GREAT BEAR LAKE

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A. LOCATION

Administrative district: *Mackenzie District of the Northwest Territories.*
Latitude and longitude: *65° - 67 °' N 118 ° - 125 ° W*
Altitude: *156 m above sea-level*

Fig. 1. Great Bear Lake

B. INTRODUCTORY DESCRIPTION OF THE LAKE

Located on the Arctic Circle (66° 30'N) Great Bear Lake is the largest lake within the borders of Canada. With its almost equally large companion, Great Slave Lake, and their combined drainage, the Mackenzie River, this water system completely dominates the geography of the Mackenzie District of the Northwest Territories.

Great Bear Lake lies across the junction between two major physiographic regions: the Kazan portion of the Canadian Shield and the Interior Plains [1]. Originally formed by the broadening and deepening of preglacial valleys by erosional effects of ice during the Pleistocene [2], the lake has subsequently been altered by changes in the land form resulting from rebound following melting of the ice.

Precambrian rocks of the Shield form the eastern margin of McTavish Arm [3]. This region of the lake has magnificent scenery amongst the many islands and long fjord-like indentations of the coastline. The complex rocks of the Precambrian are made up of sedimentary and metamorphic deposits supplemented by igneous intrusions forming dykes and sills [4,5,6,7]. Between the Shield and the Interior Plains region which forms most of the western shoreline, there is a narrow band of Ordovician rocks composed of limestone and dolomite with sandstone and conglomerate inclusions [8]. The Great Bear Plain [8,9] is largely composed of glacial till underlain with Mesozoic strata of undivided limestone. The terrain in this region is gently rolling, generally below 300 m in elevation with occasional hills such as Grizzley Bear Mountain or the Scented Grass Hills reaching an elevation of 450 m.

At the height of the most recent glaciation the majority of the land to the east of the Mackenzie River was covered by the Laurentide ice-sheet, but an unglaciated region is known to have existed to the west of Great Bear Lake along the front dividing the Laurentide from the Cordilleran ice-sheets [10]. About 10,000 y B.P. the ice-margin approximately coincided with the Shield boundary [11]. The ice-sheet crossed the basic northward slope of the land blocking drainage thus giving rise to the very large proglacial lake, Glacial Lake McConnell, covering the area now occupied by both Great Bear and Great Slave Lakes and the land between them [12,13]. This immense lake drained to the south-east; its strand-lines, still visible 145 m above the present level of Great Bear Lake, attest to its original size. With the retreat of the ice the land rebounded unequally causing a noticeable tilt to the strand-lines and the formation of an outlet at the western end of what is now Smith Arm. As the land surface continued to change the outlet switched from this region to its present location at the western end of Keith Arm. Archaeological evidence suggests this outlet was established by about 4000 B.P., some 12 m above the present lake level. Further archaeological evidence indicates that the present lake level had been established by about 2600 B.P. [14,15].

At the present time Great Bear Lake occupies a position close to the northern limit of trees. To the south and west are forests, largely of black and white spruce interspersed with muskeg in the lower-lying poorly drained regions. To the north the forest declines giving way to tundra with trees in the more sheltered areas only.

In Pre-European times the area was occupied by various Indian tribes of the Athapascan language group: the Hares on the north-western shore, Slaveys and Mountain people in the vicinity of Bear River, Dogribs along the southern-eastern shores and Copper Indians in the east, together making up a group recognised as the Satudene [15,16]. The northern shores of the lake were occasionally visitied by the Inuit on hunting forays from the Coronation Gulf region.

The lake was named by Alexander MacKenzie during his pioneering voyage to the Arctic Ocean in 1789, although he did not actually visit the lake himself. It seems possible that the name "Great Bear Lake" results from a mistranslation of the Dene Indian word for "grizzley bear" i.e. literally, "great bear". The name most likely originates from Grizzley Bear Mountain, between Keith and McVicar Arms, which resembles a sleeping giant grizzley bear, rather than a preponderance of grizzley bears in the vicinity. Presumably the Dene named the lake after this feature. Great Bear Lake has subsequently appeared appropriate on account of the lake's great size, in harmony with its sister lake, Great Slave Lake.

The first European penetration was the establishment of a fur-trading post by the Northwest Fur Company in 1799 [17,18]. After a time this, and a second post established by the rival XY Company, were abandoned so that little remained of the original occupancy when Sir John Franklin's advance party arrived in 1825 to set up the winter base (Fort Franklin) for Franklin's second Arctic expedition. In the spring of 1826 Dr. Richardson, surgeon and naturalist to the party, in company with Lieutenant Kendall, carried out the first survey of the lake by dog-team. The five 'arms' were named after members of the Hudson Bay Company who had helped the Franklin Party in this or their previous expedition: Chief Traders Dease, McTavish and McVicar and Chief Factors Smith and the brothers James and George Keith.

Following the survey Lt. Kendall carried out interesting investigations on the relationship between the speed of sound and air temperature using the flat ice-surface as his base line of observation. Values remarkably close to those accepted today were obtained.

As soon as open water permitted, Dr. Richardson sailed down the Mackenzie River by canoe, moving eastward along the coastline to the Coronation Gulf, returning up the Coppermine River and pioneering a new route across the Dismal Lakes portage, down the Dease River and across Great Bear Lake to Fort Franklin. For the next fifty years or so the Dease-Dismal Lakes-Coppermine route provided the main access to the Central Arctic.

Initial geological investigations in the region were carried out in 1898 by Dr. J. Mackintosh Bell and Charles Camsell [19]. They noted the possibility of valuable metal ores on the eastern shores of McTavish Arm [19]. In 1903, E.A. Preble entered the region *via the Camsell River, a route pioneered by Charles Camsell a year or two earlier [20]. Preble [21] collected birds and fishes along the south sides of McTavish and Keith Arms, adding considerably to the natural history of the region. In 1930 Gilbert LaBine staked claims for silver and cobalt at Echo Bay. A mine was established but it was found that the associated pitchblende deposits had the relatively high radium content of 1 g/6.5 tons of ore [22]. The uranium ore was discarded as of little commercial value. With the advance of physics the demand for radium declined, production became unprofitable and the mine was closed in 1940. However, the mine was re-opened in 1942 by Eldorado Mining and Refining Company to supply uranium for the Manhatten Project. Quantities of uranium were to be found in the tailings from the radium extraction process which, having previously been dumped in the lake, were recovered by dredging. This mine was closed in 1964 but certain workings were maintained for the extraction of silver by Echo Bay Mines Ltd.*

The first biological survey of the lake, sponsored by the Fisheries Research Board of Canada, was carried out by Miller and Kennedy in 1945 [23,24,25]. The primary aim of this survey was to determine the possibility of establishing a commercial fishery on the lake. Miller and Kennedy sampled fish stocks, collected speciments and made limnological observations along the southern reaches of the lake. They concluded that a commercial fishery was not feasible on account of the low density and slow growth of the fish present. They also established the region of deepest water off Port Radium, saving the mine from possible tragedy by alerting the manager to the possibility that one of the shafts might penetrate the lake bottom if continued.

Apart from the domestic fishery of the people of Fort Franklin and attempts at a small scale commercial fishery for local supply, the lake has been reserved for angling. The great attraction is the relatively large number of very large lake trout. Between 1958 and 1964 four sport fishing lodges were established, one each at Sawmill Bay, Hloo Channel at the entrance to Cunjuror Bay, Cameron Bay close to Port Radium and on Cornwell Island in the McAlpine Channel. A fifth lodge was established in the late 1960's in Ford Bay at the western end of Smith Arm. Further development of sport fishing has been considered undesirable if stocks of lake trout are to be maintained.

Between 1963 and 1965 the Fishereis Research Board carried out a more detailed biological and limnological survey [26,27,28]. This three-year programme utilized the former mine tugboat M.V. Radium Gilbert as the survey ship. The relatively large size of this vessel enabled a bathymetric survey to be made as well as detailed investigations of temperature structure in the deepest regions. These investigations have had bearing on theoretical aspects of lake circulation and the temperature of maximum density of fresh water with increasing pressure [29,30]. Observations on fish, plankton and benthos distribution and density also were made.

Apart from noticeable changes in the mean size of the lake trout population [31] Great Bear Lake remains largely unaltered by human activity. At the present time it is probably the largest lake in the world to exist in a relatively pristine condition.

The northerly latitude of Great Bear Lake, combined with its great volume and immense heat budget (40,600 cal cm^{-2}) [26], ensure that it has many of the characteristics of a polar lake although in a northern continental setting. This appears to account for anomalies with respect to the fish species complement. Despite the general correlation between increasing lake size and increasing species richness [32] when the effect of latitude is removed, Great Bear Lake exhibits the opposite effect: fewer species in the lake than might be expected and fewer species in the lake than exist within the drainage basin as a whole. This is manifest in several ways: 1) all species except lake trout Salvelinus namaycush and deep-water sculpin Myoxocephalus quadricornis are confined to the warmer shallower more secluded bays, 2) certain species occurring both upstream and downstream of the lake do not occur in the lake itself (lake chub Couesius plumbeus and troutperch Percopsis omiscomaycus) and 3) other species occur in only very limited locations (walleye Stizostedion vitreum) or at very small size (relative to neighbouring lakes) and at very few locations (Burbot Lota lota). This is a very clear-cut case of environmental exclusion.

C. PHYSICAL DIMENSIONS

Surface area:	31,153	km^2	[26]
Volume:	2,236	Km^3	
Maximum depth:	446	m	[34]
Mean depth:	71.7	m	[26]

Normal range of annual of water level fluctuation: 0.2-0.3 m
Lake's water level artificially controlled: No

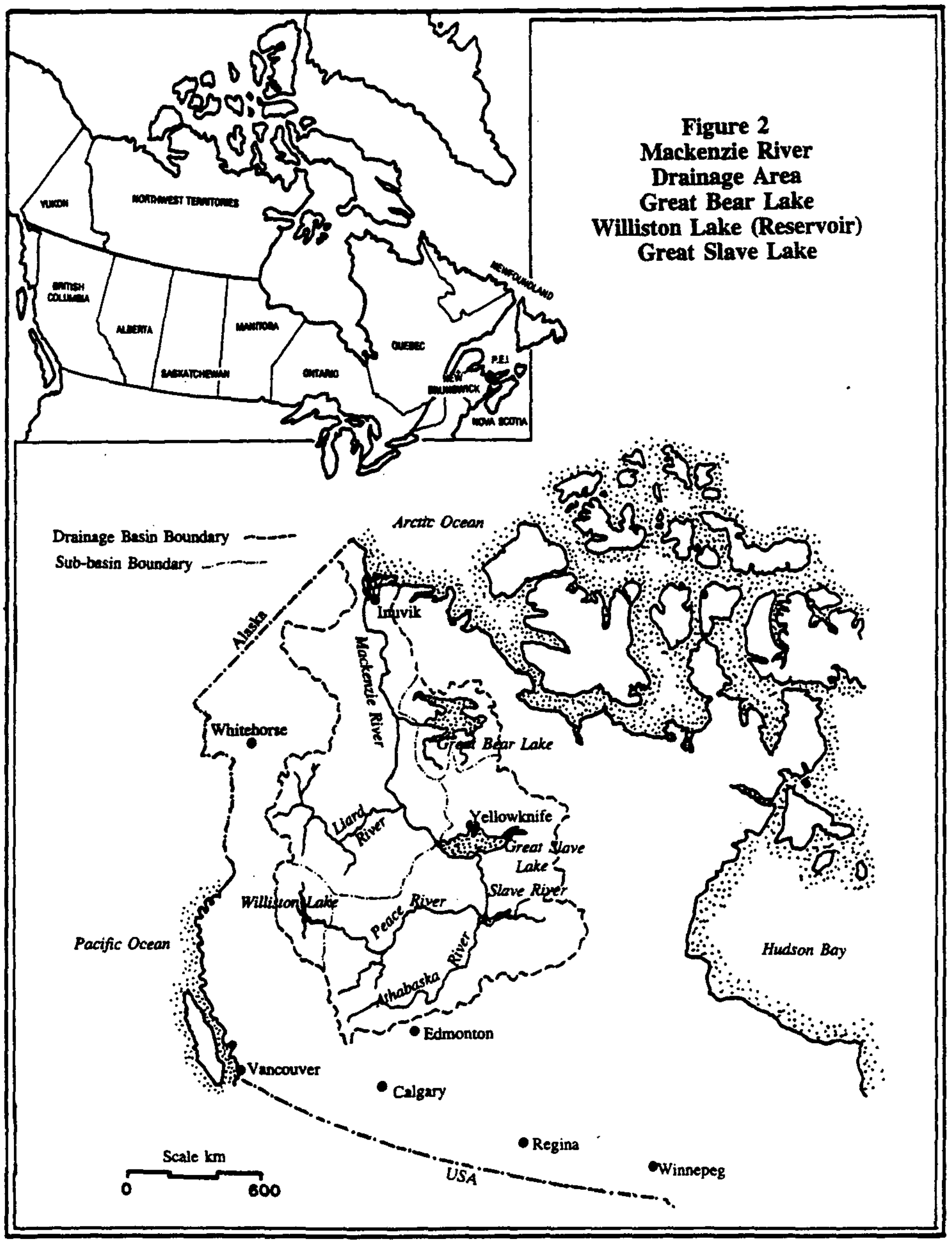

Figure 2
Mackenzie River Drainage Area
Great Bear Lake
Williston Lake (Reservoir)
Great Slave Lake

Length of shoreline: *2719 (+824 of islands) km*

Residence time: *124 yrs [26]*

Catchment area: *114,717 km²*

D. PHYSIOGRAPHIC FEATURES

D₁ GEOGRAPHICAL

Bathymetric map: *(Fig. 3).*

Names and areas of main islands on the lake: *[26]*

		Area (km²)
McTavish Arm:	*Achook*	
	Cornwall	
	Broadway	

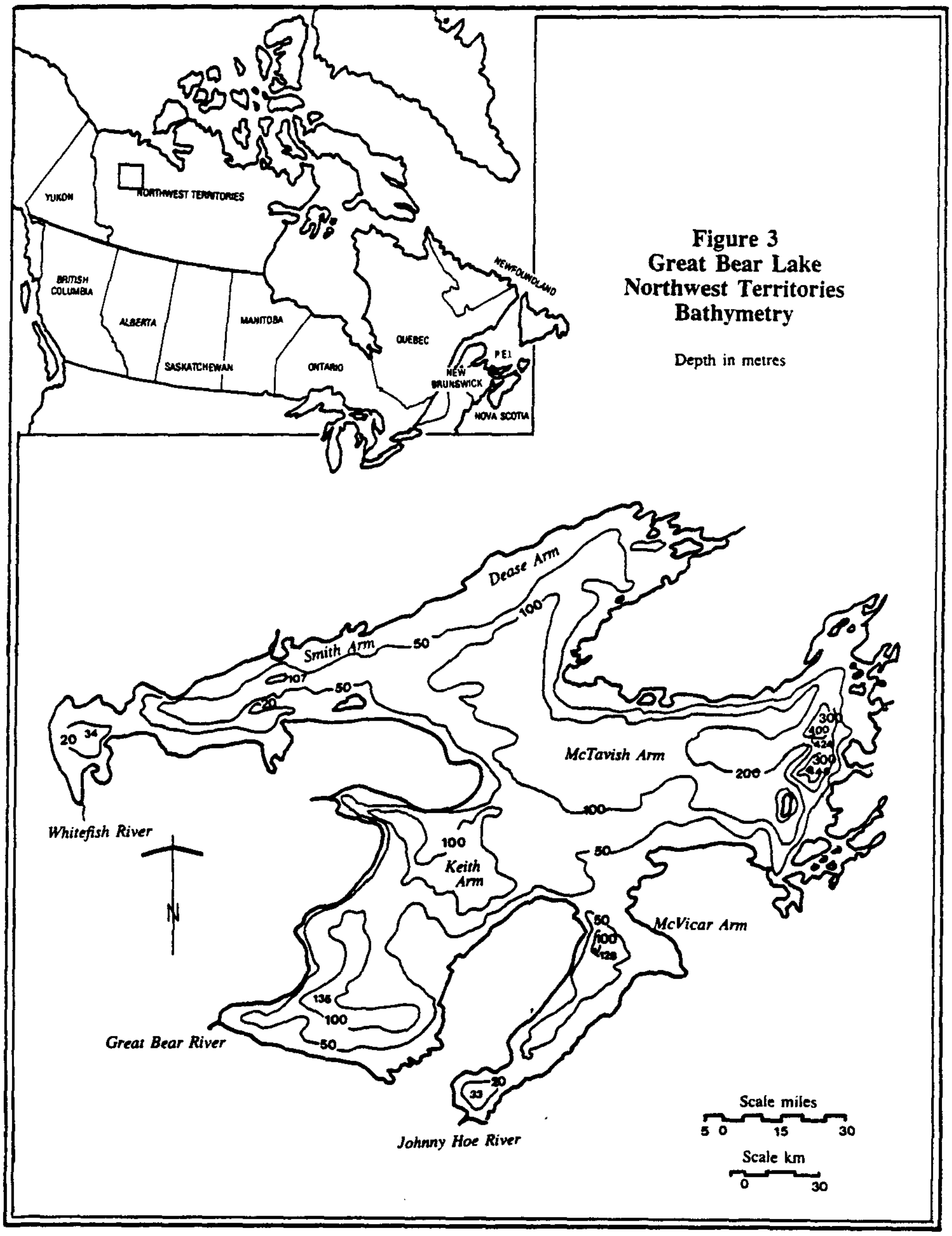

Figure 3
Great Bear Lake
Northwest Territories
Bathymetry

Depth in metres

Names and areas of main islands on the lake: [26]

		Area (km^2)
	Hogarth	432.3
	Stevens	
	Workman	
	Richardson	
	Superstition	
McVicar Arm:	Unnamed	73.5
Keith Arm:	George	
	Lionel	4.0
Smith Arm:	Ikanyo	
	Ekka	135.1
	Kroger	
	Crosswise	
Dease Arm:	Rich	
	Prospect	114.4
	Narakay Islands	
TOTAL AREA OF ISLANDS:		756.4

Outflowing rivers and channels: *(1) Bear River*

D$_2$ CLIMATIC

Place name: *Port Radium* **Period of observation:** *1950-74* *[35]*

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean temp ºC	-27	-27	-19.1	-10.7	1.2	9.0	12.0	10.6	5.3	-3.2	-14.8	-23	
Precip. [mm]	10.9	7.9	14.2	6.4	13.7	14.2	35.1	42.7	25.2	26.7	25.2	14.0	236.2

Number of hours of bright sunshine per year:

1854 hr yr $^{-1}$ at Norman Wells (40% of total possible)
(approximately 120 km west of Great Bear Lake)

Water temperature [°C]:

Station name: *6 miles west of Port Radium*

Period of observation: *1963-65* *[26,29,30]*

	1964			
Depth (m)	July 15	July 22	Aug 11	Aug 27
0	2.36	3.00	3.77	5.22
3		2.92		
5		2.92		
10		2.93		4.30
19			3.71	
20				4.26
30		2.90		
48			3.65	
50	2.33			4.12
100	3.02	3.03		3.93
106			3.64	
123		3.52		
150	3.37	3.57		3.87
155			3.65	
188		3.64		
200		3.63		3.87
201			3.63	
230	3.59			
250			3.62	3.62
280	3.61		3.60	
299			3.59	
300		3.57		3.59
317		3.57		
328			3.57	
347			3.57	
350				3.59
396			3.56	
398		3.56		
400		3.56		3.58

	1965		
Depth (m)	Apr 9	Aug 2	Aug 25
0	ice	2.75	3.54
2	0.04		
5	0.04		
10	0.04	2.68	
20	0.06	2.64	
30	0.18		
49			3.42
50	1.37	2.68	
99			3.41
100	2.91	2.66	
148			3.43
150	3.50	2.67	
200	3.53	3.55	
246			3.42
250	3.53	3.55	
295			3.43
300	3.51	3.53	
350	3.52	3.55	
390	3.52		
400		3.51	

Freezing period (lake): *From November to July*

Mixing type: *Monomictic*

Notes on watermixing and thermocline formation:

Complete circulation only occurs intermittently (1 year in 3 of observation) when heating is slow. In other years circulation only occurs in upper 200-250 m.

E. LAKE WATER QUALITY

E$_1$ TRANSPARENCY [m]:

30 m in August 1963-65 at a station 35 km west of Port Radium (66°3'N, 118°49'W) in a water depth of 200 m [26].

27-29 m at Bear's Bottom. Maximum reading 10 m in McVicar Arm.

E_2 pH: *All readings in the lake fell between 7.8 and 8.1 [26].*

E_4 DO [mg l^{-1}]:

Station name: *Bear's Bottom* **Period of observation:** *1964* *[26]*

Depth [m]	Jul 22	Aug 11	Aug 27	April9(1965)
0	14.05	13.4	13.21	ice
3	14.31	13.35	-	14.4 (2m)
10	14.17	13.27	14.0	14.37
19	14.31			14.06 (30m)
50	14.17			
100	14.03	13.32	13.4	12.87
200	13.25	12.83	13.73	12.62
300	13.05	12.79	13.48	12.56
350	12.05	12.72	13.05	12.53
400	12.27	12.40	12.78	12.60

E_7 NO_3-N CONCENTRATION [mg l^{-1}]:

Station name: *Bear's Bottom* **Period of observation:** *1963-64* *[26]*

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0								0.49				

Samples were filtered in the field and analysed 2-3 months later.

E_8 TOTAL-P CONCENTRATION [mg l^{-1}]:

Station name: *Bear's Bottom* **Period of observation:** *1963-64* *[26]*

Samples filtered in the field and analysed 2-3 months later. Most samples showed no measurable phosphate. Maximum values: <0.1 mg L^{-1}.

F. BIOLOGICAL FEATURES

F_1 FLORA:

Emergent macrophytes: *There is little emergent vegetation along the shorelines on account of ice-scour. In the most secluded bays there are stands of Equisetum (list incomplete).*

Submersed macrophytes: *Hippuris vulgaris (list incomplete).*

F_2 FAUNA

Zooplankton: *Limnocalanus macruras, Senecella calanoides, Diaptomus sicilis, Cyclops scutifer, C. vernalis, Daphnia middendorfiana, D. longispina hyalina var. microcephala, Bosmina longirostris, Leptodora kindtii, Epischura nevadensis [27]*

Benthos: *<10 m: Gammarus lacustris, Pontoporeia affinis, Hyalella azteca; Molluscs: Valvata cincerahelicoidea, Gyraulus deflectus, Lymnea elodes, Sphaerium nitidum, Pisidium idahoensis, P. casertanum, P. lillieborgi; Chironomidae: Mysis relicta. >10 m: Pontoporia affinis, Mysis relicta, Chironomidae, Myoxocephalus quadricoruis. >100 m: Myoxocephalus quadricornis, Hydra sp., Mysis relicta (rare) [27].*

Fish (economically important species marked with asterisks):

**Salvelinus namaycush (lake trout); *Coregonus clupeaformis (lake whitefish); C. artedii (cisco); Porsopium cylindoaceum (round whitefish); Stizostedion vitueum (walleye); Esox lucius (northern pike); Catostomus catostomus (longnose sucker); Thymallus arcticus (grayling); Myoxocephalus quadriconnis thompsonii (deep-water* *sculpin); Cuttus cognatus (slimy sculpin); Pungitius pungitius (9-spine stickleback) [23,24,25,27,28].*

Also taken: Oncorhynchus keta (Chum salmon); O. kisutch (Coho salmon, one specimen only), Salvelinus malma (Dolly varden).

See notes on distribution in the Introduction.

F_3 PRIMARY PRODUCTION RATE: *No information.*

F_4 BIOMASS

Total zooplankton standing crop in August and September 1964-65 in the different arms of Great Bear Lake ranged between 38,000 to 471,000 m^{-2} (mean=167,000 m^{-2}).

F_5 FISHERY PRODUCTS:

Annual fish catch [metric tons]: (in *1988*)

Sport catch: 20 tons; native domestic fishery: 15 tons.

Fishery products other than fish (shrimp, shellfish, etc.): *Nil.*

F_6 PAST TRENDS OF PRIMARY PRODUCTIVITY, BIOMASS AND FISHERY PRODUCTION:

G. SOCIO-ECONOMIC CONDITIONS

G_1 LAND USE IN THE CATCHMENT AREA (in 1988):

	Area (km^2)	[%]
Natural landscape		
Woody vegetation	*80,360*	*70*
Herbaceous vegetation	*11,400*	*10*
Swamp	*22,960*	*20*
Others		
Agricultural land		
Crop field	*nil*	
Pasture land	*nil*	
Settlement area		

Types of important forest or scrub vegetation:

Coniferous forest, largely white spruce (Picea glauca), black spruce (P. mariana) and jack-pine (Pinus banksiana).

Types of important herbaceous vegetation: *Tundra.*
Types of the other important vegetation : *Muskeg swamp.*

Main kinds of crops and/or cropping systems: *Nil.*
Levels of fertilizer application on crop fields: *None*

G_2 INDUSTRIES IN THE CATCHMENT AREA AND THE LAKE (in *1988*):

	Gross product Per year[1] (=US$1.00)	No. of persons engaged	No. of establishments	Main products or major industries
Fisheries[2] *[Sport]*	*$5M*	*300*	*5*	*Trophy-sized lake trout*
Others				
Secondary industry				*Silver mine now closed*
Tertiary industry				

1 On monetary basis (current conversion rate to US dollars).
2 Fisheries on the lake concerned.

G_3 POPULATION IN THE CATCHMENT AREA (IN 1988):

	Population	Mean population density [no km^{-2}]	Names of major cities
Urban			
Rural	*700*	*0-19*	*Fort Franklin (1969 population 368) [16]*
Total	*700 [summer population includes staff at fishing lodges and visitors]*		

Urban area = all cities with a population greater than 30,000.

H. LAKE UTILIZATION

H_1 LAKE UTILIZATION:

Sport-fishing *[31]*

Fisheries *(Limited domestic fishery)*

H_2 THE LAKE AS WATER RESOURCE (in 1988)

	Use rate
Domestic water	*Negligible*
Irrigation	-
Industrial water	-
Power plant	-
Others	-

I. DETERIORATION OF LAKE ENVIRONMENTS AND HAZARDS

I_1 ENHANCED SILTATION

Extent of damage: *None*

I_2 TOXIC CONTAMINATION

Present status of toxic contamination: *None*

I_3 EUTROPHICATION

No eutrophication has occurred.

I_4 ACIDIFICATION

Extent of damage: *None*

J. WASTEWATER TREATMENTS

J_1 GENERATION OF POLLUTANTS IN THE CATCHMENT AREA:

No major human settlements or activities producing significant pollution (pristine lake environment).

J_2 APPROXIMATE PERCENTAGE DISTRIBUTION OF POLLUTANT LOADS

	Percentage
Non-point sources (agricultural, natural and dispersed settlements)	*not significant*

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: *None*

K. IMPROVEMENT WORKS IN THE LAKE *None*

L. DEVELOPMENT PLANS *None*

M. LEGISLATIVE AND INSTITUTIONAL MEASURES FOR UPGRADING LAKE ENVIRONMENTS

M_1 NATIONAL AND LOCAL LAWS CONCERNED

Names of the laws (the year of legislation):

(1) *Fisheries Act (1970).*
(2) *Northwest Territories Fishing Regulations (1978).*

(Both Act and Regulations updated annually)

Responsible authorities:

(1) *Department of Fisheries and Oceans, Ottawa.*

M_2 INSTITUTIONAL MEASURES:

(1) *Great Bear Lake Management Committee (established 1986).*

M_3 RESEARCH INSTITUTE ENGAGED IN THE LAKE ENVIRONMENT STUDY:

(1) *Freshwater Institute, Department of Fisheries and Oceans, Winnipeg.*

Supplementary notes: *Active research on fish stocks only.*

N. SOURCES OF INFORMATION

[1] Bostock, H.S. 1970. Physiographic regions of Canada. In R.J.W. Douglas, ed. Geology and economic minerals of Canada. Ottawa: Department of Energy, Mines and Resources. p. 9-30.
[2] Flint, R.F. 1971. Glacial and quaternary geology. New York: Wiley. 892 p.
[3] Douglas, R.J.W. 1968. Geological map of Canada no. 1250A, 1:500,000. Ottawa: Geological Survey, Department of Energy, Mines and Resources.
[4] Kidd, D.F. 1932a. Great Bear Lake-Coppermine River area. Can.Min.Metall.Bull. no 245:512-526.
[5] Kidd, D.F. 1932b. Great Bear Lake-Coppermine River area, Mackenzie District, Northwest Territories. Can.Geol.Surv.Summ.Rep. 1931. p. 47-69.
[6] Kidd, D.F. 1932c. The Great Bear Lake-Coppermine River district. Can.Min.J. 53:5-12
[7] Kidd, D.F. 1933. Great Bear Lake area, Northwest Territories. Can.Geol.Surv.Summ. Rep. 1932. p. 1-36.
[8] Douglas, R.J.W., ed. Physiographic regions of Canada. Geology and economic minerals of Canada. Vol. II. Maps and charts. Ottawa: Geological Survey, Department of Energy, Mines and Resources.
[9] Douglas, R.J.W., D.K. Norris, R. Thorsteinson & E.T. Tozer. 1963. Geology and petroleum potentialities of northern Canada. Can.Geol.Surv.Paper 63-31. 28 p.
[10] Prest, V.K., D.R. Grand & V.N. Rampton. 19676. Glacial map of Canada. Ottawa: Geological Survey, Department of Energy, Mines and Resources.

[11] Bird, J.B. 1967. The physiography of Arctic Canada. Baltimore: Johns Hopkins. 336 p.
[12] Craig, B.D. 1965. Glacial Lake McConnell and the surficial geology of parts of the Slave and Redstone rivers map area, District of Mackenzie. Geol.Surv.Can.Bull. 122. 33 p.
[13] Craig, B.G., & J.G. Fyles. 1960. Pleistocene geology of Arctic Canada. Geol.Surv.Can. Pap. 60-10. 21 p.
[14] McNeish, S.S. 1964. Two archaeological sites on Great Bear Lake, N.W.T., Canada. American antiquity 19:234-253.
[15] Clark, D.W. 1987. Archaeological survey of Canada. Paper 136. Ottawa: National Museum.
[16] Morris, M.W. 1972. Great Bear Lake Indians: a historical and human ecology. Musk-ox 11:3-17.
[17] Franklin, J. 1828. Extracts from Franklin's second journey to the Polar Sea in the years 1825, 1826 and 1827. London: John Murray. 320 p.
[18] Johnson, L. 1976. The Great Bear Lake: its place in history. Arctic 28:230-244.
[19] Bell, J.M. 1902. Report on the topography and geology of Great Bear Lake and a chain of lakes and streams thence to Great Slave Lake. Canada, Geological Survey, Annual report 1899. Ottawa: S.E. Dawson.
[20] Camsell, C. 1937. Great Bear Lake exploration. Can.Geog.J. 14:126-151.
[21] Preble, E.A. 1908. A biological investigation of the Mackenzie-Athabasca region. Washington, D.C.: U.S. Department of Agriculture (North American fauna, no. 27).
[22] Eldorado Mining and Refining Co. 1967. Annual Report. Port Hope, Ontario.
[23] Miller, R.B. 1947. Great Bear Lake. In Northwest Can.Fish.Surv. 1944-45. Bull. Fish.Res.Board Can. 72. 94 p. p. 31-44.
[24] Miller, R.B., & W.A. Kennedy. 1948. Observations on the lake trout of Great Bear Lake. J.Fish.Res.Board Can. 7:176-189.
[25] Kennedy, W.A. 1949. Some observations on the coregonine fish of Great Bear Lake, N.W.T. Bull.Fish.Res.Board Can. 82. 10 p.
[26] Johnson, L. 1975a. Physical and chemical characteristics of Great Bear Lake. J.Fish. Res.Board Can. 32:1971-1987.
[27] Johnson, L. 1975b. Distribution of fish species in Great Bear Lake, Northwest Territories, with reference to zooplankton, benthic invertebrates and environmental conditions. J.Fish.Res.Board Can. 32:1989-1975.
[28] Johnson, L. 1976. The stability of populations of lake trout (Salvelinus namaycush (Walbaum)), Arctic char (Salvelinus alpinus L.) and whitefish (Coregonus clupeaformis (Mitchill)) and their associated species in unexploited lakes of theCanadian Northwest Territories. J.Fish.Res.Board Can. 33:2459-2488.
[29] Johnson, L. 1964. Temperature regime of deep lakes. Science 144:1336-1337.
[30] Johnson, L. 1966. Temperature of maximum density and its effect on the circulation in Great Bear Lake. J.Fish.Res.Board Can. 23:963-973.
[31] Yaremchuk, G.C.B. 1986. Results of a nine-year study (1972-80) of sport fishing exploitation of Lake Trout (Salvelinus namaycush) on Great Slave and Great Bear Lakes, NWT: the nature of the resource and management options. Can.Tech.Rep.Fish. Aquat.Sci. no. 1436.
[32] Barbour, C.L., & J.H. Brown. 1974. Fish species diversity in lakes. Amer.Nat. 108:473-489.
[33] Clarke, A.H. 1973. Freshwater molluscs of the Canadian Interior Basin. Malacologia 13:1-509.
[34] Hydrographic chart no. 6390: Great Bear Lake. 2 August 1974.
[35] Anon. 1950-74. Monthly record of meteorological observations. Ottawa: Environment Canada Atmospheric Environmental Service, Meteorological Branch.

ARCTIC LAKES (Figure 6)

The Canadian Arctic covers an enormous area and includes some of the least known lake districts on earth. There are many large lakes, particularly in the southeastern sector on the shield. Lakes are less numerous in the High Arctic which is a cold desert. Along coastal plains and poorly drained inland areas, particularly in the sector near the Mackenzie Delta and Yukon, thermokarst lakes are dominant. During summer, a shallow layer of permafrost thaws in many locations throughout the arctic and the resulting melt water can form vast marshy areas where a myriad of small thermokarst lakes afford nesting sites for migratory birds. The geology of the ecozone varies from Precambrian in the southeast to Mezozoic and Palaeozoic in the northwest.

Despite the Arctic's harsh environment, it contains a variety of plants and animals. Several hundred species of plants are found, and the animal species, though few in number, are abundant. All are linked to form a fragile ecology that often exhibits cycles of overpopulation and food scarcity.

A special characteristic of arctic lakes is the long nine to twelve months winter stagnation period. The ice-free period ranges from 0 to 90 days. At Char Lake and Garrow Lake described here, the ice-ree period begins in mid August and the fist freeze-up typically occurs less than a month later. Maximum ice thickness on typical Canadian arctic lakes ranges from about 1.5 to 2.5 m. When an arctic lake ices over, the ice prevents wind from acting on the underlying water body. Comparatively small and shallow lakes display winter bottom temperatures of about 0.5 to 1 °C during the period of ice cover. Because water is a poor conductor of heat, the winter bottom temperature of large and deep arctic lakes is around 4 °C. Glaciers are common throughout the Canadian Arctic archipelagoes. Ice sheets occur on a number of Arctic Islands including Ellesmere and Baffin Islands.

Oxygen concentrations in Arctic lakes during the brief open water summer period is excellent. Typically dissolved oxygen exceeds 8 mg/L from surface to bottom. The winds of the large, flat polar regions easily stir up the water and oxygenate it from top to bottom. Stratification of large deep lakes in sheltered areas happens only occasionally during the ice-free period, and then only for short periods of time. During winter, however, dissolved oxygen (DO) may decline as the hypolimnetic DO values are sometimes low at the end of the winter stagnation period.

In addition to the large and small lake dichotomy, there is a second dichotomy between lakes receiving little or no glacial sediments and those receiving appreciable amounts of glacial sediment (Gilbert and Church 1983). Zooplankton abundance and algal biomass were an order of magnitude lower in lakes receiving appreciable amounts of glacial sediments. The glacial sediments reduce light penetration and adsorb nutrients. Low nutrient flux appears to limit arctic lake phytoplankton biomass (Dickman 1971, Rigler 1978). Arctic lakes appear to share a number of common fish species such as the arctic char, fourhorn sculpins, white fish, lake trout, ciscoes, pike-perch, goldeneye, northern pike and arctic grayling.

Because conditions in large and small arctic lakes differ quite substantially, information on both is reported in this book. P&N and Char Lakes in NWT are examples of well studied small basin lakes. In the high arctic, one large basin lake, Hazen Lake on Ellesmere Island has ten years of accumulated study. Hazen is the most northerly lake described here at 81 °N. It is a large, very deep lake fed by glaciers from the Grant Land Mountains of Ellesmere Island. Without glacier melt, the lake would probably not exist as precipitation is only 2.5 cm per year. The lake has only one fish species (arctic Char, *Salvelinus alpinus*) and rarely loses its ice cover during the short arctic summer when the air temperature rises above 10°C for about a month.

Char Lake on Cornwallis Island in the central part of the high arctic is a small lake used as a drinking water reservoir for the village of Resolute Bay. It was the subject of intensive limnological investigations under the auspices of the IBP between 1968 and 1973. In general, the benthic community in arctic lakes plays a relatively greater role than in temperate lakes. *Pseudodiamesa arctica* and two species of orthoclad chironomids were the dominant benthos in Char Lake. In Char Lake as in many other small arctic lakes, the benthic community is responsible for most of the primary production and respiration and has the greatest diversity of species. As simple as the Char lake benthic community was, the dominant zooplankton community was ever simpler; only two species, *Limnocalunus macrurus* and *Keratella cochlearis* are found in Char Lake. In Char Lake, *Gymnodinium helveticum, Rhodomonas minuta* and *Chromulins* spp. were the dominant phytoplankton species. Between 60 and 75 species were found in 21 arctic and subarctic lakes in the western region of the Northwest Territories (Moore 1979). In most Arctic lakes, a single phytoplankton pulse occurs shortly after ice out, attributed to nutrient enrichment and to increased light intensity and day length. The unimodal phytoplankton pulse in large arctic lakes is associated with the short growing season. Smaller arctic lakes at the same latitudes warm up more quickly and typically display bimodal phytoplankton cycles. A few arctic lakes may display many fluctuations in phytoplankton biomass over the course of the year (Kalff 1967).

Garrow Lake is the most northerly hypersaline lake in the world (salinity = 82 parts per thousand). Garrow Lake is the only meromictic lake described in this book and is used for tailings disposal from a lead/zinc mine because of this feature. The high salinity of this ultraoligotrophic lake qualifies it as a solar lake. The mean temperature in this part of the arctic is - 5°C while the temperature under 2.1 m of ice in Garrow Lake at a depth of 20 m is 9.1°C throughout the year (Dickman and Ouellet 1987). The lake is ice covered for over 11 months of the year and temperature transfer (0.6°C m^{-1}) is interannually constant. Even though numerous studies on high arctic meromictic lakes have been published, none were as hypersaline as Garrow Lake (Dickman *et al.* 1990). Density-stratified high arctic lakes have been reported for Ellesmere Island, the Mackenzie Delta, Cornwallis Island and Little Cornwallis Island.

P+N lake was a nameless lake experimentally eutrophied with phosphorus (P) and nitrogen (N) between 1979 and 1983. The data presented here, however, refer to the conditions that existed before nutrient enrichment took place. The lake is probably typical of the many headwater lakes which dot the landscape in the the southeastern Shield area of the Arctic.

REFERENCES

Dickman, M.D. (1971). Preliminary notes on changes in algal primary productivity following exposure to crude oil in the Canadian Arctic. Canadian Field Naturalist 85(3): 249-251.

Dickman, M. and Ouellet, M. (1987). Limnology of Garrow Lake, NWT, Canada. Polar Record 23(146): 531-549.

Dickman, M., Lewkowics, A.G. and Price, J. (1990). A unique lake in Canada's High Arctic. Syllogeous [Canadian Arctic Islands Special Issue, C.R. Harington, Ed]. pp. 188-203.

Gilbert, R. and Church, M. (1983). Contemporary sedimentary environments on Baffin Island, NWT, Canada: reconnaissance of lakes on Cumberland Peninsula. Arctic and Alpine Research 15: 321-332.

Kalff, J. (1967). Phytoplankton abundance and primary production rates in two Arctic ponds. Ecology 4: 558-565.

Moore, J.W. (1979). Factors influencing the diversity, species composition and abundance of phytoplankton in twenty one arctic and subarctic lakes. Int. Revue ges. Hydrobiol. 64: 485-499.

Rigler, F.H. (1978). Limnology in the high arctic: a case study of Char Lake. Verh. Internat. Verein. Limnol. 20: 217-149.