# Maskenthine Lake and Willow Creek Nebraska

# Phase I Diagnostic Assessment

Clean Lakes Program
February 1992

Open-file report WC/WSL 92-2

A completion report in fulfillment of a contract between the Lower Elkhorn Natural Resources District and the Water Center, Institute of Agriculture and Natural Resources, University of Nebraska.

The following report was prepared by the Water Center (University of Nebraska-Lincoln) and the Lower Elkhorn Natural Resources District. Water Center personnel included:

Roy Spalding, Project Director
Daniel Snow, Laboratory Manager
Mark Burbach, Field and Sample Coordinator
David Cassada, Organic Separation Chemist
Shelly Unger, Project Assistant
Jeff Toavs, Field Technician
Thomas Papiernik, Data Manager
Karen Burbach, Graduate Student

Additional personnel included:

James Gross and Roger Gipson performed the monthly sampling on both Maskenthine and Willow Lakes and also macrophyte surveys on both lakes.

Jennifer Carr-Burtwhistle performed algae counts and chlorophyll a analyses on both lakes.

Mary Exner Spalding helped sample both lakes and also reviewed the manuscript.

Phil Garland helped in underwater coring of both lakes.

Rollin Hotchkiss helped design gaging stations and directed bathymetry.

Stan Staab, Don "Skip" Kahler, George Benson, and Marla Rohrke assisted and coordinated local involvement.

Dan Sutherland assisted and coordinated Nebraska Game and Parks Commission involvement.

The High Plains Climate Center provided precipitation data for both lakes.

The Nebraska Resources Commission provided maps of land use for the drainage areas on both lakes and were called upon for other inputs to the AGNPS model.

Paul Brakhage (DEC) assisted in the sampling protocol and QA/QC and is providing oversight for the project.

EXECUTIVE SUMMARY

The interpretation of data derived from the sampling and chemical analysis of Maskenthine and Willow Lakes has provided strong evidence that although the lakes are less than 50 miles apart, their problems and remedies are unique.

Maskenthine Lake's existence is dependent on runoff from a relatively small drainage area. This runoff is truly ephemeral and results in large fluctuations in the lake's water level. The drainage area is extensively row cropped and has several fields that have steep slopes (>20%). Predictive models support the conclusion that the lake is acting as a sediment trap. Because the wetter months usually occur in the spring and early summer the tilled and still primarily fallow fields are prone to erosion. This erosion deposits large amounts of sediments and associated agrichemicals (nutrients and pesticides) into the upper arm of the lake. The agrichemicals appear to rapidly mix throughout the water body and in the case of several herbicides appear relatively persistent. A smaller associated problem is an extensive growth of macrophytes.

Solutions to these problems will not be cheap or without political and land-owner resistance. In order to return the lake to the original volume, sediments from the upper third of the lake will need to be removed. Several sediment removal alternatives are briefly discussed in the report. These will need to be evaluated for both efficacy and for restrictions relating to spoil disposal. However, sediment removal should not be considered without first implementing strategies to prevent the continued sediment deposition of the lake. The facts are that the lake is about 16 years old and the upper reaches are filled in. In order to limit this rapid siltation several steps are in order. These include the improved watershed management and the installation of siltation traps along Maskenthine Creek. Watershed management should include the removal of steep-sloped land from row cropping, using a combination of terracing and contour-farming throughout the remainder of the watershed, and maintaining a fenced-off riparian strip along the length of the creek, and controlling erosion on unimproved roads.

The major problems at Willow Lake relate to nutrient-driven algal productivity and bank erosion and slumping. Unlike Maskenthine, Willow receives its water from two ground water-fed streams and the lake is assumed to be in hydrologic connection with the ground water. While the lake receives an occasional input of runoff containing farm chemicals, these inputs appear rapidly diluted in this larger water body. There does not appear to be a major siltation problem at Willow Lake from stream runoff; however, bank slumping occurs and appears to be nearly impossible to stabilize due to fluctuating water tables. High phosphate and nitrate are common to ground water in the agriculturally developed sandhills and their transport in low concentrations to drains like Willow Creek will probably be next to impossible to control. Solutions to Willow Lake are very complex and will not be easily remedied.

While eutrophication probably can not be prevented at Willow Lake, nutrient water quality degradation is exacerbated by several local inputs of nutrients. Inputs to address include animal feedlots along the lake's tributaries in close proximity to the lake and the presence of cattle and pigs wading in the streams feeding the lake. These sources of nutrients to the lake should be restricted by the implementation of riparian strips of grass and trees. Best nutrient and water management education for farmers located near the lake and tributaries is important because agrichemical laden ground water can be and probably is transported to surface water drains feeding the lake.

Other problems needing attention include localized bank erosion at Maskenthine, a lack of basic data to interpret ground and surface water chemical transport to Willow Lake, increased education as to the benefits of best management practices in irrigated croplands of primarily Willow Lake, and the development of detailed cost estimates for alternatives for remediation.

The Technical Advisory Committee unanimously recommends for Lake Maskenthine the following in-lake and watershed treatment alternatives. Sediment removal by lowering the lake level and removing accumulated sediments with earth movers and/or drag lines is recommended. The accumulated sediment to be removed is in the north arm of the lake from the boat dock and boat ramp to the road. Estimated costs for the removal of 72 acre-feet, 15 acres x 6 feet, (261,600 cubic feet) of sediment are ~$500,000. This estimate does not include costs for engineering and final design. Prior to sediment removal the group strongly advises construction of sediment traps and a wetland within the watershed. The cost of constructing a sediment trap is ~$125,000. This estimate does not include costs for engineering and final design. The wetland should be relatively cheap to construct. Long term clean out and maintenance of these traps will be mandatory and probably will require NRD oversight and resources. Additional land treatments in the watershed (terracing and contouring) is also recommended on sights that AGNPS has suggested to be most vulnerable. While funding for construction of sediment upgradient structures is being sought, the committee advises that the NRD seek funding for localized bank stabilization project. Locations needing stabilization have been delineated that need immediate attention and will cost from $50,000 - 100,000 to repair. The total project can be viewed as one which must be developed by a logical progression of events. The phases of implementation include (1) local bank stabilization (2) watershed treatment and (3) in-lake sediment removal. (Refer to Attachment A for specific Phase II recommendations and budget.)

The Technical Advisory Committee recommends that more information be gathered to better define the ground/surface water interrelationships at Willow Lake. Interrelationships that are pivotal for solving the problem at Willow Lake include the association of ground water levels to surface water levels and the potential transport of nutrients from the ground water to the lake. Until the system is better defined, in-lake bank stabilization remedies and nutrient control alternatives can not be addressed with any certainty of success. Thus, although all the Clean Lakes Phase I protocol was followed, additional Phase 1 type investigations are need. These should include installation and monitoring of piezometers and multilevel samplers and lake stage gauges. Additional analyses of both quantity/quality of ground water from pressure release wells are necessary to predict feasibility of using this water to stabilize lake water levels.

In the meantime the advisory committee strongly recommends implementation of watershed improvements at obvious highly erodible sites and at sites where nutrient contributions to the lake input tributaries were observed. Riparian strips along these tributaries are strongly recommended.

# I. DIAGNOSTIC STUDY

## I-1. Lake Identification and Description

Maskenthine Lake is located in Stanton County two miles north of the town of Stanton and eight miles east of Norfolk. The lake's legal location is T23N R2E S 6, 7, & 18 and at the normal waterline occupies 0.13 square miles (85.3 acres) with a watershed of approximately 9.37 square miles (6,000 acres). The lake is owned and managed by the Lower Elkhorn Natural Resources District (NRD).

Willow Lake is located in Pierce County two miles southwest of Pierce and is 14 miles northwest of Norfolk. The lake's legal location is T25N R2W S 4, 5, & 6 and T26N R2W S 31, 32, & 34 and the permanent pool level occupies 1.1 square miles ( 700 acres) with a watershed of approximately 210 square miles (134,400 acres). The lake is owned by the Lower Elkhorn NRD and managed by the Nebraska Game and Parks Commission as a state recreation area.

## I-2. Geological and Hydrological Description of the Drainage Basin

The drainage area of Maskenthine Lake occupies the western extent of glacial till in northeastern Nebraska. The lake's permanent pool water line is 1535 feet above sea level while 1800 feet above sea level is the maximum elevation of the surrounding hills that comprise the drainage area.

Agriculture and recreation are the primary landuses in the watershed. Most of the farmland that is not in the CRP program is used for dryland row crops (sorghum, soybeans, corn, wheat and some alfalfa). The upland soils represented within the watershed are silty loams and are represented by the Nora-Crofton-Moody association, all of which are derived from loess and contain about 20% clay. They are generally considered well drained. Within Maskenthine Creek and the lake bottom, the soils are >6 feet thick silty clay loams that are poorly drained. The pre-development vadose zone was 40-50 feet thick beneath the lake's bottom. The unconsolidated sediment of Quarternary age consists of wind deposited silt (loess), glacial till, and lacustrian deposits of silts and clays. The regional water table is at ~1490 feet above sea level.

The drainage area of Willow Lake is much larger than that of Maskenthine Lake and occupies 210 square miles (134,400 acres). Soil associations are quite variable and include: Ord and Orwet soils in the upper creek bottom and Elsmere-Ovina-Loup associations in the lower bottomlands surrounding Willow Lake. Willow Lake and Creek represent a divide between eolian sandy and loamy soils of the Thurman-Ortello-Boellis association on the north and sandy soils of the Vallentine-Thurman association. These soils characterize the eastern sandhills region of Nebraska. The topography in close proximity to the lake is flat with a standing water elevation of 1625 feet above sea level and the highest surrounding elevation of 1795 feet above sea level. Landuse in the drainage area consists of cattle grazing, row cropping and confined feedlot operations. Since there is an abundance of shallow ground water much of the row crops are irrigated in the Willow Creek drainage basin.

Both lakes are in the subhumid region of eastern Nebraska. Average annual precipitation in Stanton County and Pierce County amounts to 25.5 and 25 inches, respectively. Average summer and winter temperatures in Stanton County are 73°F and 23°F, respectively.

Average windspeed is highest, 14 miles per hour, during the spring. The sun shines 70% of the time in the summer and 60% of the time in the winter.

I-3. Lakes Public Access

Public access is by three entrances at Maskenthine Lake. There are 5 entrances to the Willow Creek State Recreational Area.

I-4. Size and Economic Structure of Population Using Lake

Individuals using Maskenthine Lake and Willow Creek travel an average of 21 and 50 miles, respectively, to get to the lake (Kris Reed, Natural Resources Commission). The nearest large city to both Maskenthine Lake and Willow Creek is Norfolk, which is approximately 11 miles from Maskenthine Lake and 14 miles from Willow Creek. Maskenthine Lake is in Stanton County, which has a population of 6,244, average annual income of $12,796, and mean age of 31.6 years according to the 1990 census. Willow Creek is in Pierce County, which has a population of 7,827, average annual income of $14,563, and mean age of 35.4 years according to the 1990 census.

I-5. Historical Lake Uses and Trends in Use

The Maskenthine Reservoir Project was initially conceived by the U.S. Army Corps of Engineers in 1966. The Lower Elkhorn NRD began planning the project in March, 1973 and applied for funds the following year. In May, 1974 the Nebraska Games and Parks Commission approved a grant for Phase I land acquisition which was completed in 1975.

Field work and design of the flood control dam were completed by the Soil Conservation Service in 1974-75. Construction was completed in 1975-76 under a grant from the Nebraska Resources Development Fund which is administered by the Nebraska Natural Resources Commission. The initial recreation facilities, a part of the Phase II development, were constructed under an additional grant from the Land and Water conservation Fund through the Nebraska Game and Parks Commission, and were completed during 1978. The Maskenthine Reservoir Project opened to public use as a State Wildlife Management Area on January 1, 1979. In 1987 the Lower Elkhorn NRD began operating it as a recreation area. Major recreational activities include hunting, boating, swimming, camping, fishing, and hiking.

Construction on the Willow Creek reservoir project began in 1982 by the Lower Elkhorn Natural Resources District with cost-sharing by the Nebraska Natural Resources Commission. Recreation is managed by the Game and Parks commission and the area opened to the public in August of 1984. There are many recreational activities including camping, fishing, hunting, boating, swimming, horseback riding, hiking, and snowmobiling.

I-6. Lake User Population Impacted by Lake Degradation

Fishing has already been adversely impacted at Maskenthine Lake by siltation and degradation of water quality. In its initial years Maskenthine was and still is a productive bass fishery. The best fishing was at the upper reaches where the habitat was initially very favorable to bass. Heavy siltation has impacted this area, and it no longer is the highly productive region that it was originally. Boating also has been deleteriously impacted by low water levels and siltation in the upper third of the lake. No adverse effects have occurred for campers; however, bathers must swim in very turbid waters.

The water level at Willow Lake remained relatively static during the sampled period; however, the lake remained at low levels during the study period relative to earlier years. Willow Lake has experienced several algal blooms over the past 5 years. These algal blooms tend to stain bathing suits and are not aesthetically pleasing for bathers. According to a LENRD board member, foul odors originating from decaying organic matter from the blooms or deep water detritus within the lake were reported in past summers (personal communication from NRD advisor), but were not observed during the monitoring period. The blooms were extensive during the mid- to late-1980s (Sutherland, 1992) and had a deleterious effect on the lakes' fish (Schuckman, 1992)

I-7. Comparison of Lake Use to Other Lakes in 80 km. Area

Table 1 provides a list of lakes that are within 80 km distance of Norfolk. Use criteria provided at each lake is denoted with an X.

| Lake | Recreation | Water Supply | Wildlife Management | Flood Control | Storage |
|---|---|---|---|---|---|
| Buckskin Hills Lake | X | | X | X | |
| Chalkrock SWA | X | | X | X | |
| Grove Lake | X | | X | | |
| Lake Babcock | X | | | | |
| Lake North | X | | | | |
| Lewis & Clark Lake SRA | X | X | X | X | X |
| Pilger Lake | X | | X | X | |
| Skyview Lake | X | | | X | |
| Wood Duck SWA | X | | X | | |

Table 1. Use criteria of lakes within an 80 km distance of Norfolk.

I-8. Inventory of point source discharges

Potential point source contributors are limited to animal feedlots located along Willow and Maskenthine Creeks. Depending on the direction of channeling, irrigation flow may be considered a point or nonpoint source contributor, and may be a factor for Willow.

I-9. Watershed Landuse and Pollutant Production

Figures 1 and 2 indicate the results of the landuse survey done by the Natural Resources Commission that was conducted in 1983 and 1984. In the Maskenthine watershed 80% of the land area is used for row cropping with only 4 - 5% being irrigated (figure 1). The remaining 15-16% is used for rangeland and pasture. The lands in the quarter section just north of the lake have been purchased by the NRD and are planted to natural grasses in the conservation reserve program (CRP). Landuse in the Willow Creek watershed in Pierce County is a 60/40 mix of cropland and range/pasture (figure 2). Approximately one half of the cropland is irrigated. One quarter section not shown in the 1984 data which borders the lake on the northwest side now is cropped to irrigated corn.

I-10. Lake Limnology

A. Approach

The objective of this program is to define the ecologic health of two different, closely spaced, recently constructed man-made lakes in northeast Nebraska. Biological, chemical, and geological indicators of the lakes' stations were determined. Inputs to

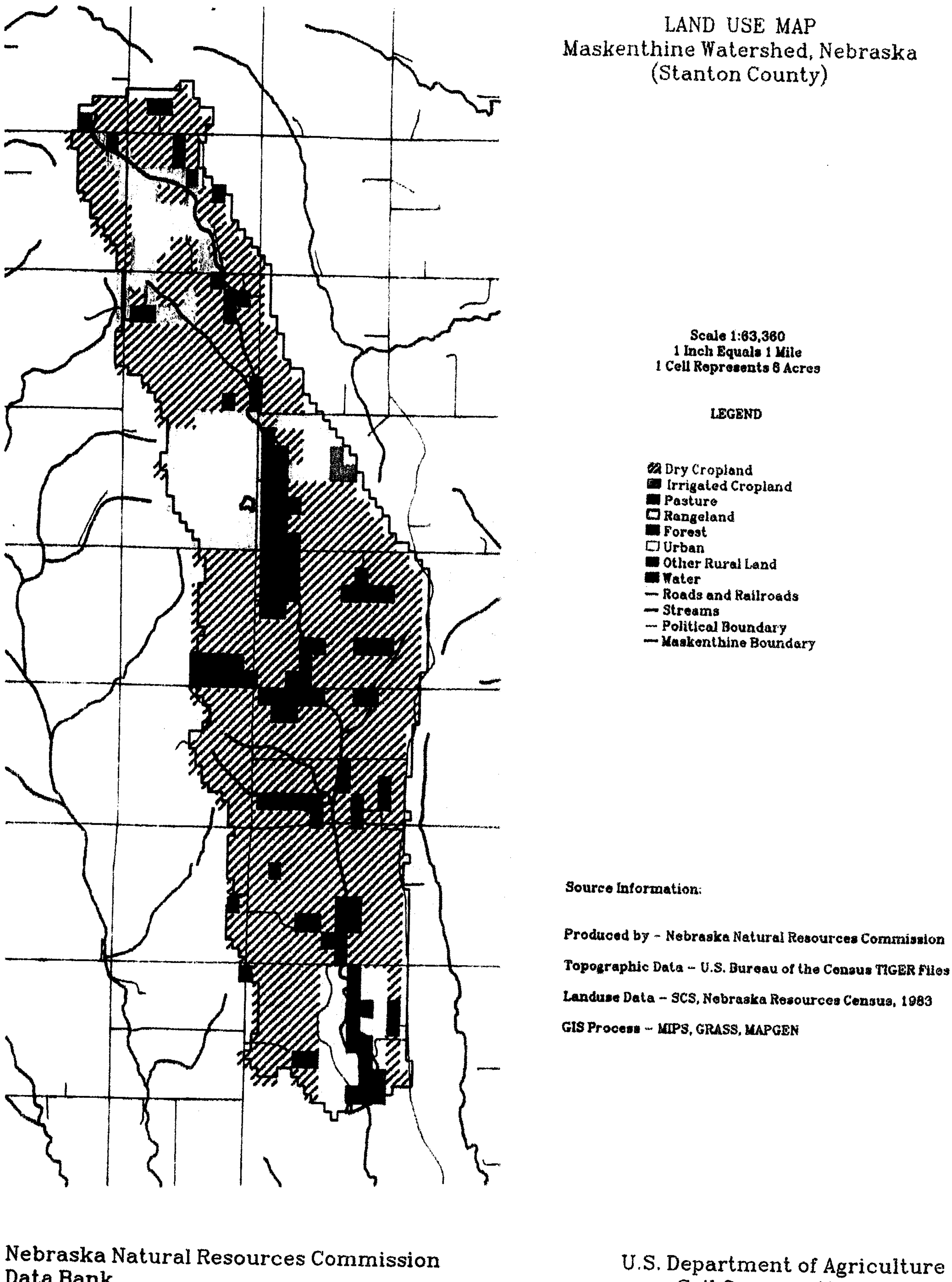



Figure 1. Land use map in the watershed at Maskenthine Lake.

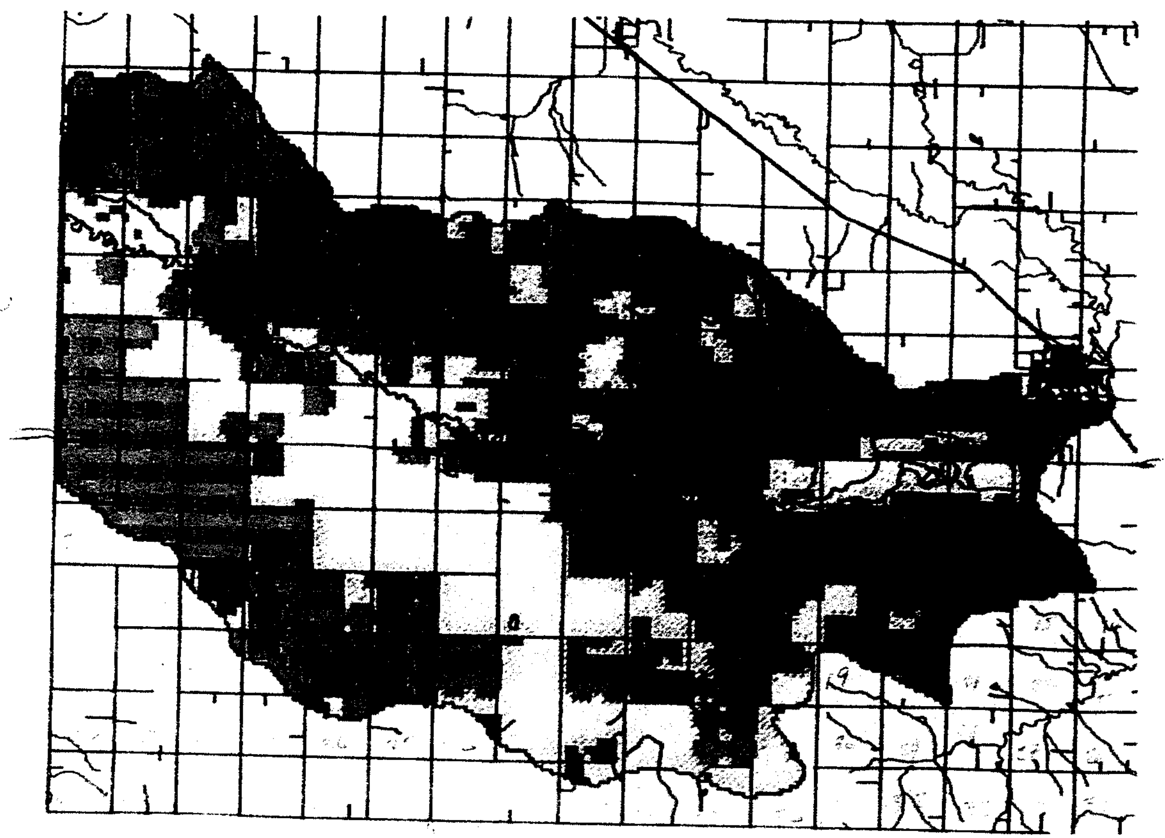



Figure 2. Land use map in the watershed at Willow Creek.

the lakes were both directly measured and projected in models. Chemical measurements of ag-related compounds occurred bimonthly from April through September. The remainder of the sampling occurred on a monthly basis. Runoff events were monitored whenever possible. Due to distance requirements only the well-publicized predicted heavy rainfalls were successfully monitored.

B. Experimental Procedures

1. Lake and Tributary Sampling

Samples for lake characterization were collected from one station on Maskenthine Lake (ML-1, figure 3) and two stations on Willow Lake (WL-1 and WL-2, figure 4). Lake water samples were collected at three depths from each station using a teflon Kemmerer sampler. Tributary samples were collected by taking grab samples from inflow stations (figures 3 and 4). The majority of samples collected from the intermittent Maskenthine Input (MI-1) were collected during runoff events. Tributary samples from Willow Creek Inputs were collected quarterly and during runoff events.

Temperature and conductance were measured in the field using a digital S-C-T meter. Raw conductance was subsequently converted to a value which compensated for the effect of temperature (LabComp, 1990). pH was measured in the field using hand-held pocket pH meters. Dissolved oxygen was measured using the Winkler method (APHA, 1989) and by dissolved oxygen meter (Yellow Springs Instruments) which was checked by Winkler titration in the field. Alkalinity was measured by titration using a field test kit (LaMotte Chemical).

All samples were collected and preserved, if necessary, following USEPA or APHA *et al.* (1989) guidelines for each analyte. Samples for pesticide analysis were analyzed by GC/MS following a modified USEPA Method 525 (USEPA, 1988) solid phase extraction procedure. Samples for total phosphorus, dissolved organic carbon (DOC), suspended material, and major ions were also analyzed at the Water Sciences Laboratory using APHA *et al.*, (1989) or USEPA (1983) methods. Nitrate-N, ammonium-N, total kjeldahl N and ortho P were determined by USEPA (1983) methods in the UNL Agronomy Department Analytical Laboratory. Dissolved metals were determined by inductively coupled plasma (ICP) emission spectrophotometry (USEPA Method 200.7) at A&L Midwest Laboratories, Omaha, Nebraska. Bacterial analyses were performed at the Nebraska Health Department State Laboratory.

Quality assurance/control was monitored throughout the project through the analysis of duplicate samples (5%), field blanks (5%), and trip blanks. Method blanks (5%) and spikes (5%) were included with each set of samples submitted for analysis. Blind reference samples were also included as a check on the accuracy of analyses. Accuracy of standards were checked against certified reference standards when they were available. Precision of each analyses was monitored using the results of duplicate analyses (USEPA, 1979). Accuracy of analyses was monitored using the results of spikes, matrix spikes, and blind reference samples (USEPA, 1979). Cross contamination was monitored by analysis of field blanks and analysis of an equipment blank produced by rinsing the Kemmerer sampler three times between lakes with reagent water.

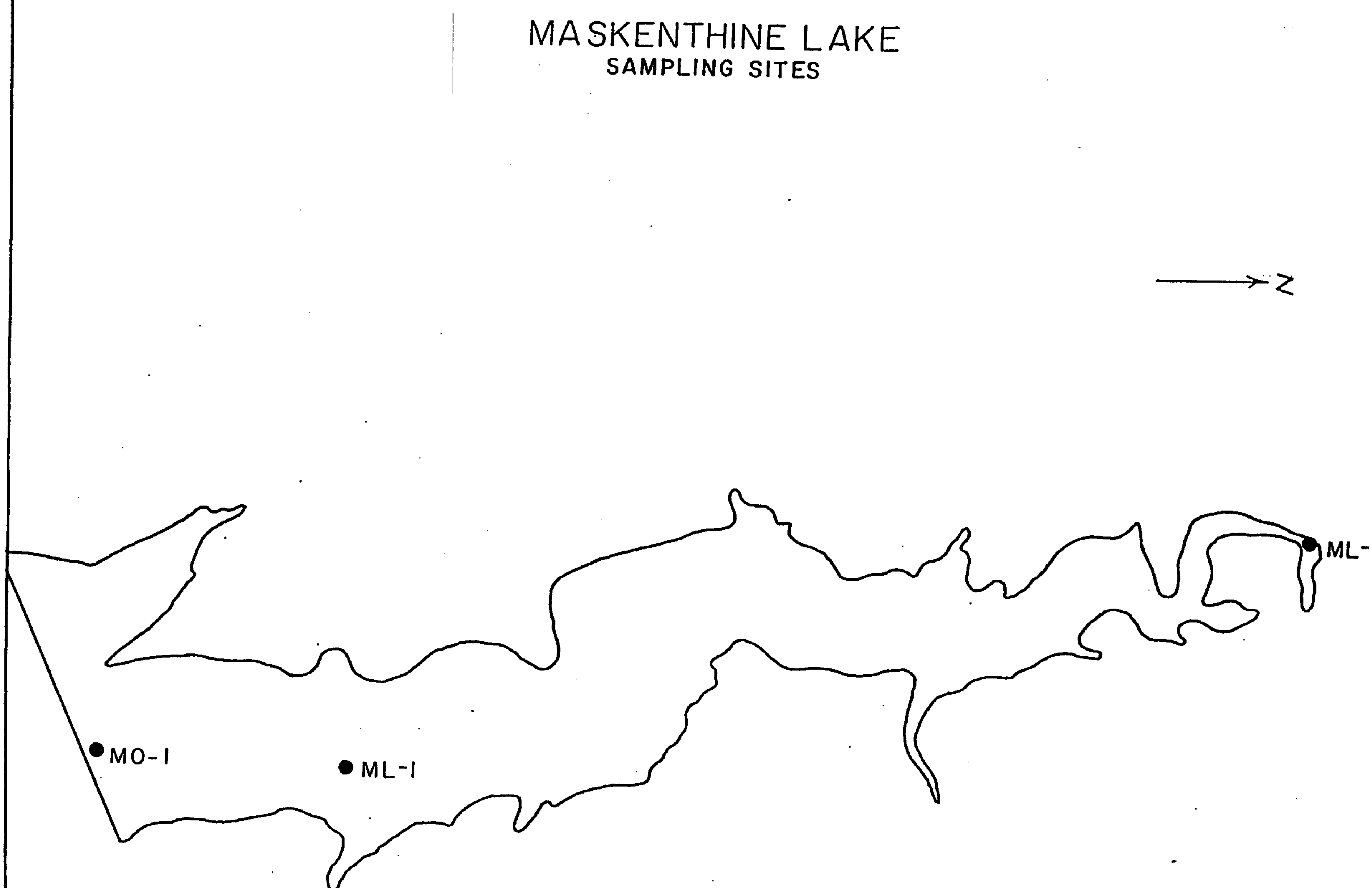



Figure 3. Sampling stations at Maskenthine Lake.

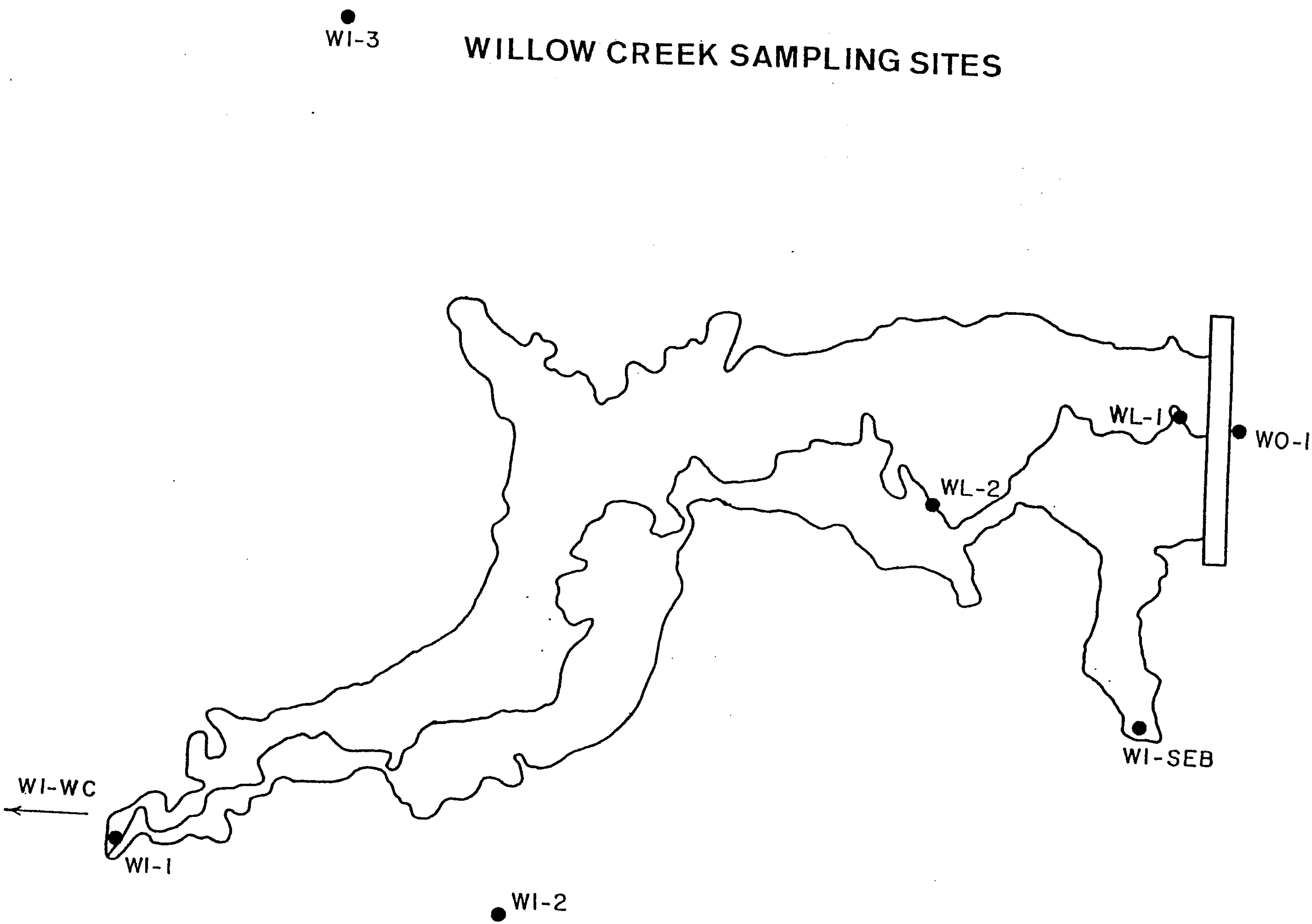



Figure 4. Sampling stations at Willow Creek.

2. Lake Coring

Sediment cores were collected from each lake in April 1990 and again in July 1990 (figures 5 and 6). Cores collected in April were obtained using a portable vibracoring device. The vibracorer consisted of a high-frequency vibrating bulkhead clamped to a 3-inch diameter aluminum pipe. The vibrations cause the sediment at the end of the pipe to liquify, thus allowing the pipe to slowly penetrate the bottom sediment. Cores were retrieved by scuba divers. The July cores were "push" or gravity cores produced by scuba divers forcing 3-inch aluminum pipe into the lake bottom. All cores were capped and transported on ice back to the Water Sciences Laboratory where they were stored frozen until they could be prepared for analysis.

Core preparation involved splitting the frozen core lengthwise in half, thawing, and sampling at 1-foot or shorter intervals. A description of each core may be found in Appendix 1. A composite subsample for pesticide extraction was scraped from the center of each interval to minimize cross contamination. Pesticides were extracted from sediments with 80% methanol in water using a $^{13}C$-labelled atrazine internal standard. Sediment slurries were allowed to equilibrate overnight, shaken, and centrifuged. The supernate was diluted with water and extracted on a C-18 solid phase extraction cartridge which was subsequently eluted with ethyl acetate. The concentrated eluate was then analyzed by gas chromatography/mass spectrometry.

Each core interval was also analyzed for gravimetric moisture content, pH, $NO_3$-N, and $NH_4$-N. Dried and composited sections were used for pH measurement, and $NH_4$-N and $NO_3$-N extraction with 1M KCl (Keeney and Nelson, 1982). Bray phosphorus (Olsen and Sommers, 1982) was measured on dried and composited sections of two cores from each lake. DTPA extractable metals (Baker and Amacher, 1982) were determined on the uppermost section of two cores from each lake.

3. Bathymetric Survey

The bathymetry of both Maskenthine and Willow Lakes was determined through the use of recent surveys of the lakes and pre-existing topographical information. The surveys were performed by civil engineering students from the University of Nebraska under a grant from the Water Center. The results of the two bathymetric surveys are shown in figures 7 and 8. Appendix 2 contains a plan map of Maskenthine Lake showing where surveyed cross-sections exist and plots of the cross-sections.

Cross-sections along the entire length of Maskenthine Lake were surveyed in 1991 and compared to earlier surveys by the Soil Conservation Service in 1988. The new cross-sections indicate that Maskenthine Lake has experienced significant sedimentation since the 1988 survey, especially in the upper part of the lake. Maximum infilling appears to be in the range of 10 to 12 feet. Maximum depth of Maskenthine Lake currently is about 20 feet. Since closure, ~8.6 acre-feet/year (~14,000 $yd^3$/year) has been lost to sedimentation for the entire lake. A total of ~121 acre-feet (~200,000 $yd^3$) of the lake has been lost to sedimentation. Considering only that portion of the lake upstream from the west boat dock, there has been ~37 acre-feet (~60,000 $yd^3$) of deposition since 1988. Since closure, there has been a total of ~88 acre-feet (150,000 $yd^3$) of deposition.

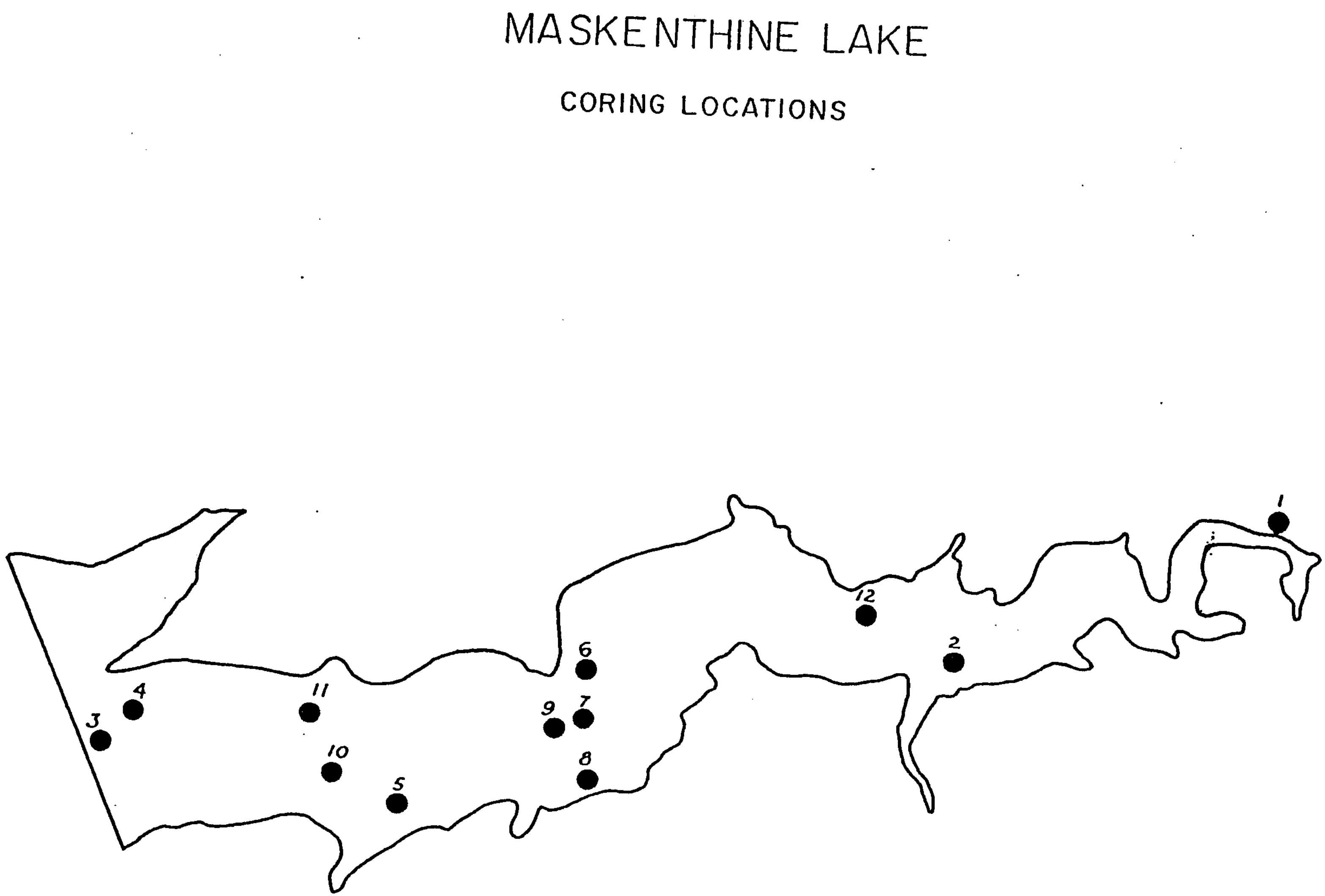



Figure 5. Coring locations at Maskenthine Lake.

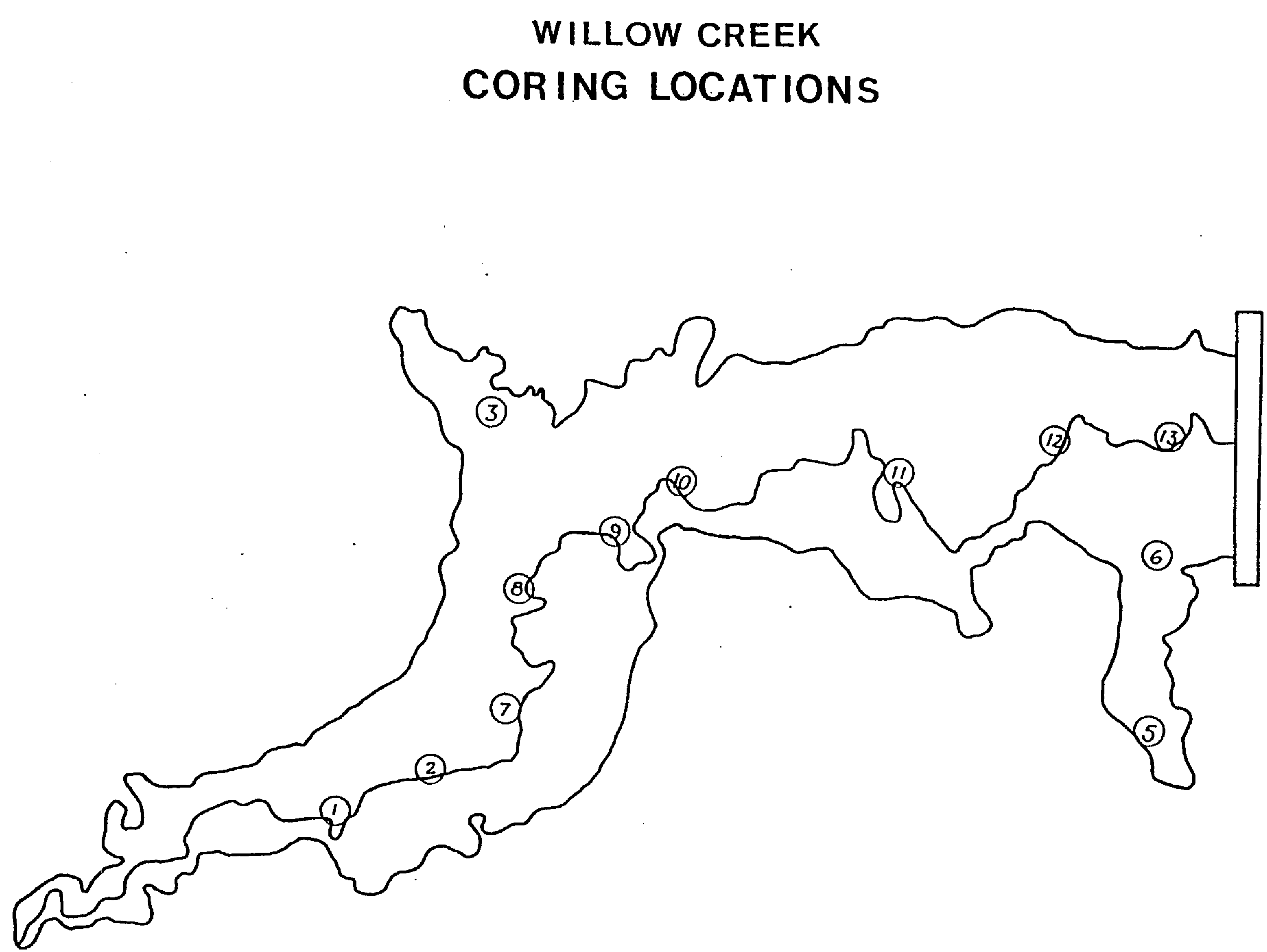



Figure 6. Coring locations at Willow Creek.

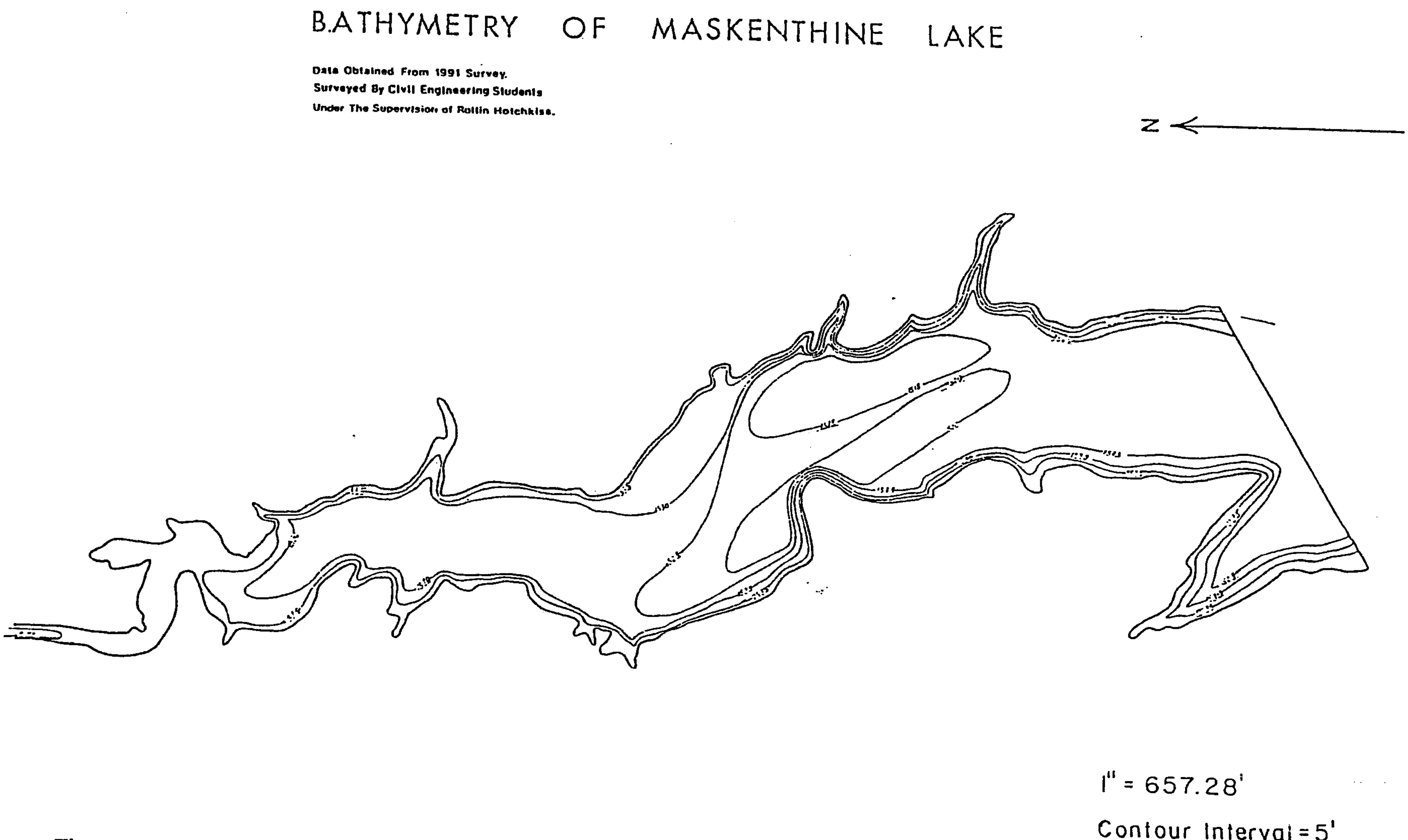



Figure 7. Bathymetry of Maskenthine Lake.

# Bathymetry Of Willow Lake

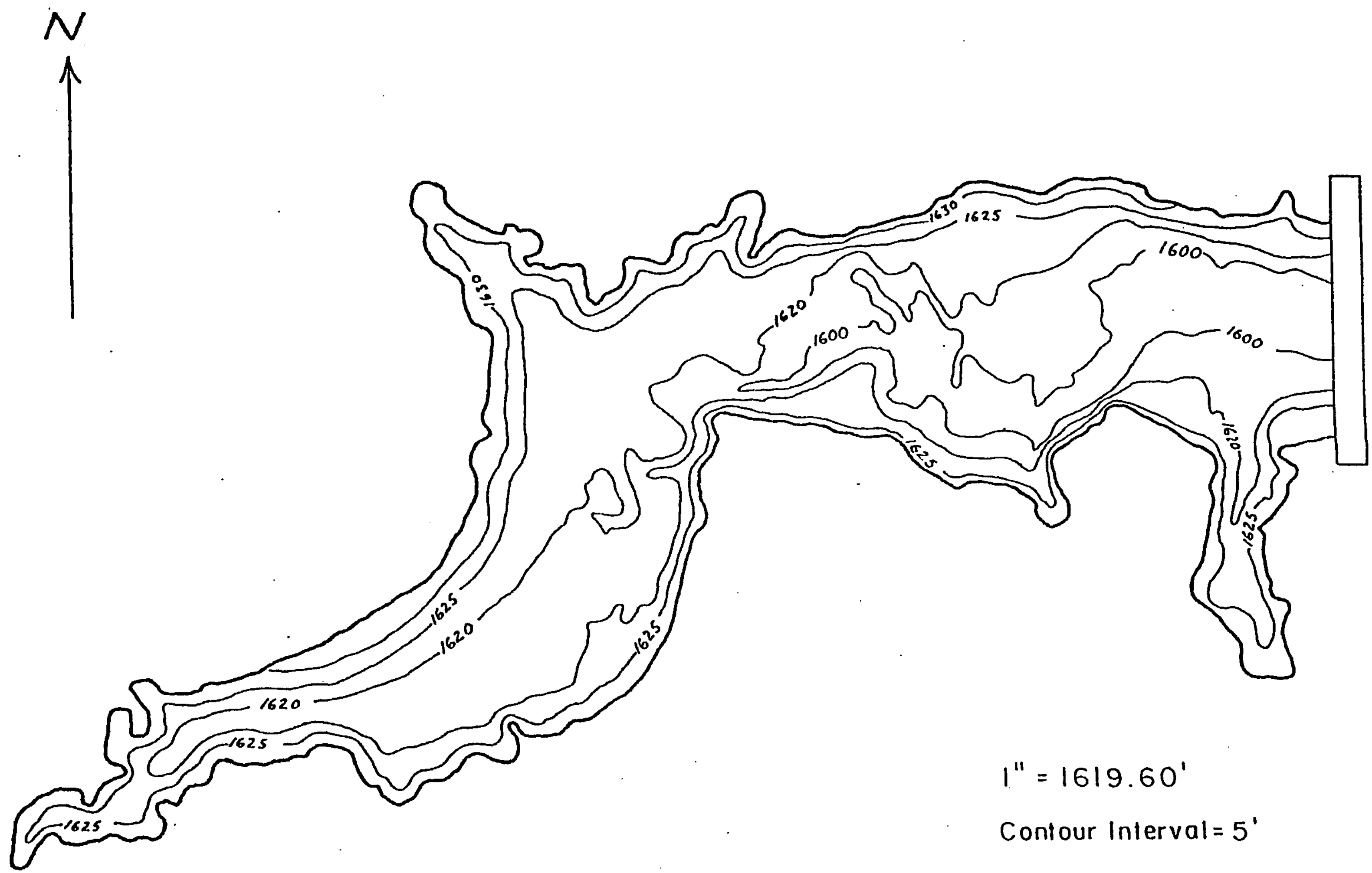



Figure 8. Bathymetry of Willow Lake.

It was apparent that little sedimentation had occurred on Willow Lake except for the uppermost portion. Cross-sections were, therefore, surveyed only on the upper one-fourth of the lake. The remaining bathymetry of Willow Lake was generated from topographic maps of the area before the lake was filled. Maximum depth of Willow Lake currently appears to be in the range of 20-25 feet.

4. Method of Flow Measurement

The stream gage on Willow Creek located approximately 1.5 miles from the lake is a Stevens Type F Water Level Recorder, Model 68. The recorder is both float and time driven. This instrument records varying levels of any liquid surface with respect to time. The graph, which is called a hydrograph, shows water level versus time.

The ball bearing mounted chart drum responds to a 0.1 foot change at the 1:10 scale using a five-inch float although the manufacturers claim the instrument itself can actually be sensitive to 2 thousandths of a foot and can record to such a degree of accuracy if a large enough float is installed. However, it is possible that with this particular installation using a remote unit, that at times the connecting cord can occasionally stick due to debris, making such accuracy of little interest. The time is governed by a quartz multi-speed timer set to eight day intervals on chart length.

The same type stream gage is on Maskenthine Creek on highway 275 approximately two miles upstream from the lake.

C. Morphological and Hydrological Characteristics of the Lake

Hydrology

Maskenthine Lake is a relatively small reservoir fed by an ephemeral stream, Maskenthine Creek. It is an undissected water body with the deepest area located near the dam and along the submerged stream bed. Willow Lake is a much larger reservoir fed by two relatively continuous, ground water fed streams and subject to runoff from two smaller drainage areas. Willow Creek, the main tributary for the area, averages 10,400 acre-ft/year (USGS, 1990) at the USGS gauging station approximately seven miles upstream from the lake. Maximum discharge between 1975 to the present was 574 c.f.s. in March 1987. Minimum recorded daily discharge in Willow Creek was 1.5 c.f.s. in February 1981. Normal annual precipitation of the watersheds ranged from 18.9 to 33.8 inches (NOAA, 1990).

It is difficult to assess how anomalous the precipitation and impacts of the precipitation were during the study period in comparison to previous years. The problem in assessing representativeness of the weather during the study period can only be accomplished with on site weather data. Since spring and summer storms are major sources of precipitation and their spatial distributions are erratic, accumulated precipitation in Norfolk may vary considerably from that at either lake. Lake levels however indicate that Willow did not have any large lake level fluctuations (impacts) during the period and was ~8 feet lower than it was in mid- and late-1980 (Sutherland, 1992). On the other hand, the water level at Maskenthine was six to eight feet below its present level at the beginning of the study. The major rebound occurred after a heavy storm as the lake level raised over 6 feet in less than 24 hours.

Figure 9 shows the daily precipitation recorded at Norfolk, Nebraska, located midway between the two watersheds, for the period of study. Maximum daily precipitation occurred June 5, 1991 at 5.42 inches.

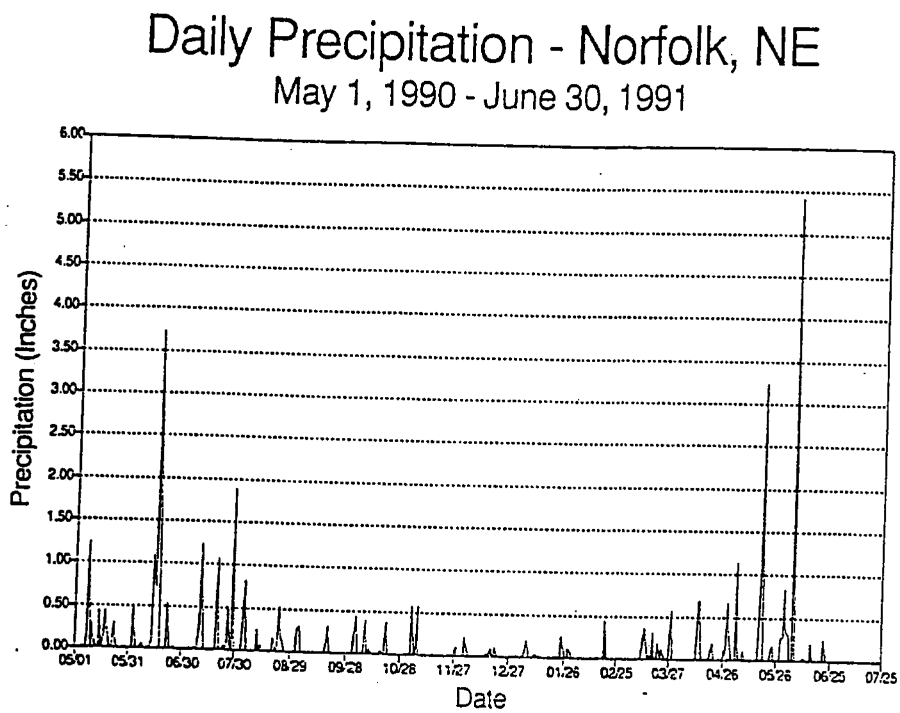



Figure 9. Daily precipitation from May 1990 through June 1991 in Norfolk, Nebraska.

2. Tributary Water Quality

Results of the analyses of water samples collected from the tributaries may be found in Appendix 3.

Maskenthine Creek was sampled for pesticides in conjunction with runoff events. Nutrient levels and suspended sediments were monitored less frequently. The highest level of atrazine (94.7 ppb) was measured in a runoff sample collected June 16, 1990. Atrazine was determined in runoff samples collected in July 1990 and May and June 1991 ranging from 6.74 to 17.2 ppb. The maximum acceptable atrazine amounts allowable for the protection of aquatic life are an acute (1 hour) exposure level at 170 ppb or a chronic exposure (4 day) of 1 ppb. Cyanazine and metolachlor were also measured during runoff events, and they ranged from <0.10 to 9.07 and from <0.05 to 3.46, respectively. Metolachlor is considered to be less toxic to aquatic life than atrazine and has an acute (1 hour) maximum exposure level of 100 ppb. As yet, there are no aquatic exposure levels for cyanazine.

Willow Creek and another Willow Lake input (WI-2) were sampled quarterly and during runoff events for pesticides and other water quality characteristics. Total phosphorus ranged from 0.05 to 16.0 mg/L. An anomalously high total P value was recorded in a WI-2 sample in January 1991. The runoff was from feedlot runoff. The runoff was flowing over frozen ground and spreading over frozen water in the drainageway. When the ground is not frozen some of the runoff infiltrates the soil with the remainder diluted with water in the drainageway. This drainageway comprises a very small portion of the total input into Willow Lake. Nitrate levels in Willow Creek were consistently high for surface water, ranging from 1.56 to 5.91 mg/L, reflecting the ground water flow source for this stream. The second Willow input exhibited nitrate-N levels up to 11.0 mg/L and ammonium-N levels up to 31.7 mg/L. The high ammonium-N in WI-2 was also found in January 1991 in the sample contaminated with feedlot runoff.

A major runoff event in the Willow Creek watershed was monitored June 4-5, 1991 in conjunction with the maximum precipitation recorded at Norfolk, Nebraska. Samples were collected from both inputs for approximately 22 hours during this event to determine the changes in pesticide and nutrient levels during a single runoff. Figure 10 illustrates the changes in atrazine, cyanazine, and nitrate-N levels during this runoff event.

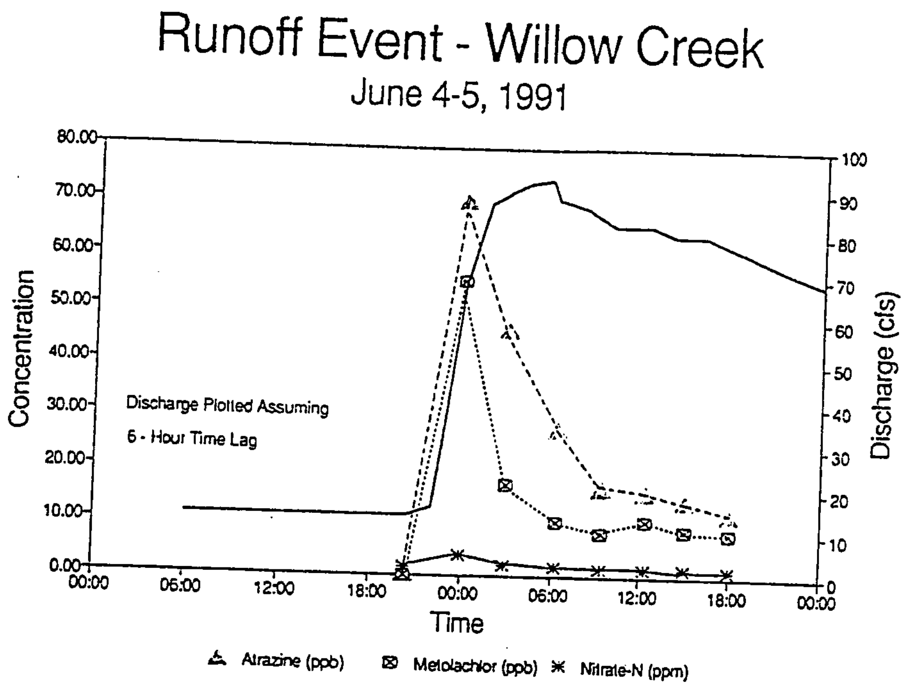



Figure 10. Comparison of atrazine, metolachlor, and nitrate levels to discharge during a runoff event at Willow Creek assuming a 6-hour time lag.

These levels are compared to a discharge hydrograph for the stream recorder located approximately 2 miles upstream from the sampling location. A 6-hour time lag was assumed between the two stations. Peak discharge was estimated to be 93 c.f.s. Measurable levels of butylate, trifluralin, simazine, propazine, metribuzin, alachlor, and cyanazine were also encountered during this event. Atrazine concentrations peaked at 70.2 ppb and metolachlor levels peaked at 55.1 ppb. In general, pesticide levels peaked near the beginning of the runoff event and slowly declined as observed in other studies (Spalding and Snow, 1989). Nutrient levels were not unusually high during the event and loading to Willow Lake would be expected to be small relative to in-lake nutrient levels due to the additional flux. Other inputs to Willow Lake also had high levels of dissolved pesticides during this precipitation event. Atrazine levels ranged up to 32.4 ppb in WI-2, 23.2 in WI-3, and 45.1 ppb in WI-SEB. Cyanazine in WI-3 during the event was 73.2 ppb.

## D. Results

### 1. Water Quality of the Lakes

A water quality monitoring program was conducted at Maskenthine and Willow Lakes and their tributaries from May 1, 1990 through June 15, 1991. Sampling frequency was bimonthly in May through September and monthly in October through April. A total of 19 sampling expeditions to one sampling station on Maskenthine and two stations on Willow Lake where shallow, mid-depth and deep samples were routinely collected. A total of 168 in-lake samples were collected for the major parameters which included: alkalinity, dissolved oxygen, pesticides, total phosphate, ortho phosphate, kjeldahl N, nitrate-N, ammonia-N, dissolved organic carbon, suspended sediments, and volatile suspended sediments. Five expanded quarterly sample collections were made and included the additional parameters chlorophyll a, bacteria, calcium, magnesium, potassium, sodium, chloride and sulfate. Parameters that were measured *in situ*, such as temperature, conductivity, and dissolved oxygen, were profiled with data recorded in 1-foot intervals from the surface.

Lake inflow was routinely sampled at Willow Lake where the two tributaries always flowed. Monitoring inflow at Maskenthine was primarily restricted to heavy runoff events when flow occurred.

#### A. Thermal Structure of the Lakes

The thermal profile for the three stations on these shallow lakes was essentially identical (Figure 11). Temperatures ranged from 1.4 to 29.5$^0$C at Maskenthine Lake and from 0.7 to 28.6$^0$C at Willow Lake. Temperature isopleths indicate that there was sporadic thermal stratification during the summer of 1990 and both lakes remained well mixed with maximum differences of 6$^0$C from the surface to the bottom. The shallow nature of these lakes combined with the relatively windy summer conditions has maintained a mixed surface water body throughout the warm season. At Willow Lake there is little, if any, shelter from the wind and the combined heavy summer use by high horsepower outboard and inboard-outboard motor boats provides additional mixing. Turbulence from these high speed boats causes mixing to depths greater than 15 feet (Exner, 1990). The data indicates that cold water fish would have a difficult time surviving in these shallow lakes.

#### B. Dissolved Oxygen

Dissolved oxygen isopleths are similar to those of temperature (Figure 12). Dissolved oxygen readings at Maskenthine ranged from 0.7 to 14.1 ppm and averaged 7.3 ppm while those from Willow Lake ranged from 2.4 to 14.3 and averaged 8.4 ppm. Lowest oxygen would be expected in the warmer waters since oxygen saturation levels decrease with increased temperatures. Lowest DO levels were less than 4 ppm only in the deep sampling stations in June and August, 1990 and May, 1991. Anoxic conditions never did develop in either lake in this study. During the study period, the lakes were quite aerobic and well mixed with respect to DO. However, during 1988 in a survey by NE Game and Parks Commission, oxygen stratification was noted in Maskenthine Lake and anoxic conditions developed (Schuckman, 1990).

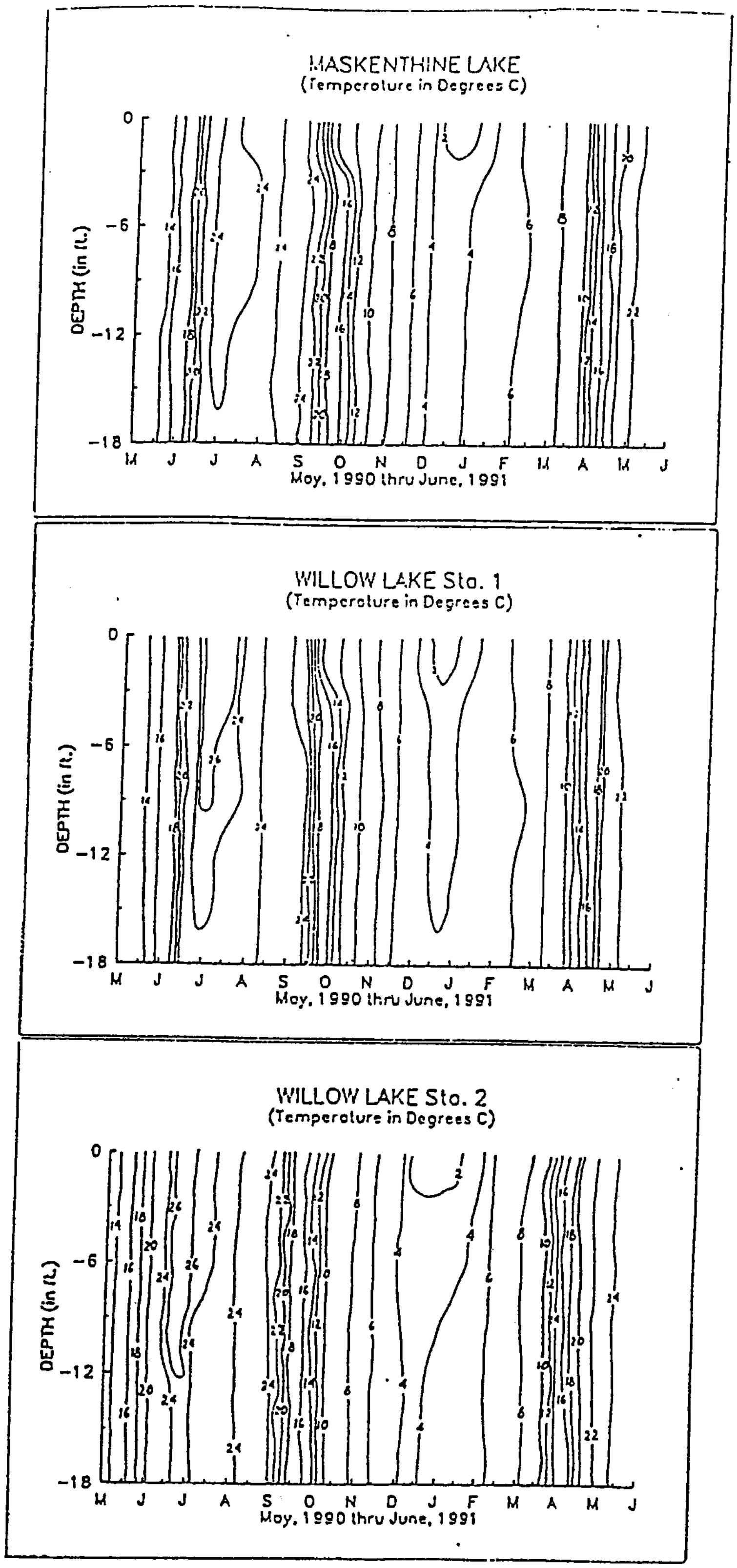



Figure 11. Thermal profiles for Maskenthine Lake and Willow Lake Stations 1 and 2 from May 1990 through June 1991.

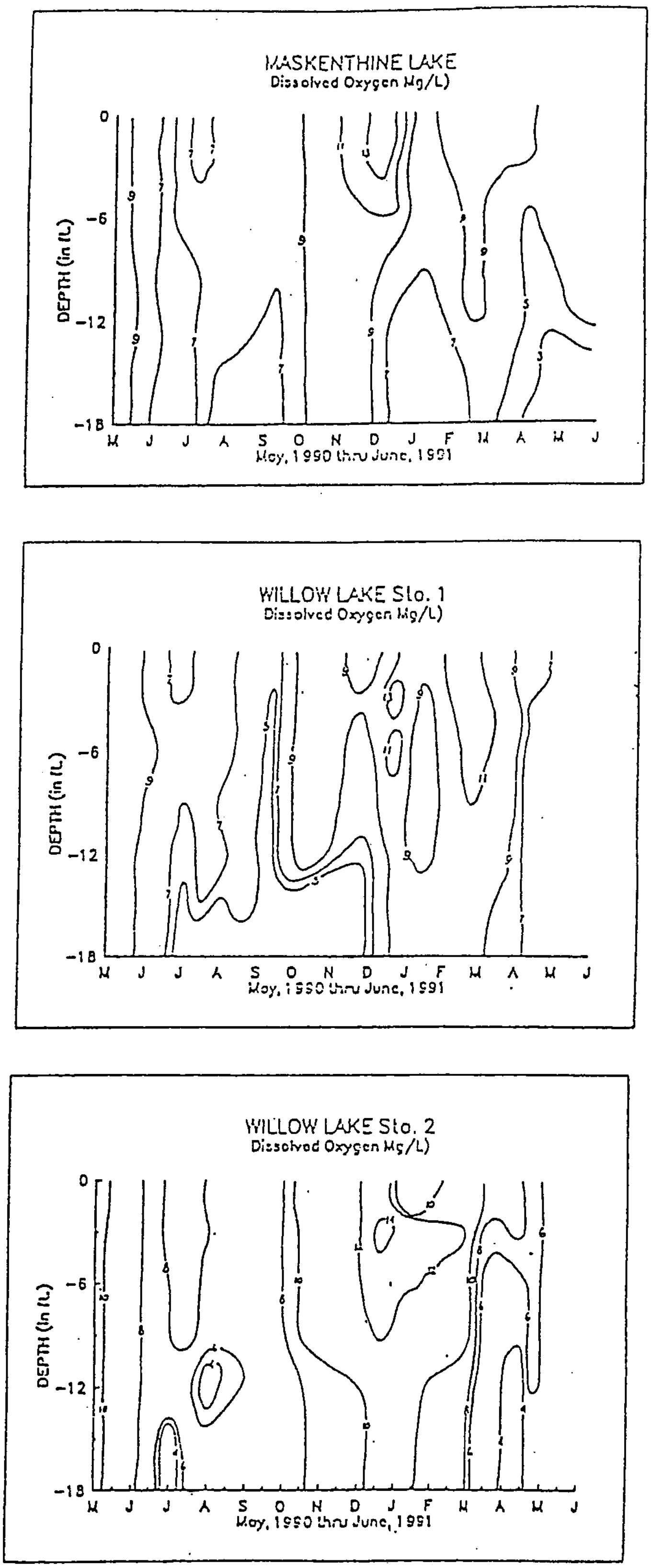



Figure 12. Isopleths of dissolved oxygen for Maskenthine Lake and Willow Lake Stations 1 and 2 from May 1990 through June 1991.

At the Maskenthine station oxygen depletion was more apparent in the early summer of 1991 than that of 1990. These lower readings in 1991 may have been associated with high carbon loadings on sediments which were washed into the lake after very heavy rains in May and early June. There was an apparent loss of DOC in the deeper water during this period that may be interpreted as evidence for increased oxidation of organic matter.

A DO of 2.5 ppm in the deep samples at both Willow Lake stations occurred on June 30, 1990. A DO of 3.0 ppm and 3.3 ppm at Willow Lake stations occurred on May 12, 1991. These were not sustained and were the only DO concentrations < 4.0 ppm recorded. Although hydrogen sulfide production from the deep sediments had been reported in past seasons, the sustained high DO levels during the study period thermodynamically eliminate reducing conditions that could produce $H_2S$.

C. Chlorophyll a and Secchi Depth

Figure 13 presents the chlorophyll a and secchi depth data obtained during the sampling period. Chlorophyll a is an indicator of biomass. Values are the mean for duplicate samples.

Chlorophyll a samples in Maskenthine Lake were collected at station ML-1 bi-monthly throughout the swimming season (May 1 to September 22, 1990). The data indicate a rise from 7.3 $mg/m^3$ on May 1 to 24.5 $mg/m^3$ on June 30 with a dip to 14.2 $mg/m^3$ on July 14. Values were greater than 25.0 $mg/m^3$ for the remainder of the swimming season until a decline to 13.6 $mg/m^3$ in the last samples. Three duplicate samples were also collected in late spring 1991 (May 15 to June 15). Data rose from 16.7 $mg/m^3$ to 32.8 $mg/m^3$. The mean value of ML-1 during the summer months was 18.6 $mg/m^3$ indicating that all uses of the lake are fully supported.

Chlorophyll a samples in Willow Lake were collected bi-monthly at stations WL-1 and WL-2 throughout the swimming season. At WL-1 the data indicate a rise from 5.9 $mg/m^3$ on May 1 to 48.6 $mg/m^3$ on July 14, declining to 26.8 $mg/m^3$ on September 9. There was a slight incline to 35.5 $mg/m^3$ in the last samples. The data from three duplicate samples collected in late spring 1991 indicate a rise from 19.6 to 76.4 $mg/m^3$. The mean summer value for WL-1 was 27.6 $mg/m^3$ indicating that all uses of the lake are fully supported.

At WL-2 the data indicate a rise from 4.2 $mg/m^3$ on May 1 to 65.3 $mg/m^3$ on June 30, declining to 27.81 $mg/m^3$ on September 22. Data from duplicate samples collected in late spring 1991 indicate a rise from 31.9 $mg/m^3$ to 102.9 $mg/m^3$. The mean summer value for WL-2 was 35.1 $mg/m^3$ indicating that one or more uses of the lake are partially supported and remaining uses are fully supported.

There appears to be little relationship between secchi depth and planktonic chlorophyll. Secchi depth appears to be more dependent on turbidity at the time of sampling. Secchi depth is lower in both lakes after storm events and when readings were taken at the time of strong wind. Some of the deeper secchi depth readings occurred when chlorophyll a values were greatest. Maskenthine secchi depths were generally greater than 3 feet except after storm events. Willow lake secchi depths at both stations were generally less than 2 feet.

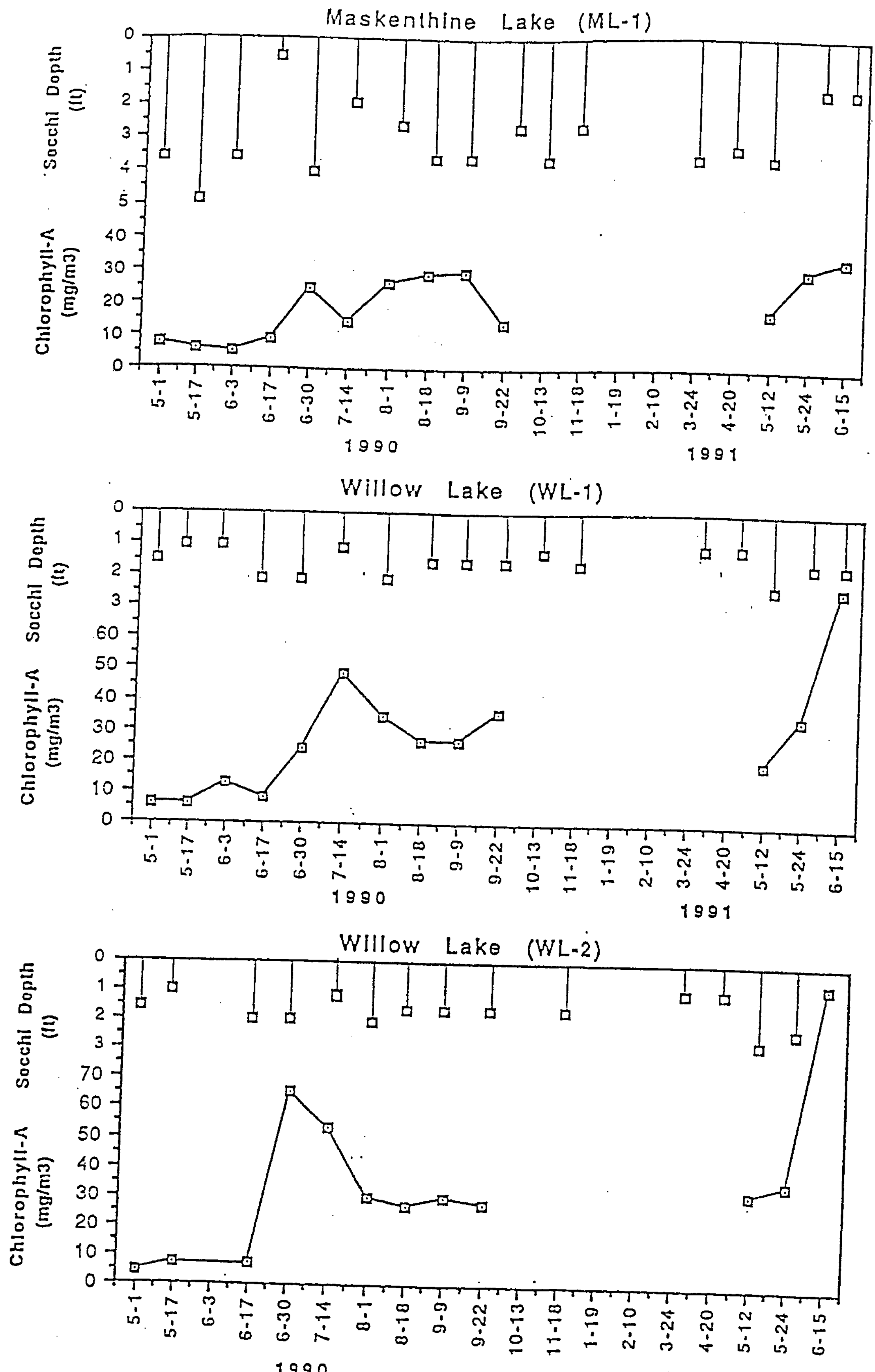



Figure 13. Chlorophyll a and secchi depth for Maskenthine Lake and Willow Lake Stations 1 and 2 from May 1990 through June 1991.

D. Conductance

In natural waters conductance values are used as indicators of changes in the gross concentrations of the sum of the dissolved ions. As the concentration of dissolved ions increases the conductance increases. The degree of proportionality varies with the ratio of divalent to monovalent ions; however, for most natural waters the dissolved solids concentration can be estimated by multiplying the conductance in $\mu S$ by 0.62. The conductance values discussed in this report are temperature compensated.

At Maskenthine, isopleths of conductivity reflect temporally well mixed vertical profiles (Figure 14). The initial high conductance values reflect the combined effect of two previous years of low water inflow along with the concentrating effects of evaporative processes. Runoff from heavy rains in June and July 1990 resulted in lake water level rise of about 6 feet to the permanent pool level. The additional runoff inputs lowered the conductance at Maskenthine to about 50% of its initial value. The conductance was relatively invariant after August 1990.

Willow Lake conductivities did not appear to be influenced by those same precipitation events that caused major conductivity changes at Maskenthine. The results indicate that Willow Lake is not located in an area prone to high levels of runoff. The reason for the anomalously higher values in June and July of 1990 are unknown.

E. Macrophytes

An aquatic macrophyte survey of Maskenthine Lake was conducted on June 21, 1990. Recent heavy rains in the area had caused an increase in lake depth and turbidity so a garden rake was used to bring up samples from the bottom.

Maskenthine Lake is well populated with emergent vegetation, mainly cattails (Typha latifolia L. and Typha angustifolia L.). A few bulrush (probably a species of Scirpus) were observed mixed in with some cattails (Figure 15). The submergent vegetation found included two different species of the "pondweeds", curly pondweed (Potamogeton crispus L.) and a very narrow-leaved pondweed, Potamogeton panormitanus (Biv.). The curly pondweed was found around the shoreline throughout the northern half of the lake. The lake was full at the time of the survey with water spilling over the overflow at the dam. This rise in the lake level created some new lake-marsh at the north end, which had been dry for a number of years and overgrown with grass, weeds and small trees. At the time of the survey there was standing water under the bridge at the north end. Macrophytes inhabit less than 5% of the current lake shoreline. The upper reaches of the old lake are completely silted in and vegetated.

A survey was also taken on September 9, 1990 of Maskenthine Lake. The only noted change was that the curly pondweed had died.A study conducted by the Nebraska Game and Parks Commission in 1989 found that 40% of the lake was covered with macrophytes and 100% was covered on the north side (Schuckman, 1990).

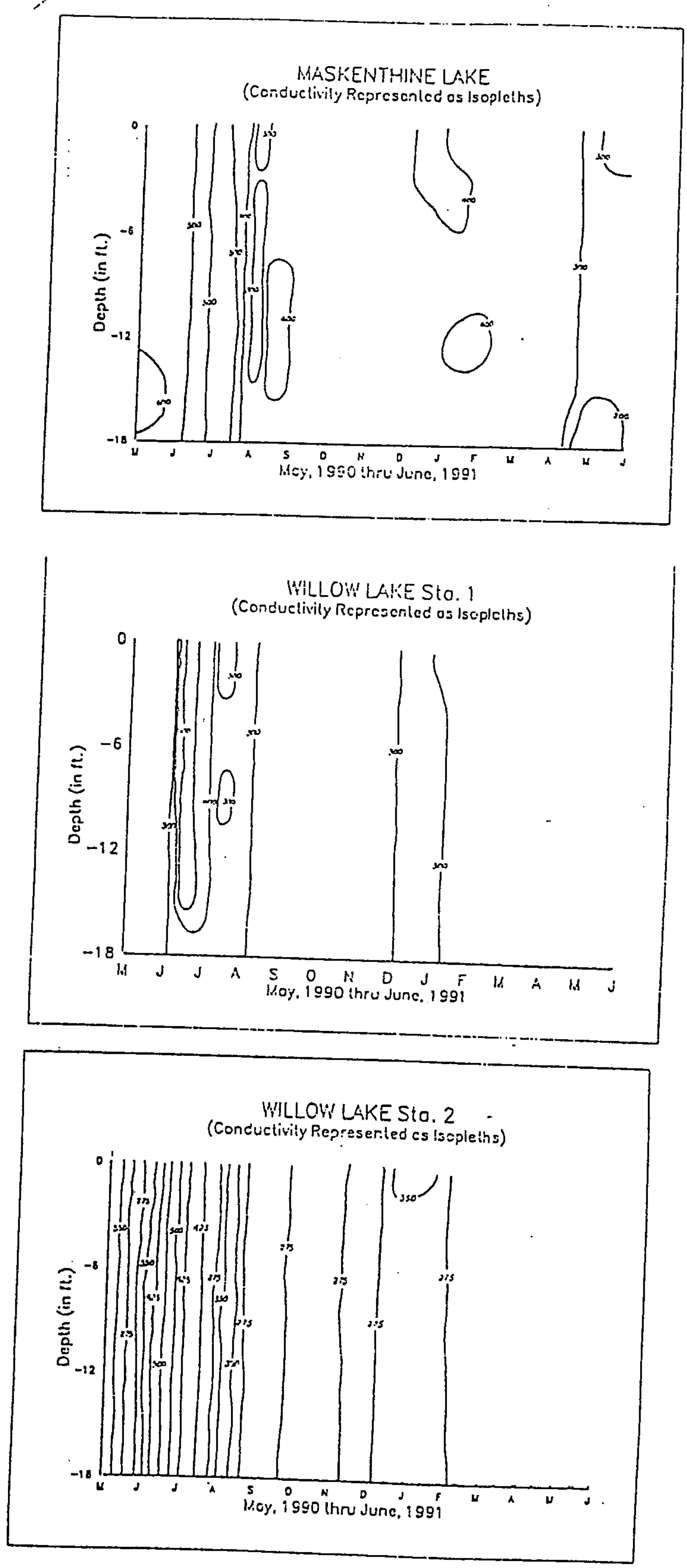



Figure 14. Conductivity isopleths for Maskenthine Lake and Willow Lake Stations 1 and 2 from May 1990 through June 1991.

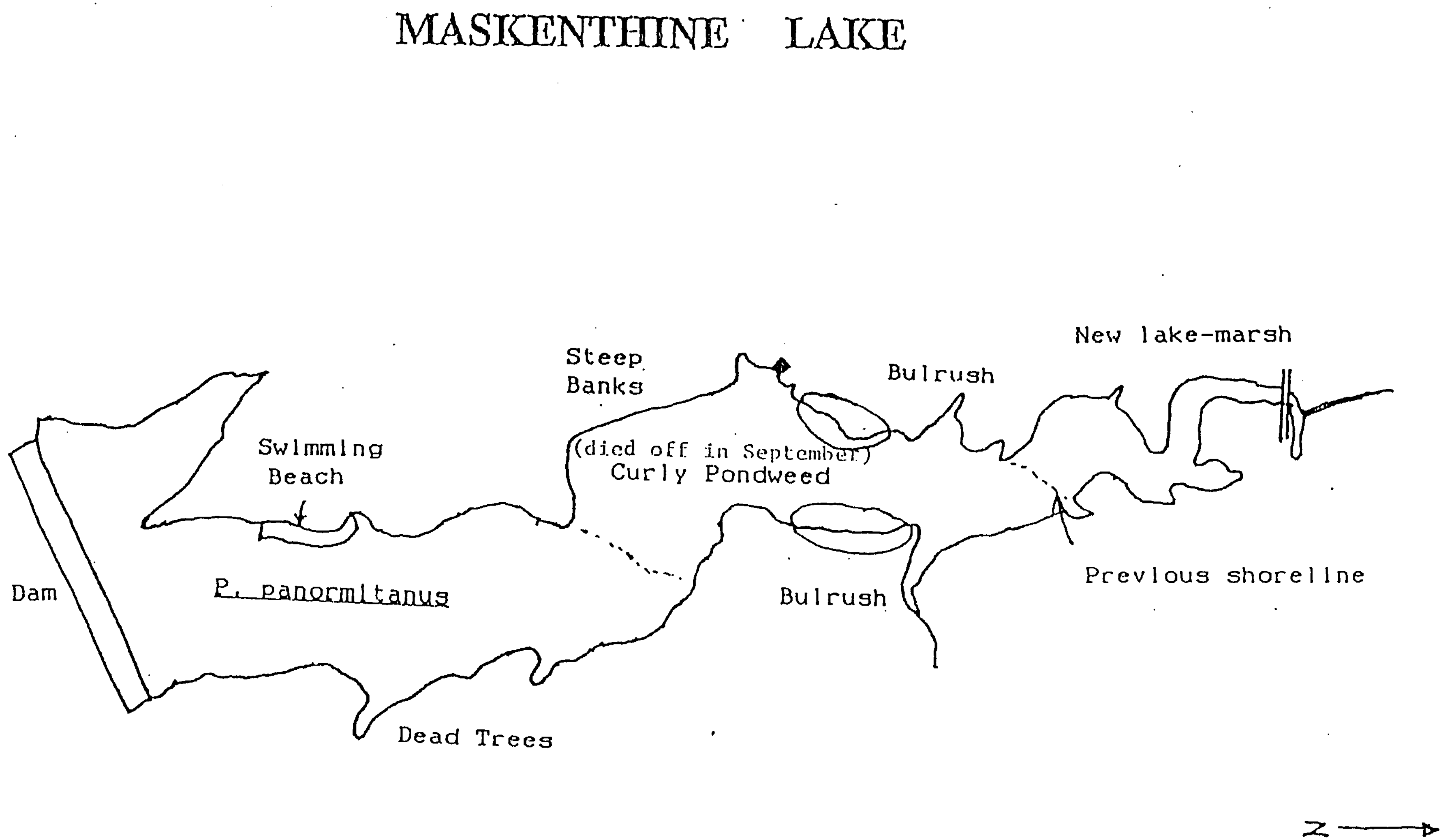



Figure 15. Results of the aquatic macrophyte survey conducted in June and September 1990 on Maskenthine Lake.

On June 19, 1990, a survey of the aquatic macrophytes was conducted on Willow Lake. The only aquatic macrophytes observed in the water were just a few dozen cattails (probably Typha latifolia L.) just starting to grow and establish themselves on the northwest portion of the lake (Figure 16). It did appear the lake had risen around six inches from the recent rains, as there were some areas in which terrestrial grasses and weeds were partially submerged. A noticeable bloom of the blue-green algae (Aphanizomenon flos-aquae L.) was floating at the surface of the lake. Some algal mats of Rhizoclonium sp. were washed up against the shoreline, mostly on the south side of the lake.

In general there were very few aquatic vascular plants found at Willow Lake. One contributing factor may have been the lower water level during the study period.

On September 9, 1990, another survey of Willow Lake was completed with no changes in macrophyte distribution.

F. Phytoplankton

Actual algal counts were conducted during the swimming season in shallow stations at both lakes and are in Appendix 4. Taxonomic identification was carried to the species level, and species of chlorophyta (greens), species of chrysophyta (browns), species of cyanophyta (bluegreens), and species of euglenophyta (flagellates) were identified. Pyrrophyta species were in both lakes; however, their concentrations were very low. The total count at each sampling are shown in figure 17.

At Maskenthine Lake the succession of blooms was from browns in May, to greens in June, to bluegreens. Highest euglenophyta levels appeared simultaneous to bluegreen blooms. The algal succession at the Willow Lake stations follow the same pattern. By mid-July bluegreens appear to dominate both lakes. The bluegreens had the highest concentration of near $3 \times 10^6$ cells/L.

G. Phosphorus

Phosphorus is usually considered a limiting nutrient for algal growth. Thus, algal activity can be controlled by depleting phosphorus from the system. Available phosphorus can enter the lakes in runoff, from anoxic sediments when ferric phosphates are released, degradation of organic matter, and from ground water.

Total P and ortho phosphate P were determined. The difference between total P and ortho phosphate P is equal to the phosphorus incorporated organic matter plus phosphate sorbed to particulate matter (Figures 18 and 19).

At Maskenthine Lake, ortho phosphate ranged from below detection to 0.08 ppm and values above detection averaged 0.06 ppm, and total phosphate range from below detection to 0.57 ppm. In deep samples for Maskenthine ortho phosphate concentration remained low throughout the period of investigation. This is further indication that the bottom sediments at Maskenthine were consistently aerobic. Aerobic sediments tend to release phosphate that has been

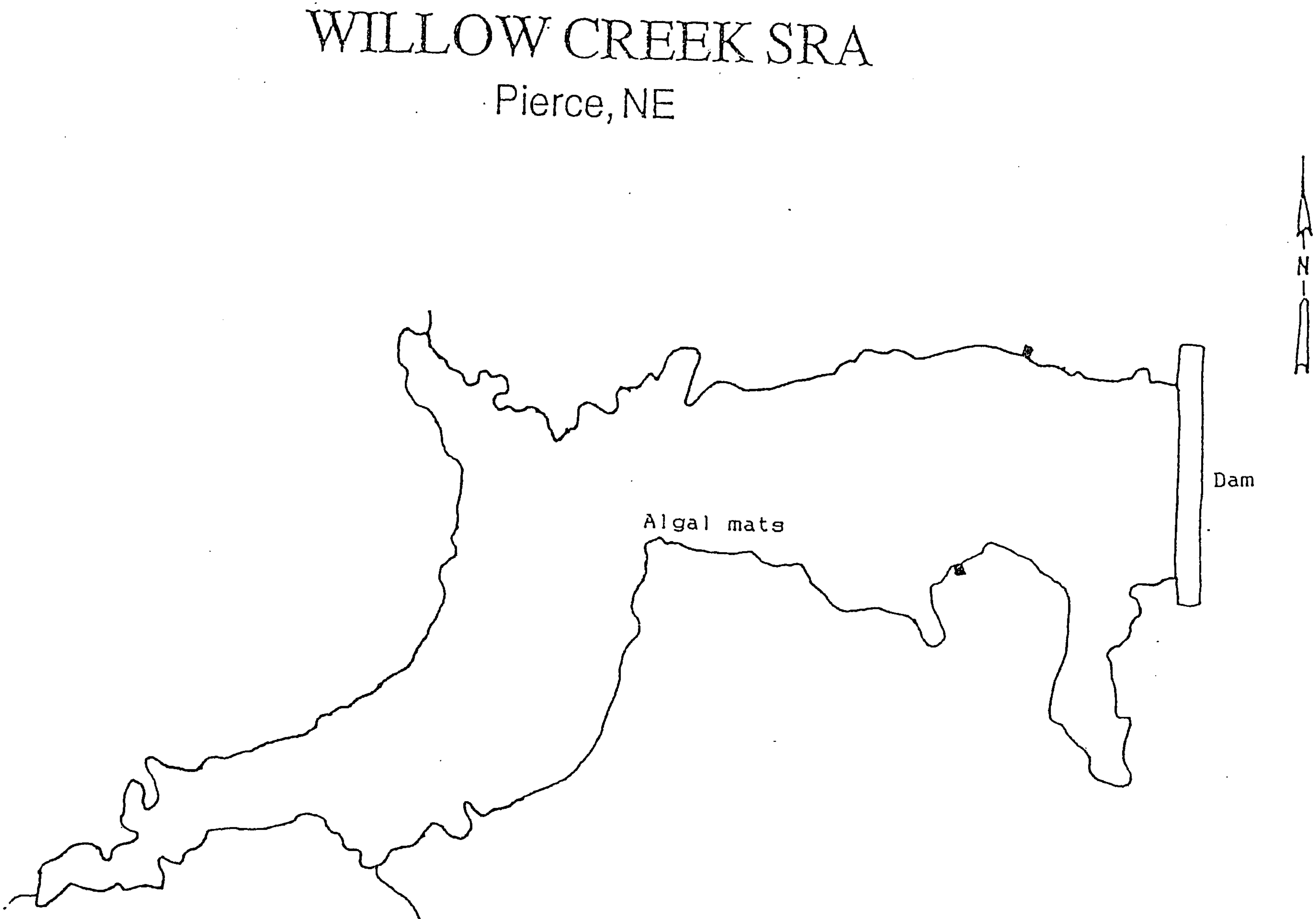



Figure 16. Results of the aquatic macrophyte survey conducted in June and September 1990 on Willow Lake.

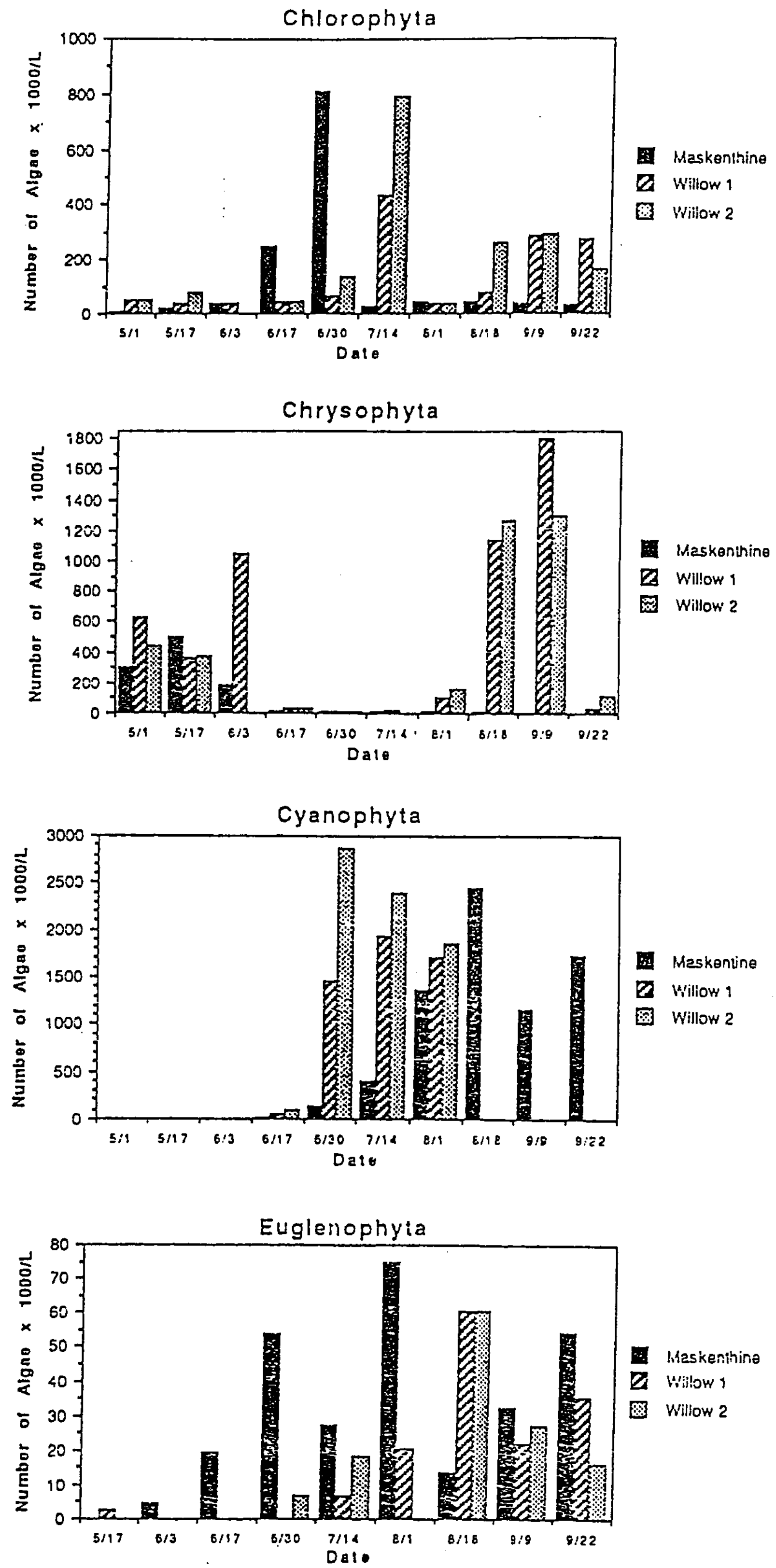



Figure 17. Phylum of algae for Maskenthine Lake and Willow Lake Stations 1 and 2 from May 1990 through September 1990.

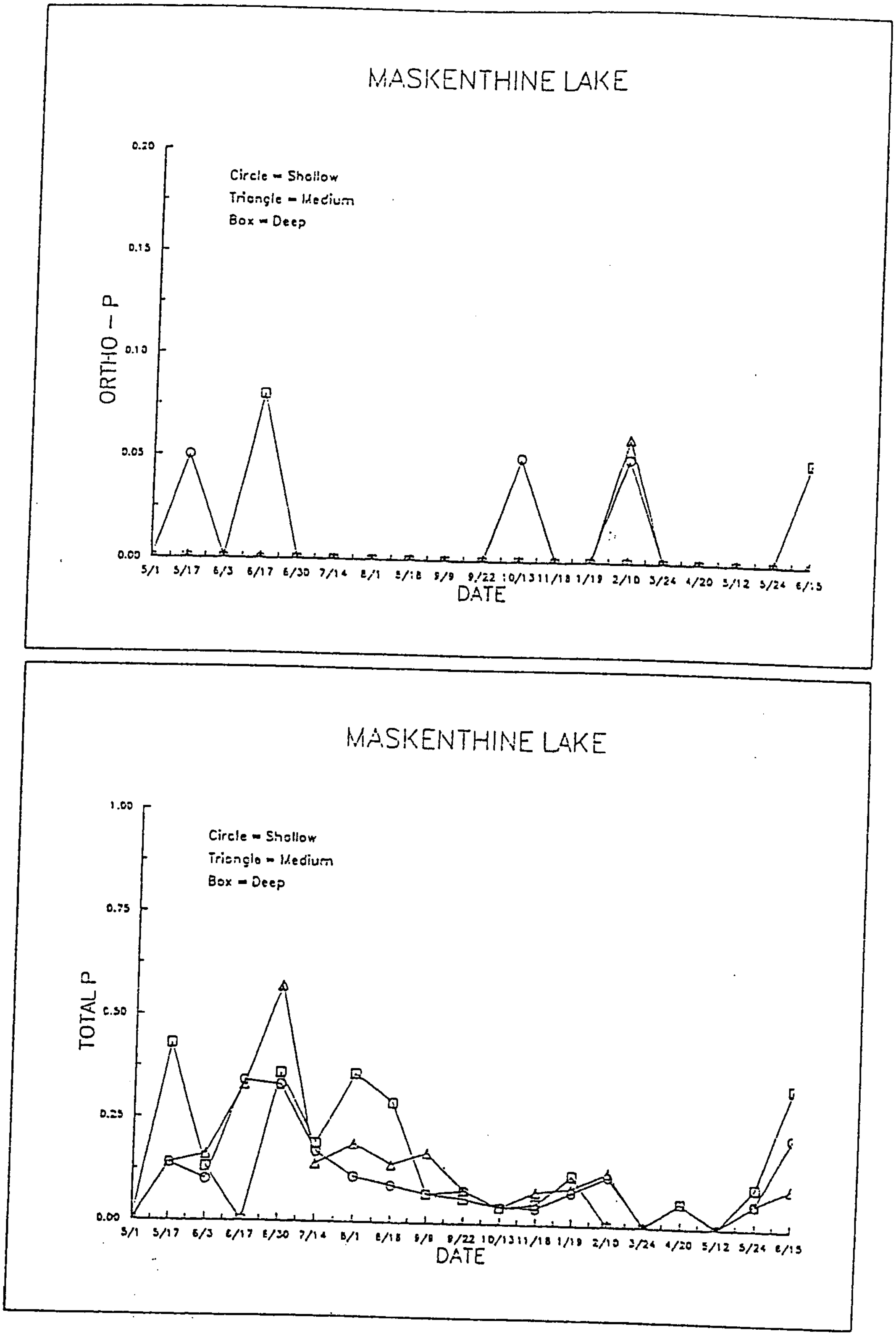
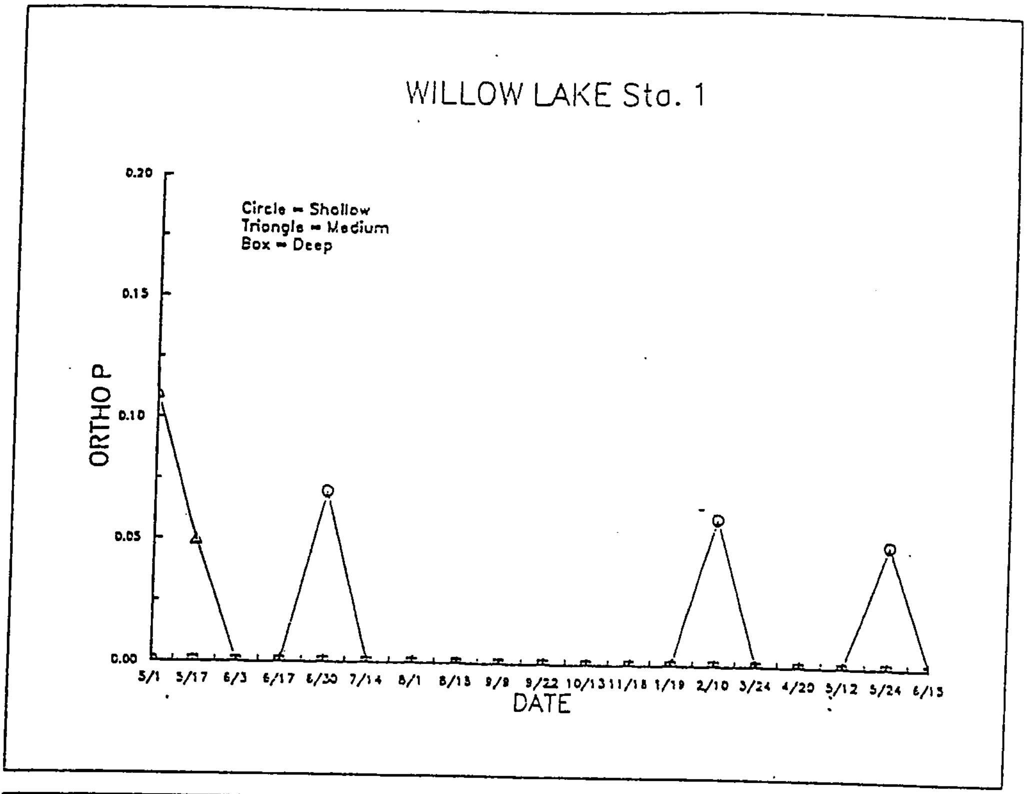



Figure 18. In-lake Ortho P and Total P for Maskenthine Lake from May 1990 through June 1991.



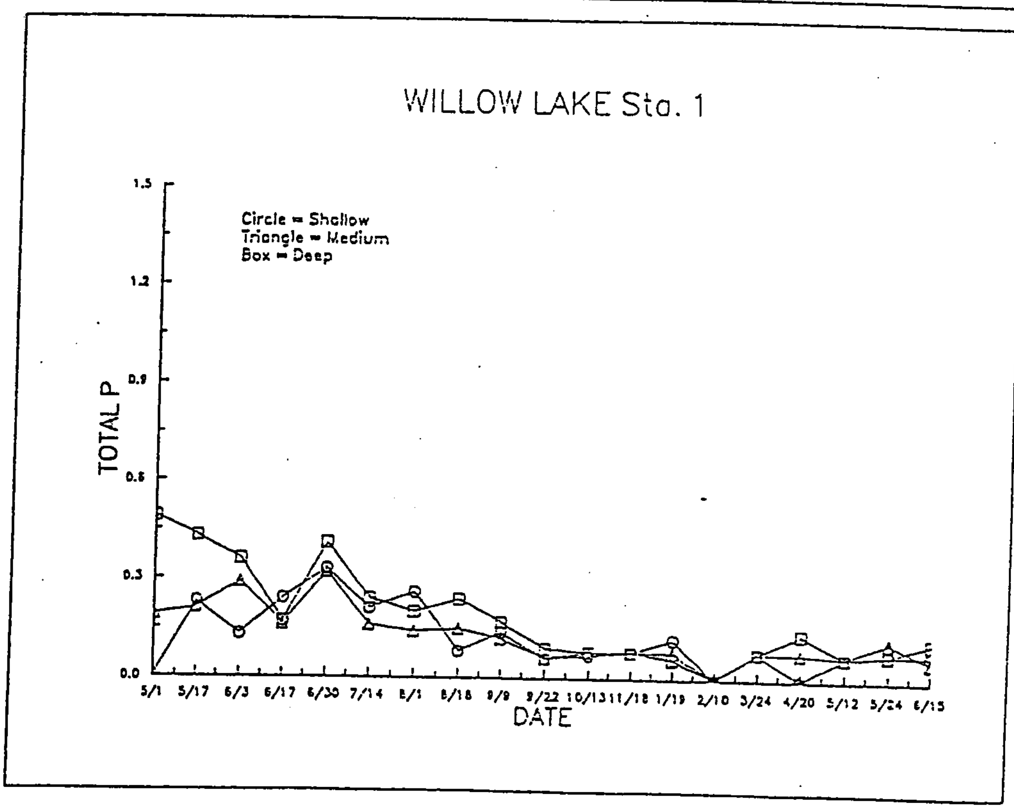




Figure 19. In-lake Ortho P and Total P for Willow Lake Station 1 from May 1990 through June 1991.

incorporated in $Fe_3(PO_4)_2$. When reduction in ferric iron occurs in anoxic conditions phosphate is solubilized. Total P tended to increase after runoff events at Maskenthine suggesting that increased inputs were sorbed soil particulates.

At Willow Lake ortho phosphate levels remained at or below the detection limit throughout the study. Total phosphorus ranged from below detection to 1.25 ppm, and values above detection averaged 0.16 ppm for station 1 and 0.19 ppm for station 2. Highest concentration (1.25 ppm) appeared in surface water in September and may have been an anomalous concentration since it did not coincide with high SS or DOC.

In the summer, available phosphorus concentrations were very low throughout the study period. This would suggest that phosphate is a limiting nutrient for algal blooms in those lakes.

H. Nitrogen

Aqueous forms of nitrogen include nitrate, nitrite, ammonia, and organic-N. Nitrate and ammonia occur in trace concentrations in most surface water bodies. In estuaries such as the Chesapeake Bay nitrate and ammonia are limiting nutrients for algal blooms.

In Maskenthine Lake nitrate-N concentrations ranged from below detection to 0.66 ppm and values above detection averaged 0.16 ppm while ammonia-N ranged from below detection to 1.10 and averaged 0.3 ppm. In almost all cases the highest ammonia-N was synonymous with high kjeldahl-N indicating the ammonia was primarily from the ammonification of organic-N (Figure 20). Highest nitrate-N occurred in cooler months with less biological assimilation and after high runoff periods.

At Willow Lake nitrate-N concentrations were influenced by seasonal cycles. Nitrate-N concentrations ranged from below detection to 22 mg/l and values above detection averaged 0.81 - 1.4 ppm. During the late fall, winter, and early spring nitrate-N concentrations were greater than 1 ppm but were below detection limits in warmer months (Figure 21). This indicates that the nitrate rapidly assimilated during the major algal growth periods. The higher cold water concentration of nitrate-N at Willow Lake than at Maskenthine Lake is probably due to a relatively constant ground water contribution at Willow Lake. In contrast ammonia-N levels were highest in the summer when organic-N from algal bloom was subject to ammonification and lowest in the lower productive winter months. In part kjeldahl-N followed the same pattern as ammonia-N at Willow and ranged from below detection to 10.4 ppm.

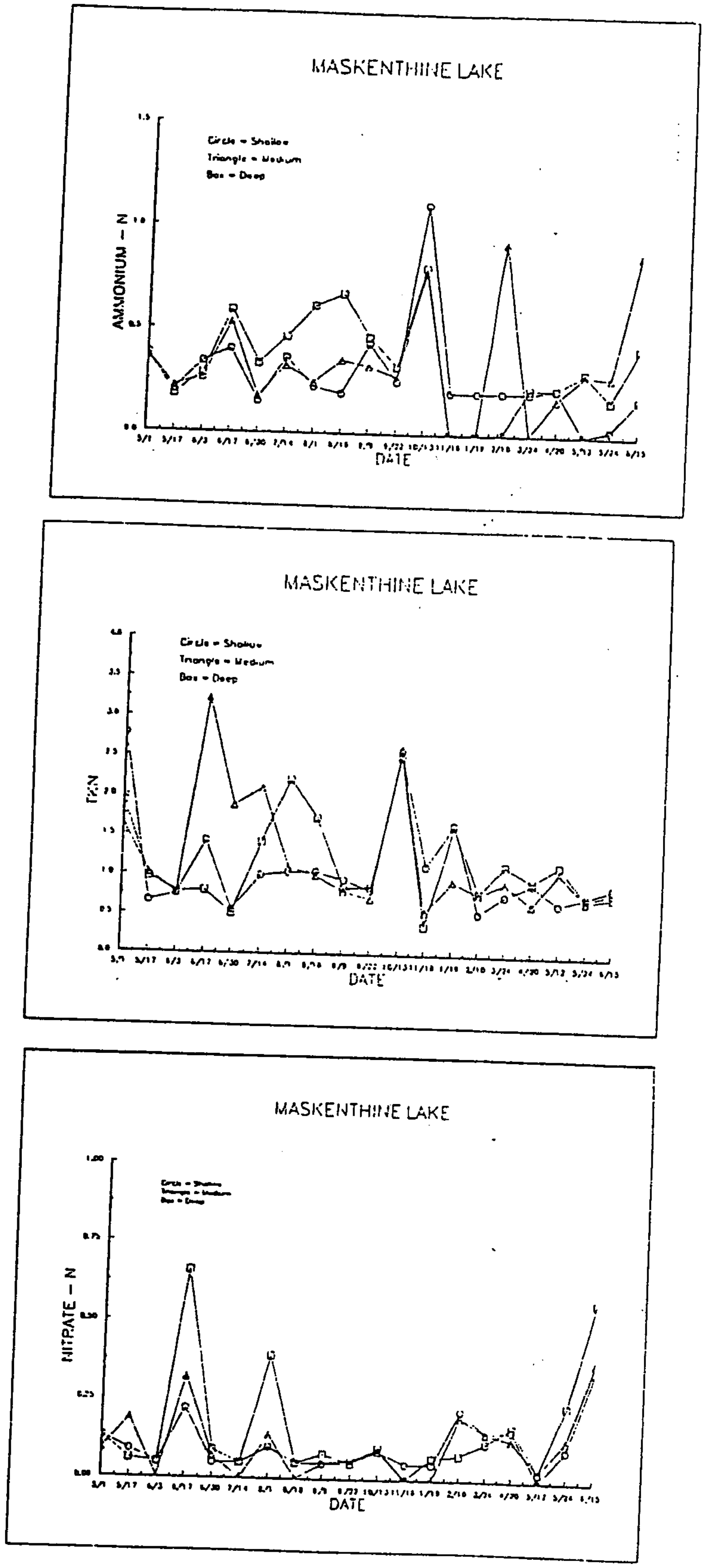



Figure 20. In-lake nitrogen concentrations for Maskenthine Lake from May 1990 through July 1991.

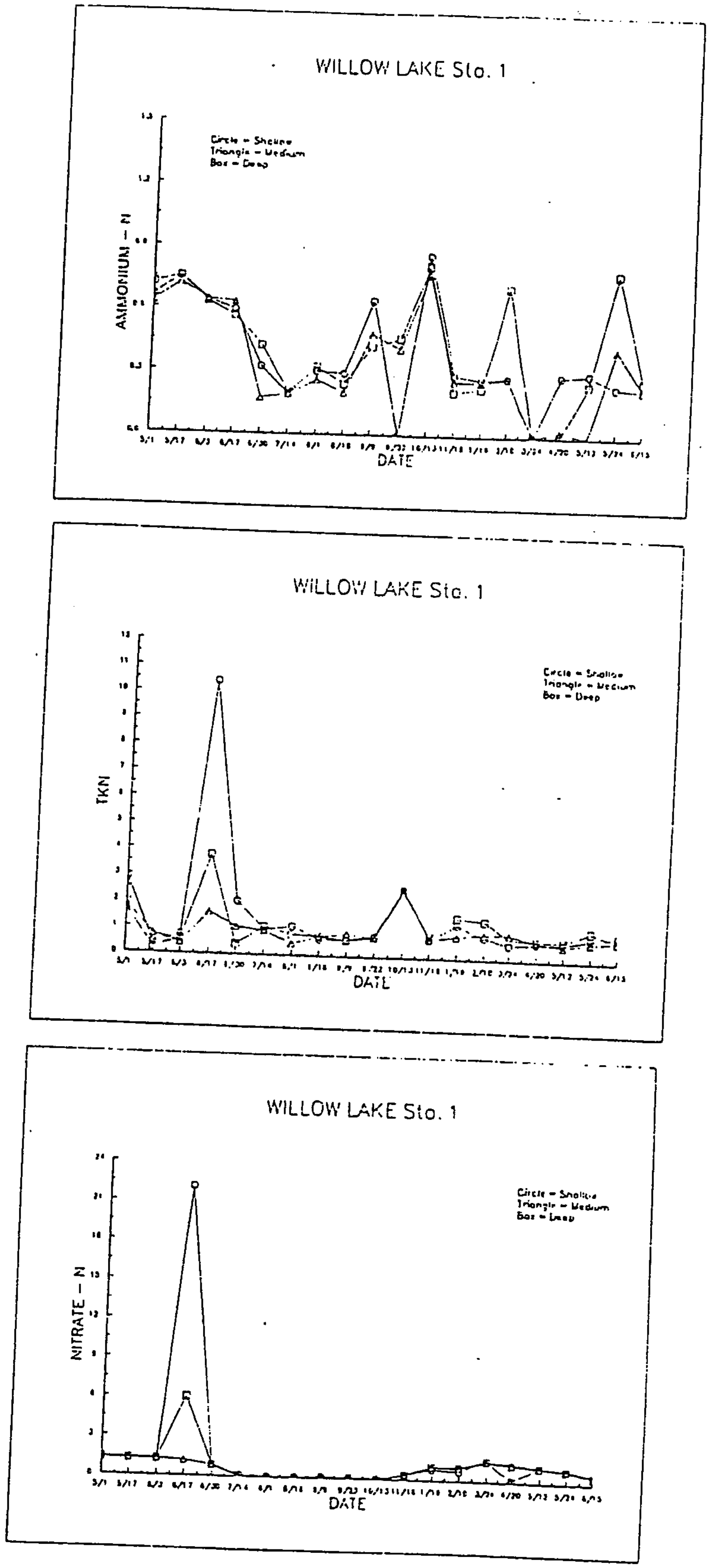



Figure 21. In-lake nitrogen concentrations for Willow Lake Station 1 from May 1990 through June 1991.

I. Suspended sediment (SS), volatile suspended sediment (VSS), and dissolved organic carbon (DOC)

Suspended sediment (SS) concentrations were highly variable in both lakes. Highest concentrations were usually from deep samples which may in part be from bottom disturbances during sampling. Higher shallow station SS at Maskenthine was associated with times of high runoff. In general the warm months with increased boating were associated with high SS loads than the colder months. Lowest suspended solids occurred when the lake surface was ice covered and insulated from wind. Suspended solid levels appeared to be associated with wind conditions, power boating, deep sampling, and runoff.

Volatile suspended solids represent the organic contribution to the total SS. No obvious relationships between total SS and VSS occurred on either lake.

Average levels of dissolved organic carbon (DOC) were much higher in Maskenthine than Willow Lake. Average DOC levels in Maskenthine were 8.4 ppm while those at Willow were 5.2 ppm. The higher levels at Maskenthine may be associated with fine sediments (high clay content) having large surface areas for carbon sorption that accumulate in the lake during runoff events (Figure 22). No seasonal trends in DOC concentrations were observed in Willow Lake data; however, Maskenthine DOC levels were highest in the spring runoff months and in the coldest months of January and February, when bacterial activity is limited and there is minimal carbon assimilation by bacteria.

J. Alkalinity and pH

Rivers and lakes in Nebraska generally have higher pH values and lower total alkalinity values in the summer time than at other times during the year. In lakes that become stratified, shallow water pH generally is considerably higher than deep water pH. As primary productivity progresses alkalinity ($HCO_3^-$) tends to decrease due to algal uptake. Since water transparency limits primary production to the lakes surface, its effects are also most obvious in shallow samples. The rise in pH is a direct result of the uptake in $CO_2$ which causes the conversion of hydrogen ions ($H^+$) and bicarbonate to $CO_2$ and $H_2O$, thereby decreasing both acidity and alkalinity.

At Maskenthine Lake the pH ranged from 7.3 to 8.8 and averaged 8.1, and the alkalinity ranged from 30 to 281 and averaged 154. The lowest alkalinity was from a surface sample which appeared to have a contribution from ice melt on February 10, 1991. The distribution in vertical pH values were rather constant further substantiating the lack of stratification. Alkalinities were slightly lower in the shallowest samples during most of the investigation period. Acceptable pH values for lakes range from 6.5 to 9.0 (NDEC, 1991).

At Willow Lake's two stations the pH values ranged from 7.0 to 9.4 and averaged 8.2. Alkalinities ranged from 68 to 173 and averaged 109. The lower alkalinities at Willow reflect regional differences in soil types. Waters in glacial till areas are usually much higher in bicarbonate than those in sandhills regions. The differences are a result of the low leaching potential of eolian inert sands versus those for high clay and silt content tills. This lack of ionic leachates in the sandhills reduces the buffering capacity of water from changes in pH. Algal

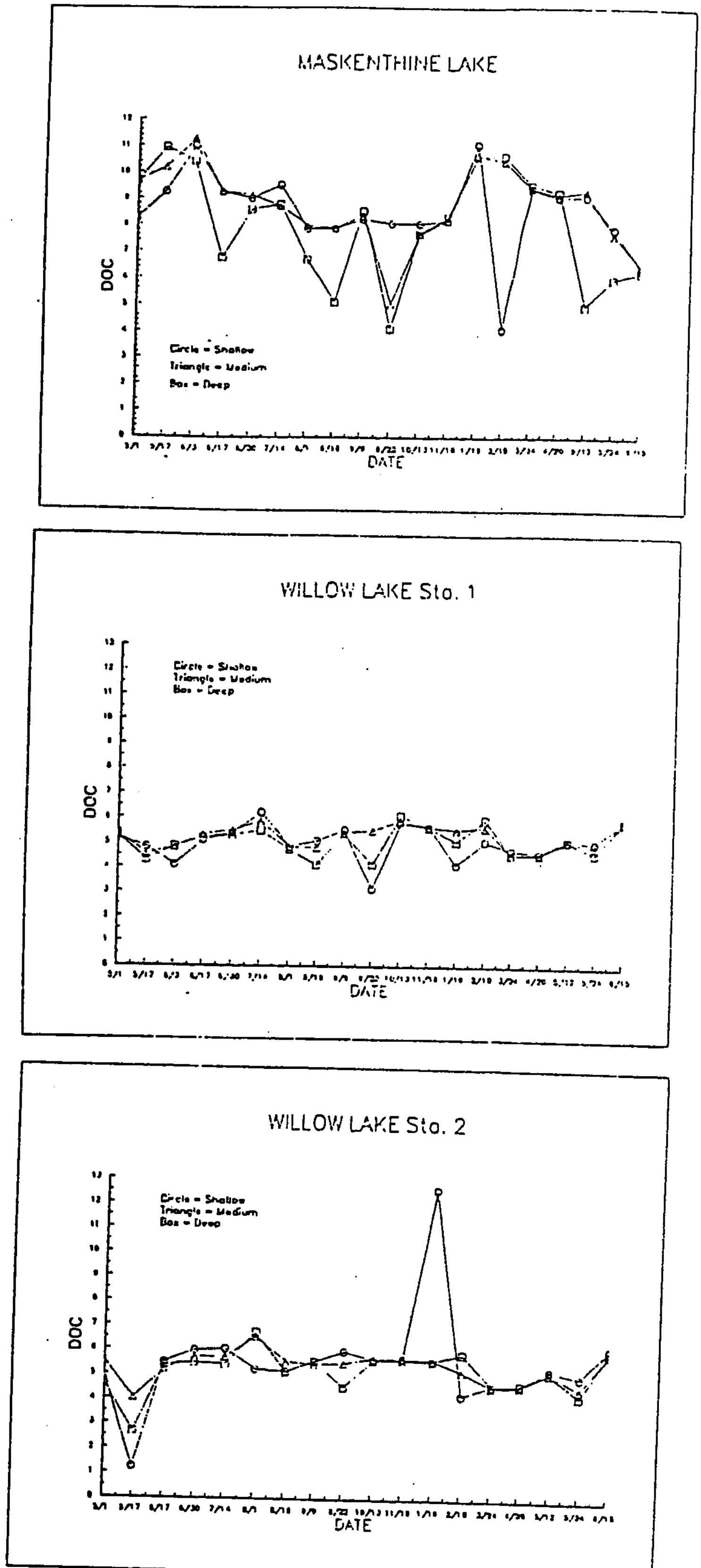



Figure 22. In-lake DOC concentrations for Maskenthine Lake and Willow Lake Stations 1 and 2 from May 1990 through June 1991.

activity at Willow Lake results in strong alkaline shifts monthly in pH and alkalinity. Vertical differences were slight as stratification never developed.

K. Sanitary Quality

Bacteriological results include shallow lake samples collected for total coliform, fecal coliform and fecal streptococcus bacteria. Fecal coliform are associated with human feces while fecal streptococcus bacteria are more associated with domestic and wild animal feces. Maskenthine Lake had excessive levels of these bacteria after June runoff events in both years. Maskenthine fecal coliform bacteria ranged from <10 to 650/100 ml and fecal strep ranged from 0 to 5,200/100 ml. Contamination limits for potable water are 0/100 ml. The fecal coliform limit for bathers is based on a geometric mean of 200/100 ml (AWWA, 1989) and cannot equal or exceed 400/100 ml in more than 10% of the samples (NDEC, 1991).

These levels may impact recreational users of the lake. However, an apparent high natural die off rate occurs after runoff events. At Willow Lake both stations reported a much lower bacteriological presence than at Maskenthine. This is due to the lake's lack of impact from overland runoff. Since the lake has a constant source of water from ground water seepage, only small additional contributions are noted during precipitation. The lack of topographic slope to promote runoff, very well drained soils, and dilution from ground water tend to reduce bacteriological impacts from overland runoff at Willow Lake. While at Willow Lake occasional samplings detected slightly elevated fecal coliforms and strep bacteria, the levels did not approach the high levels observed at Maskenthine.

L. Pesticides

The pesticide results are in Appendix 5. In-lake pesticides that were detected included atrazine and its degradates deethylatrazine (DEA) and deisopropylatrazine (DIA), alachlor, metolachlor, cyanazine, EPTC, butylate, propachlor, trifluralin, simazine, prometon, propazine, fonofos, disulfoton, metribuzin, and terbufos in Maskenthine Lake, and all but terbufos and disulfoton in Willow Lake.

Seasonal trends in triazine concentrations at Maskenthine indicated the pesticide loads were a result of runoff (Figure 23). After spring runoff events the atrazine concentrations showed an overall decrease until the following spring's runoff event. It took about 4 months for maximum atrazine levels of ~14 ppb in the end of June to be halved. Atrazine concentrations continued to decrease to levels of 2-4 ppb prior to a runoff event in late May after which concentrations again were about 15 ppb. Conductance values (Figure 24) indicate that dilution effects from runoff occurred twice in the spring of both 1990 and 1991. While dissolved solids (0.62 x conductance) concentrations decrease immediately after runoff events, pesticide levels increase. Periods when conductance values remain constant or decrease represent periods in which the lake is not being impacted by runoff. As shown in the figure atrazine levels seldom were below the MCL of 3 ppb and always exceeded the chronic limit set for aquatic life.

Cyanazine concentrations were also impacted by runoff, and lake concentrations were very similar to those of atrazine throughout the investigated period. The association is shown in figure 25 where the correlation coefficient was 0.92 for 57 paired observations.

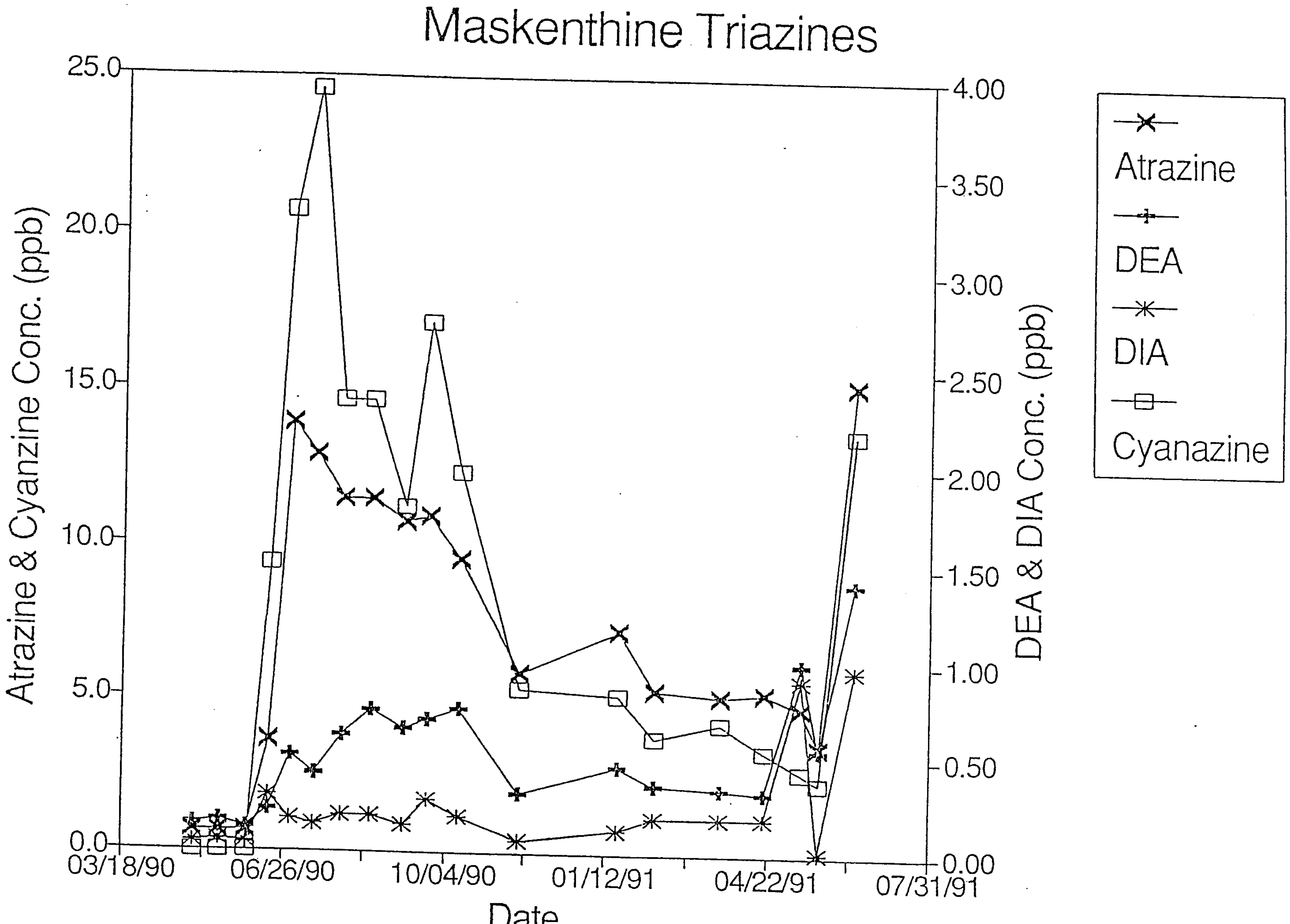



Figure 23. In-lake concentrations of atrazine, deethylatrazine (DEA), deisopropylatrazine (DIA) and cyanazine for Maskenthine Lake from March 1990 through July 1991.

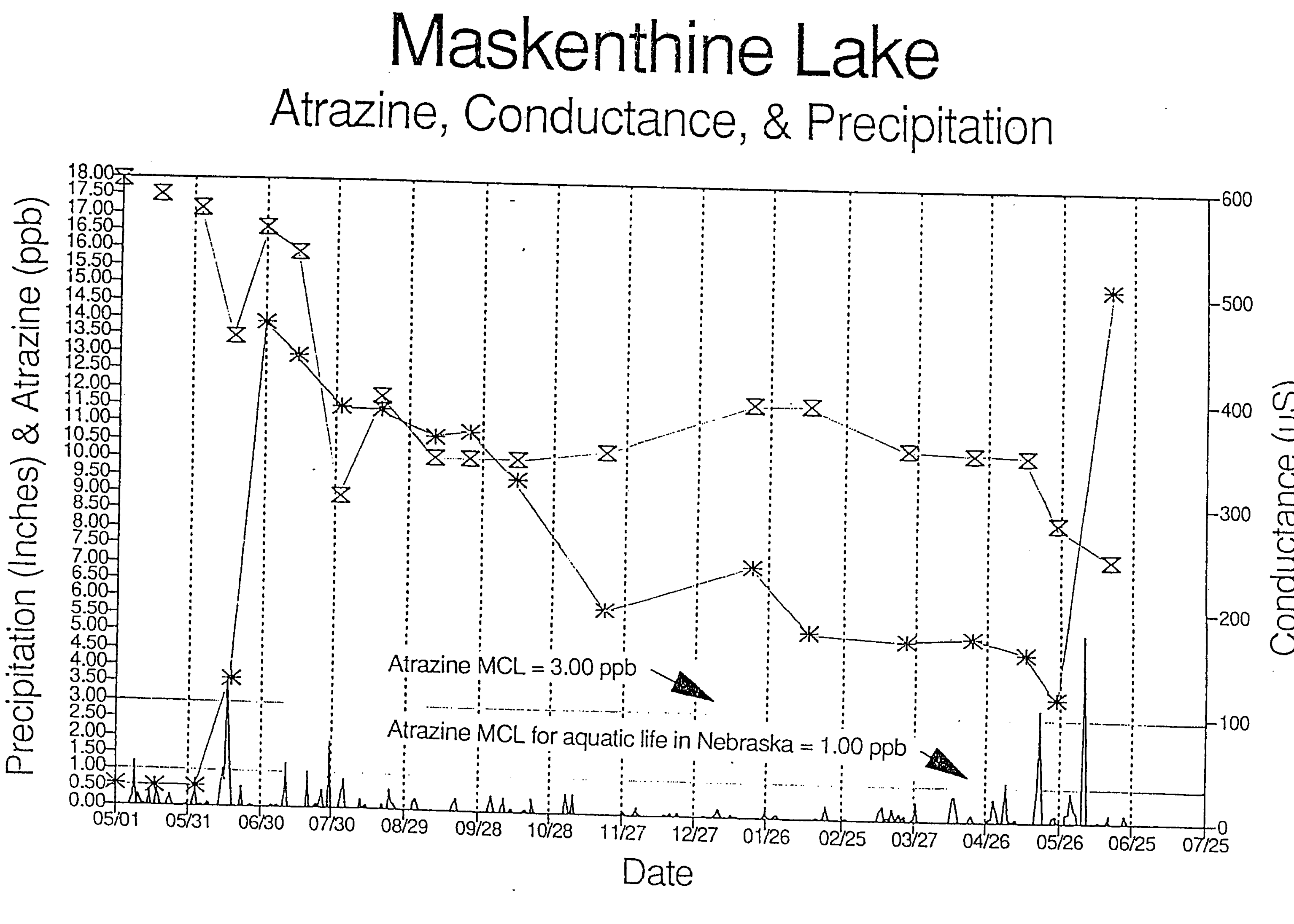



Figure 24. In-lake concentrations of atrazine and conductance for mid-depth sampling at Maskenthine Lake and daily precipitation amounts from Norfolk, Nebraska.

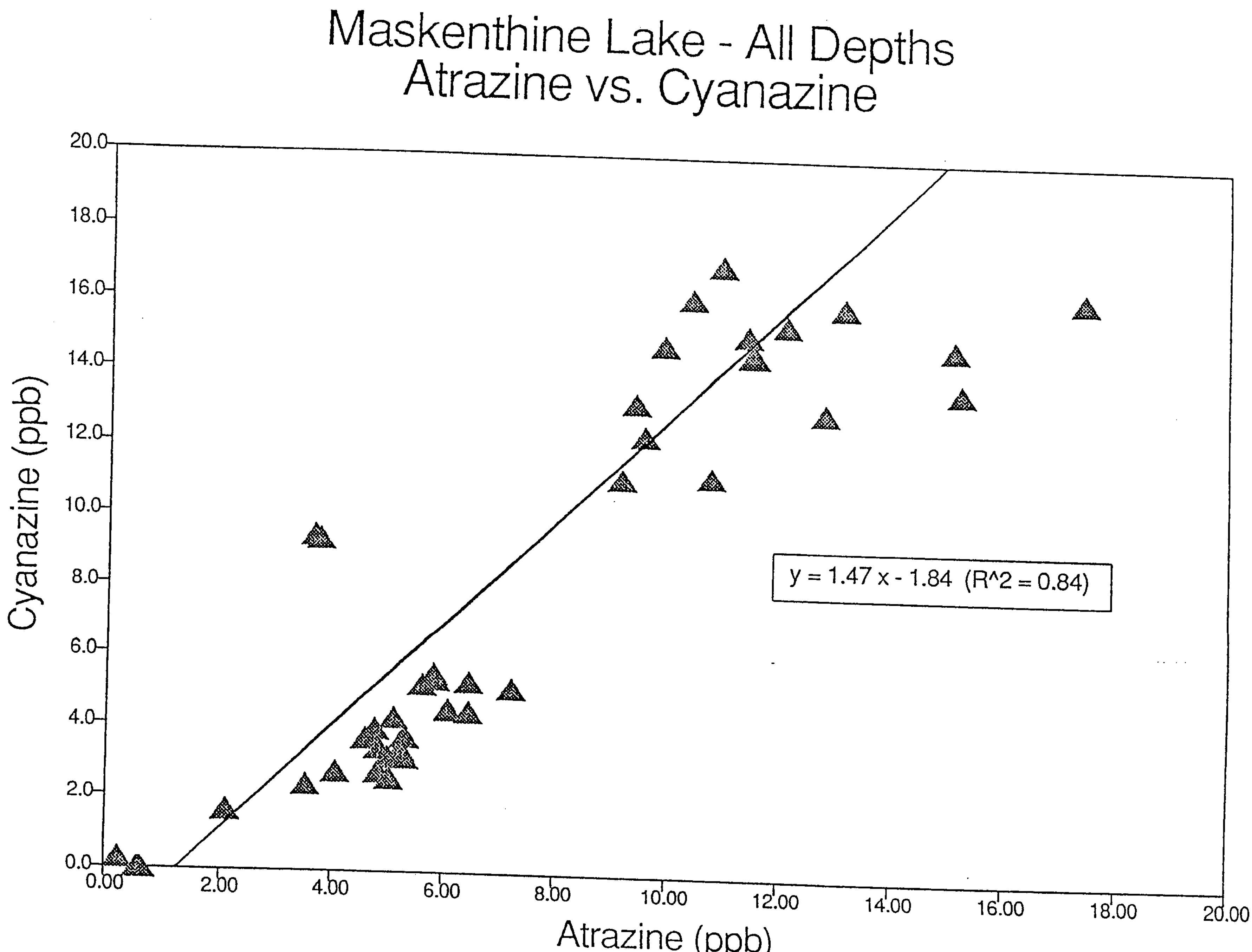



Figure 25. Scatter plot for atrazine concentrations versus cyanazine concentrations with regression line ($r = +0.92$).

Atrazine concentrations were halved over an approximate 2 month period between mid-September and mid-November. The stable conductance readings and lack of precipitation suggest that the pesticide losses during the period are due primarily to degradation. Since similar declines were observed for atrazine degradates DEA and DIA, the degradation is probably not a result of the microbiological cleavage of the aliphatic side chains but more likely chemical hydrolysis to insoluble hydroxyatrazine.

The next most commonly encountered pesticides were from the acetanilide family. Concentrations were much lower than those of atrazine and cyanazine. Concentrations for alachlor and metolachlor peaked after the spring runoff event in 1990 and like the triazines declined until the next spring's event. Alachlor concentrations declined to below detectable levels by November while low levels (< 0.100 ppb) of metolachlor remained throughout the winter. The degradation or half life of these compounds appears faster than atrazine and is estimated to be <1 month. Alachlor levels did not exceed the acute (760 ppb) or the chronic (76 ppb) limits set for aquatic life. Neither of the limits for metolachlor were exceeded.

Pesticide concentrations were much lower at Willow Lake than Maskenthine. Small increases to <0.5 ppb occurred in early spring for the four pesticides: atrazine, cyanazine, alachlor, and metolachlor (Figure 26). These declined to below detection limits of the method during the fall and winter. The much lower levels are another inclination of small runoff contribution to Willow Lake.

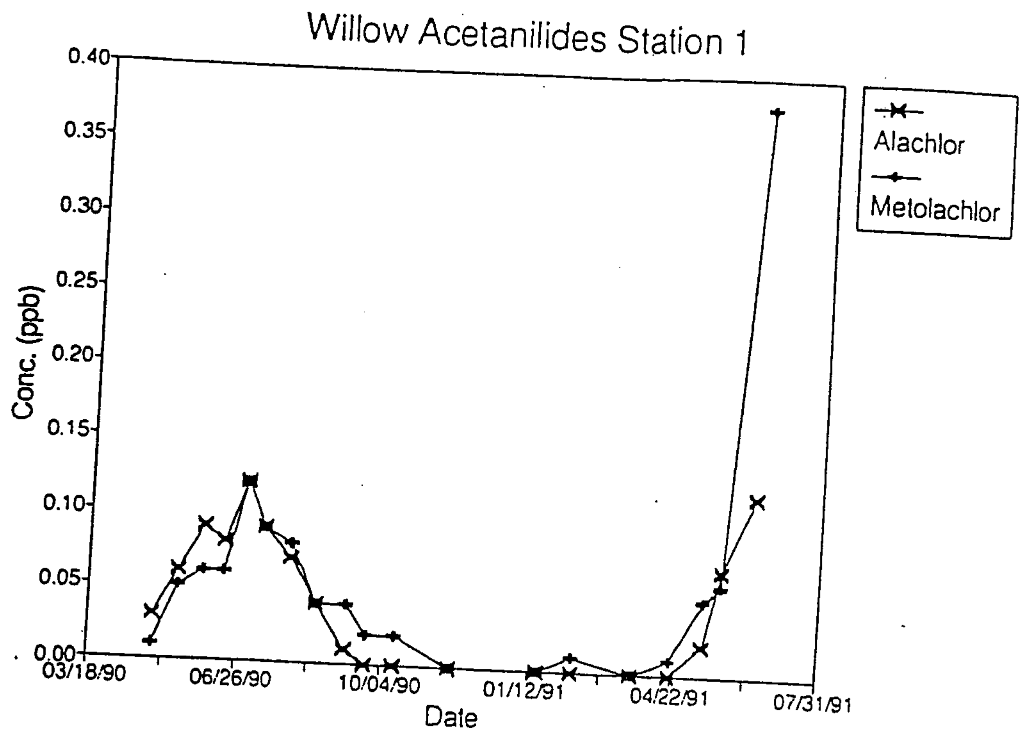
M. Heavy Metals and Trace Elements

The results of trace element analyses may be found in Appendix 6.

Concentrations of trace elements are discussed below with respect to 1991 Nebraska Surface Water Quality (SWQ) standards for chronic exposure to aquatic life. "Chronic criteria" refers to the threshold concentration of a substance that aquatic organisms can be exposed to for a period exceeding 96 hours with no resulting chronic toxicity (NDEC, 1991). SWQ standards for cadmium, chromium, copper, nickel, and zinc are calculated from a formula based on water hardness. In these cases, the SWQ level was calculated from the lowest hardness measured at each station thus producing the most conservative maximum level for chronic exposure. Metal concentrations are compared to the SWQ standard for each individual station. Values for hardness and NDEC SWQ standard are listed in Appendix 6. Drinking water standards are not considered since neither reservoir is a water supply.

a. Aluminum

Aluminum was detected in 15 out of 15 samples collected from Maskenthine Lake in concentrations ranging from 0.08 to 0.34 mg/L. Willow Lake exhibited a wider range of aluminum concentrations up to 0.62 mg/L with levels above the detection limit in 19 out of 21 samples. Aluminum exceeded the Nebraska SWQ standard for chronic exposure of aquatic life of 0.087 mg/L in 13 samples from Maskenthine Lake and 12 samples from Willow Lake (69% of samples collected).



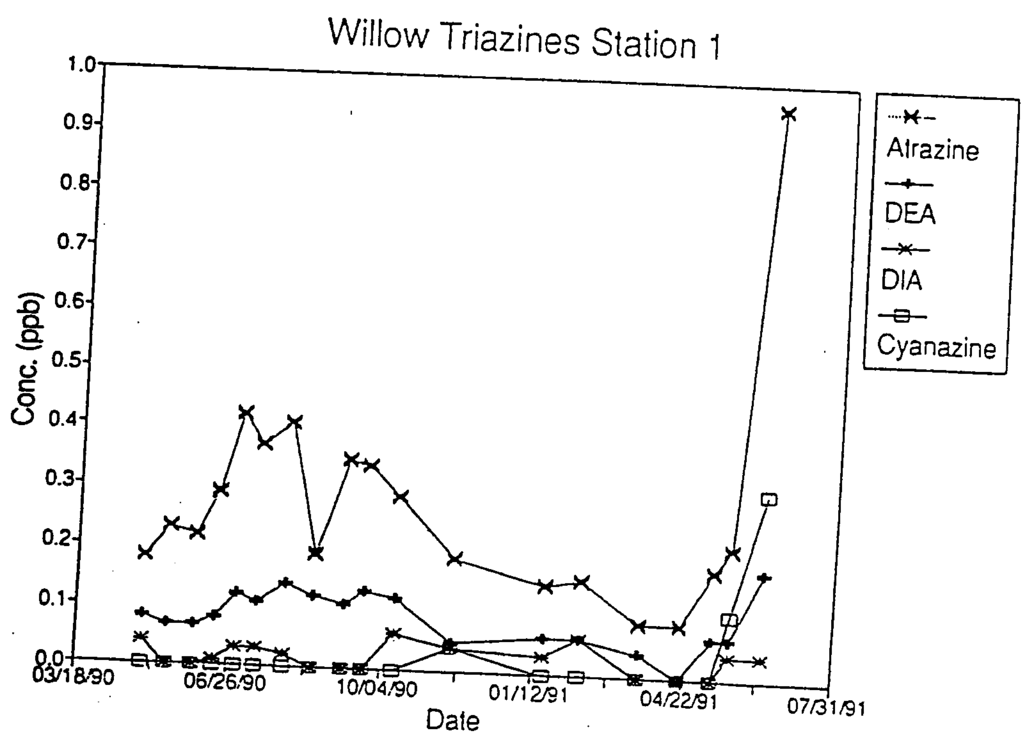




Figure 26. In-lake concentrations of acetanilides and triazines at Willow Lake Station 1 from May 1990 through June 1991.

Aluminum levels in near-neutral waters rarely exceed a few tenths of a mg/L and the chemical behavior of aqueous aluminum is still not fully understood (Hem, 1983). High aluminum levels have been associated with industrial inputs and acidic precipitation (Wetzel, 1983), however, neither of these two mechanisms would appear to be significant in the watersheds of this study. Elevated aluminum levels (0.20-0.50 mg/L) have been shown to be toxic to trout and white sucker fry in acidified (pH=4.4-5.2) lake water (Driscoll *et al.*, 1982). However, the levels of aluminum found in Maskenthine and Willow Lake occur at near-neutral pH and may not be toxic to the species native to these reservoirs. The cause of the elevated aluminum in both lakes cannot be determined from the available data.

b. Arsenic

Arsenic did not occur in any of the samples from either lake above the 0.10 mg/L detection limit.

c. Barium

Barium was detected in all samples from both lakes of this study. Concentrations of barium ranged from 0.12 to 0.22 mg/L in Maskenthine Lake and from 0.09 to 0.22 mg/L in Willow Lake (both stations). No SWQ standard exists for chronic or acute exposure of aquatic life to dissolved barium.

d. Boron

Boron was detected in all 15 samples collected from Maskenthine Lake in 10 out of 21 samples collected from Willow Lake. Concentrations of boron ranged from 0.04 to 0.30 mg/L in Maskenthine Lake and up to 0.28 mg/L in Willow Lake. Boron tended to be higher in samples collected during cooler months (October, January, April) in both lakes. No SWQ standard exists for chronic or acute exposure of aquatic life to dissolved boron.

Boron is a micronutrient required by many algae and other organisms with an average concentration of ~0.01 mg/L in natural freshwaters (Wetzel, 1983). Elevated concentrations of boron tend to be found in closed saline lakes.

e. Cadmium

Samples from Maskenthine Lake contained no detectable levels of cadmium. Three out of 21 samples from Willow Lake had concentrations of cadmium ranging from 0.01 to 0.05 mg/L. The SWQ standard for cadmium is based on the water hardness and was determined to be 0.007 mg/L for station WL-1 and 0.009 mg/L for station WL-2. The three samples which contained detectable levels of cadmium exceeded the SWQ standard for chronic exposure of aquatic life.

f. Chromium

No sample from Maskenthine Lake contained levels of chromium in excess of the detection limit. One sample out of 21 from Willow Lake exhibited a chromium concentration of 0.01 mg/L. This level did not exceed the SWQ standard of 0.216 mg/L for chronic exposure of aquatic life.

g. Cobalt

Cobalt did not occur in any of the samples from either lake above the 0.01 mg/L detection limit.

h. Copper

Copper appeared in three out of 15 samples from Maskenthine Lake at levels up to 0.07 mg/L and in six out of 21 samples from Willow Lake also at levels up to 0.07 mg/L. The SWQ standard for copper was determined to be 0.04 mg/L for Maskenthine Lake and was determined to be 0.018 and 0.025 mg/L for Willow Lake, stations 1 and 2, respectively. At Maskenthine Lake the standard was exceeded in one sample collected in October. At Willow Lake the SWQ standard was exceeded in one sample collected in October (WL-1) and one sample collected in July (WL-2).

Copper is a micronutrient essential for the nutrition of plants and animals with solubility aerated water at pH=7.0 limited to about 0.064 mg/L (Hem, 1983). Solubility decreases to one-tenth as much at pH=8.0. Reducing conditions also tend to decrease copper solubility. Copper is used extensively in water treatment, in the fabrication of pipe and valves, and as an algalcide in the form of $CuSO_4$.

i. Iron

Iron was detected in six out of 15 samples from Maskenthine Lake in concentrations up to 0.85 mg/L, and in five out of 21 samples from Willow Lake in concentrations up to 0.25 mg/L. No samples exceeded the SWQ standard of 1.00 mg/L for chronic exposure of aquatic life.

Concentrations of dissolved iron in surface water depend primarily on pH, Eh, and temperature. Iron concentrations found in most typical neutral or alkaline lakes range from 0.05 to 0.20 mg/L (Wetzel, 1983). In Maskenthine Lake, dissolved iron exceeded this range in one sample collected in July. In Willow Lake, iron levels exceeded this range in one sample collected in April. Neither sample was collected near the lake bottom, however, which would be expected if the elevated dissolved iron is the result of diffusion from anaerobic bottom sediments.

j. Lead

Concentrations of lead exceeded the detection limit in two out of 15 samples from Maskenthine Lake and three out of 21 samples from Willow Lake. Maximum levels of lead were 0.08 mg/L in Maskenthine and 0.91 mg/L in Willow Lake. All five samples contained lead above the SWQ standards for chronic exposure of aquatic life (0.002-0.006 mg/L depending on water hardness).

Lead possesses a very low solubility in water. According to Hem (1983), equilibrium with carbonate and sulfate forms of lead indicates a level of dissolved $Pb^{+2}$ of about 0.002 mg/L with the median value of dissolved lead in North American rivers running around 0.004 mg/L. The use of leaded gasoline has considerably increased the occurrence of lead in rainfall and freshwaters.

k. Manganese

Manganese was detected in 14 out of 15 samples from Maskenthine Lake and in two out of 21 samples from Willow Lake. Maximum concentrations in Maskenthine Lake ranged up to 0.37 mg/L and in Willow Lake ranged up to 0.04 mg/L. No SWQ standard currently exists for exposure of aquatic life to dissolved manganese.

The chemistry of manganese is controlled to a large extent by the same processes that affect iron. Concentrations of manganese in surface waters are highly variable and range from about 0.01 to 0.85 mg/L (Wetzel, 1983). Higher levels of dissolved manganese found in this study tended to occur in samples collected near the bottom of both lakes, which suggests that diffusion from reducing bottom sediments may be occurring.

l. Molybdenum

Molybdenum was not detected in any of the samples collected from Maskenthine Lake and was detected in two out of 21 samples collected from Willow Lake at concentrations up to 0.02 mg/L. No SWQ standard exists for the effects of molybdenum on aquatic life.

Molybdenum is also a micronutrient essential for many aquatic organisms and plants. Wetzel (1983) lists some average lake concentrations of molybdenum from less than 0.001 to 0.03 mg/L.

m. Nickel

Nickel was not detected in any of the samples collected from either lake.

n. Selenium

Selenium was not detected in any of the samples collected from either lake.

o. Silicon

Silicon was detected in all samples collected from both lakes in concentrations ranging from 0.13 to 1.56 mg/L in Maskenthine Lake and from 1.37 to 3.53 mg/L in Willow Lake. No SWQ standards currently exist for chronic exposure of aquatic life to dissolved silicon.

Silicon is most often found in natural waters in the form of monomolecular silicic acid ($H_4SiO_4$). Hem (1983) notes the range of concentrations of dissolved silica ($SiO_2$) commonly observed in natural waters is from 1 to around 30 mg/L as $SiO_2$ which is equivalent to about 0.5 to 14 mg/L dissolved silicon.

p. Silver

Silver was not detected in any sample from Maskenthine Lake and was detected in one out of 21 samples collected from Willow Lake at a concentration of 0.01 mg/L. This level did not exceed the SWQ standard of 0.12 mg/L for chronic exposure to aquatic life.

q. Tin

Tin was not detected in any of the samples collected from either lake.

r. Zinc.

Levels of zinc in excess of the detection limit occurred in four out of 15 samples from Maskenthine Lake and two out of 21 samples collected from Willow Lake. Maximum zinc concentrations for both lakes was 0.02 mg/L, which was well below the SWQ standards which are based on water hardness.

Zinc is also a micronutrient essential for certain plants and animals. Wetzel (1983) lists a range of dissolved zinc in surface waters from about 0.001 to 0.013 mg/L. Zinc is a widely used metal and may be dissolved from galvanized pipe (Hem, 1983).

Of the metals analyzed for in this study, aluminum would appear to be of the greatest concern since it appeared most frequently in both lakes in concentrations exceeding the SWQ standard for chronic exposure to aquatic life. Other metals such as cadmium, copper, and lead appear much less frequently, and very infrequently at levels exceeding the SWQ standards, and are less likely to pose a problem with respect to chronic exposure. Sediment samples which were analyzed for trace metals are discussed in the following section.

N. Lake Sediments

The results for the lake sediments can be found in Appendix 7.

Coring and analyses of intervals for 15 pesticides and two degradates occurred at both lakes. Of the 17 pesticides only two were not detected in any of the analyzed intervals from the 11 cores collected at Maskenthine. While cyanazine was not detected in April cores, it was quite high in cores collected in July. This indicates that cyanazine is degraded within the shallow bottom sediments. Atrazine concentrations were also much higher in cores from July than those from April. While several pesticides had vertical distributions limited to the top foot other pesticides appeared quite persistent and were distributed throughout the length of the core. The more persistent pesticides were fonofos, butylate, EPTC, alachlor, and atrazine. Fonofos and EPTC are highly sorptive and enter the lake with overland runoff on the sediments.

Thirteen cores were collected from Willow Lake and analyzed for 17 residues of which 11 were detected. In general concentrations were lower and the frequency of detection was much lower in Willow Lake sediments than in those of Maskenthine. With the exception of atrazine, the remaining pesticides were usually limited to the top 2 feet of the core. The data indicate that Maskenthine is much more prone to transport of pesticides on sediments than Willow Lake, and implies that Willow Lake has not been impacted by any recent (past years) intense runoff event.

a. Extractable Metals

Two cores from each lake were selected for analysis of DTPA extractable metals. The DTPA method uses diethylenetriamine pentaacetic acid to extract the adsorbed labile supply of an element from soil or sediment (Baker and Amacher, 1982). Results from this test can be used as an indicator of the amounts of some metals which are available to plants or which may be likely to partition into the aqueous phase. According to Ure (1990), the DTPA method is one of the most generally useful methods for determination of the availability of heavy metals. DTPA extracts indicate the amounts of these elements which are: 1) in the soil pore water; 2) exchangeable; 3) sorbed and organically bound; and, to a lesser extent, 4) bound, occluded in oxide and secondary clay minerals (Ure, 1990). Extracts do not indicate the amount of an element situated in a primary mineral lattice, as a total digest would.

Results for four analyses are listed in Appendix 7. Samples from the uppermost section of each core were selected for extraction because the metals of these sediments are most likely to influence the composition of the overlying lake water.

The concentration ranges for most of the metals were similar for both reservoirs. DTPA chromium exhibited the lowest concentration range (0.10-0.14 ppm) followed by DTPA cadmium (0.08-0.24 ppm). DTPA zinc ranged from 0.62 ppm to 2.60 ppm and DTPA lead ranged from 1.36-2.70 ppm. DTPA nickel and DTPA copper levels ranged somewhat higher at 0.32-4.58 ppm and 1.26-8.15 ppm, respectively. DTPA iron and DTPA manganese levels were considerably higher and more variable than the rest of the metals. DTPA iron in Maskenthine Lake ranged from 56.5 to 59.5 ppm, while Willow Lake samples ranged from 110 to 300 ppm. DTPA manganese in Maskenthine Lake ranged from 218 to 293 ppm and ranged from 76.5 to 215 ppm in Willow Lake.

With the exception of iron and manganese, the low levels of extractable metals in these sediments suggests that the bottom sediments are not a major source/sink for heavy metals in these two reservoirs. The higher levels of DTPA iron and manganese probably reflects accumulation due to redox cycling between the sediments and overlying lake water. Overall, the levels of extractable metals in the sediment samples from both lakes do not indicate any unusually high occurrence of any metals studied.

b. Nutrients

In addition to pesticide content and trace metals, the cores collected for this study were analyzed for moisture content, pH, $NH_4$-N, $NO_3$-N, and Bray-phosphorus. Bray-P was measured on composited sections of two cores from each lake. The nitrogen extracts and Bray-P were utilized instead of a total digest to give an indication of the availability of these nutrients to the overlying lake water. The results of these analyses may be found in Appendix 7.

Sediment pH in Maskenthine Lake cores ranged from 6.5 to 8.8 and from 5.0 to 7.4 in Willow Lake cores. Exchangeable $NH_4$-N ranged from 23.7 mg/kg to 332.0 mg/kg in Maskenthine Lake cores and from below detection to 184.0 mg/kg in Willow Lake cores. Exchangeable $NO_3$-N ranged from 0.12 to 3.40 mg/kg in Maskenthine Lake and from below detection to 1.50 mg/kg in Willow Lake cores. Bray-phosphorus ranged from 1.56 mg/kg to 23.0 mg/kg in Maskenthine Lake and from 4.63 to 22.10 mg/kg in Willow Lake cores.

According to Wetzel (1983), the nitrogen dynamics of lake sediments are poorly understood. Sediment pore water usually possesses much higher levels of soluble nitrogen, mainly $NH_4$-N and organic N, than the overlying lake water. Nitrogen exchange between the sediments and lake varies greatly with sediment composition (Wetzel, 1983). Most studies have shown that lake bottom sediments are a major reservoir of nitrogen and a site of significant nitrogen metabolism. Measurable levels of nitrate-N were not expected to be found since $NO_3$-N in the lake bottom sediments is rapidly reduced. The nitrate measured may be an artifact of sampling since the sediments were air-dried prior to extraction and some of the ammonia present in the samples could have been converted to nitrate.

Lake bottom sediments tend to become sinks in the phosphorus cycle of most reservoirs (Wetzel, 1983). The phosphorus content of sediments can be several orders of magnitude greater than that of the overlying water. The relatively high Bray-P levels encountered in the sediments of both lakes suggests that exchange of phosphorus may be an important process and that the sediments may also serve as a source for phosphorus. Overall, it appears that the bottom sediments for both lakes contain appreciable, though probably not unusual, amounts of both nitrogen and phosphorus. These nutrients may be readily exchanged with the lake water at various times of the year.

## I-11. Lake Biological Resources

### A. Fisheries

#### 1. Past and Present Activities and Suitability of the Lake

Willow Creek was initially stocked in 1982 with bluegill, fathead minnows and channel catfish. Largemouth and smallmouth bass were added in 1983 along with walleye, tiger muskie, additional bluegill and fathead minnows. A second stocking of bass was made in 1984 and annual stockings of walleye, tiger muskie and catfish have been made since that time. It was believed the lake would have good water quality and clarity and a bass/bluegill fishery would develop along with other sight feeding predators such as the walleye and tiger muskie. The watershed was not renovated, with the exception of one small pond located in the proposed lake bed, and northern pike, carp, black bullhead, and black crappie entered the lake from the stream.

Initially, population abundance and growth was good for largemouth bass, walleye, tiger muskie and northern pike. However, in recent years, walleye, largemouth bass, and bluegill have declined dramatically. Black crappie and carp are the only species that have shown an increase in relative abundance.

Maskenthine Lake was initially stocked in 1976 with largemouth bass, bluegill, and channel catfish. Following a second year stocking of bass and catfish subsequent annual maintenance stockings have been made for walleye, northern pike and catfish. The dominant species in the lake are largemouth bass, bluegill, black crappie, walleye, channel catfish, and northern pike. Black crappie and yellow perch in the lake are the result of the unwanted stocking made by the public. Healthy, abundant populations are present for bass, bluegill, walleye, catfish, and crappie.

2. Wholesomeness of Fish Tissue

Nebraska, along with other USEPA Region VII states, participate in the Regional Ambient Fish Tissue Monitoring Program (RAFTMP). In this program, whole fish (usually common carp) are analyzed at USEPA's laboratories for metals, pesticides and other organic compounds.

On September 15, 1988, five largemouth bass fillets were collected from Maskenthine Lake for tissue analysis. After collection, they were wrapped in aluminum foil and frozen on dry ice until delivery to USEPA laboratories in Kansas City. Following is a listing of the pollutants, and their concentrations, which were detected in the fish tissue:

| | |
|---|---|
| Lead | 0.27 ppm |
| Copper | 0.19 ppm |
| Zinc | 8.40 ppm |

Also on September 15, 1988, five black bullhead fillets were collected from Willow Lake for tissue analysis. After collection, they were wrapped in aluminum foil and frozen on dry ice until delivery to USEPA laboratories in Kansas City. The following pollutants were detected in the fish tissue:

| | |
|---|---|
| Nonchlor | 0.002 ppm |
| P,P'DDD | 0.009 ppm |
| P,P'DDE | 0.02 ppm |
| Mercury | 0.29 ppm |

B. Nutrient Sources for the Lake

1. Estimates of Nutrient Load Based on Land Use

The AGNPS (Agricultural Nonpoint Pollution Source) model is event based. The model simulates runoff, sediment, and nutrient transport from agricultural watersheds. Nitrogen (N) and phosphorus (P), both essential plant nutrients and major contributors to surface water pollution, are addressed. Basic model components include hydrology, erosion, and sediment and chemical transport. In addition, the model considers point sources of sediment nutrients from animal feedlots, springs and other point sources. Temporary water impoundments, such as tile-outlet terraces, also are considered as depositional areas of sediment and sediment-association nutrients.

The model operates on a cell basis. Cells are uniformly square areas sub-dividing the watersheds, allowing analyses at any point within the watershed. Potential pollutants are routed through cells from the watershed divide to the outlet in a stepwise manner so that flow at any point between cells may be examined. All watershed characteristics and inputs are expressed at the cell level.

Following is a listing of the inputs used in AGNPS. Parameter values may be obtained from published data, available watershed records, or on-site inspection.

*Watershed Input*

Watershed identification
Cell area (acres)
Total number of cells
Precipitation (inches)
Energy-intensity value

*Cell Parameter*

Cell number
Number of the cell into which it drains
SCS curve number
Average land slope (%)
Slope shape factor (uniform, convex, or concave)
Average field slope length (feet)
Average channel slope (%)
Average channel side slope (%)
Mannings roughness coefficient for the channel
Soil erodibility factor (K) from USLE)
Cropping factor (C) from USLE
Practice factor (P) from USLE
Surface condition constant (factor based on land use)
Aspect (one of 8 possible directions indication the principal drainage direction from the cell)
Soil texture (sand, silt, clay, peat)
Fertilization level (zero, low, medium, high)
Incorporation factor (% fertilizer left in top 1 cm of soil)
Point source indicator (indicates existence of a point source input within a cell)
Gully source level (estimate of amount, tons, or gully erosion in a cell)
Chemical oxygen demand factor
Impoundment factor (indicating presence of an impoundment terrace system within the cell)
Channel indicator (indicating existence of a defined channel within a cell)

A. Maskenthine Lake

The AGNPS model included a drainage area of 7,040 acres and a runoff volume of 3.1 inches. All drainage was directed to cells near the dam at the bottom of the lake. The predicted concentrations are based on a single storm event with a duration of 24 hours. The model was not field calibrated. Thus, these model estimates should only be utilized in a qualitative manner.

Estimated sediment load was very high at ~6 tons/acre for the near worst-case scenario. A 1986 field survey indicated the location of acreages with contour farming and terraces. The effect of the impact of these land improvements was to lower the predicted sediment load to ~4 tons/acre. The soluble nitrate-N and phosphorus were ~3 ppm and 0.5 ppm, respectively. As anticipated the nutrient loads are mostly in the suspended sediment where total nitrogen amounts exceeded 15.7 lbs/acre and total phosphorus were 7.85 lbs/acre. The model predicted the sediment loads to be approximately 60% silts and clays and 40% sands.

In January 1992, a windshield survey of additional land improvements in the Maskenthine drainage area indicated that some changes in landuse and land improvements occurred since the 1986 SCS field survey. The noted changes are additions of terraces, both sod and underground outlets, and the construction of 2 dam sites within the lake area. A previous value of ~6 tons/acre with a cell erosion of ~30 tons/acre was given for a worst-case scenario in which there were no improvements within the watershed. The addition of the improvements, at their exact location within the watershed, gave a value of ~0.6 tons/acre sediment with cell erosion at ~7 tons/acre yielding ~4500 tons. The number is estimated from a 10 year 24 hour storm. Since a 24 hour storm is rare in Nebraska, the model was manipulated to give output for a 5 year 1 hour storm which is considered to be more typical. This storm produced 0.08 tons/acre with a cell erosion of 0.9 tons acre with present values. The total sediment eroded was ~550 tons.

The windshield survey of Maskenthine drainage area found that the current land use map indicated for pasture, range and cropland was accurate. The present value given from AGNPS reflects present CRP land being returned to row crop farming.

B. Willow Lake

Input for the three drainageways was used in this AGNPS model at Willow Lake. Willow Input 1 is the main tributary and is a continuously flowing stream. This input has two feedlots within Pierce County that are in close proximity to the creek and may impact the water quality in Willow Creek.

The AGNPS model suggests that non-uniform erosion occurs in the drainage area. The worst erosion was predicted to occur in the creek channel itself, and where the main tributary empties into the lake.

Input estimates from Willow Creek are based on a 10 year 24 hour storm, which is close to a worst-case scenario. The estimates suggest only 0.33 ton/acre sediment load composed almost of equal parts of clay, silt, and small aggregate. The removal of feedlots from the model did not significantly impact the amounts of nutrient loads to the main creek (See Appendix 8).

In addition to sediment, soluble nitrogen concentrations of 2.30 ppm and soluble phosphate levels of 0.41 ppm were estimated. The model did not indicate that contouring would lower soluble stream levels; however, it did lower the lbs/acre lost.

Lesser water quality deterioration would be expected for the smaller volume input on the south side (#2) and that on the north side (#3) of the lake. Input 2 is contaminated by pigs and cattle that are allowed to graze unrestrained in the creek bottom. A small feedlot for hogs and cattle also drains toward the stream. The total drainage is relatively small at 3,640 acres; however, it is projected to deliver 2 times more sediment/acre than the main tributary. Input 3 has no point sources but has a much higher gradient. Total sediment yield for 9,320 acres involved is 1.38 tons/acre or ~4 times greater than the main tributary. In terms of model-estimated, feedlot-initiated soluble nutrient input concentrations, input 2 contributes the most.

Again no field calibrations were made for the Willow drainage cells at these sites and calibration would be needed for partial verification. A windshield survey indicated areas adjacent to the north side of the dam had been improved. Terraces were added to the AGNPS model at T26N R2W S 32 and 33. The watershed was divided into four principal drainageways. A projection using worst case scenarios (no improvements in contour farming or terracing) for each of the three drainage areas was modeled. The model was then changed to predict present conditions and then used to predict a 5 year 1 hour storm which is more typical for Nebraska. The progression from worst case to a 5 year 1 hour storm with above changes resulted in a drop from 7,500 total tons to 400 yield tons on the north input. On the main input the drop was from 4,500 to 200 yield tons. Yield from the half section near the lake with the 3 center pivots decreased from 850 to 35 total tons. See Appendix 8 for additional model estimates.

C. Comparison

The steeper slopes at Maskenthine combined with the lack of improved farmland make this watershed much more susceptible to erosion during storm events than the watershed at Willow Lake. AGNPS predicts eroded farmland soils at Maskenthine transport a high contribution of nutrients and pesticides during spring or early summer intense rainfall events.

C. Phosphorus Load - Eutrophication Response

The results of phosphorus loading calculations performed in AGNPS were applied to three lake response models (USEPA, 1988) to predict lake phosphorus, chlorophyll a and secchi transparency. Average inflow phosphorus was calculated for each lake assuming a wide range of mean annual outflow (discharge) because actual outflow either does not occur or cannot readily be measured. Maximum annual outflow from Maskenthine Lake was estimated at one-third the permanent pool storage (927.5 acre-ft). Maximum annual outflow from Willow Lake was assumed to be equivalent to the average annual discharge for Willow Creek (USGS, 1987). The results of these calculations are tabulated in Appendix 9. The equations used to predict phosphorus, chlorophyll a, and secchi transparency are those based on data from northern, natural lakes (USEPA, 1988) and deviations of the actual values from the predicted values may merely reflect the fact that these two lakes are not 'typical' northern, natural lakes. In addition, the assumptions that go into the calculation for phosphorus loading and estimates for mean annual outflow may also result in erroneous predictions for the three parameters.

In Maskenthine Lake, the highest predicted phosphorus concentration (92 ppb, mean outflow = 1 acre-ft/year) was lower than the measured average (120 ppb). The average measured chlorophyll a level (18.6 ppb) fell between the predicted values for mean outflows of 1 acre-ft/year and 5 acre-ft/year. Average measured secchi transparency (0.91 meters) fell between the predicted values in the same range. These average measured values can be converted to Carlson's Trophic State Index (TSI) values ranging from 60 to 75 which would classify Maskenthine Lake as eutrophic to hypereutrophic. Carlson's classification is based on responses observed in northern, natural lakes which may be considerably different from the lakes of this study. Turbid, rapidly flushed impoundments tend toward lower responses and exhibit less sensitivity to phosphorus loading (USEPA, 1988). Comparison of the average measured values to the results of an USEPA National Eutrophication Survey (USEPA, 1988) also suggest that Maskenthine Lake borders on eutrophic to hypereutrophic states.

In Willow Lake, the highest predicted phosphorus level, using surface sources of total phosphorus loading from all three inputs and assuming a mean outflow of 1 acre-ft/year, was 19 ppb. This is well below the average measured value of 155 ppb. Average measured chlorophyll a (31.4 ppb) was also much higher than the predicted value (5 ppb) and average measured secchi transparency (0.44 meters) falls far short of the minimum predicted value (2.6 meters). The predicted values for lake phosphorus, chlorophyll a, and secchi transparency could be recalculated using a mean annual outflow of less than 1.0 acre-ft/year to bring them into the range of the average measured values; however, it is not clear whether or not this would be appropriate. The average measured values for the three parameters indicate a trophic state index (TSI) of 65-75 which would result in a hypereutrophic classification for Willow Lake. The exceptionally high measured phosphorus levels compared to the low predicted lake phosphorus levels derived from surface sources in Willow Lake suggest that agrichemical sources are less significant than in the Maskenthine watershed where the predicted levels from surface sources are much closer to the measured levels. Ground water phosphorus inputs appear to be more important in the Willow Creek watershed. It is important to note that these models neglect the ground water contribution.

## II. FEASIBILITY STUDY

### II-1. Lake Restoration and Maintenance Goals

Phase I monitoring has shown Lake Maskenthine to be experiencing accelerated siltation and high levels of agrichemicals contaminates from uncontrolled storm runoff. The nutrients load from the runoff is fertilizing macrophytes which are especially abundant in the upper arm (1/3 of the lake) where an artificial wetland has developed. Localized bank slumping is also noted (Figure 27) in the deeper sections near the dam. Maskenthine restoration will involve sediment removal which will include mechanical macrophyte removal. Control strategies to protect the lake from rapid siltation after restoration are as important as sediment removal in the overall lake rehabilitation. Figure 27 shows the location of the proposed siltation trap and wetland. Watershed control strategies have a goal to reduce the total sediment and chemical transport to the lake by a minimum of 50%. AGNPS shows this to be a feasible goal.

At Willow Lake Phase I monitoring suggested that the lake is in hydraulic connection with the ground water. Historical problems of large fluctuations in the lake level, shoreline erosion, and algal blooms have been discussed. Solutions to these problems can best be strategized when the ground/surface water interrelationships are better defined. The technical advisory committee suggests that a system of piezometers and multilevel samplers be installed around the lake. Data would be used to estimate water and nutrient transport across the ground/surface water boundary. Cost for the project should not exceed $50,000. The advisory group proposes another related feasibility study to use artesian well yields from pressure release wells to maintain higher in-lake water levels. Data on the water quality, quantity, and design criteria need to be documented and should not be expensive to acquire.

While additional in-lake documentation is being gathered there are immediate and obvious problems in the watershed that need attention (Figure 28). The installation of fenced-in riparian strips along the inputs with strict controls on the direct or indirect discharges of animal wastes will protect the lake from an obvious source of nutrients. The elimination of irrigated row-cropping in the bottomland should decrease nutrient and pesticide loading to the lake. The implementation of additional terracing and contour farming along with an educational program designed to extend best nutrient and water management to the farmers in the watershed is advised. These should significantly lower both point and nonpoint inputs to the lakes.

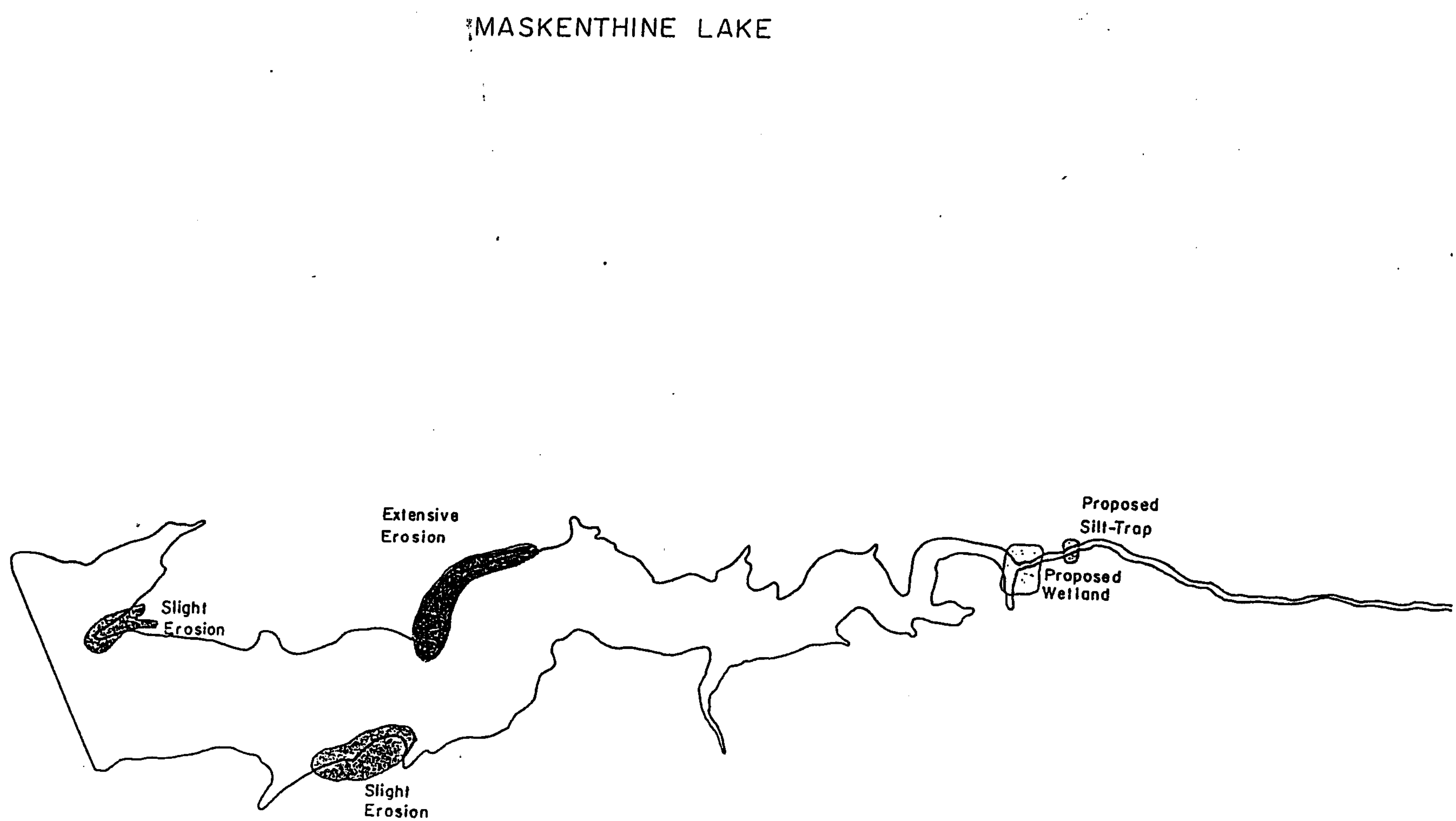



Figure 27. Approximate sites for in-lake improvements at Maskenthine Lake.

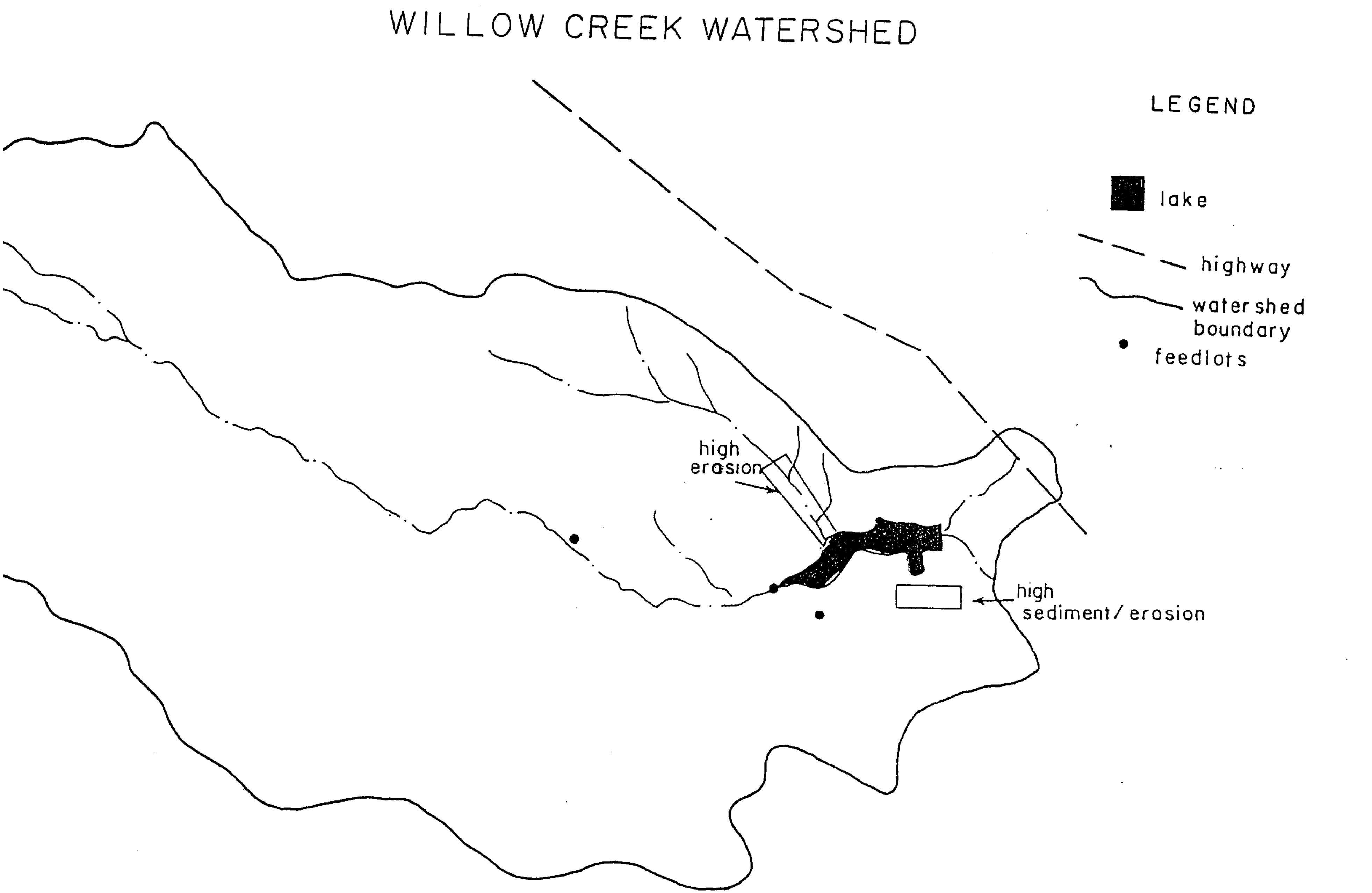



Figure 28. Approximate sites for watershed improvements at Willow Creek.

## II-2. Lake Restoration and/or Pollution Control Alternatives

### A. No Action

This alternative represents the least costly approach, at least on the short term. It would provide a diversity of benefits in that the lake would remain one-third wetland and thus be a habitat for water fowl and marsh animals. Adopting this plan would allow users of the lakes to utilize them less and less over the next few years as a fishery, although restocking could prolong this use. The trophic state of the lakes would increase over time, as more nutrients enter the lakes, until phytoplankton levels finally eliminate the aesthetic quality for boaters, picnickers, etc. The lakes at this point may also exhibit definite odor problems by mid summer. Siltation could be expected to eliminate the northern arms of Maskenthine Lake, halving its surface area.

Annual long term losses from the 'No Action' alternative of the fishing (300 fisherman/acre/year) at Maskenthine are estimated to exceed $400,000. An additional loss to the area from the loss of the beach is estimated to exceed $100,000/year. The total yearly loss to the area would be ~$500,000. A similar loss is projected for Willow; however, Willow is used more for boating and skiing than for fishing.

### B. Localized Bank Stabilization

There are a few areas at Lake Maskenthine in which attention to bank slumping is warranted. Bank retainers are needed in these areas. Retaining devices such as Soil Erosion Synthetic Blankets (BonTerra), Tri-lock Concrete Erosion Blocks, Wire Rock Bails, Hydroseeding and Tracking Mixtures, and PermaMat are suggested as possible alternatives.

### C. Sediment Removal

Deposition of sediments in reservoirs has several negative impacts. Major deleterious effects occur in the area of water quantity (loss of storage) and water quality (release of toxins into the water body from bottom sediments). Since the sediments run off agrichemically treated fields they tend to concentrate nutrients and pesticides.

Mechanical dredging is effective; however, it is not economically feasible. Estimates for dredging are about $3.00/yd$^3$. An estimated 150,000 yd$^3$ have accumulated in the lake. The volume of sediment occupies 15 acres and is ~6 feet deep. Estimated cost of this method of remediation is $500,000.

Annandale (1987) concludes that dredging is usually so expensive that it is more economical to replace the reservoir. Sediment sluicing can be used to extract sediment. In this case, low level outlets at the dam are opened and the reservoir is partly drained; increased velocities in the immediate vicinity dam are effective in removing local sediment deposits. This may not work in the case of Maskenthine since sediments are deltaicly formed at the input arm of the lake. A more promising system for Maskenthine Lake is a submerged piping system in which high local entrance velocities entrain sediments deposits in the upper end of the lake and transport them to the dam outlet (Eftekharzadeh, 1987). Either system would first need to be tested as a research project.

An alternative to dredging is to drawdown the lake and remove the dried sediment in the upper arm with earth movers and/or a drag line. If a clamshell is used for sediment removal, costs will be \$2.00 - 3.00/yd$^3$. Using the volume of sediment estimates above, the cost will range from \$300,000 - 450,000. Obviously this would only be used for removal in selected areas. A similar technique was instituted at the 130-acre East Twin Lake where Nebraska Game and Parks Commission estimates the costs were \$1.10/yd$^3$. An earth mover will cost ~\$1.25/yd$^3$ for dry sediment, with a total cost of ~\$190,000.

D. Macrophyte and Algae Control

Macrophytes are not a problem at Willow and certainly not the major problem at Maskenthine Lake. The use of herbicides at Maskenthine such as 2,4-D and endothall would temporarily solve the macrophyte problem; however the problem would just return at a later date. Only when the excess nutrients are removed will the pond weed disappear. Mechanical harvesting the macrophyte would be possible and removal from the pond would also limit nutrient recycling from the plant decay. This would be a recurring activity with little hope of permanent success.

Sediment covers have effectively controlled macrophyte growth in several lakes. This solution does not address the problem's source and only temporarily solves the problem.

E. Watershed Management

Watershed management must be implemented in both lakes. Management must include an insistence on maintaining riparian strips along all tributaries. The Wildlife Habitat Improvement Program (WHIP) can be used to establish or improve habitat on critical erosion areas identified by AGNPS and to treat riparian areas with buffer strips. WHIP also makes annual payments to landowners to maintain these habitat areas. Both critical erosion areas and riparian areas that have been cropped are eligible for bid into the 10 year Conservation Reserve Program of USDA. These areas would be planted to grass and trees and landowners would receive annual payments to maintain the cover. These strips must be off limits to cattle and hogs. These strips must act as filter strips for nutrients and runoff. Siltation needs to be controlled at Maskenthine by (1) taking steeped-sloped land out of production, and (2) using terraces and contour farming throughout the remaining watershed. Sediment traps in the main tributary and the upper arm of Maskenthine will be a necessity even if the farmland is improved. If these precautions after Maskenthine is dredged are heeded, the new lake should be much less vulnerable to degradation.

The elimination of irrigated row-cropping in the bottomland should decrease nutrient and pesticide loading to the lake. The LENRD will offer cost share for soil and water sampling and analysis in the Willow Creek Watershed. This can be combined with incentive programs for management of irrigation water, nutrient and ag chemicals.

Although the model did not suggest that feedlot runoff was a major cause of the water quality degradation at Willow, it only makes sense to limit this activity in close proximity to influent tributaries. Cattle excrement was observed to be degrading one of Willow Lakes' inputs in a winter sampling.

F. Water Level Adjustment

A water level adjustment might be used in conjunction with a dredging process at Maskenthine. Hand removal of some macrophyte might then be accomplished. Since the lake is not that large it would be beneficial to remove the macrophytes at the same time in which the dredging occurs.

## II-3. Benefits of Various Alternatives

The benefits of each alternative from the previous section are contrasted with potential problems in list form within this section.

No Action (Both lakes)

Benefits - Low short term cost

Continued marsh development with associated wildlife and educational benefits

Problems - Siltation and agrichemical inputs unchecked

Long term eventual loss of recreation facility valued at $500,000/year/lake in terms of usage by fisherman and water sportsmen

Bank Stabilization (Maskenthine - rip-rap, Willow - floating break waters)

Benefits - Lessen bank slumping and sediment to lake

Reduce turbidity

Increase access for fishermen

Problems - Costs for Maskenthine to rock riprap slump areas range from $17.00 - 18.00/linear foot while Tri-lock control system costs range from $3.00 - 4.00/linear foot

Construction and anchoring of floating breakwaters at Willow Lake

Sediment Removal (Maskenthine)

Benefits - Removal of accumulated nutrients and pesticides

Deepening of lake, extending useful life

Improvement of fishery

Removal of macrophyte beds

Land disposal should be possible since metals are not a problem

Problems - Expensive to implement dredging technique

Cost of construction and maintenance of siltation traps in upper arms of lakes and in tributaries

Possible reintroduction of sediment material to water

Costs of conversion of marsh to lake with subsequent construction of upgradient wetland area

Temporary measure unless linked to siltation traps and wetland purification

Temporary measure unless linked to watershed management including riparian areas along contributing drainage areas

Macrophyte and Algae Control (Both lakes)

Benefits - Temporary elimination of nuisance organisms

Improvement of recreation uses

Problems - Treats symptoms of eutrophication only

Expensive and difficult in large lakes and considered appropriate for Willow Lake

Requires seasonal, repeated implementation

Can introduce contaminants to lake waters and lower DO

Does not address siltation or pesticide problem

Watershed Management (Both lakes)

Benefits - Provides gains to all involved

Reduces siltation and ag runoff

Partially in place already

Would help alleviate nutrient and sediment source from watershed

Problems - May not provide short term lake nutrient improvements due to internal cycling in lake and ground water contributions at Willow Lake

Water Level Adjustment (Maskenthine remediation)

Benefits - Improves fishery

Allows access to parts of lake during drawdown

Problems - Does not provide vegetation control

May exacerbate algae problems

Does not address siltation

Reduces recreation value during drawdown

Sediment Covering, Inactivation (Both lakes)

Benefits - Cheaper than dredging

Trapping of sediment nutrients and pesticides

Possible, but not probable, elimination of macrophyte beds

Problems - Adds to loss of lake volume

Implementation could affect fisheries

Temporary measure unless linked to silt traps and improved farmland management

Does solve the immediate problems. May be difficult to install in the lake with hydraulic connection to ground water

Not considered a viable option by the Technical Advisory Committee

Siltation Traps (Both lakes)

Benefits - Traps silts

Removes sorbed pesticides and nutrients

Can be designed for easy clean out

Wetland purification

Problems - Silt has to be periodically removed

Spoils may have to be analyzed before disposal

Wetlands (Maskenthine only)

Benefits - Purification system for inputs

Removes nutrients, organics, and metals

Provides habitat for water fowl and wildlife

No permit required

Simple to construct

Problems - Costs of construction (less than $10,000)

## II-4. Recommended Actions from Technical Advisory Committee

The Technical Advisory Committee unanimously recommends for Lake Maskenthine the following in-lake and watershed treatment alternatives. Sediment removal by lowering the lake level and removing accumulated sediments with earth movers and/or drag lines is recommended. The accumulated sediment to be removed is in the north arm of the lake from the boat dock and boat ramp to the road. Estimated costs for the removal of 72 acre-feet, 15 acres x 6 feet, (261,600 cubic feet) of sediment are ~$500,000. This estimate does not include costs for engineering and final design. Prior to sediment removal the group strongly advises construction of sediment traps and a wetland within the watershed. The cost of constructing a sediment trap is ~$125,000. This estimate does not include costs for engineering and final design. The wetland should be relatively cheap to construct. Long term clean out and maintenance of these traps will be mandatory and probably will require NRD oversight and resources. Additional land treatments in the watershed (terracing and contouring) is also recommended on sights that AGNPS has suggested to be most vulnerable. While funding for construction of sediment upgradient structures is being sought, the committee advises that the NRD seek funding for localized bank stabilization project. Locations needing stabilization have been delineated that need immediate attention and will cost from $50,000 - 100,000 to repair. The total project can be viewed as one which must be developed by a logical progression of events. The phases of implementation include (1) local bank stabilization (2) watershed treatment and (3) in-lake sediment removal. (Refer to Attachment A for specific Phase II recommendations and budget.)

The Technical Advisory Committee recommends that more information be gathered to better define the ground/surface water interrelationships at Willow Lake. Interrelationships that are pivotal for solving the problem at Willow Lake include the association of ground water levels to surface water levels and the potential transport of nutrients from the ground water to the lake. Until the system is better defined, in-lake bank stabilization remedies and nutrient control alternatives can not be addressed with any certainty of success. Thus, although all the Clean Lakes Phase I protocol was followed, additional Phase 1 type investigations are need. These should include installation and monitoring of piezometers and multilevel samplers and lake stage gauges. Additional analyses of both quantity/quality of ground water from pressure release wells are necessary to predict feasibility of using this water to stabilize lake water levels.

In the meantime the advisory committee strongly recommends implementation of watershed improvements at obvious highly erodible sites and at sites where nutrient contributions to the lake input tributaries were observed. Riparian strips along these tributaries are strongly recommended.

## II-5. Description of Phase II Monitoring Program

The Lakes should be sampled, at minimum, twice each year, once in late spring and again in late summer. Parameters at each sampling should include temperature and oxygen profiles, Secchi depth, nutrients, pesticides, and chlorophyll a. Sediment samples should be taken once a year, at least at two points in the lake, for nutrients and heavy metals. Macrophyte cover should be estimated in each of the three lake segments at the late summer sampling. Fish tissue samples should also be taken yearly for heavy metals and pesticide analysis.

Should Phase II include dredging, then bottom samples should also be taken for chemical parameters, regardless of depth, to assess hypolimnetic release. Any Phase II plan should attempt to take advantage of SCS plans to carry out long term studies on the effectiveness of land management practices.

If Phase II monitoring is meshed with SCS efforts, inflows should be sampled with each significant runoff event. Parameters should include TSS, nutrients, turbidity, and pesticides.

II-6. Lake Restoration and Pollution Control Workplan

At this time, no Phase II plan exists for either lake. However, any future plans should include continued treatment in the watershed for control of agricultural runoff, plus practices for controlling urban runoff and construction site pollutant production within the watershed.

II-7. Sources of Non-Federal Funds

Funds for possible future corrective action of a non-federal source would be from the county government, Natural Resources District, Game and Parks Commission, and Nebraska Soil and Water Conservation Fund.

II-8. Relationship of Project to Other Pollution Control Programs and Watershed Maintenance Plan

The Lower Elkhorn NRD has been involved in pollution control in both the Maskenthine and Willow Creek watersheds since before the construction of the reservoirs. The NRD's efforts have primarily been related to sediment and erosion control. It is anticipated that upon completion of the Phase I project a renewed emphasis will be placed on erosion and sediment control in both watersheds.

The LENRD has the following specific programs: Nebraska Soil and Water conservation Funds, Lands for Conservation, Conservation Cost Share, Erosion and Sediment Control act. These watersheds may be targeted with higher rates to accelerate the construction of terraces, dams, sediment basins, tile outlets and waterways.

As required by the federal Clean Water Act the State of Nebraska has developed a Nonpoint Source Management Program. The implementation of the states program involves multiple federal, state, and local agencies as well as several nongovernmental entities. The Nebraska Department of Environmental Control has been designated by the Governor of Nebraska as the lead state agency in implementing the state's NPS management program. Given the nature of the water quality problems in Willow Creek and Maskenthine Lakes it is evident that the state's nonpoint source management program will be an essential tool in addressing NPS problems in the lake watersheds.

Point source controls to ensure the proper disposal of livestock wastes and prevent surface water contamination fall under NDEC regulations for feedlots. Cost sharing for waste control facilities are up to $10,000 for construction. Other examples of LENRD point source control programs which may impact the lake are: Chemigation, which insures that safety equipment is in place and functioning properly to prevent ag chemicals applied with irrigation water from being backflushed down the ground water well; and well sealing, which prevents surface water and contaminates from entering abandoned wells and thus contaminating ground water.

II-9. Summary of Public Participation Activities

The Natural Resources District, Water Center, Nebraska Game and Parks Commission, and Department of Environmental Control conducted a public meeting at the local NRD in Norfolk to inform the public of the purpose and nature of the project. The Citizens Advisory Group for the Clean Lakes project has met three times during the Phase I process.

II-10. Necessary Permits

None are anticipated; however, an investigation of the need for 404 permits will ensue prior to sediment removal.

III. PROJECT ENVIRONMENTAL EVALUATION

III-1. Displacement of People

There will be no displacement of people as a result of any action taken.

III-2. Defacement of Residences and Residential Areas, Available and Applied Mitigative Actions

There will be no defacement of residences and residential areas as a result of any action taken.

III-3. Changes in Land Use Patterns

In the agricultural sector of this watershed, changes in land use are noted.

III-4. Impacts of Prime Agricultural Land

The use of terracing, siltation, ponds, wetlands, and riparian strips in the watershed will have beneficial impact on agriculture operations due to decreased erosion.

III-5. Impact on Park Land, Public Land, and Scenic Value Lands

The use of terracing, holding ponds and in-lake restoration would have beneficial impacts upon any parkland, public land, and scenic value lands. No negative impacts are anticipated.

III-6. Impact on Lands or Structures of Historic, Architectural, Archaeological or Cultural Value

There are no known lands or structures of historic, architectural, archaeological or cultural value within the watersheds of either lake.

III-7. Short and Long Term Energy Impacts

If any of the terracing, dredging, siltation and wetland areas are implemented, and the water quality is improved, it is anticipated that it will result in a greater use of the lake as a fisheries resource. That is, the recreational use will increase. Improving the water quality of Maskenthine Lake could decrease the energy usage by the public by providing improved recreational opportunities closer to home.

III-8. Short and Long Term Ambient Air Quality and Noise Level Impacts

Construction of terraces and holding ponds in this very rural setting will not necessitate human exposure to air quality and noise level impacts during daylight hours. No long term impacts are anticipated.

III-9. Short and Long Term Impacts of In-Lake Chemical Treatment

No water treatment is anticipated at this time. (This is a very low priority for both lakes.)

III-10. Flood Plain Impacts

There are no anticipated flood plain impacts.

III-11. Impacts of Sediment Removal Activities

Sediment removal, if implemented, would have some temporary short term impacts on fisheries due to sediment stirring and disruption of the benthos. Long term gains would outweigh any adverse impacts by deepening the lake and extending its life, removing sediment nutrients and contaminants, and removing macrophytes. Sediment removal would be in the north arm of the lake where shallow conditions are most extreme. Fisheries would rebound with a few years. Cost of the operation and disposal of spoil may be high.

III-12. Wetland, Fish and Wildlife, Endangered Species Impacts

No net loss of wetlands is anticipated. No known endangered species will be affected by any proposed activity in either watershed. Fisheries would be improved by many of the proposed management alternatives, due to improvement of the overall water quality of the lake. Favorable impacts would be measured through increased use of the lake for recreation.

III-13. Feasible Alternatives to Project

See our recommendations.

III-14. Other Measures of Impacts Not Previously Discussed

All impacts have been investigated to the best of our knowledge.

IV. PROJECT PUBLIC PARTICIPATION ACTIVITIES

IV-1. Public Participation Coordinators

Stan Staab and Marla Rohrke, Lower Elkhorn NRD

IV-2. Project Advisory Committee

Paul Brakhage, Environmental Specialist, Department of Environmental Control

Ken Berney, Assistant Manager, Lower Elkhorn NRD

Mark Burbach, Field and Sample Coordinator, UNL

Rollin Hotchkiss, Civil Engineering Professor, UNL

Jeff Schuckman, Nebraska Game and Parks Commission

Roy Spalding, Water Sciences Laboratory Director, UNL

Dave Speidel, Soil Conservation Service, Stanton County

Stan Staab, Lower Elkhorn NRD Manager

Dan Sutherland, Nebraska Game and Parks Commission

Rick Wozniak, Water Resources Assistant Manager, Lower Elkhorn NRD

IV-3. Project Public Meetings and Hearings

There have been three meetings of the Citizens Advisory Committee

IV-4. Public Information Depository

The Lower Elkhorn NRD was designated as the public information depository.

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ATTACHMENT 1 - FY93 Clean Lakes Phase II Funding Request For Willow Creek and Maskenthine Lakes.

**Maskenthine Lake**

| Activity | NRD Contribution | EPA Contribution |
|---|---|---|
| Shoreline Stabilization | $25,000 | $25,000 |
| Dredging | 250,000 | $250,000 |
| Final Engineering Review and Design | 25,000 | 25,000 |
| Wetland Construction | 50,000 | 50,000 |
| Final Engineering Review and Design | 5,000 | 5,000 |
| Sediment Trap Construction | 62,500 | 62,500 |
| Final Engineering Review and Design | 15,500 | 15,500 |
| Total | 433,000 | 433,000 |

**Willow Creek Reservoir**

| Activity | NRD Contribution | EPA Contribution |
|---|---|---|
| Lake Elevation Stabilization | $52,000 | $52,000 |
| Final Engineering Review and Design | 5,000 | 5,000 |
| Total | $57,000 | $57,000 |

The projected budget for Clean Lakes Phase II activities on Maskenthine Lake is $866,000. This includes costs for dredging, wetland construction, the construction of a sediment trap above the wetland area, and the treatment of shoreline areas with riprap. The budget also includes costs for the final engineering and design. The dredging and construction of the wetland and sediment trap will take place after the recommended watershed treatments have been completed.

Clean Lakes Phase II activities on Willow Creek Reservoir will be targeted at stabilizing lake elevations. The proposed activity is to divert ground water flow originating from relief wells located below the earthen dam structure to Willow Creek Reservoir. These wells were designed to relieve uplift pressure on the dam and year around output ranges from 4.5 to 9.1 cubic feet per second. The ground water will be pumped with a 75 horsepower pump through a 12 inch pipe that will extend over the dam. The pump will be powered by electricity and is capable of delivering up to 4000 gallons per minute. To prevent oxygen deficient water from entering the lake the flows will be diverted over riprap before entering the lake. The budget for the project includes costs for the purchase, installation, and operation (2 years) of the pumping system as well as for pre-implementation assessments of the ground water quality and soils. Prior to the installation of the pumping system water quality samples will be collected from the relief wells and analyzed for nutrients, heavy metals, and pesticides. Samples will be collected one time per month from April through October. In addition, soil borings will be reviewed to determine the water retention capabilities of the reservoir. Information on the soils should be available from preconstruction assessments. If sufficient soils information is not available additional borings will be collected.