PINE LAKE, FOREST COUNTY

Feasibility Study Results;

Management Alternatives

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by

Office of Inland Lake Renewal

Wisconsin Department of Natural Resources

INTRODUCTION

Pine Lake is located in Hiles Township, Forest County, Wisconsin (Figure 1). It is 1,500 acres in size with a storage capacity of approximately 14,275 acre-feet. Maximum depth is 16 feet, and the mean depth is about 9.5 feet (Figure 2 and Table 1). Three streams discharge into the lake. The flow in one, Pine Creek, is largely controlled by the dam at Hiles Millpond, located approximately one mile upstream. The uncontrolled drainage area encompasses 11.6 square miles. The lake outlet is considered the headwaters of the Wolf River. The Little Rice Lake Wildlife Area is roughly 2-3 miles downstream.

The lake is heavily used for recreation. There are 14 resorts, 147 dwellings, and 5 boat rentals. The sport fishery is reportedly very good for a variety of species. Fish species known to be present include walleye, northern pike, largemouth bass, perch, bluegill, black crappie, pumpkinseed, and black bullhead. The lake is also used by nesting and migratory waterfowl.

The lake level was naturally controlled until about 1927. At that time installation of culverts under a downstream railroad trestle resulted in a somewhat lower stream channel. A control structure for the lake was therefore constructed about 1937-38 to maintain the lake near original levels. Initially the dam was owned and operated by Forest County; however, the Town of Hiles is now responsible for its operation. The ordered maximum and minimum lake levels are 91.0 and 90.0 feet, respectively.

Selected areas of shoreline have received some alteration in the past (e.g. riprap, bulkhead line, sand blankets) but the lake has not been manipulated significantly. The primary concerns include dense growths of submergent macrophytes, periodic and occasionally severe fishkills in the winter, shallowness of the lake and unsatisfactory water levels in the lake. The water levels, in particular, have been much criticized for many years. Low precipitation and high evaporation losses cause levels near the ordered minimum, while heavy precipitation or snow melt often results in levels greater than 91.0 feet. This causes shoreline erosion and flooding of some dwellings on low ground. Because of the large lake size and characteristics of the downstream channel, lake levels recede relatively slowly.

Under Chapter 33, Wisconsin Statutes, an Inland Lake Protection and Rehabilitation District was formed in 1975. In response to a request for technical assistance, the Office of Inland Lake Renewal designed a one-year data collection program for the Lake District. The study included measurement of: 1) nutrient loading from the watershed and from ground water inflow, 2) inlake water chemistry, 3) algal composition and densities, 4) macrophyte abundance and distribution, and 5) depth of soft sediments.

FEASIBILITY STUDY RESULTS

Pine Lake is an unusual lake both from the standpoint of trophic condition and hydrology. First of all, the fertility (trophic status) is much greater than would be expected using standard predictive methodology. Also, ground water is furnishing most of the water supply despite three inflowing streams. In addition, a significant portion of the ground water results from vertical upwelling rather than horizontal flow toward the lake. These findings are uncommon when compared to our past experience.

The basic water chemistry is shown in Table 2. The data, in general, indicates a lake of moderate to low fertility without significant cultural influence. According to Figure 3, the spring total phosphorus (TP) concentration (15 μg/1) should have produced an average summer chlorophyll a concentration of 3.7 μg/1. The actual value was 9.7 μg/1 for the June-August period, with a range of 7.9 to 11.2 μg/1. Concentrations of 0-4 μg/1, 5-9 μg/1, and 10 μg/1 or higher are considered indicative of oligotrophic, mesotrophic and eutrophic lakes, respectively. As shown in Figure 4, the chlorophyll a concentration was low in spring (average

April/May, 4.0 μg/l) but exceeded 7 μg/l after June, and concentrations were greater than 10 μg/l for approximately one month during July/August. In addition, the algal population was dominated by Anabaena spp. These blue-green species are common in fertile lakes.

There are four major components of the P transport system into Pine Lake--direct precipitation, Pine Creek, ground water and surface runoff from the watershed. These combined to deliver an estimated loading of 0.21-0.28g P/m^2 of lake surface/year. The hydraulic residence time for Pine Lake falls between 0.33 and 0.56 years. In other words, the water in the lake is replaced on the average every 4 to 7 months. Based on this information, Pine Lake should be oligotrophic (Figure 5). However, this conclusion is contradicted by the algae and macrophyte data, and by the reportedly high fish production.

The magnitude of P loading to the lake from the various sources is shown in Table 3. Most of the P is supplied by runoff from the uncontrolled portion of the watershed. Direct precipitation, ground water and Pine Creek together provide less than 50 percent of the total. Two of these--direct precipitation and Pine Creek--would definitely be unaffected by man's activity in the area. The value for precipitation was determined using pertinent data from studies conducted elsewhere. Pine Creek was monitored at the discharge point from Hiles Millpond. About 163 kg P was carried in the streamflow during the March-October period, resulting in an estimated 245 kg for the entire year (Table 4). Hiles Millpond is completely surrounded by extensive wetlands; no streams enter the lake and there are no developments near the shoreline except at the outflow. There is little likelihood of any significant change in the situation in the future.

The nutrient (P) inflow via ground water was estimated to be 137-275 kg/yr. The average concentration of phosphorus was 6 μg/l while flow was 26-52 cfs. Ground water alone would therefore cause the lake water to be replaced roughly every

4.5 to 9 months. The direction of ground water flow is shown in Figure 6. Ground water flows into the lake on all sides except for a small area around the dam. The inflow from the east is, however, about 2.5 times greater than from the west. Also, about 95 percent of the inflow results from ground water upwelling near the lake edge.

The size ratio of the watershed acreage (uncontrolled portion) to the lake is approximately 5:1. The nutrient loss from this area was determined using a planimeter and the 1965 U.S.G.S. quadrangle maps (e.g. Figure 1). The urbanized area was estimated to be 335 acres. This area includes the Town of Hiles as well as the developments on both sides of the lake. The theoretical loss of P from urban lands is 1.5 kg P/hectare of land/year, yielding a calculated 202 kg P/year to the lake. The non-urban area encompasses 7115 acres. Most of the land is forested, although agriculture is being used in some select locations. The theoretical P loss from this area would be 0.2-0.3 kg P/hectare of land/year, resulting in the transport of 576-864 kg P/year to the lake. The magnitude of the nutrient transport from the uncontrolled watershed versus the other P sources and the high P loss from urbanized versus forest or agricultural lands underlines the importance of the watershed and prevailing land use practices to the lake.

The question still remains--why are the predictive methods underestimating the lake's fertility? There apparently is an unaccounted for, significantly large nutrient supply to the lake during the summer growing period. Septic systems and/or an internal P recycling mechanism seem the most likely source. It is possible that the monitoring well locations failed to intercept plumes from septic systems. Also, cottage usage would increase during the summer months. High water levels in the spring would, in addition, cause flooding of the low lying systems, permitting direct leakage into the lake water. The moderate number of residences around the lake and the dominance of vertical upwelling over horizontal ground water flow, however, suggests that internal recycling is the more important source. Approximately 60-70 percent of the estimated P loading was retained in the lake. The lake sediments may be storing large quantities of P. This P would be potentially available to the macrophytes via their root system, and to the algae both through the macrophytes as well as direct release into the water column.

Macrophytes cover most of the lake bottom (Figure 7) down to a depth of 13 feet. Only about 90 acres are weed-free. Emergent species (e.g. bulrushes) and floating-leaf species (e.g. lily pads) occur in about 30 and 25 acres, respectively. Submergent species are abundant in 860 acres and sparse in another 495 acres. Therefore, over 90 percent of the lake contains aquatic macrophytes. Based on the average water clarity for June-August (5.7 feet), the predicted maximum depth of growth was only 9.7 feet (Figure 8). The discrepancy may be due to the greater water clarity in May. Water clarity averaged 9.3 feet in May, suggesting that macrophytes would grow to the 14 foot depth. Beyond a depth of 4-5 feet the macrophytes were unable to reach the lake's surface. As a result, only about 265 acres of the lake actually had growths at the surface.

Macrophyte species present in at least 10 percent of the sampling sites are shown in Table 5, from the most to the least abundant. Ceratophyllum occurred at almost 50 percent of the locations. The depth and bottom type preferences for the four most common species are demonstrated in Table 6. Vallisneria americana definitely preferred sand bottom, but results were inconclusive for the other species, primarily because of the lack of comparison for most depths. Sand comprised 80 percent of the bottom to 7 feet, and thereafter only 10 percent. The greatest densities for Ceratophyllum, Myriophyllum and Potamogeton Richardsonii occurred within the 8-10 foot depth zone, although Ceratophyllum was abundant at 7-12 feet.

Although the quality of the sport fishery was not assessed in the feasibility study, it is reportedly excellent for several species. The last survey on the lake was conducted in August 1949. At that time spawning areas were considered adequate for northern pike, largemouth bass and panfish. However, despite heavy walleye stockings in previous years, survival and reproduction was apparently limited, resulting in a small adult population. The rate of growth was near normal for most species. Abundant, extensive growths of macrophytes were also noted during the survey, and the lake bottom was composed primarily of sand, gravel and rock with shallow muck present in some areas.

In recent years fish stocking has been limited to walleye fingerlings planted at a rate of 10–12 per acre in 1970, 1972 and 1976. There have been no reports of an excessive abundance of small fish and the growth rates are apparently good (e.g. no stunting). The only known fish related problem in the lake is the occurrence of occasional winterkills. Records are sparse but the last serious one was noted in 1964-65. Dissolved oxygen (D.O.) levels were under 0.5 mg/l during that winter. Winter D.O. readings have been infrequent. In March, 1970 and 1974, the D.O. concentration was measured at 3.0 and 5.1 mg/l, respectively. During the summer, D.O. conditions remain satisfactory. The lake is large and shallow, and periodically mixes from top to bottom. D.O. and temperature profiles were taken in August of 1973 and 1974. The temperatures were in the mid 70°F's, and only varied 2°F between surface and bottom. The lowest D.O. concentration was 7.8 mg/l.

MANAGEMENT ALTERNATIVES

Recreational usage of Pine Lake is primarily hampered by excessive aquatic macrophytes. Algal densities and species composition, although indicative of a slightly eutrophic lake, are not a problem at the present time. Nutrient transport into the lake is relatively low and the vegetative growths are apparently supported mostly by inlake nutrient recycling. There is a need to prevent the development of major, additional nutrient and sediment sources within the watershed, but general conditions seem satisfactory now. In terms of the watershed, the emphasis should therefore be on protection from further degradation.

Within the lake, dredging, harvesting, herbicides and/or aeration might be considered. The objective would be prevention of undesirable conditions and enhancement of recreational usage. The nutrient balance within the system would be affected by some of these measures, but probably not significantly.

These alternatives mav not be inclusive and the Lake District should consider their needs and priorities in arriving at a final lake management plan.

Protection of Ground Water Quality

Ground water quality is now good and nutrient transport to the lake is low. However, because ground water is the major water supply system for the lake, any significant deterioration in quality will have a serious impact. The areas of ground water inflow were shown in Figure 6.

Pine Lake lies within a region of Wisconsin that has a relatively high percentage of area unsuitable for septic systems. Some areas that at first appear open to development may in fact have very shallow ground water or poor soil percolation capabilities. Thorough site inspections should precede approval of new developments. Surveillance during the construction phase would also help to ensure compliance with the sanitary ordinance requirements.

According to Figures 9-11, the present 50-foot setback requirement for disposal systems may not be adequate. A greater minimum distance (e.g. 100 feet) may be possible through discussions with the County Board. Equally important, however, is the proper installation and maintenance of these systems. This especially applies to the older, already established systems. Septic system failures are often intermittent; they may be dependent on ground water levels versus the lake level; or they may fail only during high water usage or when the ground water is high following heavy rains. The older systems are most often at fault, especially the ones on a slope, or close to the shoreline, or where the drainage field is at or near the ground water or lake level.

Septic tanks should be cleaned periodically. Also, dye testing is advised in an attempt to document the present status of the septic systems. Corrective measures should definitely be taken wherever sewage wastes can pass directly into the lake (e.g. straight pipe or periodic flooding) for health reasons as well as nutrient transport. Section 8.0 (PERMITS) of the Forest County Sanitary Ordinance provides a mechanism for ensuring the proper installation and maintenance of private sewage systems. Although phosphorus transport is now low via ground water inflow, it would be wise to take the necessary precaution against future problems.

<u>Protection of the Watershed</u>

The uncontrolled portion of the watershed (area below Hiles Millpond) is approximately 7,450 acres in size. The estimated nutrient loss to the lake is now 778-1,066 kg P/year. Pre-development losses were 603 kg P/year. The increased phosphorus loading to the lake now versus during pre-settlement has had little effect (Figure 12). However, if total urbanization would be possible, the nutrient loss from the watershed could increase to 4,521 kg P/year. The average summer chlorophyll <u>a</u> would be about 16-25 μg/1, and the water clarity would be reduced to 3.3-4.7 feet.

A variety of zoning now occurs within the watershed (Figure 13). Almost all of the land immediately surrounding the lake is single family residential (RS-20) with some commercial service (C-S); however, it has not yet been developed fully, and much "wild" shoreline still exists. Beyond the near lake area, the watershed is zoned forestry (O-2) and general agriculture (A-G). A natural resource preservation zone (O-1) has also been established primarily adjacent to the watercourses. Despite the zoning category, few of the A-G lands are actually being used for agriculture. The types of land use practices permitted in these zoning categories are described in the Forest County Zoning Ordinance.

The primary types of land use activities to be avoided regardless of the zoning category include unnecessary emplacement of impervious land surfaces; excessive fertilization, especially prior to a rainstorm; and topsoil disturbance without adequate protection against erosion. Any method of promoting soil infiltration versus overland runoff of water will reduce the nutrient and soil transport into the lake. The rapid runoff of water over impermeable surfaces is the primary problem of urbanization. Storm sewers, roads, sidewalks, etc., should not lead to the lake. The application of fertilizer to lawns or gardens should be limited to the recommended dosage (various soil testing services are available to determine the proper amount and type of fertilizer needed) at the appropriate times. Improper application could permit the transport of large amounts to the lake. Appropriate erosion control measures should be implemented during construction activities. Mulches, porous blankets, etc. should be used to protect the bare soil from raindrop impact and erosion. Major excavations should not be allowed near the lakeshore. The soil erosion hazard in this area is considered severe. In general, the limitations for construction activities are greater on the west side of the lake than the east side. Other activities that should be avoided include raking leaves and dumping lawn clippings into the lake. Many additional items could be included, but these are all in the common sense category.

The Lake District should begin discussions with the County Board to advise them of the District's concerns in the watershed. A close cooperation between the Lake District and County Board, in addition to local and regional planning agencies should be fostered to ensure a rational, organized approach to problem solving.

Costs will depend upon the equipment selected, but a small harvester can be obtained for under $15,000. Macrophytes can be cut and removed from 1-4 acres per day, depending on abundance. Labor costs would probably be about $5.00 per hour per person, or $120.00 per day for 3 men. Disposal may be a problem, although application to cropland or gardens has proven to be beneficial elsewhere. Raking or some similar technique might also be considered, especially around special usage shoreline areas. Because of the presence of species that routinely fragment and/or free-float in the water, macrophytes will continue to wash up on the shoreline, especially on the windward side of the lake. Also, some cuttings will escape during the harvesting process. None of the macrophyte control measures will completely eliminate this problem. A few private companies advertise macrophyte harvesting services. Prices vary between companies and will be influenced by lake location and macrophyte density. Anticipated costs would, however, be $150.00-$200.00 per acre. Disposal of the macrophytes is usually, but not always, included in the services available.

During 1977, macrophytes grew over almost the entire lake bottom. However, growth did not reach the surface beyond 4-5 feet deep. Surface growths were therefore limited to about 265 acres. At 4 acres per day, 66 days would be required for one complete harvest using one machine. Of course, it would be neither necessary nor desirable to harvest such an extensive area. Critical use areas (e.g. boat access to open water, swimming areas, boating and water skiing, etc.) need to be identified before an accurate cost projection is possible.

Dredging

Dredging may be the best method of controlling the macrophytes as well as simply deepening the lake. There would seem to be three possible objectives of a dredging project: 1) reduction of the area where macrophyte growth interferes with lake surface activities. Removal of soft sediments down to a depth of 10 feet will permit continued growth on the lake bottom, but should eliminate any limitation on boating or other near surface activity. About 680,000 cubic yards of sediment would have to be taken from the lake (Table 8). 2) reduction of the area where macrophyte growth is possible. Soft sediments would have to be removed down to a depth of 15 feet. Dredging over the entire lake bottom would involve 6 million cubic yards of material. 3) clean out all of the soft sediments. Over 12.5 million cubic yards are present in the lake, making a project of this magnitude totally impractical.

The lake could also be divided up, with each area being dredged according to usage need. This might range from no dredging to removal of all of the soft sediments. Table 8 and Figures 14 and 15 can be used to determine the sediment volumes. In designing a project, District Commissioners should keep in mind that growth will not be totally eliminated at depths under 13 feet. Removal of soft sediments may uncover primarily sand bottom. Although studies elsewhere have shown that macrophyte biomass will be reduced by more than 50 percent, growth will not be inhibited entirely.

Due to the very slow rate of sediment infilling noted in other natural lakes, dredging should be a relatively permanent lake restoration approach. Availability of dredge spoil disposal sites needs to be considered--upland sites (non-wetland or flood plain) may be required--and the consistency of the sediments will have to be evaluated in more detail. Hydraulic dredging equipment could probably be utilized. Anticipated costs should be $1.25 per cubic yard; however, this will depend on the consistency of the sediments, distance to the disposal site and magnitude of the dredging project. Recent projects in the Inland Lake Renewal Program have been under $1.00 per cubic yard. Permits would be necessary from the Department of Natural Resources District Headquarters at Rhinelander, and preparation of an Environmental Impact Statement may be necessary.

Aeration/Circulation

The need for an artificial circulation system seems questionable at this time. Despite periodic, sometimes severe, winterkill of fish, the sport fishery is reportedly good. Fishkills would not be advantageous to the population; however, the effect may be insignificant. Because an extensive survey has not been undertaken since 1949, the Lake District may wish to request a fishery investigation through the DNR District Headquarters at Rhinelander before making a final decision. If an aeration system is istalled, it should be operated in the fall with the objective of prolonging the open water season as long as possible. A permit for its installation would be required from the Rhinelander office.

6/19/78

TABLE 1: WATER DEPTH - STORAGE CAPACITY RELATIONSHIP

Depth	Acreage	Storage (acre-feet)
0	1,500	14,275.2
3	1,327.6	10,033.8
6	1,147	6,321.4
9	944.6	3,184.5
12	565.5	919.3
15	35.5	17.8
16 (maximum depth)		

TABLE 2: INLAKE WATER CHEMISTRY

Parameter*	April 23, 1963	May 1, 1974	May 21, 1975
Nitrite -N	.18	<.002	<.002
Nitrate -N		.09	.16
Ammonia -N	.01	<.03	<.03
Organic N	.43	.42	.33
Total N	.62	.52	.50
SRP	<5	---	< 5
TP	---	15	<10
Calcium	9.3	27	7
Magnesium	4.1	20	1.5
Sodium	1.4	5	2.5
Potassium	0.8	2.5	1.3
Conductivity	87	80	90
Sulfate	5	10	6
Chloride	.7	3	2
pH	6.9	7.5	7.2
Alkalinity	37	34	40
Turbidity	---	1.5	1.8

*mg/l except conductivity is in micromhos/cm at 77°F, turbidity is in Formazin units, pH is in Standard units, and SRP and TP are in μg/l.

TABLE 3: P LOADING SOURCES

Source	Quantity (kg/yr.)
Direct Precipitation	129.5
Ground Water (vertical and horizontal components)	137 - 275
Watershed	
Pine Creek (controlled portion of watershed)	244.7
Uncontrolled Drainage Area	
Urban (est. 335 acres)	202
Non-urban (est. 7,115 acres)	576 - 864
TOTAL	1290 - 1715 kg/yr.

TABLE 4: STREAMFLOW AND P TRANSPORT VIA PINE CREEK

Month	Ave. flow (cfs)	Ave. P conc. (μg/l)	P Transport (kg)
February	---	6	---
March	4.5	17	5.7
April	17.4	28	36.3
May	8.0	29	17.3
June	6.3	32	15.0
July	7.0	50	26.0
August	3.1	60	13.8
September	10.9	37	30.0
October	11.1	23	19.0
			*163.1/8 months

*Therefore 244.7 kg P/year.

TABLE 5: MACROPHYTE SPECIES LIST*

Ceratophyllum demersum

Vallisneria americana

Myriophyllum exalbescens

Potamogeton

Richardsonii

P. praelongus

P. Robbinsii

Elodea canadensis

P. zosteriformis

Najas flexilis

Isoetes spp.

P. amplifolius

P. berchtoldii

Chara sp.

*Species listed in order of abundance (most to least). Includes only the species with a frequency occurrence of 10% or more.

TABLE 6: MACROPHYTE SPECIES DENSITY VERSUS WATER DEPTH AND BOTTOM TYPE*

Depth (ft.)	0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13
Species and Bottom Type													
C. demersum													
Muck						1.2		3.2	4.0	4.1		3.1	1.3
Sand				0.6	0.6	1.3	1.7						
V. americana													
Muck						0.8		0.9	0.7	0.3		0	0
Sand				2.6	3.2	3.7	3.5						
M. exalbescens													
Muck						0.7		1.5	2.2	2.2		0.7	0.4
Sand				0.8	0.7	0.8	1.4						
P. Richardsonii													
Muck						1.0		1.7	2.4	1.2		0.3	0
Sand				0.9	0.6	0.4	0.5						

* Values were calculated only where there were at least 10 sampling sites. Density as determined by the Jessen and Lound methodology.

TABLE 7. Aquatic Weed Control with Organic Herbicides.

Aquatic Plant	Aqua.* K	Aqua. +	Ortho* Diquat	Iso-Octyl* 2,4-D	Silvex-4# 2,4,5-TP	Potassium Silvex 6#	Hydro. 47
Largeleaf Pondweed *Potamogeton amplifolins*	C	C	NC	NC	NC	NC	--
Sago Pondweed *P. pectinatus*	C	C	C	NC	NC	NC	--
American Pondweed *P. nodosus*	C	C	CC	NC	NC	NC	--
Small Pondweed *P. pusillus*	C	C	C	NC	NC	NC	--
Floating Leaf Pondweed *P. natans*	C	C	C	NC	NC	NC	--
Waterthread Pondweed *P. diversifolium*	C	C	NC	NC	NC	NC	--
Flatstem Pondweed *P. zosteriformis*	C	C	NC	NC	NC	NC	--
Curlyleaf Pondweed *P. crispus*	C	C	C	NC	NC	NC	--
Narrowleaf Pondweed *P. strictifolius*	C	C	C	NC	NC	NC	--
Claspingleaf Pondweed *P. Richardsonii*	C	C	NC	NC	NC	NC	--
Leafy Pondweed *P. foliosus*	C	C	C	NC	NC	NC	--
Horned Pondweed *Zannichellia spp.*	C	C	NC	NC	CC	CC	--
Bushy Pondweed *Najas flexilis*	NC	NC	C	NC	CC	C	--
Southern Naiad *Najas guadalupensis*	NC	NC	C	NC	CC	C	--
Burreed *Sparganium spp.*	C	C	NC	NC	NC	NC	--
Waterstar Grass *Heteranthera spp.*	C	C	C	NC	CC	CC	--
Coontail *Ceratophyllum spp.*	C	C	C	C	C	C	--
Water Milfoil *Myriophyllum spp.*	NC	C	C	C	C	C	--
Bladderwort *Utricularia spp.*	NC	CC	C	NC	CC	C	--
Fanwort *Cabomba spp.*	NC	C	NC	NC	C	C	--
Water Cress *Rorippa spp.*	NC	CC	NC	C	CC	C	--
Smartweed *Polygonum spp.*	NC	CC	NC	C	CC	C	--
Water Buttercup *Ranunculus spp.*	NC	NC	C	NC	NC	NC	--
Canada Waterweed *Elodea spp.*	NC	CC	C	NC	CC	C	--
Widgeon Grass *Ruppia spp.*	NC	CC	C	NC	CC	C	--
Duckweed *Lemna spp.*	NC	NC	C	NC	NC	NC	--
Watermeal *Wolffia spp.*	NC	NC	C	NC	NC	NC	--
Watershield *Brasenia spp.*	NC	NC	NC	C	C	C	--
Spatlerdock *Nuphar spp.*	NC	NC	NC	C	CC	C	--
Sweetflag *Acorus spp.*	NC	NC	NC	C	C	C	--
Eel Grass *Vallisneria spp.*	NC	NC	NC	NC	CC	CC	CC
Arrowhead *Sagittaria spp.*	NC	CC	NC	C	C	C	--
Spikerush *Eleocharis spp.*	NC	CC	NC	NC	C	C	--
Lotus *Nelumbo spp.*	NC	C	NC	CC	C	C	--
Water Lily *Nymphaea spp.*	NC	C	NC	CC	C	C	--
Cattails *Typha spp.*	NC	NC	C	CC	C	C	--
Bulrush *Scirpus spp.*	NC	NC	NC	C	CC	C	--
Wildrice *Zizania spp.*	NC	NC	NC	NC	NC	CC	--
Water Willow *Dianthera spp.*	NC	NC	NC	CC	CC	C	--

C = Controlled by Herbicide.
CC = Conditionally Controlled by Herbicide
NC = Not Controlled by Herbicide.
* The only approved herbicide at the present time.

TABLE 8: SEDIMENT VOLUMES POTENTIALLY REMOVABLE (CUBIC YARDS)

If Dredge To:	10 Feet	15 Feet	20 Feet
Shore - A*	30,041	54,781	70,684
A - B	147,792	356,635	491,581
B - C	61,051	276,308	440,168
C - D	35,344	260,255	411,238
D - E	38,568	327,720	517,271
E - F	54,620	353,411	600,805
F - G	32,137	289,153	604,012
G - H	9,638	208,842	552,615
H - I	12,845	199,205	526,909
I - J	9,638	208,842	600,805
J - K	16,069	208,842	668,270
K - L	25,706	215,257	703,614
L - M	19,276	221,688	787,148
M - N	16,069	481,927	1,079,524
N - O	22,499	539,754	1,066,663
O - P	22,499	353,411	902,819
P - Q	28,914	420,892	909,249
Q - R	48,189	440,168	777,510
R - S	35,344	228,118	375,910
S - T	9,638	160,653	285,946
T - U	3,223	128,516	253,825
U - V	0	0	0
V - shore	0	0	0
	679,100	5,934,378	12,626,566

* The letters refer to the transects shown in Figures 14 and 15. The volumes correspond to the amount of soft sediment removable between the two transects.

Figure 1: Pine Lake Watershed

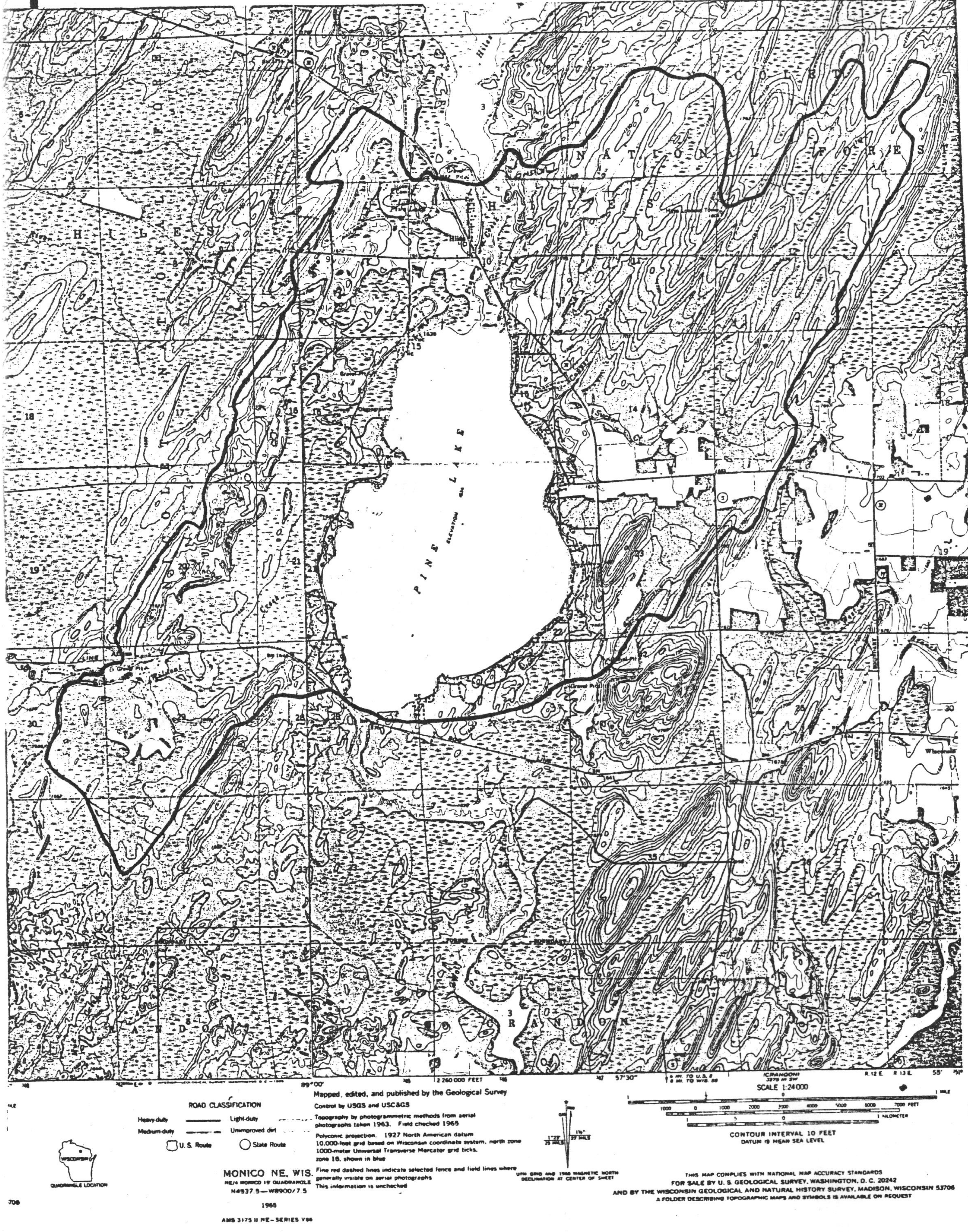
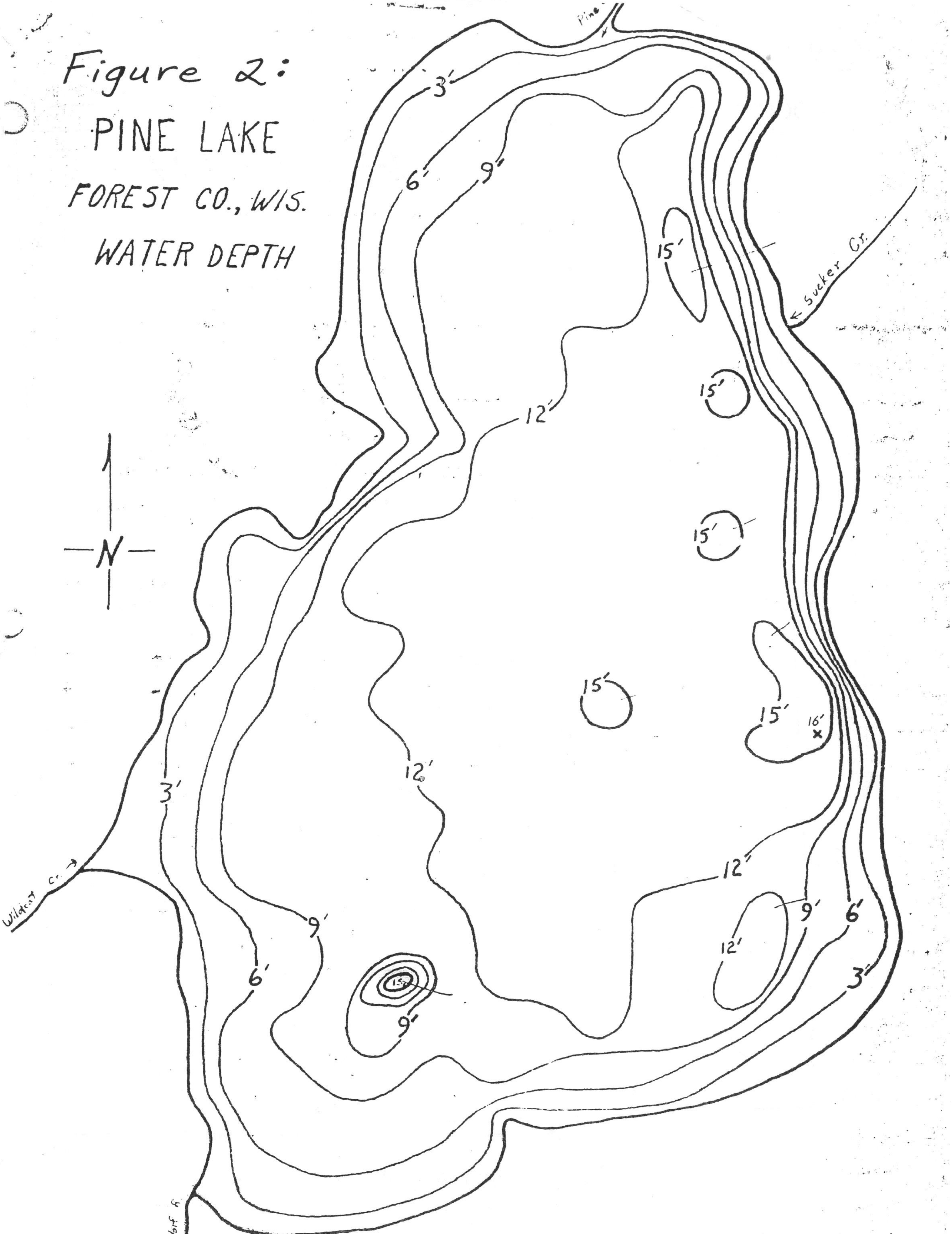


Figure 2:

PINE LAKE

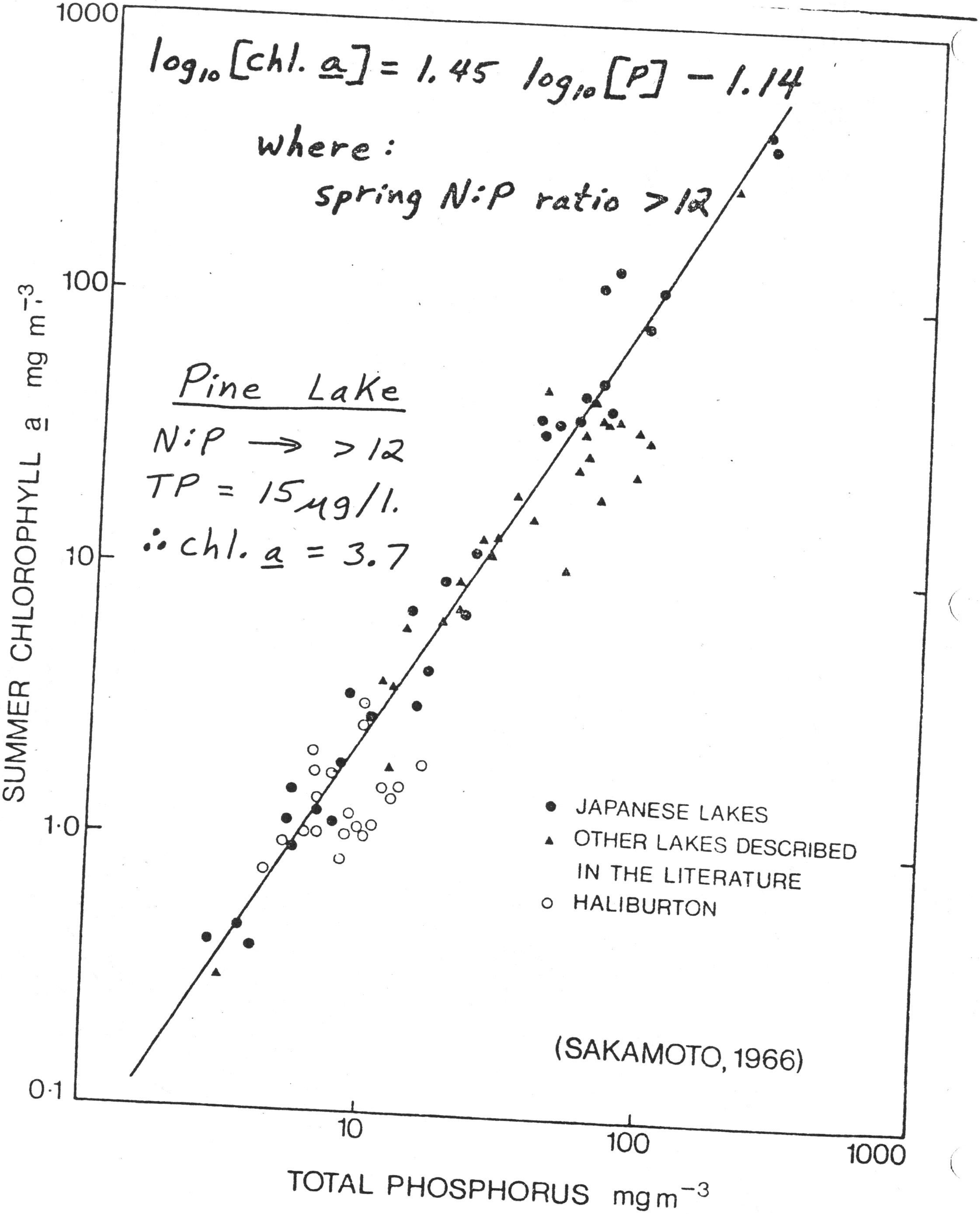
FOREST CO., WIS.

WATER DEPTH



Northern Lake Service, Inc.

Figure 3



log₁₀[chl. a] = 1.45 log₁₀[P] − 1.14
where:
spring N:P ratio >12
Pine Lake
N:P → >12
TP = 15 µg/l.
∴ chl. a = 3.7
1000
100
10
1·0
0·1
SUMMER CHLOROPHYLL a mg m⁻³
10
100
1000
TOTAL PHOSPHORUS mg m⁻³
JAPANESE LAKES
OTHER LAKES DESCRIBED IN THE LITERATURE
HALIBURTON
(SAKAMOTO, 1966)

Figure 4: Inlake chlorophyll a concentration during 1977

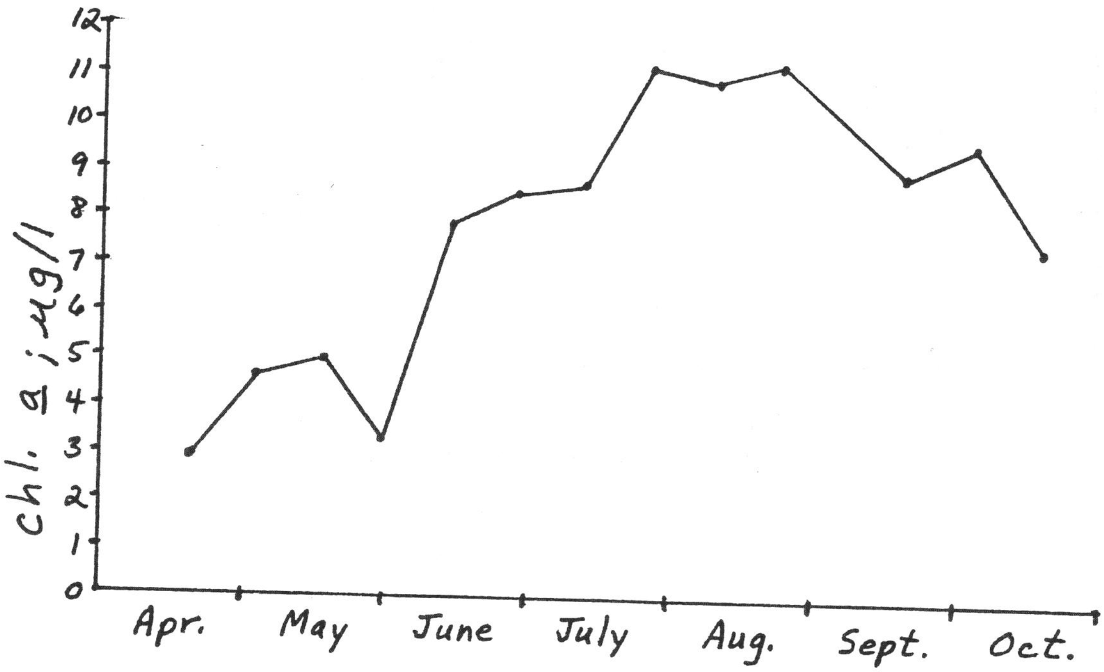


Figure 5: Existing Lake Trophic Status
(using predictive models)

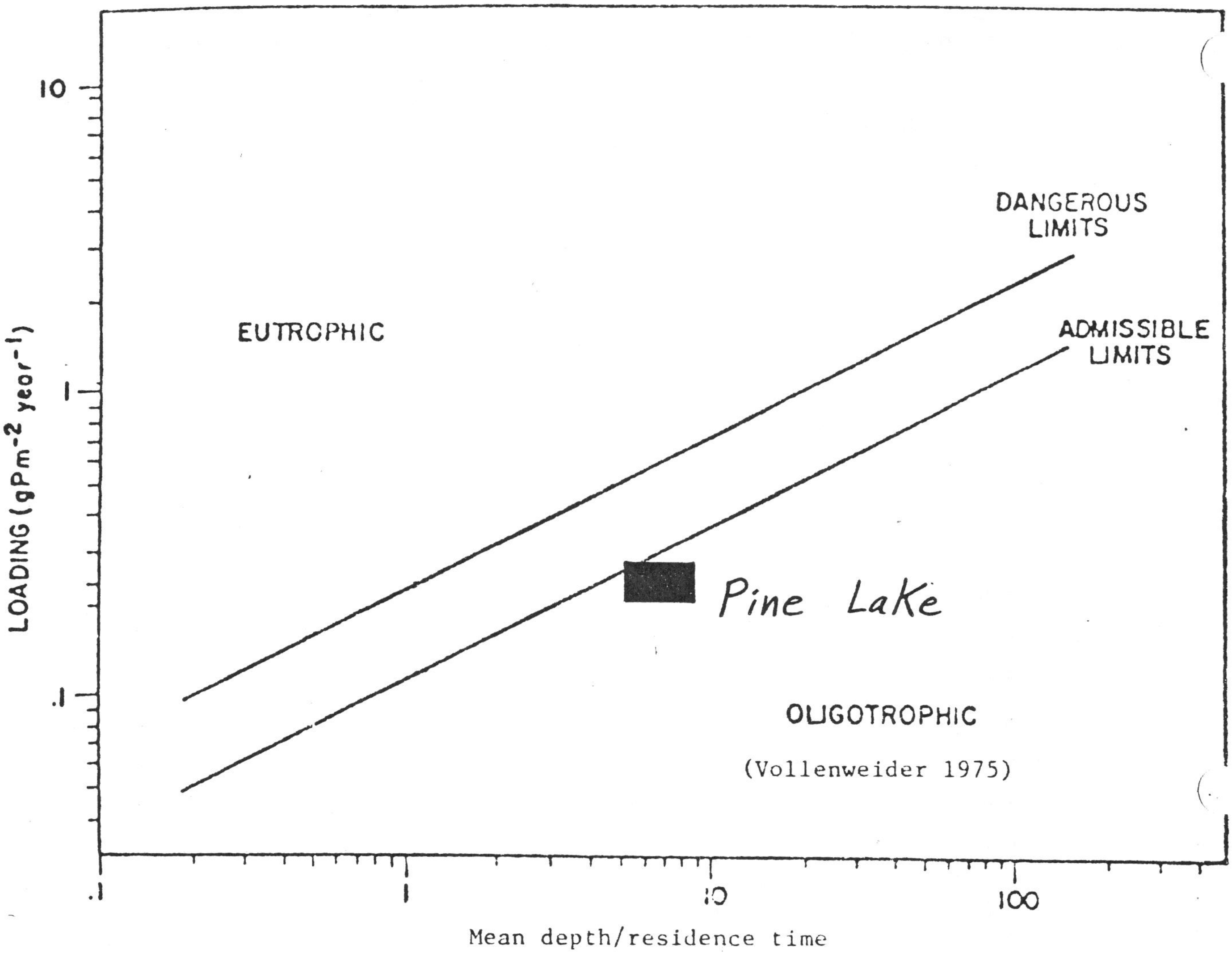


Figure 6: Direction of Ground Water Flow

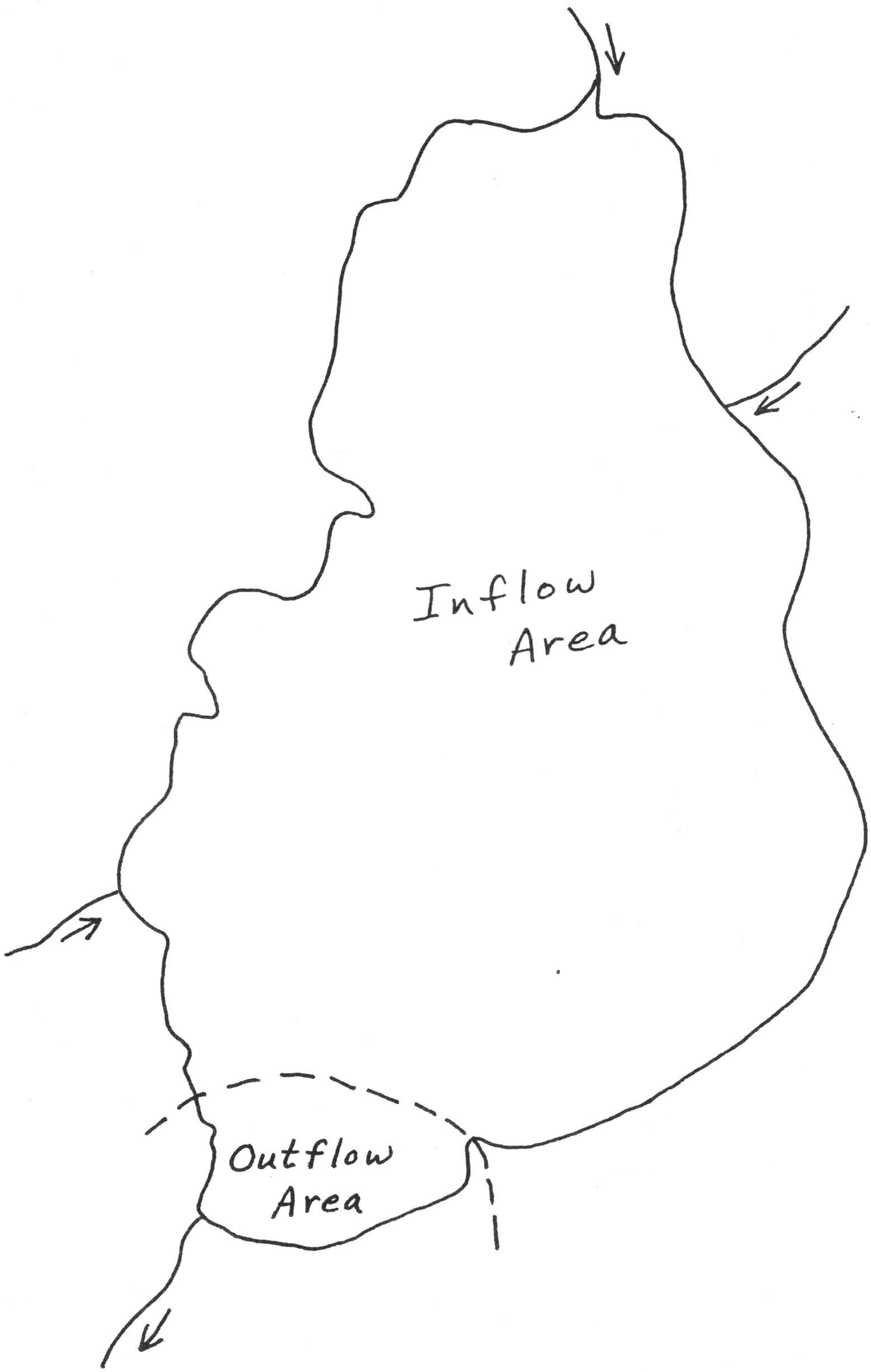


Figure 7

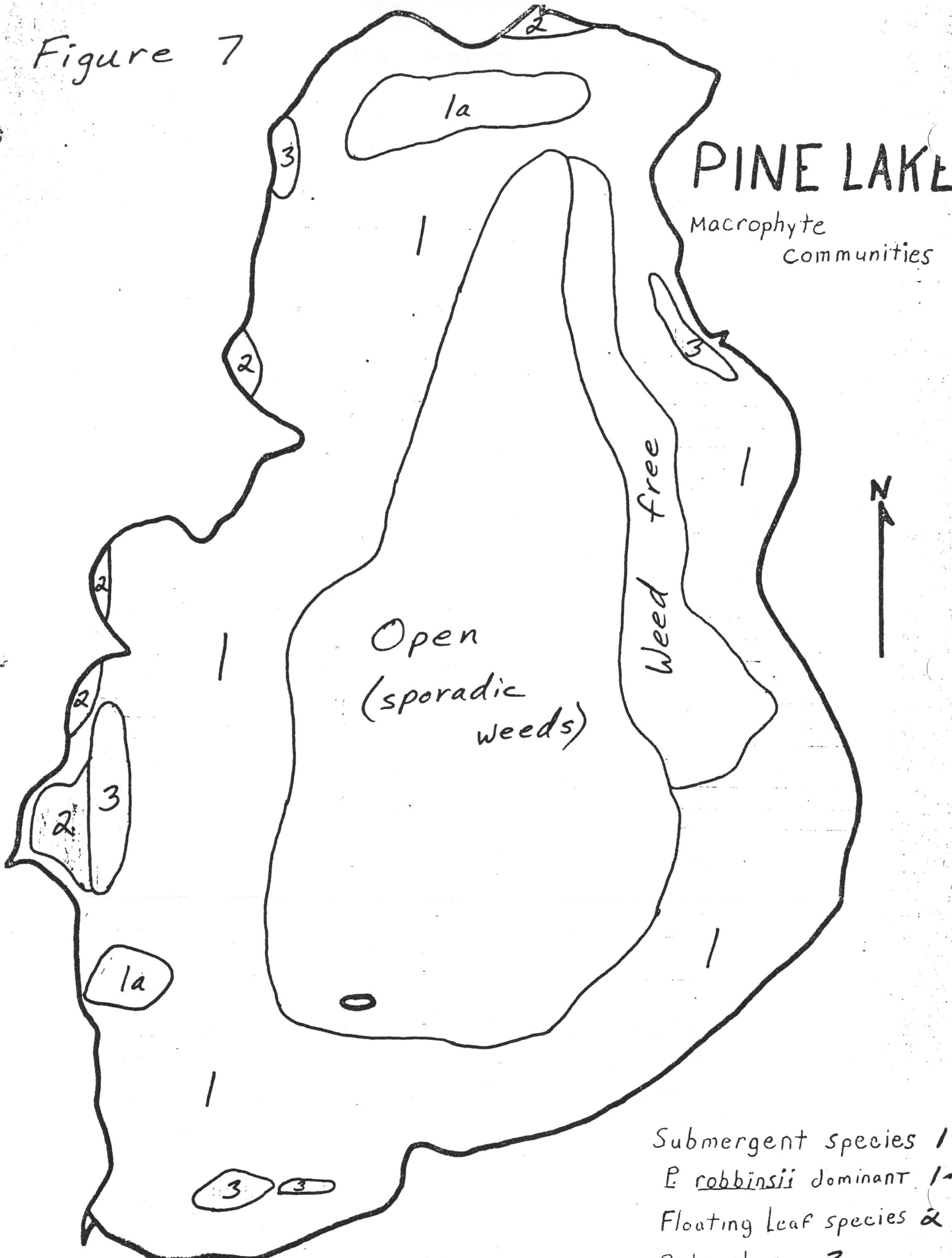

PINE LAKE
Macrophyte Communities
Open (sporadic weeds)
Weed free
1a
1
2
3
N
Submergent species 1
P. robbinsii dominant 1a
Floating Leaf species 2
Bulrushes 3

Figure 8:

Water Clarity Versus Depth of Weed Growth

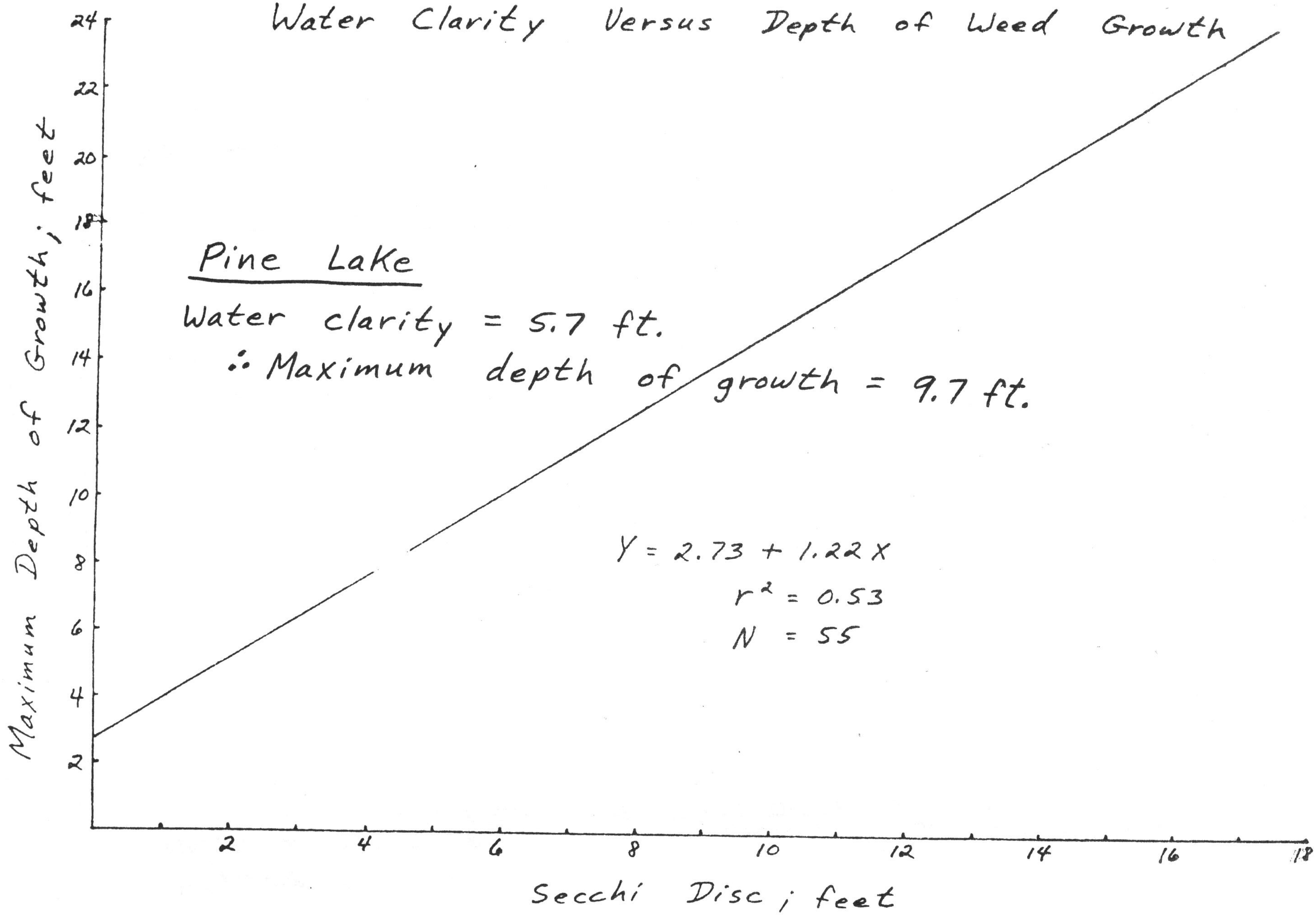


Figure 9:

DISTRIBUTION OF NITRATE NITROGEN IN GROUND WATER ADJACENT TO THE ELEVEN MONITORED SYSTEMS
(DATA POINTS REPRESENT THE MEAN CONCENTRATION FROM EACH WELL)

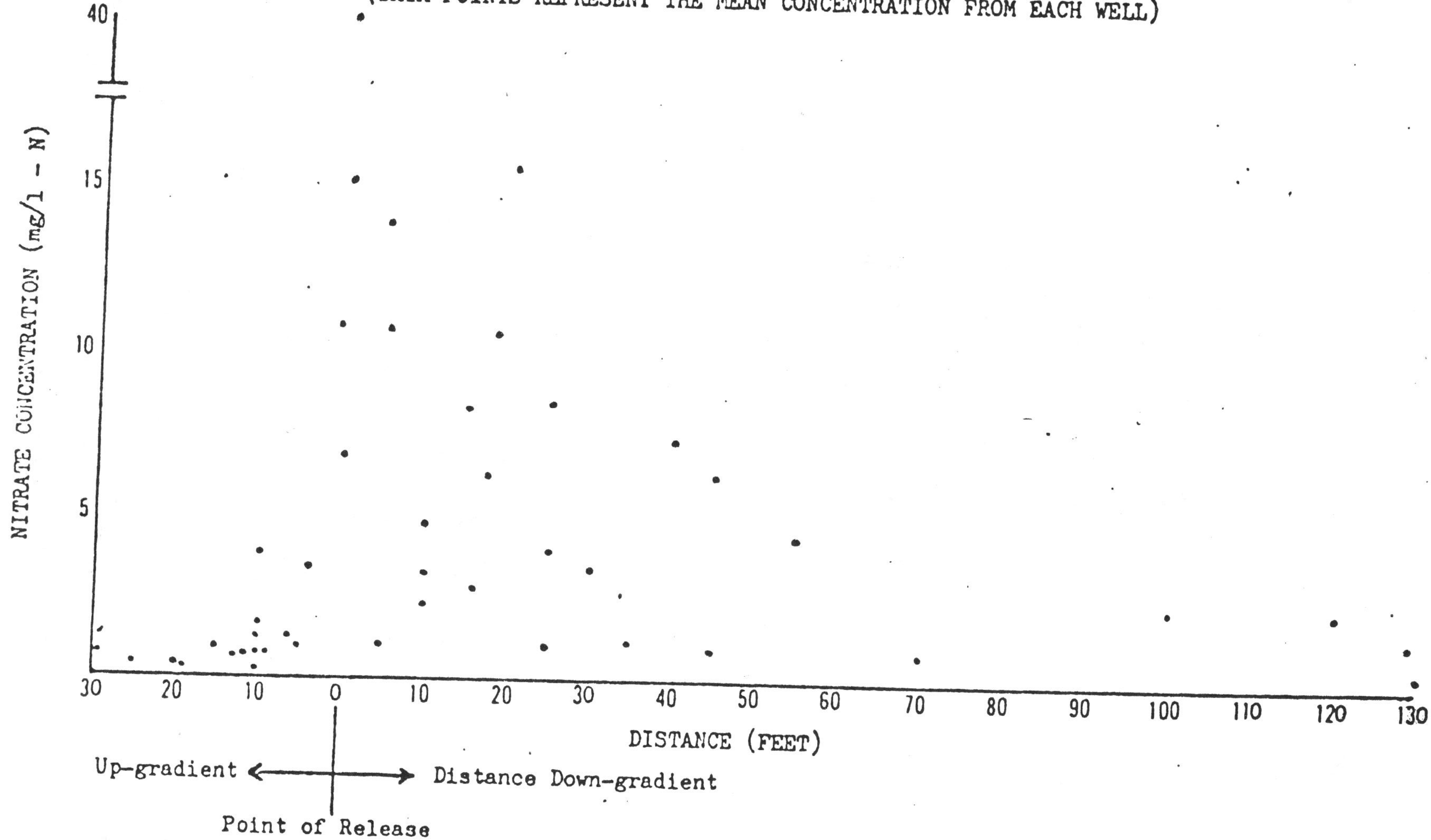


Figure 10:

DISTRIBUTION OF AMMONIA NITROGEN IN GROUND WATER ADJACENT TO THE ELEVEN MONITORED SYSTEMS
(DATA POINTS REPRESENT THE MEAN CONCENTRATION FROM EACH WELL)

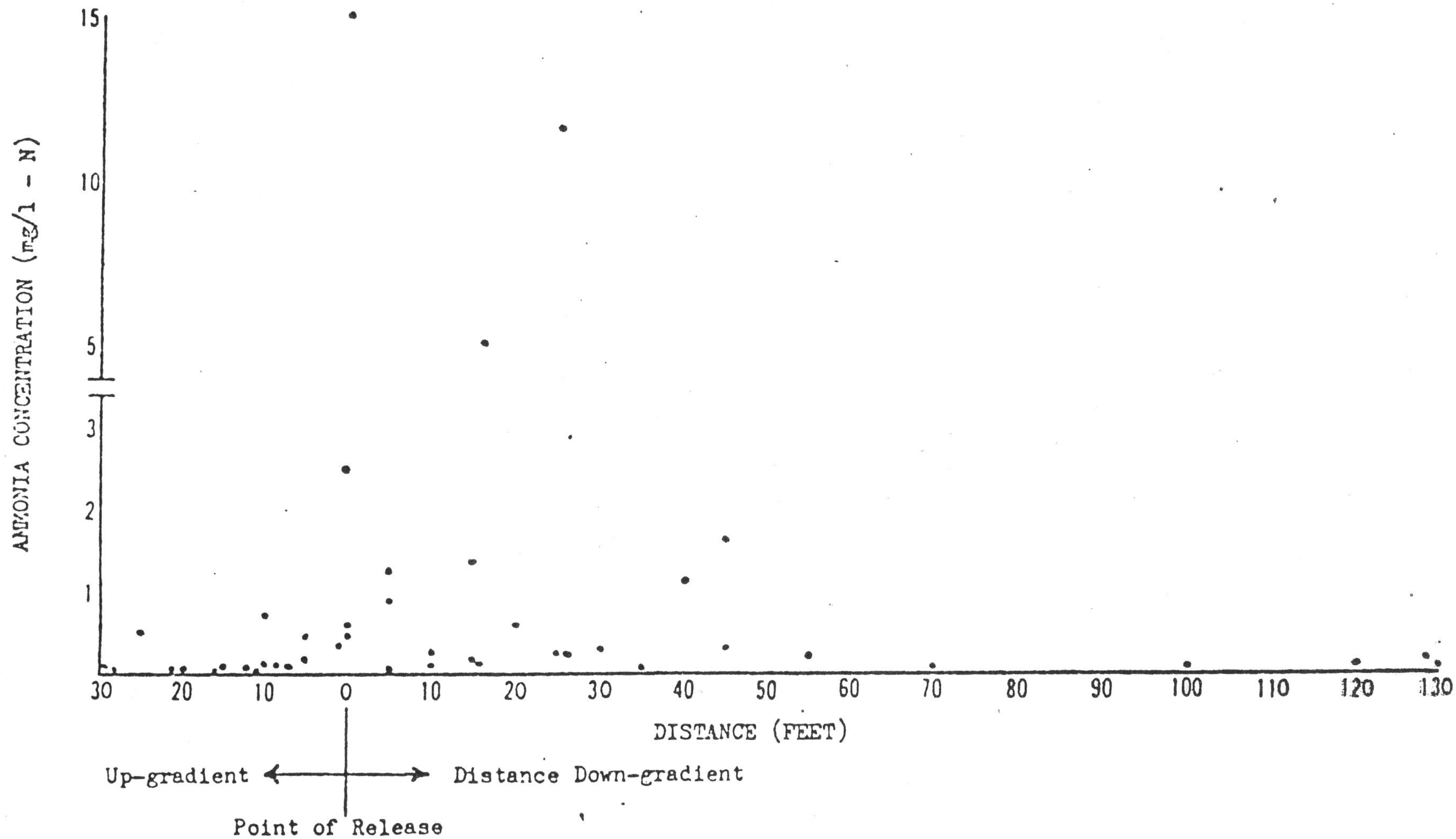


Figure 11:

DISTRIBUTION OF TOTAL PHOSPHORUS IN GROUND WATER ADJACENT TO THE ELEVEN MONITORED SYSTEMS
(DATA POINTS REPRESENT THE MEAN CONCENTRATION FROM EACH WELL)

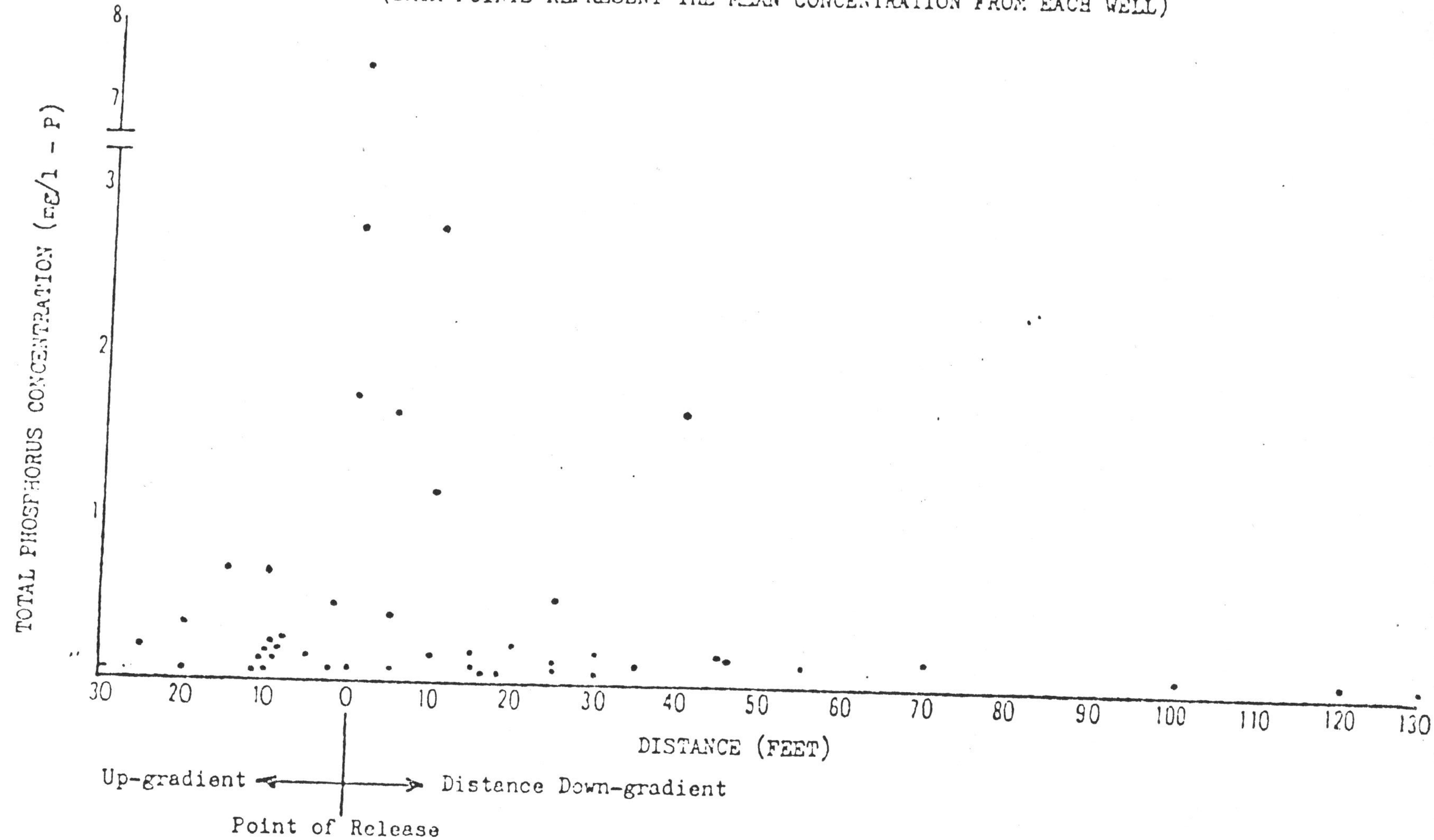
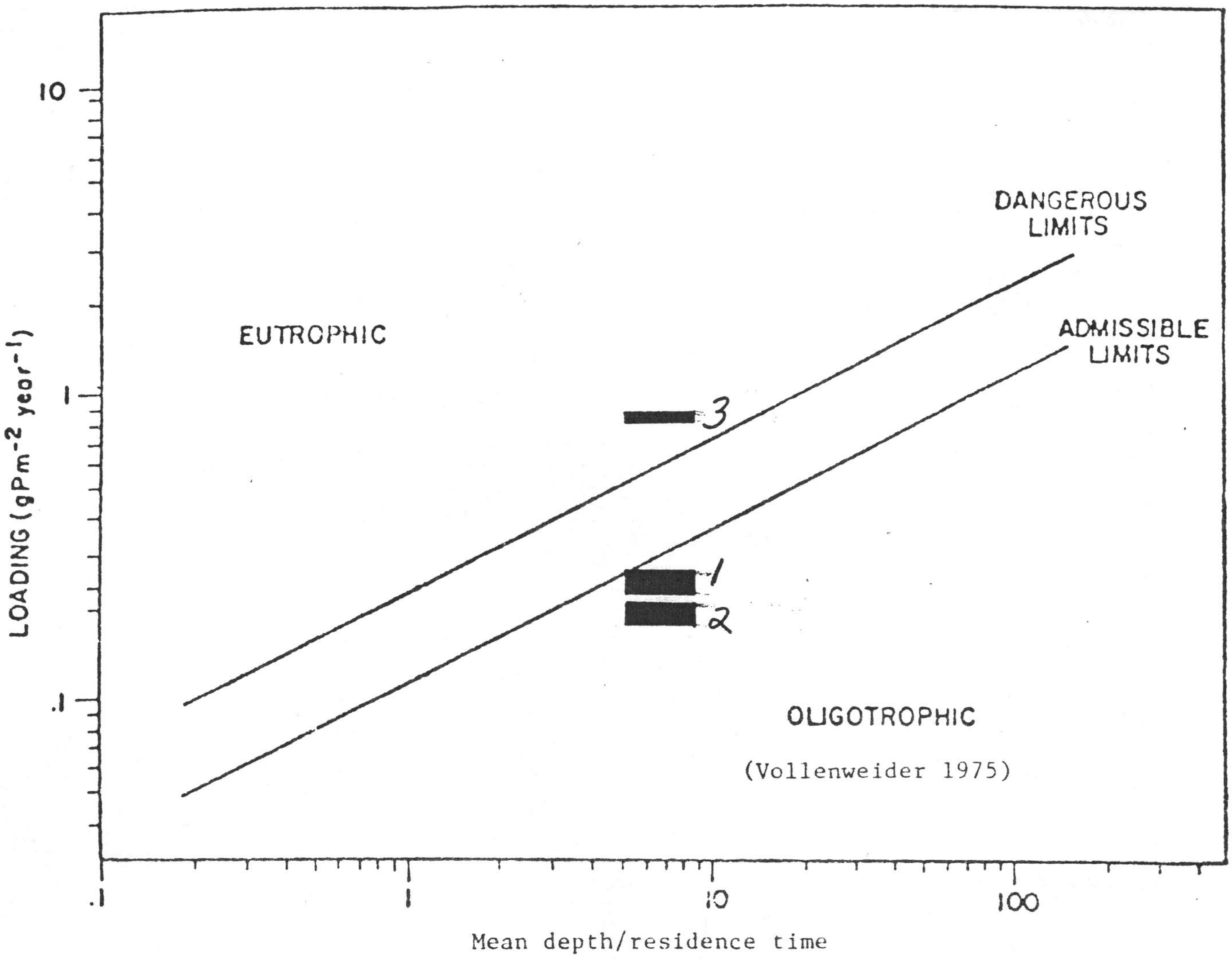


Figure 12: Predicted Lake Trophic Status Under Various Watershed Conditions



1 = existing condition.

2 = if all of the watershed was still forested, the predicted trophic status would be changed insignificantly.

3 = if all of the watershed became urbanized, the lake would be changed greatly.

Figure 13: Watershed Zoning

APR 1 7 1978

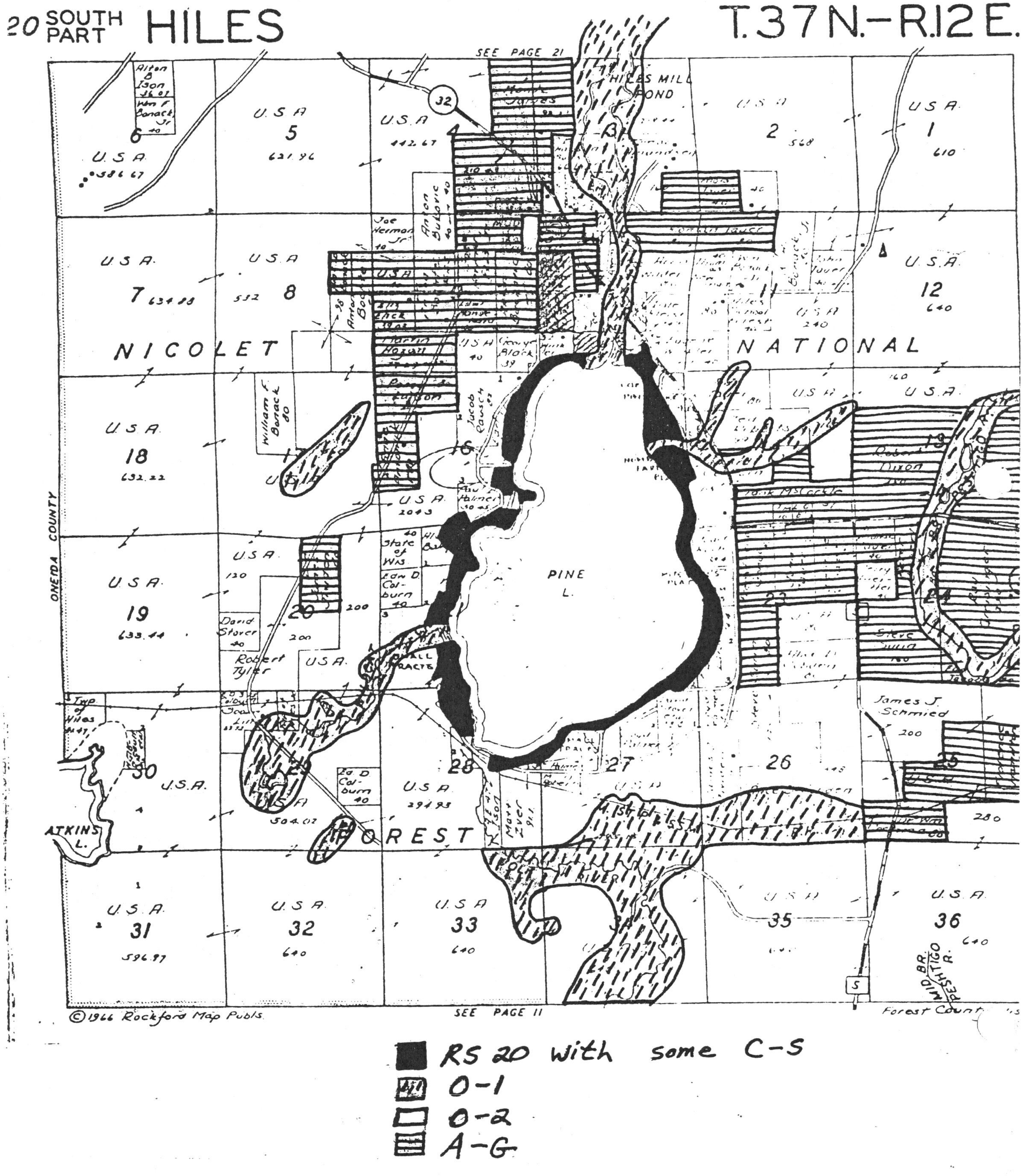
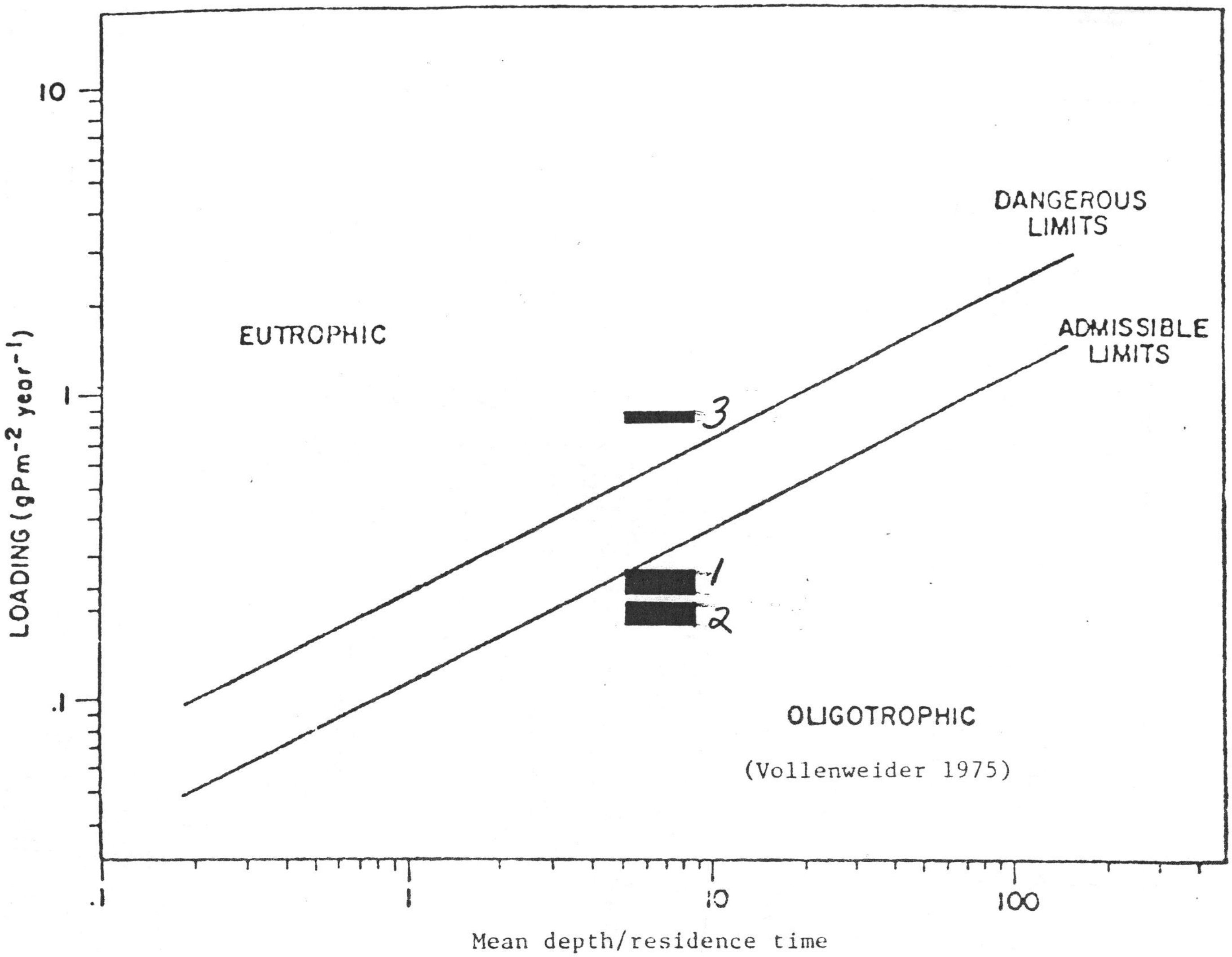


Figure 12: Predicted Lake Trophic Status Under Various Watershed Conditions



1 = existing condition.

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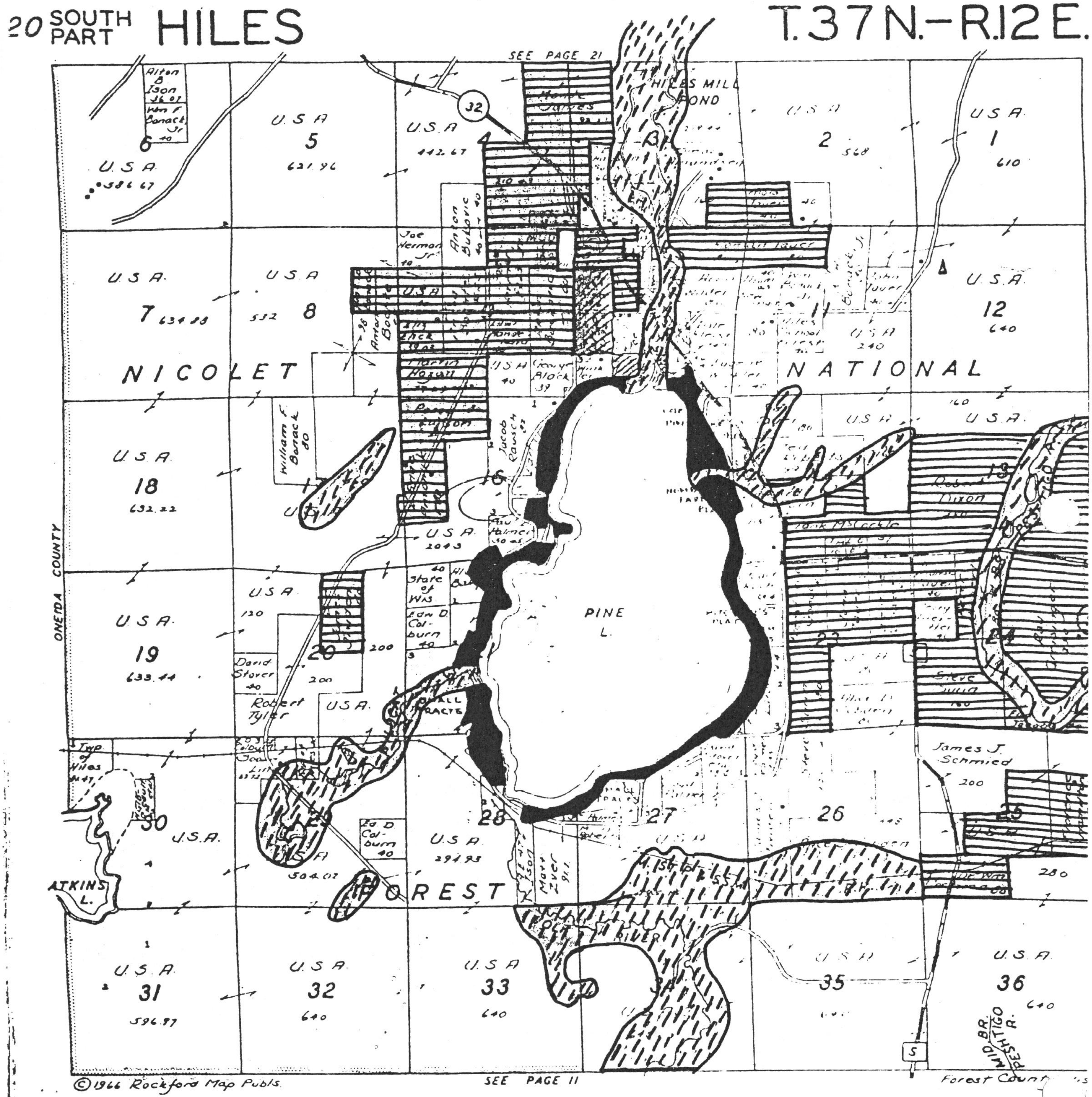
Figure 13: Watershed Zoning

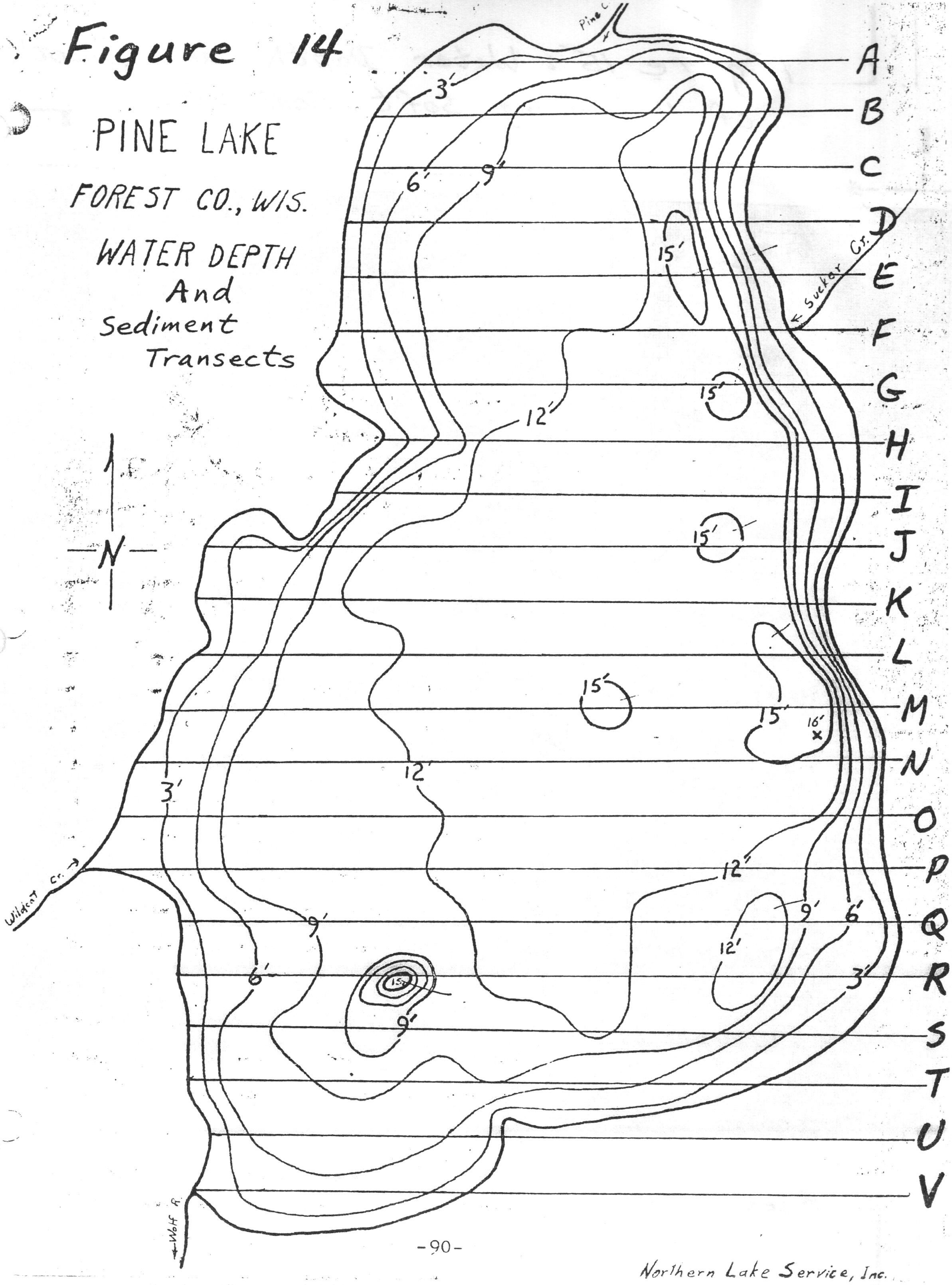
APR 1 7 1978



RS 20 with some C-S
O-1
O-2
A-G

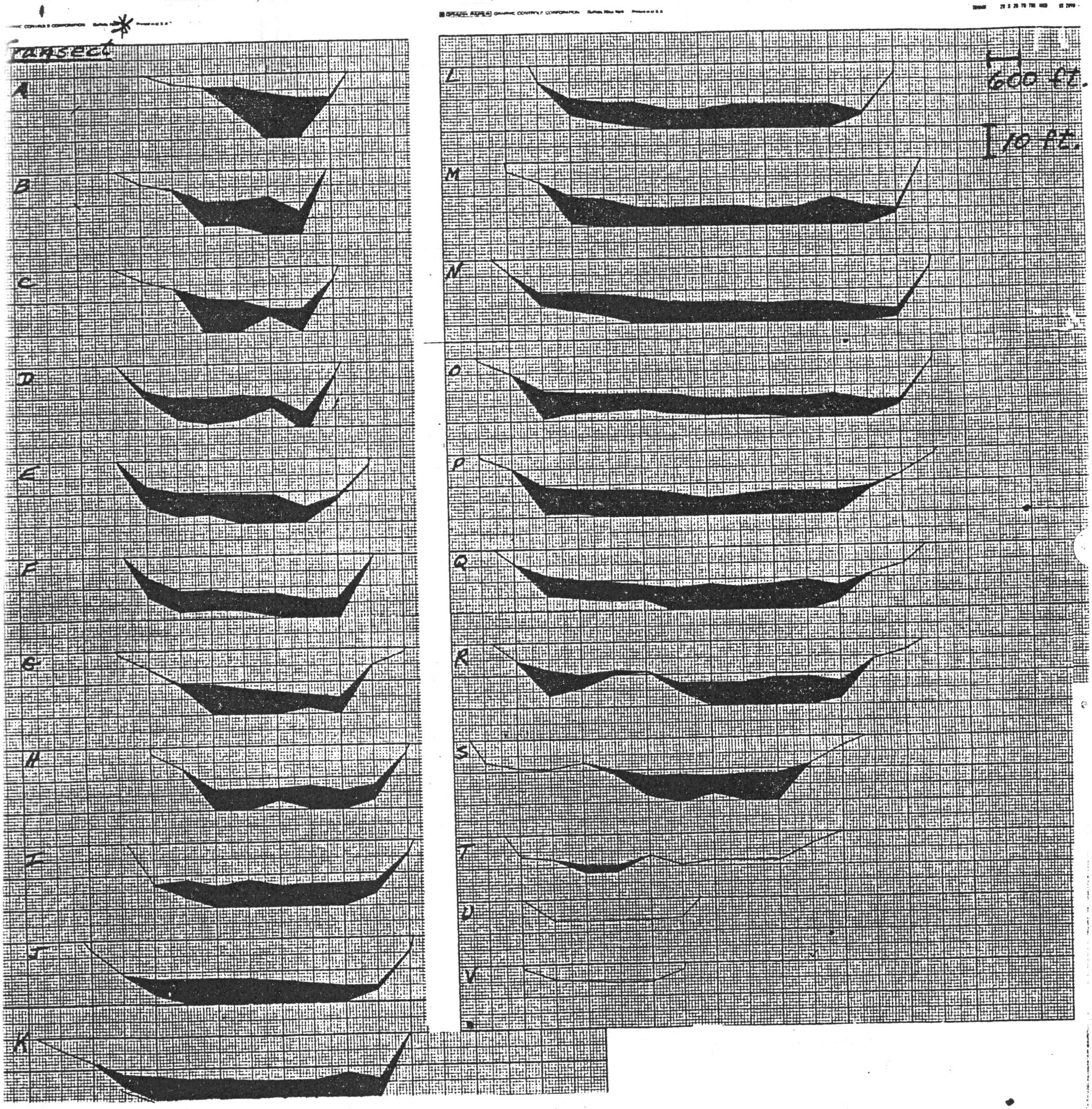
Figure 14

PINE LAKE
FOREST CO., WIS.
WATER DEPTH
And
Sediment
Transects



Northern Lake Service, Inc.

Figure 15: Water Depth and Depth of Underlying Soft Sediments



*see Figure 14 for locations