MINISTRY OF ENVIRONMENT
PROVINCE OF BRITISH COLUMBIA

THE WATER QUALITY OF WESTON LAKE
SALTSPRING ISLAND

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INTRODUCTION

During the spring of 1985, the Fulford Harbour Waterworks District experienced many difficulties with supplying water to customers because of large amounts of algae in the water being drawn from Weston Lake. The algae caused difficulty in maintaining chlorination, and resulted in a variety of customer complaints. The lake itself was reported to be very turbid and the intake was difficult to service because of the low visibility for the SCUBA diver.

The Waterworks District intake in Weston Lake is in the southwest arm of the lake at a depth of 4.6 m (15 feet) at approximately the 12 m contour (Figure 1). The intake is a plastic pipe which is weighted and tethered at that depth. The water normally flows by gravity out through the intake line along the creek bottom which drains Weston Lake toward Fulford Harbour. When the lake level drops in lake summer, a small pump is used to move water out of the lake into the pipeline. Water treatment consists only of a chlorination unit. No filtration or settling is carried out.

Requests to the Ministry of Environment were made for assistance and information. The Regional Director requested that Resource Quality Section of Water Managment Branch review the data which were available and determine if some change could be made which might improve the situation.

BACKGROUND

Some preliminary data were collected in 1973 by Groundwater Section of what is now Water Management Branch. A more detailed sampling was carried out in 1974-75. This information was reported on and summarized in a report by Goddard (1975).

Some limited sampling was done in 1976 and a more intensive effort carried out in 1981 coincident with the study of St. Mary Lake (Nordin _et al_. 1981). No sampling has been done since 1981.

METHODS

The primary purpose of this review is to determine what change (if any) in water quality occurred between the 1974-76 period when the lake was sampled and the 1981 sampling. In 1981 there was some indication, even from visual observation, that some deterioration had taken place. This was one of the reasons why the sampling was initiated.

To compare the 1974-76 data and the 1981 data, the two data sets were summarized. Insufficient time was available to examine the data in detail; however, the differences between the periods are significant and make any detailed examination unnecessary for the purpose of this report.

RESULTS

The results for water chemistry are shown as Table 1. The comparison shown is for the central lake station (1100133). Some data also are available for stations 1400552 (east basin, 9 m depth), 1400553 (same as 1100133) and 1400554 (location unknown) for 1973 and stations 1100131 and 1100132; however, they do not differ significantly from the central lake station. The lake bathymetry and sampling sites are shown in Figure 1.

WATER CHEMISTRY

The problems which have been experienced by the Waterworks District appear to be caused primarily by heavy algal growth. The cause of this growth is nutrients and consequently nitrogen and phosphorus are examined here in some detail. The first question to be asked was whether nutrients had increased between the 1974-76 period and 1981. The answer is yes. In 1974-76 the overall average of all phosphorus results (total phosphorus) was 0.023 mg/L. In 1981 the mean was 0.033. Similar increases are seen in total dissolved phosphorus. The increases in nitrogen over the approximate five year period are equally significant. The average nitrite plus nitrate nitrogen concentration increased from 0.060 to 0.112 mg/L. The average Kjeldahl nitrogen from 0.325 to 0.743 mg/L. Overall average concentrations are not the best indicators of nutrient availability and the spring overturn concentrations provide better information. Since the lake is well mixed (no stratification) from December until late February or March, samples taken in this period can be used to represent spring overturn concentrations and consequent nutrient supply for the following growing season. In 1974, samples in late December averaged 0.024 mg/L total phosphorus. In 1976 (February) water column concentrations were 0.011 mg/L. The nitrogen concentrations were 0.105 mg/L (nitrate) and 0.510 mg/L (Kjeldahl nitrogen) in December 1974, and 0.200 and 0.312 mg/L respectively in February 1976. In 1981 (January) total phosphorus was 0.024 mg/L, nitrate was 0.260 mg/L, and Kjeldahl was 0.720 mg/L although the latter was not homogeneously distributed in the water column. Ammonia concentration was not sampled in 1974-76; however, in spring 1981 concentrations were in the range of 0.031 - 0.061 mg/L, and averaged 0.049 mg/L in January.

Spring overturn concentrations can also be used to evaluate whether nitrogen or phosphorus is likely to be the nutrient limiting algal growth. The N:P ratio (TN:TP) in December 1974 was 0.617: 0.024 or 25.7:1. In February 1976, 0.512:0.011 or 46.5:1. In January 1981 the N:P ratio was 40.8:1. These data would indicate the algae are strongly phosphorus limited since algae require N:P in a ratio of approximately 8:1.

The nutrient data indicate fairly significant changes over the five year period. As well there are indications that changes have occurred in more conservative water chemistry characteristics (see Table 1). It appears that specific conductance has increased as well as alkalinity, inorganic carbon and calcium. Other measurements related to algal growth have also changed (water clarity, turbidity, organic carbon).

SUITABILITY FOR DRINKING WATER

Both the provincial government (Ministry of Health 1982) and the federal government (Health and Welfare Canada 1978) have specified standards for drinking water. In comparison to these standards, Weston Lake water is generally good except for colour (mean value 21.6, standard 15 units). Other standards which may not be met at times are iron (<0.3 mg/L), temperature (<15°) and turbidity (<5 NTU). These and some other parameters have been measured too infrequently to make any conclusions; however, the water is generally quite acceptable as a source of drinking water. The major problem, in terms of suitability, appears to be the biological productivity of the lake which is manifested in summer by high amounts of algae (for which no standards exist) and low hypolimnetic oxygen.

There are very few data on coliform concentrations in Weston Lake. In the mid 1970's two samples were taken. This very obvious and important gap should be filled if any future sampling is undertaken.

LAKE BIOLOGY

Some data are available to evaluate the amount of algae present in the lake in 1974-75. Samples were taken in June, August and October 1974 and April 1975. They showed relatively low numbers of algae and species which would not be expected to cause problems with water treatment or taste and odour. There is insufficiently frequent sampling to discern any annual pattern. The peak numbers of algae do not appear to exceed 2000 cells/mL in the samples which were taken. A summary of the algae data is shown in Table 2.

In contrast, the algal samples taken in 1980 and 1981 show very different numbers and dominant species. The highest number of algae occurred in winter and spring. Between December and April numbers of algae were between 10 000 and 20 000 cells/mL. In May, June, July and October numbers were an order of magnitude lower. Although the 1974 and 1981 data are not directly comparable, it would appear that the numbers of algae are higher in the 1981 period. This would be expected with the higher nutrient levels which were measured. There also appears to be a substantial difference in the types of algae present. The dominant algae in 1974-75 were diatoms and green algae. In 1980-81 the dominants were the far less desirable (from water supply or aesthetics perspective) blue-green algae.

LAKE STRATIFICATION

Weston Lake goes through an annual cycle of temperature stratification which can affect water quality (Figure 2). During the winter (December to February) the lake is cool and mixes from top to bottom. In 1981 the winter water temperature was about 6°. In late February or early March the surface water warms and the lake begins to stratify. In April the thermocline is centred at about 3 m and as warming continues the thermocline becomes stronger and deeper. Maximum surface temperature occurred in July and August (21°) at which time the thermocline is centred at about 5 m. In late August, September and October the surface waters cool and mix deeper and deeper into the lake. The thermocline was 6 to 7 metres below the surface by October 1981. In November or early December the lake is generally mixed completely to the bottom and overturn is said to have occurred.

The major consequence of the temperature stratification is the oxygen depletion which occurs in the hypolimnion. Figure 3 shows the dissolved oxygen percent saturation values for 1980-81. Two points which are notable are firstly a zone of very high oxygen concentration which occurs in May and June (and possibly July) at 3 to 5 meters depth. This is likely a consequence of a concentration of algae at that depth. The other point is the oxygen depletion which takes place in the hypolimnion. As early as March there is a significant lowering of oxygen concentration. In March the percent saturation is about 50% in bottom waters and decreases to 30% in April. From the end of April the deepest waters become anoxic. The anoxic zone becomes larger and occupies the zone below 7 meters by the beginning of June. The anoxic water may be within 6 meters of the surface in late summer. The anoxic water is mixed into the entire lake volume as the lake cools and mixes in the fall.

DISCUSSION

There are a number of points which can be made regarding the future of the Weston Lake water quality in general and its use as a source of domestic water for the Fulford Harbour area. One difficulty in making comments is that they are based on an interpretation of the most recent data which exist, but which is now more than 4 years old. The situation is likely to have changed and if the trend follows the pattern shown by the existing data, the water quality may have deteriorated further. It would appear from the anecdotal information which the Waterworks has provided, that the spring of 1985 had very large amounts of algae which caused substantial problems with water treatment. During the summer, fewer algae were present and less problems were encountered. This information concurs with the limited water sampling done previously. Thus from the small amount of data which are available, the generalization might be made that the most severe problems occur in the spring of the year (February through May).

The root cause of the deteriorating water quality in Weston Lake is an increasing supply of nutrients. There seems to be good evidence that both nutrient concentration and algal biomass have increased significantly over the period of sampling. In examining the watershed land use, it would appear that there are increases in the number of people living in the watershed and in the amount of agriculture. The watershed is quite large in comparison to the lake surface area so, in relative terms, there is a large supply area for the lake. The watershed is not particularly well defined so it is difficult to quantify accurately the domestic and agricultural waste increases. There is air photo coverage of the Weston Lake area for 1975 (BC 7754), 1980 (BCC 249) and 1985 (BC 85011). These air photos were examined in an effort to determine the number of homes within the watershed during these three periods, and to make some estimate of population changes. Although the airphotos are difficult to use for this purpose, since many houses are obscured in the trees, there appears to be an increase of at least 10 homes from 1975 (25 ± 5) to 1985 (35 ± 5) within the watershed and within 500 meters of the lake. As well as the land clearing and soil disturbance related to these new houses, which can cause increased nutrient input to the lake, there was a portion of land of one to two hectares, north east of the lake which was cleared between 1980 and 1985.

The agricultural loading is another aspect which may be significant. There appear to be only a few cows within the watershed. However, each cow is equivalent to ten humans in terms of waste produced and the manure is deposited on the land surface and can be easily washed into the lake. Thus the effect on the lake water quality may be disproportionally larger than the nutrients from human waste, which are partially removed by passage through soil. The amount of phosphorus (the limiting nutrient) which annually enters the lake is very small so amounts of manure washed into the lake could be significant.

No sampling has been done to provide an estimate of phosphorus input to Weston Lake. However, a number of researchers have presented relationships which allow derivation of loadings from lake concentration and basic lake morphometric characteristics. The relationships used are shown in Table 3. The three equations were solved for "L" (phosphorus load) and the results compared. Two showed similar results and are used here to discuss lake loadings and water quality response. The 1976 loading was estimated by this method at approximately 14 kg and the 1981 loading approximately 30 kg phosphorus.

To place these quantities in perspective, human sewage is estimated to contain 1.5 kgP/yr/person and cattle waste 15 kgP/yr/animal (450 kg animal) (McKean 1982). However these quantities would not reach the lake since some attenuation takes place as sewage or manure leachate passes through soil. The longer the distance from the water, the lower the percentage of phosphorus which would reach the lake. Other factors also have some effect. These include soil type, topography, depth to water table etc. The important point is that an increase of a few individuals in the watershed or additional livestock could affect the water quality of the lake. It is in a relatively sensitive position due to the small amount of phosphorus which is needed to change the amount of algae in the lake.

The change in nutrient and algae concentrations which occurred between 1975 and 1981 can certainly be rationalized with even minor increases in population or agricultural activity. Other factors that may have also contributed to the increase in phosphorus in Weston Lake include watershed clearing, land disturbance and perhaps an increase in internal loading of phosphorus from lake sediments. However, it appears that sewage or manure appear to be the most likely sources of the increased nutrients to the lake.

OPTIONS FOR LAKE WATER QUALITY IMPROVEMENT

The obvious solution to the unacceptable water quality presently being experienced by the Waterworks District is to reduce the amount of phosphorus which enters the lake. However, this is neither easy nor inexpensive since both the sewage disposal and agriculture practices are established and difficult to modify. In any case these areas should be the primary focus of any future activities to improve water quality. One option which is open is to increase the level of treatment of the water, for example by installing a filtration unit to remove algae from the water. This is, however, expensive considering the number of people served by the system. Another possibility is to use in-lake restoration to modify the lake and cause an improvement. Both these methods would be less desirable since no change is made to the cause (nutrients) of the unacceptable algal growth.

A variety of in-lake restoration techniques have been used to improve water quality by manipulation of the lake itself. Each method is suitable for different types of problems and as such has inherent advantages and disadvantages. The opportunities for lake restoration appear to be very limited both because of the characteristics of the lake and the relative expense of any restoration program. However, it is useful to list those possibilities which have some potential for Weston Lake.

Hypolimnetic aeration: this would likely be too expensive to be practical as a means of providing cool, aerated water for the water works. It might reduce internal loading if this were contributing phosphorus to the lake. The few data which are available show increases in total phosphorus in the hypolimnion but not in the orthophosphorus form which is usually indicative of internal loading. More sampling is necessary to determine if internal loading is a significant factor as it is in many eutrophic lakes in the southern Vancouver Island area such as St. Mary and Langford Lakes. To take advantage of hypolimnetic aeration, the water intake would need to be relocated and lowered. Feasibility of many aspects would need to be investigated before a better evaluation could be made.

Nutrient inactivation: increasing the concentration of calcium, aluminum or iron in the water column or sediments might be useful, but more detailed evaluation would be necessary. This would unquestionably be expensive and would need to be repeated at regular intervals (every few years).

A variety of other techniques, such as dredging, drawdown, biological manipulation, enhanced flushing rate or hypolimnetic discharge, seem to be entirely impractical for the circumstances at Weston Lake.

Some modification of present intake operation may be of benefit. The problem of heavy algal growth occurs in spring and increasing the depth of intake at that time below the depth where algae are growing (>7 metres) should reduce the amount of algae drawn into the intake. The intake would need to be raised by early or mid May since deoxygenated water would be drawn in at that time.

In summary there appears to be no easy solution to the problem of heavy algal growth in Weston Lake. There should be some effort to reduce the amount of nutrients (specifically phosphorus) which originate from sewage disposal and cattle. The possibility exists of modifying the intake depth during parts of the year to avoid concentrations of algae.

Before any expensive options are pursued it would be useful to conduct a monitoring program to quantify nutrient inputs more accurately than is available at present. Such a program might be carried out at reasonable costs if the Waterworks could assist with sample collection. Sampling of bacterial concentrations and identification of sources should also be considered.

Reduction of nutrient and/or bacterial inputs to Weston Lake may require action from agencies such as Islands Trust to modify zoning regulations or put in place some special measures for protection of the lake as a long term supply of drinking water. Because of the importance of water to Saltspring Island in particular, protection of Weston Lake is an important issue.

REFERENCES CITED

Canfield, D.E., and R.W. Bachmann. 1981. Prediction of total phosphrous concentrations, chlorophyll a, and Secchi depths in natural and artificial lakes. Can. J. Fish. Aquat. Sci. 38:414-423.

Goddard, J.M. 1975. Lake Weston, Saltspring Island, B.C. Data report for the water quality monitoring program, June 1974 to June 1975. Water Investigations Branch, B.C. Government. 52 p.

Health and Welfare Canada. 1978. Guidelines for Canadian Drinking Water Quality. Ottawa. 76 p.

McKean, C.J.P. 1982. Dragon Lake, general water quality and nutrient loading in 1980. Aquatic Studies Branch, B.C. Ministry of Environment. APD Bulletin 24. 76 p.

Ministry of Health. 1982. British Columbia drinking water quality standards. Province of British Columbia. 18 p.

Nordin, R.N., C.J.P. McKean and J.H. Wiens. 1983. St. Mary Lake water quality: 1979-1981. B.C. Ministry of Environment. 121 p.

Reckhow, K.H., and J.T. Simpson. 1980. A procedure using modeling and error analysis for the prediction of lake phosphorus concentration from land user information. Can. J. Fish. Aquat. Sci. 37:1439-1448.

Vollenweider, R.A. 1969. Moglichkeiten and Grenzen elementares Modelle der Stoffbilanz von Seen. Arch. Hydrobiol. 66:1-36.

TABLE 1
Comparison of Weston Lake Water Quality
1974-76 and 1981
(Site 1100133)

	1974-1976				1981			
	mean	n=	range	standard deviation	mean	n=	range	standard deviation
pH	7.3	40	6.7 - 8.1	0.4	7.2	19	6.3 - 8.6	0.58
specific conductance	83.3	146	57 -167	24.1	96.6	19	50 -118	12.4
turbidity	1.8	23	0.6 - 7.8	1.9	2.6	19	0.7 - 7.6	1.9
Secchi depth	3.5	27	1.2 - 4.6	0.9	2.8	8	1.5 - 5.0	1.3
alkalinity	26.8	39	22.4 - 44.0	3.9	28.6	7	14.8 - 41.4	7.8
organic carbon	6.8	39	3.0 - 12.0	2.0	8.9	19	4.0 - 14.0	2.7
chloride	6.6	4	6.5 - 6.6	0.05				
nitrate plus nitrite N	0.060	39	<0.02 - 0.21	0.06	0.112	26	<0.02 - 0.26	0.105
Kjeldahl N	0.325	39	0.26 - 2.0	0.32	0.743	26	0.160 - 3.00	0.71
total N	0.538	19	0.26 - 1.03	0.23	0.844	26	0.160 - 3.00	0.70
ortho P	0.004	38	<0.003- 0.041	0.004	0.004	26	<0.003 - 0.017	0.003
total dissolved P	0.007	19	0.004- 0.014		0.011	26	0.005 - 0.043	0.008
total P	0.023	38	0.010- 0.078	0.020	0.033	26	0.02 - 0.158	0.034
inorganic carbon	6.33	27	2.0 - 13.0	2.7	7.9	19	2.0 - 21.0	4.0
boron diss	<0.1	4						
cadmium total	<0.0005	18	all < 0.0005					
calcium diss	9.8	23	9.2 - 11.0	0.4	10.6	8	5.1 - 12.9	2.33
copper total	<0.001	18	<0.001- 0.002					
iron total	0.19	18	<0.1 - 0.9		0.88	1		
lead total	0.001	18	<0.001- 0.003					
magnesium diss	1.5	23	1.3 - 1.6	0.10	1.6	8	1.1 - 1.7	
mercury total		10	all < 0.00005					
nickel	0.01	15	all but 1 <0.05					
sodium diss	4.7	4	4.6 - 4.7	0.05				
potassium diss	0.5	4	all 0.5					
zinc			all <0.005					
colour true					21.6	16	<5.0 - 30.0	7.7
colour TAC					19.6	3	19 - 21	0.6
Residue 105					73.9	19	38 - 90	9.9
Res 550					36.2	19	16 - 48	7.9
Res NF 105					4.0	19	<1.0 - 10.0	0.6
Res NF 550					1.7	19	<1.0 - 4.0	1.0
hardness					33.1	8	17.3 - 38.0	6.5
ammonia					0.136	26	<0.005 - 1.36	0.32
C.O.D.					18.7	19	<10.0 - 34.2	6.8
silica					6.1	19	1.1 - 8.2	1.7

TABLE 2
Dominant phytoplankton algae in Weston Lake 1974-75 and 1980-81 at station 1100133

DATE	Number of algal cells/mL	Dominant Species
27 June 1974	419 (2 samples)	Rhizosolenia longiseta Synedra radians
29 August 1974	1056 (4 samples)	Ankistrodesmus falcatus Oscillatoria tenuis*
29 October 1974	247 (2 samples)	Dinobryon divergens Gomphosphaeria*
16 April 1975	1376 (2 samples)	Synedra radians Rhizosolenia longiseta
17 December 1980	17 395	Oscillatoria* Aphanizomenon flos-aquae*
14 January 1981	20 903	Oscillatoria* Aphanizomenon*
4 February 1981	23 503	Oscillatoria* Aphanizomenon*
4 March 1981	12 910	Oscillatoria* Aphanizomenon*
25 March 1981	4882	Oscillatoria* Asterionella*
28 April 1981	8655	Oscillatoria* Aphanizomenon*
28 May 1981	1045	Oscillatoria*
16 June 1981	644	Rhizosolenia
8 July 1981	1145	Microcystis*
5 October 1981	2633	Aphanizomenon* Oscillatoria*

*blue-green algae

TABLE 3

Weston Lake, phosphorus loading estimates

$$TP = \frac{L}{Z(\sigma + \rho)}$$ (Vollenweider 1969)

$$TP = \frac{L}{11.6 + 1.2\ qs}$$ (Reckhow and Simpson 1980)

$$TP = \frac{0.603\ L}{Z(0.257 + \rho)}$$ (Canfield and Bachman 1981)

TP	total phosphorus in mg/L
L	loading in $g/m^2/yr$
Z	mean depth (5.9)
σ	phosphorus sedimentation (0.5 est.)
ρ	flushing rate (0.5/yr)
T	hydraulic detention time (2 years est.)
qs	water overflow rate (3.9 m)

Morphometry of Weston Lake

elevation	61 m
surface area	18.4 ha ($184,129 m^2$)
volume	718.4 dam^3
mean depth	5.9 m
maximum depth	12.2 m
littoral area	(<6 m) 52%
watershed area	1.7 km^2 (est.)
water exchange time	2 years (est.)

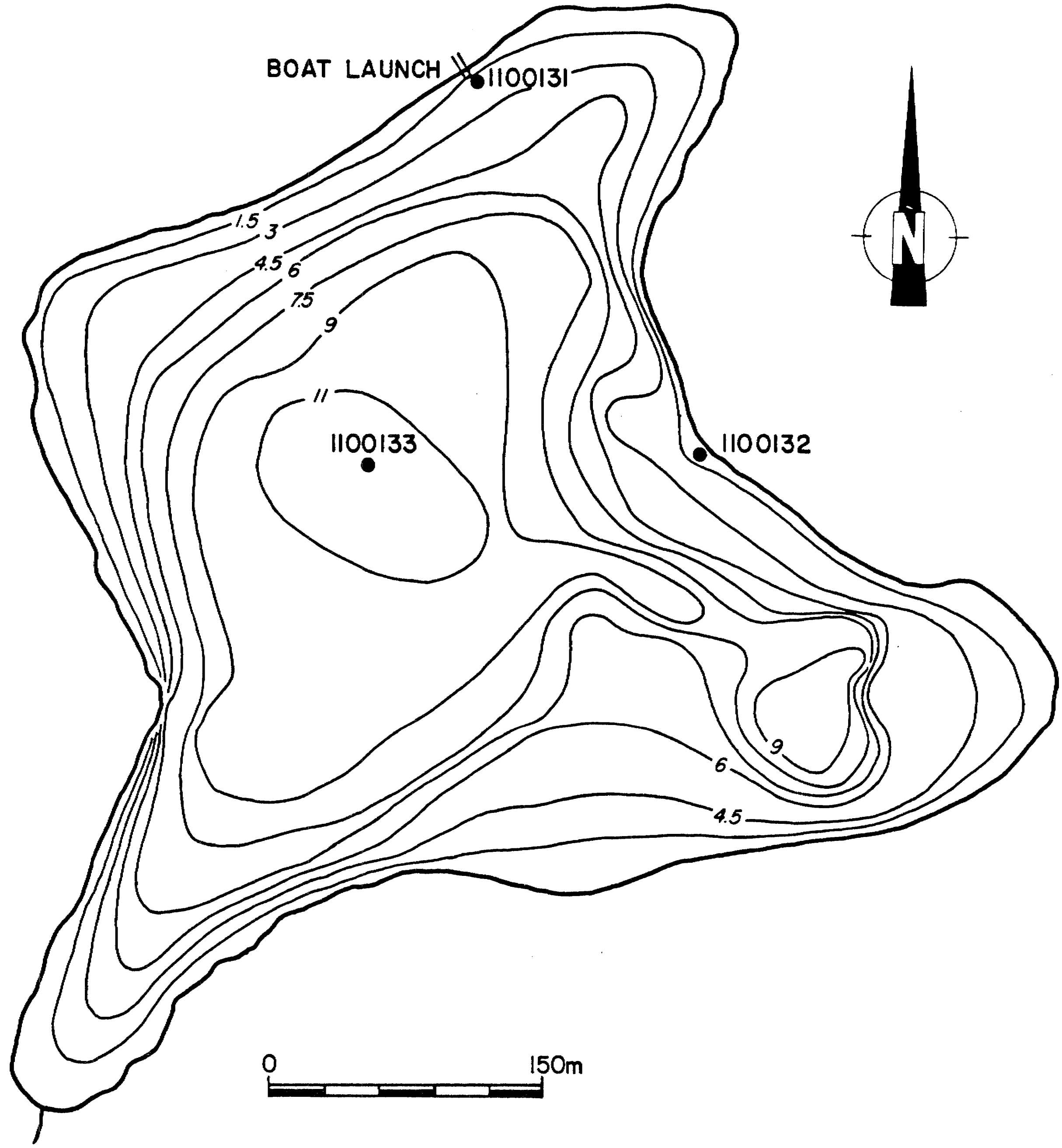

Figure 1: Bathymetry of Weston Lake and Sampling Stations

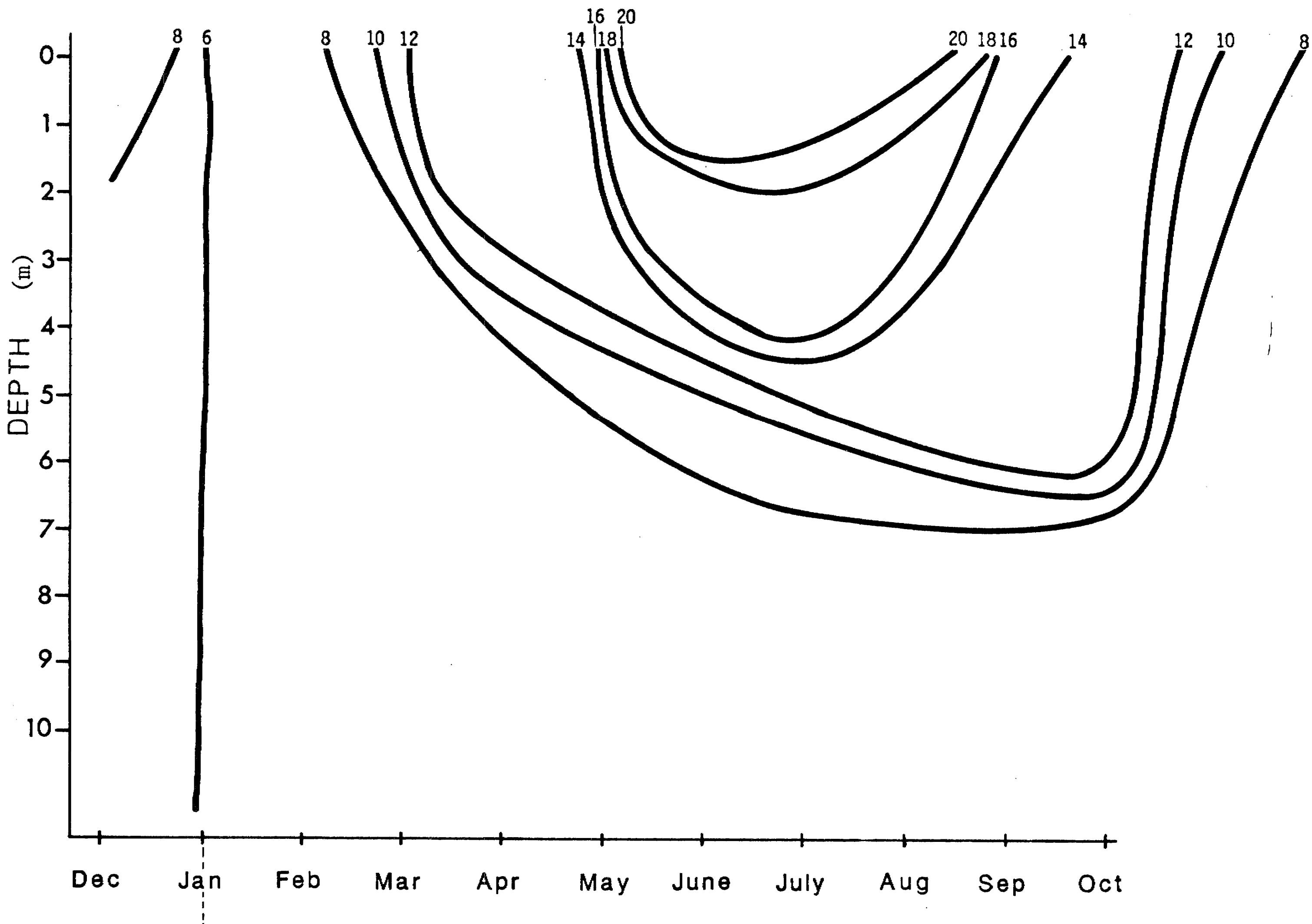

Figure 2: Time-depth diagram (temperature) for Weston Lake, 1981.

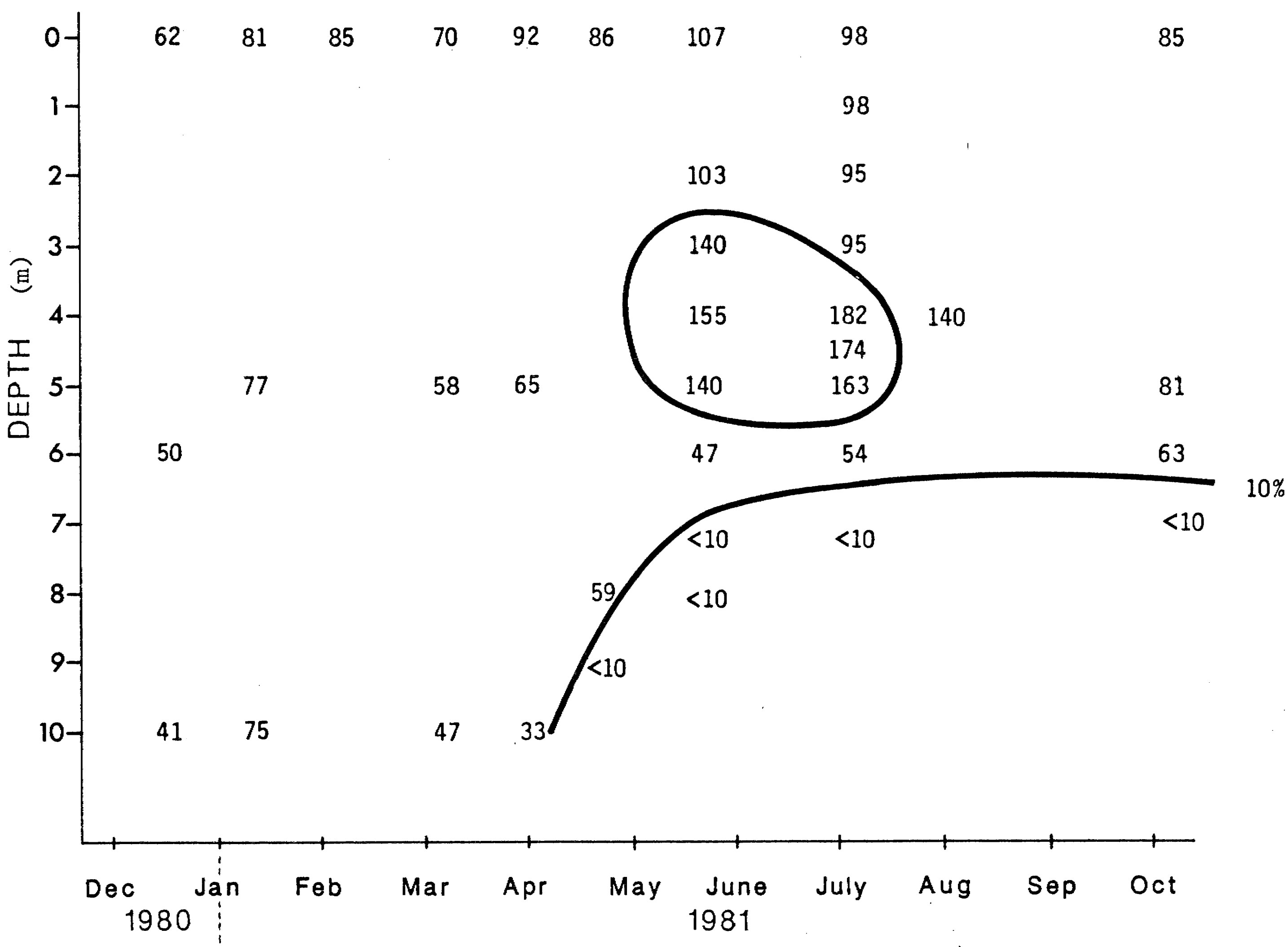

Figure 3: Percent Saturation of Dissolved Oxygen Weston Lake, 1981