation, industrial water and power plant.

I. DETERIORATION OF LAKE ENVIRONMENTS AND HAZARDS (Q)

I1 ENHANCED SILTATION

§ Extent of damage : Not serious.
§ Supplementary notes : Localized development problems with runoff.

I2 TOXIC CONTAMINATION

§ Present status : Detected but not serious.
§ Environmental quality standards for contaminations in the lake

Surface Public Water Supply Standards*

Constituent	Concentration [mg l^{-1}]
Arsenic	0.05
Barium	1.0
Cadmium	0.01
Chloride	250
Chromium(total)	0.05
Copper	1.0
Foaming agents (as methylene blue active substances)	0.5
Iron	0.3
Lead	0.05
Manganese(soluble)	0.05
Mercury	0.002
Nitrate(as N)	10
Phenols	0.001
Selenium	0.01
Silver	0.05
Sulfate	250
Total dissolved solids	500
Zinc	5.0
Endrin	0.0002
Lindane	0.004
Methoxychlor	0.1
Toxaphene	0.005
2,4-D	0.1
Silvex	0.01

* Data from Commonwealth of Virginia Water Quality Standards.

Water quality criteria — metals in water*

Substance	Value [$\mu g\ l^{-1}$]
Arsenic(trivalent)	190
Cadmium	0.7852 (ln(hardness)) −3.49
Chromium(hexavalent)	11
Copper	0.8545 (ln(hardness)) −1.465
Iron	1000
Lead	1.266 (ln(hardness)) −4.661
Nickel	0.76 (ln(hardness)) +1.06
Selenium(total inorganic)	35
Zinc(total)	47

* Data from Commonwealth of Virginia Water Quality Standards.

§ Other standards (national): Fish tissue contamination standards, Water quality standards for drinking water and swimming.

I3 EUTROPHICATION

§ Nuisance caused by eutrophication: Algal blooms in early 1970's — attributed to sewage treatment plants in Roanoke Valley upstream.

§ Nitrogen and phosphorus loadings to the lake

EPA document, 1973

Sources	Industrial [$kg\ yr^{-1}$]	Total [$kg\ yr^{-1}$]
T-N (TKN)	33,215	2,262,870
T-P	5,475	180,360

§ Supplementary notes: Complete upgrading of STP's in Roanoke River Basin, tracking through the NPDES (National Pollution Discharge Elimination System) permit system. Development of zoning regulations surrounding lake.

I4 ACIDIFICATION

§ Extent of damage: None.

§ Past trends in hydrogen ion concentration in lake water: The pH value is quite stable in many data.

J. WASTEWATER TREATMENTS (Q)

J1 GENERATION OF POLLUTANTS IN THE CATCHMENT AREA: (d) Measurable pollution with limited wastewater treatment.

J2 APPROXIMATE PERCENTAGE DISTRIBUTION OF POLLUTANT LOADS

	Percentage
Non-point sources	90
Point sources (21 industrial discharges)	10

J3 SANITARY FACILITIES AND SEWERAGE

§ Percentage of municipal population in the catchment area provided with adequate sanitary facilities (on-site treatment systems) or public sewerage: 100 %.

§ Municipal wastewater treatment systems

Number of secondary treatment systems: 22.

Number of primary treatment systems: 9.

§ Industrial wastewater treatment systems: 11 (no "typical" system — depends on facility).

L. DEVELOPMENT PLANS

Smith Mountain Lake Shoreline Management Plan, 1985 ; Comprehensive Management Plan for land use, sewerage system requirements, erosion and sedimentation controls ; flood plain ordinances ; subdivision ordinances ; etc.

M. LEGISLATIVE AND INSTITUTIONAL MEASURES FOR UPGRADING LAKE ENVIRONMENTS (Q)

M2 INSTITUTIONAL MEASURES

(1) Virginia Water Control Board, West Central Regional Office
(2) Smith Mountain Lake Shoreline Management Plan Technical Advisary Committee and West Piedmont Planning District Commission Staff

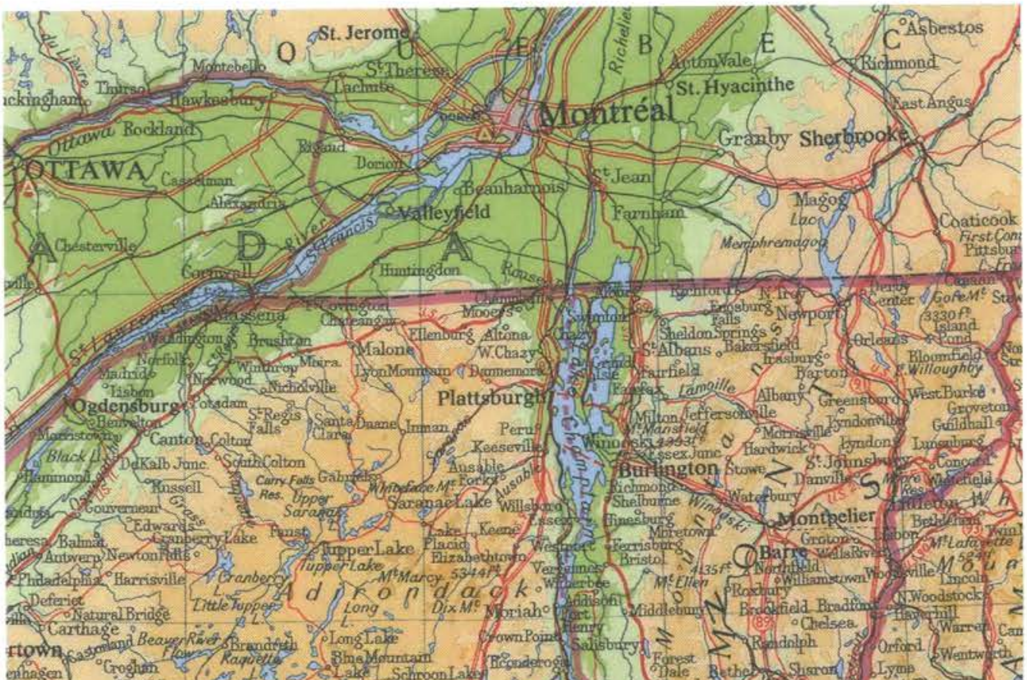
N. SOURCES OF DATA

(Q) Questionnaire filled by Dr. Robert T. Ray, Office of Environmental Research and Standards, Commonwealth of Virginia, State Water Control Board.
(1) Sligh, D. W. & Liptak, T. L. (1988) Lake Monitoring Program 1987. West Central Region. Virginia Water Control Board. 40pp.
(2) Smith Mountain Lake Technical Advisory Committee & West Piedmont Planning District Comission (1985) Smith Mountain Lake Shoreline Management Plan, I & II.
(3) U. S. Environmental Protection Agency(1975) Report on Smith Mountain Reservoir, Bedford, Franklin and Pittsylvania Counties, Virginia. Working Paper 465.
(4) Simmons, G. M. & Neff, S. E. (1969) The Effect of Pumped-straged Reservoir Operation on Biological Productivity and Water Quality. Water Resources Research Center, Virginia Polytechnic Institute Bulletin 21.
(5) Virginia Water Control Board (1980) The Impact of Non-point Sources on the Water Quality of Smith Mountain Lake. West Central Regional Office Planning Bulletin 329.
(6) Court, A. (1974) The climate of the conterminous United States. "World Surveys of Climatology, Volume 11, Climates of North America" (ed. Bryson, R. A. & Hare, F. K.), p. 337. Elsevier Scientific Publishing Company, Amsterdam-London-New York.

LAKE CHAMPLAIN

A view from a lakeside hill

Photo: E.B. Henson



A. LOCATION

§ Vermont and New York, USA ; Quebec, Canada.
§ 43°33′-43°45′N, 73°05′-73°25′W ; 29.38 m above sea level.

B. DESCRIPTION

Lake Champlain has unusual characteristics. It occupies a long, deep, and narrow valley ; it has a northerly flow ; and for a period after the glaciation the lake was marine. It then became the sixth largest lake in the United States. Lake Champlain may have the largest shore development index of any lake in the United States.

The lake occupies a north-south fault zone, and extends 174 km from Whitehall, N. Y. to its outlet in Canada. The lake flows northerly through its outlet, the Richeleau River, into the St. Lawrence River near Montreal. The maximum width of the lake is 19 km. The drainage basin of the lake of 19,881 km² includes portions of the States of New York and Vermont and the Province of Quebec in Canada.

The basin was overridden by the Wisconsin glaciation during the Pleistocene. As the ice melted towards the north, proglacial Lake Vermont was formed and flowed south through the Hudson valley. When the ice margin retreated north of the St. Lawrence Valley, the Champlain basin was inundated with saline ocean water, forming the Champlain Sea. After glacial rebound of the land to the north, the marine incursion ended and the present Lake Champlain was formed about 12,000 years B. P. The uplift resulted in a complex and irregular lake basin with drowned valleys to the east and precipitous cliffs to the west. Large islands to the north, more than 70 islands in the lake, and peninsulae have divided the lake into five major basins. The southern lake is riverine and opens into the main basin. The Missisquoi River delta forms Missisquoi Bay to the northeast. The large islands to the north and natural causeways form Malletts Bay. Between these two bays, and to the east of the islands is the Northeast arm of the lake. Each of these five basins exhibits distinct limnological characteristics.

Lake Champlain has been the focal point for much of the early history of this part of North America. For nearly 150 years after being discovered by Samuel de Champlain in 1609, the lake was the focus of the British, French, and Indian wars ; the lake was the scene of significant naval battles during the Revolutionary War and the war of 1812.

Approximately $9{,}830 \times 10^6$ m³ of water drain from 19,881 km² of land into the lake per year providing a refilling rate of 2.6 years at average lake level. The population in the basin is approximately 500,000. Although the lake appears to have been deteriorating since the turn of the century, the trend for inter-governmental cooperation is increasing. Environmental sense is strong among the inhabitants (Q).

C. PHYSICAL DIMENSIONS

	Missiquoi Bay	Northeast Region	Malletts Bay	Main Lake	South Lake	Whole Lake
Surface area [km²]	77.5	270.2	54.2	671.4	56.9	1,130.[illegible]
Volume [10^6m³]	220.444	3,982.159	699.319	20,744.577	155.575	25,802.[illegible]74
Maximum depth [m]	–	–	–	–		123
Mean depth [m]	2.8	14.7	12.9	30.9	2.7	22.[illegible]
Normal range of annual water level fluctuation [m]	–	–	–	–	–	0.[illegible]–2.56
Length of shoreline [km]	–	–		–	–	944.[illegible]
Residence time [yr]	–	–		–	–	2.[illegible]
Catchment area [km²]	2,963.96	234.10	2,032.29	11,577.49	3,075.25	19,881.[illegible]

D. PHYSIOGRAPHIC FEATURES (Q)

D1 GEOGRAPHICAL

§ Bathymetric map (Fig. NAM-38-1).

§ Main islands (name and area): Grand Isle* (208.4 km²), North Hero* (121.2 km²), Valcour* (4.0 km²), Butler (2.3 km²).

* The islands are connected to the mainland by bridges and roads. There are approximately 60 islands with areas less than 1 km².

§ Outflowing rivers and channels (number and names): 1 (Richeleau R. draining into the St. Lawrence R.).

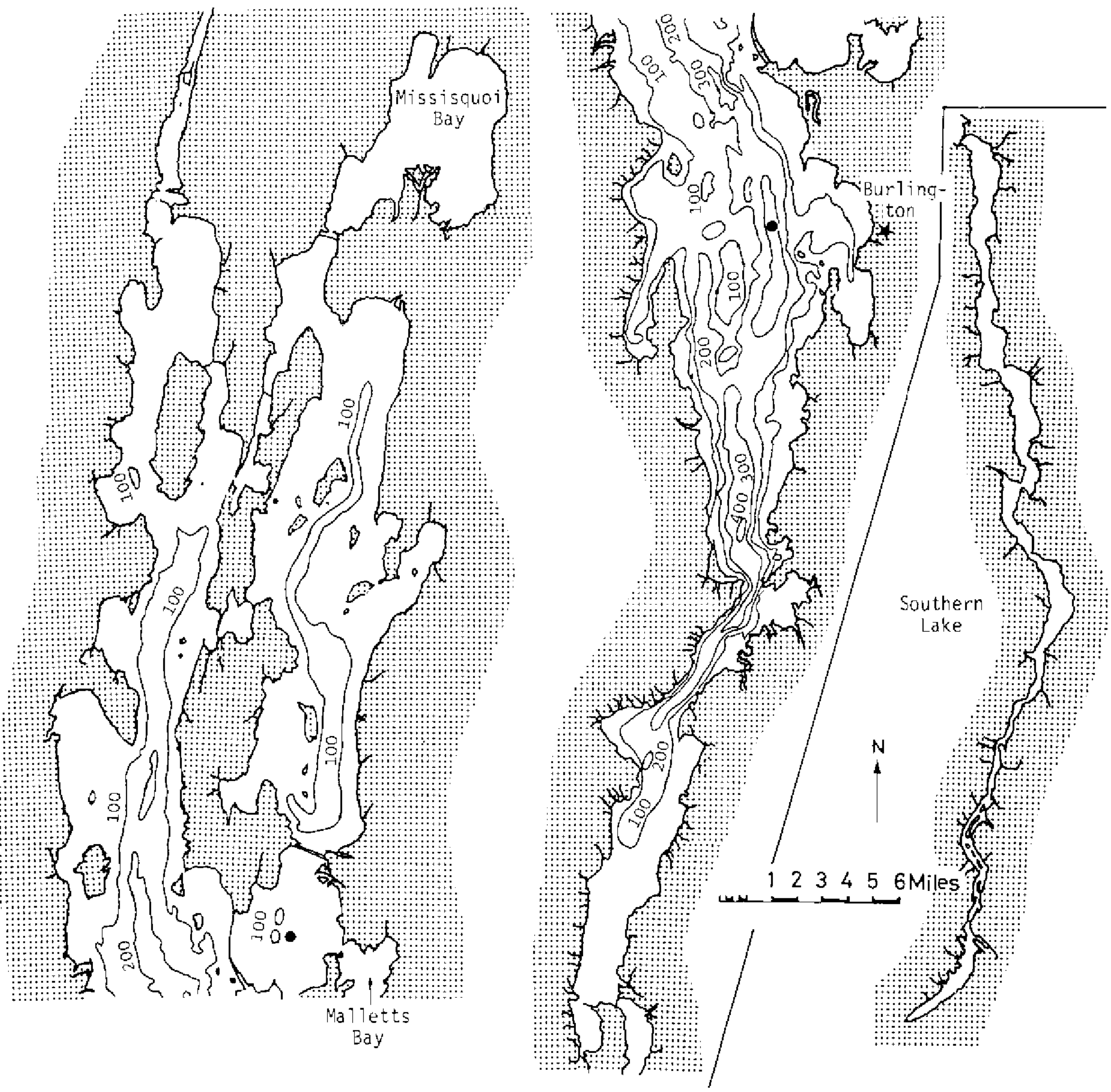
D2 CLIMATIC

§ Climatic data at Burlington (1944-1988)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean temp. [°C]	-8.5	-7.7	-1.6	5.9	12.9	18.3	20.9	19.5	14.9	8.8	2.6	-5.2	6.7
Precipitation [mm]	47	44	56	70	75	93	87	98	71	71	71	62	845

Fig. NAM-38-1 Bathymetric map [m] (Q).

● Observation station in the lake.
★ Meteorological observatory.



§ Water temperature [°C] (7)

Main lake, 1975

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	–	–	–	1.25	6.0	12.5	23.0	22.0	15.6	12.3	10.5	–
5	–	–	–	–	5.8	12.0	22.0	21.6	15.4	12.3	10.5	–
10	–	–	–	–	5.7	11.0	17.0	21.0	15.2	12.3	10.5	–
15	–	–	–	–	5.4	10.0	11.5	19.0	15.2	12.3	10.5	–
20	–	–	–	–	5.2	9.0	9.5	16.0	15.1	12.3	10.5	–
25	–	–	–	–	5.0	7.5	9.0	9.0	13.5	12.3	10.5	–
30	–	–	–	–	4.8	6.7	8.0	8.2	9.5	12.3	10.4	–
35	–	–	–	–	4.7	5.6	6.0	7.5	8.6	12.3	10.4	–
40	–	–	–	–	4.5	5.5	5.3	6.8	8.2	9.4	10.4	–
45	–	–	–	–	4.4	5.3	5.1	6.5	8.0	9.0	10.4	–
50	–	–	–	–	4.2	5.0	5.0	6.5	7.5	8.9	10.4	–
55	–	–	–	–	4.2	4.9	4.9	6.4	7.2	8.7	10.0	–
60	–	–	–	1.5	4.2	4.9	4.9	6.3	7.0	8.6	9.9	–
65	–	–	–	–	4.2	4.8	4.9	6.2	6.8	8.5	9.6	–
70	–	–	–	–	4.2	4.7	4.8	6.1	6.6	8.3	9.4	–
75	–	–	–	–	4.2	4.6	4.7	6.1	6.5	8.3	9.1	–
80	–	–	–	–	–	4.4	4.6	6.1	6.5	8.3	9.1	–
85	–	–	–	–	–	4.3	4.5	6.1	6.5	8.0	9.1	–
90	–	–	–	–	4.1	4.3	4.5	6.0	6.5	8.0	9.0	–
95	–	–	–	–	–	4.2	4.4	6.0	6.5	8.0	9.0	–
100	–	–	–	1.75	–	4.2	4.2	5.9	6.5	8.0	8.9	–
105	–	–	–	–	4.0	4.1	4.2	–	–	7.9	8.9	–

Malletts Bay, 1974

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	–	–	–	–	6.7	19.0	19.0	23.0	–	11.2	–	–
2	–	–	–	–	–	19.0	19.0	22.0	–	–	–	–
4	–	–	–	–	–	19.0	18.8	21.8	–	–	–	–
6	–	–	–	–	–	19.0	18.6	21.7	–	–	–	–
8	–	–	–	–	–	16.6	18.4	21.6	–	–	–	–
10	–	–	–	–	6.0	15.4	17.0	21.4	–	–	–	–
12	–	–	–	–	–	10.0	14.5	21.0	–	–	–	–
14	–	–	–	–	–	10.5	11.5	16.0	–	–	–	–
16	–	–	–	–	–	9.0	10.0	9.6	–	–	–	–
18	–	–	–	–	–	8.8	9.0	9.0	–	–	–	–
20	–	–	–	–	–	8.8	8.6	8.8	–	–	–	–
22	–	–	–	–	–	8.5	8.5	8.5	–	–	–	–
24	–	–	–	–	–	8.4	8.4	8.4	–	–	–	–
26	–	–	–	–	–	8.3	8.3	8.2	–	–	–	–
28	–	–	–	–	–	8.2	8.2	8.0	–	–	–	–
30	–	–	–	–	5.5	–	8.2	8.0	–	–	–	–
32	–	–	–	–	–	–	–	–	–	10.6	–	–

§ Freezing period : Northern and southern ends of the lake and the northeast arm : Dec.-late Apr. Main lake : complete freezing Feb. 11-Apr. 8 (average ; with 160 years of record the lake failed to freeze over on only 12 years). Maletts Bay : Dec.-May.

§ Mixing type : Dimictic.

§ Notes on water mixing and thermocline formation : Mixing takes place in Apr.-May and Nov.-Dec. in the main lake, and in May and Oct. in Mallets Bay.

E. LAKE WATER QUALITY

E1 TRANSPARENCY [m] (7)

Main lake, 1972-1975

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
—	—	—	4.5	3.8	2.8	3.6	3.7	4.2	3.6	4.7	6.0

Malletts Bay, 1964-1975

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
—	2.0	2.8	3.0	2.7	4.1	4.7	4.4	4.8	3.6	3.1	—

E2 pH

Main lake, 1975 (7)

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	—	—	—	8.0	7.4	8.4	8.4	8.3	7.5	7.4	7.6	—
5	—	—	—	—	—	—	8.3	—	—	—	—	—
15	—	—	—	—	—	—	—	8.2	7.2	—	—	—
20	—	—	—	—	7.4	7.9	—	7.8	—	—	—	—
22	—	—	—	—	—	—	—	—	7.5	—	—	—
25	—	—	—	8.0	—	—	—	—	—	7.3	7.5	—
29	—	—	—	—	—	—	—	—	7.3	—	—	—
30	—	—	—	—	7.1	—	—	—	—	—	—	—
35	—	—	—	—	—	—	—	7.3	7.2	—	—	—
40	—	—	—	—	—	7.5	7.5	—	—	—	—	—
45	—	—	—	—	—	—	—	—	—	—	7.5	—
46	—	—	—	—	—	—	—	—	6.9	—	—	—
50	—	—	—	8.0	—	—	—	—	—	7.1	—	—
55	—	—	—	—	—	—	—	—	—	—	7.4	—
61	—	—	—	—	—	—	—	—	7.2	—	—	—
75	—	—	—	8.0	—	—	—	—	—	—	—	—
76	—	—	—	—	—	—	—	—	7.2	—	—	—
91	—	—	—	—	—	—	—	—	7.0	—	—	—
100	—	—	—	8.0	—	—	7.4	—	—	6.9	—	—
105	—	—	—	—	7.2	7.5	—	7.4	—	—	—	—
108	—	—	—	—	—	—	—	—	—	—	7.3	—

Malletts Bay, 1974 (7)

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	—	—	—	—	7.2	7.4	6.5	8.2	—	7.2	—	—
5	—	—	—	—	—	7.3	—	8.3	—	—	—	—
6	—	—	—	—	—	—	6.6	—	—	—	—	—
10	—	—	—	—	7.2	7.1	—	8.0	—	—	—	—
12	—	—	—	—	—	—	—	—	—	7.2	—	—
15	—	—	—	—	—	7.0	—	6.9	—	—	—	—
20	—	—	—	—	7.1	6.9	—	6.8	—	—	—	—
24	—	—	—	—	—	—	6.2	—	—	—	—	—
25	—	—	—	—	—	6.8	—	6.8	—	—	—	—
28	—	—	—	—	—	—	—	6.7	—	—	—	—
29	—	—	—	—	7.2	—	5.6	—	—	—	—	—
30	—	—	—	—	—	6.8	—	—	—	—	—	—
34	—	—	—	—	—	—	—	—	—	7.2	—	—

Rouses Point, N. Y., 1980-1986 (1)

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	—	—	7.3	7.5	8.0	7.2	7.7	7.9	7.4	7.2	7.3	—

E4 DO [mg l⁻¹] (1, 7)
Main lake, 1975

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	—	—	—	13.0	12.9	12.1	9.9	8.9	8.8	10.4	10.6	—
5	—	—	—	—	—	—	9.8	—	—	—	—	—
15	—	—	—	—	—	—	—	8.7	9.1	—	—	—
20	—	—	—	—	12.7	11.9	—		—	—	—	—
22	—	—	—	—	—	—	—	—	8.9	—	—	—
25	—	—	—	13.0	—		—	—	—	9.3	9.9	—
29	—	—	—	—	—	—	—	—	8.4	—	—	—
30	—	—	—	—	12.7	—	—	—	—	—	—	—
35	—	—	—	—	—	—	—	10.3	—	—	—	—
40	—	—	—	—	—	12.5	11.8	—	—	—	—	—
45	—	—	—	—	—	—	—	—	—	—	10.1	
46	—	—	—	—	—	—	—	—	9.1	—	—	—
50	—	—	—	13.0	—	—	—	—	—	8.6	—	—
55	—		—	—	—		—	—	—	—	10.2	—
61	—	—	—	—	—	—	—	—	8.8	—	—	—
75	—	—	—	13.0	—	—	—	—	—		—	—
76	—	—	—	—		—	—	—	8.8	—	—	—
91	—	—	—		—	—	—	—	9.2	—	—	—
100	—	—	—	13.0	—	—	11.8	—	9.4	8.9	—	—
105	—	—	—	—	12.6	12.7	—	11.0	—	—	—	—
108	—	—	—	—		—	—	—	—	—	9.1	—

Malletts Bay, 1974

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	—	—	—	—	11.6	9.5	8.7	8.5	—	10.4	—	—
5	—	—	—	—	—	9.6	—	8.5	—	—	—	—
6	—	—	—	—	—	—	8.8	—	—	—	—	—
10	—	—	—	—	11.6	9.7	—	8.1	—	—	—	—
12	—	—	—	—	—	—	—	—	—	10.1	—	—
15	—	—	—	—	—	9.6		4.8	—	—	—	—
20	—	—	—	—	11.7	9.1	—	5.1	—	—	—	—
24	—	—	—	—	—	—	7.1	—	—	—	—	—
25	—	—	—	—	—	8.9	—	4.8	—	—	—	—
28	—	—	—	—	—		—	2.8	—	—	—	—
29	—	—	—	—	11.6	—	6.4	—	—	—	—	—
30	—	—	—	—	—	8.6	—	—	—	—	—	—
34	—	—	—	—	—	—	—	—	—	10.4	—	—

Rouses Point, 1980-1986

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	–	–	11.6	12.1	11.8	9.4	8.4	8.7	8.3	10.7	11.5	–

E6 CHLOROPHYLL CONCENTRATION [μg l^{-1}] (9)

Main lake, 1988

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
–	–	–	–	–	–	4.3	1.9	3.0	–	–	–	–

E7 NITROGEN CONCENTRATION (1)

§ NO_3-N+NO_2-N [mg l^{-1}]

Rouses Point, 1980-1986

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	–	–	.26	.20	.27	.14	.10	<.10	<.10	<.10	.16	–

E8 PHOSPHORUS CONCENTRATION [μg l^{-1}]

§ Total-P

Main lake, 1988 (9)

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
–	–	–	–	–	–	16	14	13	–	–	–	–

Rouses Point, N. Y., 1980-1986 (1)

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	–	–	20	22	34	10	10	22	5	58	10	–

E9 CHLORINE [mg l^{-1}] (1)

Rouses Point, N. Y., 1980-1986

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	–	–	8.1	8.7	8.5	8.0	8.2	8.3	8.0	8.5	8.7	–

E10 PAST TRENDS (7)

§ Trend of transparency [m]

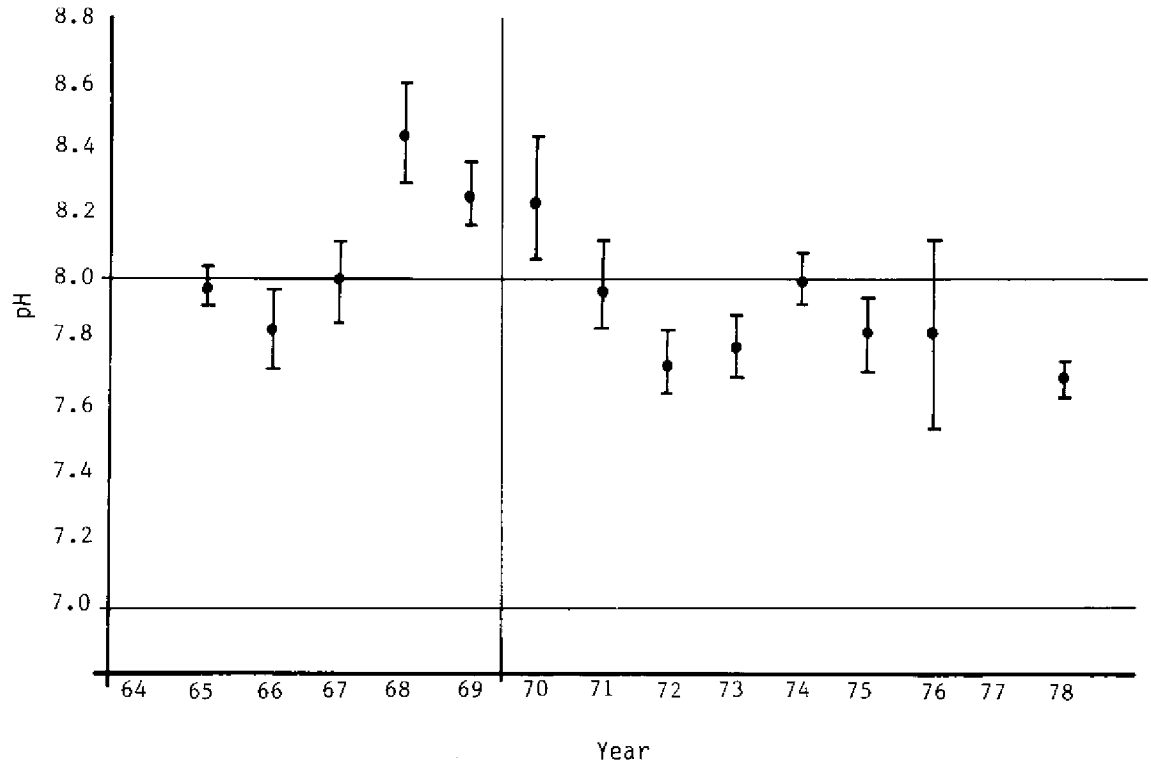
Main lake

1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977
5.38	4.33	5.37	3.75	4.22	3.87	3.95	4.01	3.27	3.55	4.05	5.05	4.89

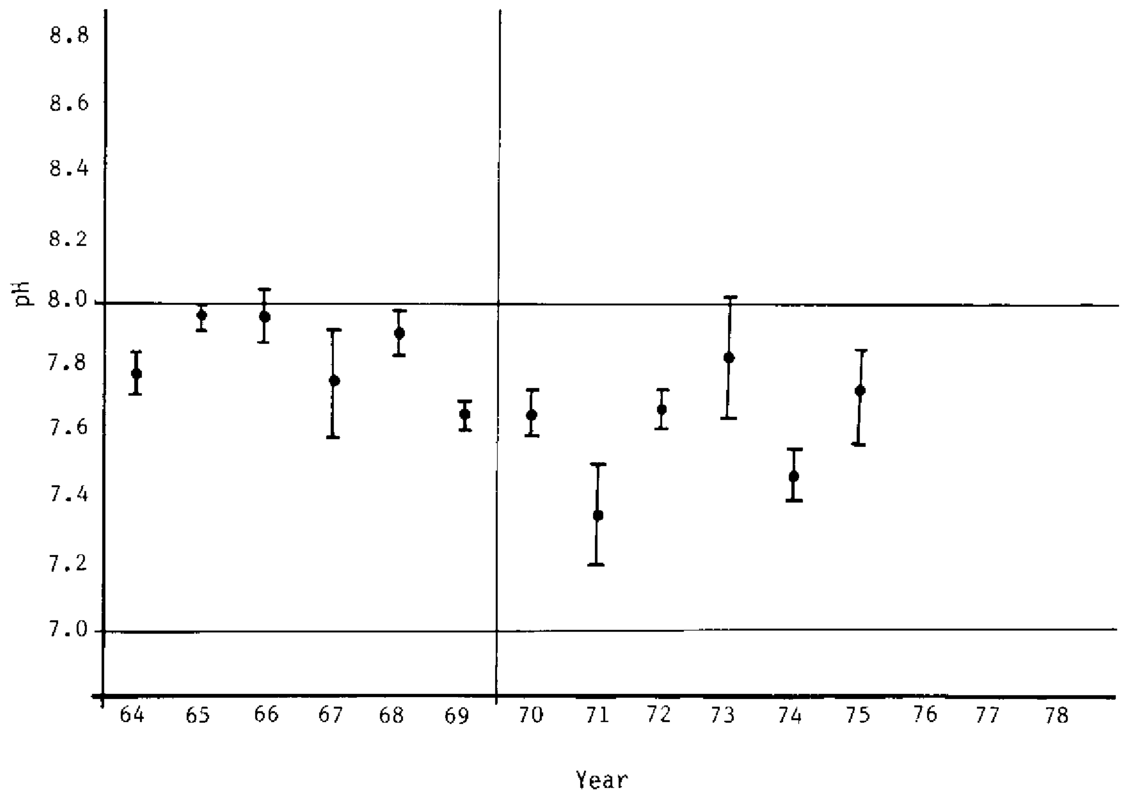
Malletts Bay

1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976
4.57	5.36	4.35	3.50	4.48	3.99	3.64	4.00	4.19	2.70	3.10	5.30	–

Fig. NAM-38-2 Past trend of pH.
Main lake



Annual mean of whole lake



F. BIOLOGICAL FEATURES (Q, 1, 2, 10)

F1 FLORA (Main lake)

§ Emerged macrophytes : *Spartina pectinata, Zizania aquatica.*

§ Floating macrophytes : *Trapa natans, Nymphoides peltatum.*

§ Submerged macrophytes : *Vallisneria americana, Myriophyllum spicatum.*

§ Filamentous algae : *Cladophora glomerata, Dichotomosiphon tuberosa, Ulothrix zonata.*

§ Phytoplankton

Chlorophyceae (*Ankistrodesmus*) ; Bacillariophyceae (*Asterionella* sp., *Cyclotella* sp., *Fragillaria crotonensis, Melosira islandica, Stephanodiscus* sp., *Tabellaria fenestrata*) ; Cyanophyta (*Anabaena planktonica, A. circinalis, Anacystis* sp., *Oscillatoria* sp.).

F2 FAUNA (Main lake)

§ Zooplankton

Calanoid copepods (*Diaptomus minutus,· D. dregonensis, D. sicilis, Epischura lacustris, Limnocalanus macrurus, Senecella calanoides*) ; Cyclopoid copepods (*Cyclops bicuspidatus*) ; Cladocera (*Daphnia retrocurva, Leptodora kindtii*).

§ Benthos

Mysis relicta, Pontoporeia hoyi, Manayunkia speciosa, Limnodrilus hoffmeisteri, L. claparedianus, Stylodrilus heringianus, Peloscolex variegatus.

§ Fish

Yellow perch*, rainbow smelt*, lake trout, sea lamprey, lake sturgeon (endangered), atlantic salmon (*economically important).

§ Supplementary notes on the biota

Myriophyllum is now common in much of the lake. The water chestnut (*Trapa*) and the floating heart (*Nymphoides*) are now nuisances in the southern end of the lake and in some bays.

Pontoporeia was reported to be in the lake in 1966 (11), and later by Dadswell (12). One specimen has so far been collected in an on-going survey in 1988–1989 (13).

49 species of fish are reported living in the lake. Control measures are being implemented to control the sea lamprey, a species that is damaging the cold water fisheries (4).

F5 FISHERY PRODUCTS

§ Fishery products other than fish : None.

F7 NOTES ON THE REMARKABLE CHANGES OF BIOTA IN THE LAKE IN RECENT YEARS

Atlantic salmon became extinct in the lake by the mid 1800's.

A number of foreign aquatic plants have invaded the lake. Three are nuisance plants : Eurasian milfoil, water chestnut, and yellow floating heart.

New York and Vermont began cooperative stocking of the lake trout in 1958 with encouraging success.

G. SOCIO-ECONOMIC CONDITIONS

G1 LAND USE IN THE CATCHMENT AREA (1968, 1972) (4)

	Area [km²]	[%]
Natural landscape		
Forest	12,221	61.3
Scrub	1,276	6.4
Lakes, ponds	1,380	6.9
Wetlands	397	2.0
Agricultural land		
Crop field	2,750	13.8
Orchards	43	0.2
Pasture	943	4.8
Settlement area	727	3.6
Public lands	194	1.0
Total	19,931	100.0

§ Types of important forest vegetation : Sugar maple, yellow birch, beech (6,532 km^2), spruce, fir (2,168 km^2), elm, oak, soft maple (1,778 km^2), white and red pine (1,702 km^2), red spruce (at high elevations).

§ Main kinds of crops : Mostly dairy products ; apple.

§ Trends of change in land use in recent years

Conversion of farm and pasture land to scrub and forests, and the spread of settled areas away from the population centers and along roadways and the lake shore.

G2 INDUSTRIES IN THE CATCHMENT AREA (1970) (4)

	No. of persons engaged	[%]
Primary industry		
Agriculture	8,914	5.2
Secondary industry		
Construction	11,635	6.8
Manufacturing	33,943	19.7
Mining	1,539	0.9
Tertiary industry		
Service	46,516	27.0
Trade	28,247	16.4
Educational service	18,272	10.6
Public administration	9,273	5.4
Public utilities	8,086	4.7 *
Finance	5,796	3.4 **
Total	172,221	100

* Utilities, transportation and communication.
** Banking, insurance and real estate.

§ Supplementary notes

The main industries in the Champlain basin are tourism and recreation (including skiing, fishing, boating, and camping), agriculture, and manufacture of technical durable goods. Meaningful dollar values are not available because of reports from overlapping interest groups and two States. The data mentioned above, extracted from the reference, is based on a sample from the U. S. Bureau of the Census, and does not include data from Canada. The spectrum of employment provides a perspective of the industries within the basin.

§ Numbers of domestic animals in the catchment area : Cattle 171,602 (14).

G3 POPULATION IN THE CATCHMENT AREA (1970) (4)

	Population*	[%]	Population density [km^{-2}]	Main cities (population)
Urban**	202,431	43.6	N. A.	Burlington, Vt.
Rural	263,670	56.4	N. A.	(38,633)
Total	466,101	100		

* Population in the 11 counties of New York, Vermont, and the Province of Quebec, Canada adjacent to the lake.

** The U. S. Census defines urban as any incorporated place of 2,500 inhabitants or more.

H. LAKE UTILIZATION

H1 LAKE UTILIZATION (Q)

Source of water, navigation and transportation, sightseeing and tourism, recreation (swimming, sport-fishing, yachting) and aesthetics.

H2 THE LAKE AS WATER RESOURCE (1988) (15)

	Use rate [$m^3 day^{-1}$]
Domestic water*	58,675

* Burlington area.

I. DETERIORATION OF LAKE ENVIRONMENTS AND HAZARDS

I1 ENHANCED SILTATION (16)

§ Extent of damage : Not serious (serious in portion of the lake during high lake levels).

Erosion status	Length of shore [km]	[%]
None	212	26.4
Slight	188	23.4
Moderate	143	17.8
Severe	261	32.4

I2 TOXIC CONTAMINATION (17)

§ Present status : Little information available.

§ Main contaminants, their concentrations and sources

Name of contaminants	Range of concentrations [ppm]				Main Sources
	Water	Bottom mud	Fish*	Other organisms	
Mercury	–	–	0-1	–	Industrial, air
PCB's	–	–	75	–	Unknown
DDT	–	–	72	–	Unknown
Trace metals	–	x	–	–	Unknown

* Fish species concerned : various species for Hg ; lake trout for PCB's and DDT (there are Canadian data for plants, mollusca and invertebrates).

§ Environmental quality standards for contaminants in the lake : Federal Dept. Agriculture standards for Hg, DDT, PCB's in fish tissue.

§ Food safety standards or tolerance limits for toxic contaminant residue : Federal Dept. Agriculture standards for Hg, DDT, PCB's in food tissue.

§ Supplemetary notes

Little is known about toxics in Lake Champlain. No data describe Hg, PCB's and DDT in fish tissues. Some data exist concerning levels of trace metals in lake sediments, and effluent monitoring for toxics is done at major industrial discharge at a paper mill in the southern part of the lake.

Some toxic materials are known to exist in an abandoned canal in Burlington, Vt. (Q).

§ Past trends of the above concentrations : Little data available to detect trends, but limited data seem to indicate decreased mercury levels in fish during the past ten years.

I3 EUTROPHICATION

§ Nuisance caused by eutrophication

Cladophora aufwuchs along certain rocky shores ; excessive weeds in certain bays.

§ Phosphorus loadings to the lake (2, 14)

Sources	Industrial	Domestic	Agricultural	Natural	Total
T-P	268,000	38,800	199,030	128,770	634,600 [kg yr^{-1}]
	0.237	0.034	0.176	0.114	0.561 [g m^{-2} yr^{-1}]

§ Supplementary notes

Non-point sources include natural and agricultural sources. A report on the trophic status of Lake Champlain was presented in 1977 (2). The natural background loading of total phosphorus was estimated to be 0.115 g per m^2 of lake surface per year. Both New York and Vermont have enacted legislation requiring holding tanks on boats ; have banned phosphate in detergents, and Vermont is requiring waste treatment plants to discharge no more than 1 mg l^{-1} of Total-P in waste treatment effluents.

I4 ACIDIFICATION

§ Extent of damage : None.

§ Supplementary notes

Some lakes in the Adriondack Mountains are being severely damaged by acidification. Acid deposition appears to be killing the source trees in the higher elevations in Vermont. Detailed studies on mechanisms and political efforts by representation at the State and National levels are being made.

J. WASTEWATER TREATMENT

J1 GENERATION OF POLLUTANTS IN THE CATCHMENT AREA : (d) Measurable pollution with limited wastewater treatment (Q).

J2 APPROXIMATE PERCENTAGE DISTRIBUTION OF POLLUTANT LOADS AS ESTIMATED FROM PHOSPHORUS LOADINGS (2)

Source	[%]
Non-point sources	38.0
Point sources	
Municipal (directly into lake)	5.2
Industrial (ditto)	1.5
Tributary discharge	86.8
Atmosphere	2.7

J3 SANITARY FACILITIES AND SEWAGE (14)

§ Percentage of municipal population in the catchment area provided with adequate sanitary facilities (on-site treatment systems) and public sewerage : 100 %.

§ Percentage of rural population with adequate sanitary facilities (on-site treatment systems) : Exact figures not available.

§ Municipal wastewater treatment systems
No. of tertiary treatment systems: 0.
No. of secondary treatment systems: 38.
No. of primary treatment system: 20.
§ Industrial wastewater treatment systems: 1 (pulp and paper plant).

K. IMPROVEMENT WORKS IN THE LAKE

K1 RESTORATION

Vermont and New York States are attempting to control nuisance aquatic weeds in bays and the south lake.

Reduction of phosphate loading to the lake; both States have adopted a detergent-phosphate ban, and in Vermont, selected waste treatment plants must remove phosphorus to 1 mg l^{-1}.

M. LEGISLATIVE AND INSTITUTIONAL MEASURES FOR UPGRADING LAKE ENVIRONMENTS (Q)

M1 NATIONAL AND LOCAL LAWS CONCERNED

§ Names of the laws (the year of legislation)
(1) National Rivers and Harbors Act (1899)
(2) Flood Control Act (1936, and amended)
(3) Federal Water Pollution Control Act (1972, and amended)

§ Responsible authorities
(1) Corps of Army Engineers
(2) Corps of Army Engineers
(3) U. S. Environmental Protection Agency

§ Main items of control
(1) Dredging, filling, shore construction, discharges
(2) Flood control
(3) Water pollution

§ Supplementary notes

Both States have enacted a number of acts to protect the lake. These include banning phosphorus in detergent and requiring all watercraft to have holding tanks. All waters have been classified and no discharge is allowed to degrade the quality class.

M2 INSTITUTIONAL MEASURES

(1) On August 27, 1988, the Governors of New York and Vermont, and the Premier of Quebec signed a Memorandum of Understanding to emphasize the increased cooperation and management of Lake Champlain.
(2) In April, 1989, the UNESCO Man and the Biosphere Program selected Lake Champlain and the Adirondack Mountains as a Biosphere Reserve (Lake Champlain/Adirondack Massif Biosphere Reserve).
(3) The Lake Champlain Committee is an organization with about a thousand members within the entire basin that examines environmental issues as they come up, engages in study, and is effective in protecting the lake.

M3 RESEARCH INSTITUTES ENGAGED IN LAKE ENVIRONMENT STUDIES

(1) The University of Vermont, Burlington, Vt.
(2) Plattsburgh State University College, Plattsburgh, N. Y.
(3) St. Micheal's College, Colchester, Vt.

N. SOURCES OF DATA

(Q) Questionnaire filled by Dr. E. B. Henson, Dept. of Zoology, University of Vermont, Burlington, Vermont.
(1) U. S. Geological Survey Water-Data Reports NH-VT, 1967-1986.

(2) Henson, E. B., & Gruendling, G. K. (1977) The Trophic Status and Phosphorus Loadings of Lake Champlain. U. S. Environ. Protection Agency, Environ. Res. Lab., Office of Res. and Development, Ecological Res. Series, EPR-600/3-77-106. 141pp.
(3) Hunt, A. S. & Boardman, C. C. (1970) The Volume of Lake Champlain. Lake Champlain Studies Center, Univ. Vt., Res. Rep. No. 3, with 1 map.
(4) New England River Basins Comm. (1976) Lake Champlain Planning Guide. 233pp.+Appendices.
(5) Dunnington, F. (1978) Lake Champlain Islands Report, Nov. 1978. Prepared for the Water Oriented Recreation Task Force, Lake Champlain Basin Study, New England River Basins Comm. Tech. Rep. 25. 34pp, maps.
(6) National Oceanic and Atmospheric Adm., National Weather Service.
(7) Henson, E. B. & Potash, M. (1987) Sampling Strategies for Detecting Water Quality Trends in Lake Champlain. Completion Rep., U. S. Dept. Int., Office of Water Res. and Tech., Proj. No. 03. 44pp.
(8) Lake Champlain Transportation Co. Lake Champlain Ferries. Burlington, Vt.
(9) State of Vermont, Dept. of Environmental Conservation, Water Quality Division (1988) Lay Monitoring Program.
(10) Legge, T. N. (1969) A study of the seasonal abundance and distribution of calanoid copepods in Burlington Bay, Lake Champlain. Unpubl. Ph. D. Thesis, Univ. Vt., Dept. Zool. 133pp.
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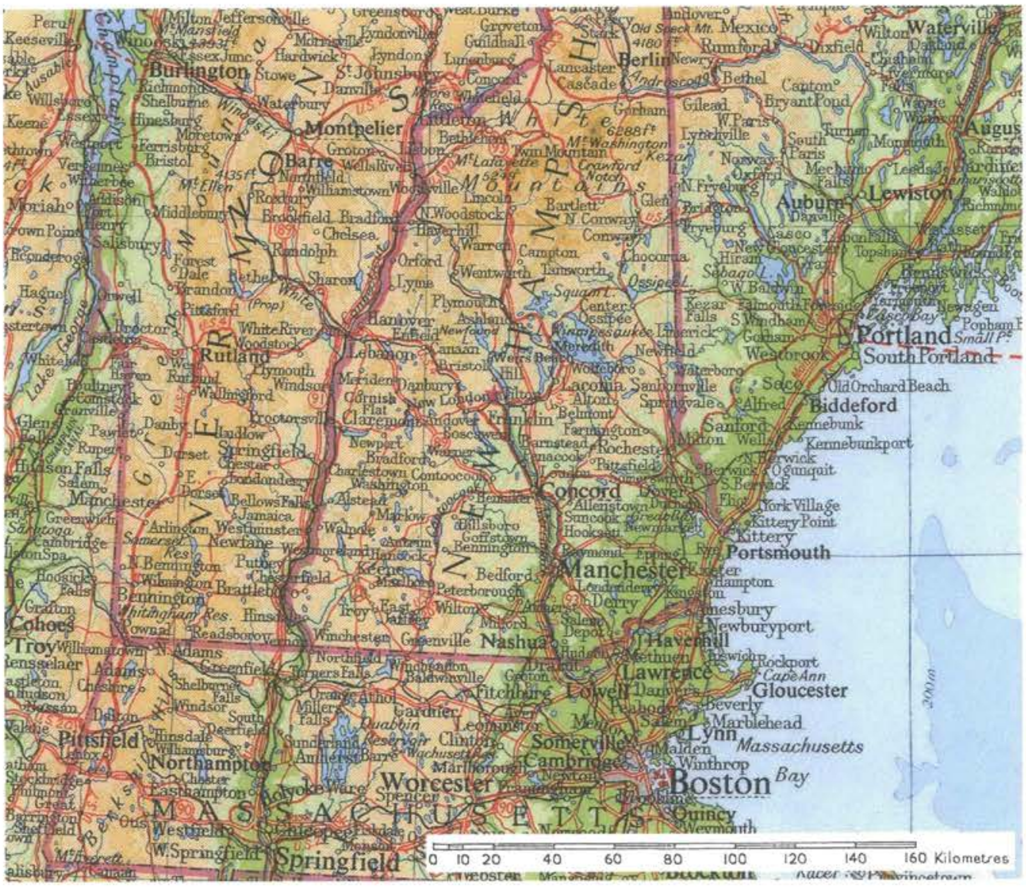
(12) Dadswell, M. J. (1974) Distribution, Ecology, and Postglacial Dispersal of Certain Crustaceans and Fishes in Eastern North America. Natl. Mus. Can., Publ. in Zoo. No. 11. 110pp.
(13) Henson, E. B. (1988) Assessment of the presence of *Pontoporeia* in Lake Champlain. Res. Grant, Univ. Vt. Comm. Res. and Schlor. Unpubl. Results.
(14) Bogdan, K. G. (1978) Estimates of the Annual Loading of Total Phosphorus to Lake Champlain. N. E. River Basins Comm., Lake Champlain Basin Study, Eutrophication Task Force. 49pp.
(15) Burlington Water Dept., and Champlain Water District, personal communication.
(16) Hunt, A. S.(1977) Shoreline Erosion, Lake Champlain. N. E. River Basins Comm., Lake Champlain Basin Study, Lands in Transition Task Force. 13pp.
(17) McIntosh, A., School of Natural Resources, Univ. of Vermont, personal communication.

WEBSTER LAKE

Routine sampling at the designated station in winter

Photo:Dufresne-Henry Inc.



A. LOCATION

§ New Hampshire, U. S. A.
§ 43°28′N ; 71°41′W ; 122.2 m above sea level.

B. DESCRIPTION

The Webster Lake Watershed spans two municipals in the south-central portion of the Lakes Region of New Hampshire. The total watershed consists of approximately 11,432 acres, contains two major lakes, numerous small ponds and an extensive system of tributaries. The majority of the watershed — 8,363 acres (73.2 % of the total basin) — is in the eastern portion of the town of Andover, New Hampshire. The watershed can be considered typical of the Lakes Region in New Hampshire. Vast forested areas and agricultural corn fields are broken only by scattered single-family dwellings which parallel existing road networks, with dwelling concentrations around typical "village" layouts.

The watershed is dominated by Highland Lake in Andover, and Webster Lake in Franklin. The two lakes are connected by Sucker Brook, the largest of the many tributaries within the watershed. Webster Lake (612 acres) is the larger of the two lakes, being 1.6 miles in length by 1.0 mile wide.

Presently, approximately 90 % of the 4.3 miles of shoreline is developed. The lake is subject to extensive recreational use. The lake, at an elevation of 401 feet above sea level, has an average depth of 19 feet, a maximum depth of 45 feet, and has two public beaches and one public launch.

A priority list developed by the Department of Environmental Services' Biology Bureau has rated Webster Lake as high for both restoration and preservation. The lake is located within 25 miles of the Capitol City of Concord and is also within 25 miles of the City of Laconia.

An earlier Water Quality Management Investigation of Wabster Lake in 1980, revealed that Sucker Brook, the main tributary to Webster Lake accounted for approximately 67 % of the total water input to the lake, drains about 80 % of the entire watershed area and is responsible for approximately 63 % of the phosphorus loading to the lake during a normalized year.

The trophic classification of Webster Lake was determined to be mesotrophic, based on data collected and a comparison with the trophic classification System for New Hampshire Lakes and Ponds. These guidelines were formulated to classify New Hampshire lakes and ponds for the federal "Clean Lakes" program. A total of six points were awarded to Webster Lake based on this rating system. This ranked Webster Lake as number 24 on the priority list for restoration.

An on-site inspection of the Webster Lake watershed revealed several agricultural areas which were in close proximity to Sucker Brook or had feeder streams flowing into Sucker Brook as possible sources of nutrient loads.

Many of the recommendations suggested in the Water Quality Management Investigation of Webster Lake deal with stricter ordinances around the lake and best management practices. The report calls for proper agricultural management implementation at individual farms sites (1).

C. PHYSICAL DIMENSIONS (1)

Surface area [km^2]	2.5
Volume [$10^6 m^3$]	140.5
Maximum depth [m]	13.7
Mean depth [m]	5.7
Normal range of annual water level fluctuation (regulated) [m]	6.0
Length of shoreline [km]	6.9
Residence time [yr]	0.56
Catchment area [km^2]	43

D. PHYSIOGRAPHIC FEATURES

D1 GEOGRAPHICAL

§ Bathymetric map (Fig. NAM-39-1).
§ Main islands : None.
§ Outflowing rivers and channels (number and names) : 1 (Chance Pond Brook)

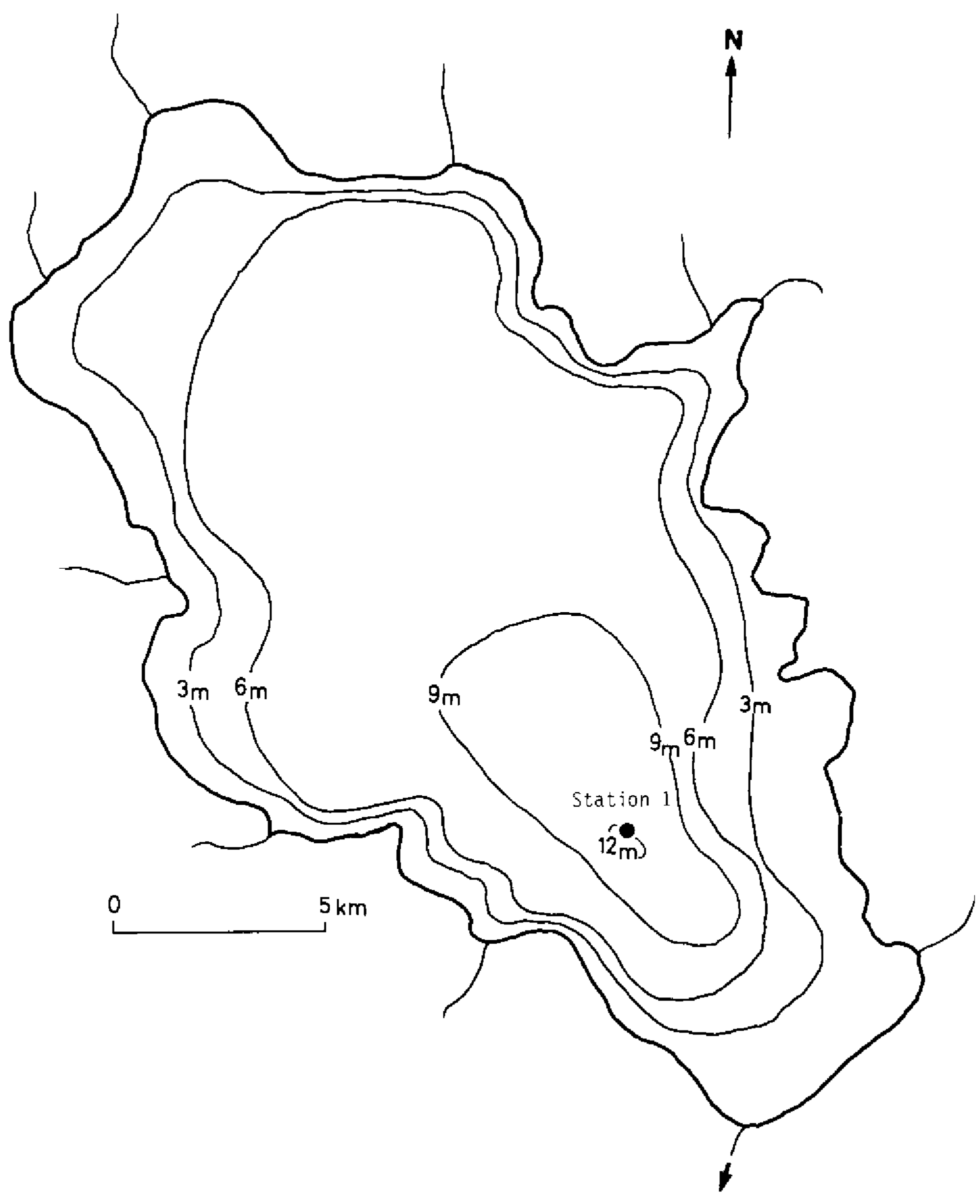
D2 CLIMATIC

§ Climatic data (1, 2)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean temp. [°C]*	-9.3	-4.7	0.0	6.9	13.8	17.3	21.1	19.3	14.9	7.7	3.5	-4.1	7.2
Precipitation [mm]**	50	45	54	67	76	89	98	86	84	75	67	54	845

* Concord, Sep. 1974-Aug. 1982.
** Burlington (VE), 1931-1960.

Fig. NAM-39-1 Bathymetric map (Q).



§ Water temperature [°C]
1988

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Surface	–	–	–	8.8	–	–	24.1	–	–	13.7	6.5	–
1	–	–	–	7.6	–	–	24.0	–	–	13.7	6.5	–
2	–	–	–	7.4	–	–	23.9	–	–	13.7	6.5	–
3	–	–	–	7.6	–	–	23.8	–	–	13.7	6.5	–
4	–	–	–	7.5	–	–	23.6	–	–	13.7	6.5	–
5	–	–	–	7.6	–	–	21.6	–	–	13.7	6.5	–
6	–	–	–	7.5	–	–	19.2	–	–	13.7	6.5	–
7	–	–	–	7.5	–	–	17.4	–	–	13.6	6.5	–
8	–	–	–	7.6	–	–	16.3	–	–	13.6	6.5	–
9	–	–	–	7.7	–	–	14.9	–	–	13.6	6.5	–
10	–	–	–	7.9	–	–	14.2	–	–	13.6	6.5	–
11	–	–	–	7.7	–	–	13.5	–	–	13.5	6.5	–
12	3.0	–	–	–	–	–	13.2	–	–	13.5	–	–

§ Freezing period : Nov. to Mar. (Q).
§ Mixing type : Dimictic (Q).
§ Notes on water mixing and thermocline formation : Stratifies in the summer and in the winter.

E. LAKE WATER QUALITY

E1 TRANSPARENCY [m]

Nov. 1987-Oct. 1988 (1)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
–	–	–	3.4	4.2	4.1	4.7	4.5	4.5	3.9	2.2	–

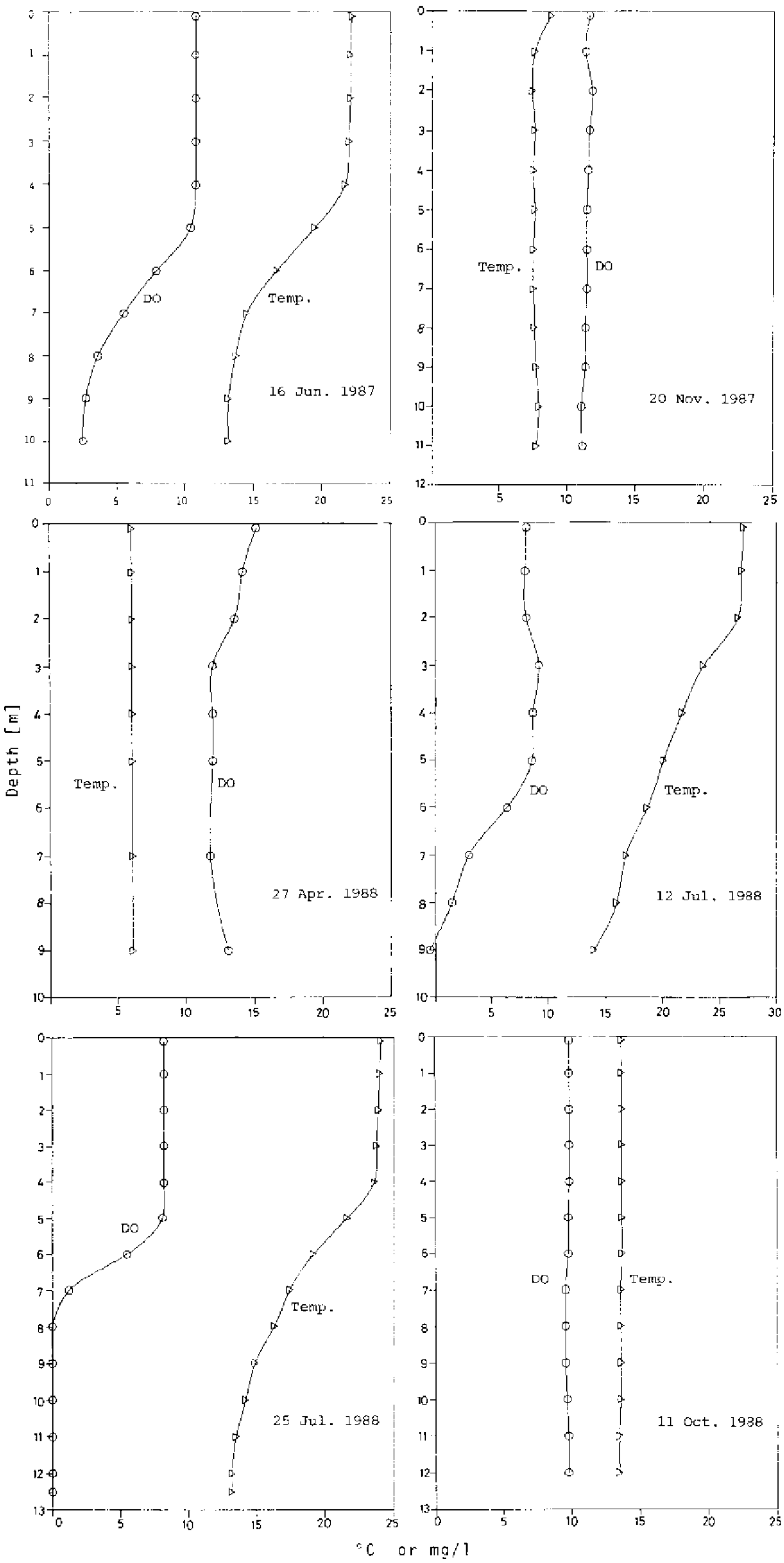
E2 pH

Station 1, Sep. 1979-Aug. 1980 (1)

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	6.2	–	–	6.4	7.0	6.4	6.8	6.8	6.5	–	6.2	–
3	6.4	6.0	–	6.3	7.1	6.7	6.8	6.7	6.3	–	6.2	
6	6.2	5.9	–	6.2	6.7	6.8	6.8	6.7	6.4	–	6.3	–
9	–	–	–	6.1	6.5	6.4	6.1	6.4	6.2	–	6.3	–
12	–	–	–	–	–	6.1	6.4	6.5	–	–	–	–

E4 DO

Fig. NAM-39-2 Vertical distribution of DO [mg l^{-1}] and water temperature [°C]



E6 CHLOROPHYLL CONCENTRATION [mg l^{-1}]
Nov. 1987-Oct. 1988 (1)

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
–	–	–	–	6.16	2.97	6.13	6.53	2.47	4.98	7.09	6.88	–

E7 NITROGEN CONCENTRATION
§ Total-N [mg l^{-1}] (1)
Station 1, Sep. 1974-Aug. 1980

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	.20	–	–	.25	<.10	.22	.26	.74	.16	–	.39	–
3	1.00	.27	–	.18	.15	.20	.24	.64	.15	–	.19	–
6	1.95	.24	–	.21	.13	<.10	.21	.62	.13	–	.13	–
9	–	–	–	.23	<.10	.19	.24	.26	.14	–	.16	–
12	–	–	–	–	–	<.10	.28	.37	–	–	–	–

§ Kjeldahl-N [mg l^{-1}] (1)
Station 1, Sep. 1979-Aug. 1980

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	.20	–	–	.25	<.10	.37	.23	.24	.16	–	.39	–
3	1.00	.27	–	.18	.15	.39	.27	.22	.15	–	.19	–
6	1.95	.24	–	.21	.13	.44	.29	.24	.13	–	.13	–
9	–	–	–	.23	<.10	.42	.26	.23	.14	–	.16	–
12	–	–	–	–	–	–	.49	–	–	–	–	–

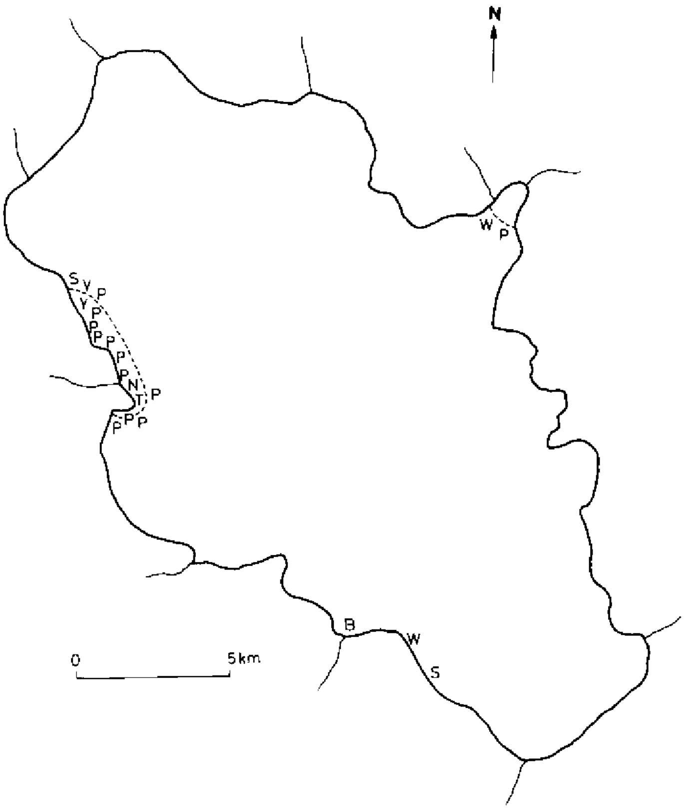
E8 PHOSPHORUS CONCENTRATION
§ Total-P [mg l^{-1}] (1)
Station 1, Sep. 1979-Aug. 1980

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	.010	–	–	.014	.010	.012	.021	.006	.010	–	.009	–
3	.008	.008	–	.014	.011	.015	.020	.009	.011	–	.009	–
6	.008	.008	–	.013	.012	.005	.008	.014	.010	–	.011	–
9	–	–	–	.012	.016	.003	.022	.021	.013	–	.009	–
12	–	–	–	–	–	.142	.057	.068	–	–	–	–

F. BIOLOGICAL FEATURES

F1 FLORA (1979) (3)
§ Emerged macrophytes : *Sparganium, Scirpus, Pontederia, Typha.*
§ Floating macrophytes : *Nymphaea, Nuphar.*
§ Submerged macrophytes : *Potamogeton, Vallisneria americana, Nitella.*
§ Phytoplankton
Tabellaria, Melosira, Mallomonas, Asterionella, Dinobryon, Ceratium, Uroglenopsis, Anabaena, Fragilaria, Staurastrum, Sphaerocystis, Rhizosolenia, Peridinium, Mougeotia.

Fig. NAM-39-3 Distribution of aquatic plants, July 1979 (3).



Submerged plants
W : *Potamogeton*
V : *Vallisneria americana*

Floating plants
N : *Nymphaea* sp.
Y : *Nuphar* sp.

Emergent plants
S : *Sparganium* sp.
B : *Scirpus* sp.
P : *Pontederia cordata*
T : *Typha* sp.

F2 FAUNA

§ Zooplankton : *Kellicottia, Keratella, Polyarthra, Bosmina, Diaptomus, Cyclops, Vorticella, Codonella, Arcella* (3).

§ Benthos : Cironomids, tubificid worms, planarians and caddis worms (3).

§ Fish : *Catostomus commersoni, Rhinichthys atratulus, Perca flavescens, Morone americana, Micropterus dolomieui, Notemigonus crysoleucas*, smelts, sunfish, *Ictalurus nebulosus, Esox* (4, 5).

G. SOCIO-ECONOMIC CONDITIONS

G1 LAND USE IN THE CATCHMENT AREA (1981) (1)

	Area [km^2]	[%]
Forest	3,601.8	83.7
Agricultural land		
Inactive	195.1	4.5
Active	185.8	4.3
Residential	127.9	3.0
Lake front		
Low density	50.7	1.2
Med. density	29.1	0.7
High density	19.0	0.4
Industry	2.8	0.4
Public	60.3	1.4
Conservation	29.5	0.7
Total	4,302	100

G2 INDUSTRIES IN THE CATCHMENT AREA (1)

§ Main agricultural products : Grapes, dairy products, beef.
§ Number of domestic animals in the catchment area : Cattle 60, horses 10.

G3 POPULATION IN THE CATCHMENT AREA (1)

		Population	Population density [km^{-2}]	Main cities
Rural	Year around	792		
	Seasonal	825		None
Total		1,622	18.4(37.7)	

H. LAKE UTILIZATION

H1 LAKE UTILIZATION

Sources of water, sightseeing and tourism and recreation (swimming, sport-fishing).

I. DETERIORATION OF LAKE ENVIRONMENTS AND HAZARDS

I1 ENHANCED SILTATION (Q)

§ Extent of damage : Not serious.

I2 TOXIC CONTAMINATION

§ Present status : None.

§ Environmental quality standards for contamination in lake water

Quality	Classification		
	A	B	C
DO [ppm]	>6	>6	>5−6
	(>75 % of saturation)		
Sludge deposit	None	No reasonable kinds or quantity	
Oil & Greese	None	No reasonable kinds or quantity	
Gross β radioactivity	←<1000 picocuries l^{-1}→		
Strontium-90	←<10 picocuries l^{-1}→		
Phenol [ppm]	<0.001	<0.001	<0.002

I3 EUTROPHICATION

§ Phosphorus loadings to the lake (1)

Sources	Total [kg yr^{-1}]
14 tributaries	45,870
Natural	6,812
Dry fallout (30 % of precipitation)	2,043
Sewage loading	7,131
Total	61,956

§ Supplementary notes

Eutrophication is mainly caused by nutrient enrichment from upstream dairy farms (Q).

J. WASTEWATER TREATMENTS (Q)

J1 GENERATION OF POLLUTANTS IN THE CATCHMENT AREA : (d) Measurable pollution with limited wastewater treatment.

J3 SANITARY FACILITIES AND SEWERAGE

§ Percentage of rural population with adequate sanitary facilities (on-site treatment systems) : Common but exact figure not available.

§ Municipal wastewater treatment systems : None.

L. DEVELOPMENT PLANS (1)

Watershed population projections up to the year 2000 show an expected increase of 6.1 %. Part of this growth may include conversion of secondary homes to primary, and with this accompanying impact upon the septic systems, and therefore Webster Lake. Future development is expected to be primarily of a moderate residential nature.

M. LEGISLATIVE AND INSTITUTIONAL MEASURES FOR UPGRADING LAKE ENVIRONMENTS

M1 NATIONAL AND LOCAL LAWS CONCERNED

§ Names of the laws (the year of legislation)

(1) Water Supply & Pollution Control (1984)

§ Responsible authorities :

(1) Federal
(2) State
(3) Local

§ Main items of control
(1) Algae and other aquatic nuisances
(2) Exotic weeds
(3) Illegal dumping and other violations

M2 INSTITUTIONAL MEASURES

(1) New Hampshire Department of Environmental Services, Water Supply and Pollution Control Division, Biology Bureau

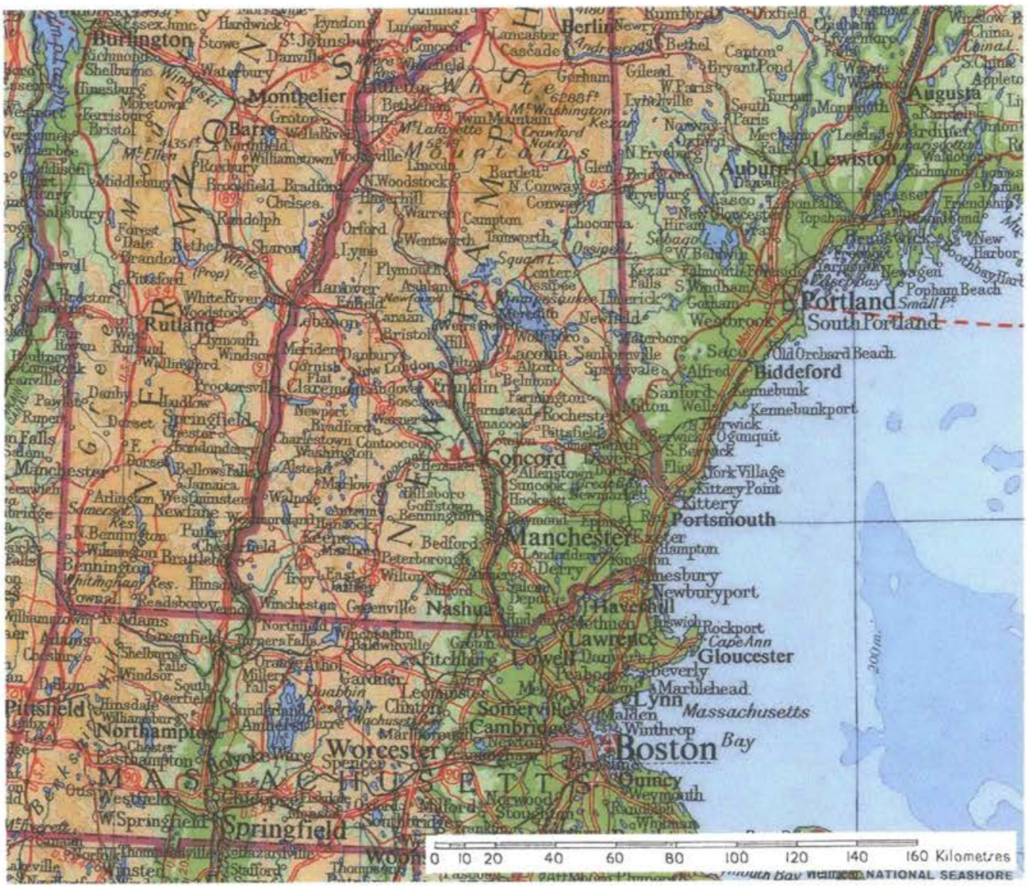
N. SOURCES OF DATA

(Q) Questionnaire prepared by the editors with the support of Dufresne-Henry Inc., based on the following sources.
(1) Dufresne-Henry Inc. (1981) Water Quality Management Investigation, Webster Lake, Franklin, New Hampshire.
(2) Court, A. (1974) The Climate of the Conterminous United States. "World Survey of Climatology, Volume 11, Climates of North America" (ed. Bryson, R. A. & Hare, F. K.), p. 336. Elsevier Scientific Publishing Company, Amsterdam — London — New York.
(3) Department of Environmental Services, New Hampshire Water Supply and Pollution Control Division (1987) Webster Lake Diagnostic/Feasibility Study Grant Application.
(4) Newell, A. E. (1977) Biological Survey of the Lake and Ponds in Sullivan Merrimack, Belknap and Stratford Counties. State of New Hampshire Fish and Game Survey Report # 8b.
(5) Scarola, J. F. (1973) Freshwater Fishes of New Hampshire. New Hampshire Fish and Game Department, Division of Inland and Marine Fisheries.

KEZAR LAKE

An aerial view of the whole lake

Photo: W. Howard



A. LOCATION

§ New Hampshire, U. S. A.
§ 43°22'N ; 71°56'E ; 276.2 m above sea level.

B. DESCRIPTION

Prior to the early 1960's, Kezar Lake was an attractive and popular recreational area. The fact that Kezar Lake was chosen as the site of Wadleigh State Park in 1934 reflects the aesthetic value the lake once enjoyed.

As a result of the construction of the New London Waste Water Treatment Plant in 1931, water quality deteriorated in Kezar Lake. Secondary effluent from the treatment plant contributed high concentrations of phosphorus to Lion Brook, much of which became entrapped in the sediment and biomass of Kezar Lake. As a result of this phosphorus input, massive blooms of obnoxious blue-green algae began in 1961 and deteriorated the water quality in the lake.

Remedial attempt to improve the recreational quality of Kezar Lake has been undertaken by the New Hampshire Water Supply and Pollution Control Commission. The use of copper sulfate as an algicide, as an acceptable method which was utilized with considerable success for several years, was the first attempt to improve the aesthetic lake conditions. Although this method does not reverse the eutrophication trends, it temporarily alleviates nuisance algal blooms and provides an acceptable recreational season.

In 1968, the New Hampshire Water Supply and Pollution Control Commission attempted a new method to remedy the poor aesthetic conditions of the lake. This new approach was to completely mix the lake by releasing compressed air from the deep spot of the lake. Mixing of large bodies of water was shown to alter the ecology in some way which may affect algal growth. Although destratification of Kezar Lake by mixing was initially considered a success, the procedure was abandoned in 1974, when water clarity again declined, marking the end to the effectiveness of destratification.

In 1970, tertiary treatment for phosphorus removal was added to the New London Treatment Plant, resulting in an appreciable decrease of phosphorus input to Lion Brook. In January of 1981, effluent from the plant was diverted outside the watershed to the Sunapee Wastewater Plant.

In 1981, biologists from the New Hampshire Water Supply and Pollution Control Commission began an exhaustive three-year study of Kezar Lake to identify the lake's hydrologic and nutrient budgets. As a result of these budgets, biologists were able to recommend various lake restorative techniques to limit the phytoplankton's main source of food, phosphorus (Q).

C. PHYSICAL DIMENSIONS (1)

Surface area [km^2]	1.4
Volume [10^6m^3]	2.0
Maximum depth [m]	8.2
Mean depth [m]	2.8
Normal range of annual water level fluctuation (regulated) [m]	0.3
Length of shoreline [km]	3.4
Residence time [yr]	0.12
Catchment area [km^2]	27.9

D. PHYSIOGRAPHIC FEATURES

D1 GEOGRAPHICAL

§ Bathymetric map (Fig. NAM-40-1).
§ Main islands (name) : Loon.
§ Outflowing rivers and channels (number and names) : 1 (Lane Brook).

D2 CLIMATIC

§ Climatic data at Concord

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean temp. [°C]*	-9.3	-4.7	0	6.9	13.8	17.3	21.1	19.3	14.9	7.7	3.5	-4.1	7.2
Precipitation [mm]**	102	74	64	79	48	198	71	64	117	165	89	107	1,176

* Sep. 1979-Aug. 1982.
** Sep. 1981-Aug. 1982.

§ Solar radiation : 32.5 MJ m^{-2} day^{-1}.

Possible sunshine [% yr^{-1}]

1979	1980	1981	1982
53	59	58	58

(Data from NOAA located in Concord, New Hampshire)

Fig. NAM-40-1 Bathymetric map (Q).

§ Water temperature [°C] (1)
Sep. 1980-Aug. 1982

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Surface	—	—	—	7.0	18.5	19.0	27.2	22.5	19.3	10.8	5.6	0.8
1	—	—	—	7.0	17.6	19.0	27.1	22.2	19.3	9.0	5.6	0.8
2	—	—	—	7.0	17.1	18.9	27.1	21.5	19.3	8.5	5.6	—
3	—	—	—	7.0	16.4	19.5	20.9	21.3	19.1	8.3	5.6	—
4	—	—	—	7.0	15.2	17.0	18.1	20.8	19.0	8.0	5.6	1.0
5	—	—	—	7.0	14.3	14.0	16.7	17.7	18.8	8.0	5.6	—
6	—	—	—	7.0	12.8	12.8	14.7	13.9	18.0	8.0	5.6	—
Bottom	—	—	—	7.0	10.5	11.5	13.0	13.7	15.0	7.5	5.6	—

§ Freezing period : Dec.-Mar.
§ Mixing type : Dimictic.

E. LAKE WATER QUALITY

E1 TRANSPARENCY [m] (1)
Sep. 1981-Aug. 1982

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
—	—	—	2.6	2.5	1.8	1.2	1.5	2.0	1.8	2.0	2.0

E2 pH (1)
Sep. 1981-Aug. 1982

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2	6.0	6.0	6.2	6.2	6.0	6.7	8.4	6.7	6.6	6.9	6.6	6.4
4	6.2	5.9	5.9	6.2	5.9	6.6	6.4	6.7	6.7	6.8	6.7	6.4
6	6.0	5.9	6.1	6.2	6.1	6.2	6.4	6.4	6.5	6.7	5.9	6.5
7.5	6.0	5.9	6.1	6.3	6.4	6.8	6.4	6.2	6.3	6.6	6.6	6.4
Inlet	—	—	—	6.2	6.9	6.6	6.3	6.3	—	—	—	—

E3 TURBIDITY [NTU] (1)
Sep. 1981-Aug. 1982

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2	0.85	0.40	0.73	2.1	2.9	3.7	6.6	4.0	2.7	3.4	4.5	3.3
4	1.5	1.1	2.2	2.3	3.4	4.2	6.9	5.5	4.7	3.5	2.5	2.6
6	2.6	1.3	2.0	2.2	4.4	6.0	11.0	18.0	2.9	3.9	2.8	3.9
7.5	4.6	1.1	6.3	2.9	5.9	16.0	9.2	16.0	4.1	4.2	2.9	2.8
Inlet	—	—	—	1.0	2.1	4.1	15.9	5.5	—	—	—	—

E4 DO [mg l⁻¹] (1)

Sep. 1981-Aug. 1982

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Surface	—	—	—	2.4	10.8	10.2	8.5	10.4	8.5	11.6	13.3	14.8
1	—	—	—	2.4	10.4	10.0	8.5	10.6	8.5	11.8	13.5	14.8
2	—	—	—	2.4	10.2	10.0	8.5	10.2	8.5	11.6	13.5	14.8
3	—	—	—	2.4	10.0	9.8	5.5	9.9	8.4	11.6	13.5	—
4	—	—	—	2.4	9.2	8.0	0.1	8.8	8.3	11.2	13.4	—
5	—	—	—	2.4	8.8	3.3	0.1	0.4	7.3	11.1	13.4	—
6	—	—	—	2.4	8.8	1.4	0.1	0.3	1.2	11.2	13.4	—
Bottom	—	—	—	2.4	1.3	0.4	0.5	0.5	0.8	11.2	13.4	—

E6 CHLOROPHYLL CONCENTRATION [μg Chl *a* l⁻¹] (1)

Sep. 1981-Aug. 1982

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Surface	3.01	1.95	1.71	3.54	7.24	9.14	14.02	14.07	13.08	17.31	12.90	11.42

E7 NITROGEN CONCENTRATION

§ Total Kjeldahl-N [mg l⁻¹] (1)

Nov. 1981-Aug. 1982

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2	.42	.29	.34	.39	.56	.63	.73	.29	—	—	.46	.34
4	.56	.45	.35	.37	.24	.63	.68	.67	—	—	.50	.34
6	.72	.48	.41	.39	.60	.44	.94	1.0	—	—	.40	.40
7.5	.66	.33	.51	.39	<2.0	.94	.72	1.58	—	—	.46	.29
Inlet	—	—	—	.40	.57	.70	.81	.50	—	—	—	—

E8 PHOSPHORUS CONCENTRATION

§ Total-P [μg l⁻¹] (1)

Sep. 1981-Aug. 1982

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2	13	18	14	15	22	23	11	15	25	26	21	22
4	16	19	15	15	19	25	24	26	27	33	20	21
6	23	26	21	16	30	34	33	22	24	38	26	33
7.5	30	32	31	17	52	50	27	43	46	61	28	20
Inlet	—	—	—	12	65	—	111	33	—	—	—	—

E9 CHLORIDE ION CONCENTRATION [mg l⁻¹] (1)

Sep. 1981-Aug. 1982

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2	30	23	26	—	20	19	19	23	22	—	—	29
4	27	21	26	—	18	20	19	23	22	—	—	20
6	30	21	26	—	20	25	18	22	22	—	—	27
7.5	30	44	33	—	23	19	18	22	22	—	—	27
Inlet	—	—	—	—	25	23	32	37	—	—	—	—

E10 PAST TRENDS (3)

Fig. NAM-40-2 Past trend of transparency.

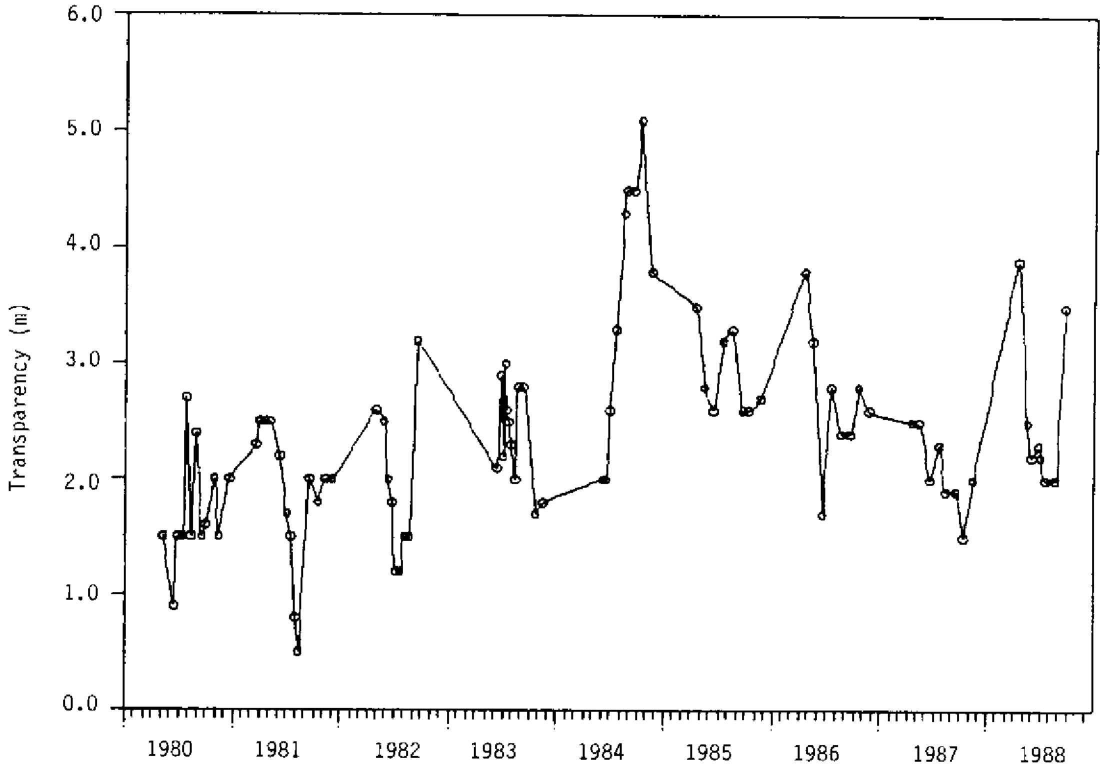


Fig. NAM-40-3 Past trend of summer mean transparency.

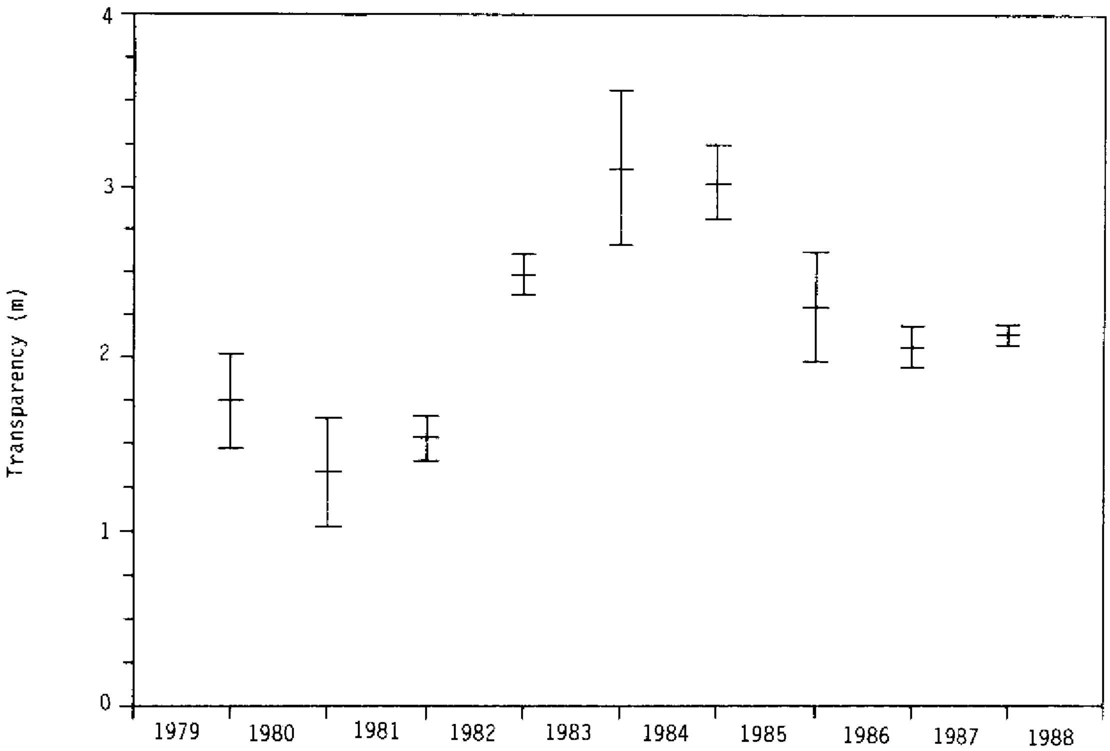


Fig. NAM-40-4 Past trend of pH.

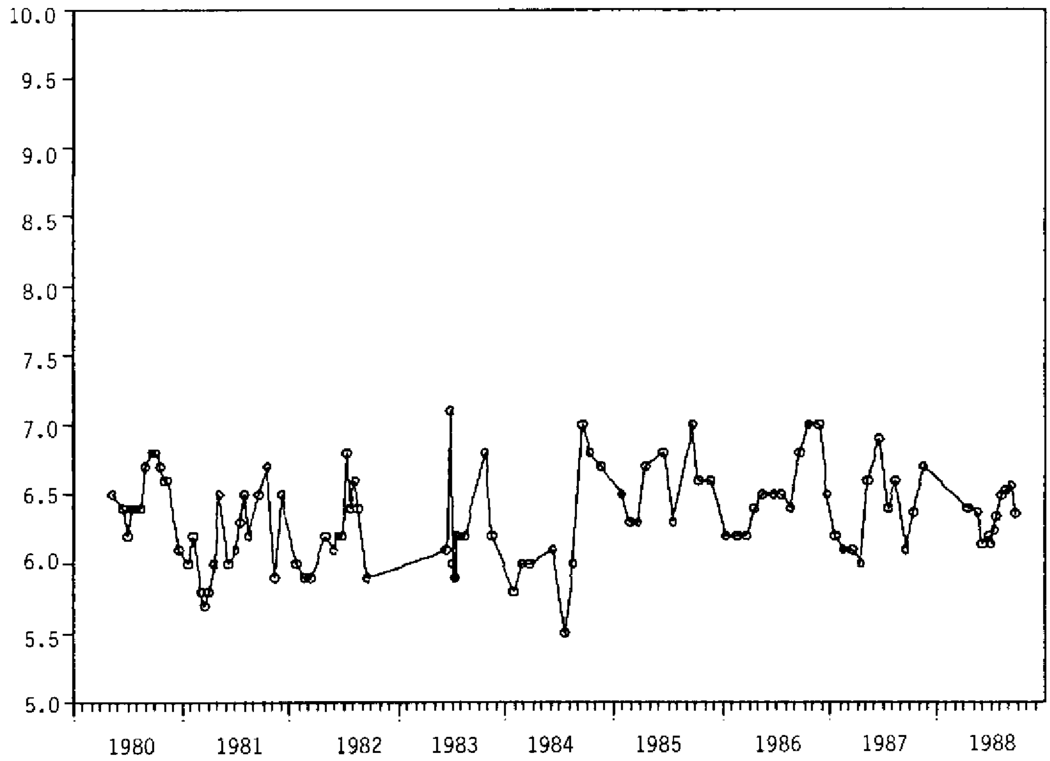


Fig. NAM-40-5 Past trend of chlorophyll *a* concentration.

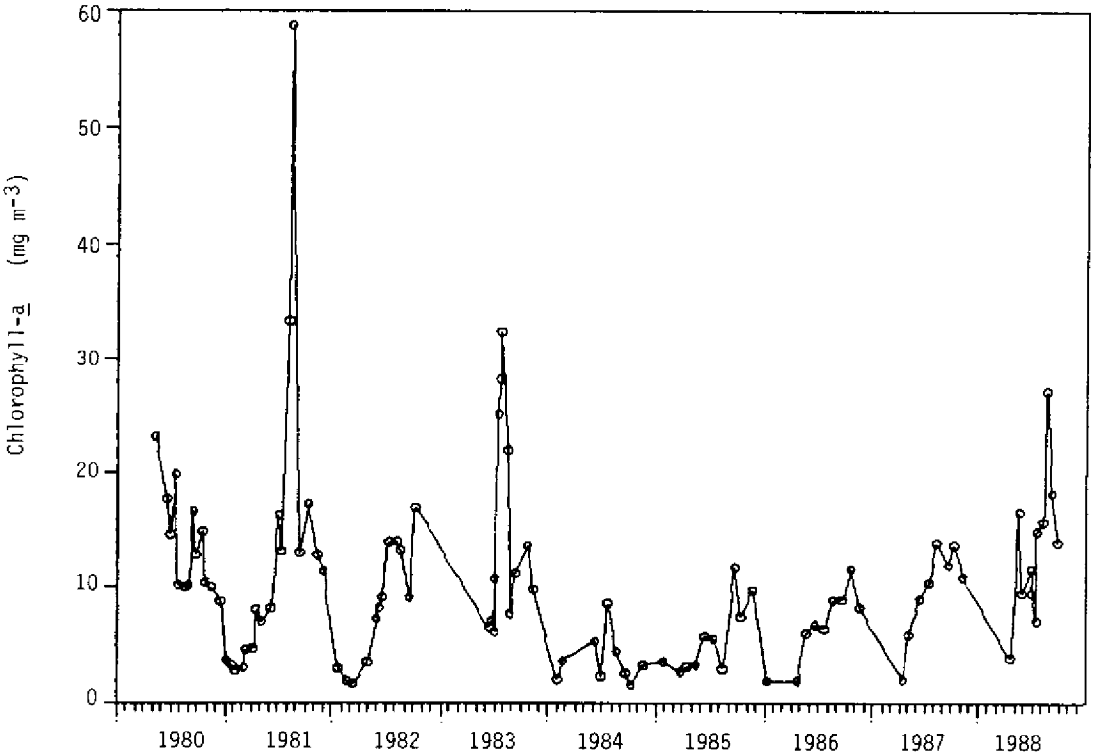


Fig. NAM-40-6 Past trend of Total-P concentration (summer 2 m).

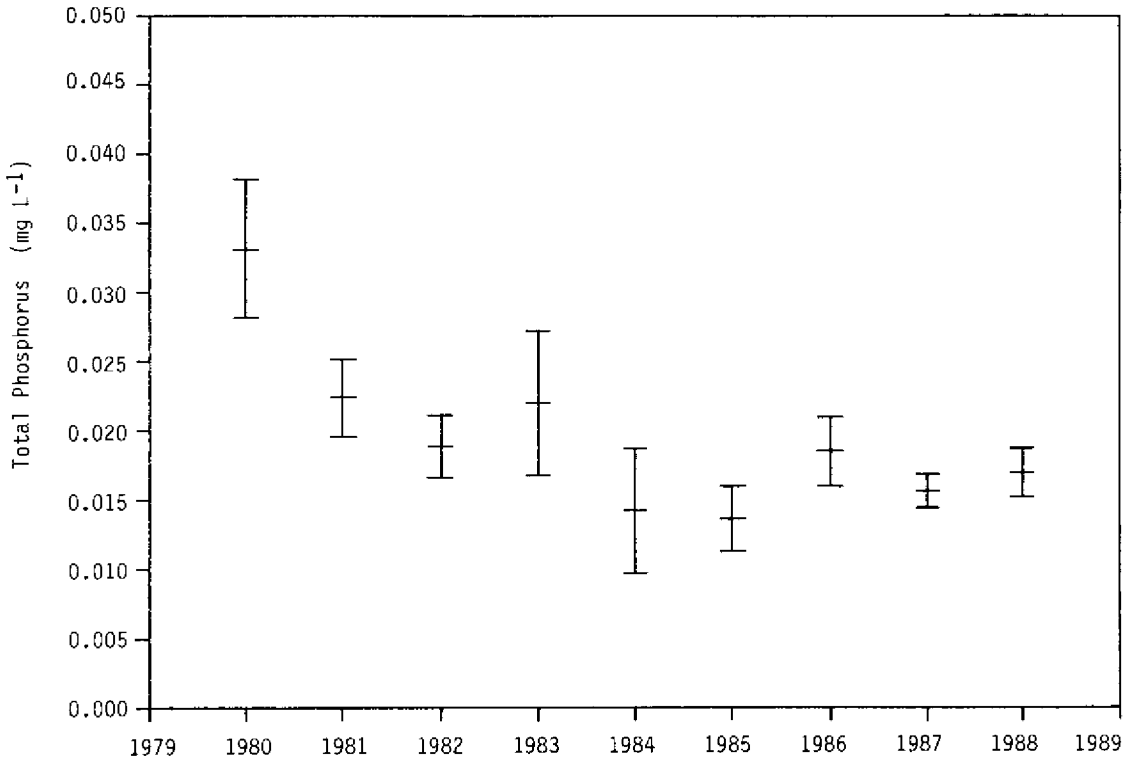


Fig. NAM-40-7 Past trend of Total-P concentration (summer 6 m).

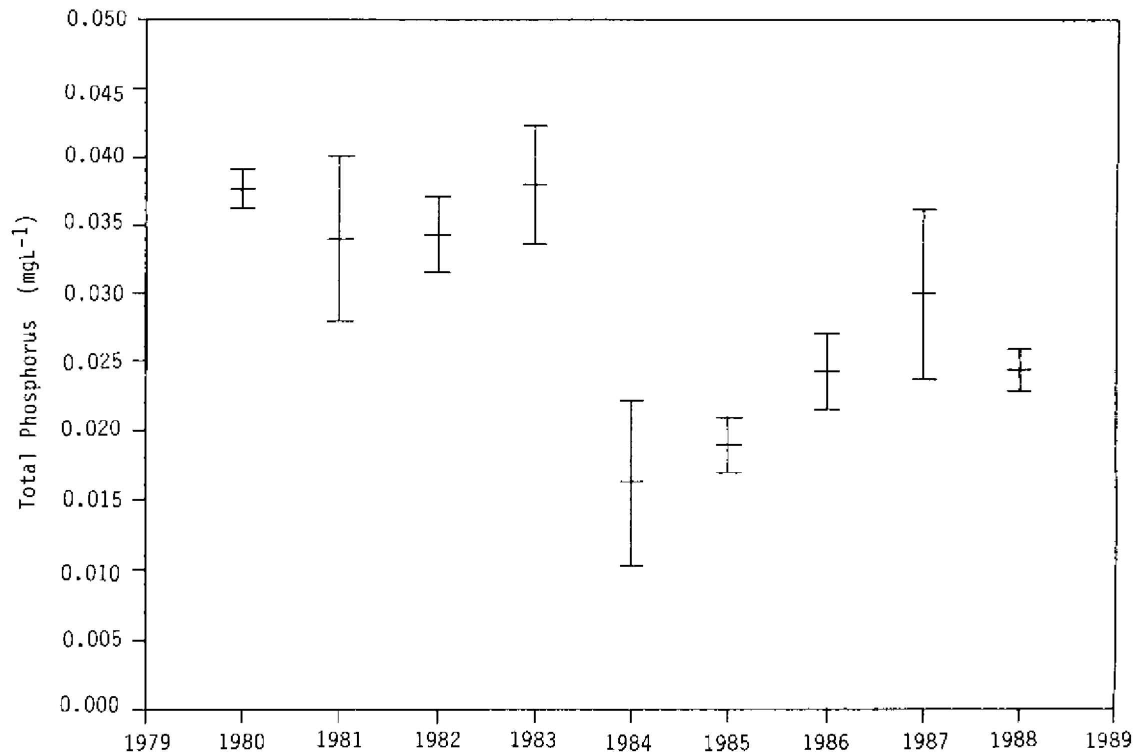
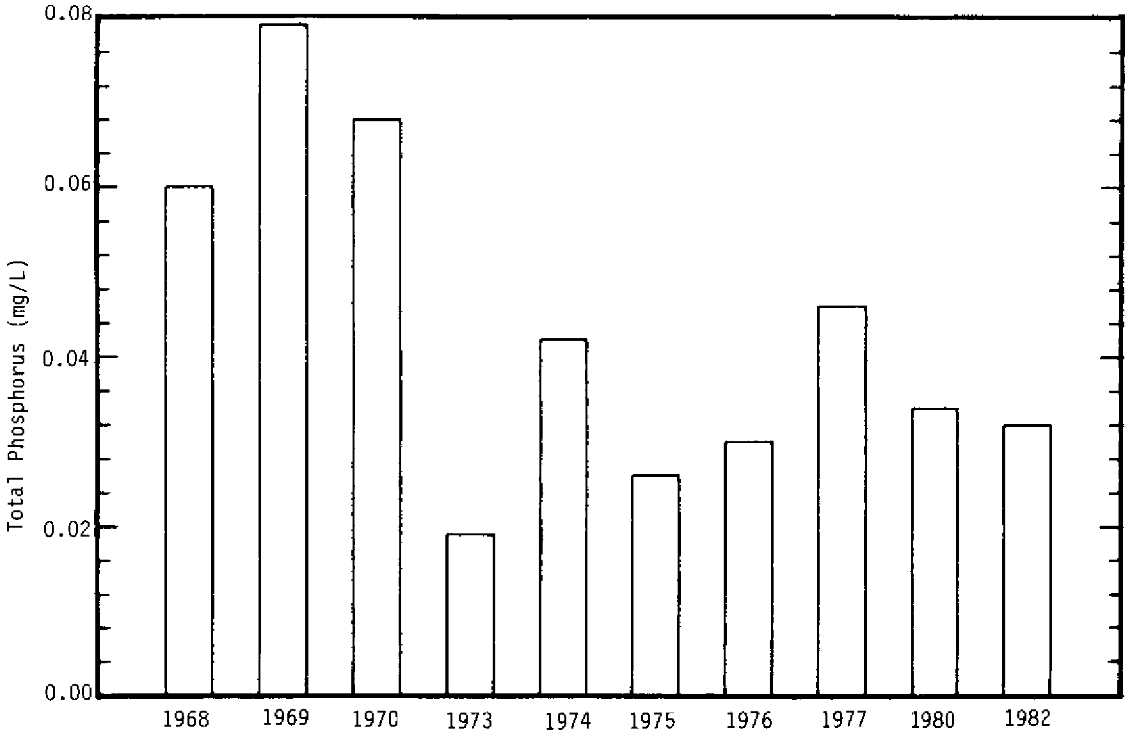


Fig. NAM-40-8 Historical data of mean Total-P concentration.



F. BIOLOGICAL FEATURES

F1 FLORA (1979) (1)

§ Emerged macrophytes : *Pontederia cordata, Typha, Myrica gale, Juncus.*

§ Floating macrophytes : *Nuphar, Nymphaea, Brasenia schreberi.*

§ Submerged macrophytes : No submerged plants apparent at time of survey.

§ Phytoplankton

May-Sep. (*Anabaena, Lyngbia, Microcystis, Melosira, Aphanizomenon, Asterionella, Mallomonas, Tabellaria, Dinobryon*), Oct.-Apr. (*Asterionella, Microcystis, Melosira, Tabellaria, Rhizosolenia, Fragilaria, Coelosphaerium, Uroglenopsis*).

F2 FAUNA (1982)

§ Zooplankton (1)

Keratella, Polyarthra, Kellicottia, Synchaeta, Bosmina, Daphnia, Calanoid copepods, *Codonella.*

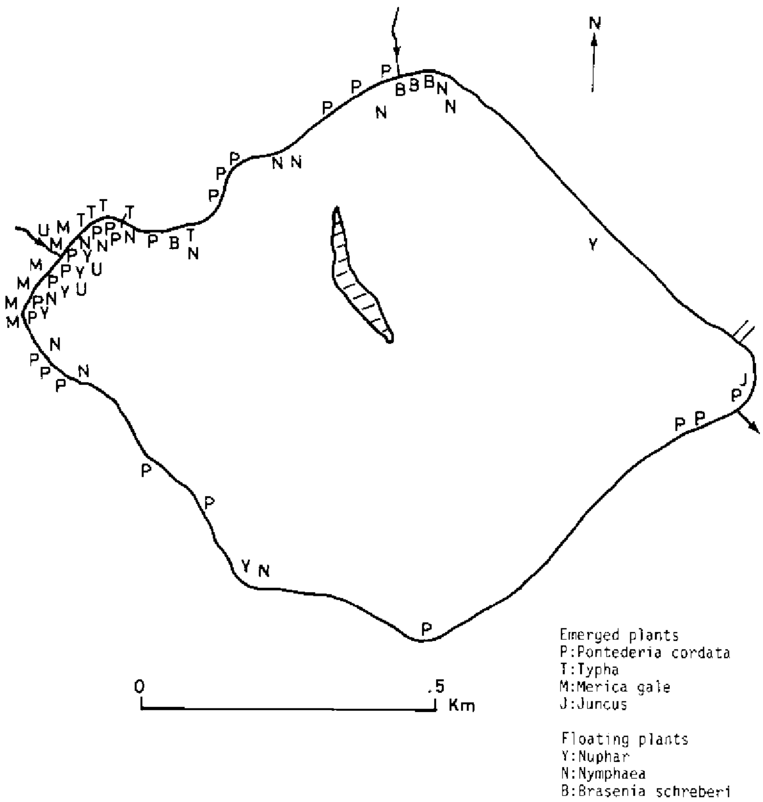
§ Benthos (2)

Chaoborus larvae, Sialidae, Megaloptera, Chironomidae, Diptera, Oligochaeta, Annelida.

§ Fish (3, 4)

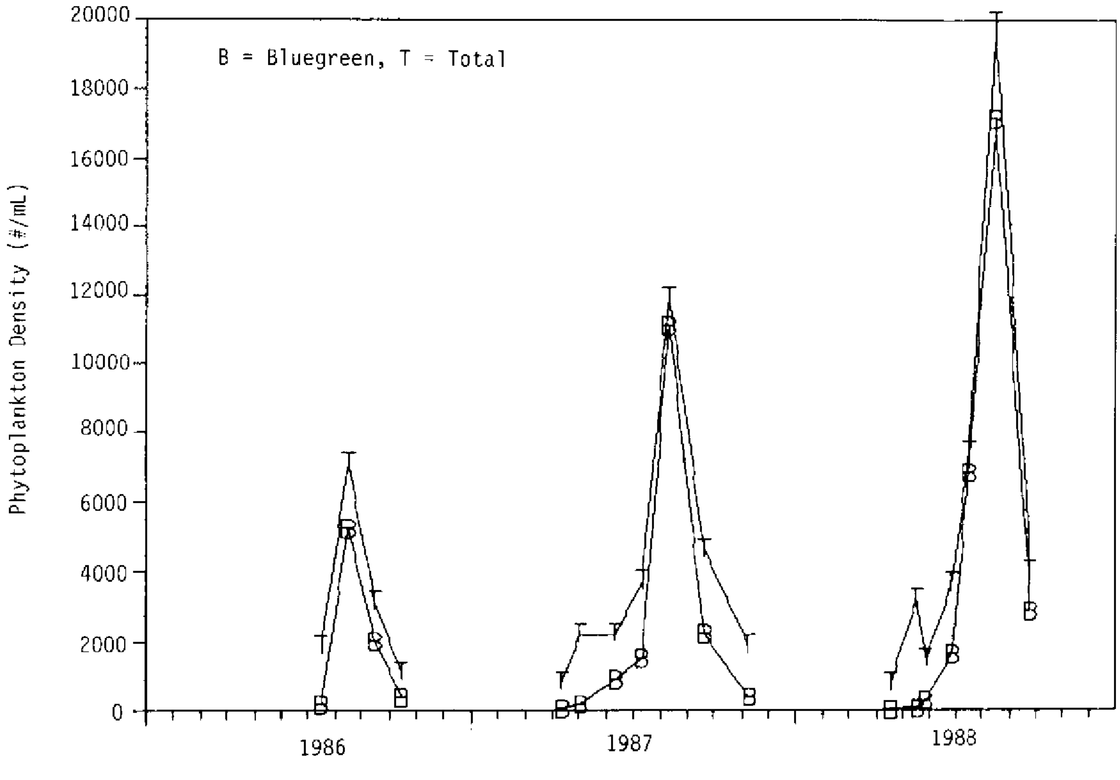
Micropterus dolomieui, M. lectalurus, Notemigonus crysoleucas, Esox niger, Perca flavescens, Anguilla rostrata, Catostomus commersoni, Lepomis gibbosus, Cyprinidae.

Fig. NAM-40-9 Distribution of aquatic plants, June 25, 1979 (1).



F6 PAST TREND

Fig. NAM-40-10 Phytoplankton density for whole water column (3).



G. SOCIO-ECONOMIC CONDITIONS (1)

G1 LAND USE IN THE CATCHMENT AREA (1983)

	Area [km^2]	[%]
Natural land scape		
Forest/abandoned field	19.9	77.1
Wetland	0.95	3.7
Agricultural land	1.1	4.3
Rural residential	1.8	7.0
Urban	0.64	2.5
Others (golf course, ski area, sewage disposal, gravel pit)	1.4	5.5
Total	25.9	100

G3 POPULATION IN THE CATCHMENT AREA (1987) (21)

	Population	Population density [km^{-2}]	Main cities
Rural	3,440		None
Total	3,440	123.3	

H. LAKE UTILIZATION

H1 LAKE UTILIZATION

Sightseeing and recreation (swimming, sport-fishing, yachting).

I. DETERIORATION OF LAKE ENVIRONMENTS AND HAZARDS (Q)

I1 ENHANCED SILTATION

§ Extent of damage : Serious.

I2 TOXIC CONTAMINATION

§ Present status : None.

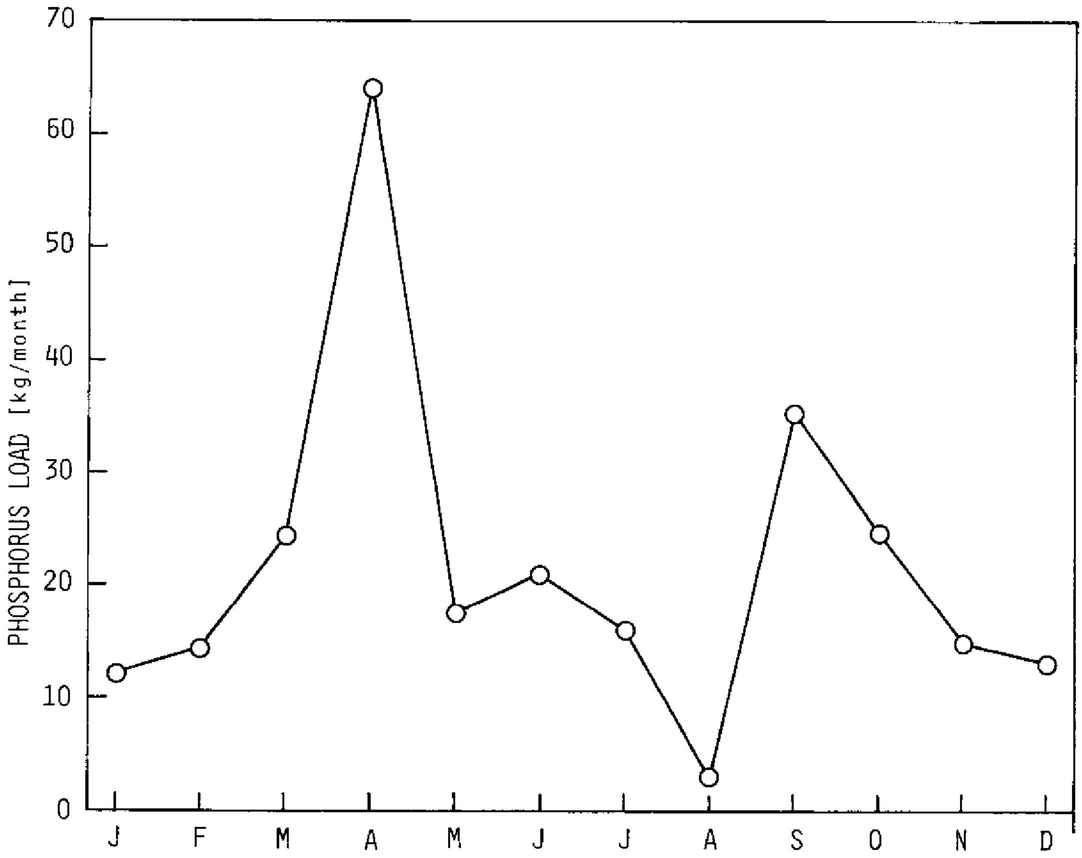
I3 EUTROPHICATION

§ Nuisance caused by eutrophication : Unusual algal bloom (*Microcystis*, *Anabaena*, *Aphanizomenon*, *Lyngbya*) and fish kill from endotoxins.

§ Phosphorus budget of the lake (Q)

Sources	Total-P [kg yr^{-1}]
Tributaries	260.7
Direct runoff	36.3
Atmospheric	39.6
Groundwater	7.3
Septic leachate	12.5
Subtotal	356.4
Net sediment uptake (−)	−123.6
Total net influx	232.8
Total outflux through outlet	234.1

Fig. NAM-40-11 Monthly Total-P load from rivers (1981-1982) (1).



I4 ACIDIFICATION

§ Extent of damage : Detected but not serious.

J. WASTEWATER TREATMENTS (Q)

J1 GENERATION OF POLLUTANTS IN THE CATCHMENT AREA : (e) Severe pollution with limited wastewater treatment.

J2 APPROXIMATE PERCENTAGE DISTRIBUTION OF POLLUTANT LOADS

	Percentage [%]
River discharge	72.0
Direct runoff	10.1
Atmospheric	12.2
Groundwater	1.9
Septic leachate	3.9

M. LEGISLATIVE AND INSTITUTIONAL MEASURES FOR UPGRADING LAKE ENVIRONMENTS (Q)

M1 NATIONAL AND LOCAL LAWS CONCERNED

§ Main items of control

(1) Algae & other aquatic nuisances

(2) Exotic weeds
(3) Illegal dumping & other violations

M2 INSTITUTIONAL MEASURES

(1) New Hampshire Department of Environmental Services, Water Supply and Pollution Control Division, Biology Bureau

N. SOURCES OF DATA

(Q) Questionnaire filled by Dr. W. Howard, Program Manager, U. S. Environmental Protection Agency Region I, Boston, Massachusetts, U.S.A.

(1) Connor, J. N. (1983) Kezar Lake Diagnostic and Feasibility Study. N. H. Water Supply & Pollution Control Commission, Staff Report No. 135.

(2) Connor, J. N. & Michael, R. M.(1985) An evaluation of Aluminium Salts Injection and Wetlands Management at Kezar Lake, North Sutton, New Hampshire. New Hampshire Water Supply & Pollution Control Commission, Staff Report No. 142.

(3) Connor, J. N. (1989) An Assessment of Wetlands Management and Sediment Phosphorus Inactivation, Kezar Lake, New Hampshire. Water Supply and Pollution Control Division, NH Department of Environmental Services, Staff Report No. 161.

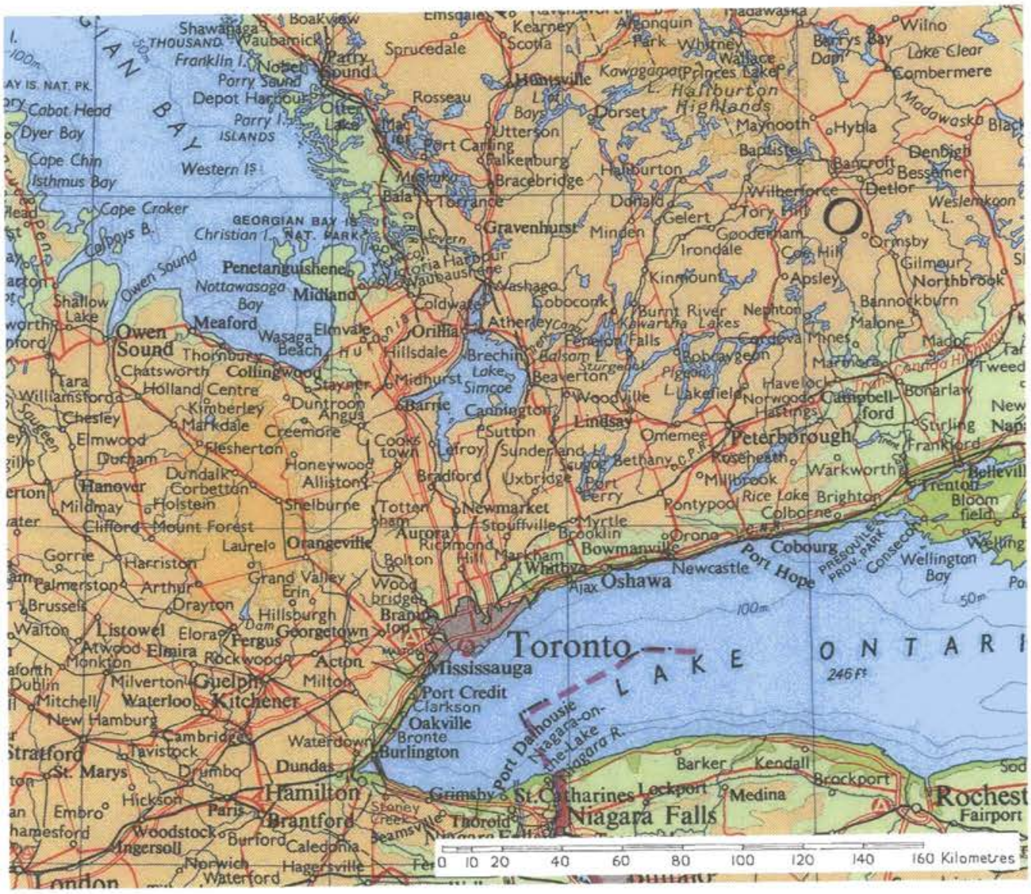
(4) Newell, A. E. (1977) Biological Survey of the Lakes and Ponds in Sullivan, Merrimack, Belknap and Stratford Counties. State of New Hampshire Fish and Game Department, Report No. 86, p. 135.

(5) Scarola, J. F. (1973) Freshwater Fishes of New Hampshire. New Hampshire Fish and Game Department, Devision of Inland & Marine Fisheries.

LAKE SIMCOE

Ice fishing huts on the lake

Photo: J. Overton, K. Nicholls, M. Dickman and M. Foy



A. LOCATION

§ South Central Ontario, Canada.
§ 44°15′-44°35′N, 79°10′-79°40′W ; 220 m above sea level.

B. DESCRIPTION

Lake Simcoe is southern Ontario's largest body of water excluding the Great Lakes. It serves as an important recreational resource for cottagers, anglers, campers and boaters. The population of the lake's basin was approximately 190,000 people in 1985. During the summer, there is an influx of 40,000 to 50,000 cottagers who occupy the 12,000 cottages surrounding the lake. Seventy percent of these cottagers rent or own boats and 35 marinas provide a moorage for the larger boats and yachts that can then access the Trent-Severn Canal System waterway which connects Lake Simcoe to Georgian Bay (via the Talbot River), Lake Huron, Lake Ontario and the Rideau Canal System which allows boats to reach the nation's capital and from there, the Ottawa River and the St. Lawrence.

Lake Simcoe's shoreline is composed of 55 % cobble, 35 % sand and 10 % organic muck. The lake is located within the eastern portion of the Simcoe Lowlands where well-drained till soils predominate. Along the northern and western shores of the lake, the lowland consists of a narrow bouldery terrace confined by a low bluff. The southern and eastern shores are characterized by poorly drained sandy loams and large organic deposits located along the major river courses.

The lake's basin is drained by 35 tributary inflows with 5 major rivers draining approximately 60 % of the watershed area. Annual mean discharges for the major river systems range from 2 to 4 m^3s^{-1}. Peak flows range from 20 to 60 m^3s^{-1} and usually occur during the spring melt period.

The 1980 survey of Ontario sport anglers indicated that Lake Simcoe received more fishing effort than any other Ontario inland lake. During the winters of 1980-1983, 400,000 to 500,000 angler-hours were spent on the lake during each winter and 2,000 to 3,000 ice fishing huts were rented during each year. Lake Simcoe's proximity to major urban centers in the Oshawa-Toronto-Hamilton corridor is primarily responsible for the intense sport fishery that exists on the lake, which is located about 50 km from Toronto and is within an hour's drive for over half the population of Ontario.

Water quality in the lake has been affected by an excessive supply of phosphorus which has stimulated an over-growth of aquatic weeds and algae in certain parts of the lake. This results in critically low dissolved oxygen levels in deep portions of the lake which in turn has been linked to a decline in whitefish and lake trout populations within the lake. Beginning in 1975, lake shore municipalities, Ontario ministries and conservation authorities responsible for Lake Simcoe began working together to study the lake and in 1979 they published the Lake Simcoe-Couchiching Basin Environmental Strategy which evaluated measures designed to reduce phosphorus inputs to the lake. This strategy also established baselines for physical, chemical and biological data, some of which are described below. Considerable reductions in point source phosphorus loading have been achieved in recent years. Present-day inputs (1989) may be near acceptable levels (2, 3, 4, 5, 7, 8).

PHYSICAL DIMENSIONS (5, 9)

Surface area [km²]	725
Volume [km³]	11.6
Maximum depth [m]	41
Mean depth [m]	15
Normal range of annual of water level fluctuation (regulated) [m]	0.4
Residence time [yr]	16
Catchment area [km²]	2,840

D. PHYSIOGRAPHIC FEATURES

D1 GEOGRAPHICAL

§ Bathymetric map (Fig. NAM-42-1).

§ Main islands (number and names): 4 (Georgina, Thorah, Snake, and Fox Island) (1).

§ Outflowing rivers and channels (number and names): Atherly Narrows (Mean flux 37.1 $m^3 s^{-1}$) (5).

§ Main inflowing rivers and channels (number and names): Talbot R. (4.35 m^3s^{-1}), Holland R. (3.9 $m^3 s^{-1}$) and Pefferlaw Brook (3.78 $m^3 s^{-1}$) (5).

D2 CLIMATIC

§ Climatic data at Orillia, 1989 (6)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean temp. [°C]	-9.3	-12	-2.8	4.6	13	16.2	20.4	19.2	14.6	7.4	2.3	-5.9	5.6
Precipitation [mm]	89	63	59	64	70	79	83	82	82	85	82	95	932

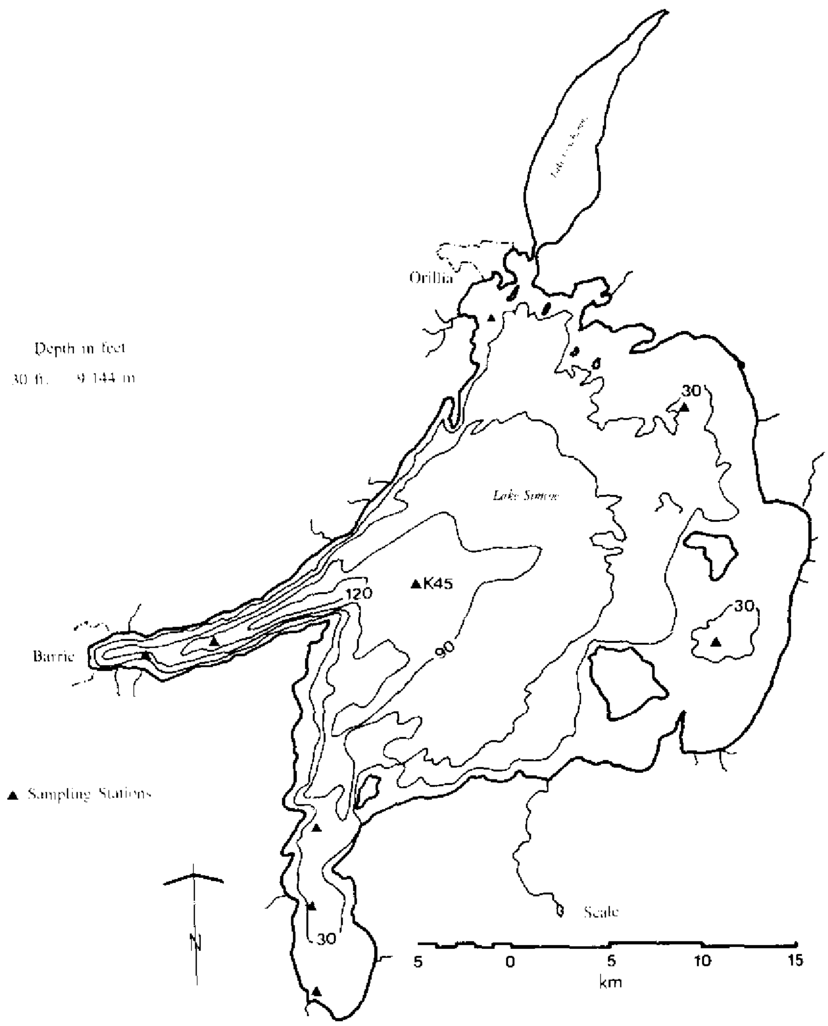
§ Number of hours of bright sunshine (Toronto): 2,045 hr yr^{-1}.

§ Solar radiation (Toronto): 13 MJ m^{-2} day^{-1} (6).

Mean daily global solar radiation [MJ m^{-2}]

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
5.2	8.2	12.1	16.1	19.8	22	22	18.7	14	9.2	4.8	3.9

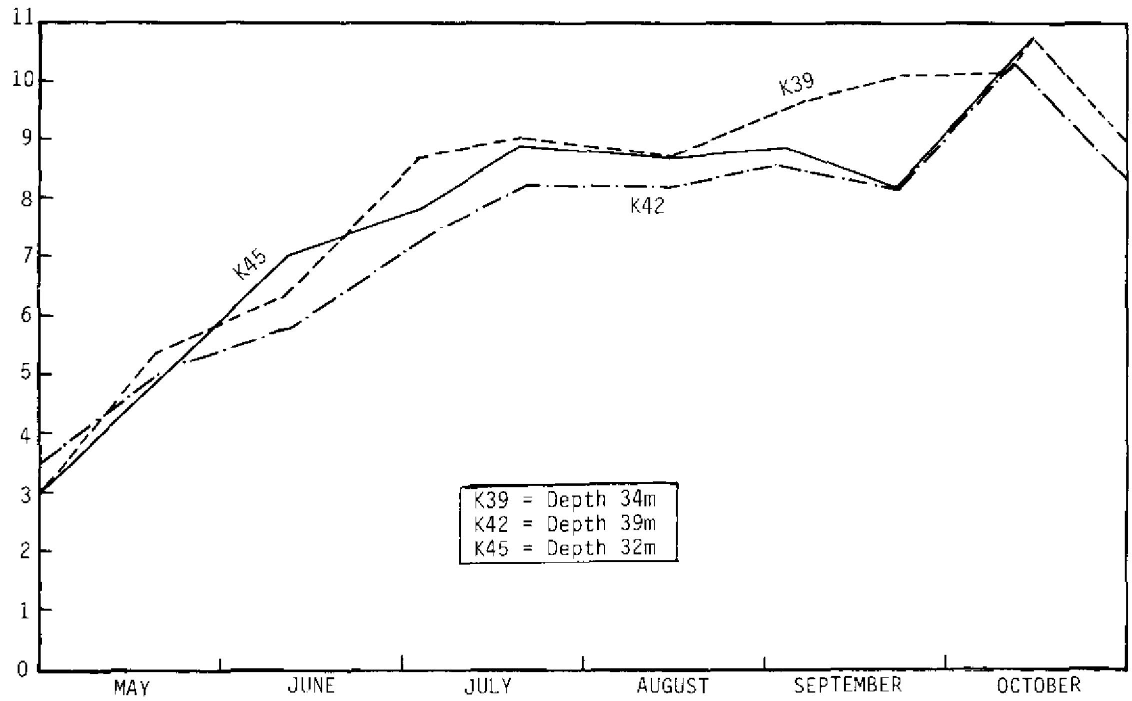
Fig. NAM-42-1 Bathymetric map (Q).



§ Water temperature [°C]
Station K45, 1984

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	—	—	—	—	4.8	14.8	17.2	22.2	13.7	12.0	—	—
5	—	—	—	—	4.8	14.5	17.3	22.2	14.5	12.0	—	—
10	—	—	—	—	4.8	12.1	15.6	22.2	15.1	12.0	—	—
15	—	—	—	—	4.8	9.3	13.9	15.1	15.2	12.0	—	—
20	—	—	—	—	4.8	7.7	8.5	9.9	10.4	12.0	—	—
25	—	—	—	—	4.8	7.6	8.2	8.2	7.5	12.0	—	—
30	—	—	—	—	4.7	7.6	8.0	8.1	6.7	12.0	—	—

Fig. NAM-42-2 Water temperature at one meter above the lake bottom at 3 stations in Lake Simcoe (2).



§ Freezing period : Dec. to Mar.
§ Mixing type : Dimictic.
§ Supplementary note : A very gradually sloping thermocline forms between 13 m and 20 m each summer and remains there from Jun. to Sep.

E. LAKE WATER QUALITY

E1 TRANSPARENCY [m]

Mean Secchi depth at the open water location station K45 was 4.4 m for 1981-1985. That for the same period in Cook Bay was 2.9 m (2)

Station K45, 1981-1985

1981	1982	1983	1984	1985	Average
4.5	4.4	3.9	4.5	4.8	4.4

E2 pH (2)

Station K45, 1981-1982

Depth [m]	1981	1982	Average
0	8.3	8.45	8.38
30	–	8.0	8.0

E3 SS [mg l^{-1}] (Cond 25) (2)

Station K45, 1982-1985

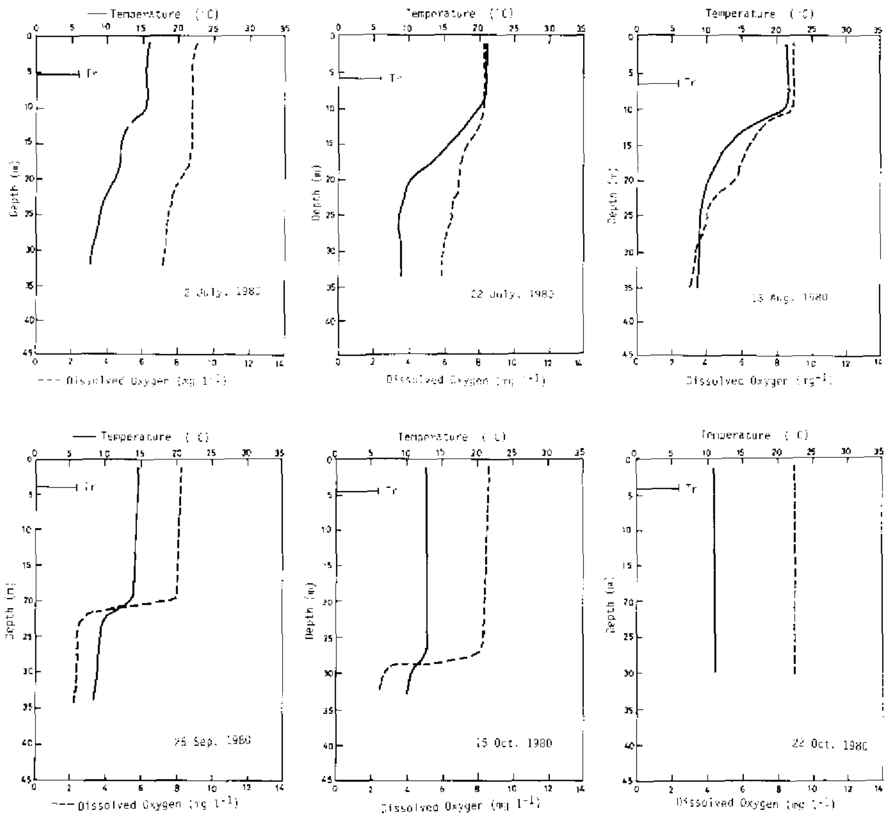
Depth [m]	1982	1983	1984	1985	Average
0	329.4	318.0	334.6	335.1	329.6
30	345.8	331.7	346.2	344.7	342.1

E4 DO [mg l^{-1}] (2)

Station K45, 1985

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	–	–	–	12.0	12.0	9.6	8.1	7.9	8.8	9.2	–	–
5	–	–	–	12.0	12.0	9.6	7.6	7.8	8.8	9.2	–	–
10	–	–	–	11.9	12.1	9.4	6.9	7.8	8.6	9.2	–	–
15	–	–	–	11.8	12.2	9.6	6.7	5.6	8.4	9.2	–	–
20	–	–	–	11.8	12.1	9.9	5.9	3.9	6.6	9.2	–	–
25	–	–	–	11.8	11.9	8.9	4.9	3.7	1.4	9.2	–	–
30	–	–	–	11.8	11.8	8.8	2.4	3.7	0.9	8.9	–	–

Fig. NAM-42-3 Dissolved oxygen, transparency [m] and temperature [°C] profile at Station K45, 1980 (11, 12).



E6 CHLOROPHYLL CONCENTRATION [mg l⁻¹] (2)

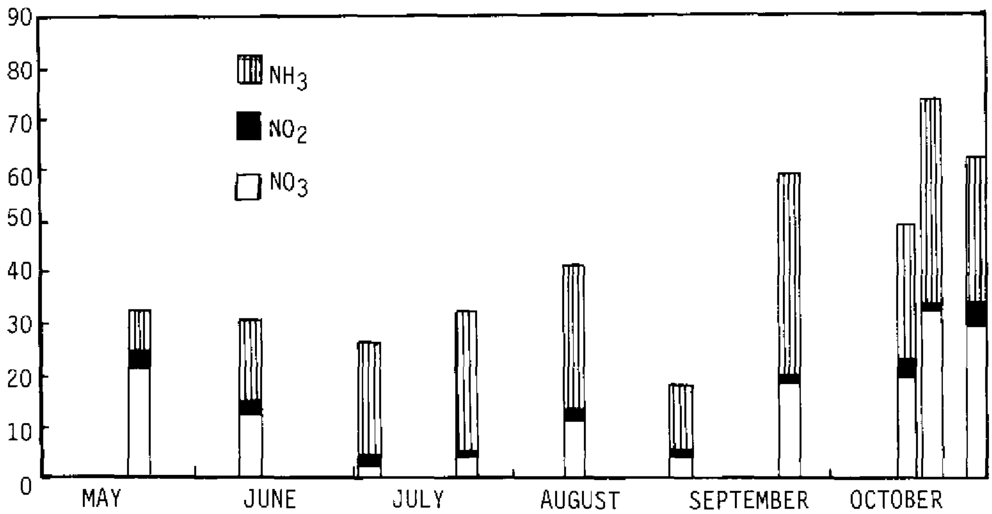
1981	1982	1983	1984	1985	Average
2.1	1.6	1.6	2.2	2.6	2.02

E7 NITROGEN CONCENTRATION

§ NO_2-N, NO_3-N, NH_4-N and total kjeldahl-N [mg l^{-1}]

	NO_2		NO_3		NH_3		TKN	
Depth [m]	0	30	0	30	0	30	0	30
1982	0.005	0.015	0.045	0.135	0.039	0.015	0.39	0.40
1983	0.002	0.007	0.009	0.072	0.021	0.005	0.40	0.36
1984	0.002	0.003	0.041	0.082	0.074	0.012	0.62	0.37
1985	0.002	0.007	0.028	0.113	0.069	0.075	0.51	0.48
Average	0.003	0.008	0.031	0.101	0.051	0.027	0.46	0.40

Fig. NAM-42-4 Inorganic nitrogen concentrations measured 1 m above the bottom.

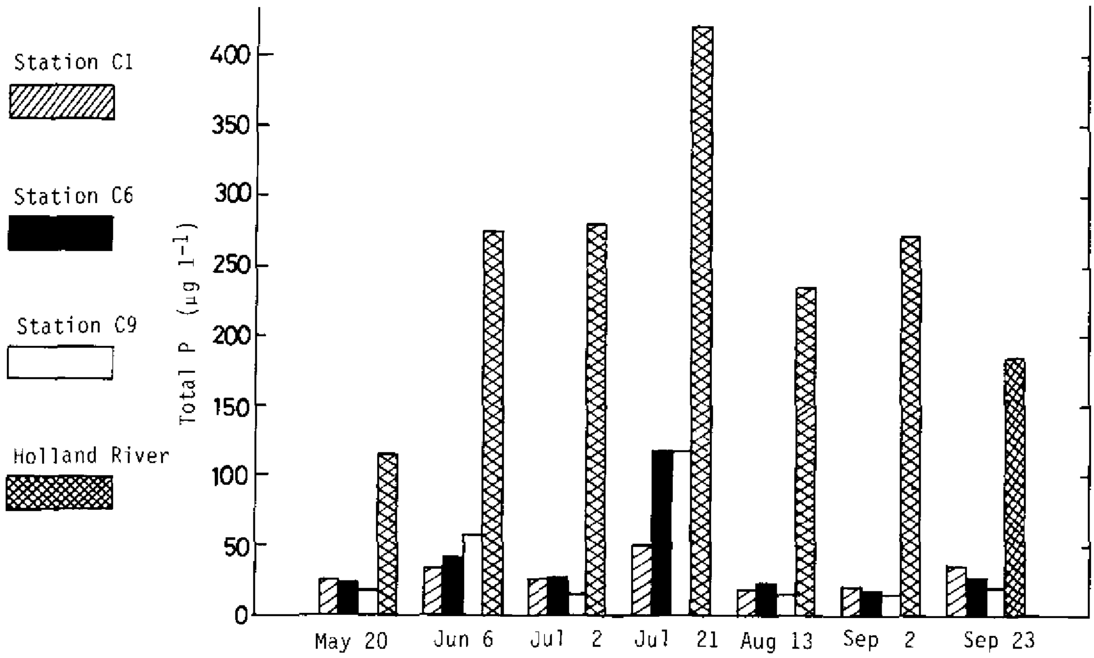


E8 PHOSPHORUS CONCENTRATION

§ PO_4-P and Total-P [mg l^{-1}]

	PO_4		Total unfiltered P	
Depth [m]	0	30	0	30
1982	0.003	0.009	0.012	0.031
1983	0.003	0.007	0.021	0.030
1984	0.002	0.010	0.017	0.023
1985	0.002	0.008	0.020	0.025
Average	0.0027	0.009	0.017	0.027

Fig. NAM-42-5 Euphotic zone total phosphorus concentrations at stations C1, C5 and C9 in Cook Bay and in the Holland River, 1980 (11).



E1O PAST TRENDS

The levels of dissolved oxygen in the deeper basins of the lake began falling in the 1960's and improvements were noted in the 1980's following the implementation of phosphorus abatement strategies (12).

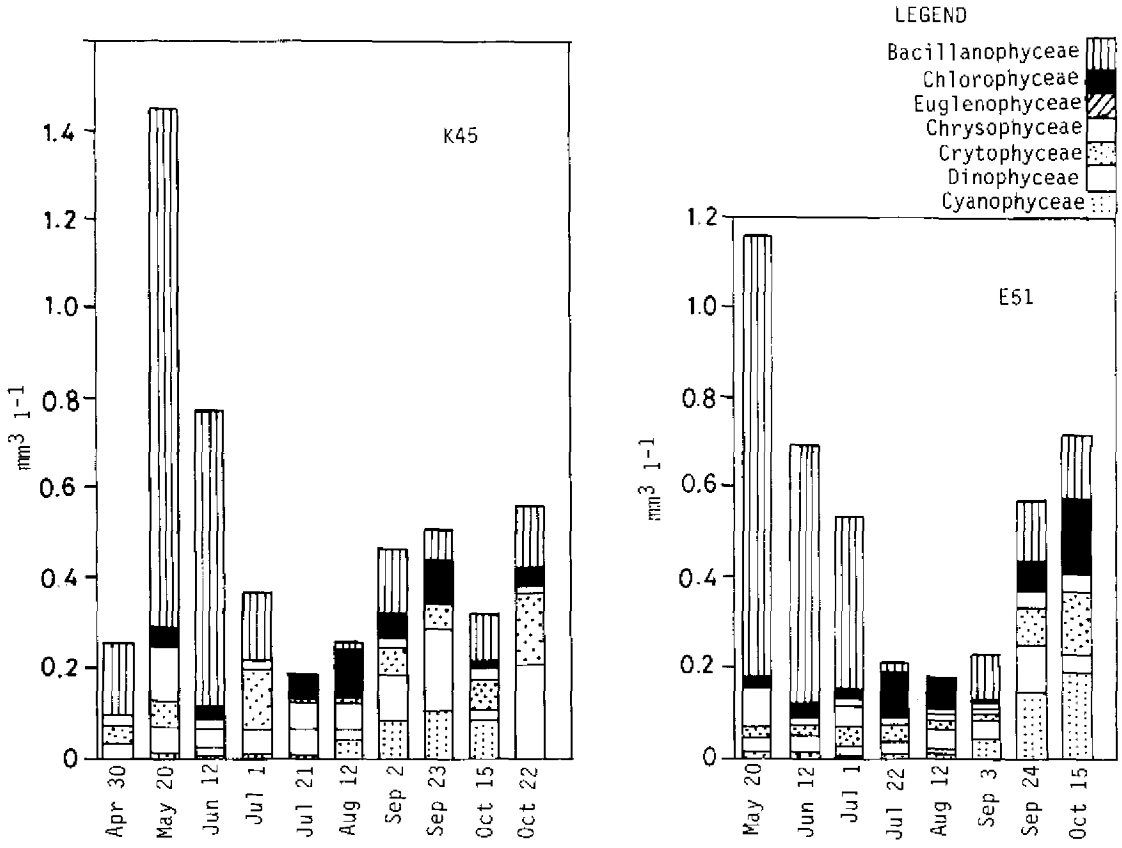
F. BIOLOGICAL FEATURES (1971-1979)

F1 FLORA (9)

§ Emerged macrophytes : *Typha latifolia, Typha angustifolia, Scirpus* spp.
§ Floating macrophytes : *Lemna minor, Wolffia* sp.
§ Submerged macrophytes : *Potamogeton pectinatus, Elodea canadensis, Myriophyllum spicatum.*
§ Benthic algae : *Cladophora, Dichtomosiphon tuberosus, Chara.*
§ Phytoplankton

Ceratium hirundinella, Stephanodiscus hantzschia, S. astreaea, Melosira granulata, M. ambigua, and *Cryptomonas* spp. are the dominant taxa at most stations in Lake Simcoe. During late summer, *Anabaena flos-aquae* forms dense surface blooms reaching densities of 0.06 mm^3l^{-1} in Cook Bay which is the most eutrophic part of the lake (2). *Dinobryon, Mallomonas, Scenedesmus, Pediastrum, Aphanizomenon, Coelosphaerium, Lyngbya, Oscillatoria, Euglena, Trachelomonas* and *Phacus* never reached more than 5 % of the total annual (May to Oct.) algal biomass (11).

Fig. NAM-42-6 Seasonal distribution of phytoplankton density for the 7 most abundant classes at stations K45 and E51, 1980 (2).



F2 FAUNA

§ Zooplankton

The rotifers were not abundant. Surface tows in the fall (Oct.) of 1982 revealed *Karatella cochlearis*, *K. quadrata*, *Syncheata*, sp., *Brachionus* spp. and *Polyarthra*. sp. (15). The common copepods were *Senecella calanoides*, *Epischura lacustris* and *Diaptomus sicilis* (calanoid copepods) ; *Cyclops bicuspidatus thomasi* and *Mesocyclops edax* (cyclopoid copepods) ; and *Daphnia galeata mendotae* and *Bosmina coregoni coregoni* (dadocerans) (15).

§ Benthos

Micropsectra sp., *Phanopsectra* sp. (chironomids) ; *Pisidium conventus* and *P. caserianum* (clams).

§ Fish

Lake trout (*Salvelinus namaycush*)*, large mouth bass (*Micropterus salmoides*)*, small mouth bass (*Micropterus dolomieui**), northern pike (*Esox lusius*), whitefish (*Coregonus clupeaformis*), white sucker (*Catosomus commersoni*), American smelt (*Osmerus mordax*) walleye or yellow pickerel (*Stizostedion vitreum*), ling or burbot (*Lota lota*), rock bass (*Ambloplites rupestris*), yellow perch (*Perca flavescens*) (*economically important) (8).

F4 BIOMASS

§ Average total phytoplankton biomass in 1981 [mm^3 l^{-1}] at Station K45 (11).

Apr. 30	May 20	Jun. 12	Jul. 1	Aug. 12	Sep. 23	Oct. 14
0.23	0.42	0.79	0.38	0.25	0.57	0.38

F7 NOTES ON THE REMARKABLE CHANGES OF BIOTA IN THE LAKE IN RECENT YEARS

Whitefish populations are decreasing and there is some year-class inferred evidence that the whitefish population is not reproducing (8).

G. SOCIO-ECONOMIC CONDITIONS

G1 LAND USE IN THE CATCHMENT AREA (1982) (15)

Vegetation and land use type	Area [km^2]	[%]
Natural landscape	–	37
Woody vegetation	158	
Agricultural land	–	61
Crop field	984	
Pasture land	214	
Others	–	2
Total	(1,356)	100

§ Types of important forest : Red pine.
§ Main kinds of crops : Hay, corn, small grains (wheat, oat, barley and rye) and row crops as onion and carrot.
§ Levels of fertilizer application on crop fields : Moderate.
§ Trends of changes in land use in recent years : Housing developments have increased most rapidly with agricultural developments next (16).

G2 INDUSTRIES IN THE CATCHMENT AREA AND THE LAKE (1986) (16)

	Gross production during the year (Canadian \$=US \$)	Number of establishments	Main products and main industries
Primary industry			
Crop production Animal husbandary	127,000,000	2,500	Vegetables, grain, milk, cheese, beef and poultry
Fisheries*	20,000,000		Whitefish
Others			Sport fishery

* Information from R. Desjardin, OMNR Biologist, Central Region.

§ Numbers of domestic animals in the catchment area : Cattle 63,000, sheep 11,500, swine 62,000, poultry 910,000, milk cows 20,000, horses 4,800.

G3 POPULATION IN THE CATCHMENT AREA (1985) (16)

	Population	Population density [km^{-2}]	Main cities
Urban	87,095 ***	1,371	Barrie Newmarket
Rural	132,905	47	
Total	220,000 *	76**	

* This figure does not include the 50,000 seasonal residents of the cottages in the catchment area.

** This figure would increase to 93±15 km^{-2} if seasonal residents were included.

***All cities with a population greater than 30,000.

H. LAKE UTILIZATION

H1 LAKE UTILIZATION (2)

Source of water, sightseeing and tourism (number of visitors in 1985 ; 50,000), recreation (swimming, sport-fishing and yachting) and fisheries.

H2 THE LAKE AS WATER RESOURCE

Domestic water

Municipality	Capacity of Plant [$\times 10^3 m^3\ day^{-1}$]
Brock Township	7.27
Mara Township	4.0
Georgia Township	4.56

I. DETERIORATION OF LAKE ENVIRONMENTS AND HAZARDS

I1 ENHANCED SILTATION

§ Extent of damage : Serious.

I2 TOXIC CONTAMINATION

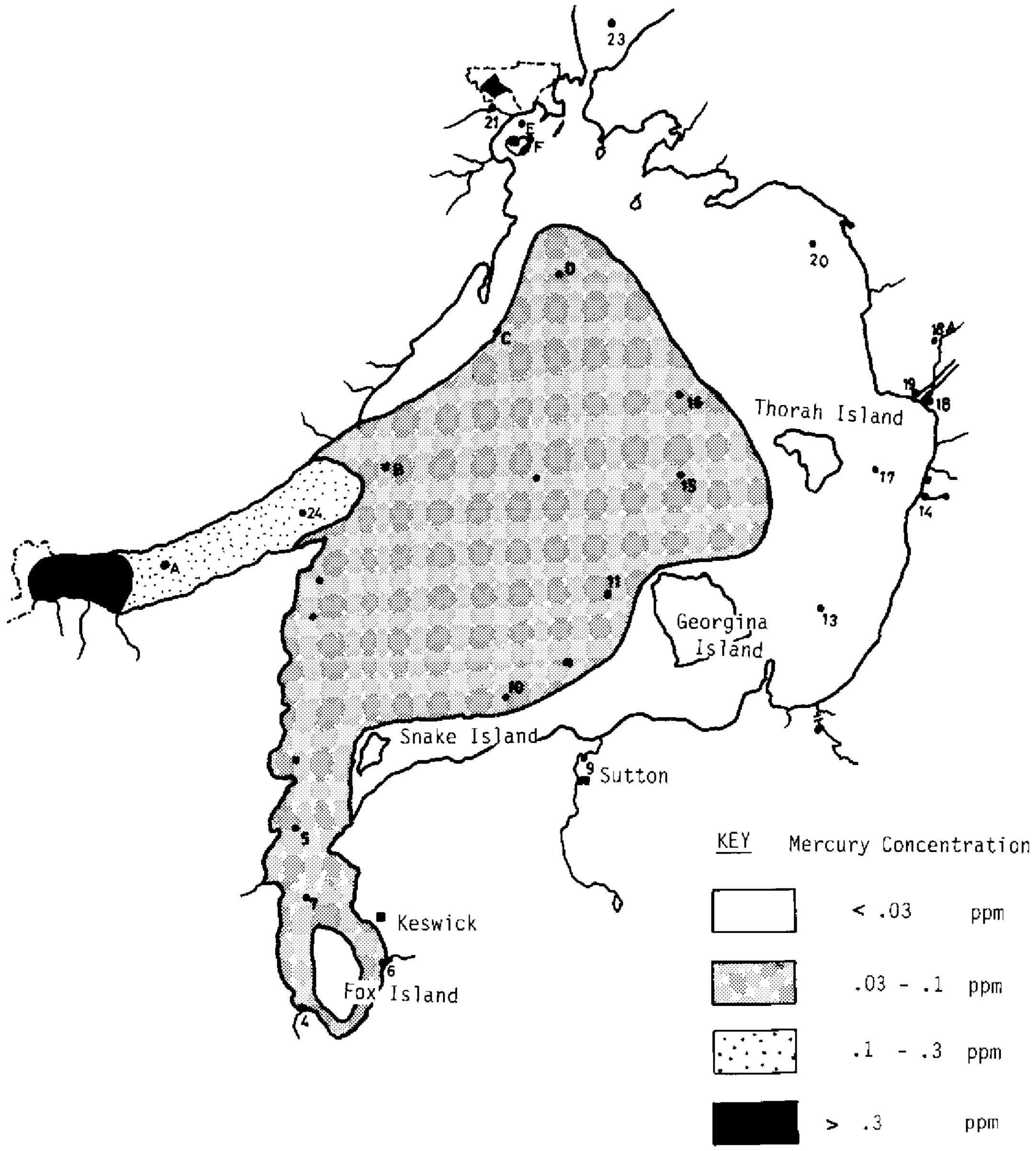
§ Present status : Detected but not serious.

Mercury levels in L. Simcoe fish by species and size (from "Guide to Eating Ontario Sport Fish," 1978).

Sepcies	Fish size [cm]									
	15	15-20	20-25	25-30	30-36	36-46	46-56	56-66	66-76	76
Large mouth bass	–	A	A	A	A	A	B	–	–	–
Small mouth bass	–	A	A	A	A	B	B	–	–	–
Yellow perch	A	A	A	A	A	–	–	–	–	–
Northern pike	–	–	–	A	A	A	A	A	A	A
Walleye	–	–	–	A	A	A	B	B	C	D
Lake trout	–	–	–	–	A	A	A	A	A	B
White sucker	–	–	–	–	A	A	A	–	–	–
Whitefish	–	–	–	A	A	A	A	–	–	–
Rock bass	–	A	A	A	A	–	–	–	–	–
Ling	–	–	–	–	–	–	–	A	B	B

Key to mercury levels [ppm] : A : <0.5
B : 0.5-1.0
C : 1.0-1.5
D : >1.5
– : projections not made for this size class.

Fig. NAM-42-7 Spatial distribution of mercury in the surface sediments of the lake (14).



§ Past trends

Mercury concentration in fish collected in the lake (11).

Species	Year of collection	Number of fish	Hg concentration [ppm] Mean	Min.	Max.	Length of fish [cm] Mean	Min.	Max.
Walleye (Pickerel)	1970	22	0.27	0.07	0.96	51.9	30.7	75.2
	1971	12	0.55	0.18	2.04	53.5	30.0	71.6
	1975	15	0.73	0.15	1.28	60.7	48.0	74.0
	1976	50	0.98	0.18	1.70	66.2	36.6	80.1
	1977	27	0.60	0.10	1.60	53.8	29.0	75.0
Lake trout	1970	20	0.39	0.16	0.58	72.5	54.1	82.8
	1975	16	0.24	0.13	0.39	62.3	55.0	71.0
	1976	12	0.35	0.18	0.56	69.9	57.2	85.3
	1977	20	0.48	0.20	0.93	66.6	49.5	87.0
Whitefish	1915 *	6	2.4 **	1.4 **	4.9 **	38.0	35.4	44.5
	1928 *	6	0.08	0.06	0.11	39.9	36.8	42.3
	1952 *	10	0.06	0.05	0.09	19.3	17.5	23.3
	1970	11	0.06	0.04	0.08	44.3	35.6	49.0
	1971	12	0.04	0.03	0.07	43.8	40.4	47.7
	1975	13	0.03	0.02	0.05	46.9	44.0	51.0
	1977	20	0.03	0.01	0.07	52.2	50.8	54.5
Large mouth bass	1971	12	0.25	0.14	0.50	30.8	19.3	42.2
Small mouth bass	1970	24	0.48	0.17	1.44	32.1	22.6	41.4
	1971	12	0.27	0.13	0.82	31.1	19.3	48.3
	1975	10	0.13	0.09	0.18	29.1	19.0	34.5
	1977	30	0.25	0.06	0.93	29.3	19.4	43.5
Cisco	1928 *	8	0.16	0.11	0.21	25.3	20.7	29.2
	1952 *	9	0.16	0.13	0.19	20.0	18.3	21.3
	1969 *	15	0.14	0.09	0.19	26.0	23.0	29.1
	1970	9	0.06	0.05	0.08	23.2	22.5	24.5
	1977	26	0.13	0.09	0.17	32.8	26.8	40.3
Rainbow smelt	1970	10	0.08	0.05	0.11	20.9	16.8	24.9
Emerald shiner	1971	4	0.08	0.06	0.11	7.6	5.1	10.0
Rock bass	1952 *	3	0.20	0.18	0.24	22.2	21.7	22.7
	1970	12	0.14	0.10	0.24	17.4	13.5	21.3
	1975	10	0.16	0.08	0.25	21.5	17.0	25.0
Yellow perch	1952 *	4	0.12	0.10	0.13	14.5	13.4	15.5
	1967 *	4	0.29	0.19	0.36	17.5	15.8	21.1
	1970	15	0.17	0.10	0.27	25.6	20.1	32.5
	1971	12	0.30	0.15	0.80	25.8	20.6	31.8
	1975	12	0.21	0.06	0.49	23.8	14.0	30.0
	1977	22	0.23	0.07	0.42	24.7	12.0	31.0
Northern pike	1967 *	2	0.13	0.12	0.14	43.4	—	—
	1971	12	0.19	0.12	0.44	69.8	54.9	96.5
	1975	3	0.16	0.05	0.31	63.0	43.0	86.0
	1977	22	0.20	0.07	0.47	67.4	51.2	105.0
Ling (burbot)	1970	10	0.39	0.14	0.55	69.8	33.0	81.3
	1975	5	0.53	0.45	0.65	76.8	70.0	86.0
	1977	15	0.44	0.15	0.98	59.4	43.7	79.0
White sucker	1952	4	0.04	0.03	0.05	30.6	23.8	35.9
	1970	12	0.17	0.09	0.23	43.0	38.4	46.5
	1971	12	0.09	0.05	0.14	41.4	35.0	48.0
	1975	6	0.14	0.07	0.19	43.5	39.0	46.0

* Specimens from Royal Ontario Museum.

**Mercury contamination of preserving fluid suspected.

I3 EUTROPHICATION

§ Nuisance caused by eutrophication (8)

Unsusal algal bloom: In 1971 a surface bloom of *Anabaena flos-aquae* was observed for the first time. This continued in the late summer and early fall of subsequent years. In 1983, the two main sewage sources were diverted from Lake Simcoe and it is believed that this will reduce by half, the algal biomass by 1990.

Cladophora is the dominant on-shore alga on the cobblestone beach just east of the Orilla sewage treatment plant. *Cladophora* reaches its highest densities in June, July and August at a depth of 0.5-1.0 m.

§ Supplementary notes

On August 1, 1970, federal regulations reduced the phosphorus content as P_2O_5 in laundry detergents from approximately 50 % to 20 %. Additional regulations which were proclaimed by the federal government of Canada on January 1, 1973 further decreased the phosphorus content to 5 % (15).

I4 ACIDIFICATION

§ Extent of damage: None.

J. WASTEWATER TREATMENT

J1 GENERATION OF POLLUTANTS IN THE CATCHMENT AREA: (d) Measurable discharge of pollution load into the lake with limited wastewater treatment.

J3 SANITARY FACILITIES AND SEWERAGE (19)

§ Municipal wastewater treatment systems

Number of secondary treatment systems: 1 (conventional method with phosphorus removal).

Number of other types: 1 (conventional lagoon with seasonal phosphorus removal).

K. IMPROVEMENT WORKS IN THE LAKE

K1 RESTORATION

Sewage diversion began in 1983

K2 AERATION

Aeration studies in the deep basins have been considered (10).

L. DEVELOPMENT PLANS

The number of marinas and housing developments continue to expand.

M. LEGISLATIVE AND INSTITUTIONAL MEASURES FOR UPGRADING LAKE ENVIRONMENTS

M1 NATIONAL AND LOCAL LAWS CONCERNED

§ Names of the laws

(1) Canada Fisheries Act
(2) Canada Navigable Waters Protection Act
(3) Canada Water Act
(4) Canada Environmental Contaminants Act

§ Responsible authorities

(1) Ontario Ministry of the Environment (O. M. E.)
(2) Ontario Ministry of Natural Resources (O. M. N. R.)
(3) Environment Canada

§ Main items of control

(1) Municipal and industrial discharges of wastes and waste waters
(2) Consumption withdrawal

(3) Sport and commercial fishery
(4) Habitat protection and water related resources

M2 INSTITUTIONAL MEASURES
(1) Environment Ontario, Central Region, and Aquatic Biology and River Systems Sections
(2) Lake Simcoe Region Conservation Authority
(3) Ontario Ministry of Natural Resources — Central Region
(4) Ministry of Tourism and Recreation, Ontario

M3 RESEARCH INSTITUTES ENGAGED IN THE LAKE ENVIRONMENT STUDY
(1) Fisheries Research Section, Fisheries Branch, Ontario Ministry of Natural Resources
(2) Water Resources Branch, Ontario Ministry of the Environment

N. SOURCES OF INFORMATION

(Q) Questionnaire filled by Drs. K. Nicholls, J. Overton (Aquatic Biology Section, Ontario Ministry of the Environment), M. Foy (Water Quality Branch, O.M.E.) and M. Dickman (Biological Sciences Department, Brock University).
(1) Surveys and Mapping Branch, Department of Mines and Technical Services, 1 : 50,000 scale maps. Government of Canada.
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ratory. 183 pp. and 5 plates.
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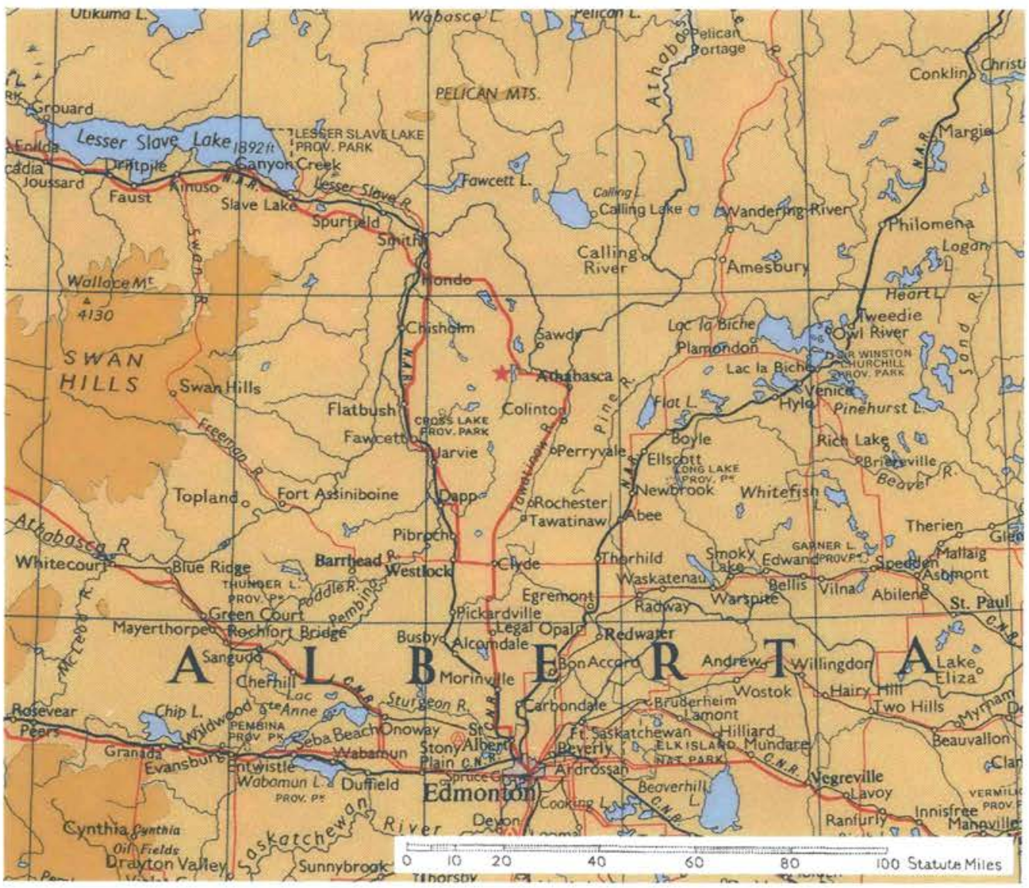
BAPTISTE LAKE

An aerial view of the whole lake

Photo:E.E. Prepas, D. Webb and D.D. Trew



A. LOCATION

§ Alberta, Canada.
§ 54°45′N, 113°33′W ; 578 m above sea level.

B. DESCRIPTION

Baptiste Lake is a very productive medium-sized lake located within the County of Athabasca in central Alberta. It has two distinct basins joined by a long neck, called the Narrows. Both basins are similar in size; the north basin is shallow (15.5 m), whereas the south basin is deep (27.5 m). The lake is situated 165 km northwest of the City of Edmonton and 16 km west of the Town of Athabasca.

The lake was named after Baptiste Majeau, an early settler in the area. The first permanent native settlement on Baptiste Lake was established in the 1880's by a group of Metis from Saskatchewan. They lived on long, narrow lake-front lots. By 1904 farming had begun in the drainage basin, and by 1909 most of the land that was not already settled was available for homesteaders. Much of the present agricultural land was broken first in the period up to 1915.

Although most of the drainage basin, particularly in the western section, remains undeveloped, much of the land around the lake is cleared. There are three private campgrounds and five summer villages on the lake.

The lake is used heavily for fishing, boating and swimming. The public boat launch on the southwest corner is part of a day-use area that includes a large dock, washrooms, picnic shelter and picnic tables. It is operated by the County of Athabasca. There are also private boat launches at the resorts on the south side of the lake, and a small confectionary store. Popular sport fishes include yellow perch, northern pike and walleye. The water quality in Baptiste Lake reflects the nutrient-rich soils in the drainage basin; very dense algal blooms can develop in summer. The shallower north basin generally has heavier blooms than the deeper south basin, but both are classified as hypertrophic.

In the early 1970's, concerns were raised about the effects of rapid development on the many users of the lake and on aspects of water quality. These concerns were followed up in 1975 with an evaluation of cottagers. From 1976 through 1979, Alberta Environment carried out an intensive water quality study of the lake. The goals of this project were to develop methods to evaluate the impact of past, present and future developments, and to manage the water quality of Alberta lakes. In 1977, most lake development was halted while a management plan was developed. In 1979, Alberta Municipal Affairs, in conjunction with the County of Athabasca, developed a plan that would prohibit further subdivision of land for non-farm related residential use at Baptiste Lake. This plan also recommended an approach to deal with concerns about fluctuating water levels and hazardous boating speeds near the lakeshore. As of August 1988, no regulations had been implemented to deal with the concerns on water levels and boating speeds (2 ~8).

C. PHYSICAL DIMENSIONS (9, 10, 11)

Surface area [km²]	9.81
Volume [10⁶m³]	84.6
Maximum depth [m]	15.5 (north)
	27.5 (south)
Mean depth [m]	5.9 (north)
	12.7 (south)
Normal range of annual waterlevel fluctuation [m] (unregulated)	0.2-1
Length of shoreline [km]	26.4
Residence time [yr]	6
Catchment area [km²]	288

D. PHYSIOGRAPHIC FEATURES

D1 GEOGRAPHICAL

§ Sketch map (Fig. NAM-43-1).
§ Bathymetric map (Fig. NAM-43-2).
§ Main islands : None.
§ Outflowing rivers and channels (number and name) : 1 (Baptiste Creek).

D2 CLIMATIC

Temperature : Athabasca (16 km east of lake), 1951-1980 (12).
Precipitation : Baptiste Lake, 1972-1977 (10).

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean temp. [°C]	-17.9	-11.9	-6.4	3.4	10.1	14.1	16.2	14.8	9.5	4.6	-6.1	-13.8	1.4
Precipitation [mm]	25	25	17	18	45	66	114	69	46	20	22	33	499

§ Number of hours of bright sunshine : 2,160 hr yr^{-1} (12a).
§ Average solar radiation (Edmonton Stony Plain) : 12.4 MJ $m^{-2}day^{-1}$ (13).

Mean daily global solar radiation [MJ m^{-2}], Edmonton Stony Plain (140 km south of lake) (14).

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
3.65	7.09	12.43	17.53	20.21	21.87	21.89	18.09	12.11	7.69	3.95	2.59

Fig. NAM-43-1 Sketch map of the lake.

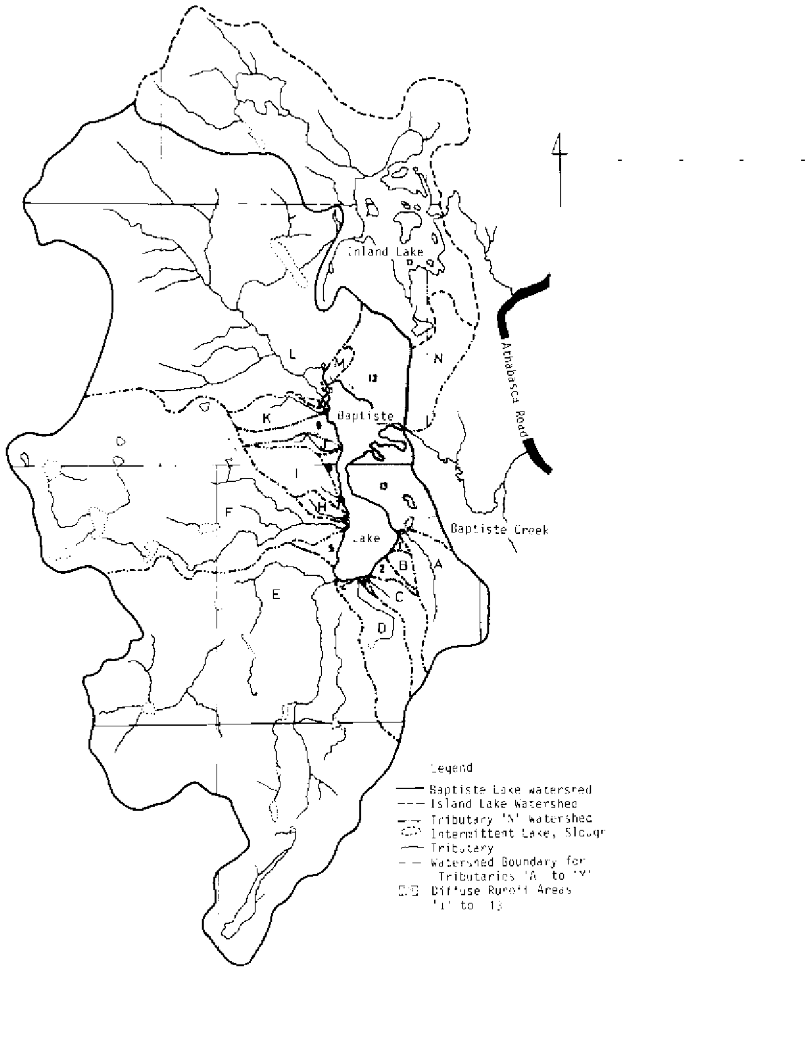


Fig. NAM-43-2 Bathymetric map [m] (11).

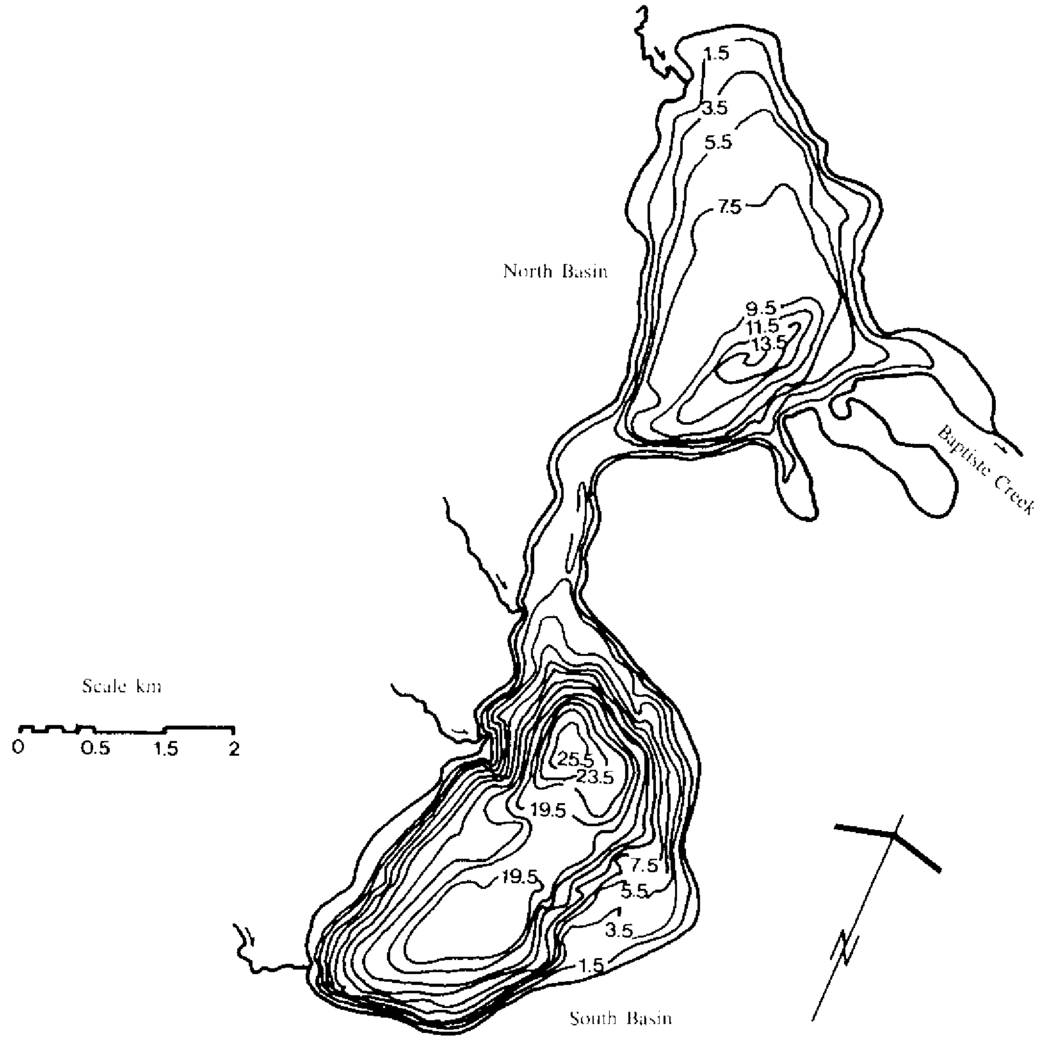


Fig. NAM-43-3 Water temperature [°C] South basin, Jun.-Oct., 1986 (1) and Nov.-Mar. 1982-83 (14).

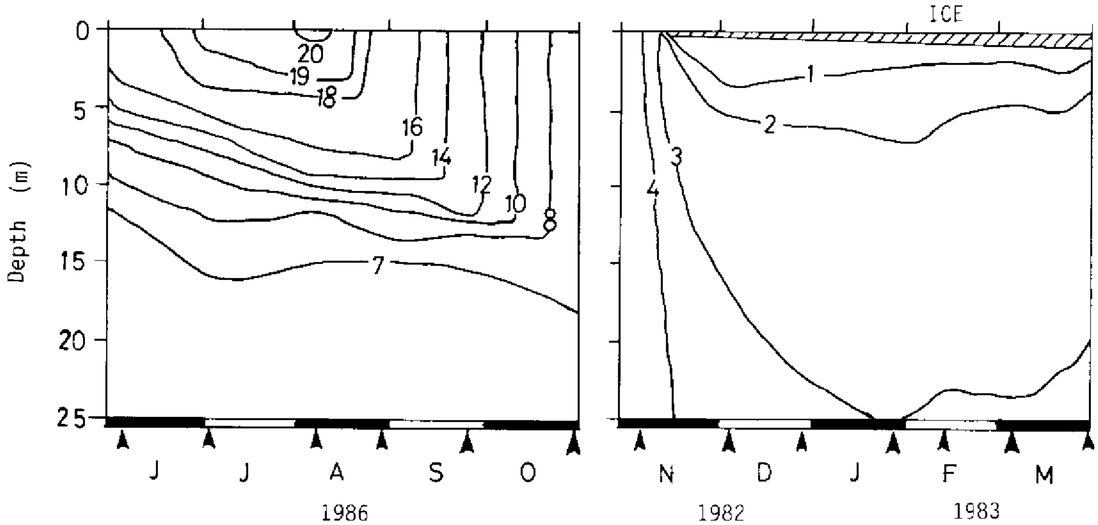
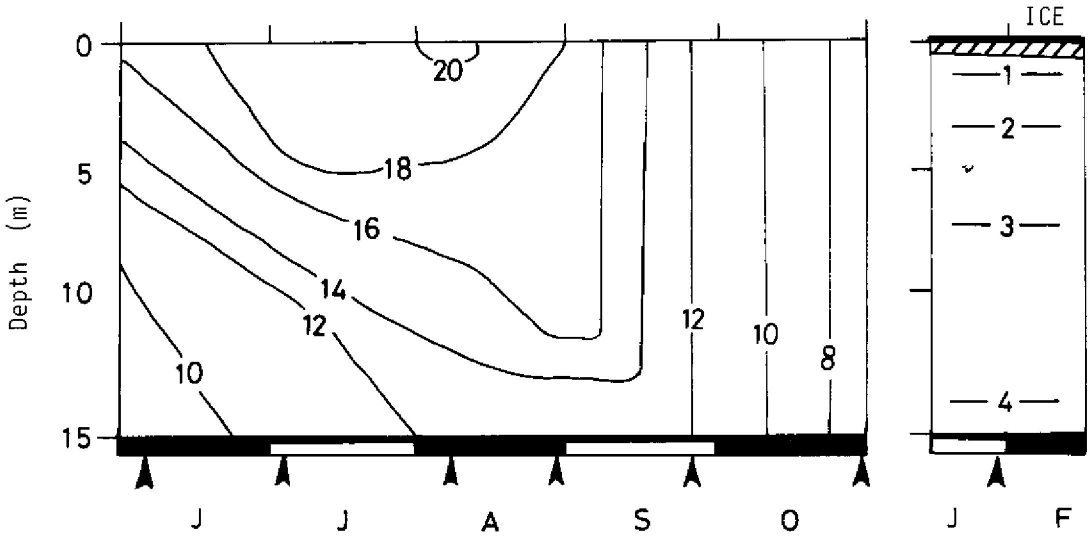


Fig. NAM-43-4 Water temperature [°C] North basin, Jun.-Oct., 1986 and Jan. and Feb., 1987 (1).



§ Freezing period : From mid to late Nov. to mid to late Apr.
§ Mixing type : Partially meromictic.
§ Notes on water mixing and thermocline formation

Appears to exhibit partial meromixis. Difference in specific conductance between surface and bottom waters varies from <10 to >50 over the course of a year. Mixing in spring and fall incomplete in the south basin in most years.

E. LAKE WATER QUALITY

E1 TRANSPARENCY [m]

South basin, 1986 (1)

Jun	Jul	Aug	Sep	Oct
2.2	2.2	1.1	2.2	2.6

E2 pH

South basin, 1986 (1)

Depth [m]	Jun 5	Jul 3	Aug 7	Aug 28	Sep 25	Oct 29
0	8.3	8.4	8.7	8.8	8.2	7.6
2	8.4	8.4	8.4	8.8	8.1	7.6
4	8.2	8.3	8.1	8.5	8.2	7.6
6	7.7	7.8	7.7	8.4	8.2	7.6
8	7.4	7.5	7.3	8.3	8.1	7.6
10	7.3	7.4	7.1	7.4	8.1	7.6
12	7.1	7.4	7.0	7.3	8.1	7.6
14	7.0	7.4	6.9	7.2	7.3	7.6
16	6.9	7.4	6.9	7.1	7.2	7.6
18	6.9	7.4	6.8	7.1	7.2	7.4
20	6.8	7.4	6.7	7.0	—	7.3
22	6.8	7.3	6.6	7.0	—	7.2
24	—	7.3	—	—	—	7.0

E3 SS [mg m^{-2}]

Apr.-Nov., 1976 ; 5,986 (mean ash-free dry wt.) (10).
Apr.-Nov., 1977 ; 5,028 (mean ash-free dry wt.) (10).

E4 DO [mg l^{-1}]

Fig. NAM-43-5 South basin, Jun.-Oct., 1986 (1), Nov.-Mar., 1982-83 (15).

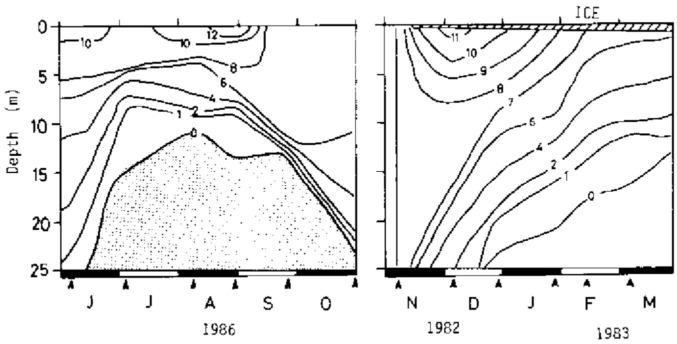
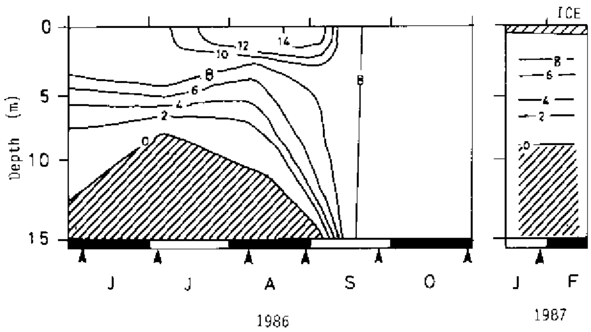


Fig. NAM-43-6 North basin, Jun.-Oct., 1986, Jan.-Feb., 1987 (1).



E6 CHLOROPHYLL CONCENTRATION [μg l^{-1}] (1)

South basin, 1986

Depth	Jun 5	Jul 3	Aug 7	Aug 28	Sep 25	Oct 29
Euphotic zone (composite sample)	11.1	10.9	33.6	41.2	19.3	5.7

E7 NITROGEN CONCENTRATION

§ Total-N concentration [mg l^{-1}] (1)

South basin, 1986

Depth	Jun 5	Jul 3	Aug 7	Aug 28	Sep 25	Oct 29
Euphotic zone (composite sample)	0.863	1.019	1.173	1.18	0.954	1.060

E8 PHOSPHORUS CONCENTRATION

§ Total-P concentration [mg l^{-1}] (1)

South basin, 1986

Depth	Jun 5	Jul 3	Aug 7	Aug 28	Sep 25	Oct 29
Euphotic zone (composite sample)	0.039	0.033	0.042	0.051	0.047	0.084

Fig. NAM-43-7 Total-P, Chlorophyll *a* and Secchi depth in North basin in 1986 (2).

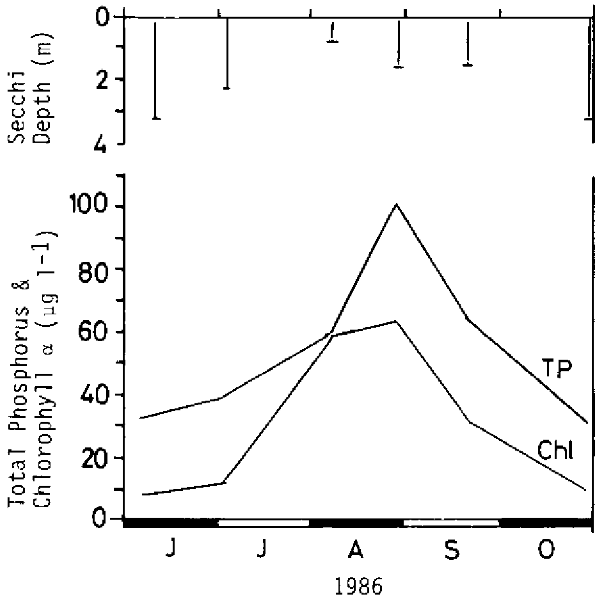
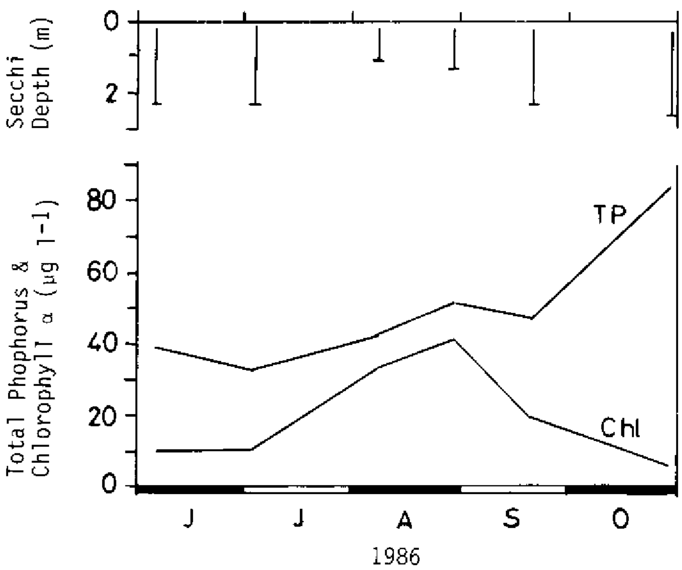


Fig. NAM-43-8 Total-P, chlorophyll *a* and Secchi depth in South basin in 1986 (2).



E9 CHLORIDE ION CONCENTRATION

2 [mg l^{-1}].

F. BIOLOGICAL FEATURES

F1 FLORA

§ Emerged macrophytes

Typha latifolia, *Scirpus validus*, *Nuphar variegatum*, *Phragmites communis*. Additional species identified ; *Carex* sp., *Equisetum fluviatile*, *Polygonum natans*, *Sparganium eurycarpum* (16).

§ Floating macrophytes : *Lemnor minor*, *L. trisulca*, *Spirodela polyrhiza* (16).

§ Floating leaf macrophytes : *Nuphar variegatum* (16).

§ Submerged macrophytes

Potamogeton richardsonii, *P. friesii*, *P. pectinatus*, *P. pusillus*, *P. vaginatus*, *P. zosteriformis*, *Myriophyllum exalbescens*, *Ranunculus circinatus*, *Ruppia maritima*, *Sagittaria cuneata* (16).

§ Phytoplankton

Dominant phytoplankton in the South basin in order of biomass (epilimnion composites), 1986 (1).

Date	Species
Jun. 5	*Synedra delicatissima, Peridinium willie, Uroglena americana, Cyclotella kutzingiana, Cryptomonas erosa*
Jul. 3	*Anabaena flos-aquae, Oscillatoria agardhii, Aphanizomenon flos-aquae, Ceratium hirundinella*
Aug. 7	*Ceratium hirundinella, Anabaena flos-aquae, Aphanizomenon flos-aquae, Peridinium willie, Microcystis aeruginosa*
Aug. 28	*Ceratium hirundinella, Melosira granulata, Anabaena flos-aquae, Stephanodiscus niagarae, Peridinium willie*
Sep. 25	*Melosira italica, M. granulata, Ceratium hirundinella, Stephanodiscus niagarae, Cryptomonas erosa*
Oct. 29	*Cryptomonas erosa, C. reflexa, Melosira italica, Mallomonas tonsurata*

Phytoplankton composition [%] in the South basin (epilimnion composites), 1986 (1).

	Jun 5	Jul 3	Aug 7	Aug 28	Sep 25	Oct 29
Chlorophyta	3.0	1.0	1.3	0.5	1.0	6.5
Cyanophyta	0.0	86.7	38.4	7.4	15.9	14.8
Chrysophyta	15.5	0.6	0.2	0.0	0.9	11.0
Bacillariophyta	44.6	4.2	1.0	9.9	58.4	20.2
Pyrrhophyta	25.4	5.1	57.9	80.3	10.7	1.1
Cryptophyta	11.5	2.3	1.1	1.8	13.2	46.3

F2 FAUNA (10)

§ Zooplankton

South basin

Rotifers (*Keratella quadrata, K. cochlearis, K. testudo, Kellicottia longispina, Asplanchna priodonta, Filinia longiseta, Conochilus unicornis, C. natans, Synchaeta, Polyarthra dolichoptera, Pompholyx sulcata, Trichocerca multicrinis, Brachionus angularis*); Crustacea (*Diacyclops bicuspidatus thomasi, Bosmina longirostris, Daphnia galeata mendotae, D. pulex, D. pulicaria, D. retrocarva, Ceriodaphnia lacustris, Chydorus sphaericus, Diaptomus oregonensis, Acanthocyclops vernalis, Leptodora kindti, Diaphanosoma leuctenbergianum, Mesocyclops edax*); Diptera (*Chaoborus flavicans*).

§ Fish

Perca flavescens, Esox lucius, Stizostedion vitreum, Coregonus artedii, Lota lota, Catostomus commersoni, Notropis hudsonius, Etheostoma exile, Culaea inconstans, Pungitius pungitius, Thymallus arcticus (in tributary streams).

F3 PRIMARY PRODUCTION RATE

§ Annual primary production rate [g C $m^{-2}yr^{-1}$] (10)

South basin, Oct. 1976–Nov. 1977 : 250.

F4 BIOMASS

§ Algal biomass [mg (wet wt.) l^{-1}]

South basin, 1986 (1)

Depth	Jun 5	Jul 3	Aug 7	Aug 28	Sep 25	Oct 29
Euphotic zone (composite sample)	2.16	2.57	8.26	11.88	2.30	0.95

§ Zooplankton biomass (>250 μm) [μg P l^{-1}] (in equivalent of total phosphorus)
South basin, 1982 (17)

Depth	May 18	Jun 8	Jun 28	Jul 20	Aug 10	Sep 1	Sep 21
Euphotic zone (composite sample)	0.2	0.2	1.9	7.6	9.3	7.2	3.9

G. SOCIO-ECONOMIC CONDITIONS (10)

G1 LAND USE IN THE CATCHMENT AREA (1976)

	Area [km^2]	[%]
Natural landscape		
Woody vegetation (forested)	1,706.5	59.3
Swamp (wetland)	644.2	22.4
Others (lakes & ponds)	<34.7	1.2
Agricultural land	482.3	16.8
Settlement area	<10	0.3
Total	2,877.7	100

§ Types of important forest or scrub vegetation
Picea mariana, *Populus tremuloides*, *P. balsamifera*, *Salix* sp., *Betula* sp.
§ Main kinds of crops and cropping system : Mixed farming.

G3 POPULATION IN THE CATCHMENT AREA (1976) (10)

	Population	Population density [km^{-2}]	Main cities
Urban	0	0	
Rural	100	<1	None
Total	100	<1	

H. LAKE UTILIZATION

H1 LAKE UTILIZATION

Recreation (swimming, sport-fishing and boating).

I. DETERIORATION OF LAKE ENVIRONMENTS AND HAZARDS

I2 TOXIC CONTAMINATION

§ Present status : No information.

I3 EUTROPHICATION

§ Nuisance caused by eutrophication : Unusual algal bloom (*Anabaena* spp., *Gomphosphaeria* sp., *Aphanizomenom flos-aquae*, *Microcystis aeruginosa*, *Coelosphaerium* sp.).
§ Nitrogen and phosphorus loadings (1977) [kg yr^{-1}] (10)

Sources	Industrial	Others (total)
T-N	0	37,136
T-P	0	3,407

§ Supplementary notes

Sediment core analysis confirms that Baptiste Lake has been hypertrophic for centuries (10).

I4 ACIDIFICATION

§ Extent of damage: None.

J. WASTEWATER TREATMENTS

J1 GENERATION OF POLLUTANTS IN THE CATCHMENT AREA: (c) Some discharge of pollution load into the lake.

J2 APPROXIMATE PERCENTAGE DISTRIBUTION OF POLLUTANT LOADS

	Percentage
Non-point sources (agricultural, natural and dispersed settlements)	100
Total	100

L. DEVELOPMENT PLANS

Restricted at present (18).

M. LEGISLATIVE AND INSTITUTIONAL MEASURES FOR UPGRADING LAKE ENVIRONMENTS

M1 NATIONAL AND LOCAL LAWS CONCERNED

§ Names of the laws
- (1) Clean Water Act
- (2) Clean Air Act
- (3) Public Health Act

§ Responsible authorities
- (1) Alberta Ministry of the Environment
- (2) Alberta Ministry of the Environment

§ Main items of control
- (1) Industrial and municipal discharges

M2 INSTITUTIONAL MEASURES

- (1) Edmonton, Monitoring of Lakes and Pollution Control (1970); Alberta Environment
- (2) Alberta Environment, Environmental Quality Monitoring Branch (1976-1978) and long-term monitoring (1983-present)

M3 RESEARCH INSTITUTE ENGAGED IN THE LAKE ENVIRONMENT STUDY

- (1) University of Alberta.

N. SOURCES OF DATA

(Q) Questionnaire filled by Drs. E. E. Prepas and D. Webb, Department of Zoology, Faculty of Science, University of Alberta, and by Dr. D. D. Trew, Environmental Quality Monitoring Branch, Environmental Assessment Division, Alberta Environment, based on the following sources.

(1) Alberta Environment, Environmental Quality Monitoring Branch, Environmental Assessment Division, Environmental Protection Services.

(2) Prepas, E. E. (1990) Baptiste Lake. "Atlas of Alberta Lakes" (ed. Mitchell, P. A. & Prepas, E. E.), in press, the University of Alberta Press, Edmonton.

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(4) Athabasca Historical Society, D. Gregory and Athabasca University (1986) Athabasca Landing: An Illustrated History. Athabasca Historical Society, Athabasca.

(5) Stone, D. (1970) The process of rural settlements in the Athabasca area, Alberta. M. A. Thesis, Department of Geography, University of Alberta, Edmonton.
(6) Thomas, J. G., Erickson, R. R., Warren, W. W. & Dack, C. T. (1977) Cottage Owner Survey : Island Lake, Baptiste Lake. Alberta Municipal Affairs, Planning Services Division, Edmonton.
(7) Trew, D. O., Beliveau, D. J. & Yonge, E. I. (1978) The Baptiste Lake Study Summary Report. Alberta Environment, Water Quality Control Branch, Pollution Control Division, Environmental Protection Services, Edmonton.
(8) Alberta Municipal Affairs, Planning Services Division, Regional Planning Section (1979) Baptiste Lake Area Structure Plan. Prepared for County of Athabasca and Summer Village of Sunset Beach.
(9) Alberta Environment, Technical Services Division, Survey Branch. Unpublished data, Edmonton.
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(11) Alberta Environment, Technical Services Division, Hydrology Branch. Unpublished data, Edmonton.
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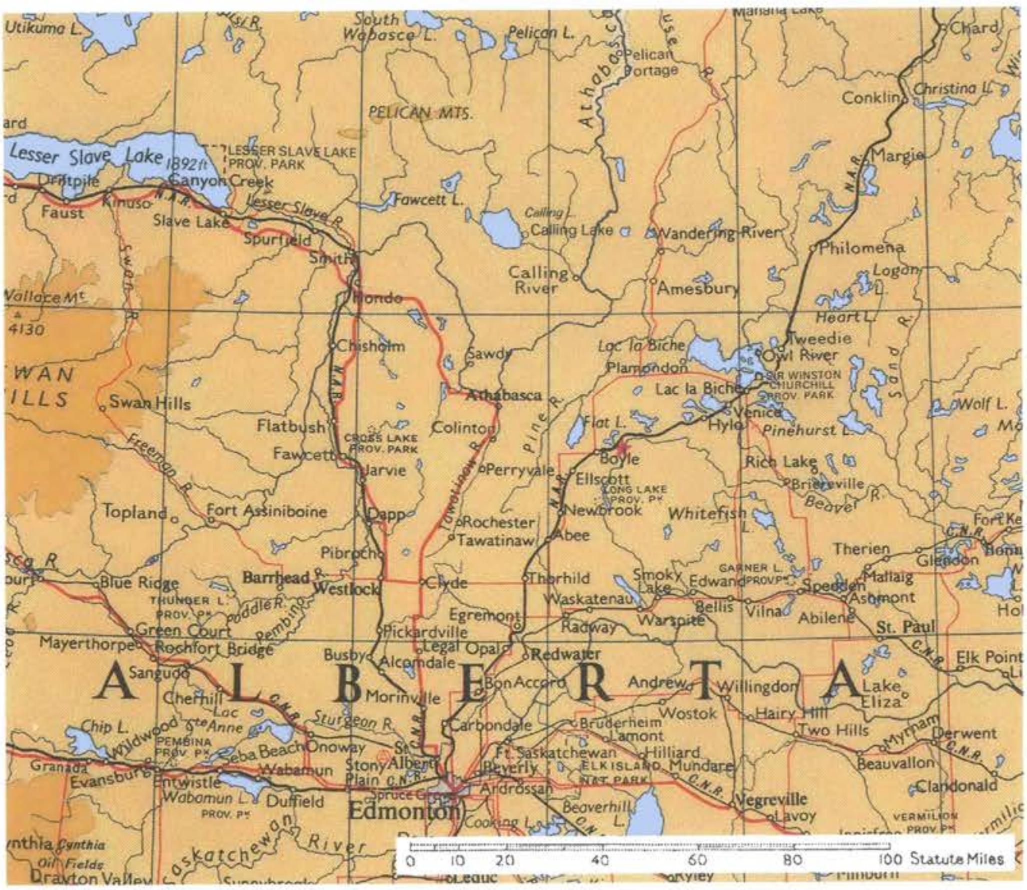
(12a) Environment Canada, Atmospheric Environment Service (1982) Canadian Climate Normals, Vol. 7 : Bright sunshine (1951-1980). Supply and Services, Ottawa.
(13) Environment Canada, Atmospheric Environment Service (1982) Canadian Climate Normals, Vol. 1 : Solar radiation (1951-1980). Supply and Services, Ottawa.
(14) Prepas, E. E. & Babin, J. (University of Alberta). Unpublished data, Edmonton.
(15) Babin, J. (1984) Winter oxygen depletion in temperate zone lakes. M. Sc. Thesis, Department of Zoology, University of Alberta, Edmonton.
(16) Stockerl, E. C. & Kent, R. L. (1984) Aquatic Macrophyte Survey of Baptiste and Nakamun Lakes (1984) Prepared for Alberta Environment, Pollution Control Division, by Okanagan Diving Services (OSD) Consultants, Edmonton.
(17) Prepas, E. E. & Vickery, J. (1984) Contribution of particulate phosphorus (>250 μm) to the total phosphorus pool in lake water. Can. J. Fish. Aquat. Sci., 41 : 351-363.
(18) Alberta Municipal Affairs (1979) Baptiste Lake Area Structure Plan. prep. Prepared for County of Athabasca and summer village of Sunset Beach by Planning and Services Division, Regional Planning Section, Edmonton.

AMISK LAKE

A view on the lake

Photo: D. Webb and E.E. Prepas



A. LOCATION

§ Alberta, Canada
§ 54°35′N, 112°37′W ; 611.6 m above sea level.

B. DESCRIPTION

Amisk Lake is located within Athabasca County in central Alberta. It is 175 km northeast of the city of Edmonton and 15 km east of the village of Boyle. The lake is long and narrow with its main axis running north and south. It has two distinct basins : the larger south basin is very deep (60 m) and the north basin is moderately deep (33 m). The lake derived its name from the local abundance of beaver, "Amisk" in Cree.

Amisk Lake lies at the western edge of the Beaver River drainage basin. Skelton Lake drains into Amisk Lake from the west ; Long Lake drains into Amisk Lake from the south. Water from Amisk Lake flows over a small control structure at the north end into the Amisk River.

In the early 1940's a mink farm and resort with boat and cabin rentals were established on the northwest shore of the lake. The mink were fed with fish from the lake. Over the years these developments were replaced by two subdivisions and a trailer park which was built at the north end of the lake.

The majority of the shoreline, however, remains undeveloped. Fishing, boating and swimming are popular on Amisk Lake. A public boat launch and a day-use area on the northwest side are operated by the Recreation Board of the County of Athabasca. The sport fishery includes yellow perch, northern pike and walleye. The water quality in Amisk Lake reflects the rich soils in the drainage basin. The lake is surrounded by aspen, willow and clumps of white spruce and lodgepole pine. Waterfowl and shorebirds are abundant, especially in the shallow marshy bays.

Amisk Lake is typical of many deep parkland/boreal lakes of Alberta : it experiences high summer algal biomass and phosphorus levels and very low hypolimnetic oxygen levels in mid to late summer and during the last half of ice-cover. In May 1988 researchers from the University of Alberta, the National Water Research Institute (Environment Canada) and Linde (Union Carbide Canada) designed and installed a system to inject pure oxygen into the deep waters of the north basin. The main objective of this unique long-term project is to increase dissolved oxygen levels in the hypolimnion of the north basin. It is anticipated that this will lead to improved water quality as a consequence of decreased phosphorus release from the lake's bottom sediments. The proportion of the basin providing year-round habitat and food resources for sport fish should also be increased (1～8).

C. PHYSICAL DIMENSIONS (7, 8, 9)

Surface area [km²]	5.2
Volume [$10^6 m^3$]	99.8
Maximum depth [m]	60
Mean depth [m]	15.5
Normal range of annual of water level fluctuation (regulated)	0.13
Length of shoreline [km]	24.6
Residence time [yr]	8
Catchment area [km²]	244.0

D. PHYSIOGRAPHIC FEATURES

D1 GEOGRAPHICAL (8)

§ Bathymetric map (Fig. NAM-44-1).
§ Main islands: None.
§ Outflowing rivers and channels (number and names): 1 (Amisk R.).

D2 CLIMATIC

Meanook (45 km west of lake, 1951-1980 (12)

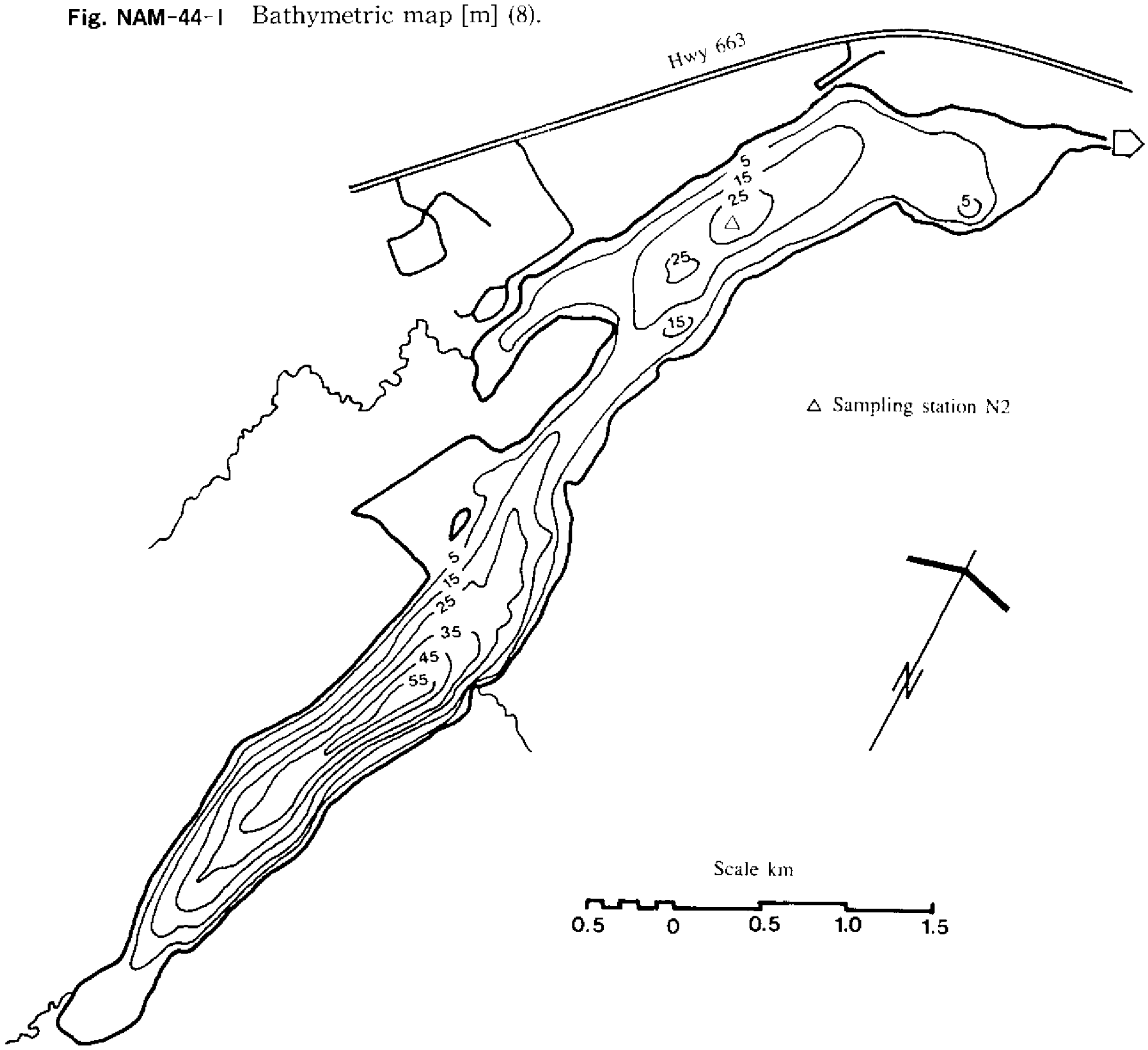
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean temp. [°C]	-16.0	-11.0	-6.0	-3.1	10.4	14.1	16.6	15.2	9.8	4.9	-5.4	-11.8	1.5
Precipitation [mm]	27	23	21	22	41	92	83	78	45	22	24	24	503

§ Number of hours of bright sunshine: 2,263.7 hr yr^{-1} (13).
§ Average solnr radiation: 12.4 MJ $m^{-2}day^{-1}$ at Edmonton Stony Plain (14).

Mean daily global solar radiation [MJ m^{-2}] at Edmonton Stony Plain

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
3.65	7.09	12.43	17.53	20.21	21.87	21.89	18.09	12.11	7.69	3.95	2.59

Fig. NAM-44-1 Bathymetric map [m] (8).

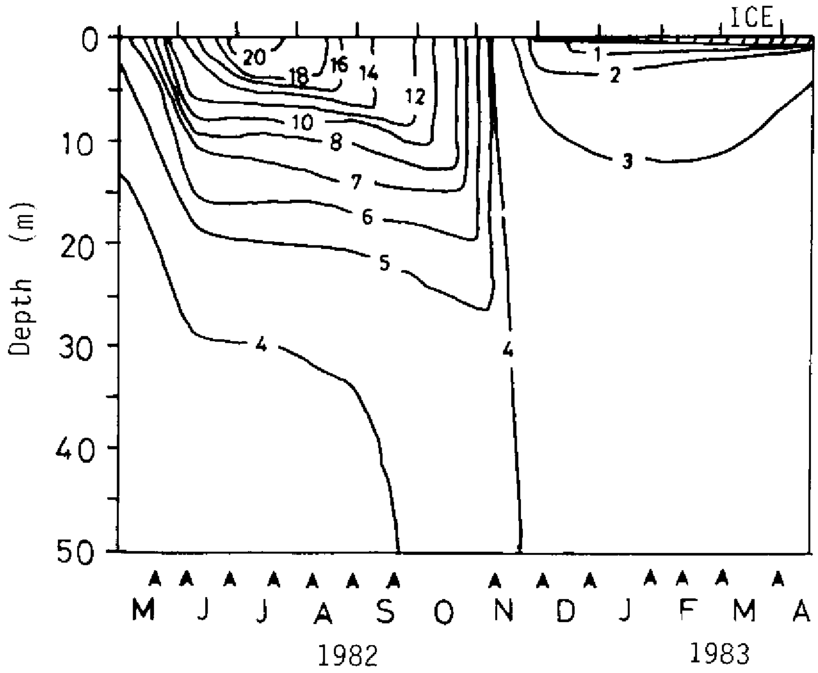


§ Water temperature [°C]
North main deep, May 1982-Apr., 1983 (8, 15)

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Surface	–	–	–	*–	8.1	18.0	20.6	17.6	13.3	–	3.8	ice
1	0.8	0.9	1.0	–	7.8	16.9	20.5	17.5	13.3	–	3.9	0.4
2	1.6	2.4	2.0	–	7.6	15.9	20.4	17.5	13.3	–	4.0	1.4
3	2.2	2.5	2.4	–	6.8	15.3	20.3	17.4	13.3	–	4.0	2.2
4	2.6	2.6	2.7	–	6.6	14.2	18.8	16.4	13.3	–	4.0	2.4
5	2.7	2.9	2.8	–	6.3	12.4	18.0	16.4	13.2	–	4.0	2.6
6	2.8	3.0	2.8	–	6.1	11.0	16.4	16.4	13.2	–	4.0	2.6
7	2.9	3.1	3.0	–	5.9	10.3	12.4	13.6	13.2	–	4.0	2.8
8	3.0	3.1	3.0	–	5.8	9.7	10.7	12.2	12.6	–	4.0	2.9
9	3.0	3.1	3.1	–	5.6	8.8	8.6	9.0	12.3	–	4.0	3.0
10	3.0	3.1	3.2	–	4.9	8.0	7.2	8.0	11.2	–	4.0	3.0
11	3.1	3.2	3.2	–	4.8	7.2	7.0	7.4	9.3	–	4.0	3.1
12	3.1	3.2	3.2	–	4.7	6.8	6.8	7.2	7.8	–	4.0	3.1
13	3.1	3.2	3.2	–	4.7	6.4	6.6	6.9	7.5	–	4.0	3.2
14	3.1	3.2	3.2	–	4.7	6.1	6.2	6.6	7.2	–	4.0	3.2
15	3.1	3.3	3.2	–	4.5	5.8	6.2	6.4	7.0	–	4.0	3.2
16	3.2	3.3	3.4	–	5.4	5.8	6.0	6.4	6.8	–	4.0	3.2
17	3.2	3.3	3.4	–	4.3	5.6	5.9	6.2	6.6	–	4.0	3.2
18	3.2	3.3	3.4	–	4.3	5.5	5.8	6.2	6.6	–	4.0	3.4
19	3.3	3.3	3.4	–	4.2	5.5	5.8	6.1	6.5	–	4.1	3.4
20	3.3	3.4	3.4	–	4.2	5.4	5.8	6.0	6.5	–	4.1	3.4
21	3.4	3.4	3.4	–	4.1	5.4	5.8	6.0	6.4	–	4.1	3.4
22	3.5	3.4	3.4	–	4.1	5.4	5.8	6.0	6.4	–	4.1	3.4
23	3.5	3.5	3.4	–	4.1	5.4	5.6	6.0	6.4	–	4.2	3.6
24	3.5	3.5	3.4	–	4.1	5.3	5.6	6.0	6.3	–	4.2	3.6
25	3.5	3.5	3.5	–	4.1	5.3	5.6	5.8	6.3	–	4.2	3.6
26	3.5	3.4	3.6	–	4.0	5.2	5.6	5.8	6.3	–	4.1	3.6
27	3.6	4.6	3.6	–	4.0	5.2	5.6	5.8	6.3	–	4.1	3.6
28	3.6	3.6	3.6	–	4.0	5.2	5.6	5.8	6.3	–	4.1	3.6
29	3.6	3.6	3.8	–	4.0	5.2	5.6	5.8	6.3	–	4.1	3.6
30	3.6	3.8	3.8	–	4.0	5.2	5.6	5.8	6.3	–	4.1	3.6

* Blanks indicate no data collected.

Fig. NAM-44-2 Temperature-depth profile for South basin (1).



§ Freezing period : Mid to late Nov. to mid to late Apr.
§ Mixing type : Partially meromictic.
§ Notes on water mixing and thermocline formation : Spring and fall mixing has been incomplete in both basins in the past. Thermocline forms any time from early May to early Jun. between depths of 5 m to 10 m.

E. LAKE WATER QUALITY

E1 TRANSPARENCY [m] (8)

North main deep, May 1988-Mar. 1989

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
4.8	6.9	6.0	–	3.1	3.3	2.5	2.2	2.7	3.9	–	7.5

E2 pH (8)

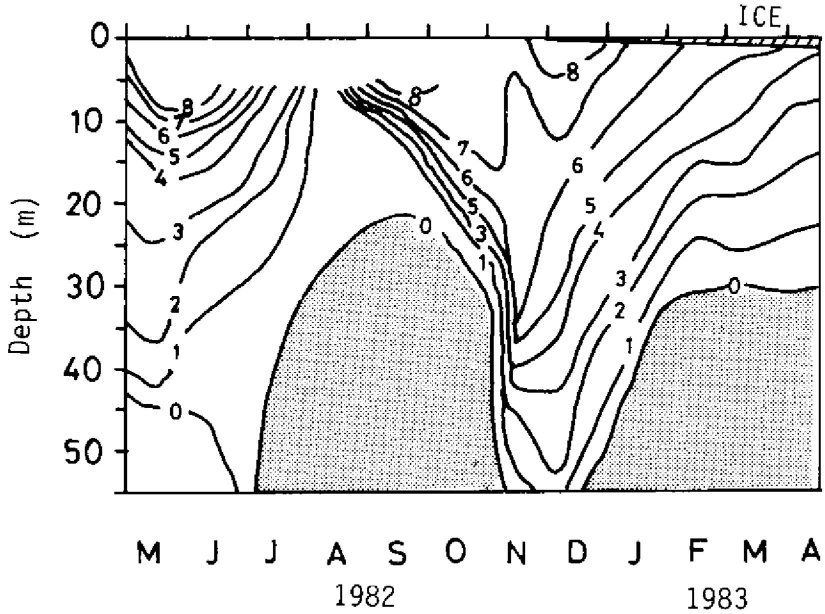
North main deep, May 1988-Mar. 1989

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
0	7.9	7.8	7.7	–	8.3	8.6	8.8	9.0	8.4	8.0
3	8.0	7.8	7.7	–	8.3	8.6	8.8	8.8	8.4	7.7
8	8.0	7.8	7.8	–	7.8	7.9	7.8	7.8	8.4	7.7
18	7.9	7.8	7.8	–	7.7	7.6	7.5	7.6	7.7	7.6
30	7.8	–	7.8	–	7.6	7.5	7.5	7.5	7.6	7.7

E4 DO [mg l⁻¹] (8, 16)
North main deep, May 1982–Mar. 1983

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	6.45	6.04	5.62	*—	—	—	—	—	—	—	8.12	8.34
2	6.22	5.80	5.24	—	—	—	—	—	—	—	8.09	7.96
3	6.01	5.46	4.78	—	—	—	—	—	—	—	8.06	7.70
4	5.79	5.35	4.41	—	—	—	—	—	—	—	7.80	7.64
5	5.50	5.25	4.10	—	—	—	—	—	—	—	7.53	7.81
6	5.37	4.71	3.62	—	—	—	—	—	—	—	7.74	7.97
7	5.15	4.47	3.18	—	—	9.34	3.30	3.98	9.32	—	7.94	8.14
8	4.73	4.23	3.23	—	—	—	—	—	—	—	7.95	7.93
9	4.31	3.52	2.60	—	—	—	—	—	6.76	—	7.95	7.72
10	3.89	3.08	2.12	—	—	—	—	—	3.38	—	8.01	7.57
11	3.75	2.64	1.72	—	—	—	—	—	1.12	—	8.06	7.36
12	3.60	2.45	1.51	—	—	4.04	1.12	0.06	0.05	—	8.06	7.14
13	3.37	2.25	1.14	—	—	—	—	—	0.06	—	8.06	6.94
14	3.14	2.05	0.74	—	—	—	—	—	0.04	—	8.05	6.74
15	2.90	1.82	0.36	—	—	—	—	—	—	—	8.04	6.43
16	2.65	1.44	0.21	—	—	—	—	—	—	—	8.06	6.13
17	2.21	1.05	0.11	—	—	2.53	0.08	0.21	—	—	8.08	5.83
18	1.77	0.73	0.01	—	—	—	—	—	—	—	8.03	5.40
19	1.27	0.40	0.01	—	—	—	—	—	—	—	7.98	4.96
20	0.77	0.31	0.01	—	—	—	—	—	—	—	8.08	4.34
21	0.59	0.22	0.00	—	—	—	—	—	—	—	8.19	3.72
22	0.40	0.18	0.00	—	—	2.19	0.06	0.00	—	—	8.20	3.11
23	0.27	0.13	0.00	—	—	—	—	—	—	—	8.20	2.79
24	0.13	0.07	0.00	—	—	—	—	—	—	—	8.19	2.46
25	0.00	0.00	0.00	—	—	—	—	—	—	—	8.17	2.04
26	0.00	0.00	0.00	—	—	—	—	—	—	—	8.17	1.87
27	0.00	0.00	0.00	—	—	1.90	0.16	0.00	—	—	8.17	1.74
28	0.00	0.00	0.00	—	—	—	—	—	—	—	8.12	1.60
29	0.00	0.00	0.00	—	—	—	—	—	—	—	8.06	1.60
30	0.00	0.00	0.00	—	—	1.96	—	0.00	—	—	8.06	0.98

Fig. NAM-44-3 DO-depth profile for South basin (1).



E6 CHLOROPHYLL CONCENTRATION [μg l^{-1}] (8)

North main deep ; euphotic samples (*0–6 m) are whole lake values (mean of 6 or 8 sampling sites) ; May 1988-Mar. 1989

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
*0–6	1.2	0.8	0.8	–	5.3	7.7	10.9	11.9	9.1	–	–	–
3	–	–	–	–	4.1	9.0	16.4	18.5	–	–	–	–
8	–	–	–	–	7.3	4.4	3.9	4.6	–	–	–	–
18	–	–	–	–	2.3	0.8	1.0	0.8	–	–	–	–

E7 NITROGEN CONCENTRATION

§ NO_2-N, NO_3-N, NH_4-N concentration [μg l^{-1}] (8)

North main deep, 1987

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
3	–	–	–	–	1.4	12.2	10.9	6.0	21.1	9.7	–	–
8	–	–	–	–	7.7	74.8	59.9	9.4	13.5	19.0	–	–
18	–	–	–	–	197	248	279	275	309	229	–	–
30	–	–	–	–	227	287	287	301	340	318	–	–

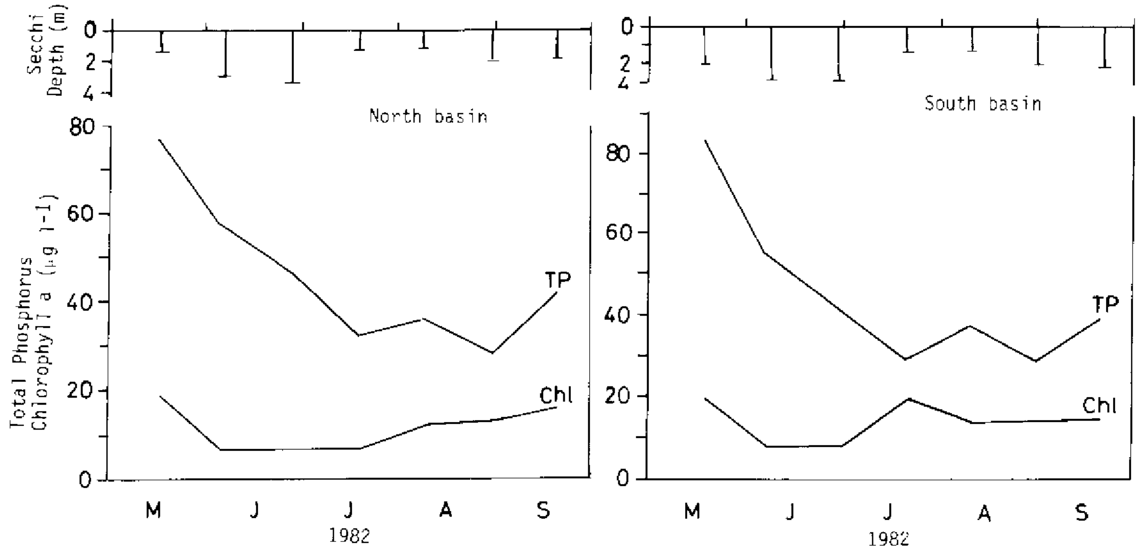
E8 PHOSPHORUS CONCENTRATION

§ Total-P concentration [μg l^{-1}] (8)

North main deep, euphotic samples (*0–6 m) are whole lake values (mean of 6 or 8 sampling sites) ; May 1988-Mar. 1989

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
*0–6	59.1	57.6	61.3	–	34.3	27.6	31.0	28.2	31.2	43.4	–	–
0–6	50.4	54.5	55.6	–	34.5	28.4	30.2	29.1	29.9	51.8	–	48.6
6–12	51.0	54.8	55.7	–	49.5	61.3	68.0	62.8	49.9	48.0	–	46.8
12–18	51.8	54.8	57.2	–	69.5	85.4	100	107	114	44.5	–	47.3
18–24	53.8	56.9	57.1	–	77.5	88.8	107	118	123	42.5	–	47.3
24–30	61.8	58.2	57.5	–	66.8	93.0	113	122	147	42.5	–	65.4
30–33	–	–	–	–	81.6	96.0	114	124	144	45.9	–	–

Fig. NAM-44-4 Seasonal changes in Total-P, chlorophyll *a* and transparency (Secchi depth) (1).



E9 CHLORIDE ION CONCENTRATION

2 [mg l^{-1}].

F. BIOLOGICAL FEATURES

F1 FLORA

§ Emerged macrophytes : *Scirpus validus*.
§ Floating macrophytes : *Nuphar variegatum*.
§ Submerged macrophytes
Potamogeton richardsonii, *P. vaginatus*, *Myriophyllum exalbescens*, *Chara* spp.
§ Phytoplankton (8)
Spring : Bacillariophyta and Cryptophyta.
Summer : Cyanophyta (*Aphanizomenon flos-aquae*, *Gomphosphaeria* sp., *Anabaena dircinalis*) and Pyrrophyta (dinoflagellates).

F2 FAUNA

§ Zooplankton (8, 16, 17)
Spring : *Acanthocyclops vernalis*, *Mesocyclops edax*.
June : *Bosmina longirostris*.
July : *Daphnia galeata mendotae*.
August : *Diaphanosoma leuchtenbergianum*.
§ Benthos : Western limit of *Oreonectes virilus* (crayfish).
§ Fish
Perca flavescens, *Esox lucius*, **Stizostedion vitreum vitreum*, *Coregonus clupeaformis*, **C. artedii*, *Catostomus commersoni*, *Lota lota*, *Notropis hudsonius*, *Culaea inconstans*, *Pungitius pungitius*, *Etheostoma exile* (*economically important) (18).

F4 BIOMASS

§ Plankton biomass [mg (dry wt) m^{-3}]

Depth [m]	Size fraction	May	Jun.	Jul.	Aug.
0-6	<64 μm	247	440	532	483
0-6	<243 μm	165	317	251	161

F5 FISHERY PRODUCTS (19)

§ Annual fish catch : 4,870 kg yr^{-1} sport fisheries in 1985.
4,913 kg yr^{-1} commercial fisheries in 1981-86.

F6 PAST TRENDS

Average commercial harvest has dropped from 9,848 kg yr^{-1} (1944-1961) to 4,913 kg yr^{-1} (1981-1986) (20).

G. SOCIO-ECONOMIC CONDITIONS

G1 LAND USE IN THE CATCHMENT AREA (1985) (1)

	Area [km^2]	[%]
Natural landscape	214.7	88
Agricultural land	9.8	4
Others	19.5	8
Total	244.0	100

§ Types of important forest vegetation : *Populus tremuloides*, *P. balsamifera*, *Pinus contorta* (20).

G2 INDUSTRIES IN THE CATCHMENT AREA AND THE LAKE (1988) (1)

	Main products and major industries
Primary industry	
Crop production	Hay, cereal crops
Tertiary industry	Small public boat launch on northwest side of the lake

G3 POPULATION IN THE CATCHMENT AREA (1988) (8)

	Population	Population density [km^{-2}]	Main cities
Urban	0	0	
Rural	<100 (gross estimate)	<1	None
Total	<100	<1	

H. LAKE UTILIZATION

H1 LAKE UTILIZATION

Recreation (swimming, sport-fishing, boating) and fisheries.

H2 THE LAKE AS WATER RESOURCE (1988)

Use rates of a small amount of domestic water unknown.

I. DETERIORATION OF LAKE ENVIRONMENTS AND HAZARDS

I1 ENHANCED SILTATION

§ Extent of damage : None.

I3 EUTROPHICATION

§ Nuisance caused by eutrophication : Unusual algal bloom (Cyanophyta : *Aphanizomenon flos-aquae, Anabaena circinalis, Gomphospheria*) (8).

§ Supplementary notes

Limited settlement along the lake shore may have enhanced phosphorus loading. However, most of the phosphorus load comes from the rich soils in the drainage basin and from internal loading (6, 17).

J. WASTEWATER TREATMENTS

J1 GENERATION OF POLLUTANTS IN THE CATCHMENT AREA : (b) No major pollution of the lake.

K. IMPROVEMENT WORKS IN THE LAKE

K2 AERATION

A project started in May 1988, involving the injection of pure oxygen into the deep waters of the north basin. The intent is to keep dissolved oxygen concentrations above 2 mg l^{-1} throughout the entire water column year round. Injection rates over the first year have varied from 0.25 to 1 ton liquid oxygen per day. The system involves a pressurized storage tank on the shore, approximately 1.4 km of thick walled hose from the shore to the deepest site in the basin and a 15×2.4 m diffuser constructed with Porex tubing. The diffuser sits at a depth of 34 m. This process was chosen to improve fisheries habitat. The impact on water quality is also being evaluated. This process was chosen because it is relatively economical and ideal for remote sites.

M. LEGISLATIVE AND INSTITUTIONAL MEASURES FOR UPGRADING LAKE ENVIRONMENTS

M1 NATIONAL AND LOCAL LAWS CONCERNED

§ Names of the laws

(1) Clean Water Act
(2) Clean Air Act
(3) Public Health Act

§ Responsible authorities

(1) Alberta Ministry of the Environment
(2) Alberta Ministry of the Environment

§ Main items of control

(1) Industrial and municipal discharges

M2 INSTITUTIONAL MEASURES

(1) Alberta Ministry of the Environment, Edmonton — Monitoring of lakes and pollution control (1970)

M3 RESEARCH INSTITUTES ENGAGED IN THE LAKE ENVIRONMENT STUDY

(1) University of Alberta has been monitoring water quality since 1980; oxygenation project started 1988
(2) National Water Research Institute, Environment Canada, involved with oxygenation project started 1988

N. SOURCES OF DATA

(Q) Questionnaire filled by Drs. D. Webb & E. Prepas, Department of Zoology, The University of Alberta Edmonton, Alberta.

(1) Prepas, E. E. (1990) Amisk Lake. "Atlas of Alberta Lakes" (ed. Mitchell, P. A. & Prepas, E. E.), in press, the University of Alberta Press, Edmonton.

(2) Chipeniuk, R. C. (1975) Lakes of the Lac la Biche District. R. C. Chipeniuk, Lac la Biche, Alberta.

(3) Holmgren, E. J. & P. M. (1976) Over 2000 Place Names of Alberta. 3rd ed. Saskatoon, Saskatchewan: Western Producer Prairie Books, Saskatoon.

(4) Boyle and District Historical Society (1982) Forests, Furrows and faith: A History of Boyle District. Boyle, Alberta: Boyle and District Historical Society, Athabasca.

(5) Prepas, E. E. & Trimbee, A. M. (1987) Evaluation of indicators of nitrogen limitation in deep prairie lakes with laboratory bioassays and limnocorrals. Hydrobiol. 159; 269-276.

(6) Prepas, E. E. & Vickery, J. (1984) Seasonal changes in total phosphorus and the role of internal loading in western Canadian lakes. Verh. Int. Verein. Limnol., 223: 303-308.

(7) Babin, J. & Prepas, E. E. (1985) Modelling winter oxygen depletion rates in ice-covered temperate zone lakes in Canada. Can. J. Fish. Aquat. Sci., 42: 239-249.

(8) Prepas, E. E., Webb, D. J., Wisheu, I. & Trimbee, A. M. Unpublished data. University of Alberta, Edmonton.

(9) Alberta Environment, Technical Services Division, Hydrology Branch. Unpublished data. Edmonton.

(10) Prepas, E. E. & Trew, D. O. (1983) Evaluation of the phosphorus-chlorophyll relationship for lakes off the Precambrian Shield in western Canada. Can. J. Fish. Aquat. Sci., 40: 27-35.

(11) Province of Alberta, Canada 1987 Official Road Map. Government of Alberta.

(12) Environment Canada, Atmospheric Environment Service. Canadian Climate Normals, Temperature and Precipitation (1951-1980), Prairie Provinces. Supply Serv., Ottawa.

(13) Environment Canada, Atmospheric Environment Service (1982) Canadian Climate Normals, Vol. 7, Bright Sunshine (1951-1980). Supply Serv., Ottawa.

(14) Environment Canada, Atmospheric Environment Service. Canadian Climate Normals, 1951-1980, Solar Radiation. Supply Serv., Ottawa.

(15) Prepas, E. E. (1983) The Influence of Phosphorus and Zooplankton on Chlorophyll Levels in Alberta Lakes. Alberta Environment, Res. Manage. Div., Rep. 83/23. Edmonton.

(16) Babin, J. (1984) Winter oxygen depletion in temperate zone lakes. M. Sc. Thesis, University of Alberta, Edmonton. 108 pp.
(17) Prepas, E. E. & J. Vickery (1984) The contribution of particulate phosphorus (>250 μm) to the total phosphorus pool in lake water. Can. J. Fish. Aquat. Sci., 41 : 351-363.
(18) Norris, H. J. (1987) Personal communication as cited in (1). Alberta Fish and Wildlife Division, St. Paul.
(19) Sullivan, M. G. (1987) Characteristics and Impact of the Sport Fishery at Amisk Lake during May-August 1985. Alberta Energy and Natural Resources, Fish and Wildlife Division, St. Paul.
(20) Strong, W. L. & K. R. Leggat (1981) Ecoregions of Alberta. Alberta Energy Nat. Res., Resource Eval. Plan. Div., Edmonton.

WABAMUN LAKE

An aerial view of the lake

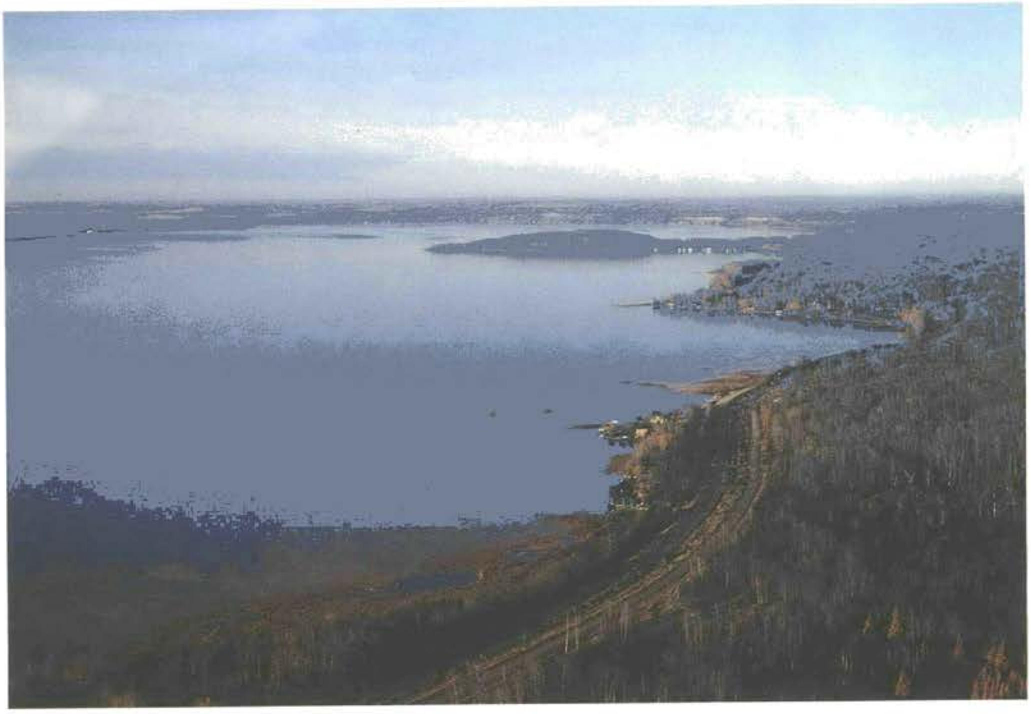
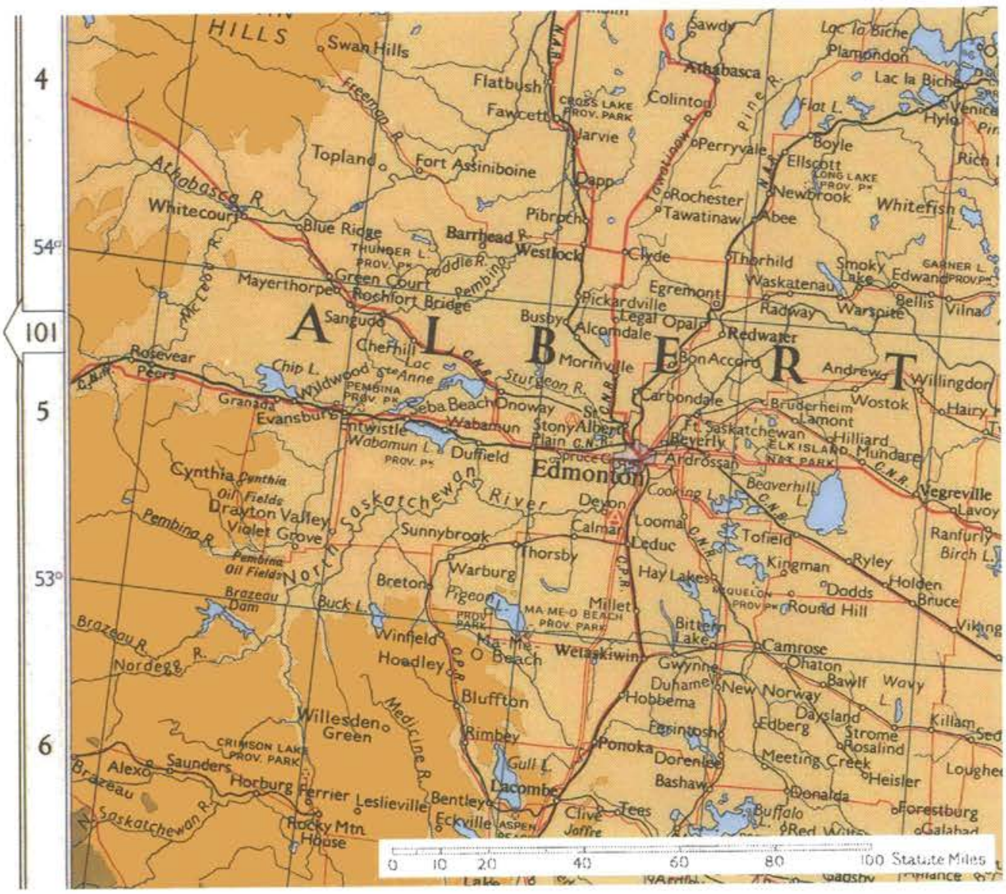


Photo: P. Mitchell



A. LOCATION

§ Alberta, Canada.
§ 53°33′N, 114°36′W ; 724.7 m above sea level.

B. DESCRIPTION

Lake Wabamun, one of the best-known lakes of Alberta, lies 60 km west of Edmonton. The name "Wabamun" is a Cree word meaning mirror.

Lake Wabamun is a large shallow lake that is 19.2 km long and 6.6 km wide. Its long fetch along the prevailing wind results in heavy wave action at times. The deepest area reaching 11 m is at the western end. There are natural beaches along much of the shoreline, but emergent vegetation restricts their use. The littoral zone (<5 m depth) includes 31 % of lake bottom. Sandy areas are found at depths less than 2 m with soft clay or organic sediments over most of the lake bottom.

The range of water level fluctuation since the earliest records (1915 ; continuous records since 1933) amounts to about 1.4 m, although normal range is about 1 m on approximately a ten-year cycle. Since 1912 a number of control structures have been built and subsequently destroyed on one or the other of the two outlet creeks. As of 1989 investigations were underway to determine an elevation for a suitable control structure.

Despite abundant aquatic vegetation along shorelines and in bays, the water in L. Wabamun is often fairly clear and blue-green algal blooms are rare. The popular oipinion is that the nuisance growth of an aquatic weed, *Elodea canadensis*, which was not observed in the lake before 1968, caused poor water quality. The cooling water discharge from two power plants on the shore were implicated as the cause. Since the diversion of cooling water to a large cooling pond in 1975, *Elodea* began to decline simultaneously, and is now rare in the lake, except near the cooling water discharge canal from the 3rd power plant.

The drainage basin surrounding the lake is about three times as wide as the lake surface ; the terrain is gently rolling to undulating hills to the south of the lake. The native vegetation is dominated by trembling aspen, balsam poplar and willow with white spruce in undisturbed areas. About half of the land is used for agriculture. Coal is strip-mined extensively north and south of the lake. As coal excavation moves west, the mined-out land is reclaimed, primarily for agricultural purposes, but reclamation efforts will include recontouring and the return of native vegetation.

At least 35 drainage courses convey runoff and groundwater to the lake, of which the seven largest account for about 70 % of the total runoff. Mine drainage enters the lake after settling in several ponds. Two outlets, one of which is a man-made through-cut, join to form Wabamun Creek, which flows intermittently toward the North Saskatchewan River.

The community of Wabamun was established in 1912. The first coal mines in the lake's watershed began underground operations in 1910 ; strip mining began in 1948. Three power plants have been built by TransAlta Utilities to take advantage of the abundant supply of local coal. At present only one (started operation in 1983) uses lake water for cooling, and heated effluent is returned to Kapasiwin Bay, where a large portion of the bay area remains ice-free in winter.

The provincial park located on Moonlight Bay is a focus of activity on warm summer weekends, such as boating, swimming, fishing, camping, and hiking. Fishing is one of the most popular activities on the lake. In summer, fishing is often excellent for northern pike and increasingly so for walleye. In winter, ice-fishing for whitefish draws hundreds of fishermen on mild weekends and large pike may be taken from the outlet canal at the power plant (4, 5, 11, 12).

C. PHYSICAL DIMENSIONS

Surface area [km^2]	81.8
Volume [$10^6 m^3$]	513
Maximum depth [m]	11
Mean depth [m]	6.3
Normal range of annual water level fluctuation (unregulated) [m]	1
Length of shoreline [km]	57.3
Residence time [yr]	>100
Catchment area [km^2]	259

D. PHYSIOGRAPHIC FEATURES

D1 GEOGRAPHICAL

§ Bathymetric map (Fig. NAM-45-1).
§ Main islands : None.
§ Outflowing rivers and channels (number and name) : 1 (Wabamun Creek).

D2 CLIMATIC

§ Climatic data at Highvale (3 km from Wabamun Lake), 1985 (17)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean temp. [°C]	-6.9	-11.3	-0.7	5.6	12.5	13.0	17.9	14.5	7.3	4.0	-12.4	-3.2	3.4
Precipitation [mm]	23	18	3	49	38	73	44	112	69	25	17	–	471

§ Mean annual precipitation : 534 mm (6).
§ Number of hours of bright sunshine : 2,315 hr yr^{-1} (10).
§ Average solar radiation (Edmonton Stony Plain, 22 km east of Wabamun Lake) : 12.4 MJ m^{-2} day^{-1} (10).

Mean Daily Global Solar Radiation [MJ $m^{-2}day^{-1}$]

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
3.65	7.09	12.43	17.53	20.21	21.87	21.89	18.09	12.11	7.69	3.95	2.59

Fig. NAM-45-1 Bathymetric map [m] (1).

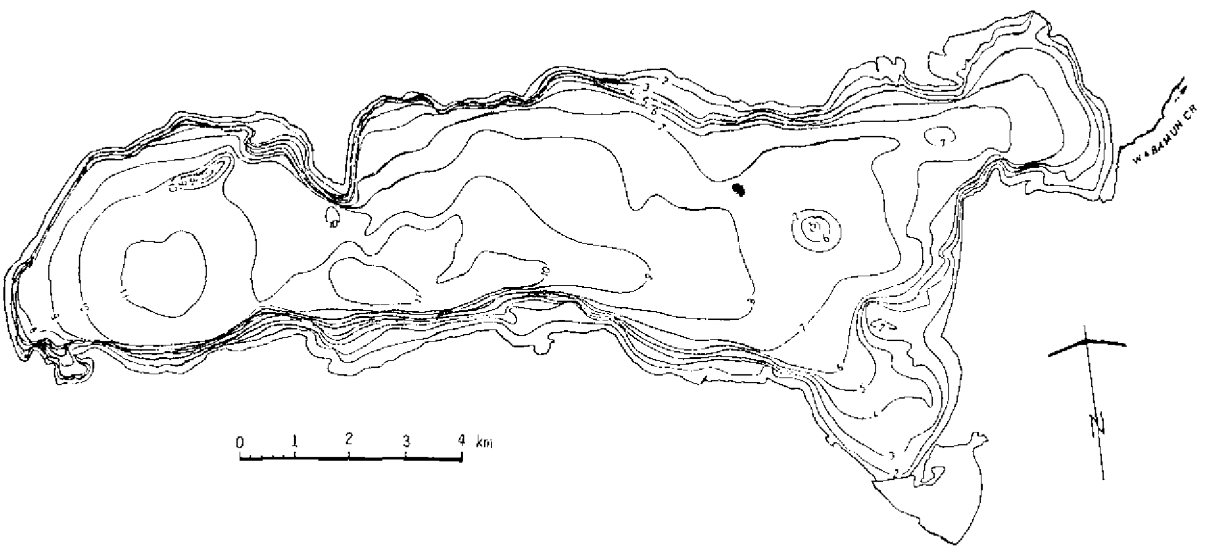


Fig. NAM-45-2 Area/capacity curve for Wabamun Lake (16).

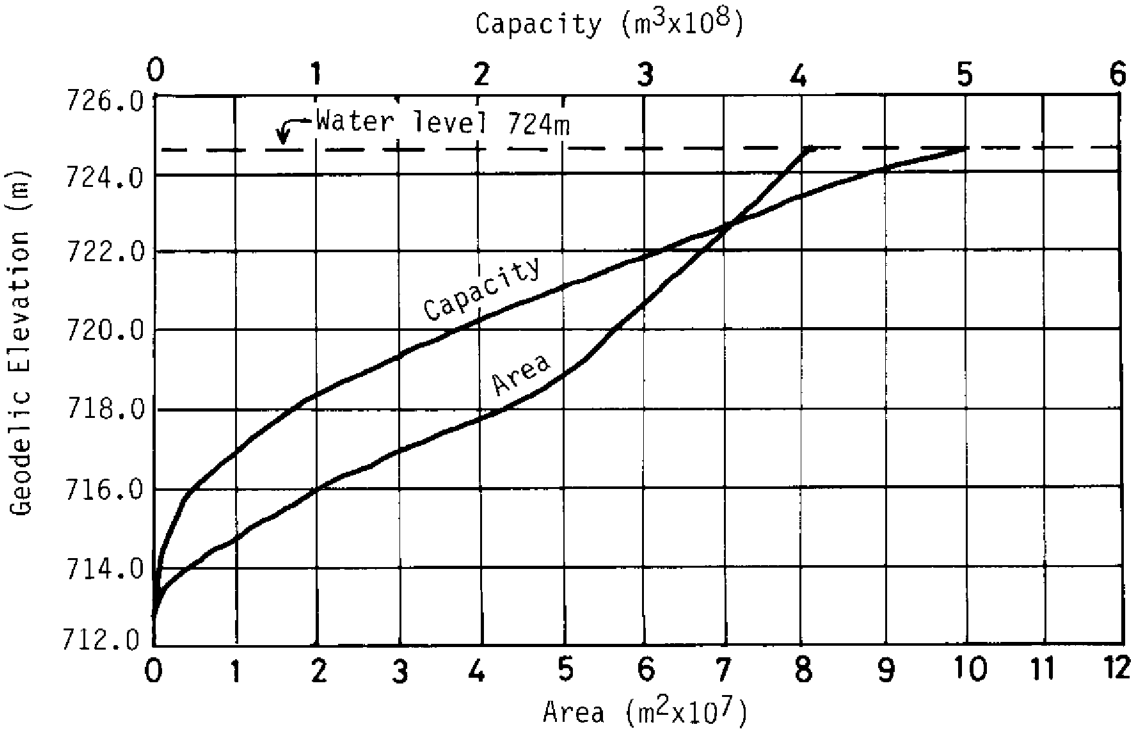
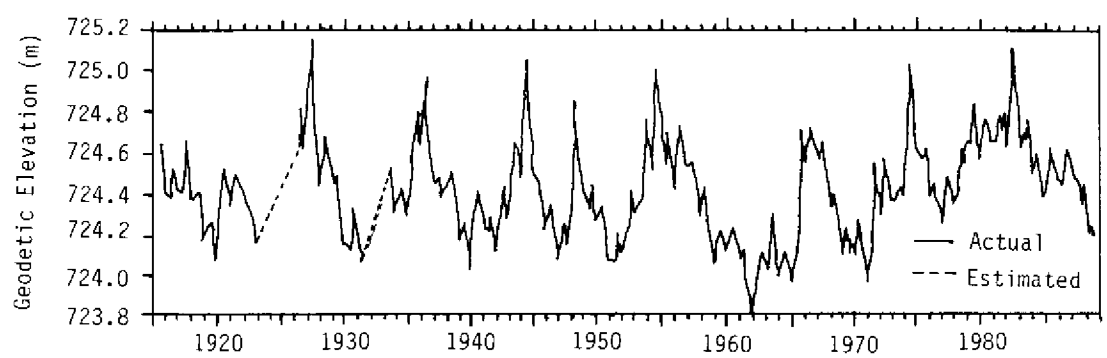


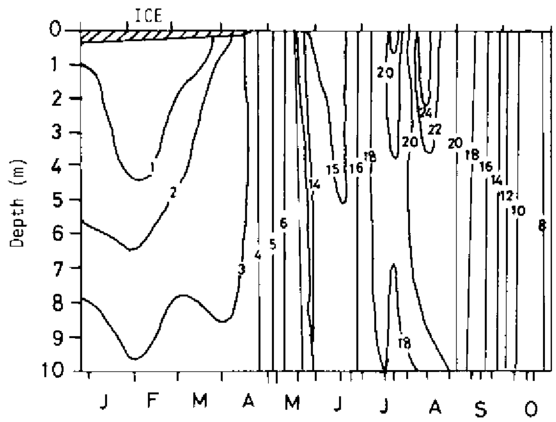
Fig. NAM-45-3 Water level of the lake between 1915 and 1987 (29).

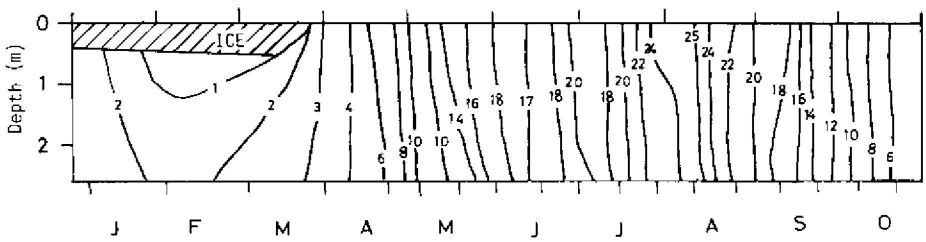


§ Water temperature [°C]
Centre of East basin, 1981 (18)

Depth [m]	1980 Nov	Dec	1981 Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
0	3.5	–	0.4	0.1	0.1	3.4	7.0	15.7	18.0	25.6	17.9	10.3
1	3.5	–	0.6	0.4	0.6	3.4	7.0	15.8	17.9	25.2	17.9	10.3
2	3.5	–	0.8	1.2	1.0	3.0	7.0	15.8	17.9	25.2	17.8	10.3
3	3.5	–	1.0	2.5	1.5	2.9	7.0	15.8	17.9	24.5	17.7	10.3
4	3.5	–	1.4	3.1	2.3	2.6	7.0	15.8	17.9	22.7	17.5	10.2
5	3.5	–	2.9	3.4	2.9	2.6	7.0	15.8	17.9	21.8	16.7	10.2
6	3.5	–	3.2	3.5	3.8	2.6	7.0	15.8	17.9	21.4	16.5	10.2
7	3.5	–	3.3	3.5	3.9	2.7	7.0	15.8	17.9	20.6	16.4	10.2

Fig. NAM-45-4 Temperature profile [°C] for 1981, at Wabamun West (top) and Moonlight Bay (bottom), (1, 18).





§ Freezing period : Nov. 1 to Apr. 26.
§ Mixing type : Polymictic.
§ Notes on water mixing and thermocline formation

Usually the lake does not stratify. On rare occasions in midsummer. When a thermocline forms, it may last only a few days. Normally, the lake is mixed to its bottom during summer (cold polymictic).

E. LAKE WATER QUALITY

E1 TRANSPARENCY [m]

Centre East, 1987 (18)

May	Jun	Jul	Aug	Sep	Oct
3.5	3.0	2.1	1.8	2.5	3.3

E2 pH

Centre East, 1987 (18)

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
0	–	–	–	–	8.5	8.1	8.6	8.9	8.8	8.4
1	8.2	–	–	–	8.5	8.2	8.5	8.9	8.8	8.3
2	8.3	–	–	–	8.5	8.2	8.5	8.9	8.8	8.5
3	8.4	–	–	–	8.5	8.2	8.5	8.9	8.8	8.6
4	8.4	–	–	–	8.6	8.2	8.5	8.9	8.8	8.6
5	8.3	–	–	–	8.6	8.2	8.4	8.9	8.8	8.7
6	8.2	–	–	–	8.5	8.2	8.3	8.9	8.7	8.7
7	7.4	–	–	–	8.5	8.2	8.3	8.8	8.5	8.7

E3 SS [mg l⁻¹]

Centre East, 1987 (18)

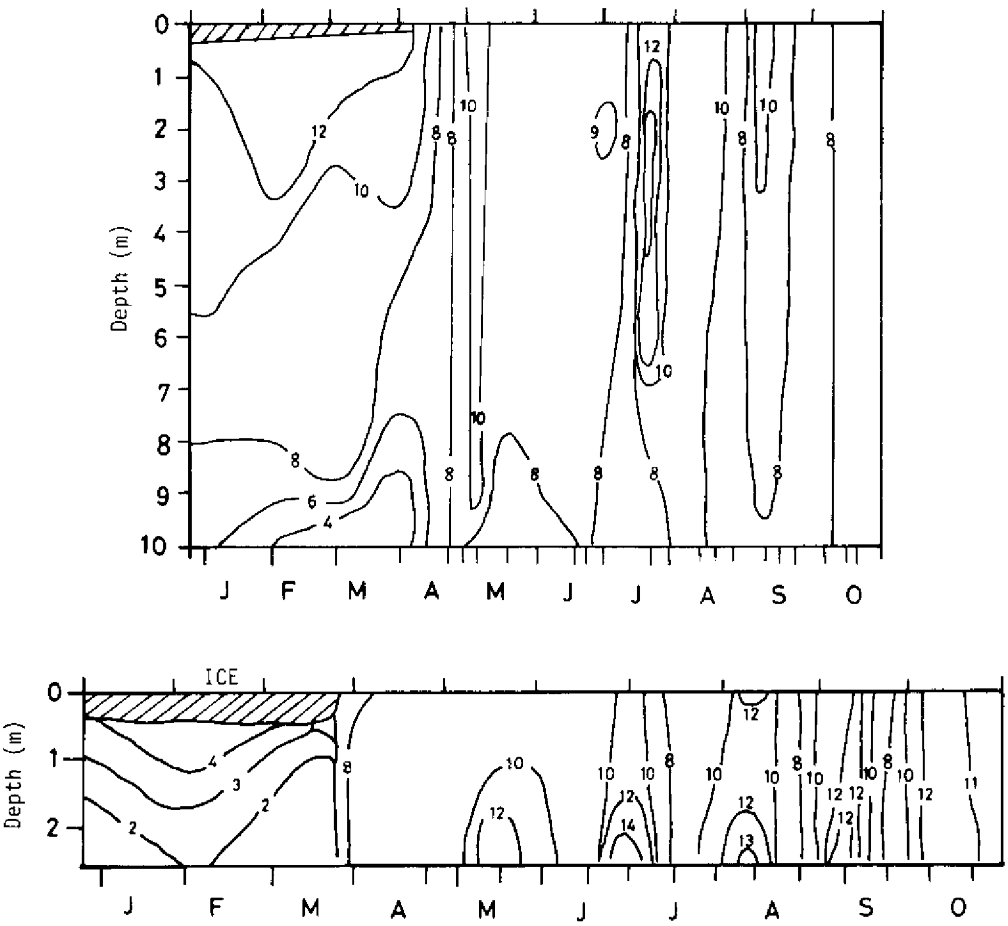
Depth [m]	May	Jun	Jul	Aug	Sep	Oct
Euphotic composite	2.0	3.0	3.0	5.0	5.0	3.0

E4 DO [mg l⁻¹]

Centre East, 1981 (18)

Depth [m]	1980 Nov	Dec	1981 Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
0	12.4	—	12.4	12.8	12.9	9.05	10.5	8.5	9.3	8.0	11.2	8.2
1	12.3	—	12.7	12.7	12.2	9.05	10.5	8.6	9.3	8.1	11.3	8.2
2	12.2	—	12.5	12.1	11.2	9.10	10.6	8.6	9.5	8.2	11.3	8.3
3	11.8	—	12.5	11.4	10.2	9.18	10.6	8.6	9.6	8.1	11.2	8.2
4	11.6		12.4	11.5	10.0	9.19	10.8	8.6	9.7	8.2	10.8	8.2
5	11.6	—	11.4	11.0	8.0	9.21	10.8	8.6	9.8	8.2	9.2	8.2
6	11.5	—	10.9	10.7	4.6	9.21	10.8	8.6	9.9	7.9	8.5	8.2
7	11.4	—	3.1	3.2	0.5	9.19	10.8	8.6	9.8	2.7	7.8	8.2
8	10.6					8.55	10.6	—	9.8	—	—	—

Fig. NAM-45-5 Dissolved oxygen profile [mg l⁻¹], 1981 (1, 18). Wabamun West on top, Moonlight Bay on bottom.



E6 CHLOROPHYLL CONCENTRATION [$\mu g\ l^{-1}$]

East (main), 1987 (18)

Depth [m]	May	Jun	Jul	Aug	Sep	Oct
Euphotic composite	4.4	6.2	15.8	19.6	19.4	14.2

E7 NITROGEN CONCENTRATION

§ Total-N concentration [$mg\ l^{-1}$] (18)

East (main), 1987

Depth [m]	May	Jun	Jul	Aug	Sep	Oct
Euphotic composite	0.837	0.738	0.975	1.021	1.008	0.984

E8 PHOSPHORUS CONCENTRATION

§ Total-P concentration [$mg\ l^{-1}$] (18)

East (main), 1987

Depth [m]	May	Jun	Jul	Aug	Sep	Oct
Euphotic composite	0.036	0.028	0.038	0.036	0.045	0.035

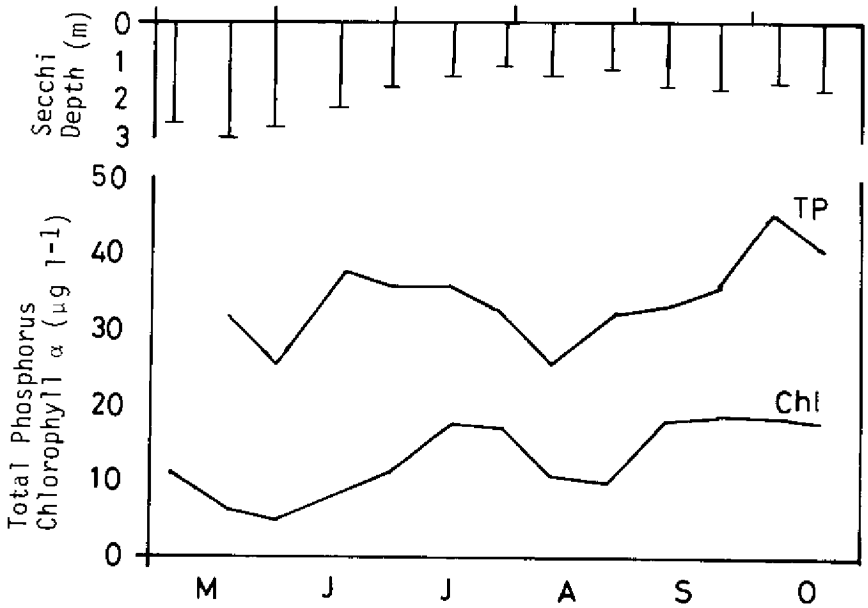
Major ions and related water quality variables. Average concentrations in mg l^{-1} except as noted for composite samples from the euphotic zone collected 19 times during the ice-free period from May 1983 to Oct. 1985. S. E. = standard error.

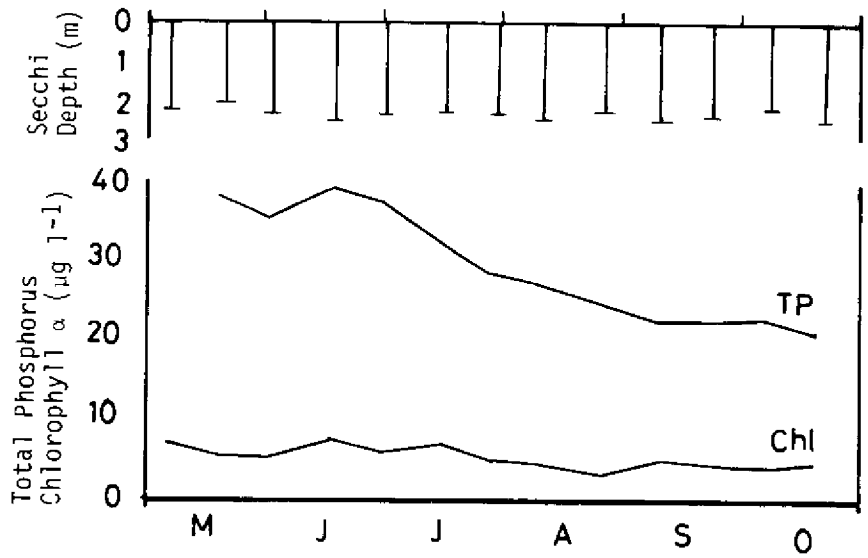
	Mean	S. E.
pH range	7.6-9.1	—
Total alkalinity (as $CaCO_3$)	1931	1
Specific conductivity ($\mu S\ cm^{-1}$)	417	2
Total dissolved solids	235	1
Total hardness (as $CaCO_3$)	111	1
Total particulate carbon	2	0.17
Dissolved organic carbon	11	0.1
HCO_3	220	2
CO_3	8	0.78
Mg	12	0.2
Na	46	0.4
K	8	0.08
Cl	3	0.16
SO_4	26	0.55
Ca	24	0.43

Average concentrations of nutients and chlorophyll *a* with Secchi disc data for composite euphotic zone samples collected 14 times from Apr.-Oct. 1981 and May -Oct. 1983.

	1981 Mean	S. E.	1983 Mean	S. E.
Total phosphorus	34.2	1.65	30.4	1.5
Total dissolved phosphorus	11.3	1.06	9.8	0.46
Soluble reactive phosphorus	3.5	0.57	2.7	0.42
Total Kjeldahl nitrogen	1,040	48	767	37
NO_3+NO_2 nitrogen	4.2	0.56	5.4	3.3
NH_4 nitrogen	76	23	17.3	4.7
Iron	<20	—	<20	—
Chlorophyll *a*	12.6	1.36	10.4	1.8
Secchi depth [m]	1.9	0.14	2.3	0.34

Fig. NAM-45-6 Total phosphorus, chlorophyll *a* for Wabamun West (top) and Moonlight Bay (bottom), 1981 (1, 18).





E9 PAST TRENDS

Summer concentrations of chlorophyll *a* and Total-P [$\mu g\ l^{-1}$].
Mean value ± S. E., (1, 18).

Year	Sample no.	Chlorophyll *a*		Total-P	
1980	6	13.0	2.6	29.8	2.4
1981	7	12.6	1.5	33.0	1.5
1982	4	11.1	3.8	30.0	3.0
1983	3	12.4	2.7	30.5	2.7
1984	3	13.5	1.9	32.9	2.6
1985	3	11.5	1.6	–	–
1986	4	10.6	2.3	32.8	1.8
1987	3	14.3	3.5	36.3	0.9

§ Supplementary notes

The water quality of L. Wabamun has been studied off and on since 1968. Investigations included the effects of the thermal discharges from the two power plants (20, 21, 22, 23); the iron chemistry (24); and ground-water (25). Additional reports and studies are listed in a comprehensive literature review (5). Studies by Alberta Environment on the limnology of the lake and its nutrient sources began in 1980 (12) and have been on-going (18, 19).

F. BIOLOGICAL FEATURES

F1 FLORA

§ Emerged macrophytes: *Typha latifolia, Sagittaria cuneata, Polygonum coccineum, Scirpus* spp.

§ Floating macrophytes: *Lemna minor, Nuphar variegatum, Potamogeton natans.*

§ Submerged macrophytes

Chara globularis, Ceratophyllum demersum, Ranunculus circinatus, Myriophyllum exalbescens, Potamogeton pectinatus, P. praelongus, P. richardsonii, P. vaginatus, P. filiformis, Elodea canadensis.

§ Supplementary notes on macrophytes

The first plant survey in 1961 (30) documented species similar to those in the lake today, with the exception of *Elodea canadensis* which was not seen in the lake in 1961. It became dominant by 1970 as a result of thermal discharges from the powerplant. For further studies on *Elodea* see (20) and (31).

§ Phytoplankton

Anabaena flos-aquae, A. spp., *Lyngbya birgei, Gloeotrichia echinulata, Stephanodiscus niagarae.*

§ Supplementary notes on phytoplankton

Diatoms are usually dominant in spring and fall with blue-greens dominant in July and August. In 1987, large populations of *Lyngbya birgei, Gloeotrichia echinulata* and *Anabaena flos-aquae* developed in July, probably due to favorable climatic conditions. The diatom, *Stephanodiscus niagarae*, also attained a large biomass by the end of June 1985 and this continued through mid-September.

F2 FAUNA (1, 13, 18, 32, 34, 35, 36, 37)

§ Zooplankton

Cladocera (*Bosmina longirostris, Chydorus sphaericus, Daphnia galeata mendotae, D. retrocurva, Ceriodaphnia lacustris, C. reticulata, Eurycercus lamellatus, Simocephalus serrulatus, Diaphanosoma leuchtenbergianum, Acroperus harpae, Leptodora kindtii, Alona costata*); Rotifera (*Keratella "cochlearis", K. qyadrata, Kellicottia longispina, Filinia terminalis, F. longiseta, Asplanchna* sp., *Synchaeta* sp., *Conochilus natans, C. unicornis, Polyarthra vulgaris, P. euryptera, Notholca acuminata, Ploesoma hudsoni, P. truncatum*); Copepoda (*Skistodiaptomus oregonensis, Leptodiaptomus sicilis, Diacyclops edax, Acanthocyclops vernalis, Eucyclops agilis, E. speratus, Trichocerca multicrinis, T. cylindrica, Brachionus patulus, B. angularis, Monostyla* sp., *Lecane luna*). Based on vertical haul samples from the euphotic zone, 1980-1982 (18).

§ Benthos : *Chironomus* spp., *Polypedilium* spp., *Cladotanytarsus* spp., *Tanytarsus* spp.

§ Fish

Coregonus clupeaformis (lake whitefish)*, *Esox lucius* (northern pike), *Perca flavescens* (yellow perch), *Catastomus commersoni* (white sucker), *Culaea inconstans* (stickleback), *Notropis hudsonius* (spottail shiner), *Etheostoma exile* (Iowa darter), (*economically important).

F4 BIOMASS

§ Biomass of phytoplankton with percent composition of major groups [mg l^{-1}] (1, 18)

Composite samples collected from the euphotic zone, 1983

Percentage composition	May 3	May 31	Jun 28	Jul 27	Aug 24	Sep 20	Oct 17
Cyanophyta	0	13	18	44	54	6	18.5
Chlorophyta	16	23	15	14	11	1	4
Chrysophyta	24	33	2	4	0	0	0.5
Bacillariophyta	43	28	47	30	13	88	72
Cryptophyta	17	1	7.5	5	17	3	5
Pyrrhophyta	0	2	10.5	3	5	2	0
Total biomass	2.15	0.272	2.24	5.37	7.21	11.9	3.04

F5 FISHERY PRODUCTS

§ Annual fish catch in 1982–1988 : Northern pike 25 ; Lake white fish 135 [metric tons] (38).

§ Fishery products other than fish : None.

F6 PAST TRENDS

Estimated angler-hours, effort and harvest of lake whitefish (13, 28)

Year	Period	Total angler-hours	Total no. of fish caught	Catch rate
1982–83	Nov-Apr	364,817	192,054	0.53
1983	Mar–Apr	157,349	115,608	0.61
1984	Mar	31,348	15,204	0.48
1986	Jan-Apr	85,304	32,314	0.38
1986	Mar	33,734	16,530	0.49

F7 NOTES ON THE REMARKABLE CHANGES OF BIOTA IN THE LAKE IN RECENT YEARS

No remarkable changes noted for the period 1980–1988.

G. SOCIO-ECONOMIC CONDITIONS

G1 LAND USE IN THE CATCHMENT AREA (1980) (41)

	Area [km^2]	[%]
Natural landscape	104	40
Swamp and wetlands	7	3
Agricultural land	136	52
Settlement area	5	2
Others (coal mine)	7	3
Total	259	100

§ Main types of woody vegetation (main species) : Trembling aspen (*Populus tremuloides*), balsam poplar (*P. balsamifera*), willow, white spruce, white birch.

§ Main kinds of crops and/or cropping systems : Hay, barley, forage oats, cattle production.

§ Levels of fertilizer application on crop fields : Light.
§ Trends of change in land use in recent years : Conversion to coal mines from agricultural land, bush or forest.

G2 INDUSTRIES IN THE CATCHMENT AREA AND THE LAKE (1987) (42)

	Gross product per year (=US$1.00)	No. of persons engaged	No. of establishments	Main products or major industries
Secondary industry				
Others	400 million	330	2	Power generation

H. LAKE UTILIZATION

H1 LAKE UTILIZATION (Q)

Source of water, sightseeing and tourism (number of visitors to Wabamun Lake Provincial Park in 1987-88 : 145,300 (33)), recreation (swimming, sport-fishing, yachting) and fisheries.

H2 THE LAKE AS WATER RESOURCE (1987) (42)

	Use rate
Domestic water	25,000 US gallons day^{-1}
Industrial water	135,000 US gallons day^{-1} (process water)
Power plant	Cooling $356\times10^6 m^3yr^{-1}$ (circulates & returns to lake)

I. DETERIORATION OF LAKE ENVIRONMENTS AND HAZARDS

I1 ENHANCED SILTATION

§ Extent of damage : Not serious.

I2 TOXIC CONTAMINATION

§ Present status : None.

I3 EUTROPHICATION

§ Nuisance caused by eutrophication

Unusual algal bloom : very rare (took place in 1987) ; dominant species were *Lyngbya birgei*, *Gloeotrichia echinulata* and *Anabaena flos-aquae*.

§ Phosphorus loadings to the lake (1)

Measured Total-P loadings, averages for 1980-1981 (12)

Source	P-load [kg yr^{-1}]
Streams	2,030
Diffuse runoff	1,210
Ash lagoon effluent	743
Atmospheric precipitation	1,882
Sewage	75
Sediment release	8,000
Groundwater	260
Total	14,200

§ Supplementary notes

L. Wabamun is classified as a eutrophic lake according to OECD criteria based on maximum chlorophyll *a* concentrations.

I4 ACIDIFICATION

§ Extent of damage : None.

J. WASTEWATER TREATMENTS

J1 GENERATION OF POLLUTANTS IN THE CATCHMENT AREA : (c) Some discharge of pollution load into the lake.

J2 APPROXIMATE PERCENTAGE DISTRIBUTION OF POLLUTANT LOADS

	Percentage
Non-point sources	
(agricultural, natural and dispersed settlements)	95
Point sources	
Municipal	<1
Industrial	5

J3 SANITARY FACILITIES AND SEWERAGE

§ Percentage of municipal population in the catchment area provided with adequate sanitary facilities (on-site treatment systems) or public sewerage : 100 %.

§ Percentage of rural (sparsely settled community) population with adequate sanitary facilities : 90 %.

§ Municipal wastewater treatment systems

No. of tertiary treatment systems : 0.

No. of secondary treatment systems : 2.

No. of industrial wastewater treatment systems : 2 (one discharge out of the catchment, the other treated via lagoon system).

K. IMPROVEMENT WORKS IN THE LAKE

K3 OTHERS (42)

Macrophyte harvest : 366 acres ; average 282 ton yr^{-1} (1975–1988).

M. LEGISLATIVE AND INSTITUTIONAL MEASURES FOR UPGRADING LAKE ENVIRONMENTS

M1 NATIONAL AND LOCAL LAWS CONCERNED

§ Names of the laws

(1) Clean Water Act
(2) Clean Air Act
(3) Public Health Act

§ Responsible authorities

(1) Alberta Ministry of the Environment
(2) Alberta Ministry of the Environment
(3) Regional Health Units

§ Main items of control

(1) Industrial and municipal discharges
(2) Industrial discharges

M2 INSTITUTIONAL MEASURES (year of establishment)

(1) Alberta Ministry of the Environment, Edmonton (1970) (monitoring of lakes and pollution control)

M3 RESEARCH INSTITUTE ENGAGED IN THE LAKE ENVIRONMENT STUDY

(1) University of Alberta, Department of Zoology, Edmonton, Alberta

N. SOURCES OF DATA

(Q) Questionnaire filled by Dr. P. Mitchell, Alberta Environmental Protection Services, Environmental Assessment Division, Environmental Quality Monitoring Branch, Edmonton, Alberta.

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(11) Ivan, M., Administrator of Village of Wabamun. Personal communication.

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(18) Alberta Environment, Environmental Assessment Division, Environmental Quality Monitoring Branch. Unpublished data.

(19) Mitchell, P. A. (1984) The importance of sediment release in the assessment of a shallow eutrophic lake for phosphorus control. Proceedings of the Third Annual Conference on Lake and Reservoir Management. North American Lake Management Society. U. S. E. P. A. 440/5-84-001. Washington, D. C. 129 pp.

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(23) Nursall, J. R., Nuttall, J. B. & Fritz, P. (1972) The effect of thermal effluent in Lake Wabamun, Alberta. Verh. Int. Ver. Limnol., 18 : 269-277.

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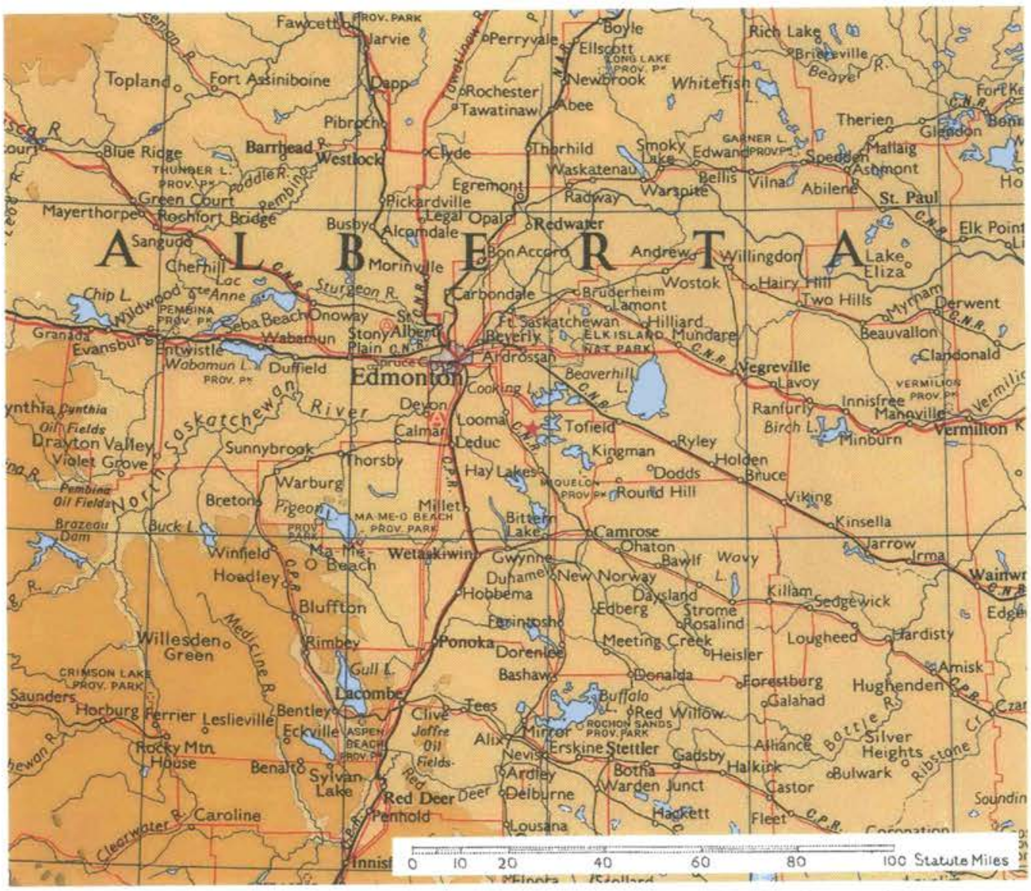
MIQUELON LAKE

A view on the lakeshore

Photo: S. Allen



A. LOCATION

§ Alberta, Canada.
§ 53°21′N, 112°55′W ; 763.1 m above sea level.

B. DESCRIPTION

Miquelon Lake is a shallow body of saline water located within the county of Camrose in central Alberta, about 40 km southeast of the city of Edmonton. It lies on the southern edge of the Cooking Lake moraine. The lake was once part of a considerably larger lake that receded and left three isolated basins, the largest of which is called "Miquelon Lake".

Miquelon Lake is representative of a large group of inland saline lakes that are scattered throughout the three prairie provinces (Manitoba, Saskatchewan and Alberta). Sulphate concentrations are relatively high and nutrient concentrations are extremely high. In contrast, phytoplankton and rooted macrophyte biomass are relatively low. Many of the moderately saline lakes are ideal for contact recreation, although they have a poor (if any) recreational fishery.

Miquelon Lake has been used for recreation by local residents since the turn of the century, especially after a railway line was established between Camrose and Tofield in 1909. The nearby hamlet of Kingman became known as the "Gateway to Miquelon". The access and facilities at the lake were greatly improved when Miquelon Lake Provincial Park was established in 1958. The park provides facilities for swimming, boating, camping and picnicking. Much of the land surrounding the three basins is a wildlife sanctuary which provides nature-viewing opportunities.

Presently, Miquelon Lake is heavily used for recreation, especially on warm sunny weekends. Game fish are no longer present in the lake but the beach area at the provincial park is generally clean and attractive for swimming. The saline water tends to inhibit the growth of algae and the lake is often very clear.

There has been no surface outflow from Miquelon Lake since the 1920's. Drainage may have been toward the North Saskatchewan River through the moraine although there is geological evidence that the formerly large lake drained south toward the Battle River. In recent times (1927) southward flow occurred only after the outlet creek at the southern basin was deepened to divert water for the town of Camrose water supply. The flow in the diversion ditch ran only about three years even though the ditch was deepened when flow declined. The water level in the lake has declined considerably since then, separating the three basins. Many local residents blame the diversion for the drastic decline in water level in Miquelon Lake, but Woodburn suggests that this had a minor effect in comparison to climatic factors. The outlet canal has been blocked for many years (1, 2, 3, 4).

C. PHYSICAL DIMENSIONS (5, 6)

Surface area [km^2]	8.72
Volume [$10^6 m^3$]	23.74
Maximum depth [m]	6
Mean depth [m]	2.7
Normal range of annual of water level fluctuation	Uncontrolled
Length of shoreline [km]	19.5
Residence time [yr]	No surface outflow
Catchment area [km^2]	35.4

D. PHYSIOGRAPHIC FEATURES

D1 GEOGRAPHICAL

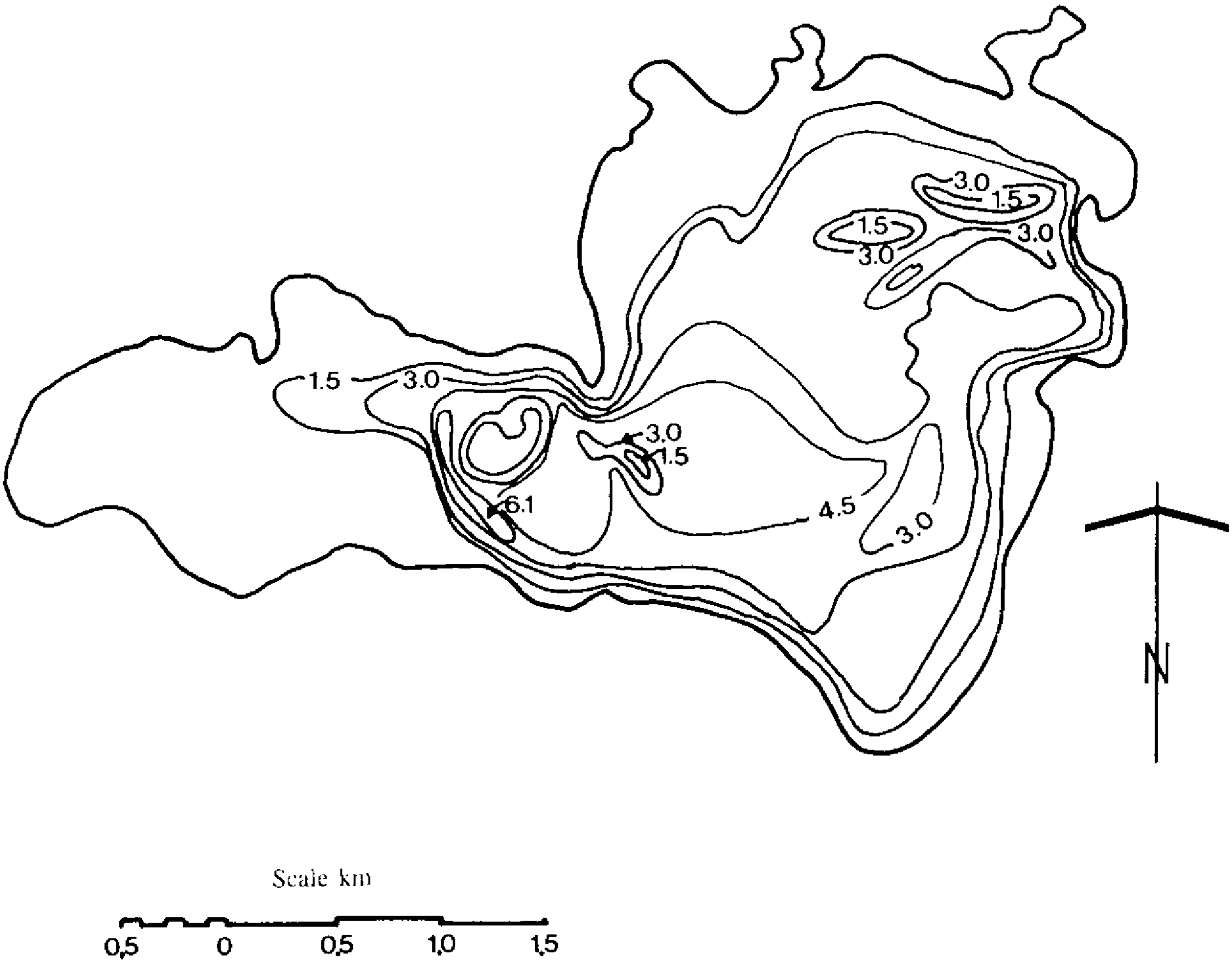
§ Bathymetric map (Fig. NAM-46-1).

§ Main islands : None.

§ Outflowing rivers and channels : None.

No surface outlet flow has occurred since the 1920's and there are no permanent inlet streams. The lake is spring fed.

Fig. NAM-46-1 Bathymetric map [m] (6).



D2 CLIMATIC

Camrose (53°1′N, 112°50′W), 1951-1980 (7a)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean temp. [°C]	-16.9	-11.9	-6.8	3.3	10.6	14.4	16.7	15.5	10.1	4.6	-4.9	-12.0	1.9
Precipitation [mm]	27	19	20	20	46	80	74	74	40	15	17	22	453

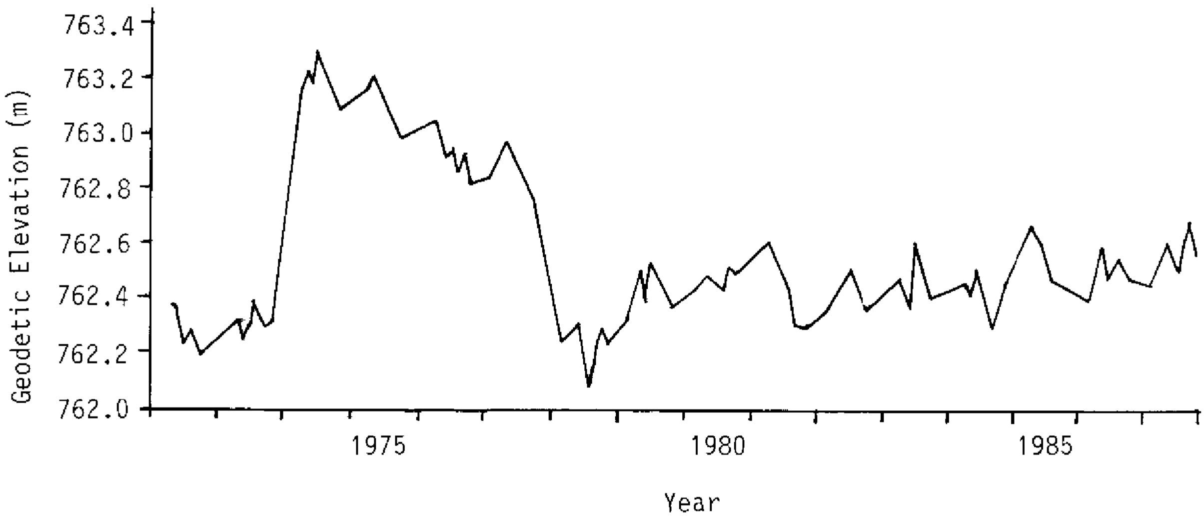
§ Number of hours of bright sunshine : 2,317 hr yr^{-1} (7).

§ Average solar radiation : 12.8 MJ $m^{-2}day^{-1}$ (7b).

Mean daily global solar radiation [MJ m^{-2}] at Edmonton Municipal Airport

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
3.74	7.06	12.61	17.49	20.94	22.54	23.20	18.08	13.07	8.06	4.20	2.78

Fig. NAM-46-2 Water level fluctuations of Miquelon Lake between 1965 and 1985.



§ Water temperature [°C]

June 1975-April 1976 (8)

Depth [m]	Jan 29	Feb	Mar 9	Apr 29	Jun 4	Jul 2	Jul 28	Aug 25	Sep 22	Oct 22
0	−0.4	−	−0.3	4.6	14.6	17.0	20.7	12.8	13.0	5.0
0.5	−0.4	−	−0.3	5.8	14.5	16.8	20.7	12.8	12.6	5.0
1.0	−0.5	−	−0.5	6.0	14.5	16.8	20.9	12.8	12.5	4.9
1.5	−0.5	−	−0.5	5.6	14.5	16.8	20.9	12.8	12.5	4.9
2.0	−0.4	−	+0.1	7.2	14.5	16.8	20.9	12.8	12.4	4.6
3.0	+0.3	−	+0.1	3.9	14.5	16.8	20.9	12.8	12.4	4.5
4.0	−	−	−	3.9	14.5	16.6	−	12.6	−	−

§ Freezing period : From mid to late Nov. to mid to late Apr.

§ Mixing type : Polymictic.

§ Notes on water mixing and thermocline formation : Temperature is uniform from surface to bottom in summer although temporary stratification probably occurs.

E. LAKE WATER QUALITY

E1 TRANSPARENCY [m]

Jun. 1975-Apr. 1976 (8)

Jan 29	Feb	Mar 9	May 29	Apr 4	Jun 2	Jul 28	Jul 25	Aug 22	Sep 22
3.8	−	3.8	2.3	4.2	4.0	3.6	3.5	3.6	2.8

E2 pH

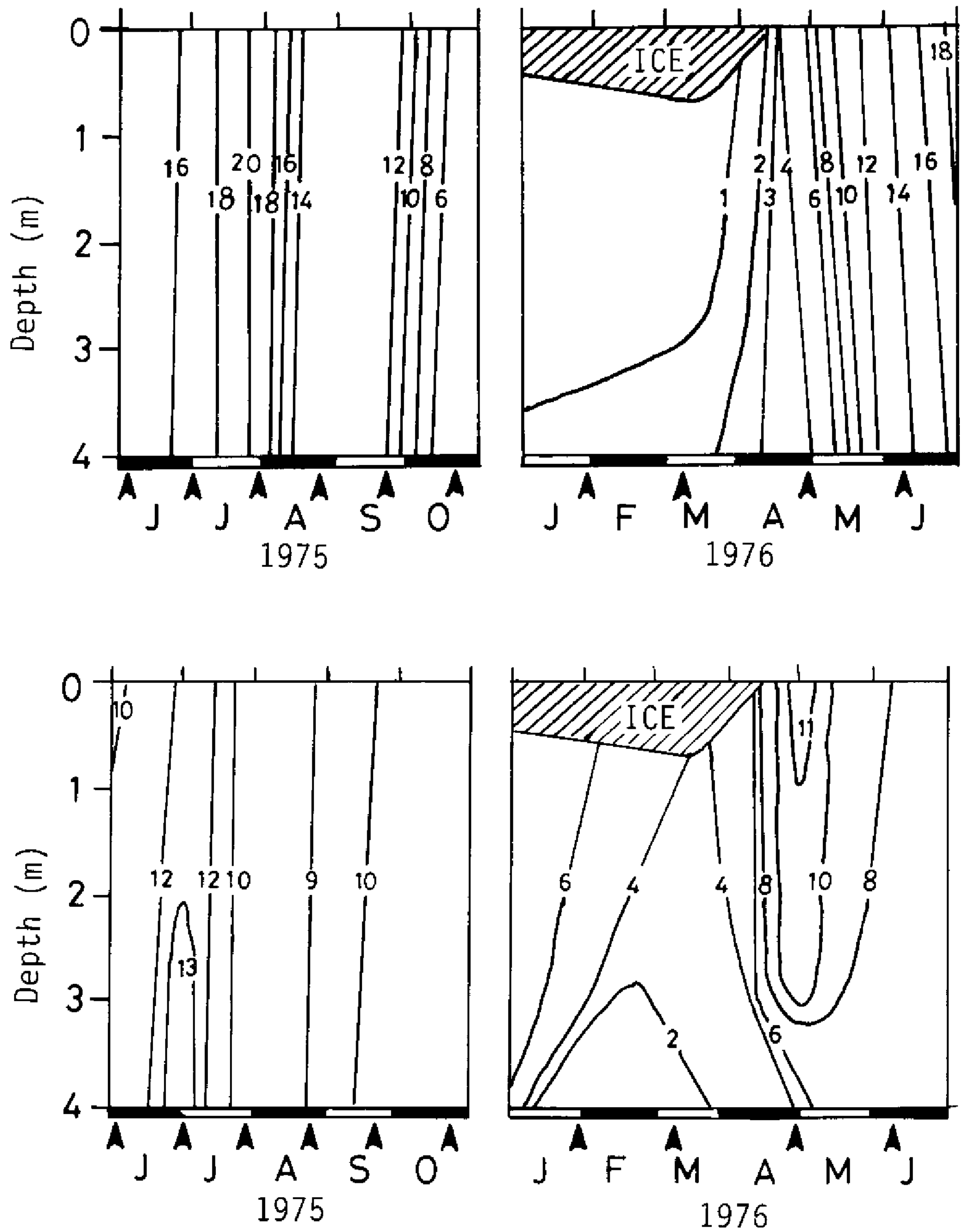
1983 (8a)

Depth [m]	Jan	Feb	Mar	May 3	May 24	Jun 13	Jul 4	Jul 25	Aug 15
0-2	−	−	−	9.28	−	−	−	−	−
0-3	−	−	−	−	9.25	9.43	9.42	9.42	9.34

E4 DO [mg l⁻¹]
Jun., 1975–Apr., 1976 (8)

Depth [m]	Jan 29	Feb	Mar 9	Apr 29	Jun 4	Jul 2	Jul 28	Aug 25	Sep 22	Oct 22	Nov	Dec
0	6.0	–	5.3	11.1	9.9	12.2	9.2	9.0	10.0	9.9	–	–
0.5	6.0	–	4.8	11.1	10.1	12.4	9.4	9.0	10.3	9.7	–	–
1.0	5.9	–	4.4	11.0	10.2	12.8	9.4	9.0	10.3	9.8	–	–
1.5	5.9	–	4.1	10.4	10.2	12.9	9.5	8.9	10.3	10.0	–	–
2.0	5.9	–	3.8	14.8	10.1	13.0	9.6	8.9	10.3	10.1	–	–
3.0	4.0	–	3.0	10.8	10.2	13.3	9.6	9.0	9.9	10.1	–	–
4.0	–	–	–	3.0	10.2	13.6	–	8.9	–	–	–	–

Fig. NAM-46-3 Temperature [°C] and dissolved oxygen [mg l⁻¹] profiles (1975–1976) (1).

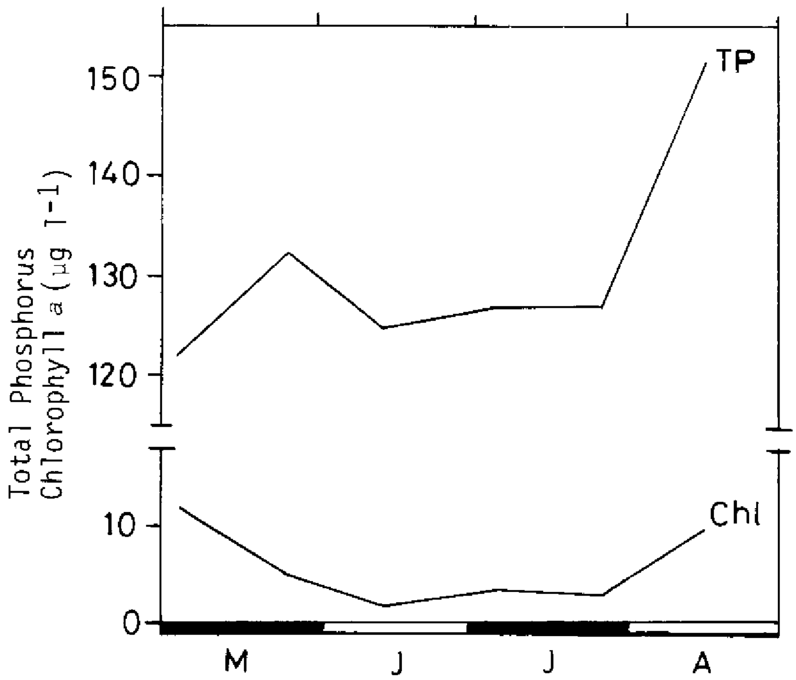


E6 CHLOROPHYLL CONCENTRATION [$\mu g\ l^{-1}$]

Jun., 1975–Apr., 1976 (8)

Depth [m]	Jan 29	Feb	Mar 9	Apr 29	Jun 4	Jul 2	Jul 28	Aug 25	Sep 22	Oct 22
0	0.0	–	0.04	2.83	0.80	1.07	2.82	–	2.09	1.08
0.5	0.0	–	0.09	2.83	0.68	0.89	2.57	2.78	2.27	1.01
1	0.0	–	0.08	2.67	0.72	0.48	2.64	2.69	2.43	1.03
1.5	0.0	–	0.06	2.44	0.70	0.63	2.62	2.46	2.08	1.01
2	0.0	–	0.08	2.44	0.89	1.04	2.64	2.31	–	0.79
3	0.0	–	1.32	3.64	0.85	1.02	2.79	2.03	2.00	0.89

Fig. NAM-46-4 Summer concentrations of Total-P and chlorophyll *a* (1983) (8a).



E7 NITROGEN CONCENTRATION

§ Total-N [$mg\ l^{-1}$], 1983 (8a)

Depth [m]	May 3	May 24	Jun 13	Jul 4	Jul 25	Aug 15
0-2	3.39	–	–	–	–	–
0-3		4.94	5.76	6.53	6.73	6.84

§ Inorganic nitrogen [$\mu g\ l^{-1}$]

NO_2-+NO_3-+NH_4-N (1983) (8a)

Depth [m]	May 3	May 24	Jun 13	Jul 4	Jul 25	Aug 15
0-2	4.3	–	–	–	–	–
0-3	–	10.5	25.2	45.4	13.7	2.2*

* Aug. 15 value: NO_2+NO_3, no data on NH_4.

E8 PHOSPHORUS CONCENTRATION

§ Total-P [$\mu g\ l^{-1}$] (1983) (8a)

Depth [m]	May 3	May 24	Jun 13	Jul 4	Jul 25	Aug 15
0	–	130.8	122.0	–	–	–
1	–	127.5	–	–	–	–
2	–	–	120.2	–	–	–
3	–	131.0	119.2	–	–	–
0-2	122.1	–	–	–	–	–
0-3	–	132.1	124.7	126.8	126.9	151.6

E9 CHLORIDE ION CONCENTRATION [$mg\ l^{-1}$]

Summer 1983 (mean±S. E.) : 99±2.5.

E10 SUPPLEMENTARY NOTES

Most of the salinity is present as sodium sulphate Na=1,473 mg l^{-1} and sulphate=2,413 mg l^{-1} (8a).

Total dissolved solids [$mg\ l^{-1}$] (8a)

May 3	May 24	Jun 13	Jul 4	Jul 25
5,290	3,500	5,720	5,250	5,250

It should be noted that total dissolved solids and sulphate are higher when the water level is low. In 1974, a heavy spring runoff raised the lake level and diluted its salt content. Since 1976, the dissolved solids again become more concentrated (1).

F. BIOLOGICAL FEATURES

F1 FLORA

§ Emerged macrophytes

Scirpus americanus, S. paludosus, S. validus (these three dominant bulrushes are all tolerant of saline conditions as is *Ruppia*).

Subdominants : *Carex rostrata, Typha latifolia, Eleocharis palustris* var. *major*, *Phragmites communis, Beckmannia syzigachne, Rumex* sp., *Hordeum jubatum, Juncus balticus* var. *littoralis*, *Triglochin palustris* (8).

§ Floating macrophytes : None.

§ Submerged macrophytes

Ruppia occidentalis (the dominant macrophyte with maximum densities at 1-2 m), *Potamogeton pectinatus* (8).

§ Phytoplankton

Ceratium hirundinella, Chaetoceros elmorei, Nitzschia acicularis, Cyclotella sp., *Monoraphidium contortum, Chamaesiphon incrustans, Chlamydomonas* sp., *Characium debaryanum, Chroococcus* sp., *C. dispersus, Anabaena circinalis, Coleosphaerium* sp., *Chrysochromulina parva, Rhodomonas minuta* var. *nannoplanktica, Trachelomonas volvocina* (8a, 8c, 9).

F2 FAUNA

§ Zooplankton

Diaptomus sicilis (dominant throughout year, peak biomass in midsummer), *Daphnia* sp. and *Hexarthra* sp. (abundant in midsummer) (8).

§ Benthos

Midge (chironomid) larvae are the dominant invertebrate in the lake. Amphipoda, *Caenis* sp. (samples from 4 m depth) (8, 4, 9a).

§ Fish : *Culea inconstans* (brook stickleback) is the only fish remaining in the lake (10, 11, 12).

F7 NOTES ON THE REMARKABLE CHANGES OF BIOTA IN THE LAKE IN RECENT YEARS

Sport fishery and fish have disappeared. At the turn of the century when the Miquelon Lake outlet was flowing, northern pike, yellow perch and suckers were abundant. Presumably, they moved up the creek which connected the lake to the Battle River. Adult yellow perch were stocked in Miquelon in 1955, 1956 and possibly 1958, but occasional winter kills and isolation from population sources have limited the fish in the lake to the brook stickleback (1, 10, 11, 12).

G. SOCIO-ECONOMIC CONDITIONS

G1 LAND USE IN THE CATCHMENT AREA (1988) (1, 6a, 13)

	Area [km²]	[%]
Natural landscape		
Woody vegetation	17.7	50
Agricultural land		
Crop field	<17.7	<50
Settlement area	< 0.3	~1
Others	< 0.3	~1 *
Total	35.4	

* Highway #623 runs through the western side of the lake.

§ Types of important forest vegetation (1)

Populus tremuloides, *P. balsamifera* and *Picea glauca* historically covered the area but extensive clearing for agricultural purposes and fires at the turn of the century reduced forest cover ; natural regrowth has since restored much of the natural vegetation, particularly in Miquelon Lake Provincial Park.

§ Main kinds of crops and/or cropping systems : Cereal crops and livestock.

§ Levels of fertilizer application on crop fields : Light.

§ Trends of change in land use in recent years : In 1958 Miquelon Provincial Park was established.

G2 INDUSTRIES IN THE CATCHMENT AREA AND THE LAKE

None.

G3 POPULATION IN THE CATCHMENT AREA (1988)

Approximately 100 people in the drainage basin.

H. LAKE UTILIZATION

H1 LAKE UTILIZATION

Recreation (swimming, boating).

I. DETERIORATION OF LAKE ENVIRONMENTS AND HAZARDS

I1 ENHANCED SILTATION

§ Extent of damage : Not serious.

I2 TOXIC CONTAMINATION

§ Present status : No information.

I3 EUTROPHICATION

Although the high levels of nitrogen and phosphorus in Miquelon Lake would normally stimulate excessive algal growth, the high salinity of the lake has prevented this from taking place and the lake is classified as mesotrophic according to its Secchi transparency and chlorophyll levels (1).

Although total phosphorus (mean 131 $\mu g\ l^{-1}$) is characteristic of eutrophic lakes, the algal biomass is quite low (4.6 mg l^{-1} as chlorophyll *a*) and therefore the lake should be classified as mesotrophic or dystrophic.

I4 ACIDIFICATION

§ Extent of damage: None.

K. IMPROVEMENT WORKS IN THE LAKE

None.

M. LEGISLATIVE AND INSTITUTIONAL MEASURES FOR UPGRADING LAKE ENVIRONMENTS

M1 NATIONAL AND LOCAL LAWS CONCERNED

§ Names of the laws

(1) Clean Water Act
(2) Clean Air Act
(3) Public Health Act

§ Responsible authorities

(1) Alberta Ministry of the Environment
(2) Alberta Ministry of the Environment
(3) Alberta Ministry of the Environment

M2 INSTITUTIONAL MEASURES (the year of foundation)

(1) Alberta Ministry of Environment, Edmonton: Monitoring of lakes and pollution control (1970)

N. SOURCES OF DATA

(Q) Questionnaire filled by Drs. E. Prepas and D. Webb, Department of Zoology, Biological Sciences Centre, University of Alberta, Edmonton, Alberta.

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(1a) Allen, S., Alberta Recreation and Parks Division, Edmonton.

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(8a) Prepas, E. E., University of Alberta, Edmonton: Unpublished data.

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SHUSWAP LAKE

View of Station 5 looking north, Copper Island in the background

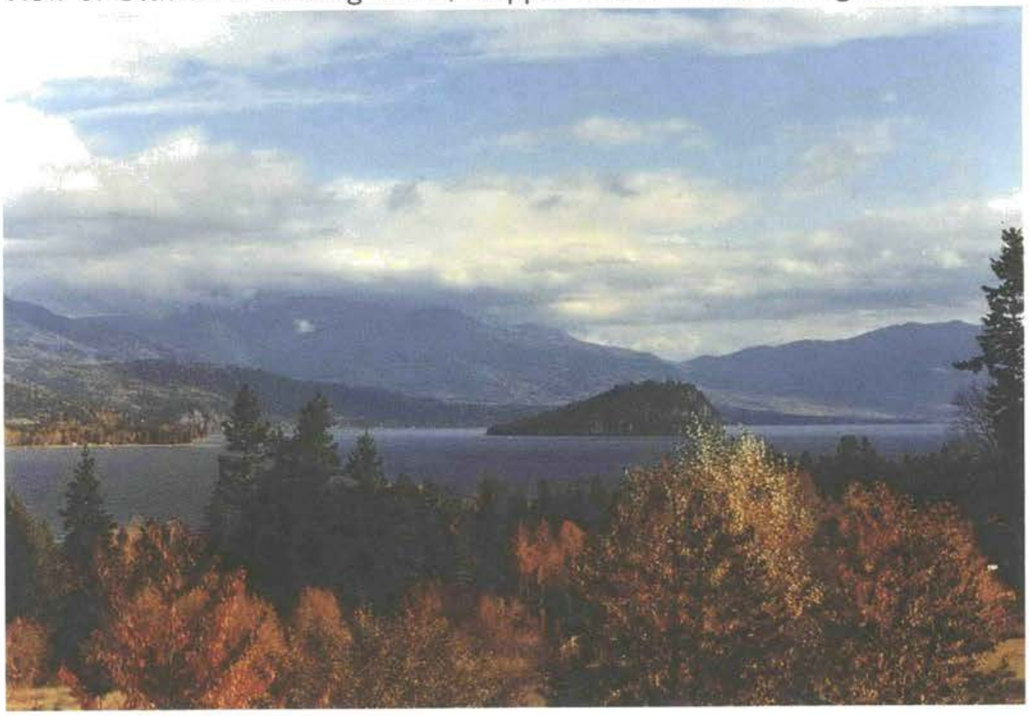
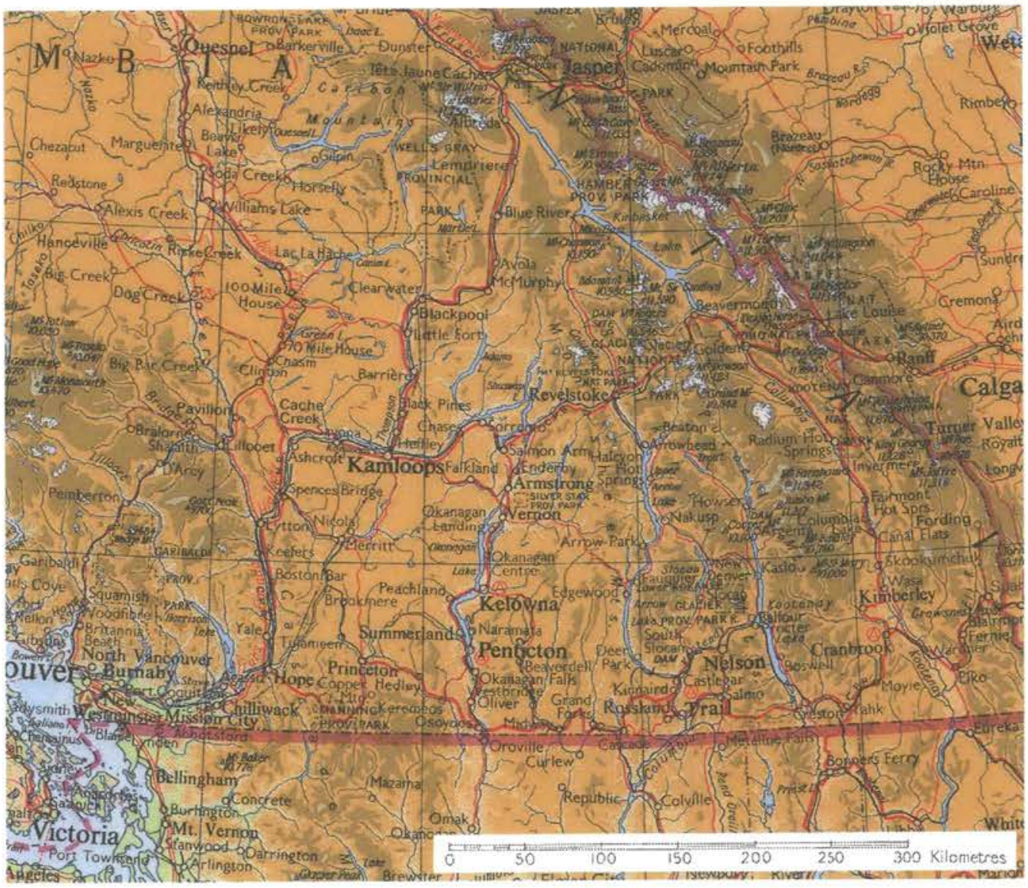


Photo: J. Stockner



A. LOCATION

§ British Columbia, Canada.
§ 50°40′-51°20′N, 119°0′-119°20′W ; 347 m above sea level.

B. DESCRIPTION

Shuswap Lake is situated in the Columbia Mountains region of British Columbia where the landscape is characterized by mountainous terrain covered by dense coniferous forests. White birch lines settled areas of the lake shore adding to the beauty of the lake during fall. The mountains surrounding the lake are formed of granite which results in a very low input of nutrients. As a result, Shuswap Lake is very clear and relatively oligotrophic. The high mountains around this lake may reduce its annual solar radiation.

This multi-basin lake is comprised of 4 arms which are joined by a short shallow passage known as the "narrows." The two south arms are developed for recreational use while the two north arms remain undeveloped. The lake has several inflow rivers in each arm but only one outlet, Little River, which flows from the southwest arm to Little Shuswap Lake. Shuswap is a nursery lake for the underyearlings of sockeye salmon which spawn in several of the lake's inflow streams. Adams River is the most conspicuous of these spawning streams, accommodating up to 2 million spawners in dominant years.

Besides being of considerable value to the west coast salmon industry, moderate weather, clear water and easy accessibility make Shuswap Lake highly desirable as a recreational area. This is evidenced by the many provincial parks surrounding the lake and the hundreds of houseboats and pleasure crafts present during the summer months (Q).

C. PHYSICAL DIMENSIONS

Surface area [km^2]	310
Volume [$10^9 m^3$]	19.1
Maximum depth [m]	161
Mean depth [m]	62
Normal range of annual of water level fluctuation (unregulated) [m]	3.0
Length of shoreline [km]	1,430
Residence time [yr]	2.1
Catchment area [km^2]	16,200

D. PHYSIOGRAPHIC FEATURES

D1 GEOGRAPHICAL

§ Bathymetric map (Fig. NAM-47-1).
§ Main islands : Copper Island.
§ Outflowing rivers and channels (number and names) : 1 (Little R.).

D2 CLIMATIC

§ Climatic data at Sicamous, 1951-1980 (2)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean temp. [°C]	-5.0	-1.4	2.4	7.8	13.1	17.1	20.0	19.2	14.0	7.7	1.5	-2.6	7.8
Precipitation [mm]	77	48	37	32	51	64	46	53	56	51	66	80	660

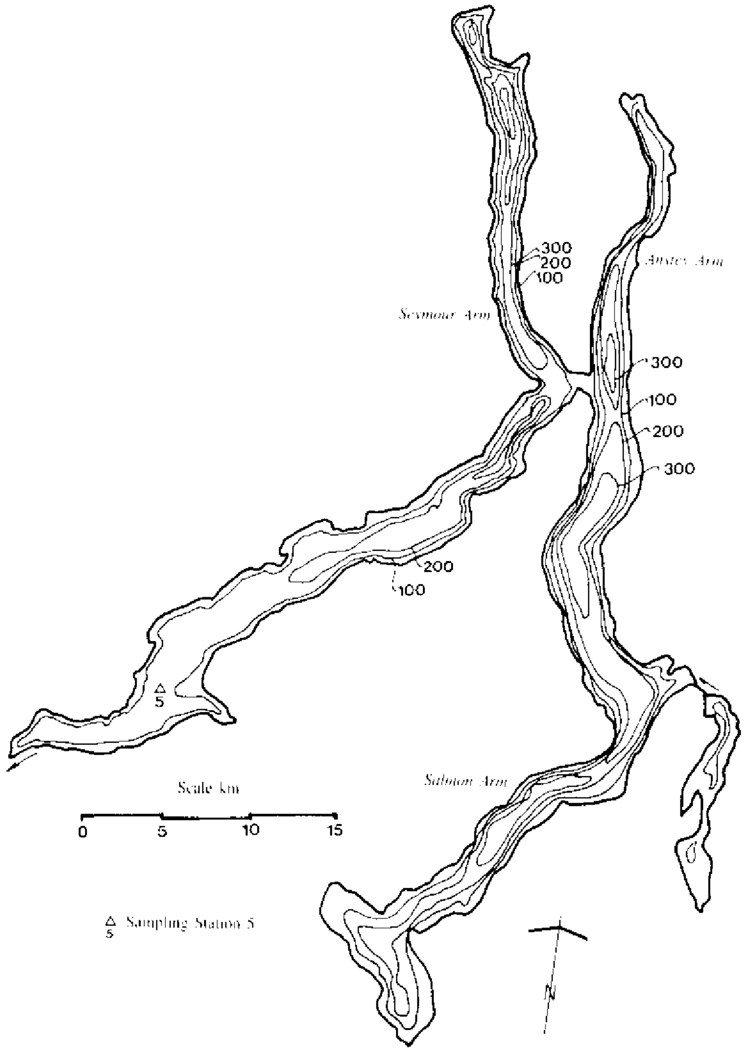
§ Number of hours of bright sunshine (Salmon Arm) : 1,632 hr yr^{-1} (2).
§ Average solar radiation : 12.8 MJ $m^{-2}day^{-1}$.

Mean daily global solar radiation [MJ m^{-2}] at Summerland

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
3.4	6.5	11.5	16.7	20.8	22.6	23.7	19.6	14.5	8.5	3.8	2.5

* Means for Shuswap area are lower than at Summerland which is 100 km south and in a slightly sunnier climate.

Fig. NAM-47-1 Bathymetric map [feet (50 feet=15.24 m)] (Q).



§ Water temperature [°C] (1)
Station 5 (Sorrento)*, 1987

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Surface	–	–	–	11.6	11.3	19.2	21.0	18.9	17.7	12.5	9.6	–
3	–	–	–	8.3	–	18.6	20.0	18.8	17.7	12.5	9.6	–
6	–	–	–	7.0	10.4	17.7	19.1	18.7	17.6	12.5	9.6	–
9	–	–	–	5.9	9.8	14.3	17.6	18.4	17.3	12.5	9.6	–
12	–	–	–	5.6	–	11.7	13.2	14.8	17.2	12.5	8.2	–
15	–	–	–	5.0	8.5	–	12.2	11.7	16.9	12.5	6.6	–
18	–	–	–	4.8	–	–	11.4	–	10.0	–	6.4	–
21	–	–	–	4.6	4.6	–	–	–	–	–	–	–
28	–	–	–	4.5	–	5.8	5.6	5.2	5.7	5.2	–	–

* Located mid-lake in the main basin adjacent to the Adams River which enters Shuswap Lake from its southwest arm.

§ Freezing period : Jan. to Mar. (freezing does not occur every year and ice rarely covers the entire lake).

§ Mixing type : Dimictic.

E. LAKE WATER QUALITY

Water quality is variable. The Salmon Arm is the most productive area because of considerable nutrient input from agricultural drainage via the Salmon River. Levels of nutrients are highest in Salmon Arm and lowest in Austy and Seymour Arms.

E1 TRANSPARENCY [m]

Station 5, 1987 (Q)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
–	–	–	11.5	8.2	13.7	10.5	11.0	10.8	10.6	8.6	–

E2 pH

Station 5, 1987 (Q)

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Surface	–	–	–	7.8	7.6	7.7	7.3	7.7	7.9	7.5	7.3	–

E6 CHLOROPHYLL CONCENTRATION [$\mu g\ l^{-1}$]

Station 5, 1987 (Q)

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean epilimnetic	–	–	–	0.91	0.70	1.60	1.18	0.98	1.04	1.62	2.29	–

E7 NITROGEN CONCENTRATION

§ NO_3-N+NH_4-N [mg l^{-1}]
Station 5, 1987 (Q)

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean epilimnetic	–	–	–	.094	.068	.013	.002	.001	.006	.008	.026	–
NO_3-N+NH_4-N	–	–	–	.015	.007	.011	.003	.003	.006	.006	.007	–

E8 PHOSPHORUS CONCENTRATION

§ Total-P [$\mu g\ l^{-1}$]

Station 5, 1987 (Q)

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean epilimnetic	–	–	–	5.7	3.0	3.8	4.0	2.9	2.4	2.4	3.6	–

E9 CHLORIDE ION CONCENTRATION [$mg\ l^{-1}$]

Station 5, 1982 : 0.5 (4).

F. BIOLOGICAL FEATURES

F1 FLORA (4)

§ Emerged macrophytes

Equisetum sp., *Alisma plantago-aquatica*, *A. gramineum*, *Scheuchzeria palustris*, *Acorus calanus*, *Ranunculus flabellaris*, *Sium sauve*, *Eleochoris palustris*.

§ Floating macrophytes

Polygonum amphibium, *Azolla filiculoides*, *Nuphar variegatum*.

§ Submerged macrophytes

Myriophyllum exalbescens, *M. ussuriense*, *M. spicatum*, *Potamogeton zosteriformis*, *P. robbinsii*, *P. pectinatus*, *P. praelongus*, *P. noclosus*, *P. crispus*, *P. epihydrus*, *P. illinoensis*, *P. perfoliatus*, *P. pusilus*, *Chara* sp., *Nitella* sp., *Callitriche hermaphroditica*, *C. heterophylla*, *C. stagnalis*, *Hippurus vulgaris*, *Zannichellia palustris*, *Bidens beckii*, *Utricularia vulgaris*, *U. intermedea*, *Elodea canadensis*, *Najas flexilis*, *Ceratophyllum demersum*, *Heteranthera dubia*.

§ Phytoplankton

Cyclotella spp., *Rhizosolenia* spp., *Asterionella* spp., *Dinobryon* spp., *Melosira* spp.

F2 FAUNA

§ Zooplankton (5, 6)

Bosmina coregoni (*longispina*), *B. longirostris*, *Diaphanosoma leuchtenbergianum*, *Daphnia thorata*, *D. longiremis*, *Holopedium gibberum*, *Sida crystallina*, *Cyclops bicuspidatus thomasi*, *Diaptomus ashlandi*, *Epischura nevadensis*.

§ Fish

*Oncorhynchus nerka**, *O. tshawytscha**, *Salmo gairdneri**, *Salvelinus malma*, *S. namaycush*, *Coregonus clupeaformis*, *Prosopium williamsoni*, *Richardsonius balteatus*, *Lota lota*, *Cottus asper* (*economically important).

F3 PRIMARY PRODUCTION RATE [$mg\ C\ m^3 hr^{-1}$]

Station 5, 1987 (1)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Net production	–	–	–	0.23	1.0	1.3	1.67	1.0	0.67	0.93	1.29	–

F4 BIOMASS

Station 5 (Sorrento), 1987 (early mean values) (6)

Bacteria : 4.8×10^5 [cells ml^{-1}].

Zooplankton : 45.9 [$mg\ m^{-3}$ dry weight].

F5 FISHERY PRODUCTS

§ Annual fish catch : 20 [metric tons] (Q).

§ Supplementary notes

Anadromus sockeye salmon is caught at sea during the commercial catch in the dominant year. Its returns are cyclic with a dominant return occurring every four years. This cyclic dominance is thought to have varying degrees of influence on all trophic levels, since dominant returns are 230 times greater than low year returns. Sockeye underyearling grazing structures the zooplankton community of the hypolimnion-thermocline area but, because of warm surface temperatures of the epilimnion in summer, the zooplankton community there is less affected. Depending on the time of year, nutrients affect community composition and size-structure of phytoplankton.

F7 NOTES ON THE REMARKABLE CHANGES OF BIOTA IN THE LAKE IN RECENT YEARS

Increase in Eurasian milfoil (*Myriophyllum spicatum*) colonization of the littoral zone.

G. SOCIO-ECONOMIC CONDITIONS

G1 LAND USE IN THE CATCHMENT AREA (1986) (8)

	Area [km²]	[%]
Natural landscape	(13,770)	(85)
Woody vegetation	12,393	76.5
Herbaceous vegetation	1,377	8.5
Agricultural land	(2,187)	(13.5)
Crop field	729	4.5
Pasture land	1,458	9
Settlement area	243	1.5
Total	16,200	100

§ Types of important forest vegetation: *Pseudosuga menziesii* (Douglas fir), *Pinus contorta* (lodgepole pine), *Betula papyrifera* (white birch).

§ Main kinds of crops and/or cropping systems: Corn, various fruit, hay, alfalfa.

§ Levels of fertilizer application on crop fields: Light.

§ Trends of change in land use in recent years

Increase in recreational boating, fishing and shoreline development of summer houses.

G2 INDUSTRIES IN THE CATCHMENT AREA AND THE LAKE (1987)

This is an area of little urban industrial development. The largest agglomeration, Salmon Arm, has a population, in 1981, of 10,780 and only a few service functions.

G3 POPULATION IN THE CATCHMENT AREA (1986) (9)

	Population	Population density [km^{-2}]	Main cities (population)
Urban	ca. 10,000		Salmon Arm
Rural	ca. 5,000		(10,780)
Total	15,000*	0.9	

* Increases during summer.

H. LAKE UTILIZATION

H1 LAKE UTILIZATION

Source of water, navigation and transportation (not commercial except for some log transport), sightseeing and tourism (number of visitors in 1987 : over 10,000), recreation (swimming, sport-fishing and yachting), fisheries and hundreds of house boats cruise the lake each year.

H2 THE LAKE AS WATER RESOURCE (1988)

	Use rate
Domestic water	From wells+tributaries
Irrigation	Not estimated
Industrial water	Saw mill

I. DETERIORATION OF LAKE ENVIRONMENTS AND HAZARDS

I1 ENHANCED SILTATION

§ Extent of damage : None.

I2 TOXIC CONTAMINATION

§ Present status : No information.

I3 EUTROPHICATION

§ Nuisance caused by eutrophication : Increase of Eurasian milfoil (*Myriophyllum spicatum*). There has been mild eutrophication of the Salmon Arm.

I4 ACIDIFICATION

§ Extent of damage : Slight acidification detected in watershed, but not serious.

§ Supplementary notes

Hydrogen ion concentrations in lake water, stream and rain water have been stable. The lake water has a hardness of 39 and an alkalinity of 34 mg l^{-1} (conductivity 81 $\mu S\ cm^{-1}$), and relatively well-buffered with a pH value typically above 7 (1982 pH mean was 7.4).

J. WASTEWATER TREATMENTS

J1 GENERATION OF POLLUTANTS IN THE CATCHMENT AREA : (c) Limited pollution with wastewater treatment.

J2 APPROXIMATE PERCENTAGE DISTRIBUTION OF POLLUTANT LOADS

	Percentage
Non-point sources	
(agricultural, natural and dispersed settlements)	75
Point sources	
Municipal	25

J3 SANITARY FACILITIES AND SEWERAGE

§ Municipal wastewater treatment systems

Tertiary treatment with outflow to the lake at depth of 3 m. The effluent contains <10 ppm suspended solids.

L. DEVELOPMENT PLANS

Development and activity in the Shuswap Lake watershed has intensified in recent years. Upland residential development, increased residential use and selected commercial developments along the lake's shorelines have impacted on its environmental resources. As a result, the Shuswap Lake Environmental Management Plan was undertaken by the B. C. Ministry of Environment (10). During 1985 the Regional District of Columbia Shuswap initiated a management program for the lake. The following are some of the actions and recommendations taken by this agency.

The spread of Eurasian water milfoil in Shuswap Lake has resulted in the implementation of a mechanical harvesting control program in 1981. To date, the density of this macrophyte remains low (11, 12).

Water quality in the relatively enclosed portion of Tappen Bay and Salmon Arm (Fig. NAM-47-1) failed to meet the Provincial guidelines for phosphorus for fisheries and recreational uses (10). Tributary streams are also enriched with phosphorus from agricultural inputs rather than from septic systems. A major water quality monitoring program has been set up to determine the optimal waste treatment management program for the lake and to determine appropriate methods for reducing phosphorus loadings (10).

Given the historical patterns of activity and risk that have been commonly associated with alluvial fans, it was recommended that no more development occur on five of the major alluvial fans in the Shuswap Watershed (13).

Given the importance of shoreline areas in the production of fisheries and waterfowl resources, a shoreline habitat protection program was recommended and special action has been taken to protect the Western Grebe colony along the foreshore east of the Salmon River as well as the Bighorn Rocky Mountain Sheep near Chase. Finally, wildlife habitat areas in the Salmon River estuary, the mouth of the Eagle River, Seymour River estuary and Bughouse Bay areas have been kept free of development (10). A fisheries management study is currently underway to assess fishery production and to determine areas for special attention (10).

M. LEGISLATIVE AND INSTITUTIONAL MEASURES FOR UPGRADING LAKE ENVIRONMENTS

M1 NATIONAL AND LOCAL LAWS CONCERNED

§ Names of laws
- (1) Federal Fisheries Act
- (2) Canada Water Act

§ Responsible authorities
- (1) Department of Fisheries and Oceans
- (2) Ministry of Environment, Waste Management Branch
- (3) Ministry of Environment, Fish and Wildlife

§ Main items of control
- (1) Protection of anadromous fish species
- (2) Waste disposal
- (3) Fishing and hunting regulations
- (4) Domestic and commercial water usage

M2 INSTITUTIONAL MEASURES

- (1) British Columbia Ministry of the Environment, Kamloops, BC.
- (2) British Columbia Ministry of Forests, Kamloops, BC.
- (3) Environment Canada, Atmospheric Environment Service, Kamloops, BC.
- (4) Salmon Arm Chamber of Commerce, Mclead Avenue, Salmon Arm, BC.
- (5) Mr. Fred Harper, Regional Wildlife Biologist

M3 RESEARCH INSTITUTES ENGAGED IN THE LAKE ENVIRONMENT STUDIES

- (1) Canada Department of Fisheries and Oceans, Biological Sciences Branch, West Vancouver, BC.
- (2) British Columbia, Ministry of the Environment, Fish and Wildlife Branch
- (3) British Columbia, Ministry of the Environment, Waste Management Branch

N. SOURCES OF DATA

(Q) Questionnaire filled by Dr. J. G. Stockner, Department of Fisheries and Oceans, West Vancouver Laboratory, West Vancouver, British Columbia.

(1) Stockner, J. G. & Shortreed, K. S. (1983) A Comparative Limnological Survey of 19 Sockeye Salmon (*Oncorhynchus nerka*) Nursery Lakes in the Fraser River System, British Columbia. Department of Fisheries and Oceans. Can. Tech. Rep. of Fish. and Aquat. Sci. 1190 pp.

(2) Canadian Climate Normals. 1951–1980. Temperature and Precipitation. Environment Canada, Atmospheric Environment Service.

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(4) Hebdem, B., Ministry of Environment. Personal communication.
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(6) Goodlad, J. C., Gjernes, T. W. & Brannon, E. L. (1974) Factors affecting sockeye salmon (*Oncorhynchus nerka*) growth in four lakes of the Fraser River system. J. Fish. Res. Board Can., 31 : 871-892.
(7) Ward, F. J. & Larkin, P. A. (1964) Cyclic Dominance in Adams River Sockeye Salmon. International Pacific Salmon Fisheries Commission, Progress Report no. 11.
(8) NTS scale 1 : 250,000 Vernon British Columbia Sheet 82L/edition 1 (1963).
(9) Census of Canada (1981) Population Series, British Columbia, pp. 93-910, Table 4.
(10) B. C. Ministry of Environment (1987) Shuswap Lake Environmental Management Plan. B. C. Ministry of Environment, West Vancouver, British Columbia.
(11) Einarson, E. D. (1986) The 1985 Eurasian Water Milfoil Surveilance and Control Program in Shuswap Lake. Littoral Resources Unit, Water Management Branch, B. C. Ministry of Environment Resource Quality Section, Water Management Branch, B. C. M. O. E., Victoria.
(12) Einarson, E. D. (1986) Preliminary Assessment of Water Quality of Shuswap Lake Area. Unpublished manuscript. Resource Quality Section, Water Management Branch, B. C. M. O. E., Victoria, B. C. 15 pp.
(13) Thurber Consultants (1983) Floodplain Management on Alluvial Fans. Report to the Ministry of the Environment, Water Quality Branch, B. C. M. O. E., Victoria.

LAKE MEMPHREMAGOG

A view on the lake

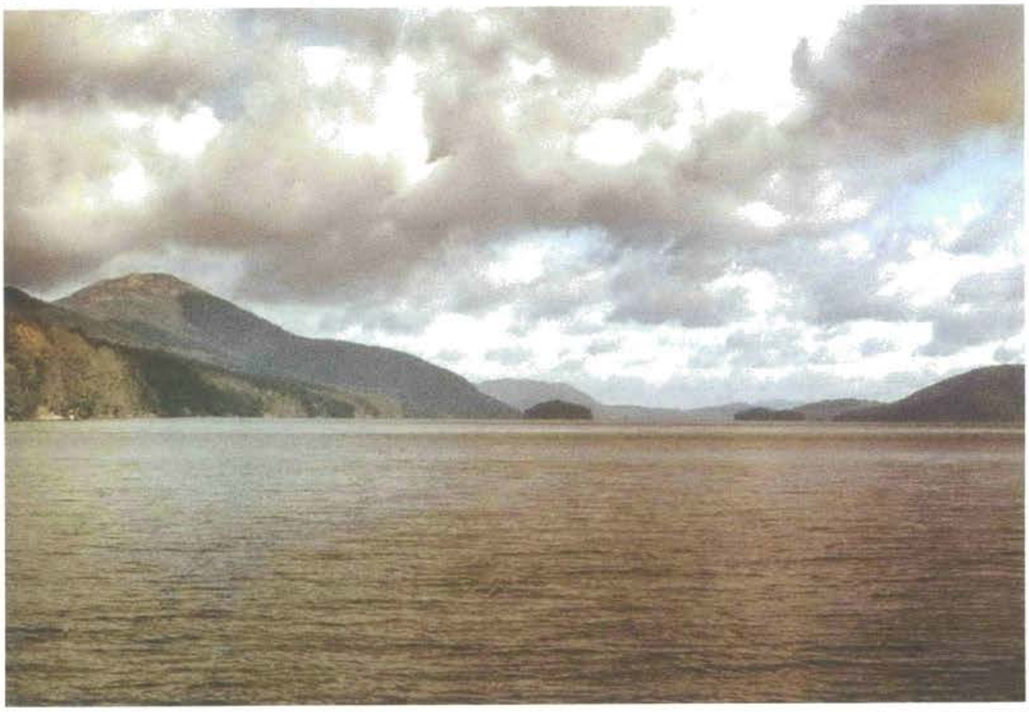
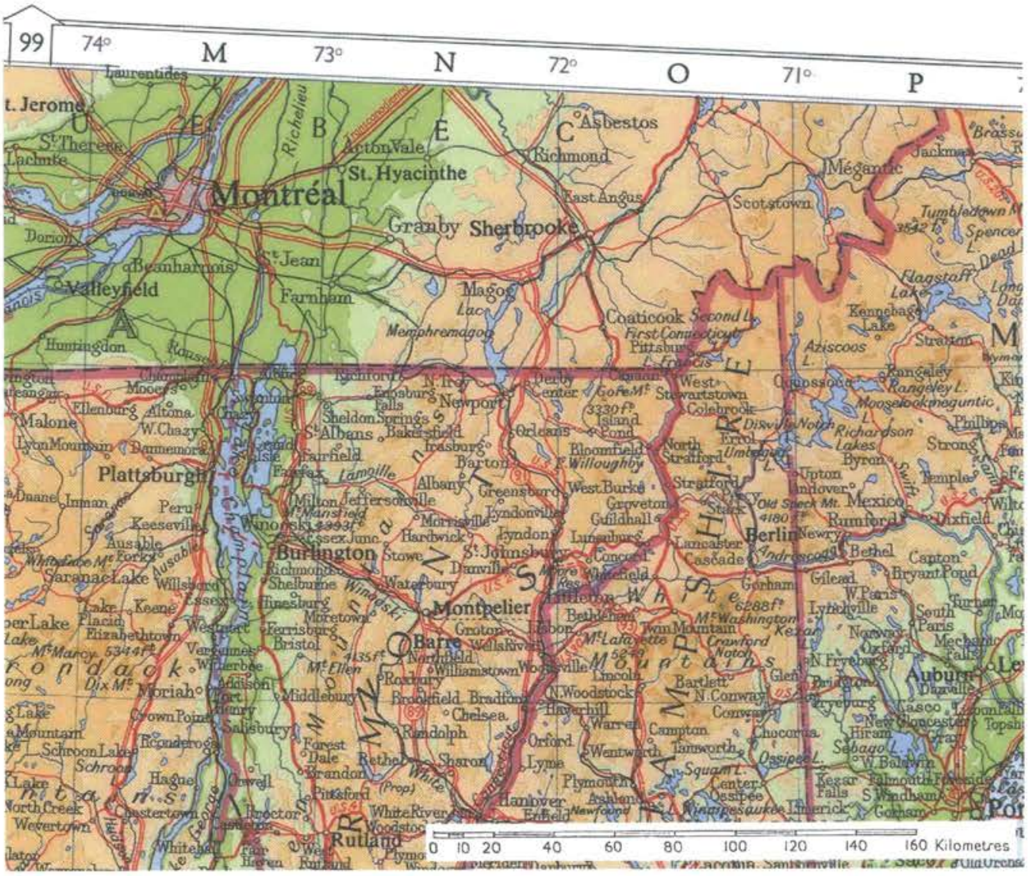


Photo: J. Kalff



A. LOCATION

§ Quebec, Canada ; Vermont, USA.
§ 44°55′-45°15′N, 72°17′-72°10′E ; 208 m above sea lével.

B. DESCRIPTION

Lake Memphremagog is a long (40 km) but narrow (1-3 km) lake, located 130 km to the east of Montreal, Quebec. It is a transboundary lake, receiving 71 % of its stream inflow from the Vermont, U. S. A., portion of its catchment, but with 75 % of the lake surface area in Quebec, Canada. It is a lake of exceptional, rugged beauty ; set in a diverse landscape, hilly and mountainous to the west, but with pastoral, rolling farmland to the east.

The drainage basin of Lake Memphremagog is situated in the physiographic region of the Piedmont. Its early geologic history is tied to the uplift and folding of the Appalachian Mountain chain. The present lake basin was formed about 11,000 B. P. by glacial gouging of a preexisting valley during the final retreat of the Wisconsin glaciation. Following the termination of the Champlain Sea phase, the present lake was formed about 9,500 B. P.

The lake has three distinct basins, a deep Central, and shallower North and South basins. 70 % of the lake's watershed is drained by three rivers which enter the lake at the extreme south end and provide the primary input of nutrients into the lake. This has resulted in a distinct nutrient gradient within the lake — the southern end is mesotrophic, while the Central and North basins remain oligotrophic.

The first known settlements were established by the St. Francis Indian community on what they called Lake "Mem-plow-bouque" (large, beautiful expanse of water). The first European settlements were founded in 1793 at Ducansborough (now Newport, Vermont) and in 1794 at Gibraltar Point (now Bolton, Quebec). The Canadian side was largely settled by United Empire Loyalists (settlers who left America after the revolution because they wanted to remain under the British Flag). The lake was popular as a recreation and vacation area in the mid-to-late 1800's, but tourism dropped off sharply after the turn of the century and the area was not subjected to the intensive development pressures and related problems that have affected other river basins in the northeastern United States or southern Quebec. These historical trends are changing as the 1980's brought a new tourism boom and a steady wave of related development to both the American and Canadian portions of the lake basin. The problems associated with increased development have, for the present, been offset by a continuing reduction in crop growing and increased forest regrowth, as well as the installation of tertiary sewage treatment at Newport in 1983 (1, 2, 3).

C. PHYSICAL DIMENSIONS (1, 2)

	North basin	Central basin	South basin	Total
Surface area [km^2]	—	—	—	102
Volume [10^9m^3]	—	—	—	1.7
Maximum depth [m]	33 (2)	107	12	107
Mean depth [m]	13	55	8	15.5
Normal range of annual of water level fluctuation (regulated) [m]	—	—	—	0.5
Length of shoreline [m]	—	—	—	121
Residence time [yr]	—	—	—	1.7
Catchment area [km^2]	—	—	—	1,764

D. PHYSIOGRAPHIC FEATURES

D1 GEOGRAPHICAL

§ Bathymetric map (Fig. NAM-48-1).
§ Main islands : Trois Soeurs, Lords, Molson, Longue, Ronde, Province, Whetstone.
§ Outflowing rivers and channels (number and names) : 1 (Magog R.).

D2 CLIMATIC

§ Climatic data at Sherbrooke*, 1987 (6)

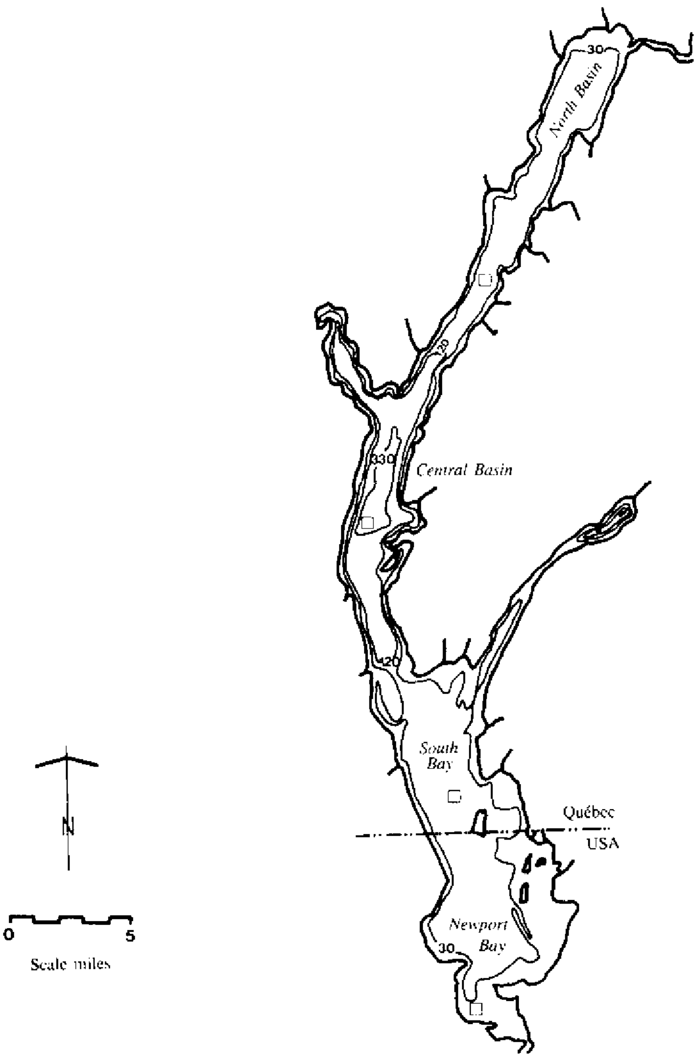
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean temp. [°C]	-11	-13	-2	7	11	18	19	16	13	6	-1	-6	4
Precipitation [mm]	58	22	54	41	99	124	85	58	93	117	112	62	925

*23 km from the outflow.

§ Number of hours of bright sunshine : 1,895 hr yr^{-1}.
§ Average solar radiation at Montreal Jean Brebeuf (100 km from the outflow) : 12.5 MJ $m^{-2}day^{-1}$.
Mean daily global solar radiation [MJ $m^{-2}day^{-1}$]

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
5.30	8.80	12.51	15.87	9.07	20.25	20.96	17.23	13.45	8.04	4.61	3.92

Fig. NAM-48-1 Bathymetric map [feet (30 feet=9.14 m)] (Q).



§ Water temperature [°C] (4)
South basin, 1985

Depth [m]	Jan	Feb	Mar	Apr	May 13	Jun 12	Jul 17	Aug 28	Sep	Oct	Nov	Dec
Surface	–	–	–	–	9.5	14.4	22.7	22.3	–	–	–	–
1	–	–	–	–	9.3	14.4	21.1	22.6	–	–	–	–
2	–	–	–	–	9.0	14.2	20.6	22.8	–	–	–	–
3	–	–	–	–	8.8	14.2	20.3	23.1	–	–	–	–
4	–	–	–	–	8.7	14.2	20.2	23.5	–	–	–	–
5	–	–	–	–	8.5	14.1	20.1	23.9	–	–	–	–
6	–	–	–	–	8.5	14.1	19.9	24.1	–	–	–	–
7	–	–	–	–	8.4	14.1	16.2	23.9	–	–	–	–
8	–	–	–	–	5.2	13.7	15.6	23.9	–	–	–	–
9	–	–	–	–	5.1	11.2	–	–	–	–	–	–

§ Freezing period : From early Dec. to middle Apr.
§ Mixing type : Polymictic.

North basin, 1985

Depth [m]	Jan	Feb	Mar	Apr	May 14	May 28	Jul 17	Aug 28	Sep	Oct	Nov	Dec
Surface	–	–	–	–	4.9	13.2	24.1	22.1	–	–	–	–
1	–	–	–	–	4.9	13.1	23.8	22.1	–	–	–	–
2	–	–	–	–	4.8	12.4	22.1	22.1	–	–	–	–
3	–	–	–	–	4.8	12.2	21.3	22.1	–	–	–	–
4	–	–	–	–	4.8	12.2	21.0	22.1	–	–	–	–
5	–	–	–	–	4.8	11.3	20.3	22.1	–	–	–	–
6	–	–	–	–	–	10.0	19.8	22.1	–	–	–	–
10	–	–	–	–	–	6.6	16.4	22.1	–	–	–	–
15	–	–	–	–	–	–	–	16.1	–	–	–	–

Central basin, 1985

Depth [m]	Jan	Feb	Mar	Apr	May 23	Jun 12	Jul 17	Aug 28	Sep	Oct	Nov	Dec
Surface	–	–	–	–	8.4	13.8	23.5	20.6	–			–
1	–	–	–	–	8.3	13.8	21.4	20.8	–	–	–	–
3	–	–	–	–	8.3	13.8	20.2	20.8	–	–	–	–
5	–	–	–	–	8.0	13.7	19.2	20.8	–	–	–	–
7	–	–	–	–	7.5	13.6	18.3	20.5	–	–	–	–
9	–	–	–	–	6.8	12.9	17.1	20.4	–	–	–	–
11	–	–	–	–	6.5	10.9	15.6	19.9	–	–	–	–
13	–	–	–	–	6.2	9.4	13.3	17.8	–	–	–	–
15	–	–	–	–	6.2	9.1	10.5	12.4	–	–	–	–
17	–	–	–	–	6.1	8.4	8.3	9.1	–	–	–	–
19	–	–	–	–	6.0	6.8	7.2	8.8	–	–	–	–

§ Freezing period : From mid Dec. to mid Apr.
§ Mixing type : Dimictic.
§ Supplementary notes on water mixing and thermocline formation : Thermally stratified in the Central and North basins, late May-Oct., with thermocline at 9-11 m depth.

E. LAKE WATER QUALITY

E1 TRANSPARENCY [m] (4)

North basin, 1987

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
—	—	—	—	6	5	5.3	4.8	5.8	—	—	—

Central basin, 1987

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
—	—	—	—	—	3.9	4.5	4.3	3.5	5.7	—	—

South basin, 1987

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
—	—	—	—	2.9	3.6	3.6	—	4.8	—	—	—

E2 pH

Central basin, 1987

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Surface	—	—	—	—	—	—	—	8.3	—	—	—	

Newport Bay, 1988

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Surface	—	—	—	—		6.7	—	7.1	—	—	—	—

E4 DO [mg l^{-1}]

Central Basin, 1985 (18)

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	—	—	—	—	12.5	10.8	9.5	9.3	8.8	—	—	—
3	—	—	—	—	12.6	10.8	9.7	9.3	8.9	—	—	—
5	—	—	—	—	12.6	10.8	9.9	9.4	8.9	—	—	—
7	—	—	—	—	12.7	10.8	10.0	9.5	8.8	—	—	
9	—	—	—	—	12.6	10.8	9.7	9.5	8.7	—	—	—
11	—	—	—		12.5	10.8	9.5	9.5	8.0	—		—
13	—	—	—	—	12.4	10.8	9.1	8.8	7.3	—	—	
15		—	—	—	12.3	10.8	9.1	8.2	7.5	—	—	—
17	—	—		—	12.3	10.9	9.5	7.8	8.4		—	—
19	—	—	—	—	12.3	10.9	9.7	8.1	8.7	—		—
21	—	—	—	—	12.3	11	10.2	8.8	9.3	—	—	—

E6 CHLOROPHYLL CONCENTRATION [μg l^{-1}] (4)

North Basin, monthly mean of 1987

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
5 m integrated	—	—	—	—	3.0	4.2	2.5	2.6	3.3	—	—	—

Central Basin, monthly mean of 1987

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
5 m integrated	—	—	—	—	4.0	3.9	2.1	3.6	2.9	—	—	—

South Basin, monthly mean of 1987

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
5 m integrated	–	–	–	–	4.7	6.0	4.2	3.6	2.3	–	–	–

E7 NITROGEN CONCENTRATION

§ Total-N [mg l^{-1}] (4)

North basin, monthly mean of 1987

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
5 m integrated	–	–	–	–	0.60	0.35	0.28	0.30	0.23	–	–	–

Central basin, monthly mean of 1987

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
5 m integrated	–	–	–	–	0.65	0.42	0.31	0.23	0.39	–	–	–

South basin, monthly mean of 1987

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
5 m integrated	–	–	–	–	0.46	0.42	0.36	0.29	0.27	–	–	–

E8 PHOSPHORUS CONCENTRATION

§ Total-P [mg l^{-1}] (4)

North basin, monthly mean of 1987

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
5 m integrated	–	–	–	–	.013	.013	.011	.010	.009	–	–	–

Central basin, monthly mean of 1987

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
5 m integrated	–	–	–	–	.017	.013	.012	.011	.011	–	–	–

South basin, monthly mean of 1987

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
5 m integrated	–	–	–	–	.016	.016	.016	.015	.014	–	–	–

E10 PAST TRENDS

Fig. NAM-48-2 Mean summer concentration of chlorophyll *a*, 1972-1986 [$\mu g\ l^{-1}$].

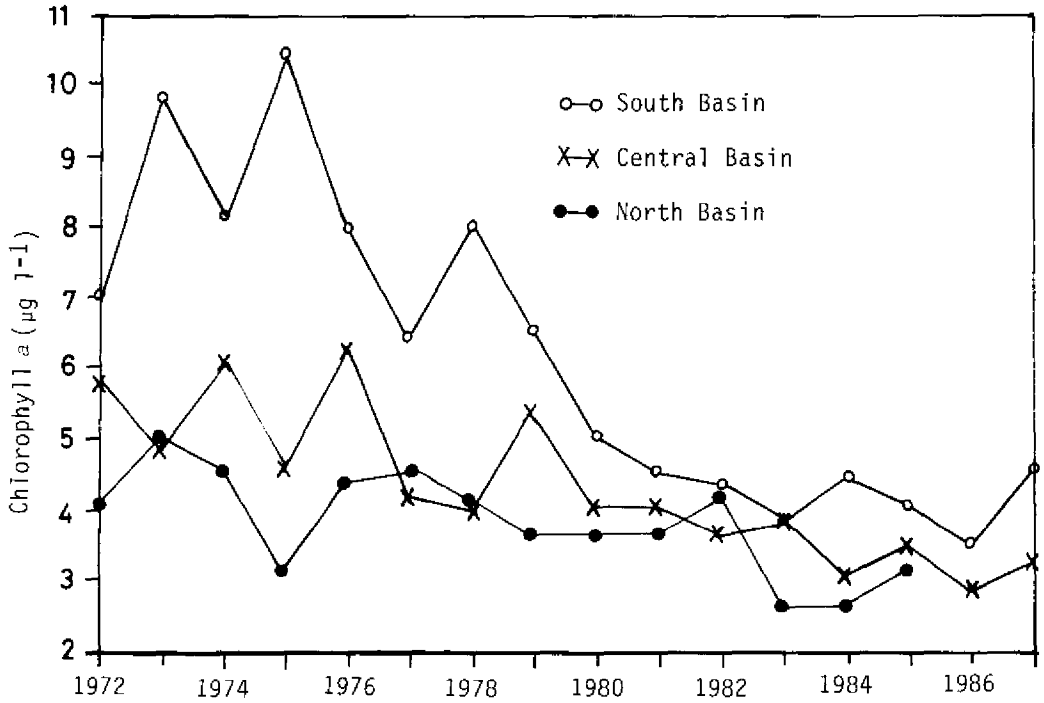
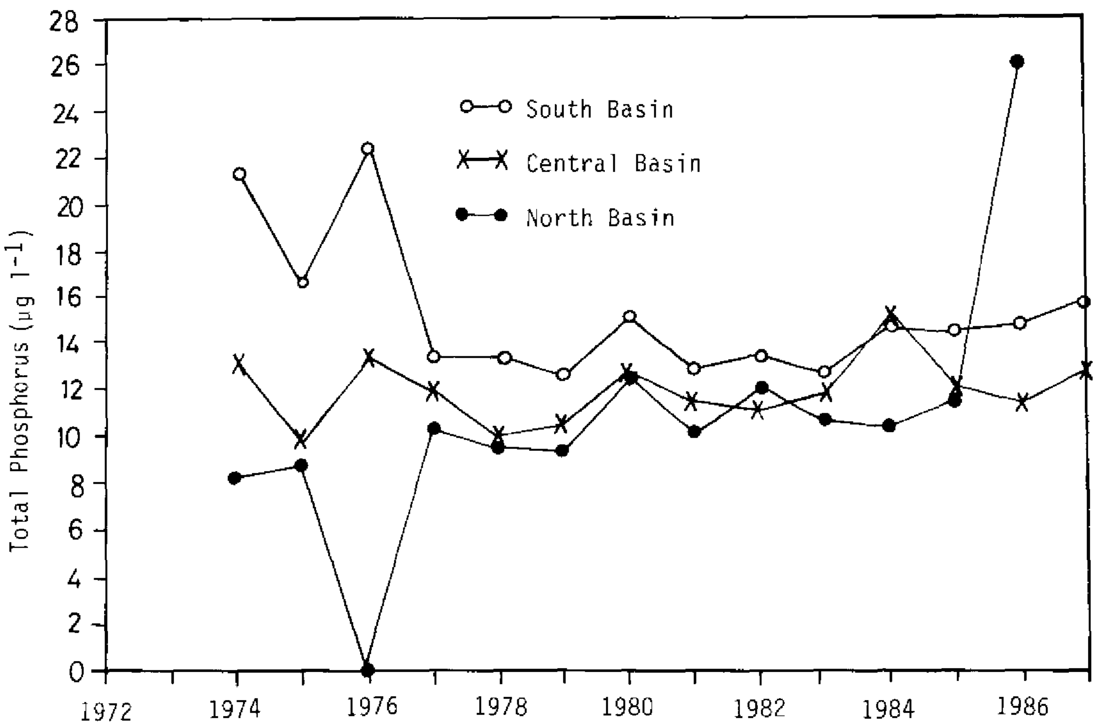


Fig. NAM-48-3 Mean summer concentration of Total-P, 1972-1986 [$\mu g\ l^{-1}$].



F. BIOLOGICAL FEATURES

(All stations combined, 1973-1987)

F1 FLORA

§ Submerged macrophytes

Cabomba caroliniana, Elodea canadensis, E. septangular, Heteranthera dubia, Isoetes sp., *Myriophyllum spicatum, Najas* sp., *Potamogeton richardsonii, P. praelongus, Vallisneria americana, Nitella* sp. (7).

§ Phytoplankton

South basin: *Diatoma tenue* var. *elongatum, Oscillatoria redekei, Ceratium hirundinella, Rhodomonas minuta, Melosira italica, Cryptomonas reflexa, Stephanodiscus astraea, S. hantzschii, Asterionella formosa, Fragilaria crotonensis, Uroglena volvox, Anabaena flos-aqae, Gleococcus schraeteri, Coelosphaerium naegelianum.*

North basin: *Diatoma tenue, Oscillatoria redekei, Fragilaria crotonensis, Rhizosolenia eriensis, R. minuta, Botryococcus braunii, Cyclotella bodanika, C. hirundinella, Synedra ulna* var. *danica, Chrysochromulina parva, Gleococcus schroeteria, Coelosphaerium naegelianum* (14).

F2 FAUNA

§ Zooplankton

Cyclops bicuspidatus thomasi, C. vernalis, Mesocyclops edax, Diaptomus sicilis, D. minutus, Tropocyclops prasinus mexicanus, Epischura lacustris, Senecella calanoides, Daphnia galeata, Bosmina longirostris, B. coregoni, Chydorus sphaericus, Holopedium gibberum, Ceriodaphnia quadrangula, Diaphanosoma leuchtenbergianum, Keratella sp., *Monostyla* sp., *Polyarthra* sp. (12, 16, 17).

§ Benthos

Chironomus anthracinus, Chaoborus punctipennis, Tanytarsus spp., *Procladius* spp., *Phaenospectra* sp., *Microspectra* sp., *Pontoporeia hoyi, Amnicola sphaerium, Fossaria, Helisoma* (8, 12).

§ Fish

Hybognathus nuchalis, Notemigonus crysoleucas, Notropis volucellus, Pimephales notatus, Etheostoma nigrum, Perca flavescens, Fundulus diaphanus, Lepomis gibbosus, Micropterus dolomieu, Semotilus corporalis, Catostomus commersoni, Osmerus mordax (9).

§ Supplementary notes on the biota

The nutrient gradient along the axis of the lake influences the abundance and distribution of organisms. Biomass of fish species is about three times greater in the more productive southern end. Phytoplankton and benthos biomass and production too are greater in the south (8, 9).

F3 PRIMARY PRODUCTION RATE

§ Phytoplankton

Net C^{14} production rate [gC $m^{-2}day^{-1}$], Nov. 1972-Oct. 1973 (10)

	1973											1972	1972/1973
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Total
North basin	0.1	0	0.1	0.3	0.8	0.9	0.7	0.7	1.0	0.5	0.3	0.2	175
Central basin	–	–	–	–	0.6	1.0	0.7	1.0	–	–	–	–	–
South basin	0.1	0.1	0.3	0.7	0.7	0.7	1.3	1.1	1.5	0.7	0.2	0.1	219

F4 BIOMASS (9)

§ Mean annual benthic biomass (dry wt.) (1972-1973)

South basin: 3.30±0.25 g m^{-2}.
Noth basin: 1.19±0.06 g m^{-2}.

F7 NOTES ON THE REMARKABLE CHANGES OF BIOTA IN THE LAKE IN RECENT YEARS

None.

G. SOCIO-ECONOMIC CONDITIONS

G1 LAND USE IN THE CATCHMENT AREA (1981) (1, 2)

	Area [km²]	[%]
Natural landscape	(1,424)	(81)
Woody vegetation	1,300	74
Herbaceous vegetation	88	5
Swamp	36	2
Agricultural land		
Crop field	240	14
Settlement area	80	5
Total	1,744	100

§ Types of important forest vegetation : Maple, beech, birch, spruce, fir.
§ Types of important herbaceous vegetation : Abandoned pasture, hay.
§ Main kinds of crops and/or cropping systems : Hay, maize.
§ Levels of fertilizer application on crop fields : Light (manure application).
§ Trends of change in land use in recent years

Historically, economy based on natural resources. Now manufacturing is playing a more significant role. 37 % decline in natural resource industries (agriculture, forestry) from 1960 to 1970. In the 1980's, 10 % of woodland harvested annually (2).

G2 INDUSTRIES IN THE CATCHMENT AREA AND THE LAKE (1974) (2)

U. S. portion of the catchment area (Orleans County) only

	Gross production during the year (=US$ 1.00)	Percentage of persons engaged	No. of establishments	Main products or major industries
Primary industry	$24 million	16	666	
Crop production				Corn, hay
Animal husbandry				Dairy products
Fisheries				
Secondary industry				
Manufacturing & construction	N. A.	32	27	Machinery, clothing
Tertiary industry	N. A.	40		Service, transport, etc.
(Unemployed)		12		

§ Numbers of domestic animals in the catchment area : Cattle 25,000, others unknown.

G3 POPULATION IN THE CATCHMENT AREA (1975) (2)

	Population*	Population density [km⁻²]	Main cities
Rural	19,702		
Total	19,702	11.2	Newport, Derby

* Included — 18,702 in U. S. and 1,000 in Canada.

§ Supplementary notes

Seasonal population is +20,000, and rapidly growing. More than 1,500 vacation cottages line the shores of the lake (1).

H. LAKE UTILIZATION

H1 LAKE UTILIZATION

Source of water, sightseeing and tourism (no. of visitors in 1975 : 20,000) and recreation (swimming, sport-fishing, yachting).

H2 THE LAKE AS WATER RESOURCE (1974) (2)

	Use rate [$m^3 sec^{-1}$]
Domestic water	1
Industrial water	34

I. DETERIORATION OF LAKE ENVIRONMENTS AND HAZARDS

I1 ENHANCED SILTATION

§ Extent of damage : Not serious.

§ Supplementary notes

Excessive erosion and sedimentation on cropland on steep slopes — on Vermont rivers. Streambank erosion due to livestock and soil erosion due to poor logging practices. Offset by gradual reduction in cropland and increases in pasture and forest.

I2 TOXIC CONTAMINATION

§ Present status : Detected but not serious.

§ Main contaminants, their concentration and sources

North basin, 1988

Name of contaminants	Concentration [ppm] in bottom mud*
Zn	198
Mn	533
Ni	109
Cu	45
Pb	117
Fe [%]	4

* Dry weight basis.

§ Supplementary notes : Metal levels not highly variable throughout the lake (11).

I3 EUTROPHICATION

§ Phosphorus loadings to the lake [t yr^{-1}] (1972, 1987) (13)

Sources	Domestic	River loading	Natural recip.	Total
	1987	1972	1972	
T-P	1	21	7	29

§ Supplementary notes

Eutrophication has only been a problem in the extreme south end of the lake, while north and central basins are oligotrophic. However, a new sewage treatment system that went into operation in 1983 reduced the T-P loadings (from the town of Newport) from 20 t yr^{-1} to <1 t yr^{-1} (13).

I4 ACIDIFICATION

§ Extent of damage : None.

J. WASTEWATER TREATMENTS

J1 GENERATION OF POLLUTANTS IN THE CATCHMENT AREA : (c) Limited pollution with wastewater treatment.

J3 SANITARY FACILITIES AND SEWARAGE

§ Percentage of municipal population in the catchment area provided with adequate sanitary facilities (on-site treatment systems) or public sewerage : 100 %.

§ Percentage of rural population with adequate sanitary facilities (on-site treatment systems) : Unknown.

§ Municipal wastewater treatment systems

Number of tertiary treatment systems : 3 (P removal).
Number of secondary treatment systems : 3.
Number of industrial wastewater treatment systems : 2.

K. IMPROVEMENT WORKS IN THE LAKE

None (Q).

L. DEVELOPMENT PLANS

Increasing recreational development and condominium construction (Q).

M. LEGISLATIVE AND INSTITUTIONAL MEASURES FOR UPGRADING LAKE ENVIRONMENTS

M1 NATIONAL AND LOCAL LAWS CONCERNED

§ Names of the laws (the year of legislation)

(1) The level at which Lake Memphremagog should be maintained. Dam on outflow (1935)

§ Responsible authorities

(1) Environment Canada, U. S. Dept. of the Army/Corps of Engineers, Quebec
(2) Dept. of the Environment

§ Main items of control

(1) Lake level

M2 INSTITUTIONAL MEASURES

Memphremagog Conservation Inc., Quebec (employs students in clean-up work and public education)

M3 RESEARCH INSTITUTE ENGAGED IN THE LAKE ENVIRONMENT STUDY

(1) Limnology Research Centre, McGill University, Montreal, Quebec

N. SOURCES OF DATA

(Q) Questionnaire filled by Dr. J. Kalff, Limnology Research Centre, McGill University, Montreal, Canada.
(1) Memphremagog Conservation Inc. (1982) Environmental Land Use Guide of the Lake Memphremagog Watershed.
(2) New England River Basins Commission (1981) Lake Memphremagog — St. Francis River Basin Overview.
(3) Carlson, R. E., Kalff, J. & Leggett, W. C. (1979) The phosphorus and nitrogen budgets of Lake Memphremagog ; with a predictive model of its nutrient content following sewage removal.
(4) Limnology Research Centre (1972-1988) Lake Memphremagog Data Collection. McGill University, Montreal, Quebec.
(5) Rasmussen, J., personal communication.
(6) Environment Canada (1987) Meteorological reports.
(6a) Canadian Climate Normals, 1951-1980. Environment Canada, Atmospheric Environment

Service.
(7) Downing, J. A. & Anderson, M. R. (1985) Estimating the standing biomass of aquatic macrophytes. Can. J. Fish. Aquat. Sci., 42(12): 1860-1869.
(8) Dermott, R. M., Kalff, J., Leggett, W. C. & Spence, J. (1977) Production of *Chironomus*, *Procladius* and *Chaoborus* at different levels of phytoplankton biomass in Lake Memphremagog, Quebec-Vermont. Can. J. Fish Aquat. Sci., 34(11): 2001-2007.
(9) Gascon, D. & Leggett, W. C. (1977) Distribution, abundance and resource utilization of littoral zone fishes in response to a nutrient/production gradient in Lake Memphremagog. J. Fish. Res. Bd., 34: 1105-1117.
(10) Ross, P. E. & Kalff, J. (1975) Phytoplankton production in Lake Memphremagog, Quebec (Canada)-Vermont (USA). Verh. Int. Ver. Limn., 19: 760-769.
(11) Rowan, D., McGill Univ., personal communication.
(12) Morse, J. W. & Flanders, P. H. (1971) Primary Productivity Study of Three Vermont Lakes. State of Vermont Agency of Conservation.
(13) Kalff, J. & Lawson, A. (1988) The Capacity of Lake Memphremagog for Further Development. Limnology Research Centre, McGill University.
(14) Watson, S. (1979) Phytoplankton dynamics in Lake Memphremagog and their relationship to trophic level. M. Sc. Thesis, McGill University, Montreal.
(15) Chambers, P. & Kalff, J. (1985) Depth distribution and biomass of submerged aquatic macrophyte communities in relation to Secchi depth. Can. J. Fish. Aquat. Sci., 42: 701-709.
(16) Sarafian, V. (1984) Life cycles, biomass and production of copepods in Lake Memphremagog. M. Sc. Thesis, Concordia University, Montreal.
(17) Shoenert, R. A. & Peters, R. H. Cladoceran abundance along the trophic gradient of Lake Memphremagog. Internal report. McGill University, Montreal.
(18) Marshall, T., personal communication.

MASSAWIPPI LAKE

A view on the lakeshore

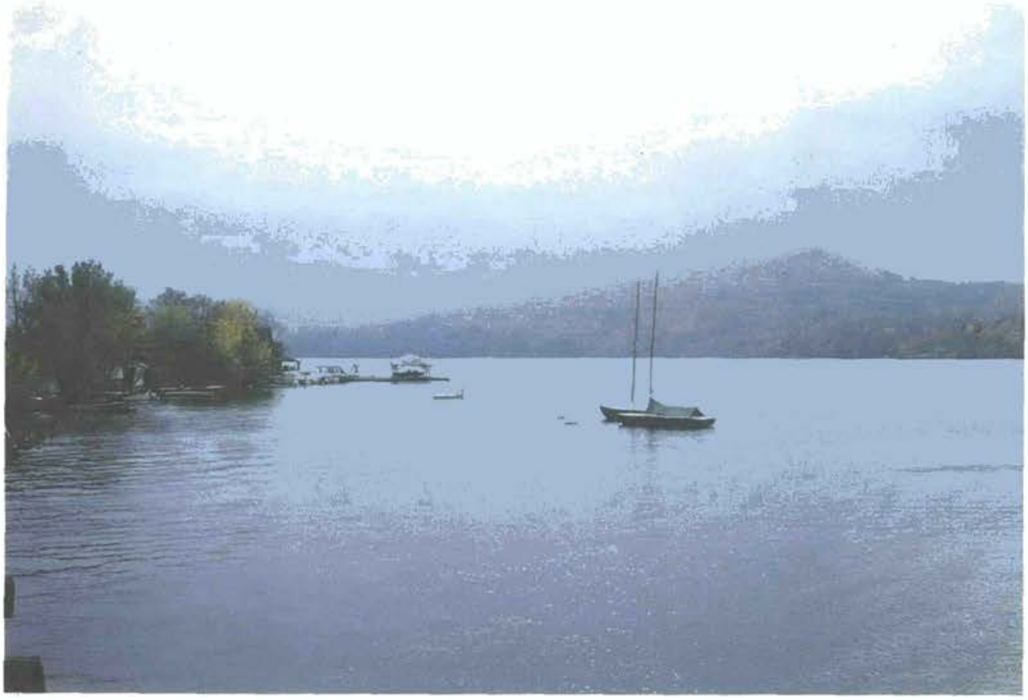
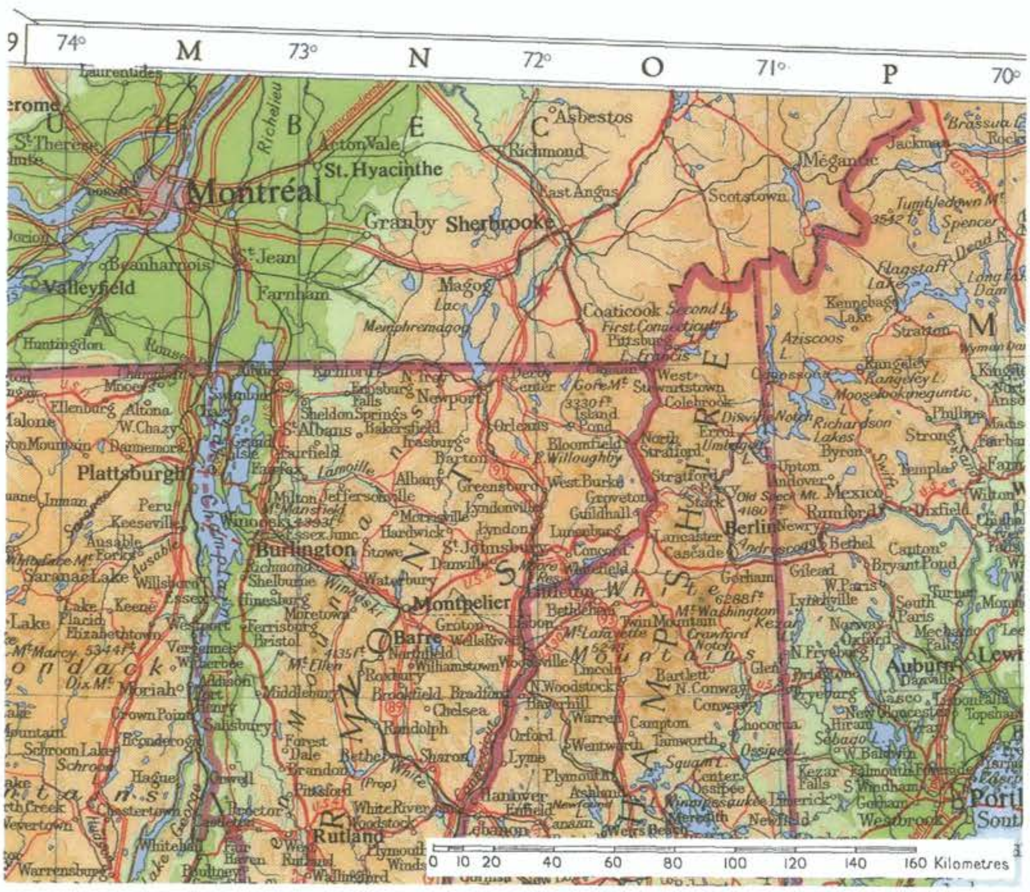


Photo: J. Dupont



A. LOCATION

§ Quebec, Canada.
§ 45°10′-45°17′N, 71°58′-72°04′W ; 160.8 m above sea level.

B. DESCRIPTION

From the morphometric point of view, Lake Massawippi is a lake of which the maximum and average depth are very large. The dissolved mineral content is high compared to other Quebec lakes and even elevated compared to lakes of the Eastern Townships. The specific conductivity, for example, ranges from 120 to 230 μS cm^{-1} and the waters are dominated by HCO_3 (64-72 mg l^{-1}) and Ca (26-35 mg l^{-1}). The general geology of the Lake Massawippi watershed consists of two lithology groups. Calcareous fine to coarse-grained clastic sedimentary rocks are found in the southwest of the lake, while non-calcareous siliceous sedimentary rocks characterize the northwest portion of the watershed. It is a dimictic lake. The temporal variations in the percentage saturation of dissolved oxygen at the bottom of the lake (deep zone) are characteristic of a mesotrophic lake. One notes in effect, a percentage of oxygen saturation at the bottom of the order of 50 % in August. The concentrations of phosphorus and nitrogen are elevated and it could be assumed that these waters are productive. The parameters of the primary production are high at the south end of the lake and show medium values in the zone of the outlet of the lake. In addition, the transparency of the water of this lake is in the mesotrophic range (4-6 m).

In the immediate environment, 71 % of the perimeter of the lake have been strongly affected, above all by the following criteria : cottages too close to the lake, railway bordering the beach of the lake and excessive clearing of trees. 21 % of the perimeter of the lake have not yet been touched.

The catchment basin of the lake is only 46 % wooded and agriculture occupies a bit more than 44 % of the area of the basin. The rest is in a zone of leisure and urban development.

The amount of phosphorus received annually by Lake Massawippi surpasses theoretically the dangerous limit, above which accelerated eutrophication can be expected. Of all the total input more than 54 % comes from the animal population. Agricultural husbandry contributes enormously to the eutrophication of the lake. The spreading of chemical fertilizers as well as the animal population contribute more than 75 % of the total input to the lake. The natural input constitutes only 16 % of all the total input. The effect of this input seems to make itself felt in the southwest section of the lake receiving the principal load of phosphorus.

Eutrophication of the southwest part of Massawippi Lake has been accelerating for the past several years due to various human activities in the environment near the lake and in a developing sector of its drainage basin (1, Q).

C. PHYSICAL DIMENSIONS

Surface area [km^2]	17.9
Volume [10^{6}m^3]	745
Maximum depth [m]	85.7
Mean depth [m]	41.6
Normal range of annual of water level fluctuation	Regulated
Length of shoreline [km]	38.3
Residence time [yr]	1.5
Catchment area [km^2]	586.3

D. PHYSIOGRAPHIC FEATURES

D1 GEOGRAPHICAL

§ Bathymetric map (Fig. NAM-49-1).

§ Outflowing rivers and channels (number and names) : 1 (Massawippi R.).

D2 CLIMATIC

§ Climatic data at Bonsecours (25 km from the lake), 1951-1980 (2)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean temp. [°C]	-11.5	-10.4	-3.9	3.6	10.6	15.8	18.2	16.8	12.5	6.8	0.2	-8.4	4.2
Precipitation [mm]	75	68	85	91	96	96	123	134	97	93	95	84	1,136

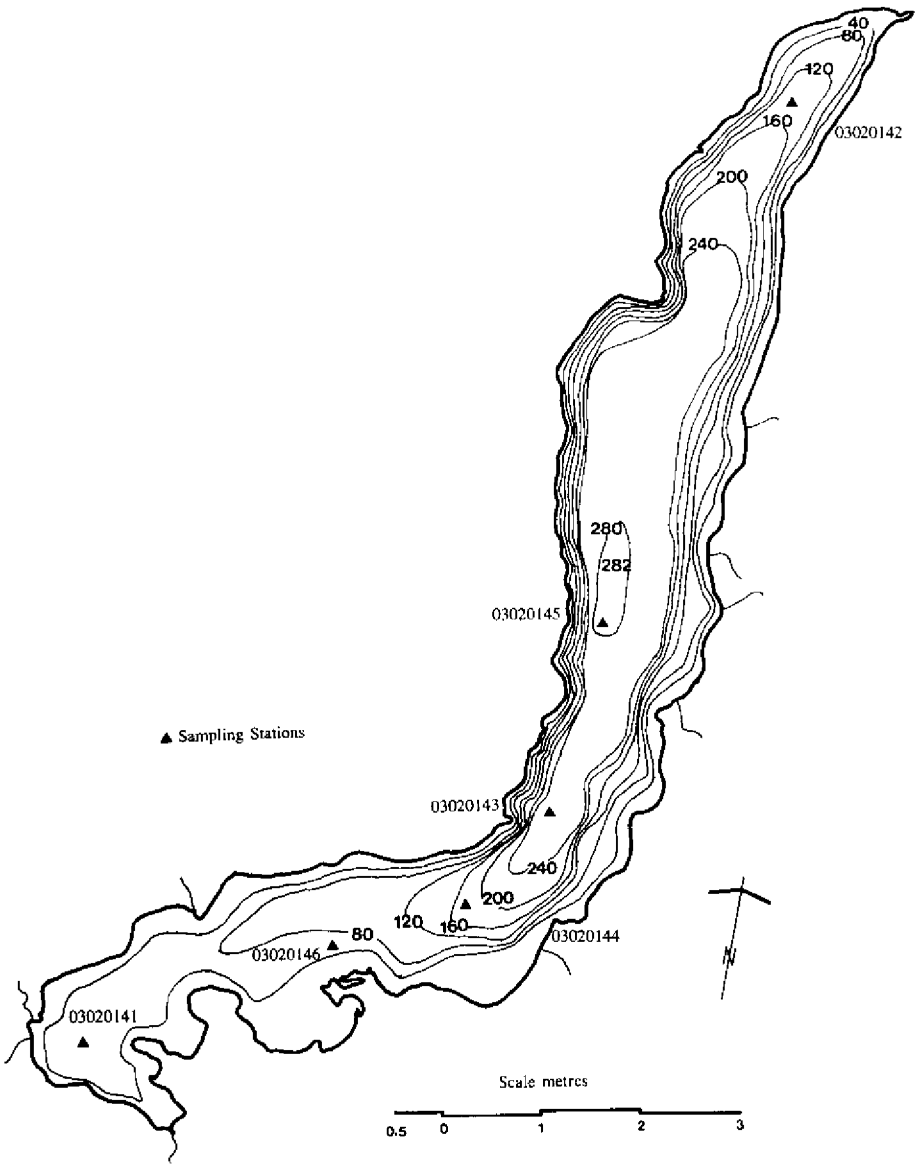
§ Number of hours of bright sunshine (Sherbrooke, 120 km west of the lake) : 1,900 hr yr^{-1}.

§ Average solar radiation (Montreal Jean Brebeuf) : 12.5 MJ $m^{-2}day^{-1}$.

Mean daily global solar radiation (Montreal Jean Brebeuf) [MJ $m^{-2}day^{-1}$]

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
5.30	8.80	12.51	15.87	19.07	20.25	20.96	17.23	13.45	8.04	4.61	3.92

Fig. NAM-49-1 Bathymetric map [feet (40 feet=12.2 m)] (Q).



§ Water temperature [°C]
Station 03020145, 1984

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	—	2	—	5.6	—	—	—	24.5	—	—	10.7	—
5	—	—	—	—	—	—	—	22.5	—	—	—	—
8	—	—	—	—	—	—	—	17.0	—	—	—	—
10	—	—	—	—	—	—	—	11.9	—	—	—	—
12	—	—	—	—	—	—	—	9.4	—	—	—	—
15	—	—	—	—	—	—	—	8.3	—	—	—	—
20	—	—	—	—	—	—	—	7.5	—	—	—	—
30	—	—	—	—	—	—	—	6.1	—	—	—	—
40	4.1	—	—	—	—	—	—	—	—	—	5.1	—
84 F*	4.3	—	—	3.9	—	—	—	4.6	—	—	4.4	—

*F: bottom.

§ Freezing period: From Dec. to Apr.

§ Mixing type: Dimictic.

E. LAKE WATER QUALITY

E1 TRANSPARENCY [m]

Station 03020145, 1984

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
—	—	—	—	4.0	—	—	4.0	—	—	—	6.0

E2 pH

Station 03020145, 1982

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Surface	—	—	7.6	—	7.0	—	—	8.9	—	8.0	—	—
1	—	—	—	—	6.6	—	—	8.6	—	7.8	—	—
3	—	—	—	—	—	—	—	8.6	—	—	—	—
5	—	—	—	—	—	—	—	8.4	—	—	—	—
7	—	—	—	—	—	—	—	8.3	—	—	—	—
8	—	—	—	—	—	—	—	7.9	—	—	—	—
9	—	—	—	—	—	—	—	6.7	—	—	—	—
10	—	—	—	—	—	—	—	6.5	—	—	—	—
11	—	—	—	—	—	—	—	6.6	—	—	—	—
12	—	—	—	—	—	—	—	6.6	—	—	—	—
20	—	—	—	—	—	—	—	6.8	—	—	—	—
30	—	—	—	—	6.4	—	—	—	—	—	—	—
40	—	—	—	—	—	—	—	7.0	—	7.0	—	—
50	—	—	—	—	—	—	—	7.0	—	—	—	—
70	—	—	—	—	—	—	—	7.0	—	—	—	—
84 F	—	—	—	—	6.3	—	—	7.0	—	6.9	—	—

E3 SS [mg l^{-1}]

Station 03020145, 1981

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Surface	—	—	—	—	1.0	—	—	1.0	—	—	2.0	—

E4 DO [mg l^{-1}]
Station 03020145, 1983

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	—	11.4	—	—	10.9	—	—	9.7	—	—	8.9	—
3	—	—	—	—	—	—	—	9.7	—	—	—	—
5	—	—	—	—	—	—	—	9.5	—	—	—	—
7	—	—	—	—	—	—	—	9.3	—	—	—	—
8	—	—	—	—	—	—	—	8.0	—	—	—	—
9	—	—	—	—	—	—	—	8.1	—	—	—	—
10	—	—	—	—	—	—	—	8.2	—	—	—	—
11	—	—	—	—	—	—	—	8.4	—	—	—	—
12	—	—	—	—	—	—	—	8.5	—	—	—	—
15	—	—	—	—	—	—	—	8.8	—	—	—	—
20	—	—	—	—	—	—	—	9.2	—	—	—	—
35	—	7.0	—	—	—	—	—	—	—	—	—	—
40	—	—	—	—	10.8	—	—	9.8	—	—	8.5	—
60	—	—	—	—	—	—	—	9.5	—	—	—	—
80 F	—	5.0	—	—	9.3	—	—	7.4	—	—	8.5	—

E5 COD [mg l^{-1}]
Station 03020145, 1984

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Surface	—	3.2	—	—	3.2	—	—	4.0	—	2.8	—	—
80 F	—	—	—	—	—	—	—	3.0	—	—	—	—

Method used : Cobalt oxide.

E6 CHLOROPHYLL CONCENTRATION [μg l^{-1}]
Station 03020145, 1984

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Surface	—	—	—	—	—	—	—	4.9	—	—	—	—

E7 NITROGEN CONCENTRATION
§ NO_3-N+kejhdahl-N
Station 03020145, 1984

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Surface	—	0.67	—	—	0.65	—	—	0.34	—	0.58	—	—
80 F	—	—	—	—	—	—	—	0.70	—	—	—	—

E8 PHOSPHORUS CONCENTRATION
§ Total-P [mg l^{-1}]
Station 03020145, 1982

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Surface	—	0.007	—	—	0.030	—	—	<0.007	—	—	<0.007	—

E9 CHLORIDE ION CONCENTRATION [mg l^{-1}]
Station 03020145, 1984

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Surface	–	6.0	–	–	7.0	–	–	8.0	–	–	9.0	–
80 F	–	–	–	–	–	–	–	8.0	–	–	–	–

F. BIOLOGICAL FEATURES

F1 FLORA (Q)

§ Emerged macrophytes
Eleocharis sp., *Pontederia cordata, Scirpus validus, Typha latifolia, Equisetum littorale, Sparganium chlorocarpum.*

§ Floating macrophytes : *Nuphar variegatum.*

§ Submerged macrophytes
Myriophyllum exalbescens, Najas flexilis, Potamogeton amplifolius, P. pusillus, P. richardsonii, P. robinsii, Elodea canadensis.

§ Phytoplankton (major occurrence)
Bacillariophyceae (Jun. to Aug.), Cryptophyceae (May to Jul.), Chrysophyceae (Jun.), Chlorophyceae (May).

F2 FAUNA (Q)

§ Fish (in order of relative abundance)
*Perca flavescens, Ambloplites rupestris, Catostomus commersoni, C. catostomus, Notemigonus crysolencas, Coregonus carinatum, Moxostoma carinatum, Micropterus dolomieui, Lepomis gibbosus, Ictaleurus nebulosus, Moxostoma anisurum, Salmo trutta**, *Salvelinus namaycush**, *Esox lucius** (*economically important).

F5 FISHERY PRODUCTS
No commercial fishing, only sport fishing.

G. SOCIO-ECONOMIC CONDITIONS

G1 LAND USE IN THE CATCHMENT AREA (1976)

	Area [km²]	[%] (for Canada)
Watershed located in Canada	498.3	
in USA	105.9	
Natural landscape		
Woody vegetation	231.2	46.4%
Herbaceous vegetation	28.9	5.8%
Swamp	0.3	<0.1%
Agricultural land		
Crop field	170.0	34.1%
Pasture land	53.8	10.8%
Settlement area	10.6	2.1%
Others	4.0	0.8%
Total	498.3	100.0%

§ Types of important forest vegetation : Maple, yellow birch, spruce.
§ Levels of fertilizer application on crop fields : Moderate.
§ Main kinds of crops and/or cropping systems : Corn, cereal, vegetables.

G2 INDUSTRIES IN THE CATCHMENT AREA AND THE LAKE (1981) (3)

	Main products or major industries
Primary industry	Agriculture
Secondary industry	Manufacturing, construction
Tertiary industry	Various service industries

§ Numbers of domestic animals in the catchment area : Cattle 19,336, sheep 5,166, swine 10,980, poultry 316,114.

G3 POPULATION IN THE CATCHMENT AREA (Canadian part) (1986) (4)

Population	Population density [km^{-2}]	Main cities
Total 3,850 (permanent) (2,180) (seasonal for 1971)	7.7	None

H. LAKE UTILIZATION

H1 LAKE UTILIZATION

Source of water, sightseeing and tourism, and recreation (swimming, sport-fishing, yachting, and high speed boat racing).

H2 THE LAKE AS WATER RESOURCE (1988)

	Use rate
Domestic water	N. A.

I. DETERIORATION OF LAKE ENVIRONMENTS AND HAZARDS

I1 ENHANCED SILTATION

§ Extent of damage : Not serious.

I2 TOXIC CONTAMINATION

§ Present status : Detected but not serious.

§ Main contaminants, their concentrations and sources (1986)

Name of contaminant	Concentrations [mg kg^{-1}] Fish*	Main sources
Mercury	0-1.59	Natural

* Yellow perch flesh ; high concentration in large fish.

§ Food safety standards for toxic contaminant residue : 0.5 mg kg^{-1} for mercury.

I3 EUTROPHICATION

§ Nuisance caused by eutrophication

Unusual algal bloom : Bacillariophyceae and Chrysophyceae.

§ Phosphorus loadings to the lake (1974) [kg yr^{-1}]

Sources	Domestic	Agricultural	Natural	Total
T-P	2,780	25,220	5,340	33,340

§ Supplementary notes : No known program implemented to control agricultural inputs.

I4 ACIDIFICATION

§ Extent of damage : None.

I5 OTHER HAZARDS

Shore arrangement and management is deficient in 73 % of the total length of shore. 7 % is well arranged while 21 % of the shores are in their natural state. The Lake Massawippi Water Protection Group has put pressure on the railroad authorities (the railroad follows the north side of the lake) to remove slags that have been brought from Thedford Mines. These materials were containing high concentrations of Asbestos fibres. According to John Rasmussen (President of the Group), they were able to change this practice.

J. WASTEWATER TREATMENT

J1 GENERATION OF POLLUTANTS IN THE CATCHMENT AREA : (c) Limited pollution with wastewater treatment.

J2 APPROXIMATE PERCENTAGE DISTRIBUTION OF POLLUTANT LOADS

	Percentage
Non-point sources (agricultural, natural and dispersed settlements)	92.4
Point sources (municipal)	7.6

J3 SANITARY FACILITIES AND SEWERAGE

§ Municipal wastewater treatment systems

Number of secondary treatment systems : 2 (aerated lagoon in North Hatley and activated sludge + chlorination in Ayer's Cliff).

K. IMPROVEMENT WORKS IN THE LAKE

None.

L. DEVELOPMENT PLANS

No development plans around the lake. No data for the rest of the catchment.

M. LEGISLATIVE AND INSTITUTIONAL MEASURES FOR UPGRADING LAKE ENVIRONMENTS

M1 NATIONAL AND LOCAL LAWS CONCERNED

§ Names of the laws

(1) Law related to the quality of the environment of the Quebec Provincial Government

§ Responsible authorities

(1) Quebec Ministry of the Environment

M2 INSTITUTIONAL MEASURES

(1) Ministry of Environment, Quebec City
(2) Massawippi Water Protection Inc., North Hatley (Quebec)

M3 RESEARCH INSTITUTE ENGAGED IN THE LAKE ENVIRONMENT STUDY

(1) Biology Department, Sherbrooke University

N. SOURCES OF DATA

(Q) Questionnaire filled by Dr. J. Dupont, Ministry of Environment, Government of Quebec, Canada.

(1) Government of Quebec, Ministry of Natural Resources (1978) Limnological Study, Lake Massawippi, Quebec.

(2) Canadian Climate Normals, 1951-1980. Environment Canada, Atmospheric Environment Service.

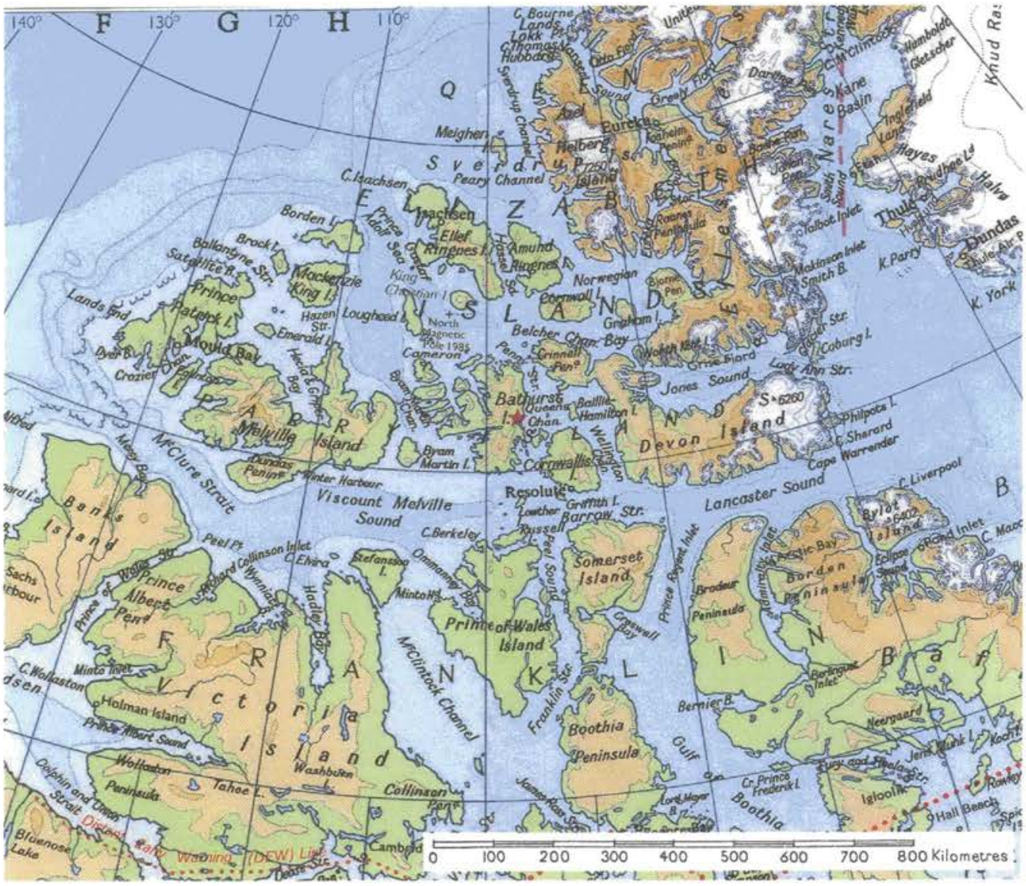
(3) Statistics Canada, Census of Canada, 1981. Population Economic Characteristics of Quebec, Vol. 2, pt. 6, § 5. Ottawa.

(4) Statistics Canada (1987) Census of Canada, 1986. Profile Series. Census Division & Subdivisions, Ottawa.

GARROW LAKE

Across width of the lake from west to east near Station A

Photo: M. Dickman



A. LOCATION

§ North West Territories, Canada.
§ 75°23′N, 96°50′W ; 7 m above sea level.

B. DESCRIPTION

First surveyed in 1974, Garrow Lake lies on Cornwallis Island, NWT, 95 km NNW of Resolute and 3 km from the coast. The lake is ice-covered for 11 months of the year. It is one of only two arctic lakes discovered to date which are both permanently stratified (meromictic) and containing layers of high salinity water (hypersaline). Near the lake surface the salinity approaches that of freshwater, while it is nearly three times that of sea water near the bottom. The water is anoxic below 20 m.

The watershed is gently rolling desert tundra overlying Ordovician shale and limestone. A thick glacial drift covers the area and soils are fluvial with smooth slopes and thick regolith, abundant polygons, frost cracks and solifluction structures. There are several small stream-valley systems with runoff generally restricted to June-August. Wide-spread fossil shells indicate post-glacial uplift from marine or brackish water during Wisconsin post-glacial period. It is estimated that the lake was established approximately 3,000 years B. P. Lead and zinc deposits are located near the lake.

In November 1981, COMINCO Ltd's Polaris Mine Project began discharging lead and zinc mine tailings into Garrow Lake at a depth of 20 m at the rate over 2,500 metric tons per day, which might irreversibly alter the lake by the impact to its anaerobic bacterial population. This is unfortunate because the anaerobic production of sulfide causes the precipitation of lead and zinc ions from the mine tailings, which, in the absence of sulfide producers, will remain in solution and may eventually find their way into the sea. The sulfide producers also form an essential link in the web of life in Garrow Lake, since the photosynthetic bacteria, the major primary producer in the lake, are dependent on the supply of H_2S from anaerobic sulfide producers. To date this major primary producer has all but been eliminated from the lake's chemocline.

The only fish living in the lake is the fourhorn sculpin (*Myoxocephalus quadricornis*). It is likely that the marine form of this species was trapped in Garrow Lake 3,000 years ago, and has slowly been changing within the lake to adapt to a virtually predator-free system of variable salinity. Chironomids and copepods, the most frequent invertebrates in the lake, are assumed to represent this fish's basic diet. In one sense, Garrow Lake can be viewed as a sort of time capsule offering an ideal area for the study of natural selection and speciation. However, the extirpation of the sculpin is likely to occur over the next decade unless COMINCO changes its mode of discharging toxic mine tailings into this unique body of water (Q, 1-8, 20-23).

C. PHYSICAL DIMENSIONS (4, 10)

Surface area [km^2]	4
Volume [$10^6 m^3$]	102
Maximum depth [m]	50
Mean depth [m]	24.5
Normal range of annual water level fluctuation [m] (unregulated)	<1
Length of shoreline [km]	10
Residence time	*
Catchment area [km^2]	10.5

* Although surface waters may be replaced in only three years, the permanently stagnant monimolimnion (bottom water, 20-50 m) appears to retain some of the original sea salts which entered the lake over 3,000 years ago.

D. PHYSIOGRAPHIC FEATURES (4)

D1 GEOGRAPHICAL

§ Bathymetric map (Fig. NAM-50-1).
§ Main islands : None.
§ Outflowing rivers and channels (number and names) : 1 (name unknown).

D2 CLIMATIC

§ Climatic data at Resolute Airport (1951-1980) (4a)*

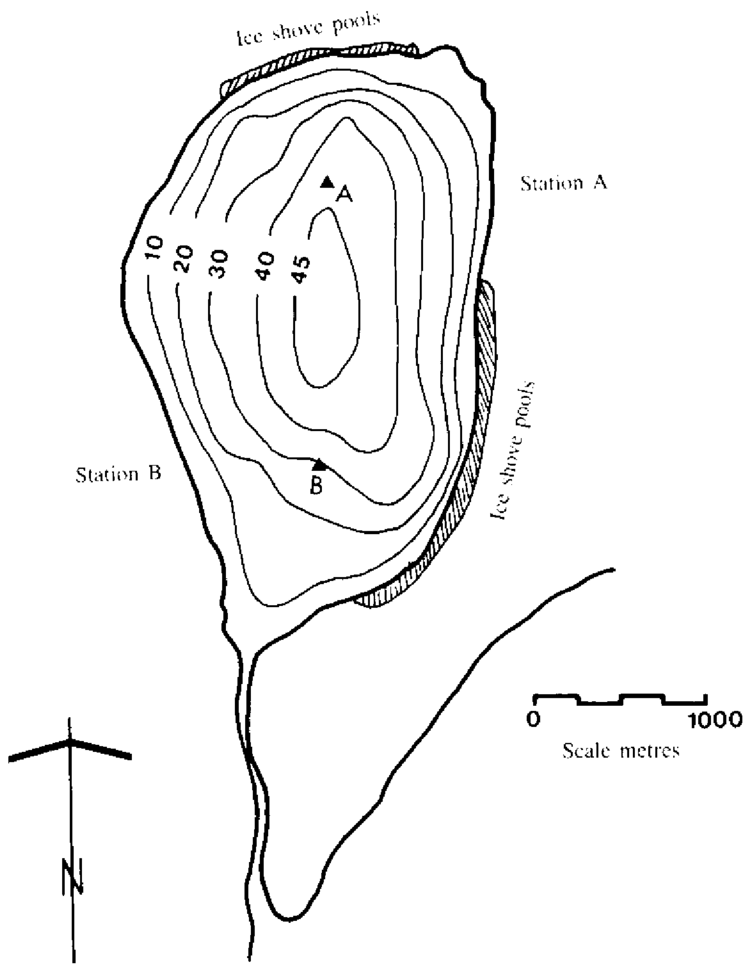
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean temp. [°C]	-32.1	-33.2	-31.4	-23.1	-10.9	-0.6	4.1	2.4	-5.1	-15.1	-24.5	-29.3	-16.6
Precipitation [mm]	3	3	3	6	8	12	23	31	18	14	6	5	131

* Until recently, the Resolute Airport monitoring station on Cornwallis Island was the nearest site where reliable weather data were recorded. The Airport is approximately 60 km from Garrow Lake and the data recorded at COMINCO's Polaris mine site indicate that the two locations experience similar weather. The mean daily temperature remains above 0°C from 15 June to 15 August (Q).

§ Number of hours of bright sunshine at Resolute Airport : 1,505 hr yr^{-1}.
§ Average solar rediation : 10.5 MJ $m^{-2}day^{-1}$.
Mean daily global solar radiation (Alert, NWT) [MJ m^{-2}]

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
–	0.03	2.01	11.78	22.63	24.57	18.78	10.66	3.61	0.35	–	–

Fig. NAM-50-1 Bathymetric map [m] (Q).



§ Water temperature [°C]
1980-1986 (typical*) (4)

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	-0.3	-0.3	-0.3	-0.3	-0.3	-0.1	-0.1	3.0	2.0	-0.3	-0.3	-0.3
5	-0.3	-0.3	-0.3	-0.3	-0.3	-0.1	-0.1	2.5	2.0	-0.3	-0.3	-0.3
10	0.4	0.4	0.4	0.5	0.5	0.5	3.5	4.0	4.0	2.5	0.5	0.4
15	5.0	5.0	5.0	5.0	5.0	5.5	6.0	6.0	5.5	5.0	5.0	5.0
20	8.7	8.7	8.7	8.7	8.7	8.7	8.7	8.7	8.7	8.7	8.7	8.7
25	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	9.0	8.0	8.0	8.0
50	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0

* Hypothesized "typical" pattern based on data from Jan. and Feb. 1984, Jun. 1984, Aug. 1980 and 1986, Sep. 1981 and Aug. and Sep. 1982.

§ Freezing period : Sep. to 10 Aug. (ice does not clear from the lake on average), about 1 year (4). In years when ice out is complete, a thermocline forms between 5 and 15 m (Q).

§ Mixing type : Meromictic.

§ Notes on water mixing and thermocline formation : Lake permanently stratified throughout the year with a pycnocline at 15-20 m (4).

E. LAKE WATER QUALITY

E1 TRANSPARENCY [m]

Station A (1980-1986) : 10-15 (mean 12 m).

With the exception of spring runoff periods when transparency may decline to 8 m. Transparency also decreases during ice out periods after an inadvertent mine tailing discharge onto surface ice which occurred twice over the 8 years of monitoring (Q).

E2 pH

Stations A & B, 1984 & 1986

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	–	–	–	–	–	–	–	7.0	7.0	–	–	–
5	–	–	–	–	–	–	–	7.0	7.0	–	–	–
10	–	–	–	–	–	–	–	7.0	7.0	–	–	–
15	–	–	–	–	–	–	–	7.0	7.0	–	–	–
20	–	–	–	–	–	–	–	7.1	7.1	–	–	–
25	–	–	–	–	–	–	–	7.2	7.2	–	–	–
50	–	–	–	–	–	–	–	7.5	7.5	–	–	–

E3 TDS [mg l^{-1}]

Station A, 1981 (3)

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	–	–	–	–	–	–	–	2,240	–	–	–	–
20	–	–	–	–	–	–	–	1,750	–	–	–	–
50	–	–	–	–	–	–	–	32,200	–	–	–	–

E4 DO [% saturation]

Station A, 1980-1984 (4)

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	—	—	—	—	100		100		—	—	—	—
5	—	—	—	—	100		110		—	—	—	—
10	—	—	—	—	120		120		—	—	—	—
15	—	—	—	—	60		70		—	—	—	—
20	—	—	—	—	0		0		—	—	—	—
25	—	—	—	—	0		0		—	—	—	—
50	—	—	—	—	0		0		—	—	—	—

E5 CARBON CONCENTRATION [mg l^{-1}]

Station B, 1986

Depth [m]	Total inorganic carbon	Total carbon
0	15	30
20	72	130
40	190	270

E6 CHLOROPHYLL CONCENTRATION [μg l^{-1}] (4, 18)

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	—	—	—	—	—	—	—	0.3	0.2	—	—	—

E8 PHOSPHORUS CONCENTRATION

§ Total-P [mg l^{-1}] (3)

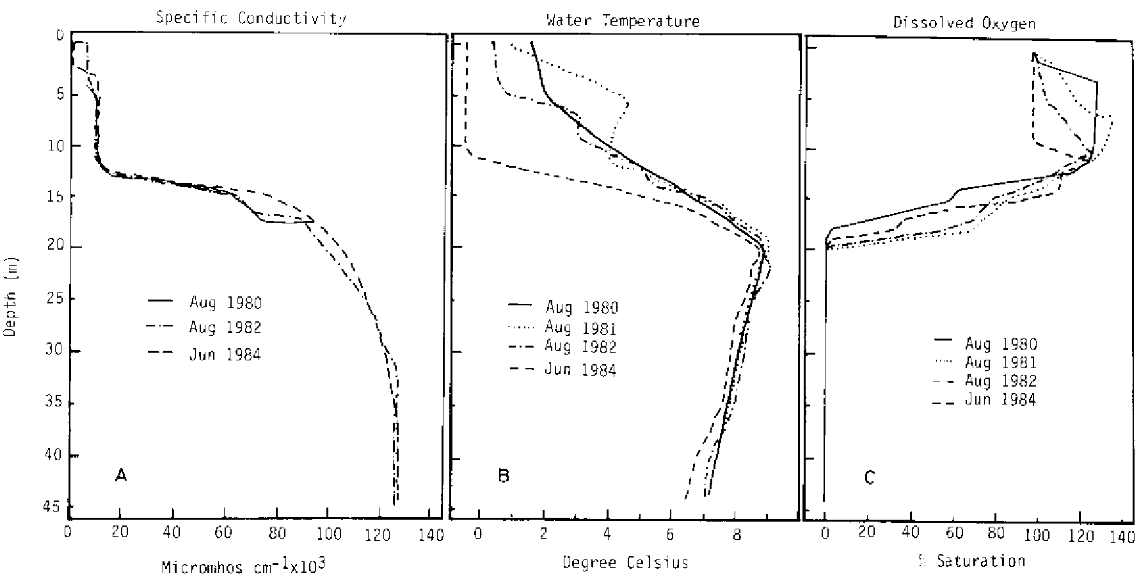
Station A, 1981 : 0.01 (0 m), 0.3 (20 m), 1.0 (40 m).

E9 CHLORIDE ION CONCENTRATION [mg l^{-1}] (3)

Station A, 1981 : 87 (0 m), 51,072 (20 m), 54,264 (40 m).

E10 PAST TRENDS

Fig. NAM-50-2 Physico-chemical profiles at Station A during 1980 (before discharge of mine tailings) — 1984 (after the discharge) (4).



F. BIOLOGICAL FEATURES

F1 FLORA (18)

(All sites, 1980-1986)

§ Submerged macrophytes

Mosses (*Calliergon richardsonii* and *Drepanocladus brevifolios*; abundant near the lake's outlet).

§ Phytoplankton

Bacillariophyta (*Amphora veneta*, *A.* sp., *Anomoeneis serians*, *Asterionella formosa*, *Cyclotella comta*, *C. glomerata*, *C. kutzingiana*, *Cymbella cymbiformis*, *C. minuta*, *Diploneis interrupta*, *Fragilaria laponica*, *Navicula amphibia*, *N. mutica*, *N. rhyncocephala*, *N.* spp., *Nitzschia frustulum*, *N. lacuna*, *N. parvula*, *Pinnularia major*, *P.* sp., *Rhizosolenia longiseta*, *Stephanodiscus astrea*, *Surirella striatula*, *Synedra actinasteroides*, *Tabellaria fenestrata*); Chrysophyta (microflagellates); Chlorophyta (*Arthrodesmus incus*, *Chlamydomonas lapponica*, *Cosmarium* sp., *Oocystis parva*, *Scenedesmus bijuga*); Cryptophyta (*Cryptomonas* spp., *Rhodomonas minuta*); Cyanophyta (*Aphanocapsa* sp., *Gloeococcus schroeteri*, *Phacomyxa sphagnolia*); Pyrrophyta (*Glenodinium* sp., *Gymnodinium helveticum*, *G.* spp., *Peridinium deflanderi*, *P. inconspicum*).

F2 FAUNA

§ Zooplankton

Copepods (*Limnocalanus macruras* (dominant), *Onychocamptus mohamedi*, *Cleocamptus* sp. (Herpacticoid copepods)); Cladocerans (*Cyclopina* sp.).

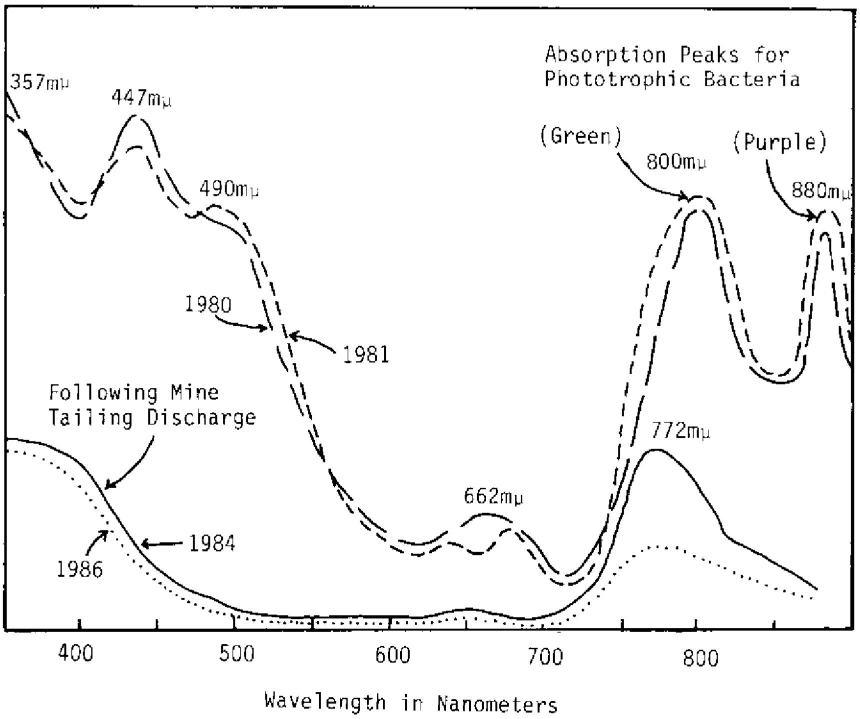
§ Benthos

Chironomids (*Orthocladius* and *Chironomus* groups); oligochaetes (*Elofsonella concinna*, *Hemicythere angulata*).

§ Fish: *Myoxocephalus quadricornis* (fourhorn sculpin) (only one species).

F7 NOTES ON THE REMARKABLE CHANGES OF BIOTA IN THE LAKE IN RECENT YEARS

Fig. NAM-50-3 Absorption spectra for acetone extracts of glassfiltered samples containing bacteria taken from 20 m depth at Station A before (1980 and 1981) and after discharge of mine tailings (1984 and 1986), showing the decrease of phototrophic bacteria, the major primary producer in Garrow Lake (4).



G. SOCIO-ECONOMIC CONDITIONS

G1 LAND USE IN THE CATCHMENT AREA (1980) (2)

	Area [km²]	[%]
Natural landscape		
Tundra	8.4	80
Agricultural land	0	0
Others		
Mine tailings and mining equipment	2.1	20
Total	10.5	100

§ Types of important woody vegetation : Tundra willow and arctic birch.
§ Types of important herbaceous vegetation : Arctic saxifrages and poppies.
§ Main kinds of crops and/or cropping systems : None.

G2 INDUSTRIES IN THE CATCHMENT AREA AND THE LAKE (1980) (4)

	Main products and major industries
Primary industry Mining	Lead/Zinc ore concentrate

§ Numbers of domestic animals in the catchment area : None.

G3 POPULATION IN THE CATCHMENT AREA (1989)

Approximately 150 mine workers and staff employed by COMINCO.

H. LAKE UTILIZATION

H1 LAKE UTILIZATION

Garrow Lake has been receiving mine tailings from the COMINCO Ltd. Polaris lead and zinc mine since November 1981. Tailings are discharged to the lake from the xanthate thickener at the rate of approximately 100 metric tons per hour (4). The ore body is expected to last for 30-40 years at the present rate of extraction.

H2 THE LAKE AS WATER RESOURCE (1988) (17)

	Use rate
Industrial water	N. A.

I. DETERIORATION OF LAKE ENVIRONMENTS AND HAZARDS

I1 ENHANCED SILTATION

§ Extent of damage : Serious.
§ Supplementary notes : Due to the discharge of mine tailings (Q).

I2 TOXIC CONTAMINATION

§ Present status : Little information.
§ Supplementary notes

Analyses of sediments and biota for toxic contaminants have been very limited to date. The disappearance of the photosynthetic bacteria may have been caused by toxic components in the mine tailings or by disruptions in the physiochemical environment, particularly light and ionic gradients. There is the potential for methylation of lead in the anaerobic bottom waters which could enhance the rate of contamination of the biota (Q).

I3 EUTROPHICATION

The lake is ultraoligotrophic. Even though total surface water phosphorus was 10 ppb (close to the detection limit), it is believed that the elevated salinity and perhaps the low light intensities after passing through the 2 to 3 m of ice on the lake may result in the observed low algal standing crop. The fact that phototrophic bacteria at 20 m reach relatively high population densities indicates that light alone cannot be the entire reason for the observed low primary productivity (Q).

I4 ACIDIFICATION

§ Extent of damage : None.

J. WASTEWATER TREATMENTS

J1 GENERATION OF POLLUTANTS IN THE CATCHMENT AREA : (a) Pristine lake environments (Q).

J2 APPROXIMATE PERCENTAGE DISTRIBUTION OF POLLUTANT LOADS (Q)

	Percentage
Point sources	
Industrial	100

No domestic wastes are disposed of in the watershed.

J3 SANITARY FACILITIES AND SEWARAGE

None (Q).

K. IMPROVEMENT WORKS IN THE LAKE

None (Q).

M. LEGISLATIVE AND INSTITUTIONAL MEASURES FOR UPGRADING LAKE ENVIRONMENTS (Q)

M1 NATIONAL AND LOCAL LAWS CONCERNED

§ Names of the laws (the year of legislation)

(1) Clean Water Act
(2) Canada Fisheries Act (1972)

§ Responsible authorities

(1) Environment Canada
(2) Environment Canada, Northern and Western Region, Department of Fisheries and Oceans, Winnipeg, Manitoba

§ Supplementary notes

Mining Association of Canada announced a commitment by the mining industry to spend 4 million dollars for a cooperative program of environmental research into the long term management of mine tailings (August, 1988).

M2 INSTITUTIONAL MEASURES

(1) Water Board Hearing Officers, Yellowknife, Northwest Territories
(2) Science Institute of the Northwest Territories, Yellowknife, Northwest Territories

M3 RESEARCH INSTITUTES ENGAGED IN THE LAKE ENVIRONMENT STUDY

(1) Biological Sciences Department, Ontario
(2) Environment Canada, Department of Fisheries and Oceans, Manitoba

N. SOURCES OF DATA

(Q) Questionnaire filled by Dr. M. Dickman, Brock University, St. Catharines, Ontario, Canada.

(1) Rigler, F. W. (1978) Polaris Mine Aquatic Environmental Studies. Unpublished Report for COMINCO Ltd. Vancouver, British Columbia.

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(10) Pagé, P. M., Ouellet, C., Hillaire-Marcel & Dickman, M. (1984) Isotopic analyses (^{18}O, ^{13}C, ^{14}C) of two meromictic lakes in the Canadian arctic archipelago. Limnol. Oceanogr, 79: 554-573.

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(14) Ouellet, M. & Pagé, P. (1988) Canada's most fascinating lake. Geos., 17: 1-7.

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(16) Rigler, F. W. (1978) Limnology in the high arctic: a case study of Char Lake. Verh. Intern. Verein. Limnol., 20: 127-140.

(17) Drake, J. (1984) Polaris underground and undersea. Orbit., 14: 3-8.

(18) Dickman, M., Biology, Brock University. Unpublished data.

(19) Canadian Water Watch (1988) Vol. 1(5), p. 35.

(20) Duthie, H., Biology Department, University of Waterloo, Ontario. Personal communication.

(21) Kerr, J. W. (1977) Cornwallis fold belt and the mechanism of basement uplift. Can. J. Earth Sci., 14: 1374-1401.

(22) —— (1977) Cornwallis lead-zinc district, Missippii Valley-type deposits controlled by stratigraphy and tectonics. Ibid., 14: 1402-1426.

(23) Andrews, J. T. (1971) Comparison of elevations of archeological sites and calculated sea levels in arctic Canada. Arctica, 24: 210-228.

(24) Dymond, J. R. (1926) The fishes of Lake Nipigon. Univ. of Toronto Stud. Biol. Ser., 27: 1-108.

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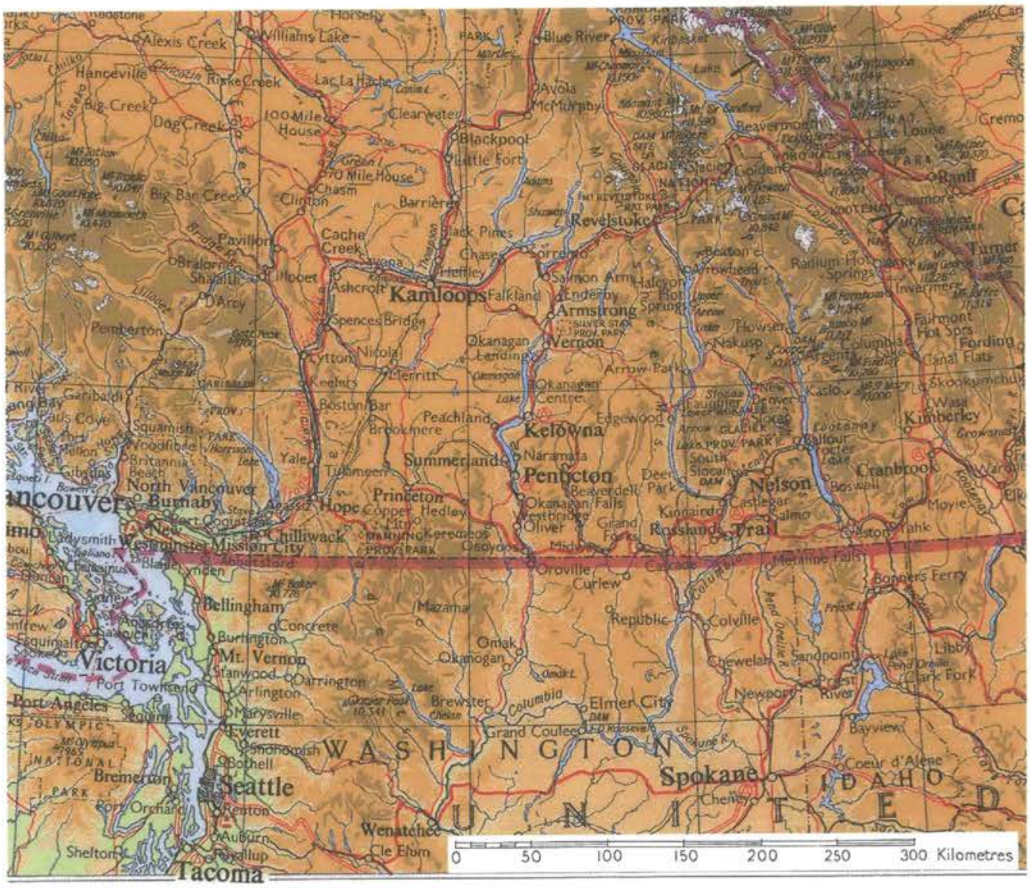
OKANAGAN LAKE

A view from the lakeside hill

Photo: J.E. Bryan and E.V. Jensen



A. LOCATION

§ British Columbia, Canada.
§ 49°30′-50°22′N ; 119°20′-119°45′W ; 342 m above sea level.

B. DESCRIPTION

Okanagan Lake is situated in south central British Columbia. It has a catchment area of over 6,000 km² and is the largest of the five main and interconnected lakes in the Okanagan valley. The Okanagan valley is U-shaped with mountains rising on both sides to 1,000-2,500 m.

Okanagan Lake in general is a deep, oligotrophic water body with two shallower reaches with poorer water circulation, higher nutrient levels, and greater plankton abundance. The lake in profile is composed of three basins, a large north basin, a mid basin and a southern basin. It is jointed to Kalamalka Lake in the north by Vernon Creek and at the south end to Skaha Lake by the Okanagan River. This river flows south through Skaha Lake, Vaseaux Lake and Osoyoos Lake ; it joins the Columbia River near Brewster, Washington.

Several hundred meters of unconsolidated materials deposited during the Pleistocene epoch line the valley bottom. These materials probably resulted from glacial outwash, direct glaciation, and lacustrine fluvial sedimentation. Notable characteristics of the valley, particularly at the south end, are the terraces which were formed as the lowering of postglacial lake levels were repeatedly arrested. These fertile benches have been used extensively for horticulture, principally fruit trees and grape growing.

Three major population centers are located along lake Okanagan shores : Vernon at the north end, Kelowna at the mid point and Penticton at the south end (Penticton's sewage effluent is discharged to the outflow of Okanagan Lake). The major industrial development in the valley is associated with agriculture and forestry. As well, a large copper deposit has been developed in the drainage basin. Tourism is also a major economic factor in the local economy. These facts coupled with the arid nature of the region have resulted in a very high economic value being given to water quality and quantity. This is reflected by the number of studies conducted on the Okanagan lakes in recent history. Federal-provincial studies in 1969-1974 and 1977-1982 provided the first basic technical information on all the valley lakes and tracked water quality following sewage treatment improvements at Vernon and Penticton. Water quality improvement in the central basin of the lake is expected now, so that the city of Kelowna has instituted tertiary treatment (1).

C. PHYSICAL DIMENSIONS (2, 3)

Surface area [km²]	351
Volume [10⁶m³]	24,644
Maximum depth [m]	230
Mean depth [m]	76
Normal range of annual water level fluctuation [m]	Regulated
Length of shoreline [km]	270
Residence time [yr]	52.8
Catchment area [km²]	6,187.5

D. PHYSIOGRAPHIC FEATURES

D1 GEOGRAPHICAL

§ Sketch map (Fig. NAM-51-1).
§ Bathymetric map (Fig. NAM-51-2).
§ Main islands (name and area) : Grant Island (<1 ha) and Rattlesnake Island (<1 ha).
§ Outflowing rivers and channels (number and names) : 1 (Okanagan R.).

D2 CLIMATIC

§ Climatic data at Pentiction Airport, 1950-1980

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean temp. [°C]	-2.7	0.6	3.9	8.6	13.4	17.2	20.3	19.5	14.7	8.7	3.0	0.4	8.9
Precipitation [mm]	32	20	17	21	29	28	21	27	18	15	24	31	236

Fig. NAM-51-1 Sketch map (Q).

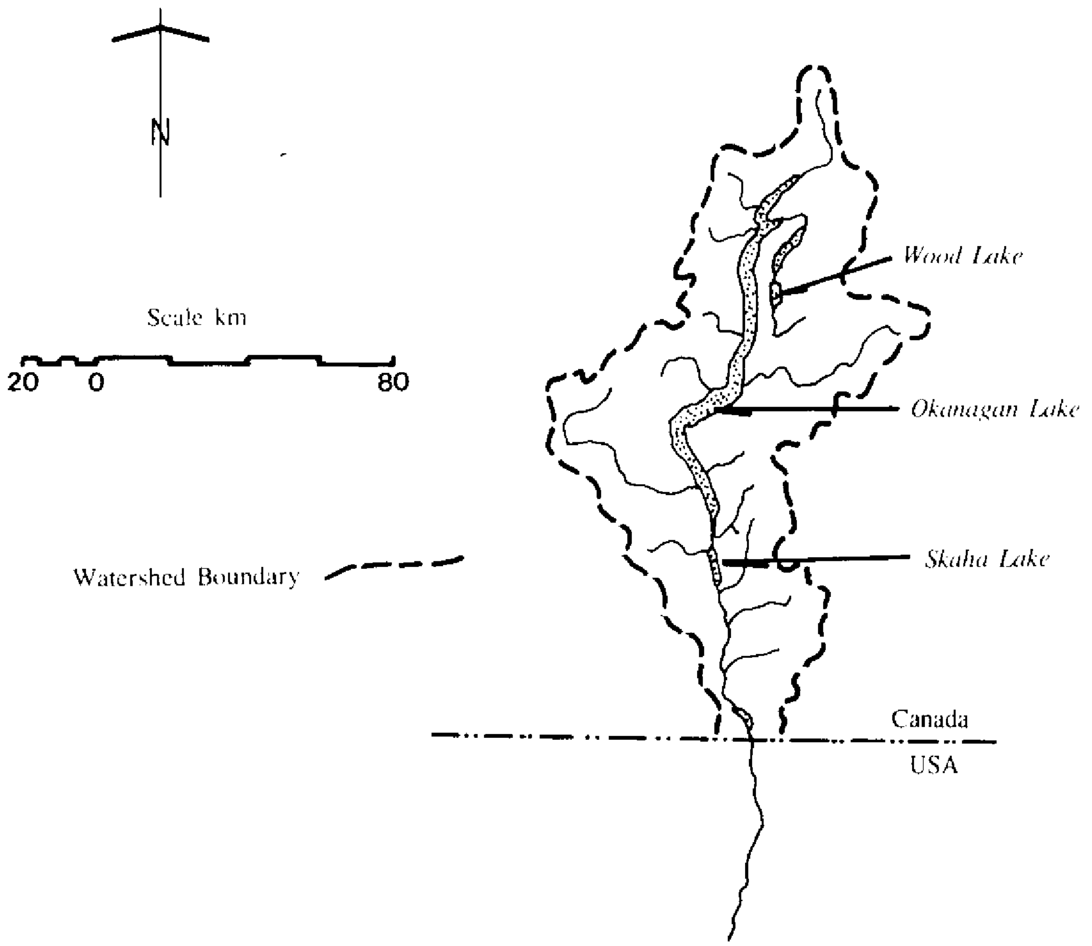
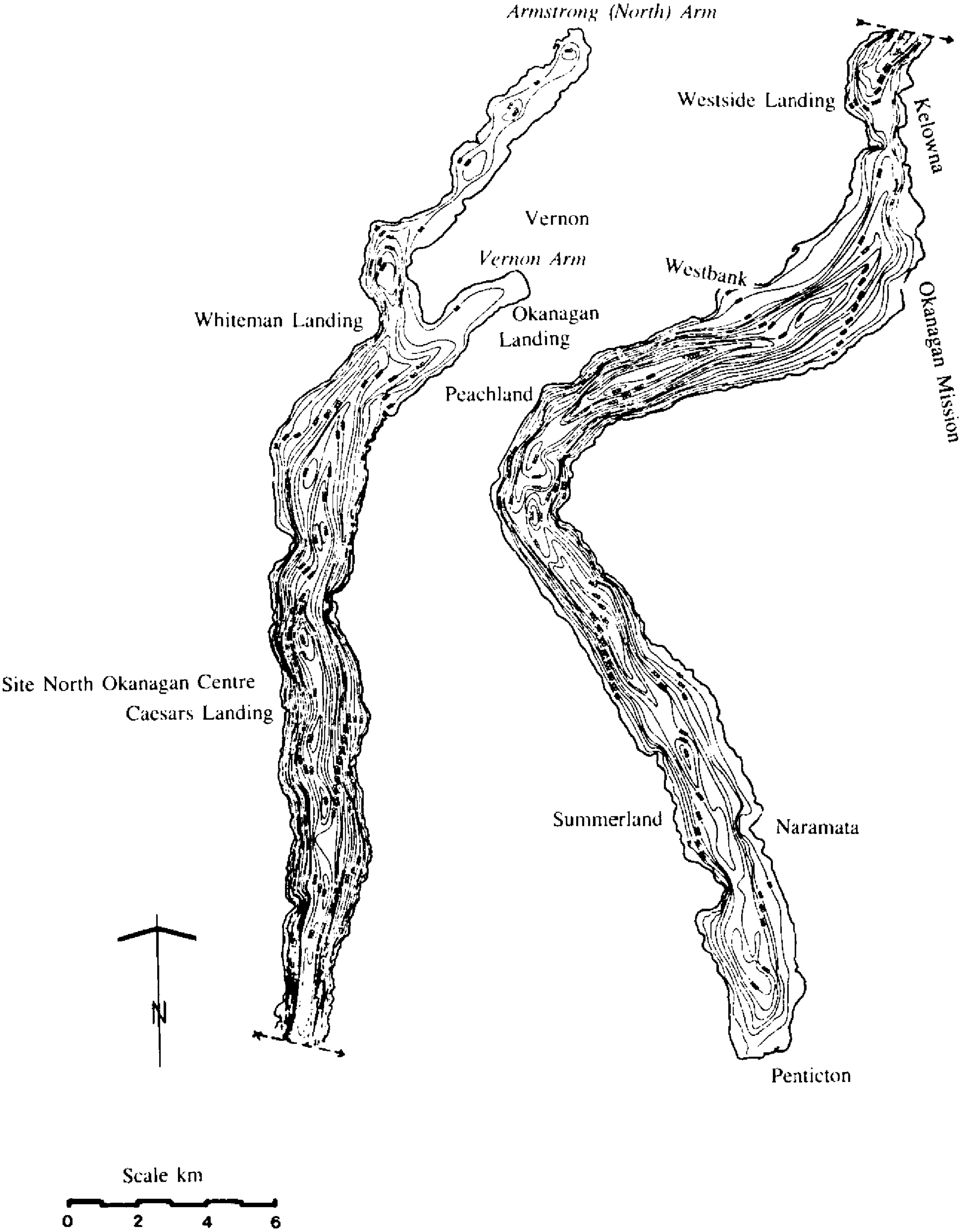


Fig. NAM-51-2 Bathymetric map [50 feet = 15.24 m] (4).



§ Number of hours of bright sunshine at North of Okanagan and at Pinticton Airport : 2,032 hr yr^{-1}.
§ Average solar radiation at Summerland : 12.8 MJ $m^{-2}day^{-1}$.

Mean daily global solar radiation [MJ $m^{-2}day^{-1}$] (5)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
3.4	6.5	11.5	16.7	20.8	22.6	23.7	19.6	14.5	8.5	3.8	2.5

§ Water temperature [°C] (6, 7, 8)

North Okanagan Centre, 1977-1988

Depth [m]	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
0	3.75	6.0	11.0	14.0	20.0	22.0	18.8	15.0
5	3.75	6.0	–	–	20.0	–	18.5	15.5
10	3.75	6.0	–	–	15.0	–	18.5	15.0
15	3.75	5.5	–	–	14.0	–	13.3	14.0
20	3.75	5.5	–	–	9.0	–	9.8	14.0
25	3.75	5.0	–	–	7.5	–	8.3	10.5
35	3.75	5.0	–	–	6.0	–	6.2	6.0
45	3.75	5.0	–	–	5.5	–	5.8	5.0

Vernon Arm, 1979-1988

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	1.5	–	3.8	5.0	12.0	17.5	20.0	23.0	19.1	16.0	8.0	3.0
2	–	–	3.8	–	–	–	–	–	18.8	–	–	–
4	–	–	3.8	–	–	–	–	–	18.5	–	–	–
6	–	–	3.8	–	–	–	–	–	18.3	–	–	–
8	–	–	3.8	–	–	–	–	–	18.0	–	–	–
10	–	–	3.8	–	–	–	–	–	17.6	–	–	–
14	–	–	3.8	–	–	–	–	–	16.4	–	–	–
18	–	–	3.8	–	–	–	–	–	12.9	–	–	–

§ Freezing period at Vernon Arm : From Jan. to Feb.
§ Mixing type : Monomictic, partially dimictic (North Okanagan Centre).
§ Notes on water mixing and thermocline formation

North Okanagan Centre and the entire lake have only had complete ice cover 3 to 4 years in the past 100 years. As a result the lake stratifies in spring and mixes throughout the winter. Partial freezing of sheltered areas such as Vernon Arm can occur, i. e. Vernon Arm is dimictic during cold winters but monomictic during warm winters.

E. LAKE WATER QUALITY

E1 TRANSPARENCY [m]

N. Okanagan Centre, 1983-1984 (8)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
16.5	–	11.9	6.4	5.8	5.8	8.4	8.1	9.0	9.7	10.7	14.2

Vernon Arm, 1979-1984 (7, 8)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
10.0	–	6.5	3.0	2.4	2.0	3.6	4.25	8.0	8.9	7.5	9.0

E2 pH

N. Okanagan Centre, 1983-1984 (8)

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1.5	8.0	8.1	8.3	8.3	8.4	8.3	8.5	8.5	8.5	8.4	8.2	8.0

Vernon Arm, 1984 (8)

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1.5	8.2	–	8.4	8.4	8.3	8.6	8.7	8.5	8.5	8.3	8.2	8.0

E3 SS [mg l^{-1}]

South Okanagan Centre, Jul. 29, 1975 : 1.

E4 DO [mg l^{-1}]

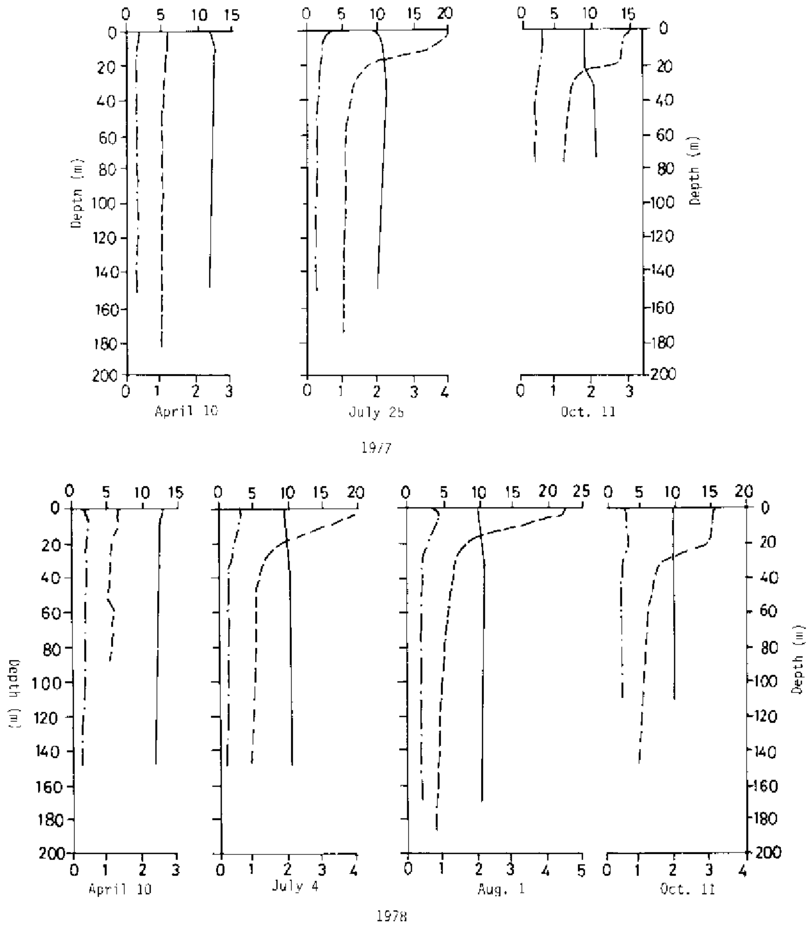
N. Okanagan Centre, 1971-1988

Depth [m]	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
0	11.6	12.5	12.9	10.2	9.3	9.5	9.8	9.3	9.2
5	11.6	12.5	–	–	10.0	–	10.0	9.3	–
10	11.6	13.0	–	–	10.0	9.5	10.2	9.3	–
15	11.6	–	–	–	10.5	–	11.3	9.3	–
20	11.6	–	–	–	10.5	–	11.9	9.3	–
25	11.6	12.0	–	–	11.0	11.5	11.9	9.8	–
35	11.6	12.0	–	–	11.0	11.8	11.9	10.0	–
45	11.6	12.0	–	–	11.0	11.8	12.0	10.0	–
150	–	11.6	11.8	–	–	–	–	–	–

Vernon Arm, Mar. and Sep., 1988

Depth [m]	Mar	Sep
0	13.6	10.3
2	13.6	10.3
4	13.6	10.4
6	13.6	10.4
8	13.6	10.4
10	13.6	10.6
14	13.6	10.8
18	13.6	11.2

Fig. NAM-51-3 Profiles of temperature, dissolved oxygen and turbidity for Okanagan Lake North, 1977 & 1978 (7).



E6 CHLOROPHYLL CONCENTRATION [$\mu g\ l^{-1}$]

N. Okanagan Centre, 1984-1987

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0-10	0.8	0.9	0.8	2.0	2.0	1.2	1.0	1.0	0.7	1.0	1.2	1.0

Vernon Arm, 1979-1987

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0-10	1.2	2.7	2.4	2.5	2.2	2.7	2.2	2.8	2.0	<1.0	2.3	1.8

E7 NITROGEN CONCENTRATION

§ Total-N [mg l^{-1}]

N. Okanagan Centre, 1979-1987 (9)

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0-10	0.27	0.23	0.2	0.15	0.17	0.11	0.24	0.11	0.20	0.14	0.23	0.18
20-45	—	—	0.2	0.13	0	0.17	—	—	—	0.35	—	—

Vernon Arm, (1979) (9)

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0-10	0.25	0.21	0.19	0.20	0.20	0.21	0.22	0.22	0.20	0.19	0.15	0.18

E8 PHOSPHORUS CONCENTRATION

§ Total-P [mg l^{-1}]

N. Okanagan Centre, 1971-1987 (9)

<table>
<tr><th>Depth [m]</th><th>Jan</th><th>Feb</th><th>Mar</th><th>Apr</th><th>May</th><th>Jun</th><th>Jul</th><th>Aug</th><th>Sep</th><th>Oct</th><th>Nov</th><th>Dec</th></tr>
<tr><td>0-10</td><td>.009</td><td>—</td><td>.008</td><td>.009</td><td>.001</td><td>.009</td><td colspan="2">.008</td><td>.008</td><td>0.01</td><td>.009</td><td>.009</td></tr>
<tr><td>20-45</td><td>—</td><td>—</td><td>.006</td><td>.010</td><td>—</td><td>—</td><td colspan="2">.007</td><td>.010</td><td>0.01</td><td>—</td><td>—</td></tr>
</table>

Vernon Arm, 1979-1986 (7, 9)

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0-10	0.13	0.16	0.09	0.12	0.12	0.15	0.18	0.14	0.11	0.10	.008	.009

E9 CHLORIDE ION CONCENTRATION [mg l^{-1}]

Okanagan Centre, 1983-1988: 1.66 (mean; N=7) (7).

E10 PAST TRENDS

Fig. NAM-51-4 Spring Total-N at 4 sites in North Basin. Vernon discharge stopped by 1978 (8).

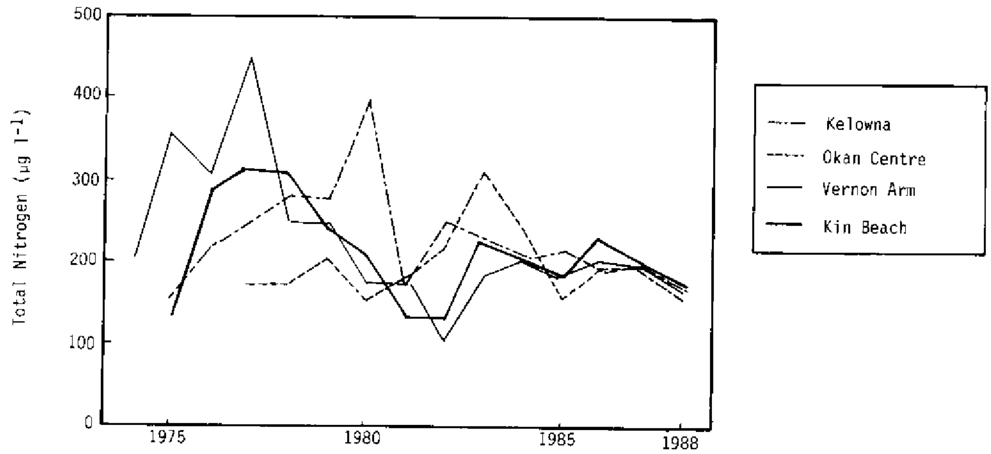


Fig. NAM-51-5 Spring Total-P at 4 sites in North Basin. Vernon discharge stopped by 1978 (8).

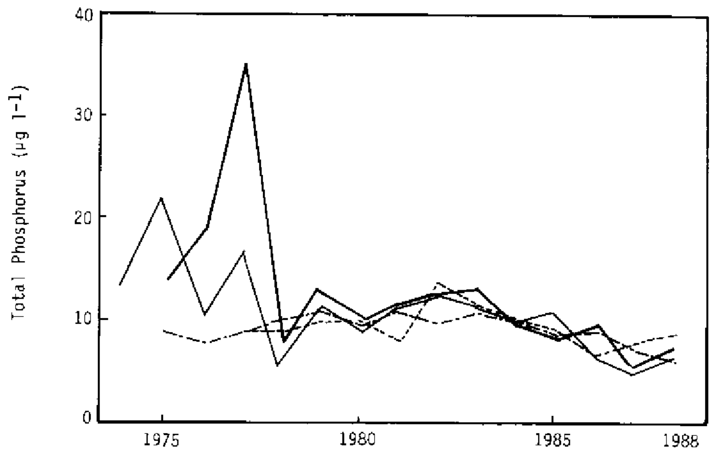


Fig. NAM-51-6 Fall phytoplankton at 4 sites in North Basin (8).

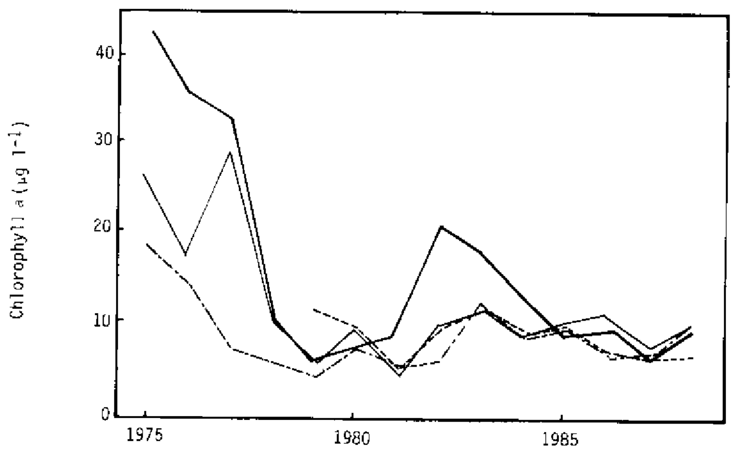
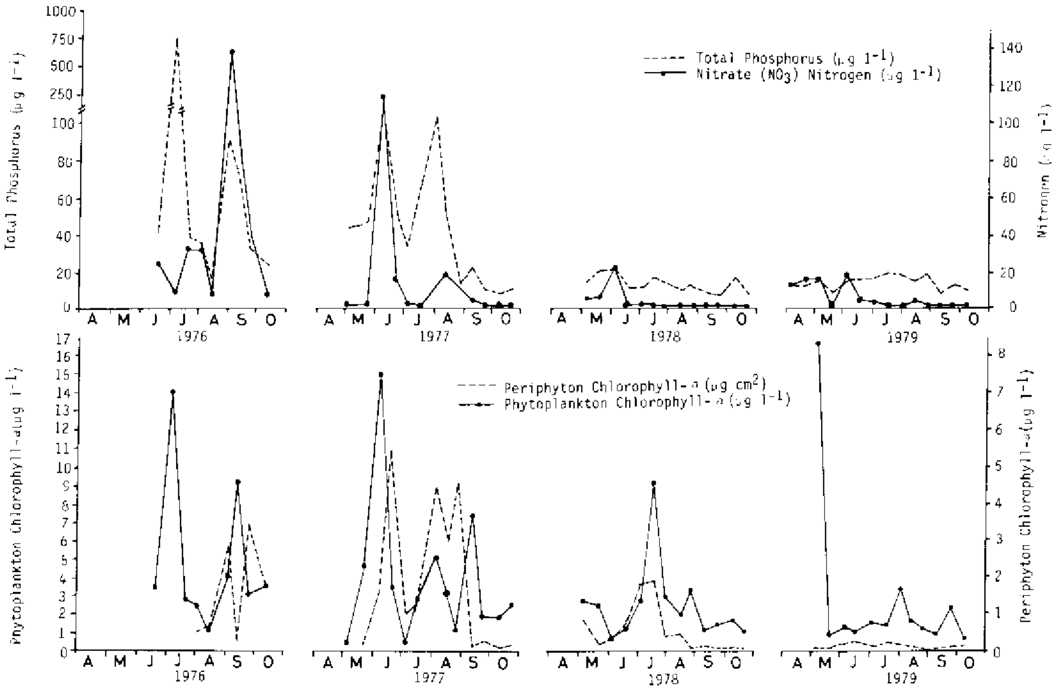


Fig. NAM-51-7 Total-P, phytoplankton chlorophyll *a* and periphyton chlorophyll *a* and nitrogen at Vernon Arm (OK-S2), 1976-1979 (7).



F. BIOLOGICAL FEATURES

1977

F1 FLORA

§ Emerged macrophytes : *Scirpus lacustris*, *Typha latifolia* (10).

§ Floating macrophytes : *Potamogeton gramineus*, *P. natans*, *Nuphar polysepalum* (10).

§ Submerged macrophytes (10)

Myriophyllum spicatum, *Potamogeton perfoliatus*, *P. pectinatus*, *P. crispus*, *Elodea canadensis*.

§ Phytoplankton (8)

Dominants (*Lyngbya limnetica*, *Fragilaria crotonensis*, *Melosira italica*) ; Sub-dominants (*Merismopedia*, *Oscillatoria*, *Botryococcus*, *Ankistrodesmus*, *Teraspora*, *Asterionella*, *Cyclotella*, *Rhizosolenia*, *Stephanodiscus*).

F2 FAUNA

§ Zooplankton (8)

Dominants (*Diaptomus ashlandi*, *Cyclops bicuspidatus*) ; Sub-dominants (*Bosmina*, *Notholca*, *Kellicottia*).

§ Benthos (11, 12)

Oligochaeta (*Tubifex tubifex*, *Ilyodrilus templetoni*, *Limnodrilus hoffmeisteri*, *L. udekemianus*, *L. claparedeanus*, *Nais variabilis*, *N. pardalis*) ; Hirundinea (*Helobdella stagnalis*, *Placobdella monifera*) ; Amphipoda (*Gammarus limnaeus*, *Hyalella azteca*) ; Ephemeroptera (*Caenis* sp., *Choroterpes* sp.) ; Odonata (*Enallagma cyathigerum*) ; Trichoptera (*Ithytrichia* sp., *Hydroptila* sp., *Polycentropus* sp., *Oecetis avara*, *Mystacides* spp.) ; Hemiptera (*Notonecta* sp., *Corixa* sp.) ; Diptera (*Chironomus*, *Endochironomus*, *Cryptochironomus*, *Allochironomus*, *Prochironomus*, *Paratendipes*, *Pentapedilum*, *Polypedilum*, *Procladius*, *Tanytarsus*, *Cladotanytarsus*) ; Coleoptera (*Hydroporus* sp.) ; Hydracarina (*Hygrobates longipalpis*) ; Gastropoda (*Lymnaea caperata*, *Gyraulus parvus*, *Menetus exacuus*) ; Perecypoda (*Anodonta oregonensis*, *A. beringiana*, *Pisidium compressum*, *Valvata sincera*, *V.* sp.).

§ Fish (13)

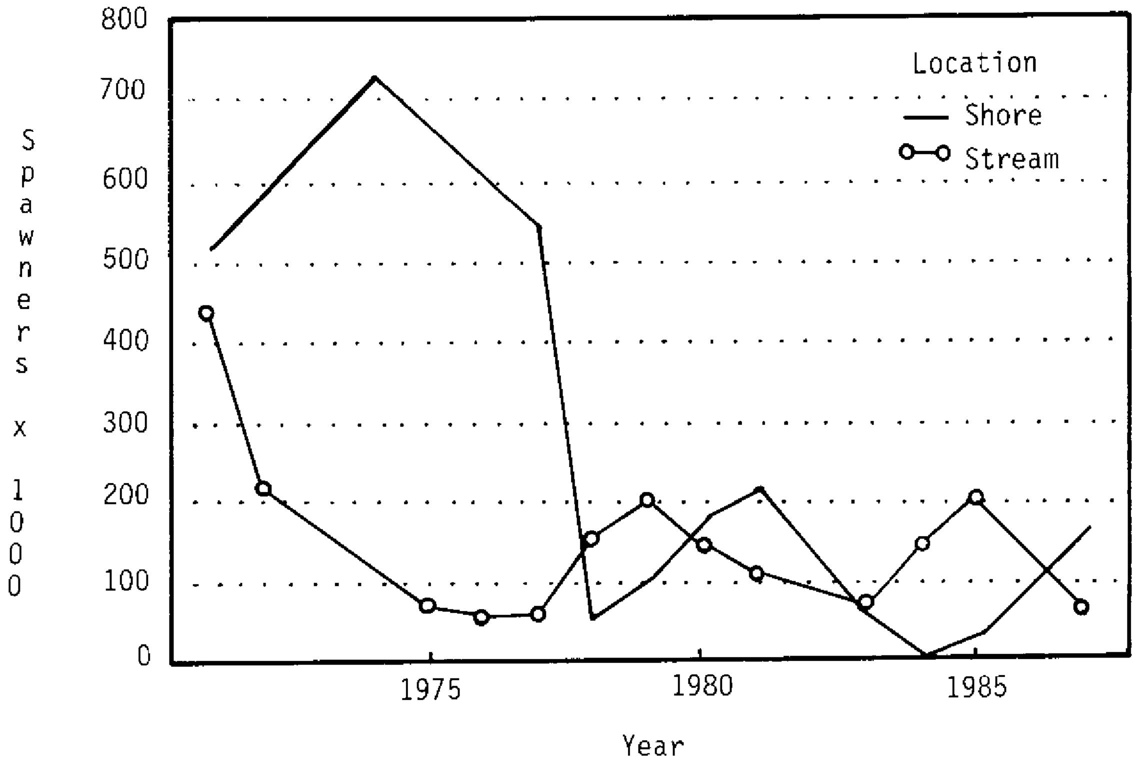
*Oncorynchus nerka**, *O. mykiss**, *Salvelinus namaycush**, *Prosopium williamsoni**, *Perca fluviatilis flavescens**, *Lota lota**, *Coregonus clupeaformis**, *Catostomus macrocheilus*, *C. catostomus*, *Cyprinus carpio**, *Ptychocheilus oregonensis*, *Mylocheilus caurinus*, *Acrocheilus alutaceus*, *Richardsonius balteatus*, *Rhinichthys falcatus*, *Cottus asper*, *C. cognatus* (*important for sport fishing).

F5 FISHERY PRODUCTS

§ Annual fish catch in 1980 : Rainbow trout 13,109, kokanee 222,867 [no.] (2).

F6 PAST TRENDS

Fig. NAM-51-8 Trends in kokanee escapement in Okanagan Lake.



§ Supplementary notes

Reduced kokanee fishery (14) possibly due to introduction of carp, whitefish, mysid shrimp and Eurasian milfoil or to loss of spawning habitat and quality due to channelization, dam construction and diversion of water for irrigation and domestic use. Fishing pressure has increased with the increase in human population near the lake.

F7 NOTES ON THE REMARKABLE CHANGES OF BIOTA IN THE LAKE IN RECENT YEARS

Eurasian milfoil (*Myriophyllum spicatum*) had colonized about one quarter of the lake's littoral zone by 1979 after invading sometime in the early 1970's. It presented a nuisance to boaters and swimmers and a major control effort was undertaken by the provincial authorities to limit these effects on beaches and on boat harbours. The milfoil beds have shrunk to some extent in the last ten years but control (i. e. harvesting, dredging) is still implemented in some areas (23).

G. SOCIO-ECONOMIC CONDITIONS

G1 LAND USE IN THE CATCHMENT AREA (1970) (15)

	[km²]	[%]
Natural landscape		
Woody and herbaceous vegetation	4,208	68
Others	990	16
Agricultural land	495	8
Settlement area	186	3
Others (lake surface areas)	309	5
Total	6,188	100

§ Types of important forest vegetation : *Pinus ponderosa* (mid-altitudes), *Pseudotsuga menziesii* (high altitudes), *Abies lasiocarpa*, *Picea engelmanii* (high & exposed subalpine).

§ Types of important herbaceous vegetation : *Artemisia* spp., *Agropyron spicatum* (low & mid-altitudes), *Calamagrostis rubescens* (high altitudes), *Carex* spp. (high & exposed subalpine).

§ Types of other important vegetation : *Balsamorhiza sagittata*, *Opuntia fragilis*, *Lewisia rediviva*, *Typha latifolia*, *Salicornia europaea rubra*, *Purshia tridentata*.

§ Main kinds of crops and/or cropping systems : Fruits (apple, cherry, grape, peach, apricot. pear, plum), hay, alfalfa.

§ Levels of fertilizer application on crop fields : Moderate.

§ Trends of changes in land use in recent years : Gradual loss of agricultural land to urban development.

G2 INDUSTRIES IN THE CATCHMENT AREA AND THE LAKE (1970) (15)

	Gross production per year (US$ 1.00)	No. of persons engaged	Main products and major industries
Primary industry			
Crop production	40,300,000	2,650	Fruit trees, grapes
Fisheries*			
Others	49,710,000	660	Lumber, mining
Secondary industry			
Manufacturing	77,860,000	4,170	Wood products, fabricating
Tourism	11,240,000	1,230	
Tertiary industry			
Retail		19,760	

* There is no commercial fishery.

§ Number of domestic animals in the catchment area : Cattle 9,350, sheep ~1,000, swine 6,975, poultry 372,800, others 4,500 (17).

G3 POPULATION IN THE CATCHMENT AREA (1986)*

	Population	Population density [km^{-2}]	Main cities
Urban	62,700		Kelowna, Summerland, Peachland,
Rural	62,300		Westbank, Vernon, Armstrong, Naramata, Okanagan Center, Spallumcheen
Total	125,000	20.2	

* Last Canadian Census year.

H. LAKE UTILIZATION

H1 LAKE UTILIZATION

Source of water, sightseeing and tourism (no. of visitors in 1980 : 1.05 million for entire Okanagan Valley (15)), recreation and fisheries.

H2 THE LAKE AS WATER RESOURCES in 1979 (2)

	Use rate [$m^3 day^{-1}$]
Domestic water	2,117
Irrigation	14,165,159
Industrial water	85,435
Others (water work)	2,340

I. DETERIORATION OF LAKE ENVIRONMENTS AND HAZARDS

I1 ENHANCED SILTATION

§ Extent of damage : Not serious.

§ Supplementary notes

Relative composition of phosphorus transported to the Okanagan Valley lakes in suspended sediments during snowmelt averaged 62 % apatite P, 16 % non-apatite P and 22 % organic P (18).

I2 TOXIC CONTAMINATION

§ Present status : Detected but not serious.

§ Main contaminants, their concentrations and sources

Name of contaminants	Range of concentrations [ppm]			Main Sources
	Water*	Bottom mud	Fish**	
	1987 (19)	1974 (4)	1988 (8)	
Hg	<0.00005 0.00019	34-777 ppb	0.06 0.33	
PCB	<0.0004		<0.1-0.6	
PCP/TcP	<0.0001		0	
DDT			<0.01-3.63	
Organophosphorus	<0.0025			Pesticides
Organochlorine	<0.00025			Pesticides

* Volume basis [mg l^{-1}].

** Dorsal muscle of rainbow trout ; wet weight basis [mg l^{-1}].

§ Food safety standards or toletance limits for toxic contaminant residue : Canadian Food and Drug Directorate, World Health Organization.

§ Past trends

Fig. NAM-51-9 Mercury in rainbow trout muscle (wet weight basis). Circles indicate means and vertical lines indicate ranges (1970-1988).

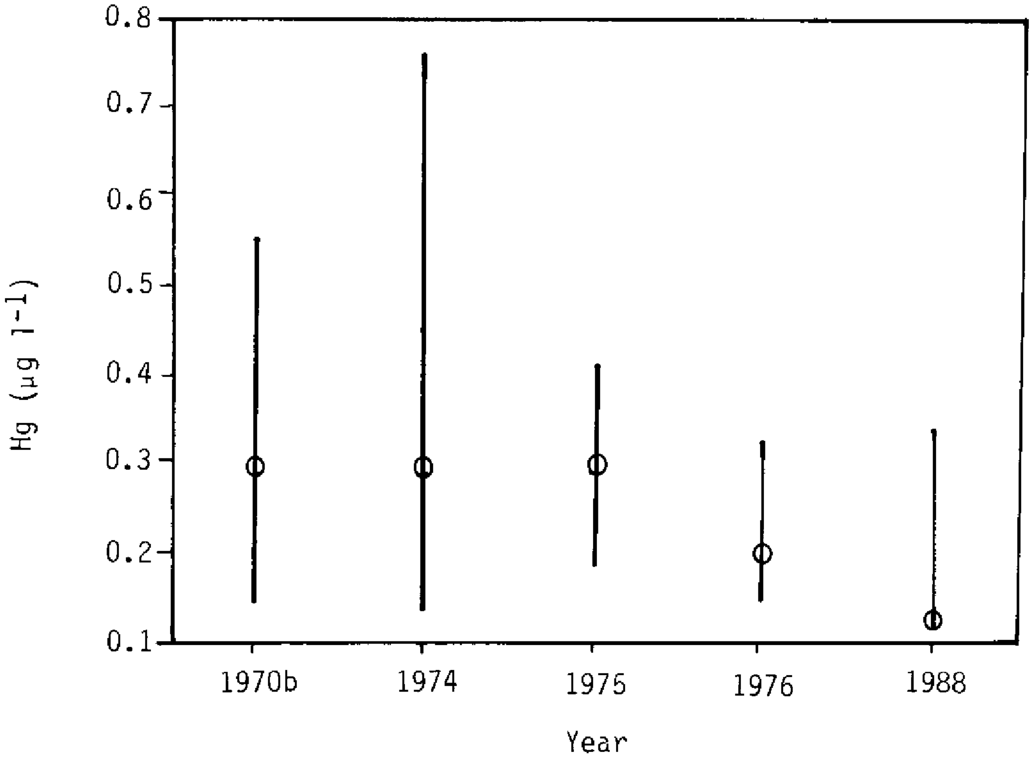
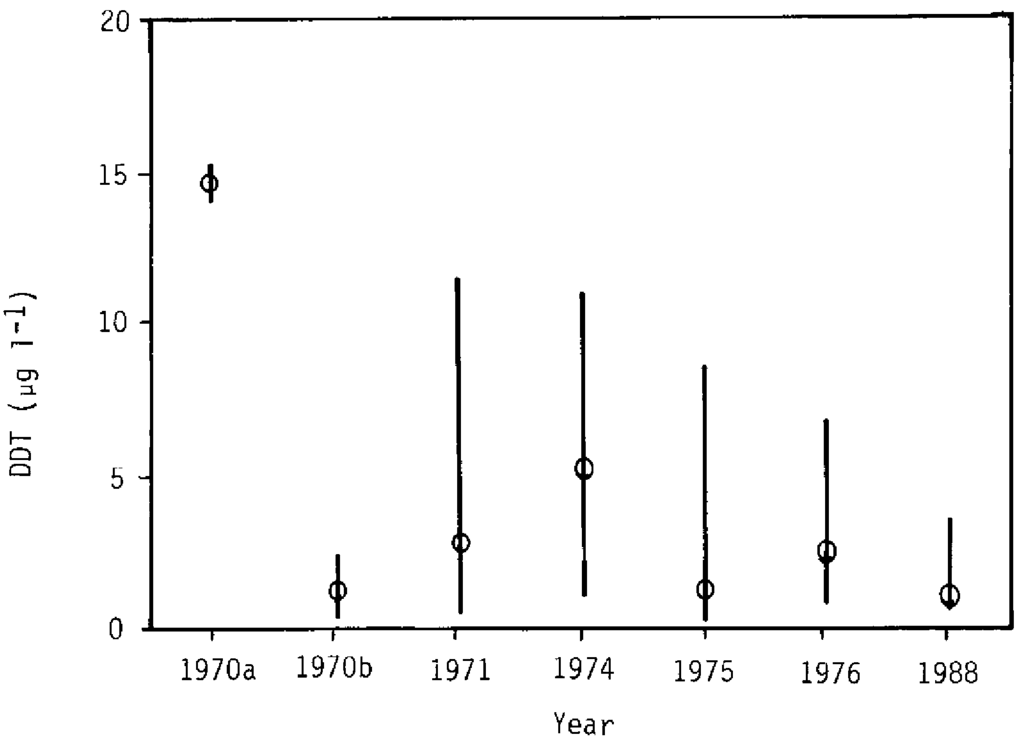


Fig. NAM-51-10 DDT in rainbow trout muscle. Circles indicate means and vertical lines indicate ranges (1970-1986).



§ Supplementary notes : British Columbia banned the use of DDT in 1971.

I3 EUTROPHICATION

§ Nuisance caused by eutrophication : Unusual algal bloom (*Anabaena* sp. ; Vernon Arm, June 1975), foul odour of tap water, and degraded aesthetic value (reduced tourist and local use).

§ Nitrogen and phosphorus loadings to the lake [t yr^{-1}]

Past, present and predicted bioavailable phosphorus loadings [t yr^{-1}] (2, 15, 17)

	1970	1980	1990
Controllable*[1]			
Point sources			
Municipal*[4]	37.5	17.0	8.5
Storm sewers	0.3	0.5	0.7
Industrial	0.7	1.1	1.2
Non-point sources			
Agriculture			
Animals	2.2	8.8	8.9
Fertilizer	0.3	0.4	0.4
Septic tank	3.8	6.6	8.3
Logging	N. A.	6.0	6.0
Others	0.2	1.3	0.3
Subtotal			
Non-controllable*[5]			
Dustfall & precipitation*[2]	8.9	8.9	8.9
Watershed sources*[3]	24.5	18.5	18.5
Mainstem loadings*[3]	0.1	0.1	0.1
Subtotal	33.5	27.5	27.5
Total loadings	78.5	69.2	61.8

*[1] Assumes that all controllable sources of P are biologically available.

*[2] Assumes that dustfall and precipitation P are bio-available.

*[3] Bio-available P loadings from watershed and mainstem sources were calculated as set out in (22).

*[4] Future loadings are estimated on the basis of population growth assuming that minimum objectives 90 % of P will be removed.

*[5] Loadings from uncontrollable sources are shown to be the same for all years because of the lack of data basis, except for watershed loadings.

§ Supplementary notes

Water quality objective for phosphorus is 0.010 mg l^{-1} (2) (British Columbia Ministry of Environment water quality criteria documents). Countermeasures are to reduce P contributions from point and non-point sources through the 1982 Okanagan Basin Implementation Agreement (15) and the Okanagan Water Quality Project (1986-1989) described below.

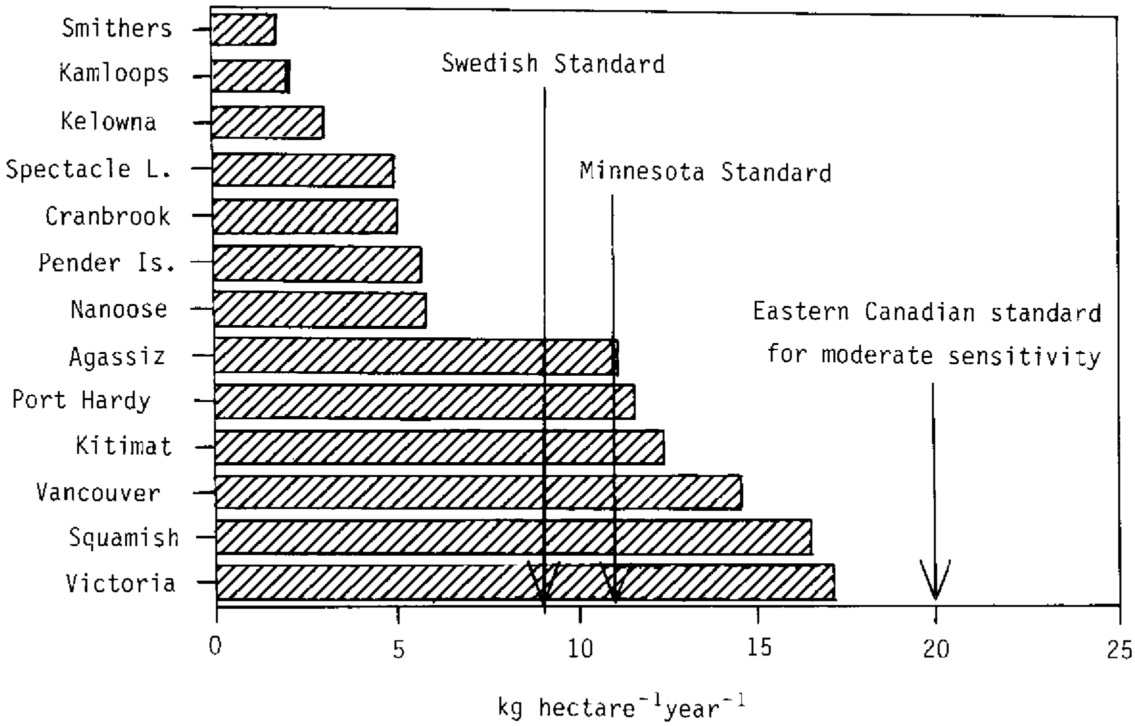
Goals : 90-95 % removal of P from sewage sources through upgrading of sewage treatment plants and waste management planning for centers without collection systems. Implementing best management practices for agriculture and logging to reduce contributions from these diffuse sources of phosphorus.

I4 ACIDIFICATION

§ Extent of damage : None.

§ Supplementary notes: Based on the high calcium content and alkalinity of Okanagan Lake water, it is considered of low sensitivity to acidic inputs (20).

Fig. NAM-51-11 Sulphate deposition at Kelowna near center point of Okanagan Lake (21).



I5 OTHER HAZARDS
Log booms.

J. WASTEWATER TREATMENTS

J1 GENERATION OF POLLUTANTS IN THE CATCHMENT AREA: (d) Measurable pollution with limited wastewater treatment.

J2 APPROXIMATE PERCENTAGE DISTRIBUTION OF POLLUTANT LOADS

Sources	1970	1980	1987	[%]
Sewage treatment plants	59.1	19.1	11.7	14
Septic	8.0	11.5	16.9	21
Agriculture	4.5	11.9	2.5	3
Forestry	8.4	8.4	8.4	10
Other	41.9	41.9	41.9	51
Total			81.4	100

J3 SANITARY FACILITIES AND SEWERAGE
§ Percentage of municipal population in the catchment area provided with adequate sanitary facilities (on-site treatment systems) or public sewerage: 100 %.
§ Percentage of rural population with adequate sanitary facilities: 100 %.
§ Municipal wastewater treatment systems
No. of tertiary treatment systems: 3 (Kelowna, Vernon, Westbank).
No. of secondary treatment tystems: 1 (Armstrong).

K. IMPROVEMENT WORKS IN THE LAKE

K1 RESTORATION : None.

K2 AERATION : None.

K3 OTHERS

Diver operated dredges used to control milfoil in Vernon Arm, Kelowna and Summerland.

L. DEVELOPMENT PLANS

Most of the land is owned privately and has been developed or can be. Most of the lakeshore suitable for housing development has been developed or will be within a few decades. Dense subdivisions have or will have tertiary treatment for wastewater. Tile fields from septic tanks are not allowed closer than 33 m from the lakeshore and are usually not permitted in area of high groundwater or porous soils which do not remove most of the phosphorus from wastewater. Livestock operations are being encouraged to conform to pollution control guidelines.

M. LEGISLATIVE AND INSTITUTIONAL MEASURES FOR UPGRADING LAKE ENVIRONMENTS

M1 NATIONAL AND LOCAL LAWS CONCERNED

§ Names of the laws (the year of legislation)

(1) British Columbia Environment Management Act/Waste Management Act (1982)

(2) British Columbia Health Act/Sewage Disposal Regulations (1986)

§ Responsible authorities

(1) Government of British Columbia, Ministry of Environment

(2) Government of British Columbia, Ministry of Health

§ Main items of control

(1) All discharges of wastewater >5,000 IGD

(2) All discharges of wastewater <5,000 IGD

§ Supplementary notes : Limited control over nutrient from agriculture, forestry and urban runoff — most control measures are not regulations but guidelines.

M2 INSTITUTIONAL MEASURES

(1) Okanagan Basin Study — Joint Canada/British Columbia interdisciplinary program

(2) British Columbia Pollution Control/Waste Management Branch, British Columbia Ministry of Environment

(3) Okanagan Basin Implementation Program — Joint Canada/British Columbia project to implement recommendations of the Okanagan Basin Study

M3 RESEARCH INSTITUTES ENGAGED IN THE LAKE ENVIRONMENT STUDIES

(1) British Columbia Waste Management Branch

(2) British Columbia Water Management Branch

N. SOURCES OF DATA

(Q) Questionnaire filled by Drs. J. E. Bryan, Head of Environmental Section & E. V. Jensen, Impact Assessment Biologist, Waste Management Program, Ministry of Environment, British Columbia.

(1) Stockner, J. G. & Northcote, T. G. (1974) Recent limnological studies of the Okanagan basin lakes and their contribution to comprehensive water resource planning. J. Fish. Res. Board Can., 31 : 955-976.

(2) Anon. (1985) Phosphorus in the Okanagan Valley Lakes : Sources, Water Quality Objectives and Control Possibilities. Ministry of Environment, Waste Management Branch, Victoria, B. C.

(3) Anon. (1974) Main Report of the Consultative Board Including the Comprehensive Framework Plan. Canada-British Columbia Okanagan Agreement, Office of the Study Director,

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(14) Bull, C. J. (MS1987) Okanagan Lake Plan. Technical Report, Ministry of Environment, Fisheries Section, Okanagan Sub-region, Penticton, B. C.
(15) Anon. (1982) Okanagan Basin Implementation Board, Report of the Okanagan Basin Implementation Agreement.
(16) Taylor, R. L. & MacBride, B. (1977) Vascular Plants of British Columbia. Technical Bulletin no. 4, University of British Columbia.
(17) Anon. (1982) 1980 Update -- Nutrient Loadings from Non-point Sources, Review Item B-4, Non-point Sources, Okanagan Basin Implementation Agreement. Prepared by Canadian Bio-Resources Engineering Ltd. for the Okanagan Basin Implementation Board.
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(19) Jensen, E. V. (MS1987) Results of Trace Contaminant Monitoring on Okanagan and Skaha Lake Water, April 1987. 11 pp. B. C. Ministry of Environment.
(20) Swain, L. G. (1985) Chemical Sensitivity of Lakes in British Columbia to Acidic Inputs. Water Management Branch, Victoria, B. C.
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(23) Newroth, P. (1981) Case Studies of Aquatic Plant Management for Lake Preservation and Restoration in British Columbia, Canada. Restoration of Lakes and Inland Waters. U. S. EPA Report 440/5-81-010.
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WOOD LAKE

An aerial view of the lake

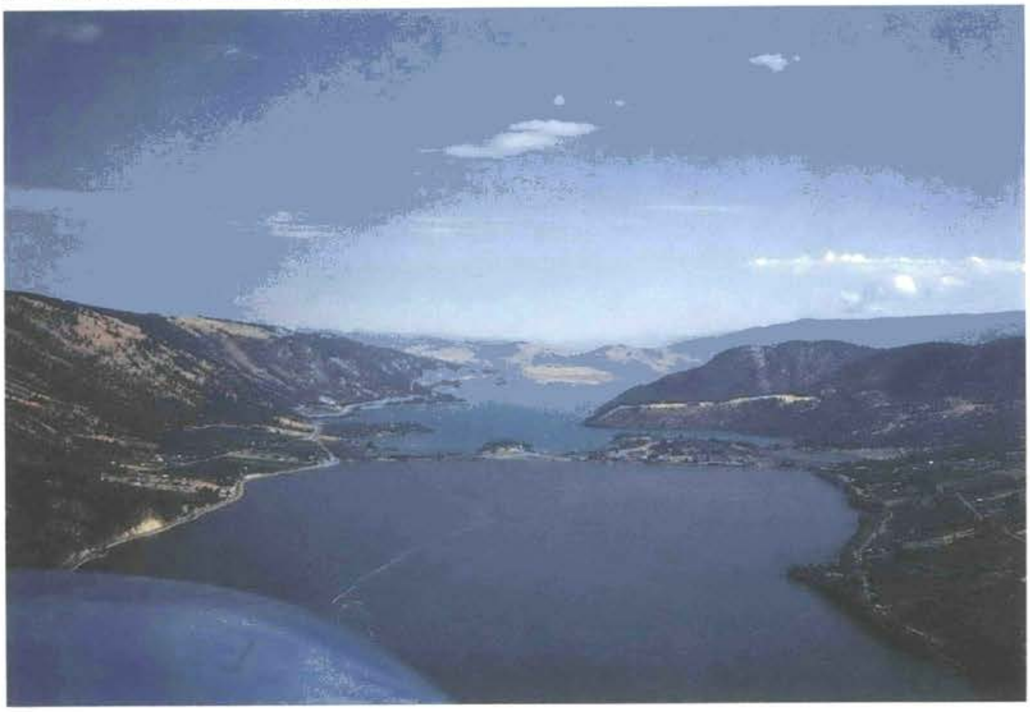
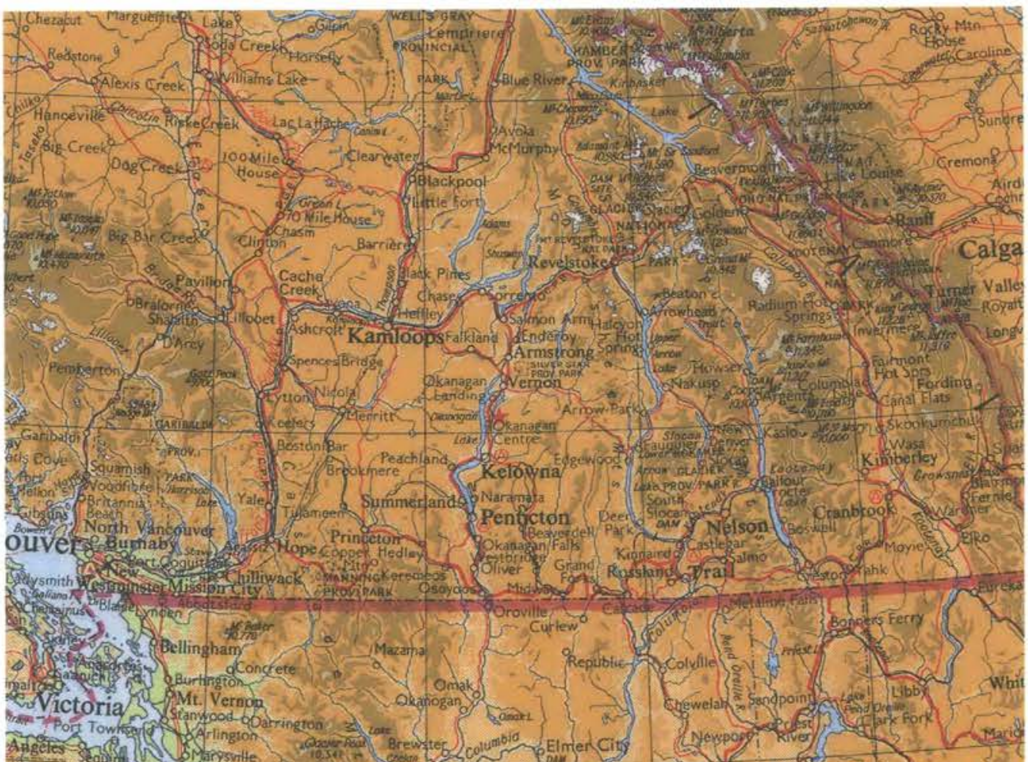


Photo: R.N. Nordin



A. LOCATION

§ British Columbia, Canada.
§ 50°05′N, 119°23′W ; 391 m above sea level.

B. DESCRIPTION

Wood Lake is the first (uppermost) of the chain of five major lakes which occupies portions of the Okanagan Valley in the interior of British Columbia. The Okanagan Valley is a structural trench overlying a system of subparallel linked faults that separate the late Paleozoic or early Mesozoic group of metamorphic rocks of differing lithology but of similar age. The trench is partially filled with up to several hundred meters of unconsolidated material. In the Wood Lake area this material is approximately 125 m thick under the centre of Wood Lake. It is likely that the unconsolidated material was deposited in association with earlier glaciations of the Pleistocene Epoch. Glaciation was well advanced by 9750 B. P. and the lakes of the Okanagan Valley were formed by about 8900 B. P.

Wood Lake has a simple "bath tub" shaped basin. This morphometry makes it very suitable for a variety of investigations, particularly the internal physical structure and mass balance study. The natural water residence time is quite long (30 years) and this may be a factor in the generally eutrophic conditions.

The watershed was first settled by Europeans in the last half of the 19th century. The climate (dry warm summers), well drained soils and availability of irrigation water led to the development of a substantial tree fruit industry around the lake and throughout the valley. The upper watershed is heavily forested (predominantly Douglas fir, *Pseudotsuga menziesii*) and has been logged for several decades. The lower elevation of the watershed is described as a Ponderosa pine (*Pinus ponderosa*)/bunchgrass community.

Little limnological informations was collected prior to 1969 when the Okanagan Basin Study was undertaken. Initiative for this comprehensive program came about primarily due to complaints of poor water quality in Wood Lake and deteriorating water quality in Skaha and Osoyoos Lakes.

Wood Lake has displayed some remarkable changes in the past 20 years. Wood Lake is immediately adjacent to Kalamalka Lake, a larger oligotrophic marl lake, and connected to it by a dredged channel (the Oyama canal). The two lakes have generally demonstrated a dramatic side-by-side contrast in nutrient water chemistry and biological production. Wood Lake was, during the intensive study of the Okanagan Basin Study, described as eutrophic with summer cyanobacterial blooms and large hypolimnetic oxygen depletion. Recent water quality has improved with much better water clarity and other changes. Cooling water taken from Okanagan Lake is used by a distillery in the Wood Lake basin and flows into Wood Lake have reduced the normal water residence time of the lake by half. This change in water residence time as well as other hydrologic and climatic trends may play a role in the water chemistry changes noted in recent years.

During the 1970's, Eurasian milfoil (*Myriophyllum spicatum*) colonized significant portions of the littoral zone, especially in the shallower southern end of the lake. Combinations of dredging and herbicide treatments have been employed from time to time to limit this nuisance (Q, 2).

C. PHYSICAL DIMENSIONS (1, 2, 3)

Surface area [km^2]	9.3
Volume [$10^6 m^3$]	199.5
Maximum depth [m]	34
Mean depth [m]	21.5
Normal range of annual of water level fluctuation [m] (regulated)*	1.2
Length of shoreline [km]	13.5
Residence time [yr]	16.9(1971-1985)
Catchment area [km^2]	190

* The lake is same elevation as Kalamalka Lake which has a control structure at the outlet.

D. PHYSIOGRAPHIC FEATURES

D1 GEOGRAPHICAL

§ Bathymetric map (Fig. NAM-52-1).
§ Main islands : None.
§ Outflowing rivers and channels (number and names) : 1 (Oyama "canal" (short artificial connection to Kalamalka Lake).

D2 CLIMATIC

Kelowna Airport, 1940–1970 (4)

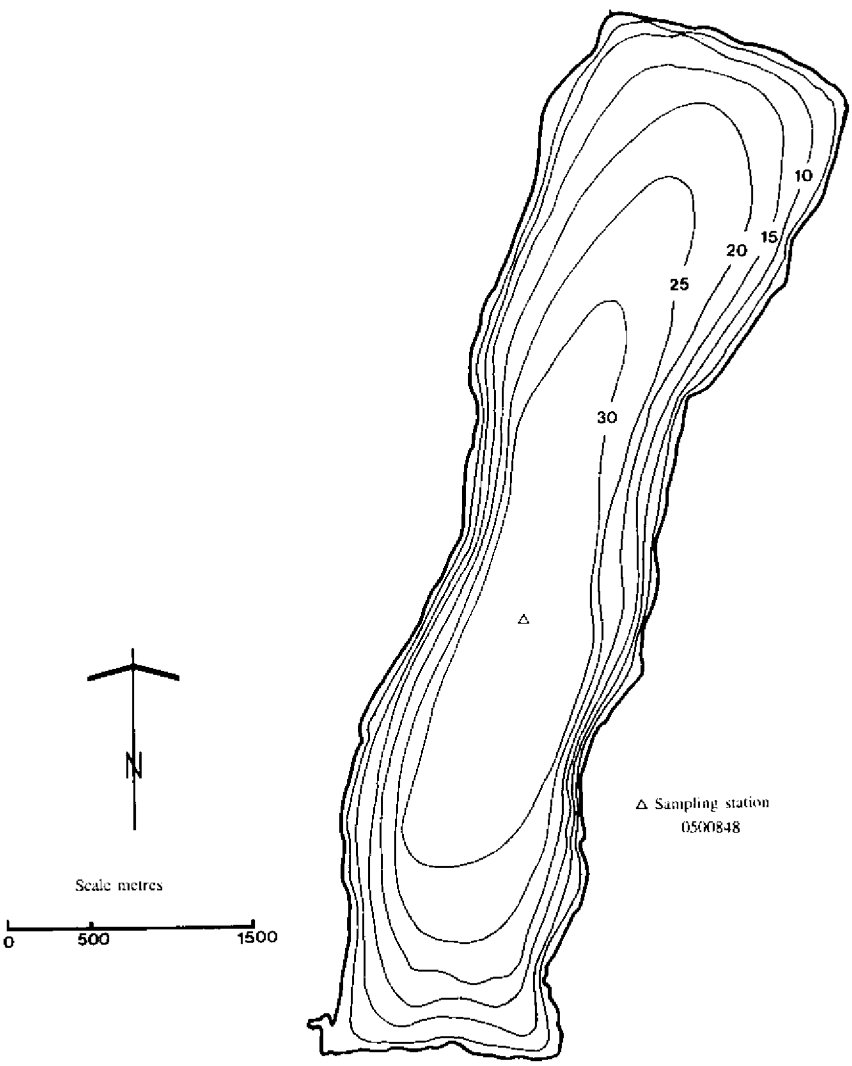
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean temp. [°C]	-5.8	-2.6	2.0	7.6	12.1	15.8	18.9	17.5	13.1	7.0	0.8	-2.4	7.0
Precipitation [mm]	4	8	12	20	23	31	30	22	21	26	26	18	242

§ Number of hours of bright sunshine : 1981.3 hr yr^{-1} (4a).
§ Average solar radiation at the Summerland Station : 12.84 MJ $m^{-2}day^{-1}$.

Mean daily global solar radiation [MJ $m^{-2}day^{-1}$]

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
3.4	6.5	11.5	16.7	20.8	22.6	23.7	19.6	14.5	8.5	3.8	2.5

Fig. NAM-52-1 Bathymetric map [m] (Q).

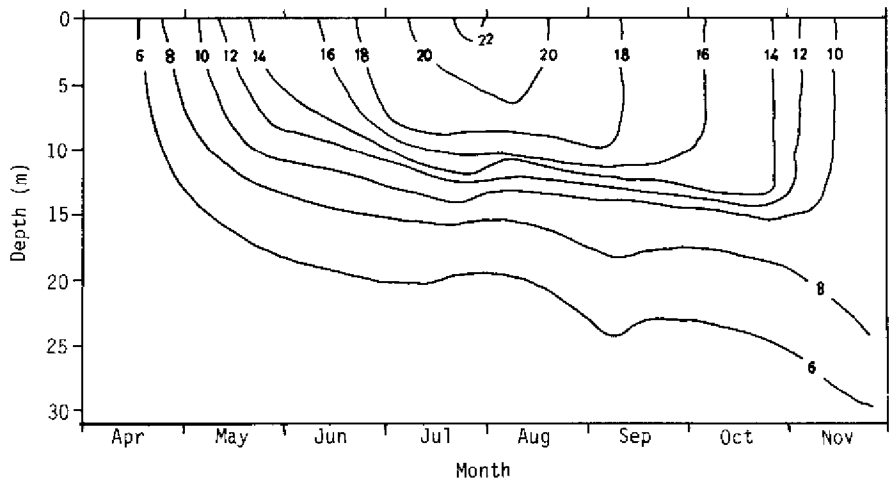


§ Water temperature [°C]
Station 0500848, 1987 (5)

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	—	—	2.5	5.0	15.5	19.5	21.8	20.5	8.8	13.5	11.0	6.0
5	—	—	2.0	4.2	13.9	18.0	21.1	19.5	18.8	13.3	10.8	6.0
10	—	—	2.0	4.0	9.2	13.0	12.8	15.8	18.6	13.5	10.8	6.0
15	—	—	2.0	4.0	6.9	7.8	8.2	8.8	8.3	8.6	10.8	6.0
20	—	—	2.0	4.0	6.0	6.5	6.0	6.2	6.4	6.3	6.8	6.0
25	—	—	2.0	4.0	5.6	6.0	5.6	5.5	5.7	5.9	6.0	6.0
30	—	—	2.0	4.0	5.2	5.5	5.0	5.5	5.3	5.2	5.5	6.0

Data for 1969-1988 also available.

Fig. NAM-52-2 Temperature distribution [°C], 1980 (6).



§ Freezing period : Dec. to Feb. (occasionally).
§ Mixing type : Cold monomictic.
§ Notes on water mixing and thermocline formation : See (6), (17-20), (34) and (35).

E. LAKE WATER QUALITY (5)

E1 TRANSPARENCY [m]

Station 0500848, 1987

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
—	—	6.7	4.3	5.6	8.8	3.3	3.0	4.0	7.3	10.5	6.7

E2 pH

Station 0500848, 1987 (field data)

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	—	—	8.2	8.4	8.7	8.4	9.3	8.7	8.6	7.8	—	—
5	—	—	7.9	8.0	8.7	8.4	9.2	8.7	8.4	7.9	—	—
10	—	—	—	—	8.5	8.4	8.8	8.2	8.0	7.8	—	—
20	—	—	—	—	8.2	8.0	7.5	7.4	7.2	7.0	—	—
25	—	—	7.8	7.9	8.0	7.6	7.2	—	7.1	6.9	—	—
30	—	—	—	—	7.9	7.2	7.1	7.4	7.0	6.9	—	—

E3 SS [mg l⁻¹]

Station 0500848, 1987

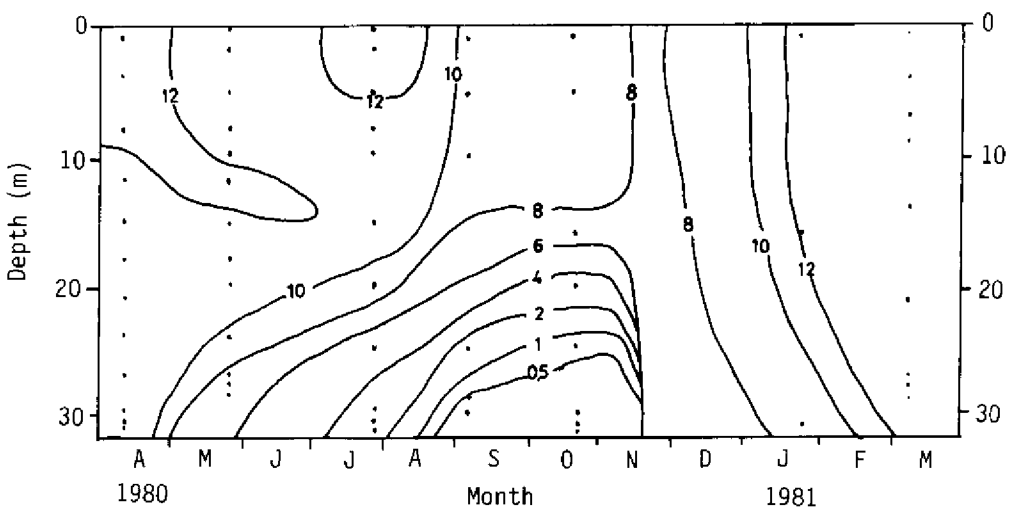
Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	–	–	–	–	–	<1	3	1	2	1	2	<1
10	–	–	–	–	–	<1	1	1	2	1	1	1
20	–	–	–	–	–	<1	1	1	2	6	1	–
30	–	–	–	–	–	<1	–	–	–	–	–	–

E4 DO [mg l⁻¹]

Station 0500848, 1987

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	–	–	14.4	15.8	13.2	10.5	11.1	11.0	9.8	9.6	9.0	8.2
5	–	–	14.7	16.0	13.4	10.7	11.7	10.9	9.8	9.6	9.1	8.3
10	–	–	14.8	15.6	13.6	10.2	9.4	5.2	9.0	9.5	9.1	8.3
15	–	–	14.8	15.2	12.5	9.4	7.7	4.0	1.1	0.8	9.1	8.2
20	–	–	14.8	15.1	12.2	9.8	6.4	3.9	0.4	0.8	0.6	8.2
25	–	–	14.8	15.0	11.5	9.0	4.5	1.0	0.3	0.7	0.5	8.2
30	–	–	14.8	14.8	11.1	6.3	2.3	0.6	0.2	0.6	0.4	8.2

Fig. NAM-52-3 Time-depth diagram of dissolved oxygen concentrations [mg l⁻¹], 1980 (6).



E5 COD [mg l⁻¹]

Station 0500848, 1987
($K_2Cr_2O_4$ method)

Depth [m]	Aug	Sep
0	17	22
5	23	22
10	14	18
15	13	17
20	15	17
25	20	15
30	18	18

E6 CHLOROPHYLL CONCENTRATION [$\mu g\ l^{-1}$]

Station 0500848, 1987

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0-10 m average	—	—	3.9	8.4	2.8	2.4	2.6	3.3	5.6	2.0	2.9	2.4

E7 NITROGEN CONCENTRATION

§ Kjeldahl N + Nitrate N [$mg\ l^{-1}$]

Station 0500848, 1987

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0-10 composite	—	—	0.450	0.460	0.340	0.380	—	—	—	—	—	—
20-30 composite	—	—	0.490	0.440	0.430	0.560	0.590	—	—	—	—	—
1	—	—	—	—	—	0.380	0.380	—	—	—	—	0.520
5	—	—	—	—	—	0.410	0.390	—	—	—	—	0.500
10	—	—	—	—	—	0.430	0.450	—	—	—	—	0.460
20	—	—	—	—	—	—	—	—	—	—	—	0.470
30	—	—	—	—	—	—	—	—	—	—	—	0.570

Fig. NAM-52-4 Time-depth diagram of nitrate plus nitrite concentration [$\mu g\ N\ l^{-1}$], 1980 (6).

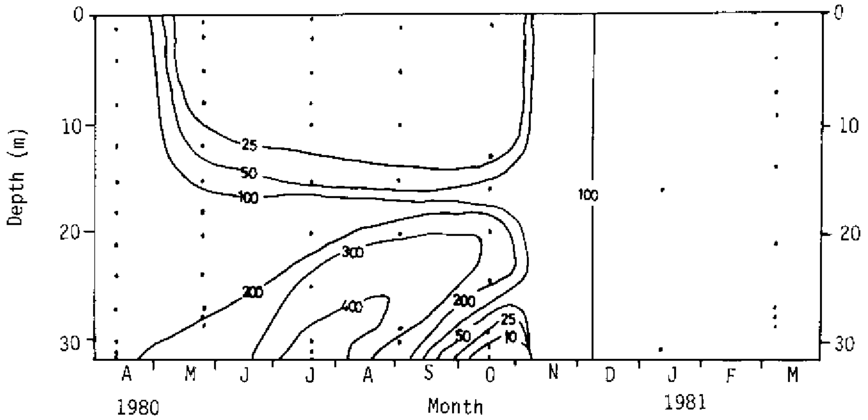
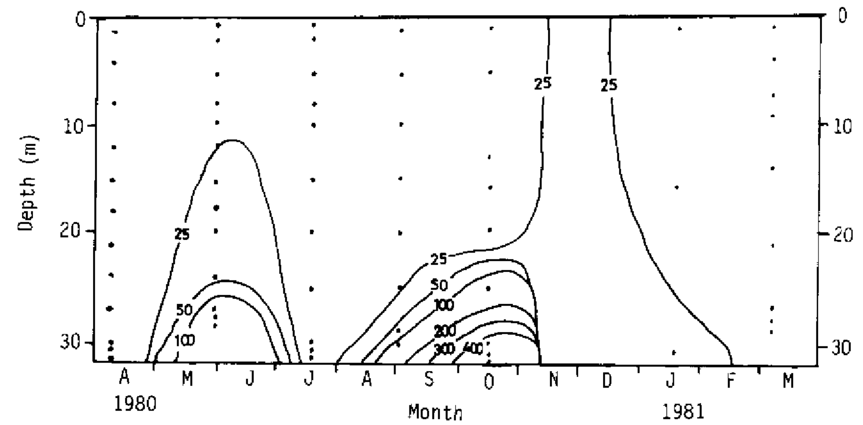


Fig. NAM-52-5 Time-depth diagram of ammonium concentration [$\mu g\ N\ l^{-1}$], 1980 (6).

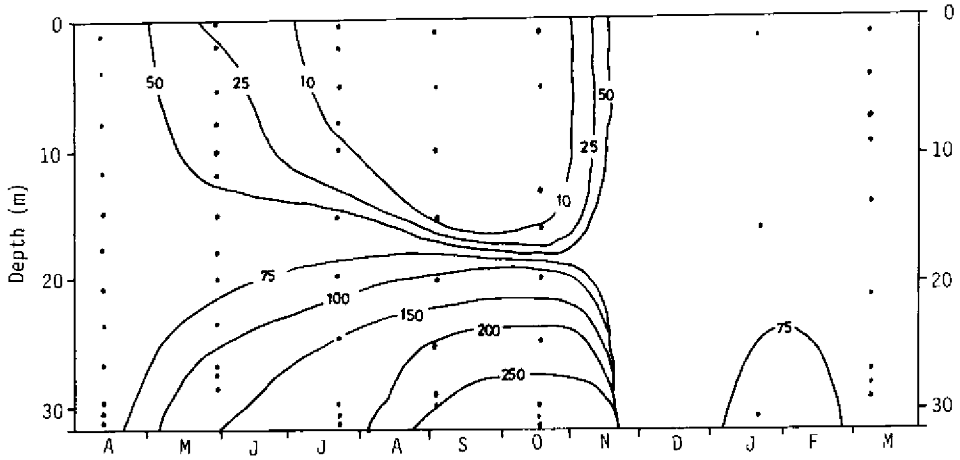


E8 PHOSPHORUS CONCENTRATION

§ Total-P [μg l^{-1}]
Station 0500848, 1987

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0-10 composite	–	–	40	–	–	–	–	–	–	9	–	–
20-30 composite	–	–	40	–	–	–	86	–	–	124	133	–
1	–	–	–	37	15	14	16	17	23	11	13	52
5	–	–	48	32	19	15	11	24	13	12	53	–
10	–	–	38	25	23	20	13	19	11	12	55	–
20	–	–	34	33	28	–	40	34	47	48	56	–
30	–	–	34	54	89	–	138	197	235	214	58	–

Fig. NAM-52-6 Time-depth diagram of dissolved phosphorus concentrations [μg P l^{-1}] (6).



E9 CHLORIDE ION CONCENTRATION [mg l^{-1}]

Station 0500848, May-Oct. 1982 : 3 [mean value] (2).

F. BIOLOGICAL FEATURES

F1 FLORA

§ Emerged macrophytes

Typha latifolia, *Scirpus* sp., *S. lacustris*, *Equisetum* sp., *E. fluviatile*, *Ranunculus* sp., *R. aquatilis*.

§ Submerged macrophytes

Myriophyllum spicatum (abundant), *M. exalbescens*, *Potamogeton perfoliatus*, *P. gramineus*, *P. crispus*, *P. illinoensis*, *P. pectinatus*, *P. nodosus*, *Chara* sp., *Elodea canadensis*, *Ceratophyllum* sp., *C. demersum*.

§ Phytoplankton : *Aphanizomenon*, *Anabaena*, *Lyngbya*, *Oscillatoria rubescens* (1, 6, 31, 32, 47).

F2 FAUNA

§ Zooplankton : *Cyclops bicuspidatus thomasi*, *Diaptomus ashlandi* (1, 23, 58, 60).

§ Benthos : Very sparse ; *Chironomus* spp. (1, 10, 54).

§ Fish : Peamouth chub, squawfish, kokanee (sport fishing) (1, 22).

§ Supplementary notes on the biota

Clemens, *et al.* (9) reported that in 1935 there was high biomass of benthos. In contrast Saether (10) in 1969 found virtually no benthos present in Wood Lake. No explanation has yet been proposed for this dramatic change.

F6 PAST TRENDS

Mean annual epilimnetic (0-10 m) chlorophyll *a* concentration [$\mu g\ l^{-1}$], Station 0500245 and 0500848 (5).

1975	18.5	1979	3.1	1983	3.9
1976	11.9	1980	3.9 *	1984	–
1977	9.8	1981	5.7	1985	5.5
1978	10.8	1982	2.7		

* 1980 annual mean = 5.5 according to (6).

F7 NOTES ON THE REMARKABLE CHANGES OF BIOTA IN THE LAKE IN RECENT YEARS

Apparent changes in nutrient loading have caused changes in standing crop. May be changes in species composition of phytoplankton (data not analysed), zooplankton (data may not be available) and fisheries (probably no data). Change in benthos standing crop noted in F2.

Increases in littoral zone *Myriophyllum spicatum* population which was introduced from Europe via eastern Canada have been considerable in this and numerous other lakes of British Columbia (2).

G. SOCIO-ECONOMIC CONDITIONS

G1 LAND USE IN THE CATCHMENT AREA (1987) (7)

	[km²]	[%]
Natural landscape		
Woody vegetation (forested)	76	40
Swamp		<1
Agricultural land		
Crop field (orchards)	57	30
Settlement area	28.5	15
Others (grassland/pasture)	28.5	15
Total	190	100

§ Types of important forest vegetation : Douglas fir forest (upper elevations of watershed), Ponderosa pine/open grassland (lower elevations).

§ Main kinds of crops and/or cropping systems : The watershed directly around the edge of the lake is intensively developed in orchards (mainly apples) which are irrigated from Wood Lake.

§ Levels of fertilizer application on crop fields : Moderate.

§ Trends of change in land use in recent years : Increasing residential development ; the Okanagan Valley is a popular retirement area.

G2 INDUSTRIES IN THE CATCHMENT AREA AND THE LAKE (1981) (8)

	Gross production per year (=US$ 1.00)	No. of establishments	Main products or major industries
Secondary industry	N. A.	1	Distillery

§ Numbers of domestic animals in the catchment area : Small number of horses and cattle.

G3 POPULATION IN THE CATCHMENT AREA (1981) (8)

Sparsely populated largely agricultural area. Total population of much larger North Okanagan Regional District is 54,352. Town of Winfield (population 3,000) occupies part of the watershed south of Wood Lake.

H. LAKE UTILIZATION

H1 LAKE UTILIZATION (11)

Source of water, sightseeing and tourism (no. of visitors in 1980 : total Okanagan receives 6.28 million visitor•days ; North Okanagan 25 %) and recreation (swimming and sport-fishing).

H2 THE LAKE AS WATER RESOURCE (1985)

	Use rate	Use rate [$m^3 day^{-1}$]	[$m^3 yr^{-1}$]
Domestic water	Waterworks	341	
	Private intakes	9	
Irrigation			363,075
Industrial water		20	

I. DETERIORATION OF LAKE ENVIRONMENTS AND HAZARDS

I1 ENHANCED SILTATION

§ Extent of damage : Not serious.

I3 EUTROPHICATION

§ Nuisance caused by eutrophication : Unusual algal bloom (*Anabaena flos-aquae, Oscillatoria rubescens, Aphanizomenon flos-aquae* ; serious problem in early 1970's).

§ Phosphorus loadings to the lake [t yr^{-1}], (1980) (11)

	Industrial (forestry)	Domestic (septic tanks)	Agricultural (fertilizer & livestock)	Natural	Total*
T-P	0.5	0.8	0.6	1.3	3.3

* Internal loading may be significant, but is not included.

§ Supplementary notes

Concern in early 1970's as a result of heavy cyanobacterial blooms. Since that time water quality has improved, apparently partially as a result of increased flushing rate of the lake (cooling water from a distillery imported from outside the watershed), and possibly due to an increase in the loading N : P ratio (13). Nitrate from the distillery infiltration ponds may be the source of this change. Water quality in recent years remarkably better than early 1970's (3, 6, 11, 13, 16, 64).

Water column treatment with alum (15) and sediment treatment with iron (3) considered as means of reducing eutrophication problem.

I4 ACIDIFICATION

§ Extent of damage : None.

J. WASTEWATER TREATMENTS

J1 GENERATION OF POLLUTANTS IN THE CATCHMENT AREA : (d) Measurable pollution with limited wastewater treatment.

J2 APPROXIMATE PERCENTAGE DISTRIBUTION OF POLLUTANT LOADS

	Percentage
Non-point sources (agricultural, natural and dispersed settlements)	100

J3 SANITARY FACILITIES AND SEWERAGE

§ Percentage of rural population with adequate sanitary facilities (on-site treatment systems) or public sewerage : 100 %.

§ Municipal wastewater treatment systems : None.

K. IMPROVEMENT WORKS IN THE LAKE (3, 13, 15)

K1 RESTORATION

Alum treatment considered ; treatment of sediments with iron considered ; enhancement of spring diatom sedimentation of phosphorus with nitrate supplements considered.

K3 OTHERS

Diver operated dredging and 2,4-D applications to control Eurasian milfoil infestation.

L. DEVELOPMENT PLANS

Development plans in the lake and catchment area are primarily residential in nature. A continued increasing in housing within the lake's watershed is predicted. No specific large single development has been planned.

M. LEGISLATIVE AND INSTITUTIONAL MEASURES FOR UPGRADING LAKE ENVIRONMENTS

M1 NATIONAL AND LOCAL LAWS CONCERNED

§ Names of the laws (the year of legislation)

(1) British Columbia Waste Management Act (1982)
(2) British Columbia Water Management Act (1979)
(3) British Columbia Environmental Management Act
(4) Canada Federal Fisheries Act

§ Responsible authorities

(1) Government of British Columbia, Ministry of Environment
(2) Government of British Columbia in cooperation with the Government of Canada

§ Main items of control

(1) Control of discharge of waste to land, air, water
(2) Licensing of water use
(3) Prevention of activities detrimental to environment
(4) Management of fisheries

§ Supplementary notes

Also indirect regulations of forestry, for example. Also federal legislation such as Environmental Protection Act.

M2 INSTITUTIONAL MEASURES

(1) Okanagan Basin Study (Canada-British Columbia Okanagan Basin Agreement) 1969-1974
(2) Kalamalka-Wood Lake Basin Water Resource Management Study 1972-1973, Water Investigations Branch, British Columbia Water Resources Service, Victoria.
(3) Okanagan Basin Water Quality Control Project, British Columbia Ministry of Environment, Pentiction, British Columbia, 1986-1989

M3 RESEARCH INSTITUTES ENGAGED IN THE LAKE ENVIRONMENT STUDY

(1) National Water Research Institute, Pacific and Yukon Region, West Vancouver
(2) Hiram Walker Distillery, Winfield, British Columbia, Environmental monitoring 1970-present
(3) British Columbia Ministry of Environment, Okanagan Sub-regional Office, Penticton, British Columbia
(4) British Columbia Ministry of Environment, Victoria, British Columbia

§ Supplementary notes: The regional office of the Ministry of Environment (Penticton) has collected considerable unpublished water quality data for 1970 to present.

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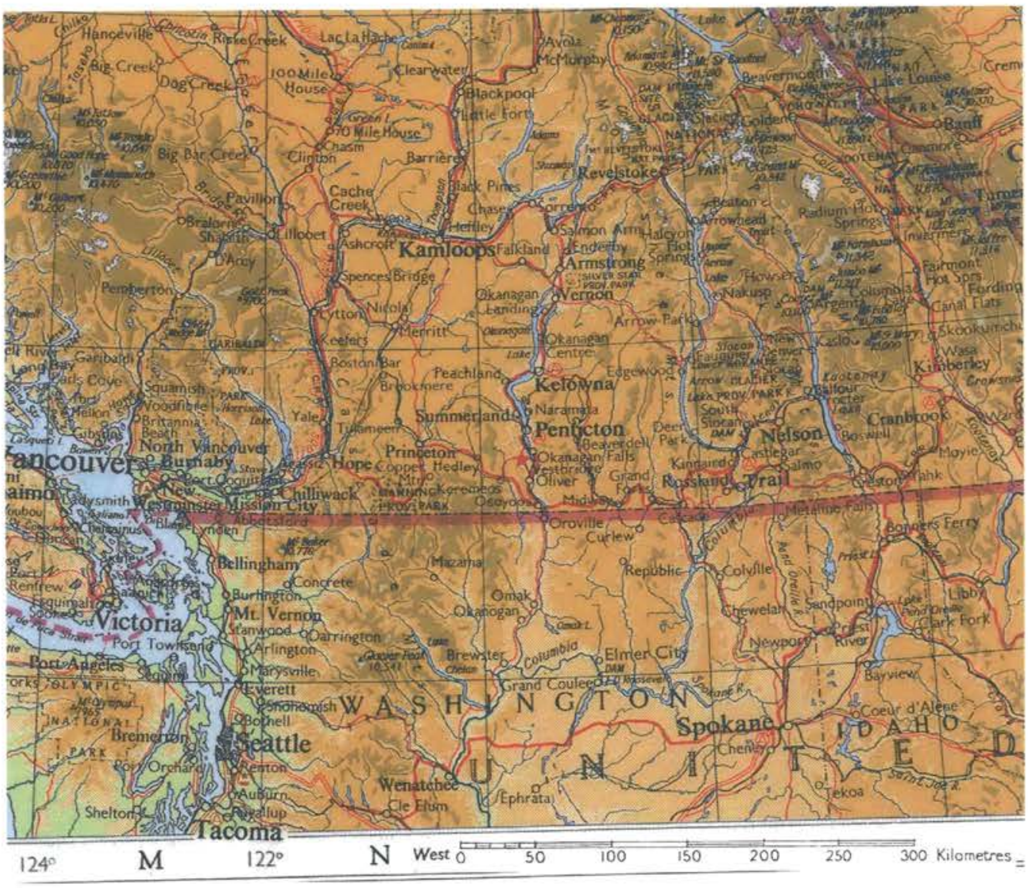
SKAHA LAKE

A view on the lake

Photo: R. Nordin



A. LOCATION

§ British Columbia, Canada.
§ 49°25′N ; 119°35′W ; 338 m above sea level.

B. DESCRIPTION

Skaha Lake is the fourth of the chain of five major lakes which occupy portion of the Okanagan Valley in the interior of British Columbia. The Okanagan Valley is a structural trench overlying a system of subparallel linked faults that separate the late Paleozoic or early Mesozoic Monoshee group of metamorphic rocks of differing lithology but of similar age. The trench is partialy filled with several hundred meters of unconsolidated material (400 m in the Skaha Lake area). It is likely that the unconsolidated material was deposited in association with early glaciations of the Pleistocene Epoch. It seems probable that during the Pleistocene the valley was the site of deposition resulting from glacial outwash, direct glaciation and lacustrine fluvial sedimentation. During deglaciation a number of terraces were formed as lowering of post glacial lake levels was repeatedly arrested.

Prominent silt and clay cliffs border Skaha Lake as a result of this period of glacial downwashing and degradation. Deglaciation was well advanced by 9750 B. P. and the lakes of Okanagan valley were formed about 8900 B. P.

Skaha Lake is comprised of two distinct basins separated by a bedrock sill at a depth of 24 m. The surrounding watershed has "benches" (terrace) along the east and west shores which rise to mountainous slopes with the flat valley bottom at the north and south ends. Skaha Lake is separated from Okanagan Lake to the north by a narrow stretch of valley bottom on which the city of Penticton has developed.

The watershed of Skaha Lake was first settled by Europeans in the last half of the 19th century. The climate (dry warm summers) and soil and availability of irrigation water led to the development of a substantial tree fruit industry around the lake and throughout the valley. Logging occurs in the upper elevation forests of the valley. The lower elevation vegetation of the Skaha Lake watershed is described as a Ponderosa pine (*Pinus ponderosa*)/bunchgrass community and the higher elevation is dominated by Douglas fir (*Pseudotsuga menziesii*) forest.

Little limnological information was collected prior to 1969 when the Okanagan Basin Study was undertaken. Initiative for this comprehensive program came about primarily due to complaints to deteriorating water quality in Skaha Lake as a result of sewage discharge from the city of Penticton to the Okanagan River draining into Skaha Lake. Tertiary treatment was undertaken in 1971. Water quality subsequently improved.

The lake is highly utilized as summer recreation location and tourism is presently a major component of the local economy (Q, 2).

C. PHYSICAL DIMENSIONS (Q, 2, 3)

Surface area [km^2]	20.1
Volume [$10^6 m^3$]	558
Maximum depth [m]	55
Mean depth [m]	26
Normal range of annual water level fluctuation (regulated) [m]	0.6
Length of shoreline [m]	29.5
Residence time [yr]	1.2
Catchment area [km^2]	6,090

D. PHYSIOGRAPHIC FEATURES

D1 GEOGRAPHICAL

§ Sketch map (Fig. NAM-53-1).
§ Bathymetric map (Fig. NAM-53-2).
§ Outflowing rivers and channels (number and names): 1 (Okanagan R.).

D2 CLIMATIC

§ Climatic data at Penticton Airport, 1940-1970 (4)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean temp. [°C]	-2.9	0.3	4.7	8.7	13.4	17.1	20.1	19.2	14.7	8.7	3.1	-0.4	8.8
Precipitation [mm]	9	10	12	23	28	36	25	22	18	20	19	10	232

Fig. NAM-53-1 Sketch map of Okanagan lakes (Q).

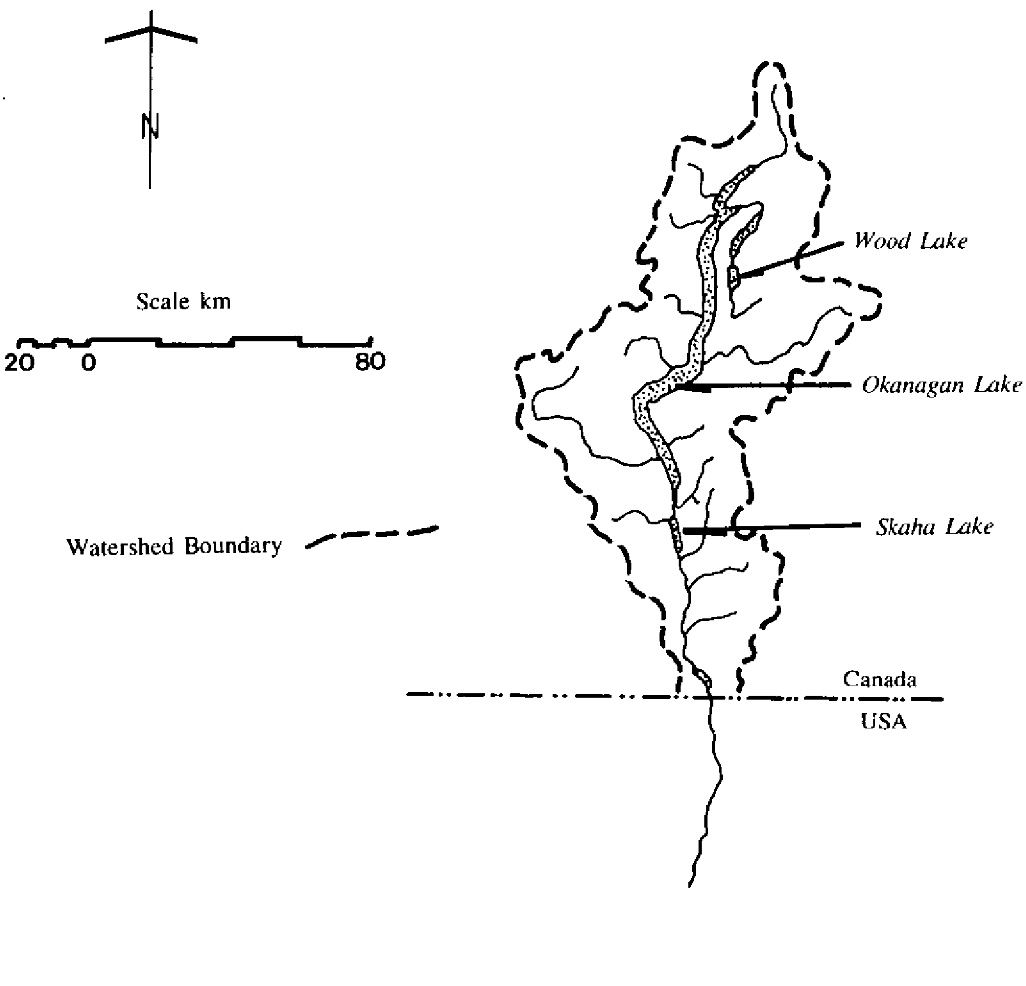
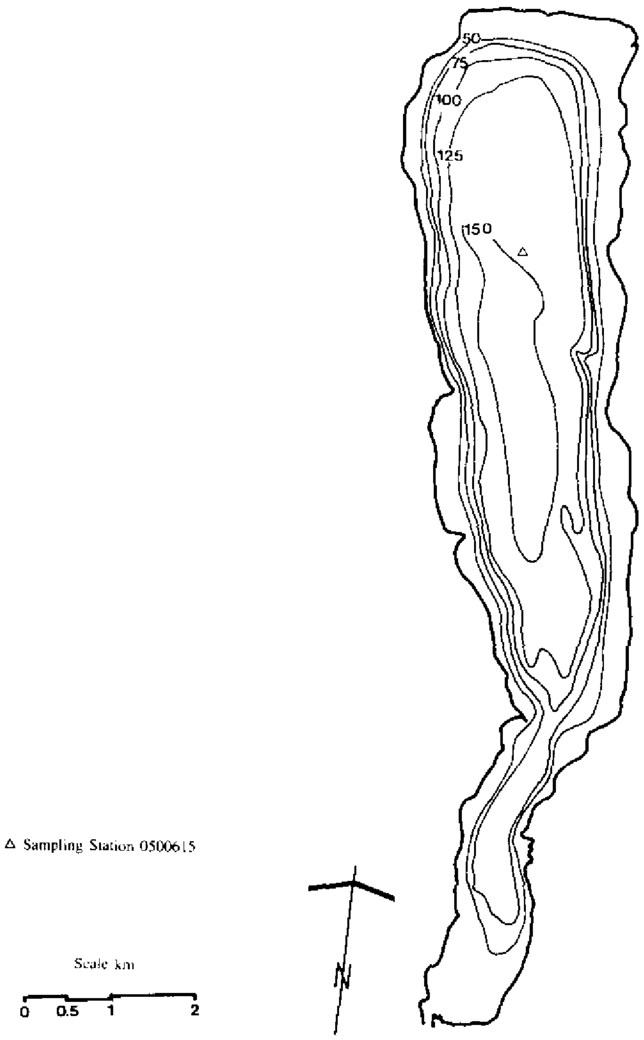


Fig. NAM-53-2 Bathymetric map [feet (50 ft.=15.24 m)] (Q).



§ Number of hours of bright sunshine : 2,032 hr yr^{-1}.

§ Average solar radiation at Summerland : 12.8 MJ $m^{-2}day^{-1}$ (5).

Mean daily global solar radiation [MJ $m^{-2}day^{-1}$]

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
3.4	6.5	11.5	16.7	20.8	22.6	23.7	19.6	14.5	8.5	3.8	2.5

§ Water temperature [°C]

Station 0500615, 1985 (6)

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.5	–	–	0.5	3.3	13.5	13.0	19.3	21.0	16.0	11.5	6.0	2.7
5	–	–	0.5	3.0	8.5	13.3	19.2	20.5	15.9	11.5	6.0	2.6
10	–	–	0.5	3.0	7.8	8.5	15.5	19.8	15.9	11.5	6.0	2.8
15	–	–	0.5	2.8	6.3	5.6	9.5	11.2	13.9	11.5	6.0	3.1
20	–	–	0.5	2.8	5.2	4.8	7.5	9.6	10.0	11.0	6.0	3.3
30	–	–	1.2	2.6	4.0	3.2	6.0	8.7	8.2	9.2	6.0	3.6
45	–	–	–	–	–	–	–	7.5	7.5	8.0	6.0	3.5
55	–	–	–	–	–	–	–	–	7.2	–	6.0	–

§ Freezing period : From Jan. to Feb. (does not freeze every year).
§ Mixing type : Monomictic.
§ Notes on water mixing and thermocline formation

Mixing dominated by the large inflow volume of the Okanagan River. Strong thermocline between 10-20 m from Jul. to Oct. Free mixed Nov. to Apr. at 1°-4°C (if ice free).

E. LAKE WATER QUALITY

E1 TRANSPARENCY [m]

Station 0500615, 1985

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
–	–	4.7	4.0	3.8	4.0	5.1	5.8	4.8	4.8	5.0	5.0

E2 pH

Station 0500615, 1986 (6)

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	–	–	8.2	8.2	8.4	5.2	8.5	8.5	8.5	8.5	–	–
6	–	–	8.1	8.2	–	–	–	–	–	–	–	–
20	–	–	–	–	–	–	–	8.0	7.8	7.8	–	–
32	–	–	8.1	7.6	8.2	8.0	8.2	7.9	7.8	7.8	–	–

E4 DO [mg l^{-1}]

Station 0500615, 1985 (6)

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.5	–	–	13.8	15.0	12.2	10.0	10.2	9.8	10.0	10.0	12.0	13.2
5.0	–	–	14.8	15.0	15.0	9.7	9.7	9.7	9.8	10.0	12.0	13.1
10	–	–	15.0	15.0	14.0	10.4	9.8	8.7	9.7	10.2	12.0	13.0
15	–	–	14.7	14.5	13.5	11.2	9.6	8.6	8.1	10.1	12.0	12.7
20	–	–	14.3	13.5	13.3	11.9	10.0	9.0	7.3	9.8	12.0	12.6
30	–	–	12.5	13.8	13.2	11.7	10.2	9.7	8.5	6.6	12.0	12.4
45	–	–	–	–	12.8	10.8	10.2	8.2	7.0	5.8	12.0	11.7
50	–	–	–	–	–	–	–	6.8	5.3	5.1	12.0	–

E6 CHLOROPHYLL CONCENTRATION [μg l^{-1}]

Station 0500615, 1986 (6)

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0-10 (mean)	–	–	9.3	5.9	3.7	1.7	1.4	1.7	1.8	–	–	–

E7 NITROGEN CONCENTRATION

§ Kjeldahl N + NO_3-N [mg l^{-1}] (6)

Station 0500615, 1986

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0-10 composite	–	–	.320	.230	.230	.230	.210	.230	.220	–	–	–
20-45 composite	–	–	.300	.240	–	–	–	–	–	–	–	–
20	–	–	–	–	.230	.200	.240	.230	.320	–	–	–
32	–	–	–	–	.270	.260	.250	.260	–	–	–	–
45	–	–	–	–	.240	.300	.370	.310	–	–	–	–

E8 PHOSPHORUS CONCENTRATION

§ Total-P [$\mu g\ l^{-1}$] (6)
Station 0500615, 1986

Depth [m]	Jan	Feb*	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0-10 composite	—	—	16	16	15	20	8	11	8	—	—	—
20-45 composite	—	—	15	16	—	—	—	—	—	—	—	—
20	—	—	—	—	17	12	6	10	16	—	—	—
32	—	—	—	—	16	14	11	14	—	—	—	—
45	—	—	—	—	20	20	44	27	—	—	—	—

* Overturn (Feb. 1987 : 24 $\mu g\ l^{-1}$). Spring overturn variable.

F. BIOLOGICAL FEATURES

F1 FLORA

§ Emerged macrophytes
Scirpus sp., *S. lacustris*, *S. americanus*, *Equisetum fluviatile*, *Polygonum amphibium*.

§ Floating macrophytes : *Lemna minor*.

§ Submerged macrophytes
Myriophyllum spicatum (dominant), *M. exalbescens*, *Elodea canadensis*, *Utricularia vulgaris*, *Ceratophyllum demersum*, *Najas flexilis*, *Chara* sp., *Potamogeton pectinatus*, *P. nodosus*, *P. praelongus*, *P. pusillus*, *P. natans*, *P. gramineus*, *P. zosteriformis*, *P. crispus*, *P. perfoliatus*, *P. foliosus*, *P. illinoensis*, *Hippuris vulgaris*, *Heteranthera dubia* (7).

§ Phytoplankton
Fragilaria crotonensis, *Asterionella formosa*, *Anabaena circinalis* (2, 31, 32, 33, 45, 46).

F2 FAUNA

§ Zooplankton
Cyclops bicuspidatus thomaso, *Diaptomus ashlandi*, *Mysis relicta* (2, 31, 32, 33, 45, 46).

§ Benthos : *Chironomus* spp., *Limnodrilus hoffmeisteri*, *Procladius* sp. (2, 29, 50).

§ Fish : Peamouth chub, squawfish*, kokanee* (*important for sport-fishing) (19, 38, 40).

§ Supplementary notes on the biota : Hatchery in operation to supplement kokanee population.

F6 PAST TRENDS

Trend of annual mean epilimnetic (0-10 m) chlorophyll *a* concentration [$\mu g\ l^{-1}$] (6).

1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
4.4	4.5	3.0	6.7	6.7	6.6	3.3	5.3	7.4	—	3.8

F7 NOTES ON THE REMARKABLE CHANGES OF BIOTA IN THE LAKE IN RECENT YEARS

Myriophyllum spicatum was introduced into Skaha Lake in the early 1970's. By the mid-1980's it had become the dominant plant in the lake's littoral zone (6).

G. SOCIO-ECONOMIC CONDITIONS

G1 LAND USE IN THE CATCHMENT AREA (8)

	[km²]	[%]
Natural landscape		
Woody vegetation (forested)	ca. 3,650	60
Agricultural land		
Crop field (horticulture/orchard)	ca. 1,220	20
Settlement area (urbanized)	ca. 1,220	20
Total	6,090	100

§ Types of important forest vegetation : Ponderosa pine (*Pinus ponderosa*)/bunchgrass community (low elevations), Douglas fir (*Pseudotsuga menziesii*) forest (higher elevations).
§ Main kinds of crops and/or cropping systems : Orchards (tree fruits).
§ Levels of fertilizer application on crop fields : Moderate.
§ Supplementary notes
Logging occurs in the upper elevation forests. Substantial tree fruit industry has developed over a larger part of the lower watershed with irrigation from Skaha Lake.

G2 INDUSTRIES IN THE CATCHMENT AREA AND THE LAKE in 1981 (9)

	Main products
Primary industry	
Crop production	Apples

G3 POPULATION IN THE CATCHMENT AREA (1981)

Total population of much larger Similkameen Regional District 57,185. Largest urban settlement, Penticton ; 23,181.

H. LAKE UTILIZATION

H1 LAKE UTILIZATION (10)

Source of water, sightseeing and tourism (no. of visitors in 1980 : total Okanagan 6.28 million ; South Okanagan area 30 % of the total), recreation (swimming, sport-fishing) and fisheries.

H2 THE LAKE AS WATER RESOURCES in 1985 (10)

		Use rate [$m^3 day^{-1}$]	[$m^3 yr^{-1}$]
Domestic	Private intake	875	
	Waterwork	3,241	
Irrigation			5.3×10^6
Industrial		9	

I. DETERIORATION OF LAKE ENVIRONMENTS AND HAZARDS

I1 ENHANCED SILTATION

§ Extent of damage : Not serious.

I2 TOXIC CONTAMINATION

§ Present status : No information.

I3 EUTROPHICATION

§ Nuisance caused by eutrophication :

Unusual algal bloom (*Lyngbya* and *Anabaena*) and aesthetic damage to recreational use (Q).

§ Total phosphorus loadings to the lake [t yr^{-1}] (1980) (11)

Sources	Industrial + Domestic (sewage plant + septic tanks)	Agricultural	Natural	Total
T-P	2.4+1.8	0.4	7.5	12.7

§ Supplementary notes

Increasing volume of discharge from Penticton sewage treatment plant in late 1960's was responsible for public concerns and complaints about deterioration of water quality (cyanobacteria blooms) in Skaha Lake. The sewage treatment plant was upgraded to incorporate tertiary treatment in 1971. The lake responded to the reduction in loading and then lake concentrations rose in the late 1970's and early 1980's. The significant effect of inter-annual variation in hydrology and increase in non-point loading appear to be major influences. Environmental standard for Total-P : 15 $\mu g\ l^{-1}$ (spring overturn). (cf. 2, 10, 12, 13, 28, 31, 33-36, 38, 39, 43, 47, 49).

I4 ACIDIFICATION

§ Extent of damage : None.

J. WASTEWATER TREATMENTS

J1 GENERATION OF POLLUTANTS IN THE CATCHMENT AREA : (d) Measurable pollution with limited wastewater treatment.

J3 SANITARY FACILITIES AND SEWARAGE

§ Municipal wastewater treatment systems

No. of tertiary treatment systems : 1.

M. LEGISLATIVE AND INSTITUTIONAL MEASURES FOR UPGRADING LAKE ENVIRONMENTS

M1 NATIONAL AND LOCAL LAWS CONCERNED

Names of the laws (the year of legislation)

(1) British Columbia Waste Management Act (1979)
(2) British Columbia Waste Management Act (1982)
(3) British Columbia Environment Management Act
(4) Federal Fisheries Act

Responsible authorities

(1) Government of British Columbia, Ministry of Environment
(2) Government of British Columbia, Ministry of Environment
(3) Government of British Columbia, Ministry of Environment
(4) Government of British Columbia in cooperation with the Government of Canada

§ Main items of control

(1) Discharge of water to land, air and water
(2) Licensing of consumptive and non-consumptive water use
(3) Prevention of detrimental environmental impacts
(4) Management and protection of fisheries

M2 INSTITUTIONAL MEASURES

(1) Okanagan Basin Study (Canada-British Columbia Okanagan Basin Agreement) 1969-1974 (2, 13, 14-27)
(2) Okanagan Basin U. C. Implementation Study — Joint Agreement between Canada and British Columbia, 1976-1982 (11, 30-32, 44)

(3) Okanagan Basin Water Quality Control Program, British Columbia Ministry of Environment, Penticton, B. C., 1986-1989 (49)

M3 RESEARCH INSTITUTES ENGAGED IN THE LAKE ENVIRONMENT STUDIES

(1) National Water Research Institute (NWRI), Pacific & Yukon, West Vancouver
(2) British Columbia Ministry of Environment, Okanagan Sub-regional Office, Penticton, B. C.
(3) British Columbia Ministry of Environment, Fisheries Research
(4) University of British Columbia, Vancouver

N. SOURCES OF DATA

(Q) Questionnaire filled by Dr. R. N. Nordon, Supervisor, Limnological Studies, B. C. Ministry of the Environment, Victoria, British Columbia.
(1) National Topographic Series Maps, 1/50,000 Map, Sheet 82E5.
(2) Pinsent, M. E. & Stockner, J. G. (ed.) (1974) Limnology of the Major Lakes of Okanagan Basin. Tech. Suppl. V, Canada-British Columbia Okanagan Basin Agreement.
(3) Historical Streamflow Summary. 606 pp. British Columbia Inland Waters Directorate, Water Survey of Canada, Ottawa, 1983. Station 08NM050.
(4) Climatic Normals 1941-1970, Climate of British Columbia. British Columbia Department of Agriculture.
(5) Canadian Climate Normals 1951-1980, British Columbia. Environment Canada.
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(9) Census of Canada (1981) Population Series, British Columbia, 93-910, Table 4.
(10) Water Management Branch, Waste Management Branch (1985) Phosphorus in the Okanagan Valley Lakes : Sources, Water Quality Objectives and Control Possibilities.
(11) Alexander, D. G. (1982) Summary of Nitrogen and Phosphorus Loadings to the Okanagan Main Valley Lakes from Cultural and Natural Sources. Working Report, Okanagan Basin Implementation Agreement. 22 pp. Penticton, B. C.
(12) Nordin, R. N. (1983) Changes in water quality of Skaha Lake, B. C., following reduction in phosphorus loading. "Lake Resotration, Protection and Management (EPA 440/5-83-001)", pp. 166-170. U. S. Environmental Protection Agency, Washington, D. C.
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The following (14)~(27) are manuscript reports prepared as part of the Canada-British Columbia Okanagan Basin Agreement Study which were used extensively in the preparation of (2).
(14) Blanton, J. O. (1972) Relationships between heat content and thermal structure in the mainstem lakes of the Okanagan Valley, British Columbia. 17 pp.
(15) Blanton, J. O. & Ng, H. Y. F. (1971) Okanagan Basin studies ; data report on the fall survey 1970. 125 pp.
(16) —— & —— (1972) The physical limnology of the mainstem lakes in the Okanagan Basin. 2 volumes, 34 pp. + 24 figures + 2 appendices.
(17) —— & —— (1972) The circulation of the effluent from the Okanagan River as it enters Skaha Lake. 23 pp.
(18) Lerman, A. (1972) Chemical limnology of the major lakes in the Okanagan Basin : nutrient budgets at present and in the future. 41 pp.
(19) Northcote, T. G., Halsey, T. G. & MacDonald, S. J. (1972) Fish as indicators of water quality in the Okanagan Basin lakes, British Columbia. 80 pp.
(20) Patalas, K. & Salki, A. (1973) Crustacean plankton and the eutrophication of lakes in the

Okanagan Valley, British Columbia. 34 pp.
(21) Saether, O. A. & McLean, M. P. (1972) A survey of the bottom fauna in Wood, Kalamalka and Skaha Lakes in the Okanagan Valley, British Columbia. 20 pp.
(22) St. John, B. E. (1972) The limnology of the Okanagan mainstem lakes. 46 pp.
(23) Stockner, J. G. (1971) Preliminary evaluation ; water quality. 4 pp. (1972) Diatom succession in the recent sediments of Skaha Lakes, British Columbia. 17 pp. (1972) Nutrient loadings and lakes management alternatives. 13 pp.
(24) ——, Pomeroy, M., Carney W. & Findlay, D. L. (1972) Studies of periphyton in lakes of the Okanagan Valley, British Columbia. 19 pp.
(25) ——, Carney, W. & McKenzie, G. (1972) Task 122 : phytobenthos, littoral mapping supplement. 10 pp. + 16 plates.
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(31) Truscot, S. J. & Kelso, B. W. (1979) Trophic Changes in Lakes Okanagan, Skaha and Osoyoos, B. C., Following Implementation of Tertiary Municipal Waste Treatment. Department of Environment, Environmental Protection Service, Pacific Region.
(32) Jensen, E. V. (1981) Results of the Continuing Water Quality Monitoring Program on Okanagan Lakes for Years 1979 to 1980. 73 pp. Waste Management Branch, British Columbia Ministry of Environment, Pentiction, B. C.
(33) Stein, J. R. & Coulthard, T. L. (1971) A Report on the Okanagan Water Investigation. University of British Columbia. Prepared for Water Investigation Branch, British Columbia Water Resources Service.
(34) Fleming, W. M. (1975) A model of the phosphorus cycle and phytoplankton growth in Skaha Lake, B. C. Verh. Int. Ver. Limnol., 19 : 229-240.
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(37) Ferguson, R. G. (1949) The Interrelations among the Fish Populations of Skaha Lake, B. C., and Their Significance in the Production of Kamloops Trout (*Salmo gardneri kamloops* Jordan). 84 pp. University of British Columbia, Vancouver.
(38) British Columbia Research (1971) Sampling of the Okanagan Lakes — Spring 1970. Prepared for the Department of Lands, Forests and Water Resources, Victoria, B. C. Project No. 1268 PHZ. 9 pp. + Tables and Figures.
(39) Nordin, R. N. (1978) An Inexpensive *in situ* Algal Bioassay Procedure with Some Preliminary Results Bearing on Nutrient Limitations in Skaha Lake. 25 pp. Water Investigations Branch, British Columbia Ministry of Environment.
(40) Parkinson, E. A. (1986) Skaha Hatchery Evaluation. Fisheries Management Report No. 87. 17 pp. Fisheries Branch, British Columbia Ministry of Environment.
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(44) Deimert, D. D. & Kelso, B. W. (1980) Algal Analysis of Okanagan Area Lakes in 1979. Report prepared for the Canada-British Columbia Okanagan Basin Implementation Agreement. 14 pp. Environmental Protection Service, Environment Canada, Vancouver.
(45) Findley, D. L., Findley, D. I. & Stein, J. R. (1973) Surface nitrogen and plankton in Skaha Lake, B. C., Canada. Freshw. Biol., 3 : 111-122.
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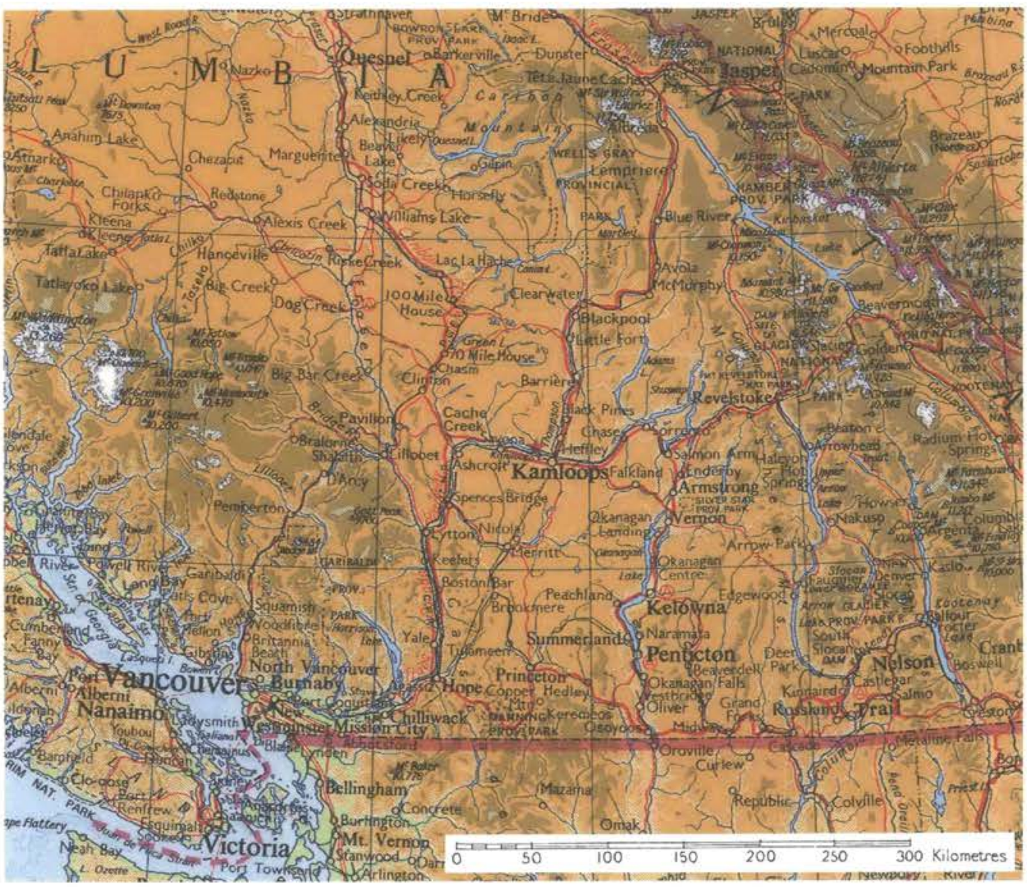
KAMLOOPS LAKE

A view from the lakeside hill

Photo: D.W. Holmes



A. LOCATION

§ British Columbia, Canada.
§ 50°42'-26'N, 120°32'-03'W ; 336 m above sea level.

B. DESCRIPTION

Kamloops Lake is located in the dry interior of British Columbia adjacent to the City of Kamloops.

The lake is bounded on all sides by steep embankments with level areas only near creek deltas and at the inlet and outlet. The surrounding land is mostly uninhabited and within the dry belt interior grasslands composed of bunchgrass and sagebrush with pockets of Douglas fir, Ponderosa pine and spruce.

The lake appears to be a widening and deepening of the Thompson River which enters at the east end and exits at the west end. The limnology of the lake is controlled by the Thompson River which has large fluctuations in annual flow with over 60 % occurring in the early summer during freshet (May-Jul.). Bulk residence times are very short, ranging from 20 days to 340 days with a mean of 60 days.

The Weyerhaeuser Pulp Mill discharges daily an average of 182,000 m^3 of biologically treated effluent to the Thompson River just upstream of the lake. The City of Kamloops periodically (Oct. & Nov.) discharges up to 35,000 m^3 day^{-1} of tertiary treated domestic effluent. Major water quality problems which became evident in the Thompson River downstream of the lake in the early 1970's were attributed to the discharges. Improvements in water quality have occurred through improved treatment of the effluents.

C. PHYSICAL DIMENSIONS

Surface area [km^2]	52.1
Volume [$10^9 m^3$]	3.7
Maximum depth [m]	143
Mean depth [m]	71
Normal range of annual of water level fluctuation (unregulated) [m]	5
Length of shoreline [km]	60.5
Residence time [yr]	ca. 0.17 (20-340 days)
Catchment area [km^2]	39,050

D. PHYSIOGRAPHIC FEATURES

D1 GEOGRAPHICAL

§ Sketch map (Fig. NAM-54-1).
§ Bathymetric map (Fig. NAM-54-2).
§ Main islands : None.
§ Outflowing rivers and channels (number and names) : 1 (Thompson R.).

D2 CLIMATIC

§ Climatic data at Kamloops Airport, 1951-present

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean temp. [°C]	-6.1	-1.3	3.5	9.1	14.1	18.0	20.8	19.8	14.9	8.4	1.6	-2.8	8.3
Precipitation [mm]	32	16	10	10	18	30	23	28	21	15	22	32	257

§ Number of hours of bright sunshine : 2,000 hr yr^{-1}.
§ Average solar radiation : 12.5 MJ $m^{-2}day^{-1}$.

Fig. NAM-54-1 Sketch map of the lake (Q).

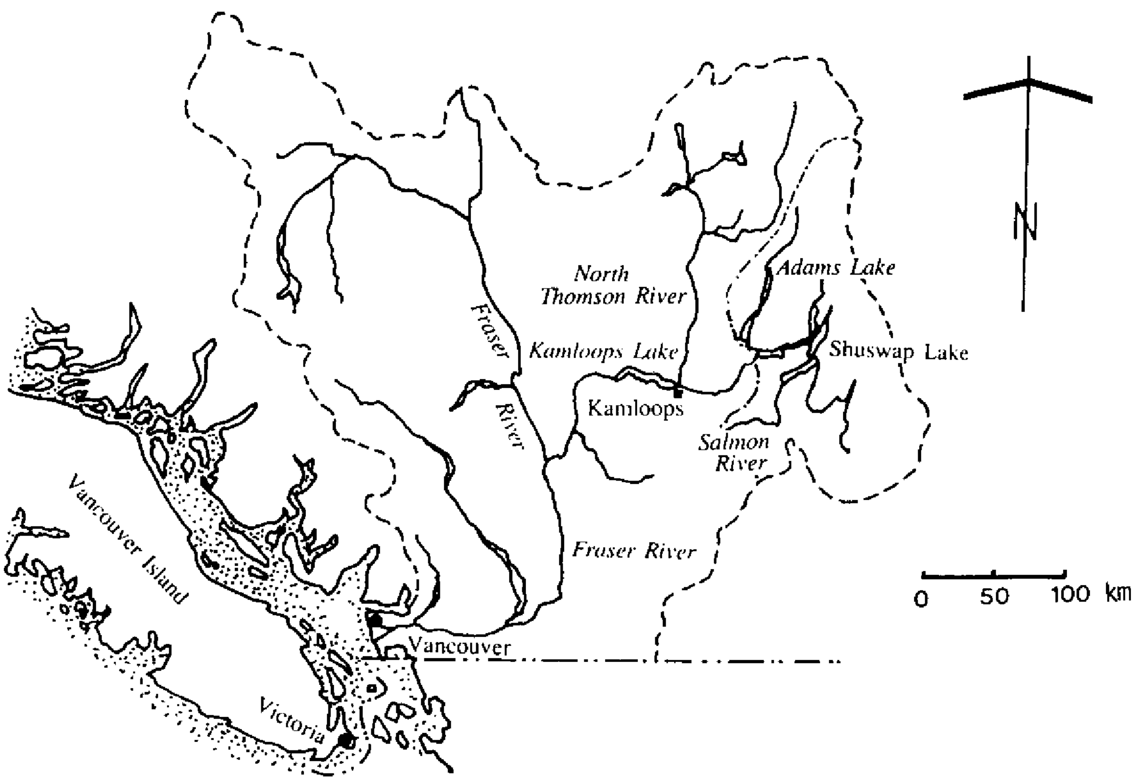
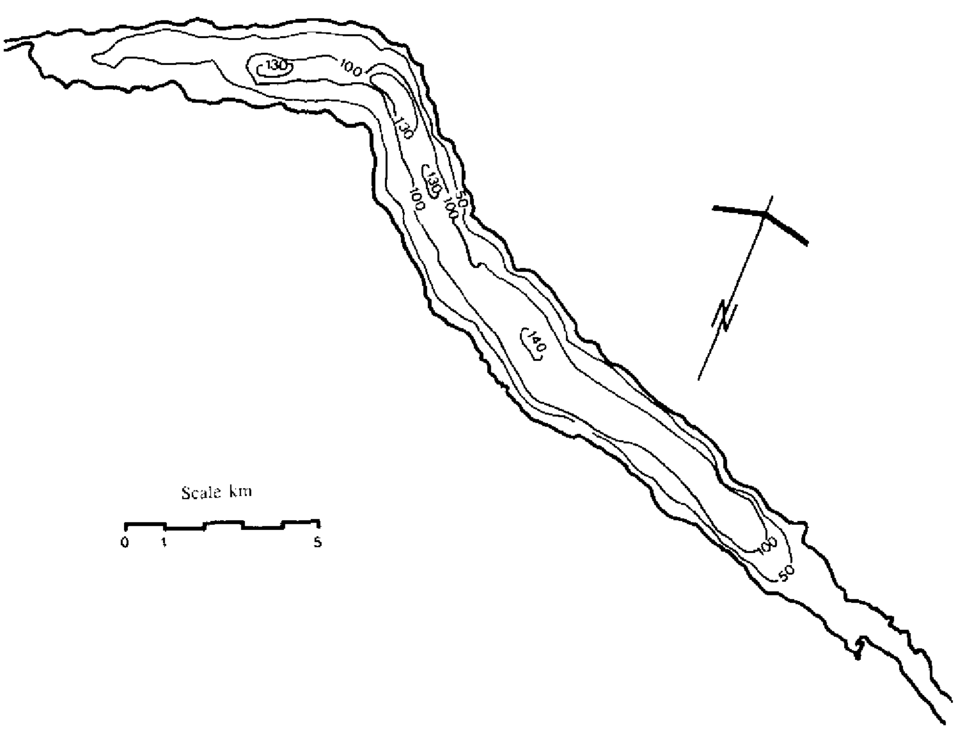
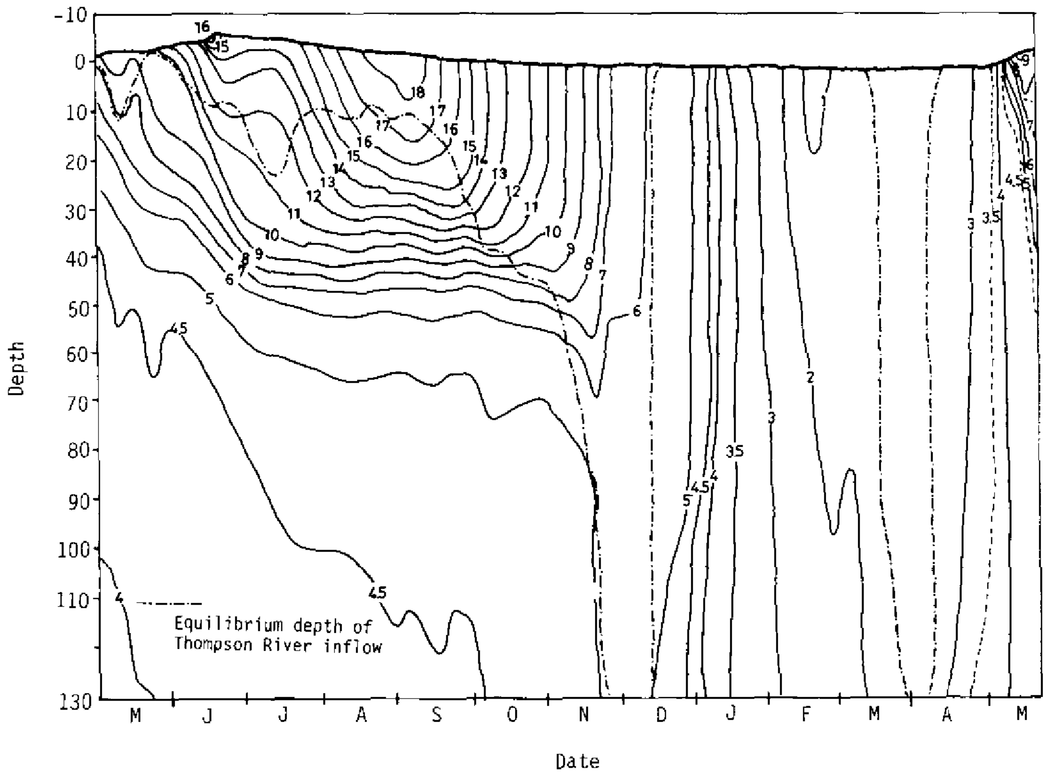


Fig. NAM-54-2 Bathymetric map [m] (Q).



§ Water temperature [°C]

Fig. NAM-54-3 Time-depth isotherm, May 1974-May 1975 (1).



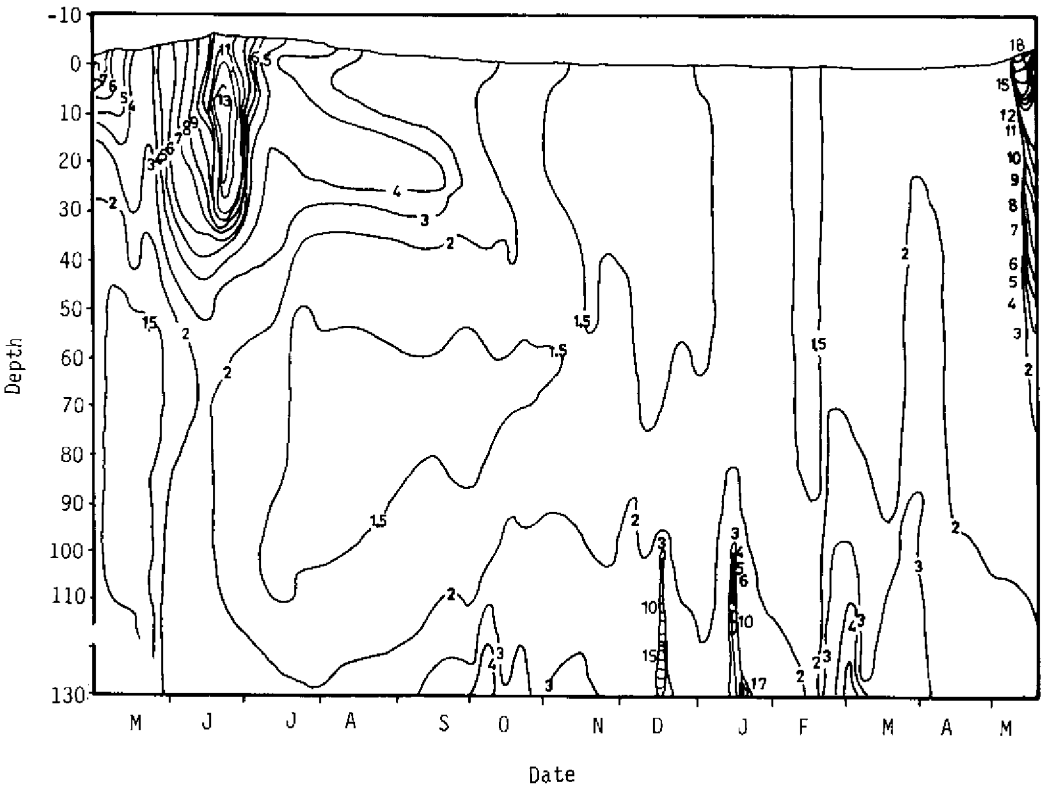
§ Freezing period : Seldom freezes over, occasional freezing in small areas in Dec. and Jan.
§ Mixing type : Dimictic.
§ Supplementary notes on water mixing and thermocline formation

Water mixing and thermocline formation are dominated by the Thompson River which has a mean annual inflow of 720 m^3 sec^{-1}. Over 60 % of the discharge comes in the early spring freshet with peak flows near 3,400 m^3 sec^{-1} in June and minimum flows of 120 m^3 sec^{-1} in February. As a result of the large and variable discharge, bulk residence times are very short (20-340 days). Throughout summer (June-October), the inflowing, highly turbid Thompson River water remains cooler than the lake surface water, thus interflowing through the epilimnion at depths of 10-30 m. Turbulence induced by this interflow effectively mix the intermediate region of the epilimnion. Only in late summer, with declining river flows and deep convective mixing of the surface waters, does the lake establish a classical two-layer thermal structure. Throughout summer, the outflow river remains warmer and less turbid than the inflow. Direct stratification slowly breaks down through November and December until complete convective overturn results. During this period, inflowing river water either sinks to the bottom, or is confined to the eastern end of the lake. Hence the outflow is derived entirely from surface lake water remaining from the summer. The lake during winter (January-March) is characterized by weak, reverse temperature stratification and low turbidity ; the inflowing river waters are less dense than the ambient lake water and, therefore, tend to remain at the surface. In spring (April-May), convective overturn again occurs, followed by direct thermal stratification. As with the autumn overturn, the spring mixing processes act to retain all the new inflow water within the lake. Thus, the outflow waters consist of surface lake water reflecting winter conditions.

E. LAKE WATER QUALITY

E1 TURBIDITY

Fig. NAM-54-4 Time-depth isopleth of turbidity, 1974-1975 (1).



E2 pH

Station G2, Mar. 1974-Feb. 1975 (1)

Depth* [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	7.6	7.6	7.5	7.6	7.8	7.6	7.7	7.7	7.7	7.5	7.8	7.6
	7.6	7.6	7.5	7.7	7.7	7.6	7.7	7.7	7.6	7.5	7.8	7.6
	7.6	7.6	7.6	7.5	7.7	7.5	7.7	7.6	7.4	7.5	7.8	7.6
	7.6	7.6	7.5	7.4	7.7	7.5	–	7.6	7.6	7.4	7.8	7.5
	7.5	7.5	7.5	7.4	7.7	–	–	–	7.4	7.3	7.9	7.6

* Depths vary with month ; see the table below.

Depths [m] at which observations were made in each month for the above and the following tables

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	1	1	1	1	1	1	1	1	1	1	1
20	15	28	23	10	20	10	14	24	30	25	30
50	40	35	45	20	40	20	40	40	40	50	70
90	90	60	60	25	70	70	70	70	70	80	100
117	115	144	130	128	135	121	125	120	118	120	120

E4 DO [mg l^{-1}]

Station G2, Mar. 1974-Feb. 1975 (1)

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	11.0	–	12.2	11.6	10.5	10.7	9.9	9.6	9.5	9.7	10.2	12.1
	11.4	–	12.1	–	10.5	10.4	9.8	8.9	9.2	9.6	10.3	12.1
(Cf. E2)	11.4	–	12.2	11.7	10.6	–	10.0	9.6	9.8	9.8	10.2	12.3
	11.3	–	12.1	12.2	10.5	11.4	10.8	11.2	10.7	10.3	10.0	12.2
	11.2	–	12.0	11.4	10.6	–	–	–	9.1	9.1	9.8	12.3

E6 CHLOROPHYLL CONCENTRATION

Chlorophyll *a* [$\mu g\ l^{-1}$] : Mean 2.9 ; max. (Sep.) 5.4 (5).

E7 NITROGEN CONCENTRATION

§ Total-N [$\mu g\ l^{-1}$] (1)

Station G2, Mar. 1974-Feb. 1975

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	230	206	201	175	215	246	193	158	143	153	156	200
	217	210	150	181	219	223	149	152	125	187	129	175
(Cf. E2)	191	221	156	163	216	262	178	187	122	208	147	179
	193	236	147	169	267	257	–	222	114	244	201	186
	114	217	158	188	230	–	–	–	144	320	232	207

§ Supplementary notes

NO_3-N+NO_2-N varied from 120 $\mu g\ l^{-1}$ (spring) to 20 $\mu g\ l^{-1}$ (late summer minimum). Ammonia was usually below 10 $\mu g\ l^{-1}$ (Q).

E8 PHOSPHORUS CONCENTRATION

§ Total-P [$\mu g\ l^{-1}$] (1)

Station G2, Mar. 1974-Feb. 1975

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	7	14	7	10	12	20	13	9	9	6	4	9
	8	10	8	9	16	25	16	23	20	6	4	6
(Cf. E2)	10	10	9	9	11	22	12	7	7	6	5	10
	2	10	6	8	9	9	14	4	7	5	4	4
	8	13	22	13	43	—	—	—	6	5	4	5

§ Supplementary notes

Dissolved-P ranged from 6 $\mu g\ l^{-1}$ in spring to a maximum of 10 $\mu g\ l^{-1}$ associated with the river plume in June, and declined to 4 $\mu g\ l^{-1}$ in late summer.

Fig. NAM-54-5 Annual nitrogen budget, 1974-1975 (Q).

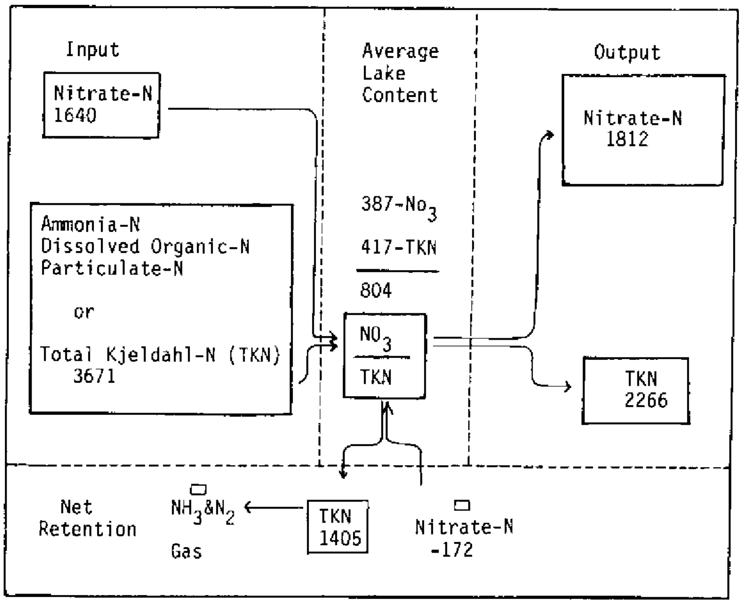
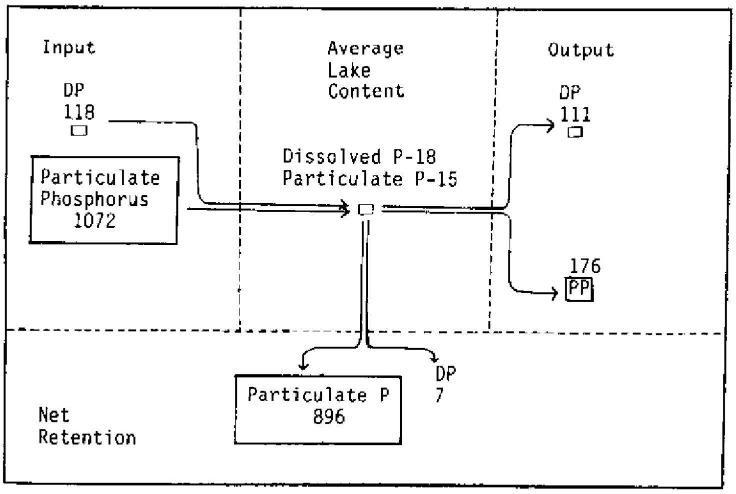


Fig. NAM-54-6 Annual phosphorus budget, 1974-1975 (Q).



F. BIOLOGICAL FEATURES

F1 FLORA

§ Emerged macrophytes : *Equisetum* sp. (4).

§ Submerged macrophytes (4)

Potamogeton pectinatus, *P. pusillus*, *P. perfoliatus*, *P. gramineus*, *Najas flexilis*, *Ranunculus aquatilis*, *Chara* sp., *Callitriche* sp., *Elodea canadensis*, *Marsilea vesta* (list not complete)

§ Phytoplankton (5)

Bacillariophyceae (*Tabellaria*, *Stephanodiscus*, *Fragilaria*, *Nitzschia*, *Asterionella*, *Stauroneis*, *Cymbella*, *Disploneis*, *Melosira*, *Mastogloia*, *Achnanthes*, *Amphipleura*, *Navicula*, *Cocconeis*, *Synedra*, *Surirella*, *Cyclotella*, *Diatoma*, *Gomphonema*, *Neidium*, *Hannaea*, *Pinnularia*) ; Chrysophyceae (*Dinobryon*, *Ceratium*) ; Chlorophyceae (*Crucigenia*, *Onychonema*) ; Cyanophyceae (*Borzia*) ; Dinophyceae.

F2 FAUNA

§ Zooplankton (5)

Copepoda (*Diaptomus ashlandi*, *Cyclops bicuspidatus thomasi*, *Epishura nevadensis*) ; Cladocera (*Daphnia longispina*, *Bosmina longirostris*, *Leptodora kindtii*, *Holopedium gibberum*) ; Rotifera (*Kellicottia longispina*, *Keratella* sp., *Notholca* sp., *Asplancha* sp.).

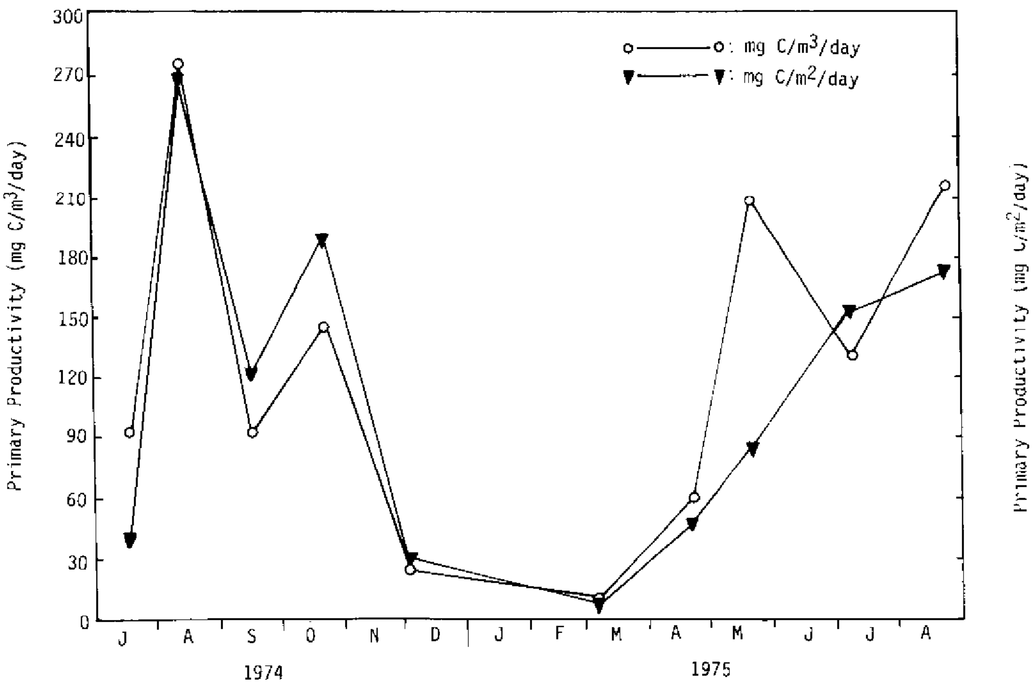
§ Fish (6)

Salmo gairdneri, *Salvelinus malmo*, *Lota lota*, *Cottus asper*, *Prosopium williamsonii*, *Ptychocheilus oregonenois*, *Mylocheilus caurinum*, *Catostomus macrochelilus*, *C. catostomus*, *Richardsonius balteatus*, *Acipenser transmontanus*, *Oncorhynchus tshawytscha*, *O. nerka* (kokanee & sockeye), *O. kisutch*.

F3 PRIMARY PRODUCTION RATE (1)

Station G2 : 88 [mg C $m^{-2}day^{-1}$].

Fig. NAM-54-7 Phytoplankton primary productivity on an areal and volumetric basis, 1974-1975 (Q).



F4 BIOMASS (5)

§ Zooplankton

Range : 4,500–21,000 [no. m^{-3}].

G. SOCIO-ECONOMIC CONDITIONS

G1 LAND USE IN THE CATCHMENT AREA (1988) (7)

	Area [km^2]	[%]
Natural landscape		
Woody vegetation	ca. 35,930	92.0
Herbaceous vegetation	ca. 1,170	3.0
Swamp		±
Others	ca. 195	0.5
Agricultural land		
Crop field	ca. 390	1.0
Pasture land	ca. 780	2.0
Settlement area	ca. 390	1.0
Others	ca. 195	0.5
Total	39,050	100.0

§ Types of important forest vegetation : Ponderosa pine, interior Douglas fir, trembling aspen, white birch, cottonwood, alder, lodgepole pine, Engelmann spruce, subalpine fir, interior western hemlock, red cedar.

§ Types of important herbaceous vegetation : Bunchgrass/bluegrass/fescues, pinegrass, alpine tundra vegetation.

§ Main kinds of crops and/or cropping systems : Alfalfa, hay grasses, corn (silage & truck garden), local commercial vegetables and tree fruits.

§ Levels of fertilizer application on crop fields : Moderate.

§ Trends of change in land use in recent years : Land clearing for pasture and hay crops ; highway and railway construction and upgrading ; extensive forestry cropping ; and residential urban development in Kamloops.

G2 INDUSTRIES IN THE CATCHMENT AREA AND THE LAKE (1988) (8)

	Gross product per year (=US$ 1.00)	No. of persons engaged	No. of establishments	Main products or major industries
Primary industry				
Crop production	$18.1 million	N. A.	N. A.	
Ranching	N. A.	N. A.	370	Cattle
Forestry	N. A.	337	N. A.	Lumber/pulp
Mining	N. A.	N. A.	N. A.	Copper

§ Numbers of domestic animals in the catchment area : Cattle 42,100, sheep 1,200, swine N. A., poultry N. A.

G3 POPULATION IN THE CATCHMENT AREA (8)

	Population	Population density [km^{-2}]	Main cities (population)
Urban	61,773	200	Kamloops (65,000)
Rural	17,727		
Total	79,500	2.04	

H. LAKE UTILIZATION

H1 LAKE UTILIZATION

Source of water, recreation (swimming, sport-fishing) and fisheries.

H2 THE LAKE AS WATER RESOURCE (1988) (9)

Type	Use rate [IGD]
Domestic water	403,000
Irrigation	1,710 ac. ft.
Industrial water	3,989,500

I. DETERIORATION OF LAKE ENVIRONMENTS AND HAZARDS

I1 ENHANCED SILTATION

§ Extent of damage : Not serious.

§ Supplementary notes

Increases in cultural activities (logging, land clearing, etc.) in the last decade have increased silt loading to the watershed especially during spring run-off.

I2 TOXIC CONTAMINATION

§ Present status : Detected but not serious.

§ Supplementary notes

Low levels of dioxins and furans have been detected in drinking water and popular sport fish (dolly varden, trout and salmon) in the lower Thompson River. Elevated levels were found in coarse fish such as suckers, squawfish and whitefish. Residents were cautioned to restrict their intake of the coarse species.

I3 EUTROPHICATION

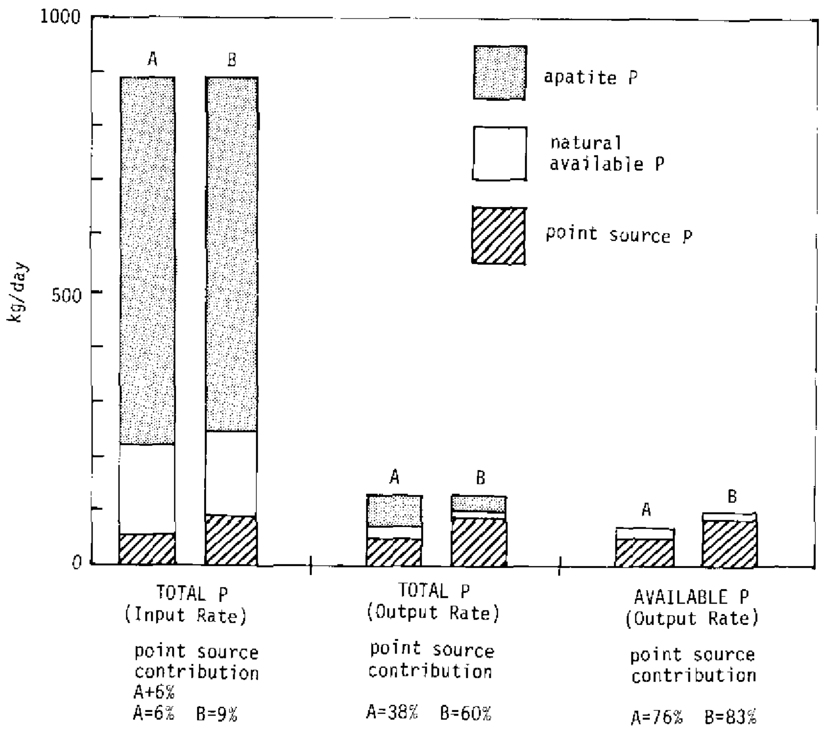
§ Nuisance caused by eutrophication : Taste and odour detected in fish (problems associated with pulp mills) (10).

§ Nitrogen and phosphorus loadings to the lake

May 1974-Apr. 1975

	[$Mg\ yr^{-1}$]	[$g\ m^{-2}yr^{-1}$]
T-P	900 ± 250	17 ± 4
T-N	$5,300 \pm 1,300$	100 ± 25

Fig. NAM-54-8 Comparison of natural and point-source P inputs to Kamloops Lake, Jan. 1–Mar. 31, 1975. A : a minimum calculation based on a 10 % particulate P content in pulp mill effluent. B : a maximum calculation based on 90 % particulate P content in pulp mill effluent (Q).



§ Supplementary notes

Increases in benthic algae downstream of the lake were observed in the late fall and winter in the 1970's, but it is not known whether this was due to increased biologically available P loadings to the upstream lake or to changes in grazing invertebrate populations which may have been affected by other factors such as mortality or migration due to toxic effluents introduced upstream.

Although the nutrient loading to Kamloops Lake is immense, the biological response to these loadings does not produce the expected eutrophic condition. The reason for this is threefold.

1) The high turbidity and deep mixing in a relatively thick epilimnion suppresses net photosynthesis.

2) The actual bio-availability of Total-P loading is very low because it is mostly in the inert mineral apatite (12).

3) Most of the algal biomass produced is exported down the outlet river, so little accumulation of these products occurs in the hypolimnion where they could affect nutrient regeneration and oxygen consumption rates.

Various levels of P control were implemented after the Federal-Provincial Task Force made its report. The pulp mill ceased adding P to their biological oxidation ponds. The municipal sewage treatment plant instigated a strategy of teritary treatment of the effluent and withholding release in large lagoons until the summer "freshet" period in 1977 until the present. Both measures resulted in a decrease of 60 % of the point-source P loading. Continued expansion of pulp mill capacity, however, has brought the point-source P input almost back to former levels. Throughout this period, the benthic algae accumulation downstream of the lake has slowly declined and large benthic invertebrates are becoming more common (14).

I4 ACIDIFICATION

§ Extent of damage: None (Q).

J. WASTEWATER TREATMENTS (11)

J1 GENERATION OF POLLUTANTS IN THE CATCHMENT AREA: (d) Measurable pollution with limited wastewater treatment.

J2 APPROXIMATE PERCENTAGE DISTRIBUTION OF POLLUTANT LOADS (Q)

	Percentage
Non-point sources	60
(agricultural, natural and dispersed settlements)	
Point sources	
Municipal (municipal sewage treatment plant)	20
Industrial (pulp mill)	20
Total	100

J3 SANITARY FACILITIES AND SEWERAGE (Q)

§ Percentage of municipal population in the catchment area provided with adequate sanitary facilities (on-site treatment systems) or public sewerage: 90-100 %.

§ Percentage of rural population with adequate sanitary facilities (on-site treatment systems): 50-75 %.

§ Municipal wastewater treatment systems:

No. of tertiary treatment systems: 2 (one alum addition extended lagoon, one modified Bardenpho mechanical plant).

No. of secondary treatment systems: 6 (small activated sludge package plants with ground disposal).

No. of other types: Numerous individual and communal septic systems.

No. of industrial wastewater treatment systems: 4 (one extended aeration biobasin type for pulpmill, three lagoon treatments types for cooling water).

M. LEGISLATIVE AND INSTITUTIONAL MEASURES FOR UPGRADING LAKE ENVIRONMENTS (Q)

M1 NATIONAL AND LOCAL LAWS CONCERNED

§ Names of the laws (the year of legislation)

(1) British Columbia Waste Management Act (1982)
(2) British Columbia Environmental Management Act (1981)
(3) Canadian Environmental Contaminants Act (1975)
(4) Canadian Fisheries Act
(5) British Columbia Pesticide Control Act (1977)

§ Responsible authorities

(1) British Columbia Waste Management Branch
(2) British Columbia Ministry of Environment
(3) Canadian Environmental Protection Service
(4) Canadian Department of Fisheries
(5) British Columbia Pesticide Control Branch

§ Main items of control

(1) Permitted waste discharges to environment
(2) General waste discharges, accidental spills, etc.
(3) General discharges to environment and permitted discharges
(4) Discharges deleterious to fish
(5) Discharge of pesticides under permit

M2 INSTITUTIONAL MEASURES

(1) British Columbia Ministry of Environment
  (a) Waste Management Branch, Kamloops, B. C. (controls discharges, monitors impact)
  (b) Water Management Branch, Kamloops, B. C. (water quality and quantity studies)
  (c) Freshwater Fisheries Branch, Kamloops, B. C. (fish studies)

(2) Canadian Government
  (a) Environmental Protection Service, Vancouver, B. C. (assess waste impacts)
  (b) Federal Fisheries Branch, Vancouver, B. C. (fish populations, impact studies)
  (c) National Water Hydrology Research Institute, Saskatoon, Sask. (water quality research)

N. SOURCES OF DATA

(Q) Questionnaire filled by Dr. D. W. Holmes, Head, Environmental Section, Waste Management Branch, Ministry of Environment, British Columbia, Canada.

(1) St. John, B. E., Cormack, E. C., Deley, R. J., Gray, C. B. J. & Pharo, C. H. (1976) The limnology of Kamloops Lake, British Columbia. "Sources and Effects of Algal Growth, Colour, Foaming and Fish Tainting in the Thompson River System". Federal-Provincial Thompson River Task Force, Dept. Environment, Vancouver.

(2) Inland Waters Directorate (1987) Surface Water Data, British Columbia. Cat. No. En 36-407/1987. Environment Canada.

(3) Atmospheric Environment Service (1988) Climatic Records for Kamloops Airport — 30 Year Normals. Environment Canada.

(4) Warrington, P. D. (1980) Studies on aquatic macrophytes. "Aquatic Plants of British Columbia", Part 33. Aquatic Studies Branch, B. C. Ministry of Environment.

(5) Kelso, B. W. & G. Derkson, G. (1976) The standing crop of plankton in Kamloops Lake, B. C. from March, 1974 to April, 1975. "Sources and Effects of Algal Growth, Colour, Foaming and Fish Tainting in the Thompson River System". Federal-Provincial Thompson River Task Force, Vancouver.

(6) Fisheries Branch, B. C. Ministry of Environment, Kamloops, B. C. Personal communication.

(7) Habitat Branch, B. C. Ministry of Environment, Kamloops, B. C. Personal communication.

(8) Thompson-Nicola Regional District, Kamloops, B. C.; Columbia-Shuswap Regional District, Salmon Arm, B. C. Personal communication.

(9) Water Management Branch, B. C. Ministry of Environment, Kamloops, B. C. Personal communication.

(10) Kovacs, T. G. & Voss, R. H. (1985) The Effect of Bleached Kraft Effluent on the Aquatic Environment: Fish Flavour Evaluation. Paprican Project No. 6312 and 7170.

(11) Waste Management Branch, B. C. Ministry of Environment, Kamloops, B. C. Personal communication.

(12) Reid, R. P., Pharo, C. H. & Barnes, W. C. (1980) Direct determination of apatite in lake sediments. Can. J. Fish. Aquat. Sci., 37(4), 640-646.

(13) Bothwell, M. L., Jasper, S. & Daley, R. J. (1989) Phosphorus Control of Algal Production and Biomass in the Thompson River, B. C. IWD Scientific Series No. 165.

(14) Bothwell, M. L., National Hydrology Research Center, Saskatoon, Saskatchewan. Personal communication.

BUTTLE LAKE

A northward view from the southwest corner of the South Basin

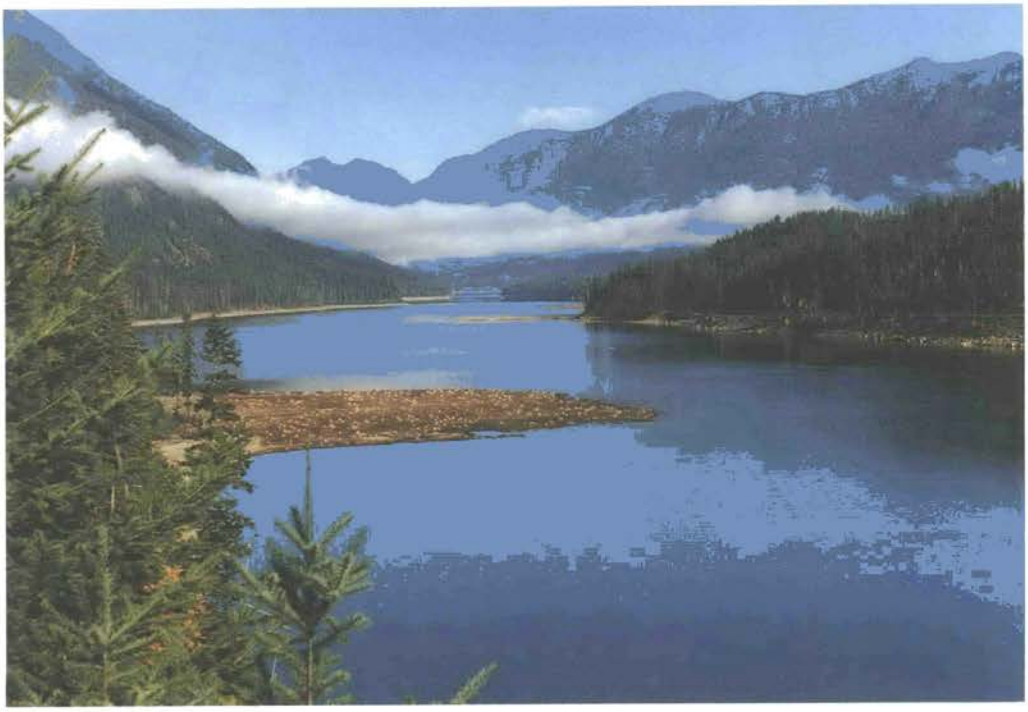
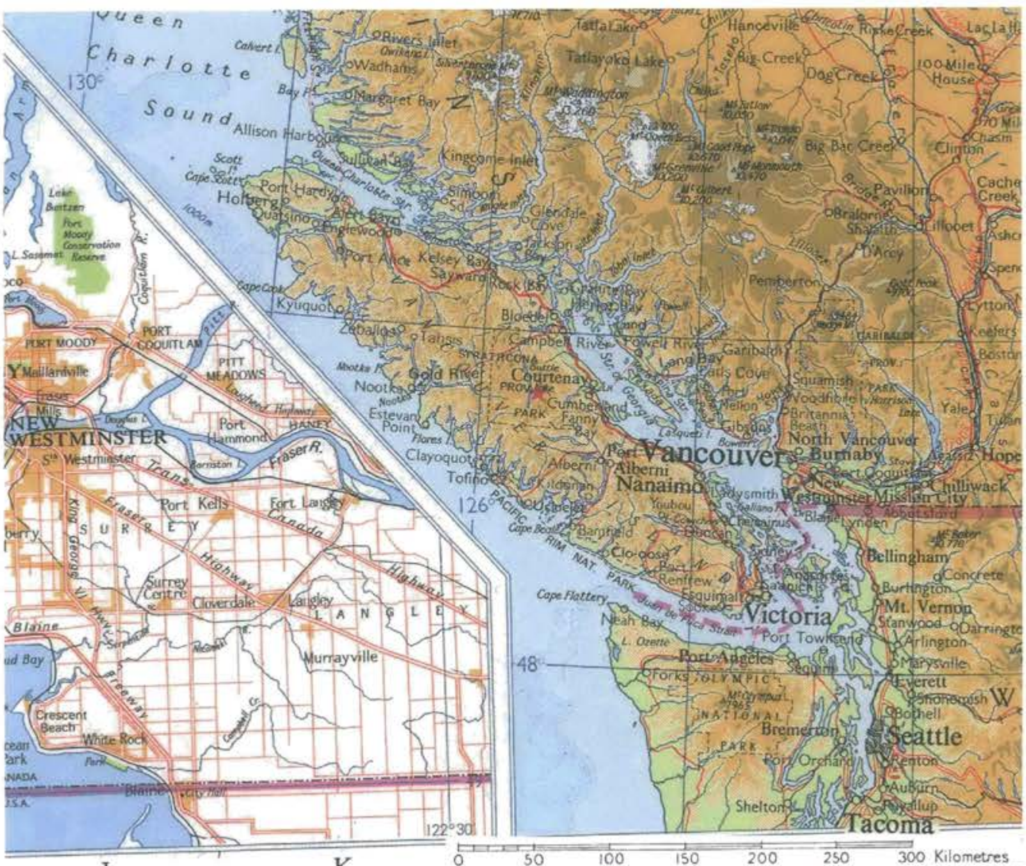


Photo: M.J.R. Clark, P.Lucey, J. Deniseger and L. Erickson



A. LOCATION

§ British Columbia, Canada.
§ 49°31′-50°04′N, 125°31′W ; 218 m above sea level.

B. DESCRIPTION

Buttle Lake lies at the head of the Campbell River system which drains an area of 1,404 km^2 in the central part of Vancouver Island. The drainage basin is located in the Coastal Mountains region of recently glaciated intrusive rocks and has a maritime climate. Buttle Lake lies within the coastal western hemlock zone characterized by Douglas fir, western hemlock and western red cedar.

Buttle Lake has a typical elevation of 218 m and is oriented in a north-south direction. It connects by a narrow passage to Upper Campbell Lake which feeds Lower Campbell Lake and in turn John Hart Lake and the Campbell River which flows to the sea 20 km away.

Buttle Lake is a long narrow lake and sits within a 'U-shaped' valley typical of the region having steep rock walls and a broad flat floor of unconsolidated glacial deposit. Surrounded on both sides by extensive mountain systems, the valley floor consists of many irregular knolls, depressions and long meandering gravel ridges characteristic of recently glaciated areas.

It is an ultra-oligotrophic soft water lake. Since the lake and much of its watershed have been within a provincial park since 1911, the watershed has been largely undisturbed except for forest fires until dam construction in 1958 and mine construction in 1966.

In 1958 the Strathcona Dam (power generation for B. C. Hydro) raised the levels of Upper Campbell and Buttle Lakes by 8.5 m while regulating the water level which now fluctuates some 9.0 m annually. Except during maximum reservoir draw-down, the two lakes usually have a common elevation. Approximately 8 km from its southern end occurs a sill of some 40 m depth which defines a well defined basin somewhat isolated from the remainder of Buttle Lake. In 1966 a copper-lead-zinc mine began operation near the southern end of the lake. Mine tailings from the mill were deposited directly into the south basin till 1984 ; additionally, acid mine generation in the drainage basin had released metals, especially copper, zinc and cadmium, which contaminated the lake via Myra Creek which discharges to the same basin. In 1983 a surface and groundwater collection and treatment system was installed at the mine site and in 1984 an on-land tailings disposal system replaced the lake disposal. These remedial measures have greatly reduced concentration of toxic metals in the lake and biological communities have returned to their former abundance (Q).

C. PHYSICAL DIMENSIONS (3, 22)

Surface area [km^2]	35.3
Volume [$10^6 m^3$]	17.2
Maximum depth [m]	125
Mean depth [m]	48.8
Normal range of annual water level fluctuation [m] (regulated)	9.0
Length of shoreline [km]	75
Residence time [yr]	1.03
Catchment area [km^2]	705

D. PHYSIOGRAPHIC FEATURES

D1 GEOGRAPHICAL

§ Sketch map (Fig. NAM-55-1).
§ Bathymetric map (Fig. NAM-55-2).
§ Main islands : None.
§ Outflowing rivers and channels (number and names) : 1 (Campbell R.).

D2 CLIMATIC DATA

§ Climatic data at Campbell River BCFS*, 30-year average 1951-1980 (4)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean temp. [°C]	1.2	3.4	4.4	7.8	11.7	14.7	17.1	17.0	13.8	9.3	4.7	2.3	9.0
Precipitation [mm]	225	189	163	78	63	60	43	67	82	185	230	271	1,656

* Approximately 32 km to the northeast.

§ Number of hours of bright sunshine at Nanaimo Airport, approximately 112 km to the south : 1,811 hr yr^{-1}.

§ Average solar radiation at Nanaimo Departure Bay : 12.4 MJ $m^{-2}day^{-1}$.

Mean daily global solar radiation [MJ $m^{-2}day^{-1}$]

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2.93	5.85	10.5	15.9	21.0	22.1	23.7	19.5	13.6	7.83	3.74	2.27

Fig. NAM-55-1 Sketch map (Q).

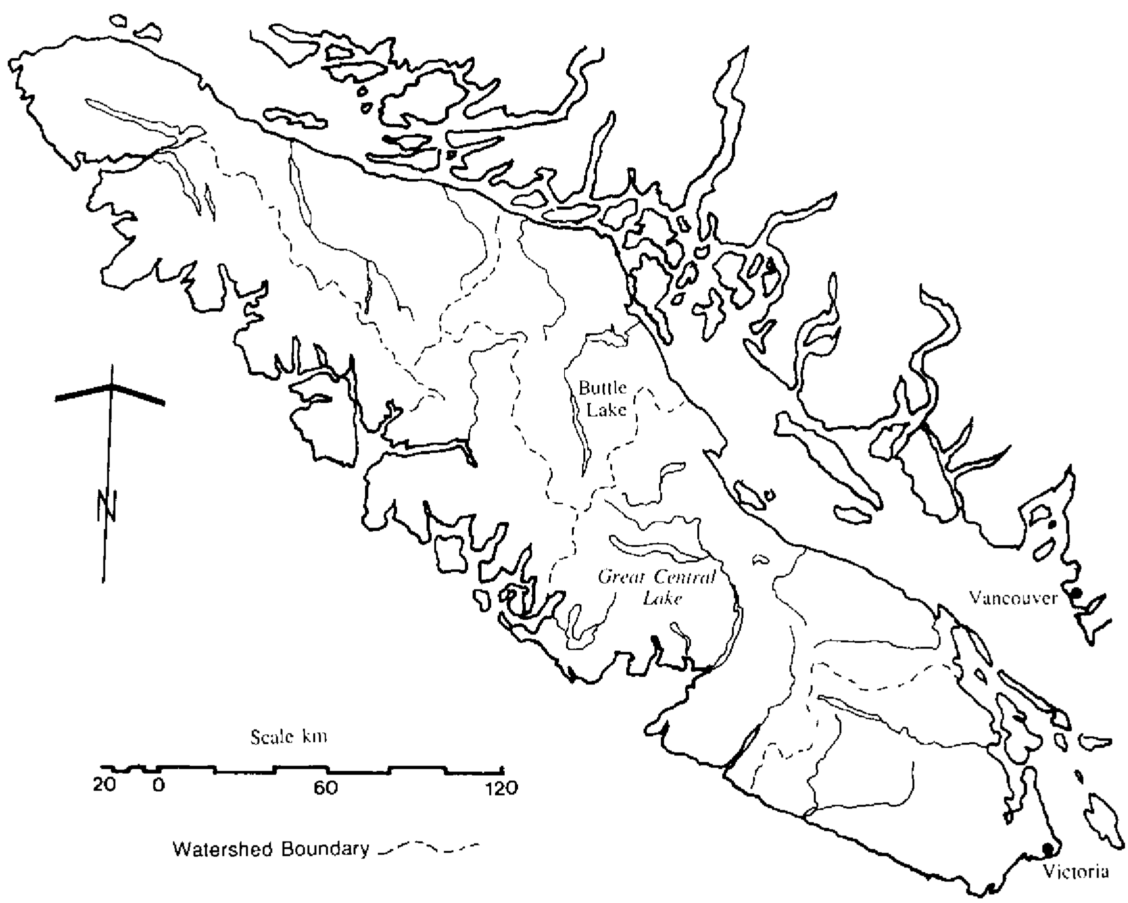
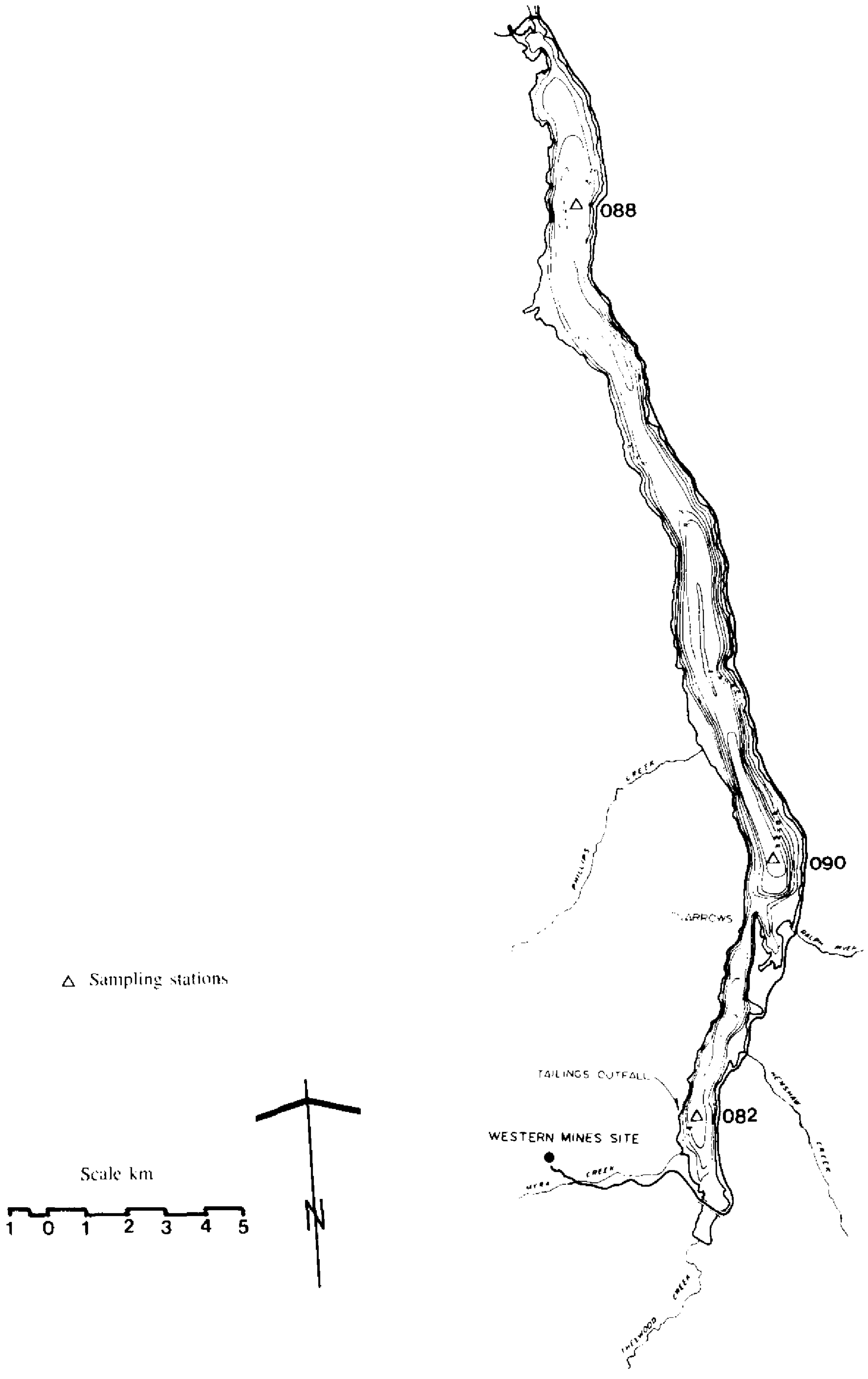


Fig. NAM-55-2 Bathymetric map [m] (3).



§ Water temperature [°C]
South basin, 3 km N of Thelwood Creek, 1985-1986

Depth [m]	1986 Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	1985 Sep	Oct	Nov	Dec
0	–	3.13	3.84	6.52	7.86	13.96	16.02	21.34	16.61	–	–	4.53
5	–	3.36	3.70	6.22	7.85	13.17	14.65	20.81	16.11	–	–	4.55
10	–	3.43	3.64	5.93	7.57	10.74	12.70	18.19	15.7	–	–	4.55
15	–	3.56	3.55	5.49	6.43	8.66	10.77	12.92	12.0	–	–	4.55
20	–	3.72	3.39	4.68	5.97	7.36	7.75	7.88	8.2	–	–	4.55
25	–	3.51	3.31	4.59	5.07	6.56	6.65	7.05	7.3	–	–	4.52
30	–	3.51	3.24	4.37	4.89	6.14	6.40	6.71	7.0	–	–	4.52
35	–	3.49	3.21	4.21	4.76	5.70	6.10	6.43	6.5	–	–	4.52

§ Freezing period : None (lake usually does not freeze over).
§ Mixing type : Monomictic.

E. LAKE WATER QUALITY

Sampling station : 3 km north of Thelwood Creek (082), south basin.

E1 TRANSPARENCY [m] (Q)

1986

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
–	5	5	7	6	6	8	14	–	–	–	–

E2 pH (Q)

Depth [m]	1986 Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	1985 Sep	Oct	Nov	Dec
0	–	7.5	7.1	7.2	7.3	7.0	7.3	7.3	7.3	–	–	7.3
5	–	7.4	7.0	7.2	7.3	7.1	7.3	7.3	7.3	–	–	7.2
10	–	7.4	7.0	7.2	7.3	7.1	7.3	7.2	7.3	–	–	7.1
15	–	7.3	7.0	7.2	7.3	7.1	7.3	7.1	7.2	–	–	7.1
20	–	7.3	7.0	7.1	7.2	7.1	7.1	7.0	7.1	–	–	7.1
25	–	7.3	7.0	7.1	7.2	7.0	7.1	7.0	7.1	–	–	7.1
30	–	7.3	7.0	7.1	7.1	7.0	7.1	6.9	7.0	–	–	7.1
35	–	7.3	7.0	7.1	7.1	7.0	7.1	6.9	7.0	–	–	7.1

E3 SS [mg l^{-1}] (Q)

Depth [m]	1986 Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	1985 Sep	Oct	Nov	Dec
0	–	2	–	1	1	1	<1	<1	<1	<1	–	–
10	–	2	–	1	1	2	<1	<1	1	–	–	–
20	–	2	–	1	1	2	<1	<1	<1	–	–	–
30	–	1	–	1	1	2	<1	<1	<1	–	–	–
40	–	2	–	1	2	2	<1	<1	<1	–	–	–
60	–	2	–	1	1	1	<1	<1	<1	–	–	–

E4 DO [mg l^{-1}] (Q)

Depth [m]	1986 Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	1985 Sep	Oct	Nov	Dec
0	—	9.4	13.2	12.5	12.1	11.1	10.2	9.0	10.1	—	—	11.4
5	—	9.5	13.0	12.5	12.1	11.2	10.1	9.1	9.9	—	—	11.3
10	—	8.9	12.9	12.4	12.1	11.3	10.5	9.2	9.9	—	—	11.3
15	—	8.7	12.8	12.5	12.2	11.6	10.4	10.3	10.8	—	—	11.2
20	—	8.3	12.7	12.5	12.2	12.1	11.5	11.1	11.6	—	—	11.2
25	—	8.4	12.6	12.4	12.1	12.1	11.7	11.3	11.7	—	—	11.2
30	—	8.4	12.4	12.3	12.1	12.0	11.7	11.3	11.7	—	—	11.1
35	—	8.5	12.2	12.2	12.1	11.9	11.6	11.3	11.7	—	—	11.1

E6 CHLOROPHYLL CONCENTRATION [mg l^{-1}] (Q)

Depth [m]	1986 Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	1985 Sep	Oct	Nov	Dec
1.0	—	<0.5	<0.5	0.7	1.0	0.6	<0.5	<0.5	<0.5	0.7	—	—

E7 TOTAL-N CONCENTRATION [mg l^{-1}] (Q)

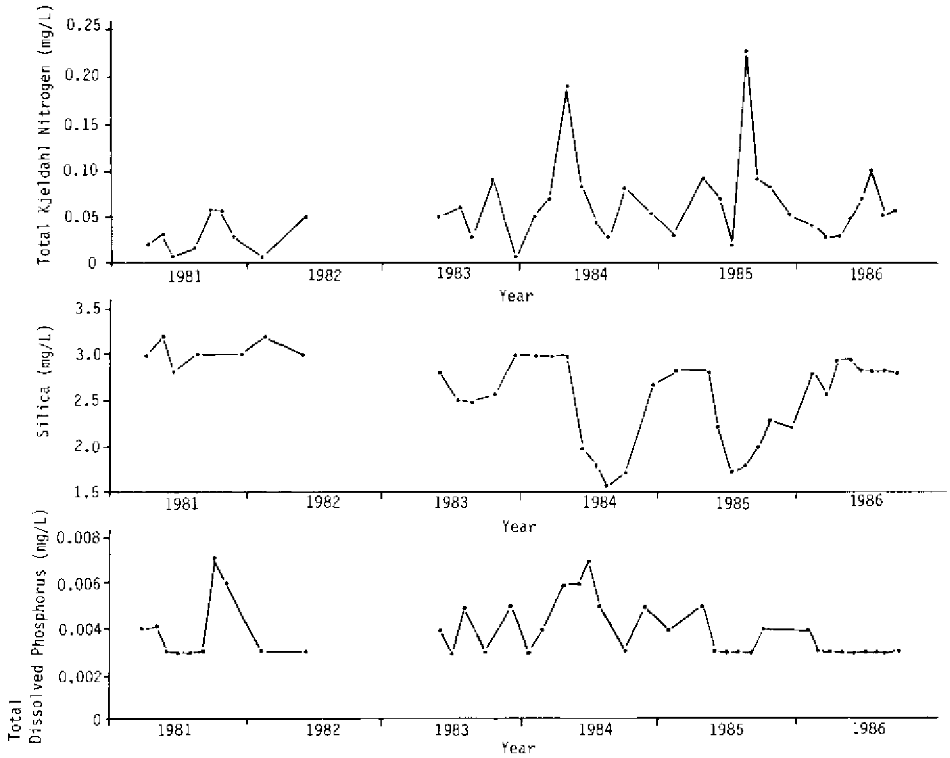
Depth [m]	1986 Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	1985 Sep	Oct	Nov	Dec
0	—	0.10	0.09	0.09	0.10	0.09	0.15	<0.07	<0.08	<0.09	—	—
10	—	0.09	0.13	0.10	0.12	0.11	0.14	0.10	0.08	—	—	—
20	—	0.13	0.18	0.15	0.09	0.12	0.13	0.08	0.08	—	—	—
30	—	0.16	0.17	0.19	0.11	0.15	0.07	0.08	0.11	—	—	—
40	—	0.15	0.17	0.12	0.12	0.18	0.08	0.09	0.11	—	—	—
60	—	0.19	0.17	0.16	0.10	0.15	0.11	0.10	0.11	—	—	—

E8 TOTAL-P CONCENTRATION [μg l^{-1}] (Q)

Depth [m]	1986 Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	1985 Sep	Oct	Nov	Dec
0	—	5	3	3	5	5	<3	<3	<3	3	—	—
10	—	5	4	5	4	5	3	5	5		—	—
20	—	5	4	4	3	5	<3	<3	<3	—	—	—
30	—	6	4	5	4	5	<3	<3	<0	—	—	—
40	—	7	4	5	4	5	<3	3	<3	—	—	—
60	—	7	5	6	4	4	3	<3	3	—	—	—

E10 PAST TRENDS

Fig. NAM-55-3 The range and seasonality of total Kjeldahl nitrogen, silica and total dissolved phosphorus at station 0130082 in the south basin from 1981 to 1986 (2).



F. BIOLOGICAL FEATURES

F1 FLORA

§ Emerged macrophytes : *Scirpus subterminalis* (5).

§ Floating macrophytes : None.

§ Submerged macrophytes (5)

Potamogeton gramineus, Callitriche heterophylla, Ranunculus aquatilis, R. flammula.

§ Phytoplankton (5)

Cyanophyta (*Aphanothece* sp., *Microcystis* sp.) ; Bacillariophyta (*Achnanthes* sp., *Cyclotella glomerata, Melosira* sp., *Rhizosolenia eriensis, Synedra acus, S. filiformis*) ; Chrysophyta (*Dinobryon sertularia*) ; Cryptophyta (*Cryptomonas* sp., *Chroomonas* sp.).

F2 FAUNA

§ Zooplankton

Cladocerans (*Daphnia* spp., *Holopedium gibberellum, Leptodora kindtii*) ; copepods (*Cyclops* sp., *Diaptomus* sp., *Polyphemus pediculus, Sida* sp.) ; rotifers (*Keratella cochlearis, Kellicottia longispina, Bosmina coregoni*).

§ Benthos

Phyacodrillus montana, Psectrocladius, Thienemannimya.

§ Fish

Salmo gairdneri, S. clarki clarki, Salvelinus malma, Cottus asper, Gasterosteus aculeatus.

§ Supplementary notes on the biota (Q)

The combination of only 11 % littoral area (<6 m depth) and widely fluctuating water level has limited macrophyte vegetation severely.

F4 BIOMASS

Phytoplankton standing crop in terms of chlorophyll *a* in this ultraoligotrophic lake was so low that it was virtually undetectable in all but 4 months of the year (Jul.-Oct.) (3).

F5 PAST TRENDS

From 1958 when the Strathcona Dam raised the water levels in the lake by 8.5 m to 1966 when a copper, lead and zinc mine began discharging to Buttle Lake's south basin, the creel census averaged 0.9 fish/rod•hour. By 1978 it had fallen to 0.4 fish/rod•hour and by 1980 it had dropped to 0 fish/rod•hour (6). In 1984 a land tailings disposal system replaced the mine's tailings disposal. Studies are currently underway to determine how long lake rehabilitation will take following the diversion of acid mine tailings from the lake (Q).

F7 NOTES ON THE REMARKABLE CHANGES OF BIOTA IN THE LAKE IN RECENT YEARS (Q)

Comparison of phytoplankton data collected in 1980 and 1981 with baseline data collected in 1966-1968 indicated that previously dominant diatoms such as *Tabellaria flocculosa*, *T. fenestrata*, *Asterionella formosa* and *Melosira distans* had become rare as had all Chlorophyta and Cyanophyta. More metal-tolerant species such as *Navicula cryptocephala*, *Synedra acus*, *S. filiformis*, *Cyclotella bodanica* and *C. glomerata* had substantially increased in abundance. As metal levels began to decrease *S. acus* and *S. filiformis* initially increased in numbers through 1983. However, from October 1983 through August 1985 *Rhizosolenia eriensis* became very abundant peaking at 18,000 cells ml^{-1} in south Buttle and 99.7 % of the community, a virtual monoculture. In September 1985 the bloom "crashed" falling to less than 600 cells ml^{-1}, a drop of 97 %. Other species such as *Dinobryon* spp. have become seasonal co-dominants (spring) while sensitive species such as *Tabellaria fenestrata*, *T. flocculosa*, *Fragilaria crotonensis* and *Asterionella formosa* have begun to return.

In 1981 when metal levels were peaking, the zooplankton community indicated a trend toward decreasing numbers of cladocerans and calanoid copepods. Throughout 1984 zooplankton were present in such low numbers that they were found in only one of forty samples. Zooplankton began to reappear in 1985, gradually becoming more abundant and diverse through the spring and summer months. By late summer species such as *Leptodora kindtii*, *Holopedium gibberellum*, *Polyphemus pediculus* and *Daphnia* spp., which had been absent for a number of years, were reappearing along with *Diaptomus* sp., *Keratella cochlearis*, *Kellicottia longispina*, *Bosmina longirostris*, *B. coregoni*, *Cyclops* sp. and *Polyarthra* sp. In 1986, only two years after the mine waste diversion, species composition was similar to that sampled in 1966-1967.

Fig. NAM-55-4 Percent composition of phytoplankton community over time at site 0130082 (2).

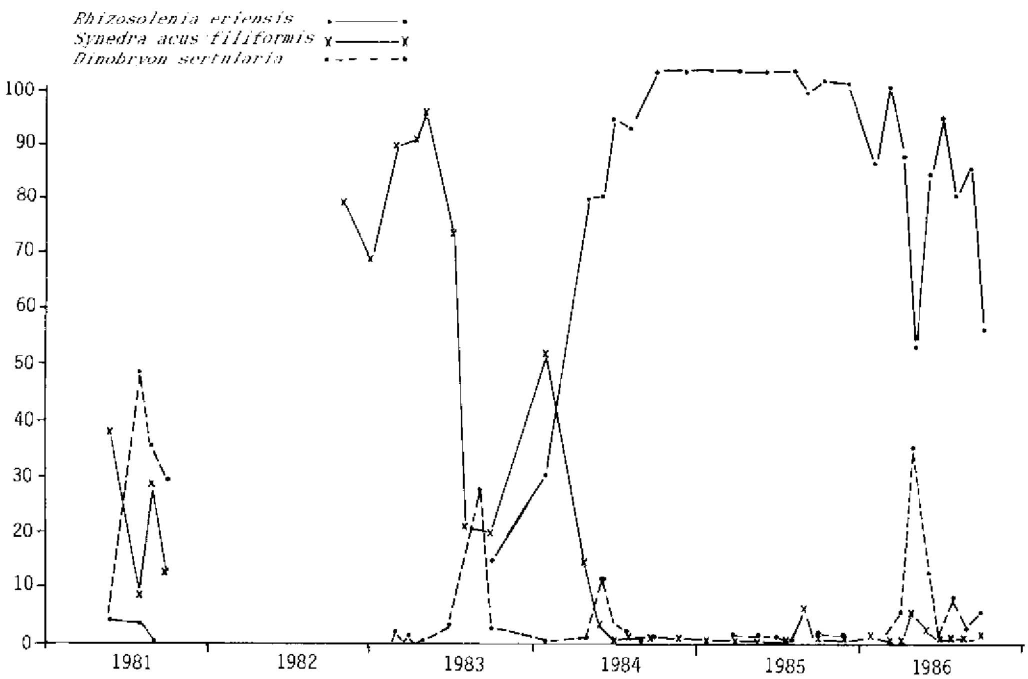
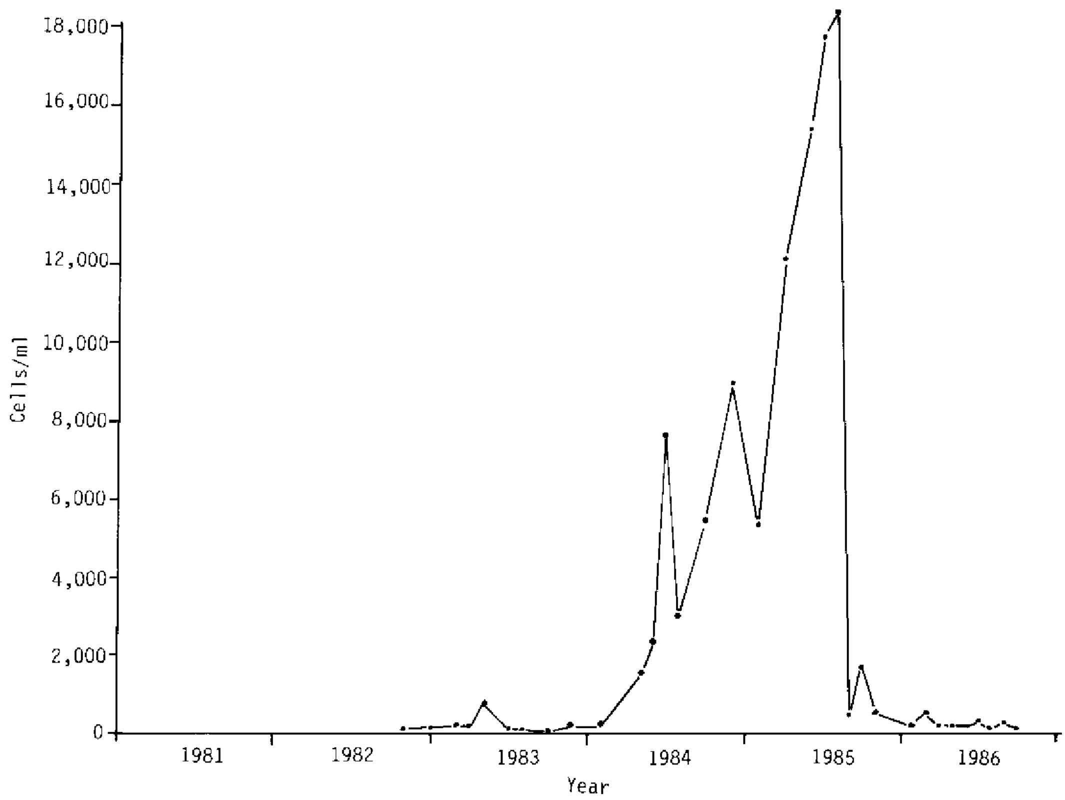


Fig. NAM-55-5 Phytoplankton cell numbers [no. ml^{-1}] over time at site 0130082 (2).



G. SOCIO-ECONOMIC CONDITIONS

G1 LAND USE IN THE CATCHMENT AREA (1980) (2a)

	Area [km^2]	[%]
Natural landscape		
Woody vegetation	1,264	90
Herbaceous vegetation	140	10
Total	1,404	100

§ Types of important forest vegetation: *Pseudotsuga menziesii* (Douglas fir), *Tsuga heterophylla* (western hemlock), *Thuja plicata* (red cedar).

§ Types of important herbaceous vegetation: *Polystichium munitum* (sword fern), *Berberis nervosa* (Oregon grape), *Vaccinum parvifolium* (red huckleberry), *Achlys triphylla* (vanilla leaf).

§ Supplementary notes: This lake lies within Strathcona Provincial Park, hence the lack of permanent population, agriculture and manufacturing industry.

G2 INDUSTRIES IN THE CATCHMENT AREA AND THE LAKE (1988)

	No. of establishments	Main products
Primary industry		
Mining	1	Copper, lead, zinc, gold, silver

H. LAKE UTILIZATION (Q)

H1 LAKE UTILIZATION

Source of water, sightseeing and tourism (no. of visitors in 1987 : 52,100) and recreation (swimming, sport-fishing).

I. DETERIORATION OF LAKE ENVIRONMENTS AND HAZARDS

I1 ENHANCED SILTATION

§ Extent of damage : Not serious.

I2 TOXIC CONTAMINATION

§ Present status of toxic contamination : Serious.

Sampling station : 3 km N of Thelwood Creek

Name of contaminant*1	Range of concentration [ppb] in*2			
	Water	Bottom mud	Fish*3	
			Muscle	Liver
	1986	1981	1983-1986	1983-1986
Copper	1−10	178±48	0.61±1.68	510.4±307.5
Zinc	20−50	209±142	21.7±19.5	110.9±99.8
Lead	1−4	55±47	−	3.14±5.74
Cadmium	<0.5	<1	−	10.1±4.3

*1 Source : Mining — acid generation.

*2 Volume basis [$\mu g\ l^{-1}$] for water, and on a dry weight basis for fish tissue (mean ± S. D.).

*3 Species examined : *Salmo gairdneri*.

§ Environmental quality standards for contaminants in lake water

Environment Canada guidelines : 0.03 mg Zn l^{-1}, 0.002 mg Cu l^{-1}, 0.0002 mg Cd l^{-1}, 0.001 mg Pb l^{-1}.

§ Past trends

Fig. NAM-55-6 Metal contents of fish muscle tissues in Buttle Lake and control lakes, with the number of samples and statistical comparisons. All metal contents are expressed on dry weight basis except mercury on wet weight basis.

> Buttle greater than control; < Buttle less than control; = no significant difference (P>0.05); ( ) borderline significance (0.05<P<0.10) (2).

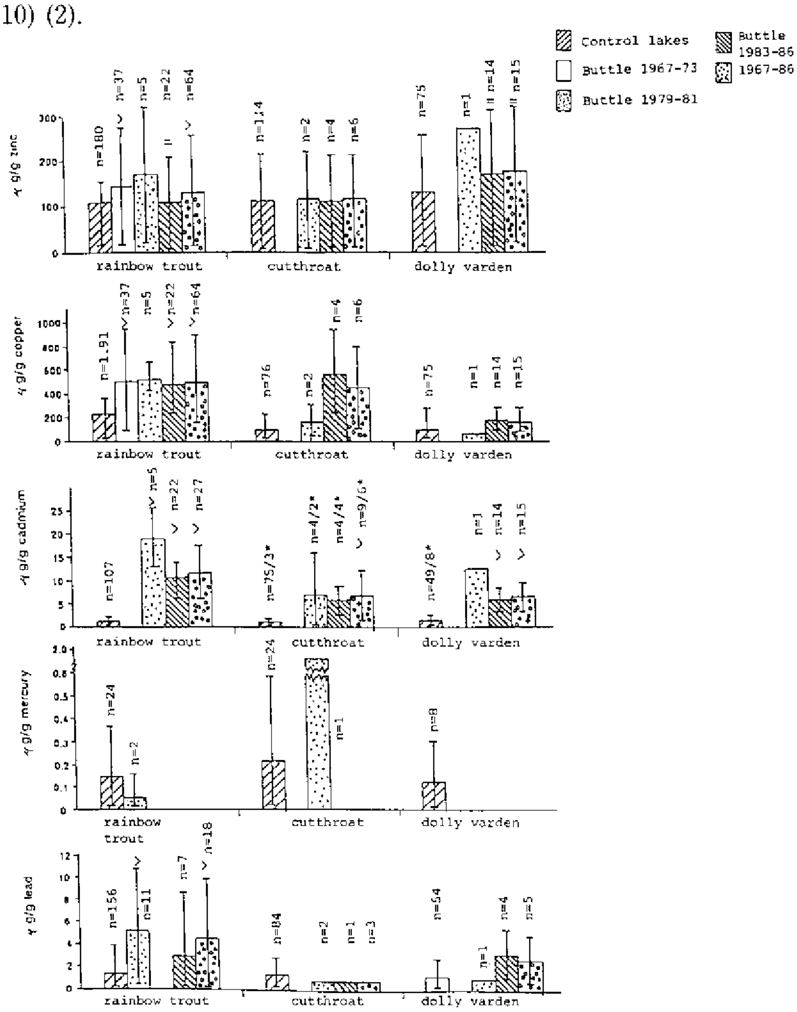
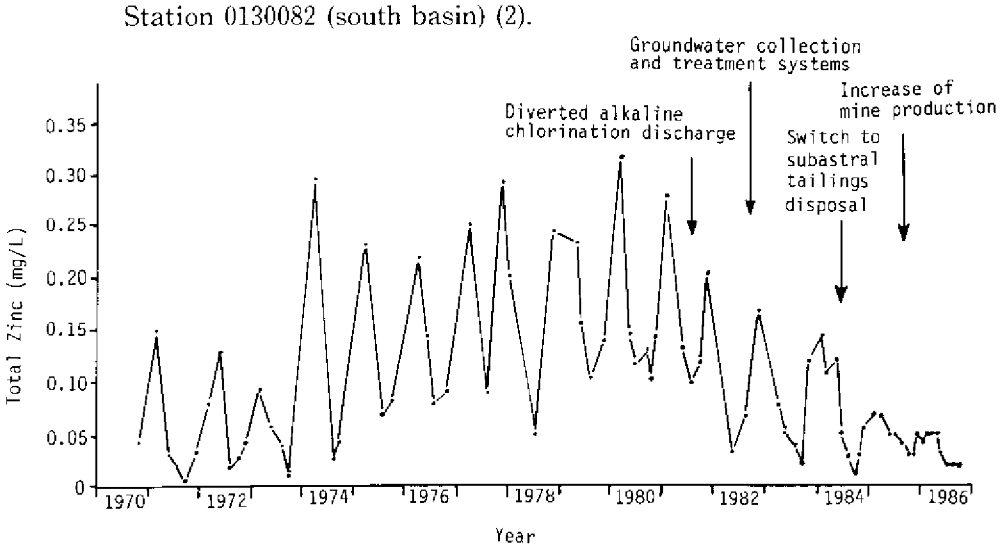


Fig. NAM-55-7 Seasonal and inter-year changes of total zinc content in the lake water at Station 0130082 (south basin) (2).



I3 EUTROPHICATION

An unusual algal bloom dominated by *Rhizosolenia eriensis* occured in 1984-1985, continuing through winter. Lake concentration for total dissolved P ranged up to 0.008 mg l^{-1} and NO_2/NO_3-N up to 0.08 mg l^{-1} — the concentrations hardly indicate significant eutrophication. This bloom was likely associated with a number of factors such as declining metals concentration, reduced numbers of herbivorous zooplankton, a slight increase in nutrients and possibly a favorable N : P ratio (Q).

I4 ACIDIFICATION

§ Extent of damage : None.

§ Supplementary notes : Acid generation from a mine (mainly from waste rock) adds heavy metals but does not affect pH in the lake.

J. WASTEWATER TREATMENTS

J1 GENERATION OF POLLUTANTS IN THE CATCHMENT AREA : (f) A mine on one tributary (south arm) with previous tailings discharge to lake, some metal leachates from waste rock and existing discharge of mine/mill effluents.

J3 SANITARY FACILITIES AND SEWERAGE

§ Industrial wastewater treatment systems

Improved collection and treatment systems at mine site are reducing metal loadings to the lake. Clarified effluent is pumped through tailings ponds.

L. DEVELOPMENT PLANS

This lake is in Strathcona Provincial Park. Therefore there are no development plans.

M. LEGISLATIVE AND INSTITUTIONAL MEASURES FOR UPGRADING LAKE ENVIRONMENTS

M1 NATIONAL AND LOCAL LAWS CONCERNED

§ Name of the laws

(1) Waste Management Act
(2) Parks Act
(3) Fisheries Act
(4) Mines Regulations

§ Responsible authorities

(1) British Columbia Ministry of Environment, Waste Management Branch
(2) British Columbia Ministry of Parks
(3) Canada Department of Fisheries and Oceans
(4) British Columbia Ministry of Mines (and Petroleum Resources)

§ Main items of control

(1) Waste management permits

M2 INSTITUTIONAL MEASURES

(1) British Columbia Waste Management Program, Ministry of Environment, Vancouver Island Region, Nanaimo, 1967-1988

M3 RESEARCH INSTITUTES ENGAGED IN THE LAKE ENVIRONMENT STUDY

(1) University of Victoria
(2) University of British Columbia

N. SOURCES OF DATA

(Q) Questionnaire filled by Drs. M. J. R. Clark, Environmental Impact Unit, Environmental Services Section, Waste Management Branch, Victoria, British Columbia, P. Lucey, Department

of Biology, University of Victoria, British Columbia, J. Deniseger and L. Erickson, Vancouver Island Region, Waste Management Branch, Ministry of Environment, Canada.

(1) British Columbia Ministry of Environment. Region 1, Waste Management Files.

(2) Deniseger, J., Erickson, L. J., Austin, A., Roch, M. & Clark, M. J. R. (In press) The effects of decreasing heavy metal concentrations on the biota of Buttle Lake, Vancouver Island, British Columbia. Water Research.

(2a) National Topographic System, Department of Energy Mines and Resources, Surveys and Mapping Branch. Sheet 92F/12 (Scale 1 : 50,000), Edition 4, 1980 and Sheet 92F/13, Edition 3, 1976.

(3) Nordin, R. N., McKean, C. J. P., Boyd, I. T., Clark, M. J. R., Roch, M. R. & Deniseger, J. (1985) Effects of Dissolved Metals on the Aquatic Biota of the Lakes of the Campbell River Watershed. 234 pp. Water Management and Waste Management Branches, Ministry of the Environment, Victoria, B. C.

(4) Canadian Climate Normals, 1951-1980. Canadian Climate Program, Environment Canada, Atmospheric Environment Service, Downsview, Ontario.

(5) British Columbia Ministry of the Environment, Waste Management Branch (1987) (Computer file of) Aquatic Plants, Morphometry and Water and Sediment Chemistry for the Lakes in British Columbia — Site 480, Buttle Lake.

(6) Clark, M. J. R. & Morrison, T. O. (1982) Impact of the Westmin Resources Ltd. Mining Operation on Buttle Lake and the Campbell River Watershed. Ministry of Environment, Waste Management Branch.

(7) Read, S. C. & Poulin, V. A. (1982) Economic evaluation of the Campbell River Fisheries. A Report Prepared for Waste Management Branch, B. C. Ministry of the Environment. 47 pp.

KEJIMKUJIK LAKE

An aerial view of the lake

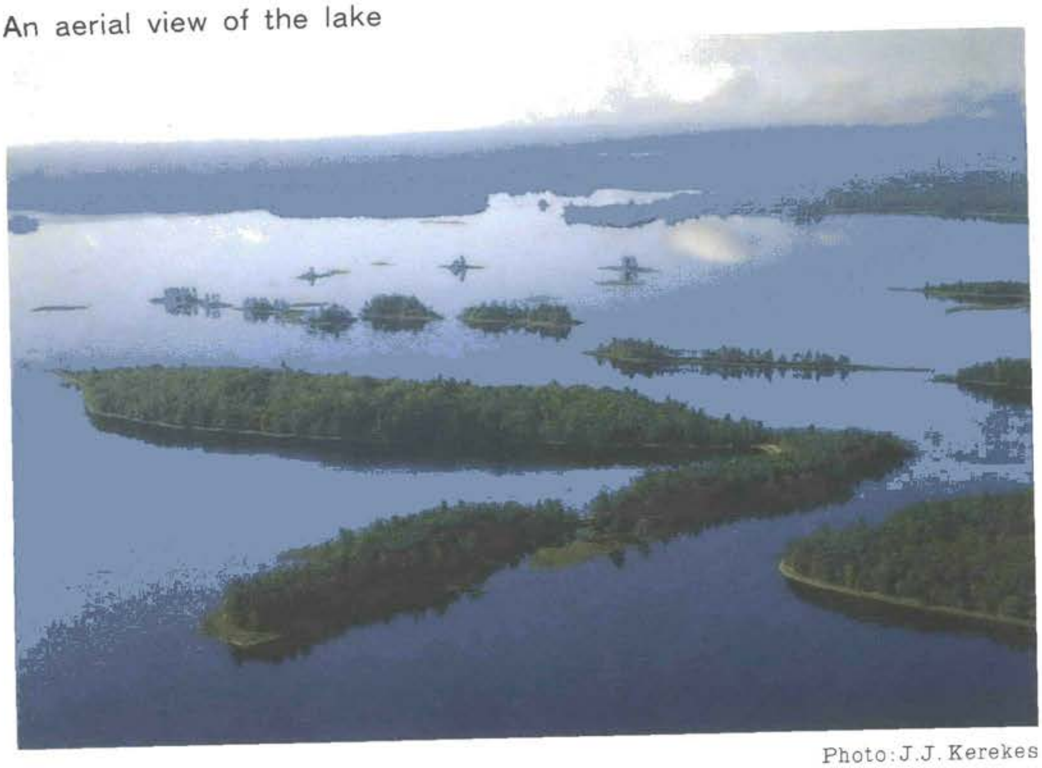
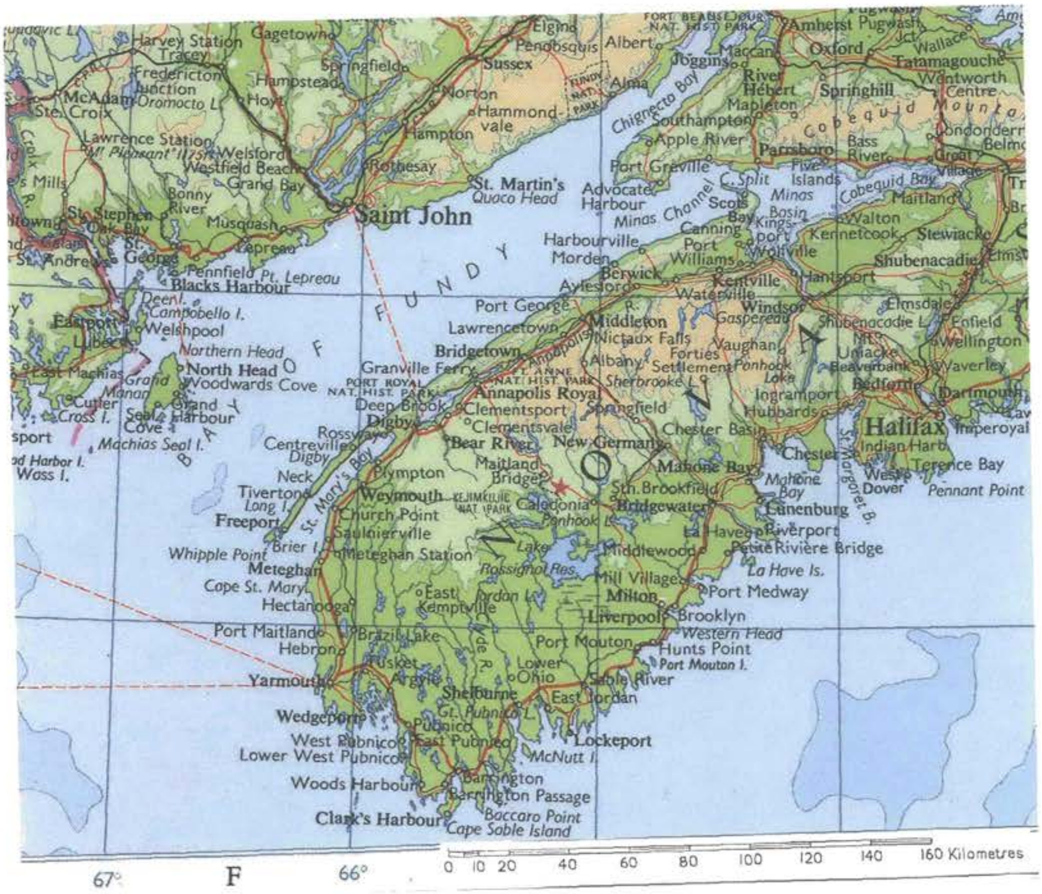


Photo: J.J. Kerekes



A. LOCATION

§ Nova Scotia, Canada.
§ 44°23′N ; 65°15′W ; 90 m above sea level.

B. DESCRIPTION

The oligotrophic Kejimkujik Lake in Kejimkujik National Park is lying on Devonian granite in central Nova Scotia approximately 60 km inland from the Atlantic Ocean and 40 km from the Bay of Fundy. Its drainage basin is covered by forest, bogs, lakes and a very limited amount of poor agricultural land (<1 % of the watershed). About two-thirds of the drainage basin is outside of the National Park boundary which contains a permanent population of <100 people, has some roads and supports some forestry and a very limited amount of agriculture. Kejimkujik Lake is a local centre of summer recreation. Up to ca. 1,500-2,500 people may be present daily during peak periods of the summer season. Water flowing into the lake is influenced by bog soils and is high in organic acids. The lake has shown a high degree of acidification and reproductive failure of Atlantic salmon due to high acidity downstream from the lake has become apparent.

In response to the need for scientific knowledge of the potential impacts of the long-range transportation of air pollutants on freshwater ecosystems in Atlantic Canada, the Government of Canada initiated the Kejimkujik Calibrated Catchment Study Program, an interdisciplinary multi-agency study in 1980.

The lake is shallow and has a relatively high flushing rate (4.5 times yr^{-1}), precipitation is 1,460 mm yr^{-1} and the runoff is 910 mm yr^{-1}. The water is extremely dilute (sum of constituents = 13 mg l^{-1}), and due to its relative closeness to the ocean, it is dominated by Na and Cl ions. Calcium and magnesium concentrations are extremely low (0.7 and 0.5 mg l^{-1}, respectively); thus under the existing ~20 kg $ha^{-1}yr^{-1}$ wet sulphate deposition, combined with the existing natural acidity, the lake responds with chronically depressed pH (4.8 annual mean). Studies in the lake and its tributaries showed that the additional sulphate deposition of anthropogenic origin gives additional acidity to the water, particularly during the winter and early spring, which explains the disappearence of Atlantic salmon downstream from the lake (Q).

C. PHYSICAL DIMENSIONS (6)

Surface area [km^2]	26.3
Volume [$10^6 m^3$]	106
Maximum depth [m]	19.2
Mean depth [m]	4.4
Normal range of annual water level fluctuation (unregulated) [m]	1.0
Length of shoreline [km]	45
Residence time [yr]	0.17
Catchment area [km^2]	289

D. PHYSIOGRAPHIC FEATURES

D1 GEOGRAPHICAL

§ Sketch map (Fig. NAM-56-1).
§ Bathymetric map (Fig. NAM-56-2).
§ Main islands (name and area): Peale, Hemlock, Norway, Dukeshire, Big Muise, Ell, Little Muise, Richie McLean (total island area 1.97 km²).
§ Outflowing rivers and channels (number and names): 1 (Mersey R.).

D2 CLIMATIC

§ Climatic data at Maitland Bridge, since 1965 (2a)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean temp. [°C]	-6.4	-5.7	-1.3	3.1	9.6	15.4	18.7	17.9	13.9	9.2	3.7	-2.6	6.3
Precipitation [mm]	155	114	127	99	104	89	103	87	107	132	141	189	1,447

§ Number of hours of bright sunshine: 1,785 hr yr^{-1}.
§ Average solar radiation at Kentville CDA: 12.7 MJ m^{-2} day^{-1}.
Mean daily global solar radiation [MJ m^{-2} day^{-1}]

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
4.95	8.48	12.45	15.26	18.90	21.18	20.48	18.32	14.11	9.04	5.14	3.71

Fig. NAM-56-1 Sketch map of Nova Scotia drainage basins (Q).

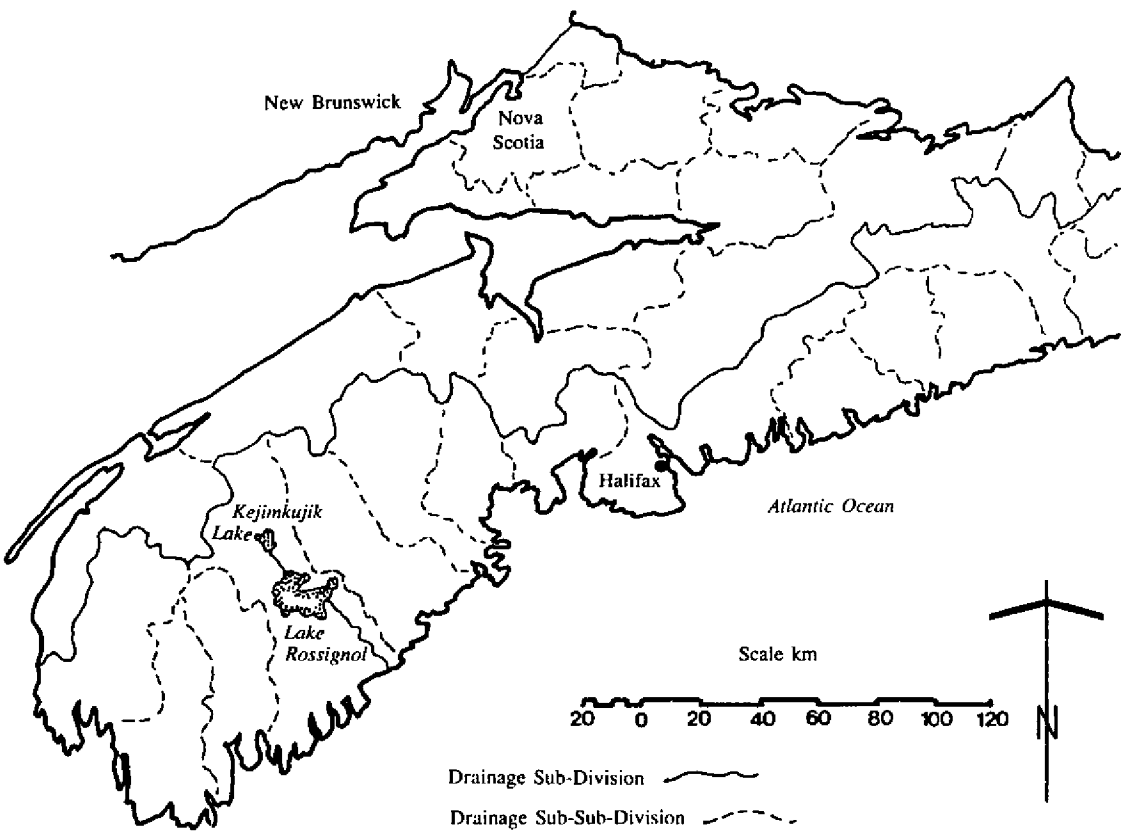
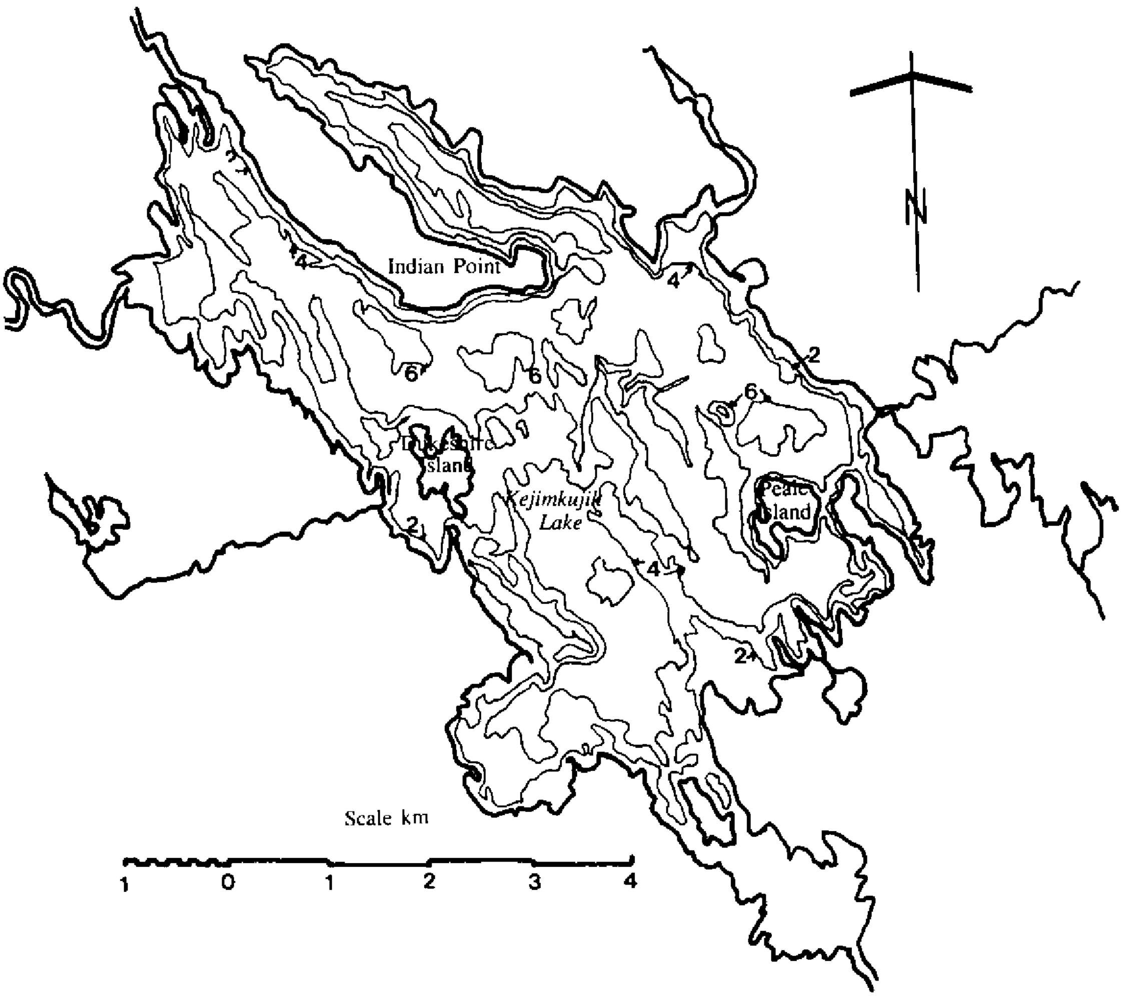


Fig. NAM-56-2 Bathymetric map [m] (7).



§ Water temperature [°C] (7)
Deep Station off Peale Island, 1980

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	0.0	0.5	–	7.0	12.5	16.5	18.5	23.5	20.5	12.0	3.4	2.0
2	2.0	1.5	–	7.0	12.5	16.0	18.5	23.5	19.9	12.0	3.0	2.0
4	2.0	2.0	–	7.0	12.0	15.6	18.5	23.5	19.5	12.0	3.0	2.0
6	2.2	2.5	–	7.0	12.0	15.5	18.5	22.0	19.3	12.0	3.4	2.0
8	2.5	3.0	–	6.7	11.5	15.0	18.5	21.0	19.1	12.0	3.4	2.0
10	3.0	4.0	–	6.7	11.0	15.0	18.5	20.0	19.0	12.0	3.4	2.0
14	3.8	4.0	–	6.7	10.5	14.9	18.2	17.0	19.0	12.0	3.4	2.0
18	4.0	4.0	–	6.7	10.6	–	–	–	–	–	3.8	2.0

§ Freezing period : From end of Dec. to mid-Apr.

§ Mixing type : Dimictic.

§ Notes on water mixing and thermocline formation

Summer thermal stratification is restricted mainly to a relatively small depression near Peale Island. Hypolimnion is absent.

E. LAKE WATER QUALITY

E1 TRANSPARENCY [m] (7)

Deep Station, 1980

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1.3	1.27	–	1.75	1.75	2.23	1.35	1.8	2.45	2.31	2.07	1.75

E2 pH (7)

Deep Station, 1980

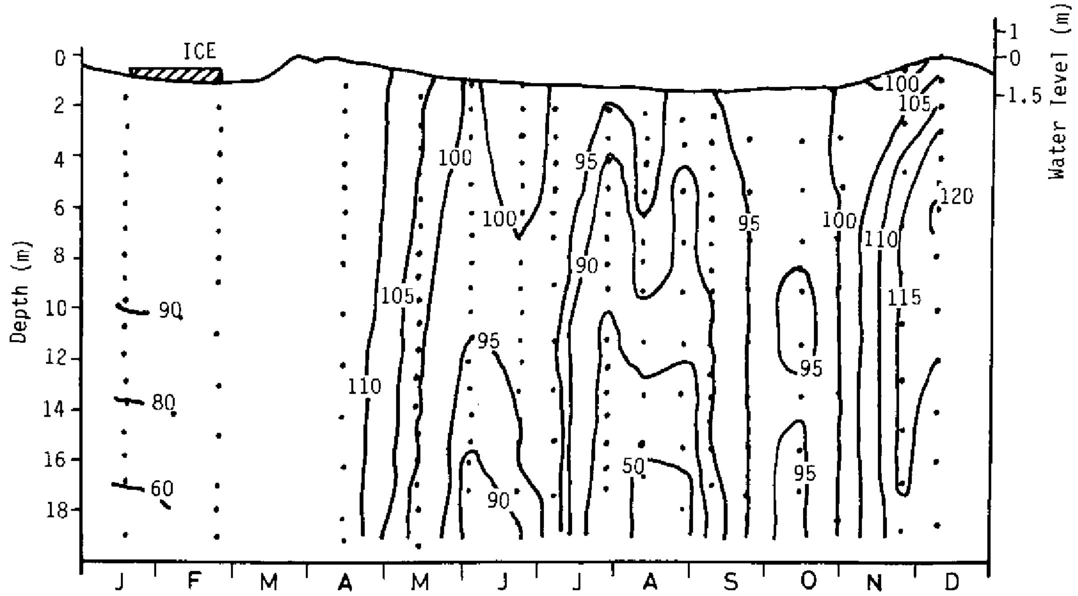
Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	4.55	4.6	–	4.8	4.8	4.6	4.9	4.9	4.9	5.1	4.5	4.6
2	4.6	4.7	–	4.8	4.7	4.7	4.9	4.9	5.0	5.1	4.7	4.6
4	4.7	4.6	–	4.8	4.7	4.7	4.9	5.0	4.9	5.1	–	4.6
6	4.7	4.6	–	4.7	4.6	4.7	4.9	5.0	5.0	–	–	4.6
8	4.7	4.6	–	4.7	4.6	4.7	4.9	5.0	5.0	5.1	–	4.6
10	4.7	4.6	–	4.7	4.6	4.7	4.8	4.9	5.0	–	4.9	4.6
14	4.8	4.7	–	4.7	4.6	4.6	4.8	4.8	5.0	5.1	–	4.6
18	4.8	4.7	–	4.7	4.6	4.6	–	–	–	–	4.9	4.6

E3 SS

Negligible levels (Q).

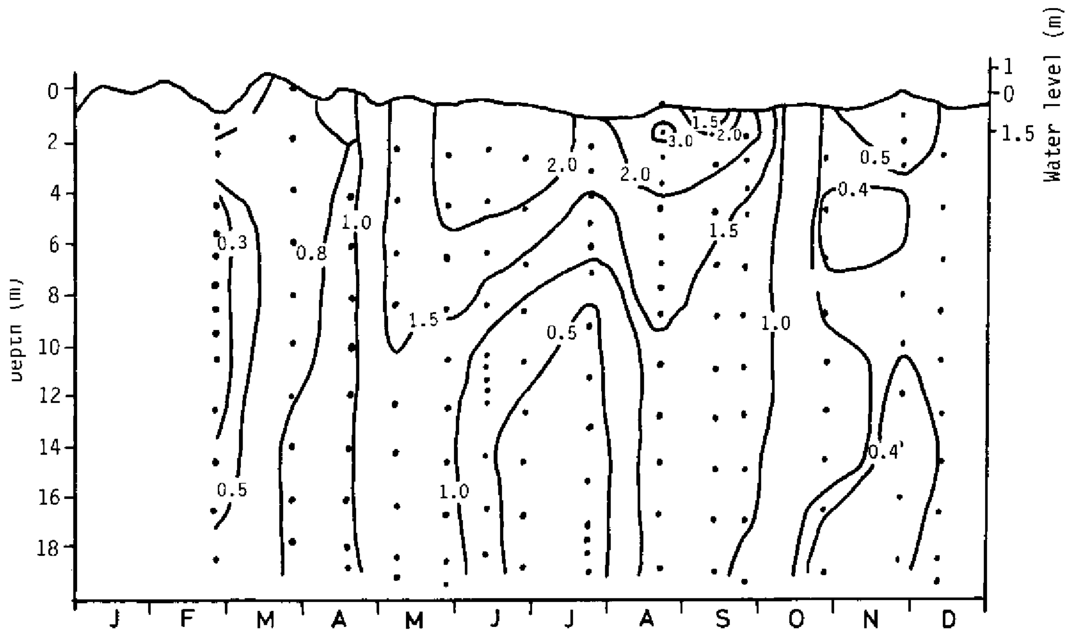
E4 DO

Fig. NAM-56-3 Time-depth isopleth of DO, 1980 [% saturation] (7).



E6 CHLOROPHYLL CONCENTRATION

Fig. NAM-56-4 Time-depth isopleth of chlorophyll *a* at Deep station, 1979 [$\mu g\ l^{-1}$] (7).



E7 NITROGEN CONCENTRATION

§ Total-N [mg l^{-1}]

Deep station, 1981 : 0.76 (annual mean) (5).

E8 PHOSPHORUS CONCENTRATION

§ Total-P [$\mu g\ l^{-1}$]

Deep station, 1981 : 9.1 (annual mean) (5).

E9 CHLORIDE ION CONCENTRATION [mg l^{-1}]

Outflow, 1978-1979 : 4.53 (annual mean) (5).

F. BIOLOGICAL FEATURES

F1 FLORA

§ Emerged macrophytes (5)

Equisetum fluviale, Sparganium americanum, S. minimum, Calamagrostis canadensis, Eleocharis acicularis, Scirpus subterminalis, Rhynchospora alba, Eriocaulon septangulare, Pontederia cordata, Juncus brevicaudatus, J. effusus, J. militaris, Lobelia dortmanna, Hydrocotyle umbellata, Sium suave.

§ Floating macrophytes (5)

Nuphar variegatum, Nymphaea odorata, Brasenia schreberi, Nymphoides cordata.

§ Submerged macrophytes (5)

Isoetes macrospora, Potamogeton confervoides, P. epihydris, P. robbinsii, P. spirillus, Utricularia cornuta.

§ Phytoplankton (2)

Diatoms (*Asterionella formosa, Tabellaria fenestrata, T. flocculosa, Rhizosolenia eriensis*) ; Greens (*Selenastrum minutum, Sphaerocystis schroeteri, Schroederia setigera, Tetradesmus wisconsinensis*) ; Blue-greens (*Agmenellum thermale*) ; chrysophyceans (*Mallomonas caudata, Dinobryon bavaricum*) ; cryptophyceans (*Cryptomonas ovata*) ; xanthophyceans (*Chlorochromonas minuta*).

F2 FAUNA

§ Zooplankton (2)

Cladocerans (*Daphnia ambigua, D. catawba, Bosmina longirostris, Eubosmina longispina, E. tubicen, Holopedium gibberum, Leptodora kindtii, Diaphanosoma leuchtenbergianum*) ; copepods (*Epischura nordenskioldi, Diaptomus minutus, D. oregonensis, Mesocyclops edas, Tropocyclops* sp.) ; rotifers (*Keratella cochlearis, Kellicottia bostoniensis, Polyarthra vulgaris, Conochilus unicornis*).

§ Benthos

Benthic macroinvertebrates in Kejimkujik Lake (Jeremy Bay ; 9 samples), Beaverskin Lake (4 samples) and Pebbleloggitch Lake (4 samples). Mean data for the three lakes and 4 sampling dates (May, Jul., Aug. and Sep., 1980) (5)

		Density [no m^{-2}]	[%]
Insecta	Ephemeroptera	30	2.8
	Odonata	7	0.7
	Plecoptera	4	0.4
	Neuroptera	1	0.1
	Megaloptera	1	0.1
	Trichoptera	27	2.5
	Coleoptera	1	0.1
	Lepidoptera	0	0.0
	Diptera	241	22.5
Crustacea	Crustacea	144	13.5
	Ostracoda	6	0.6
	Cladocera	175	16.4
	Amphipoda	91	8.5
	Isopoda	78	7.3
Oligochaeta	Naididae	217	20.3
	Lumbricuridae	7	0.7
	Enchytraeidae	1	0.1
	Tubificidae	7	0.7
Mollusca	Gastropoda	1	0.1
	Sphaeriidae	4	0.4
Turbellaria		1	0.1
Arachnida	Hydracarina	2	0.2
Nematoda		20	1.9
Total		1,066	100

§ Fish (5)

Coregonus clupeaformis (lake whitefish), *Salmo trutta* (brown trout), *Salvelinus fontinalis* (brook trout), *Notemigonus chrysoleucas* (golden shiner), *Catostomus commersoni* (white sucker), *Ictalurus nebulosus* (brown bullhead), banded killfish, ninespine stickleback, *Morone americana* (white perch), *Perca flavescens* (yellow perch), *Anguilla rostrata* (American eel).

F3 PRIMARY PRODUCTION RATE

§ Phytoplankton

Net production rate, Deep station, May 1979-Apr. 1981 (1)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual mean [g C m^{-2} yr^{-1}]
13.9	31.8	120	112	105	122	147	113	238	136	87.1	32.6	25.3

F5 FISHERY PRODUCTS
1,100 angling licenses issued in 1988.

F7 NOTES ON THE REMARKABLE CHANGES OF BIOTA IN THE LAKE IN RECENT YEARS
Atlantic salmon became extinct in the 1920's because of a series of seven power dams downstream from the lake.

G. SOCIO-ECONOMIC CONDITIONS (Q)

G1 LAND USE IN THE CATCHMENT AREA

	Area [km²]	[%]
Natural landscape	ca. 286	99 (forest, bogs and lakes)
Agricultural land	<3	<1
Total	289	100

§ Levels of fertilizer application on crop fields : Light.

G2 INDUSTRIES IN THE CATCHMENT AREA AND THE LAKE
None.

G3 POPULATION IN THE CATCHMENT AREA in 1986 (10)
<100 in the 2/3 drainage basin outside National Park Boundary.

H. LAKE UTILIZATION (Q)

H1 LAKE UTILIZATION
Sightseeing and tourism (no. of visitors in 1988 ; 217,000) and recreation (swimming, canoeing, sport-fishing, angling).

I. DETERIORATION OF LAKE ENVIRONMENTS AND HAZARDS

I1 ENHANCED SILTATION
§ Extent of damage : None.

I2 TOXIC CONTAMINATION
§ Present status : None.

I3 EUTROPHICATION
§ Phosphorus loadings to the lake (1971).
7.3 [t yr^{-1}].

I4 ACIDIFICATION
§ Extent of damage : Serious.
§ Kinds of damage : Reduction of the number of fish species previously present (10) ; depressed pH levels (11, 12).

J. WASTEWATER TREATMENTS

J1 GENERATION OF POLLUTANTS IN THE CATCHMENT AREA : (b) No sources of significant pollution.

J3 SANITARY FACILITIES AND SEWERAGE
§ Municipal wastewater treatment systems
No. of primary treatment systems : 2 (setting sewage lagoons hold campground wastewater during the summer).

M. LEGISLATIVE AND INSTITUTIONAL MEASURES FOR UPGRADING LAKE ENVIRONMENTS

M1 NATIONAL AND LOCAL LAWS CONCERNED

§ Names of the laws (the year of legislation)

(1) National Parks Act (1930, last amendament C48 in 1988)

§ Responsible authorities

(1) Canadian Parks Service

M2 INSTITUTIONAL MEASURES

Since 1978, Kejimkujik Lake and its tributaries have been a major study site in Atlantic Canada to study the impact of long range transport of air pollutants and a selected site for future monitoring. This is a multi-agency study of the Canadian Wildlife Service, Inland Water Directorate, Atmospheric Environment Service, Canadian Forestry Service, Canadian Parks Service, and Department of Fisheries and Oceans.

N. SOURCES OF DATA

(Q) Questionnaire filled by Dr. J. J. Kerekes, Canadian Wildlife Service, Bedford Institute of Oceanography, Nova Scotia, Canada.

(1) Beauchamp, S. T. (1983) Planktonic primary production in three acid-stressed lakes in Nova Scotia. 194 pp. M. Sc. Thesis, Dalhousie University, Halifax, N. S.

(2) Blouin, A. C., Lane, P. A., Collins, T. M. & Kerekes, J. (1984) Comparison of plankton-water chemistry relationships in three acid stressed lakes. Int. Revue. ges. Hydrobiol., 69 : 819-841.

(2a) Canadian Climate Normals (1951-1980). Environment Canada, Atmospheric Environment Service.

(3) Kerekes, J. (1975) Aquatic Resources Inventory, Kejimkujik National Park, Nova Scotia. Part 6. Limnological Conditions in Thirty Lakes. Manuscript report. 89 pp. Canadian Wildlife Service, Environment Canada.

(4) Kerekes, J. (1975c) Phosphorus supply in undisturbed lakes in Kejimkujik National Park, Nova Scotia (Canada). Verh. Internat. Limnol., 19 : 349-357.

(5) Kerekes, J. & Freedman, B. (1989) Characteristics of three acidic lakes in Kejimkujik National Park, Nova Scotia, Canada. Arch. Environ. Contam. Toxicol., 18 : 183-200.

(6) Kerekes, J. & Schwinghamer, P. (1973a) Aquatic Resources Inventory, Kejimkujik National Park, Nova Scotia. Part 2. Lake Drainage and Morphometry. Manuscript report. 73 pp. Canadian Wildlife Service, Environment Canada.

(7) Kerekes, J. Unpublished data.

(8) Kejimkujik National Park. Unpublished data.

(9) Canada Dept. of Energy, Mines & Resources (1976) N. T. S. Scale 1 : 50,000, Sheet 21A/6, Edition 3.

(10) Kerekes, J., Howell, G., Beauchamp, G. & Pollock, T. (1982) Characterization of three lake basins sensitive to acid precipitation in central Nova Scotia (June, 1979 to May 1980). Int. Revue ges. Hydrobiol., 67 : 679-694.

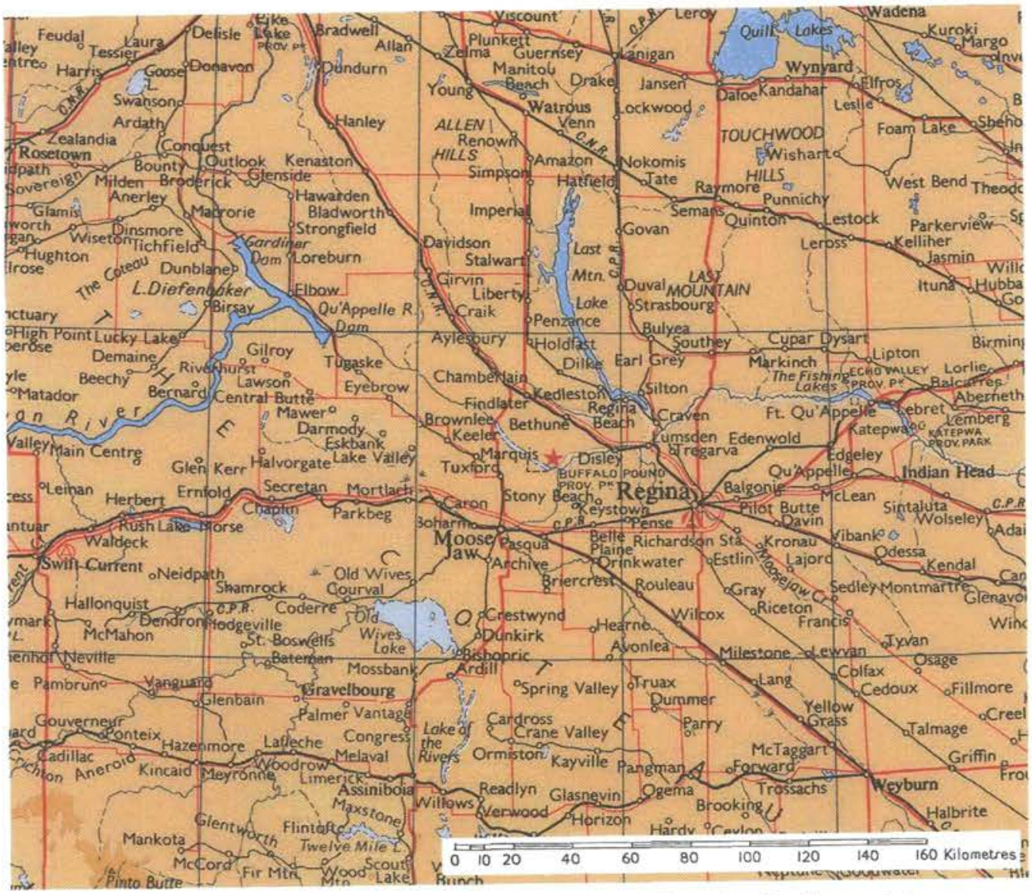
(11) Kerekes, J., Beauchamp, S., Tordon, R. & Tremblay, C. (1986) Organic versus anthoropogenic acidity in tributaries of the Kejimkujik watersheds in western Nova Scotia. Water, Air & Soil Pollution, 31 : 165-173.

(12) Kerekes, J., Beauchamp, S., Tordon, R. & Pollock, T. (1986) Sources of sulphate and acidity in wetlands and lakes in Nova Scotia. Water, Air & Soil Pollution, 31 : 207-214.

BUFFALO POUND LAKE

An aerial view of the lake's east end showing outlet control structures and heavy growth of macrophytes

Photo: Prairie Farm Rehabilitation Administration, Regina



A. LOCATION

§ Saskatchewan, Canada.
§ 50°12′-35′N, 105°03′-23′W ; 509 m above sea level.

B. DESCRIPTION

Buffalo Pound Lake is a small prairie lake located near the headwaters of the Qu'Appelle River in south central Saskatchewan. The drainage basin of the lake is located in the heart of the Canadian plain and is typically a flat to gently undulating treeless plain which has been cultivated chiefly for cereal grain production. The lake provides drinking water for the cities of Moose Jaw and Regina and is an important recreational resource, supporting a number of cottage developments, a provincial park and a sport fishery.

Buffalo Pound Lake is naturally eutrophic due to the input from nutrient rich soils in the basin. The eutrophic state was aggravated by increased erosion following the breaking of the natural prairie during the early 1900's. The small size of the drainage basin and low precipitation combined with high evaporation caused the natural lake levels to vary widely. These wide fluctuations were reduced by regulation of the outflow in 1949. The 1967 initiation of water diversion from Lake Diefenbaker on the South Saskatchewan River all but eliminated the fluctuation in lake level and also provides for a greatly increased flushing rate with high quality water from the South Saskatchewan River system. The water diversion represents more than 90 % of the inflow to Buffalo Pound Lake in most years. Despite the diversion of high quality water into Buffalo Pound Lake and controlling lake levels, the lake remains eutrophic. Major algal blooms and heavy growths of macrophytes occur every summer reducing the recreational potential of the lake and adding greatly to the cost of treating drinking water (Q).

C. PHYSICAL DIMENSIONS

Surface area [km^2]	29.5
Volume [10^6m^3]	89.8
Maximum depth [m]	5.6
Mean depth [m]	3.0
Normal range of annual of water level fluctuation	Regulated
Length of shoreline [km]	72.5
Residence time [yr]	1.5
Catchment area [km^2]	3,310

D. PHYSIOGRAPHIC FEATURES

D1 GEOGRAPHICAL

§ Sketch map (Fig. NAM-57-1).
§ Main islands : None.
§ Outflowing rivers and channels (number and names) : 1 (Qu'Appelle R.).

D2 CLIMATIC

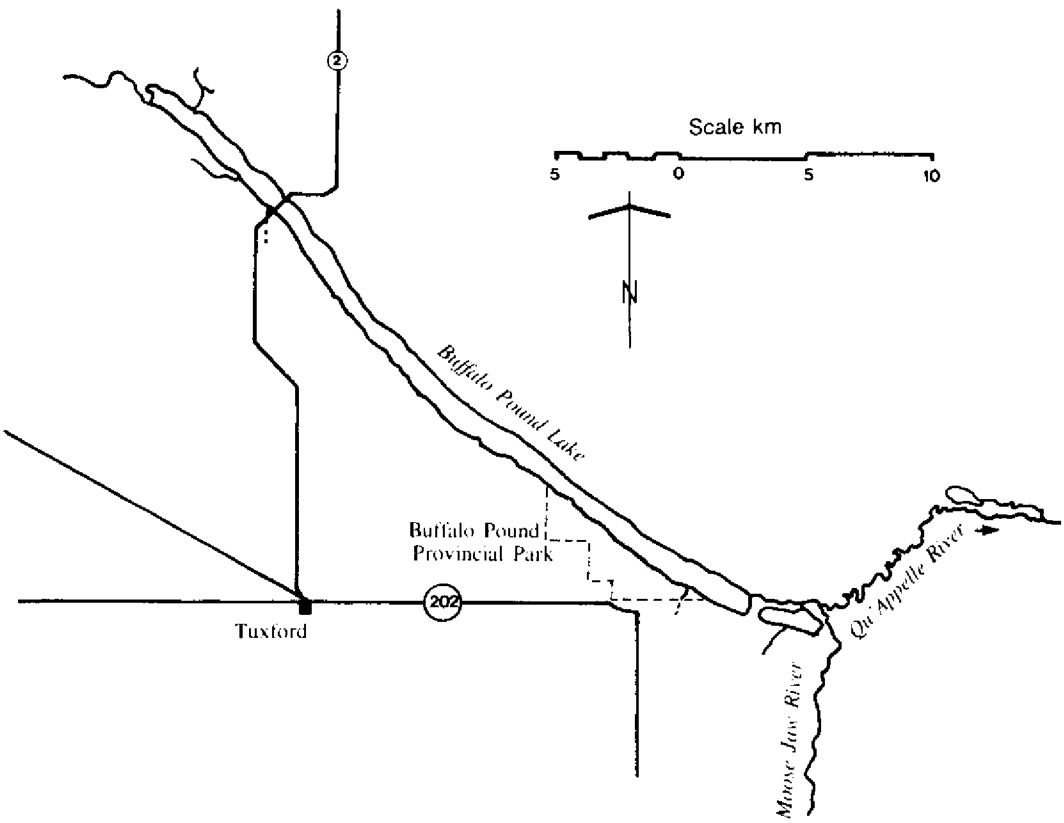
§ Climatic data at Moose Jaw A, ca. 25 km south of the lake, 1951-1980 (2)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean temp. [°C]	-15.8	-11.5	-5.6	4.2	11.5	16.6	19.7	18.6	12.5	6.4	-3.6	-10.7	3.5
Precipitation [mm]	19	15	18	30	49	66	53	40	36	18	17	21	382

§ Number of hours of bright sunshine : 2,330 hr yr^{-1}.
§ Average solar radiation (Swift Current, approximately 175 km WSW of the lake) : 13.9 MJ m^{-2} day^{-1}.
Mean daily global solar radiation [MJ $m^{-2}day^{-1}$]

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
5.05	8.72	14.05	17.86	21.58	23.14	24.35	20.13	14.36	9.45	5.27	3.83

Fig. NAM-57-1 Sketch map of the lake (Q).



§ Water temperature [°C] (3, 4)
Mid-lake opposite water treatment plant, 1980-1986

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.5	1.0	0.5	1.0	–	8.5	17.0	22.0	18.5	11.0	–	0.5	0.5

§ Freezing period : Nov. 1 to Apr. 15.
§ Mixing type : Polymictic.

E. LAKE WATER QUALITY

Mid-lake opposite water treatment plant, 1980-1986 (3, 4)

E1 TRANSPARENCY [m]

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.9	1.9	1.0	–	–	2.5	1.0	1.1	–	0.7	–	–

E2 pH

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.5	8.1	8.1	–	–	8.5	8.3	8.6	8.4	8.9	7.9	–	–

E3 SS [mg l^{-1}]

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.5	5	3	–	–	5	5	6	4	5	12	4	–

E4 DO [mg l^{-1}]

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.5	–	10.9	–	–	10.2	8.9	7.9	7.0	9.3	11.3	12.8	–

E6 CHLOROPHYLL CONCENTRATION [μg l^{-1}]

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.5	3	13	3	–	3	14	13	27	10	11	8	<1

E7 NITROGEN CONCENTRATION

§ Total Kjeldahl-N [mg l^{-1}]

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.5	0.9	0.7	–	–	0.8	0.6	1.3	0.7	1.2	0.9	–	0.6

E8 PHOSPHORUS CONCENTRATION

§ Total-P [mg l^{-1}]

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.5	0.12	0.90	–	–	0.07	0.12	0.10	0.12	0.14	0.10	–	–

F. BIOLOGICAL FEATURES

F1 FLORA

§ Submerged macrophytes

Dominant in summer 1988 (*Elodea canadensis, Myriophyllum exalbescens, Potamogeton richardsonii*); dominant in 1972-1974 (*Potamogeton richardsonii, P. pectinatus, Ceratophyllum demersum*) (5).

§ Phytoplankton

Microcystis aeruginosa, Aphanizomenon flos-aquae, Anabaena flos-aquae, Oscillatoria prolifica, Pediastrum duplex, Asterionella formosa, Stephanodiscus niagarae (5).

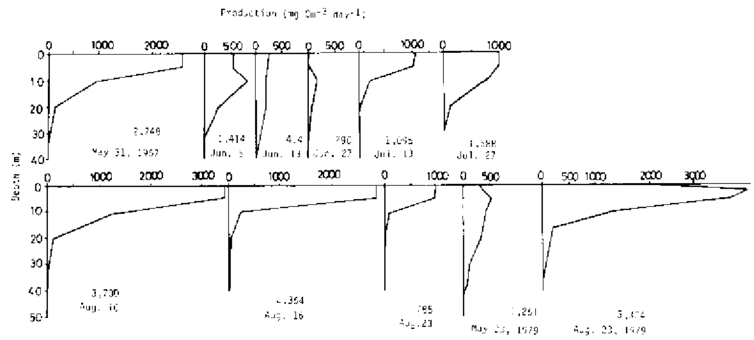
F2 FAUNA

§ Fish

Perca flavescens, Castostomus commensoni, Ictiobus cyprinellus, Esox lucius, Stizostedion vitreum, Cyprinus carpio, Pimephales promelus, Pungitius pungitius, Notropis atherinoides, N. hudsonius.

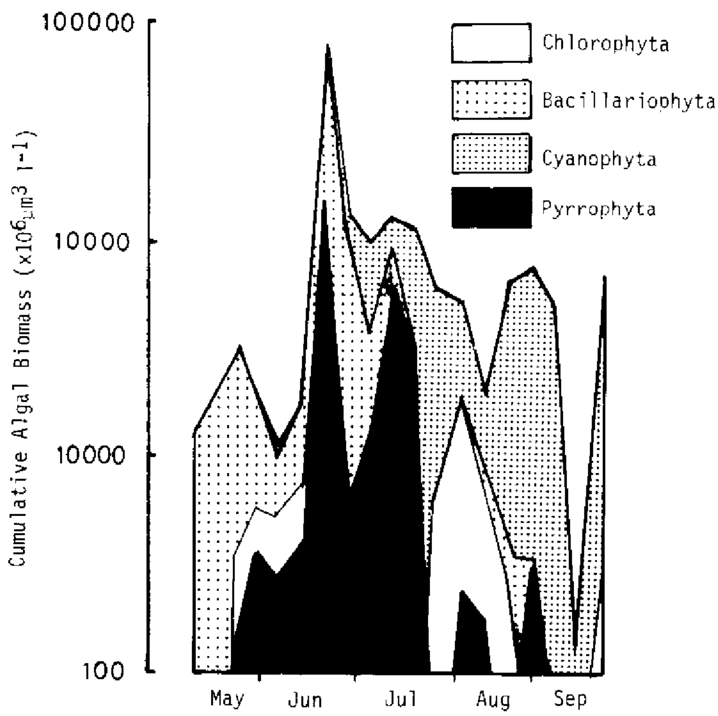
F3 PRIMARY PRODUCTION RATE

Fig. NAM-57-2 Vertical variations in daily production [mg C $m^{-3}day^{-1}$] in 1967 and 1979. Numbers above the dates represent areal productivity [mg C $m^{-2}day^{-1}$] (5).



F4 BIOMASS

Fig. NAM-57-3 Seasonal variations in phytoplankton biomass of major algal phyla, 1965 (5).



§ Zooplankton density

Average density in 1975, mid-lake: Protozoans 963 l^{-1}, rotifers 321 l^{-1}, cladocerans 321 l^{-1}, Copepods 86 l^{-1} (8).

F5 FISHERY PRODUCTS

There is no commercial fishery.

G. SOCIO-ECONOMIC CONDITIONS

G1 LAND USE IN THE CATCHMENT AREA (1986) (6)

	Area [km^2]	[%]
Agricultural land		
Crop field	ca. 2,980	90
Pasture land	ca. 330	10
Total	3,310	100

§ Types of important woody vegetation: Little or no forest/scrub communities.

§ Types of important herbaceous vegetation: Crop field and pasture land.

§ Main kinds of crops and/or cropping systems: Grains (wheat, oat, barley) and oil seeds (canola, flax).

§ Levels of fertilizer application on crop fields: Moderate.

§ Trend of change in land use in recent years: None.

G2 INDUSTRIES IN THE CATCHMENT AREA AND THE LAKE (1979)

	Main products
Primary Industry	
Crop production	Grains, oil seeds
Animal husbandry	Beef
Tertiary Industry	Machinary repair (small agricultural service industry)

G3 POPULATION IN THE CATCHMENT AREA (1986)

	Population	Population density [km^{-2}]	Main cities
Rural	4,500	1.36	None

H. LAKE UTILIZATION

H1 LAKE UTILIZATION

Source of water and recreation (swimming, sport-fishing).

H2 THE LAKE AS WATER RESOURCE (1983)

	Use rate [$t\ yr^{-1}$]
Domestic water	29.7×10^6
Industrial water	5.2×10^6

I. DETERIORATION OF LAKE ENVIRONMENTS AND HAZARDS

I1 ENHANCED SILTATION

§ Present status : Not serious.

I2 TOXIC CONTAMINATION

§ Present status : Detected but not serious.

§ Main contaminants, their concentration and sources

Water treatment plant intake, 1979-1981 (fish) and 1987 (water)

Name of contaminants	Concentration [ng l^{-1}] in	
	Water [ng l^{-1}]	Fish* [ppb]
Lindane	0.08-0.16 (4)	
Alpha-BHC	0.39-0.42 (4)	
Mercury		0.2-0.5 (7)

* Wet weight basis. Pike, walleye muscle.

I3 EUTROPHICATION

§ Nuisance caused by eutrophication : Foul odour of tap water and disruption of recreational activities.

§ Supplementary notes

Despite the high flushing rate of Buffalo Pound Lake which resulted from the 1967 diversion of a considerable flow from Lake Diefenbaker, dense blooms of algae develop each summer as do dense littoral zone stands of higher aquatic plants.

I4 ACIDIFICATION

§ Extent of damage : None.

J. WASTEWATER TREATMENT

J1 GENERATION OF POLLUTANTS IN THE CATCHMENT AREA : (f) Measurable nutrient input mainly from natural sources with limited wastewater treatment.

J2 APPROXIMATE PERCENTAGE DISTRIBUTION OF POLLUTANT LOADS

	Percentage
Non-point sources	95
Point sources	
Municipal and domestic	5
Total	100

J3 SANITARY FACILITIES AND SEWERAGE

§ Municipal wastewater treatment systems

No. of primary treatment systems : 6 (primary lagoons).

No. of industrial wastewater treatment systems : None.

K. IMPROVEMENT WORKS IN THE LAKE

Water level control (1949) — construction of control dam. Water diversion from Lake Diefenbaker (1967).

M. LEGISLATIVE AND INSTITUTIONAL MEASURES FOR UPGRADING LAKE ENVIRONMENT

M1 NATIONAL AND LOCAL LAWS CONCERNED

§ Names of the laws (year of legislation)

(1) Water Resources Management (1972)
(2) Pollution (by livestock) Control Act (1971)
(3) Pest Control Products (Sask.) Act (1973)
(4) Canada Water Act (1970)

§ Responsible authorities

(1) Saskatchewan Environment
(2) Saskatchewan Environment
(3) Saskatchewan Environment
(4) Environment Canada

§ Main items of control

(1) Water pollution
(2) Livestock operations
(3) Use of pesticides on water bodies

M2 INSTITUTIONAL MEASURES

(1) Saskatchewan Environment (1972)
(2) Saskatchewan Water Corporation (1984)
(3) Canada/Saskatchewan Qu'Appelle Agreement (1974-1984)

M3 RESEARCH INSTITUTE ENGAGED IN THE LAKE ENVIRONMENT STUDY

(1) Region Water Research Institute, University of Regina

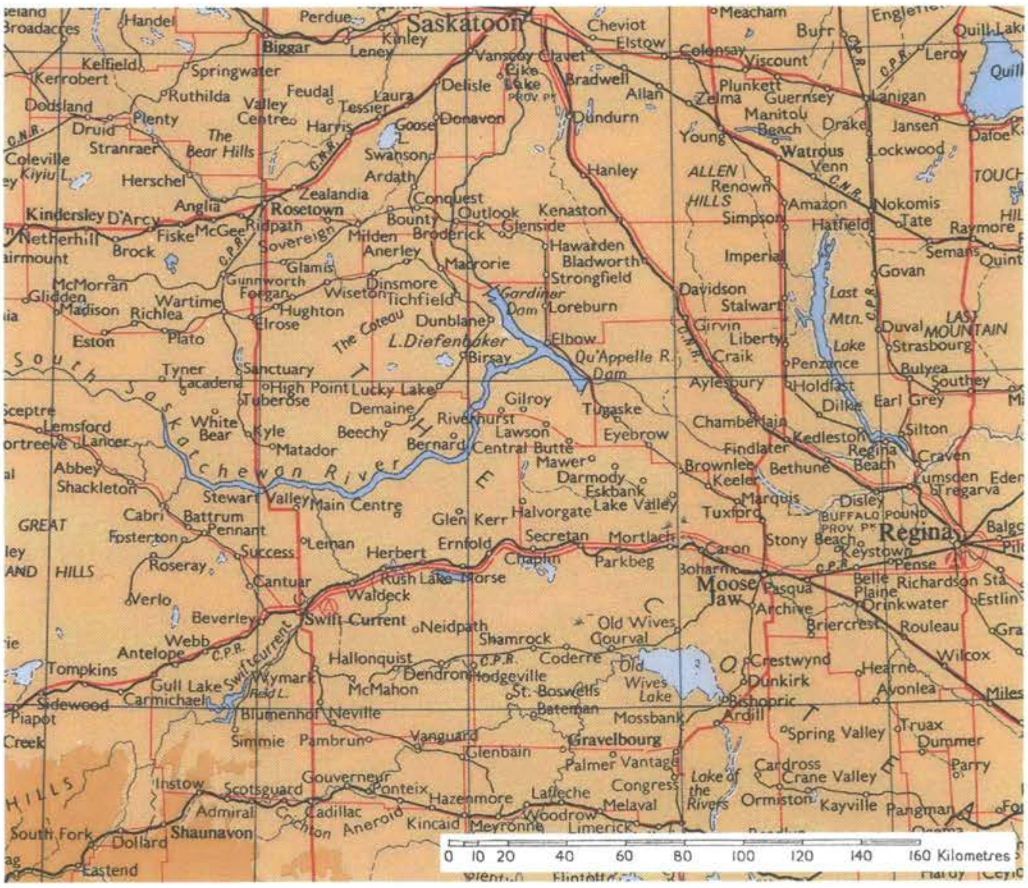
N. SOURCES OF DATA

(Q) Questionnaire filled by Dr. D. Munro, Conservation and Protection, Water Quality Branch, Environment Canada, Regina, Saskatchewan, Canada.
(1) Saskatchewan Water Corporation (1986) 1983 Operation of the Qu'Appelle River System. Resource Management Hydrology Service, Moose Jaw, Saskatchewan.
(2) Environment Canada, Atomospheric Environment Service. Canada Climate Normals, 1951 -1980. Winnipeg, Manitoba.
(3) Saskatchewan Department of Environment and Public Safety, Regina, Saskatchewan. Unpublished data.
(4) Environment Canada, Inland Waters Directorate, Regina, Saskatchewan. Unpublished data.
(5) Hammer, U. T. (1983) Limnological studies of the lakes and streams of the upper Qu'Appelle River systems, Saskatchewan, Canada. Hydrobiologia, 99 : 125-144.
(6) Saskatchewan Agriculture (1987) Agricultural Statistics 1986. Regina, Saskatchewan.
(7) Jackson, T. A. (1983) Mercury in the Qu'Appelle River System of Saskatchewan and Its Lakes and Tributaries. National Water Research Institute, Winnipeg, Manitoba.

LAKE DIEFENBAKER

An aerial view of outlet structures at lower end of the lake

Photo: Prairie Farm Rehabilitation Administration, Regina



A. LOCATION

§ Saskatchewan, Canada.
§ 50°40′-51°20′N ; 106°30′-108°15′W ; 556.8 m (full supply level) above sea level.

B. DESCRIPTION

Lake Diefenbaker is a large multi-purpose reservoir on the South Saskatchewan River in southern Saskatchewan. The reservoir was developed as a joint undertaking by the Canadian and Saskatchewan governments to provide for a wide range of uses including power production, flood control, irrigation, industrial water supply, recreation and augmentation of flows in the Qu'Applelle River by diversion through the Qu'Appelle Dam. The structures were designed and constructed by the Prairie Farm Rehabilitation Administration. Construction began in 1958 and the reservoir was filled in 1967.

Inflow to Lake Diefenbaker is primarily from the South Saskatchewan River which originates as the Oldman, Bow and Red Deer Rivers in the mountains of southwestern Alberta. These rivers drain much of southern Alberta which, except for the mountain regions, is mainly treeless prairie used for grain and livestock production. Approximately 75 % of the drainage to Lake Diefenbaker is in Alberta. The quality of water entering Lake Diefenbaker is generally very good and the lake represents a major source of high quality water in an area where water quality on other water bodies is generally poor, usually with high levels of minerals and nutrients. As a result a number of projects to draw drinking water for communities in southern Saskatchewan, including Regina and Moose Jaw, have been and are being examined.

The South Saskatchewan River traversed the sandy soils of the Missouri Coteau where Lake Diefenbaker is now situated and the valley is a deep, broad, strongly eroded meltwater channel cut 60 to 150 meters into the glacial deposits and underlying bedrock. In the upper reaches of the lake the deep valley is still evident. The recreational potential of the lake is significant, providing a healthy sport fishery, large sandy beaches and excellent boating. There are a number of cottage developments along its shores and three provincial parks (Q).

C. PHYSICAL DIMENSIONS (1)

Surface area [km²]	430
Volume [$10^9 m^3$]	9.4
Maximum depth [m]	66
Mean depth [m]	21.6
Normal range of annual water level fluctuation (regulated) [m]	7.5
Length of shoreline [km]	760
Residence time [yr]	2.5
Catchment area [km²]	135,500

D. PHYSIOGRAPHIC FEATURES

D1 GEOGRAPHICAL (1)

§ Sketch map (Fig. NAM-58-1).

§ Main islands : None.

§ Outflowing rivers and channels (number and names) : 3 (South Saskatchewan Qu'Appelle River Diversion, Saskatoon S. E. Water Supply System).

D2 CLIMATIC

§ Climatic data at Outlook*, 1951–1980 (2)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean temp. [°C]	-12.3	-6.9	-1.9	9.8	18.8	22.9	26.4	25.8	18.9	11.9	0.5	-7.1	8.9
Precipitation [mm]	15	13	17	17	28	65	53	37	32	15	9	14	315

* Approximately 25 km north of Gardiner Dam, the outlet of the lake.

§ Number of hours of bright sunshine at Swift Current* : 2,330 hr yr^{-1}.

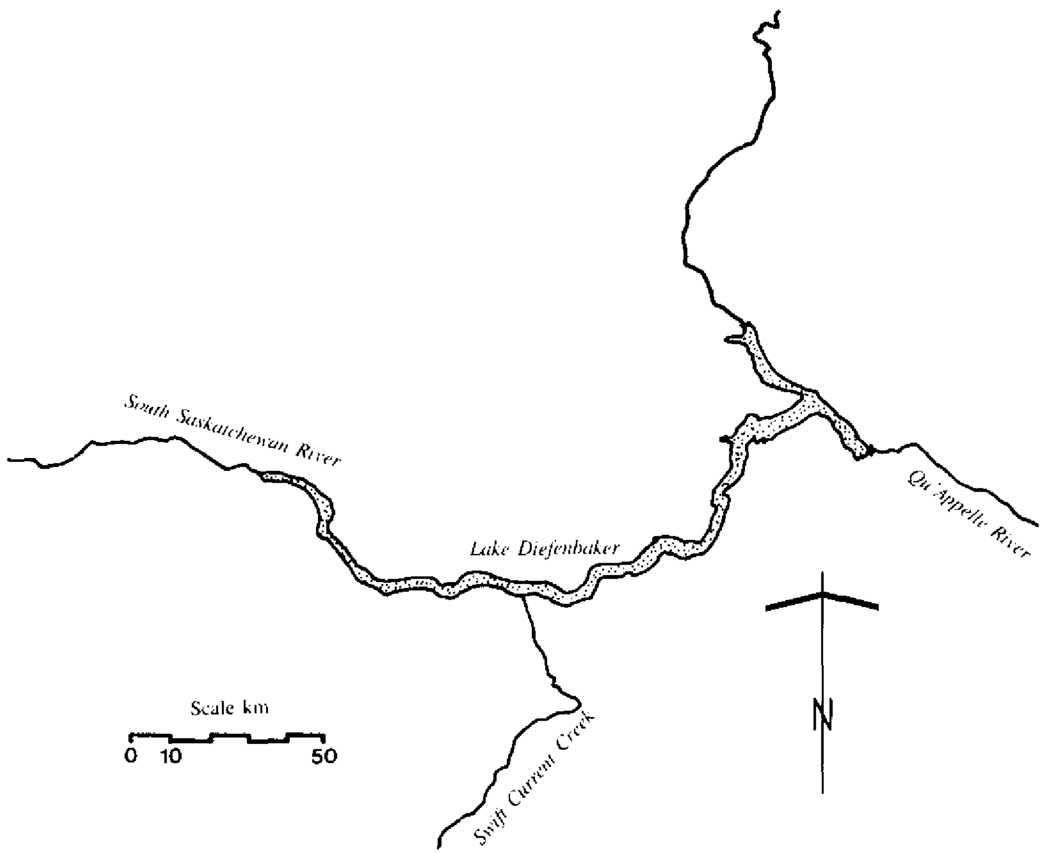
* Approximately 40 km south of the west (upstream) end of the lake.

§ Average solar radiation : 13.9 MJ $m^{-2}day^{-1}$.

Mean daily global solar radiation [MJ $m^{-2}day^{-1}$]

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
5.05	8.72	14.1	17.9	21.6	23.1	24.4	20.1	14.4	9.45	5.27	3.83

Fig. NAM-58-1 Sketch map of the lake (Q).



§ Water temperature [°C]
Riverhurst Ferry Crossing, 1984-1985 (1)

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	2	2	2	–	6	8	18	22	16	12	–	–
5	2	2	2	–	6	8	18	20	16	12	–	–
10	2	2	2	–	6	8	18	20	16	12	–	–
15	2	2	2	–	6	8	18	18	16	12	–	–
20	2	2	2	–	6	8	16	16	16	12	–	–
25	2	2	2	–	6	8	14	14	14	12	–	–
30	2	2	2	–	6	8	14	12	12	12	–	–
35	2	2	2	–	6	8	14	12	12	12	–	–

§ Freezing period : From Dec. 1 to Apr. 20.
§ Mixing type : Polymictic.
§ Notes on water mixing and thermocline formation
Thermocline develops in the deeper areas of the lake for varying lengths of time during summer months.

E. LAKE WATER QUALITY

E1 TRANSPARENCY [m]

Riverhurst Ferry*, 1984-1985 (1)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
–	–	–	–	2.2	2.0	3.1	6.5	6.5	4.6	–	–

* Approximately the mid-point of the lake.

E2 pH

Riverhurst Ferry, 1984-1985 (1)

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0-35	–	8.5	8.5	–	8.6	8.5	8.6	8.4	8.3	8.5	–	–

E3 SS [mg l^{-1}]

Non-filterable residue (particulate matter), Riverhurst Ferry, 1984-1985 (1)

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0-35	–	1	3	–	5	4	4	1	3	4	–	–

* Particulate matter or non-filterable residue.

E4 DO [mg l^{-1}]

Riverhurst Ferry, 1984-1985 (1)

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	–	12.1	11.0	–	10.1	–	9.2	8.6	9.1	9.1	–	–
5	–	12.0	11.1	–	10.1	–	9.4	8.6	9.2	9.0	–	–
10	–	12.0	11.0	–	10.1	–	9.1	8.0	9.0	9.2	–	–
15	–	12.1	11.0	–	9.0	–	8.6	8.2	8.9	9.1	–	–
20	–	10.8	11.0	–	10.0	–	8.4	8.1	7.8	9.0	–	–
25	–	10.1	10.1	–	10.1	–	8.7	6.1	5.9	9.0	–	–
30	–	8.4	8.6	–	10.1	–	8.5	4.5	4.4	9.1	–	–
35	–	6.9	7.4	–	10.0	–	8.5	2.7	3.1	9.0	–	–

E6 CHLOROPHYLL CONCENTRATION [$\mu g\ l^{-1}$]

Riverhurst Ferry, 1984-1985 (1)

Depth	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Integrated over 2×photic zone	1	1	1	–	–	5	2	3	1	1	–	–

Mean chlorophyll-*a* concentrations for the L. Diefenbaker Study (1984-1985) (1)

Sampling station	Seasonal means				Study period means
	Summer 1984	Fall 1984	Winter 1985	Spring 1985	
Danielson (downstream end)	<1	1	1	3	2
Riverhurst Ferry (mid-point)	2	1	1	5	2
Sask. Landing (upstream end)	6	7	1	12	6

E7 NITROGEN CONCENTRATION [mg l^{-1}]

§ Total-N

Riverhurst Ferry, 1984-1985 (1)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Integrated over 0-35 m	0.25	0.20	0.51	–	0.23	0.34	0.25	0.25	0.20	0.19	–	–

§ Mean Total Kjeldhl-N concentration, 1984-1985 (1)

Sampling station	Seasonal means				Study period means
	Summer 1984	Fall 1984	Winter 1985	Spring 1985	
Danielson	0.38	–	0.45	0.70	0.46
Riverhurst Ferry	0.47	0.54	0.54	0.51	0.52
Sask. Landing	0.77	0.74	0.99	0.63	0.81

E8 PHOSPHORUS CONCENTRATION [$\mu g\ l^{-1}$]

§ Total-P

Riverhurst Ferry, 1984-1985 (1)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Integrated over 0-35 m	12	12	15	–	9	8	20	8	30	8	–	–

§ Mean Total-P concentration, 1984-1985 (1)

Sampling station	Seasonal means				Study period means
	Summer 1984	Fall 1984	Winter 1985	Spring 1985	
Danielson	12	11	9	11	11
Riverhurst Ferry	14	20	11	12	14
Sask. Landing	49	30	31	35	39

F. BIOLOGICAL FEATURES

F1 FLORA

§ Phytoplankton (1)

Chlorophyta: *Actinastrum gracilimum, Ankistrodesmus falcatus, Chlamydomonas* sp., *Cladophora fracta, Closterium* sp., *Coelastrum cambricum, C. microporum, Cosmarium* sp., *Crucigenia apiculata, C. quadrata, C. tetrapedia, Dictyosphaerium pulchellum, D. simplex, Elaktothrix gelatinosa, Eudorina elegans, Gonium pectorale, G. sociale, Kirchneriella lunaris, K. obesa, Lagerheimia quadriseta, L. subsalsa, Monoraphidium contortum, Oocystis borgei, O. gigas, O. solitaria, Pandorina morum, Pediastrum boryanum, P. duplex, P. obtusum, P. simplex, P. tetras, Quadrigula chodatii, Scenedesmus acuminatus, S. arcuatus, S. bijuga, S. ecornis, S. quadricauda, Selenastrum* sp., *S. bibraianum, S. gracile, Spirogyra weberi, Staurastrum* sp.

Cyanophyta: *Anabaena flos-aquae, A. spiroides, Aphanizomenon flos-aquae, Aphanocapsa* sp., *Apahanothece* sp., *Chroococcus dispersus, C. limneticus, Coelosphaerium kuetzingianum, C. naegelianum, Gloeocapsa* sp., *Gomphosphaeria* sp., *G. aponina, Marssoniella elegans, Merismopedia elegans, M. glauca, Microcystis* sp., *M. aeruginosa, M. flos-aquae, Oscillatoria tenuis, Spirulina* sp.

Bacillariophyta: *Asterionella formosa, Centronella* sp., *Cocconeis pediculus, Cymatopeura* sp., *Cymbella* sp., *C. elongatum, Fragilaria crotonensis, Gomphonema* sp., *Gyrosigma* sp., *Melosira granulata, Meridion circulare, Navicula* sp., *Nitzschia* sp., *N. acicularis, N. linearis, Phoicosphenia curvata, Phopalodia gibba, Stephanodiscus astrea, Surirella* sp., *S. ovalis, S. ovata, Synedra* sp., *S. acus, S. ulna, Tabellaria fenestrata, Tropidoneis* sp.

Chrysophyta: *Dinobryon sertularia, D. sociale, Mallomonas* sp., *M. acardoides, Synura uvella, Tribonema utriculosum.*

Euglenophyta: *Euglena* sp., *Phacus* sp., *Trachelomonas.*, sp., *T. robusta.*

Pyrrophyta: *Ceratium hirundinella, Cryptomonas* sp., *Gymnodinium* sp., *Peridinium* sp., *P. cinctum, Rhodomonas* sp.

F2 FAUNA

§ Fish (3)

Esox masquinongy (northern pike), *Stizostedion canadense* (sauger), **S. vitreum* (walleye), *Hiodon alosoides* (goldeye), **Coregonus clupeaformis* (lake whitefish) (*economically important; whitefish for commercial fishery and walleye for sport fishing).

F5 FISHERY PRODUCTS

§ Annual fish catch in 1978: 91 [metric tons].

§ Fishery products other than fish: 4.1 tons of whitefish roe.

G. SOCIO-ECONOMIC CONDITIONS

G1 LAND USE IN THE CATCHMENT AREA (1976)

	Area [km²]	[%]
Natural landscape	30,200	20.1
Agricultural land		
Crop field	76,800	51.2
Pasture land (improved)	6,000	4.0
Others	N. A.	
Total	150,000 *	100

* Includes additonal ca. 13,000 km² of entire South Saskatchewan River basin.

§ Main kinds of crops and/or cropping systems: Wheat, mixed grains, hay.

§ Levels of fertilizer application on crop fields: Moderate.

G2 INDUSTRIES IN THE CATCHMENT AREA AND THE LAKE (1976) (4, 5)

	No. of persons engaged	No. of establishments	Main products and main kinds of industry
Primary industry	>90,000	25,700	Grains, cattle Whitefish
Secondary industry	29,700		Transportation, equipment, printing, wood products, metal fabrication, food & beverage

§ Numbers of domestic animals in the catchment area ($\times 10^3$) : Cattle 2,330, sheep 115, swine 427, poultry 4,330, horses 45.

G3 POPULATION IN THE CATCHMENT AREA (1976) (5)

	Population	Population density [km^{-2}]	Main cities
Urban	545		Calgary, Medicine Hat, Lethbridge, Red Deer
Rural	300		
Total	845	6.2	

H. LAKE UTILIZATION

H1 LAKE UTILIZATION

Source of water, navigation and transportation (ferry operation at Riverhurst), sightseeing and tourism, recreation (swimming, sport-fishing, yachting) and fisheries.

H2 THE LAKE AS WATER RESOURCES (1985) (6)

	Use rate [$t\ yr^{-1}$]
Domestic water	1×10^6
Irrigation	110×10^6
Industrial water	6×10^6
Power plant (downstream)	$1,340\times10^6$
Others	
Diversion to Qu'Appelle R.	142×10^6
SSEWS Project	50×10^6

I. DETERIORATION OF LAKE ENVIRONMENTS AND HAZARDS

I1 ENHANCED SILTATION

§ Extent of damage : Not serious.

I2 TOXIC CONTAMINATION

§ Present status : Detected but not serious.

§ Main contaminants, their concentrations and sources

Saskatchewan Landing (7, 8)

Name of contaminant	Range of concentration [ppm] in		Main source
	Water*	Fish**	
	(1985)	(1970-1985)	
2,4-D	<0.05-0.10	–	Agrochemical
Lindane	<0.002-0.010	–	〃
Mercury	–	0.23-1.57	Industrial & natural

* Volume basis [g l^{-1}].

** Muscle tissue of walleye, northern pike and goldeye [mg kg^{-1}] on wet weight basis.

§ Food safety standards or tolerance limits for toxic contaminant residue: 0.5 mg kg^{-1} Hg in fish for human consumption.

§ Past trends

Hg concentrations in fish tend to be declining. Sources of mercury believed to be a chlor-alkali plant in Saskatoon (downstream of Lake Diefenbaker) which no longer discharges Hg and is isolated from Lake Diefenbaker by Gardiner Dam and release of Hg from natural soil following filling of reservoir (9). Some of the fish with high mercury levels collected in Lake Diefenbaker, particularly in the 1970's, may have migrated from downstream of Saskatoon and been caught behind Gardiner Dam when it was closed.

I3 EUTROPHICATION

§ Nitrogen and phosphorus loadings to the lake [t yr^{-1}], 1975-1985 (mean) (1)

Sources	Total
T-N	–
T-P	1,230

§ Supplementary notes

Examination of 1984-1985 phosphorus and chlorophyll-*a* data using OECD model suggests that the upper end of the lake is mesotrophic or eutrophic while the remainder of the lake is mesotrophic or oligotrophic.

I4 ACIDIFICATION

§ Extent of damage: None.

J. WASTEWATER TREATMENTS

J1 GENERATION OF POLLUTANTS IN THE CATCHMENT AREA: (d) Measurable pollution with limited wastewater treatment.

J3 SANITARY FACILITIES AND SEWERAGE

§ Percentage of municipal population in the catchment area provided with adequate sanitary facilities (on-site treatment systems) or public sewerage: 100 % (5).

§ Municipal wastewater treatment systems

No. of tertiary treatment systems: 1 (Calgary, chemical removal of phosphorus).

No. of secondary treatment systems: 47 (lagoon systems).

M. LEGISLATIVE AND INSTITUTIONAL MEASURES FOR UPGRADING LAKE ENVIRONMENTS

M1 NATIONAL AND LOCAL LAWS CONCERNED

§ Names of the laws (the year of legislation)

(1) Water Resources Management Act (1972)

(2) Water Rights Act (1970)

(3) South Saskatchewan River Irrigation Act (1960)
(4) Pollution (by livestock) Control Act (1971)
(5) Prairie Provinces Water Board Master Agreement on Apportionment (1969)

§ Responsible authorities
(1) Saskatchewan Environment and Saskatchewan Water Corporation
(2) Saskatchewan Water Corporation
(3) Saskatchewan Water Corporation
(4) Saskatchewan Environment
(5) Prairie Provinces Water Board

§ Main items of control
(1) Water pollution
(2) Water supply
(3) Diversion of water for irrigation
(4) Waste pollution from livestock operations
(5) Water apportionment between provinces

M2 INSTITUTIONAL MEASURES (the year of establishment)
(1) Saskatchewan Environment, Regina, Sask. (1972)
(2) Saskatchewan Water Corporation, Moose Jaw, Sask.
(3) South Saskatchewan River Basin Study Board, Moose Jaw, Sask. (1986)

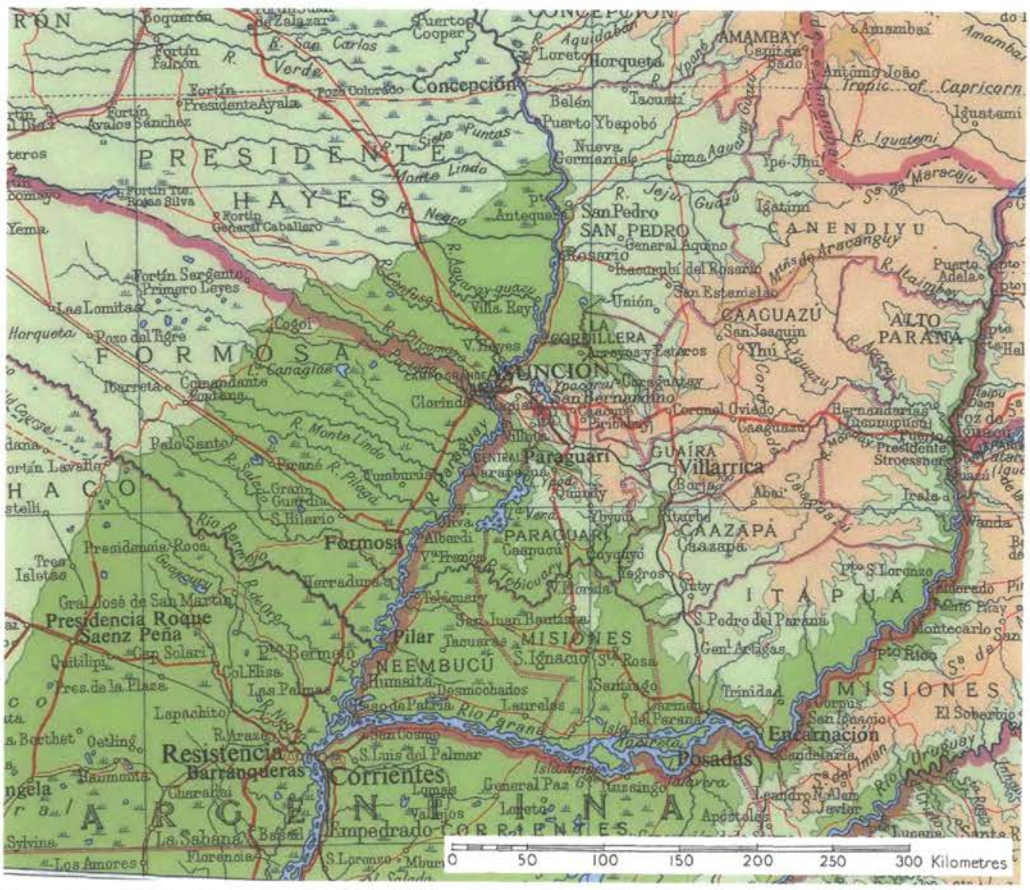
N. SOURCES OF DATA

(Q) Questionnaire filled by Dr. D. Munro, Water Quality Branch, Western and Northern Region Conservation and Protection, Environment Canada, Saskatchewan, Canada.
(1) Water Quality Branch Saskatchewan Environment and Public Safety & Water Quality Branch, Environment Canada (1988) Lake Diefenbaker and Upper South Saskatchewan River, Water Quality Study, 1984-1985. Regina, Saskatchewan.
(2) Atomospheric Environment Service, Environment Canada (1982) Canadian Climate Normals, 1951-1980, Prairie Provinces. Winnipeg, Manitoba.
(3) Prairie Provinces Water Board (1982) Water Demand Study: Historical and Current Water Uses in the Saskatchewan-Nelson Basin. Appendix 6: Environmental Considerations. Regina, Sask.
(4) Prairie Provinces Water Board (1982) Water Demand Study: Historical and Current Water Uses in the Saskatchewan-Nelson Basin. Appendix 3: Agricultural Water Use. Regina, Sask.
(5) Prairie Provinces Water Board (1982) Water Demand Study: Historical and Current Water Uses in the Saskatchewan-Nelson Basin. Appendix 2: Municipal and Industrial Water Uses. Regina, Sask.
(6) South Saskatchewan Basin Study Office (1986) South Saskatchewan River Basin Study News. November 1986. Moose Jaw, Sask.
(7) Water Quality Branch, Environment Canada, Regina. Unpublished data.
(8) Saskatchewan Parks, Recreation and Culture, Regina. Unpublished data.
(9) Harrison, J. T. & Waite, D. T. (1988) Mercury Survey of the Saskatchewan River System in Saskatchewan. Environmental Protection, Environment Canada, Regina, Sask., Report CP(EP) WNR 88/89-3.

LAGO YPACARAI

An aerial view of the whole lake

Photo: K. Nomura



A. LOCATION

§ Cordillera and Central, Paraguay.
§ 25°14′-25°22′S ; 57°17′-57°22′W ; 64.1 m above sea level.

B. DESCRIPTION

Lake Ypacarai is a shallow and swampy natural lake located some 30 km east of Asuncion, the capital of Paraguay. It has a surface area of approximately 60 km^2 and a maximum depth of 3 m. The catchment basin of 833 km^2 is largely covered by pastures and crop fields.

There are some 20 inflowing tributaries of various sizes, while only one river, Rio Slado, drains the lake joining the Paraguay River at about 20 km downstream. An extensive area of wetlands with luxuriant growth of emergent and submerged plants develops near the lake's outlet and maintains the lake water level effectively within a narrow range of fluctuation.

Since natural water bodies are particularly valuable for this flat inland country, Lake Ypacarai district offers one of the best sites for tourism and outdoor recreation in Paraguay, with abundant facilities for visitors and summer houses around the lake. The lake water is also used for drinking water supply and irrigation.

The lake has recently suffered from progressive eutrophication owing to the nutrient discharge from surrounding crop fields, livestock farms, residential areas, deforested lands and large-scale land development. An international multidisciplinary research project has been launched since 1987 by the national government to cope with this problem (Q, 1).

C. PHYSICAL DIMENSIONS (Q)

Surface area [km^2]	59.6
Volume [10^6m^3]	115.0
Maximum depth [m]	3.0
Mean depth [m]	2.0
Normal range of annual water level fluctuation (unregulated) [m]	0.17
Length of shoreline [km]	ca. 40
Residence time [yr]	0.22 (81 days)
Catchment area [km^2]	833

D. PHYSIOGRAPHIC FEATURES

D1 GEOGRAPHICAL

§ Bathymetric map (Fig. SAM-8-1).
§ Main islands : None.
§ Outflowing rivers and channels (number and names) : 1 (Rio Slado).

D2 CLIMATIC

§ Climatic data at Asuncion

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean temp. [°C]*	27.6	27.1	25.8	22.9	20.3	18.0	18.4	18.7	20.7	23.5	25.2	26.8	22.9
Precipitation [mm]**	161	146	143	159	118	74	47	54	82	125	146	141	1,396

* 1965-1988.
** 1950-1988.

§ Number of hours of bright sunshine : 2,530 hr yr^{-1}.

Fig. SAM-8-1 Bathymetric map (1).

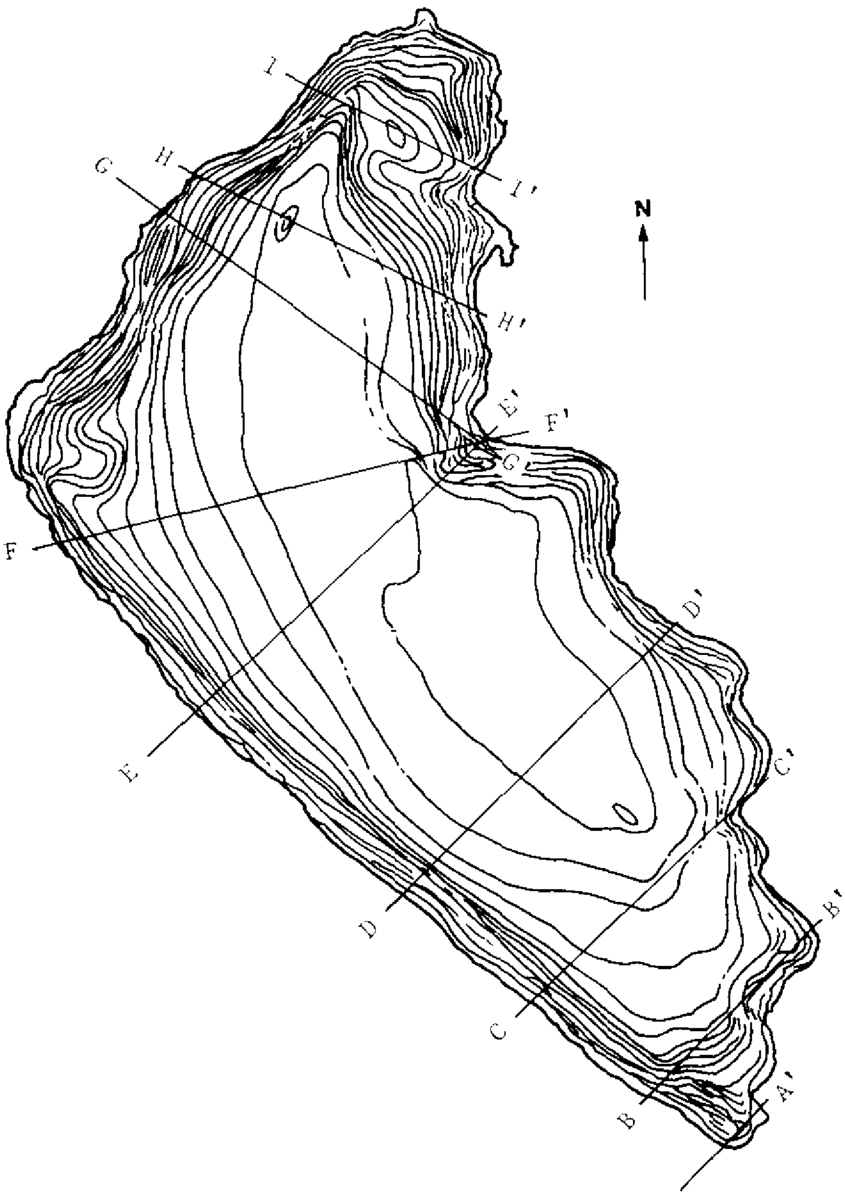
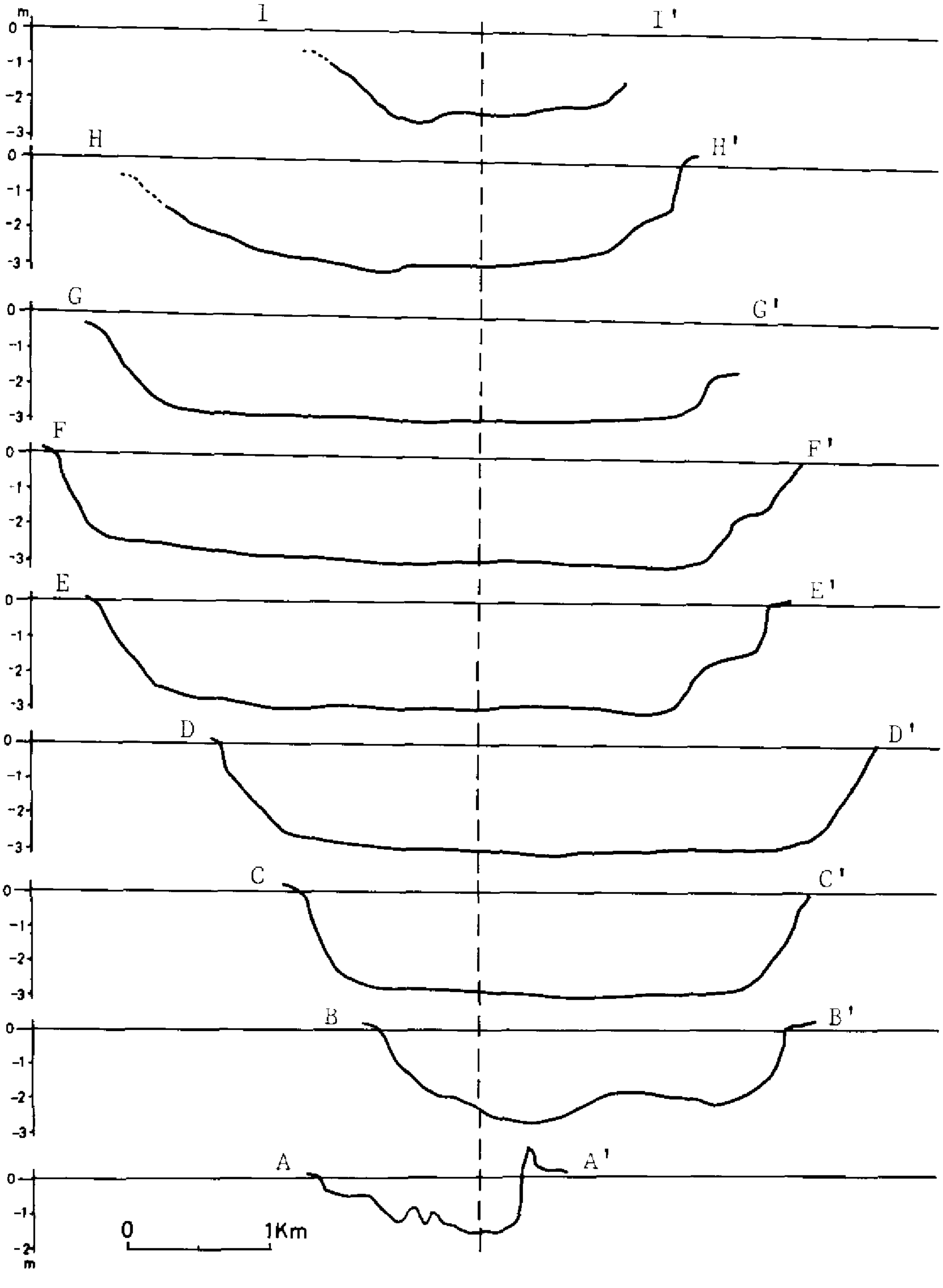


Fig. SAM-8-2 Depth profiles of the lake (1).



§ Water temperature [°C]

San Bernardino, Mar. 1988–Aug. 1988

Depth	Mar	Apr	May	Jun	Jul	Aug
Surface	28.4	23.7	19.4	16.1	15.5	18.5

§ Mixing type : Monomictic (occasionally polymictic).

E. LAKE WATER QUALITY (2)

E1 TRANSPARENCY [m]

Lake center, Feb.-Sep., 1984

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
–	0.08	0.08	0.15	0.07	0.07	0.08	0.06	0.15	–	–	–

E2 pH

Lake center, Feb.-Aug., 1984

Depth	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Surface	–	8.7	7.3	6.8	7.0	7.1	7.4	6.0	6.8	–	–	–

E3 SS [mg l^{-1}]

Lake center, Feb.-Aug., 1984

Depth	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Surface	–	–	74.4	–	–	77.0	33.1	69.1	–	–	–	–

E4 DO [mg l^{-1}]

Lake center, Feb.-Aug., 1984

Depth	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Surface	–	6.0	7.5	7.5	6.8	8.4	–	8.9	8.6	–	–	–

E5 COD [mg l^{-1}]

Lake center, Feb.-Aug., 1984

Depth	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Surface	–	10.3	12.7	12.3	12.4	15.7	12.0	15.5	–	–	–	–

Determined by $K_2Cr_2O_4$ method.

E7 NITROGEN CONCENTRATION

§ Total-N [mg l^{-1}]

Lake center, Feb.-Aug., 1984

Depth	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Surface	–	NSD	0.582	0.653	0.724	0.888	0.702	0.654	–	–	–	–

E8 PHOSPHORUS CONCENTRATION

§ Total-P [mg l^{-1}]

Lake center, Feb.-Aug., 1984

Depth	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Surface	–	0.230	0.273	0.148	0.295	0.276	0.259	0.268	–	–	–	–

F. BIOLOGICAL FEATURES (Q)

F1 FLORA

§ Emerged macrophytes : *Typha* sp., *Scirpus* sp., *Pontenderia rotundifolia*, *Philodendron undulatum*.

§ Floating macrophytes : *Hydrocleys nymphoides*, *Hydromystria* sp., *Nymphoides* sp.

§ Submerged macrophytes : *Cabomba* sp.

§ Phytoplankton

Anabaena spiroides, *Oscillatoria tenuis*, *Phormidium tenue*, *Melosira granulata*, *M. granulata* f. *spiralis*, *M. granulata* var., *Ankistrodesmus falcatus*.

F2 FAUNA

§ Zooplankton

Keratella valga, *K. americana*, *K. cochlearis*, *Daphnia* sp., *Bosmina longirostris*, *Bosmina* sp., *Diaptomus* sp..

§ Benthos

Hirudinea sp., *Hexagenia* sp., *Dero cooperi*, *Ablabesmyia* sp., *Micropsectra* sp., *Microtendipes* sp., *Paratendipes* sp., *Polypedilum* sp., *Procladius* sp., *Pseudochironomus* sp., *Pheotanytarsus* (?) sp., *Tanypus* sp.

G. SOCIO-ECONOMIC CONDITIONS (Q)

G1 LAND USE IN THE CATCHMENT AREA (1988)

	Area [km^2]	[%]
Natural landscape		
Woody vegetation	117.7	14.1
Herbaceous vegetation	35.3	4.3
Swamp	2.2	0.3
Agricultural land		
Crop field	240.5	28.9
Pasture land	302.0	36.2
Settlement area	135.2	16.2
Total	833.0	100

§ Main kinds of crops : Cotton, cassava, sugar cane, vegetables.

§ Levels of fertilizer application on crop fields : Light.

§ Trends of change in land use in recent years : Deforestation, cultivation and urbanization have rapidly proceeded in the western part of the catchment area.

G2 INDUSTRIES IN THE CATCHMENT AREA AND THE LAKE

	No. of persons engaged	No. of establishments	Main products or major industries
Primary industry			
Crop production	3,000	4	
Animal husbandry	50	4	
Secondary industry	—	—	Vegetable oil refinery, butchery, sausage, noodle, juice

§ Number of domestic animals in the catchment area : Cattle 61,100, sheep 1,800, swine 14,600, horses, goat, donkey and mule.

G3 POPULATION IN THE CATCHMENT AREA (1982)

	Population	Population density [km^{-2}]	Main cities
Total	207,326	249	Aregua, Capiata, Itaugua Lugue, San Lovenzo, Ypacarai, San Bernardino, Pirayu

H. LAKE UTILIZATION (Q)

H1 LAKE UTILIZATION

Source of water, sightseeing and tourism and recreation (swimming and yachting).

H2 THE LAKE AS WATER RESOURCE (1987)

	Use rate [m^3 day^{-1}]
Domestic water (winter)	700
(summer)	2,000

I. DETERIORATION OF LAKE ENVIRONMENTS AND HAZARDS (Q)

I1 ENHANCED SILTATION

§ Extent of damage : Serious.

§ Supplementary notes

Lake water is always turbid with suspended silt and clay derived from roads and cultivated lands. Therefore, purification process for potable water takes time.

I2 TOXIC CONTAMINATION

§ Present status : Detected but no minute data.

§ Main contaminants (1988)

Name of contaminants	Water [ppm]
T-Fe	0.38
T-Mn	0.017

§ Environmental quality standards for contamination in the lake : Under consideration.

I3 EUTROPHICATION

§ Nuisance caused by eutrophication : Unusual algal bloom (*Anabaena*, *Microcystis*).

§ Nitrogen and phosphorus loadings to the lake [kg day^{-1}] (1988)

Sources	Industrial and Domestic	Agricultural	Total
T-N	652	1,426	2,078
T-P	120	712	832

§ Supplementary notes

Trends of eutrophication in recent years are not clarified due to the lack of monitoring of water quality in the lake and rivers, though monthly observations of certain water quality items were made in 1982 and 1984. Countermeasures for water quality degradation are still under consideration.

J. WASTEWATER TREATMENTS

J1 GENERATION OF POLLUTANTS IN THE CATCHMENT AREA : (e) Severe pollution with little wastewater treatment.

J2 APPROXIMATE PERCENTAGE DISTRIBUTION OF POLLUTANT LOADS (3)

	Point source [%]		Non-point source [kg yr^{-1}]
	Domestic	Industrial	Domestic animal and siltation
COD	52	44	9.8×10^6
T-N	78	15	370×10^3
T-P	65	30	94×10^3
SS	—	—	20×10^6

J3 SANITARY FACILITIES AND SEWERAGE (Q)

§ Percentage of municipal population in the catchment area provided with adequate sanitary facilities (on-site treatment systems) or public sewerage: 98.6 %.

§ Percentage of rural population with adequate sanitary facilities (on-site treatment systems): 97.4 %.

§ Municipal wastewater treatment systems

No. of tertiary treatment systems: 0.
No. of secondary treatment systems: 0.
No. of primary treatment systems: 1.
No. of other types: 0.

§ Industrial wastewater treatment systems: 2-4 (oxidation pond).

K. IMPROVEMENT WORKS IN THE LAKE

None (Q).

L. DEVELOPMENT PLANS

Under consideration (Q).

M. LEGISLATIVE AND INSTITUTIONAL MEASURES FOR UPGRADING LAKE ENVIRONMENTS (Q)

M1 NATIONAL AND LOCAL LAWS CONCERNED

§ Names of the laws

(1) Sanitation Act (Law No. 836) (1980)
(2) Presidential Ordinance No. 18831 (1986)

§ Responsible authorities

(1) Ministry of Public Health and Social Welfare

§ Main items of control: Not yet decided

M2 INSTITUTIONAL MEASURES

(1) National Environmental Sanitation Service, Asuncion

M3 RESEARCH INSTITUTES ENGAGED IN THE LAKE ENVIRONMENT STUDIES

(1) National Institute for Technology and Standards, Asuncion
(2) Institute of Basic Science, Asuncion National University

N. SOURCES OF DATA

(Q) Questionnaire filled by Mr. K. Nomura, Shiga Prefectural Institute of Public Health and Environmental Science, Otsu, Japan.
(1) Nomura, K., personal communication.
(2) After Estudio Limnologico del Lago Ypacarai by ICB, Univ. Nac. Asuncion.
(3) Nakajima, K. (1990) The study on water pollution control plan for the Lake Ypacarai and its basin. Water Pollution Research (Suishitsu Odaku Kenkyû), 13(7): 20-23 (in Japanese).

LAGUNA DE ROCHA

Northern part of the lagoon with *Spartina* marsh in the background

Photo: R. Sommaruga

A. LOCATION

§ Rocha municipality, Uruguay.
§ 34°33′-34°41′S, 54°12′-54°22′W ; Nearly 0 m above sea level.

B. DESCRIPTION

Urguay has several coastal lagoons in the southeastern and eastern part of the country. Many of them, including Laguna de Rocha, are comprised in the Biosphere Reserve designated by Man and the Biosphere Program (MAB) of UNESCO.

Like most recent lagoons, Laguna de Rocha was formed through the rise of sea level during the last 6,000-8,000 years. It is separated from the Atlantic Ocean by a sand bar, which is sometimes opened by wave action and thixotropy as well as artificially. The intrusion of salt water during open-bar periods produces a clear gradient of salinity that controls physical and chemical water parameters. There are five inflowing rivers, of which the Arroyo Rocha (average flux 13.4 m^3 sec^{-1}) and the Las Conchas are the most important. This lagoon is known for its production of fish, crab, shrimp and molluscs harvested by fisherman families living on its southern shore.

The Limnology Department, Faculty of Sciences, Univ. de la República, has been studying the lagoon system since 1986 and is currently constructing a limnology station which is expected to serve also as an operative center for researches on other coastal lagoons.

C. PHYSICAL DIMENSIONS (1)

Surface area [km^2]	72
Volume [$10^6 m^3$]	40
Maximum depth [m]	1.40
Mean depth [m]	0.58
Catchment area [km^2]	1,312

D. PHYSIOGRAPHIC FEATURES

D1 GEOGRAPHICAL

§ Bathymetric map (Fig. SAM-9-1).

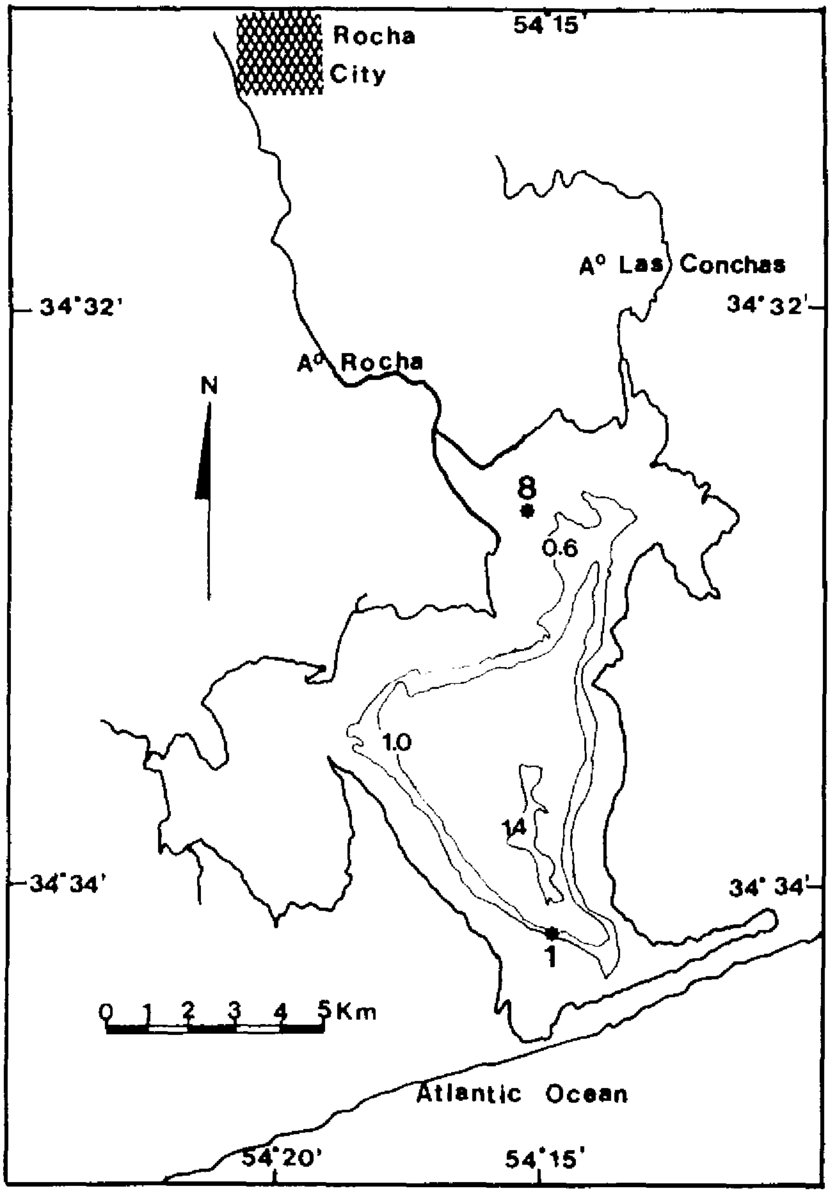
D2 CLIMATIC (2)

§ Climatic data at Rocha city, 1951-1980

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean temp. [°C]	21.5	21.3	19.9	16.4	13.7	11.2	10.9	11.2	12.6	14.8	17.4	20.2	15.9
Precipitation [mm]	98	102	87	81	78	97	96	102	109	92	70	61	1,073

§ Average solar radiation, 1979-1984 : 14.3 MJ m^{-2} day^{-1}.

Fig. SAM-9-1 Bathymetric map [m] (Q).



§ Water temperature [°C] (2)
Mean value for all stations, 1987 (*1988)

Depth [m]	Jan	Feb*	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Surface	25.1	25.0	22.8	18.3	12.5	–	12.9	8.9	15.6	18.7	25.4	18.6

§ Freezing period : None.
§ Mixing type : Polymictic.

E. LAKE WATER QUALITY (2)

E1 TRANSPARENCY [m]
Secchi disc usually reaches bottom surface.

E2 pH
Station 1 and 8, 1987 (*1988)

Depth [m]	Station	Jan	Feb*	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Surface	1	7.9	8.3	8.4	7.9	7.9	–	7.7	7.9	8.0	7.9	8.4	8.1
Surface	8	8.0	6.5	6.7	6.7	7.7	–	7.1	6.9	7.4	6.9	9.0	6.8

E3 SS [mg l^{-1}]
Station 1 and 8, 1987 (*1988)

Depth [m]	Station	Jan	Feb*	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Surface	1	8.0	10.6	11.6	11.0	24.2	–	0.0	20.2	8.1	10.0	6.7	11.5
Surface	8	3.0	65.0	49.4	32.0	18.3	–	0.8	72.9	36.0	36.8	17.0	45.5

E4 DO [mg l^{-1}]
Station 1 and 8, 1987 (*1988)

Depth [m]	Station	Jan	Feb*	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Surface	1	6.4	7.5	7.7	8.8	9.2	–	9.8	10.0	10.0	8.9	–	9.4
Surface	8	8.2	3.5	6.0	6.7	9.6	–	8.8	10.0	9.4	9.4	–	8.4

E6 CHLOROPHYLL CONCENTRATION [$\mu g\ l^{-1}$] (3)
Station 1 and 8, Dec. 1988-Nov. 1989

Depth [m]	Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Surface	1	15.7	16.7	15.8	9.3	9.1	11.3	12.0	8.9	8.0	8.0	12.8	23.1
Surface	8	12.9	14.3	11.0	21.1	6.2	8.8	14.7	13.2	10.9	16.1	24.3	56.1

E7 NITROGEN CONCENTRATION
§ NO_3-N [mg l^{-1}] (2)
Station 1 and 8, 1987

Depth [m]	Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Surface	1	0.10	–	0.36	0.10	0.17	–	0.14	0.19	–	–	–	0.17
Surface	8	0.80	–	0.20	0.11	0.17	–	0.08	0.19	–	–	–	0.27

§ NH_4-N [mg l^{-1}] (2)
Station 1 and 8, 1987

Depth [m]	Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Surface	1	0.05	–	0.00	0.19	0.04	–	0.15	0.03	–	–	–	0.03
Surface	8	0.03	–	0.35	1.32	0.01	–	0.04	0.04	–	–	–	0.27

E8 PHOSPHORUS CONCENTRATION

§ Total-P [μg l^{-1}] (2)
Station 1 and 8, 1987

Depth [m]	Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Surface	1	0	–	42	67	83	–	21	25	3	249	10	–
Surface	8	199	–	63	226	74	–	46	27	35	151	80	–

E9 SALINITY [%] (1)

Station 1 and 8, 1987 (*1988)

Depth [m]	Station	Jan	Feb*	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Surface	1	9.0	7.5	13.7	27.7	15.3	–	7.4	8.0	19.2	5.8	8.5	7.0
Surface	8	0.0	1.0	0.0	0.2	2.7	–	1.0	0.0	1.3	3.0	0.0	0.0

F. BIOLOGICAL FEATURES

1987-1989

F1 FLORA

§ Emerged macrophytes

Scirpus californicus, *Spartina montevidensis*, *Typha latifolia*, *Sagittaria montevidensis*, *Ludwigia peploides*, *L. gramineans* (3).

§ Floating macrophytes : *Eichhornia azurea* (3).

§ Submerged macrophytes : *Potamogeton* sp. (3).

§ Phytoplankton

Melosira sp., *Navicula* sp., *Diploneis* sp., *Amphiprora* sp., *Nitzchia* sp., *Cymbella* sp., *Stephanodiscus* sp., *Coscinodiscus* sp., *Peridinium* sp., *Oscillatoria* sp., *Aphanothece* sp., *Anabaena* sp., *Mallomonas* sp., *Spirogyra* sp., *Pandorina* sp., *Eudorina* sp. (4).

F2 FAUNA

§ Benthos

*Erodona mactroides**, *Heleobia australis*, *Laeonereis culveri*, *Nephtys fluviatilis*, *Heteromastus simi*, *Balanus improvisus*, *Tanais stanfordi*, *Dies fluminensis*, *Melita mangrovi*, *Amphitoe ramondi*, *Chasmagnatus granulata*, *Cyrtograpsus angulatus*, *Callinectes sapidus**, *Palemonetes argentinus*, *Penaeus paulensis** (*economically important) (5).

§ Fish

*Micropogonias furnieri**, *Pogonias chromis**, *Mugil* spp., *Paralichthys brasiliensis*, *Brevoortia* sp.* (*economically important) (1).

§ Supplementary notes on the biota

A very important population of *Cygnus melancorhphus* (black neck swan) exists in the lagoon. A maximum number of 7,066 individuals was found in 1986. Also important is *Coscoroba coscoroba* (endemic) (6).

F3 PRIMARY PRODUCTION RATE

§ Phytoplankton gross production [mg C l^{-1} hr^{-1}]
Station 1 and 8, Dec. 1988-Nov. 1989

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	1.31	0.99	0.83	0.94	0.11	0.10	0.11	0.12	0.19	0.26	0.18	0.26
8	1.02	0.99	0.78	0.63	0.03	0.07	0.09	0.11	0.19	0.11	0.12	0.07

F4 BIOMASS

§ *Erodona mactroides* [g dry weight m^{-2}]

Station	Winter	Spring	Summer	Fall
1	10.48	32.34	26.45	53.9
8	12.99	45.95	59.57	37.8

G. SOCIO-ECONOMIC CONDITIONS

G1 LAND USE IN THE CATCHMENT AREA (1976)

	Area [km^2]*	[%]
Natural landscape		
Woody vegetation	552	6.0
Agricultural land		
Crop field	215	2.4
Pasture land	8,385	91.6
Total	9,153	100

* Data based on the total area of Rocha municipality (10,551 km^2).

§ Types of important forest vegetation : Gallery forest along rivers and *Eucalyptus* sp. (non-native).
§ Main kinds of crops : Rice and maize.

G2 INDUSTRIES IN THE CATCHMENT AREA AND THE LAKE

§ Number of domestic animals in the catchment area : Cattle 477,649, sheep 1,155,604.

G3 POPULATION IN THE CATCHMENT AREA (1985) (8)

	Population	Population density [km^{-2}]	Main cities (population)
Urban	56,200		Rocha (25,200)
Rural	12,300		
Total	68,500	6.5	

H. LAKE UTILIZATION (Q)

H1 LAKE UTILIZATION

Sightseeing, tourism and fisheries.

I. DETERIORATION OF LAKE ENVIRONMENTS AND HAZARDS (Q)

I1 ENHANCED SILTATION

§ Extent of damage : None.

I2 TOXIC CONTAMINATION

§ Present status of toxic contamination : No information but not suspected.

I4 ACIDIFICATION

§ Extent of damage : None.

J. WASTEWATER TREATMENTS

J1 GENERATION OF POLLUTANTS IN THE CATCHMENT AREA : (b) No sources of significant pollution.

J3 SANITARY FACILITIES AND SEWERAGE

§ Percentage of municipal population in the catchment area provided with adequate sanitary facilities (on-site treatment systems) or public sewerage : 94.9 %.

L. DEVELOPMENT PLANS

Continuation of a highway crossing the southern part of the lagoon is planned for the next year (1991) and an ecological hotel will be built in the near future.

M. LEGISLATIVE AND INSTITUTIONAL MEASURES FOR UPGRADING LAKE ENVIRONMENTS (Q)

M1 NATIONAL AND LOCAL LAWS CONCERNED

§ Names of the laws (the year of legislation)

(1) Law of water quality control (1979)

§ Responsible authorities

(1) National Office of Environmental Health

§ Main items of control

(1) Industrial and domestic wastewater effluents

M3 RESEARCH INSTITUTES ENGAGED IN THE LAKE ENVIRONMENT STUDIES

(1) Department of Limnology, Faculty of Sciences, Univ. de la República.

N. SOURCES OF DATA

(Q) Questionnaire filled by Drs. L. W. Pintos and L. R. Sommaruga, Department of Limnology, Faculty of Sciences, Univ. de la República, Urguay.

(1) Pintos, L. W., Sommaruga, L. R., Conde, D., de León, R. & Chalar, G. (1988) Antecedents and New Contributions to the Knowledge of Laguna de Rocha. Progress Report, Univ. de la República, Uruguay.

(2) Pintos, L. W., Sommaruga, L. R., Conde, D., de León R. & Chalar, G. (in preparation) Seasonal variation of physical and chemical parameters of Laguna de Rocha.

(3) De León, R. (in preparation) Primary productivity in two zones of Laguna de Rocha.

(4) ——, personal communication.

(5) Pintos, W., Conde, D., de León, R., Cardezo, M. J., Jorcin, A. & Sommaruga, R. (in press) Some limnological characteristics of Laguna de Rocha (Uruguay). Rev. Bio. Bras.

(6) Vaz Ferreira, R., Rilla, F., Gambarotta, J. C., Arbella, E. & Skuk, G. (1987) Ornithologic importance of the East wetlands of Uruguay. III Neotropical Ornithol. Cong., Columbia.

(7) Jorcin, A. (1989) Ecological studies on *Erodona mactroides* (Daudin, 1801) of Laguna de Rocha. Graduate Thesis, Univ. de la República, Uruguay.

(8) General Office of Statistics (1986) Statistic Data Book of Uruguay.

(All references in Spanish except for (5)).