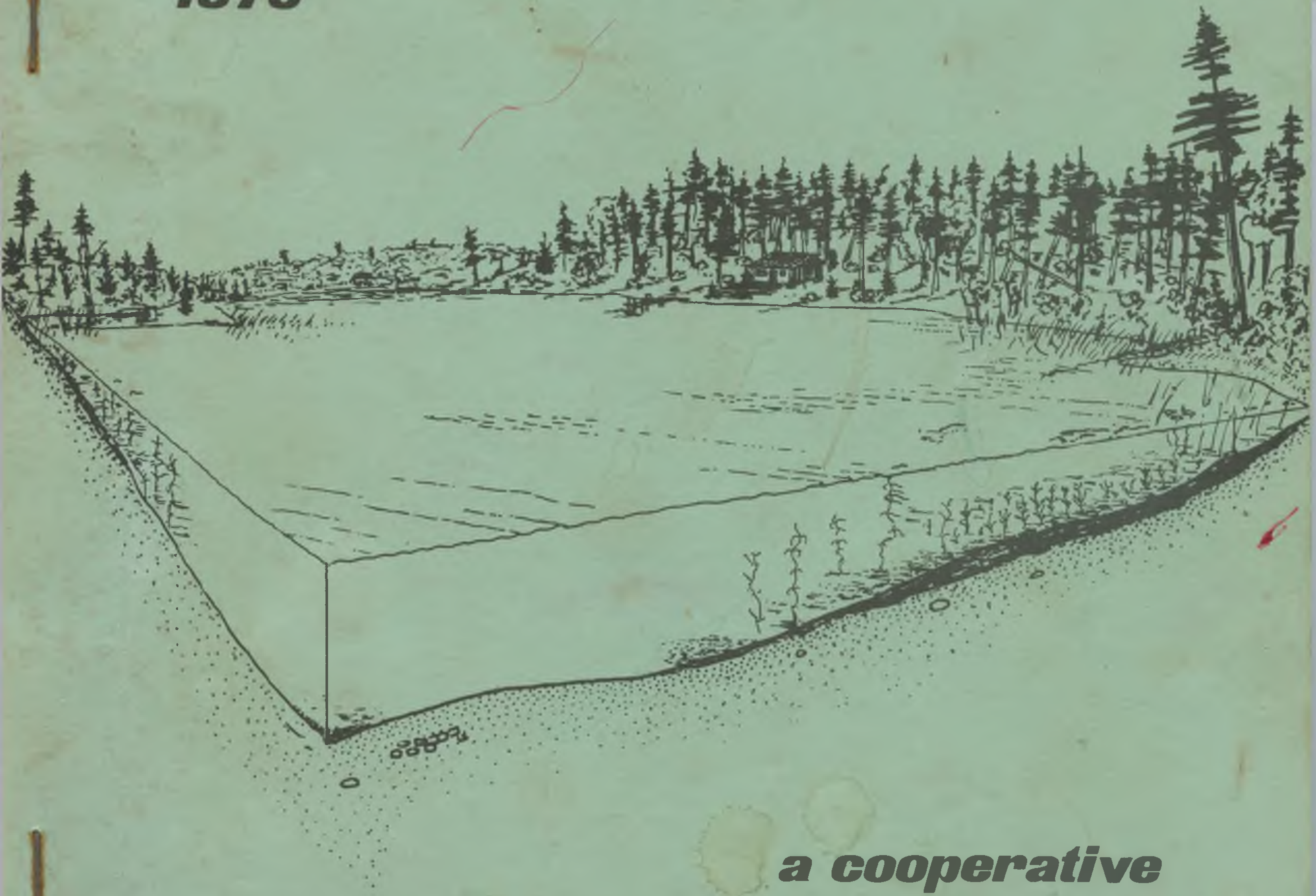
INLAND LAKE SELF-HELP PROGRAM

ANNUAL REPORT

1976



a cooperative
lake riparian -
michigan
department of natural resources
project

under direction

of

Inland Lake Management Unit

Land Resource Programs Division

Michigan

Department of Natural Resources

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CONCLUSIONS

During the summer of 1976 a cooperative water quality monitoring program was renewed between the Department of Natural Resources and lake citizens. Water clarity and chlorophyll a concentrations were determined weekly for lakes newly enrolled in the program and bi-weekly for lakes which had participated in the 1975 Self-Help Program. Surface area of the lakes ranged from 5 to 20,000 acres with 53 percent between 100-500 acres. Results of the program indicate that 11 percent would be classified oligotrophic; 70 percent mesotrophic and 19 percent eutrophic.

Water quality monitoring programs only reveal the consequences of eutrophication and not the ultimate causes. The causes of eutrophication originate on the watershed and the consequences are manifested in the lake. Annual nutrient inputs control the rate of eutrophication. Several methods of controlling non-point nutrient sources are discussed.

An attack on curtailing the nutrient sources both within the lake community and in upstream areas can be started at any time; the sooner, the better. The easiest place to begin is in familiar territory. A concentrated effort to reduce nutrient sources within the lake community can begin at any time and at any level; from voluntary action in curbing erosion or curtailing fertilizer use on lawns and gardens to strict government control over consumer products. The most effective way to start may be with you and your neighbors. Do you use high phosphate detergents in your home or fertilize your lawn? Burn leaves? Ignore servicing your septic tank? Under certain conditions one pound of phosphorus can produce 500 pounds of algae. Could you eliminate a pound or two from the sources outlined above?

The data gathered here through the Self-Help Program is a clear indication of how local citizens and state government can function together. This approach can be applied to lake protection as well as lake water quality monitoring programs.

TABLE OF CONTENTS

INTRODUCTION

To many people a lake is a place to temporarily escape the daily work routine and enjoy the recreational pursuits of swimming, fishing and boating. In an attempt to get closer to this recreational opportunity, people build homes and cottages adjacent to lakes. Over the years lake residents begin to notice a change in water quality, but they frequently do not understand exactly how and why.

Lake scientists call this change over time eutrophication. Eutrophication is a scientific term which describes the complex sequence of changes in lakes caused by an annual increased supply of plant nutrients. The initial lake response is an increase in the number and abundance of algae and aquatic plants. This starts a chain of events that gives rise to: 1) increased productivity at all levels of the food chain, up to and including fish; 2) successional changes in the types of organisms which inhabit the aquatic ecosystem; 3) and reduced levels of dissolved oxygen in the bottom waters of deep lakes. Consequently, the recreational value of the lakes is changed; it is often reduced. Swimming and boating are hampered by the large unsightly accumulations of living and dead aquatic plants. The shoreline and bottom of the lakes are filled with silty sediment, which is aesthetically unpleasant and ultimately destroys the spawning areas for many game fish and the habitat for many bottom-dwelling invertebrates.

Although the early stages of eutrophication are beneficial for fish production and fishing, the late stages result in poor fishing with few large fish and many small, undersized fish. Citizens and lake associations seeing the results of eutrophication are concerned about the water quality in their individual lakes. They are interested in maintaining good water quality and/or restoring lakes with poor water quality. But data are presently not available to develop a sound management program for each lake. Before steps are taken to improve and/or preserve the existing water quality conditions, it is necessary to determine the existing conditions. Progress can then be measured from this reference point.

As one of several initial steps taken toward a statewide inland lake management program, a cooperative eutrophication "warning" system was established in the spring of 1974 by the Inland Lake Management Unit - Michigan Department of Natural Resources; its purpose: to assess the trophic status (degree of eutrophication) of Michigan's recreational lakes. It utilizes citizens as active participants in conjunction with the State's lake scientists. Because of the citizen involvement, it goes by the name "Inland Lake Self-Help Program".

The basic purpose of this program is to obtain annual base line trophic level data on Michigan's inland lakes. With an annual lake monitoring program, changes over time can be noted. For example, one could know what the water quality was like several years ago, what it is now, and how much it has changed; and then estimate what it most likely will be five years from now. Thus, as changes (rapid or gradual) occur, the causative agents can be isolated and corrective action recommended, when possible, by lake scientists. In this manner lake associations will be able to see and measure the results of their lake management efforts.

RATIONALE AND METHODS

The program revolves around a central theme --- that is, the annual amount of nutrients (phosphorus and nitrogen) reaching a lake is responsible for the rate of eutrophication. These nutrients act as fertilizers and are responsible for an increase in the quantity of algae and aquatic plants in the water. In general, as the annual quantity of nutrients entering the lake increases, there usually follows a corresponding increase in the amount of algae and a decrease in the transparency of the water. The Self-Help Program monitors the "size" of the algae population by determining the chlorophyll a concentration and water transparency.

Chlorophyll a is used to measure algal biomass present for photosynthesis and growth. It is one of a number of green pigments in all plants, and is found in the leaves of higher aquatic plants and in the cells of algae. Chlorophyll is necessary to convert the energy of the sun into chemical energy in the form of carbohydrates, fats and proteins. This process is termed photosynthesis. There are five recognized chlorophylls; a, b, c, d, and e. Only chlorophyll a is common to all aquatic algal groups, hence it is useful in estimating algal abundance. Although there are some limitations to the use of chlorophyll a as a measure of algal standing crop, it is still a reasonable estimate for this type of program.

Water transparency measurements are used to determine the depth of light penetration. This is a relatively simple measurement requiring only the use of a round black and white 8-inch disc (Secchi) connected to a graduated line (Appendix 1, Figure 1). The relationship between Secchi transparency and algal densities is demonstrated in Figure 1.

The necessary equipment for this sampling program (Secchi disc, calibrated line, sample bucket) was constructed by association personnel following plans provided by the Division of Land Resource Programs (Appendix 1, Figures 1 and 2). The Secchi disc was used to measure transparency (clarity). Twice the depth of the Secchi disc measurement designates the euphotic zone; this is the zone that contains sufficient light for plant growth (Appendix 1, Figure 3). Composite water samples were collected from the euphotic zone, preserved with 3 - 4 drops of a supersaturated solution of magnesium carbonate, and mailed to the Department of Natural Resources Laboratory in Lansing, Michigan.

Data on water clarity and chlorophyll a were obtained weekly/biweekly between 10:00 a.m. and 2:00 p.m. from May through September by an individual appointed by the lake association. Transparency measurements and water samples were collected from the open water zone over the deepest part(s) of the lake on either Sunday or Monday. Samples taken on Monday were mailed the same day, while samples collected on Sunday were refrigerated and mailed to the laboratory on Monday.

Transparency was measured weekly in all lakes, but chlorophyll was measured at various time intervals. Chlorophyll samples were generally collected biweekly in the lakes that had participated in the 1975 program and weekly in the lakes that were "new" to the program. In addition, eight lakes in the program measured only transparency throughout the summer. This was due to the laboratory placing constraints on the number of samples that could be processed weekly.

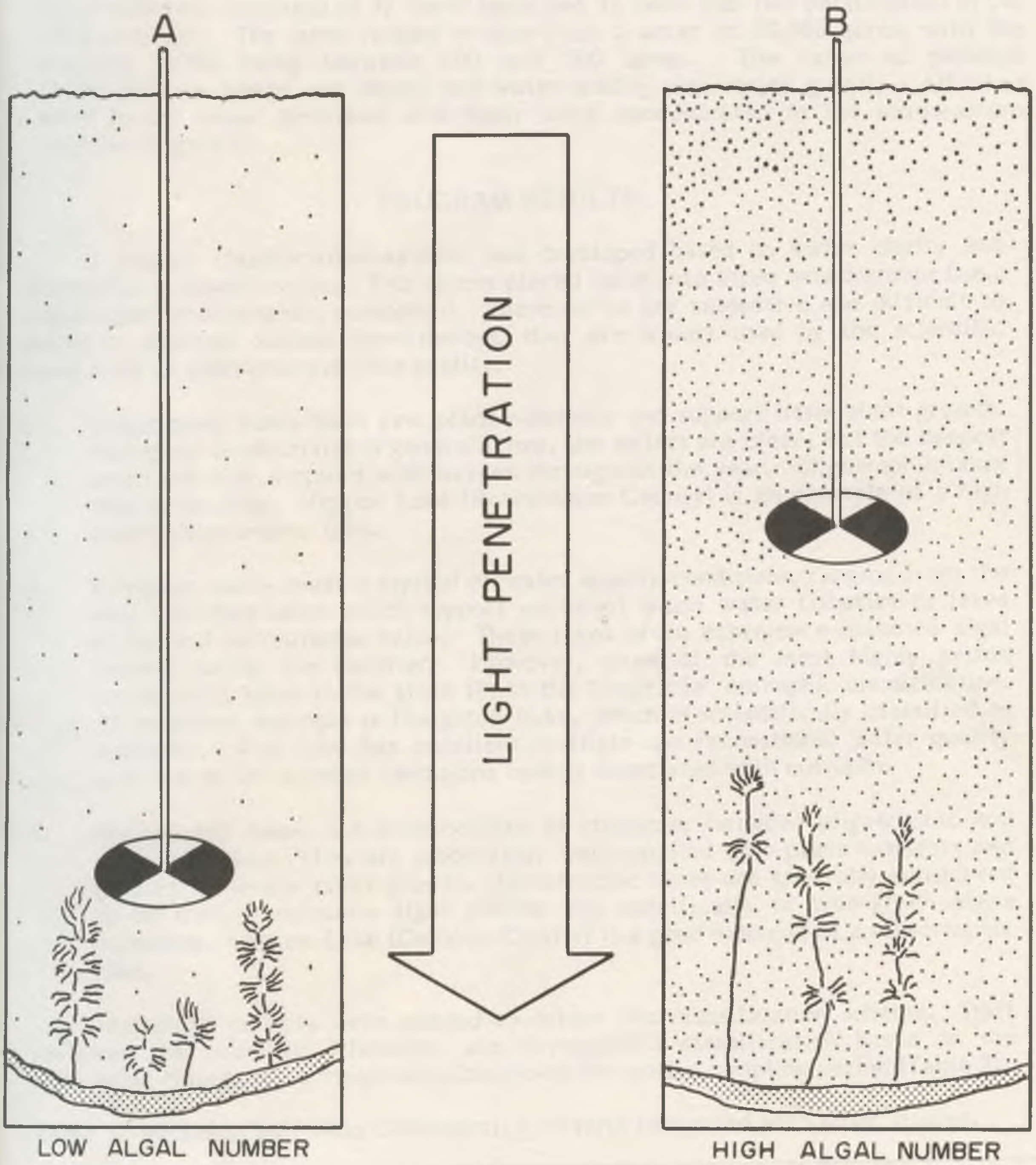


Figure 1

Diagram Illustrating the Use of a Secchi Disc to Measure Water Clarity. Clarity Decreases as Algal Densities Increase.

Eighty-nine lakes (95 basins) were enrolled in the 1976 program (Table 1). The enrollment consisted of 37 "new" lakes and 52 lakes that had participated in the 1975 program. The lakes ranged in size from 5 acres to 20,000 acres, with the majority (53%) being between 100 and 500 acres. The range of physical characteristics (shape and depth) and water quality also varied greatly. All lakes were in the lower peninsula and many were concentrated in the southeastern counties (Figure 2).

PROGRAM RESULTS

A trophic classification system was developed based on water clarity and chlorophyll a concentration. This sytem placed lakes into three broad groups (i.e., oligotrophic, mesotrophic, eutrophic). These terms are subjective and difficult to define in absolute values; nevertheless, they are widely used by the scientific community as descriptors of lake quality.

1. Oligotrophic lakes have few plant nutrients and support little plant growth. Biological productivity is generally low, the waters are clear, and the deepest zones are well supplied with oxygen throughout the year. Oligotrophic lakes tend to be deep. Higgins Lake (Roscommon County) is an example of a high quality oligotrophic lake.

2. Eutrophic lakes cover a myriad of water quality conditions, ranging from the very desirable lakes which support excellent warm water fisheries to lakes of limited recreational value. These lakes often experience nuisance algal blooms during the summer. However, some of the most highly prized recreational lakes in the state fit in the "desirable" eutrophic classification. An excellent example is Houghton Lake, which is scientifically classified as eutrophic. This lake has excellent multiple use recreational water quality with few of the adverse conditions usually associated with eutrophy.

3. Mesotrophic lakes are intermediate in character between oligotrophic and eutrophic lakes. They are moderately well supplied with plant nutrients and support moderate plant growth. Mesotrophic lakes are generally considered to be free of nuisance algal blooms and specifically of blue-green algae nuisances. Goguac Lake (Calhoun County) is a good example of a mesotrophic lake.

Numerical criteria were needed to define this classification scheme. Staff reviewed the scientific literature and developed a classification based on the arithmetic chlorophyll a mean calculated over the entire sampling period (Table 2).

Table 2. Michigan Self-Help Chlorophyll a criteria compared with other studies.

	Chlorophyll a (ug/l) - ppb					
Trophic Conditions	Michigan Self-Help Survey	National Academy of Science[2]	Sakamota[3]	Dobson[4]	National Eutro. Survey[5]	Ministry of the Envir.[1]
Oligotrophic	0-4	0-4	0.3-2.5	0-4.3	< 7	0-3
Mesotrophic	4-10	4-10	2.5-15	4.3-8.8	7-12	3-5
Eutrophic	> 10	>10	15-40	> 8.8	> 12	> 5

Table 1. (cont.)

Lake Name	County	Area (Acres)	Depth (ft.)	Range
Cedar	Livingston	117	26	
Coon	Livingston	106	42	
Long	Livingston	146	75*	
Commerce	Oakland	262	66	
Elizabeth	Oakland	363	72	
Indianwood	Oakland	122	60*	
Lakeville	Oakland	460	66	
Long (Upper)	Oakland	110	22*	
Sylvan	Oakland	458	120*	
Voorheis	Oakland	182	70	
Watkins	Oakland	238	30*	
Williams	Oakland	155	45	
Wing	Oakland	108	20*	
Wolverine	Oakland	241	57	
Tee	Oscoda	216	70	
Opal	Otsego	122	39	
Clear	St. Joseph	240	31	
Great Bear	Van Buren	150	54	
Cedar	Van Buren	269	84	
Mill	Van Buren	100	80	
Saddle	Van Buren	298	32	
Independence	Washtenaw	192	34	
North	Washtenaw	227	58	
Pleasant	Washtenaw	202	36	
Elk	Antrim (Gd. Traverse)	7730	192	>500 Acres
Intermediate	Antrim	1520	82	
Torch	Antrim	18,770	285	
Crystal	Benzie	9711	160	
Margrethe	Crawford	1920	60	
Silver	Gd. Traverse	600	96	
Skegemog	Gd. Traverse (Kalkaska)	2561	29	
Columbia	Jackson	880	30	
Long	Kalamazoo	575	57	
Portage	Livingston (Washtenaw)	644	64	
Bass	Mason	524	13	
Fremont	Newaygo	790	88	
Cass	Oakland	1280	117	
Orchard	Oakland	788	115	
White	Oakland	540	32	
Ogemaw	Ogemaw	550*	28*	
Otsego	Otsego	1972	23	
Higgins	Roscommon	9600	135	
Houghton	Roscommon	20,044	21	
Corey	St. Joseph	630	80	
Ford	Washtenaw	975	30	

* Based on data provided by lake association.

FIGURE 2

Inland Lakes in the Self-Help Water Quality Monitoring Program (1976)

Figure 3 depicts the mean chlorophyll a values for the 81 lakes (87 basins) sampled in 1976. The lakes are ranked in order of increasing chlorophyll a concentration. Based upon criteria established in Table 2, sixty percent (60%) of the basins were oligotrophic; thirty percent (30%) were mesotrophic; and ten percent (10%) were eutrophic. This can be checked by comparing the measured value for each lake in Figure 3 and Table 3 with the classification criteria listed in Table 2. This relative placement represents the trophic status as measured by chlorophyll a and does not take into account the growth of higher aquatic plants in the lakes.

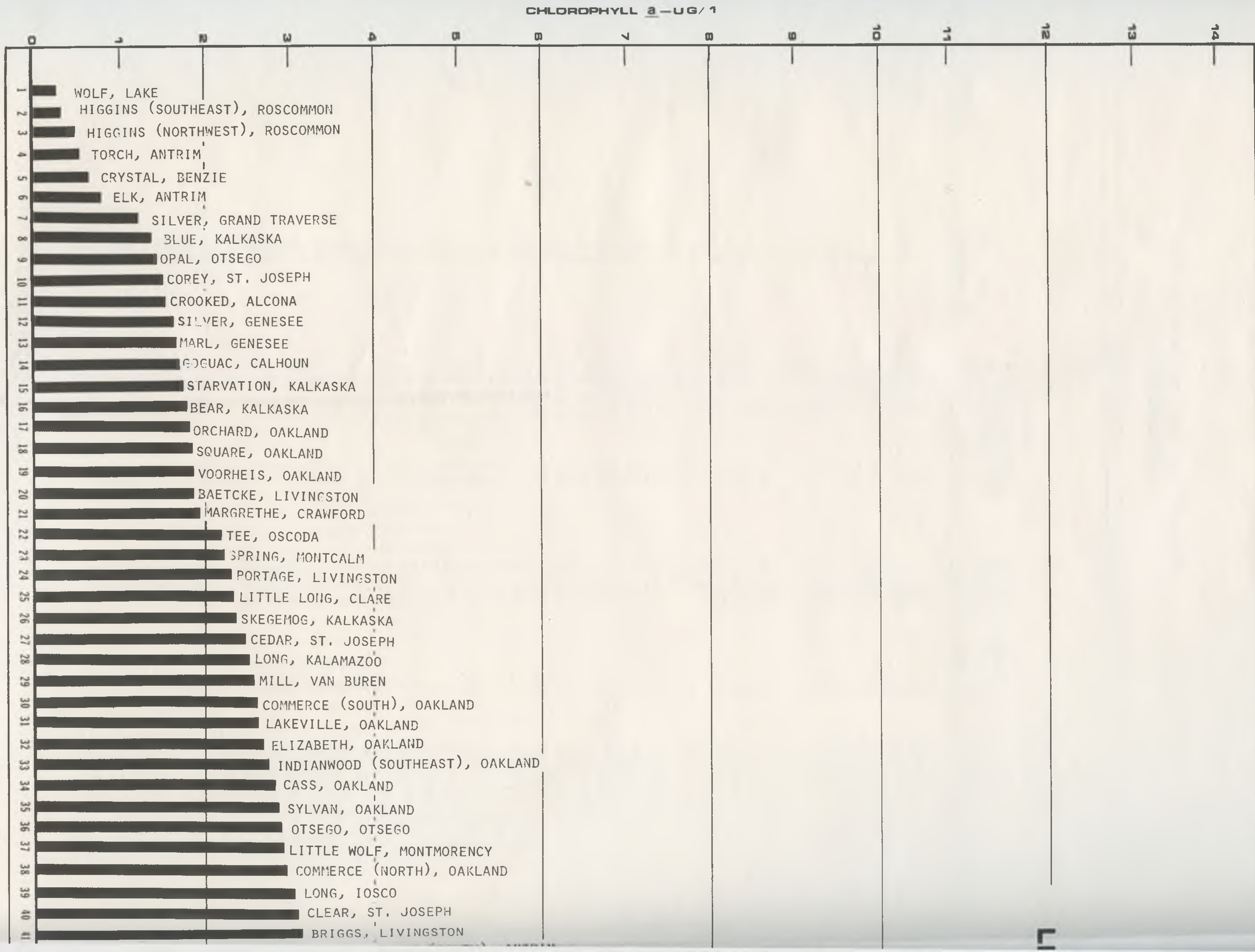
The average Secchi disc values, determined in conjunction with the weekly chlorophyll concentrations, are presented in Figure 4. Differences in depth of light penetration into the lakes were noted. Using the criteria presented in Table 4, eleven percent (11%) of the basins were oligotrophic, seventy-three percent (73%) were mesotrophic and seventeen percent (17%) were eutrophic.

Table 4. Self-Help Secchi disc criteria compared with other studies.

	Transparency (feet)			
Trophic Condition	Michigan Self-Help Study	Dobson[4]	National Eutrophication Survey[5]	Ministry of the Environment[1]
Oligotrophic	> 15	>20	>12	> 16.5
Mesotrophic	6.5-15	10-20	6.5-12	10-16.5
Eutrophic	< 6.5	<10	< 6.5	< 10

The tropic classification system designed for the Self-Help Program placed a lake in the most productive category established through the measurements of chlorophyll a and Secchi disc transparency. Thus, a lake which had a mean chlorophyll a concentration considered to be mesotrophic and a mean Secchi transparency considered to be eutrophic, was classified as a eutrophic lake (Table 3). In this way the results of the 1976 Self-Help Program indicate that 11 percent (11%) of the lakes were oligotrophic, 70 percent (70%) were mesotrophic and 19 percent (19%) were eutrophic.

Figure 5 depicts the relationship of water transparency (Secchi disc) and quantity of chlorophyll a in the lakes. Calarity of the water is directly affected by the amount of chlorophyll a, so it is plotted on the vertical axis and chlorophyll a on the horizontal axis. The data points describe a hyperbolic relationship between the two parameters. This simply means that a uniform or constant change in the concentration of chlorophyll a along the horizontal axis does not produce a constant change in water clarity along the vertical axis. For example, a 2 ug/l increase in chlorophyll a from 2 to 4 ug/l produced a change of 1.5 feet in water clarity, while a 2 ug/l increase from 6 to 8 ug/l produced a change of less than one foot in transparency. There is no significant change in transparency when the amount of chlorophyll a is 20 ug/l or more. Thus, the slope (rate of change) of the line shows a decreasing change in transparency with increased chlorophyll a concentrations.



FIGU

INCREASING CHLOROP

EIGHTY-ONE MICHIGAN LAKES [87 BASINS] IN 1976 SELF HELP MONITORING

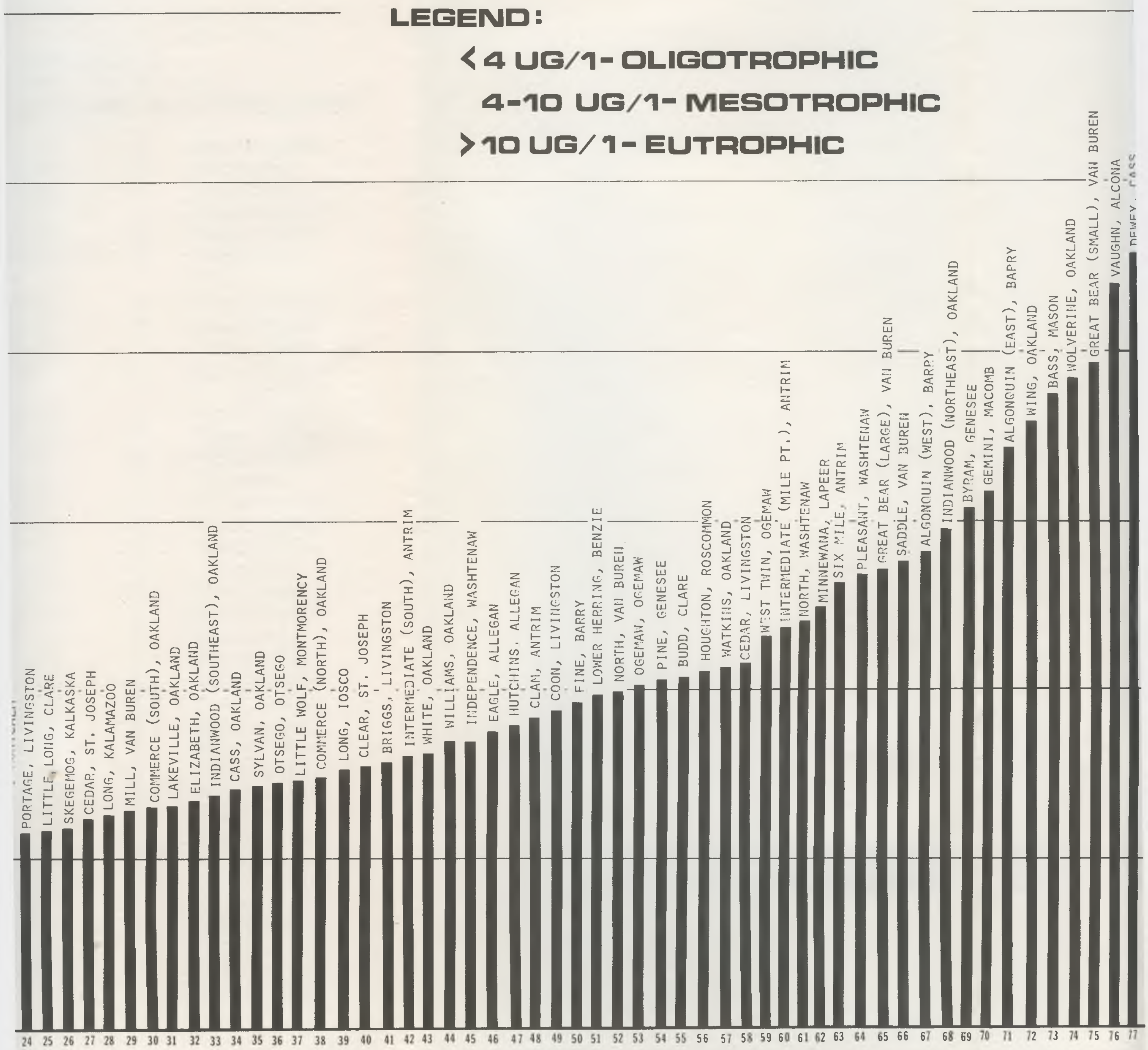


FIGURE 3

] IN 1976 SELF HELP MONITORING PROGRAM RANKED ON BASIS OF INCREASING SUMMER CHLOROPHYLL

Table 3. Self-Help Water Quality Program
1976 Results

Lake Name, County	No. on Figure 5	Secchi Transparency Mean (ft.)	No. of Samples	Chlorophyll a Mean (ug/l)	No. of Samples	Trophic Status[a]
Crooked, Alcona	1	11.12	8	1.62	5	Mesotrophic
Vaughn, Alcona	2	6.00	17	8.96	9	Eutrophic
Eagle, Allegan	3	11.47	17	3.53	17	Mesotrophic
Hutchins, Allegan	4	7.11	19	3.57	6	Mesotrophic
Clam, Antrim	5	7.63	11	3.67	11	Mesotrophic
Elk, Antrim	6	12.93	16	0.72	9	Mesotrophic
Intermediate, Antrim						
Mile Point	7	13.96	16	4.80	8	Mesotrophic
South	8	10.75	16	3.18	8	Mesotrophic
Six Mile, Antrim	9	7.00	8	5.30	7	Mesotrophic
Torch, Antrim	10	16.87	11	0.57	11	Oligotrophic
Algonquin, Barry						
East	11	10.31	16	6.81	16	Mesotrophic
West	12	12.15	16	5.85	16	Mesotrophic
Fine, Barry	13	10.07	20	3.89	20	Mesotrophic
Jordan, Barry	14	3.87	8	19.08	8	Eutrophic
Crystal, Benzie	15	18.65	19	0.65	19	Oligotrophic
Herring (Lower), Benzie	16	8.58	18	3.92	18	Mesotrophic
Goguac, Calhoun	17	12.28	19	1.80	10	Mesotrophic
Dewey, Cass	18	5.44	18	8.97	18	Eutrophic
Budd, Clare	19	11.63	18	4.19	18	Mesotrophic
Long (Little), Clare	20	14.16	12	2.34	7	Mesotrophic
Victoria, Clinton	21	5.57	7	10.14	7	Eutrophic
Margrethe, Crawford	22	13.65	13	2.14	7	Mesotrophic
Byram, Genesee	23	13.61	13	6.10	13	Mesotrophic
Marl, Genesee	24	8.50	4	1.77	4	Mesotrophic
Pine, Genesee	25	8.50	16	4.15	9	Mesotrophic
Silver, Genesee	26	8.37	4	1.72	4	Mesotrophic
Silver, Grand Traverse	27	27.84	19	1.29	11	Oligotrophic
Long, Iosco	28	8.80	21	3.08	11	Mesotrophic
Columbia, Jackson	29	5.69	17	20.15	17	Eutrophic
Mud, Jackson	-	7.52	17	-	-	Mesotrophic
Barton, Kalamazoo	30	3.46	16	38.00	16	Eutrophic
Long, Kalamazoo	31	11.28	19	2.49	19	Mesotrophic
Bear, Kalkaska	32	23.94	19	1.87	6	Oligotrophic
Blue, Kalkaska	33	12.66	5	1.56	4	Mesotrophic
Skegemog, Kalkaska	34	7.92	14	2.40	8	Mesotrophic
Starvation, Kalkaska	35	26.35	17	1.85	8	Oligotrophic
Banks, Kent	-	10.58	12	-	-	Mesotrophic

Table 3. (cont.)

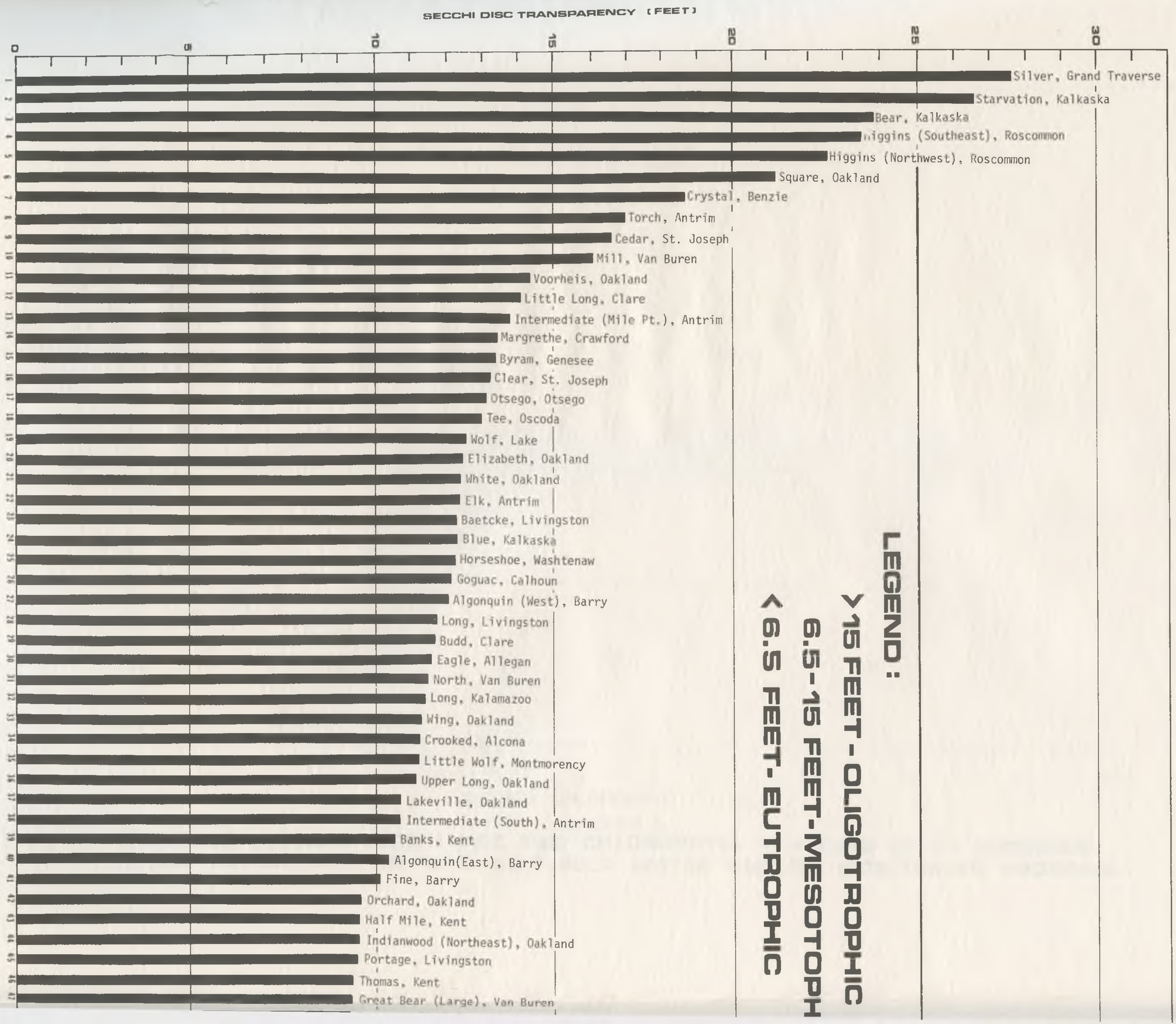
Lake Name, County	No. on Figure 5	Transparency Mean (ft.)	Transparency No. of Samples	Chlorophyll a Mean (ug/l)	Chlorophyll a No. of Samples	Trophic Status[a]
Half Mile, Kent	-	9.79	12	-	-	Mesotrophic
Horseshoe, Kent	-	7.51	34	-	-	Mesotrophic
Thomas, Kent	-	9.58	12	-	-	Mesotrophic
Woodbeck, Kent	-	7.40	34	-	-	Mesotrophic
Wolf, Lake	36	13.16	21	0.39	11	Oligotrophic[b]
Minnewana, Lapeer	37	7.42	20	5.11	19	Mesotrophic
Baetcke, Livingston	38	12.70	5	1.95	5	Mesotrophic
Briggs, Livingston	39	6.07	21	3.16	11	Eutrophic
Cedar, Livingston	40	6.77	12	4.38	12	Mesotrophic
Coon, Livingston	41	9.05	18	3.75	8	Mesotrophic
Long, Livingston	-	11.77	18	-	-	Mesotrophic
Portage, Livingston	42	9.67	17	2.31	16	Mesotrophic
Round, Livingston	-	8.15	19	-	-	Mesotrophic
Gemini, Macomb	43	5.17	17	6.23	8	Eutrophic
Bass, Mason	44	6.20	10	7.54	10	Eutrophic
Spring, Montcalm	45	8.65	17	2.30	17	Mesotrophic
Wolf (Little), Montmorency	46	11.10	19	2.97	11	Mesotrophic
Fremont, Newaygo	47	4.67	17	13.61	8	Eutrophic
Cass, Oakland	48	8.44	19	2.78	9	Mesotrophic
Commerce, Oakland						
North	49	9.48	7	3.04	7	Mesotrophic
South	50	9.51	7	2.62	7	Mesotrophic
Crescent, Oakland	51	2.95	12	19.48	6	Eutrophic
Elizabeth, Oakland	52	13.11	18	2.67	15	Mesotrophic
Indianwood, Oakland						
Northeast	53	9.75	18	5.93	18	Mesotrophic
Southeast	54	9.04	11	2.75	11	Mesotrophic
Lakeville, Oakland	55	10.76	19	2.63	18	Mesotrophic
Long (Upper), Oakland	56	11.02	10	9.49	10	Mesotrophic
Orchard, Oakland	57	9.80	15	1.89	9	Mesotrophic
Sears, Oakland	58	6.52	20	15.32	10	Eutrophic
Square, Oakland	59	21.15	20	1.89	10	Oligotrophic
Sylvan, Oakland	60	7.66	9	2.94	9	Mesotrophic
Voorheis, Oakland	61	14.25	10	1.89	10	Mesotrophic
Watkins, Oakland	62	8.42	10	4.33	10	Mesotrophic
White, Oakland	63	13.03	16	3.34	15	Mesotrophic
Williams, Oakland	64	6.50	20	3.40	11	Mesotrophic
Wing, Oakland	65	11.15	20	7.13	10	Mesotrophic
Wolverine, Oakland	66	7.66	6	7.56	6	Mesotrophic
Ogemaw, Ogemaw	67	9.22	18	4.08	11	Mesotrophic
Twin (West), Ogemaw	68	8.62	16	4.73	16	Mesotrophic
Tee, Oscoda	69	13.45	11	2.20	11	Mesotrophic

Table 3. (cont.)

Lake Name, County	No. on Figure 5	Secchi Transparency Mean (ft.)	Secchi Transparency No. of Samples	Chlorophyll a Mean (ug/l)	Chlorophyll a No. of Samples	Trophic Status
Opal, Otsego	70	8.21	18	1.59	18	Mesotrophic
Otsego, Otsego	71	13.50	14	2.96	12	Mesotrophic
Higgins, Roscommon						
Northwest	72	22.65	15	0.52	9	Oligotrophic
Southeast	73	23.64	14	0.44	8	Oligotrophic
Houghton, Roscommon	74	4.77	9	4.20	9	Eutrophic
Clear, St. Joseph	75	13.56	16	3.11	16	Mesotrophic
Corey, St. Joseph	76	12.40	16	1.61	7	Mesotrophic
Cedar, St. Joseph	77	16.67	17	2.45	16	Oligotrophic
Great Bear, Van Buren						
Large	78	9.56	8	5.37	8	Mesotrophic
Small	79	9.21	7	7.72	7	Mesotrophic
Mill, Van Buren	80	15.92	18	2.58	10	Oligotrophic
North, Van Buren	81	11.47	17	3.98	15	Mesotrophic
Saddle, Van Buren	82	7.69	11	5.58	10	Mesotrophic
Ford, Washtenaw	83	3.95	11	24.74	11	Eutrophic
Horseshoe, Washtenaw	84	5.14	14	11.03	8	Eutrophic
Independence, Washtenaw	85	6.26	14	3.50	5	Eutrophic
North, Washtenaw	86	8.39	19	4.92	19	Mesotrophic
Pleasant, Washtenaw	87	5.96	18	5.34	9	Eutrophic

[a] Lakes are placed in the most productive trophic status indicated by either Secchi transparency or chlorophyll *a*

[b] Classified using chlorophyll *a* value only because transparency was to the bottom ($\approx$ 13 feet) throughout the sampling season.



EIGHTY-NINE MICHIGAN LAKES [95 BASINS] IN 1976 SELF HELP MONITORING

DECREASING SECCHI DISC

FIGU

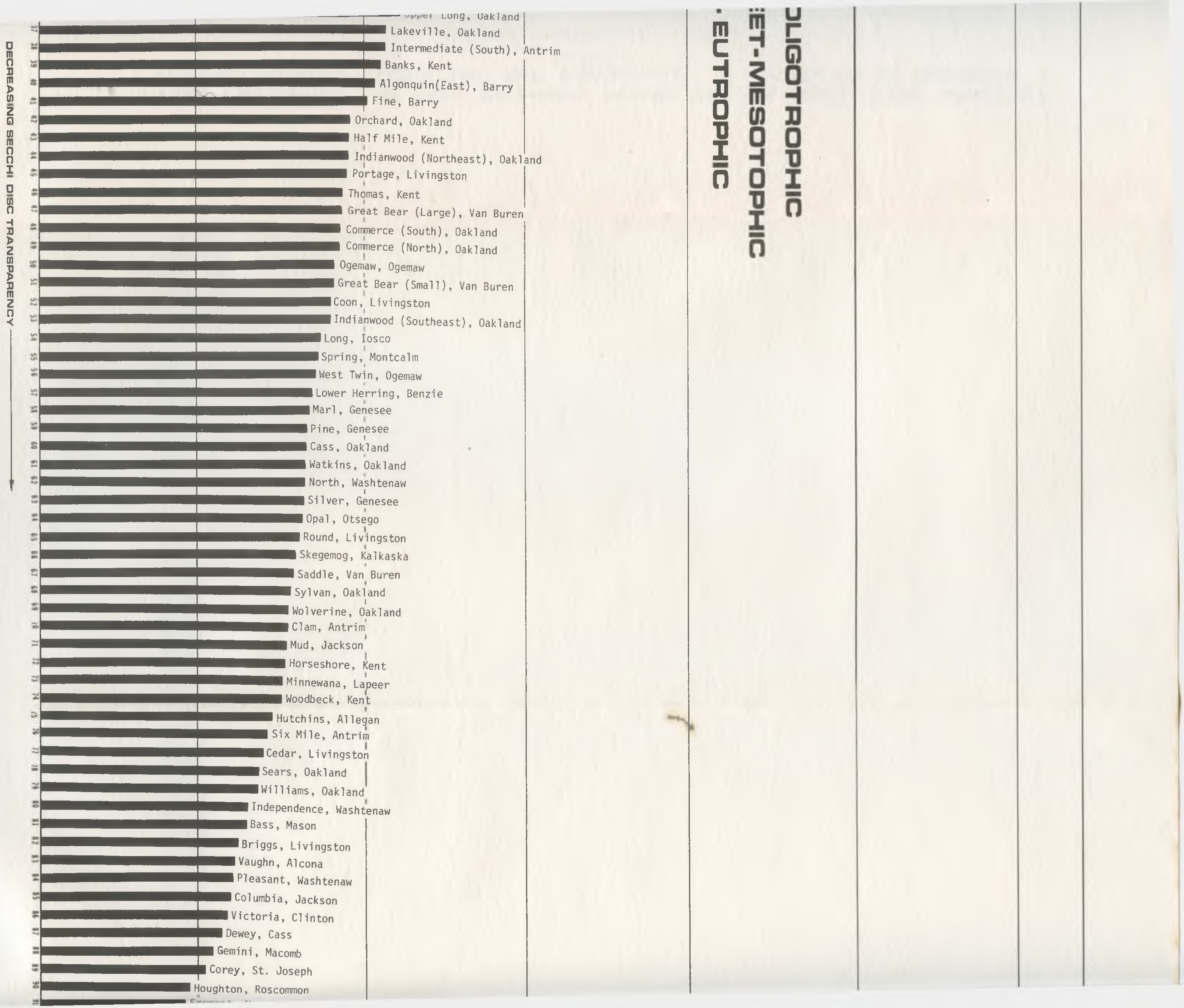


FIGURE 4

F HELP MONITORING PROGRAM RANKED ON BASIS OF DECREASING SECCHI DISC TRANSPARENCY

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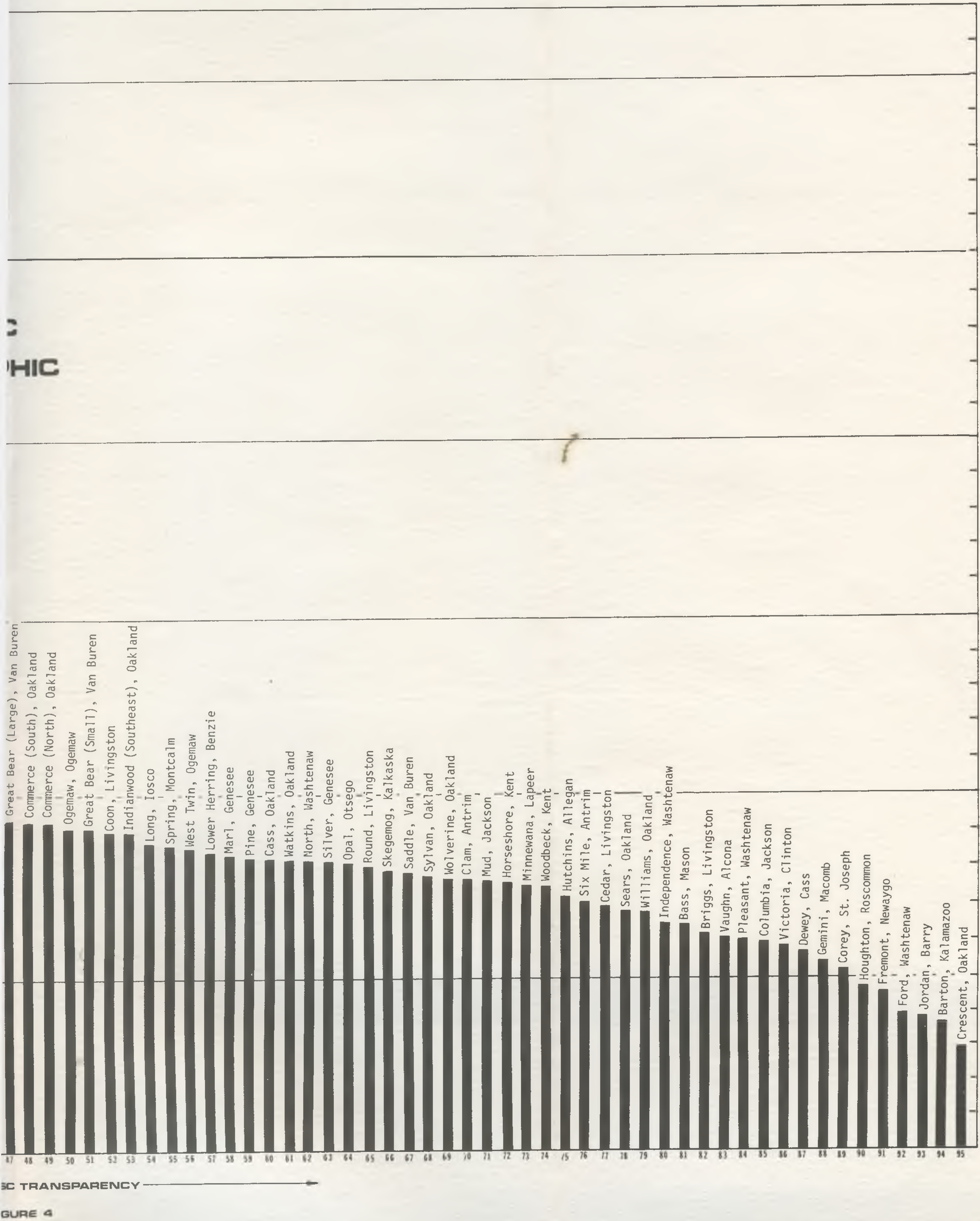

SC TRANSPARENCY →

GURE 4

IG PROGRAM RANKED ON BASIS OF DECREASING SECCHI DISC TRANSPARENCY

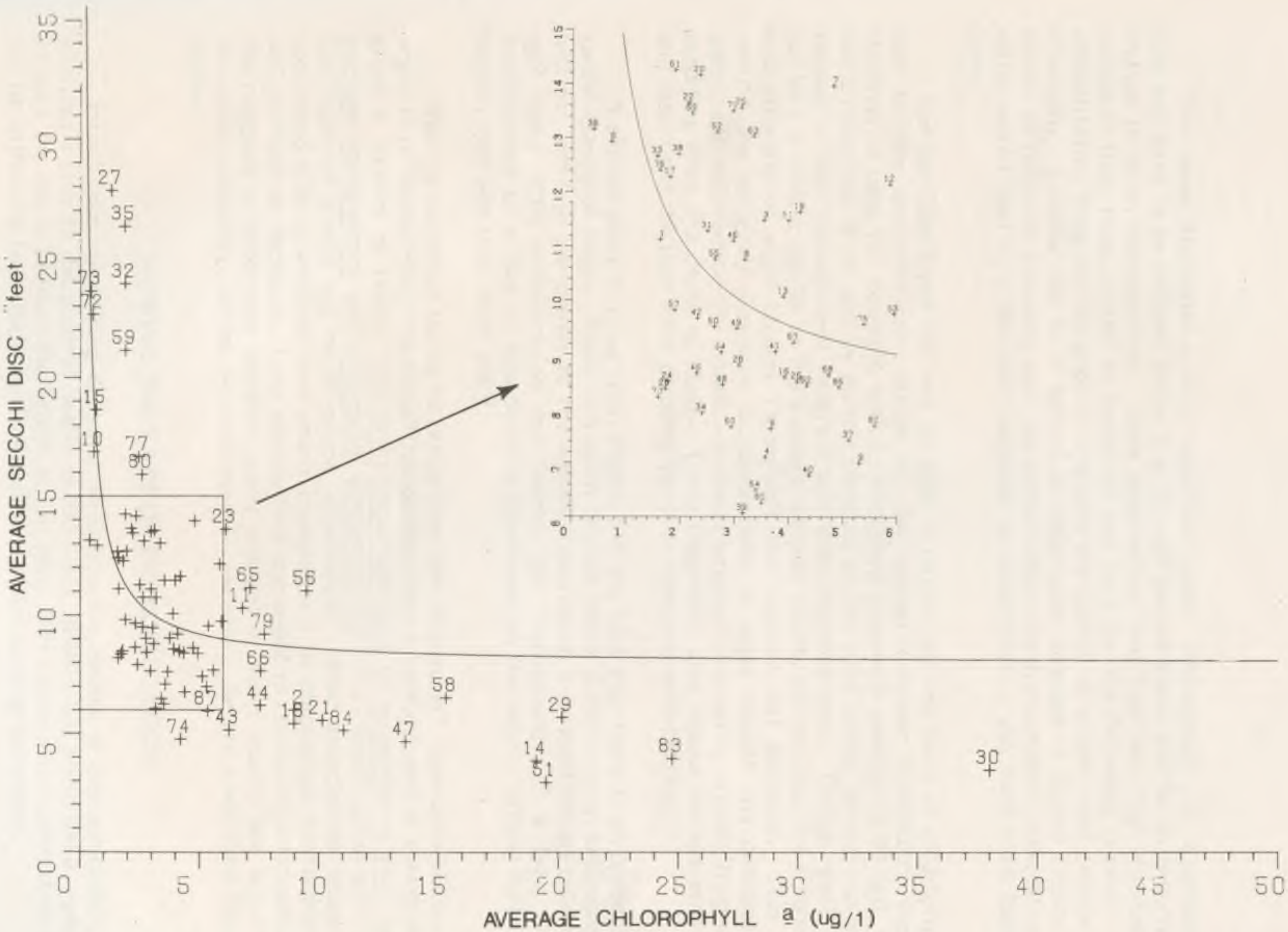

FIGURE 5

AVERAGE SUMMER SECCHI DISC AND CHLOROPHYLL a VALUES OF 81 MICHIGAN LAKES (87 BASINS) IN 1976 SELF-HELP WATER QUALITY MONITORING PROGRAM.

The curve illustrates a very important point. Chlorophyll a in a particular lake will have to be reduced below 8 to 10 ug/l before there will be an observable change in water transparency. Lake associations that find very high chlorophyll values in their lakes should be aware of this fact for the following reason. Any rehabilitation program designed to improve the clarity of a lake must reduce the chlorophyll a below this level before an observable increase in clarity occurs. It should be realized, however, that the actual reduction in chlorophyll concentration which would lead to a dramatic increase in water clarity will vary from lake to lake.

Certain lake types will not be able to obtain this low level of chlorophyll a due to the uncontrollable nature of the annual nutrient (fertilizer) inputs. However, a lake, for example, with a chlorophyll a summer average of 50 ug/l, that has a reduction of 20 ug/l by partial removal of the total annual phosphorus input through a lake management program will show improvement. Though there may not be a dramatic change in the average summer clarity of the lake, the frequency and intensity of algal blooms throughout the summer will decrease. This will reduce the unsightly shoreline accumulations of algal die-off and concomitant odors, and will reduce the amount of non-chlorophyll containing organic fragments resulting from the death of algae. These fragments also reduce transparency. It will also make the lake more pleasing for swimming and water skiing.

A second point to draw from Figure 5 is the fact that there is an upper limit to the clarity of lakes. There is a point beyond which a decrease in chlorophyll a will not increase the clarity of the water. Chlorophyll a concentrations below 2-3 ug/l exert little influence on the Secchi disc transparency of a lake. The transparency of a lake at this point is dependent on the depth, natural turbidity, bottom type and true water color.

What is the prime factor to retain from the discussion? Lake associations are urged to remember that this classification describes a method used to conveniently group a number of lakes. The most important fact to remember is your lake's average transparency and chlorophyll concentration. The classification your lake has received should not be of prime importance. What associations should be concerned with is whether next year's transparency or chlorophyll concentrations will increase or decrease. Lake associations are urged to continue participation in the program to determine whether yearly changes in water quality are occurring. Remedial measures can be implemented if necessary before conditions become serious.

SLOWING THE RATE OF EUTROPHICATION

Inland lake monitoring does not eliminate the causes of eutrophication, but provides a clue to the general health of the lake. It does not prescribe a medicine to cure the ills or protect the health of the lake. The cause of eutrophication does not lie within the lake itself, but is found on the surrounding watershed.

The reasons for this are fundamentally simple. The lake gains its water from an area of land around it called the watershed, and should the use of this land be radically altered, chances are that the quality of water it yields will be correspondingly altered. As the watershed is developed, forests are cleared and replaced with surfaces such as concrete and lawns which become depositories for the residue generated by humans, their machines and their animals. Ultimately, these surfaces are flushed by runoff, and the residues of fertilizers, oil, animal excrement and other foreign substances are carried to the lake by streams, storm sewers and drains.

To slow eutrophication, attention must be given to the ultimate cause. The problem turns out to be not the abundant algae and aquatic plants, but the annual nutrient input to a lake. A recent publication entitled "Inland Lake Watershed Analysis, A Planning and Management Approach" discusses how to minimize the nutrient input to lakes through good land use planning and management practices. This publication can be obtained from the Inland Lake Management Unit of the Michigan Department of Natural Resources. The following discussion also points out some of the different sources and the techniques lake property owners, in conjunction with local and state governments, can use to minimize the cause of eutrophication.

Nutrient Sources

Since nutrients enter lakes from a variety of sources, the present management approach is to eliminate the more easily controlled sources. In the analysis of this problem, natural resource managers divide nutrient sources into two groups, point and non-point sources. A point source is a direct discharge to a lake that is easily observed and measured. A straight forward control action will shut off the nutrient input or reduce it substantially. Conceputally, this is akin to viewing your water tap as a source of some undesirable material and the elimination of the problem is as simple as shutting off the tap. A non-point source is the entry of a substance into a lake in a diffuse manner. It is often difficult to measure and accurately document and does not lend itself to straight forward control action. For example, the entry of phosphorus into a lake off the lawns of riparians is a non-point source. This occurs due to over fertilization of the lawns with the excess being washed off in surface water runoff or wind blown drift. The control in this case is not by locating a single specific point or even a series of points. It involves a coordinated reduction by all riparians involved. Table 5 lists the nutrient sources to lakes.

Table 5. Nutrient Sources to Lakes

NATURAL	
Swamp Runoff	Aquatic bird and animal wastes
Forest Runoff	Leaf and pollen deposition
Meadow Runoff	Watershed geological composition
Soil Erosion	Sediment Recycling
Precipitation (Lake Surface)	
CULTURAL (MAN-MADE)	
Domestic Wastewater[a]	Septic systems
Agricultural Runoff[a]	Landfill drainage
Urban Runoff[a]	Industrial wastewater[a]
Managed Forest Runoff	

[a] Usually a point source. (Adapted from Shannon and Brezonik, 1972).

Atmospheric Sources

Rain and snow falling directly on lakes are nutrient sources. Lake scientists have recognized the presence of phosphorus and nitrogen in precipitation for several years. Often the concentration is higher in the rainfall than in the lake. One study has shown that rainfall in the Cincinnati, Ohio area averaged 0.69 mg/l inorganic nitrogen and 0.88 mg/l total phosphorus[9]. To appreciate the significance of these levels, it is only necessary to compare them with nutrient threshold concentrations capable of producing algal blooms in lakes[10]. Only 0.30 mg/l of inorganic nitrogen is required or one-half of the concentration found in the rainfall. Similarly, the total phosphorus level in rainfall is eighty times higher than the 0.01 mg/l inorganic phosphorus concentration. Since inorganic phosphorus is always a fraction of total phosphorus, the inorganic fraction in rainfall would often be equal to or greater than 0.01 mg/l.

How significant is nitrogen and phosphorus in rainfall to the total annual nutrient input of a lake? Though the complete answer is not available for all lakes, it can be a large fraction of the annual total. A study at Houghton Lake (Roscommon County) found the nutrients in direct precipitation accounted for 41% of the total phosphorus and 49% of the total nitrogen contributed annually from all sources[13]. Why is this information important? Because it shows the lake scientist and the lake citizen the importance of reducing controllable point source entry into the lakes. As indicated at the beginning of this section, rainfall is a diffuse non-point source and not very controllable. Available control programs for air pollution are located in urban areas ususally miles from most lakes. There is little the local lake community can do to directly reduce the phosphorus and nitrogen content of direct rainfall on the lake. Since rainfall can be a major nutrient input and is not very controllable, the lake citizen must adamantly work at reducing the controllable point sources entering a lake to the best practical degree.

In addition to rainfall and snow, another atmospheric source of nutrients is dust fallout. It can fall directly on the lake as with precipitation and also, like rainfall, on the surrounding watershed. The Cincinnati, Ohio study found that dust from atmospheric fallout averaged 300,000 pounds per square mile per year and in some areas could reach 80,000 pounds per square mile per month[9]. Since atmospheric dust and soil particles often contain phosphorus sorbed on them, reduction in the annual dust contribution to the lakes aids in slowing the rate of eutrophication. The lake citizen and local community can help reduce the annual input of dust into the lakes. Lake area residents and municipalities throughout the watershed are encouraged to keep streets, sidewalks and driveways clean. Rain or stormwater can wash this dust into lakes. A recent University of Minnesota[14] study found that a 2/3 reduction in the annual phosphorus load carried by stormwater could be achieved if the streets connected to the lake with storm drains were swept weekly. Lakeshore property owners should, for the same reasons, direct building eaves away from the lake so rainwater seeps into the ground, not directly into the lake.

Surface Runoff

Runoff from urban areas is recognized as an important source of aquatic plant nutrients. Developent in the watershed alters runoff characteristics. Rainfall which once filtered through forested soils now runs off yards, construction sites, roads, parking lots, roof tops, etc. This runoff discharges to lakes directly or via tiles, drains and storm sewers. Although it was once considered "natural", we do now know that runoff from impervious surfaces is often heavy with sediment particles, highway salt, fertilizer residues and animal excreta. Rain falling on an acre of forested or farm land will be filtered as it passes through the soil and vegetation before the water enters a lake. As development occurs, much of the ground cover is replaced by paved streets, sidewalks, driveways and rooftops. Rain falling on these impervious materials moves very quickly to a lake without benefit of natural filtration. A 10-fold increase in phosphorus content of surface runoff was found when forested land was converted to agricultural use (cropland) and a 20-fold increase when cropland was converted to urban usage[8].

Surface runoff via tributaries from agricultural areas has the potential to carry large quantities of nutrients to lakes. However, under proper soil, water and fertilizer management, it is possible to control the amount of nitrogen and phosphorus entering the streams. Information concerning the area farming practices can be obtained from your County Agricultural Extension Agent.

Lawns

Highly fertilized, manicured shoreline lawns are not recommended. Though they are often thought aesthetically pleasing, better water quality protection of a lake is achieved if the shoreline remains in its natural vegetative state. Biologists are concerned about fertilizer runoff and seepage to the lakes from shoreline lawns. Shrubs or other heavy vegetation are preferable as a buffer zone or green belt between the beach and lakeshore home[12]. Lake area property owners intent on fertilizing already established lawns should take the following precautions:

1. The soil should be tested to determine if the lawn needs phosphorus or potassium. Most fertilizers on the market for lawn use contain more phosphorus and potassium than the grass actually requires. Consequently, use of mixed fertilizers leads to an increased phosphorus level in the soil. This increase is readily detected by soil testing. Your soil can be tested for a $3.00 fee at:

   Michigan State University
   Soil Testing Laboratory
   108 Soil Science Building
   East Lansing, Michigan 48823

   If your lawn requires fertilizer, special mixtures based on the test results can be prepared by several commercial concerns. Lake associations can jointly submit bulk orders. This will provide them with economic and ecologic savings. If you don't need phosphorus fertilizer, why buy it?

2. Nitrogen fertilizer should be applied when the grass is actively growing to minimize loss of nutrients to nearby lakes or streams. For the most effective application, begin fertilizing in the spring when temperatures are sufficiently warm to produce growth of grass (Memorial Day) and discontinue before the grass ceases to grow in the fall with the last applciation not later than August 15.

Leaves

In recent years studies have shown that leaves and seeds from trees can contribute substantial quantities of phosphorus to lakes, thus increasing the rate of eutrophication[12]. Whole leaves may potentially fertilize many gallons of surface runoff entering a lake above the critical concentration of phosphorus often cited as causing excessive growths of algae or aquatic plants in natural waters. Additionally, any physical damage (i.e., mulching, burning) to leaves will increase the phosphorus release from the leaves. The burning of leaves in street gutters would be an extreme case of physical damage. This treatment would result in almost all of the phosphorus content of the leaves being solubilized from the ash and carried in the stormwater collection system.

It is apparent from recent studies[11] that municipalities and communities should initiate a program of rapid leaf pickup during the autumn leaf litter period in order to minimize nutrient transport to lakes and streams from urban runoff. Burning and storing of leaves in the gutters prior to pickup should be prohibited. Furthermore, individual lakeshore property owners should store leaves and other plant debris in such a way as to avoid losses directly to the lake or indirectly through storm drains[12].

Septic Tanks

The individual household septic tank disposal system may contribute nutrients to surface waters. Septic systems installed according to local health department specifications are effective in removing bacterial and most health contaminants. However, these systems were not primarily designed to remove nutrients, such as nitrogen and phosphorus. These elements can enter and travel in the groundwater and enter the lake with the inflowing groundwaters. The degree of movement is dependent on the soil type in which the septic system is located.

Often in non-sandy soils, nutrients can enter the lake during periods of septic tank failure due to plugging of the tile field. However, in porous sandy soils such as those frequently encountered around lakes, septic tank disposal systems rarely have any problems of plugging. However, these systems readily transmit the nutrients from the household to the nearby lake via groundwater[6]. When properly located, the individual household septic tank system is a very ecologically safe means of waste disposal. These systems should be installed according to local health codes and located as far back from the lake as possible. They should not be used in areas where the groundwater is near the surface. Michigan State University Cooperative Extension Service Bulletin #577, Farm Science Series, outlines the proper placement and maintenance of septic systems.

When septic tank systems begin to fail, riparians seek alternative methods for sewage disposal. Probably the most frequently considered alternative to individual septic systems are sewage collection and treatment facilities. Such facilities are very expensive, consume large amounts of energy to construct and maintain, and are impractical in small rural communities. Additionally, if this alternative is not fully evaluated negative consequences may offset any advantages gained in the attempt to control phosphorus. As an example, in certain communities a treatment facility may greatly stimulate housing, industrial or commercial development which may increase other phosphorus sources such as stormwater and surface runoff. The net results may be more phosphorus entering the lake instead of less.

Therefore, all possible alternatives should be considered before a decision is made on how to handle sanitary wastes. Besides septic tanks, many other onsite systems have proven to be effective and should be given consideration. Some of the more common ones are biological toilets, composting toilets, incinerating toilets, and oil-flushed toilets. Additional information on the above systems can be obtained by writing the Inland Lake Management Unit of the Michigan Department of Natural Resources.

Detergents

Many detergents used in the household contain phosphorus. One recent study indicated that 70% of all the phosphorus in the septic tanks located around the study lake was from detergents and only 30% came from human wastes[16]. Therefore, the quantity of phosphorus entering lakes from septic tanks could be substantially reduced by using phosphorus-free detergents. Riparians can determine which detergents are phosphorus-free by merely reading the label on the back of the containers.

Waterfowl

Lakes also receive nutrients from waterfowl. As part of the lake community, wild ducks and geese feed on plants and other aquatic organisms. The ducks eat the plants, remove a fraction of the nutrients and excrete some nutrients to support new plant growth. This is a natural cycle. When man establishes waterfowl feeding programs, the nutrients in the artificial feeding program also enter the lake. This is not beneficial. For example, a duck exretes 0.9 pounds of phosphorus per year[13]. Feeding programs that support a large population of semi-domesticated ducks can contribute hundreds of pounds of phosphorus per year to a lake. Waterfowl are a natural part of the lake community. They should be enjoyed and can be encouraged to stay on your lake through habitat and nesting improvement programs, but not through continuous artificial feeding programs.

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GLOSSARY

Algae: Primitive photosynthetic plants that occur as microscopic forms suspended in water (phytoplankton), and as unicellular and filamentous forms attached to rocks and other substrates. About 15,000 species of fresh water algae are known.

Bloom or Water Bloom: A sudden increase in the abundance of planktonic algae, especially at or near the water surface. A condition when water looks green because of the abundance of planktonic algae.

Chlorophyll a: A green pigment in plants which is necessary for photosynthesis.

Ecosystem: Any combination of living and non-living components that, with a supply of matter and energy, is self-sustaining over a defined period of time. An ecosystem can be an ocean, lake, small plot of land, the entire biosphere, or an aquarium, depending on the context of use.

Eutrophication: The complex sequence of changes initiated by the enrichment of natural waters with plant nutrients. The first event in the sequence is an increased production and abundance of photosynthetic plants. This is followed by other changes that increase biological production at all levels of the food chain, including fish. Successful changes in species populations occur in the process. The original meaning of eutrophication was simply nutrient enrichment. In recent years it has become more common to use the term in connection with the results rather than the cause (that is, an increase in trophic state caused by nutrient enrichment).

Lake Classification: One of the more commonly used lake classification systems recognizes two general categories of lake; dystrophic lakes with brown colored water, rich in humic materials derived from plants, and oligotrophic-eutrophic lakes with "unstained" water.

<u>Oligotrophic</u> lakes are poorly supplied with plant nutrients and support little plant growth. As a result, biological productivity is generally low, the waters are clear, and the deepest layers are well supplied with oxygen throughout the year. Oligotrophic lakes tend to be deep, with average depths greater than 15 meters (49 feet) and maximum depths greater than 25 meters (80 feet).

<u>Mesotrophic</u> lakes are intermediate in characteristics between oligotrophic and eutrophic lakes, they are moderately well supplied with plant nutrients and support moderate plant growth.

Eutrophic lakes are richly supplied with plant nutrients and support heavy plant growths. As a result, biological productivity is generally high, the waters may be turbid due to dense growths of phytoplankton or contain an abundance of rooted aquatic plants; deepest waters exhibit reduced concentrations of dissolved oxygen during periods of restricted circulation. Eutrophic lakes tend to be shallow, with average depths less than 10 meters (33 feet) and maximum depths less than 15 meters (50 feet).

Limnology: The scientific study of inland waters.

Nitrates: Nitrogen is an element found in water in many forms. When one atom of nitrogen is combined with three atoms of oxygen, the resulting substance is called nitrate. Nitrogen and its forms are key nutrients for growth of plants and aquatic weeds.

Non-Point Source: A source of pollution that does not discharge through a fixed location, such as agricultural runoff from land.

Nutrients: Any of a group of elements necessary for growth. Although over 15 elements have been identified as necessary for the growth of aquatic plants, nitrogen and phosphorus are usually limiting in Michigan surface waters.

Plankton: Community of mirco-organisms, consisting of plants (phytoplankton) and animals (zooplankton), inhabiting open-water regions of lakes and rivers.

Phosphorus: Phosphorus is an element which can affect water quality. In some of its forms, it can be used by algae in a stream or lake.

Photosynthesis: The process by which green plants convert the sun's energy into chemical energy in the form of carbohydrates, fats and proteins.

Point Source: A source of pollution that discharges through a fixed location such as a municipal or industrial outfall pipe.

Secchi Depth: Depth at which a Secchi Disc (a black and white disc, 20 centimeters or 8 inches in diameter) disappears from view when lowered into water. A measure of water transparency.

Trophic Status: The level of productivity, (oligotrophic, mesotrophic, eutrophic).

Appendix I

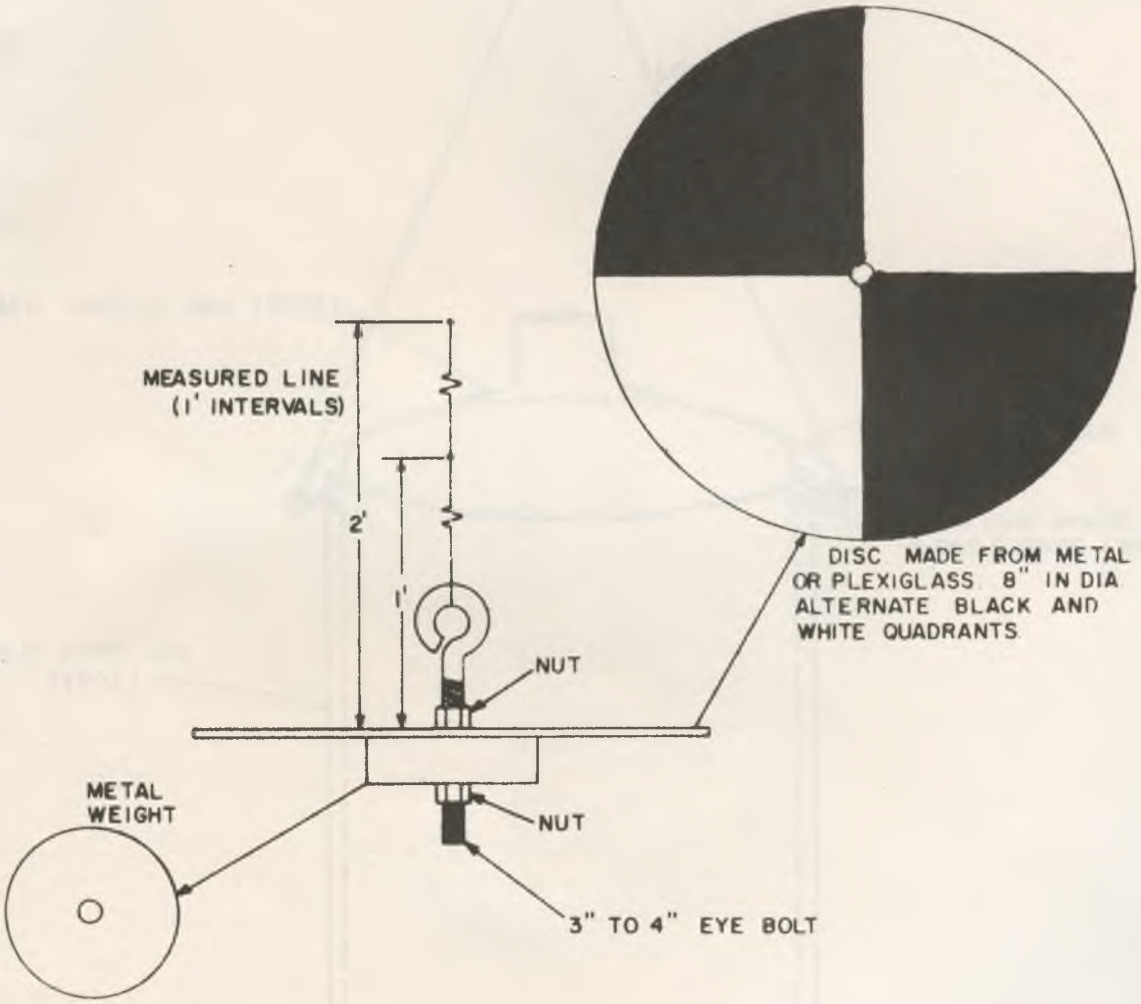

Figure 1
Secchi Disc Construction Plans

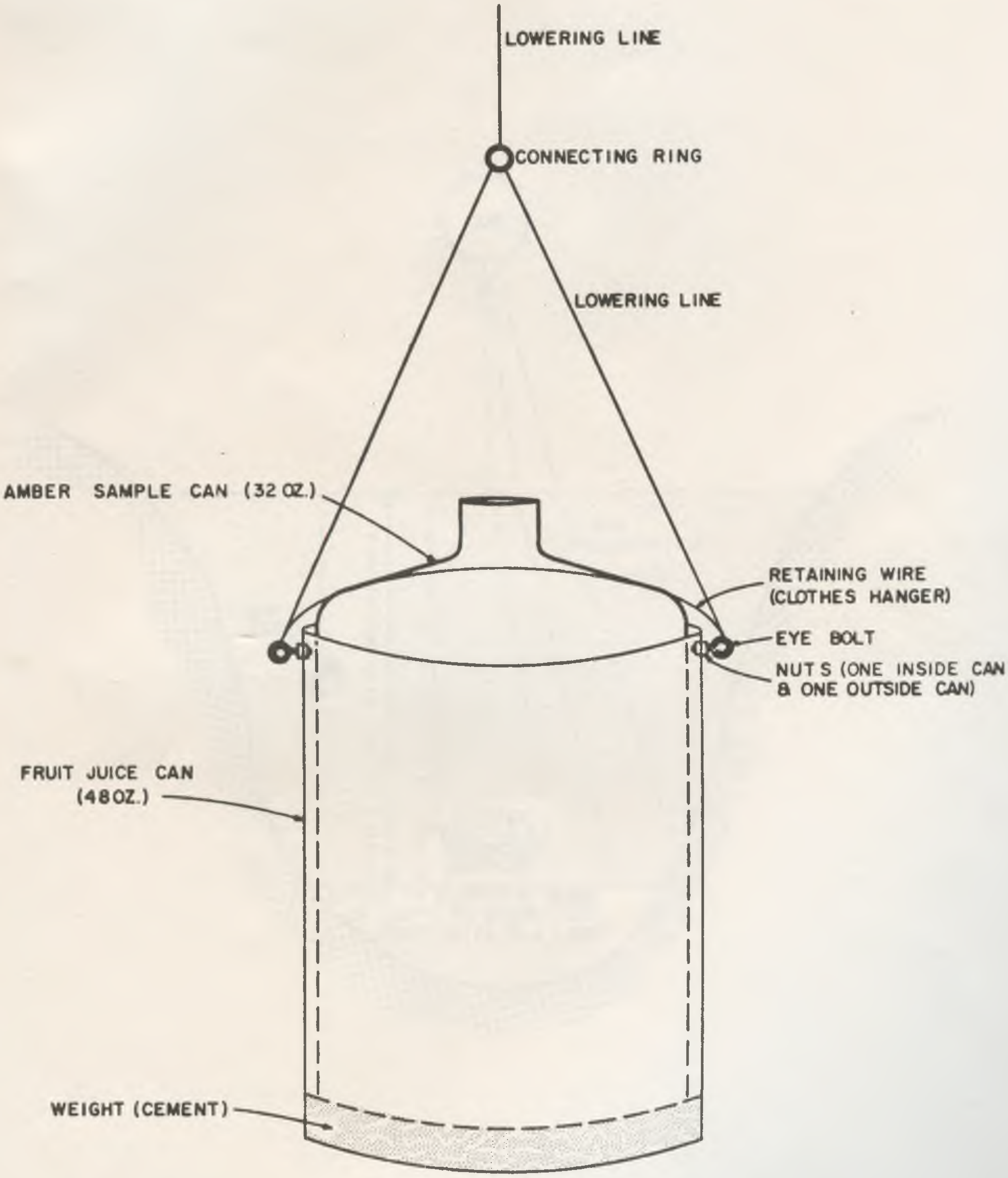

Figure 2

Phytoplankton (Chlorophyll) Sampler Construction Plans

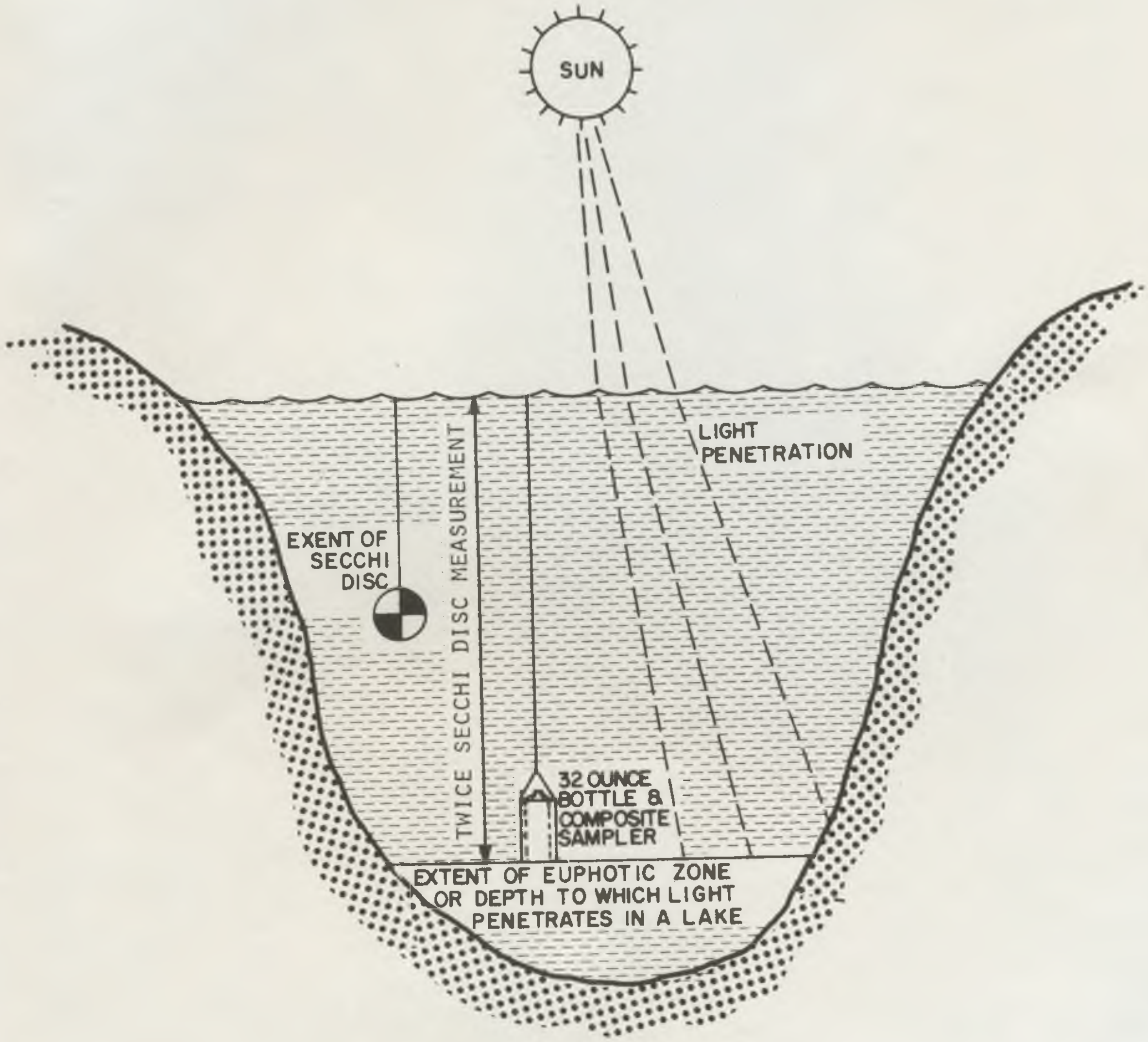

Figure 3
Sample Collection Method