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ed - Lake Assessment

1983 WATERSHED-LAKE ASSESSMENT

TO

PELICAN RIVER WATERSHED DISTRICT

BY

INSTRUMENTAL RESEARCH, INC.

April, 1984

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TABLE OF CONTENTS

INTRODUCTION

The purpose of the 1983 study was to determine the existing condition of the lakes located along the course of the Pelican River and to identify conditions in the watershed which will require corrective measures.

Lake samples were collected June 2, July 14, August 18, and September 18 from Big Floyd Lake, Little Floyd Lake, Big Detroit Lake, Little Detroit Lake, Lake Sallie, and Lake Melissa. Samples were also collected June 3, July 14 and August 18 from the Pelican River and at several other potential nutrient source points.

Sediment core samples, 4 feet by 2.5 inches in diameter, were collected January 24 and 25 from each of the above mentioned lakes and also from Muskrat Lake and Lake St. Clair. The purpose of the core sampling was to determine the rate of sedimentation in each basin, to assess current nutrient conditions, to relate current data to past conditions, and then to extrapolate the data to estimate future conditions.

BACKGROUND

Lake Data Collected

Field data collected

Secchi disc readings were collected on each of the six primary lakes throughout the season by volunteers living on each of the lakes tested. Secchi disc readings were also taken by Instrumental Research, Inc. staff during the four sample collection periods.

The purpose of the secchi disc readings was to establish a relationship for each of the lakes in the system between secchi disc depth and chlorophyll-a. Assuming that the turbidity contribution from the watershed does not change dramatically over future years, this relationship can be used as a monitor for both past and future years to look at how changes in the watershed have affected the lakes.

Each lake has a background turbidity which is not algae related. The standing biomass in each of these lakes must be seperated from this background to relate the secchi disc readings to the standing chlorophyll levels. The method used to determine this background level involves the preparation of a graph of the collected secchi disc readings versus the chlorophyll-a levels from concurrently collected samples. The resulting graph is a straight line function. The point of the Y axis intersect, varies by the turbidity constant Kw, and slope of the line by the chlorophyll-a constant times the chlorophyll-a concentration (Kc X C). The more samples collected, the better the fit, but we have found that four samples, taken through the open water season, usually provide sufficient data to do the calculation.

To determine the background turbidity levels, a least squares fit is calculated for each lake and the resulting line fit checked against the graph. The background turbidity constant is the point where the least squares line intersects the Y axis. This relationship holds very well for lakes which are not impacted by variable turbidity sources and with sufficient data, the turbidity level can be determined as a separate variable within the lake.

The chlorophyll-a constant is then deduced from the slope of the least squares fit. To determine the standing chlorophyll-a at any given time during the year, the constants are set in the equation for the lake and the measured secchi disc reading used as the independent variable. The following equation can be used for each lake.

Chl-a = (((1/(S X .3048))-KW)/KC)

Chl-a = chlorophyll-a in milligrams per cubic meter of water

S = secchi disc reading in feet

KW = background turbidity constant

KC = chlorophyll-a constant

The determined turbidity constants and chlorophyll-a constants are for each lake.

Lake	KW	KC
Big Floyd Lake	.0596	.0645
Little Floyd Lake	.0393	.0430
Big Detroit Lake	.1584	.0376

Lake	Kw	Kc
Little Detroit Lake	.1067	.0492
Lake Sallie	.0120	.0325
Lake Melissa	.2180	.0268

The temperature profiles were measured in each lake, four times over the season, to determine the position of the thermocline in the water column. The waters below the thermocline do not mix with the upper waters until the lakes turn over in the spring and fall. Because the lake waters are completely recharged with oxygen only after complete mixing, the biological activity below the thermocline has the potential of completely depleting the available oxygen.

Several important chemical and biological changes take place when the oxygen has been depleted in the hypolimnion (volume of water below the thermocline).

1. The bacteriotype changes dramatically from solublized oxygen consuming decomposers, to populations which can derive their oxygen from chemical sources such as nitrate [NO_3] and sulfate [SO_4].

a. This means that the decomposed nitrogen compounds in the detritus (incompletely decomposed plant, and animal materials) are converted to ammonia instead of nitrate or nitrogen gas. The decomposed sulfur compounds are released to the water as sulfides, some as toxic hydrogen sulfide.

b. The decomposed hydrocarbon compounds, those containing carbon, hydrogen, and oxygen, are released as water H_2O, carbon dioxide CO_2, and methane CH_4. These exist as dissolved gases contained in the hypolimnion. This allows large populations of bacteria to exist above the sediment interface and maintains high microbial activity all the way up to the thermocline.

c. The free or dissolved phosphorus levels in the hypolimnion can increase from two to one hundred times the level found above the thermocline. At the lake turn over in the fall this phosphorus then mixes with the rest of the lake water instead of remaining at the bottom in the sediments. An example of this is the depleted phosphorus level in the sediments of Lake St. Clair. Here the released phosphorus is moving

2. Iron, which exists with a +3 charge in well oxygenated water, is a major coupling agent for the dissolved phosphorus. As the oxygen concentration drops, this shifts to +2 charged iron and releases the phosphorus to the water as soluable phosphate.
3. Sulfate reducing bacteria take in the $SO_4^{=}$ ions, strip off the oxygens, and release free sulfide ions to the water. A good deal of this sulfide exists as toxic hydrogen sulfide, observable to us as the smell of rotten eggs from the water.

The lakes in the Pelican River Watershed system which developed anoxic conditions in 1983 were; Little Floyd Lake, Big Detroit, Little Detroit, Lake Sallie, Lake Melissa, Muskrat Lake, and Lake St. Clair. Lake St. Clair may exist in this condition throughout much of the year, both in the open water season and certainly throughout the winter months. The other lakes in the system showed a lack of oxygen in their hypolimnia only in July and August in 1983.

Conductivity profiles are used to detect the chemocline in the lake. The chemocline is a transition region of chemical types, such as nitrate to ammonia, sulfate to sulfide, in the water. This may not occur at the thermocline in relatively clean lake systems and usually begins at the two milligram per liter oxygen concentration. Lowered conductivity readings are also an indication of elevated chemical-biological activity below the thermocline.

Dissolved oxygen profiles also establish the position of the chemocline or chemical transition region, in the water. The oxygen depletion begins at the lower side of the thermocline but may not reach critically low levels until much lower in the water column.

The lakes in the Pelican River Watershed had established critically depleted oxygen conditions in the deeper waters only during the August sampling. Big Detroit Lake had experienced a serious oxygen depletion just prior to the August sampling, noted by the kill of whitefish which had washed up on shore.

Laboratory Analysis

Chlorophyll-a is the one chlorophyll compound found in all of the groups of phytoplankton or algae. It is one of the primary pigments in the algae for the conversion of light to energy. This converted energy then drives the biomass production in the lake. The vast majority of higher biological production, above the bacterial level, in the lake systems is driven by photochemical processes. The concentration of chlorophyll-a in the algae can range from .1% to .3% dry weight. The dry weight is usually in the range of 2% to 3% of the wet, or live weight.

A concentration of 30 milligrams of chlorophyll-a per cubic meter, as existed in Lake Sallie this last summer, becomes a wet weight of about 1.5 grams of algae per cubic meter of water or 1.5 milligrams per liter as algae. This is the lower end of an obnoxious bloom condition in a lake system. Chlorophyll-a is then a very good indicator of a lake's trophic or aging condition.

Algae determinations and cell counts point up the source and type of the nutrients which support the algae populations. Hetrocystis blue-green algae indicate a very high level of available phosphorus in the system, because they are capable of fixing their own biochemical nitrogen from the dissolved nitrogen in the water. Other algae species are indicators of current water quality conditions, and changing lake conditions. The populations found through the year are good indicators of water quality improvement, or degredation over time.

The blue-green algae are not usable as a food source by most of the animals in the lakes. Therefore these populations can multiply, virtually unchecked, until the nutrient sources are depleted. The green algae, and yellow algae are the food source for the higher organisms in the lake and so comprise the base of the food chain.

The total suspended solids in the water are comprised of the composite of algae, bacteria, and suspended dust and debris in the water column. The measurement is made by filtering the water through a .45 micrometer filter, drying the filter, weighing filter and accumulated material, and then subtracting the filter weight. The suspended dust and debris comprise the turbidity constant in the equation on page 3.

Total kjeldahl nitrogen is the sum of ammonia nitrogen and organic nitrogen compounds. The organic nitrogen can be determined by a subtraction of ammonia from the total kjeldahl nitrogen. A biological balance of organic nitrogen to organic phosphorus is about fourteen to one. An excess of phosphorus in a lake usually gives rise to the hetrocystis blue-green algae which can fix their own nitrogen. This is the reason for the seperation of the non-hetrosystis and hetrocystis blue-green algae counts in the study by Dr. Joe Neel.

Nitrate nitrogen is a measure of the available nitrogen as a nutrient for bacteria, algae, and higher aquatic plants. Nitrate nitrogen can move freely through groundwater as well as by overland sources.

Nitrite nitrogen is an unstable intermediate between ammonia and nitrate. In high concentrations it is indicative of high bacterial activity. It is a valid test in the cooler water season to detect high nutrient input conditions to a lake.

Ammonia nitrogen is usually the prevalent nitrogen ion where the waters are or have been in an oxygen poor condition. It is a good indicator of a high nutrient input condition. Ammonia nitrogen is usually the prevailing nitrogen below the thermocline in a lake.

Ortho phosphorus is the phosphorus which is available for immediate inclusion in the biomass of a lake. Excess ortho phosphorus is usually an indication of another limiting nutrient in the system. In the surface waters of a lake or stream, the ortho phosphorus is usually below .010 milligrams per liter of water (mg/l) or .010 parts per million (ppm).

Total phosphorus is the sum of available phosphorus; chemically combined phosphorus, and organic phosphorus. All of the phosphorus in the system can be assumed to be available as a nutrient for the biomass at some time.

Total alkalinity is the test for HCO_3^-, bicarbonate ion, and $CO_3^=$, carbonate ion in the water. At times, ammonia also becomes part of this test as it is conducted by titration to a standard pH end point.

EDTA hardness is a test which measures the sum of calcium, magnesium, and iron in the water. Usually the hardness is very close to the alkalinity. Where there is a significant difference, it is usually because of high biological activity in the water.

Sediment Core Sampling

Four foot long sediment cores were collected from each of the six lakes in the water sampling set as well as one each from Muskrat Lake and Lake St. Clair. The purpose of the core sampling is to look at the past history of each lake in the watershed. Graphing of each of the measured parameters can be used to estimate the current trends in the lake system.

Dating of the cores is done for the purpose of determining the loading rate per year. The dates from the eight cores collected ranged from forty years to one hundred and sixty years.

Percent solids is a method of determining the density of the sediment. It is also used as the method of equating the comparison results of the other sediment analysis. Even though the chemistry for the other tests were performed on wet weight samples the results can be related to dry weight material.

Chemical oxygen demand is a way of estimating the amount of carbon in the sediment. Much of the sedimented materials will be as carbohydrates which contain the main elements of carbon, oxygen, and hydrogen in the ratios of C:O:H, 1:1:2. Upon digestion, the hydrogens and the oxygen couple to form water, and the carbons combine with the external oxygen source to form carbon dioxide in the ratio of two oxygens to one carbon. Dividing the COD (chemical oxygen demand) by two and multiplying by 12/16, molecular weight ratios, the result is the carbon load in the sediments. There are other materials which are responsible for the chemical oxygen demand, but the percentage of these materials are very small compared to the carbon content. This makes the COD a viable method of carbon estimation.

Total kjeldahl nitrogen measures the combination of ammonia and organic nitrogen in the sediments. The ammonia is discounted here, as it will have departed as a gas, and the organic nitrogen is taken as the total kjeldahl nitrogen. The organic nitrogen load deposited by the algae, plant, and animal material comprises 99+ percent of the measured content. Changes in the organic nitrogen load over time provides information relative to the changing nutrient loading conditions of the lake. The June, 1981 report, Impact of Special Phosphorus Removal Procedures, by Professor Joe K. Neel, of the University of North Dakota, states that there is a nutrient other than phosphorus, responsible for the greatly reduced algal populations in Lake Sallie. Our sediment analysis indicate that Lake Sallie's sediments developed a very high organic nitrogen load, which dropped sharply following the change in loading from the sewage treatment plant procedures. This may be an effect of changed algae populations rather than a cause, but it appears that this lake is rapidly returning to its former, cleaner condition.

Total Phosphorus is again a measure of the changing lake conditions over time. Phosphorus comprises about two tenths of one percent of the dry weight load in the plant materials. A graph of phosphorus loading per killogram of sediment can show how the lake is aging at the present time.

As the biological populations build up in the water column with an increased nutrient load, a larger quantity of the dead material will come to reside in the sediments. With the increase in degradable materials at the sediment interface and in the water column, the size of the bacterial populations will also increase. As the system accelerates, more of the available oxygen in the water will be used up to decompose the dead biological materials. Since this is not replaceable below the thermocline in the summer months, the result in a lake with a rapidly growing biological system, is the total utilization of the available dissolved oxygen.

When the available oxygen is depleted to near zero, and the lake becomes anoxic, the bacteria begin to strip the phosphorus, nitrogen, and carbon from the sediments. This process begins at about two milligrams of dissolved oxygen per liter of water, which is equivalent to two parts of oxygen per million parts of water.

Lake St. Clair is an example of a system where much of the incoming phosphorus to the system has been released again, to continue its way through the watershed to Lake Sallie and Lake Melissa.

MATERIALS & METHODS

The water chemistry and phytoplankton analysis methods are those listed in Standard Methods, 15th edition, 1981. The examination of the phosphorus loading in the sediments and core dating procedures are those developed by Instrumental Research, Inc. using Practice of Thin Layer Chromatography, 2nd edition, 1983. Joseph C. Touchstone and Murrell F. Dobbins. Chromatography, 2nd edition, 1966. Dr. Erich Heftmann. Practical Chomatographic Techniques, A. H. Gordon, J. E. Eastoe.

Sediment phosphorus

1. The sediment sample was composited for each six inches of the microcores.
2. Dry weights were determined by weighing a wet fraction of the composite into a crucible, drying at 105 degrees celsius for three hours, and cooling in a desicator.
3. A wet portion, between 0.3 to 0.5 grams, of the composite was digested by the Nitric Acid-Sulfuric Acid Digestion method and brought up to a volume of 100 milliliters. The acidified sample was then filtered through a glass fiber filter to remove the residual solids. A 50 milliliter portion of the filterate was then neutralized and colorized by the Ascorbic Acid method.

The reason for the filteration prior to neutralization is that using the normal technique from Standard Methods, allows the phosphorus to readsorb to the inorganic particulate materials in the sample, resulting in a very low value for the contained phosphorus. This error was greatly reduced by using the above procedures.

Core Dating

The technique of dating the sediment cores has been developed by Instrumental Research, Inc. It is based on the ability of the algae in a lake system to produce and store an excess of sugars and carbohydrates in the summer months. There are more than adequate amounts of carbon, available as carbon dioxide, carbonates and bicarbonates through the open water season. The energy to drive the photosynthetic system is available as photosynthetic energy from sunlight.

In the winter, with ice and snow cover on the lakes in our area, the carbon and sunlight availability is greatly reduced. Therefore, these sugars are not produced in the same large quantities.

The algal populations are going through a continuous process of reproducing and dying during the year, and while some of the dead material is recycled to the upper waters, a certain amount is deposited continuously in the sediments each year. Not all of this deposit is decomposed before it is buried in the sediments.

During the open water season, there is a larger amount of dust and dirt which reaches the lake through the flowing waters of the streams and rivers, and by wind blown dust.

In the winter months this input is cut off by the ice cover and so the deposition to the sediments is reduced in the winter months to a narrow band. This band in the sediments is usually not obvious to the observer as a color change so the following method was developed.

By using the four millimeter microcores from the sixty five millimeter diameter core, and by relying on proven ellution techniques for the chromatography it is possible to detect the carbohydrate poor winter band for each year. Two ellution methods were used to confirm the methodology and duplicate microcores were run for the dating.

When the chromatogram has been developed, the excess carbohydrates, which were produced in the open water season, show as strong bands which are interrupted by a notch. The notch in the banding represents the winter months. There are also periods during the year when certain populations are able to reach higher numbers. The intervening regions which result show as less clearly defined bands than the annual bands.

LAKE DATA

Much of the data presented here was compiled by Instrumental Research, Inc. for the Pelican River Watershed District during the summer of 1983 and the winter of 1983-84. Information on lake size, volume, and pertinent hydraulic data was assembled from numerous sources, including published work by the Minnesota Department of Natural Resources, Minnesota Pollution Control Agency, United States Geological Survey, and work done for the watershed by Dr. Joe K. Neel, Department of Biology, University of North Dakota. The materials used are public information and were made available by the Pelican River Watershed District, the Minnesota Department of Natural Resources, the Minnesota Pollution Control Agency, and the Soil and Water Conservation District.

It was our intent to bring together as much data as possible to assess the current condition of the lakes in the watershed district without attempting to duplicate previous efforts.

RESULTS AND CONCLUSIONS

BIG FLOYD LAKE

Surface area (acres)	1234.
Volume (acre feet)	12,604.
Littoral area (acres)	864.
Maximum depth (feet)	34.
Mean depth (feet)	13.
Number of inlets	4.
Approximate inflow (acre feet)	800.
Number of outlets	1.

The south bay was the area tested for the inlake parameters. This portion of the lake is little affected by the Pelican River and was the cleanest lake in the system during 1983. The secchi disc readings for the 1983 season averaged 9.8 feet. The average secchi disc reading for the state of Minnesota is 7 feet.

Of the lakes tested in the watershed, Big Floyd Lake was the least affected by the heavy summer rains. Chlorophyll-a levels were slightly over 5 mg/cubic meter for a seasonal maximum.

The lake maintained high dissolved oxygen levels throughout the summer, assuming that this is a typical condition, the bottom sediments hold most of the annual phosphorus input. The temperature and dissolved oxygen gradients throughout the summer were minimal, indicating strong wind mixing throughout the summer season.

The algae counts through the season were low and were only dominated by non-hetrocysits blue-greens in August. In September the populations of green algae were about equal to the blue-greens.

The sediment core data from Big Floyd Lake dates back one hundred forty-six years. The sedimentation loading per year ranges from a high of 15 millimeters per year to a low of 2.5 mellimeters per year. The loading rate has been averaging 6 millimeters per year for the last forty-eight years and is fairly steady at that rate.

The carbon load has changed little in the last one hundred ten years and may be dropping off at the present time. The nitrogen loading is increasing very slightly at the present time, but has not shown any dramatic changes in the last one hundred ten years.

The phosphorus loading today is at .400 grams per killogram and is the same as it was one hundred forty-six years ago. In both cases, this is the highest loading recorded, while the low was .280 grams per killogram of sediment, occurring about sixty years ago. The rate of phosphorus loading is on the increase at the present time at a rate of 3 milligrams per killogram per year. This is not a rate for concern at this time.

This lake and its watershed are in very good condition at this time and will require no immediate attention.

Lake Data & Chemistry

BIG FLOYD LAKE
June 2 1983

Secchi Depth 19.00 ft.

Depth ft.	Temp C	pH	Cond um	D.O. mg/l	TSS mg/l	Chl-a mg/M3	Alk mg/l	EDTA mg/l	o-PO4 mg/l	t-PO4 mg/l	NO2 mg/l	NO3 mg/l	NH3 mg/l	TKN mg/l
S	21.0	7.4	375	9.8										
3	20.0	7.5	350	10.3										
6	18.0	8.0	332	11.4	1.6	1.716	215	203	.013	.017	.000	.000	.103	.450
9	17.8	8.0	331	11.5										
12	17.8	8.1	330	11.5										
15	17.5	8.2	328	11.4										
18	17.3	8.3	325	11.2										
21	17.0	8.4	322	11.2										

July 14 1983

Secchi Depth 10.50 ft.

Depth ft.	Temp C	pH	Cond um	D.O. mg/l	TSS mg/l	Chl-a mg/M3	Alk mg/l	EDTA mg/l	o-PO4 mg/l	t-PO4 mg/l	NO2 mg/l	NO3 mg/l	NH3 mg/l	TKN mg/l
S	26.0	7.5	370	9.2										
3	25.8	7.6	387	10.4										
6	25.7	7.7	390	9.4	1.4	4.05	186	188	.001	.022	.006	.038	.065	.649
9	25.9	8.1	395	11.3										
12	25.5	8.2	395	11.4										
15	25.5	8.5	395	9.6										
18	25.3	8.6	392	10.0										
21	22.0	8.4	390	6.2										

Lake Data & Chemistry

BIG FLOYD LAKE
August 18 1983

Secchi Depth 10.75 ft.

Depth ft.	Temp C	pH	Cond um	D.O. mg/l	TSS mg/l	Chl-a mg/M3	Alk mg/l	EDTA mg/l	o-PO4 mg/l	t-PO4 mg/l	NO2 mg/l	NO3 mg/l	NH3 mg/l	TKN mg/l
S	26.0	8.5	380	8.1										
3	25.8	8.5	380	7.9										
6	25.8	8.7	378	8.0	2.7	4.809	186	198	.001	.011	.005	.000	.068	.666
9	25.8	8.7	382	7.8										
12	25.8	8.6	382	7.8										
15	25.8	8.6	382	7.8										
18	25.8	8.6	382	7.8										
21	25.2	8.4	382	6.9										
23	24.8	8.3	380	5.5										

September 15 1983

Secchi Depth 8.25 ft.

Depth ft.	Temp C	pH	Cond um	D.O. mg/l	TSS mg/l	Chl-a mg/M3	Alk mg/l	EDTA mg/l	o-PO4 mg/l	t-PO4 mg/l	NO2 mg/l	NO3 mg/l	NH3 mg/l	TKN mg/l
S	17.8	7.2	350	8.2										
3	17.4	8.1	347	7.9										
6	17.5	8.6	338	7.5	2.7	5.157	204	206		.040	.007	.12	.177	.449
9	17.5	8.7	321	7.5										
12	17.5	8.7	330	7.5										
15	17.2	8.7	328	7.5										
18	17.1	8.4	322	7.6										
21	17.1	8.7	318	7.4										
24	17.0	8.7	320	7.4	2.0	5.853			.025	.09	.093	.0086	.093	.587

Algae/Phytoplankton Determinations

Algal counts in mg/L

BIG FLOYD LAKE

June 2, 1983

Depth in feet	Green	Blue-green	Euglanoids	Yellow	Diatoms	Total count
6	15	41	2	10	55	123

July 14, 1983

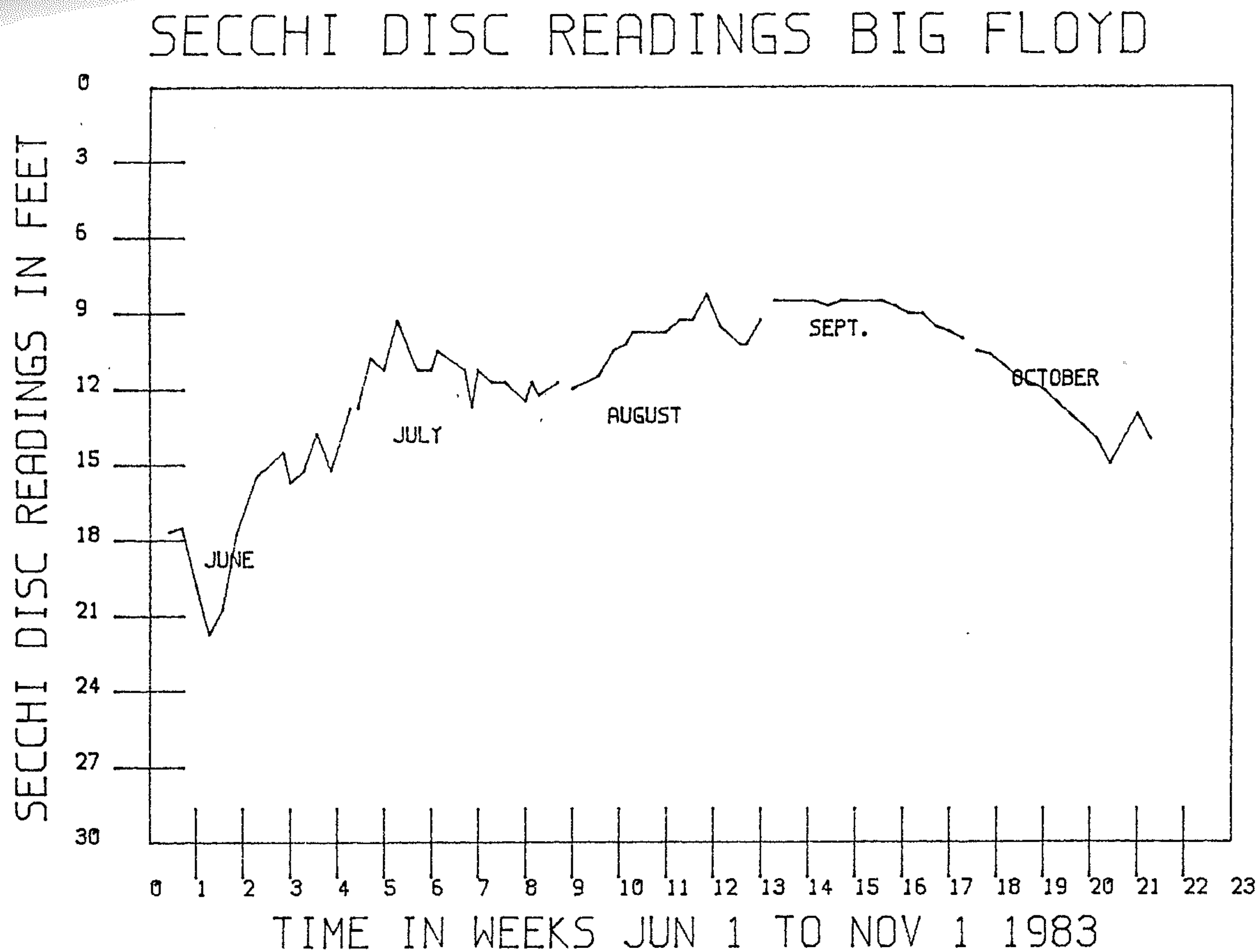
Depth in feet	Green	Blue-green	Euglanoids	Yellow	Diatoms	Total count
6	16	61	4	19	18	118

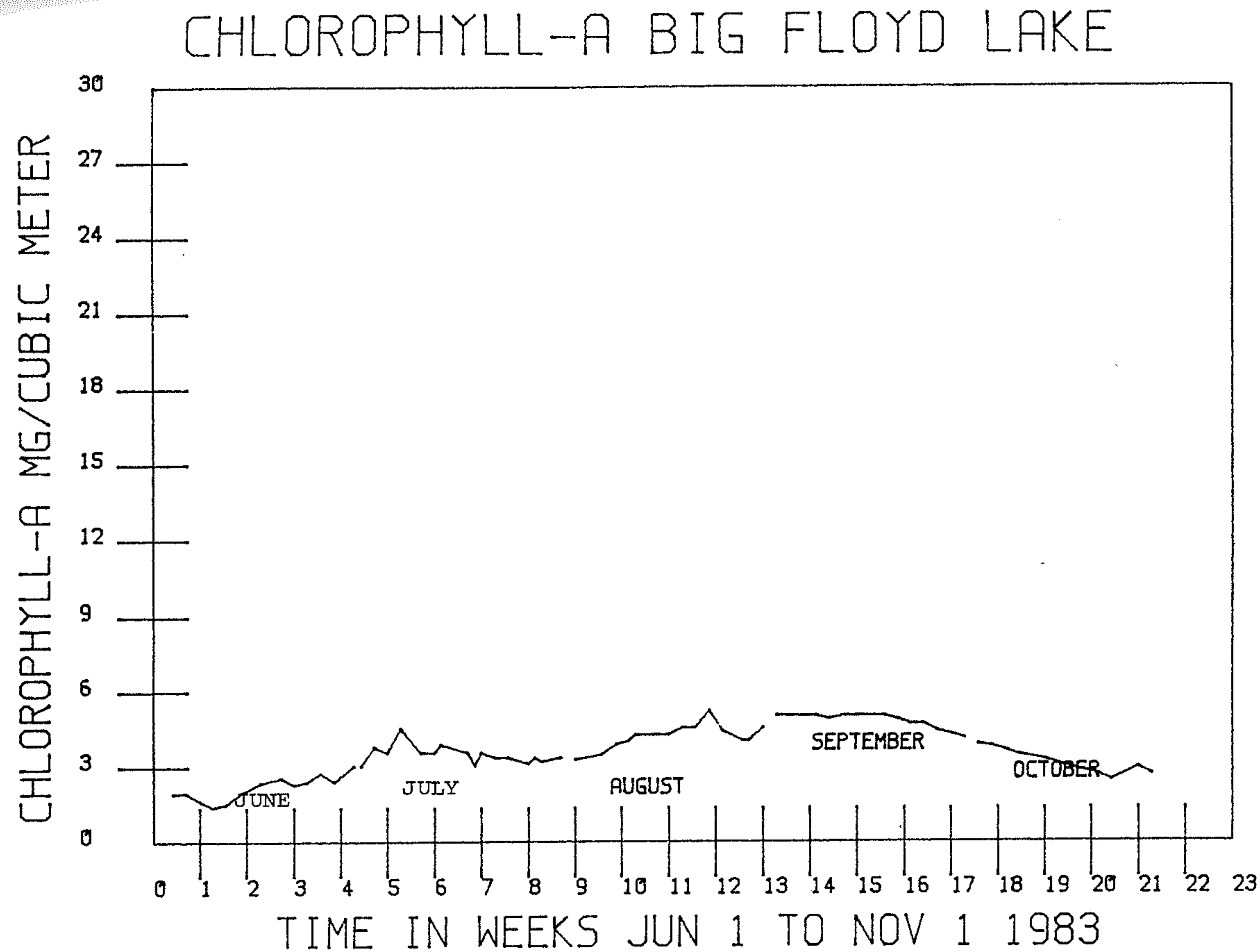
August 18, 1983

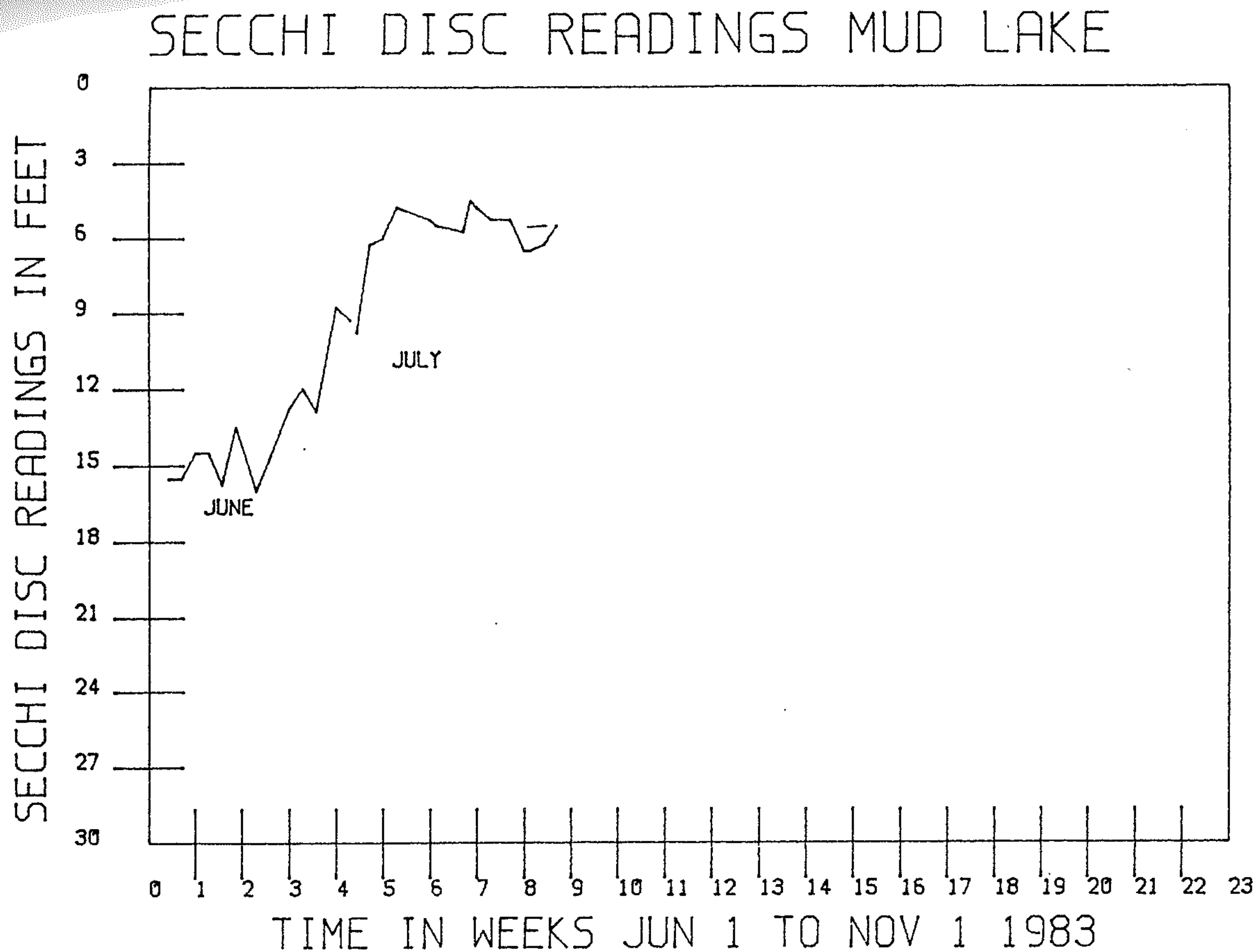
Depth in feet	Green	Blue-green	Euglanoids	Yellow	Diatoms	Total count
6	10	147	4	3	24	188

September 15, 1983

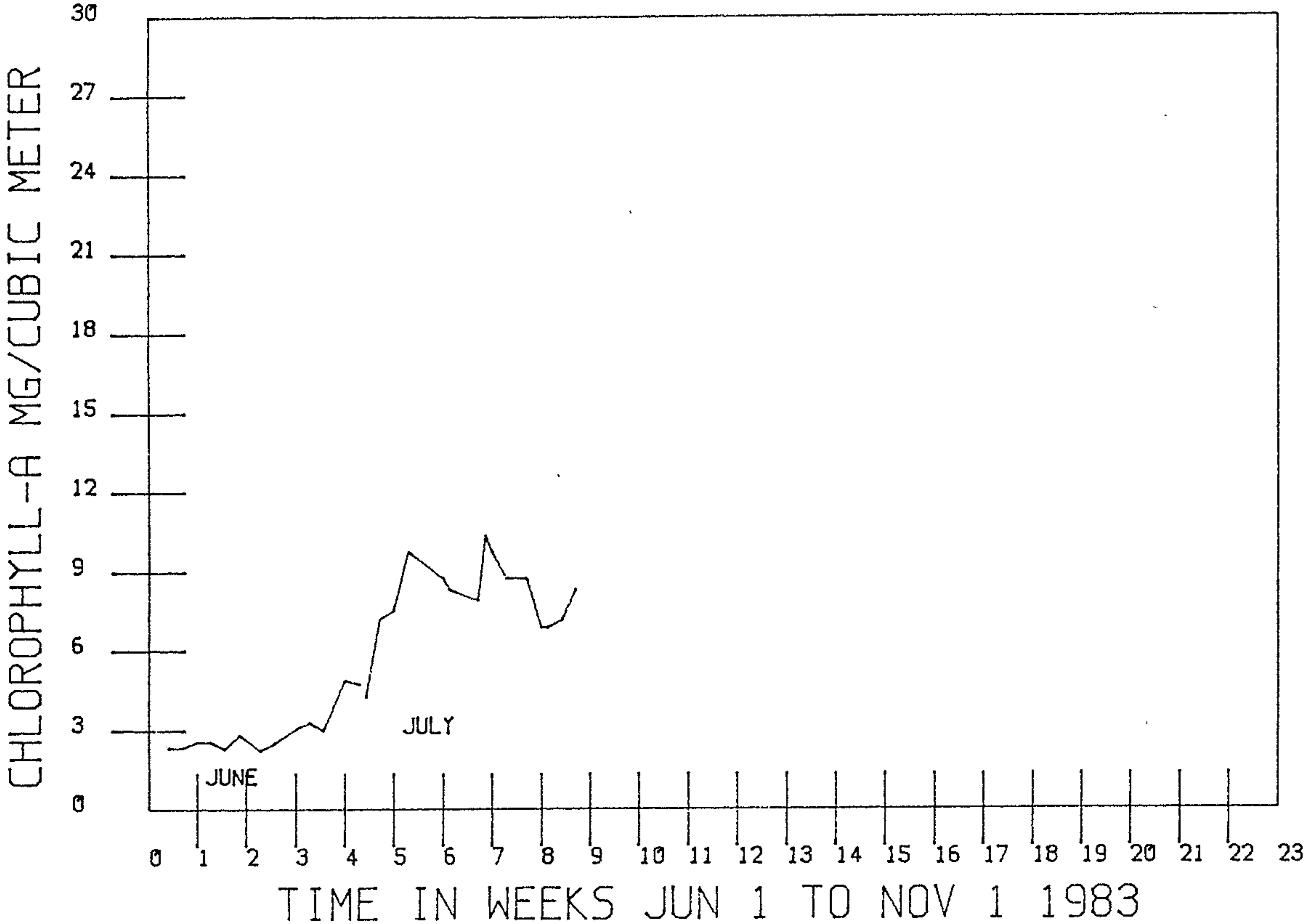
Depth in feet	Green	Blue-green	Euglanoids	Yellow	Diatoms	Total count
6	149	151	8	38	38	384
24	259	259	4	24	57	603

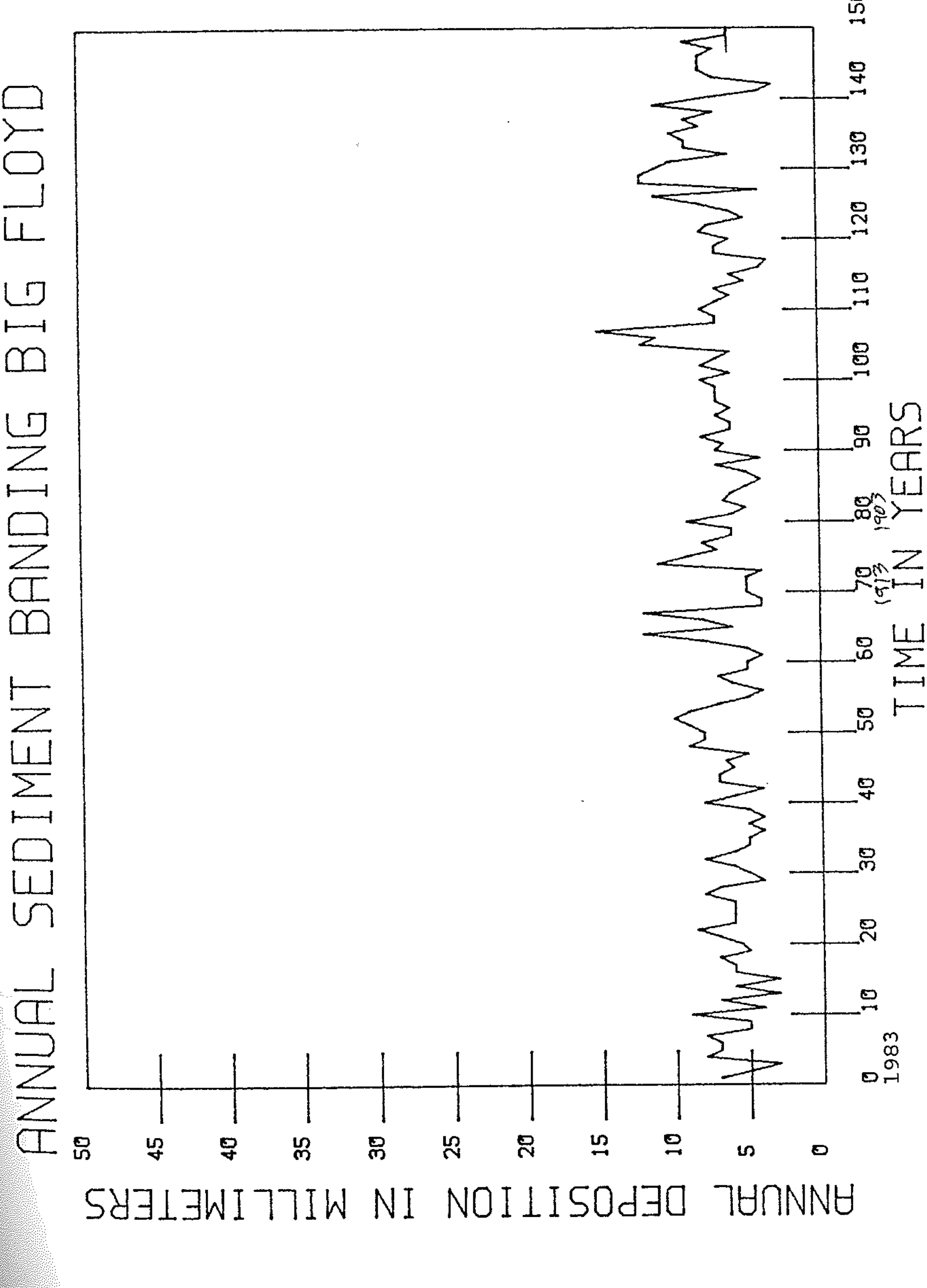

SECCHI DISC READINGS BIG FLOYD
SECCHI DISC READINGS IN FEET
0
3
6
9
12
15
18
21
24
27
30
JUNE
JULY
AUGUST
SEPT.
OCTOBER
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
TIME IN WEEKS JUN 1 TO NOV 1 1983


CHLOROPHYLL-A BIG FLOYD LAKE
CHLOROPHYLL-A MG/CUBIC METER
30
27
24
21
18
15
12
9
6
3
0
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
TIME IN WEEKS JUN 1 TO NOV 1 1983

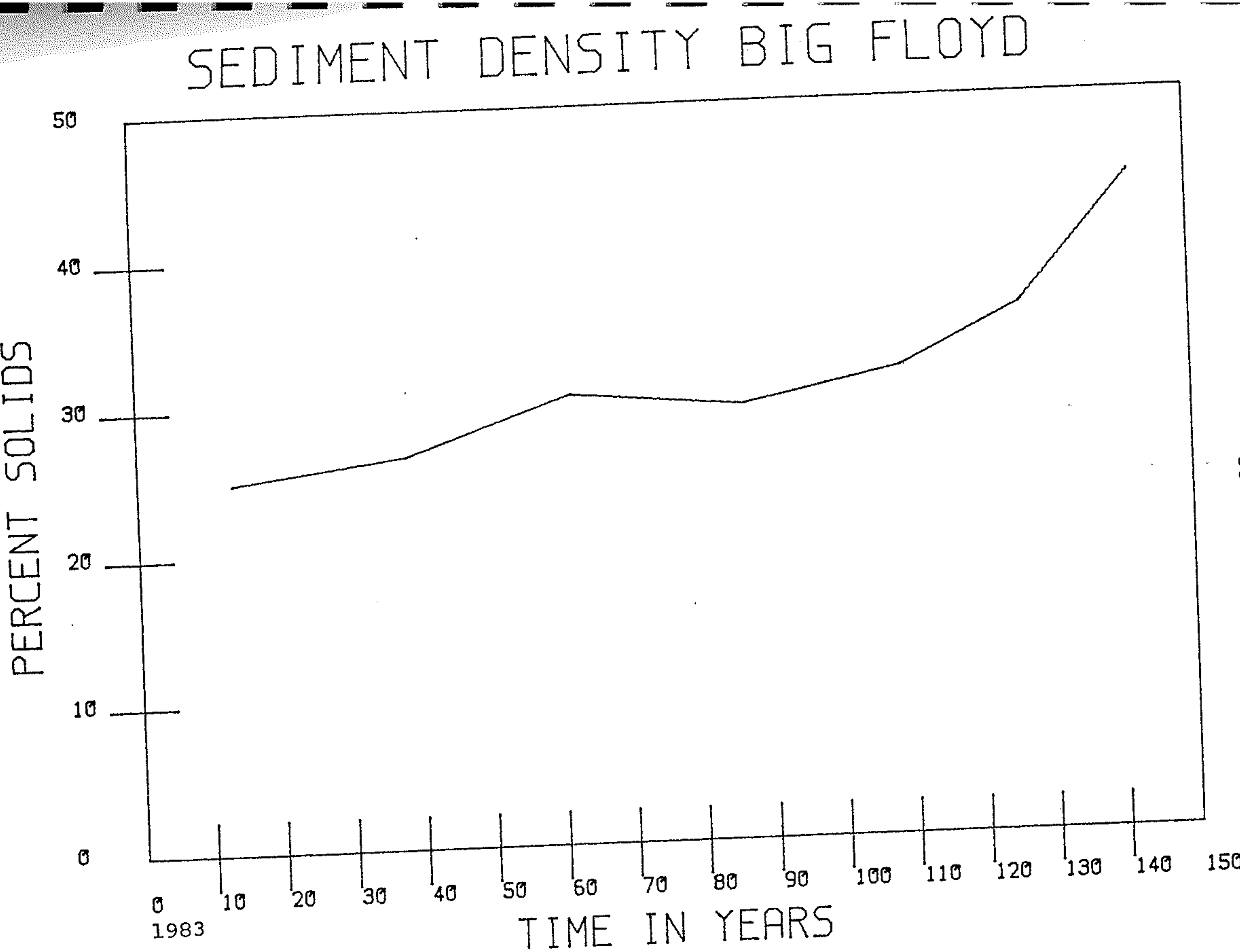

SECCHI DISC READINGS MUD LAKE
SECCHI DISC READINGS IN FEET
0
3
6
9
12
15
18
21
24
27
30
JUNE
JULY
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
TIME IN WEEKS JUN 1 TO NOV 1 1983

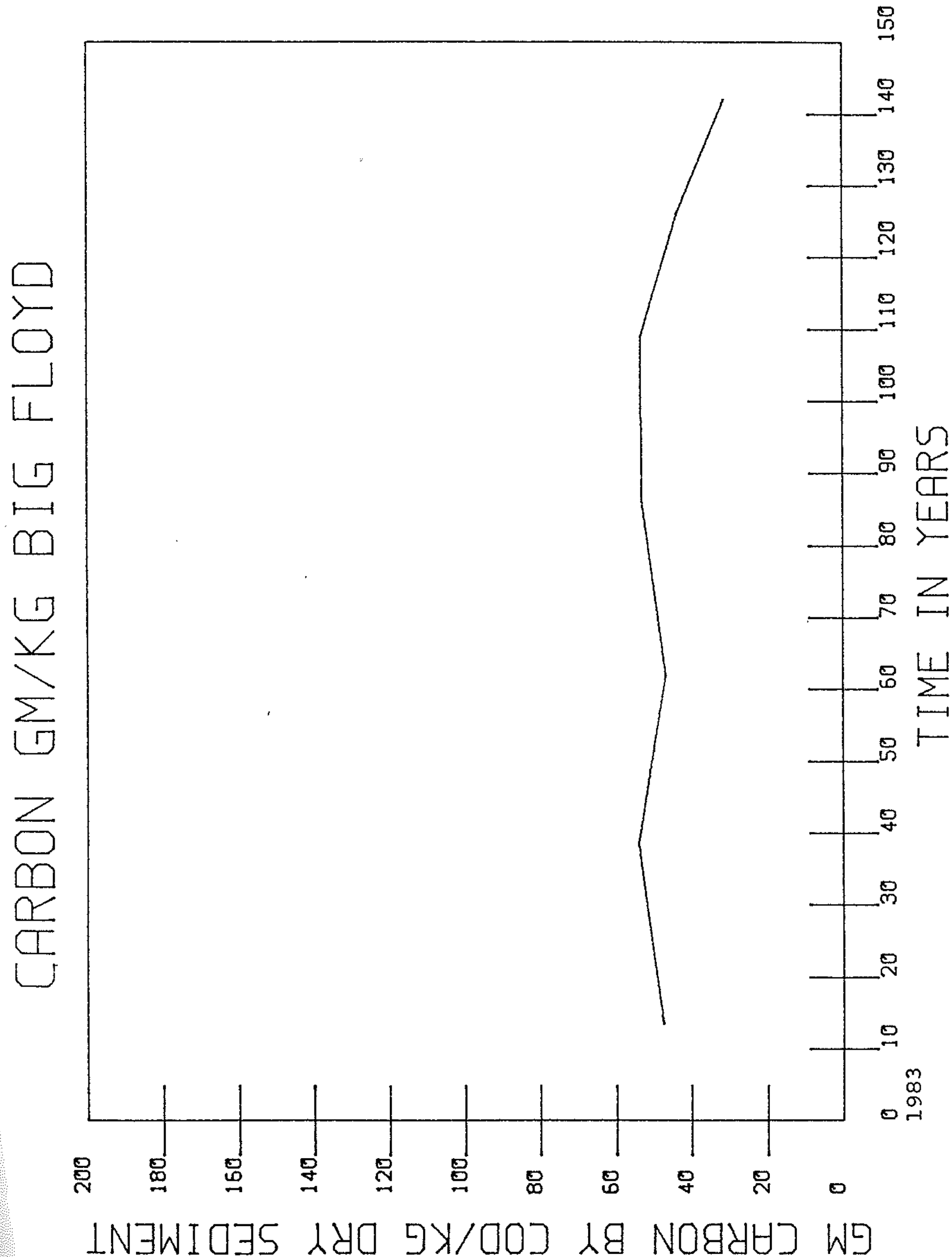
CHLOROPHYLL-A MUD LAKE





ANNUAL SEDIMENT BANDING BIG FLOYD
ANNUAL DEPOSITION IN MILLIMETERS
0
5
10
15
20
25
30
35
40
45
50
TIME IN YEARS
0
1983
10
20
30
40
50
60
70
(1913
80
1903
90
100
110
120
130
140
150


SEDIMENT DENSITY BIG FLOYD
PERCENT SOLIDS
50
40
30
20
10
0
0
1983
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
TIME IN YEARS



CARBON GM/KG BIG FLOYD
GM CARBON BY COD/KG DRY SEDIMENT
0
20
40
60
80
100
120
140
160
180
200
TIME IN YEARS
0
1983
10
20
30
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50
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70
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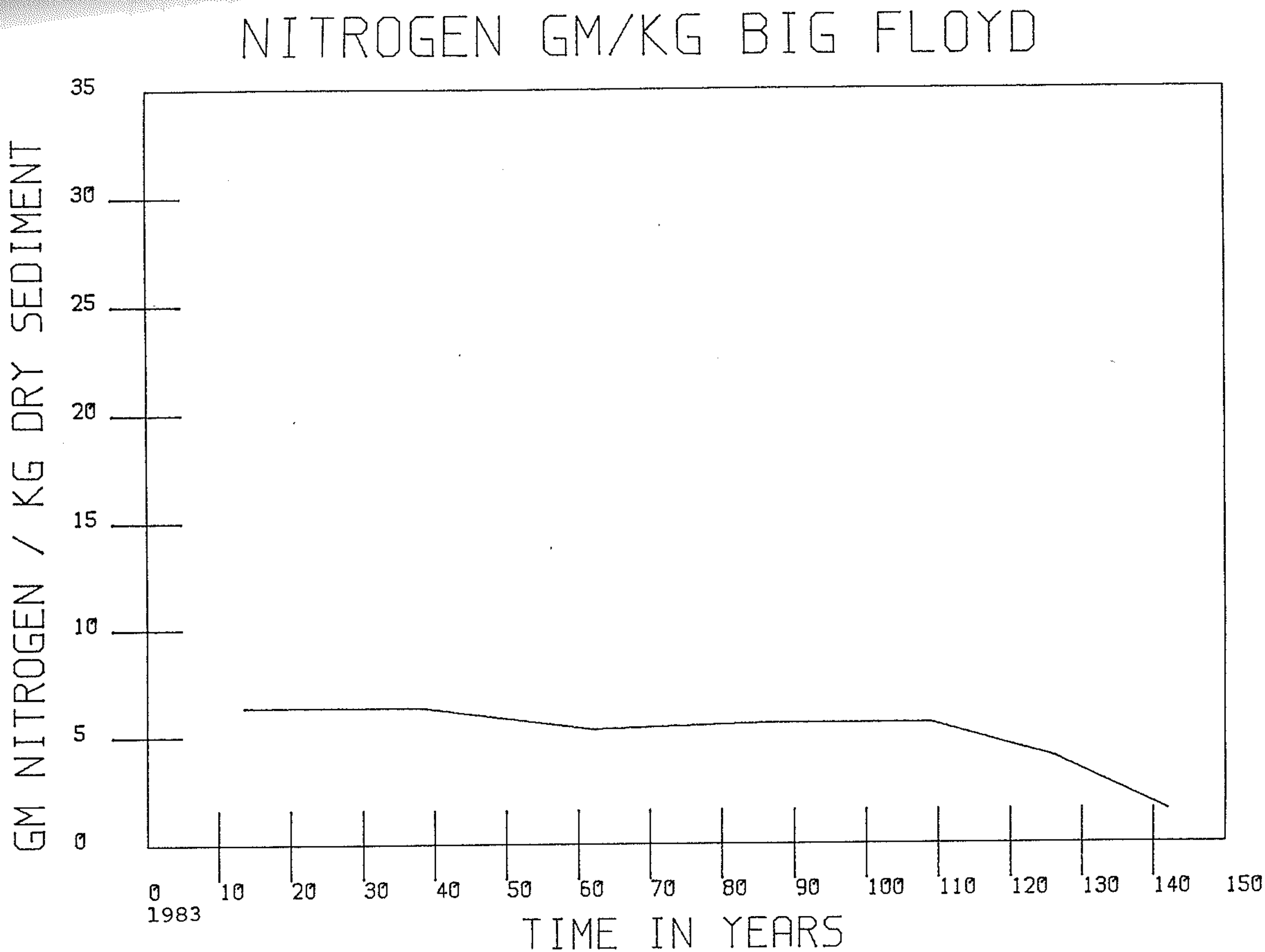
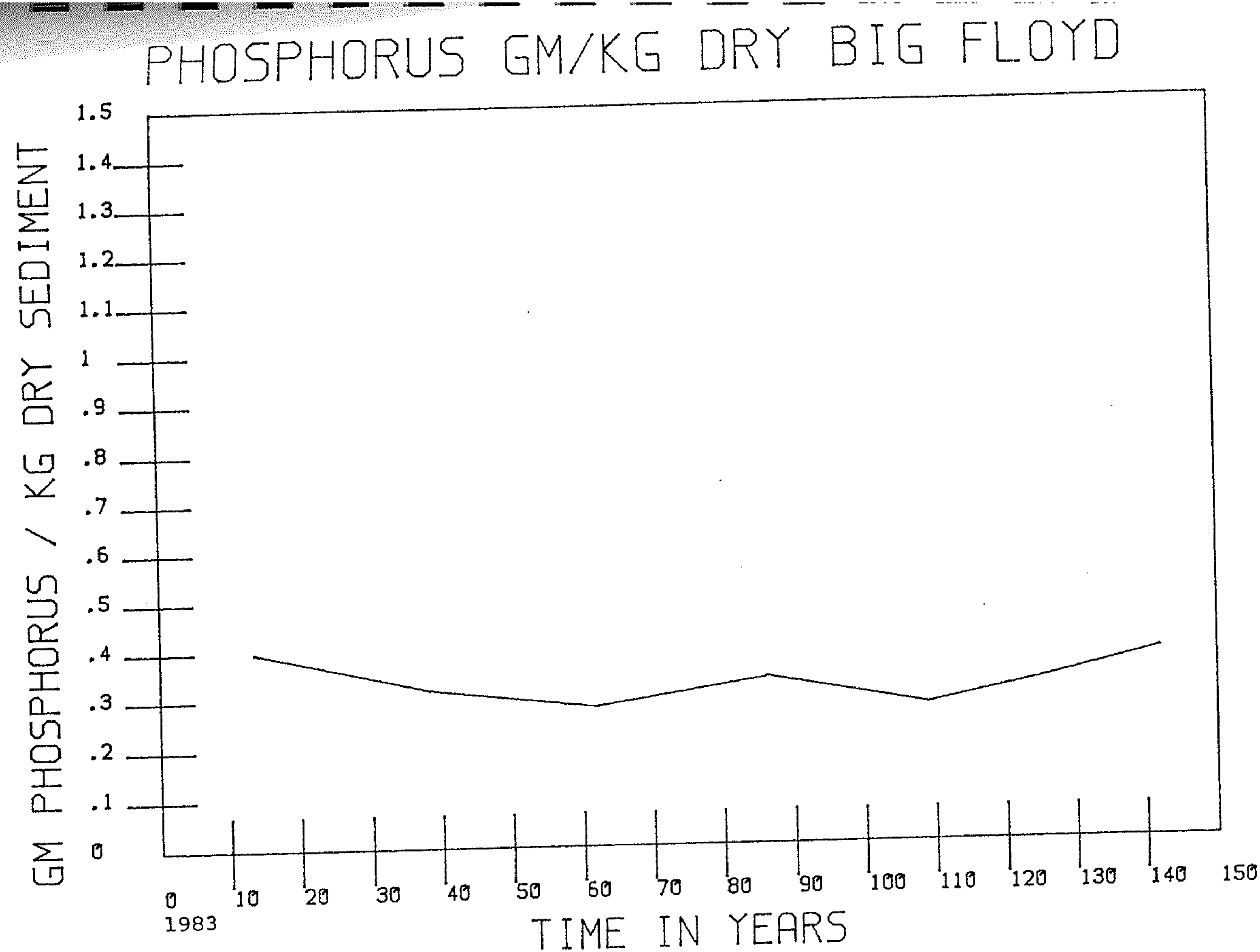
110
120
130
140
150


NITROGEN GM/KG BIG FLOYD
GM NITROGEN / KG DRY SEDIMENT
35
30
25
20
15
10
5
0
0
1983
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
TIME IN YEARS


PHOSPHORUS GM/KG DRY BIG FLOYD
GM PHOSPHORUS / KG DRY SEDIMENT
1.5
1.4
1.3
1.2
1.1
1
.9
.8
.7
.6
.5
.4
.3
.2
.1
0
0
1983
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
TIME IN YEARS

LITTLE FLOYD LAKE

Surface area (acres)	205.
Littoral area (acres)	89.
Volume (acre feet)	3,520.
Maximum depth (feet)	34.
Average depth (feet)	17.
Number of inlets	1.
Approximate flow (acre feet)	800.
Number of outlets	1.

This lake has a relatively small volume and so responds rapidly to changes in the river condition and its own watershed. The secchi disc dropped to 4.5 feet by the end of August and remained low through September and October. The average for July, August, and September was 6.56 feet. This indicates a fairly heavy loading from this lake's watershed. Unlike Big Floyd Lake, Little Floyd Lake has the Pelican River flowing through the entire lake which allows accumulation of the nutrient load from the river as well as the watershed.

No attempt was made to locate a heavy nutrient input point to Little Floyd Lake. There is a good probability at least one temporary flowage is contributing regularly to the nutrient loading of Little Floyd Lake. If runoff from the golf course is reaching this lake without any intervening ponding, this would be a likely source.

The lake was anoxic below twenty four feet by mid July this year and almost all of the oxygen was depleted below eighteen feet in mid August. By the next sampling in mid September, the lake was completely mixed again, although the oxygen content was not very high.

The volume of the lake which has little or no oxygen during the summer season cannot be used by the fish populations. Since many of the fish species require cover to exist, this limits the populations to the shallow waters at the edge of the lake for living and feeding areas.

Although the phosphorus loading was not much higher than Big Floyd Lake, the nitrogen load is considerably greater. This would indicate a major nitrogen loading source from the immediate watershed.

The Kw (non-algal background turbidity constant) for Little Floyd Lake, indicates the lake is receiving a fair amount of background turbidity as well. The chlorophyll-a readings in this lake are more than two times as high as Big Floyd Lake. There is sufficient phosphorus loading later in the season to allow the uptake of avalilable nitrogen and carbon to generate biomass. The result was the observable large algae population.

During the summer when Little Floyd is anoxic, the bottom sediments are releasing a considerable amount of phosphorus to the free water. The sediment banding in this lake has been on the increase over the last thirty years. The yearly excursions from the mean are approximately the same, but the mean loading per year is increasing. The current annual loading rate is still less than the measured high of about sixty years ago, but the rate had decreased considerably until thirty years ago. This suggests that the present condition is better than it was sixty years ago, but that at its present rate of increase, will surpass its former condition in ten to twenty years.

The algae population of this lake was dominated by blue-green algae through most of the season. The September analysis contained more than three times the algae populations found in Lake Sallie for the same time of year.

The sediment density has dropped from a high of 22 percent solids about twenty years ago to a current 15 percent, indicating a condsiderable amount of outgassing from bacterial activity. Most of this is probably occurring during the period of anoxia in the summer months.

The percent carbon in the sediments is also on the increase and the rate of carbon build up has been on the increase over the past thirty years. The source of the organic carbon loading is primarily from partially decayed plant and algae materials. The build up is a result of an inefficiency in the bacterial population, probably caused by a dominance of anaorbic or bacteria which operate in a deoxygenated condition.

At its current deposition rate the percent carbon in the sediment will exceed its past high in about fifteen to twenty years. This will mean longer periods of anoxic conditions in the summer months and poorer water quality at the surface. The carbon load is presently approaching that of Lake Sallie.

The nitrogen loading in this lake has been cycling up and down over the past eighty years. The cycle period appears to be shortning at this time and the current trend is toward an increased load per year.

The present phosphorus load in the sediments is currently decreasing. The phosphorus load is cycling similar to the carbon and nitrogen, but the trend is an inverse curve. When the nitrogen and carbon are on the increase, indicating higher biomass deposition, the phosphorus loading is on the decrease, indicating bacterial stripping.

Considering the position of Little Floyd Lake in the watershed, and its potential for flushing its accumulated load to the downstream lakes, it is important to locate the external loading sources, and clean up the offending condition.

Lake Data & Chemistry

LITTLE FLOYD LAKE
June 2 1983

Secchi Depth 13.75 ft.

Depth ft.	Temp C	pH	Cond um	D.O. mg/1	TSS mg/1	Chl-a mg/M3	Alk mg/1	EDTA mg/1	o-PO4 mg/1	t-PO4 mg/1	NO2 mg/1	NO3 mg/1	NH3 mg/1	TKN mg/1
S	19.5	6.8	345	10.6										
3	19.0	6.8	343	11.0										
6	17.8	7.1	335	11.6	1.7	5.945	213	209	.011	.031	.000	.000	.116	.599
9	17.5	7.2	335	11.4										
12	17.5	7.2	335	11.4										
15	17.5	7.3	332	11.4										
18	17.3	7.3	331	11.3										
21	17.0	7.4	331	11.3										
24	17.0	7.4	330	10.9										

July 14 1983

Secchi Depth 09.00 ft.

Depth ft.	Temp C	pH	Cond um	D.O. mg/1	TSS mg/1	Chl-a mg/M3	Alk mg/1	EDTA mg/1	o-PO4 mg/1	t-PO4 mg/1	NO2 mg/1	NO3 mg/1	NH3 mg/1	TKN mg/1
S	25.7	8.6	380	11.0										
3	26.0	8.7	382	11.2										
6	26.0	8.8	385	10.4	3.0	7.76	172	184	.001	.018	.006	.039	.073	.463
9	25.9	8.6	385	11.9										
12	25.8	8.6	387	11.2										
15	25.4	8.6	382	11.8										
18	23.0	8.5	372	11.0	3.2	10.30			.001	.017	.007	.043	.069	.646
21	22.7	8.0	370	6.2										
24	20.8	7.8	372	4.5										
27	20.0	7.2	378	2.8										
30	19.5	6.6	374	1.4	1.3	11.32			.004	.028	.012	.042	.203	.654

Lake Data & Chemistry

LITTLE FLOYD LAKE

August 18 1983

Secchi Depth 6.75 ft.

Depth ft.	Temp C	pH	Cond um	D.O. mg/l	TSS mg/l	Chl-a mg/M3	Alk mg/l	EDTA mg/l	o-PO4 mg/l	t-PO4 mg/l	NO2 mg/l	NO3 mg/l	NH3 mg/l	TKN mg/l
S	26.0	8.6	365	9.1										
3	26.0	8.5	366	8.7										
6	26.0	8.6	368	8.5	3.1	10.00	171	192	.002	.011	.010	.040	.075	.743
9	25.8	8.7	369	8.4										
12	25.6	8.8	365	8.3	3.5	8.23								
15	24.5	8.6	362	7.2										
18	23.0	7.8	373	0.3										
21	20.8	7.5	382	0.2										
24	18.8	7.4	375	0.1	2.5	7.38			.010	.014	.022	.010	.709	1.028

September 15 1983

Secchi Depth 5.75 ft.

Depth ft.	Temp C	pH	Cond um	D.O. mg/l	TSS mg/l	Chl-a mg/M3	Alk mg/l	EDTA mg/l	o-PO4 mg/l	t-PO4 mg/l	NO2 mg/l	NO3 mg/l	NH3 mg/l	TKN mg/l
S	17.2	7.6	318	6.5										
3	17.9	7.9	319	6.5										
6	17.8	8.0	319	6.6	3.4	12.510	187	212	.003	.043	.013	.19	.291	.535
9	17.5	8.2	320	6.6										
12	17.8	8.2	321	6.6										
15	17.8	8.3	320	6.6										
18	17.8	8.6	320	6.6										
21	17.5	8.5	318	6.6										
24	17.2	8.5	318	6.4	2.9	16.087			.002	.040	.012	.12	.346	.561

Algae/Phytoplankton Determinations

Algal counts in mg/L

LITTLE FLOYD LAKE

June 2, 1983

Depth in feet	Green	Blue-green	Euglanoids	Yellow	Diatoms	Total count
6	2	20	2	44	438	506

July 14, 1983

Depth in feet	Green	Blue-green	Euglanoids	Yellow	Diatoms	Total count
6	6	385	2	44	32	469
18	9	403	6	46	32	496
30	4	376	2	4	57	443

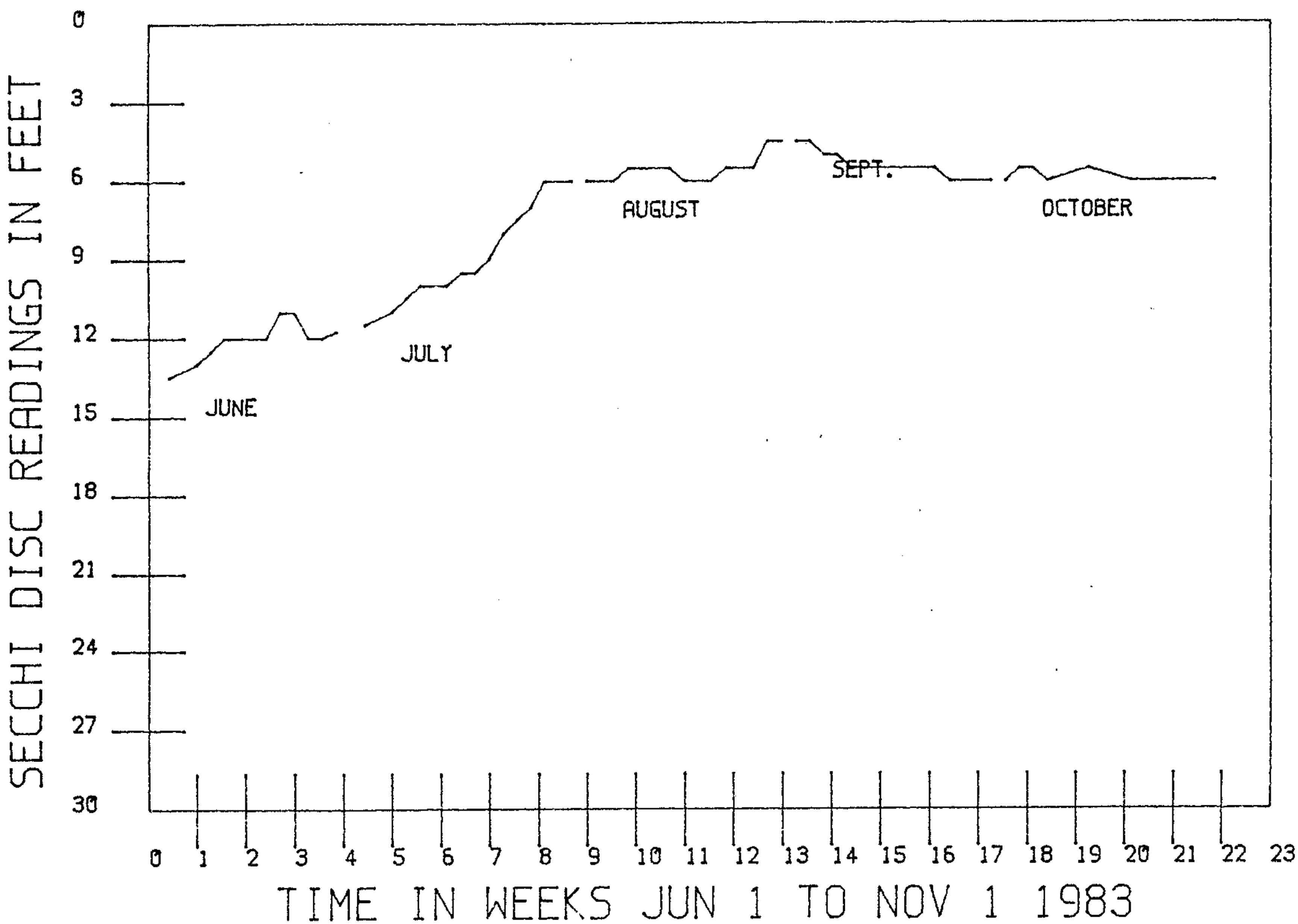
August 18, 1983

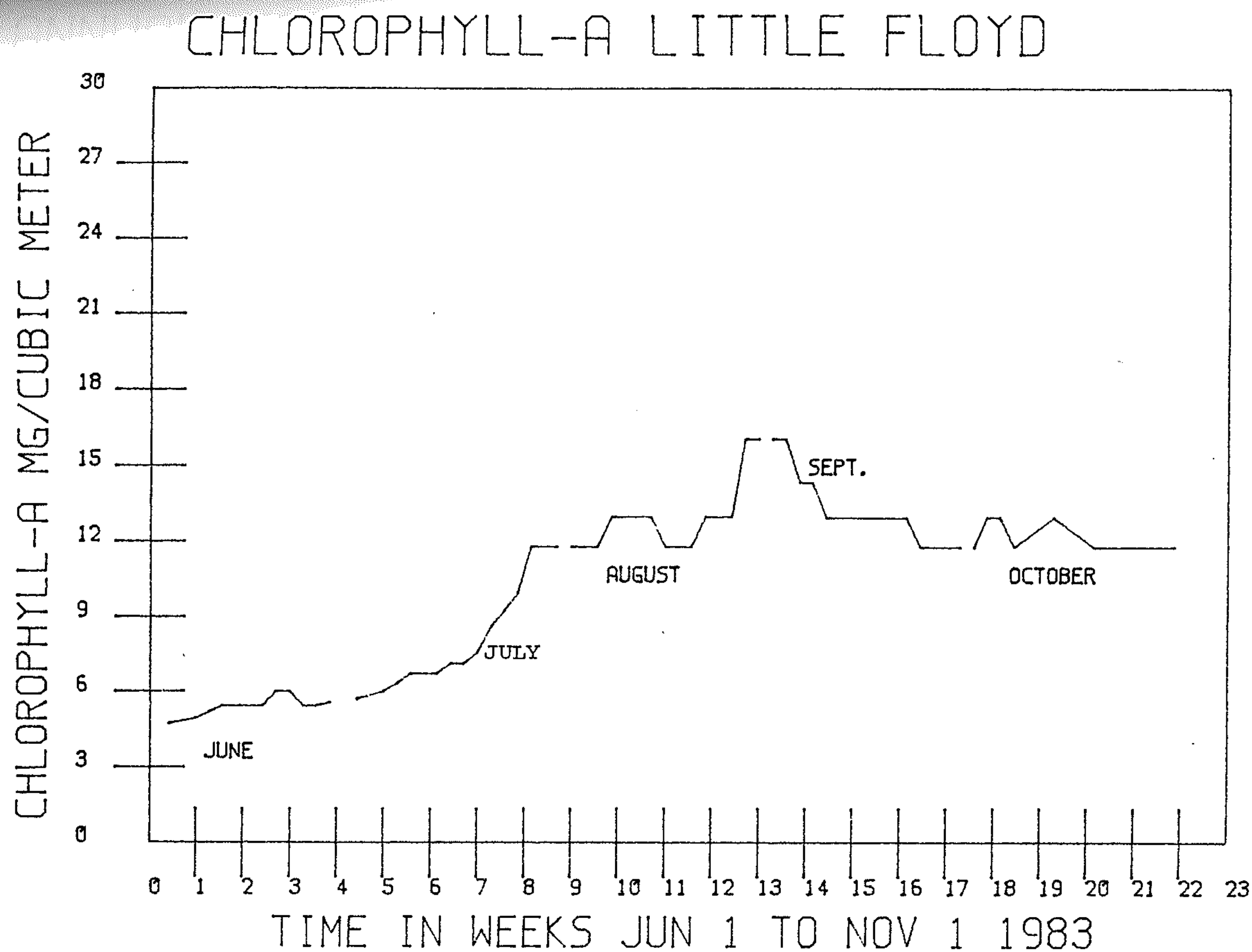
Depth in feet	Green	Blue-green	Euglanoids	Yellow	Diatoms	Total count
6	14	194	4	2	25	239
12	23	87	0	6	49	165
24	0	248	4	2	21	275

September 15, 1983

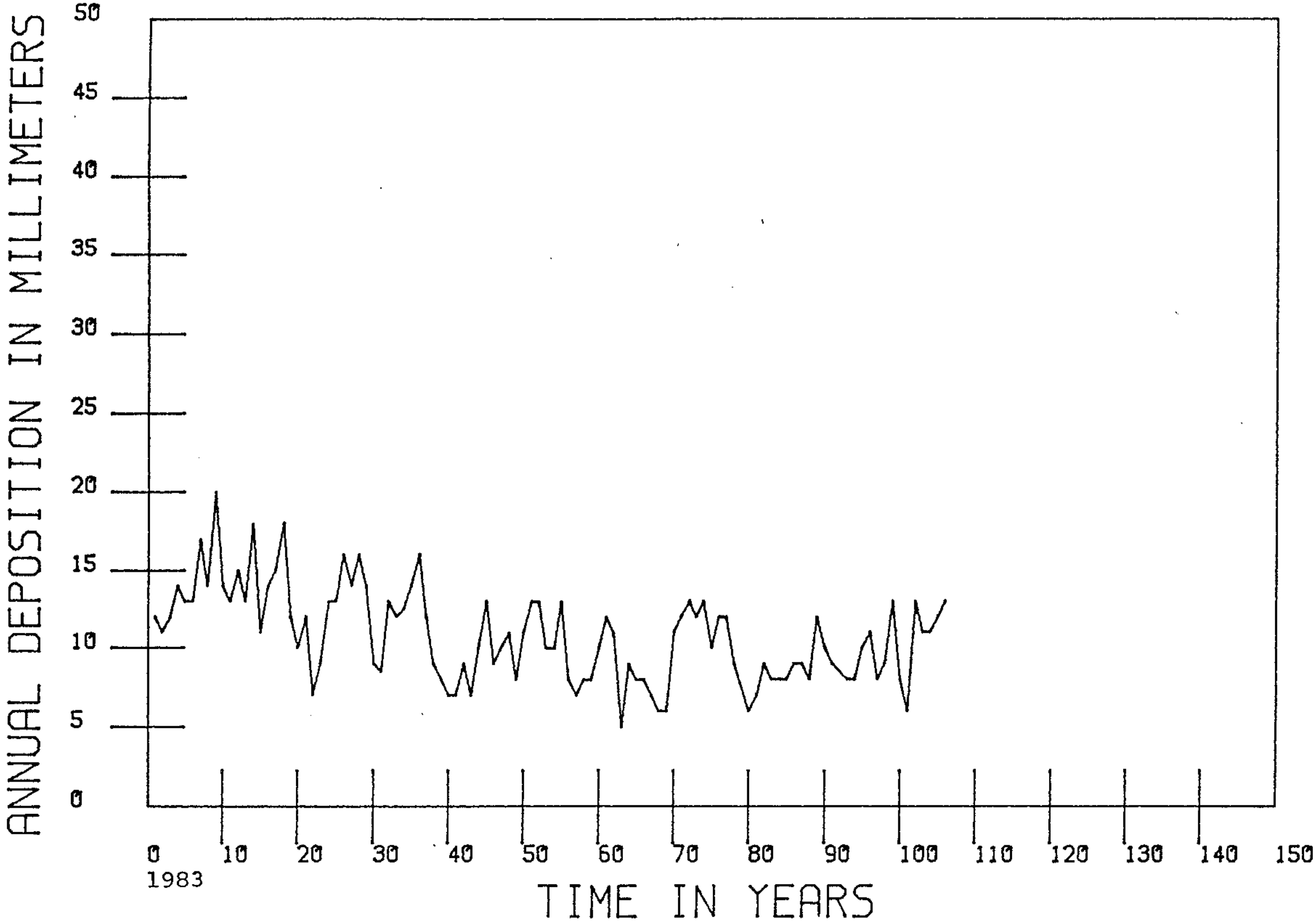
Depth in feet	Green	Blue-green	Euglanoids	Yellow	Diatoms	Total count
6	30	19,573	20	11	145	19,779
24	35	21,736	8	0	132	21,911

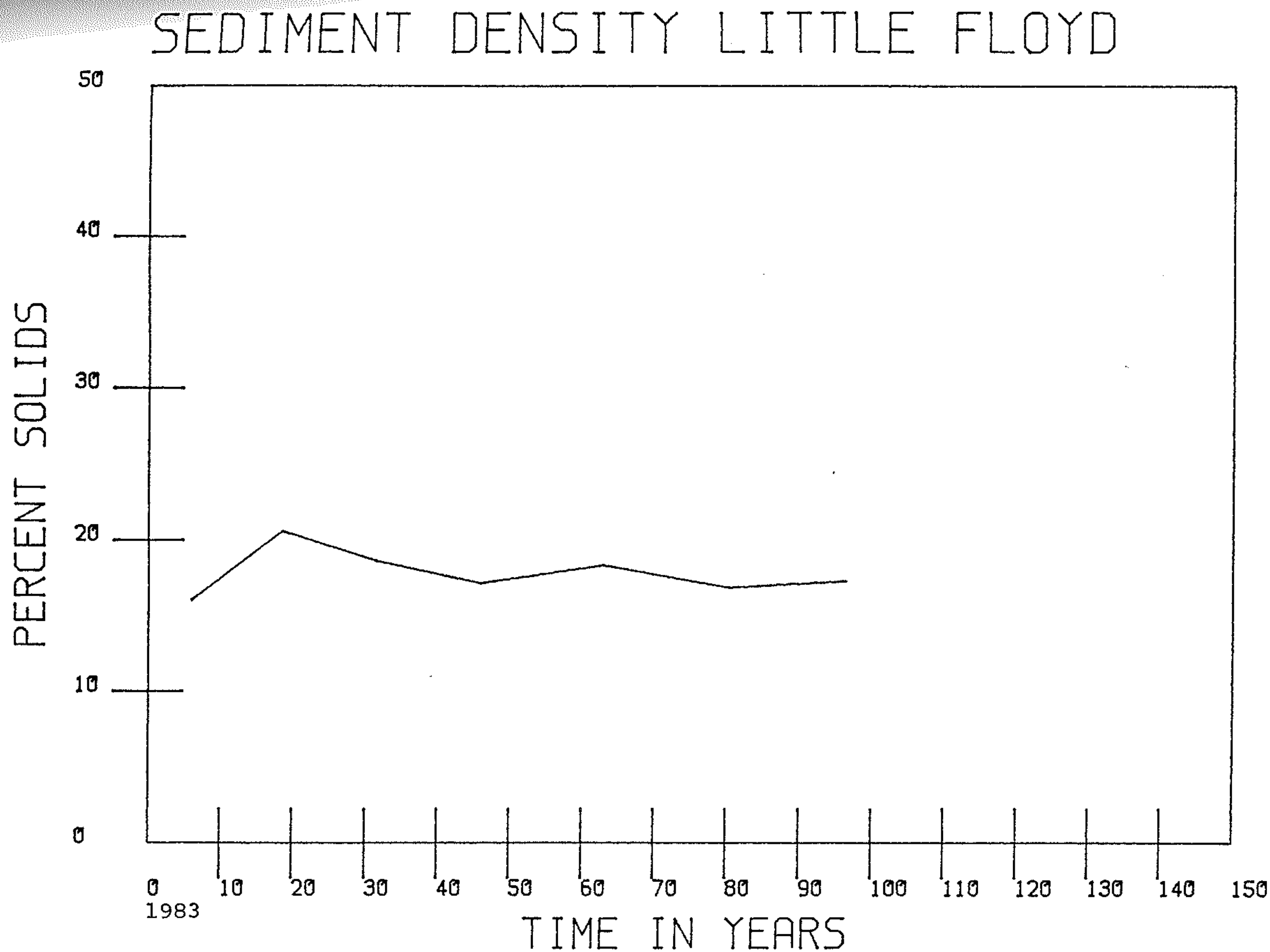
SECCHI DISC READINGS LITTLE FLOYD

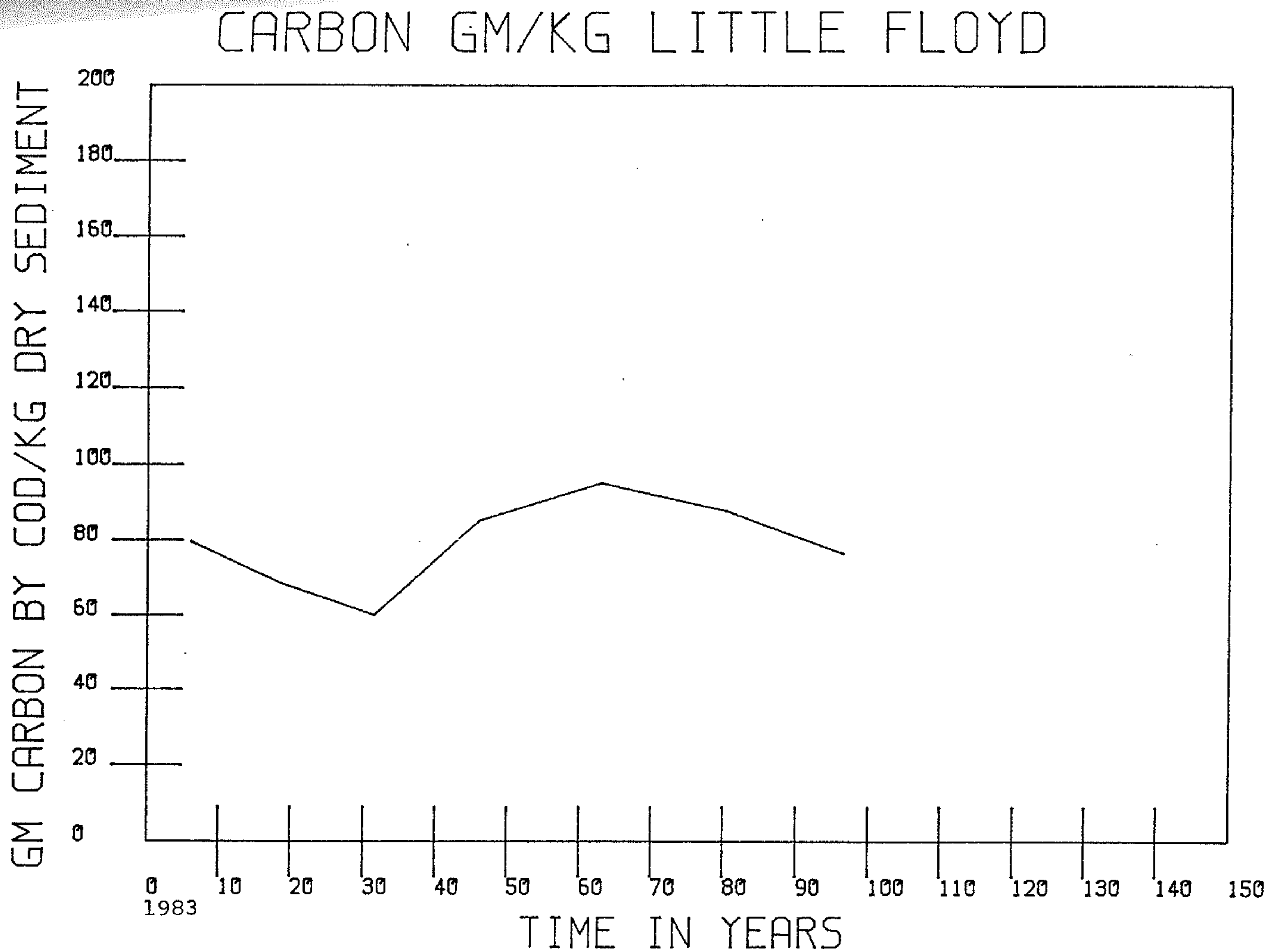


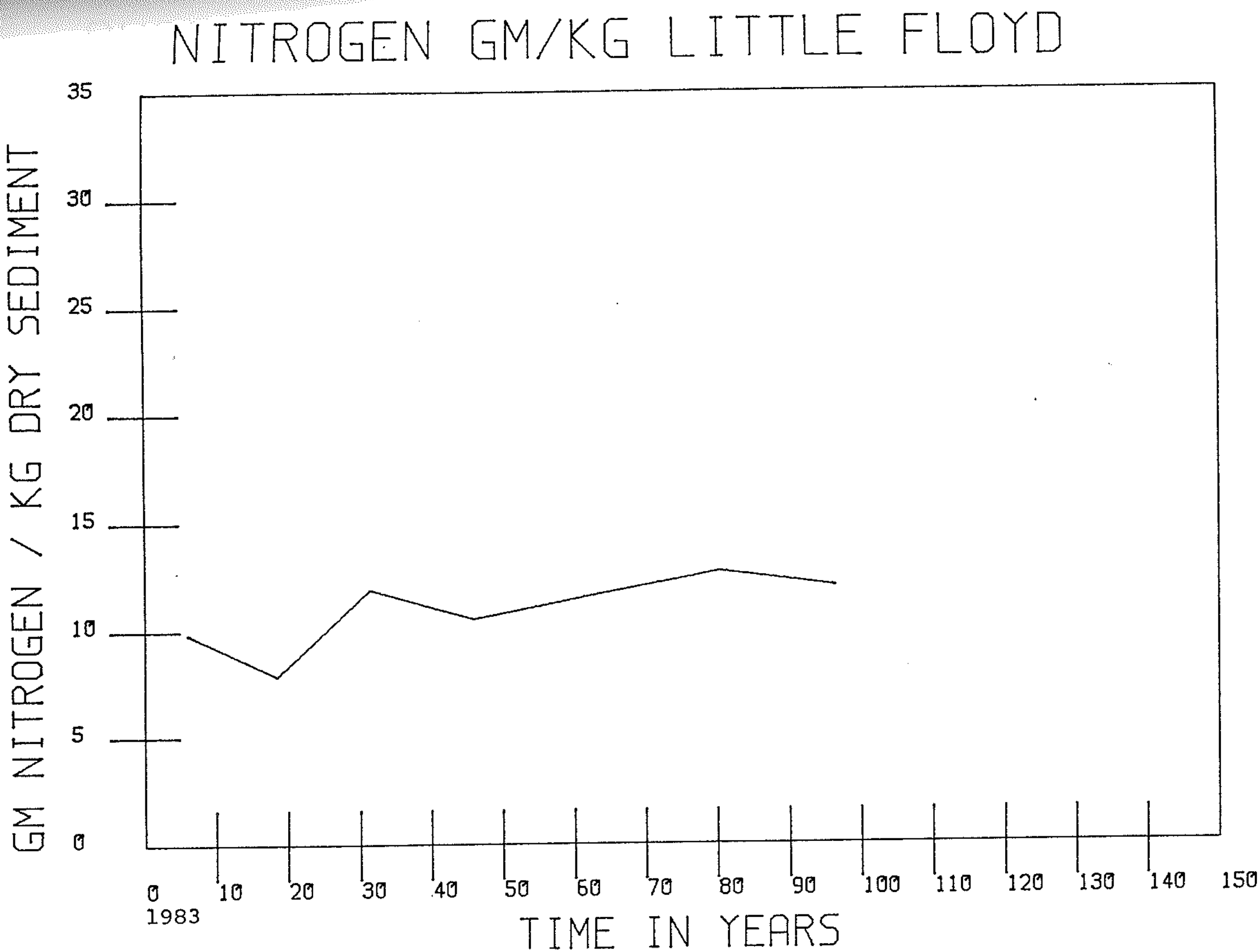

CHLOROPHYLL-A LITTLE FLOYD
CHLOROPHYLL-A MG/CUBIC METER
30
27
24
21
18
15
12
9
6
3
0
JUNE
JULY
AUGUST
SEPT.
OCTOBER
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
TIME IN WEEKS JUN 1 TO NOV 1 1983

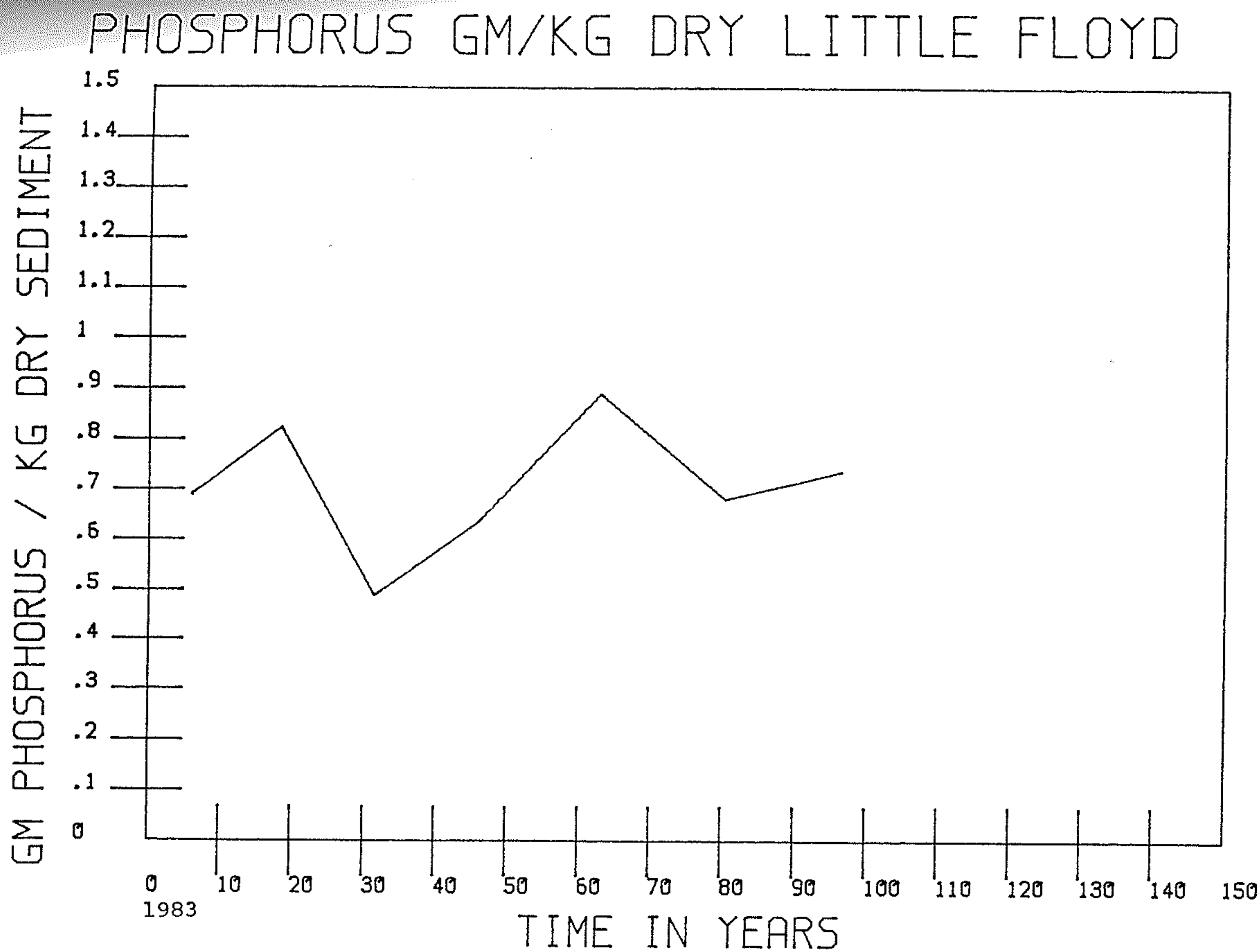
ANNUAL SEDIMENT BANDING LITTLE FLOYD




SEDIMENT DENSITY LITTLE FLOYD
PERCENT SOLIDS
50
40
30
20
10
0
0
1983
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
TIME IN YEARS


CARBON GM/KG LITTLE FLOYD
GM CARBON BY COD/KG DRY SEDIMENT
0
20
40
60
80
100
120
140
160
180
200
0
1983
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
TIME IN YEARS


NITROGEN GM/KG LITTLE FLOYD
GM NITROGEN / KG DRY SEDIMENT
35
30
25
20
15
10
5
0
0
1983
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
TIME IN YEARS


PHOSPHORUS GM/KG DRY LITTLE FLOYD
GM PHOSPHORUS / KG DRY SEDIMENT
1.5
1.4
1.3
1.2
1.1
1
.9
.8
.7
.6
.5
.4
.3
.2
.1
0
0
1983
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
TIME IN YEARS

BIG DETROIT LAKE

Surface area (acres)	2160.
Littoral area (acres)	975.
Volume (acre feet)	34,500.
Maximum depth (feet)	82.
Mean Depth	16.
Number of inlets	3.
Volume flow per year (acre feet)	17,561.
Number of outlets	1.

Despite the size and volume of Big Detroit Lake, it is sensitive to changing conditions in the watershed, particularly in the case of the input from the Pelican River. The Kw (background turbidity constant) which was used to calculate the chlorophyll-a from the secchi disc readings, changed by a factor of three from early June to mid July and then held through August and September. This "constant" is in fact another variable, but since the only poor data fit was in the early June data, the Kw which resulted from the July, August, and September data was used. This is valid since the June chlorophyll -a levels were extremely low and so the added biomass for the year does not appreciably affect the total annual loading.

During the 1983 sampling, Big Detroit Lake did develop a thermocline at fifteen feet, which came up to nine feet during August and September. However, this lake is mixed well enough by the wind throughout the year to maintain a high dissolved oxygen concentration through most of the season. At the time of the first major river discharge from the heavy summer storms, the lake developed an anoxic condition. Evidence for this was the whitefish kill observed during the August sampling.

At the August sampling the dissolved oxygen concentrations were at 5 milligrams per liter below the thermocline. This concentration is not sufficient to cause a fish kill, inidicating that the lake is capable of recovering rapidly from an anoxic condition. There is also the possibility of a bacterially induced fish kill, but these usually take place earlier in the season and are caused by the stress induced by late winter conditions.

The nitrogen and phosphorus levels are balanced in this lake throughout the season and so the algae populations were not severely limited. The observed chlorophyll-a levels in Big Detroit Lake are to be expected considering the level of nutrient input. This is not to say that the observed 20 milligram per cubic meter levels of chlorophyll-a are desirable for an August condition.

This last year was unusual in that the rains were heavy and prolonged. In theory another storm condition like this may not occur again for a very long time. It is still our belief that the number three priority for the watershed should be to modify the marshlands between Little Floyd Lake and Big Detroit Lake to allow the marsh to contain a greater amount of its accumulated nutrients and to hold more of these in the event of another severe storm loading.

The secchi disk readings collected during the summer of 1983 are not appreciably different from those collected from past years. The lake appears to respond to the influent from the Pelican River. This year that input was low until the second week in July. For the remainder of the season the algae responded to the new nutrient load until the middle of September. With the depletion of the nutrients, the algae died off, and the lake returned to its earlier condition.

The algae populations in this lake were not as large as those in Little Floyd Lake, but were dominated by blue-green algae through most of the season. During August the lake was covered with a population of Gleotrichia, a colonial blue-green algae. The bloom was diminishing at the time, but the decay of this population was probably responsible for the fish kill which had taken place prior to the August sampling.

The core collected from Big Detroit Lake dated back one
hundred thirty-two years. Until one hundred years ago the 1880
sediment load to the lake was steady and low. The mean 1880-1900
input level then doubled for the next twenty years, followed 1900-1910
by a ten year respite. Seventy years ago there were two 1910-1912
more years of very high input, and again the loading settled 1912-1942
down for the next thirty years. About thirty-five years ago 1945-50
the lake took another heavy load for about five years. This
same thing happened about twenty-five years ago and then the 1955-60
loading rate dropped steadily until four years ago. 1976

The 1983 season was as high a soil loading as the lake has seen over the last one hundred thirty years, although this last summer a statistically rare storm event occurred, the lake has experienced these in past years as well. If the marshlands upstream are the major point of nutrient release to Big Detroit Lake, then the channel through this area and the area itself should be managed for nutrient removal. In future years the upper watershed will become more heavily developed with the result that the marshlands will accumulate heavier nutrient loads. When these accumulated loadings are released by heavy storm events, the effect will be to slug load the lake again.

The sediment density was lower one hundred years ago than it is today, which indicates that there was a higher carbohydrate load to the sediments at that time. This is verified by the higher carbon, nitrogen, and phosphorus contained in those sediments. Since about sixty years ago the ratio of organic to inorganic loading has remained about the same, even though the total quantity of material which reached the lake varies considerably from year to year.

Lake Data & Chemistry

BIG DETROIT LAKE
June 2 1983

Secchi Depth 15.25 ft.

Depth ft.	Temp C	pH	Cond um	D.O. mg/l	TSS mg/l	Chl-a mg/M3	Alk mg/l	EDTA mg/l	o-PO4 mg/l	t-PO4 mg/l	NO2 mg/l	NO3 mg/l	NH3 mg/l	TKN mg/l
S	19.5	8.1	370	11.0										
3	18.0	8.0	350	11.0										
6	17.5	8.0	344	10.8	1.5	5.236	211	204	.007	.013	.000	.000	.087	.197
9	16.0	8.0	330	11.5										
12	16.0	7.9	330	11.4										
15	16.0	7.9	330	11.3										
18	15.8	7.9	330	11.3										
21	15.8	7.9	330	11.2										
24	15.7	7.9	330	11.1										

July 14 1983

Secchi Depth 08.50 ft.

Depth ft.	Temp C	pH	Cond um	D.O. mg/l	TSS mg/l	Chl-a mg/M3	Alk mg/l	EDTA mg/l	o-PO4 mg/l	t-PO4 mg/l	NO2 mg/l	NO3 mg/l	NH3 mg/l	TKN mg/l
S	26.0	8.2	400	10.2										
3	26.0		403	10.0										
6	26.0	8.2	405	10.4	5.3	6.39	201	170	.002	.016	.010	.049	.063	.568
9	25.0		403	10.6										
12	25.0		403	10.6										
15	24.5	8.17	403	10.6	6.2	6.97			.002	.018	.009	.037	.055	.545
18	24.0		398	8.9										
21	23.8		398	8.5										
24	23.5	8.13	397	8.4	3.5	7.47			.002	.043	.008	.040	.069	.512

Lake Data & Chemistry

BIG DETROIT LAKE

August 18 1983

Secchi Depth 4.25 ft.

Depth ft.	Temp C	pH	Cond um	D.O. mg/l	TSS mg/l	Chl-a mg/M3	Alk mg/l	EDTA mg/l	o-PO4 mg/l	t-PO4 mg/l	NO2 mg/l	NO3 mg/l	NH3 mg/l	TKN mg/l
S	24.0	9.1	375	8.6										
3	24.9	9.0	377	8.8										
6	25.0	8.9	375	8.6	5.4	20.77	189	182	.003	.016	.010	.050	.108	.566
9	24.5	8.8	378	7.4										
12	24.0	8.6	382	5.3	4.3	16.5								
15	23.9	8.5	382	5.0										
18	24.0	8.5	382	5.2										
19	24.0	8.4	382	4.8	2.8	7.01			.011	.013	.009	.230	.168	.666

September 15 1983

Secchi Depth 5.75 ft.

Depth ft.	Temp C	pH	Cond um	D.O. mg/l	TSS mg/l	Chl-a mg/M3	Alk mg/l	EDTA mg/l	o-PO4 mg/l	t-PO4 mg/l	NO2 mg/l	NO3 mg/l	NH3 mg/l	TKN mg/l
S	17.0	7.8	360	8.2										
3	17.4	7.9	362	8.1										
6	17.5	8.2	355	8.0	3.7	10.40	206	194	.006	.042	.011	.160	.242	.540
9	17.2	8.2	350	7.5										
12	17.2	8.2	345	7.5										
15	17.2	8.2	342	7.4										
18	17.2	8.2	340	7.4										
21	17.2	8.2	338	7.4										
24	17.2	8.3	335	7.4										
27	17.2	8.3	327	7.4	7.2	13.75			.006	.052	.011	.170	.245	.443

Algae/Phytoplankton Determinations

Algal counts in mg/L

BIG DETROIT LAKE

June 2, 1983

Depth in feet	Green	Blue-green	Euglanoids	Yellow	Diatoms	Total count
6	2	181	0	43	298	506

July 14, 1983

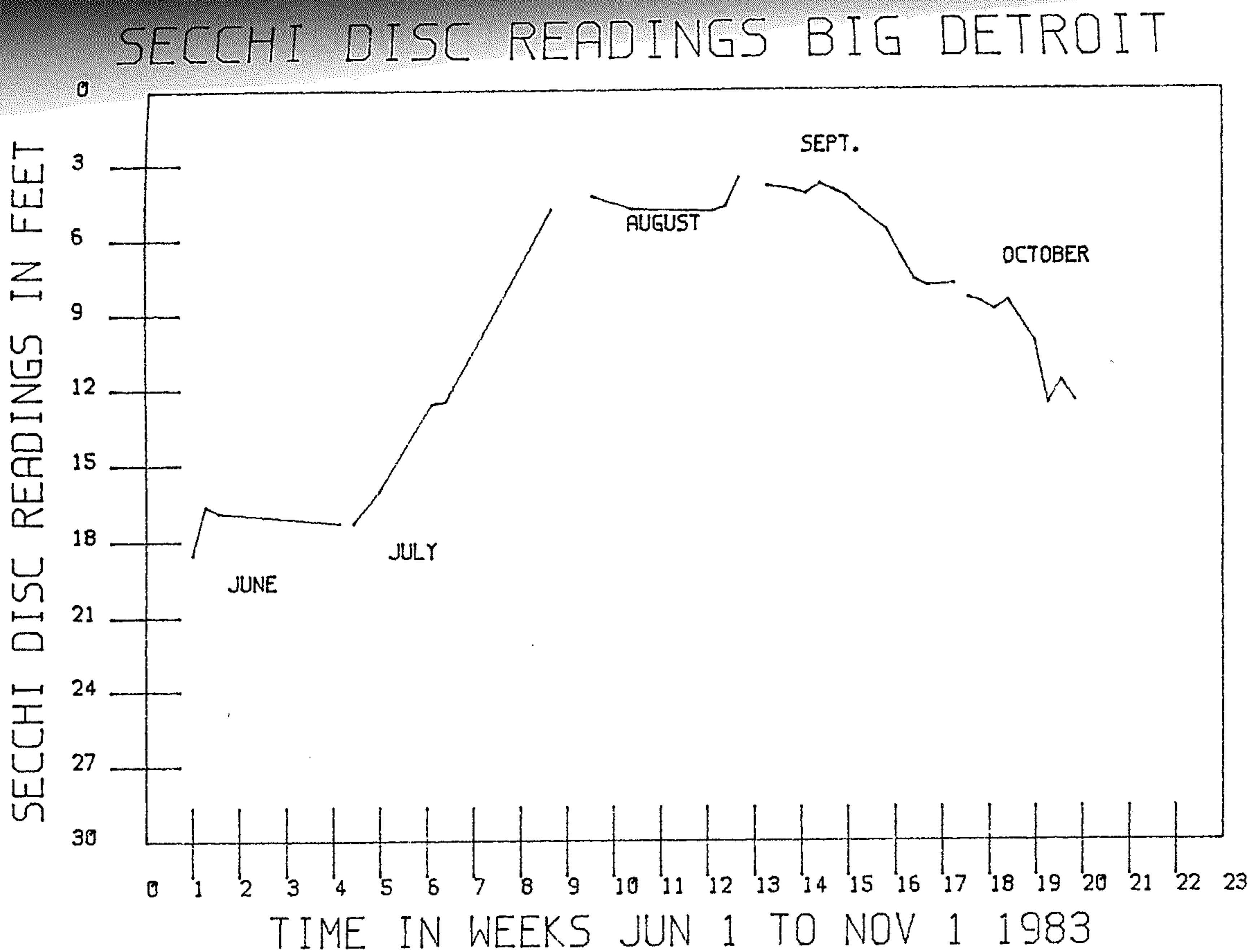
Depth in feet	Green	Blue-green	Euglanoids	Yellow	Diatoms	Total count
6	2	181	0	43	72	298
15	10	149	0	12	114	285
24	9	171	0	6	100	286

August 18, 1983

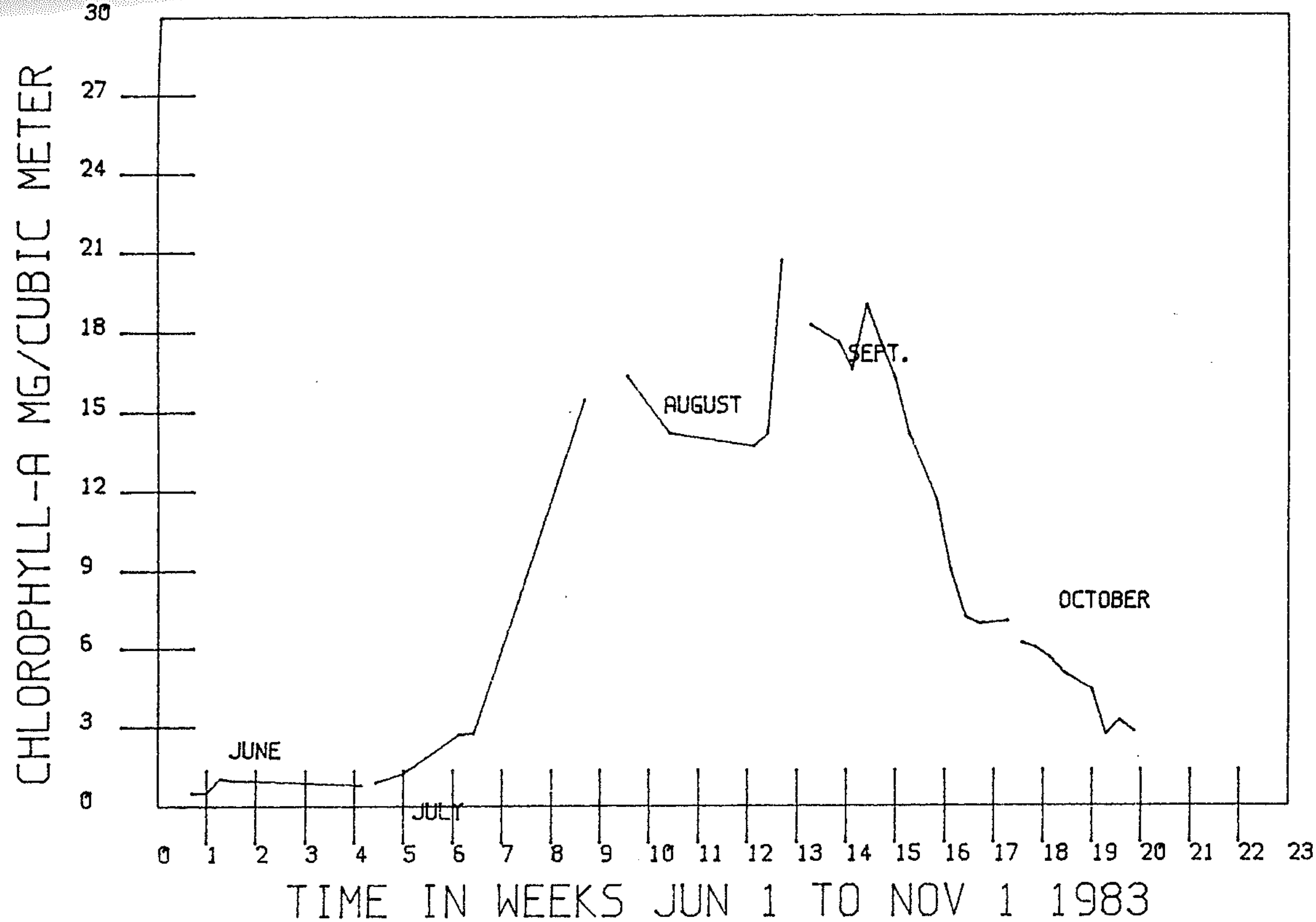
Depth in feet	Green	Blue-green	Euglanoids	Yellow	Diatoms	Total count
6	10	674	0	78	8	770
12	2	185	0	8	424	619
19	0	113	0	2	34	149

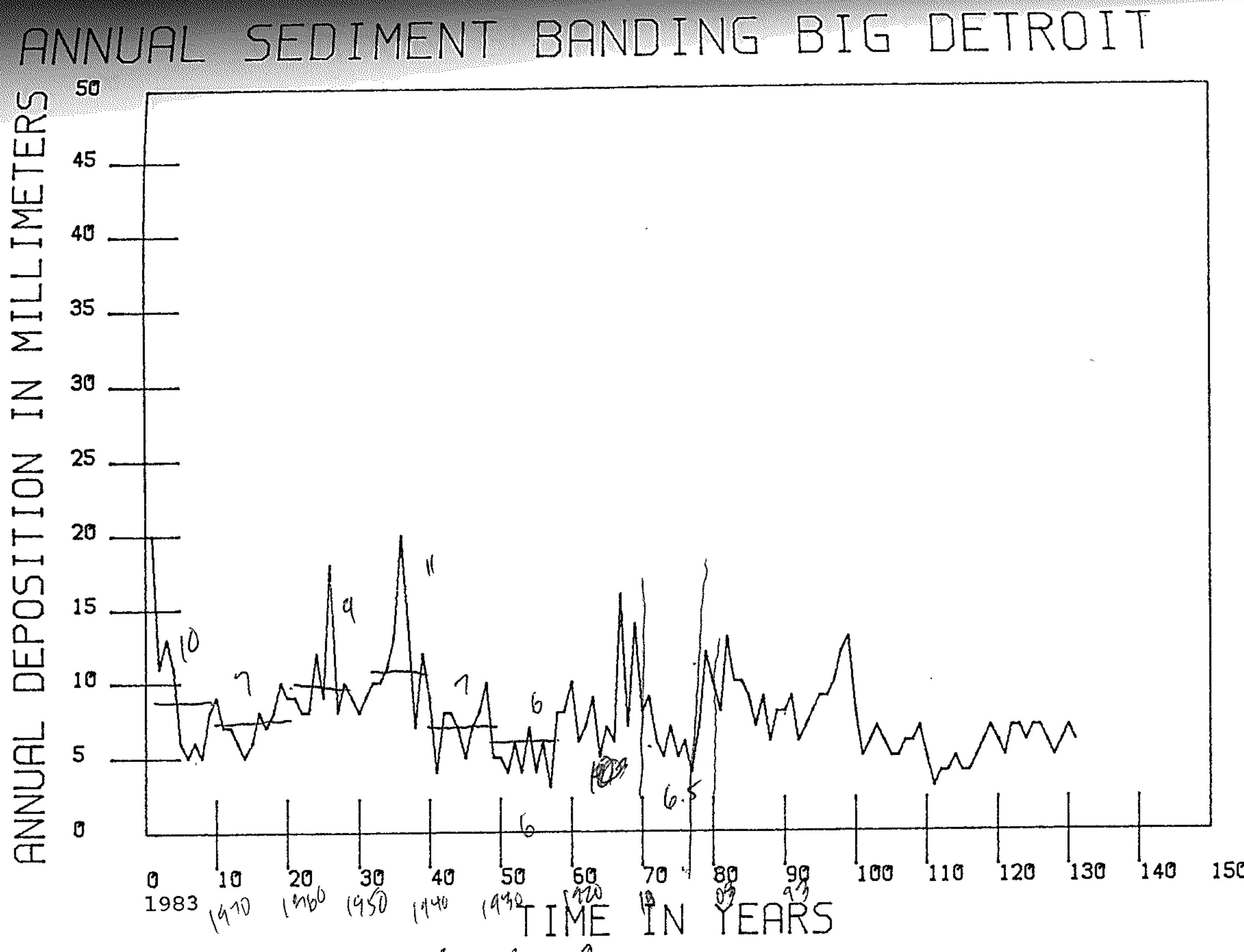
September 15, 1983

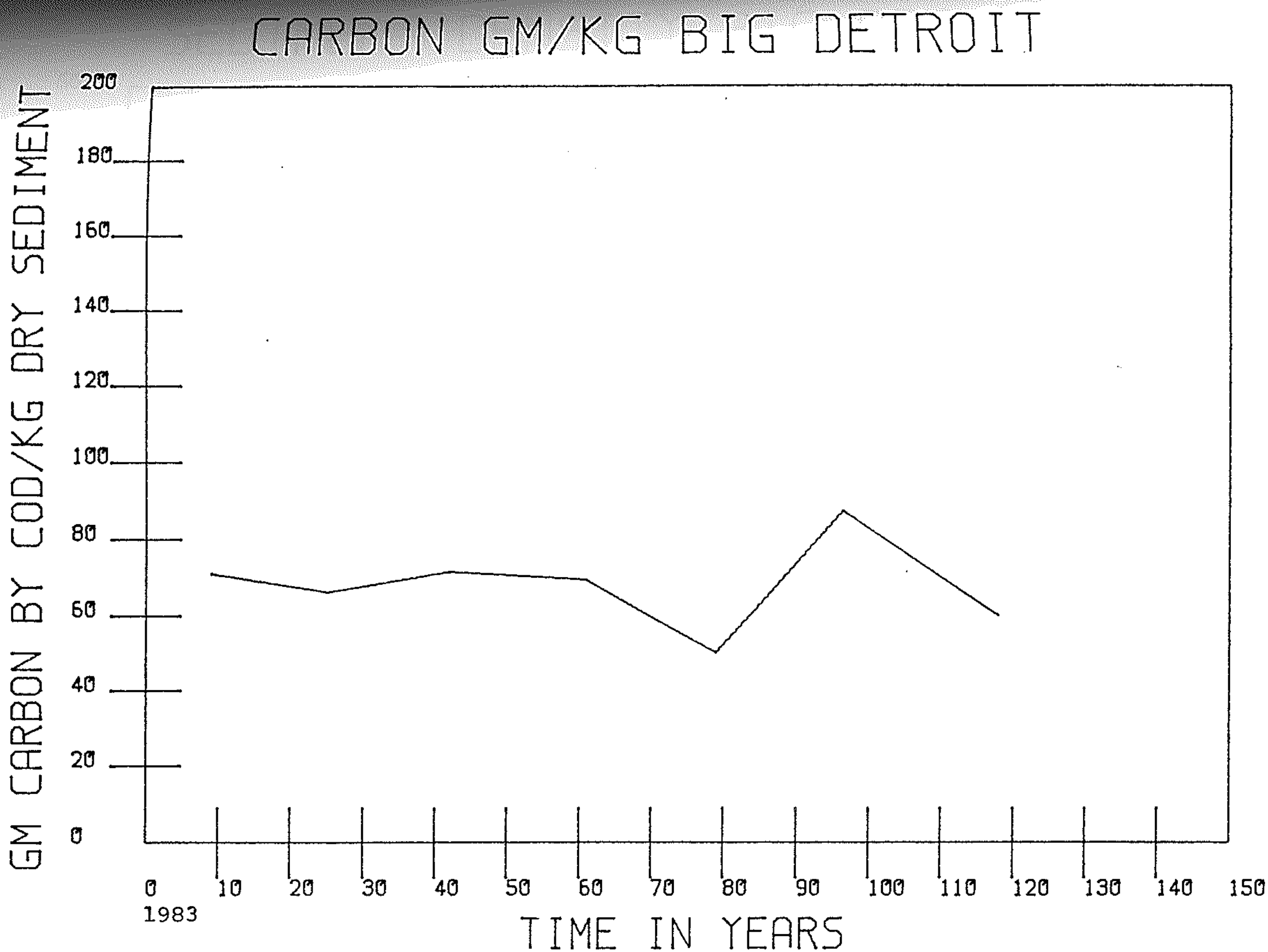
Depth in feet	Green	Blue-green	Euglanoids	Yellow	Diatoms	Total count
6	4	699	0	33	48	784
27	16	3,459	0	20	64	3,559

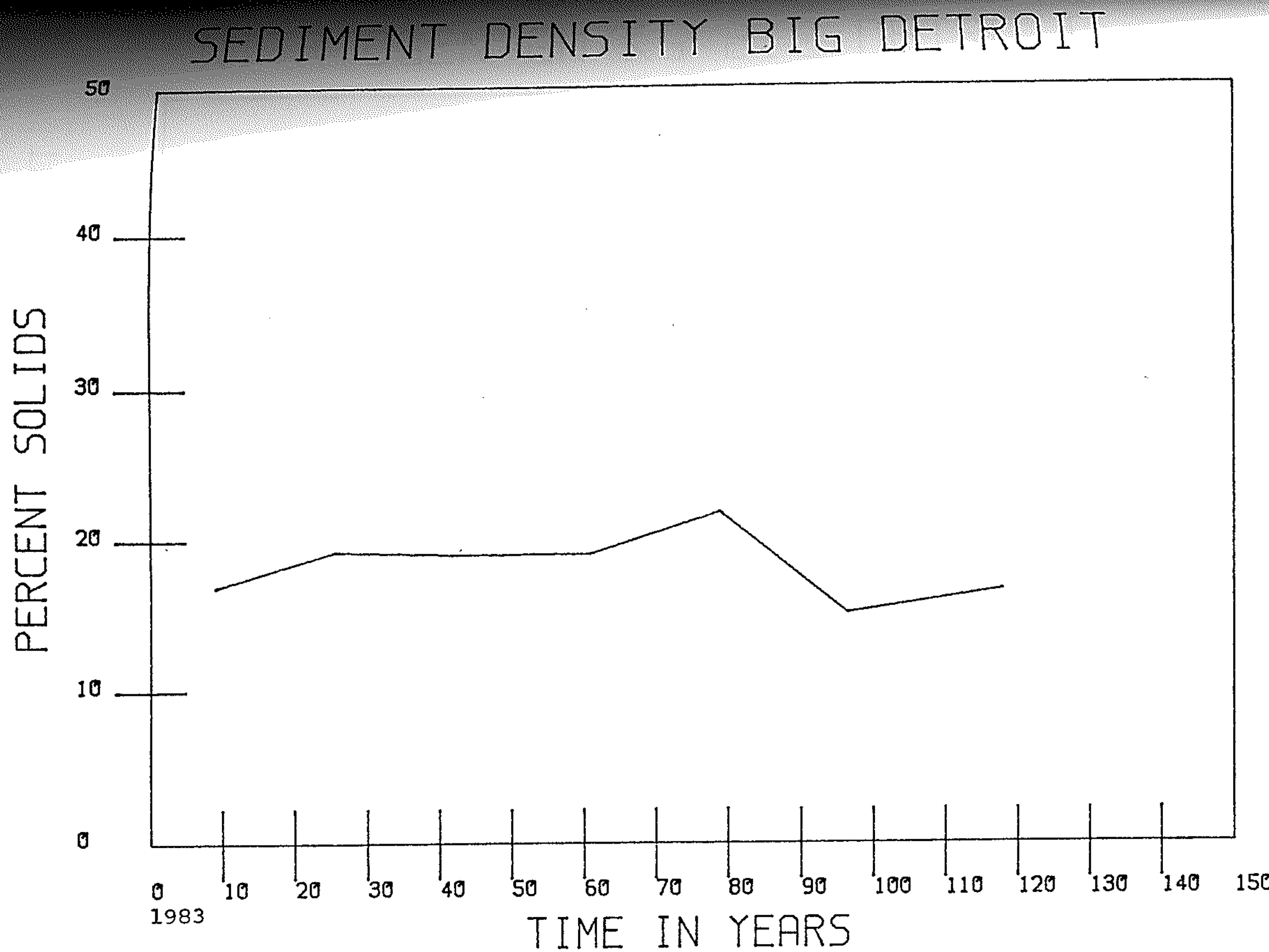

SECCHI DISC READINGS BIG DETROIT
SECCHI DISC READINGS IN FEET
0
3
6
9
12
15
18
21
24
27
30
JUNE
JULY
AUGUST
SEPT.
OCTOBER
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
TIME IN WEEKS JUN 1 TO NOV 1 1983

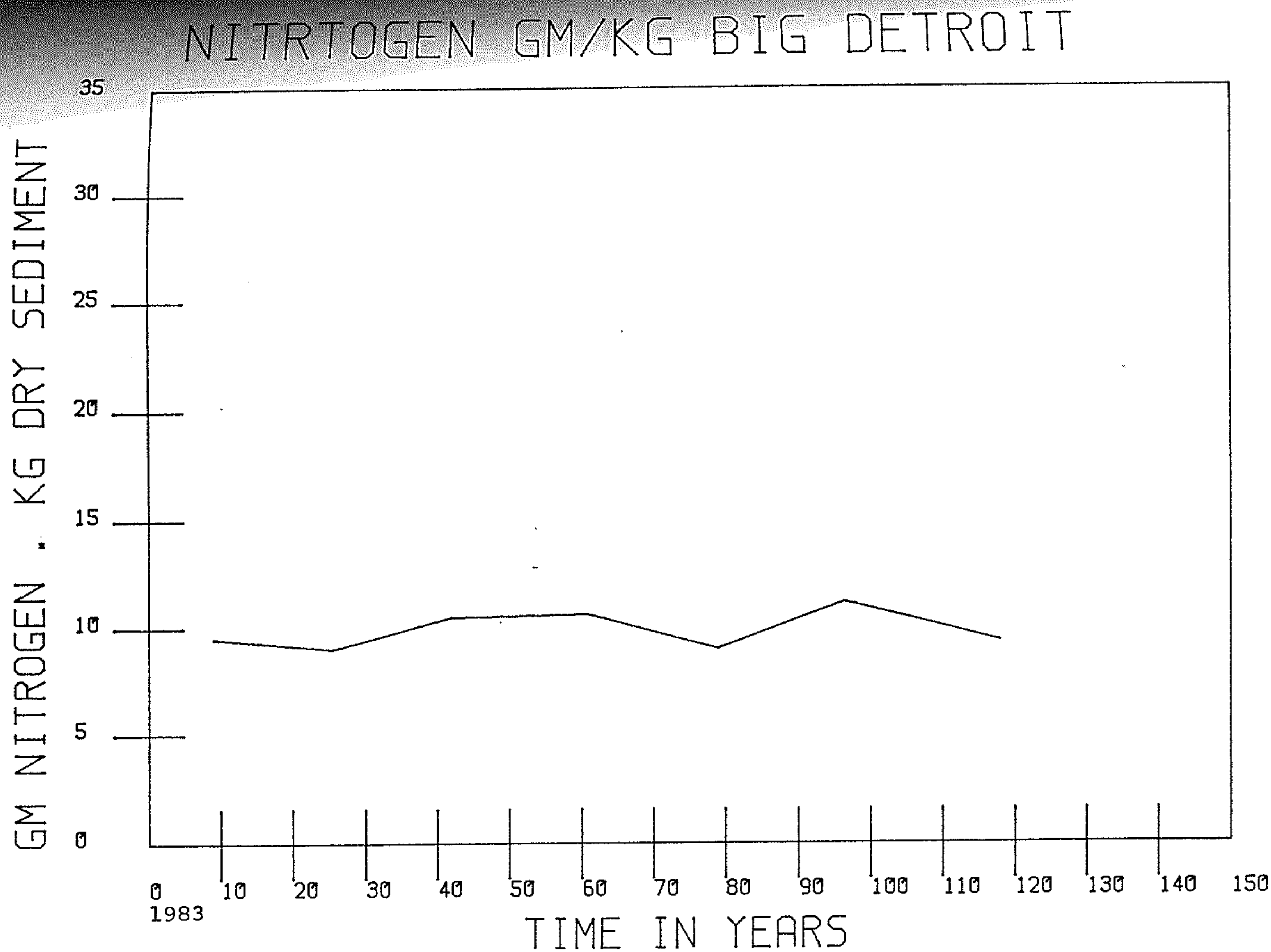
CHLOROPHYLL-A BIG DETROIT

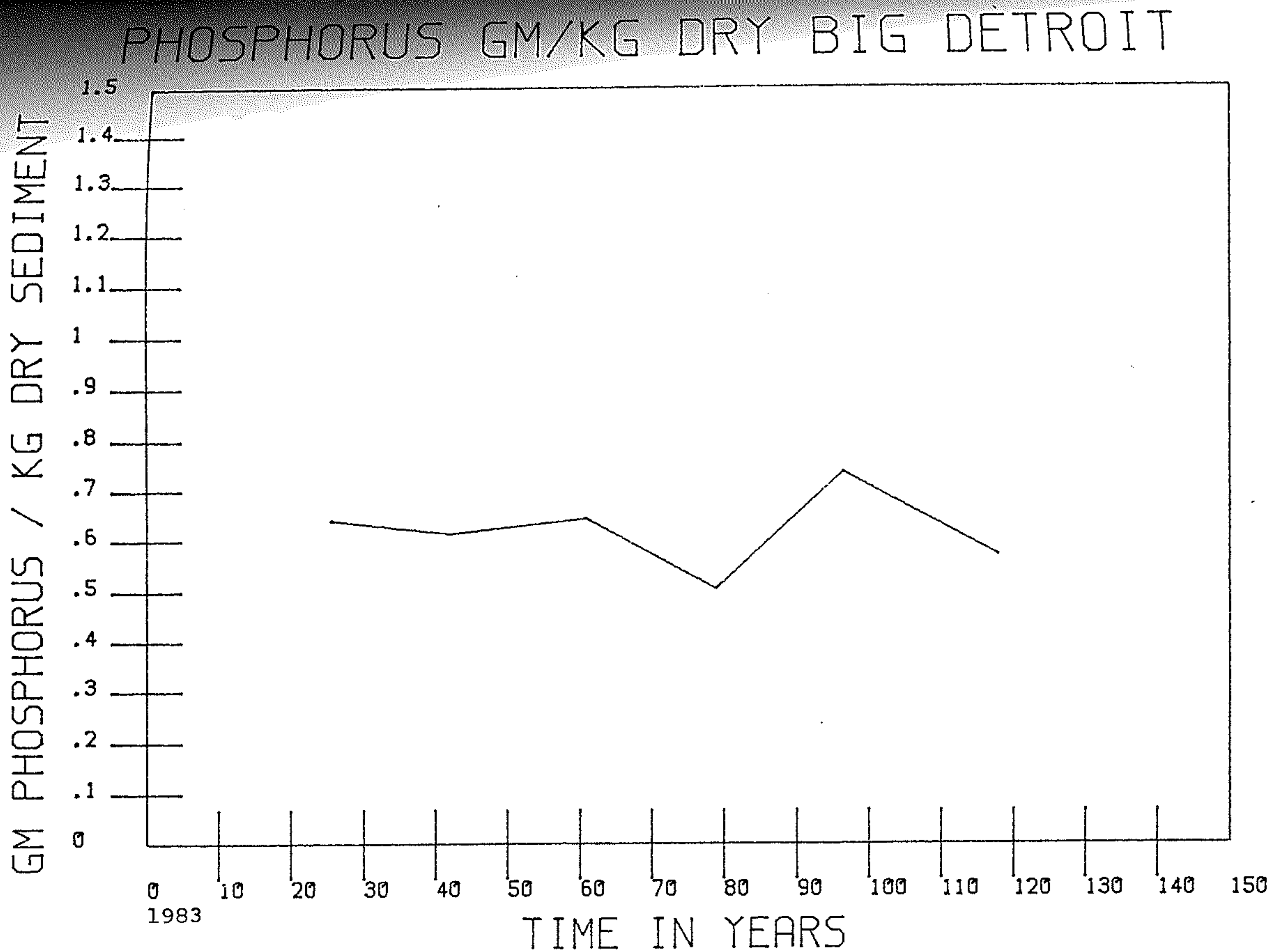



ANNUAL SEDIMENT BANDING BIG DETROIT
ANNUAL DEPOSITION IN MILLIMETERS
0
5
10
15
20
25
30
35
40
45
50
0
1983
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
TIME IN YEARS


CARBON GM/KG BIG DETROIT
GM CARBON BY COD/KG DRY SEDIMENT
200
180
160
140
120
100
80
60
40
20
0
0
1983
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
TIME IN YEARS


SEDIMENT DENSITY BIG DETROIT
PERCENT SOLIDS
0
10
20
30
40
50
TIME IN YEARS
0
1983
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150


NITRTOGEN GM/KG BIG DETROIT
GM NITROGEN . KG DRY SEDIMENT
35
30
25
20
15
10
5
0
0
1983
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
TIME IN YEARS



PHOSPHORUS GM/KG DRY BIG DETROIT
GM PHOSPHORUS / KG DRY SEDIMENT
1.5
1.4
1.3
1.2
1.1
1
.9
.8
.7
.6
.5
.4
.3
.2
.1
0
0
1983
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
TIME IN YEARS

LITTLE DETROIT LAKE

Surface area (acres)	920.
Littoral area (acres)	920.
Volume (acre feet)	11,000.
Maximum depth (feet)	22
Mean depth (feet)	12.
Number of inlets	1.
Volume flow per year (acre feet)	17,500.
Number of outlets	1.

This lake, although shallow throughout, is buffered from the river nutrient load by the volume of Big Detroit Lake. There is an offset of a month before the algae load found in Big Detroit reaches Little Detroit. The lake is reported to have received a heavy nutrient load in past years from stormwater runoff in its own watershed and in low water years from Lake St. Clair. This year the flowage was down the river through the entire season and so the source of nutrients was almost entirely from Big Detroit Lake.

The Kw for this lake is about sixty percent of that found in

Big Detroit Lake and again reflects this as a source. The chlorophyll-a constant (Kc) is higher for Little Detroit because of a very high nutrient build up in its own sediments. The dissolved oxygen levels for July and August of 1983 fell off rapidly near the sediment interface at the bottom, which is indicative of a large amount of decaying vegetation.

This lake supports a heavy concentration of large aquatic vegetation across the bottom throughout the summer season. Because the large vegetation is utilizing much of the nutrients from the sediments in the first half of the season, the algal load in the waters is relatively low. From the second week in August, through the first of September, the algal population produced secchi disc readings of four to five feet. The resulting chlorophyll-a levels then stabilized at about 15 milligrams per cubic meter of water.

Little Detroit Lake follows Big Detroit as the only recipient of flow from the larger body. The algal population was dominated by blue-green algae through July, August, and

September. The high counts in September were from Oscillatoria which is a non-hetrocystis blue-green algae. This is typical of a lake which is getting a large part of its nutrient load from recycled bottom sediment, or rotting vegetation.

The core collected from Little Detroit Lake goes back only fifty years, as a result of the heavy sedimentation rate in recent years. Fifty years ago the band width or annual load appears to be on the increase, and was sustained until about twenty years ago. For the next twelve years the input was small and fairly constant, until eight years ago. The loading rate increased sharply at this time, along with a sharp rise in the percentage of carbon, nitrogen, and phosphorus. Since the phosphorus load has not shown any decrease in these years, the effect appears to be from a very high nutrient load, possibly Lake St. Clair.

The ratio of carbon to inorganic sediment has risen about eight times over the past thirty-five years. If this trend continues, this lake will soon reach the point, if it has not already, where it begins stripping nutrients and could become a larger source of nutrients to the downstream lakes than either Lake St. Clair or Muskrat Lake.

If Lake St. Clair is the major nutrient source in low flow years, then a barrier should be installed at the Pelican River to prevent the river flowing back into Detroit Lake. If the output from St. Clair is cleaned up in the near future, then this will not be necessary.

Lake Data & Chemistry

LITTLE DETROIT LAKE
June 2 1983

Secchi Depth 14.25 ft.

Depth ft.	Temp C	pH	Cond um	D.O. mg/l	TSS mg/l	Chl-a mg/M3	Alk mg/l	EDTA mg/l	o-PO4 mg/l	t-PO4 mg/l	NO2 mg/l	NO3 mg/l	NH3 mg/l	TKN mg/l
S	18.8	7.8	347	9.9										
3	18.5	7.9	342	10.2										
6	18.5	7.9	338	10.0	2.3	2.833	209	195	.009	.013	.000	.000	.076	.518
9	18.0	8.0	330	11.8										
12	18.1	8.0	330	11.7										

July 14 1983

Secchi Depth 12.25 ft.

Depth ft.	Temp C	pH	Cond um	D.O. mg/l	TSS mg/l	Chl-a mg/M3	Alk mg/l	EDTA mg/l	o-PO4 mg/l	t-PO4 mg/l	NO2 mg/l	NO3 mg/l	NH3 mg/l	TKN mg/l
S	27.2		410	7.4										
3	27.0		410	7.2										
6	26.9	8.6	410	7.6	1.5	3.30	180	154	.002	.024	.008	.037	.058	.578
9	26.8		410	7.7										
12	25.0		410	8.4										
15	23.5		430	6.2										

Lake Data & Chemistry

LITTLE DETROIT LAKE
August 18 1983

Secchi Depth 5.25 ft.

Depth ft.	Temp C	pH	Cond um	D.O. mg/l	TSS mg/l	Chl-a mg/M3	Alk mg/l	EDTA mg/l	o-PO4 mg/l	t-PO4 mg/l	NO2 mg/l	NO3 mg/l	NH3 mg/l	TKN mg/l
S	26.5	8.6	380	8.9										
3	26.2	8.6	380	8.9										
6	26.2	8.8	380	8.9	4.7	8.920	180	182	.018	.046	.007	.000	.083	.719
9	26.0	8.7	380	8.8										
12	26.0	8.7	412	1.5										

September 15 1983

Secchi Depth 5.75 ft.

Depth ft.	Temp C	pH	Cond um	D.O. mg/l	TSS mg/l	Chl-a mg/M3	Alk mg/l	EDTA mg/l	o-PO4 mg/l	t-PO4 mg/l	NO2 mg/l	NO3 mg/l	NH3 mg/l	TKN mg/l
S	16.0	8.2	410	9.0										
3	16.2	8.3	410	8.5										
6	16.2	8.3	412	8.1	4.2	10.66	198	196	.005	.033	.011	.160	.227	.481
9	16.5	8.3	412	7.8										
12	16.2	8.4	413	7.8	3.6	11.97	198	196	.003	.036	.010	.160	.278	.532

Algae/Phytoplankton Determinations

Algal counts in mg/L

LITTLE DETROIT LAKE

June 2, 1983

Depth in feet	Green	Blue-green	Euglanoids	Yellow	Diatoms	Total count
6	10	56	6	198	119	389

July 14, 1983

Depth in feet	Green	Blue-green	Euglanoids	Yellow	Diatoms	Total count
6	55	138	4	65	27	289

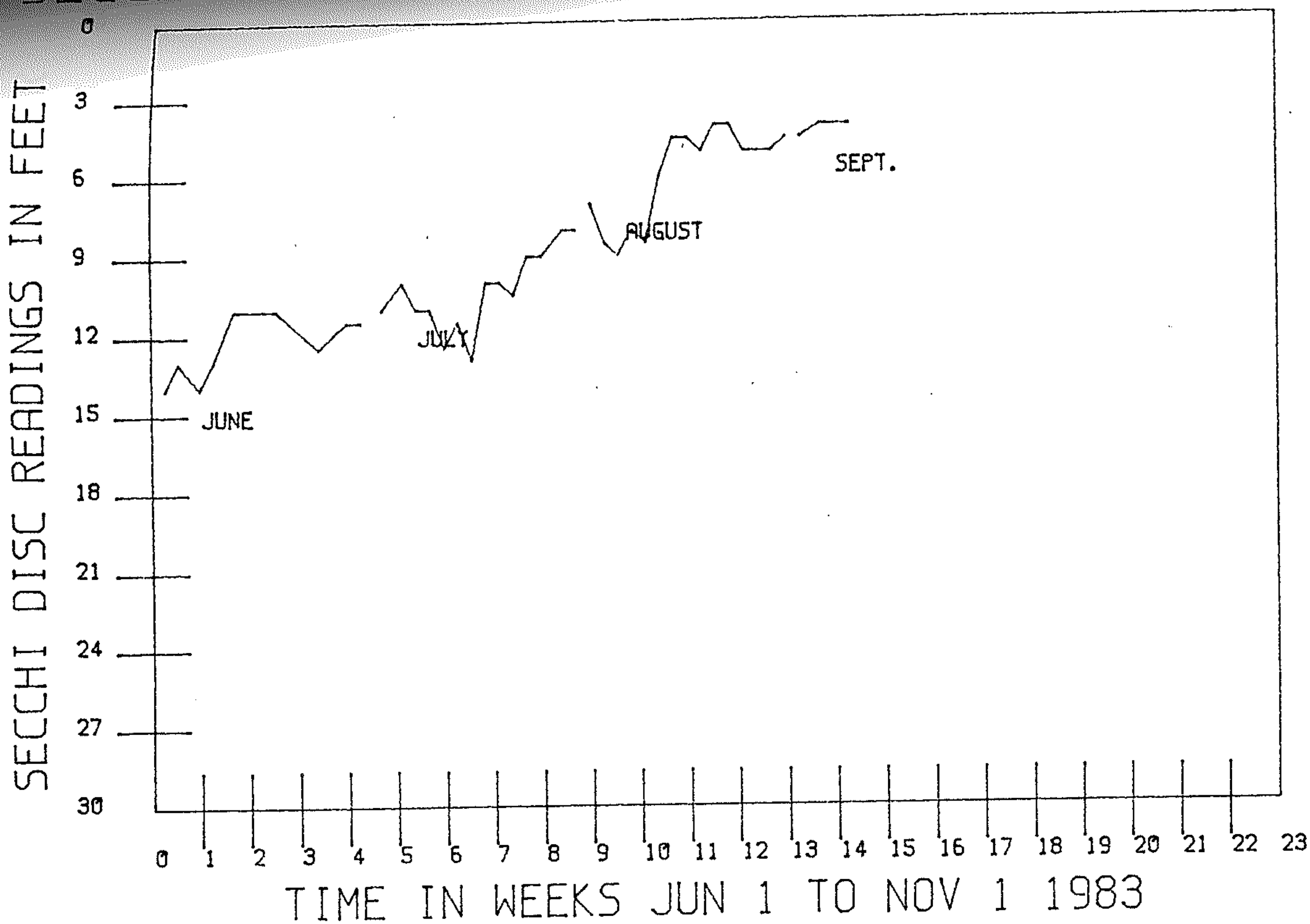
August 18, 1983

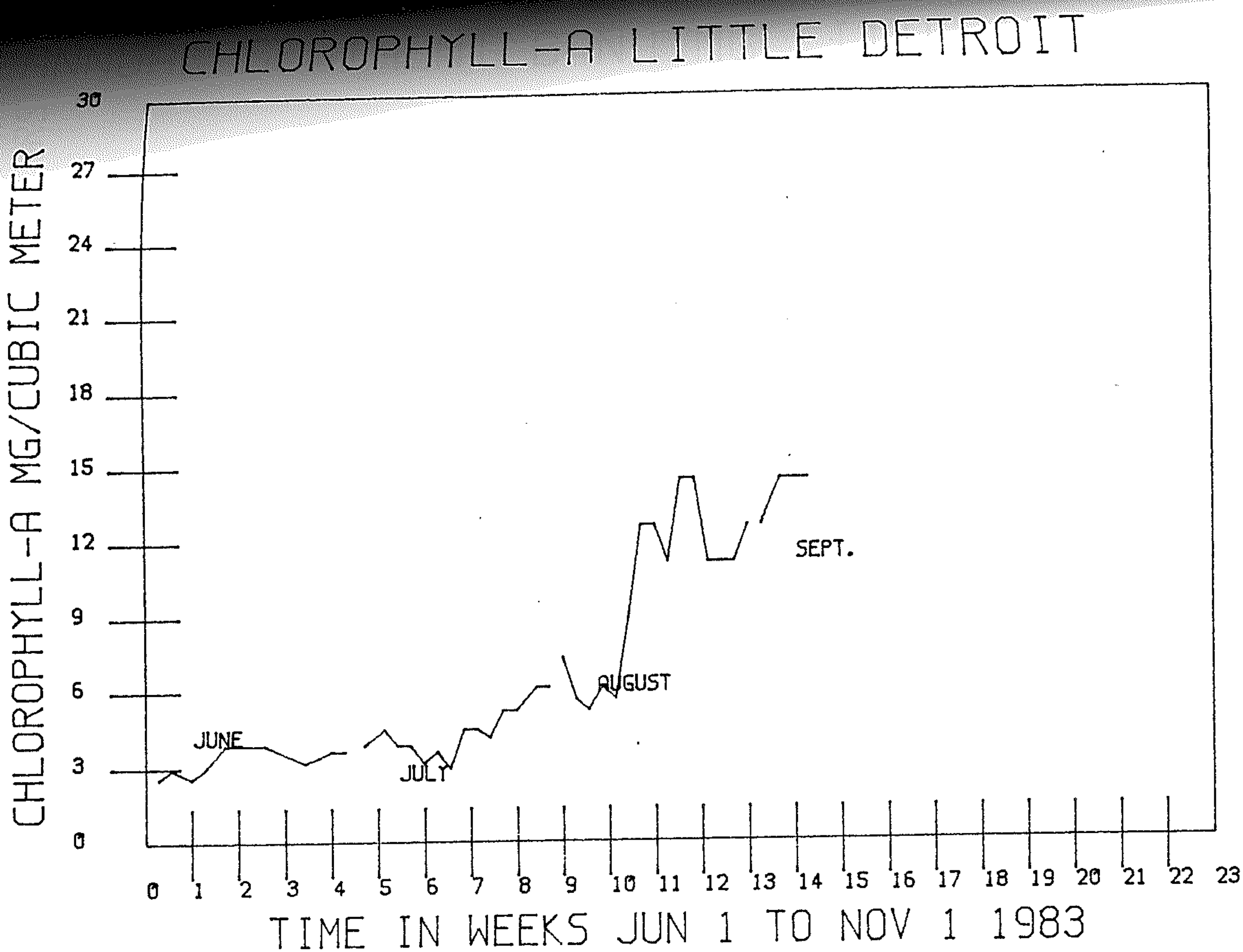
Depth in feet	Green	Blue-green	Euglanoids	Yellow	Diatoms	Total count
6	48	357	23	16	64	508

September 15, 1983

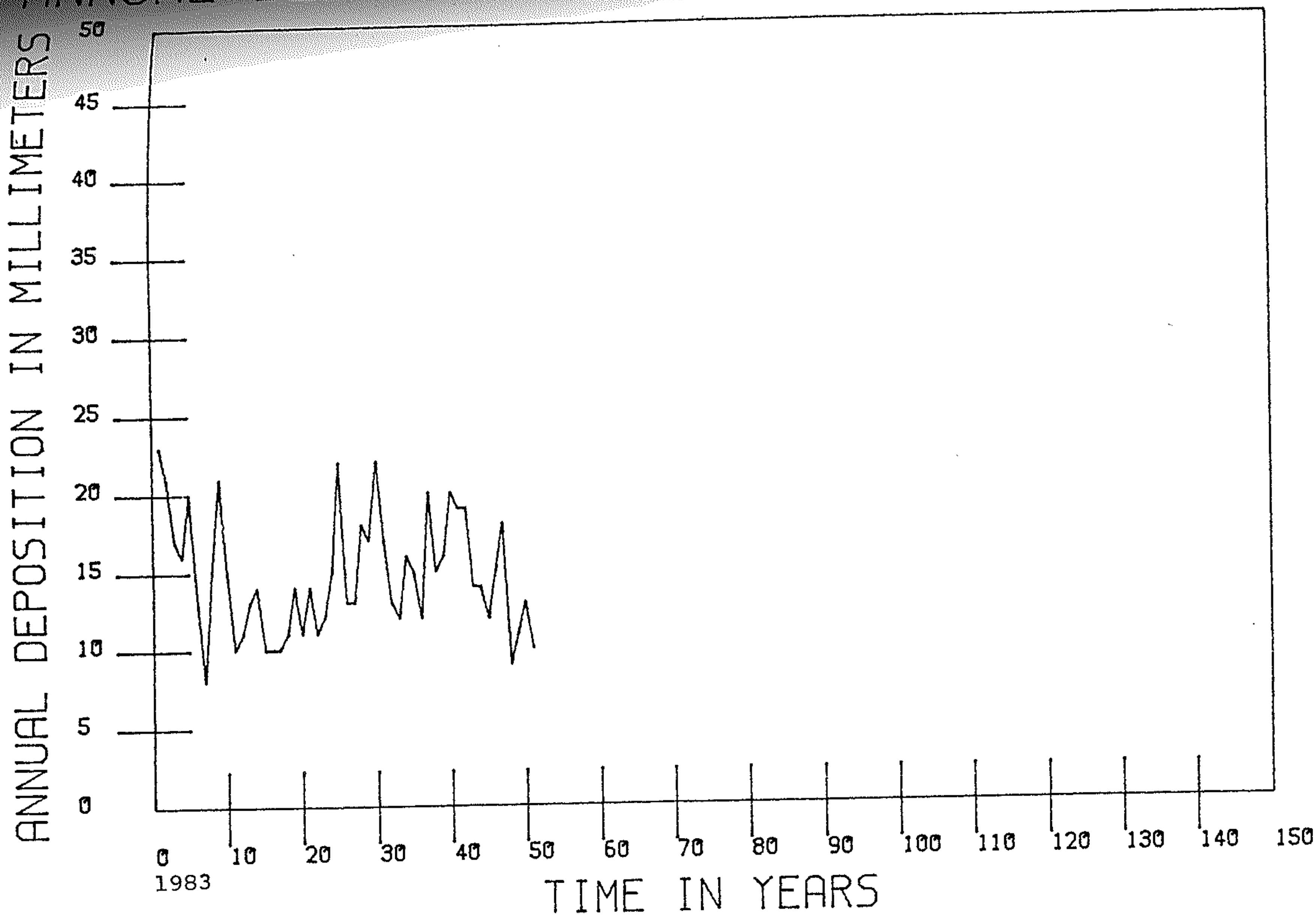
Depth in feet	Green	Blue-green	Euglanoids	Yellow	Diatoms	Total count
6	132	15,288	4	78	75	15,577

SECCHI DISC READINGS LITTLE DETROIT

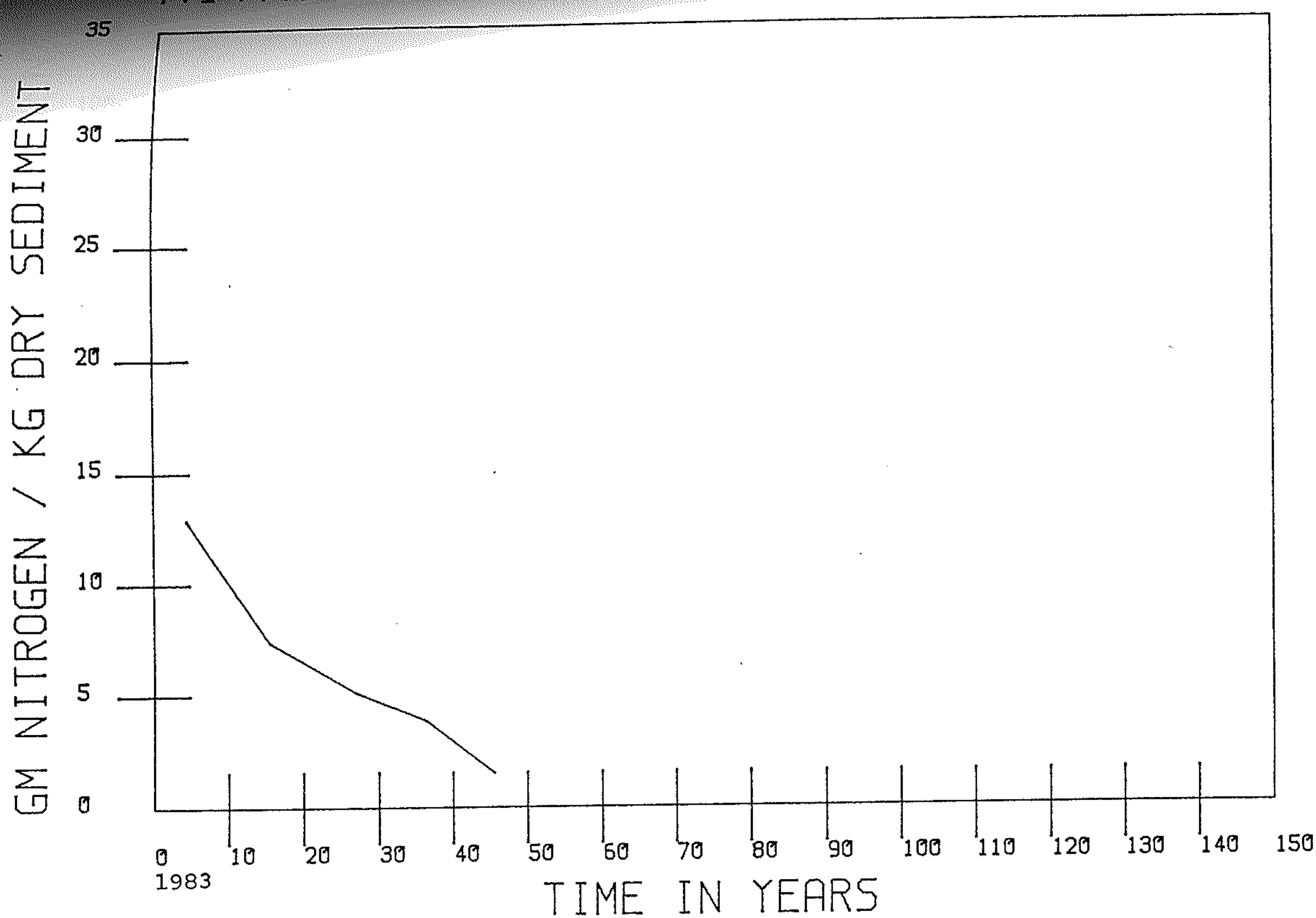


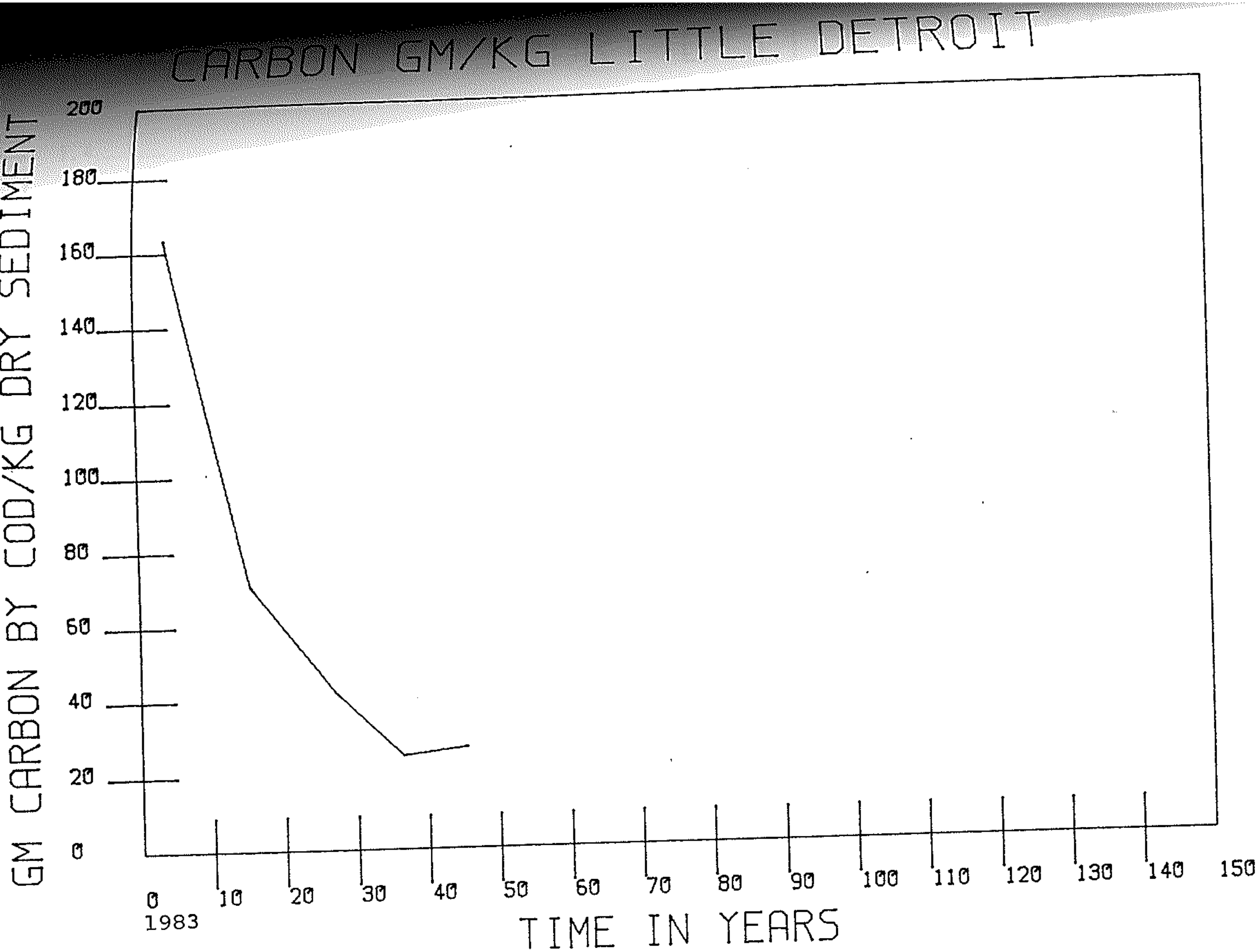

CHLOROPHYLL-A LITTLE DETROIT
CHLOROPHYLL-A MG/CUBIC METER
30
27
24
21
18
15
12
9
6
3
0
JUNE
JULY
AUGUST
SEPT.
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
TIME IN WEEKS JUN 1 TO NOV 1 1983

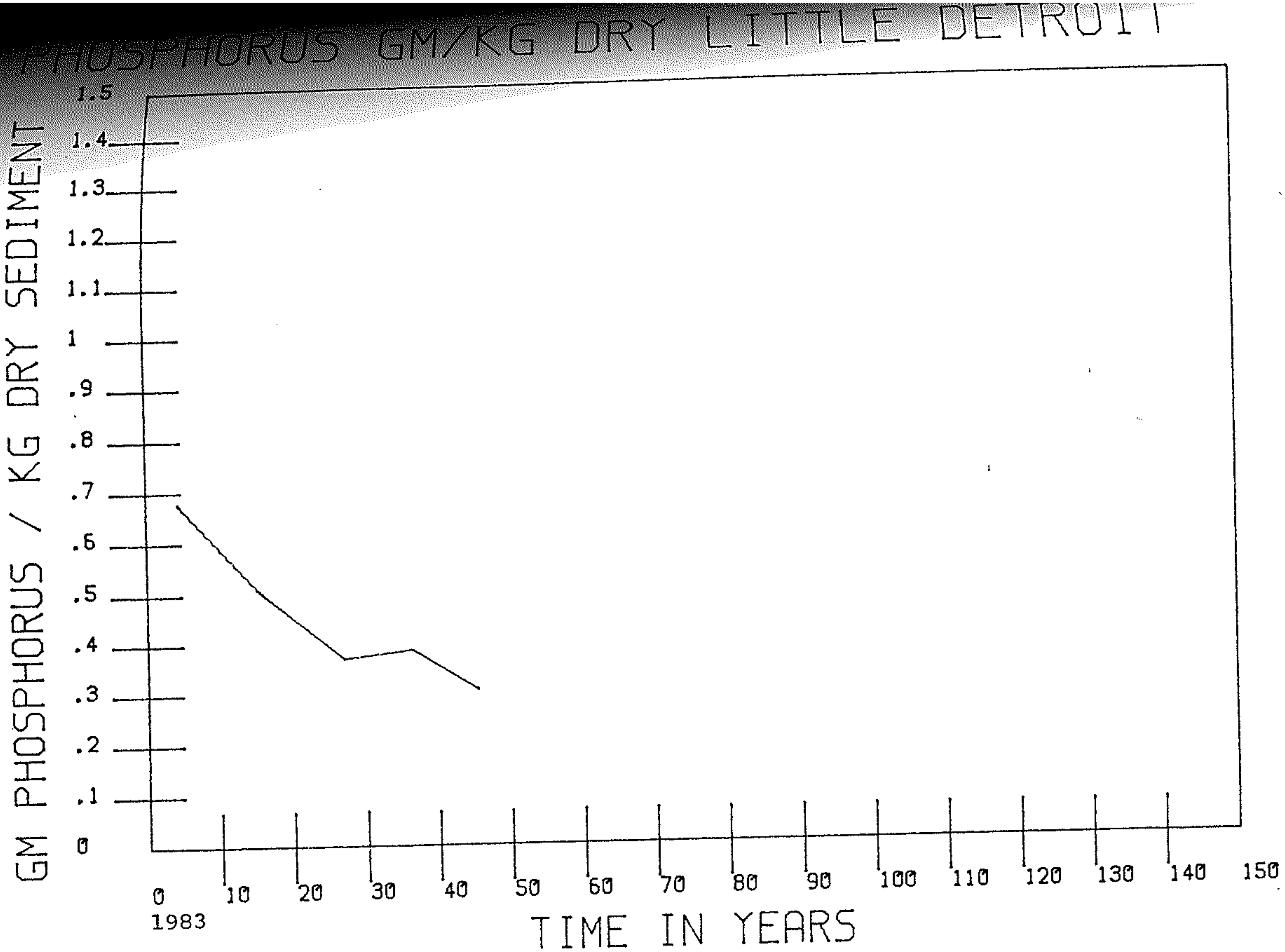
ANNUAL SEDIMENT BANDING LITTLE DETROIT



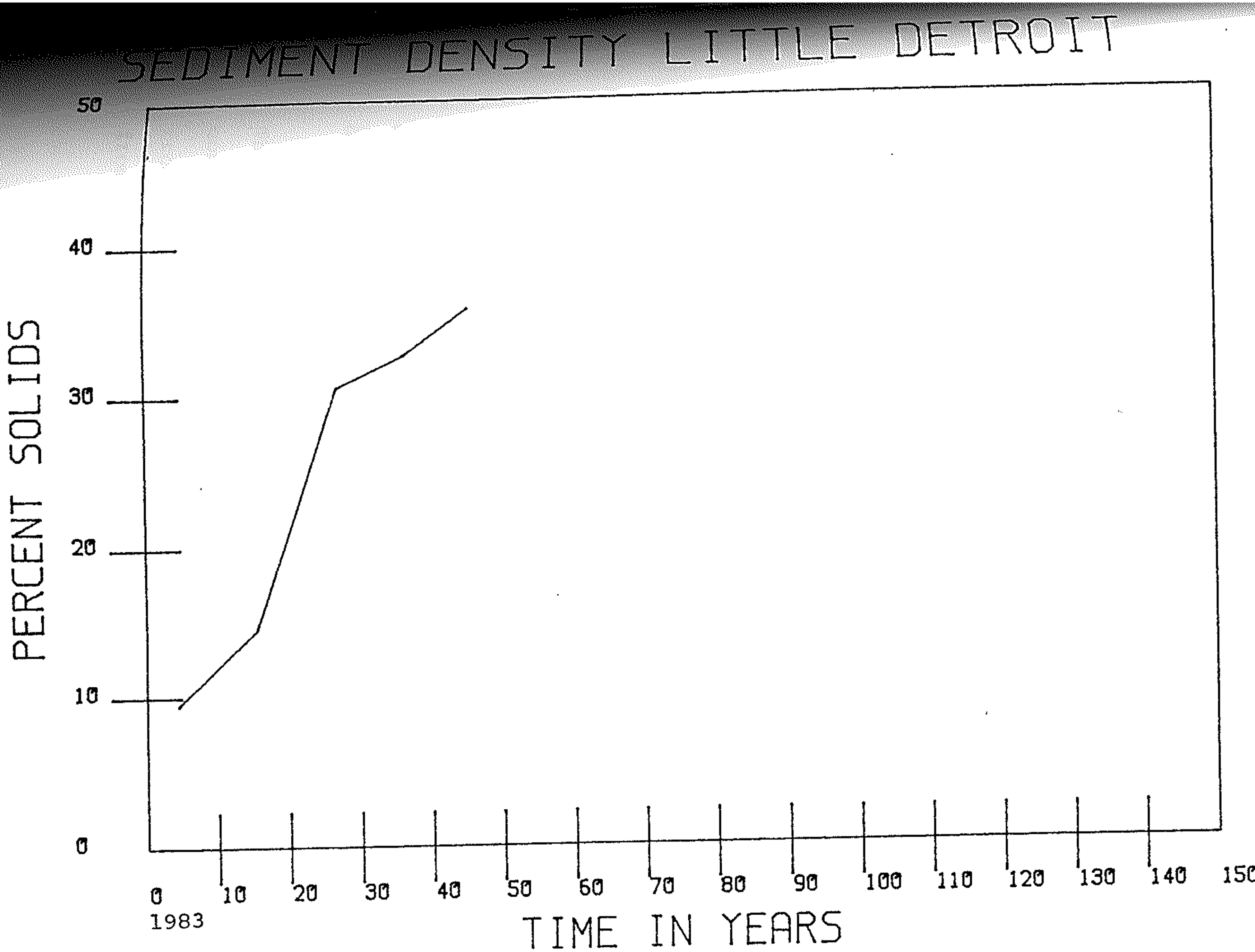
NITROGEN GM/KG LITTLE DETROIT




CARBON GM/KG LITTLE DETROIT
GM CARBON BY COD/KG DRY SEDIMENT
200
180
160
140
120
100
80
60
40
20
0
0
1983
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
TIME IN YEARS



PHOSPHORUS GM/KG DRY LITTLE DETROIT
GM PHOSPHORUS / KG DRY SEDIMENT
1.5
1.4
1.3
1.2
1.1
1
.9
.8
.7
.6
.5
.4
.3
.2
.1
0
0
1983
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
TIME IN YEARS


SEDIMENT DENSITY LITTLE DETROIT
PERCENT SOLIDS
0
10
20
30
40
50
0
1983
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
TIME IN YEARS

LAKE SALLIE

Surface area (acres)	1211.
Littoral area (acres)	520.
Volume (acre feet)	20,689.
Maximum depth (feet)	55.
Mean depth (feet)	17.
Number of inlets	5.
Volume flow per year (acre feet)	22,000.
Number of outlets	1.

Lake Sallie is a clear water lake which has taken a very high nutrient load for about the last fifty years. The hydrologic reports assign seventy percent of the hydraulic load to the Pelican River, and thirty percent to groundwater sources. Presumably the other four inlets are delivering insignificant quantities of water to the lake.

The present nutrient load to the lake is still primarily coming from Lake St. Clair, picking up accumulated nutrients from Muskrat Lake, and possibly taking released nutrients from Little Detroit's sediments.

The secchi disc readings for Lake Sallie were as good as the other lakes in the watershed through mid-July and then began to drop off, so that by the end of August the lake was carrying a heavy algal load. By late August the chlorophyll -a level was at 30 milligrams per cubic meter. This is 1.5 times the concentration of Big Detroit Lake and twice the concentration of Lake Melissa. This diminished through late September and October, but much of the nutrient load from the algae will be recycled during the next season.

The large aquatic vegetation in Lake Sallie is growing on the accumulated nutrients in waters more than twenty feet deep and supplying these waters with a large amount of oxygen. It is only later in the season when the turbidity prevents photosynthesis by the large aquatic plants, that there is a significant increase in released nutrients from the sediments. The lake had a high dissolved oxygen content through June and into mid-July, to a depth of twenty-four feet of water. In mid-August the dissolved oxygen was still high in twenty-one feet of water. By the sampling in mid-September the lake was oxygenated to twenty-four feet again.

The low background turbidity in Lake Sallie allows the macrophyte population to grow rapidly, producing the high dissolved oxygen condition observed in 1983. This is preventing the rapid release of nutrients from the sediments and is the current reason for the usability of this lake through much of the summer season.

The algae populations take all of their nutrients from the free water. The four sources are; the waters from the Pelican River, input from the watershed, the nutrients released to the free water as macrophytes decay, and recycled nutrients from the sediments.

The existing aggressive harvesting and cleanup program should be continued. Control of aquatic vegetation by herbicide application is not recomended. This harvesting should not be expected to dramatically deplete the phosphorus and nitrogen load, but will prevent the decay and cycling of the large volume of hydrocarbon compounds present in the vegetation harvested. This becomes a part of the management program for Lake Melissa, as it will prevent future build up of large algal populations in Lake Melissa.

The input of nutrients from the upper watershed should be reduced as much as possible in the near future. This means reducing the input from Lake St. Clair, removing the nutrient load from Muskrat Lake, and maintaining and improving the water quality coming from Little Detroit Lake.

These management improvements will extend the clear water period further into the summer months, maintaining the high dissolved oxygen concentrations, and further prevent the annual recycling of nutrients.

The blue-green algae dominated the population in Lake Sallie from August through September and probably through October as well. Microcystis and Oscillatoria, both non-hetrocystis blue-green algae, dominated the population in August and September. The September population was about one-quarter of what it was in 1979. The population of hetrocystis blue-green algae was down to one-third of the total population in September. This sharp drop in the algal population is most likely due to the reduced nutrient loading and the resulting extended growth period of macrophytes in the lake.

If the harvesting and the new beach cleanup program continues for a long enough period of time, the sedimentation of a low nutrient cap will naturally prevent the high quantities of macrophytes from occurring. In future years the system will establish a new balance. There is already a noticeable reduction of the phosphorus concentration in the upper sediments and the annual nitrogen load has been cut in half.

The core analysis indicates the carbon load is still on the increase, but it will fall off in future years as the algae and macrophyte populations are depleted. The sediment density is currently still decreasing, but the curve is leveling off. It is expected that the density will begin to increase in the next few years as the ratio of hydrocarbons to soil input drops.

Lake Data & Chemistry

LAKE SALLIE
June 2 1983

Secchi Depth 20.75 ft.

Depth ft.	Temp C	pH	Cond um	D.O. mg/l	TSS mg/l	Chl-a mg/M3	Alk mg/l	EDTA mg/l	o-PO4 mg/l	t-PO4 mg/l	NO2 mg/l	NO3 mg/l	NH3 mg/l	TKN mg/l
S	20.0	7.7	380	9.0										
3	19.0	7.6	380	9.4										
6	18.5	7.7	380	9.7	3.7	5.160	220	210	.011	.028	.000	.000	.074	.493
9	17.0	7.8	379	11.5										
12	17.0	7.7	379	11.5										
15	17.0	7.7	379	11.5										
18	17.0	7.8	378	11.5										
21	17.0	7.8	378	11.5										
24	16.9	7.8	375	11.3										
27	16.5	7.7	373	11.2										

July 14 1983

Secchi Depth 13.50 ft.

Depth ft.	Temp C	pH	Cond um	D.O. mg/l	TSS mg/l	Chl-a mg/M3	Alk mg/l	EDTA mg/l	o-PO4 mg/l	t-PO4 mg/l	NO2 mg/l	NO3 mg/l	NH3 mg/l	TKN mg/l
S	26.0		430	12.0										
3	25.5		435	11.8										
6	25.5	8.5	440	12.1	1.9	10.61	195	188	.002	.029	.006	.040	.065	.691
9	25.0		440	12.3										
12	25.0		440	12.2										
15	25.0		440	12.3										
18	25.0		440	12.0										
21	24.5	8.2	438	11.2	2.5	5.02			.003	.033	.004	.042	.159	.586
24	24.0		435	11.3										
27	22.0	8.1	430	4.2	7.4	9.20			.011	.029	.008	.043	.271	.503

Lake Data & Chemistry

LAKE SALLIE
August 18 1983

Secchi Depth 5.00 ft.

Depth ft.	Temp C	pH	Cond um	D.O. mg/l	TSS mg/l	Chl-a mg/M3	Alk mg/l	EDTA mg/l	o-PO4 mg/l	t-PO4 mg/l	NO2 mg/l	NO3 mg/l	NH3 mg/l	TKN mg/l
S	24.5	8.7	600	6.9										
3	24.3	8.6	550	6.8										
6	24.4	8.6	510	6.8	4.5	12.3	182	188	.004	.020	.015	.05	.103	.764
9	24.3	8.6	428	6.7										
12	24.3	8.5	418	6.6										
15	24.2	8.1	400	6.6	3.3	4.42								
18	24.2	8.0	400	6.6										
21	24.2	8.0	400	6.4										
24	23.5	7.8	418	0.8										
27	22.7	7.8	428	0.2	6.6	4.81			.092	.112	.007	.090	1.010	1.489

September 15 1983

Secchi Depth 4.75 ft.

Depth ft.	Temp C	pH	Cond um	D.O. mg/l	TSS mg/l	Chl-a mg/M3	Alk mg/l	EDTA mg/l	o-PO4 mg/l	t-PO4 mg/l	NO2 mg/l	NO3 mg/l	NH3 mg/l	TKN mg/l
S	13.0	8.5	405	8.6										
3	18.0	8.6	425	7.9										
6	18.2	8.5	422	7.8	2.4	25.9	202	194	.022	.107	.012	.13	.291	.803
9	18.2	8.4	418	7.7										
12	18.2	8.4	416	7.8										
15	18.2	8.7	415	7.8	8.0	28.83			.023	.111	.013	.14	.341	.798
18	18.2	8.7	410	7.8										
21	18.1	8.6	408	7.8										
24	18.2	7.5	400	7.8	9.2	37.96			.024	.113	.014	.16	.255	.793

Algae/Phytoplankton Determinations

Algal counts in mg/L

LAKE SALLIE

June 2, 1983

Depth in feet	Green	Blue-green	Euglanoids	Yellow	Diatoms	Total count
6	4	9	0	8	147	168

July 14, 1983

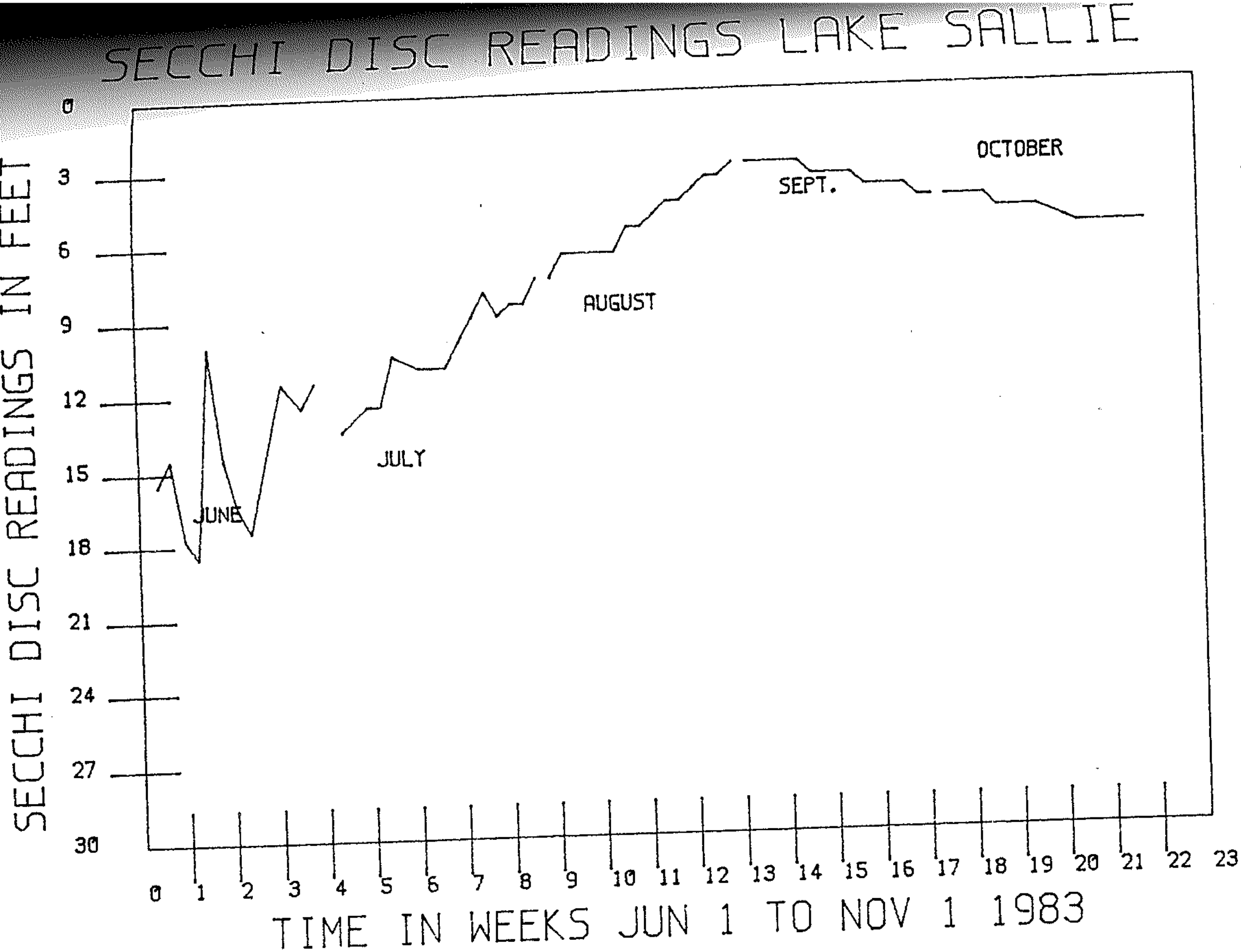
Depth in feet	Green	Blue-green	Euglanoids	Yellow	Diatoms	Total count
6	0	29	2	0	134	165
21	4	11	2	0	107	124
27	4	6	4	0	100	114

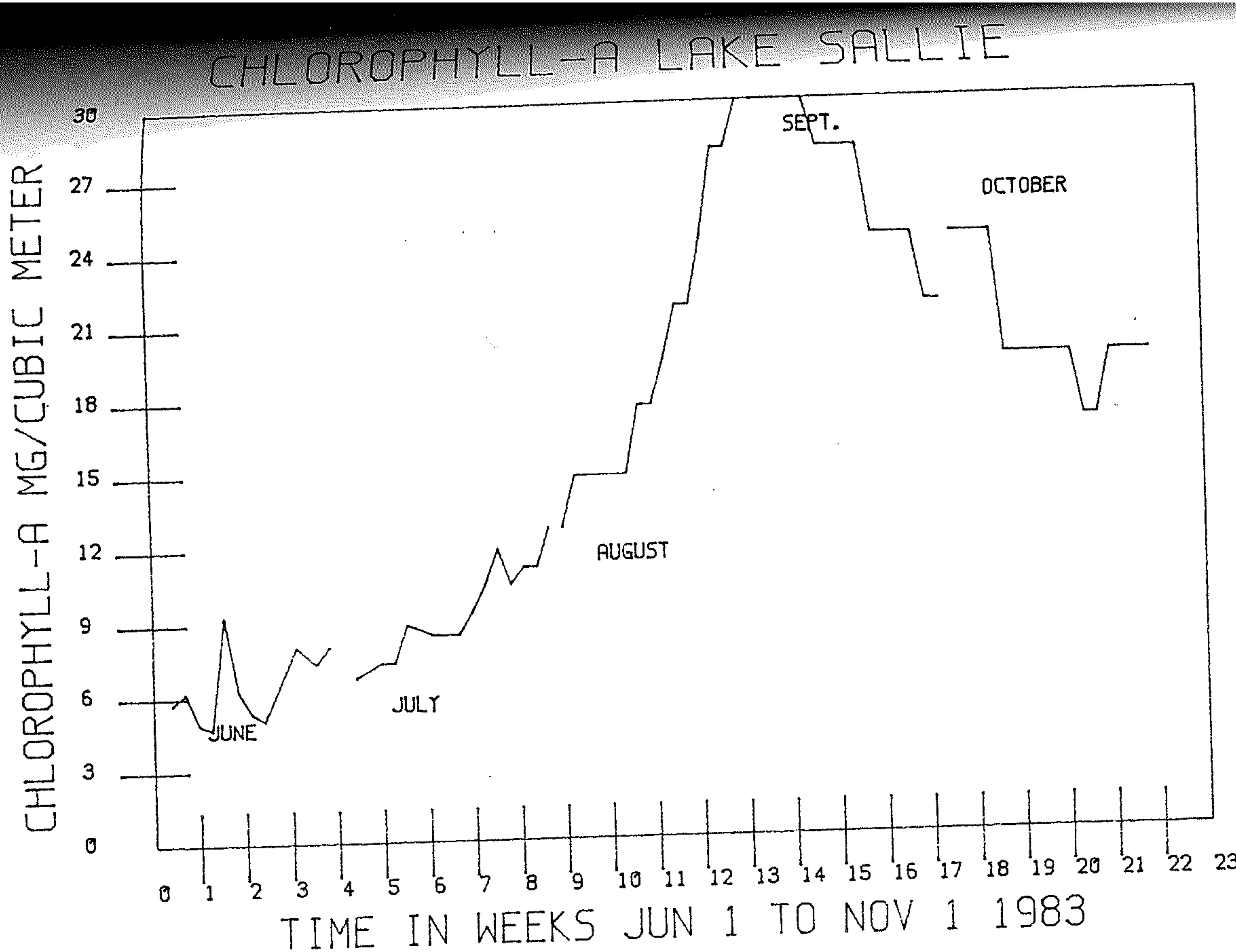
August 18, 1983

Depth in feet	Green	Blue-green	Euglanoids	Yellow	Diatoms	Total count
6	2	243	0	4	45	294
15	2	26	2	2	22	54
27	17	22	0	0	21	60

September 15, 1983

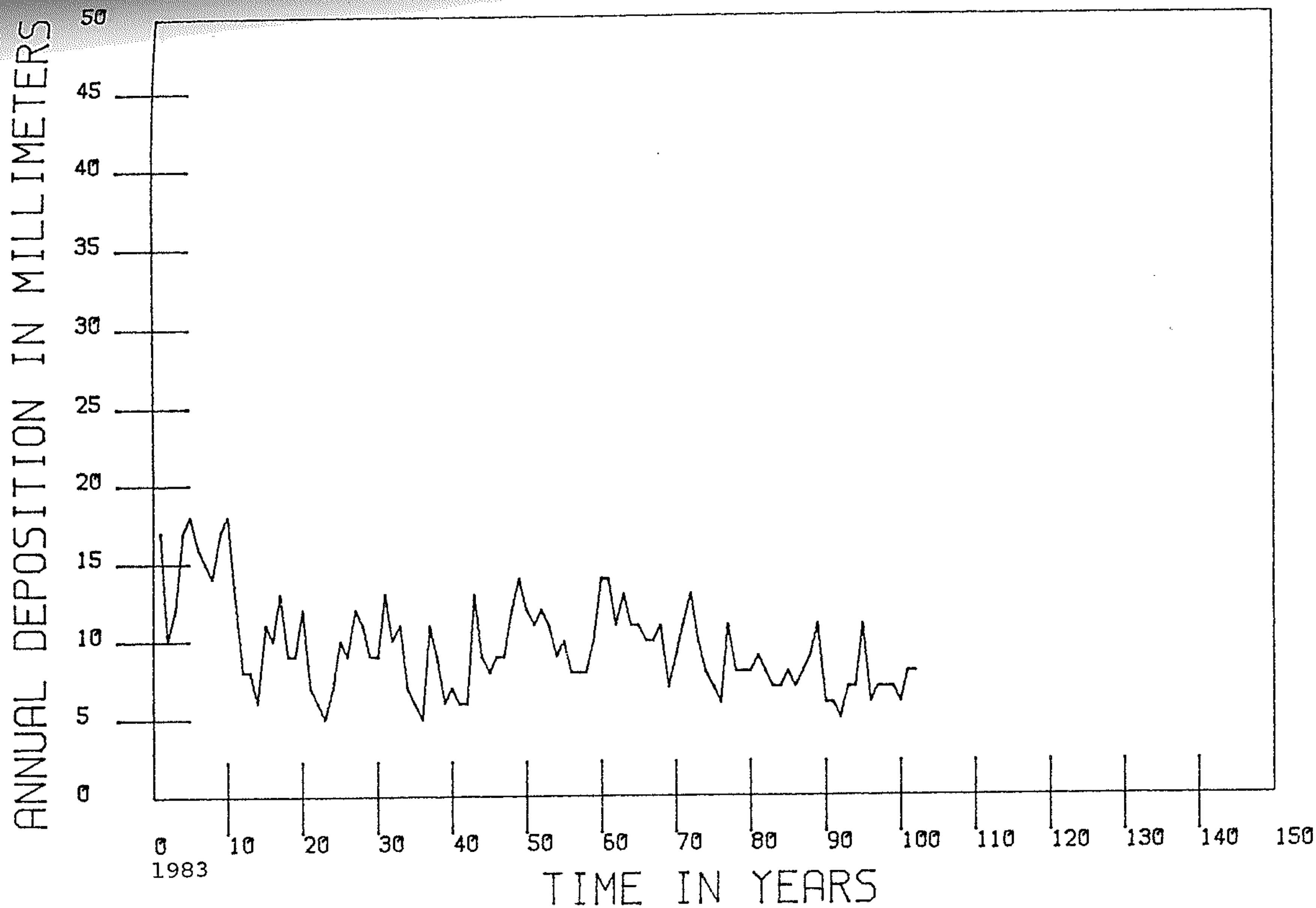
Depth in feet	Green	Blue-green	Euglanoids	Yellow	Diatoms	Total count
6	4	5,186	0	24	52	5,266
15	8	5,082	0	27	89	5,206
24	4	4,446	0	11	78	4,539

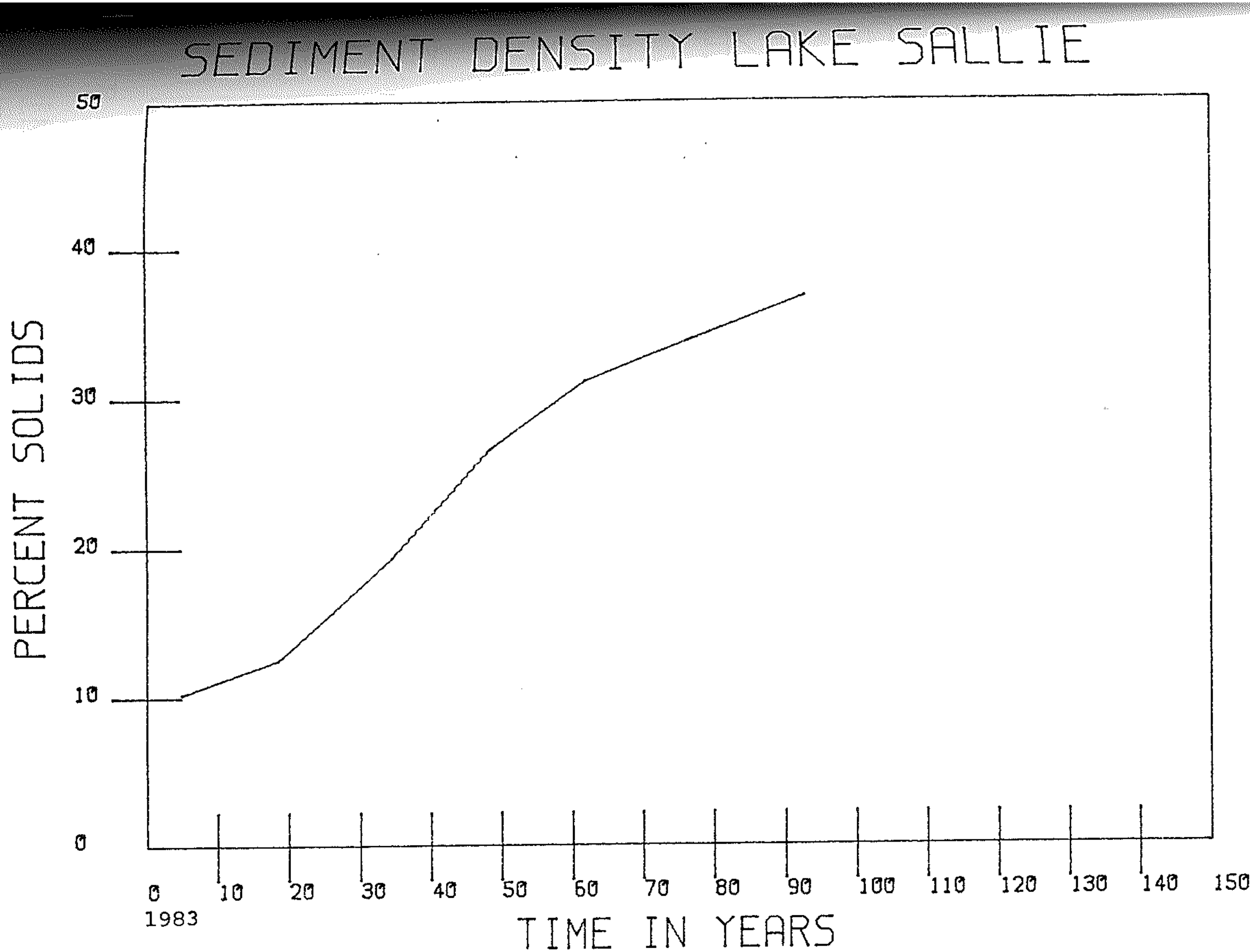

SECCHI DISC READINGS LAKE SALLIE
SECCHI DISC READINGS IN FEET
0
3
6
9
12
15
18
21
24
27
30
JUNE
JULY
AUGUST
SEPT.
OCTOBER
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
TIME IN WEEKS JUN 1 TO NOV 1 1983

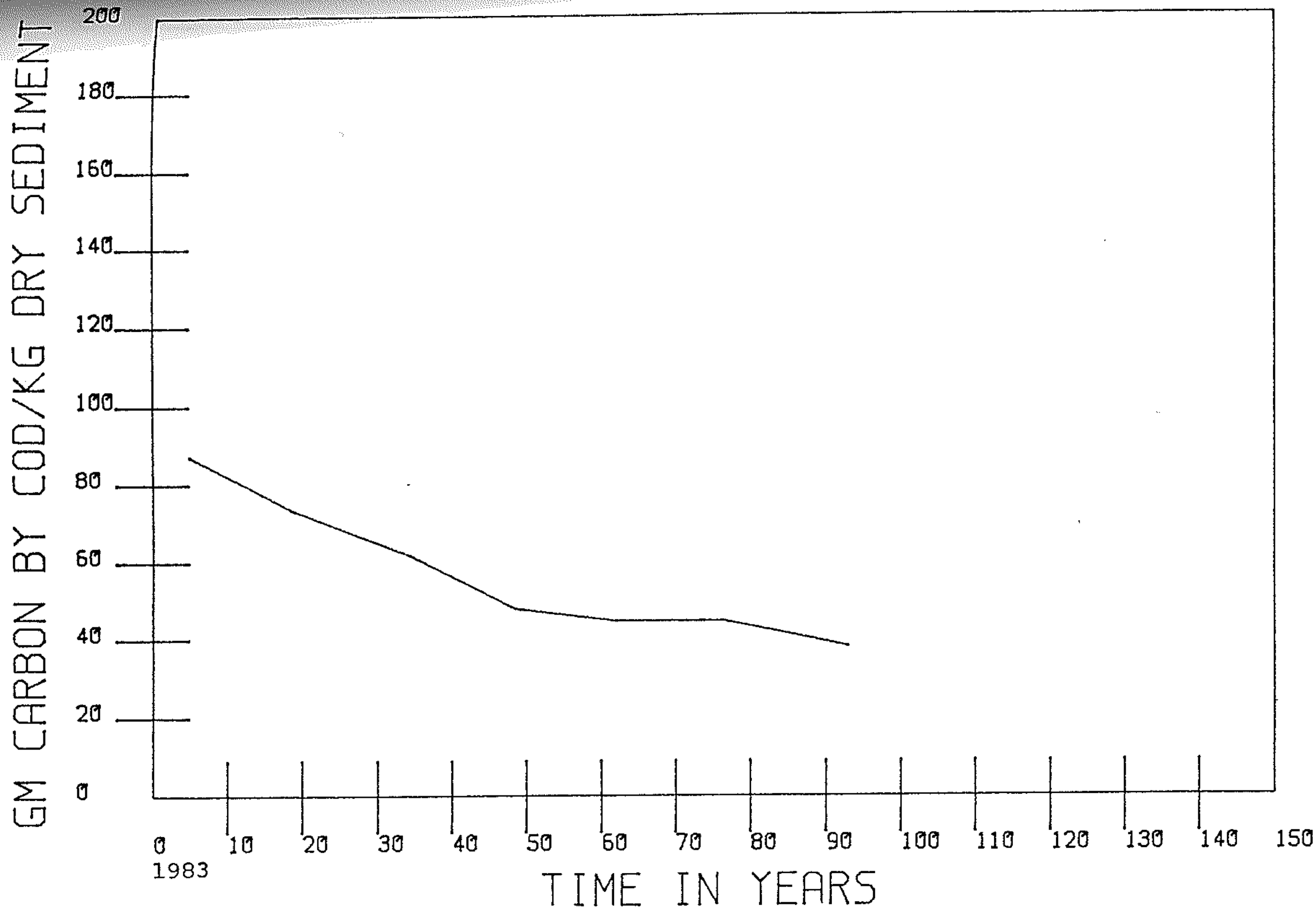


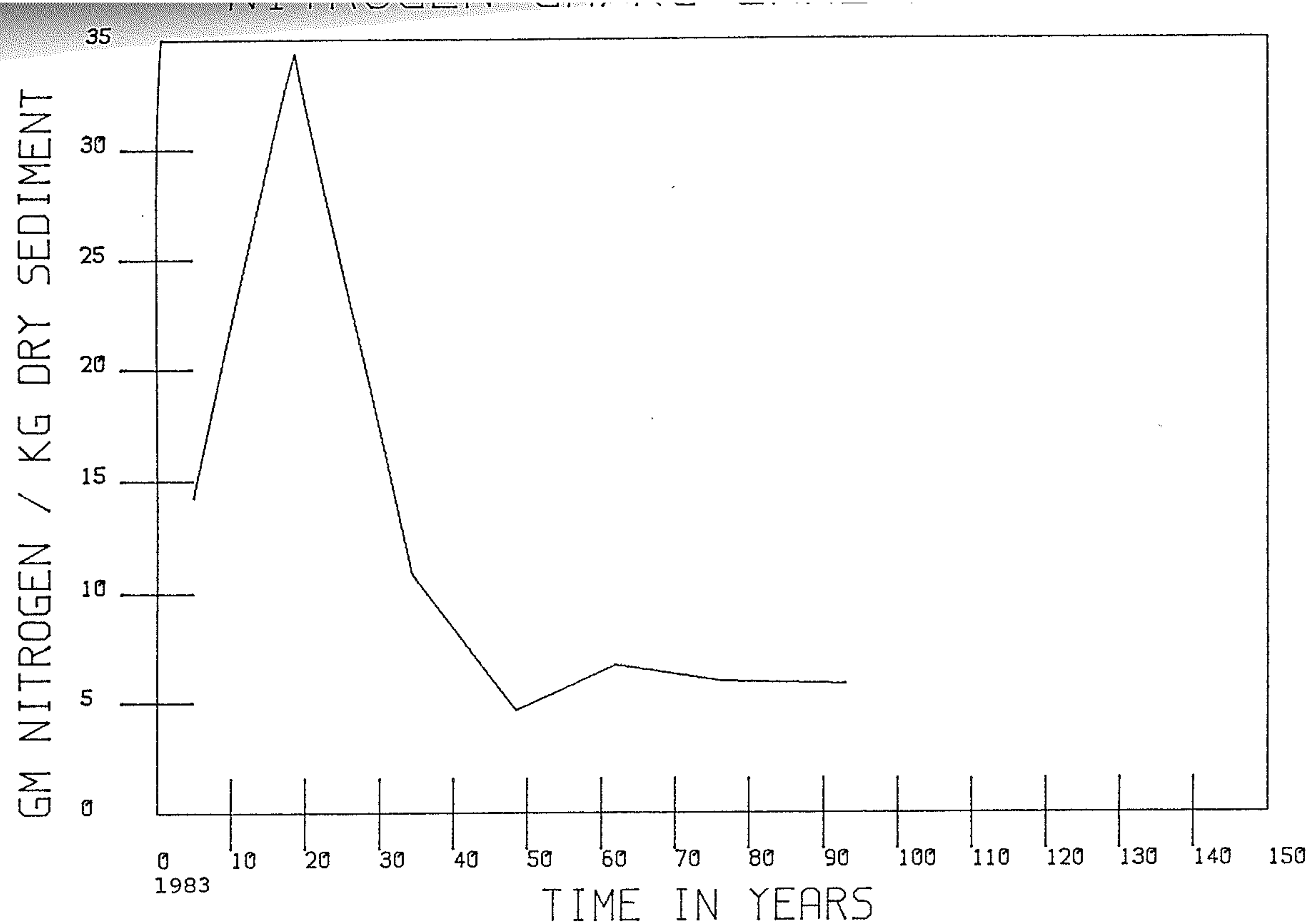
CHLOROPHYLL-A LAKE SALLIE
CHLOROPHYLL-A MG/CUBIC METER
30
27
24
21
18
15
12
9
6
3
0
JUNE
JULY
AUGUST
SEPT.
OCTOBER
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
TIME IN WEEKS JUN 1 TO NOV 1 1983

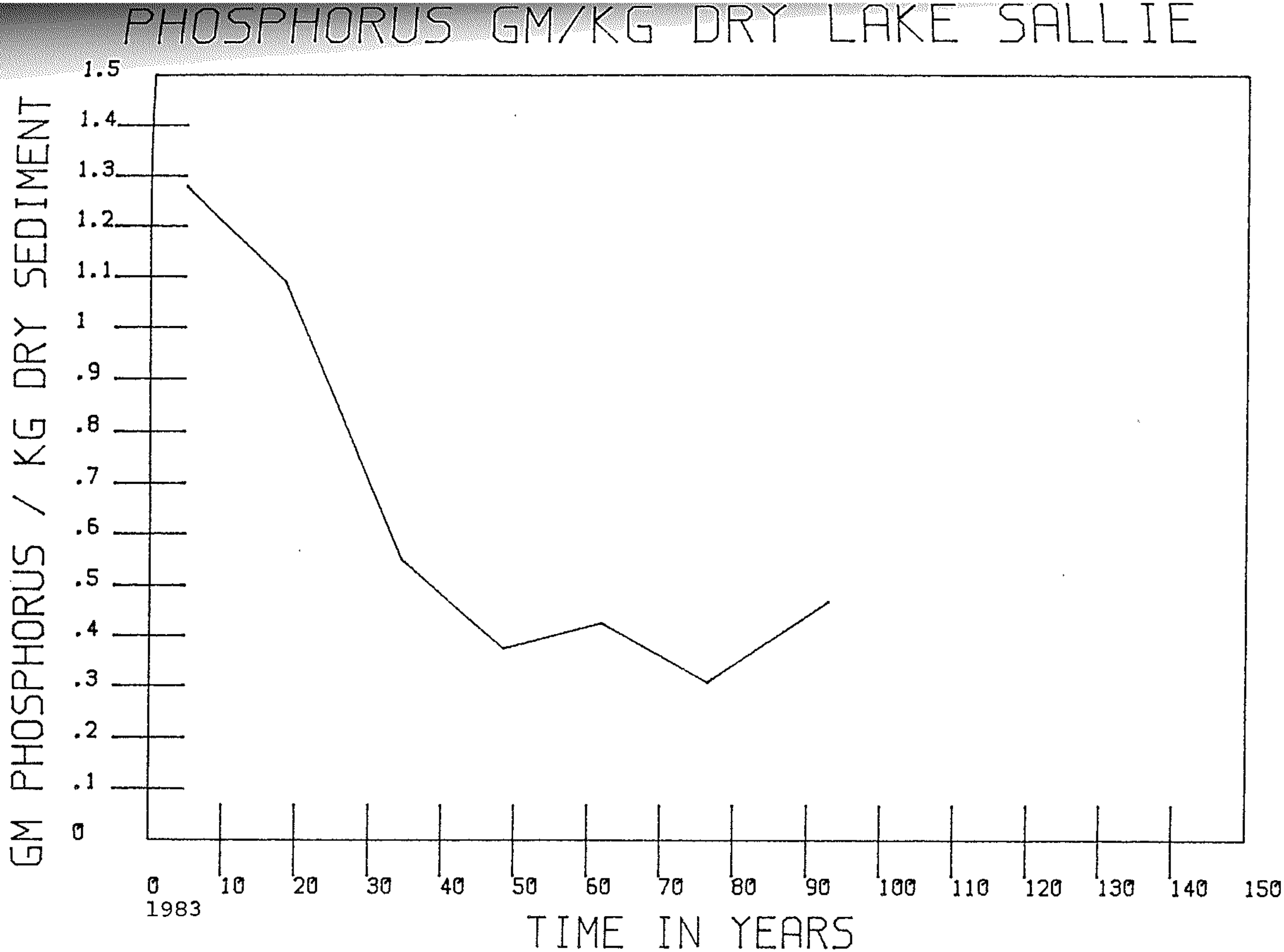
ANNUAL SEDIMENT BANDING LAKE SALLIE




SEDIMENT DENSITY LAKE SALLIE
PERCENT SOLIDS
50
40
30
20
10
0
0
1983
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
TIME IN YEARS


GM CARBON BY COD/KG DRY SEDIMENT
200
180
160
140
120
100
80
60
40
20
0
0
1983
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
TIME IN YEARS


35
30
25
20
15
10
5
0
GM NITROGEN / KG DRY SEDIMENT
0
1983
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
TIME IN YEARS


PHOSPHORUS GM/KG DRY LAKE SALLIE
GM PHOSPHORUS / KG DRY SEDIMENT
1.5
1.4
1.3
1.2
1.1
1
.9
.8
.7
.6
.5
.4
.3
.2
.1
0
0
1983
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
TIME IN YEARS

LAKE MELISSA

Surface Area (acres)	1831.
Littoral area (acres)	935.
Volume estimated (acre feet)	22,000.
Maximum depth (feet)	43.
Mean depth estimated (feet)	12.
Number of inlets	2.
Volume flow per year (acre feet)	25,000.
Number of outlets	1.

Lake Melissa has a background turbidity which appears to come from Lake Sallie. The early season secchi disc readings are close to those of the rest of the lakes in the system. This fell off rapidly through July and stablized in August. Since the chlorophyll-a levels do not correspond to the secchi disc reading in the early season, but do correspond to the levels found in Lake Sallie, the input materials are more than likely due to dead biological materials coming from the outlet on Lake Sallie.

There is a significant nutrient input attributable to Lake Melissa's own watershed as evidenced by the sharp rise in chlorophyll-a following the storm in August. The level of chlorophyll-a did not peak until early September and then fell off rapidly through October. The chlorophyll-a levels are about one-half of those found in Lake Sallie at the present time, but can only be maintained if a vigorous cleanup program is continued in the upper watershed.

The lake developed a thermocline by July 14 at twenty-one feet. By August 18 this had come up to twelve feet, but the lake was mixed again by mid September. The free water phosphorus levels climbed steadily throughout the summer season, as did the nitrogen concentrations. The mixing of the lake in September is probably responsible for turning up the nutrients from the hypolimnion to the upper waters.

Since the lake mixing began sometime in late August, the algae were able to use up the available nutrients by the end of September. This indicates that at the present time there is a limited availability of nutrients in the surface of the sediments.

The algae populations attained about three-fifths of the concentration found in Lake Sallie at the same time.

Non-hetrocystis blue-green algae dominated the population of blue-greens through the summer. The algae found here again reflect a lake which is operating on a secondary nutrient source, much of it recycled from Lake Sallie's sediments. This will continue for a number of years even though the nutrient input to the lakes upstream is reduced. The water quality will not degrade beyond its present condition and will improve as Lake Sallie improves.

The sediment core dated back to one hundred twenty years on Lake Melissa and the annual excursions do not vary considerably. Over the past fifty years, the mean deposition of materials to the sediments has been on the increase and is currently rising. The sediment density has been dropping for about the same amount of time and is currently at about twenty percent solids.

The carbon load to the sediment of this lake has been building up at an increasing rate, as have the nitrogen and phosphorus. The rate of nitrogen deposition is currently on the increase, but the rate of phosphorus accumulation is presently steady and should level off or decline in future years with upstream management of the watershed.

The lag time for the nutrient build up between Lake Sallie and Lake Melissa is about fifteen years. The rate of nutrient acquision is considerably less than that of Lake Sallie. Assuming there will be no dramatic adverse change in the watershed, the rate should not increase, but should rather decrease in future years.

The water quality of Lake Melissa is dependent on the management programs for Lake Sallie and the upper watershed.

Lake Data & Chemistry

LAKE MELISSA
June 2 1983

Secchi Depth 15.75 ft.

Depth ft.	Temp C	pH	Cond um	D.O. mg/l	TSS mg/l	Chl-a mg/M3	Alk mg/l	EDTA mg/l	o-PO4 mg/l	t-PO4 mg/l	NO2 mg/l	NO3 mg/l	NH3 mg/l	TKN mg/l
S	19.0	7.8	400	10.0										
3	19.0	7.8	385	10.2										
6	18.8	7.8	378	10.9	2.5	8.233	215	200	.010	.020	.000	.250	.105	.621
9	18.0	7.9	368	11.4										
12	17.5	7.9	370	11.4										
15	18.2	7.9	370	11.5										
18	18.2	7.9	368	11.6										
21	18.1	7.9	362	11.5										

July 14 1983

Secchi Depth 09.50 ft.

Depth ft.	Temp C	pH	Cond um	D.O. mg/l	TSS mg/l	Chl-a mg/M3	Alk mg/l	EDTA mg/l	o-PO4 mg/l	t-PO4 mg/l	NO2 mg/l	NO3 mg/l	NH3 mg/l	TKN mg/l
S	27.0		450	9.2										
3	27.0		450	9.2										
6	26.8	8.6	450	10.0	2.9	9.08	190	180	.002	.028	.008	.042	.225	.555
9	26.8		450	10.2										
12	26.8		450	10.5										
15	26.4		445	10.5										
18	26.2		445	11.4										
21	25.4	8.48	440	10.9	1.1	4.78			.005	.029	.006	.040	.065	.454
24	25.0	8.48	440	8.4	1.1	4.78			.005	.028	.006	.040	.065	.454

Lake Data & Chemistry

LAKE MELISSA
August 18 1983

Secchi Depth 7.00 ft.

Depth ft.	Temp C	pH	Cond um	D.O. mg/l	TSS mg/l	Chl-a mg/M3	Alk mg/l	EDTA mg/l	o-PO4 mg/l	t-PO4 mg/l	NO2 mg/l	NO3 mg/l	NH3 mg/l	TKN mg/l
S	25.0	8.6	399	7.6										
3	25.0	8.6	408	7.2										
6	25.0	8.5	412	7.5	3.2	9.351	177	190	.002	.016	.005	.020	.078	.566
9	25.0	8.5	412	7.4										
12	24.2	8.5	412	5.5	2.4	7.32								
15	23.7	8.1	425	0.2										
18	23.7	7.7	450	0.2	13.2	8.70			.011	.033	.036	.050	1.681	2.380

September 15 1983

Secchi Depth 5.75 ft.

Depth ft.	Temp C	pH	Cond um	D.O. mg/l	TSS mg/l	Chl-a mg/M3	Alk mg/l	EDTA mg/l	o-PO4 mg/l	t-PO4 mg/l	NO2 mg/l	NO3 mg/l	NH3 mg/l	TKN mg/l
S	17.0	8.3	850	8.2										
3	17.0	8.4	875	8.0										
6	17.0	8.4	900	7.8	2.4	13.11	195	192	.006	.043	.009	.010	.161	.478
9	17.0	8.3	910	7.9										
12	17.0	8.3	900	7.9										
15	17.0	8.3	895	7.8										
18	17.0	8.3	895	7.8										
21	17.0	7.6	900	7.8	4.8	19.2			.006	.051	.008	.11	.21	.506

Algae/Phytoplankton Determinations

Algal counts in mg/L

LAKE MELISSA

June 2, 1983

Depth in feet	Green	Blue-green	Euglanoids	Yellow	Diatoms	Total count
6	2	29	2	131	119	283

July 14, 1983

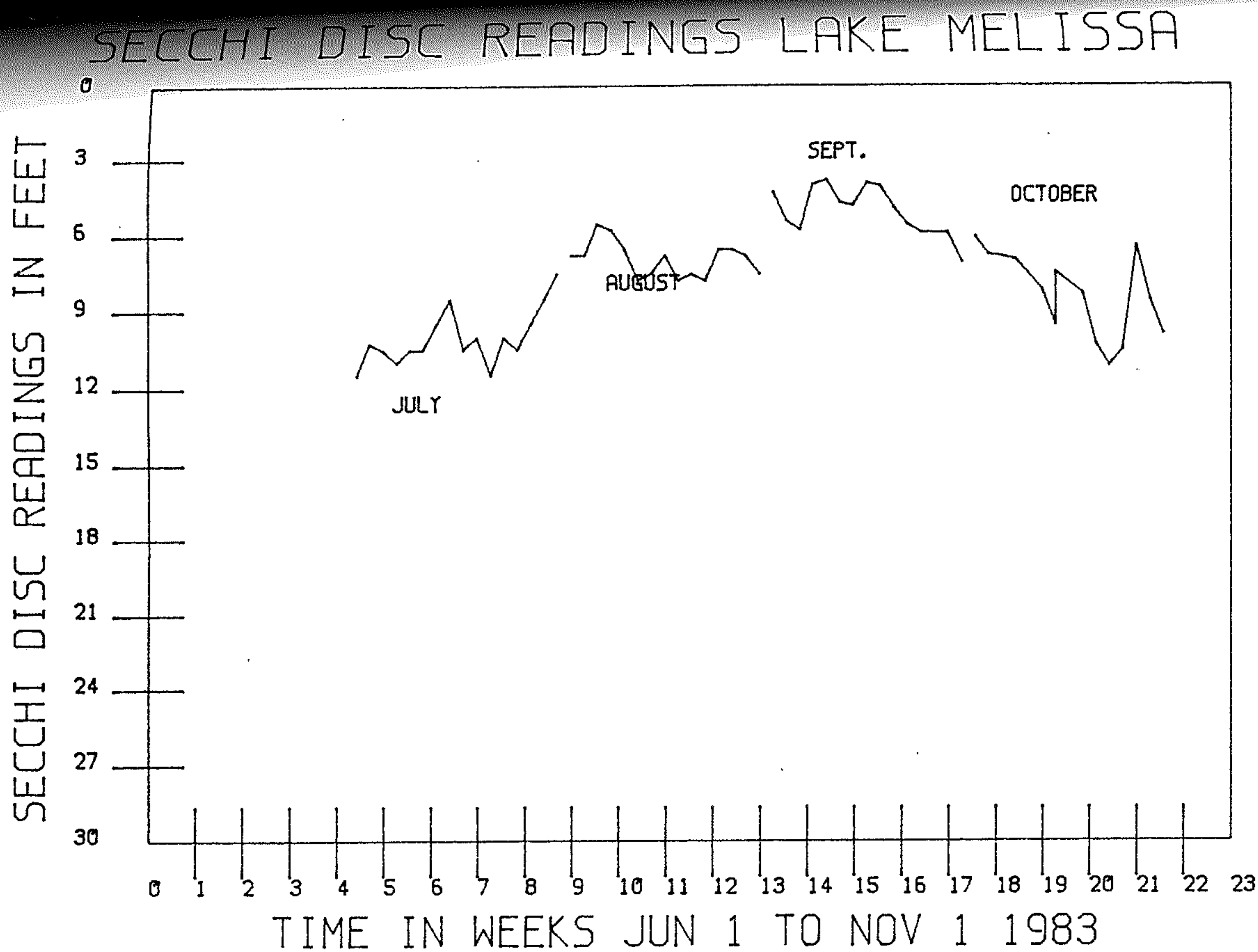
Depth in feet	Green	Blue-green	Euglanoids	Yellow	Diatoms	Total count
6	0	233	2	8	4	247
21	2	209	2	8	110	331

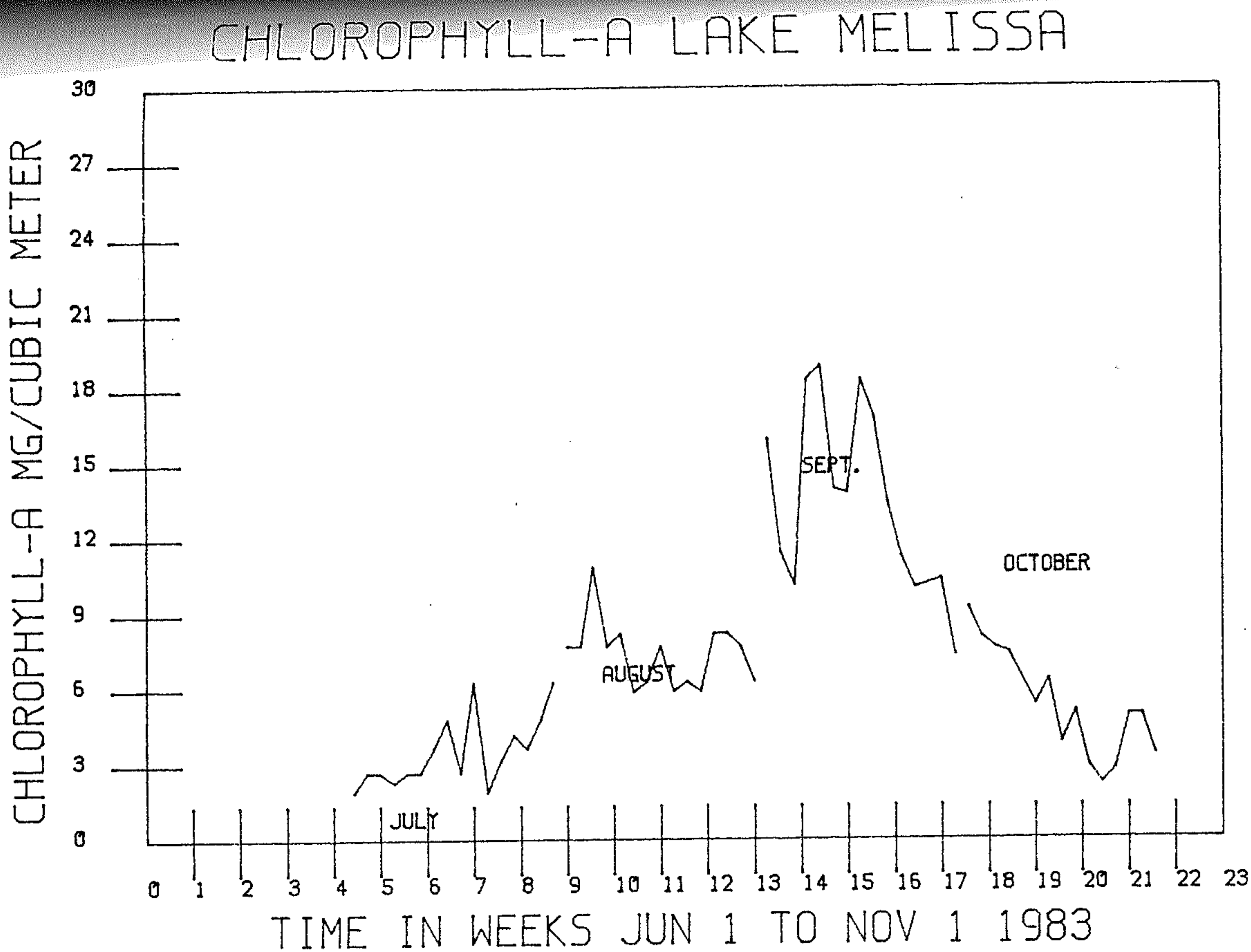
August 18, 1983

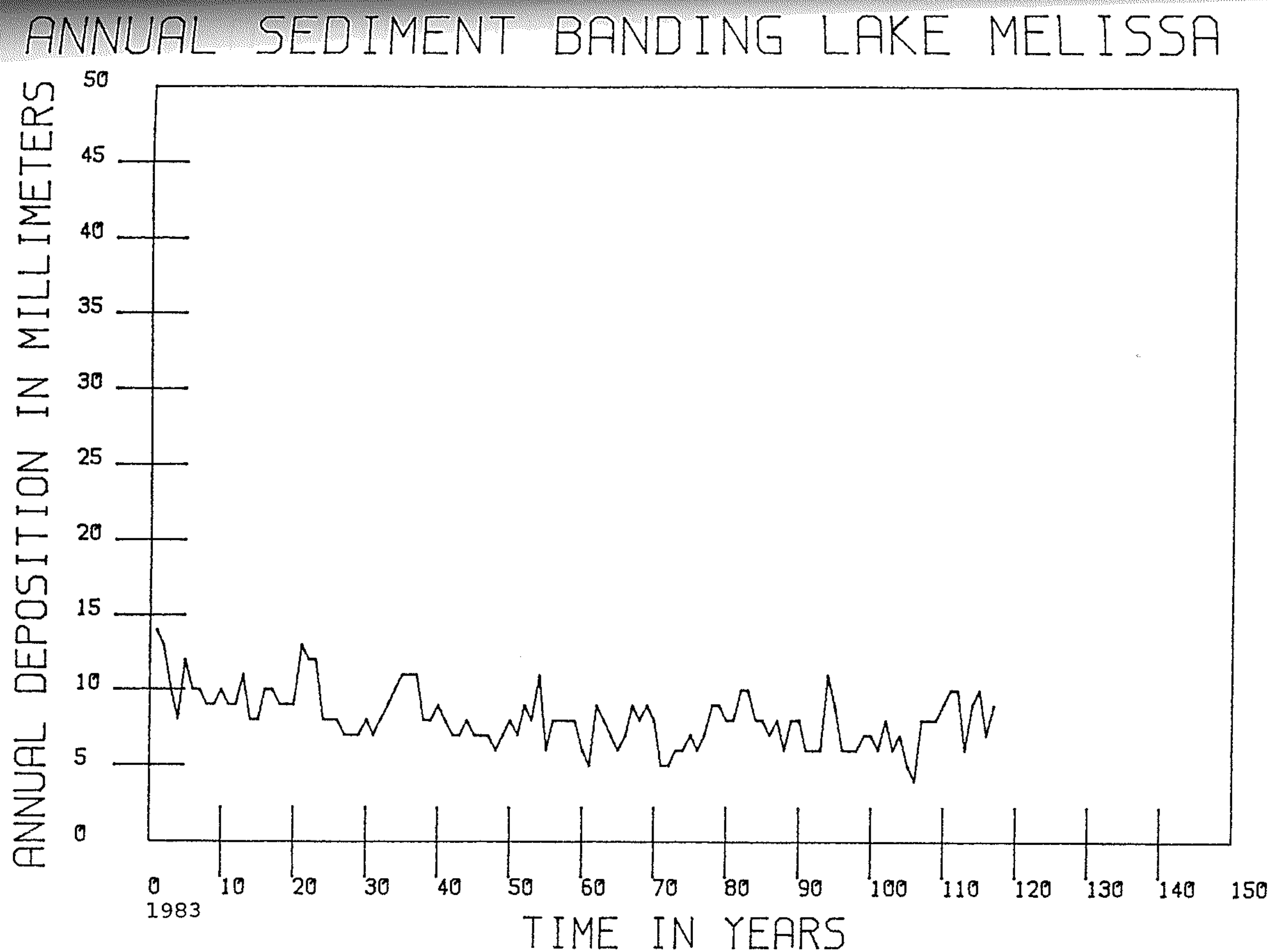
Depth in feet	Green	Blue-green	Euglanoids	Yellow	Diatoms	Total count
6	0	117	8	16	16	157
12	6	86	0	17	20	129
18	11	3,178	11	0	20	3,220

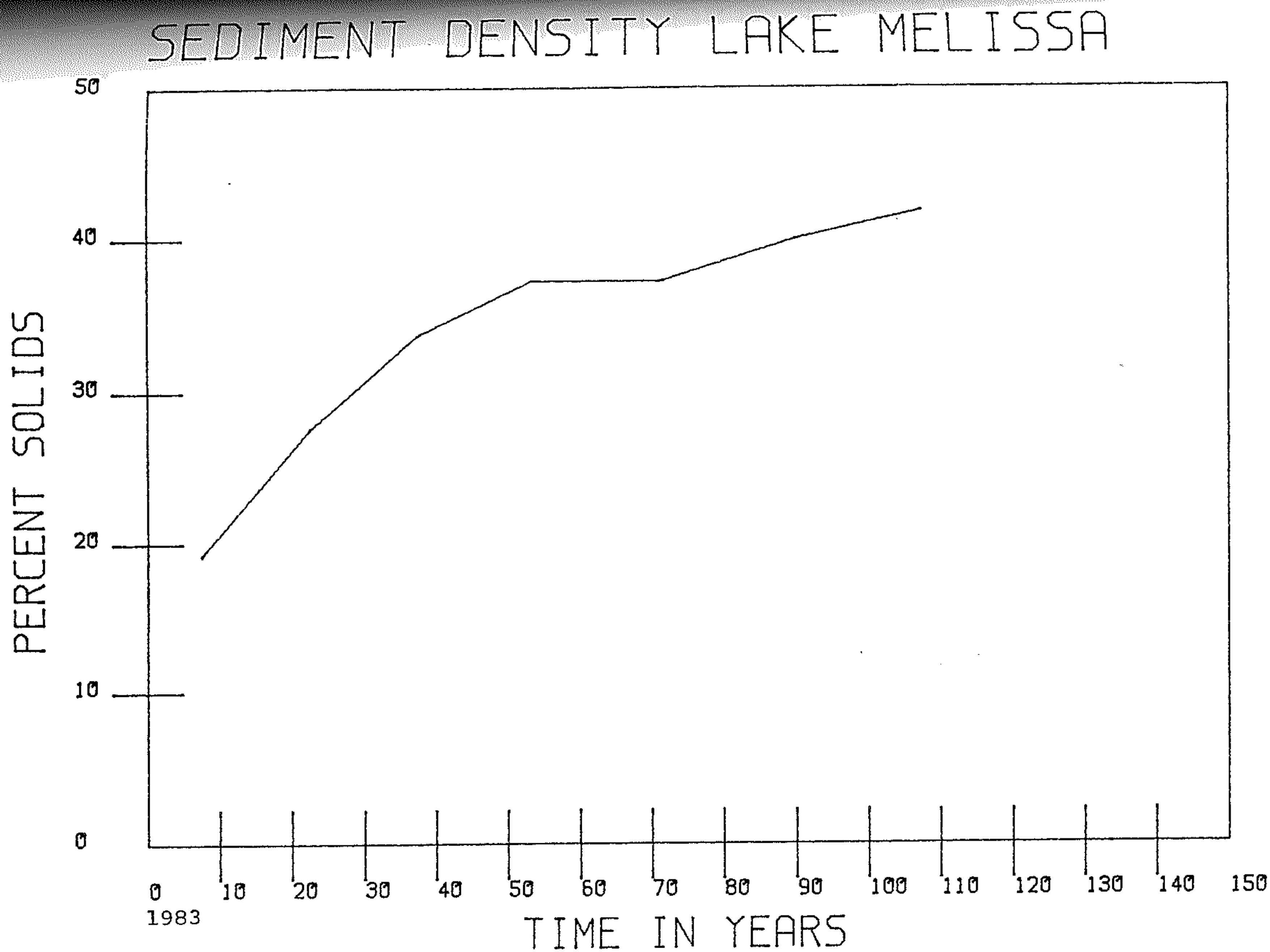
September 15, 1983

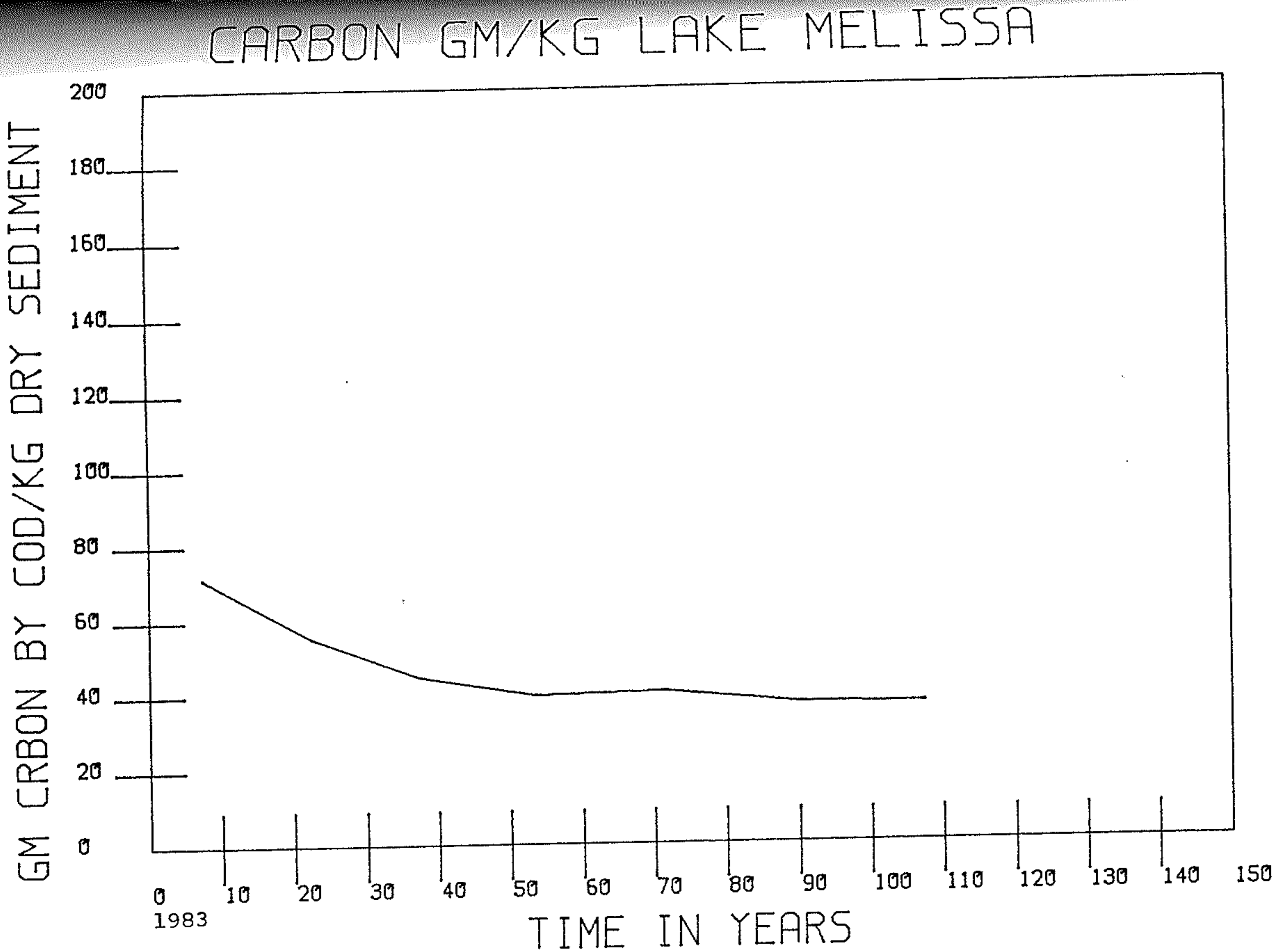
Depth in feet	Green	Blue-green	Euglanoids	Yellow	Diatoms	Total count
6	4	3,083	8	12	23	3,130
21	0	2,728	0	0	51	2,779

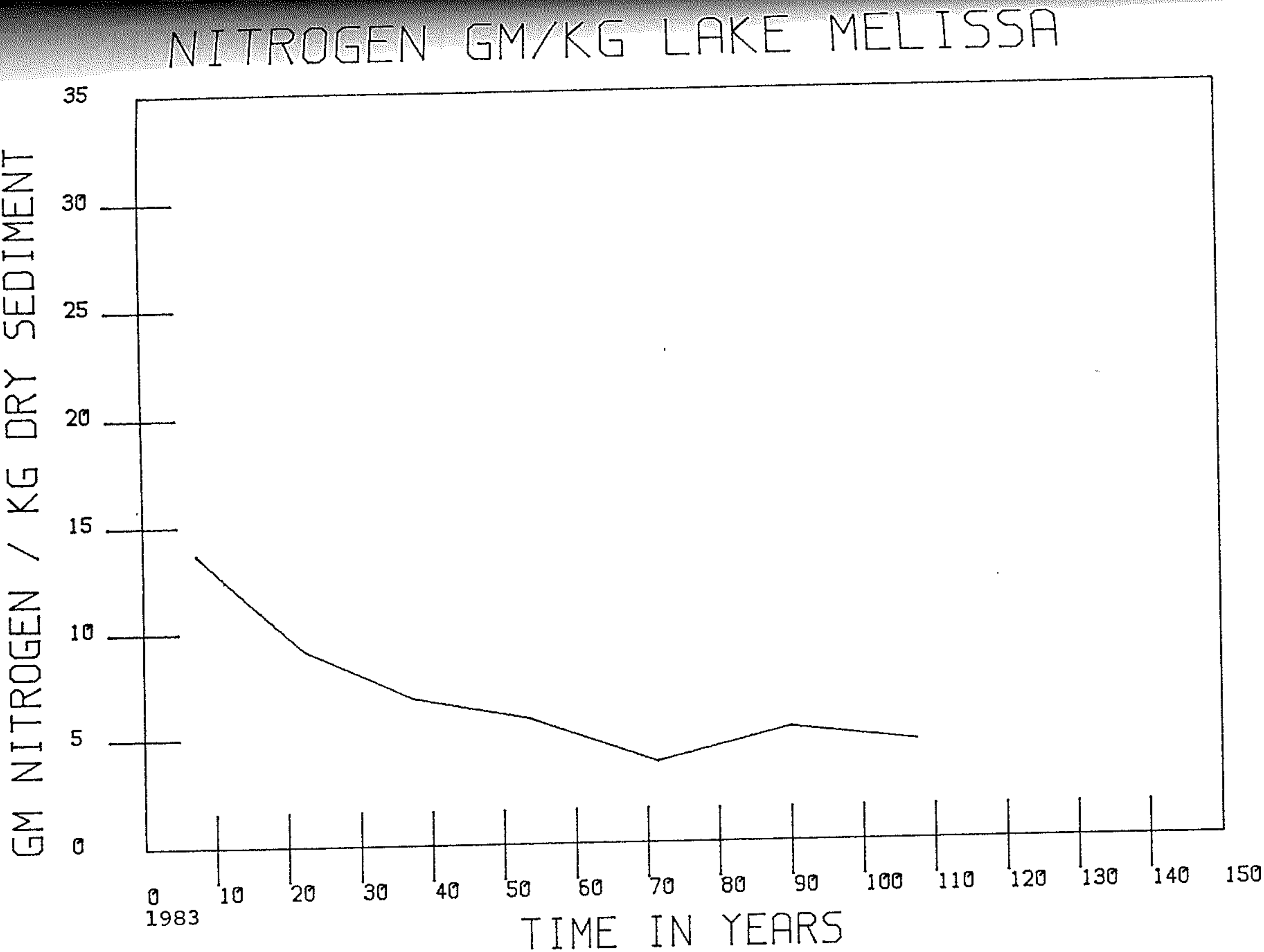

SECCHI DISC READINGS LAKE MELISSA
SECCHI DISC READINGS IN FEET
0
3
6
9
12
15
18
21
24
27
30
JULY
AUGUST
SEPT.
OCTOBER
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
TIME IN WEEKS JUN 1 TO NOV 1 1983

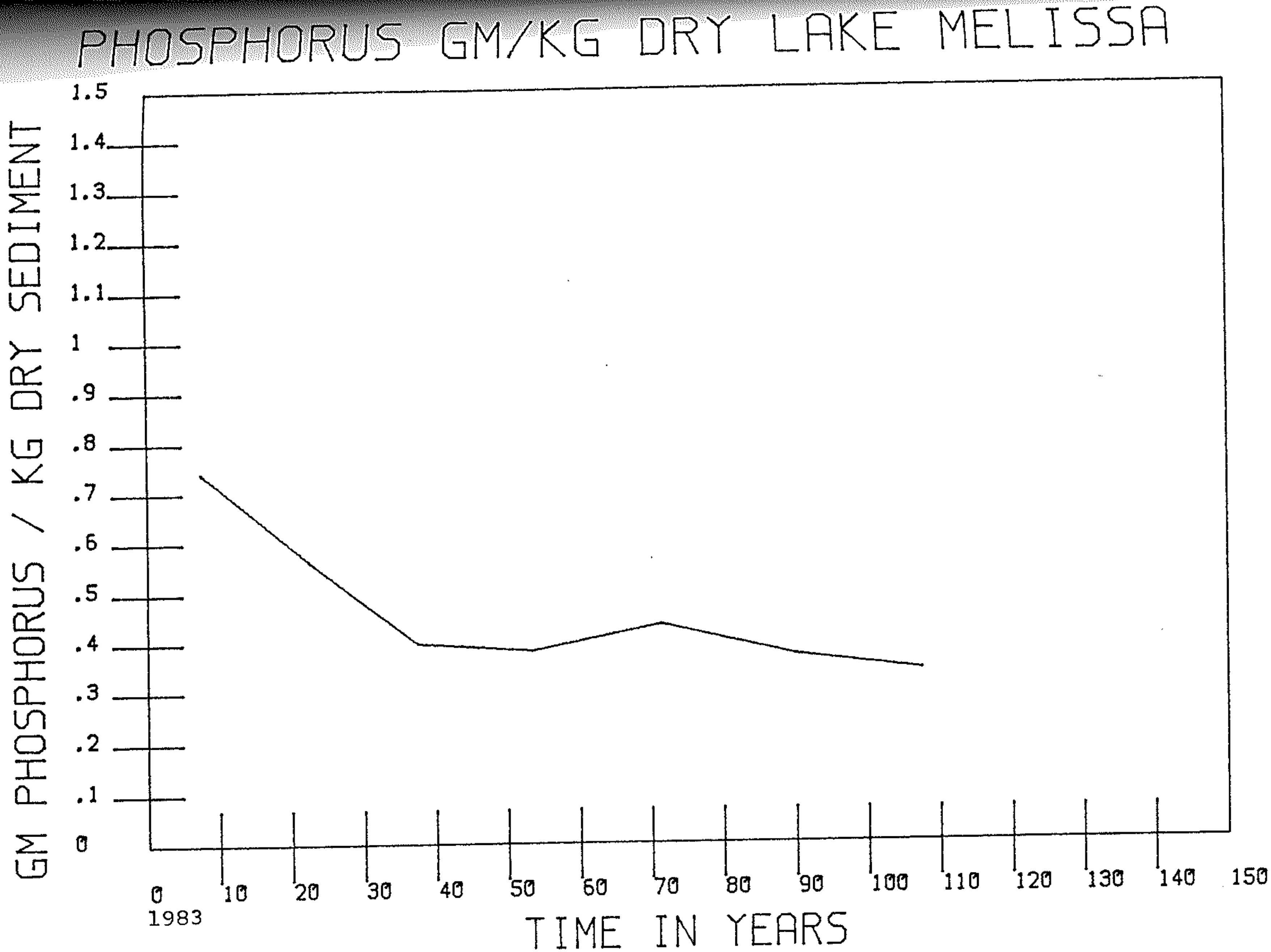

CHLOROPHYLL-A LAKE MELISSA
CHLOROPHYLL-A MG/CUBIC METER
30
27
24
21
18
15
12
9
6
3
0
JULY
AUGUST
SEPT.
OCTOBER
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
TIME IN WEEKS JUN 1 TO NOV 1 1983


ANNUAL SEDIMENT BANDING LAKE MELISSA
ANNUAL DEPOSITION IN MILLIMETERS
50
45
40
35
30
25
20
15
10
5
0
0
1983
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
TIME IN YEARS


SEDIMENT DENSITY LAKE MELISSA
PERCENT SOLIDS
0
10
20
30
40
50
0
1983
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
TIME IN YEARS


CARBON GM/KG LAKE MELISSA
GM CRBON BY COD/KG DRY SEDIMENT
200
180
160
140
120
100
80
60
40
20
0
0
1983
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
TIME IN YEARS


NITROGEN GM/KG LAKE MELISSA
GM NITROGEN / KG DRY SEDIMENT
35
30
25
20
15
10
5
0
0
1983
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
TIME IN YEARS


PHOSPHORUS GM/KG DRY LAKE MELISSA
GM PHOSPHORUS / KG DRY SEDIMENT
1.5
1.4
1.3
1.2
1.1
1
.9
.8
.7
.6
.5
.4
.3
.2
.1
0
0
1983
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
TIME IN YEARS

Lake St. Clair

Surface area (acres)	140.
Littoral area (acres)	140.
Volume (acre feet)	598.
Maximum depth (feet)	7.5
Mean depth (feet)	4.
Number of inlets	4.
Volume flow per year (acre feet)	5,000.
Number of outlets	1.

The sediment core sample collected from this lake in the winter of 1983, dated back forty-five years. The annual band width ranged from about 5 millimeters, forty-five years ago to a maximum of 50 millimeters ten years ago. The sediment density is very low, five to eight percent, which is due to the high percentage of carbon, the amount of gas in the detritus, and possibly a high inflow of groundwater at the collection site.

At the present time we believe that the sediments in Lake St. Clair are biologically active to the depth penetrated by the four foot core tube. These sediments are releasing much of their accumulated nutrient load to the free water in the winter months and possibly in the summer season as well. Water samples were not collected from this lake in the 1983 season, but the anoxic condition of the lake this winter and the strong hydrogen sulfide odor from the lake through the summer months make this a high probability.

The nitrogen and phosphorus loads, per killogram of sediment, are not excessive at the present time, when compared to other lakes in the system. However, this is due to a continuous discharge of both of these nutrients to the lakes downstream. The phosphorus contained in the top four feet of sediment throughout the lake amounts to a potential discharge over the next few years of 19,000 killograms. The current nitrogen load in the top four feet of sediment is about 532,000 killograms. These numbers assume zero input, which we know is not the case.

This discharge can be stopped in a number of ways, but there may still be a significant groundwater source of nutrients to this lake. This presents a long term treatment problem.

We believe that the present nutrient load in Lake St. Clair can be controlled in place. The prospect of removing this nutrient load from the watershed by dredging is possible, but at the current seven percent solids load, would be a pumping operation. Dewatering this sediment would require an impoundment above the water table which needs to be prepared for sufficent water percolation prior to loading. The prospect of pumping and containing 182 million gallons of detritus to remove 1.7 million cubic feet of sediment material is probably not cost effective. We suspect that the actual volume is considerably greater than this since the density of the sediment did not change appreciably in the four foot core sample.

The following is a possible approach to contain the present load on site:

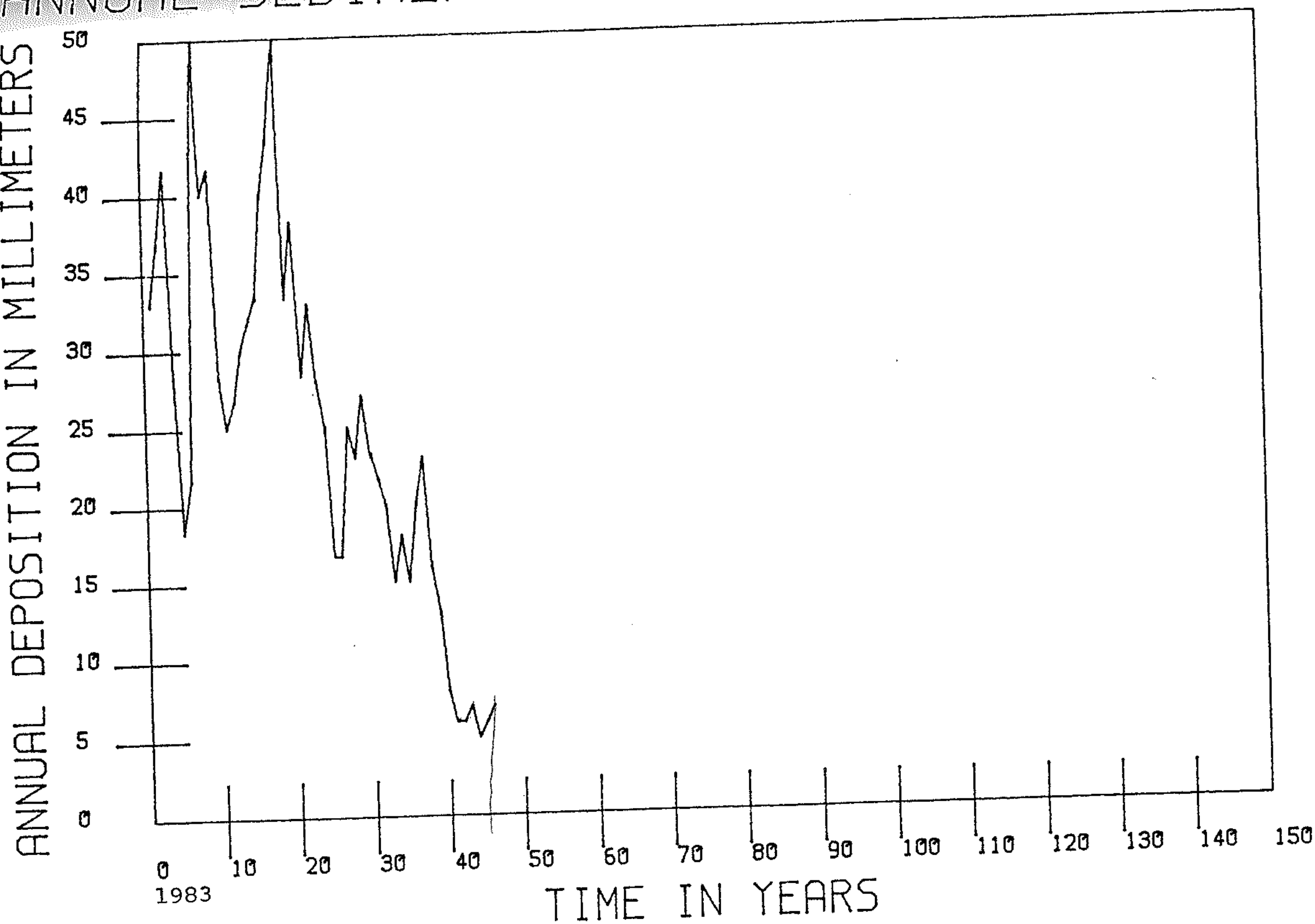
1. Reduce the hydraulic loading of clean water to Lake St. Clair. This means routing the flow from Long Lake around St. Clair and possibly adding additional clean inputs to this discharge. Channel this flow directly to the Pelican River.
2. Aerate the lake to augment the decomposition of the detritus and add ferric iron to the waters to precipitate

the phosphorus. Some of the aeration heads should be maintained throughout the winter months to prevent the lake from becoming anoxic.

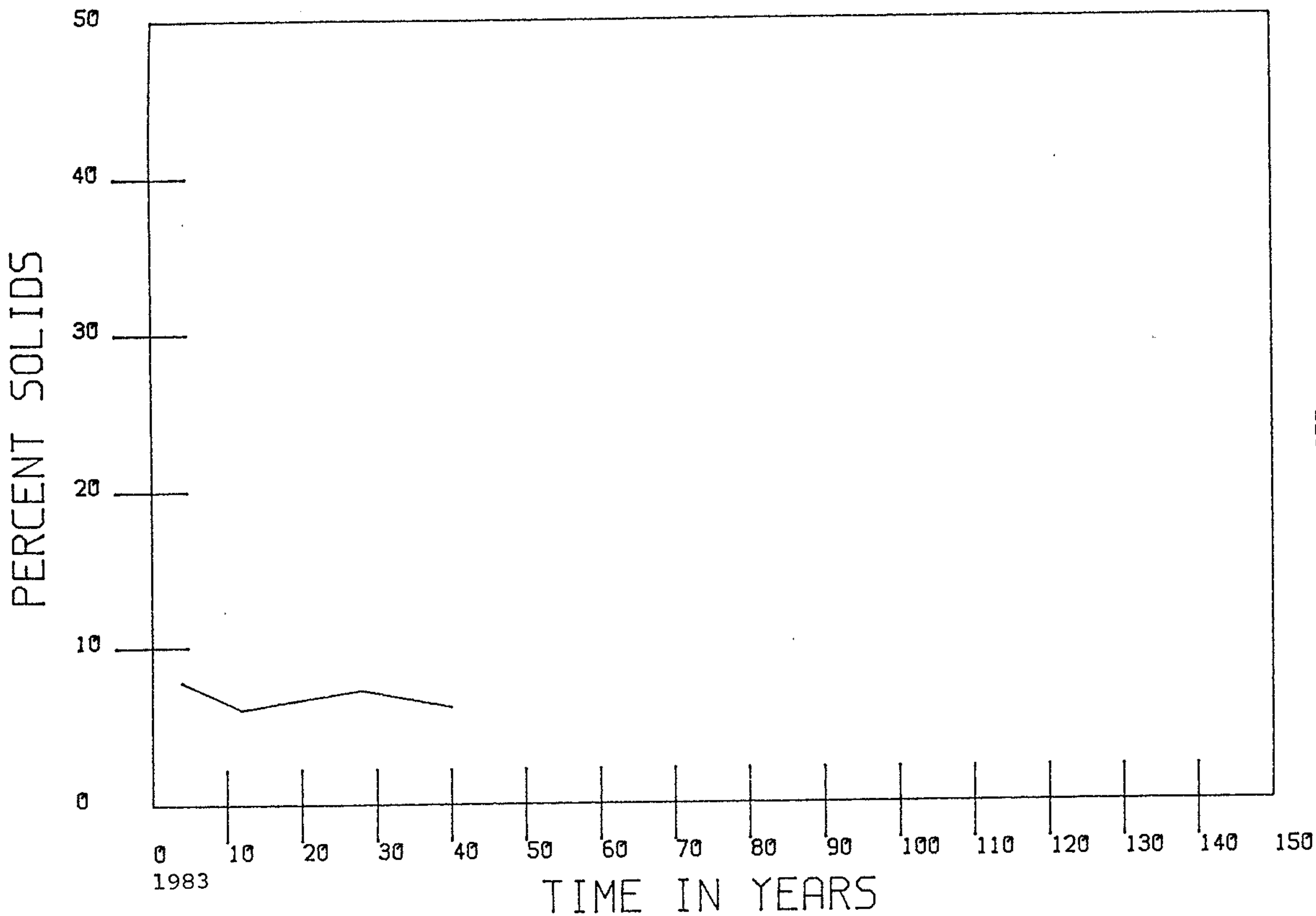
3. The present nutrient loading to Lake St. Clair needs to be determined. The stormwater discharge channel which comes into Lake St. Clair should be routed to the existing waste treatment facility and pumped to the spray irrigation fields for treatment.

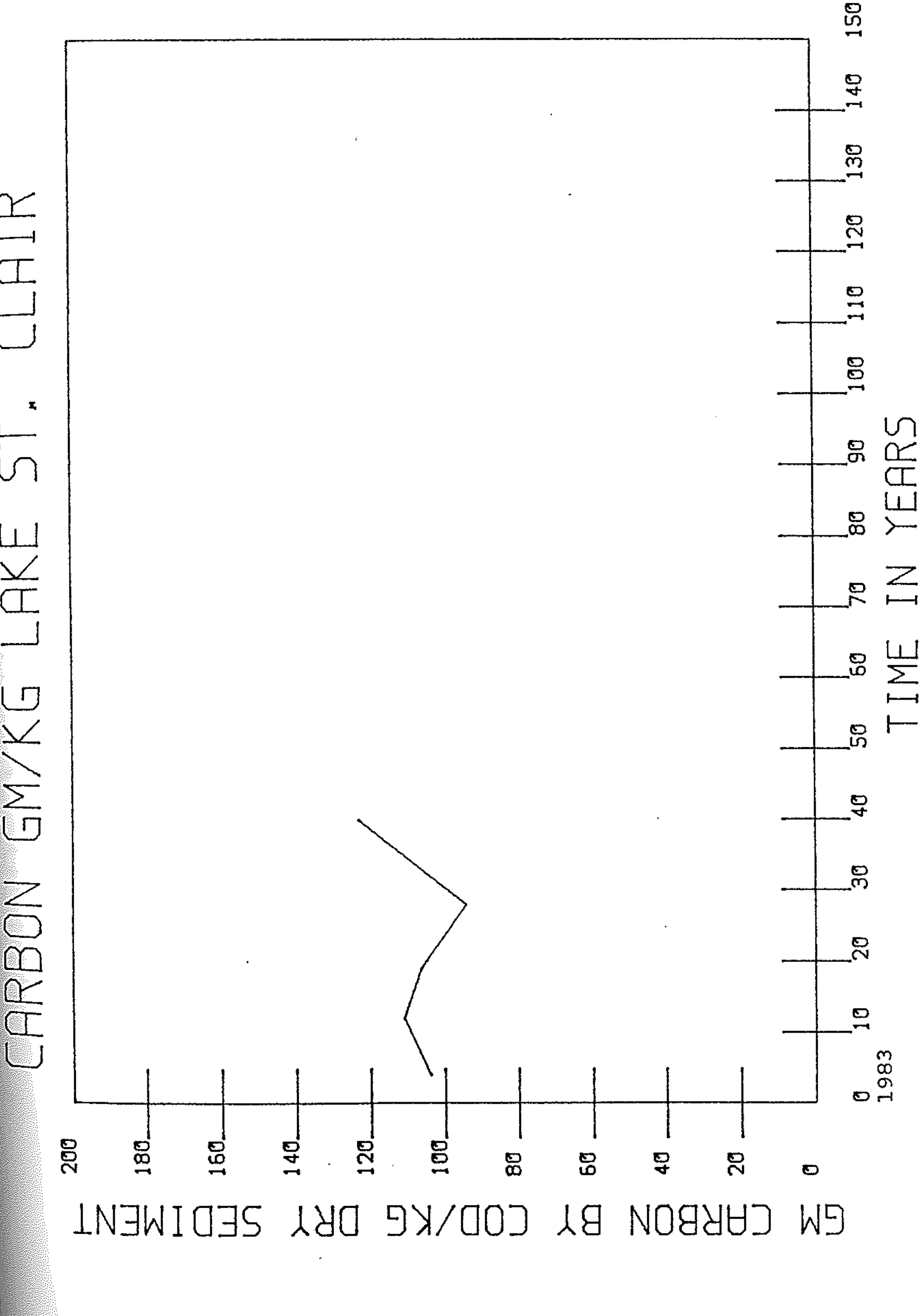
4. Assess the nutrient loading to the lake via groundwater at the lake site. This could be accomplished by driving pipes into the sediment in selected locations in the lake bottom, pumping out the loose detritus and then pump the sampling pipes at one month intervals through the year and analyze the water for total nitrogen and phosphorus. This data can be compared to existing lake conditions.

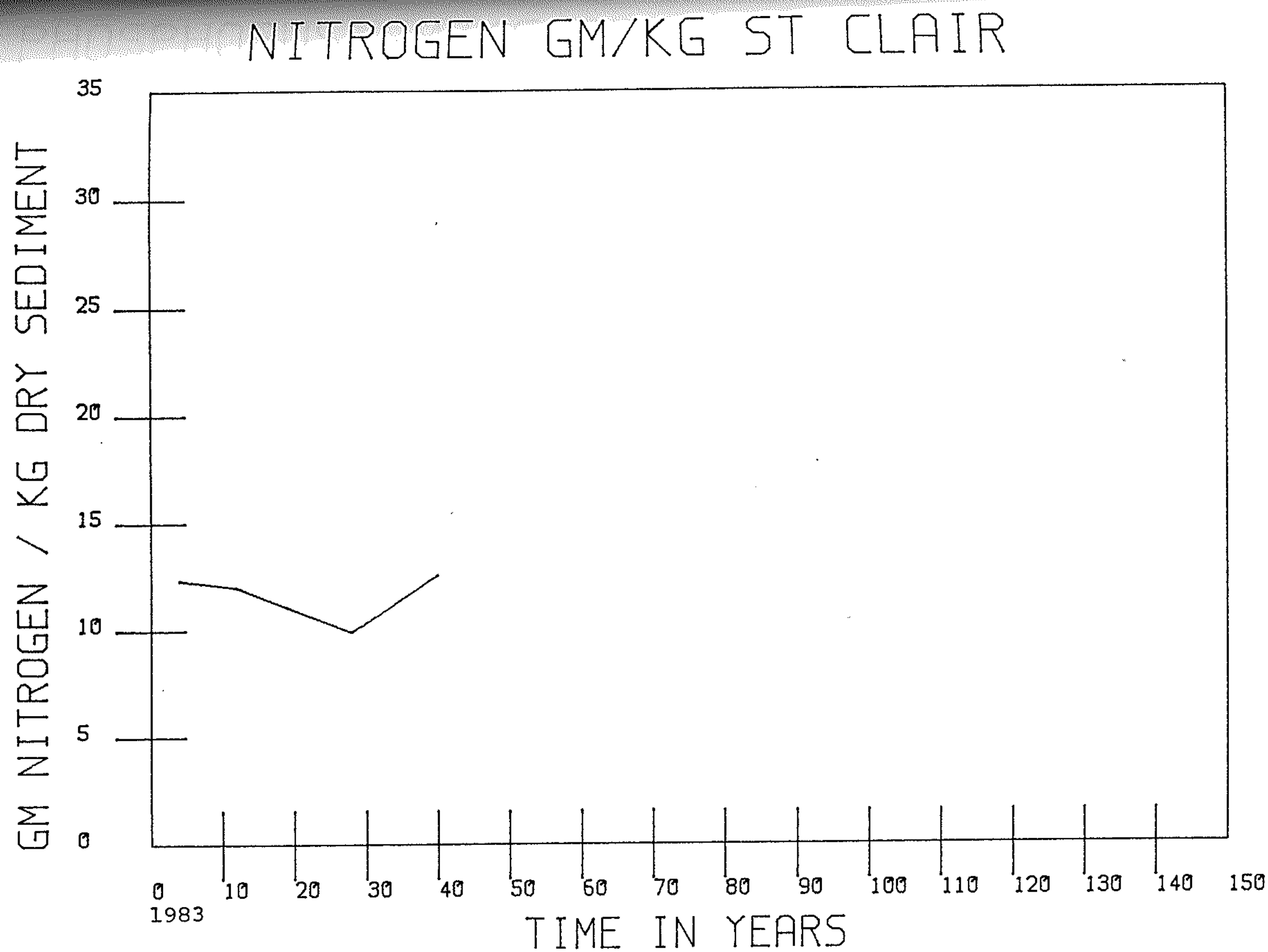
ANNUAL SEDIMENT BANDING LAKE ST. CLAIR



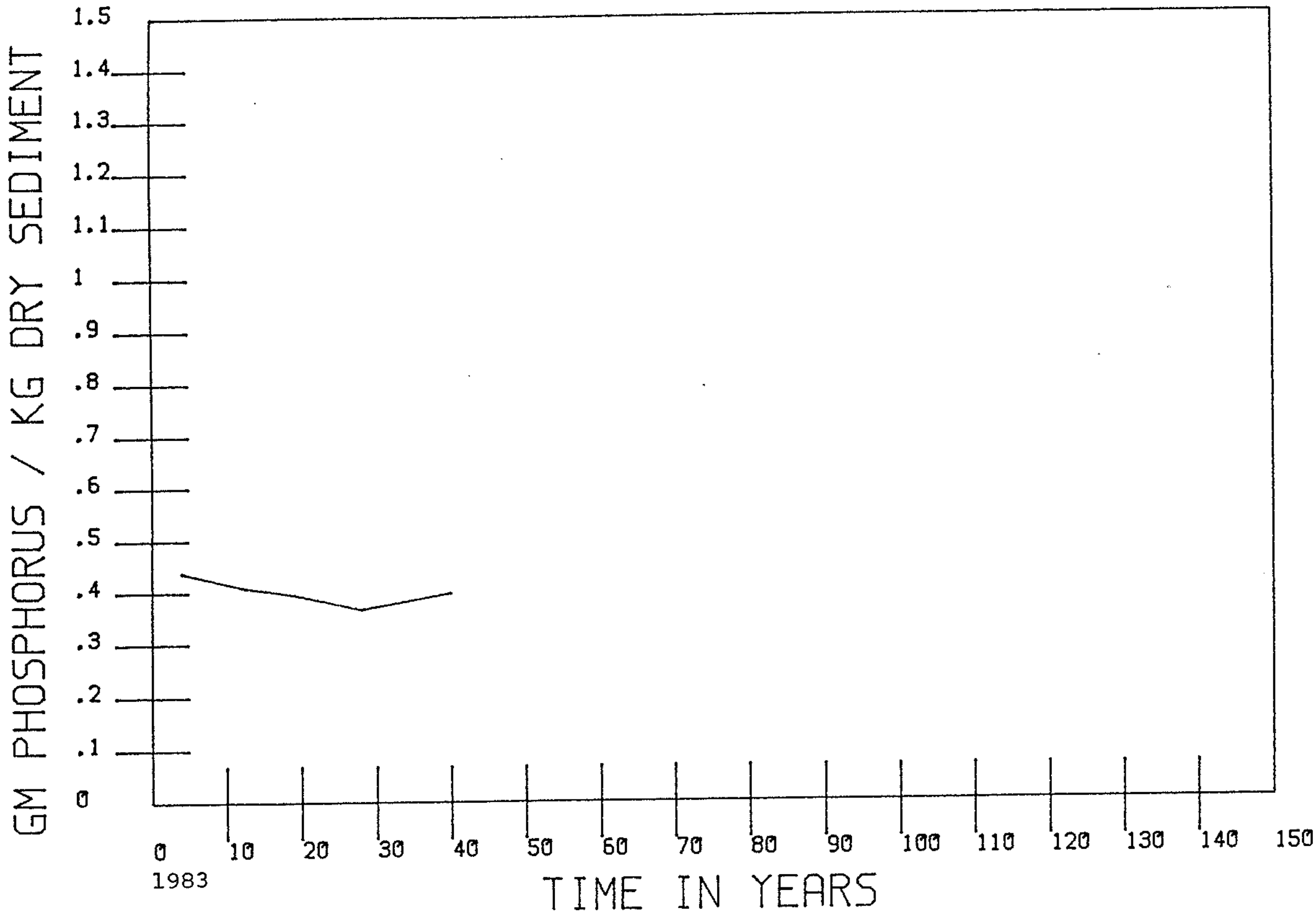
SEDIMENT DENSITY LAKE ST. CLAIR




CARBON GM/KG LAKE ST. CLAIR
GM CARBON BY COD/KG DRY SEDIMENT
0
20
40
60
80
100
120
140
160
180
200
TIME IN YEARS
0
1983
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150


NITROGEN GM/KG ST CLAIR
GM NITROGEN / KG DRY SEDIMENT
35
30
25
20
15
10
5
0
0
1983
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
TIME IN YEARS

PHOSPHORUS GM/KG DRY LAKE ST. CLAIR



MUSKRAT LAKE

Surface area (acres)	67.
Littoral area (acres)	64.
Volume (acre feet)	341.
Maximum depth (feet)	18.
Mean depth (feet)	5.
Number of inlets	2.
Volume flow per year (acre feet)	22,000.
Number of outlets	1.

The sediment core collected from Muskrat Lake dates back seventy-two years. During the period from seventy years ago to thirty years ago the mean annual sediment load increased steadily. Over the last twenty-two years the load has steadily declined. The 1983 band is high because of the mass of partially decomposed vegetation from this last year.

The sediment density is decreasing at the present time and is below ten percent for the last ten years. The deposition from the last twenty years is likely biologically active and contains a high percentage of organic carbon.

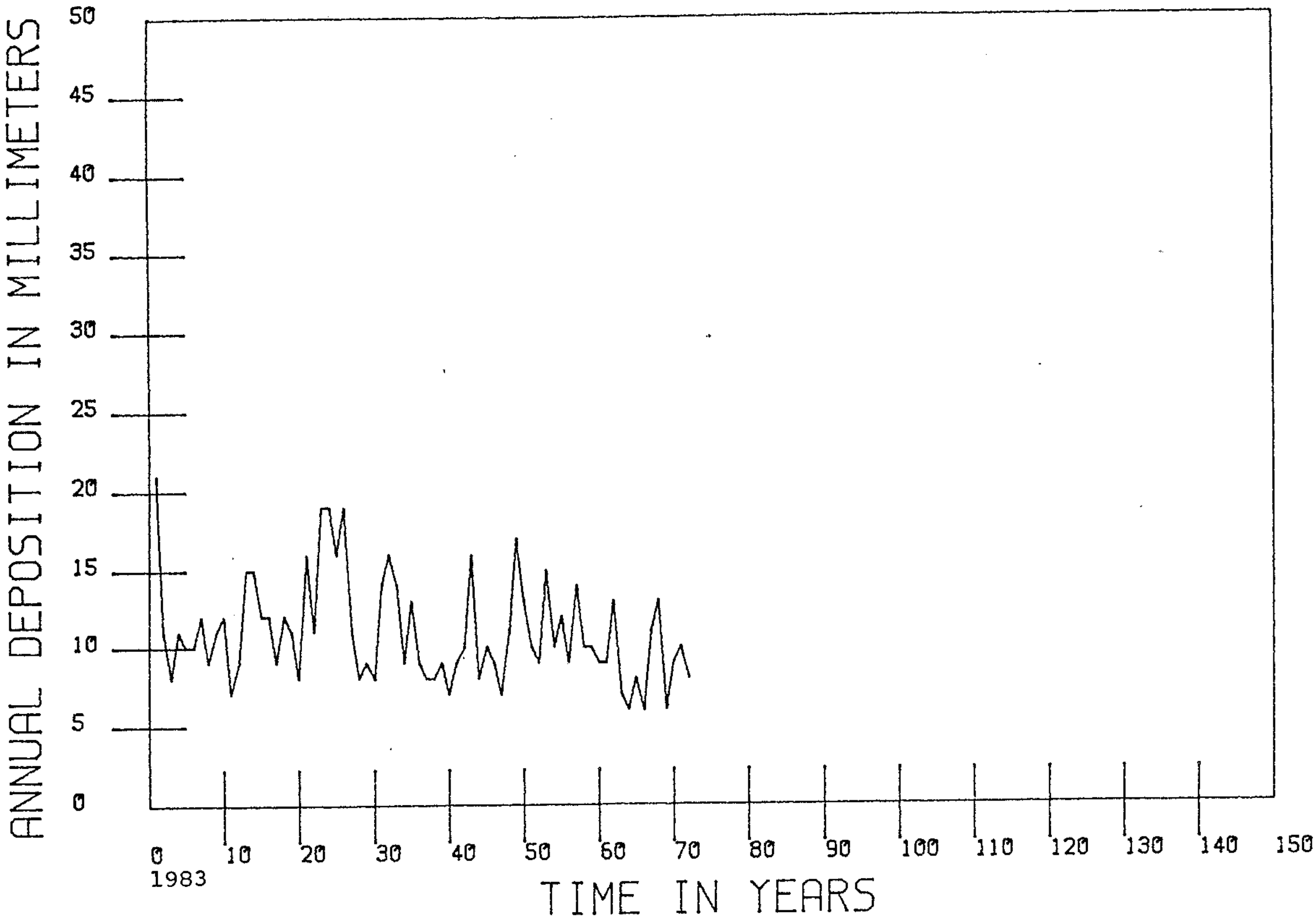
The nitrogen loading increased dramatically in the period from sixty-five years ago to about fifty years ago. From that point the load has been decreasing, either due to reduced loading or more probably to microbiological stripping. Over the last fifteen years the load has been cut in half. This corresponds to the drop in nitrogen in the sediments of Lake Sallie.

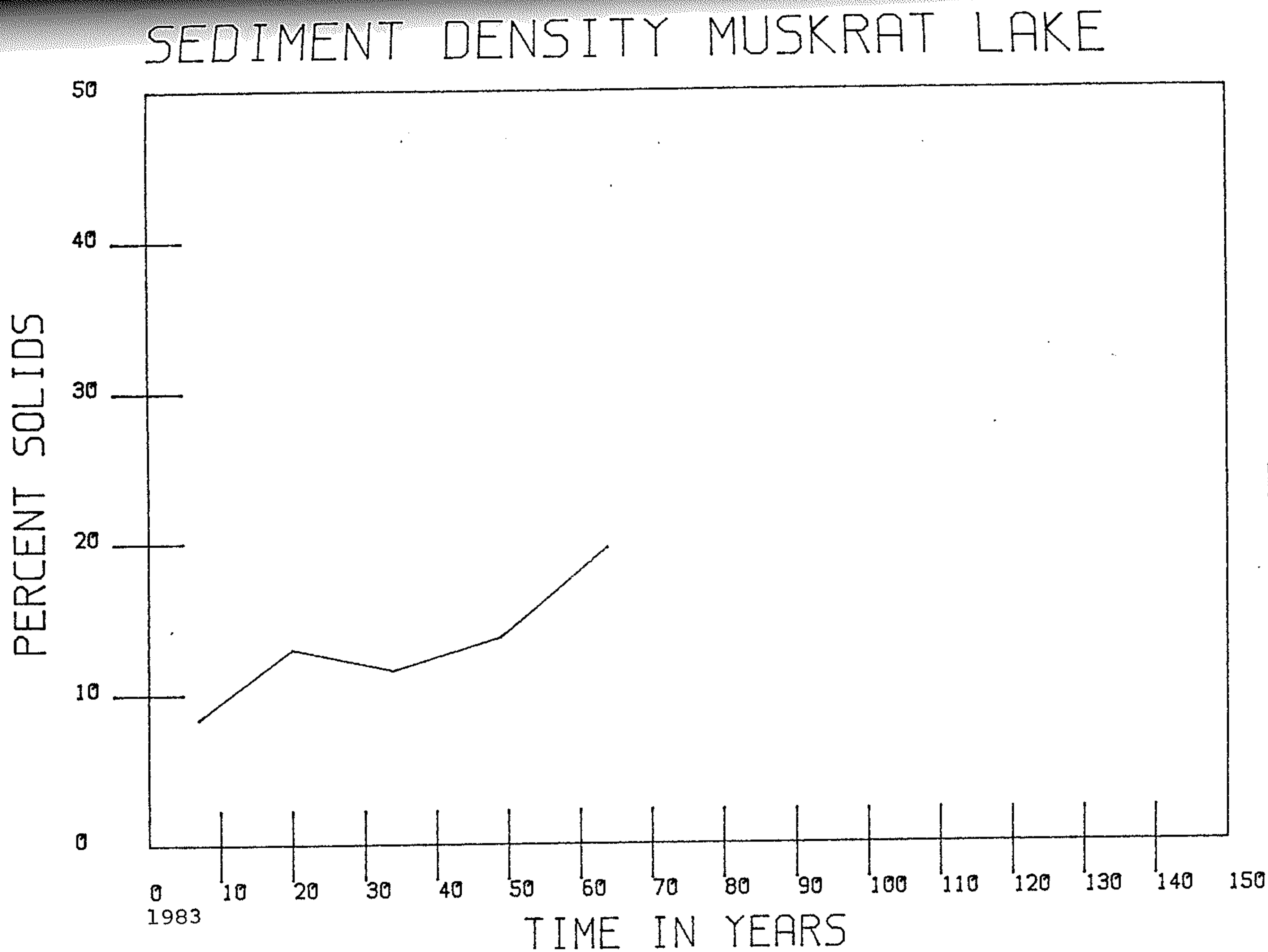
The phosphorus load went from a low fifty years ago through an oscillation to its present high of 0.9 of a gram per killogram of sediment. It is significant that the present phosphorus load in these sediments is more than twice the dry weight load in Lake St. Clair, and that the density of these sediments are more than two times that of lake St. Clair.

The phosphorus contained in the sediments of Muskrat Lake in the top four feet of sediment amounts to about 26,500 killograms and the nitrogen content is 107,000 killograms in 400,000 cubic yards of wet sediment. The dry sediment amounts to 56,000 cubic yards. This system could be bypassed with a temporary channel to circumvent the existing locks, and the lake bed then dried and scraped with conventional earth moving equipment for removal to a safe disposal site.

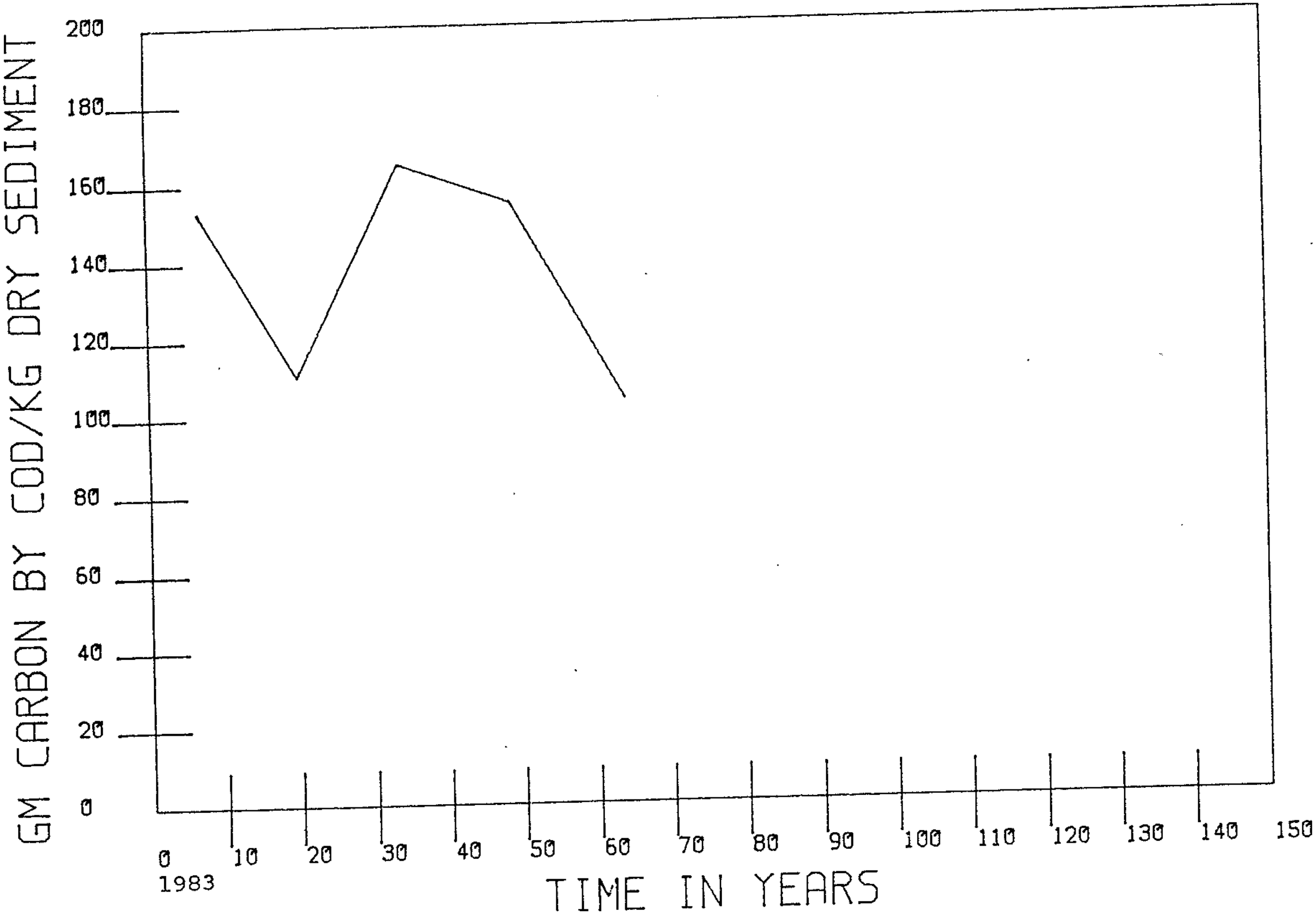
An alternative to dredging, or possibly a future nutrient trap in the watershed after dredging, would involve the installation of a duckweed growth and harvesting system. This would be used to remove the existing nutrients and trap the incoming load before it could reach Lake Sallie. The harvested material has a high potential sales value as a processed animal feed. We are currently working on a liscense agreement with a feed formulator for the rights to the process.

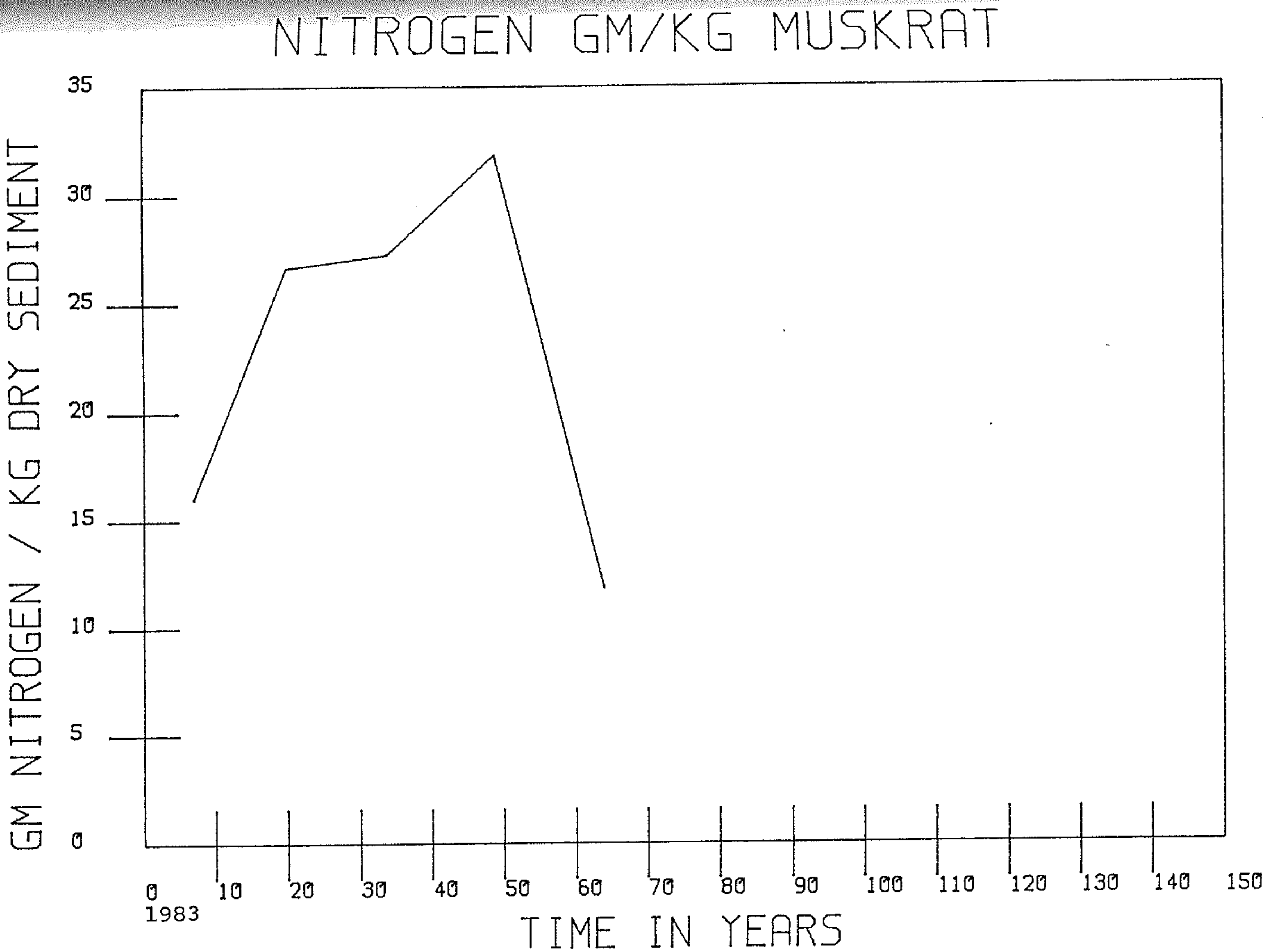
ANNUAL SEDIMENT BANDING MUSKRAT LAKE

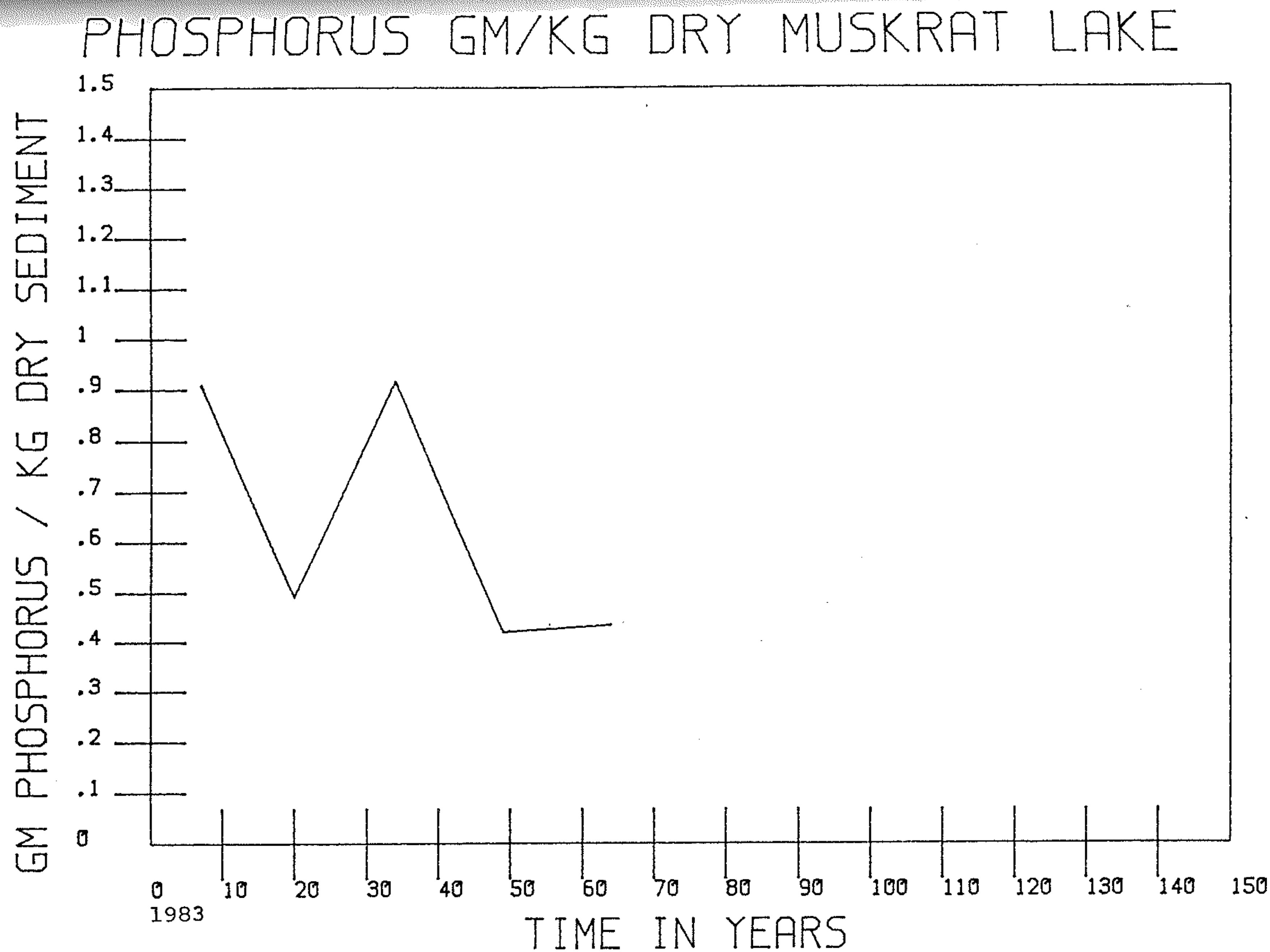



SEDIMENT DENSITY MUSKRAT LAKE
PERCENT SOLIDS
0
10
20
30
40
50
0
1983
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
TIME IN YEARS

CARBON GM/KG MUSKRAT LAKE




NITROGEN GM/KG MUSKRAT
GM NITROGEN / KG DRY SEDIMENT
0
5
10
15
20
25
30
35
0
1983
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
TIME IN YEARS


PHOSPHORUS GM/KG DRY MUSKRAT LAKE
GM PHOSPHORUS / KG DRY SEDIMENT
1.5
1.4
1.3
1.2
1.1
1
.9
.8
.7
.6
.5
.4
.3
.2
.1
0
0
1983
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
TIME IN YEARS