WHITE LAKE ENGINEERING REPORT

October 24, 1986

Cleary Engineers, Inc.
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Auburn Hills, Michigan 48057

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CLEARY ENGINEERS, INC.
71 S. Squirrel Rd., Auburn Heights, MI 48057

October 24, 1986

Mr. Thomas P. Dunleavy, Chairman
Lake Improvement Board for White Lake
One Public Works Drive
Pontiac, Michigan 48054

Gentlemen:

We are pleased to submit our report on White Lake in accordance with our Engineering Services Agreement of July, 1986.

Lake survey questionaires were mailed to lakefront residents. The excellent response from residents was positive evidence of the great interest of all who are concerned about White Lake.

Mr. Jack Portman and the staff of the Oakland County Drain Commissioner were very helpful in obtaining background data and file research.

Mr. Ernie Maier, who has treated White Lake in recent years, was very helpful in opening his files and giving a verbal history of lake treatment.

The able assistance of Dr. Wallace Fusilier in preparation of the water quality and biological studies was an important contribution to our total effort.

The Engineering Report summarizes all study efforts so as to provide a practical management plan for White Lake. We hope that you will find it useful and helpful in managing the future of White Lake. Appendix I includes a one-page summary of our report that could be used for the Public Hearing. Appendix II includes Dr. Fusilier's report to us.

Thank you for this opportunity to work with you and the residents of White Lake.

Very truly yours,

Gerald A. Cleary, P.E.

WHITE LAKE REPORT

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SUMMARY OF STUDY CONCLUSIONS FOR WHITE LAKE

WATER QUALITY

1. Oxygen concentrations are adequate in most parts of the lake. In late summer. the deep hole oxygen levels are depleted below the 20' depth.

2. Phosphorus levels increase greatly in summer, a condition that encourages plant growth. Phophorus levels in White Lake during summer sampling were lower than expected. White Lake appeared nitrate limited during the summer sampling period.

3. Most of the excess Phosphorus which enters White Lake originates from lawn fertilization and septic tanks.

4. White Lake is a water table lake and serves as a sink for excess Phosphorus which appears in the run-off from the immediate watershed.

5. Fertilizers used on lawns in the immediate lake watershed should be as Phosphorus-free as possible.

AQUATIC WEEDS

1. The late summer survey showed Native Milfoil, Narrow Leaf Pondweed and Coontail. About 60% (320 Ac) is less than 10' deep and subject to weed growth. During our survey, very few weeds could be observed due to earlier chemical treatment.

2. Lake harvesting has been done on White Lake in the past, but the program was abandoned as ineffective.

3. Herbicide treatment of shoreline areas has been done in recent years. including 1986. Not all shoreline was treated in 1986.

4. Chemical treatment offers the least expensive method of control of aquatic plants White Lake. A return to harvesting of native plants would be the method of choice supplemented by a discrete use of herbicide in shallow areas. Harvesting and discrete use of herbicide in shallow areas would be the best lake management plan for the long term.

WATER LEVELS

1. The water level in White Lake is controlled by supplemental pumping from an augmentation well located at the North end of the lake. The well system is operated by the Oakland County Drain Commissioner to maintain the legal lake level of 1019.10.

2. Lake level records since October, 1968, show lake levels to be within a few inches of legal level. Generally the pump is turned on when the lake drops about 3" and turned off upon recovery to the legal level. White Lake and Duck Lake levels may be interdependent due to ground water conditions in the area.

3. The surface outlet and control structure for White Lake is on the westerly shore of the northwest bay. Flow when White Lake is above legal level is toward Duck Lake.

RECOMMENDATIONS FOR WHITE LAKE

1. Chemical treatment for control of nuisance aquatic plants and algae is the most cost-effective method of control, based upon recent experience in treating shoreline areas.

2. The better long term management plan for White Lake would be harvesting with discrete use of herbicides and algae control. The native plants serve to take up excess phosphorus and prevent algae blooms.

3. Continued chemical treatment of shoreline and canal areas could be phased into a more favorable long-term plan. As plant growth returns in off-shore areas, the deeper areas could be harvested.

4. The resident survey revealed shallow canal areas which should be dredged. Also, there are sunken islands out in the lake which could be deepened if a suitable spoil area can be found. If the Lake Board and residents wish to consider a phased program of canal deepening, the benefits to canal owners should be considered when choosing the level of assessment for canal property.

5. For the long-term assessment, we recommend the unit factor method. If canal dredging (as needed) is accepted as part of a long term program, there would be an estimated 550 units to be assessed. If an annual budget of $62,000 were adopted, this would result in an average of $113.00 for a lakefront or canal front residence. This budget would support some dredging until off shore weeds have to be harvested. If adopted for 3 years. the annual budget could be adjusted to conditions of the program at the end of that period.

6. If the recommended long-term program is adopted. actual conditions should be field evaluated each year to allow for rational planning of the following year's program. We believe the long-term program for White Lake can best be served by an independent report of actual conditions along with resident input each year. It will take several years to phase into the proposed plan. A yearly report of conditions would also evaluate any changing condition such as an appearance of Eurasion Milfoil. which would warrant special treatment.

7. Phosphorus-free fertilizers should be used on lawns in the immediate lake watershed unless soil tests warrant its addition. Homeowners using lake water for irrigation should avoid the use of additional fertilizer.

8. A lake-wide association should be formed for White Lake to assist in the management of the whole lake.

RECOMMENDED PROJECT COSTS 1987 - 1989

1987 PROGRAM

Chemical treatment 100 acres @ $200/acre	20,000
Dredging budget (1000 L.F. of canal)	30,000
1985 Study Costs	6,000
Administration and Contingencies	4,000

TOTAL ESTIMATED COST	$60,000

1988/1989 PROGRAM

Chemical treatment	20,000
Dredging/Harvesting budget	35,000
Administration and Contingencies	5,000

TOTAL ESTIMATED COST	$60,000

RECOMMENDED METHOD OF ASSESSMENT

The unit factor method of assessment is recommended because of the variety of benefits to lakefront, canal front and off lakefront properties. We chose district lines after a general evaluation of an aerial map of White Lake and vicinity. If our boundary line drawn around benefitting properties is accepted by the Lake Board, the tax roll would be made up by the Township Assessors.

To meet the requirements of this report, we have counted houses from the aerial photo. This evaluation is preliminary and is subject to final determination by the tax assessor's report.

ESTIMATED COSTS FOR ASSESSED PROPERTIES

Unit Factor Allocation for White Lake

Description	Numbers	Unit Factor	Total Units
Lakefront Home	340	1.0 unit	340
Lakefront Business	4	2.0 units	8
Canalfront Home	144	1.0 unit	144
Canalfront Business	2	2.0 units	4
Off Lakefront Home	540	0.1 unit	54

TOTAL ESTIMATED UNITS			550

ANNUAL COST/UNIT $60,000/550 units = $113.00

	Cost/Per Year
Lakefront Home	$113.00
Lakefront Business	$226.00
Canalfront Home	$113.00
Canalfront Business	$226.00
Off Lakefront Home	$ 11.30

WHITE LAKE STUDY SCOPE OF WORK

1. REPORT

Prepare a report which includes the following:

A. Analyze aquatic weed growth and make recommendations for their removal and control. Prepare a map for White Lake which shows the locations and types of aquatic vegetation, and approximate lake bottom contours. Analyse shoreline erosion problems and make recommendations for correction and control.

B. Evaluate lake water quality with respect to oxygen content and its relationship to fish population; adverse effects of stratification, and recommend whether aeration and/or other water conditioning are required.

C. Take water samples and determine lake water quality using the following listed parameters, then recommend appropriate action for improvement:

1. Ph
2. Oxygen concentration
3. Phosphorous concentration
4. Nitrogen concentration
5. Chlorophyl a concentration
6. Secchi Disc Transparency
7. Theortical nutrient budget

D. Analyse and evaluate lake bottom sediments and associated nutrients, including their removal and appropriate disposal.

E. Investigate alternative methods of lake improvement other than weed control, aeration and dredging, etc.. if any.

F. Prepare estimates of costs for each of the above items (A thru E), individually, with an analysis of effects of proposed assessments on the local unit of government and interested land owners and residents.

G. Summarize findings and recommendations in report form for publication. Ten (10) copies of the report shall be provided to the Lake Board under the basic services contract.

2. COORDINATION

Prepare survey questionnaire for distribution by resident associations and evaluate responses when returned.

Update the Lake Board, if requested, concerning the status of the report and the progress to date.

Meet with Lake Board and lake residents to present one (1) final report.

PHYSICAL LAKE DATA

Name..........................	White Lake
Size..........................	540 Acres
Volume........................	6864 Acre feet
Maximum depth.................	32 feet
Mean depth....................	12.7 feet
Location......................	Sections 7 & 8 White Lake Township, and Sections 12 & 13, Highland Township, Oakland County, Michigan
Lake Drainage Area............	1253 Acres
Elevation.....................	1019.1 feet above mean sea level

DESCRIPTION AND LOCATION

White Lake is a 540-acre depression lake located in Sections 7 and 18 of White Lake Township, and Sections 12 and 13, Highland Township, Oakland County Michigan. The lake was formed 10-14,000 years when the retreating glacier left a depression in the glacial drift which exposed the top of the water table. The bottom contour map shows the various irregular ridges, mounds and depressions which make up the bottom of White Lake. The lake is fed by groundwater from springs and a flow augmentation well. The lake surface elevation is 1019 feet above sea level and is an expression of the ground water table. White Lake has a single outlet which controls the legal level. The lake is located in the Huron River basin. Water from this system enters Lake Erie above Monroe, Michigan. The drainage basin for White Lake is 1253 acres (Marsh & Borton, 1974). There are 490 or more residences surrounding the lake, all served with on-site septic tanks.

WATER QUALITY SUMMARY

Water quality sampling was done in mid-August 1986. Ten stations were sampled and detailed results are tabulated in Dr. Fusiliers report in Appendix II. The Lake Water Quality Index Value for White Lake ranges from 53 to 90 (Scale of 100) this indicates water quality from poor to excellent.

Water quality as measured by Chlorphyll a was less than 20 at five stations and greater concentrations than 20 at the other five stations. The average was 26 micrograms per liter and values ranged from 10 to 52 micrograms per liter. These are considered high and indicative of a lake with high biological productivity. Stations 2 and 8 were 44 and 52 respectively and suggest that algae blooms could result.

Phosphorus levels were lower than expected with an average concentration of 14 microgram per liter. Nitrate concentrations were below 10 micrograms per liter and the lake appeared nitrate limited during the sampling period.

Oxygen levels ranged from 8.1 to 8.7 with a value of 1.4 in the 28 foot deep hole. No thermocline was evident during sample taking.

Secchi Disk readings averaged 10 feet, a value higher than normal for Southeast Michigan lakes.

NUTRIENT BUDGET SUMMARY

The purpose of preparing a theoretical nutrient budget for White Lake is to help residents understand the way that excess nutrients enter the lake. Data was obtained from water quality sampling, resident responses to survey questions and observation of watershed conditions.

Water sources for White Lake include spring flow and overland flow. There are no inlet streams on the lake. The water leaves White Lake by a small outlet structure which handles some overflow. Evaporation and percolation tend to trap the nutrients in the bottom sediments.

The residential areas surrounding White Lake have septic tanks. About half of the homeowners fertilize their lawns. Approximately 7000 pounds of Phosphorus enters White Lake each year. About 66% of the Phosphorus comes from septic tanks and 33% from lawn fertilizers. It would help White Lake greatly if sewers were installed and Phosphorus-free lawn fertilizers were applied.

WEED SURVEY

A weed survey was conducted on White Lake during the August water sampling work. Only limited weed growth was observed, probably due to chemical application to the more productive shoreline areas. About 75 acres of shoreline was treated out of a possible 100 to 120 acres around the lake perimeter.

Plants observed included Narrow Leaf Pondweed(Palomogeton Sp.), Native Milfoil(Myriophylum Spp.), Coontail and some Lily Pads.

The function of weeds in a lake is to remove phosphorus from the water, making it unavailble for algae growth. Total elimination of aquatic plants could result in algae blooms. A better management program would include harvesting and a discrete use of chemicals in shallow water.

HYDROGRAPHIC SURVEY

Lake depths were checked by sonar soundings during the summer sampling period.

BOTTOM SEDIMENT SAMPLES

Bottom sediments showed a high proportion of organic material which is a sign of Euthophic lake conditions.

Plant fragments were found in sediments at four locations. Snails appeared in the Northeast bay.

Details of the bottom sediment analysis may be found on page 35 of Dr. Fusilier's report in Appendix II.

MANAGEMENT PLAN FOR WHITE LAKE

The short term plan targets shoreline plant growth with chemical treatment. Also included is dredging very shallow areas along the canals. Aquatic plants should return to offshore areas in a few years and they could be harvested when they appear.

The long term plan for White Lake would be to harvest deeper waters with discrete use of chemicals in shallow areas that cannot be effectively controlled by harvester machines. There should be some dredging to clear canals and main lake shallows. Dredging work could be budgeted over several years.

The long term plan should include resident education about the use of Phosphorus-free fertilizers and avoiding of leaf burning.

ORGANIZATION FOR LAKE MANAGEMENT

The more successful lake management programs are handled by a lakefront owner's association. These associations are non-profit corporations with elected representatives from groups of each ten to twenty homes. These area representatives elect a working board to handle the day to day management.

Association Board duties include:

1. Conduct annual meetings
2. Define annual program
3. Prepare budgets
4. Meet with the Lake Improvement Board
5. Supervise annual program
6. Receive funds from Township Treasurer
7. Provide proper accounting of all expenditures
8. Assist with public hearings as the Lake Improvement Board may require

The cost estimates for each year's program are based upon contracting the harvesting, dredging and chemical treatment work. Some associations own their own equipment and operate it with local labor. The Watkins Lake Association has had a successful program with its own equipment for several years, but this decision to do their own work was based upon a careful analysis of the people available to operate the equipment.

Appendix I includes a Spinal Column article about the Duck Lake Association formed recently. White Lake, like Duck Lake has a large number of local groups and interests which could be better served by a lake-wide Association. If the local Association Executive Board can administer the adopted program, the Lake Improvement Board could conduct the hearings and other necessary action for setting and collecting assessments.

APPENDIX I

SUMMARY OF WHITE LAKE FEASIBILITY STUDY
Prepared for
WHITE LAKE IMPROVEMENT BOARD
By
CLEARY ENGINEERS, INC.
October, 1986

BASIC FACTS ABOUT WHITE LAKE

AREA	540 Acres
WATERSHED	1253 Acres
AVERAGE DEPTH	12.7 Feet
MAXIMUM DEPTH	32 Feet
WATER SOURCE	Groundwater & Well
LAKE OUTLET	Control Structure(To Duck Lake)

WATER QUALITY

White Lake is classified Eutrophic with good and poor water quality. Phosphorus input from non-point sources is considered the major problem with White Lake. The lake is a water table lake with no inlet stream. The outlet flow is minimal. The nutrients tend to concentrate in the water and lake bottom sediments. The nutrient budget shows lawn fertilizers and other non-point sources to be the cause of excess phosphorus which encourages prolific plant growth, although the lake may be nitrogen limited.

Dissolved oxygen is adequate except for depths below 20 feet in the deep hole. The oxygen levels are adequate for the fish population but low D.O. in deep water allows the phosphorus in the sediments to return to the water column and encourage plant growth.

AOUATIC PLANTS AND ALGAE

Prolific plant growth exists with more than half of the lake subject to plant growth. Native Milfoil, Narrow Leaf Pondweed and Coontail were found. Most of the plant growth was controlled by chemical application in 1986 along the shoreline. No excessive algae was observed this season although residents have reported problem levels in recent years. The present plant growth probably takes up excess nutrients before algae can become a problem.

RECOMMENDED CONTROL PLAN

- Chemical treatment along shoreline
- Avoid using lawn fertilizers with phosphorus
- Observe returns of plants offshore - harvesting when necessary
- Use lakefront owner's association for lake management
- Phased dredging program of shallows

LONG TERM CONTROL PLAN

- Weed harvesting and discrete herbicide treatment
- Educate residents in watershed about lawn fertilization problems
- Continue phased dredging program

WHAT WILL IT COST?

About $113.00 per lakefront and canalfront residential lot
Off-lake residents would pay about $11.30

WHITE LAKE QUESTIONNAIRE
Cleary Engineers, Inc., Lake Survey Report

Date: ____________________

Respondent ________________________________

Address ____________________________________ Tel: __________________

Lake Level

Is current level satisfactory? ____yes ____no

If no, would you recommend ____higher ____lower

Lake Access

I use my lot ___ association lot ___ easement lot ___

Lake Conditions

Are nuisance growths of plants or algae commom? ___yes ___no

Are you satisfied with control? ___yes ___no

Past control near you by ___harvesting ___chemicals

Are chemicals applied at your property? ___yes ___no

Remarks ____

Are there erosion problems near your property? ___yes ___no

Are there problem drains near you? ___yes ___no

Are there soft bottom conditions near you? ___yes ___no

Are there shallows that hamper boating? ___yes ___no

Remarks ____

Sources of Enrichment

Do you have an active septic tank? ___yes ___no

Do you fertilize your lawn? ___yes ___no How often? ___________

Do you burn leaves on your property? ___yes ___no

Do you have drains from your lot to lake? ___yes ___ no

Remarks ____

Lake Usage (Check items important to you in enjoyment of the lake)

_____ Swimming
_____ Fishing
_____ Enjoy View
_____ Enjoy Wildlife
_____ Boating
_____ Water Ski
_____ Speedboating

Lake Problems (Please check problem items only)

_____ Nuisance growths of rooted plants
_____ Clarity reduced by thick blooms of algae
_____ Thick sediments
_____ Fishing is poor
_____ Sunfish small and numerous
_____ Fish kills present summer and/or winter
_____ Swimmers itch common
_____ Water level problem

Remarks (Explain above if necessary or add items)

____

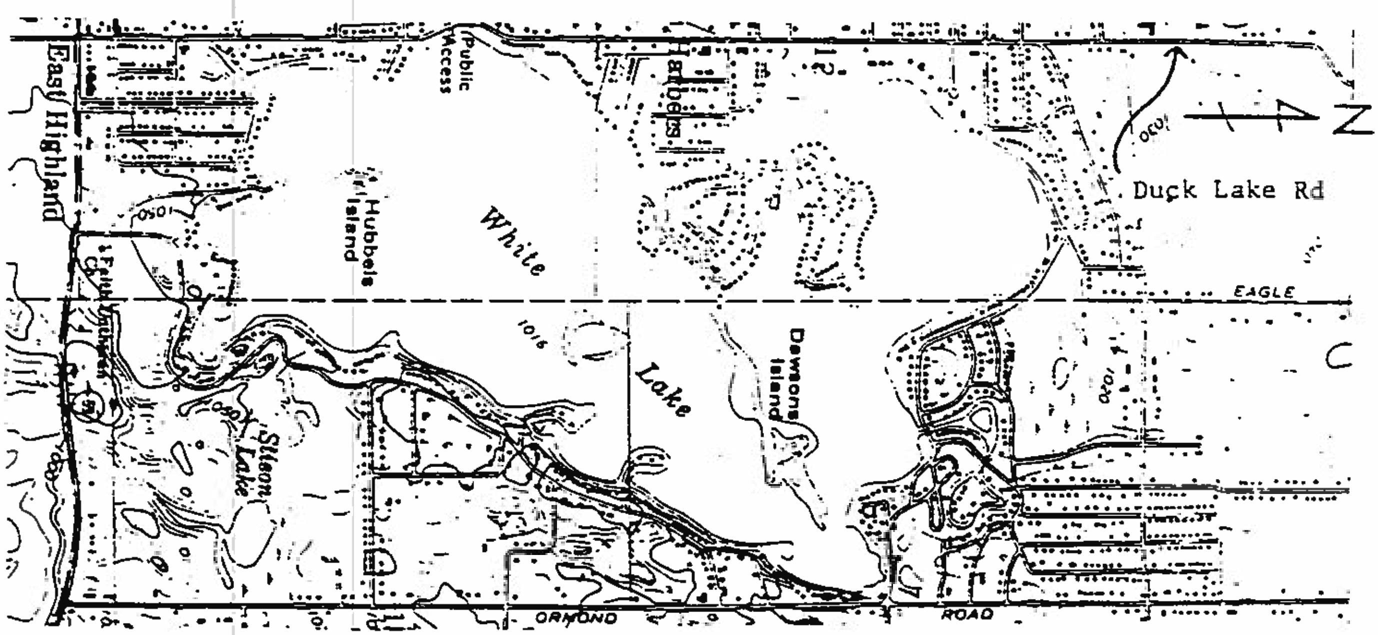
____

What are your major problems/concerns about White Lake?

____

____

Please locate your house with an "X" on the map below:



Please return to: Cleary Engineers, Inc. in enclosed envelope.

If you have questions, call Gerald Cleary at 852-6028
Thank you for your help.

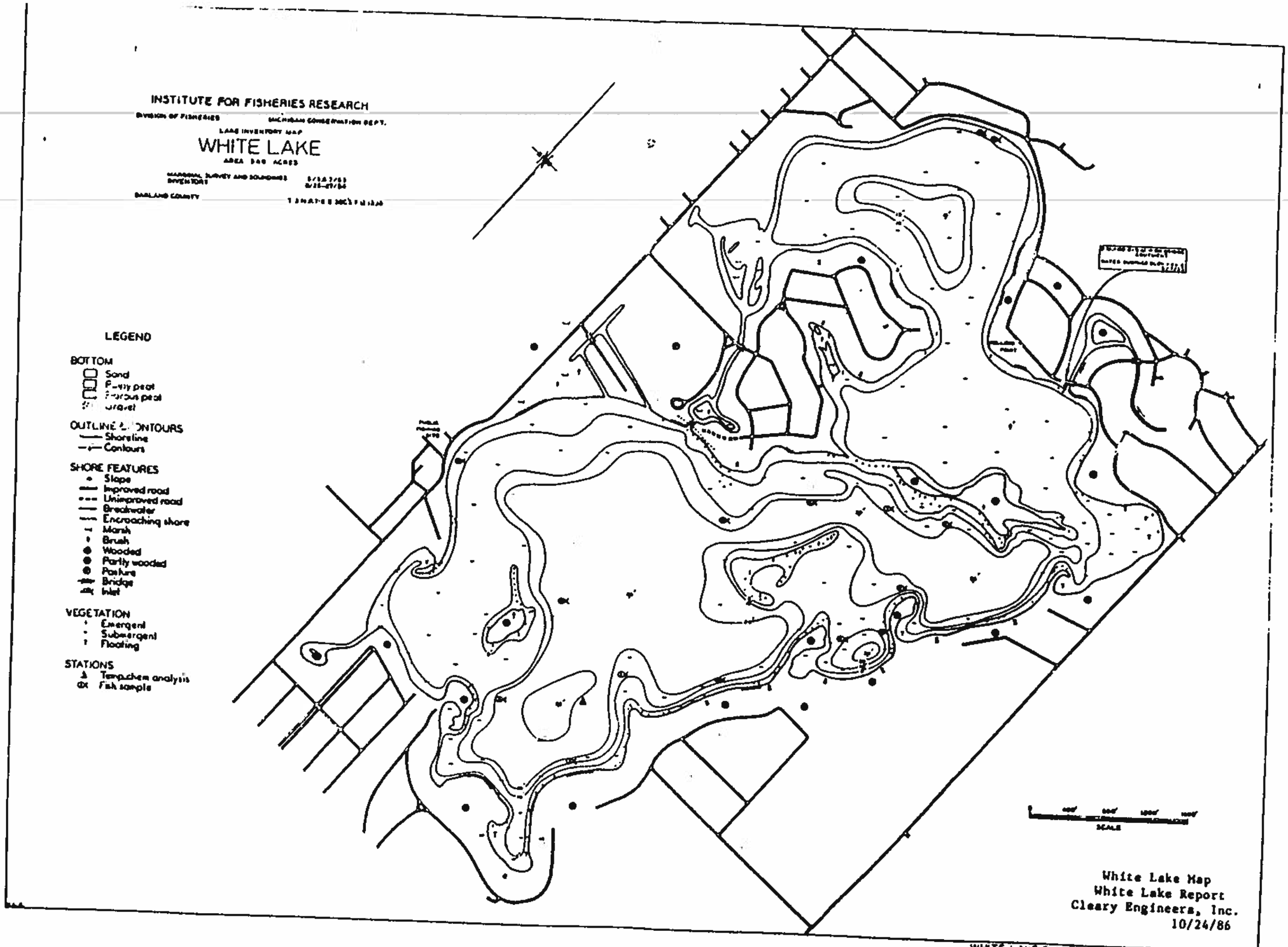
WHITE LAKE RESIDENT SURVEY SUMMARY STATISTICS
160 Returned as of 10-20-86 (428 sent)

Question Response	Number	Percentage
Lake Level		
Satisfactory	114	71%
Unsatisfactory	45	28%
Higher	37	23%
Lower	7	4%
Lake Access		
My Lot	151	94%
Association Lot	4	3%
Easement Lot	4	3%
Lake Conditions		
Algae/Weeds	120	75%
No Algae/Weeds	36	23%
Satisfied W/ Control	55	34%
Unsatisfied W/ Control	99	62%
Harvesting	57	36%
Chemical	117	73%
Chemicals applied at My Lot	71	44%
Erosion	44	28%
Problem Drains	28	18%
Soft Bottom	91	57%
Shallows	58	36%
Enrichment Sources		
Septic Tank	160	100%
Fertilize Lawn	83	52%
Burn Leaves	55	34%
Drains to Lake	8	5%
Lake Usage		
Swimming	146	91%
Fishing	114	71%
Enjoy View	131	82%
Enjoy Wildlife	124	78%
Boating	138	86%
Water Ski	96	60%
Speed Boating	54	34%
Lake Problems		
Weeds	105	66%
Blooms of Algae	66	41%
Thick Sediments	83	52%
Poor Fishing	44	28%
Small Sunfish	67	42%
Fish Kills	8	5%
Swimmers Itch	19	12%
Water Level Problem	19	12%

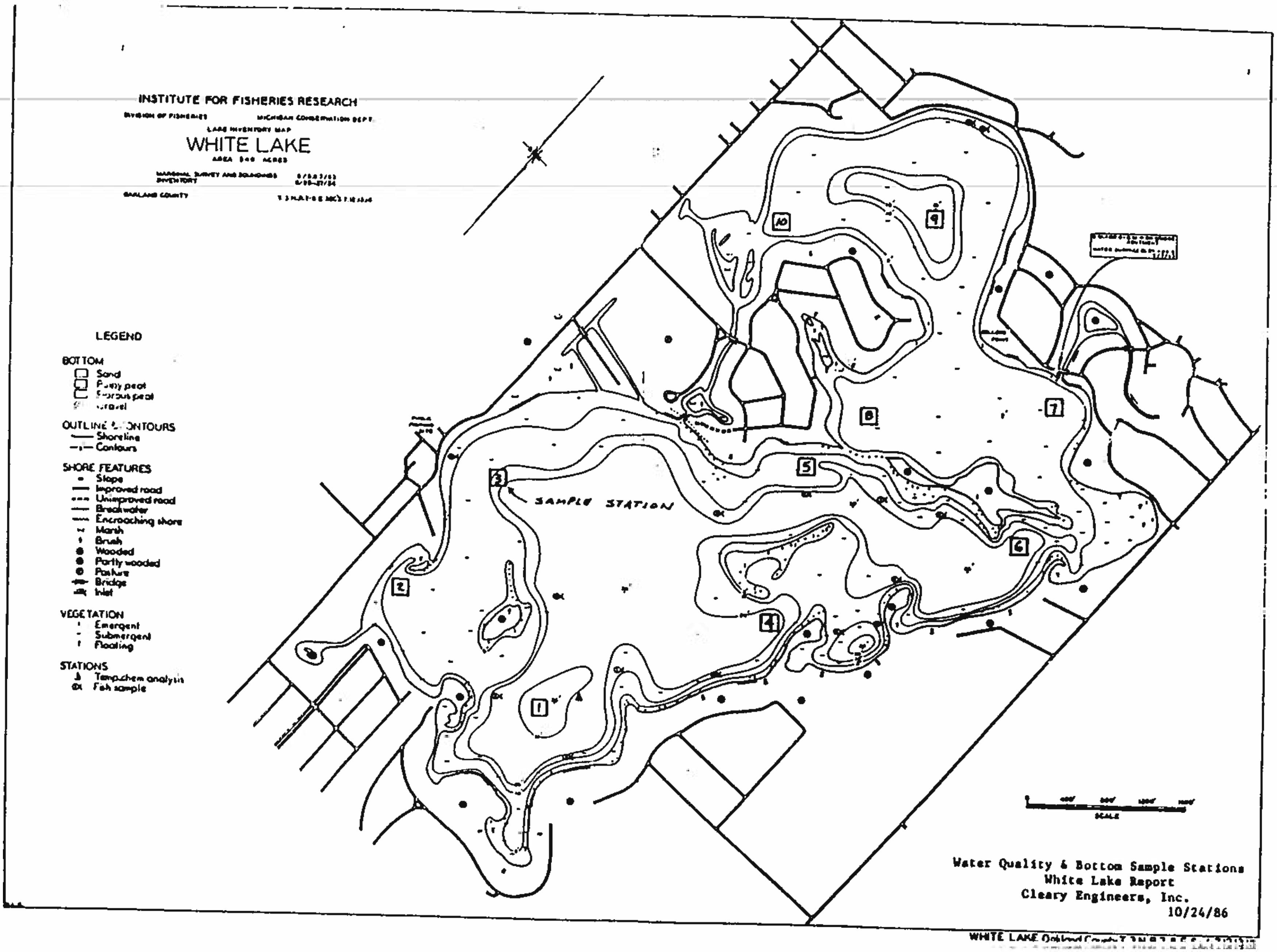
WHITE LAKE SURVEY

Notable Survey Responses

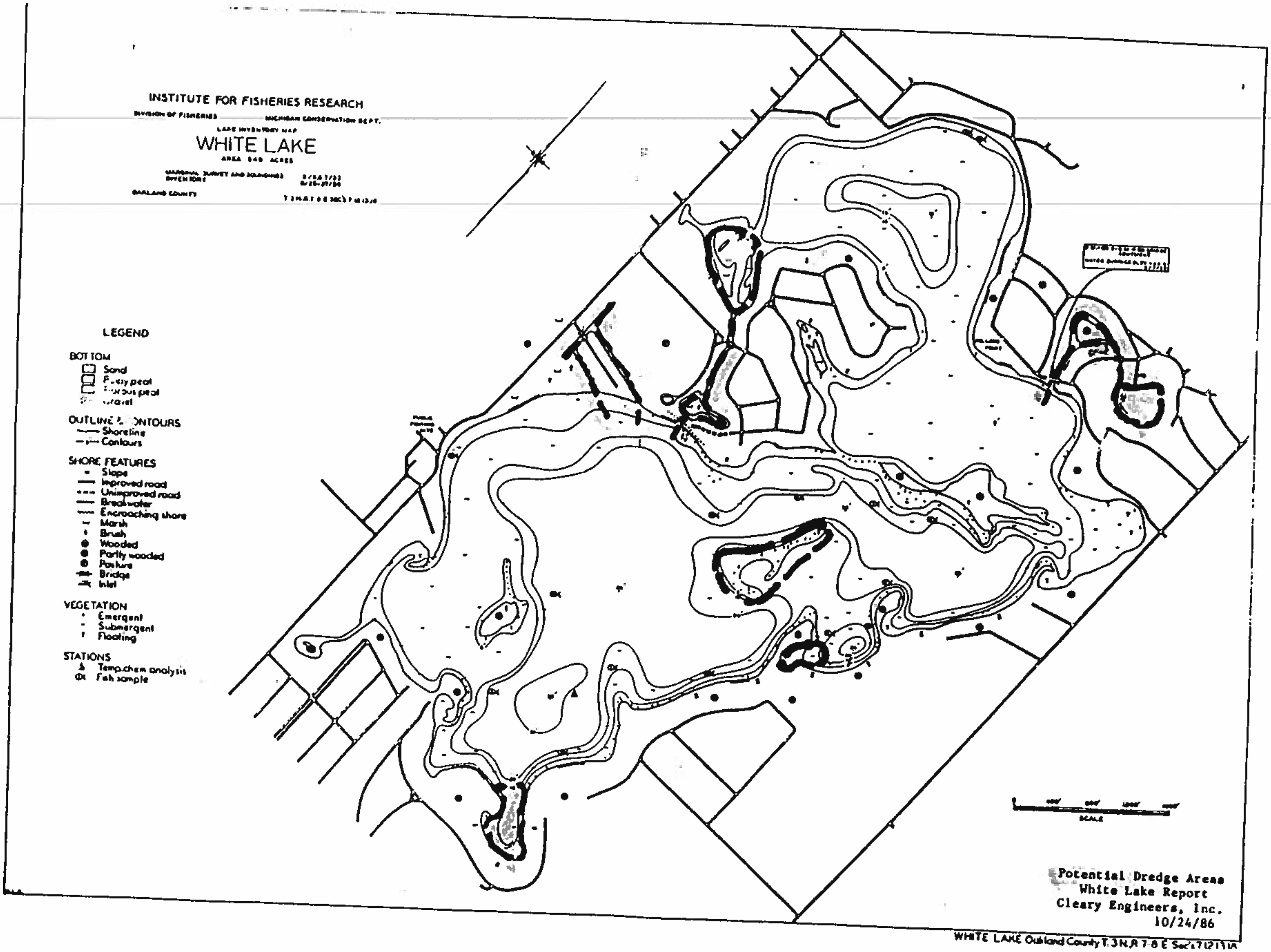
- Would like to see dredging and regular weed control paid for by all users rather than just a few.
- Chemicals kill weeds, but water quality still poor.
- Unchecked drains running into lake.
- Too many high powered boats on lake.
- No control of public, boats park up & down street and in vacant lots.
- Too many boats & no speed limit.
- Chemical control very effective at N.E. & N.W. areas of the lake.
- Need average water level all year round.
- Propose launching fee at public access.
- Sewers are needed.
- Lake is full of algae.
- Sunken island & shallows off points of land.
- We are against chemicals.
- Ph very high this year.
- Do not want chemicals may get in to wells.
- Increase in snails.
- Hubbels island is full of trash on land and in water.
- Prefer chemicals to harvesting, longer control.
- Too many geese.
- Low water, hard to enter & exit canals.
- Too many jet boats.
- Canals need cleaning out.
- Algae & weeds, bad in canals.



White Lake Map
White Lake Report
Cleary Engineers, Inc.
10/24/86



Water Quality & Bottom Sample Stations
White Lake Report
Cleary Engineers, Inc.
10/24/86


INSTITUTE FOR FISHERIES RESEARCH
DIVISION OF FISHERIES
MICHIGAN CONSERVATION DEPT.
LAKE INVENTORY MAP
WHITE LAKE
OAKLAND COUNTY
LEGEND
BOTTOM
Sand
Peaty peat
Fibrous peat
Gravel
OUTLINE & CONTOURS
Shoreline
Contours
SHORE FEATURES
Slope
Improved road
Unimproved road
Breakwater
Encroaching shore
Marsh
Brush
Wooded
Partly wooded
Pasture
Bridge
Inlet
VEGETATION
Emergent
Submergent
Floating
STATIONS
Temp.chem analysis
Fish sample
SCALE
Potential Dredge Areas
White Lake Report
Cleary Engineers, Inc.
10/24/86
WHITE LAKE Oakland County T. 3 N, R 7-8 E Sec's 7,12,13,18

Spinal Column, February 13, 1985

Duck Lake residents form association to aid lake board

By Pete McLaughlin
staff writer

Home and property owners around Duck Lake in Waterford Township now have an association to represent their concerns for continued development and improvement of the lake, and plans are already being made to implement cleanup action.

The Duck Lake association, made up of 15 residents from 15 "districts," will make recommendations and generally act in an advisory capacity to the Duck Lake board.

Ken McQuade, one of the 15 district representatives, said the association was created to help carry out actions taken by the state-created lake board to revitalize Duck Lake.

"This (the association) will help speed things up," McQuade said, "since the lake board is a little hesitant to go out on its own without knowing what a majority of the lakeside owners want."

Lake boards are comprised of state, county and local public officials and only recently have included a representative of lakeside homeowners on the board.

The board and association work together to improve water quality on the lake through a number of measures, including weed harvesting, lake level management and dredging.

There are about 509 members on the Duck Lake general association, which is made up of lake front lot owners. McQuade said additional members may be included in the association once lines are drawn for each district. Many back lot owners who use the lake often also may belong to the association, McQuade said.

The president, vice-president, treasurer and district representatives will serve one-year terms.

A water quality engineering study of Duck Lake showed that conditions on the lake were deteriorating rapidly and that the lake had reached a eutrophic (aged) state.

The study concluded that the input of phosphorus from chemical lawn fertilizers and septic tanks was causing excessive growth of weeds, which robs oxygen from fish populations when decomplosition begins.

To finance remedial projects, the association will help establish a special assessment district to charge homeowners yearly fees for clean-up costs and maintenance of the lake.

"With a little bit of work on this lake, it could be wonderful," said one homeowner [illegible]

APPENDIX II

A WATER QUALITY STUDY
OF
WHITE LAKE

October 1986

Wallace E. Fusilier, Ph.D.

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MAPS

DISCUSSION AND RECOMMENDATIONS

- Oxygen concentrations do not appear to be depleted in any part of the lake, therefore fish populations should find adequate supplies throughout the year. Hypolimnetic aeration is not recommended at this time.

- As shown in the calculated theoretical nutrient budget, White lake has a large amount of phosphorus in the bottom sediments (over 70 tons). The nutrient budget shows that the two main sources of phosphorus are septic tank effluents and lawn fertilizers.

- Lawn fertilizer used in the immediate lake watershed should be phosphorus-free, for two reasons. First, enough phosphorus is already in the soil. Secondly, phosphorus does not make lawns green. Nitrogen does. Phosphorus is a root-growth nutrient.

- Some method of exporting the septic tank effluent from the immediate watershed should be explored. The cluster system concept is a possibility. In a cluster system, each house has a septic tank and pump, which the individual home owner maintains. The effluent from each septic tank is pumped via a pressure sewer to a large tile field some distance from the lake and serves 10-15 houses. The purpose of this type of system is to remove a large amount of phosphorus from lakeshore areas, preventing it from flowing into the lake and causing more serious problems than the lake currently has.

The survey of aquatic weeds found no major problems during the survey periods. The bottom sediments at some stations did contain high concentrations of non-decomposed dead aquatic weeds.

- For White Lake, weed harvesting and removal should be used for weed control, for several reasons:

1. The build up of organic material in the bottom sediments of White Lake caused by incomplete decomposition of dead plant materials will probably cause serious eutrophication problems in the future.

2. Weed harvesting does not introduce any potentially toxic materials into the lake water.

3. Vegetation would be removed from the lake, so oxygen supplies are not depleted when the material settles to the bottom and decomposes. Hypolimnetic dissolved oxygen would remain high and the sediment phosphorus would remain precipitated.

4. Harvesting minimizes fish kills.

5. The area is immediately usable.

- Not all weeds should be removed or killed. Aquatic plants remove nutrients from the water column, and provide habitat for fishes. One of the problems often seen on local lakes is that everyone wants a sandy beach and no weeds. Since all of the shoreline nutrient filters are removed, the problems move out into the lake. Since the process is gradual, most lake front property owners don't realize the consequences of their actions.

- A White Lake Property Owners Association should be formed to implement the lake management program.

- The White Lake Property Owners Association should consider joining the Michigan Lake and Stream Associations if they are not currently members. This group is aware, concerned and knowledgeable about lake problems. Furthermore, it is the only lobbying group lake front property owners have.

- A newsletter should be published several times a year informing lake residents about current problems and solutions.

SCOPE OF WORK—BASIC SERVICES

1. **REPORT**

Prepare a report which includes the following:

A. Analyze aquatic weed growth and make recommendations for their removal and control. Prepare a map of White Lake which shows the locations and types of aquatic vegetation, and approximate lake bottom contours. Analyze shoreline soil erosion problems and make recommendations for correction and control.

B. Evaluate lake water quality with respect to oxygen content and its relationship to fish populations; determine possible adverse effects of stratification, and recommend whether aeration and/or other water conditioning are required.

C. Take water samples and determine lake water quality using the following parameters, then recommend appropriate action for improvement.

1. pH
2. Dissolved oxygen concentration
3. Phosphorus concentration
4. Nitrate concentration
5. Chlorophyll a concentration
6. Secchi disk transparency
7. Alkalinity
8. Conductivity
9. Temperature

D. Analyze and evaluate lake bottom sediments and associated nutrients, including their removal and appropriate disposal.

E. Investigate alternative methods of lake improvement other than weed control, aeration and dredging, etc., if any.

F. Prepare estimates of costs for each of the above items (A through E), individually, with an analysis of effects of proposed assessments on the local unit of government and interested land owners and residents.

G. Summarize findings and recommendations in report form for publication. Ten (10) copies of the report shall be provided to the Lake Board under the BASIC SERVICES contract.

2. COORDINATION

Prepare survey questionnaire for distribution by resident associations and evaluate responses when returned.

Update the Lake Board, if requested, concerning the status of the report and the progress to date.

Meet with the Lake Board and lake residents to present one (1) final report.

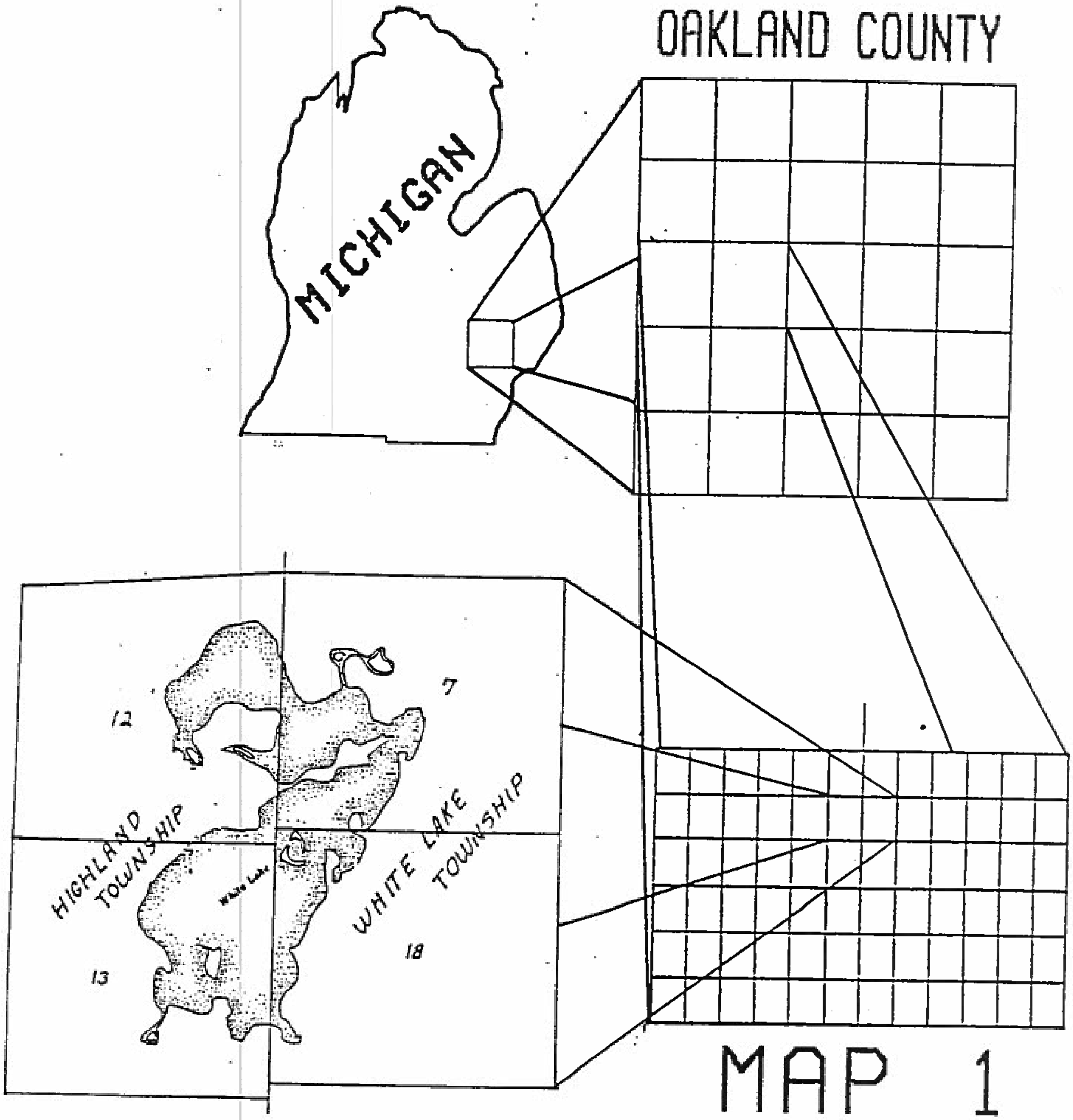
WHITE LAKE DATA

Name......................	White Lake
Size	540 Acres
Volume....................	6864 Acre feet
or........................	299,000,000 cubic feet
or........................	2,236,520,000 gallons
or........................	18,652,576,000 pounds
Maximum depth.............	32 feet
Mean depth................	12.7 feet
Location..................	Sections 7 & 18, White Lake Township, and Sections 12 & 13, Highland Township, Oakland County, Michigan
Drainage basin............	Huron River System
Lake drainage area........	1253 acres
Elevation.................	1016 feet above sea level

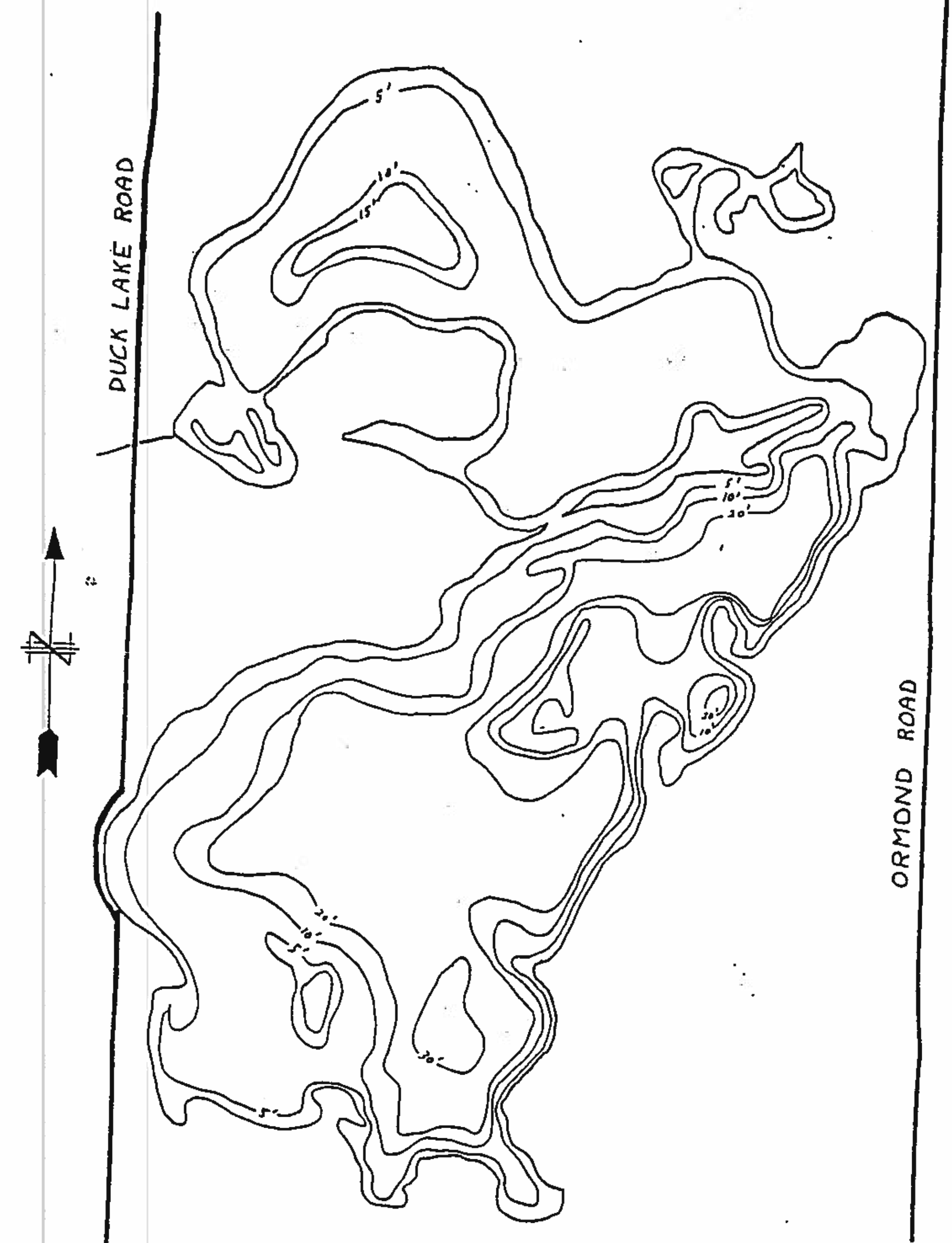
WHITE LAKE DESCRIPTION AND LOCATION

White Lake is a 540-acre depression lake located in Sections 7 and 18 of White Lake Township, and Sections 12 and 13, Highland Township, Oakland County, Michigan. See Map 1. The lake was formed 10-14,000 years ago when the retreating glacier left a depression in the glacial drift which exposed the top of the water table. The bottom contour map shows the various irregular ridges, mounds, and depressions which make up the bottom of White Lake. See Map 2. The lake is fed by groundwater from springs. The lake surface elevation is 1016 feet above sea level and is an expression of the groundwater table. White Lake has a single outlet. The lake is located in the Huron River basin. Water from this system enters Lake Erie above Monroe, Michigan. The drainage basin for White Lake is 1253 acres (Marsh & Borton, 1974). See Map 3. There are 490 or more residences surrounding the lake, all served with on-site septic tanks.

LOCATION MAP



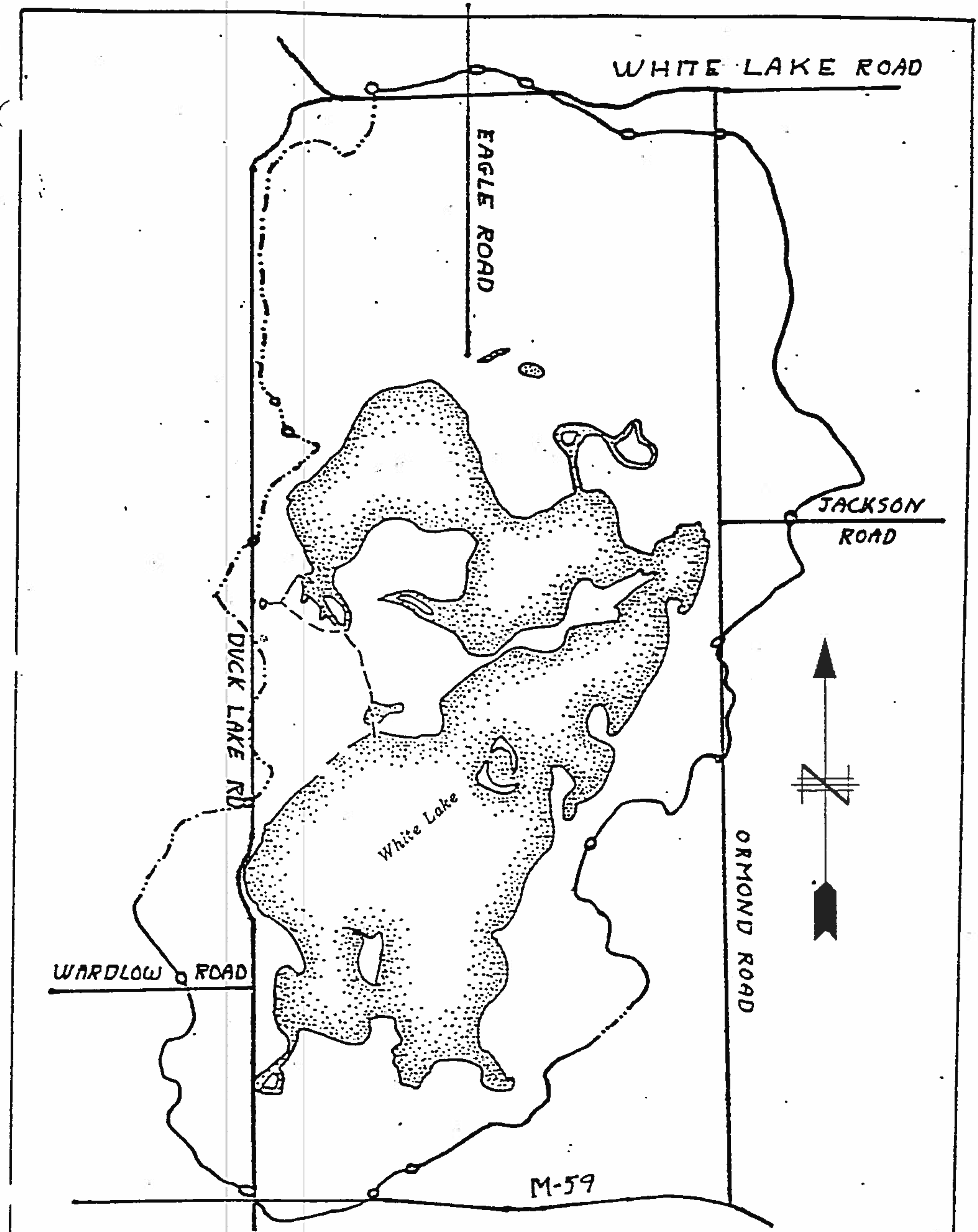
MAP 1



MAP 2
BOTTOM CONTOURS
SCALE 1" = 800'

WHITE LAKE
540 ACRES
AUGUST 1986

WQI



SCALE 1"=1600' DRAINAGE AREA MAP 3

THE WATER QUALITY STUDY

A summer series of samples was taken to detect possible high Chlorophyll a concentrations, shallow Secchi disk transparencies, and oxygen depletion from the deep bottom waters which may occur during this period. This date was August 12, 1986. Bottom contour measurements were checked, bottom sediment samples obtained and weed beds surveyed at this time.

THE SAMPLING STATIONS

The sampling stations involved ten in-lake sites and are shown on Map 4.

THE ANALYSES

Dissolved oxygen, temperature, Secchi disk transparency, conductivity and depth measurements were conducted in the field. Alkalinity, pH, total phosphorus, total nitrate, chlorophyll a and sediment analyses were performed in the Water Quality Investigators laboratory near Dexter, Michigan. All tests followed the procedures outlined in *Standard Methods for the Examination of Water and Wastewater.*

THE LAKE WATER QUALITY INDEX

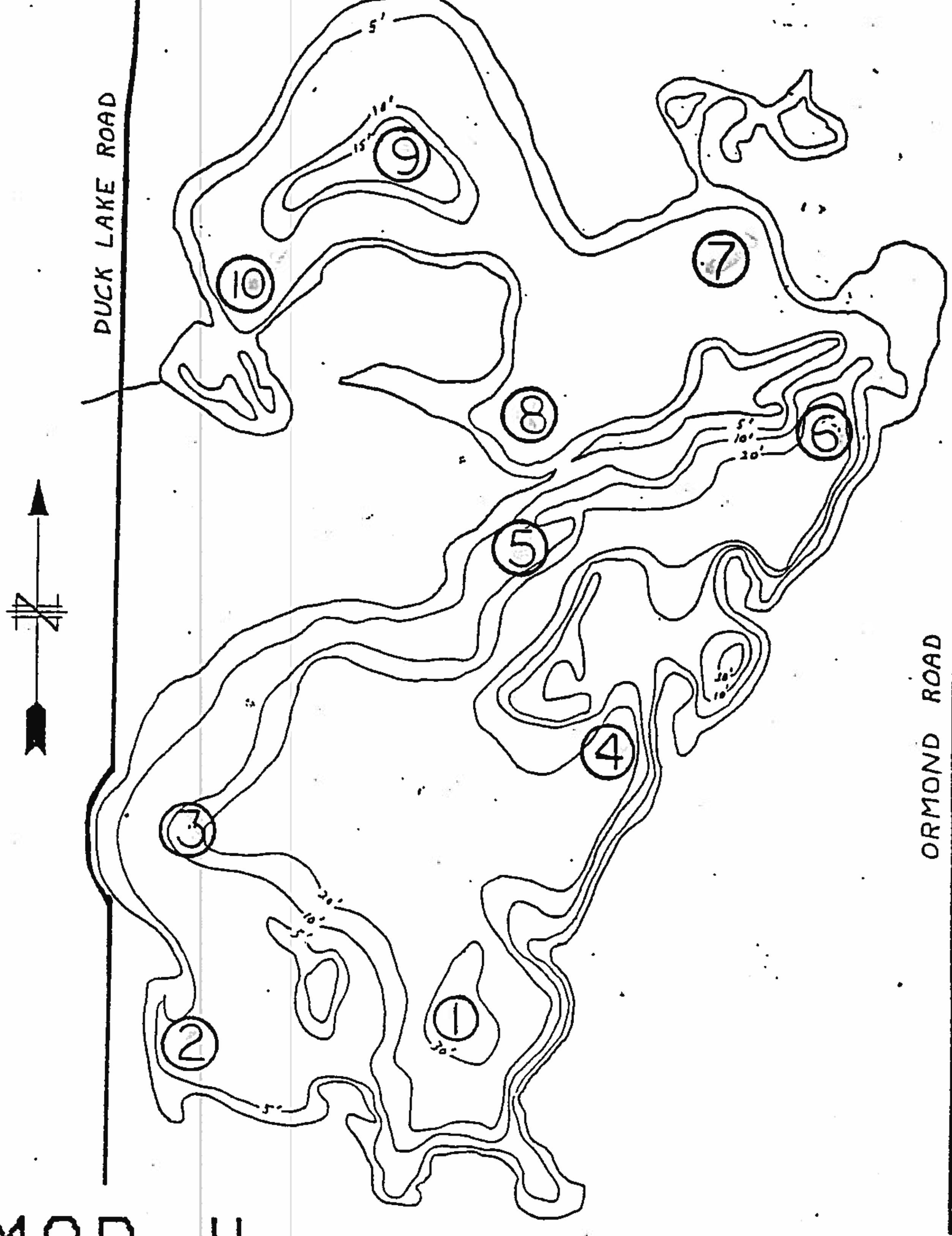
The Lake Water Quality Index (LWQI) used in this study was developed for two reasons:

1) There was no consensus among lake scientists regarding which tests should be run to define the water quality of a lake; and,

2) there was no consensus among lake scientists regarding the meaning of the data collected during lake studies.

The study involved the use of two questionnaires sent out to 555 lake water quality scientists (selected from the membership of the American Society of Limnology and Oceanography). The first questionnaire asked the scientists to indicate which tests they felt would give the best definition of lake water quality. 70% of the questionnaires were returned. The tests most often selected by the scientists became the index parameters. They are:

Dissolved Oxygen (Percent saturation)
Total Phosphate
Secchi Disk depth
Temperature
Conductivity
Chlorophyll a
Total Nitrate
Alkalinity
pH



MAP 4

SAMPLING STATIONS

SCALE 1" = 1033'

WHITE LAKE
540 ACRES
AUGUST 1986

WQI

The second questionnaire, sent out after the first was returned, asked the scientists what the results of the tests <u>they selected</u> as good indicators of lake water quality meant. The above parameters, and the accompanying rating curves were combined into a lake water quality index. The index values range from 1 to 100, with 100 being excellent lake water quality. The index seems to rate lakes about the same way teachers rate students: 90-100 = A, 80-90 = B, 70-80 = C, 60-70 = D, and below 60 = E.

The Lake Water Quality Index value for White Lake ranges from 53 to 90. This indicates that the water quality of White Lake ranges from poor to excellent.

The index sheets show by the low position of the red marks on the thermometer-type rating curves that the problem parameter at the two poor quality sites was a high concentration of chlorophyll. Station 2 had a chlorophyll concentration of 52, while station 8 had a chlorophyll concentration of 44.

The highest index for a southeast Michigan lake studied by the author is 95. The lowest was 27.

<u>A DISCUSSION OF THE INDEX PARAMETERS</u>

TEMPERATURE (AND DISSOLVED OXYGEN AND PHOSPHORUS)

Temperature exerts a wide variety of influences on a lake, such as the separation of layers of water (stratification), solubility of gases, and biological activity.

Variations in the temperature of lake water effectively isolate layers of water in a lake during the summer: (and to a lesser extent in winter). Since water is heaviest at 4 degrees Centigrade (39 degrees Fahrenheit), the cold water remains on the bottom as the surface water warms in summer. Since the warm water is lighter, it remains on the surface. Oxygen readily diffuses from the air to the surface water of a lake, so although warm water holds less oxygen than cold water, high lake surface dissolved oxygen levels are generally maintained. There are instances when this condition could be upset.

For example, bacterial decomposition occurs at a much higher rate in warm water than in cold water. And since warm water holds less oxygen (and other gases) than cold water, the increased use of oxygen by bacteria when they decompose materials, along with the lower amount of oxygen dissolved in warm water, leads to a much greater possibility that the lake oxygen will be depleted.

However, the oxygen in the cold, bottom water can be depleted in late summer, usually by bacterial decomposition of dead plants. This was found to be the case in 98% of southeast Michigan lakes and 85% of northern Michigan lakes studied by the author. This loss of oxygen in the bottom of lakes is important because of the role it plays in phosphorus release from the sediments.

Phosphorus will precipitate (usually in combination with iron) when there is oxygen present in the water. This means that in good quality lakes, the bottom sediments of a lake act as a trap for phosphorus. However, if the oxygen in the bottom water becomes depleted by bacterial decomposition of dead plant material, the phosphorus will become soluble and enter the water column. Once there, it can easily be taken up by plants and algae, which can then create the unsightly surface conditions found in many of the lakes in southern Michigan.

High dissolved oxygen conditions can occur when anaerobic conditions cause large sediment phosphorus releases which produce algal communities. Algae produce oxygen during daytime photosynthesis, so it is possible to have very high concentrations of dissolved oxygen during the late afternoon of a sunny summer day in a eutrophic lake. However, the algae use oxygen the same way animals do, in a process called respiration. It is possible for high concentrations of algae to remove almost all the oxygen in the surface water of a lake or stream during the night. Thus although it would seem that oxygen is in plentiful supply if the sample was taken in the afternoon, if the sample was taken just before daylight, test results might show that there is very little or no oxygen present.

Surface temperatures ranged from 22 to 25°C. The bottom of the deep hole was 19°C. The thermocline, defined as a change in temperature of greater than 1°C per meter was not evident during the sampling period.

DISSOLVED OXYGEN

Dissolved oxygen is the parameter most often selected by lake water quality scientists as being important. Besides its importance in providing oxygen for aquatic organisms to use, oxygen is involved in phenomena such as phosphorus precipitation and release from the lake sediments.

Summer surface dissolved oxygen concentrations for White Lake ranged from 8.1 to 8.7. The oxygen concentration at the 28 foot level in the deep hole was 1.4 milligrams per liter.

TOTAL PHOSPHORUS

Although there are several forms of phosphorus found in lakes, the experts selected total phosphorus as being the most important. This is probably because all forms of phosphorus can be converted to other forms. Currently, most lake scientists feel that phosphorus, which is measured in parts per billion (1 part per billion is one second in 31 years), is the one chemical which might be controlled. If its addition to lake water could be limited, the lake might not become covered with the algal communities so often found in eutrophic lakes. It should be pointed out that if limiting the amount of phosphorus which enters a lake will prevent eutrophic conditions, all of the other nutrients are present in the lake which will permit this condition to occur. In other words, the quality of the lake water is poor, but if phosphorus input is limited, it is hoped that the plants and algae won't grow in excess. 50 parts per billion is considered to be a high value by the Michigan DNR.

Summer surface in-lake phosphorus concentrations ranged from 8 to 18 micrograms per liter, with an average concentration of 14 micrograms per liter. These were somewhat lower values than expected.

TOTAL NITRATE

Nitrate, also measured in the parts per billion range, has traditionally be considered by lake scientists to also be a limiting nutrient. However, nitrates can be made from nitrogen by nitrifying bacteria, lightning, and a variety of other sources. Therefore it is not controllable. The experts felt that any value below 200 parts per billion was excellent in terms of lake water quality. The highest value found by the author was 633 parts per billion in Inchwagh lake in Livingston county, a lake that has a sewage treatment plant discharging into it.

White Lake had nitrate concentrations below 10 micrograms per liter. The lake appeared to be nitrate limited during the sampling period.

HYDROGEN ION CONCENTRATION (pH) AND ALKALINITY

pH has traditionally been a measure of water quality. Today it is an excellent indicator of the effects of acid rain on the lake. About 95% of the rain events in southeastern Michigan are below a pH of 5.6 and are thus considered acid. There seems to be no lakes in southeast Michigan which are being affected by acid rain. Most lakes have a pH value between 7.5 and 9.

Summer surface pH values for White Lake were exceedingly uniform at 8.2 at all stations.

Alkalinity is a measure of the ability of the water to absorb acids (or bases) without changing the hydrogen ion concentration (pH). It is in effect, a chemical sponge. In most Michigan lakes, alkalinity is due to the presence of carbonates and bicarbonates which were introduced into the lake from ground water sources. In lower Michigan, acidification of the lakes should not be a problem because of the high alkalinity concentrations. The presence of carbonates in water also provides a source of carbon which plants may use for photosynthesis.

White Lake had an average summer surface alkalinity of 123 milligrams per liter with a range from 119 to 132. The alkalinity values are normal for a southeast Michigan lake. These values also mean that White Lake will not be affected by acid rain in the foreseeable future.

CONDUCTIVITY

Conductivity, measured with a meter, detects the capacity of a water to conduct an electric current. More importantly, however, conductivity measures the amount of materials dissolved in the water, since only dissolved materials will permit an electric current to flow. Pure water will not conduct an electric current. It is the perception of the experts that poor quality water has more dissolved materials than does good quality water. We concur with this perception.

The summer surface conductivity for White Lake averaged 344 with a range of 340 to 360 at the surface. These values, which fall in the range of normal values for southeast Michigan lakes shows that the chemical makeup of White Lake water changes little.

SECCHI DISK TRANSPARENCY (originally Secchi's disk)

In 1865, Angelo Secchi of Rome, Italy devised a 20 centimeter white disk for studying the transparency of the water in the Mediterranean Sea. Later a limnologist named Whipple divided the disk into the black and white quadrants which many are familiar with today.

To take a Secchi disk reading, the disk is lowered into the water on the shaded side of the boat to a point where it disappears. Then it is raised to a point where it is visible. The average of these two readings is the Secchi disk depth. It should be pointed out that the reading should be taken between 10 AM and 4 PM. Rough water will give slightly shallower readings than smooth water. Sunny days will give slightly deeper readings than cloudy days. Wave action influences the visibility of the disk more than sunny or cloudy days.

If there are sample sites where the lake is too shallow and the disk can still be seen when it rests on the bottom, the reading should be taken at a near-by site. Since the sampling procedure is supposed to be designed to obtain representative samples, the concept of moving the boat to an area where a Secchi disk reading can be properly taken is valid.

The Secchi disk transparency is a lake water quality test widely used and accepted by lake scientists. The experts generally felt that the greater the Secchi disk depth, the better quality the water. However, one Canadian scientist pointed out that acid lakes have very deep Secchi disk values. (Would you consider a very clear lake a good quality lake, even if it had no fish in it? It would be almost like your swimming pool.) Most lakes in southeast Michigan have Secchi disk readings of less than ten feet. Secchi disk readings ranged between 8 and 11 feet, with an average of 10 feet. These summer values are higher than normal for a southeast Michigan lake.

CHLOROPHYLL a

Chlorophyll a is used by lake scientists as a measure of the biological productivity of the water. The experts felt the best quality water had about 5 milligrams per cubic meter of Chlorophyll a. They felt that very low levels of Chlorophyll were not desirable, probably from the point of view that there was a good chance that there were very few plants (and animals) living in the lake. On the other hand, they felt that high levels of Chlorophyll a were indicative of poor lake water quality. The highest Chlorophyll a found by the author in southeast Michigan lakes was 63 milligrams per cubic meter. However readings as high as 160 milligrams per cubic meter have been reported.

White Lake had an average summer chlorophyll a concentration of 26 micrograms per liter, with a range from 10 to 52 micrograms per liter. These are high chlorophyll a concentrations, indicative of a lake with high biological productivity.

THE LAKE WATER QUALITY INDEX (LWQI) CALCULATION SHEETS

The Lake Water Quality Index calculation sheets which follow were developed to show graphically what the results of nine different lake water quality tests selected by a large group of lake water quality scientists meant in terms of lake water quality.

HOW TO READ THE LAKE WATER QUALITY INDEX CALCULATION SHEETS

The calculation sheets show the tests selected by the panel and the method of relating the test results to the concept of lake water quality. The various test names are listed at the top of the sheet.

The thermometer-type rating curves convert the test results to a uniform 0-100 lake water quality rating. The quality rating for each test is found inside the thermometer.

The index combines all of the individual quality ratings into a single Lake Water Quality Index. The index ranges from 1 (very poor lake water quality) to 100 (excellent lake water quality). The index seems to rate lakes about the same way professors rate students; 90-100 = Excellent, 80-90 = good, 70-80 = fair, 60-70 = poor, and below 60, failing.

The index is portrayed in three different ways, as a number ranging between 1 and 100 in the circle marked LWQI, and by a color and position on the sheet edge scale. The purpose of the sheet-edge scale is to review quickly large numbers of lakes or test sites within a lake and determine how the quality of the various lakes or sites compare with one another.

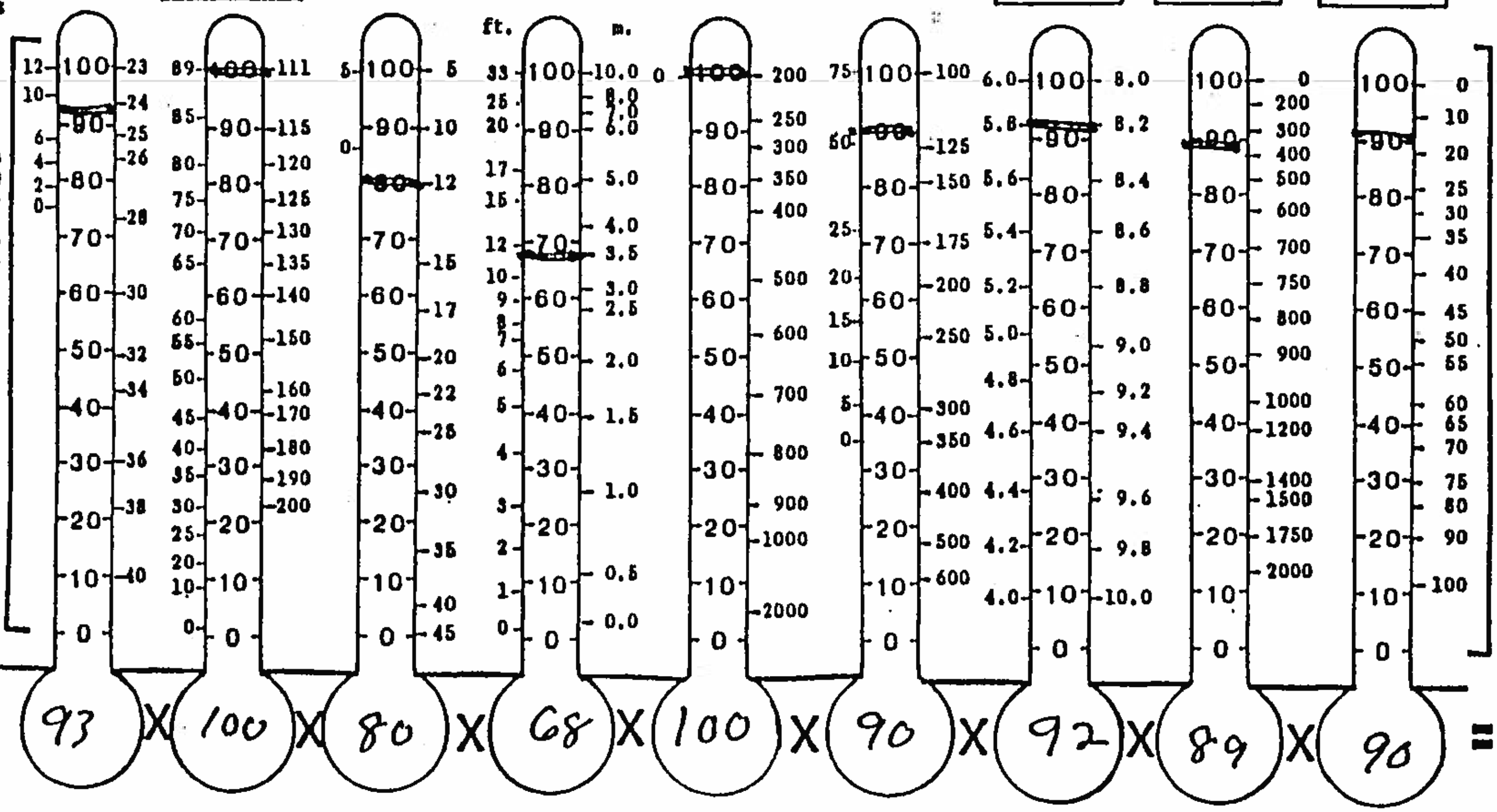
The position of the red line on the thermometer-type rating scales permits determination of the parameter (or parameters) which cause the index to be depressed. The lower the red line, the greater the problem. A glance at the top of the problem thermometer-type rating scale identifies the test and the test results. The rating scales also permit determination of what test results would be considered excellent in terms of lake water quality by the panel of experts surveyed.

CALCULATION SHEET for the UNWEIGHTED MULTIPLICATIVE WATER QUALITY INDEX for LAKES

w. fusilier

TEMPERATURE IN °C	DISSOLVED OXYGEN, % SATURATION	CHLOROPHYLL a mg/m³	SECCHI DISK DEPTH	NO_3— N ug/l	TOTAL ALKALINITY mg/l	pH su	SPECIFIC CONDUCTIVITY umhos/cm @ 25°C	TOTAL PO_4-P ug/l
24	8.5/8.5 100	12	11 ft	<10	121	8.2	360	17

QUALITY RATING CURVES (Individual quality ratings never exceed 100)



$\sqrt[9]{93 \times 100 \times 80 \times 68 \times 100 \times 90 \times 92 \times 89 \times 90} = 89$

LWQI 89

HYPOLIMNION	
19	1.4
TEMP. °C	D.O. mg/l

x 42% Mineral
WEED COVER | BOTTOM TYPE

HURON
DRAINAGE BASIN

1253AC ~~miles²~~ kilometers²
DRAINAGE AREA

6864 ~~meters³~~ acre-feet
LAKE VOLUME

OAKLAND, MI
COUNTY & STATE

White Lake
Highland
TOWNSHIP

Water Quality I.
ANALYST

32 feet ~~meters~~
LAKE DEPTH

540 acres ~~hectares~~
LAKE AREA

SET THE PARAMETER QUALITY RATING AT 1 IF THE EXTERNAL EXTREME VALUE RANGE IS EXCEEDED

LAKE WATER QUALITY INDEX

0–15	15–25	25–35	35–45	45–55	55–65	65–75	75–85	85–100
red	red	orange	orange	yellow	yellow	green	green	blue

DATE 12 AUG 86

STATION 1

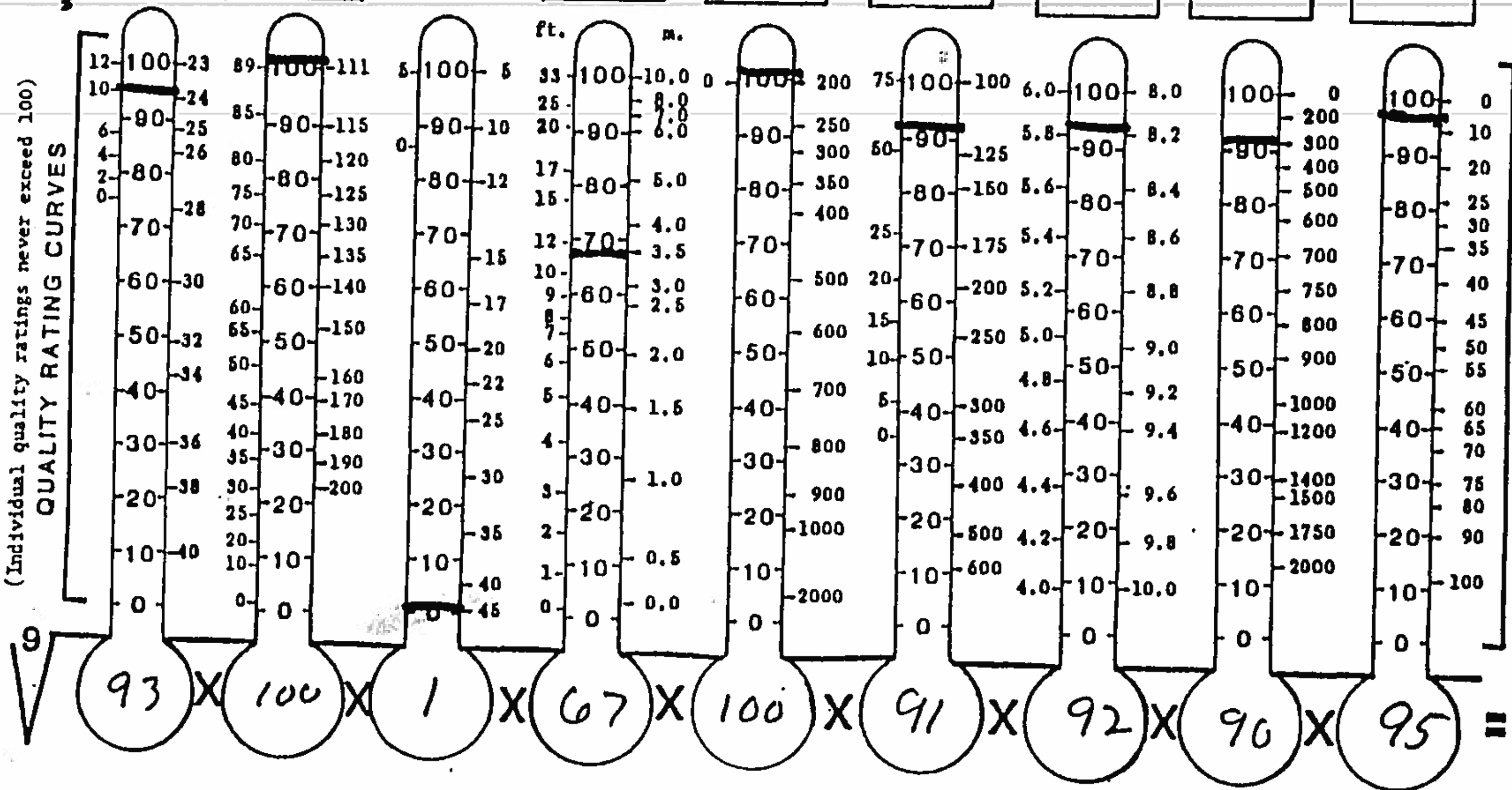
LAKE White Lake

41

CALCULATION SHEET for the UNWEIGHTED M TIPLICATIVE WATER QUALITY INDEX for LAKES

w. fusilier

TEMPERATURE IN °C	DISSOLVED OXYGEN, % SATURATION	CHLOROPHYLL a mg/m³	SECCHI DISK DEPTH (ft / m.)	NO_3 — N ug/l	TOTAL ALKALINITY mg/l	pH su	SPECIFIC CONDUCTIVITY umhos/cm @ 25°C	TOTAL PO_4-P ug/l
24	8.6/8.5 — 106	52	11 ft	<10	119	8.2	340	8
93	100	1	67	100	91	92	90	95



$\sqrt[9]{93 \times 100 \times 1 \times 67 \times 100 \times 91 \times 92 \times 90 \times 95} = 55$

LWQI: 55

HYPOLIMNION

TEMP. °C	D.O. mg/l
—	—
—	x 49% Minerva

WEED COVER | BOTTOM TYPE

HURON

DRAINAGE BASIN

1253 AC miles² kilometers²

DRAINAGE AREA

6864 meters³ acre-feet

LAKE VOLUME

OAKLAND, MI

COUNTY & STATE

White Lake

TOWNSHIP

WQI

ANALYST

32' feet meters

LAKE DEPTH

540 acres hectares

LAKE AREA

SET THE PARAMETER QUALITY RATING AT 1 IF THE EXTERNAL EXTREME VALUE RANGE IS EXCEEDED

LAKE WATER QUALITY INDEX

0–15	15–25	25–35	35–45	45–55	55–65	65–75	75–85	85–100
red	red orange	orange	orange yellow	yellow	yellow green	green	green blue	blue

DATE 12 AUG 86

STATION 2

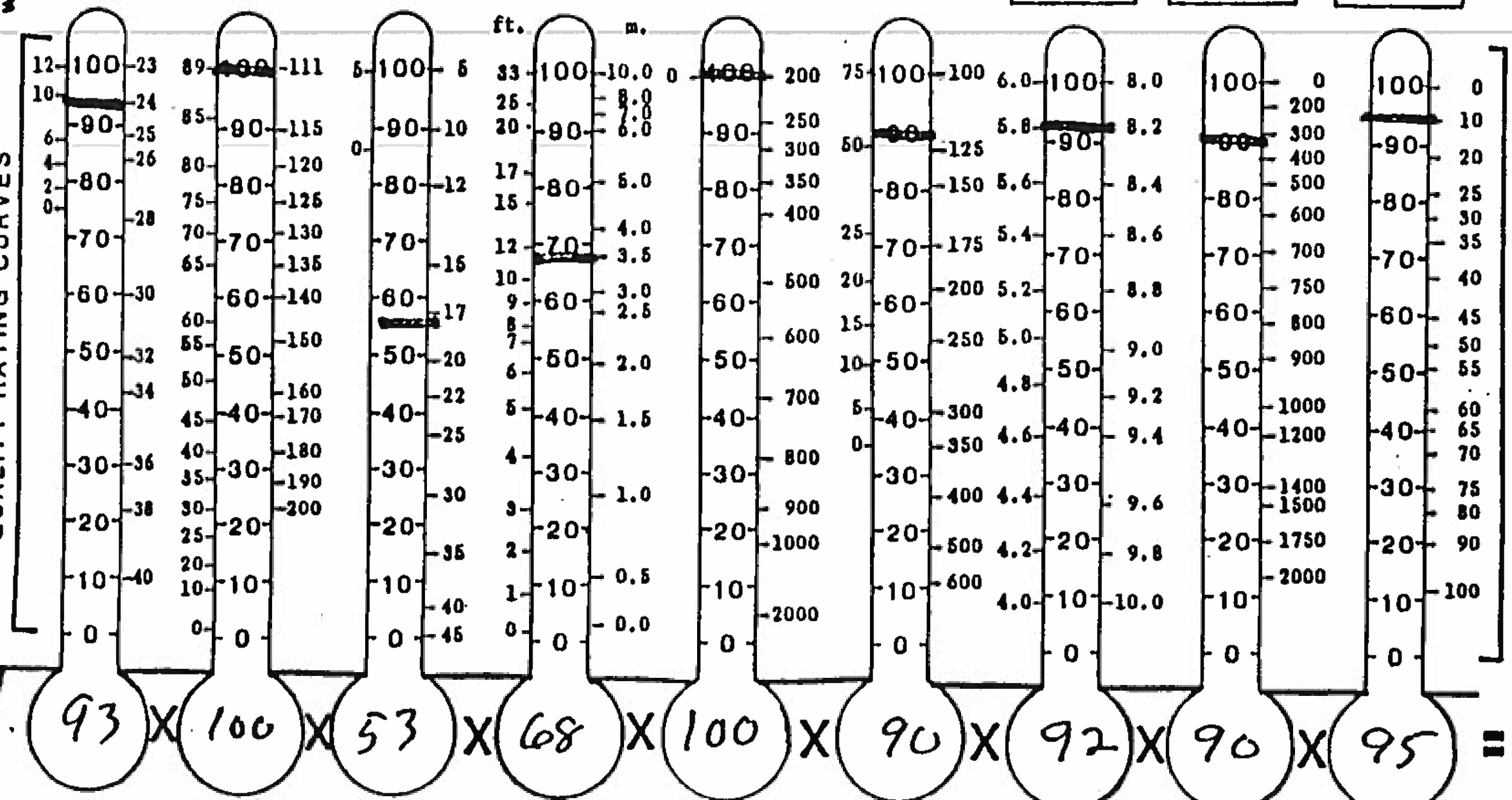
LAKE White Lake

18

CALCULATION SHEET for the UNWEIGHTED MULTIPLICATIVE WATER QUALITY INDEX for LAKES

w. fusilier

TEMPERATURE IN °C	DISSOLVED OXYGEN, % SATURATION	CHLOROPHYLL a mg/m³	SECCHI DISK DEPTH	NO₃— N ug/l	TOTAL ALKALINITY mg/l	pH su	SPECIFIC CONDUCTIVITY umhos/cm @ 25°C	TOTAL PO₄-P ug/l
24	8.8/8.5 / 164	10	11 ft	<10	121	8.2	340	8



$\sqrt[9]{93 \times 100 \times 53 \times 68 \times 100 \times 90 \times 92 \times 90 \times 95} = 85$

LWQI 85

SET THE PARAMETER QUALITY RATING AT 1 IF THE EXTERNAL EXTREME VALUE RANGE IS EXCEEDED

HYPOLIMNION

TEMP. °C	D.O. mg/l
0	x

32% Mineral

WEED COVER | BOTTOM TYPE

HURON
DRAINAGE BASIN

1253AC miles² kilometers²
DRAINAGE AREA

6864 ~~meters³~~ acre-feet
LAKE VOLUME

OAKLAND, MI
COUNTY & STATE

White Lake Highland
TOWNSHIP

Water Quality I.
ANALYST

32 feet ~~meters~~
LAKE DEPTH

540 acres ~~hectares~~
LAKE AREA

LAKE WATER QUALITY INDEX

0–15	15–25	25–35	35–45	45–55	55–65	65–75	75–85	85–100
red	red orange	orange	orange yellow	yellow	yellow green	green	green blue	blue

DATE 12 AUG 86

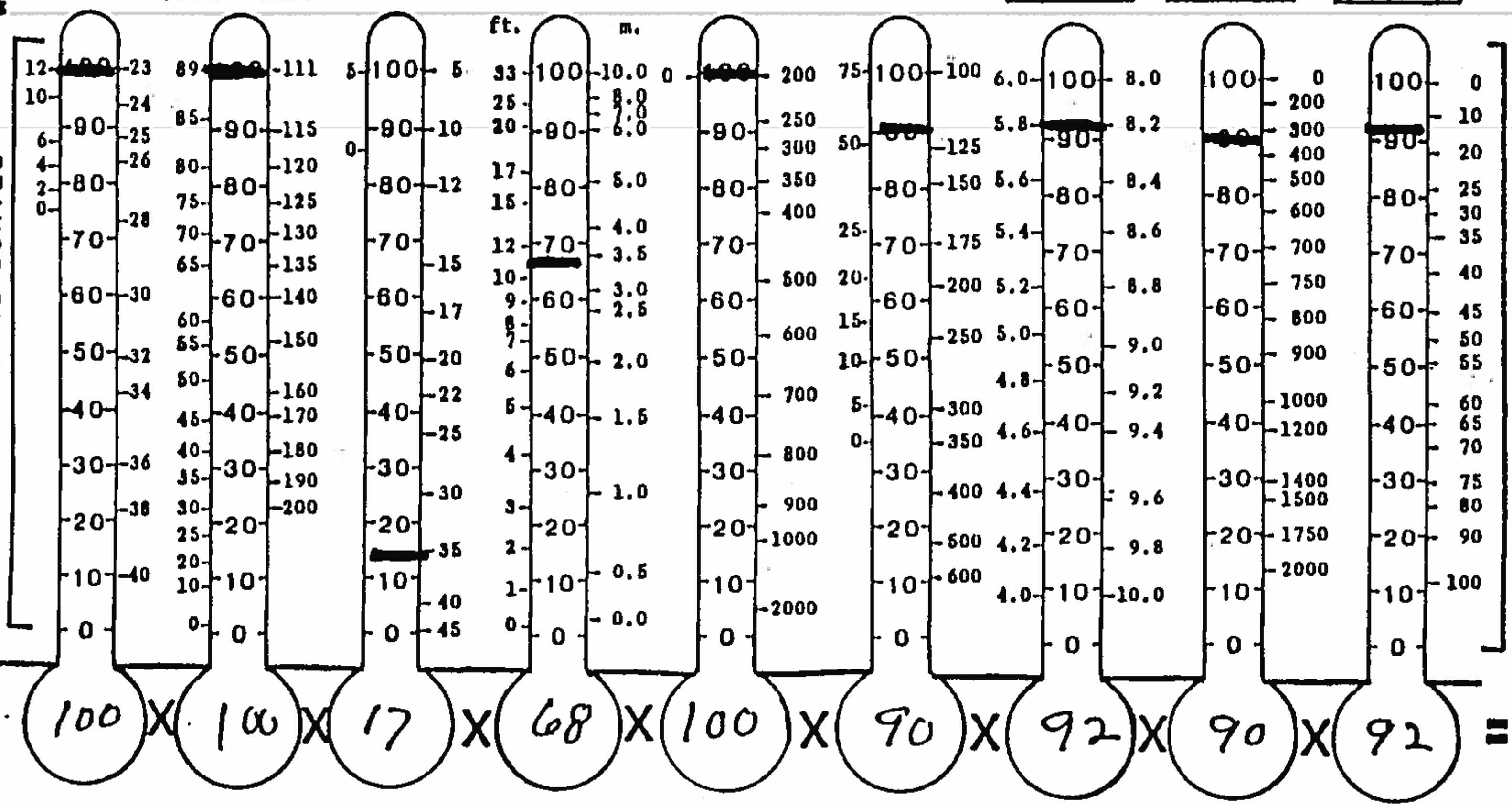
STATION 3

LAKE White Lake

CALCULATION SHEET for the UNWEIGHTED MULTIPLICATIVE WATER QUALITY INDEX for LAKES

W. fusilier

TEMPERATURE IN °C	DISSOLVED OXYGEN, % SATURATION	CHLOROPHYLL a mg/m³	SECCHI DISK DEPTH	NO_3— N ug/l	TOTAL ALKALINITY mg/l	pH su	SPECIFIC CONDUCTIVITY umhos/cm @ 25°C	TOTAL PO_4-P ug/l
23	8.5/8.7 98	34	11 ft	<10	121	8.2	340	8



$\sqrt[9]{100 \times 100 \times 17 \times 68 \times 100 \times 90 \times 92 \times 90 \times 92} = 75$ (LWQI)

HYPOLIMNION

TEMP. °C	D.O. mg/l

x 96% Mineral
WEED COVER | BOTTOM TYPE

HURON
DRAINAGE BASIN

1253AC ~~miles²~~ kilometers²
DRAINAGE AREA

6864 ~~meters³~~ acre-feet
LAKE VOLUME

OAKLAND, MI
COUNTY & STATE

White Lake
Highland
TOWNSHIP

Water Quality I.
ANALYST

32 feet ~~meters~~
LAKE DEPTH

540 acres ~~hectares~~
LAKE AREA

SET THE PARAMETER QUALITY RATING AT 1 IF THE EXTERNAL EXTREME VALUE RANGE IS EXCEEDED

LAKE WATER QUALITY INDEX

0–15	15–25	25–35	35–45	45–55	55–65	65–75	75–85	85–100
red	red orange	orange	orange yellow	yellow	yellow green	green	green blue	blue

DATE 12 AUG 86

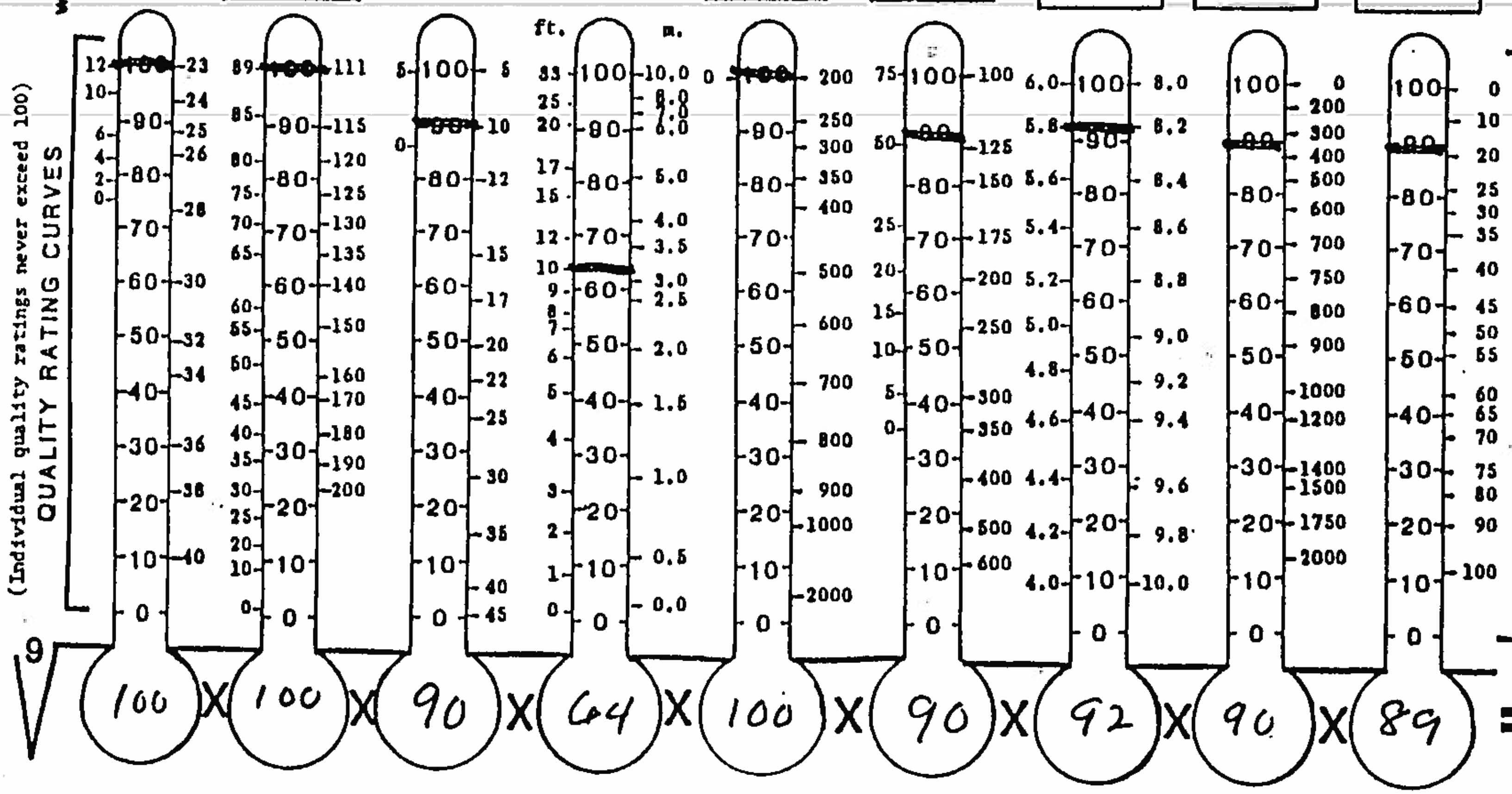
STATION 4

LAKE White Lake

CALCULATION SHEET for the UNWEIGHTED MULTIPLICATIVE WATER QUALITY INDEX for LAKES

W. fusilier

TEMPERATURE IN °C	DISSOLVED OXYGEN, % SATURATION	CHLOROPHYLL a mg/m³	SECCHI DISK DEPTH	NO₃— N ug/l	TOTAL ALKALINITY mg/l	pH su	SPECIFIC CONDUCTIVITY umhos/cm @ 25°C	TOTAL PO₄-P ug/l
23	8.8/8.7 101	10	10 ft	<10	121	8.2	340	18



$\sqrt[9]{100 \times 100 \times 90 \times 64 \times 100 \times 90 \times 92 \times 90 \times 89} = 90$

LWQI: 90

HYPOLIMNION

TEMP. °C	D.O. mg/l
	x 4.8 9. Minrv

WEED COVER / BOTTOM TYPE: HURON

DRAINAGE BASIN: 1253 AC miles² ~~kilometers²~~

DRAINAGE AREA: 6864 ~~meters³~~ acre-feet

LAKE VOLUME: OAKLAND, MI

COUNTY & STATE: White Lake

TOWNSHIP: WQI

ANALYST: 32' feet ~~meters~~

LAKE DEPTH: 540 acres hectares

LAKE AREA

SET THE PARAMETER QUALITY RATING AT 1 IF THE EXTERNAL EXTREME VALUE RANGE IS EXCEEDED

LAKE WATER QUALITY INDEX

0–15	15–25	25–35	35–45	45–55	55–65	65–75	75–85	85–100
red	red orange	orange	orange yellow	yellow	yellow green	green	green blue	blue

DATE 12 AUG 86

STATION 5

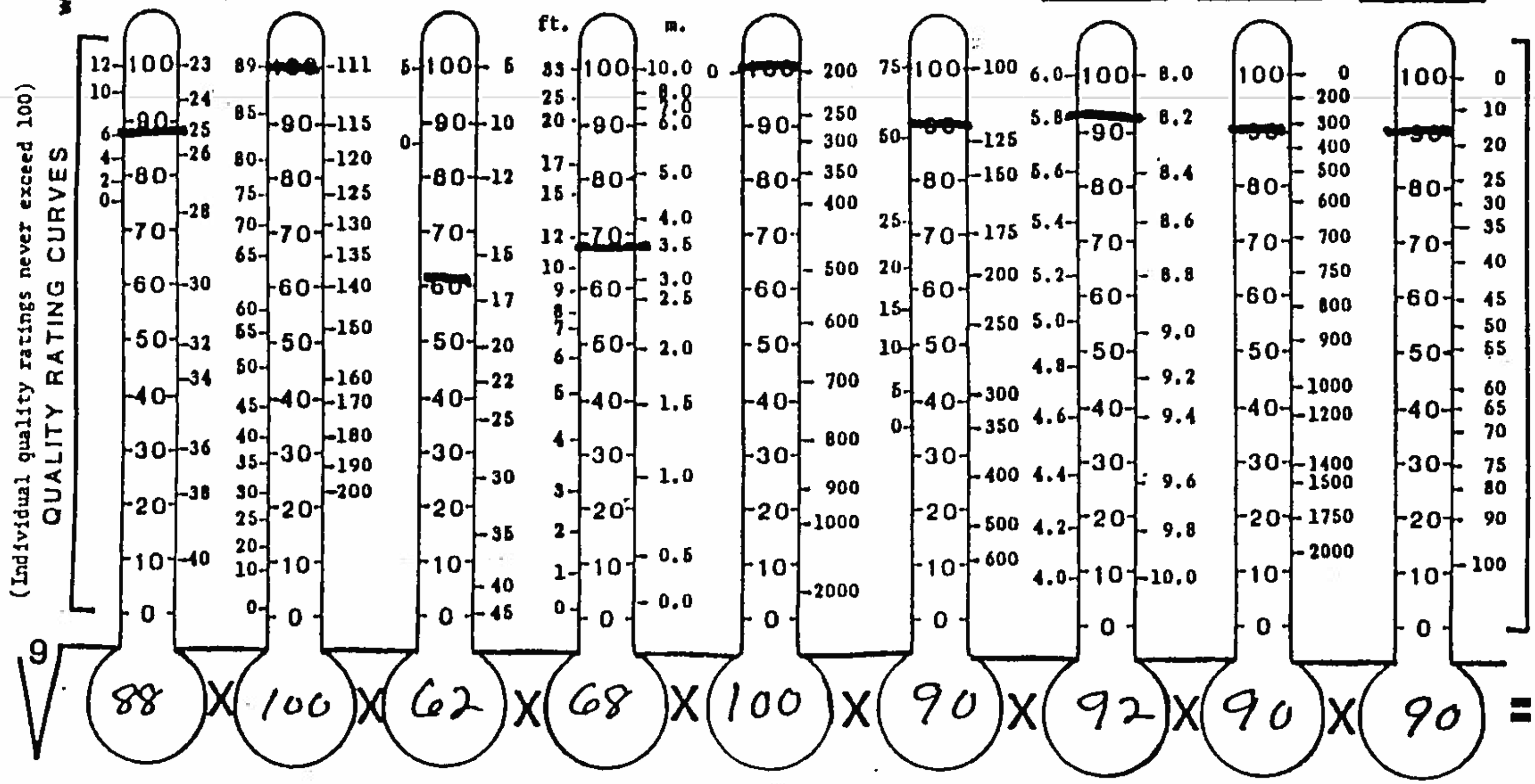
LAKE White lake

21

CALCULATION SHEET for the UNWEIGHTED MULTIPLICATIVE WATER QUALITY INDEX for LAKES

w. fusilier

TEMPERATURE IN °C	DISSOLVED OXYGEN, % SATURATION	CHLOROPHYLL a mg/m³	SECCHI DISK DEPTH	NO_3— N ug/1	TOTAL ALKALINITY mg/1	pH su	SPECIFIC CONDUCTIVITY umhos/cm @ 25°C	TOTAL PO_4-P ug/1
25	8.4/8.4 100	16	11 ft	<10	121	8.2	340	17



$\sqrt[9]{88 \times 100 \times 62 \times 68 \times 100 \times 90 \times 92 \times 90 \times 90} = 86$

LWQI 86

HYPOLIMNION

TEMP. °C	D.O. mg/l
x	43% Mineral

WEED COVER | BOTTOM TYPE

HURON
DRAINAGE BASIN

1253AC miles² / kilometers²
DRAINAGE AREA

6864 meters³ / acre-feet
LAKE VOLUME

OAKLAND, MI
COUNTY & STATE

White Lake
Highland
TOWNSHIP

water Quality I.
ANALYST

32 feet / meters
LAKE DEPTH

540 acres / hectares
LAKE AREA

SET THE PARAMETER QUALITY RATING AT 1 IF THE EXTERNAL EXTREME VALUE RANGE IS EXCEEDED.

LAKE WATER QUALITY INDEX

0–15	15–25	25–35	35–45	45–55	55–65	65–75	75–85	85–100
red	red orange	orange	orange yellow	yellow	yellow green	green	green blue	blue

DATE 12 Aug 86

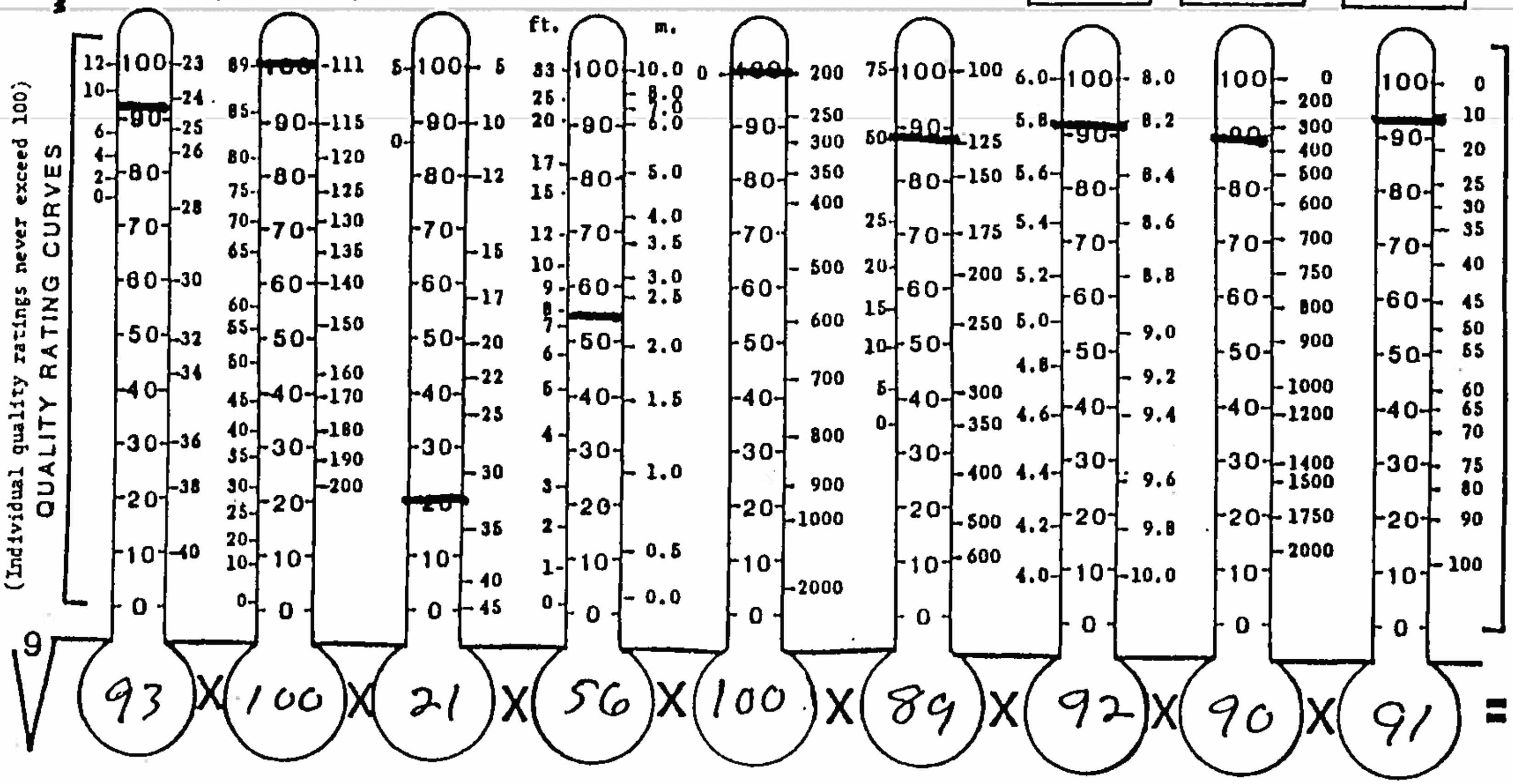
STATION 6

LAKE White Lake

CALCULATION SHEET for the UNWEIGHTED MULTIPLICATIVE WATER QUALITY INDEX for LAKES

w. fusilier

TEMPERATURE IN °C	DISSOLVED OXYGEN, % SATURATION	CHLOROPHYLL a mg/m³	SECCHI DISK DEPTH	NO_3— N ug/l	TOTAL ALKALINITY mg/l	pH su	SPECIFIC CONDUCTIVITY umhos/cm @ 25°C	TOTAL PO_4-P ug/l
24	8.1/8.5 95	32	8 ft	<10	123	8.2	340	16



$\sqrt[9]{93 \times 100 \times 21 \times 56 \times 100 \times 89 \times 92 \times 90 \times 91}$ = LWQI 75

HYPOLIMNION

TEMP. °C	D.O. mg/l

x 60% Mineral
WEED COVER | BOTTOM TYPE

HURON
DRAINAGE BASIN

1253AC miles² / kilometers²
DRAINAGE AREA

6864 meters³ / acre-feet
LAKE VOLUME

OAKLAND, MI
COUNTY & STATE

White Lake / Highland
TOWNSHIP

water Quality I.
ANALYST

32 feet / meters
LAKE DEPTH

540 acres / hectares
LAKE AREA

SET THE PARAMETER QUALITY RATING AT 1 IF THE EXTERNAL EXTREME VALUE RANGE IS EXCEEDED

LAKE WATER QUALITY INDEX

0–15	15–25	25–35	35–45	45–55	55–65	65–75	75–85	85–100
red	red orange	orange	orange yellow	yellow	yellow green	green	green blue	blue

DATE 12 Aug 86

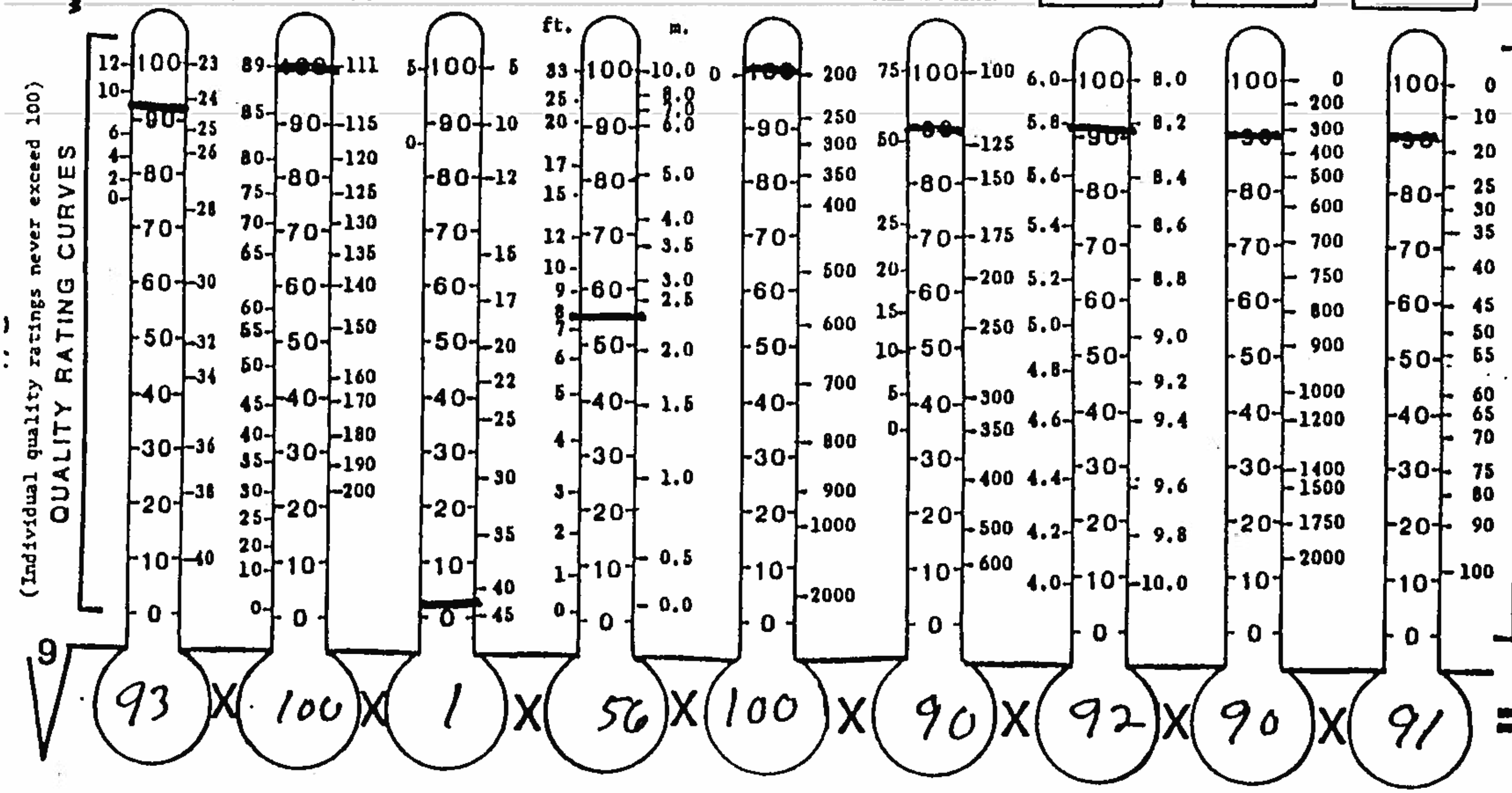
STATION 7

LAKE White Lake

CALCULATION SHEET for the UNWEIGHTED MULTIPLICATIVE WATER QUALITY INDEX for LAKES

W. fusilier

TEMPERATURE IN °C	DISSOLVED OXYGEN, % SATURATION	CHLOROPHYLL a mg/m³	SECCHI DISK DEPTH	NO_3— N ug/l	TOTAL ALKALINITY mg/l	pH su	SPECIFIC CONDUCTIVITY umhos/cm @ 25°C	TOTAL PO_4-P ug/l
24	8.2/8.5 96	44	8 ft	<10	121	8.2	340	16



$\sqrt[9]{93 \times 100 \times 1 \times 56 \times 100 \times 90 \times 92 \times 90 \times 91} = 53$

LWQI 53

HYPOLIMNION

TEMP. °C	D.O. mg/l
	x 56% Mineral

WEED COVER | BOTTOM TYPE

HURON
DRAINAGE BASIN

1253AC miles² kilometers²
DRAINAGE AREA

6864 ~~meters³~~ acre-feet
LAKE VOLUME

OAKLAND, MI
COUNTY & STATE

White Lake
Highland
TOWNSHIP

Water Quality I.
ANALYST

32 feet ~~meters~~
LAKE DEPTH

540 acres ~~hectares~~
LAKE AREA

SET THE PARAMETER QUALITY RATING AT 1 IF THE EXTERNAL EXTREME VALUE RANGE IS EXCEEDED

LAKE WATER QUALITY INDEX

<15	15–25	25–35	35–45	45–55	55–65	65–75	75–85	85–100
red	red orange	orange	orange yellow	yellow	yellow green	green	green blue	blue

DATE 12 Aug 86

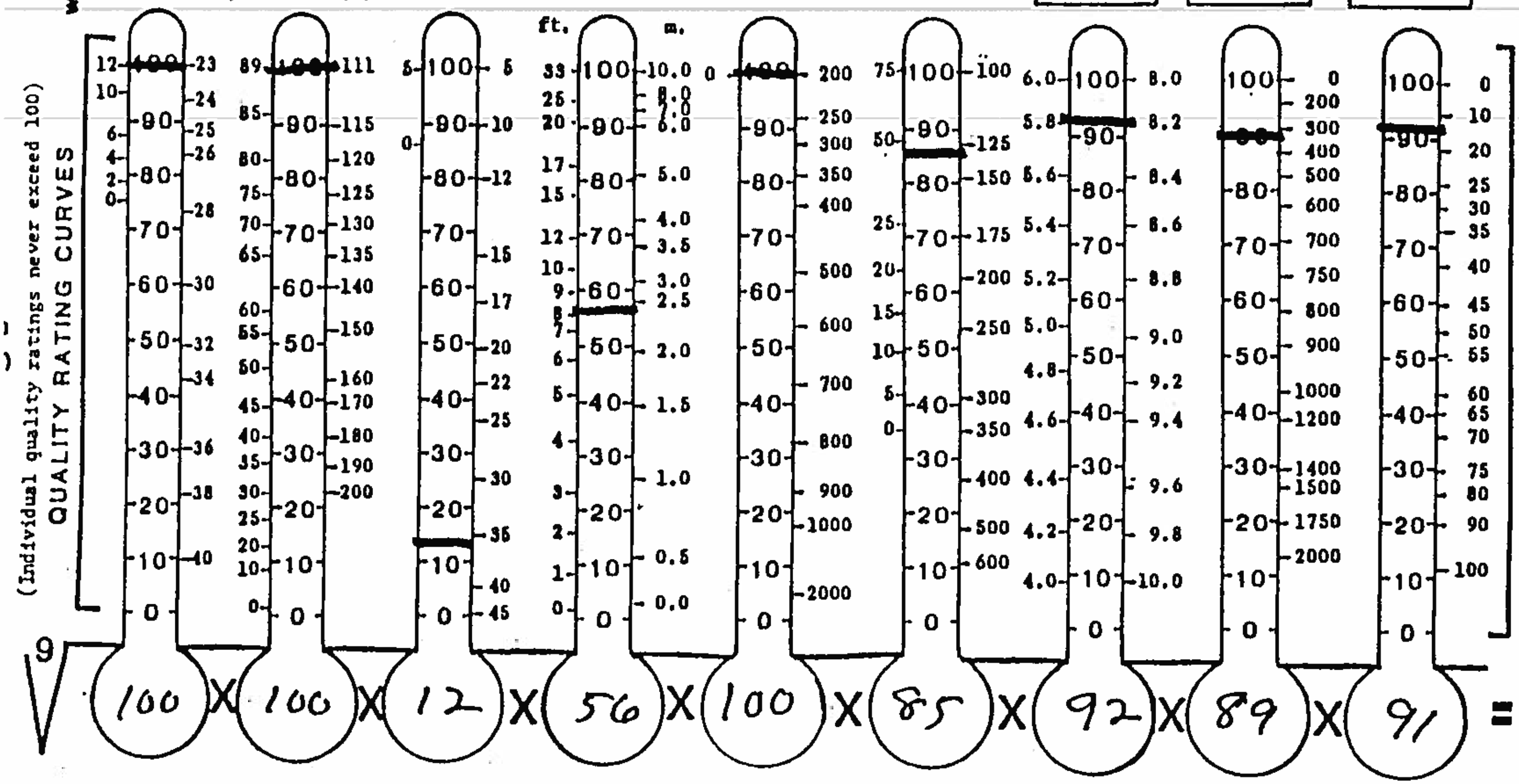
STATION 8

LAKE White Lake

CALCULATION SHEET for the UNWEIGHTED MULTIPLICATIVE WATER QUALITY INDEX for LAKES

W. fusilier

TEMPERATURE IN °C	DISSOLVED OXYGEN, % SATURATION	CHLOROPHYLL a mg/m³	SECCHI DISK DEPTH	NO₃— N ug/1	TOTAL ALKALINITY mg/1	pH su	SPECIFIC CONDUCTIVITY umhos/cm @ 25°C	TOTAL PO₄-P ug/1
22	8.5/8.8 97	36	8 ft	<10	132	8.2	350	16



HYPOLIMNION	
TEMP. °C	D.O. mg/l
x39% Mineral	
WEED COVER	BOTTOM TYPE
HURON	
DRAINAGE BASIN	
1253AC	miles² kilometers²
DRAINAGE AREA	
6864	~~meters³~~ acre-feet
LAKE VOLUME	
OAKLAND, MI	
COUNTY & STATE	
White Lake Highland	
TOWNSHIP	
Water Quality I.	
ANALYST	
32	feet ~~meters~~
LAKE DEPTH	
540	acres ~~hectares~~
LAKE AREA	

SET THE PARAMETER QUALITY RATING AT 1 IF THE EXTERNAL EXTREME VALUE RANGE IS EXCEEDED

LAKE WATER QUALITY INDEX

0–15	15–25	25–35	35–45	45–55	55–65	65–75	75–85	85–100
red	red orange	orange	orange yellow	yellow	yellow green	green	green blue	blue

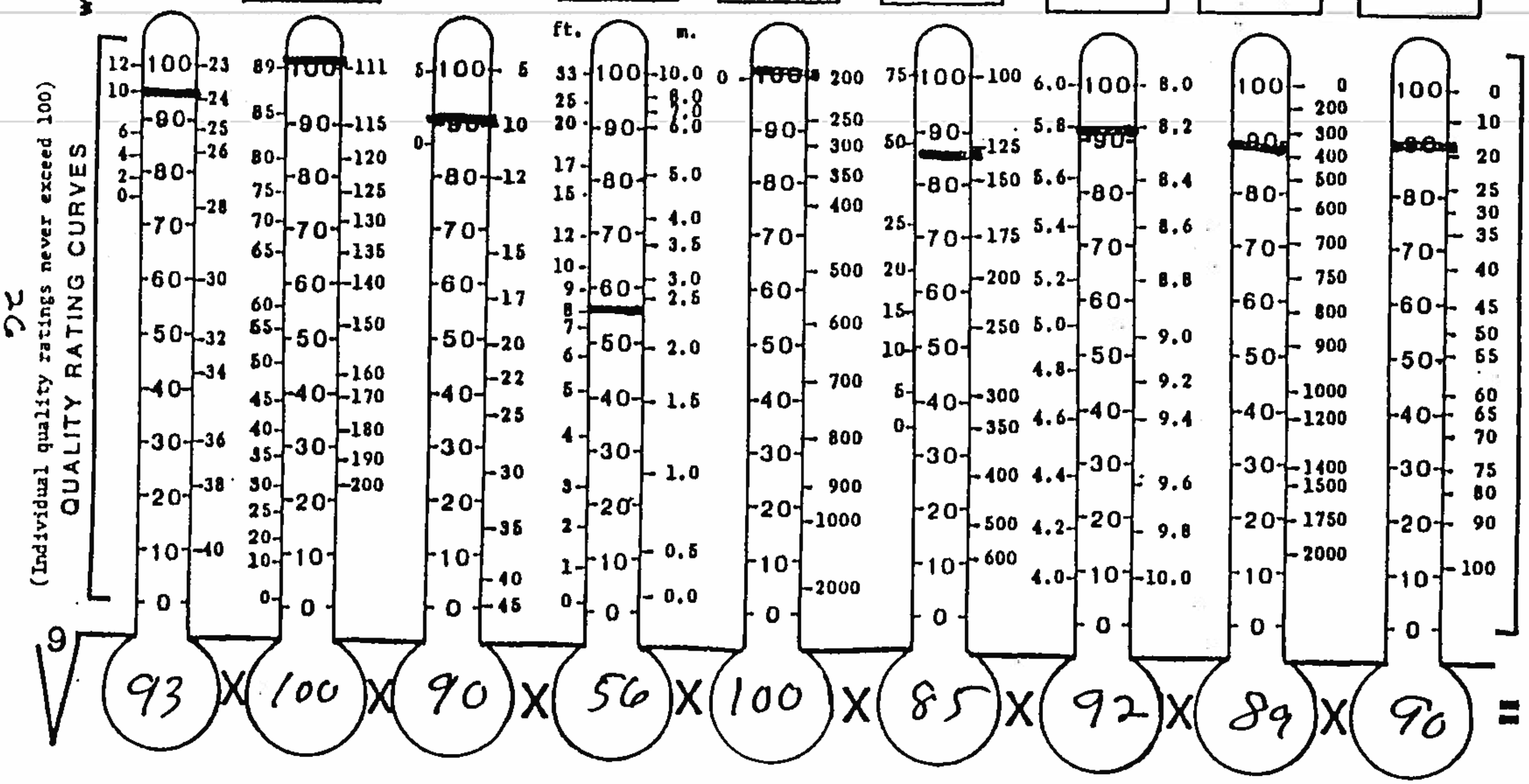
DATE 12 Aug 86

STATION 9

LAKE White Lake

CALCULATION SHEET for the UNWEIGHTED MULTIPLICATIVE WATER QUALITY INDEX for LAKES

Parameter	Value	Quality rating
TEMPERATURE IN °C	24	93
DISSOLVED OXYGEN, % SATURATION	8.7/85 / 102	100
CHLOROPHYLL a mg/m³	10	90
SECCHI DISK DEPTH (ft / m.)	8 ft	56
NO_3— N ug/l	<10	100
TOTAL ALKALINITY mg/l	132	85
pH su	8.2	92
SPECIFIC CONDUCTIVITY umhos/cm at 25°C	350	89
TOTAL PO_4-P ug/l	17	90



$$\sqrt[9]{93 \times 100 \times 90 \times 56 \times 100 \times 85 \times 92 \times 89 \times 90} = 87$$

LWQI 87

HYPOLIMNION

TEMP. °C	D.O. mg/l

x 90% Mineral

WEED COVER | BOTTOM TYPE

HURON
DRAINAGE BASIN

1253AC miles² / kilometers²
DRAINAGE AREA

6864 ~~meters³~~ acre-feet
LAKE VOLUME

OAKLAND, MI
COUNTY & STATE

White Lake Highland
TOWNSHIP

Water Quality I.
ANALYST

32 feet / ~~meters~~
LAKE DEPTH

540 acres / ~~hectares~~
LAKE AREA

SET THE PARAMETER QUALITY RATING AT 1 IF THE EXTERNAL EXTREME VALUE RANGE IS EXCEEDED

LAKE WATER QUALITY INDEX

0–15	15–25	25–35	35–45	45–55	55–65	65–75	75–85	85–100
red	red orange	orange	orange yellow	yellow	yellow green	green	green blue	blue

DATE 12 AUG 86

STATION 10

LAKE White Lake

NUTRIENT BUDGETS

Calculating a theoretical nutrient budget can help lake residents understand the sources, sinks, pathways and amounts of nutrients which can cause unwanted plant conditions in their lake. Although nitrogen and phosphorus are both nutrients, phosphorus, more than any other element, has been identified as the key element for triggering plant growth. This is because it is relatively scarce in the environment, and it is the one nutrient which man can control. Nitrogen is less often considered in nutrient budget calculations because it can be fixed in the environment by a variety of mechanisms, such as lightning and/or bacteria, thus it is pretty much uncontrollable.

Currently, most people involved in lake management feel that if the amount of phosphorus in a lake could be reduced, the lake water quality problems will be less.

A NUTRIENT BUDGET FOR WHITE LAKE

The following is a theoretical nutrient budget for White Lake. The following assumptions are being made when calculating the nutrient budget of White Lake.

The following data (and sources) were used in the nutrient budget calculations.

- Lake volume = 6864 acre feet (SEMCOG)
  299 million cubic feet (calculated)
  2.237 million gallons (calculated)
  18.65 billion pounds (calculated)

- White Lake drainage area. including lake = 540 acres. (Marsh & Borton, 1974)

- Average flow from lake = 1.2 cubic feet per second

- Summer in-lake mean phosphorus concentration = 14 ug/l (WQI)

- There are 490 homes within 300 feet of the White Lake shoreline. (Cleary Engineering)

- Water yield per square mile = .62 cfs (USGS. 1972)

- Assuming plug flow. the lake flushes once every 9.5 years.

- Average daily per capita water use = 45.6 gallons (USEPA. 1980).

- Mean phosphorus concentration in domestic waste water = 23 milligrams per liter (USEPA. 1980).

- Yearly household phosphorus released = 9.58 pounds (45.6 gallons X 3 persons X 8.34# X 365 X 23/1,000,000 = 9.58 pounds.)

- Mean phosphorus concentration of septage = 232 milligrams per liter (USEPA, 1980).

- Mean phosphorus concentration of spring lawn fertilizer = 4% (Sloan, 1984).

- Mean phosphorus concentration of fall lawn fertilizer = 20% (Sloan, 1984).

- The mean phosphorus concentration of stormwater runoff = .8 milligrams per liter (Gannon, et al, 1975).

- Water weighs 62.4 pounds per cubic foot or 8.34 pounds per gallon.

- There are 7.48 gallons in each cubic foot of water.

- One tenth of the average water yield represents overland sheet flow.

- The laboratory test results were representative of the concentrations of nutrients for a year.

- All lake lots are 1 acre lots, and 50% of each lot is lawn.

- The volume of the lake remained constant throughout the year.

- Phosphorus is the limiting nutrient.

- The mean residency rate was 3 persons per household.

WHITE LAKE PHOSPHORUS RETENTION

Using the 18.65 billion pounds of water figure, the amount of phosphorus in the lake water is 261 pounds.
pounds. The yearly average in-lake phosphorus concentration is 14 ug/l.

Since the lake flushes once every 9.5 years, 27.5 pounds of phosphorus is flushed from the lake each year.

PHOSPHORUS FROM SEPTIC TANKS

(These figures assume that all the phosphorus released from septic tanks reach the lake after a period of years.)
Using the EPA figures of 23 milligrams of phosphorus per liter in human sewage, an average flow of 136.8 gallons per day per household (45.6 gallons per capita per day X 3 people per household), 9.6 pounds of phosphorus per

household per year are discharged into the septic tank. Using the 490 households with septic tank effluents discharging into the soils surrounding the lake, it is calculated that 4704 pounds of phosphorus is released into the soils surrounding White Lake. Soils have quite an ability to absorb phosphorus, but eventually all soils become saturated. As the soils become saturated, the total septic tank phosphorus load could reach the lake if the tile fields are located near it.

Assuming that septic tanks are pumped once every ten years, that the tanks are 1000 gallon tanks, that the tank is half full of sludge (500 gallons) when it is pumped, and the concentration of phosphorus in the sludge is 232 milligrams per liter, less than one pound of phosphorus is removed with the septic tank sludge when the tank is pumped once in a ten year period. The above figures show that regular pumping of the septic tank is not a very feasible method of removing phosphorus from the lake watershed. If all 490 tanks are pumped once every ten years, less than 48 pounds of phosphorus per year will be removed from the lake watershed.

PHOSPHORUS ADDITIONS FROM LAWN FERTILIZERS

The 245 houses (50% of 490) that use lawn fertilizer at a commonly applied rate, 40 pounds of phosphorus per acre per year, will now be considered.

As stated above it is assumed that the lots are one acre in size, that half the lot is lawn, and that a spring and a fall fertilizer application is made each year (a local nurseryman reports he sells almost as much lawn fertilizer in the fall as he does in the spring, but the fall fertilizer has a much higher phosphorus concentration. Mean spring fertilizer phosphorus concentration is 4%, while mean fall fertilizer phosphorus concentration is 20%.) Most fertilizer is sold in 40 pound bags that cover 10,000 square feet. Thus each person buys 80 pounds of lawn fertilizer in the spring at 4% phosphorus and 80 pounds of fertilizer in the fall at 20% phosphorus. Each home owner who fertilizes his lawn uses about 20 pounds of phosphorus per year (4% X 80# + 20% X 80# = 19.2#). That's 4704 pounds per year for the 245 houses. Assuming that half the phosphorus is taken up by the lawn, 2352 pounds could potentially be washed into White Lake.

PHOSPHORUS ADDITIONS FROM STORM WATER RUNOFF

It is assumed that the storm water phosphorus is delivered only from the lake watershed of 1.11 square miles (1253-540/640). Sheet-flow stormwater is considered to be about one tenth of the average flow from this area, or about .07 cfs. Using the .07 cfs figure and the .8 milligrams per liter stormwater phosphorus concentration reported by Gannon, 110 pounds of phosphorus per year are contributed to the lake through stormwater runoff from the entire watershed.

Lake area....................................	540 acres
Total Watershed area.......................	1253 acres
Watershed area minus lake area.............	713 acres
Average Flow (USGS, 1972)	.62 CFS/Sq. Mi.
Stormwater sheet flow from White lake watershed (minus lake area).............	.07 CFS
Average stormwater phosphorus concentration.	.8 mg/l

SUMMARY OF POTENTIAL PHOSPHORUS ADDITIONS PER YEAR

Potential phosphorus input from septic tanks....	4704 pounds
Phosphorus removed by septic tank pumping........	-48 pounds
Potential input from lawn fertilizers...........	2345 pounds
Phosphorus additions from stormwater runoff......	110 pounds
Phosphorus lost through lake flushing............	-28 pounds
TOTAL POTENTIAL PHOSPHORUS INPUT PER YEAR.......	7083 pounds

SUMMARY

The above calculations show that the single largest contributor of phosphorus to White Lake are the septic tanks surrounding the lake. Lawn fertilizers are the second highest contributor. This is based on the assumptions that only half of the houses fertilize the lawns, and half the applied fertilizer is captured by the soil. Neither of these assumptions may be correct.

The above calculations show that pumping septic tanks once every ten years removes very little phosphorus from the watershed.

WHERE DOES ALL THE PHOSPHORUS GO?

As the above summary shows, it is possible for 7083 pounds of phosphorus could enter the lake each year, yet the lake as an average has about 261 pounds of phosphorus in it. Where did the rest go?

As long as there is oxygen in the water phosphorus will precipitate to the bottom sediments. And that is probably where most of it is going, to the bottom sediments of the lake. If the rates of input and precipitation to the sediments were constant over the last 20 years, over 70 tons are being retained by the lake sediments. This breaks down to almost 262 pounds of phosphorus per acre. The above calculations show that White Lake may have more than 6 times more phosphorus in the lake sediments than is recommended for lawn application (at 40 lbs per acre per year).

It is certainly valid to ask why one should worry if the phosphorus is precipitated to the bottom sediments?

Currently, White Lake has excessive weed problems which are being controlled through the use of herbicides. However, the sediment analyses show a build-up of organic material not usually found in southeast Michigan lakes. This organic build-up is caused by more organic matter being produced in the lake each year than can be decomposed by the oxygen in the sediments. Real problems can occur when the amount of oxygen required to decompose the plant materials in the lake is exceeded, and the phosphorus which has been precipitating over the years goes back into solution, causing algal blooms. The high chlorophyll concentrations at stations 2 and 8, and to a lesser extent at stations 4, 7, and 9, show that this process is beginning to occur. When excessive, these are extremely undesirable conditions. Not only can the algae form a green scum over the entire surface of the lake, but when they die and decompose, they stink.

The ability of the lake to precipitate phosphorus to the bottom sediments was not addressed in this nutrient budget calculation. The reason it was not addressed is because in the future, it is quite possible for the precipitated phosphorus to re-dissolve and cause serious water quality problems such as those discussed above.

GEOLOGY OF THE WHITE LAKE BASIN

White lake is located in the Huron River basin which is underlaid by two major types of earth materials; consolidated bedrock and unconsolidated glacial deposits. Overlying the bedrock are glacial drift materials deposited during glacial time, about 14,000 years ago.

The bedrock formations that directly underlie the glacial deposits dip generally west and north west. Coldwater Shale is found under the White Lake Basin at depths of 300+ feet. This shale is primarily a greenish to bluish gray shale with some lenticular beds of sandstone. Its thickness ranges from 400 to 700 feet.

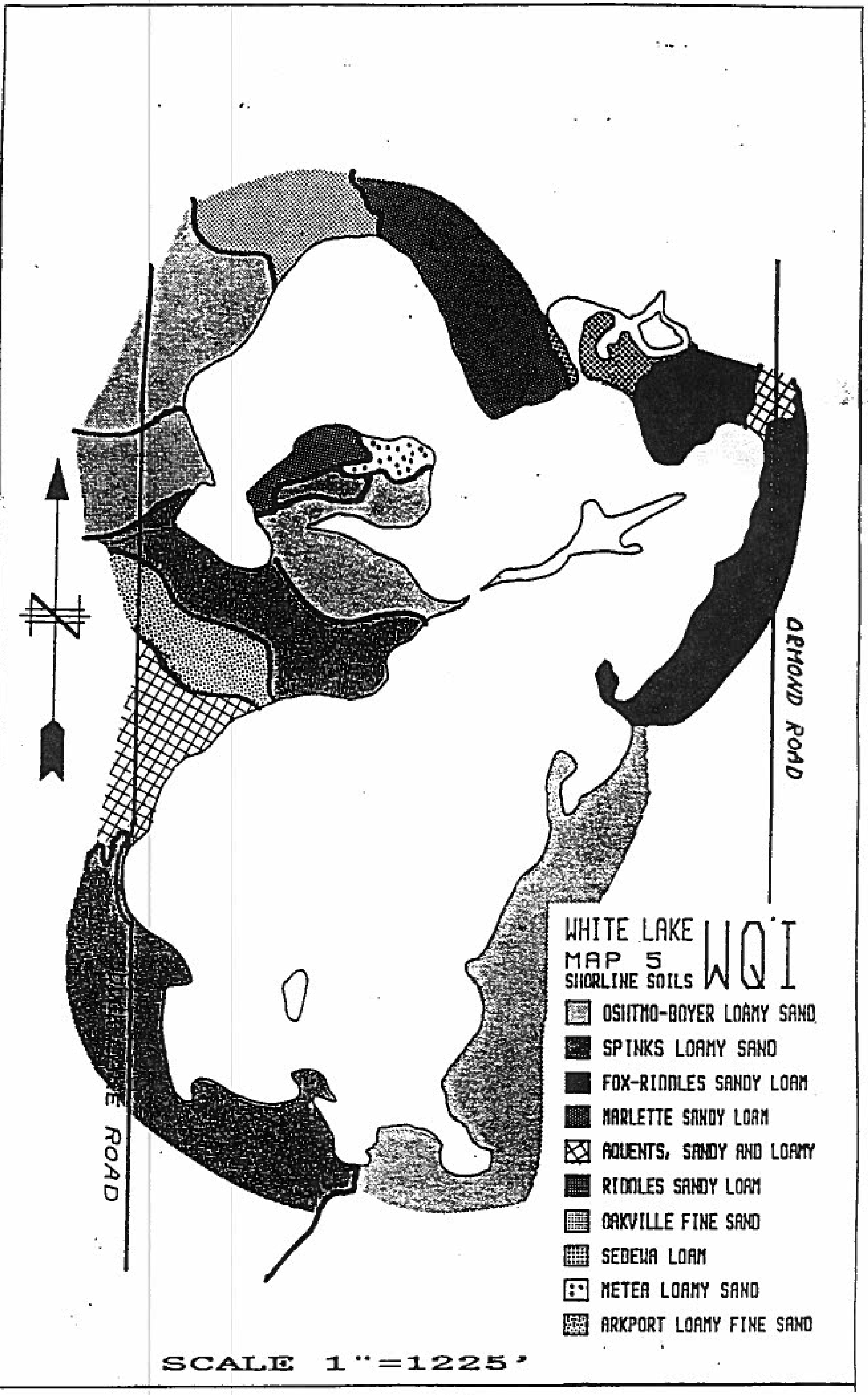
All surface geologic features of the area were formed by the continental glaciers that formerly covered most of North America north of the Ohio and Missouri rivers, including all of Michigan. The glacial out wash areas were areas deposited as the glacier melted during the period of its final retreat. The till plains--level areas of mixed material--were deposited by downward melting of forward ice sheets as the glacier lay temporarily stagnant.

White Lake is in a glacial outwash area in the upper (northern) edge of the Huron River Basin and is underlaid by well drained, coarse soils underlaid by sand and gravel.

SOIL TYPES SURROUNDING WHITE LAKE

A literature review was conducted to identify the soil types which form the immediate shore of White Lake. In most cases, the soils were sands and sandy loams. This is in sharp contrast to the highly organic soils which form the lake bottom, and indicates that the bottom materials are not of geologic origin.

Map 5 shows the locations of the various soil types around White Lake.


WHITE LAKE
MAP 5
SHORLINE SOILS
WQI
OSHTMO-BOYER LOAMY SAND
SPINKS LOAMY SAND
FOX-RIDDLES SANDY LOAM
MARLETTE SANDY LOAM
AQUENTS, SANDY AND LOAMY
RIDDLES SANDY LOAM
OAKVILLE FINE SAND
SEDEWA LOAM
METEA LOAMY SAND
ARKPORT LOAMY FINE SAND
ORMOND ROAD
ROAD
SCALE 1"=1225'

Listed below are the SOIL TYPES and PERCENT OF DISTANCE around White Lake. Note that the predominant soil is sand. Originally, the bottom of the lake probably consisted of sand, but over the years, the amount of organic material increased as excessive production of aquatic vegetation occurred.

TABLE ONE

SOIL TYPE	PERCENT OF DISTANCE
Ostemo Boyer loamy sand	36
Spinks loamy sand	28
Fox Riddles sandy loam	15
Marlette sandy loam	6
Aquents, sandy and loamy	5
Riddles sandy loam	4
Oakville fine sand	2
Sebewa loam	2
Arkport loamy fine sand	1

BOTTOM SEDIMENT ANALYSES

Bottom sediment samples were taken at all in-lake sample stations with a Peterson Dredge. The samples were air dried, then dried at 103 °C over-night. After weighing, the samples were fired at 500 °C for 2 hours to burn off the organics, then weighed again.

The amount of mineral material found in the bottom sediments varied from 32 to 96%, with an average of 50%. See Table Two below. If the 96% mineral sample at station 4 is disregarded, the range of mineral material in the sediments ranges from 32 to 60%. These are low percentages of minerals and indicates that "muck" is building up on the bottom of White Lake at an unacceptable rate. This high build-up rate of organic materials indicates that the lake is highly productive, an undesirable condition. The weed control processes being used (killing the plants with herbicides and allowing them to settle to the bottom where they are supposed to decompose) are adding to this problem. The presence of plant fragments in some of the sediments are further indicators that this problem is occurring.

Sediment organic mineral contents below 40-50 % are usually observed in highly eutrophic lakes.

TABLE TWO

BOTTOM SEDIMENT ANALYSES

Site	% Mineral	Comments
1	42	
2	49	PLANT FRAGMENTS PRESENT
3	32	PLANT FRAGMENTS PRESENT
4	96	SAND AND GRAVEL
5	48	
6	43	
7	60	
8	56	PLANT FRAGMENTS PRESENT
9	39	
10	40	PLANT FRAGMENTS AND SNAILS PRESENT
	50%	Mean sediment mineral content

The significance of the presence of snails in sample 10 is unknown at this time. A note was made of it because the snails were quite obvious in this sample, and absent in the others.

THE WEED SURVEY

A weed survey of White Lake was conducted during the August water quality sampling period. Near-shore waters were inspected for weeds which would interfere with boating or swimming.

Although there may have been some weed beds which interfered with swimming, boating and fishing earlier in the year, the widespread use of herbicides diminished the weed populations to a point where very little interference with fishing, boating were observed.

Isolated beds of weeds were found at the following sampling locations (see map 4):

Station 2. Narrow leaf pondweed *(Potomogeton sp.)* and native milfoils *(Myriophyllum spp.)* were found in this area but did not appear to be interfering with swimming and boating during the study period.

Station 5. Coontail was found on the bottom but since this station was in 10-15 feet of water the plants caused no problems.

Station 7. Narrow leaf pondweed *(Potomogeton sp.)* and native milfoil *(Myriophyllum spp.)* were widely distributed in this area, but again, did not appear to be interfering with swimming or boating.

Weeds have a function in a lake. In White Lake they remove phosphorus from the water column, making it unavailable for phytoplankton. Total elimination of the weed beds should not be a goal when considering the management of White Lake.

WATER QUALITY DATA FOR WHITE LAKE

DATE	STATION	DEPTH	TEMP	D.O.	CHL A	SECCHI	NITR	ALK	pH	COND	PHO
8/12/86	1	0	24	8.5	12	11	<10	121	8.2	360	17
8/12/86	1	5	23	8.5	6	---	<10	121	8.1	340	30
8/12/86	1	10	22	8.5	6	---	<10	119	8.1	340	17
8/12/86	1	15	22	8.5	6	---	<10	119	8.1	340	23
8/12/86	1	20	22	7.0	12	---	<10	121	8.1	340	17
8/12/86	1	25	20	1.4	20	---	<10	120	8.1	340	16
8/12/86	1	28	19	1.4	18	---	---	---	---	---	---
8/12/86	2	0	24	8.6	52	11	<10	119	8.2	340	8
8/12/86	3	0	24	8.8	13	11	<10	121	8.2	340	8
8/12/86	4	0	23	8.5	34	11	<10	121	8.2	340	8
8/12/86	5	0	23	8.8	10	10	<10	121	8.2	340	13
8/12/86	6	0	25	8.4	16	11	<10	121	8.2	340	17
8/12/86	7	0	24	8.1	32	8	<10	123	8.2	340	16
8/12/86	8	0	24	8.2	44	8	<10	121	8.2	340	16
8/12/86	9	0	22	8.5	36	8	<10	132	8.2	350	16
8/12/86	10	0	24	8.7	10	8	<10	132	8.2	350	17

TEMP Temperature in °C
D.O. Dissolved oxygen in milligrams per liter
CHL A Chlorophyll a in micrograms per liter (corrected)
SECCHI Secchi disk transparency in feet
NITR Total nitrate in micrograms per liter
ALK Alkalinity in milligrams per liter as $CaCO_3$
pH Hydrogen ion concentration in standard units
COND Conductivity in umhos/cm at 25°C
PHOS Total phosphorus in micrograms per liter

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