Spring Lake Restoration and Management Feasibility Study

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TABLE OF CONTENTS

TABLE OF CONTENTS CONTINUED

"Water is the most critical resource issue of our lifetime and our children's lifetime. The health of our waters is the principal measure of how we live on the land"

-Luna Leopold

Introduction

Spring Lake is a 79-acre natural waterbody located in southeastern Waushara County in the Town of Marion. The lake lies in a northeast – southwest axis, and has two basins that are separated by a shallow narrows. The two basins are distinctly different in physical, chemical and biological characteristics. The northeasterly basin, which will be referred to as the *north basin* in this report, has a maximum depth of 28 feet. The southwesterly basin, which will be referred to as the *south basin* in this report, has a maximum depth of 37 feet. Spring Lake is aptly named, for an incredible number of springs supply fresh water to the lake. Spring Lake is also fed by three short creeks, two of which drain into the north basin and one that drains into the south basin. Its single outlet, Sucker Creek, drains into the White River, which in turn drains into the Upper Fox River and the Winnebago System.

Approximately 10% of Spring Lake's shoreline is swamp forest. The remaining 90% is upland that is developed with cottages and year-around homes. A number of "off lot" homes with communal lake access also exist on the west shore of the lake. A dairy farm operates on the north end of the lake. All homes surrounding Spring Lake are served by on-site septic systems. Despite the number of lakefront homes, an abundance of emergent vegetation persists in the shallows of the lake.

Spring Lake has two public boat launches, and is a popular destination for area anglers. Spring Lake supports at two-story fishery. A warmwater fish community typical of Waushara County lakes, including largemouth bass (*Micropterus salmoides*), bluegill (*Lepomis macrochirus*), northern pike (*Esox lucius*), black crappie (*Pomoxis nigromaculatus*) yellow perch (*Perca flavescens*) and brown bullhead (*Ictalurus nebulosus*), tends to occupy the upper water column of the lake. A coldwater fishery composed of stocked rainbow trout (*Oncorhynchus gairdneri*) and brown trout (*Salmo trutta*). A fish barrier placed at the outlet was designed to prevent carp (*Cyprinus carpio*) migrating up Sucker Creek from entering into the lake. Despite this fish barrier, Spring Lake also contains significant numbers of riverine species, notably carp and bowfin (*Amia calva*).

The unique depth contours found in Spring Lake are the result of past marl mining efforts. Deep craters with sheer sides, made by the draglines used to excavate the marl, can be found in several locations in the lake. The rich marl deposits found in the lakebed were prized as agricultural fertilizers in lime-deficient soils, and as a soil conditioner sandy soils. The abundance of marl in Spring Lake is the result of the calcium rich groundwater entering into the lake. The aquatic plant, *Chara*, extracts calcium carbonate from lake waters and stores it in and on plant tissues. As *Chara* dies and decomposes, the calcium carbonate becomes part of lakebed sediments. After thousands of years, this process results in a clay-like, off-white substance known as marl (*When Marl Meant Money,* Wisconsin Natural Resources Magazine, August, 2001). | one mechanisms marl ppt due to pH shifts primary mechanism

Spring has historically been known for its excellent water quality. It has also been one of the few lakes in the county capable of supporting a trout fishery. In recent years traditional lake uses, such as boating and angling, have been threatened by the proliferation of two exotic aquatic plants: Eurasian watermilfoil (*Myriophyllum spicatum*) and curly-leaf pondweed (*Potamogeton crispus*). Water quality, particularly in the north basin, has also rapidly declined over the last several years. Water quality declines have been manifested by filamentous and planktonic algae blooms, decreased water clarity and fish kills. Because of these recent occurrences, water quality improvement and exotic plant control have become the major concerns of the Spring Lake Management District.

In 2002, the Spring Lake Management District contracted for treatment of Eurasian watermilfoil. All of the milfoil found in the lake was treated in spring using the herbicide Navigate®. This treatment covered approximately seven acres. Most milfoil beds were found in the north basin. This treatment proved to be very effective. Only one small follow-up treatment was required to bring Eurasian watermilfoil to sub-nuisance levels. In 2003, the Lake District contracted for treatment of a one-acre area of curly-leaf pondweed using the herbicide Aquathol®. This treatment targeted the densest beds of curly-leaf pondweed, and was also very effective.

In order to further restore Spring Lake to a more desirable condition, the Spring Lake Management District retained Aquatic Biologists, Inc. to conduct a comprehensive survey of the lake, and to research and review management options for lake improvement. This report presents and discusses the findings of this study and provides recommendations for the betterment of Spring Lake.

Project Goals

The three primary goals of this project were 1) to evaluate water quality parameters and identify factors contributing to declining water quality in the lake, 2) to survey aquatic plant communities and assess the impact and extent of invasive exotic species, and 3) to research and review water quality improvement and invasive species management options suitable for Spring Lake.

Project Work Elements

Field studies for this project focused on 1) the aquatic plant community, including surveys of submergent species, surveys of emergent species, and mapping of exotic species, 2) water quality, including assessment of both lake basins throughout the year, and periodic assessment of four inflowing tributaries, 3) hydrology, including seasonal measurement of inlet and outlet flow rates, analysis of groundwater flow patterns using mini-piezometers, and mapping of flowing springs, and 4) the watershed, including delineation of boundaries, identification of drainage patterns, and assessment of land uses and cover types.

The literature review portion of this study included 1) review of county soil survey and USGS data, 2) research of the habitat and water quality values of aquatic plants native to Spring Lake. 3) research of management techniques available for exotic species control, 4) research of water quality improvement practices for riparian landowners, and 5) review of local, state and federal programs and regulations pertaining to water quality management.

Algae blooms on Spring Lake during June 2003. Top photo: view from northeast inlet; bottom photo: view from north inlet.

Methods

Submergent Plant Surveys

Two submergent plant surveys were conducted, on in May and one in August, in order to assess seasonal changes to the plant community. A series of 17 transects (labeled A through Q) were laid out at equal distances along shore (**Figure 1**). These transects ran perpendicular to shore. Plant samples were collected in four quadrants along each transects using a tethered short-toothed garden rake. Quadrants were established at 2.5, 5, 10, and 15-foot depths. Four rake tows were made at each quadrant. All plants collected were identified to *genus* and *species*. Data were recorded separately for each transect. This data was used to calculate species distribution, composition, and percent frequency.

Emergent Plant Surveys

A survey of emergent plants was conducted in August. For this survey, a series of 17 transects (labeled AB through QH) were laid out along equal lengths of shoreline. These transects ran parallel to shore, in-between the submergent plant survey transects (**Figure 1**). All emergent and floating-leaf plants observed along each transect were identified to genus and *species*. Data were recorded separately for each transect. Along each transect, each species encountered was given a rank based on relative abundance using the following criteria:

0	*Absent*	not found along transect
1	*Rare*	found along less than 5% of transect
2	*Present*	found along 5 – 25% of transect
3	*Common*	found along 25 – 50% of transect
4	*Abundant*	found along more than 50% of transect

From this data, percent frequency and percent composition were calculated.

Exotic Species Mapping

The location and extent of Eurasian watermilfoil beds were identified visually and with rake tows. The dimensions of beds, minimum and maximum depths, and distances from shore were measures and recorded on a contour map. The map drawings were then superimposed upon an acreage grid to determine the area of the beds.

Hydrology

In February and in April actively flowing springs were mapped around the lake basin. Springs that were recorded were those that maintained sufficient flow to create open water areas in winter. During April, 17 mini-piezometers were placed around the shoreline of the lake at the plant survey transect points. The mini-piezometers identified the extent and direction of passive groundwater flow at each site. Results of both surveys were used to map groundwater flow patterns around the lake.

Very limited data for conclusion.

During the June, July and August water sampling periods, flow rates were calculated for each inlet as well as the Sucker Creek outlet. Data was used to calculate water budgets for the lake.

In-lake Water Quality Monitoring

Physical and chemical water quality parameters were analyzed on Spring Lake once during each of the following months: February, April (spring turnover), June, July, August and November (fall turnover). Water samples and other data were collected over the deepest point of each lake basin. All parameters not tested in the field were sent to the State Lab of Hygiene for analysis. Lab samples were collected one foot below the surface at each point. The following parameters were analyzed:

- Total phosphorus
- Nitrate + nitrite as nitrogen
- Chlorophyll *a*
- pH
- Secchi disc depth
- Dissolved oxygen profiles
- Temperature profiles

During August, a more thorough water quality analysis was done in each basin. On this date samples were collect one foot below the surface and one foot off of the bottom. The following additional parameters were tested:

- Dissolved phosphorus
- Total Kjeldahl nitrogen
- Ammonia as nitrogen
- Conductivity
- Hardness
- Alkalinity
- Total suspended solids
- Total dissolved solids
- Total volatile solids

Inflowing Stream Water Quality Monitoring

Water quality parameters were analyzed from four inlet streams (see **Figure 2**) on three dates. Sampling dates were selected within 48 hrs of a 1-inch plus rain event once in each of the following months: June, July and August. The following parameters were tested at each of the inlets:

- Total phosphorus
- Nitrate + nitrite as nitrogen → WL should consider TN especially when animal feedlots are suspect.
- pH
- Dissolved oxygen
- Temperature

Water quality data was used to identify nutrient sources, to determine nutrient loading and to calculate trophic state indices.

Watershed Analysis

The boundaries of Springs Lake's watershed, and the drainage patterns with the watershed were determined from USGC topographical data. Soil types within the watershed were obtained from *Soil Survey of Waushara County, Wisconsin* (USDA 1985). Land uses and cover types were mapped from extensive ground surveys and from aerial photos. Results were used to identify existing and potential threats to Spring Lake's water quality.

See Page 50 map? → How many acres?

Figure 1. Spring Lake 2003 survey plant survey transects and piezometer stations.

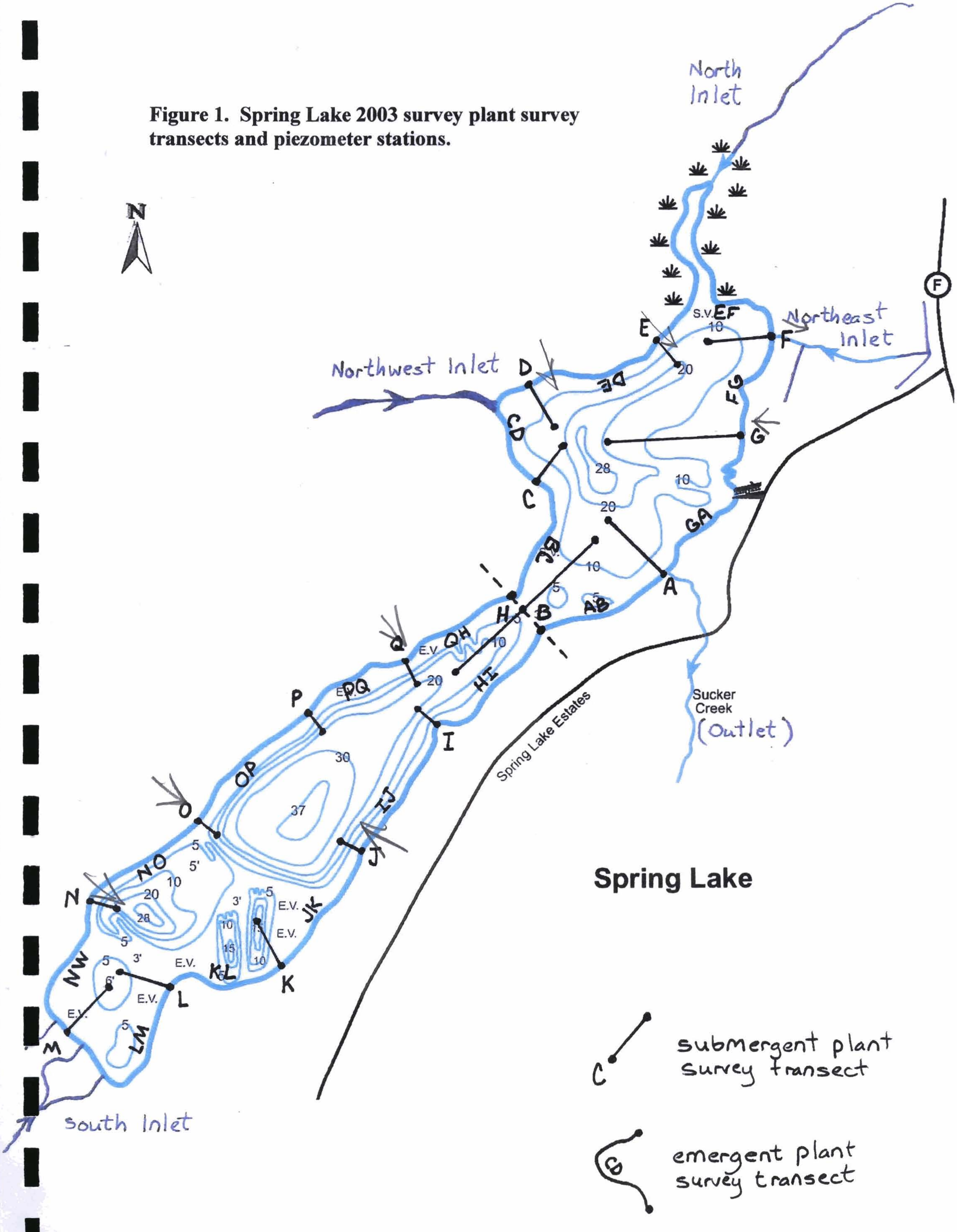
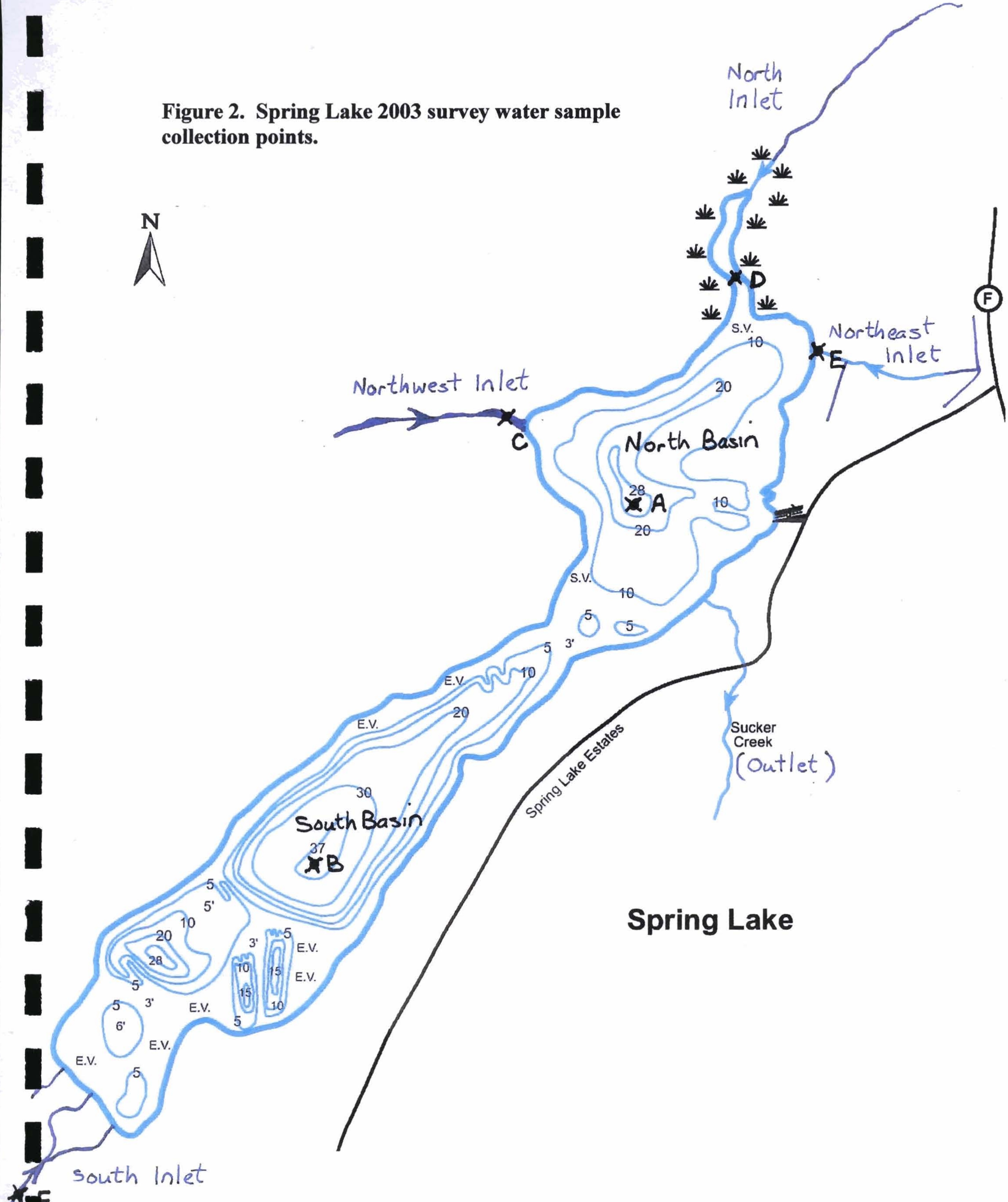


Figure 2. Spring Lake 2003 survey water sample collection points.



Results and Discussion

June Aquatic Plant Survey

During the June 2003 aquatic plant survey a total of 18 native macrophytes and two exotic macrophytes were found (**Table 1**). The two exotic plants found were curly-leaf pondweed and Eurasian watermilfoil. Musk grass (*Chara spp.*) was the most widespread and abundant plant, having been found in 54.5% of quadrants, and comprising 29.6% of the plant community. The next most abundant plant was the exotic curly-leaf pondweed, found in 26.0% of quadrants, and comprising 14.2% of the plant community. Flatstem pondweed (*Potamogeton zosteriformis*) and coontail (*Ceratophyllum demersum*) were the next most abundant plants. A high diversity of aquatic plants is indicative of a healthy lake environment. Unfortunately the exotic plant curly-leaf pondweed made up a large percentage of the plant community. Eurasian watermilfoil was found in less than 2% of quadrants as a result of selective herbicide treatments.

Another major component of the plant community found during the June survey was floating mats of filamentous algae. Three genera of algae were found: *Cladophora, Pithophora* and *Spirogyra*. Collectively, they made up 13.5% of the plant community. While all three types of algae are commonly found in area lakes, they are typically a minor component of the plant community. In a stable small lake environment rooted aquatic plants tend to predominate. When algae growth becomes prolific it is usually the result of ecosystem instability. This instability may be the result of sudden and excessive nutrient loading or disturbances.

Table 1. Results of the aquatic plant survey conducted on Spring Lake during June 2003.

Species Common name	Scientific name	Percent Frequency	Percent Composition
Musk Grass	*Chara spp.*	54.5	29.6
Curly Leaf Pondweed	*Potamogeton crispus*	26.0	14.2
Flatstem Pondweed	*Potamogeton zosteriformis*	19.7	10.7
Coontail	*Ceratophyllum demersum*	14.4	7.8
Filamentous Green Algae	*Spirogyra spp.*	13.3	7.2
Elodea	*Elodea canadensis*	9.8	5.3
Horsehair Algae	*Pithophora spp.*	9.1	4.9
Stonewort	*Nitella spp.*	7.6	4.1
White Water Crowfoot	*Ranunculus longirostris*	4.2	2.3
Hardstem Bulrush	*Scripus acutus*	3.4	1.9
Sago Pondweed	*Potamogeton pectinatus*	3.0	1.7
Water Stargrass	*Zosterella dubia*	3.0	1.7
Spadderdock	*Nuphar variegata*	3.0	1.7
Floating Leaf Pondweed	*Potamogeton natans*	2.7	1.4
Eurasian Watermilfoil	*Myriophyllum spicatum*	1.9	1.1
Filamentous Green Algae	*Cladophora spp.*	1.5	0.8
Whorled Watermilfoil	*Myriophyllum verticillatum*	1.5	0.8
Large Leaf Pondweed	*Potamogeton amplifolius*	1.1	0.6
Northern Watermilfoil	*Myriophyllum exalbescens*	1.1	0.6
Variable Leaf Pondweed	*Potamogeton diversifolius*	1.1	0.6
Water Moss	*Drepanocladus spp.*	0.8	0.4
White Water Lily	*Nymphaea odorata*	0.8	0.4
Bushy Pondweed	*Najas flexilis*	0.4	0.2
No Plants Found		10.6	

August Aquatic Plant Survey Results

During the August 2003 aquatic plant survey a total of 21 native macrophytes and two exotic macrophytes were found (**Table 2**). The two exotic plants found were again curly-leaf pondweed and Eurasian watermilfoil, however curly-leaf pondweed declined to only 3.1% frequency. This late-season die-off is typical of curly-leaf pondweed. This invasive exotic is a cold-adapted plant that begins growing well before most native plants. When water temperatures near 80° F though, the plant dies back. This often allows certain native species to recover. Unfortunately, Eurasian watermilfoil increased to 5.5% frequency.

Musk grass was still the most widespread and abundant plant, having been found in 66.8% of quadrants, and comprising 26.2% of the plant community. The next most abundant plant was bushy pondweed (*Najas flexilis*), found in 41.0% of quadrants, and comprising 16.1% of the plant community. Bushy pondweed, unlike most other native macrophytes, is an annual plant. Therefore it is often one of the first species to colonize a disturbed area. Its dramatic increase in Spring Lake may have been the result of curly-leaf pondweed dying back. Flatstem pondweed and coontail were again found in abundance, as were algae. This time however, the predominant alga was *Oscillatoria. Oscillatoria* is noxious colonial blue green alga that forms floating mats. These floating mats or globs often resemble fecal matter in both odor and appearance.

A comparison of June and August survey data is shown in **Table 3**. Most macrophytes exhibited increases in percent frequency as the season progressed. The three exceptions were curly-leaf pondweed, flatstem pondweed and stonewort. Three species found during the June survey were not found in the August survey, and six species found during the August survey were not found during the June survey. In most cases, these plants were not abundant. Their presence or absence in the survey data is most likely due to limitations in the study design.

Table 2. Results of the aquatic plant survey conducted on Spring Lake during August 2003.

Species Common name	Scientific name	Percent Frequency	Percent Composition
Musk Grass	*Chara spp.*	66.8	26.2
Bushy Pondweed	*Najas flexilis*	41.0	16.1
Coontail	*Ceratophyllum demersum*	26.6	10.4
Elodea	*Elodea canadensis*	19.1	7.5
Flatstem Pondweed	*Potamogeton zosteriformis*	16.8	6.6
Sago Pondweed	*Potamogeton pectinatus*	15.6	6.1
Water Stargrass	*Zosterella dubia*	8.2	3.2
Colonial Blue green Algae	*Oscillatoria spp.*	7.8	3.1
Eurasian Watermilfoil	*Myriophyllum spicatum*	5.5	2.1
Whorled Watermilfoil	*Myriophyllum verticillatum*	5.5	2.1
White Water Crowfoot	*Ranunculus longirostris*	4.7	1.8
Floating Leaf Pondweed	*Potamogeton natans*	4.7	1.8
Hardstem Bulrush	*Scripus acutus*	4.3	1.6
White Water Lily	*Nymphaea odorata*	4.3	1.7
Illinois Pondweed	*Potamogeton illinoensis*	3.9	1.5
Spadderdock	*Nuphar variegata*	3.5	1.4
Curly Leaf Pondweed	*Potamogeton crispus*	3.1	1.2
Lesser Duckweed	*Lemna minor*	2.7	1.1
Bladderwort	*Utricularia vulgaris*	2.7	1.1
Stonewort	*Nitella spp.*	2.3	0.9
Filamentous Green Algae	*Cladophora spp.*	2.0	0.8
Northern Watermilfoil	*Myriophyllum exalbescens*	2.0	0.8
Horsehair Algae	*Pithophora spp.*	0.8	0.3
Horned Pondweed	*Zannichellia palustris*	0.4	0.2
Small Pondweed	*Potamogeton pusillus*	0.4	0.2
Common Arrowhead	*Sagittaria latifolia*	0.4	0.2
No Plants Found		4.3	

Table 3. A comparison of Spring Lake aquatic plant survey data from June, and August 2003.

Species Common name	Scientific name	Percent June	Frequency August
Musk Grass	*Chara spp.*	54.5	66.8
Curly Leaf Pondweed	*Potamogeton crispus*	26.0	3.1
Flatstem Pondweed	*Potamogeton zosteriformis*	19.7	16.8
Coontail	*Ceratophyllum demersum*	14.4	26.6
Filamentous Green Algae	*Spirogyra spp.*	13.3	0.0
Elodea	*Elodea canadensis*	9.8	19.1
Horsehair Algae	*Pithophora spp.*	9.1	0.8
Stonewort	*Nitella spp.*	7.6	2.3
White Water Crowfoot	*Ranunculus longirostris*	4.2	4.7
Hardstem Bulrush	*Scripus acutus*	3.4	4.3
Sago Pondweed	*Potamogeton pectinatus*	3.0	15.6
Water Stargrass	*Zosterella dubia*	3.0	8.2
Spadderdock	*Nuphar variegata*	3.0	3.5
Floating Leaf Pondweed	*Potamogeton natans*	2.7	4.7
Eurasian Watermilfoil	*Myriophyllum spicatum*	1.9	5.5
Filamentous Green Algae	*Cladophora spp.*	1.5	2.0
Whorled Watermilfoil	*Myriophyllum verticillatum*	1.5	5.5
Large Leaf Pondweed	*Potamogeton amplifolius*	1.1	0.0
Northern Watermilfoil	*Myriophyllum exalbescens*	1.1	2.0
Variable Leaf Pondweed	*Potamogeton diversifolius*	1.1	0.0
Water Moss	*Drepanocladus spp.*	0.8	0.0
White Water Lily	*Nymphaea odorata*	0.8	4.3
Bushy Pondweed	*Najas flexilis*	0.4	41.0
Illinois Pondweed	*Potamogeton illinoensis*	0.0	3.9
Lesser Duckweed	*Lemna minor*	0.0	2.7
Bladderwort	*Utricularia vulgaris*	0.0	2.7
Colonial Blue green Algae	*Oscillatoria spp.*	0.0	7.8
Horned Pondweed	*Zannichellia palustris*	0.0	0.4
Small Pondweed	*Potamogeton pusillus*	0.0	0.4
Common Arrowhead	*Sagittaria latifolia*	0.0	0.4
No Plants Found		10.6	4.3

Emergent Plant Survey

The emergent and floating-leaf plant survey conducted in August revealed a very high diversity of plants. 27 species of plants were identified along the shores of Spring Lake. The most abundant plant found was hardstem bulrush (*Scirpus acutus*), found at % frequency. The most widely distributed plant, white water lily (*Nymphaea odorata*), was found in every transect. Sedges (*Carex spp.*), common arrowhead (*Sagittaria latifolia*), and cattails (*Typha spp.*) were also abundant and widely distributed (**Tables 4 and 5**).

Aquatic plants, particularly emergents, are vitally important to the health of lake ecosystems. Emergent plant beds, such as those found in Spring Lake, stabilize shorelines and bottom sediments, capture runoff-borne sediments and nutrient, and provide important nesting, denning and foraging habitat for water birds and other wildlife (Kahl, 1993). Emergent plants also provide important spawning, nursery, and feeding habitat for fish (Engle, 1985). The diversity and abundance of emergent plants found in Spring Lake is directly related to the diversity and quality of its fishery.

Emergent plant communities are the most degraded habitats in Wisconsin's lakes. These plant communities are destroyed by the activities of riparian property owners seeking "clean" frontage. They are also are lost or damaged by direct boat traffic or from the wave energy produced by boat wakes. The "Slow – No Wake" ordinance in effect on Spring Lake has no doubt been instrumental in protecting the lake's emergent plant communities.

Table 4. Results of the shoreline aquatic plant survey conducted on Spring Lake in August 2003.

Species Common name	Scientific name	Percent Frequency	Percent Composition
Hardstem Bulrush	*Scripus acutus*	77.9%	14.4%
Sedge	*Carex spp.*	63.2%	11.7%
White Water Lily	*Nymphaea odorata*	60.3%	11.1%
Common Arrowhead	*Sagittaria Latifolia*	58.8%	10.9%
Narrow Leaved Cattail	*Typha angustifolia*	35.3%	6.5%
Broad Leaved Cattail	*Typha latifolia*	32.4%	6.0%
Jewelweed	*Impatiens capensis*	30.9%	5.7%
Marsh Milkweed	*Asclepias incarnata*	30.9%	5.7%
Spadderdock	*Nuphar variegata*	22.1%	4.1%
Floating Leaf Pondweed	*Potamogeton natans*	22.1%	4.1%
Shrubby Cinquefoil	*Potentilla fruticosa*	20.6%	3.8%
Bottlebrush Sedge	*Carex comosa*	13.2%	2.4%
Needle Rush	*Eleocharis acicularis*	10.3%	1.9%
Joe Pye Weed	*Eupatorium maculatum*	10.3%	1.9%
Boneset	*Eupatorium perfoliatum*	8.8%	1.6%
Porcupine Sedge	*Carex hystericina*	7.4%	1.4%
Reed Canary Grass	*Phalaris arundinacea*	5.9%	1.1%
Three-square Bulrush	*Scripus americanus*	4.4%	0.8%
Softstem Bulrush	*Scripus validus*	4.4%	0.8%
Marsh Marigold	*Caltha palustris*	4.4%	0.8%
Dock	*Rumex spp.*	4.4%	0.8%
Marsh Aster	*Aster simplex*	2.9%	0.5%
Blue Vervain	*Verbena hastata*	2.9%	0.5%
Water Cress	*Rorippa nasturtium...*	2.9%	0.5%
Water Smartweed	*Polygonum amphibium*	1.5%	0.3%
Blue Flag Iris	*Iris versicolor*	1.5%	0.3%
Giant Reed Grass	*Phragmites australis*	1.5%	0.3%

Importance of Native Plants

An exceptional diversity of aquatic plants was found between the three surveys. A total of 48 higher plants were found, along with four types of filamentous algae. A list of species found is shown in **Table 6.**

Table 6. Aquatic plants found in Spring Lake during the 2003 surveys

Emergent and Floating-leaf Plants	Submergent Plants
blue flag iris	bladderwort
blue vervain	bushy pondweed
boneset	coontail
bottlebrush sedge	curly leaf pondweed
broad-leaved cattail	elodea
common arrowhead	Eurasian watermilfoil
dock sp.	flatstem pondweed
floating leaf pondweed	horned pondweed
giant reed grass	Illinois pondweed
hardstem bulrush	large-leaf pondweed
jewelweed	musk grass
Joe Pye weed	northern water milfoil
marsh aster	sago pondweed
marsh marigold	small pondweed
marsh milkweed	stonewort
narrow-leaved cattail	variable-leaf pondweed
needle rush	water moss
porcupine sedge	water stargrass
reed canary grass	white water crowfoot
sedge sp.	whorled watermilfoil
shrubby cinquefoil	(20)
softstem bulrush	
spadderdock	**Filamentous and Colonial Algae**
three-square bulrush	*Cladophora spp.*
water cress	*Oscillatoria spp.*
water smartweed	*Pithophora spp.*
white water lily	*Spirogyra spp.*
(27)	(4)
Free Floating Plants	
lesser duckweed	

Aquatic plants serve an important purpose in the aquatic environment. They play an instrumental role in enhancing the ecological balance in ponds, lakes, wetlands, rivers, and streams. Native aquatic plants have many values: To touch on a few, plants serve as: 1) an important buffer (filter) against nutrient loading and toxic chemicals, 2) key components in erosion control, 3) important fish and wildlife habitat. Therefore, it is essential that the native aquatic plant community in Spring Lake be protected. The following is a list of common native aquatic plants present in Spring Lake. Ecological values and a description will be discussed for each plant. Plant information was researched from (Borman et.al. 1997, Eggers 1997, Fink 2000, and Whitley et.al.1999).

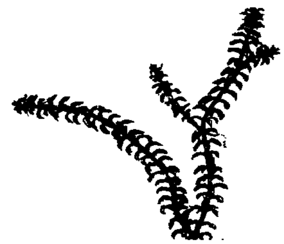
Submersed Plants (Plants that tend to grow with their leaves under water.)

Musk grass (*Chara spp.*) is a complex alga that resembles a higher plant. It's identified by its pungent, skunk-like odor and whorls of toothed branched leaves. Ecologically, musk grass provides shelter for juvenile fish and is associated to black crappie spawning sites. Waterfowl love to feast on *Chara* when the plant bears its seed-like oogonia. Musk grass serves an important role in stabilizing bottom sediment, tying up nutrients in the water column, and aiding with water clarity.

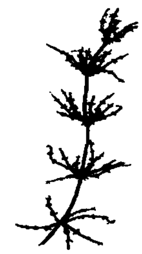
Flat-stem Pondweed (*Potamogeton zosteriformis*) emerges from a rhizome, which has strongly flattened stems. The leaves are narrow and grow 4-8 inches long. Leaves contain a prominent mid-vein and many fine parallel veins. Ecologically, flat-stem pondweed provides a home for fish and invertebrates, and is grazed by waterfowl and muskrats.

Coontail *(Ceratophyllum demersum)* produces whorls of narrow, toothed leaves on a long trailing stem that often resembles the tail of a raccoon. The leaves tend to be more crowded toward the tip. Coontail blankets the bottom, which helps to stabilize bottom sediments. Tolerant to nutrient rich environments, coontail filters a high amount of phosphorus out of the water column. Coontail provides a home for invertebrates and juvenile fish. Seeds are consumed by waterfowl, but are not of high preference.

Elodea (*Elodea canadensis*) is made up of slender stems with small, lance shaped leaves that attach directly to the stem. Leaves are in whorls of 2 or 3 and are more crowded toward the stem tip. Elodea serves as cover for fish and is home to many invertebrates that fish feed upon. Elodea is grazed by waterfowl and muskrats. Studies revealed that elodea can filter toxic chemicals, including turbine oil.



Stonewort (*Nitella spp.*) is a complex alga that resembles a higher plant. Its branches are arranged in whorls around the stem. Nitella looks very similar to musk grass. Ecologically, stonewort provides a home for algae and invertebrates that fish and waterfowl forage on.

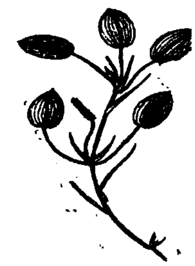


Bushy Pondweed (*Najas flexilis*) has a finely branched stem that grows from a rootstock. Leaves are short (1-4 cm), pointed and grow in pairs. Bushy pondweed is an annual and must grow from seed each year. It tends to establish well in disturbed areas. Bushy pondweed is a one of waterfowl's favorite foods and considered very important. Seeds, leaves and stems are relished by waterfowl, marsh birds, and muskrats. Bushy pondweed stabilizes bottom sediment and offers cover for fish.

Sago Pondweed (*Potamogeton pectinatus*) is a perennial herb that emerges from a slender rhizome that contains many starchy tubers. Leaves are sharp, thin, and resemble a pine needle. Reddish nutlets (seeds) that resemble beads on a string, rise to the water surface in mid-summer. Sago pondweed produces a large crop of seeds and tubers that are valued by waterfowl. Juvenile fish and invertebrates utilize sago pondweed for cover.

Large-Leaf Pondweed (*Potamogeton amplifolius*) also referred to by fisherman as cabbage weed, is a perennial herb that emerges from a ridged black rhizome. This pondweed is the largest of all pondweeds. The sturdy stem supports large broad leaves that are numerously veined (25-37). Growing upright throughout most of the water column, Large-leaf pondweed provides excellent shade, shelter, and foraging habitat for fish. Producing a large number of nutlets, cabbage weed is also valued by waterfowl.

Floating Leaf Pondweed (*Potamogeton natans*) is a perennial that emerges from a red-spotted rhizome. Leaves that rest at the waters surface are heart shaped. Submerged leaves tend to be longer and skinnier than floating leaves. Fish find this pondweed to be useful for foraging opportunities and shelter. Growing upright in the water column, floating leaf pondweed attracts many aquatic invertebrates. Muskrats, ducks, and geese all graze on the plant.



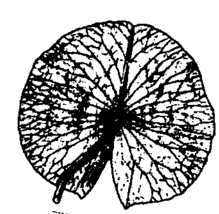
Illinois Pondweed (*Potamogeton illinoensis*) is a perennial herb that emerges from a rhizome. The stout stem supports large lance-shaped leaves that come to a sharp point. Leaves have 9-19 veins. Illinois pondweed provides excellent cover for fish and invertebrates. Ducks, geese, muskrats, and beaver find most parts of this plant to be a tasty meal.

White Water Crowfoot (*Ranunculus longirostris*) produces white flowers with 5 petals that emerge above the water's surface. Leaves are finely cut into thread-like divisions and are in an alternate arrangement along the stem. White water crowfoot is not tolerant to pollution and considered an indicator of good water quality. Waterfowl graze on both fruit and plant foliage. Crowfoot provides habitat for invertebrates, which in turn are fed upon by fish.

Floating Leaf Plants

(Plants that are rooted into the bottom and have leaves that float at the water's surface.)

White Water Lily (*Nymphaea odorata*) emerges from a buried rhizome. Durable round stalks grow up from the rhizome. This perennial herb supports large round leaves (4-10 inches) wide that float at the water's surface. Leaves appear waxy green on top and reddish-purple on their undersides. At mid-summer showy white flowers float at the waters surface. Lilies serve as important fish cover, especially for largemouth bass. White water lily seeds are eaten by waterfowl. Rhizomes, flowers, and leaves are consumed by muskrats, beaver, deer, and moose. With large broad leaves, lilies also help prevent shoreline erosion by slowing wave action.



Spatterdock (*Nuphar variegata*) is a perennial herb that produces yellow, rounded flowers. Large (4-10 inches) long, heart-shaped leaves float at the waters surface. Leaf stalks have flattened wings and emerge from a buried spongy rhizome. With large buried rhizomes, spatterdock helps stabilize bottom sediment. The large leaves also help buffer the impact of wave action on the shoreline. Like lilies, spatterdock offers excellent fish habitat. Seeds are eaten by waterfowl; leaves, rhizomes, and flowers are relished by muskrats, beaver, moose, and deer.

Emergent Plants (Plants that are rooted into the bottom and have leaves that emerge above the water's surface.)

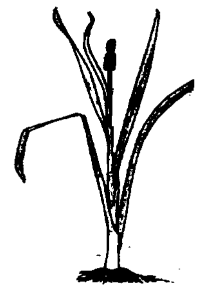
Hardstem Bulrush (*Scripus acutus*) is a perennial herb that prefers growing in hard bottom substrates. Olive-green, cylindrical stems emerge above the water's surface. Stems grow 3-9 ft., and can grow in water up to 6 ft. deep. Bulrushes provide important spawning, nursery, and foraging habitat for fish, especially northern pike. Seeds are feasted on by a variety of waterfowl. They also provide food and shelter for muskrats. Hardstem bulrush offers important cover and nesting opportunities for marsh birds. Bulrushes are second only to pondweeds in the number of animal users. Hardstem bulrush also plays an important role in improving water quality. They are known for their ability at up-taking excessive nutrients and stabilizing both shoreline and bottom sediment.

Common Arrowhead (*Sagittaria latifolia*) also known as duck potato, is a perennial herb that is a very common shoreline plant. As its' name implies, leaves are shaped like an arrowhead. The size and shape of leaves has great variability. Common arrowhead produces small white flowers made up of three rounded petals. Ecologically, duck potato is considered one of the highest valued aquatic plants for wildlife. The large high-energy tubers are relished by migrating waterfowl, muskrats, and beavers. Marsh birds, ducks, and songbirds all eat arrowhead seeds. Arrowhead stands provide rearing habitat for fish and help aid in shoreline stabilization.

Sedges (*Carex spp.*) are perennial herbs that appear grass-like and have triangular solid stems. Sedges contain a perigynium, a sac-like structure that covers the ovary and nutlet. The perigynium distinguishes sedges from all other plants. Sedges provide important nesting cover and food for a wide variety of songbirds, upland game birds, shore birds,

and waterfowl. Amphibians, including frogs and salamanders utilize *Carex* for feeding, shade, and protection. Sedges also serve as important buffer species against nutrient loading and shoreline erosion.

Broad-Leaved Cattail (*Typha latifolia*) emerges from a robust spreading rhizome. This perennial herb has pale green, sword-like leaves that grow up to 9 ft. tall. The male and female flowers grow on the same spike and there's no gap between them. Cattails provide cover and or food for a variety of wildlife including muskrats, black birds, marsh wrens, and waterfowl. Deer and pheasants also seek cattail stands for winter cover. Cattails serve as a home to many invertebrates and are an important spawning habitat for fish. With a network of large rhizomes, cattails also are sturdy shoreline stabilizers.



Narrow-Leaved Cattail (*Typha angustifolia*) is a perennial herb that emerges from a large spreading rhizome. Leaves are dark green, sword-like, and grow up to 9 ft. tall. The male and female flowers grow on the same spike and have a gap of up to 1 inch between them. Narrow leaved cattail is very similar in ecological values as broad-leaved cattail.

Exotic Plant Distribution

Eurasian watermilfoil

On June 1, 2001 ABI staff and Spring Lake Management District surveyed Spring Lake for the purpose of mapping the distribution of Eurasian watermilfoil. On this date a total of 6.6 acres of Eurasian watermilfoil were found (**Figure 3**). Milfoil clearly dominated the aquatic plant community at this time. Dense, canopied beds of the plant covered most of the littoral area in the north basin. In the south basin the milfoil was limited to a few isolated beds immediately off of the boat landing.

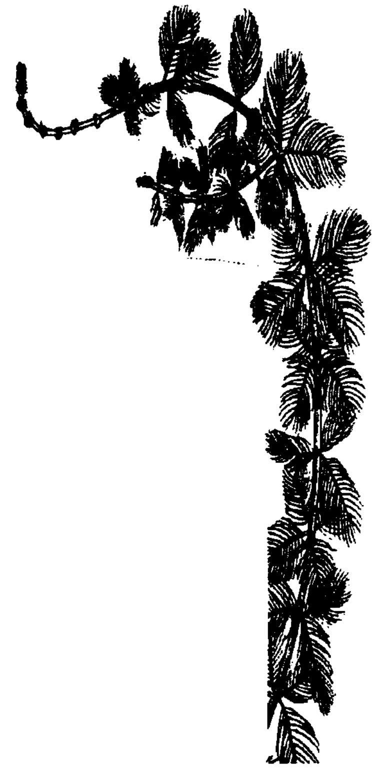
The Eurasian watermilfoil found in Spring Lake was treated with the herbicide Navigate® on May 13th and 29th, 2002. A total of 7.1 acres were treated. The treatment provided a high level of control. Eurasian watermilfoil was not found during the follow-up survey conducted in 2002. In the spring of 2003 the lake was again searched for milfoil, but only a few individual plants were found. By the fall of 2003 however, Eurasian watermilfoil beds had begun to reform in many of the previous locations. Milfoil was also found in several new locations in the narrows between the basins. A total of 2.92 acres were mapped on November 6, 2003 (**Figure 4**).

Curly-leaf pondweed

The approximate distribution of curly-leaf pondweed in June, 2003 is shown in **Figure 5.** Most of the curly-leaf pondweed was found in the north basin and in the narrows between basins. Several isolated patches were found in the south basin. Curly-leaf pondweed was not nearly as dense as Eurasian watermilfoil had been in 2001. Nonetheless it did reach nuisance levels in the north basin. Greatest densities were found along the western and northern shores of the north basin. On April 28, 2003 a 1.5 acre bed of curly-leaf pondweed along the western shore was treated with Aquathol K. Thus, the June 2003 map shows post treatment distribution. The Aquathol treatment was apparently quite successful, as the only curly-leaf pondweed found in the area was located in deeper water outside the treatment area.

Impacts of Exotic Aquatic Plants

Eurasian watermilfoil



Eurasian Watermilfoil (*Myriophyllum spicatum*) produces long spaghetti-like stems that often grow up to the water's surface. Leaves are feather-like and resemble bones on a fish. 3-5 leaves are arranged in whorls around the stem, and each leaf contains 12-21 pairs of leaflets. At mid-summer small reddish flower spikes emerge above the water's surface. Perhaps the most distinguishing characteristics though, are the plant's ability to form dense, impenetrable beds that grow to the water's surface, inhibiting boating, swimming, fishing, and hunting.

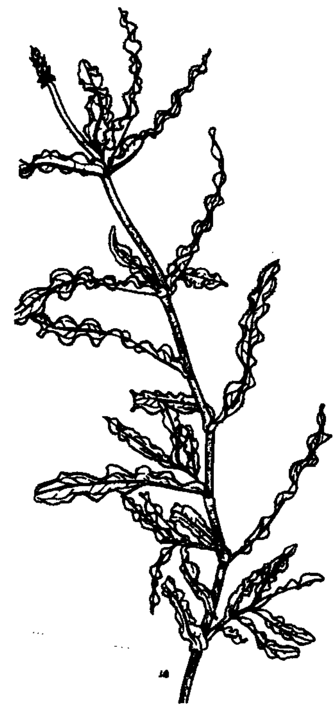
Eurasian watermilfoil is native to Europe, Asia and Northern Africa. Of the eight milfoil (*Myriophyllum*) found in Wisconsin, Eurasian watermilfoil is the only exotic. The plant was first introduced into U.S. waters in 1940. By 1960, it had reached Wisconsin's lakes. Since then, its expansion has been exponential (Brakken, 2000).

Eurasian watermilfoil begins growing earlier than native plants, giving it a competitive advantage. The dense surface mats formed by the plant block sunlight and have been found to displace nearly all native submergent plants. Over 200 studies link declines in native plants with increases in Eurasian watermilfoil (Madsen, 2001). The resultant loss of plant diversity degrades fishery habitat (Pullman, 1993), and reduces foraging opportunities for waterfowl and aquatic mammals. Eurasian watermilfoil has been found to reduce predatory success of fish such as largemouth bass (Engle, 1987), and spawning success for trout (*Salmonidae spp.*) (Newroth, 1985).

The continued spread of Eurasian watermilfoil can produce significant economic consequences. In the Truckee River Watershed below Lake Tahoe, located in western Nevada and northeastern California, economic damages caused by Eurasian watermilfoil to the recreation industry have been projected at $30 to $45 million annually (Eiswerth, et.al., 2003). In Tennessee Valley Authority Reservoirs Eurasian watermilfoil was found to depress real estate values, stop recreational activities, clog municipal and industrial water intakes and increase mosquito breeding (Smith, 1971).

Eurasian watermilfoil has been found to reduce water quality in lake by several means. Dense mats of Eurasian watermilfoil have been found to alter temperature and oxygen profiles – producing anoxic conditions in bottom water layers (Unmuth, et.al., 2000). These anoxic conditions can cause localized die-offs of mollusks and other invertebrates. Eurasian watermilfoil has also been found to increase phosphorus concentration in lakes through accelerated internal nutrient cycling (Smith and Adams, 1986). Increased phosphorus concentrations caused by Eurasian watermilfoil have been linked to algae blooms and reduced water clarity.

Curly-leaf pondweed



Curly Leaf Pondweed (*Potamogeton crispus*) has oblong leaves that are 2-4 inches long and attach to a slightly flattened stem in an alternate pattern. The most distinguishing characteristics are the curled appearance of the leaves, and the serrated leaf edges. Curly-leaf pondweed produces a seed-like turion, which resembles a miniature pinecone. This exotic pondweed is a cold-water specialist. Curly-leaf pondweed can begin growing under the ice, giving it a competitive advantage over native plants, which are still lying dormant. By mid-summer when water temperatures reach the upper 70° F, it begins to die off.

Curly-leaf pondweed has been found in the U.S. since at least 1910. A native of Europe, Asia, Africa and Australia, this plant is now found throughout much of U.S. (Baumann, et.al., 2000). Curly-leaf pondweed has oblong leaves that are 2-4 inches long and attach to a flattened stem in an alternate pattern. The most distinguishing characteristics of this plant are the crenellated appearance of the leaves, and the serrated leaf margins. Curly-leaf pondweed is a cold-adapted plant. It can begin growing under the ice while other plants are dormant. By mid-summer when water temperatures reach the upper 70° F range however, the plant begins to die off (Borman, et.al, 1997).

As with Eurasian watermilfoil, curly-leaf pondweeds aggressive early season growth allows it to out compete native species and grow to nuisance levels. Because the plant dies back during the peak of the growing season for other plants though, it is better able to coexist with native species than Eurasian watermilfoil. Perhaps the most significant problem associated with curly-leaf pondweed involves internal nutrient cycling. The die-off and decomposition of the plant during the warmest time of year leads to a sudden nutrient release in the water. This often leads to nuisance algae blooms and poor water quality.

Control of Eurasian watermilfoil

Mechanical harvesting

Boat-mounted mechanical weed harvesters are usually used to control Eurasian watermilfoil in lakes that have historically used harvesters to control native macrophytes, and is situations where lake management units have done insufficient planning to receive permits for herbicide use. Mechanical harvest is not a recommended control method for Eurasian watermilfoil, however. Eurasian watermilfoil can reproduce by fragmentation (Borman, et. al. 1997), and the free-floating plant matter left from cutting operations can accelerate dispersal of the plant – both within the lake and to nearby lakes. Mechanical harvest does offer several distinct advantages, though. Harvested plant matter can be removed from the lake system, reducing the possibility of low dissolved oxygen due to bacterial decomposition. The possibility of algae blooms due to a sudden nutrient release is also greatly reduced. There are no water use restrictions following mechanical harvest either. A disadvantage of mechanical harvest is that it is not species selective. While cutting does not typically kill plants, there is little evidence to suggest that cutting can induce a shift back to native species (Shardt, 1999). Intensive mechanical harvesting (multiple cuttings per year) done over a period of several years has been found to diminish Eurasian watermilfoil production. Unfortunately it has been found to have a greater negative impact to native plants (Pullman 1993) (Nichols, 1974).

Milfoil weevils

There has been considerable research on biological vectors, such as insects, and their ability to affect a decline in Eurasian watermilfoil populations. Of these, the milfoil weevil has received the most attention. Native milfoil weevil populations have been associated with declines in Eurasian watermilfoil in natural lakes in Vermont (Creed and Sheldon, 1995), New York (Johnson, et. al., 2000) and Wisconsin (Lilie, 2000). However there is scant evidence that *stocked* weevils can produce a decline in Eurasian watermilfoil density. A twelve-lake study called "The Wisconsin Milfoil Weevil Project" (Jester, et. al. 1999) conducted by the University of Wisconsin, Stevens Point in conjunction with the Wisconsin Department of Natural Resources researched the efficacy of weevil stocking. This report concluded that milfoil weevil densities were not elevated, and that Eurasian watermilfoil was unaffected by weevil stocking in any of the study lakes.

There have been numerous reasons given for the lack of success of weevil stocking as a management option, including calcium carbonate deposits on plants (Jester, et. al. 1999), poor over-wintering habitat (Newman, et, al. 2001), high pH (C. Kendziorski, 2001) and sunfish predation (Newman, pers. comm.). Perhaps the most compelling reason why weevil stocking has been unsuccessful may be that weevil populations are already at carrying capacity in many lakes. Recent studies indicate that milfoil weevils are widely distributed throughout Wisconsin's lakes (Jester, et. al. 1997).

One reason that native weevil populations may be able to impact Eurasian watermilfoil in some lakes but not others may have to do with a lake's surface are and its wind fetch. Recent studies conducted by Aquatic Biologists, Inc. staff (Cason, 2003) concluded that a relationship might exist between wind energy and the ability of milfoil weevils to affect a decline in Eurasian watermilfoil. It appears that lakes must be large enough (300 acres +) to generate sufficient wave action before milfoil stems burrowed by weevils will collapse.

Herbicides

Herbicides have been the most widely used and most successful tools for controlling Eurasian watermilfoil. The two herbicide groups most commonly employed are fluridone (Avast®, Sonar®) and 2,4D (Aquacide®, Aquakleen®, Navigate®, Weedar 64®). Fluridone treatments have shown considerable promise for providing both good control and species selectivity for Eurasian watermilfoil (Welling, et al., 1997). Whole-lake Sonar® treatments have been done on several Wisconsin Lakes. While initial results were encouraging (species selectivity, 95-100% initial control), continued monitoring found that desired long-term control was not achieved (Cason, 2002).

2,4D herbicides, on the other hand, have been used on hundreds of Wisconsin Lakes with good success. The E.P.A. lists 2,4D as a Class D herbicide, which means that there is no data to support that it is harmful to humans. The E.P.A. product label lists no water use restrictions for swimming or fish consumption following treatment with 2,4D either. 2,4D is a biodegradable organic herbicide that does not persist in the environment in any form. Applied correctly at prescribed rates, 2,4D is highly selective to Eurasian watermilfoil.

Aquathol®, an endothol-based herbicide, has also shown promise as a tool for controlling Eurasian watermilfoil. Aquathol® treatments performed by ABI on several Wisconsin Lakes during 2003 were successful in controlling Eurasian watermilfoil. While little is known about the degree of long-term control provided by Aquathol®, the herbicide does offer an advantage over 2,4D in that it will also control curly-leaf pondweed. Conducting treatments early in the season before other species begin growing provides species selectivity for Eurasian watermilfoil and curly-leaf pondweed. dosage too ≤1.5 ppm

same for 2,4D, "...before other species begin growing..."

Control of Curly-leaf Pondweed

Both mechanical harvesting and herbicide treatments are commonly used to control curly-leaf pondweed. The herbicide most often used is Aquathol®. While endothol herbicides are effective on a broad range of aquatic monocots, early season applications made at low rates are highly species-selective. Both mechanical harvesting and herbicide treatments are very effective in providing short-term control. However neither method, as they are commonly applied, tend to provide any long-term control of the plant. Curly-leaf pondweed produces a vegetative reproductive structure in early summer that is called a turion. While herbicides effectively kill the parent plant, the turions are resistant to herbicides. This allows curly-leaf pondweed to regenerate annually.

Recent studies conducted by the Army Corps of Engineers however, have found that conducting treatments of curly-leaf pondweed using Aquathol when water temperatures are in the 50° F range will kill plants before turions form, thus providing long-term control. These treatments conducted over time were able to significantly reduce curly-leaf pondweed populations (Skogerboe and Poovey, 2002). These findings may make Aquathol® the tool of choice for controlling curly-leaf pondweed.

Lake Hydrology

Water sources

The hydrological characteristics of Spring Lake are very complex. In order to make sense of water quality data, we need to gain an understanding of lake hydrology. Water enters Spring Lake from four sources: rainfall, surface water drainage (creeks and ditches), passive groundwater percolation (groundwater seepage) and flowing springs (groundwater under pressure). Water primarily leaves Spring Lake via the outlet creek, direct evaporation and groundwater seepage.

One element of this study was to map out flowing springs. A total of 20 springs were found flowing directly into the lake (**Figure 6**). Twelve of these had enough flow to maintain open water in winter. Most springs were in the north basin. Three small spring fed creeks drained into the lake: one at the south end, one at the north end, and one at the northwest corner. A drainage ditch at the north end also carried intermittent flow. Flow rates were measured at these four sites, and at the sucker creek outlet.

Another element of this study was to measure the direction and intensity of groundwater seepage using piezometers. Piezometers were temporarily placed in 17 locations around the lake. The locations corresponded to the starting points of the plant survey transects shown in **Figure 1**. The results obtained are given below. A positive reading (+) indicates groundwater inflow. A negative reading (-) indicates groundwater outflow. Where groundwater flow was not detected, the site was labeled NC (no communication).

SAMPLE LOCATION	PIEZOMETER READING
A	NC
B (west shore)	NC
C	NC
D	+8 mm
E	+5 mm
F	-77 mm
G	+39 mm
H (east shore)	NC
I	NC
J	+40 mm
K	NC
L	NC
M	NC
N	+190 mm
O	+30 mm
P	NC
Q	+38 mm

In 9 of the 17 sites passive groundwater flow was not detected. The sites where passive groundwater flow was detected tended to be near areas where flowing springs also occurred. The presence of groundwater flow in these locations is most likely an indicator of soil permeability. Generally, groundwater flowed into the lake. The most significant inflow was detected in the southwest corner of the lake. The only site where groundwater outflow was detected was in the northeast corner of the lake.

Water budget

From the flow readings taken at the inlets and outlet, and from regional precipitation data, the following water budget was determined for Spring Lake.

INFLOW	
Direct Rainfall	201 acre-ft/year
Surface Water	
South Inlet	246 acre-ft/year
Northwest Inlet	85 acre-ft/year
North Inlet	1448 acre-ft/year
Northeast Inlet	11 acre-ft/year
Ground Water (all sources)	9343 acre-ft/year
Total	11,334 acre-ft/year
OUTFLOW	
Surface Drainage (Sucker Creek Outlet)	10,054 acre-ft/year
Evaporation (estimated)	480 acre-ft/year
Groundwater percolation (estimated)	800 acre-ft/year
Total	11,334 acre-ft/year

Based on the above calculations, and using a lake volume of 1738 acre-feet, the average hydraulic residence time for Spring Lake is 56 days. In other words, the total water volume of Spring Lake is replenished 6.5 times per year.

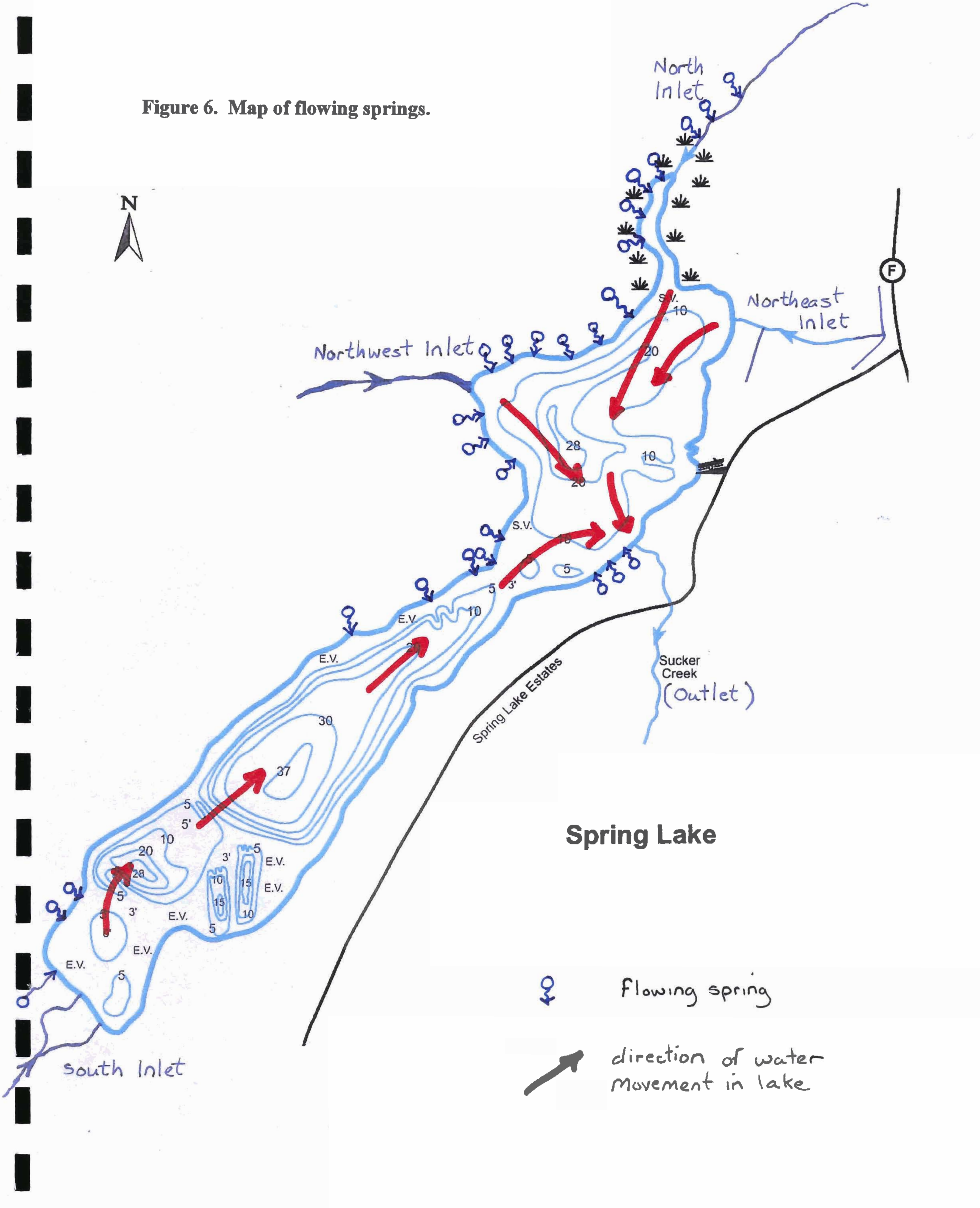
In-lake water movement

The two lake basins often look like different lakes. This is because hydraulic force from water entering the south basin prevents water from the north basin from entering (**Figure 6**). Thus water, as well as sediments, nutrients and other chemicals, from the two basins seldom mix. The exception is when high winds from the NNE create waves with enough force to counteract this hydraulic pressure. This phenomenon occurred in the spring of 2003.

Evaporation > ppt?

Really need explanation here. How were these #'s derived. I may have missed it, but I couldn't find acreage of watershed. If Evap is greater than ppt you must use watershed area in calculations

Figure 6. Map of flowing springs.



Lake Water Quality Parameters

The results of water chemistry analyses conducted in the south basin of Spring Lake are shown in **Table 7**. The results of water chemistry analyses conducted in the north basin of Spring Lake are shown in **Table 8**. These results are discussed in the following sections.

Phosphorus

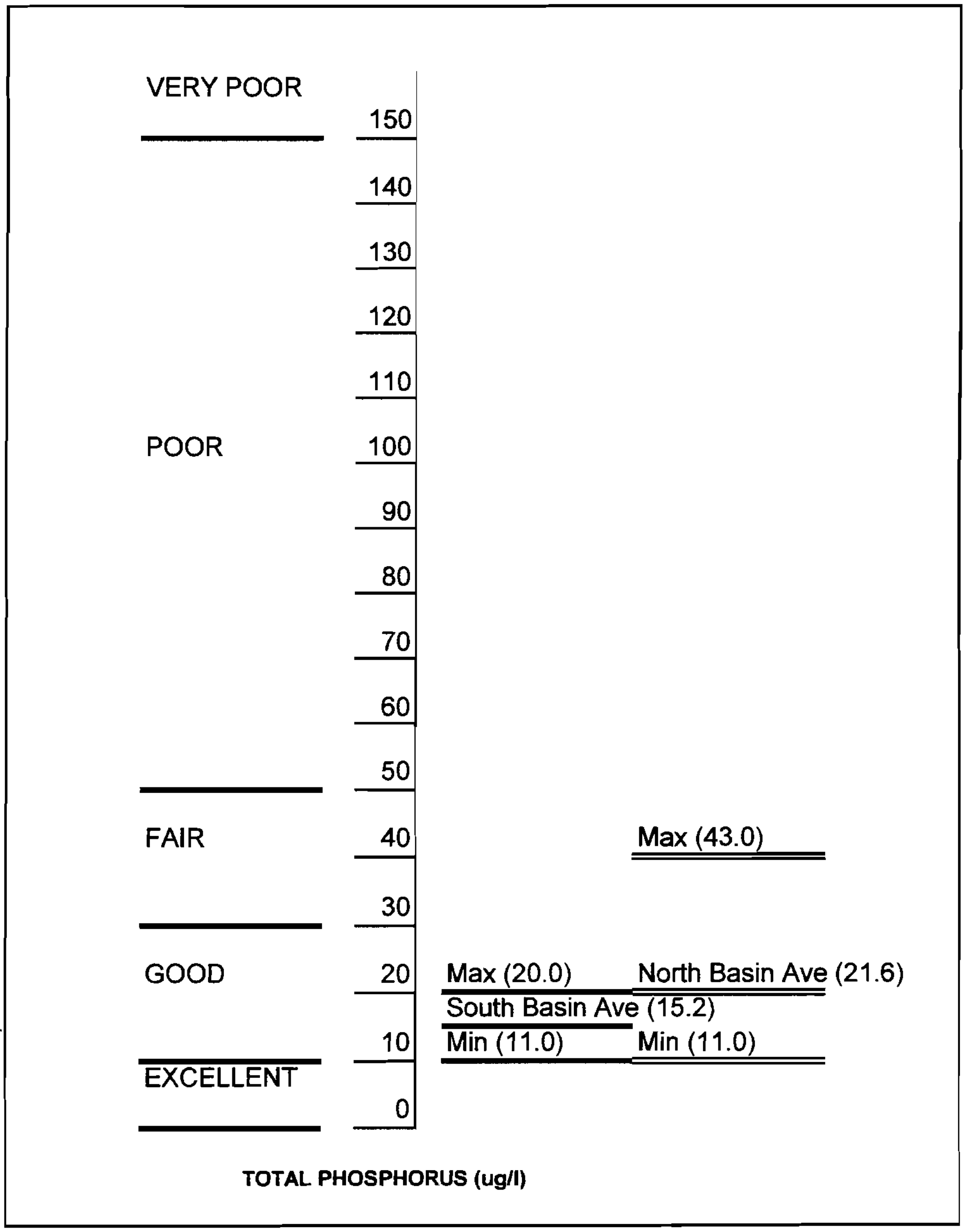
Phosphorus has been found to be the nutrient that limits plant and algae growth in more than 80% of Wisconsin lakes. As phosphorus levels increase, so does plant productivity. Failing septic systems, detergents, lawn and crop fertilizers, soil erosion and feedlot runoff are all major sources of phosphorus found in lakes. Phosphorus analyses done in Spring Lake included total phosphorus and dissolved phosphorus. Total phosphorus is a measure of available phosphorus plus phosphorus tied up in living cells. Results indicate that it was indeed the limiting factor in plant growth in both basins of Spring Lake. Generally, a total phosphorus concentration of 30 ug/l or less is considered an indicator of good water quality. Concentrations above 30 ug/l often lead to nuisance algae blooms. Surface total phosphorus readings were below 30 for both basins except during February in the north basin. These results are surprising, considering the algae blooms that occurred in Spring Lake during 2003. Spring Lake is ranked on the Total Phosphorus Water Quality Index in **Figure 7**.

Dissolved phosphorus is phosphorus that is in solution in the water column that is readily available for plant growth. Dissolved phosphorus plus the phosphorus found in living cells, such as algae that are suspended in the water column, equals total phosphorus. Surface dissolved phosphorus concentrations were not detectable in 2003 in either basin. This indicates that all available phosphorus was tied up in living cells.

During August, when total and dissolved phosphorus concentrations were analyzed from samples collected one foot off of bottom, we find that concentrations are substantially higher. These high concentrations are likely the result of anoxic conditions at the sediment layer. Anoxia causes a chemical reaction that releases phosphorus from sediments. These findings suggest that internal nutrient cycling may play a role in Spring Lake's water quality problems. It is important to note that anoxic conditions in the hypolimnion (lower water column) are directly related to productivity in the epilimnion (upper water column). Therefore things that encourage plant and algae growth, such as nutrient run-off, can actually encourage nutrient release from bottom sediments.

foreshadowing

Figure 7. Total phosphorus water quality index (ug/l).



Adapted from Shaw, et. al. (2000).

Table 7. South Basin 2003 water quality parameters.

All data collected over the deepest point of the lake. Samples were collected at the surface unless emphasized (*B*=bottom).

parameter	unit	Feb.	Apr.	June	July	Aug.	Nov.	Average
alkalinity	mg/l					170		170.0
chloride	mg/l					20.5		20.5
chlorophyll *a*	ug/l	1.15	2.91	7.44	2.86	10.4		5.0
cloud cover	%	100	5	100	0	100		61.0
conductivity	um/cm					424		424.0
dissolved oxygen - *B*	mg/l	0.6	5.2	0.52	0.15	0.1	0.7	1.2
dissolved oxygen	mg/l	9.6	11.4	8.9	7.1	8.7	8.86	9.1
hardness	mg/l					214		214.0
ammonia as N - *B*	ug/l					1620		
ammonia as N	ug/l					31		
Kjeldahl nitrogen - *B*	ug/l					2140		2140.0
Kjeldahl nitrogen	ug/l					790		790.0
nitrate + nitrite as N - *B*	ug/l					838		838.0
nitrate + nitrite as N	ug/l	3110	2810	1970	1950	2930		2554.0
total phosphorus - *B*	ug/l					103		103.0
total phosphorus	ug/l	12	18	15	11	20		15.2
dissolved phosphorus - *B*	ug/l					8		8.0
dissolved phosphorus	ug/l					ND		ND
nitrogen : phosphorus - *B*						29 : 1		
nitrogen : phosphorus						186 : 1		
pH, field	s.u.	8.2	8.4	8.5	8.1	8.5	8.4	8.4
Secchi disc depth	ft.	38	10.6	4.2	13.5	6.2	19	15.3
temperature	C	1.5	3.4	20	23.9	23.9	7.9	13.4
temperature - *B*	C	4.4	3.5	7.2	7.5	7.9	7.5	6.3
total calcium	mg/l					37.9		37.9
total magnesium	mg/l					28.9		28.9
total suspended solids	mg/l					5		5.0
total volatile solids	mg/l					98		98.0
total dissolved solids	mg/l					242		242.0

ND = not detected, concentration below limit of detection

Table 8. North Basin 2003 water quality parameters.

All data collected over the deepest point of the lake. Samples were collected at the surface unless emphasized (*B*=bottom).

parameter	unit	Feb.	Apr.	June	July	Aug.	Nov.	Average
alkalinity	mg/l					161		161.0
chloride	mg/l					16.2		16.2
chlorophyll *a*	ug/l	37.6	9.34	3.77	1.62	2.81		11.0
cloud cover	%	100	5	100	0	100		61.0
conductivity	um/cm					376		376.0
dissolved oxygen - *B*	mg/l	0.64	7.5	0.19	0.16	0.1	0.65	1.5
dissolved oxygen	mg/l	9	12.1	10.6	8	8.7	8.95	9.6
hardness	mg/l					192		192.0
ammonia as N - *B*	ug/l					1130		1130.0
ammonia as N						36		36.0
Kjeldahl nitrogen - *B*	ug/l					248		248.0
Kjeldahl nitrogen	ug/l					550		550.0
nitrate + nitrite as N - *B*	ug/l					1160		1160.0
nitrate + nitrite as N	ug/l	7110	4200	3430	3080	1680		3900.0
total phosphorus - *B*	ug/l					158		158.0
total phosphorus	ug/l	43	25	18	11	11		21.6
dissolved phosphorus - *B*	ug/l					4		4.0
dissolved phosphorus	ug/l					ND		ND
nitrogen / phosphorus - *B*						9 : 1		
nitrogen / phosphorus						203 : 1		
pH, field	s.u.	8.6	8.7	8.2	8.3	8.5	8.1	8.4
Secchi disc depth	ft.	8.6	7.6	4.9	9.7	6.2	18	9.2
stream flow	cfs		14.3		9.1	18.2		13.9
temperature - *B*	C	4.6	3.7	8.9	9.2	10.3	7.2	7.3
temperature	C	3.7	3.6	19.4	23.9	23.9	7.3	13.6
total calcium	mg/l					30.3		30.3
total magnesium	mg/l					28.3		28.3
total suspended solids	mg/l					3		3.0
total volatile solids	mg/l					104		104.0
total dissolved solids	mg/l					216		216.0

ND = not detected, concentration below limit of detection

Nitrogen

Next to phosphorus, nitrogen is the nutrient most likely to contribute to excessive weed and algae growth. Nitrogen can enter lakes from groundwater, surface runoff and precipitation. In drainage lakes though, nitrogen concentrations most often correspond to local land uses. Nitrogen analyses for Spring Lake included ammonia, nitrate + nitrite and Kjeldahl nitrogen, which is organic nitrogen plus ammonia. Total nitrogen is determined by adding nitrate + nitrite to Kjeldahl nitrogen. When the ratio of total nitrogen to total phosphorus is less than 15:1, a lake is considered nitrogen limited. When this occurs, additions of nitrogen to the lake can lead to increases plant productivity.

The nitrogen : phosphorus ratio found in Spring Lake were 186:1 in the south basin and 203:1 in the north basin, indicating that the lake is clearly phosphorus limited. Nitrate + nitrite levels were exceedingly high in Spring Lake, particularly in the north basin. Concentrations varied considerably through the season, and ranged as high as 7110 ug/l in the north basin. Concentrations were high enough to be considered a health hazard to humans. High nitrate + nitrite levels are typical for groundwater in the area, however the elevated concentrations found in the north basin are likely the result agricultural runoff, lawn fertilizers or failing septic systems.

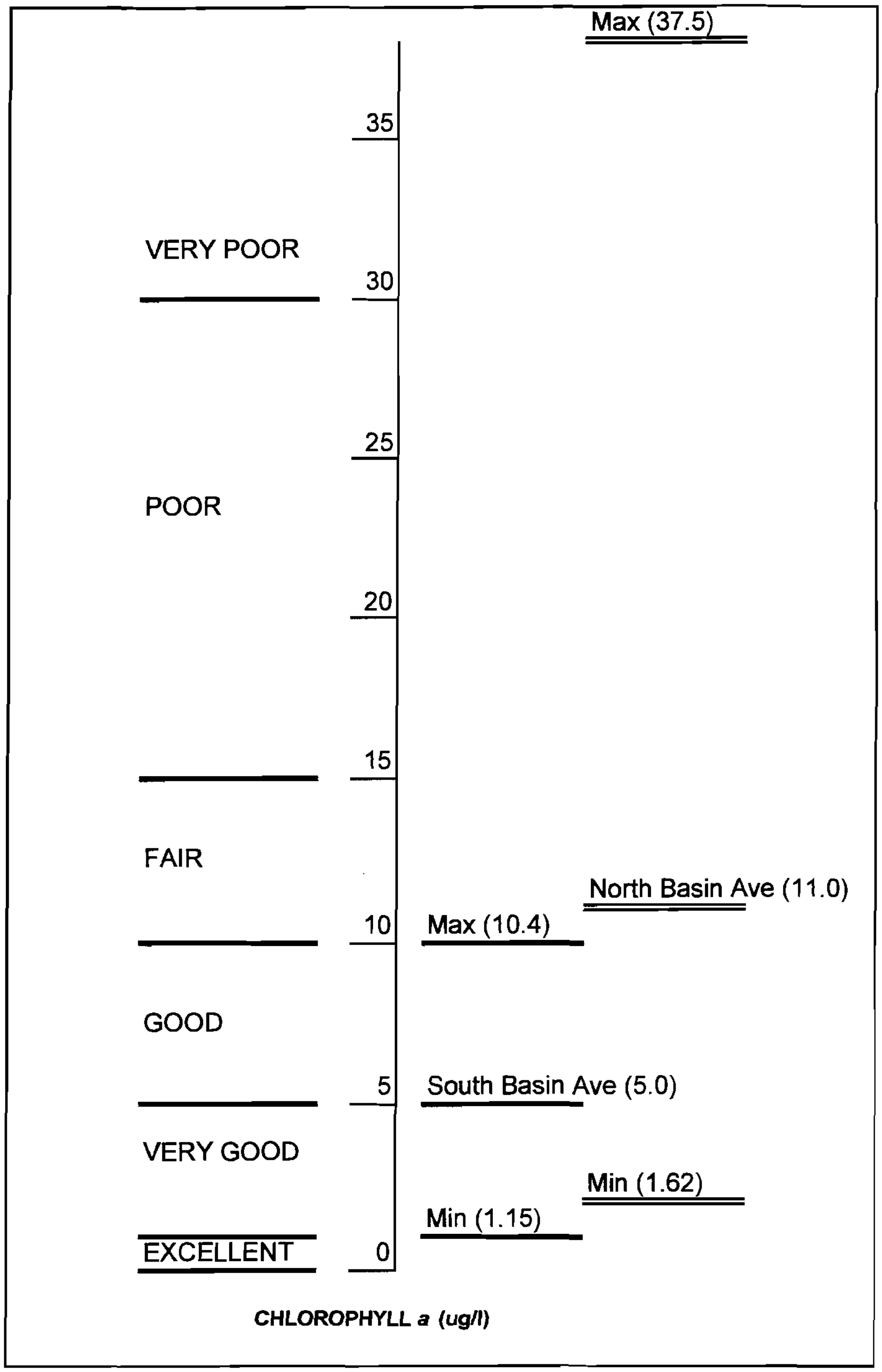
Chlorophyll *a*

Chlorophyll is a pigment found in all plants. It is the only pigment that can convert light to chemical energy in photosynthesis. Chlorophyll *a* concentrations are often used to gauge algal abundance. Because algal abundance is often related to nutrient inputs in a lake, chlorophyll *a* can be a good indicator of water quality. Chlorophyll *a* readings varied considerably in Spring Lake. In the south basin they were typically in the "good" to "very good" range on the Chlorophyll *a* Water Quality Index shown in **Figure 8**. In the north basin they averaged in the "fair" range, but were off the chart in the "very poor" range during February. This spike corresponded to high levels of nitrogen and phosphorus found on that sample date.

Secchi disc depth

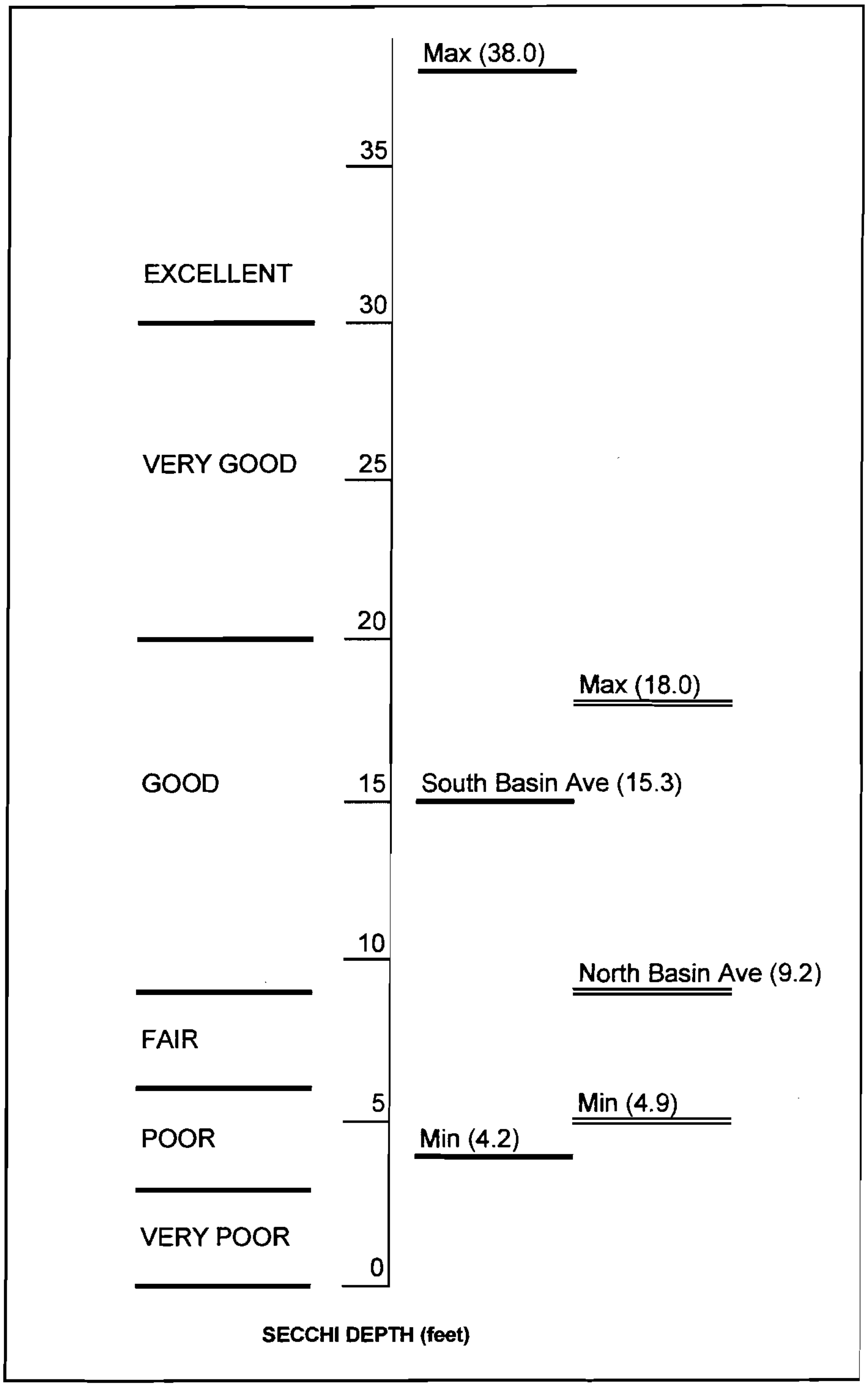
A Secchi disc is an eight-inch diameter black and white plate that is lowered into the water on a calibrated cord. The depth at which the disc is last visible is used as the standard measure of water clarity. Water clarity is often a function of suspended solids and/or phytoplankton density, and is thus often related to water quality. Secchi disc readings on Spring Lake were at their lowest in June for both basins, and were at their highest in November in the north basin, and February in the south basin. Amazingly, the Secchi disc could be seen on bottom in 38 feet of water on this date. Readings ranged from "poor" to "excellent" on the Secchi Disc Depth Water Quality index shown in **Figure 9**.

Figure 8. Chlorophyll *a* water quality index (ug/l).



Adapted from Shaw, et. al. (2000).

Figure 9. Secchi disc depth water quality index (feet).



Adapted from Shaw, et. al. (2000).

Dissolved Oxygen and Temperature

Dissolved oxygen and temperature data are taken together, as dissolved oxygen saturation concentrations are inversely related to temperature. Seasonal profiles for these two parameters taken from both basins in Spring Lake are shown in **Figures 10** through **15**. This inverse relationship is apparent in the February, April and November readings when water temperatures were at their coolest and dissolved oxygen readings were at their highest. Conversely, when water temperature were at their highest in June, July and August, dissolved oxygen concentration were at their lowest.

In most cases, more productive lakes will have a greater oxygen deficit in the depths than less productive lakes. Therefore the productivity of a lake can often be estimated from the nature of its oxygen curve (Ruttner, 1953). There was a distinct oxycline apparent on each sampling date for both basins. On each date, the very bottom layers of the water column were devoid of oxygen. The extent of this anoxic layer increased as temperatures warmed. The anoxic layer was greatest in August. By November however, cooling water temperatures slowed productivity and oxygen was once again replenished. Only a thin layer of water above the bottom was depleted in oxygen.

Oxygen and temperature profiles were generally good in the south basin, and were suitable for maintaining a trout fishery. In the north basin though, a more significant oxycline occurred. This was due to more algae production in the epilimnion. This would have crowded fish into the upper water column. Looking at temp profiles, we see that this could present a problem for trout, which prefer cooler temperatures. If water quality continues to decline in Spring Lake it may not be suitable for sustaining a trout fishery.

Figure 10. Spring Lake dissolved oxygen and temperature profiles, February 2003.

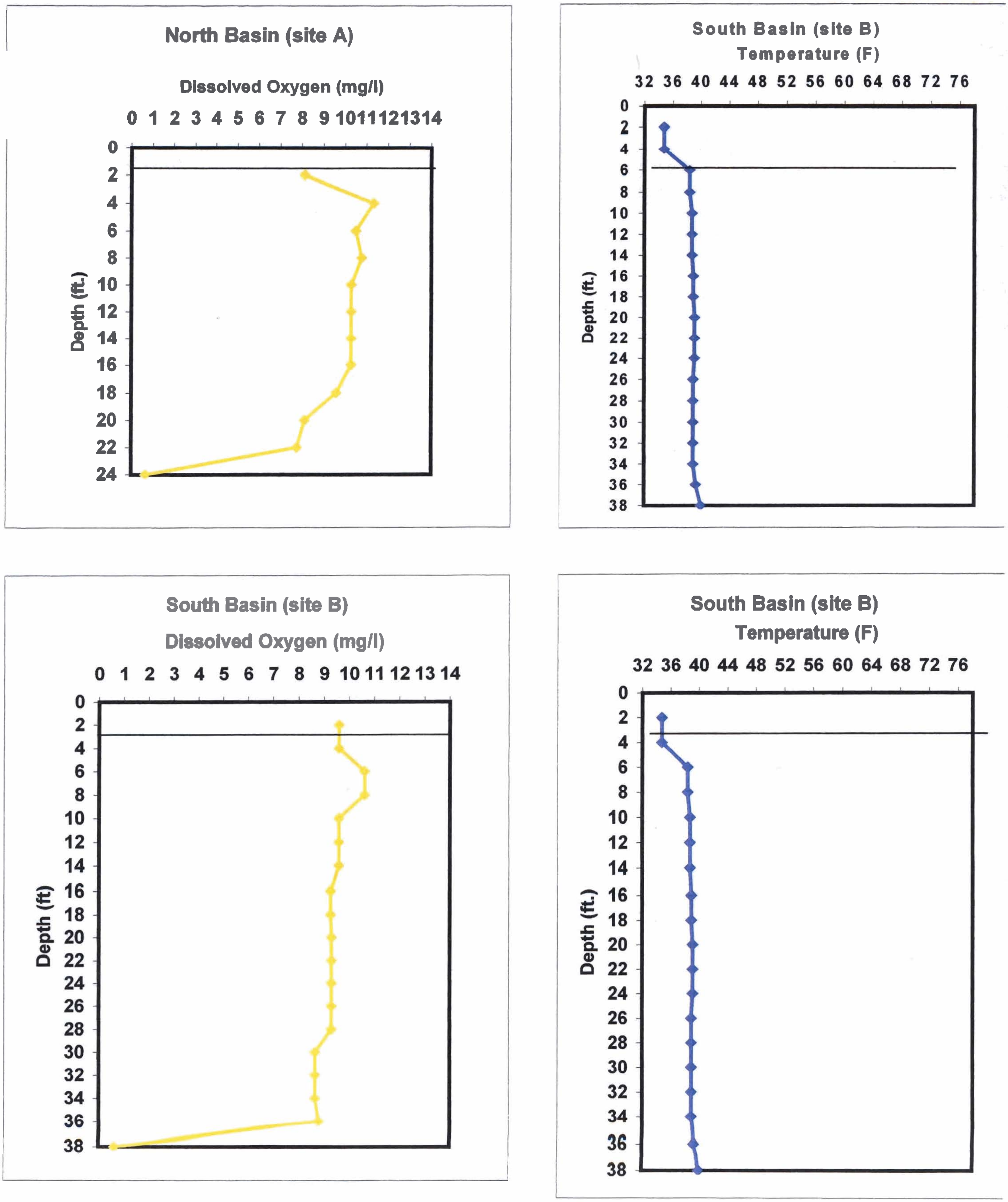


Figure 11. Spring Lake dissolved oxygen and temperature profiles, April 2003.

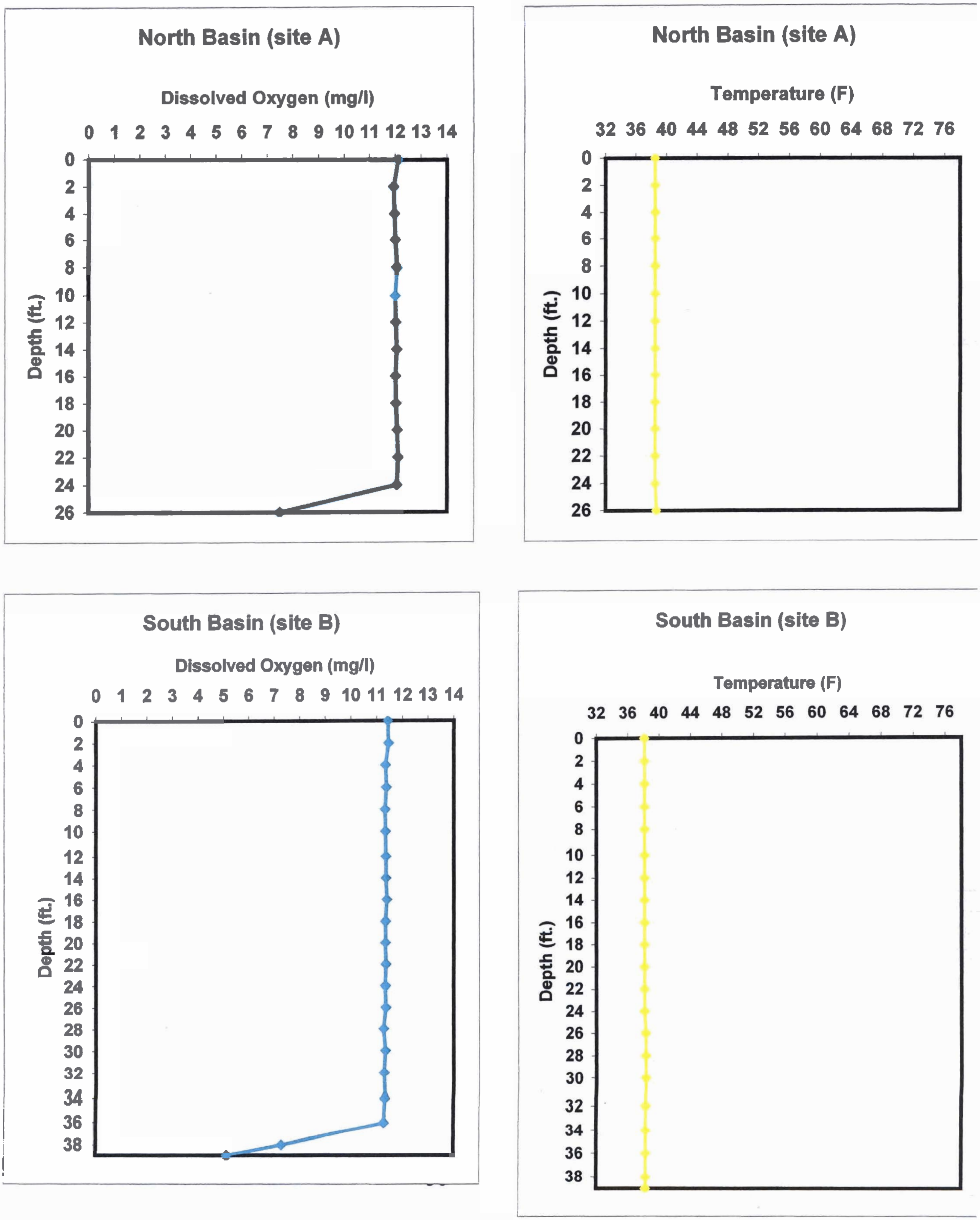


Figure 12. Spring Lake dissolved oxygen and temperature profiles, June 2003.

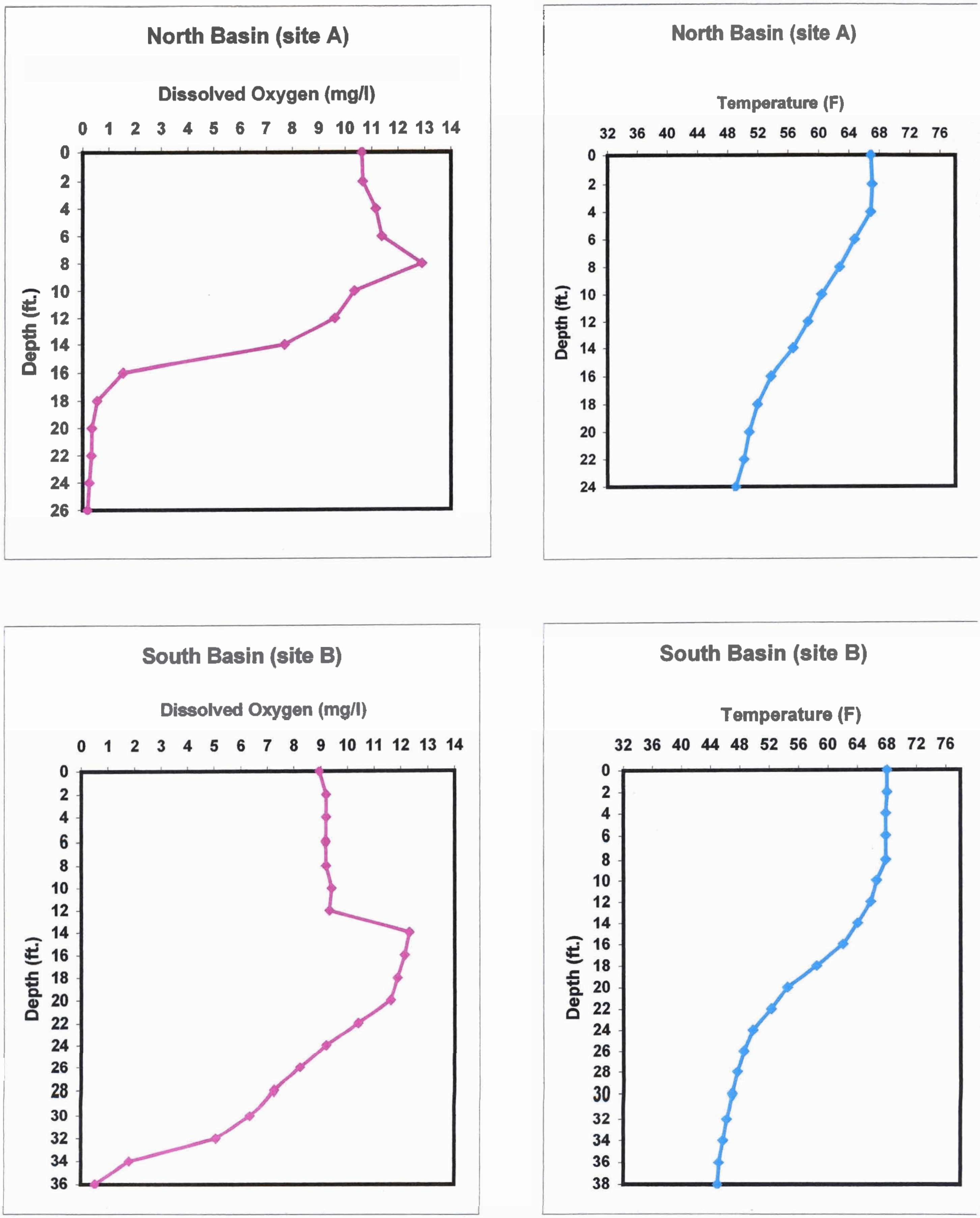


Figure 13. Spring Lake dissolved oxygen and temperature profiles, July 2003.

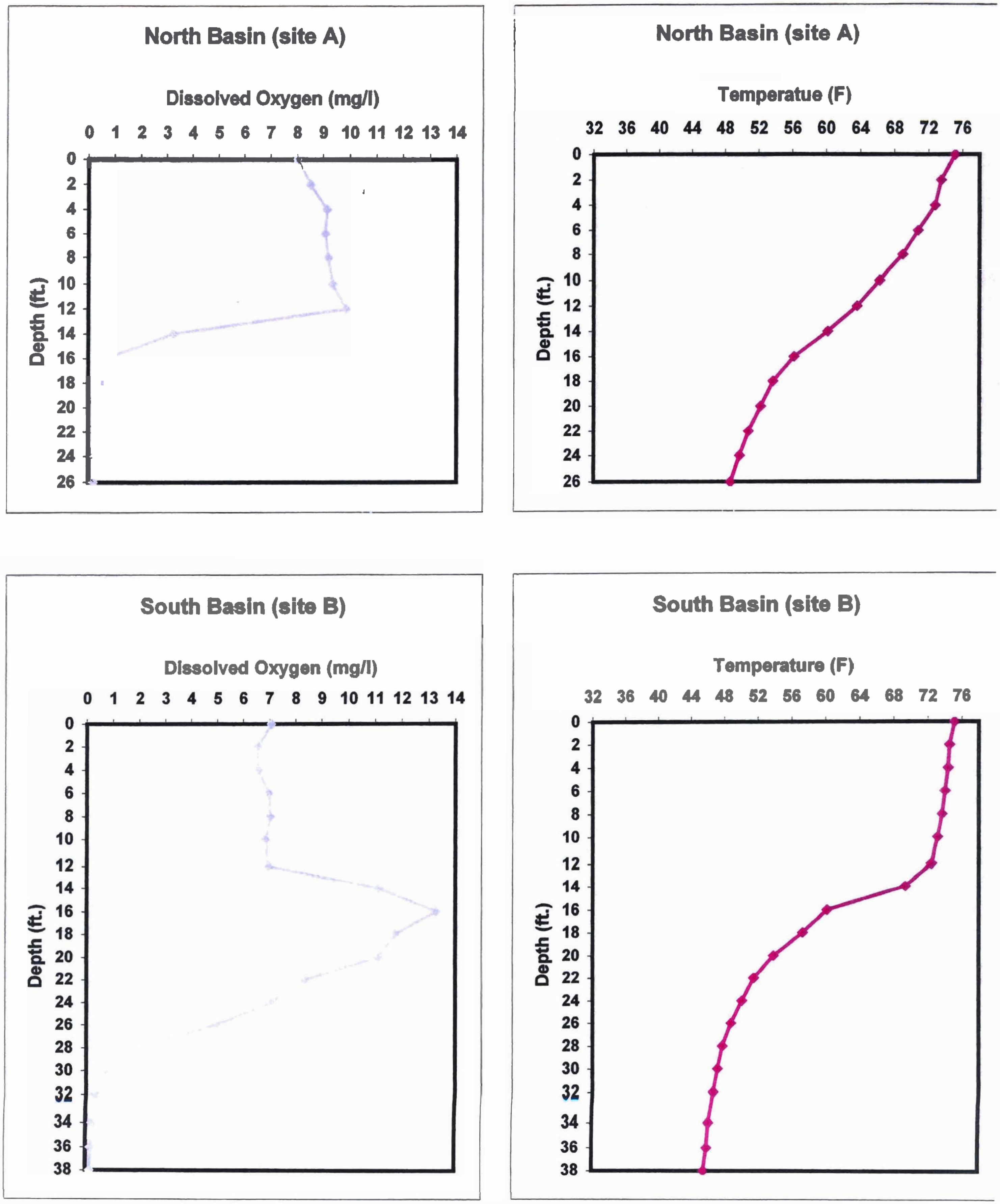


Figure 13. Spring Lake dissolved oxygen and temperature profiles, July 2003.

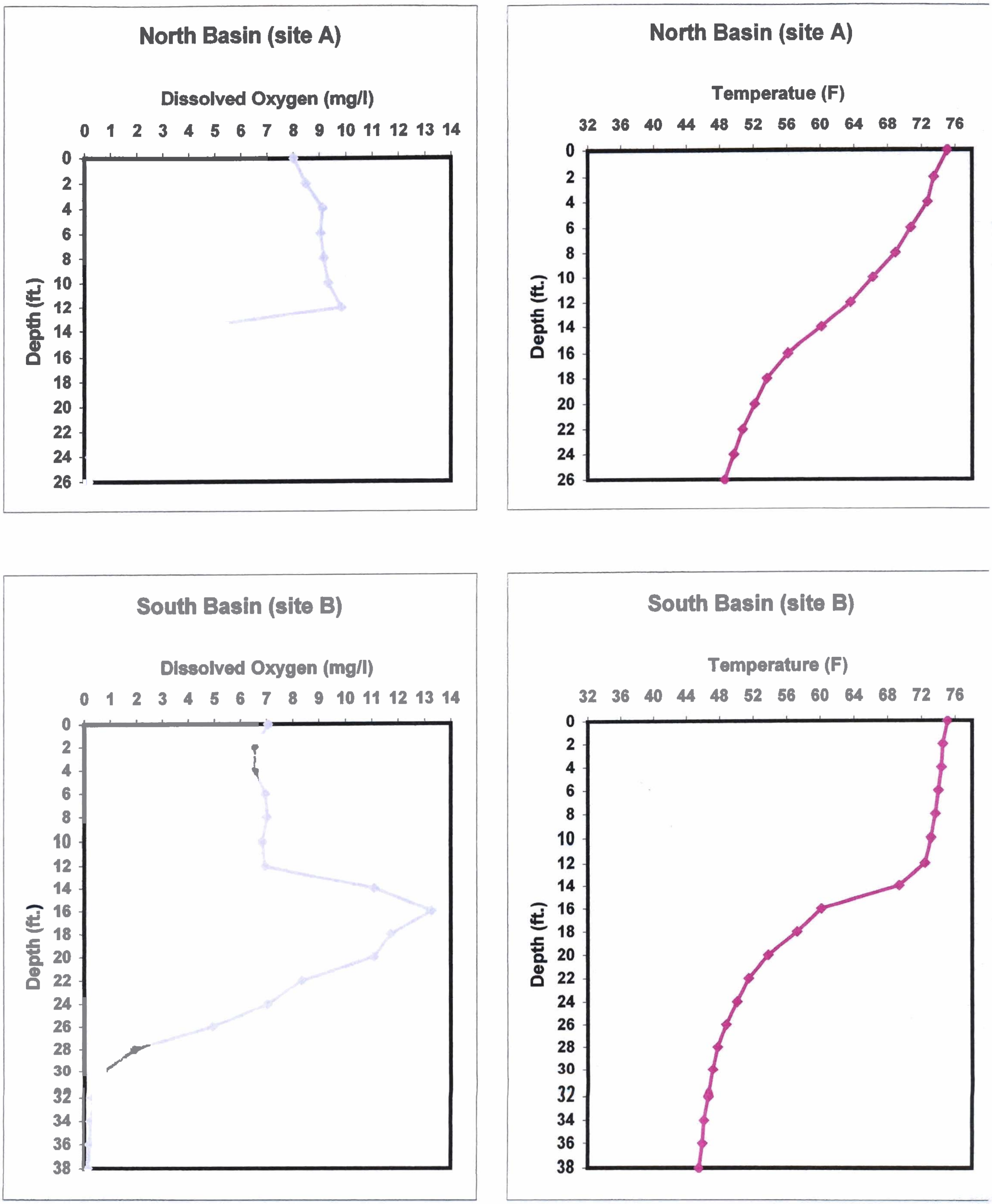


Figure 14. Spring Lake dissolved oxygen and temperature profiles, August 2003.

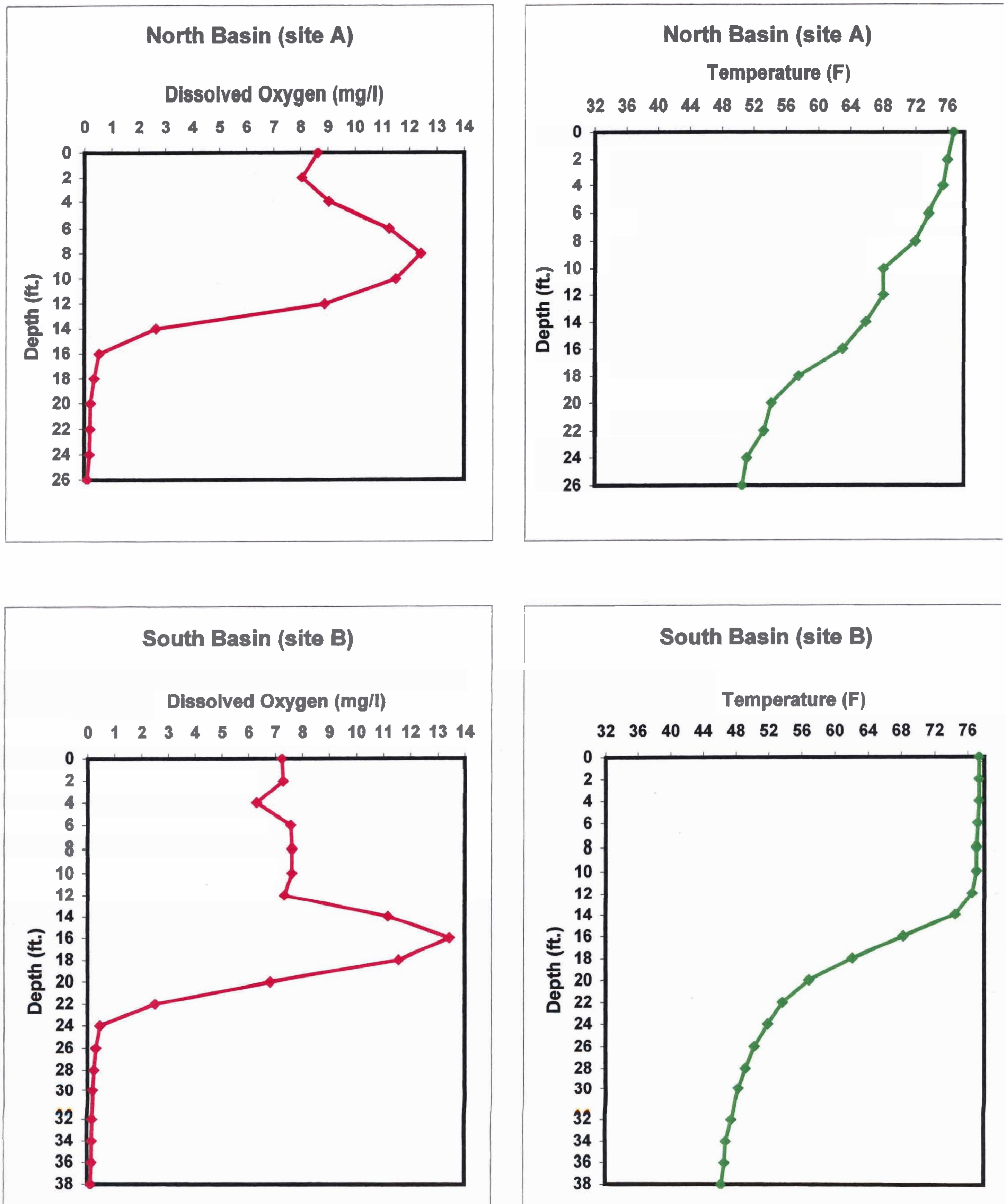
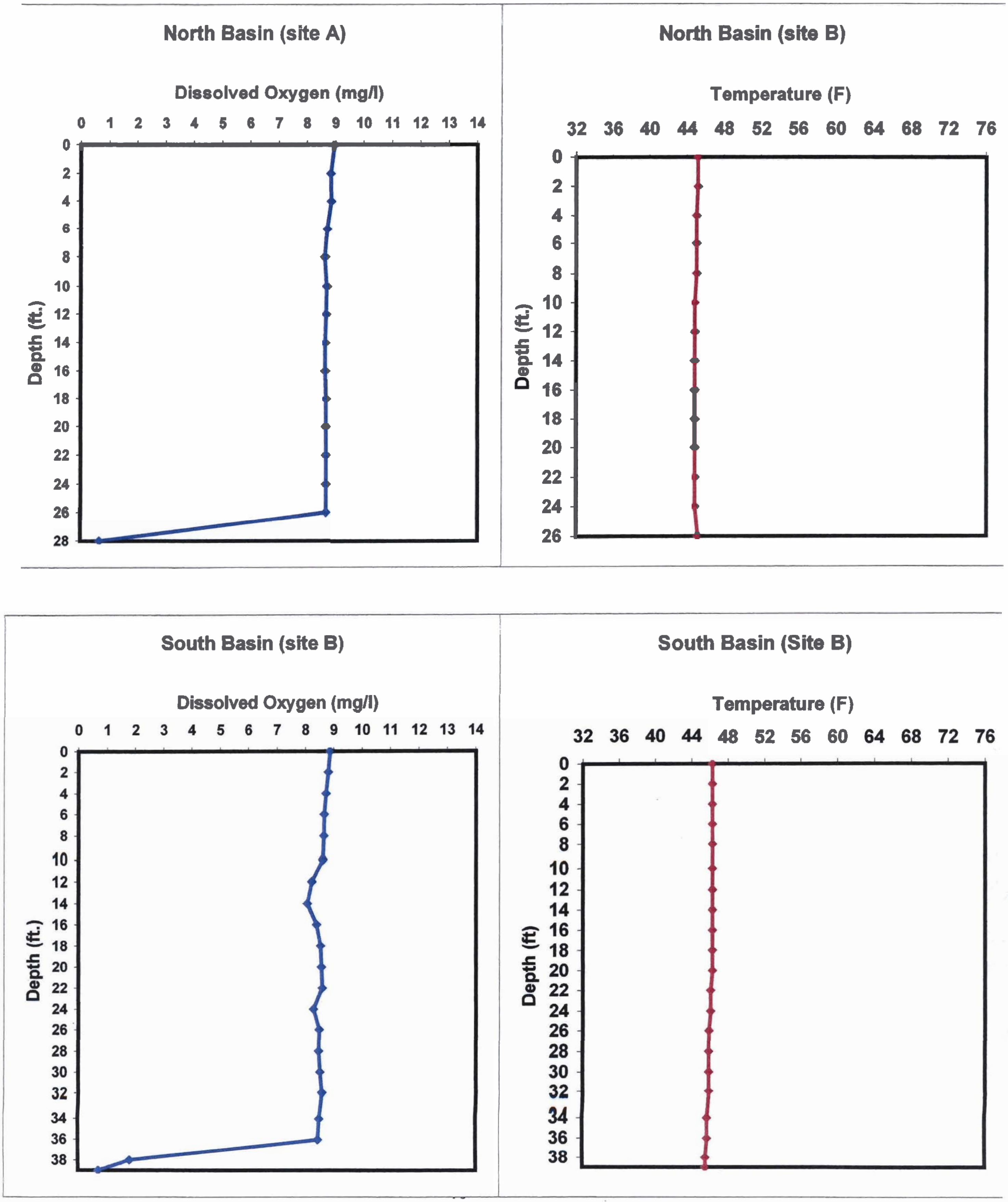


Figure 15. Spring Lake dissolved oxygen and temperature profiles, November 2003.



pH

pH is the negative logarithm of the H+ (hydrogen ion) concentration. The product of H+ and OH- (hydroxyl) ions present in water is a constant. This constant is known as the dissociation constant of water. Theoretically, pure water has equal concentrations of H+ and OH- and is neutral in reaction. Neutral water has a pH of 7. When OH- becomes greater than H+, pH rises and water is considered basic or alkaline. When H+ becomes greater than OH-, water is considered acidic. Since pH is a logarithmic scale, an increase of 1.0 in pH equals a ten-fold increase in OH- concentration. Thus water with a pH of 9 is 100 times more alkaline than water with a pH of 7.

The pH of lakes is affected by many factors. Rainwater is acidic and can lower pH. However this reaction is often buffered by calcium bicarbonate. Plant productivity will raise pH. Calcium bicarbonate is actively broken down by plants in the reactions of photosynthesis. The release of OH- from this reaction raises pH (Ruttner, 1953).

Extremes in pH can have negative effects on aquatic life. In Wisconsin, most pH – related problems with lakes are due to low pH. Low pH can inhibit fish spawning and even cause fish kills. Low pH can also lead to the precipitation of mercury, zinc and aluminum from bedrock. These metals can cause health problems for fish and animals that feed upon them, notably: loons, eagles and humans (Shaw, et.al., 2000). Fortunately the pH found for Spring Lake is high, and these are not concerns. The high pH found in Spring Lake is predominantly the result of local geology, as area lakes tend to be alkaline, but is also partly the result of plant productivity.

Alkalinity and Hardness

Alkalinity is a measure of the ~~calcium carbonate~~ concentration of water. Hardness relates to the presence of two ions Magnesium (Mg++) and Calcium (Ca++). In reactions where acid is added to water containing calcium bicarbonate in solution, bicarbonates combine with hydrogen ions thereby limiting changes in pH. Not until additions of acids have exhausted available carbonates will pH values drop sharply. This buffering capacity is very important for organisms in aquatic environments in its ability to prevent major fluctuations in pH. Not surprisingly, alkaline lakes tend to have a greater abundance of aquatic life than acidic lakes.

A lake's hardness and alkalinity depend on local geology, and often, on the rate of groundwater inflow. When groundwater feeding a lake flows through aquifers containing calcite (CaCO3) and dolomite (CaMgCO3), hardness and alkalinity will be high. Lakes having hardness levels of 60 mg/l or less are considered soft. Lakes having hardness levels of 120 or more are considered hard. With hardness readings of 192 – 214, Spring Lake's waters would be considered extremely hard. Lakes that have an alkalinity of 10 mg/l or less are considered moderately to highly susceptible to acid rain. With alkalinities of 161 - 170 mg/l, Spring Lake is most certainly not sensitive to acid rain. The alkalinity and hardness, as well as the calcium and magnesium concentrations found in Spring Lake are products of local geology and the abundant springs feeding the lake.

Chloride

While chloride ions are essential for plant photosynthesis, free chlorine is highly toxic to living cells. Chlorine kills by oxidation of cell membranes, but the process quickly converts it to harmless chloride ions. Thus chloride concentration is used to identify chlorinated waste discharges in lakes. Other sources of chloride are septic effluent, feedlot runoff, lawn fertilizers and road salts. Elevated levels of chloride indicate that these sources may be affecting the lake.

Chloride occurs naturally in the surface waters of Wisconsin. At typical concentrations it is not harmful to aquatic life. Typical values for area lakes are 3 – 10 mg/l. The chloride concentrations of 16.2 – 20.5 mg/l are not unusually high, but may suggest that runoff-borne pollutants are contaminating Spring Lake.

Conductivity

The ability of water to conduct an electrical current is called conductivity. Conductivity is dependant upon the concentration of inorganic compounds suspended in the water column. Like chloride, conductivity can be used to determine if human activities are influencing water quality. A general guideline is that conductivity should be about two times the hardness of water. The conductivity readings found in Spring Lake do meet these criteria, and are not cause for concern.

Suspended and dissolved solids

Dissolved solids are a measure of dissolved organic compounds present in water. Sources of dissolved solids commonly include decomposing plant matter and tannins leached from bogs. Water having high concentrations of dissolved solids limits the depth at which photosynthesis can take place. Thus it is an important parameter that can affect lake ecosystems. The high concentrations of dissolved solids found in Spring Lake likely limits the aquatic plant community.

Suspended solids are a measure of a lake's turbidity. Suspended solids can include clay particle and decaying plant matter as well as living organisms such as zooplankton and phytoplankton. More productive lakes and lakes having large watersheds with erodeable soils tend to have higher concentrations of suspended solids. Suspended solids and dissolved solids affect Secchi disc depth, and are thus determinants for a major water quality parameter. Suspended solids concentrations for Spring Lake were very low during the August sampling date, but probably vary with weather conditions.

Trophic State Indices

The tropic state index (TSI) is a rating that can be used to summarize the water quality of a lake. The trophic state index rating is based on Secchi disc, total phosphorus, and chlorophyll-a measurements. Developed by Carlson in 1977, the trophic state index rates the three water quality parameters on a scale of 0 to 100. Values that fall between 0 and 35, describe lakes ranked as *oligotrophic.* Any values ranked 50 or above describe *eutrophic* lakes. Values ranging from 35-50 lie in between oligotrophic and eutrophic lakes and are categorized as *mesotrophic* lakes. A low index number generally indicates nutrient poor conditions. Therefore, the higher the index number, the more fertile the lake.

The following equations were used to find (TSI) results.

1) T.S.I. (Secchi disc) = $60 - 33.2 \log_{10} *$ Secchi disc

2) T.S.I. (chlorophyll a) = $36.25 + 15.5 \log_{10} *$ chlorophyll a

3) T.S.I. (total phosphorus) = $60 - 33.2 \log_{10} * 40.5/$total phosphorus

Oligotrophic lakes tend to be deep, clear and produce limited algae and rooted vegetation. They also are nutrient limited and tend to have a slow-growing fishery. A prime example of an oligotrophic lake would be the pristine waters of Lake Superior.

Mesotrophic lakes generally are moderately deep, clear and support a mixture of aquatic vegetation. Mesotrophic lakes do experience algae blooms but not at extreme and chronic levels. Many Waushara county lakes are categorized as mesotrophic.

Eutrophic lakes are nutrient rich and support a large biomass of vegetation or algae. These lakes may to have major algae blooms and suffer from poor water clarity. Eutrophic lakes generally are shallow and are quick to warm up. Being nutrient rich, they have the ability to support a very productive fishery. Rush Lake is an excellent example of a eutrophic lake.

Spring Lake TSI

Three trophic state index graphs were produced for Spring Lake: one for the north basin, one for the south basin, and one for both basins combined. In the north basin the TSI values for Secchi disc and chlorophyll a ranged anywhere from the upper oligotrophic zone to the lower eutrophic zone (**Figure 16**). TSI values for total phosphorus remained in the mesotrophic zone. In the south basin, values for Secchi disc also fluctuated from the upper oligotrophic zone to the lower eutrophic zone . Chlorophyll a TSI values remained in the upper oligotrophic zone. Combined basin data revealed trophic state index values that were closely associated to the mesotrophic zone (**Figure 17**). Secchi disc and total phosphorus lied within the mesotrophic zone and lower eutrophic zone. All but one chlorophyll a sample point lied within the mesotrophic zone. In conclusion, the tropic Spring Lake would be characterized as a mesotrophic lake.

Figure 16. Trophic State Index (TSI) for Spring Lake 2003.

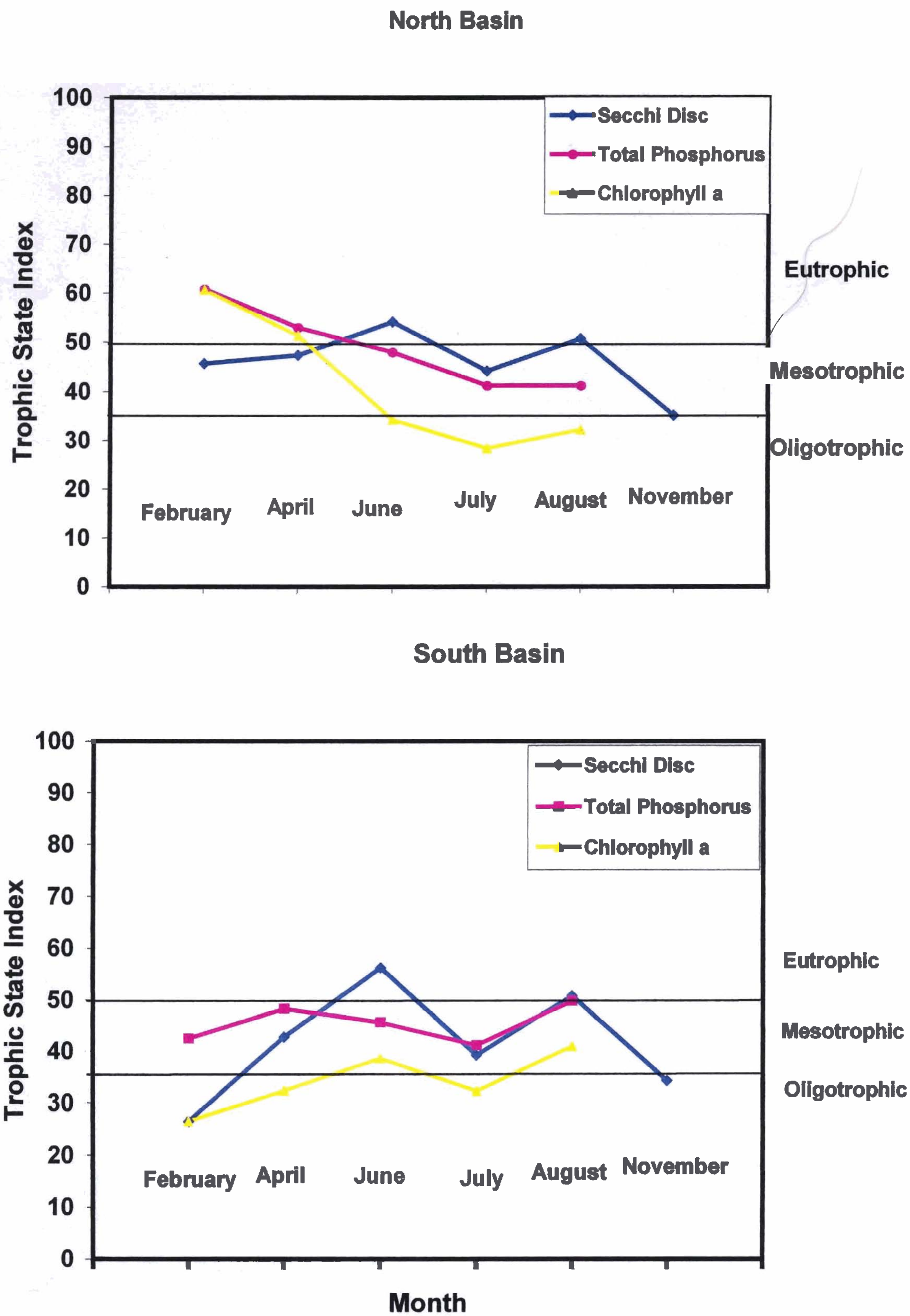
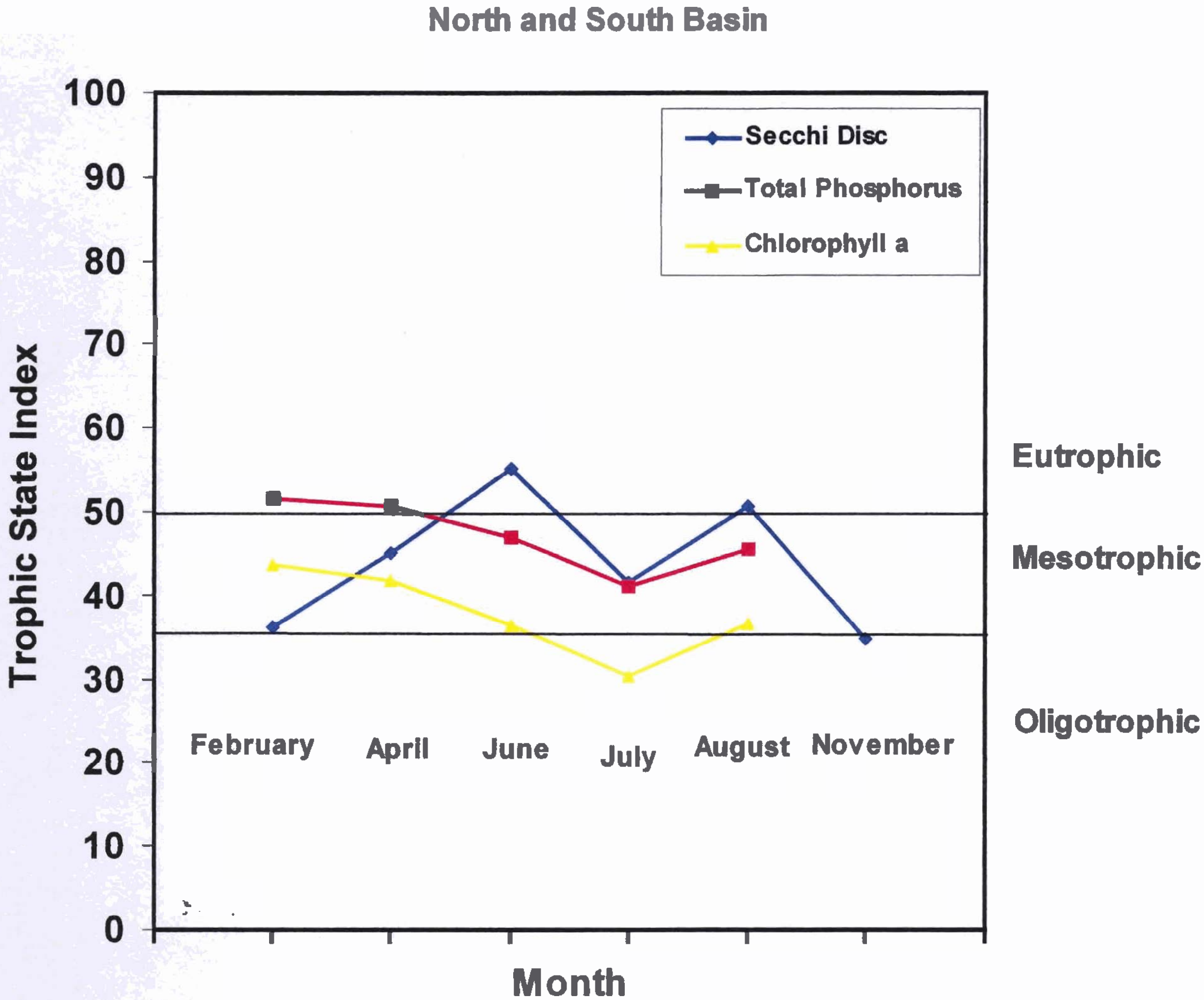


Figure 17. Tropic State Index averages of north and south Basin on Spring Lake 2003.

Why the averages of the lake isn't "mixing"



Inlet Water Quality Parameters

If budget is off this is ?

Nutrient loading

From the data presented in **Table 16**, the following nutrient loading data were calculated:

Location	Phosphorus Load	Nitrogen Load
South inlet	20 lbs/yr	1923 lbs/yr
Northwest inlet	5 lbs/yr	618 lbs/yr
North inlet	138 lbs/yr	27,769 lbs/yr
Northeast inlet	4 lbs/yr	290 lbs/yr

As evident in the data, the greatest nutrient loading came from the north inlet. Despite the high concentrations found at the northeast inlet, the limited water flow reduced the impact to the lake. The nitrogen load from the north inlet is astoundingly high at 27,769 lbs/yr. Indeed, 27,769 lbs of anything entering into the lake is cause for concern. Nonetheless, since Spring Lake is phosphorus-limited, these high nitrogen loads cannot contribute to algae blooms or excess plant growth.

Should have an explanation what assumptions were made when calculating H_2O budget - Explanation of how #'s were derived in this case at least.

Table 16. Spring Lake inlet water quality parameters.

Northwest Inlet

parameter	unit	June	July	Aug.	Average
dissolved oxygen	mg/l	7.1	6.1	6.5	6.6
nitrate + nitrite as N	ug/l	2540	2680	2800	2673.3
total phosphorus	ug/l	19	19	28	22.0
pH, field	s.u.	7.8	7.5	7.5	7.6
stream flow	cfs	2.7	0.03	0.2	1.0
field temperature	C	11.9	13.9	14.6	13.5

North Inlet

parameter	unit	June	July	August	Average
dissolved oxygen	mg/l	7.6	7.1	6.7	7.1
nitrate + nitrite as N	ug/l	7320	5880	7960	7053.3
total phosphorus	ug/l	32	28	45	35.0
pH, field	s.u.	8	8	8	8.0
stream flow	cfs	2.7	2.2	1	2.0
temperature	C	12.8	15.8	17.9	15.5

Northeast Inlet

parameter	unit	June	July	August	Average
dissolved oxygen	mg/l	7.9	2.9	2.1	4.3
nitrate + nitrite as N	ug/l	9610	10900	8950	9820.0
total phosphorus	ug/l	150	92	168	136.7
pH, field	s.u.	7.6	7.5	7.5	7.5
stream flow	cfs	ND	ND	ND	ND
temperature	C	14	16.2	18.9	16.4

South Inlet

parameter	unit	June	July	August	Average
dissolved oxygen	mg/l	5.3	5.6	5.4	5.43
nitrate + nitrite as N	ug/l	3170	2860	2570	2866.67
total phosphorus	ug/l	29	32	30	30.33
pH, field	s.u.	7.5	7.8	7.5	7.60
stream flow	cfs	0.2	0.1	0.7	0.34
temperature	C	12	18.8	18.3	16.37

Phosphorus budget

See comments on p. 46

There are many sources of phosphorus loading in lakes. The primary sources for Spring Lake were used the budget calculations below. A significant source of phosphorus that was not included in the calculations is phosphorus released from lakebed sediments under anoxic conditions. Insufficient data existed to make this estimate. Likewise, the amount of phosphorus captured by sediments and by living plants was not included in calculations.

INFLOW:

Source	Phosphorus Load	%
Atmospheric	14.7 lbs/yr	2.1
Tributary	167.0 lbs/yr	23.9
Groundwater – Res. (septic)	34.3 lbs/yr	4.9
Groundwater - Agricultural	464.8 lbs/yr	34.3
Groundwater – Forest	16.6 lbs/yr	2.4
Total	697.4 lbs/yr	100

OUTFLOW:

Source	Phosphorus Load	%
Sucker Creek Outlet	590.0 lbs/yr	84.4
Groundwater percolation	105.8 lbs/yr	15.2
Total	695.8 lbs/yr	100

This phosphorus budget was calculated based on the following assumptions:

1. Phosphorus from atmospheric sources was estimated using the export coefficient: 0.186 lbs/acre/year, and was calculated on a 79 acre surface area.

2. Loading from riparian septic systems was calculated using the export coefficient: 1.37 lbs/unit/year. Calculations were only made for those units located along shorelines where piezometer readings indicated groundwater flow moving toward the lake (25 units). short data set for gw flow direction

3. Agricultural and forest influences were calculated using watershed data and the export coefficients: 2.14 and 0.05 lbs/acre/year, respectively. Since the watershed is characterized by well-drained soils, it was assumed that most waters enter the lake via groundwater. It was further assumed that soils captured 80% of phosphorus.

4. Since piezometer readings indicated that groundwater outflow equaled 22% of inflow, it was assumed that an equivalent concentration of phosphorus left the lake via groundwater percolation. Internal? This is a marl lake!

As is most often the case when calculating nutrient budgets, the budget calculated for Spring Lake was based on numerous assumptions and estimates. Therefore relative, rather than actual, numbers should be considered. The important things to take from

Yes ↑

these findings are 1) that phosphorus enters the lake from numerous sources, 2) that agricultural activities in the watershed likely have the greatest influence on lake water quality, and 3) that the north inlet is the single greatest source of nutrient loading. It should also be noted that due to Spring Lake's hydrology, any changes in land use within the watershed could have an impact on phosphorus budgets – and ultimately water quality.

Watershed Characteristics

Needed this way earlier!

The total watershed area of Spring Lake was delineated at 2,875 acres. The watershed boundaries and the surface water drainage patterns within the watershed are shown in **Figure 18**. The vast majority of the watershed encompasses a large valley to the north of the lake. The Village of Spring Lake lies in the bottleneck between this valley and the lake. It is important to note that most of the watershed drains into the north basin. The portion draining into the south basin is relatively small. Due to this fact, the north basin will always be more fertile than the south basin.

Soil types within the watershed are predominantly Boyer, Okee and Richford loamy sands and Plainfield sands. These soil types range from excessively drained to moderately well drained. Due to the rapid permeability of these soils, it is safe to assume that very little direct surface runoff enters the lake. Instead, rainfall percolates through the soil and enters the lake as groundwater. Therefore the watershed would more accurately be called an area of groundwater influence.

Land uses and cover types within the watershed were identified as follows:

56% upland forest	(1605 acres)
2% swamp forest	(57 acres)
23% non-irrigated cropland	(658 acres)
13% irrigated cropland	(373 acres)
2% pasture	(55 acres)
4% residential	(127 acres)

During the course of assessing the watershed, the following observations were made:

1. There appears to have been a significant increase in forest cover in the last 25 years.
2. Agricultural lands were composed primarily of three farms.
3. Nine pastures, including three feedlots, were found.
4. Residential lands included the Village of Spring Lake and lakefront and off-lot homes.
5. Approximately 54 homes or cottage existed within 100 yards of the lake.
6. Two new construction sites were found within 100 yards of the lake.
7. There appears to have been a significant increase in the number of homes around the lake in the last 25 years.

The following areas of concern were identified within the watershed:

1. Feedlot runoff entered directly into the headwaters of the north inlet.
2. Construction site runoff from a new development will enter directly into the northeast inlet.

3. The use of conventional septic systems in homes located over areas of high groundwater flow may be ineffective in preventing nutrient loading into the lake.
4. Irrigated agriculture may be causing increased nitrogen and phosphorus concentrations in groundwater.

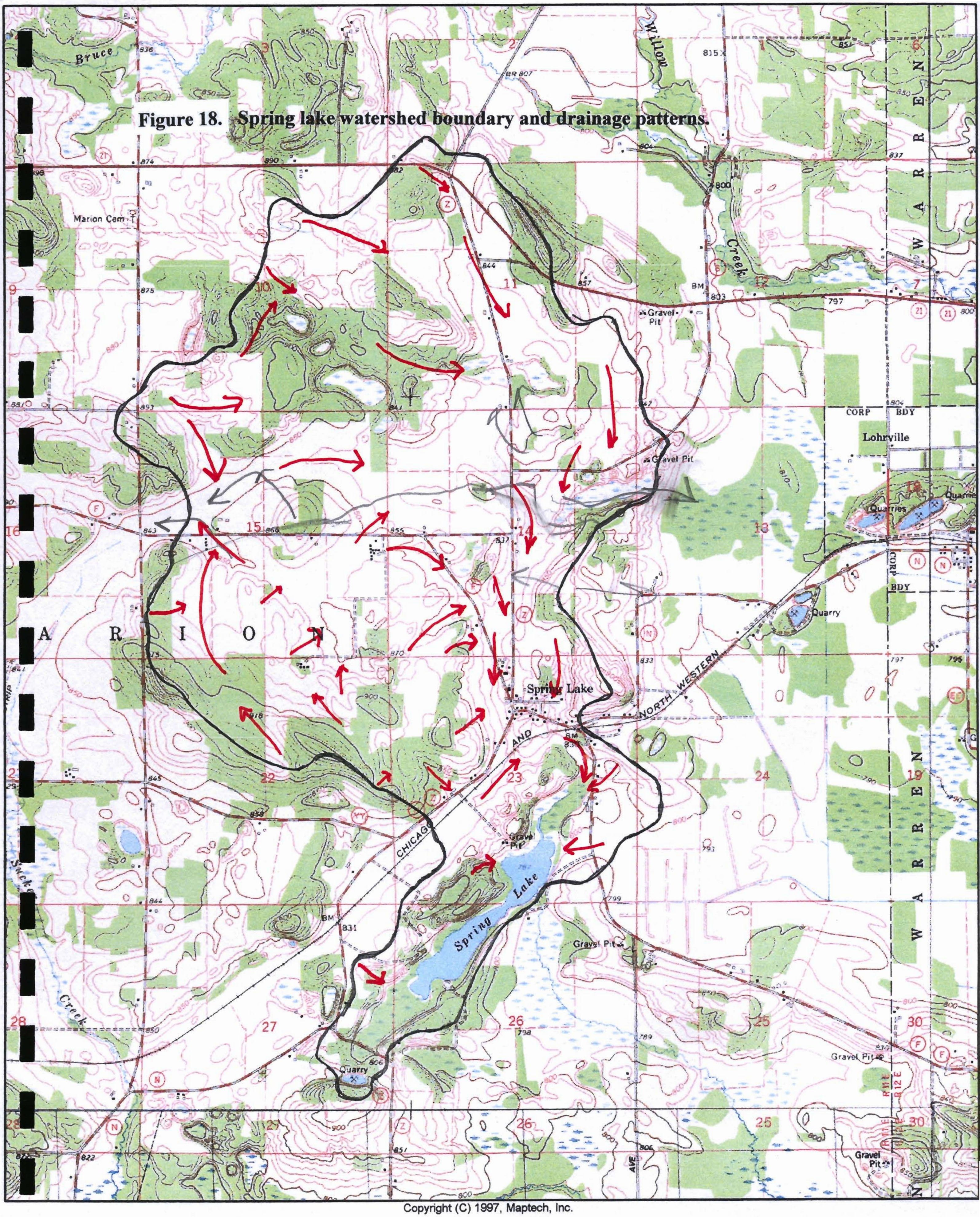


Figure 18. Spring lake watershed boundary and drainage patterns.

Water Quality Improvement for Lakefront Property Owners

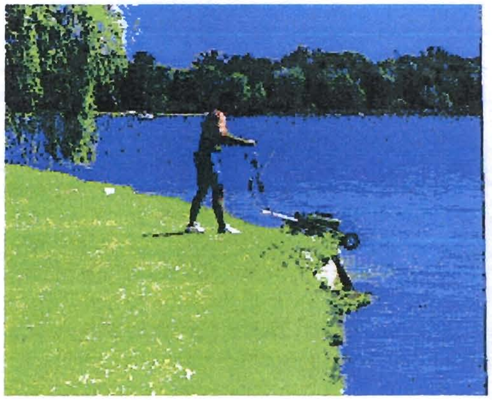
Vegetative Buffer Zones

There are beneficial alternatives to the tradition-mowed lawn. The best alternative is to protect the natural shoreline (vegetative buffer zone) and leave it undisturbed. If clearing is necessary to access and view the lake, consider very selective removal of vegetation. Restoring the vegetative buffer zone (shoreline) is also an important alternative.

A buffer zone consists of native vegetation that may extent from 25 – 100 feet or more feet from the water's edge onto land, and 25 – 50 feet into the water. The buffer should cover at least 50% and preferable 75% of the shoreline frontage (Henderson, et al). In most cases this still allows plenty of room for a dock, swimming area, and lawn. Buffer zones are made up of a mixture of native trees, shrubs, upland plants, and aquatic plants.

Shoreline vegetation serves as an important filter against nutrient loading and trapping loose sediment. The buffer provides excellent fish and wildlife habitat, including nesting sites for birds, and spawning habitat for fish. Properly vegetated shorelines also play a key role in bank stabilization. A valuable source of information on buffers zones can be found in *Lakescaping for Wildlife and Water Quality,* and can by ordered by calling 1-800-657-3757.

Lawn Care Practices



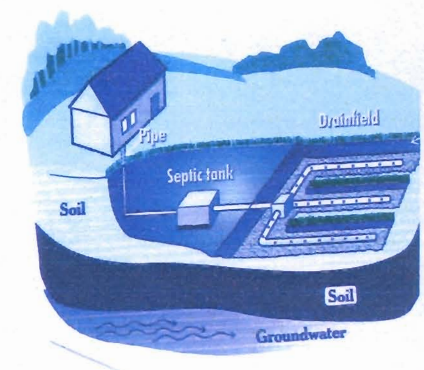
Which would you prefer, a pea soup colored lake or a dark-green lawn? Mowed grass up to the water's edge is a poor choice for the well being of the lake. Studies show that a mowed lawn can cause 7 times the amount of phosphorus, and 18 times the amount of sediment to enter the water body (Korth and Dudiak, 2003). Lawn grasses also tend to have shallow root systems that cannot protect the shoreline as well as deeper-rooted native vegetation (Henderson, et al).

Landowners living in close proximity to the water are not encouraged to use lawn fertilizers. Fertilizers contain nutrients, especially phosphorus that can wash directly into the lake and cause unsightly algae blooms and excessive aquatic plant growth. Landowners are encouraged to perform a soil test before fertilizing. A soil test will help determine if you need to fertilize, and give you direction on fertilizing. For assistance in having your soil tested, contact your county UW- extension office. If there is a need to fertilize your lawn, use a fertilizer that does not include phosphorus. Most lawns in Wisconsin don't need additional phosphorus. Phosphorus free fertilizers will read 0 in the middle of the label (25-0-5).

To further reduce nutrient loading, avoid raking twigs, leaves, and grass clippings into the lake. They contain nitrogen and phosphorus. The best disposal for organic matter, like leaves and grass clippings is to compost them. Composted material can then be used for gardening.

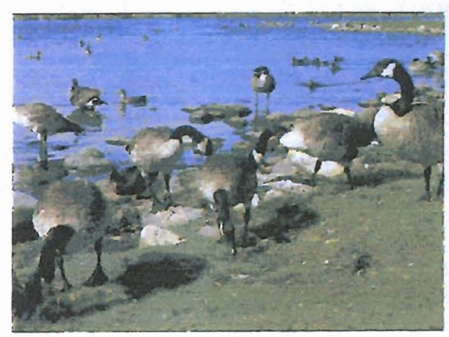
Septic System Maintenance

It is the responsibility of the landowner to ensure that septic systems are properly functioning. A failing septic system can contaminant both surface and ground water. Failing septic systems are a major cause of nutrient loading in lakes. Lakes like Spring Lake, were groundwater recharge inlets (springs) are in close proximity to septic system drain fields, are at a greater risk. Systems should be professionally inspected every 3 years, and pumped every 2-5 years depending on operating circumstances (EPA, 2002). Avoid flushing toxic chemicals into the system. This can harm important bacteria that live in your tank and naturally break down wastes. Avoid planting trees in the drain field, compacting soil within the drain field, and directing additional surface runoff on top of the drain field.



Waterfowl Feeding

Avoid feeding ducks and geese. When fed, waterfowl tend stay in a concentrated area near the feeding location. Waterfowl produces a large amount of nutrient rich manure that is deposited directly into the lake. Studies show that in one week an adult goose can produce 15 pounds of droppings (MDNR, 2002). Resident ducks and geese are also attracted to manicured lawns that are mowed up to the water's edge. Waterfowl also serve as a host to the parasite that causes swimmers itch.



Wetland Protection

Wetlands are a vital part in the aquatic community and provide many unnoticed services to society. They act as a sponge in flooding events, filter nutrients and toxic chemicals, provide valuable fish and wildlife habitat, cleanse our groundwater, and serve many more important functions. Under law they are protected and should not be altered in anyway. Swamps, marshes, bogs, and fens are all categorized as wetlands (Read, 2001). Priority must be taken to protect all wetlands located within the Spring Lake watershed. If you own or are familiar

with a drained or filled wetland, consider taking measures at restoring it.

Building Plan

If you choose to establish on a lake, you should develop a building plan that considers the well being of the lake first. Your decisions affect all lake users. Locate buildings and driveways as far from the lake as possible. This helps protect water quality by allowing more land surface to filter runoff. During construction use silt fencing and or erosion control blankets to help hold loose sediment intact. Be very selective on the clearing of vegetation, it serves an important purpose. Inform the contractor about your concerns, and fence off areas that don't need to be disturbed. If possible direct any runoff from buildings and driveways away from the lake.

Erosion Control

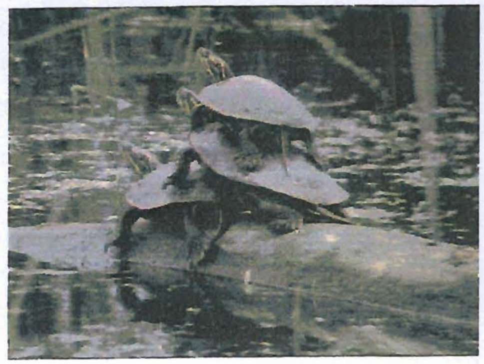
Erosion is a natural process, but it's for the benefit of the landowner and health of the lake that erosion control practices be carried out to slow the process as much as possible. Sedimentation into the lake causes nutrient pollution, turbid water conditions, eliminates fish spawning habitat, and increases eutrophication. Shoreline owners are encouraged to leave existing vegetation, which is a great shore stabilizer. The placement of logs, brush mats, and rock riprap are also options against erosion. When riprap is used it is recommended that desirable shrubs and aquatic plants be planted within the riprap. The plantings serve as nutrient filters and habitat.

Rainfall is one of the most powerful things on earth (Holdren et al, 2001). When a rain event occurs loose sediment can be washed directly into the lake or into inlets that drain into the lake. Disturbed areas with loose soil, including plowed farm fields, pastures, and construction sites, should all be areas of concern. Precautions in disturbed areas need to be addressed. The use of silt fencing is a popular tool designed to help control erosion on construction sites. Farming practices that help prevent erosion include developing vegetative buffer strips, contour farming, conservation tillage, grassed waterways, and strip cropping.

Fish and Wildlife Habitat

. " *Our lakes are a place to live or vacation--for us they are a chosen landscape. For the wildlife that live there, however, our lakes are their only home* "
- Robert Korth

Fish and wildlife are an important part of the aquatic community. In order for fish and wildlife to naturally function and exist, they must have a home. Providing fish and wildlife habitat can be as simple as leaving fallen trees and natural vegetation in place. Many shore owners consider woody debris as worthless, and quickly remove it from the water. Consider leaving trees in the water. Woody debris provides excellent habitat for a variety of fish and wildlife. Floating trees are like docks for turtles, frogs, marsh birds, muskrats, and beaver. Trees offer excellent cover and spawning habitat for a variety of fish. Woody debris also attracts many invertebrates that fish feed upon. Shoreline vegetation can benefit wildlife tremendously. A properly vegetated shoreline provides habitat for a variety of birds, furbearers, amphibians, and reptiles. If your shoreline is lacking character (native vegetation), consider restoring it



The placement of bat and purple martin houses near the lake is also an option for providing habitat. Constructing bat houses and purple martin houses is a natural way to control of insect pests like mosquitoes. One adult bat can consume up to 7,000 mosquitoes in one evening (Henderson, 1992). For more information on homes for birds and mammals read *Woodworking for Wildlife,* which can be ordered by calling 1-800-657-3757

Water Quality Improvement for Watersheds

Many conservation-based programs geared at improving lakes exist in Wisconsin. The following paragraphs contain information on programs that may pertain potential conservation improvement practices for Spring Lake's watershed.

Targeted Runoff Management Grant (TRM)

Targeted runoff management grants are offered through the Wisconsin Department of Natural Resources (WDNR). (TRM) grants are used to develop projects for controlling polluted runoff. Example projects include stream bank protection, wetland construction, agricultural field buffers, and livestock waste management practices. This grant offers up to 75% cost share for project construction, and 70% for agricultural easements. Only governmental units are eligible to apply. For more information look under (TRM) grants on the DNR website: http://www.dnr.state.wi.us/ or call John Young at (920) 492-5854.

Lake Management Protection Grant

Lake protection grants are available through the (WDNR). Lake protection grants can be used for shoreline and wetland restoration, watershed protection, land acquisition or easement, agricultural best management practices including barnyard and manure management, and many more lake improvement practices. The protection grant offers a 75% cost share with a maximum amount of $200,000 per project. Eligible applicants include counties, towns, villages, cities, lake associations, districts, and non-profit organizations. For more information check out the DNR website: http://www.dnr.state.wi.us/ or contact DNR lake coordinator, Mark Sesing at (920) 485-3023.

Wetland Reserve Program (WRP)

The Wetland Reserve Program is sponsored through the U.S. Dept. of Agriculture (USDA) Natural Resource Conservation Service (NRCS). This program offers landowners the opportunity to protect, enhance, and restore wetlands on their property. Historic wetlands that have been filled or degraded are eligible for funding along with many other projects dealing with wetlands. (WRP) pays 75-100% of restoration costs and 75% of easement costs. For more information call your local (NRCS) office. The local (NRCS) closest to Spring Lake can be reached at (920) 787-3828.

Conservation Reserve Program (CRP)

The Conservation Reserve Program is available through the (USDA) Farm Service Agency. Through (CRP) farmers can receive annual rental payments, and cost-share assistance to establish long-term resource conserving covers on eligible farmland. Projects include tree planting, native-grass planting, developing buffer strips, and many other environmental practices. (CRP) agreements are for 10-15 years. For more information call your local (USDA)-Farm Service Agency. The contact number for farmers in the Spring Lake watershed is (920) 787-2116.

Stewardship Incentive Program (SIP)

The Stewardship Incentive Program provides funding to protect, enhance, and restore forestry resources. Projects include tree planting, forestry management for fish and wildlife, and soil and water erosion practices. Landowners must own between 10-1000 acres. (SIP) is a 10-year agreement. Contact your local (USDA)-Farm Service Agency or your local DNR Forestry division. Contacts for the Spring Lake area are the Farm Service Agency at (920) 787-2116, or WDNR at (920) 787-4686.

Wildlife Habitat Incentives Program (WHIP)

The Wildlife Habitat Incentives Program provides 75% cost-share funding for people who want to develop wildlife habitat on their land. Almost any land is eligible for this program. Landowners work with (NRCS) professionals to develop a wildlife habitat plan. Projects are then implemented to develop wildlife habitat. Landowners must own add least 5 acres. (WHIP) offers a maximum of $10,000. For more information contact your local (NRCS) station. Landowners in the Spring Lake area seeking more information can call (920) 787-3828

Conclusions and Recommendations

Three of the greatest threats facing Wisconsin's lakes today are excess nutrient loading, exotic plant invasion, and loss of habitat due to human encroachment. Spring Lake now faces all three of these threats. Exotic plant invasion may be the most immediate concern, but is also the most readily definable, and is relatively easy to deal with. Excessive nutrient loading has a greater potential to harm Spring Lake and is a much more difficult problem to define and deal with. Loss of habitat is no less of a problem than the other two, and is directly related to them in many ways.

The following paragraphs provide recommendations for dealing with these problems. These recommendations are not intended to be all-inclusive. They are intended to provide guidance and direction to the Lake Management District in its efforts to improve Spring Lake. The Lake Management District will need to carefully review the information presented in this report, then prioritize management needs, then finally, adopt a plan of action and a timeframe for implementing management practices. This then will become the Lake District's management plan.

Water Quality Improvement

Goals

The Lake District should establish goals for water quality improvement. Many lake management tools, such as the water quality indices and trophic state indices presented in this report, have been developed to facilitate trend monitoring and the establishment of definable goals. Oddly, the indices used to measure water quality in this study did not always reflect the poor water quality that was observed. This may be due to factors such as high zooplankton densities that skew chlorophyll indices, or a high flushing rate that skews total phosphorus indices. While improvements to Spring Lake's water quality should be evident in some parameters, we do not seem to have a good mathematical index for measuring Spring Lake's overall water quality. Therefore the Lake District should adopt a simple goal: *to eliminate algae blooms*. This will include planktonic blooms that give the water a greenish tint and reduce clarity, and filamentous blooms that create noxious floating mats of algae. The elimination of algae blooms will be the surest indicator of reduced nutrient loading.

Watershed assessment

A more detailed assessment of Spring Lake's watershed will be needed to specifically identify nutrient loading sources. The scope of this study did not include detailed assessment of all activities within the watershed that may impact Spring Lake's water quality. Hopefully though, the results of this study will help to focus the efforts of further watershed assessment. The Lake District should present the findings of this study to the Waushara County Land Conservation Office to discuss conducting a more detailed watershed assessment.

Inter-agency cooperation

Efforts at improving Spring Lake will clearly need to extend beyond the shoreline. Successful nutrient management will require cooperation with other units of government that have a management interest in Spring Lake's watershed. The Lake District should cultivate relationships with these agencies by making the concerns of the Lake District known, and by including agency staff in the lake management planning process, and in meetings and other activities.

Education

Education will be an important component of a program to improve water quality in Spring Lake. The Lake District should strive to inform lakefront property owners about practices for improving and maintaining lake water quality. Information in this report will serve as an important educational tool, and should be distributed to all District members. The Lake District should also make an effort to inform farmers within the watershed about the lake's water quality concerns, and about the conservation programs listed in this report.

New construction

The construction of new homes and cottages around Spring Lake is likely to continue. Additional home sites will further threaten Spring Lake's water quality. Construction site erosion control practices should be utilized. Homes constructed over areas of permeable soils and / or groundwater inflow, including off-lots, should be built with holding tank type septic systems, not conventional systems that allow septic leachate to contact groundwater.

Monitoring

Continued water quality monitoring will serve to track improvements in lake water quality, as well as serving to identify new threats to the lake. The Lake District should continue with the annual Self Help Monitoring program. Both basins should be monitored every year. The same methods should be employed each year as well in order to provide comparable data. More extensive water quality monitoring, that utilizes some of the methods of this study, should be done every other year (2005, 2007....) until water quality goals are achieved. The Lake District should seek funding from the WDNR's Small Scale Lake Management Planning Grant program in order to help fund these projects.

Management of Exotic Plants

Goals

While management efforts directed at Eurasian watermilfoil should strive to eradicate the plant, this is often not a realistic goal given the difficulty of locating every plant in the lake, and given the constant threat of re-introduction. A realistic goal for management of both Eurasian watermilfoil and curly-leaf pondweed will be to reduce the plants to sub-nuisance levels, and to maintain them at sub-nuisance levels for the long term. In practical terms, Eurasian watermilfoil should be reduced to, and kept below 10% of its pre-treatment distribution (about ½ acre). Given the plant's propensity for rapid dispersal, the total of Eurasian watermilfoil beds should not be allowed to exceed ½ acre in any given year. Curly-leaf pondweed should be controlled whenever dense mono-typic stands form. These dense beds cause a nuisance to boaters and anglers. These dense beds also impact native plants and reduce water quality. In areas of the lake where curly-leaf pondweed grows sporadically and does not reach nuisance levels the plant does not need to be controlled.

Methods

Given both the high degree of efficacy and the high level of species selectivity of the herbicide treatments conducted on Spring Lake, these methods should continue to be used to control exotic plants. For Eurasian watermilfoil, the herbicide Navigate® (2,4D) should be used. Application rates should be 100-150 lbs / acre for larger treatments (> 0.5 acre). Rates of 150 – 200 lbs per acre should be used for spot treatments. Eurasian watermilfoil should be treated as soon as plants are actively growing in 2004. Curly-leaf pondweed should be treated with Aquathol (Endothol) early in the season before other pondweeds (*Potamogetons*) begin growing. Early season treatments kill plants before turions form. Two to three seasons of treatments have been found to provide significant long-term control of the plant. Thus the area treated in 2003 should be re-treated in 2004. Rates should be 0.75 to 1.5ppm, depending on treatment area size.

Monitoring

The success of an exotic plant control program will rely upon active lake monitoring. It is necessary for lake residents to become familiar with Eurasian watermilfoil and curly-leaf pondweed and to be on the lookout for the plant. If the plants can be regularly monitored they can be treated before they reach nuisance levels. It will be beneficial to also conduct more thorough plant surveys – reproducing the methods used in this study – every few years. This could be combined with future water quality monitoring and funded with a Lake Management Planning Grant.

Protection of Native Plant Communities and Habitats

Carp barrier

An overabundance of carp will negatively affect native plant communities through both over-foraging and increased turbidity. Excluding carp from Spring Lake will be necessary to protect lake habitats. The existing carp barrier at the Sucker Creek outlet has deteriorated and is probably not fully effective in excluding carp from the lake. This barrier should be repaired as soon as possible.

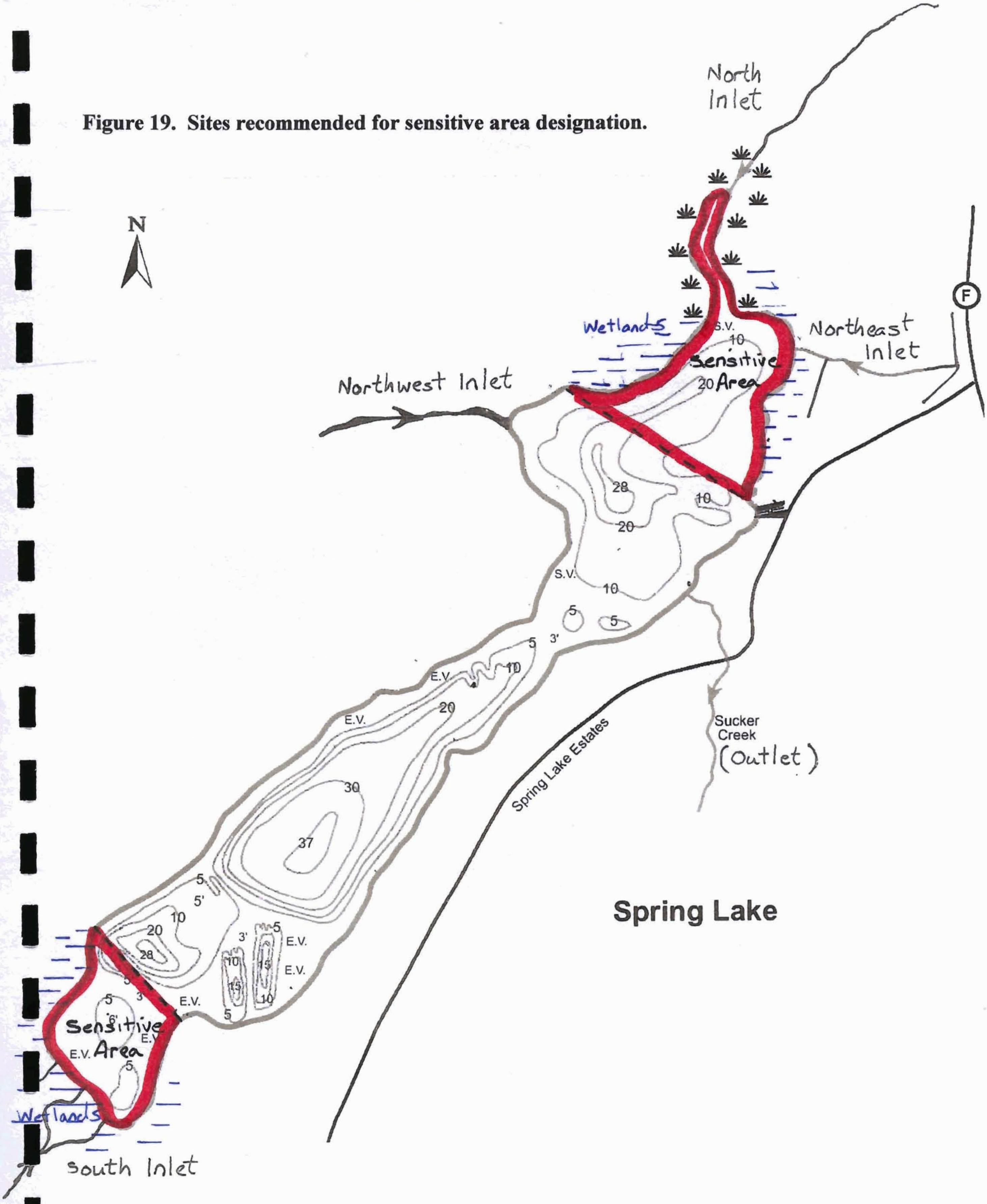
Sensitive area designation

To protect important fish and wildlife habitats in Spring Lake, the Lake District should consider establishing "Sensitive Areas". Under Wisconsin Administrative Code NR 107, areas of important aquatic habitat can be designated as Sensitive Areas. When so designated by the Department of Natural Resources, the area can be protected from chemical weed control and activities that require Chapter 30 permits. Areas recommended for Sensitive Area designation are shown in **Figure 19**. The designation process is outlined in Chapter NR 103 of the Wisconsin Administrative Code. The Lake District should ensure that Sensitive Area designation will not interfere with exotic plant control plans.

Slow - no wake

The slow – no wake ordinance currently enforced on Spring Lake has been instrumental in the protection of emergent plant beds in the lake. If this regulation were removed, these important fish spawning and nursery areas would be compromised. Therefore the Lake District should continue to support the slow – no wake regulation on the lake.

Figure 19. Sites recommended for sensitive area designation.



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