Contract Report 638

Sedimentation Survey of The Morton Arboretum Lakes, DuPage County, Illinois

by
William C. Bogner and K. Erin Hessler

Prepared for
Harza Engineering Company
The Morton Arboretum
Illinois Environmental Protection Agency

April 1999

Illinois State Water Survey
Watershed Science Section
Champaign, Illinois

A Division of the Illinois Department of Natural Resources

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SEDIMENTATION SURVEY OF THE MORTON ARBORETUM LAKES, DU PAGE COUNTY, ILLINOIS

Introduction

The Illinois State Water Survey (ISWS) conducted a sedimentation and hydrographic survey of three small lakes at The Morton Arboretum in Lisle, Illinois, during the summer of 1998. The survey was undertaken in support of an Illinois Clean Lakes Program diagnostic/feasibility study of the lakes. The lakes are owned and maintained by The Morton Arboretum and serve primarily as landscape accents on the grounds.

Lake sedimentation occurs when sediment-laden water enters the reduced flow velocity regime of a lake. As the water velocity is reduced, suspended sediment is deposited in patterns related to the size and fall velocity of each particle. The soil particles are partially sorted by size along the longitudinal axis of the lake during this process. Larger, heavier sand and coarse silt particles are deposited in the upper end of the lake while finer silts and clay particles tend to be carried further into the lake.

A sedimentation survey is a measure of the rate of volume and/or depth loss of the reservoir. The sedimentation survey provides detailed information on distribution patterns of sediment within the lake as well as temporal changes in overall sedimentation rates.

Acknowledgments

The project was funded by a grant from the Illinois Clean Lakes Program to The Morton Arboretum. David Pott of Harza Engineering was the project manager. Pat Kelsey of The Morton Arboretum provided invaluable background information and assisted with site access and equipment storage.

The views expressed in this report are those of the authors and do not necessarily reflect the views of the sponsor or the Illinois State Water Survey.

This project was conducted by the authors as part of their regular duties at the Illinois State Water Survey under the administrative guidance of Derek Winstanley, Chief, and Nani G. Bhowmik, Head of the Watershed Science Section. Susan Shaw and Amy Russell assisted with the field data collection. Yi Han analyzed the sediment samples. Richard Allgire and William Saylor provided technical review. Eva Kingston edited the report.

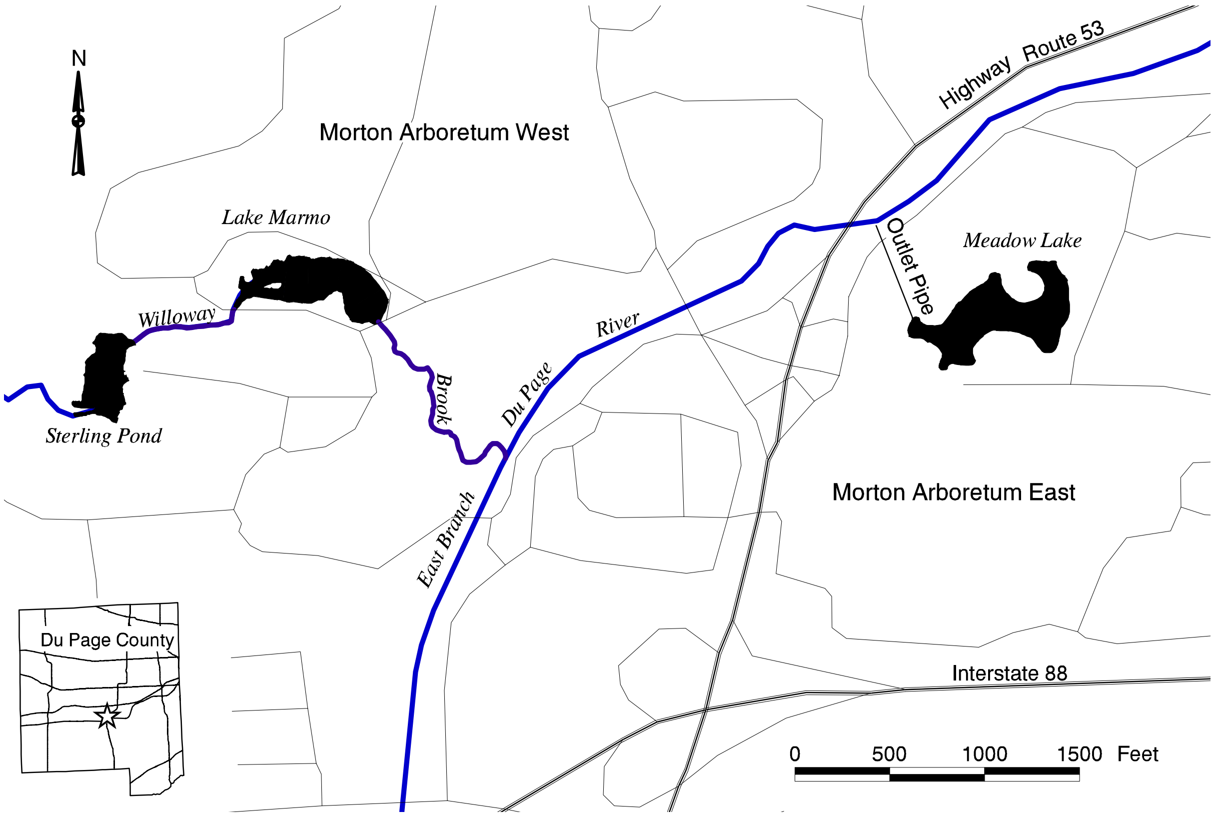


Figure 1. Location map for The Morton Arboretum and the lakes

Lake and Watershed Information

The lakes included in this study are Meadow Lake, Lake Marmo, and Sterling Pond. They are located on the grounds of The Morton Arboretum, which is located one mile north of Lisle, Illinois, in Du Page County (figure 1). The primary outlet of each lake is located as follows:

Meadow Lake	Latitude	41° 49’ 01”	Longitude	88° 04’ 06”
Lake Marmo	Latitude	41° 49’ 05”	Longitude	88° 04’ 41”
Sterling Pond	Latitude	41° 49’ 05”	Longitude	88° 05’ 00”

History

The Morton Arboretum was formally established on December 14, 1922, by Mr. Joy Morton (1855-1934), founder of the Morton Salt Company. The mission of The Morton Arboretum is:

> To collect and study trees, shrubs, and other plants from around the world, to display them across naturally beautiful landscapes, and to learn how to grow them in ways that enhance our environment. Our goal is to encourage the planting and conservation of trees and other plants for a greener, healthier, and more beautiful world (Morton Arboretum Web page).

The original grounds of the Arboretum were the estate of Joy Morton. The present grounds cover 1,700 acres and serve as a botanical garden, specializing in the display and study of trees, shrubs, and vines. More than 30,000 plants, representing 3,600 different types of plants from around the world are included in the collection. The Arboretum's staff perform both research and service activities (Morton Arboretum Web page).

The three lakes included in this study were formed as sources of borrow material for a variety of construction projects either on the Arboretum grounds or for the local road system. Lake Marmo was dug in 1920-1921 and allowed to fill with water in 1922. Meadow Lake was constructed from 1958 to 1960 and filled in 1960. Sterling Pond was dug and filled in 1963 (personal communication, Pat Kelsey, March 15, 1999). There is no documentation available to indicate that the lakes have ever been dredged or modified with the exception of limited efforts at bank reshaping. Lake Marmo may have had small volumes of sediment removed on two occasions.

Construction of Sterling Pond and Lake Marmo included excavation combined with the installation of a stabilized, concrete spillway outlet.

Watersheds

The watershed area of Meadow Lake is very limited. The lake receives no defined streams and the extent of the surface inflow is dispersed flow down the banks of the lake. The outflow conduit from the lake to the East Branch of the Du Page River is a corrugated metal pipe passing under the parking lot from the west lobe of the lake. Due to the limited drainage area of the lake, this outlet rarely or never passes flow out of the lake. Instead, the outlet pipe more regularly functions as a conduit to carry less desirable river water into the lake.

Sterling Pond and Lake Marmo share the common watershed of Willoway Brook. Water from a relatively large drainage area enters the southwest corner of Sterling Pond, then passes through the lake to another section of the brook that flows into Lake Marmo. Based on the U.S. Geological Survey "Wheaton, Ill." (1993) 7.5-minute quadrangle map, the watershed of the brook entering Sterling Pond includes large portions of the Danada County Forest Preserve and two small residential neighborhoods.

Lake Sedimentation Survey

The three lakes were previously surveyed in 1978 by Arboretum staff. Sketches of hydrographic maps developed on the basis of these surveys were reviewed for the present studies.

A survey was conducted in 1998 by measuring water depths along a series of documented transects across each of the lakes. The locations of the surveyed transects are shown in figure 2 for Meadow Lake, figure 3 for Sterling Pond, and figure 4 for Lake Marmo. Plots of the surveyed transects are given in Appendix I. None of the lakes were at the reference (spillway) elevation at the time of survey. In the plots for appendix I, the bank slopes at Meadow Lake have been

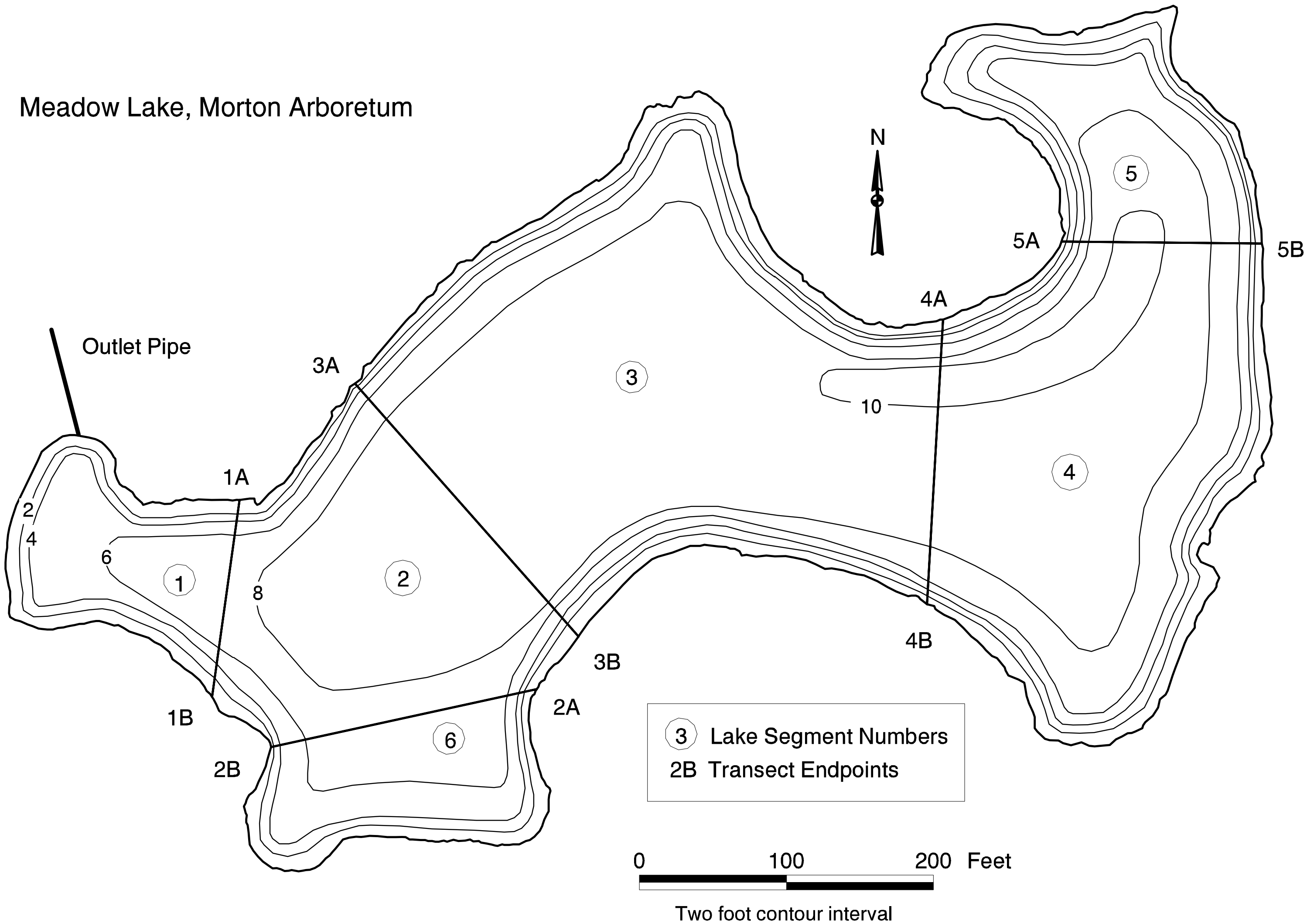


Figure 2. Meadow Lake cross-section lines and bathymetry

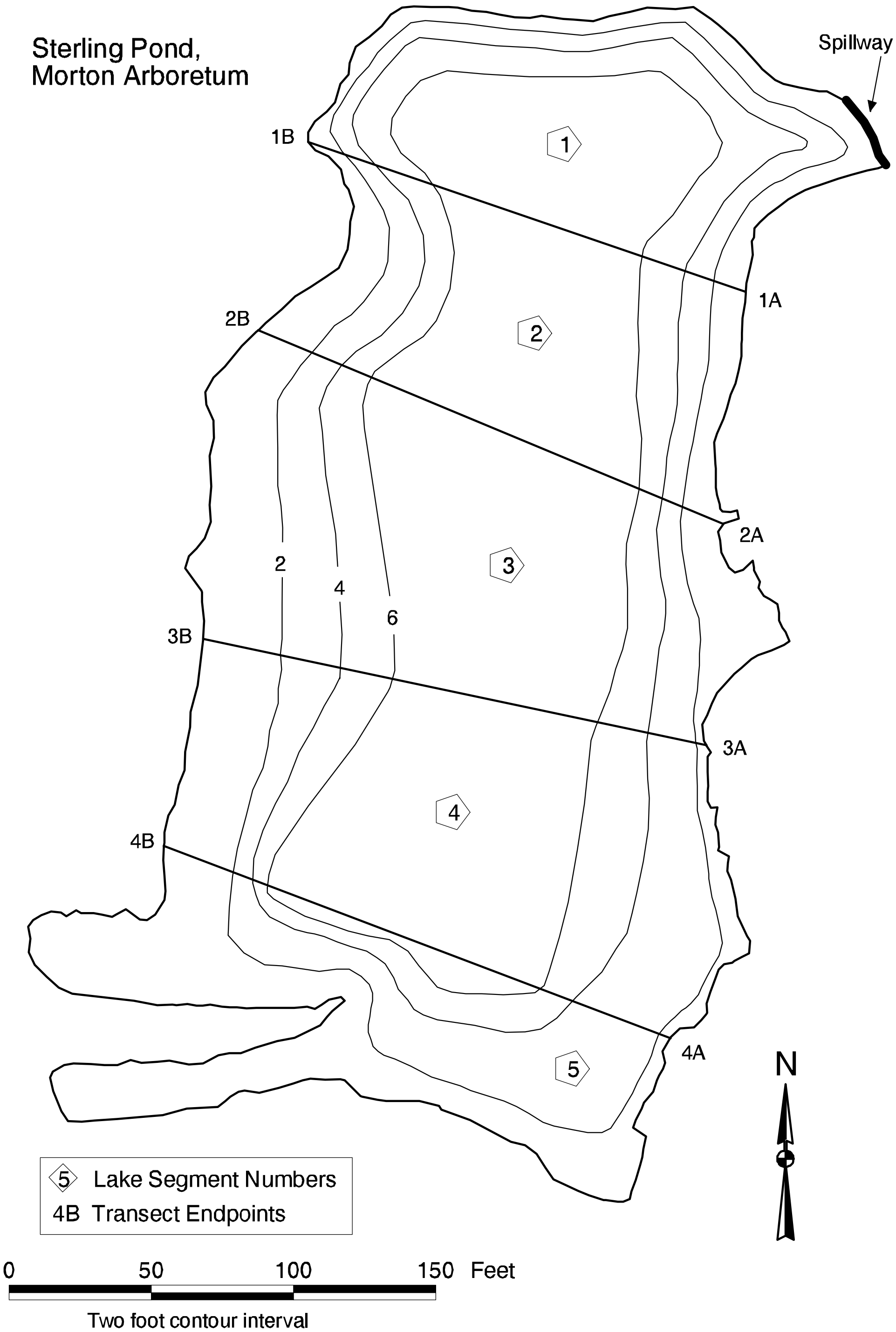


Figure 3. Sterling Pond cross-section lines and bathymetry

Lake Marmo, Morton Arboretum

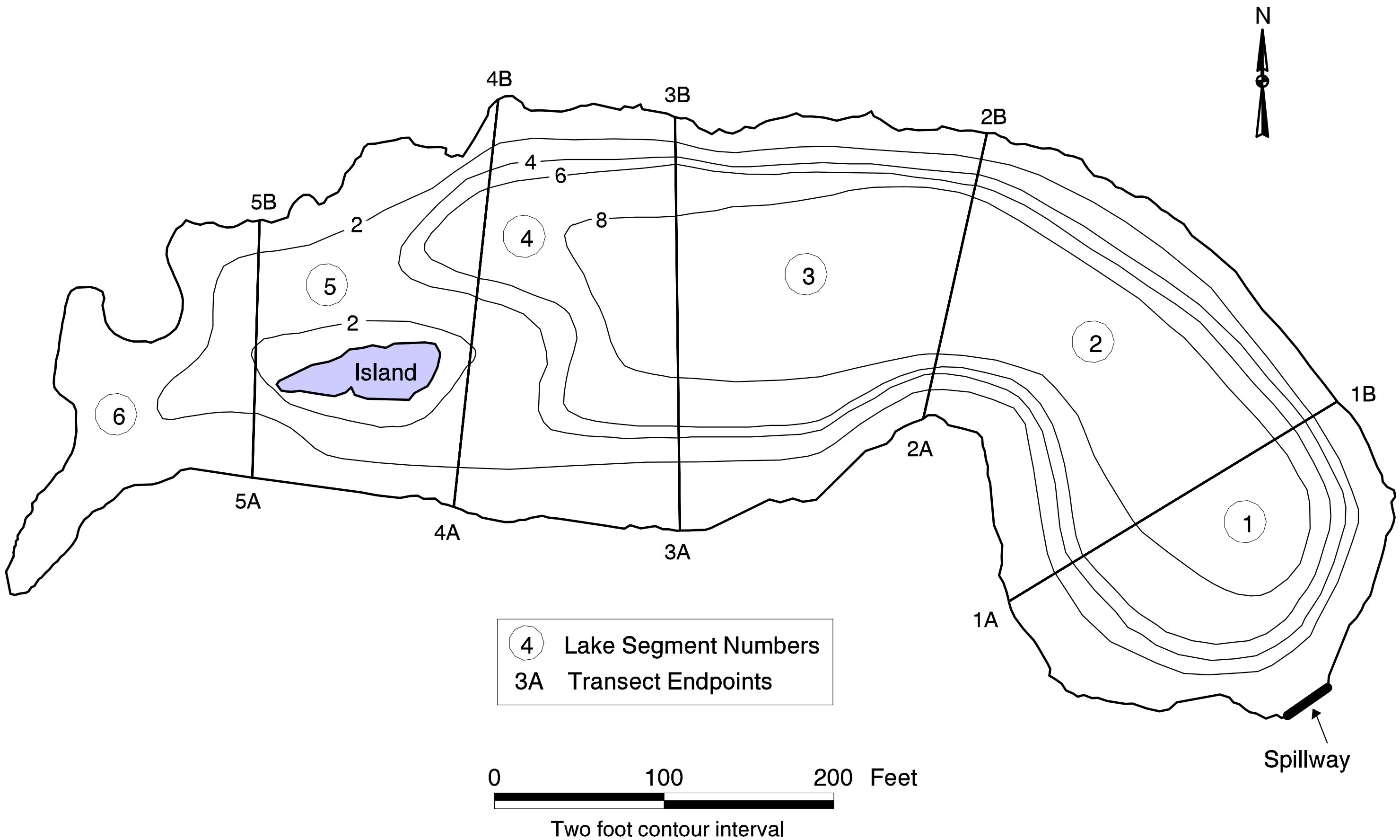


Figure 4. Lake Marmo cross-section lines and bathymetry

extended from a low pool level at the time of survey to close at the water normal reference pool level. The plots for Sterling Pond and Lake Marmo show an extension above the reference level because the lakes were slightly above the spillway level at the time of survey.

For the field measurements, a 2-inch diameter sounding pole with a sliding shoe on the pole end was used for all depth measurements. During a measurement, the sliding sounding shoe rests on the surface of the soft surficial lake sediments, improving the accuracy of the water depth measurements. Following the water depth measurement, the pole is pressed down through the accumulated sediments to a point of resistance that is presumed to be the original lake bottom surface. A calibrated polyethylene cable was used for horizontal control. Transect ends were documented for future reference using a Global Positioning System (GPS). The GPS positions were differentially corrected using RTCM correction signals broadcast by the U.S. Coast Guard from St. Louis, Missouri, or Rock Island, Illinois.

Lake Basin Volumes

Calculations of the lake capacities were made using an average end area analysis. The reference elevation for each lake was the lowest controlled outlet level: the bottom of the outlet pipe in Meadow Lake and the top of the spillway crest of Lake Marmo and Sterling Pond.

The lake volumes presented in table 1 represent the capacity of the lakes below the reference spillway elevation.

The loss of capacity, in percent, is the best indicator of the sedimentation condition of the lakes. These conditions vary considerably due to distinct inflow source conditions for each lake. Meadow Lake has lost 10 percent of its original capacity and is in good condition. Sterling Pond, on the other extreme, has lost 51 percent of its original capacity and has been severely impacted by sedimentation. Lake Marmo has lost 29 percent of its original capacity and has been moderately impacted.

The 1998 water depths for the lakes were used to generate the bathymetric maps in figures 2-4 as well as the volume distribution curve data in figure 5. Figure 5 can be used to determine the portion of the capacity of each lake that is below a given stage elevation.

Sedimentation Rates

Sedimentation rates for The Morton Arboretum lakes were analyzed in terms of accumulation rate in the reservoir. The in-lake accumulation rate provides a means of extrapolating future lake conditions from past and present lake conditions in order to evaluate the integrity of the lake as a resource.

The rates for The Morton Arboretum lakes are given in table 2 for the periods 1960-1998 for Meadow Lake, 1963-1998 for Sterling Pond, and 1922-1998 for Lake Marmo.

Table 1. Volume, Volume Loss, and Sediment Tonnage Summary

Meadow Lake

Segment	*Water volume (acre-feet)*	*Sediment volume (acre-feet)*	*Original volume (acre-feet)*	*Loss of volume (percent)*	*Water depth (feet)*	*Sediment depth (feet)*	*Deposited Sediment (tons)*
1	2.07	0.34	2.42	14.2	5.5	0.9	224
2	5.28	0.62	5.90	10.5	6.4	0.8	405
3	12.83	1.40	14.24	9.8	6.7	0.7	916
4	10.20	1.08	11.28	9.6	7.4	0.8	707
5	3.75	0.42	4.17	10.0	7.3	0.8	273
6	2.67	0.22	2.89	7.7	6.9	0.6	146
Total	36.81	4.09	40.89				2,670
Averages				10.0	6.8	0.8	

Sterling Pond

Segment	*Water volume (acre-feet)*	*Sediment volume (acre-feet)*	*Original volume (acre-feet)*	*Loss of volume (percent)*	*Water depth (feet)*	*Sediment depth (feet)*	*Deposited Sediment (tons)*
1	1.82	1.62	3.44	47.1	5.2	4.6	1,596
2	1.71	1.56	3.27	47.8	5.2	4.7	1,481
3	2.54	2.66	5.20	51.2	4.8	5.1	2,413
4	2.35	2.69	5.03	53.4	4.6	5.3	2,649
5	1.72	1.93	3.65	52.8	4.8	5.4	1,901
Total	10.13	10.46	20.59				10,041
Averages				50.8	4.8	5.0	

Lake Marmo

Segment	*Water volume (acre-feet)*	*Sediment volume (acre-feet)*	*Original volume (acre-feet)*	*Loss of volume (percent)*	*Water depth (feet)*	*Sediment depth (feet)*	*Deposited Sediment (tons)*
1	3.68	1.15	4.82	23.8	6.4	2.0	789
2	5.54	1.77	7.31	24.2	6.6	2.1	1,366
3	5.16	1.80	6.96	25.9	6.5	2.3	1,393
4	3.30	1.46	4.76	30.7	4.9	2.2	966
5	1.43	0.99	2.42	41.0	3.1	2.1	851
6	0.75	0.82	1.57	52.0	2.1	2.3	702
Total	19.85	7.98	27.84				6,068
Averages				28.7	5.4	2.2	

Note:
Surface areas are 5.4 acres (Meadow Lake), 2.1 acres (Sterling Pond), and 3.7 acres (Lake Marmo).

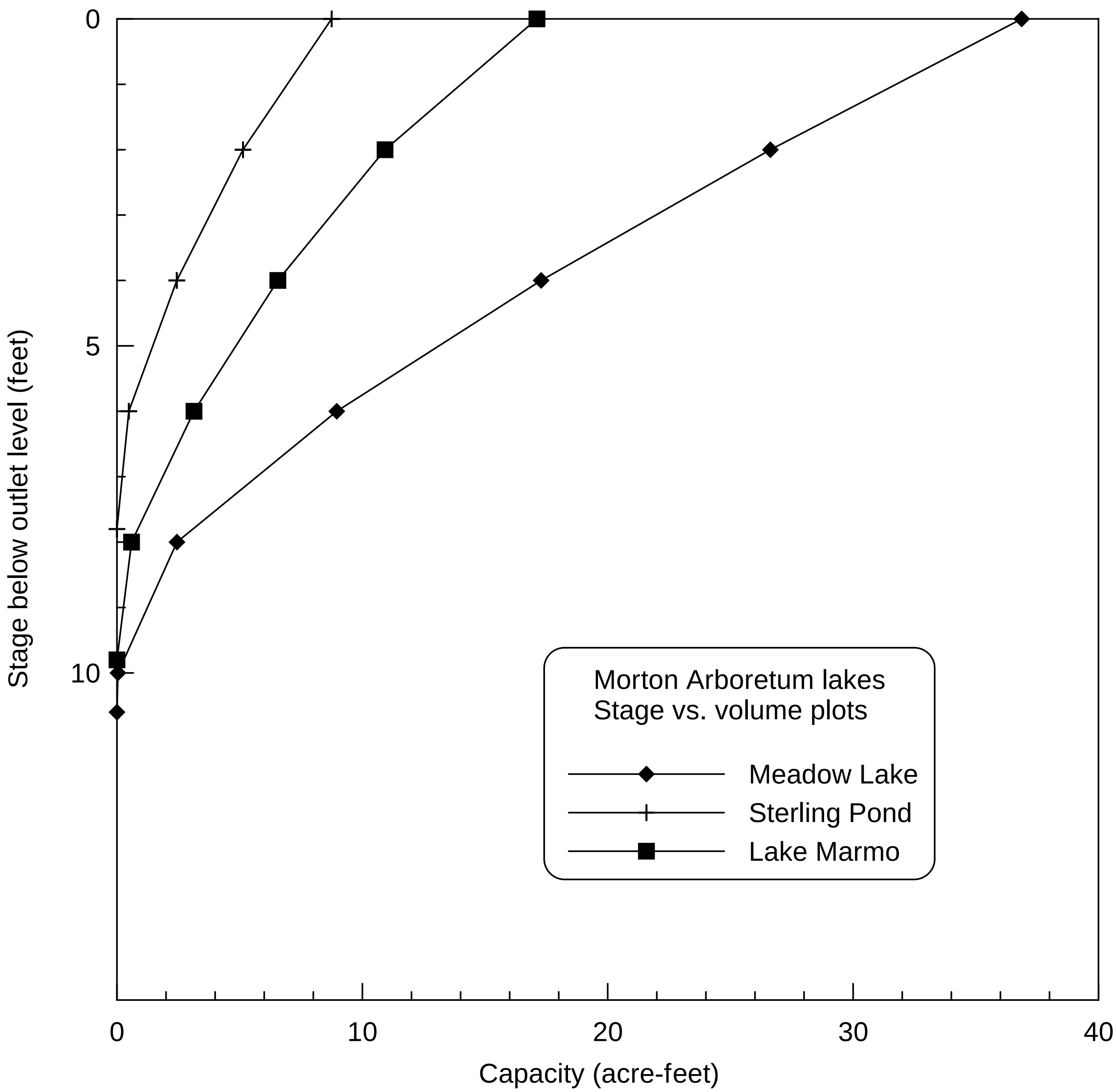


Figure 5. Stage vs. volume relationship

Table 2. Sedimentation Rate Analysis for Morton Arboretum Lakes

Lake	*Construction date*	*Age (years)*	*Accumulated sediment volume (acre-feet)*	*Loss of volume (percent)*	*Deposited sediment (tons)*	*Sedimentation rate (acre-feet/year)*	*Volume loss rate (percent/year)*	*Sediment deposition rates (tons per year)*
Meadow Lake	1960	39	4.09	10.0	2,670	0.10	0.26	68.5
Sterling Pond	1963	36	10.46	50.8	10,041	0.29	1.41	278.9
Lake Marmo	1922	77	7.98	28.7	6,068	0.10	0.37	78.8

Note:
Sedimentation rates are for the following periods: 1960-1998 (Meadow Lake), 1963-1998 (Sterling Pond), and 1922-1998 (Lake Marmo).

These rates indicate that of the three lakes, the sedimentation at Sterling Pond has been the most severe. Over the 36-year life of the lake, on average, over 1.4 percent of the original lake volume has been lost each year.

A brief analysis was made to compare the available results from the 1978 depth survey to those of the present study. The survey methods and plan used for the 1978 survey were not available for this analysis. The sketches of the lakes differ significantly from the plots presented for the present study and only the drawing for Lake Marmo contains a reference to the spillway as a reference lake level.

The 1978 drawing of Meadow Lake closely approximates the shape of the lake at present. However, shallower depths indicated on the drawing suggest that the water depths were not adjusted to the elevation of the outlet pipe (or a lower outlet was used at that time).

The 1978 drawing of Sterling Pond poorly represents the present shape of the lake. The identification of an island rather than the peninsula that currently exists along the left bank of Willoway Brook as it enters the lake suggests that the water level was slightly higher in 1978.

Lake Marmo most closely approximates the present shape of the lake, and the spillway structure has not changed since 1978.

Due to the concern about the accuracy of the shapes of the lakes from the 1978 drawings, an average depth analysis of the lakes was constructed to compare the two surveys. The results of this analysis are presented in table 3. Due to uncertainty of the reference elevations for the 1978 survey this analysis could not be completed for Meadow Lake and is somewhat questionable for Sterling Pond. On the basis of the analysis presented in table 3, the sedimentation rates for Sterling Pond and Lake Marmo have been higher during the last 20-year period than they had been prior to 1978.

The analysis presented in table 3 is supplemental to the results of the 1998 survey as presented in table 2. The values of table 2 should be used rather than those presented in table 3.

Factors Impacting Lake Sedimentation Rates

Sedimentation rates in a lake can vary over time due to changes in either watershed or in-lake conditions. Watershed conditions that affect the sediment delivery rates to the lake can vary over time and include precipitation patterns, streamflow variability, and changes in land use patterns. In-lake conditions that also affect the sedimentation rate involve the variation of reduced trap efficiency (due to reduced storage capacity) and sediment consolidation.

Of these watershed conditions that may alter sedimentation rates, altered land use patterns are likely sources of changes in the sedimentation rates for Lake Marmo and Sterling Pond but not on Meadow Lake. Residential development has occurred at a rapid pace in the suburban Chicago area since the 1940s. For the Willoway Brook watershed, most residential development occurred after 1965.

Table 3. Comparison of 1978 and 1998 Depth Conditions for The Morton Arboretum Lakes

Year	*Listed Surface Area (acres)*	*Calculated volume (ac-ft)*	*Average depth (feet)*	*Annual loss of depth (feet)*
Meadow Lake				
1960	5.4	40.9	7.6	
1978	4.9	29.6	6.0	
1998	5.4	36.8	6.8	0.02
Sterling Pond				
1963	2.1	20.6	9.8	
1978	2.7	21.6	8.0	0.12
1998	2.1	10.1	4.8	0.16
Lake Marmo				
1922	3.7	27.8	7.5	
1978	3.7	25.7	7.0	0.01
1998	3.7	19.8	5.4	0.08

Note: Date of construction values are based on the 1998 survey results.
Annual rate of loss was calculated from the date of previous survey.
Meadow Lake 1978 annual loss was not calculated.

Lakeshore erosion is another factor that is contributing to sedimentation rates. While shoreline erosion is generally perceived as a purely aesthetic concern, it can be a significant factor in lake sedimentation. Each of the lakes exhibited some areas of bank failure through both direct erosion and slumping. Meadow Lake is least impacted by sedimentation but appeared to exhibit the most bank erosion.

Sediment Deposition Distribution

The distribution of sediment in the lakes is shown in table 1. Sediment thickness ranges from less than 1 foot in Meadow Lake to more than 5 feet in Sterling Pond. The distribution of sediment is very even in each lake although Sterling Pond does show a slight reduction in sediment thickness from the south end to the north end, or upstream to downstream. This distribution pattern is normal for an impounded lake.

The weight of sediment accumulated in the lakes was determined by multiplying the sediment volume determined previously by the dry unit weight of the sediment samples. Field samples for sediment unit weight were collected for Lake Marmo and Sterling Pond. The laboratory results for these samples are presented in appendix II. No unit weight samples could be collected at Meadow Lake due to the loose character of the sediments. Based on samples collected for Lake Marmo and Sterling Pond, the unit weight of sediments for Meadow Lake was estimated to be 30 pounds per cubic foot. For Lake Marmo and Sterling Pond, the average sediment unit weights were 35 and 44 pounds per cubic foot, respectively.

These sediment unit weights are based on an in-situ volume to weight relationship. As these materials accumulate on the lake bottom, they form a loose mix of sediment, organic material, and water. The low unit weights associated with these sediments are a result of high void ratio and organic content. Other sites in Illinois have had unit weights less than 20 pounds per cubic foot in highly organic sediments and greater than 60 pounds per cubic foot in sediments that were coarse materials or consolidated by frequent water level drawdown. Unit weight values in the 35 to 45 pound per cubic foot range are most common.

This analysis found that 2,670 tons of sediment had accumulated in Meadow Lake, 6,068 tons in Lake Marmo, and 10,041 tons in Sterling Pond (table 1).

Sediment Grain Size Distribution

A total of 12 lakebed sediment samples were collected for particle size distribution analysis (figure 6). Field examination of these samples indicated that only one sample contained apparent sand size material. This sample was collected in Meadow Lake adjacent to the outlet pipe to the East Branch of the Du Page River. The laboratory analysis of this sample as shown in figure 6a is indicative of the likely significance of inflowing water from the river on the sedimentation of Meadow Lake. All other sediment samples collected at Meadow Lake were wholly composed of fine silt and clay size materials.

Particle size plots for sediments from Sterling Pond are shown in figure 6b, and the results of the laboratory analyses for these samples are included in appendix III. These samples indicate a very uniform consistency in the surface sediments of the lake. The single core sediment sample is distinctly different than the surface sediment samples. This core sample (shown with the square symbol in figure 6b) indicates that significantly finer sediments were more typical during earlier sediment accumulation. The fact that coarser materials have accumulated in more recent times may be a factor of natural variation in streamflow and sediment transport or the reduced trap efficiency of the lake. It may also be indicative of a change in the character of the sediment supply due to some alteration to the stream channel or watershed.

Particle size plots for Lake Marmo are shown in figure 6c. Once again, the surficial sediments are of uniform size, but the core sample analysis indicates that somewhat finer sediments were deposited during earlier sediment accumulation periods.

Evaluation and Comparison to Other Illinois Lakes

The sedimentation rates for The Morton Arboretum lakes are similar to the rates for other Illinois lakes of similar size and character. Table 4 presents comparative data for other lakes of less than 10 acres surface area from the Water Survey’s lake sedimentation files and for The Morton Arboretum lakes. The sedimentation rate for Sterling Pond is slightly higher than those

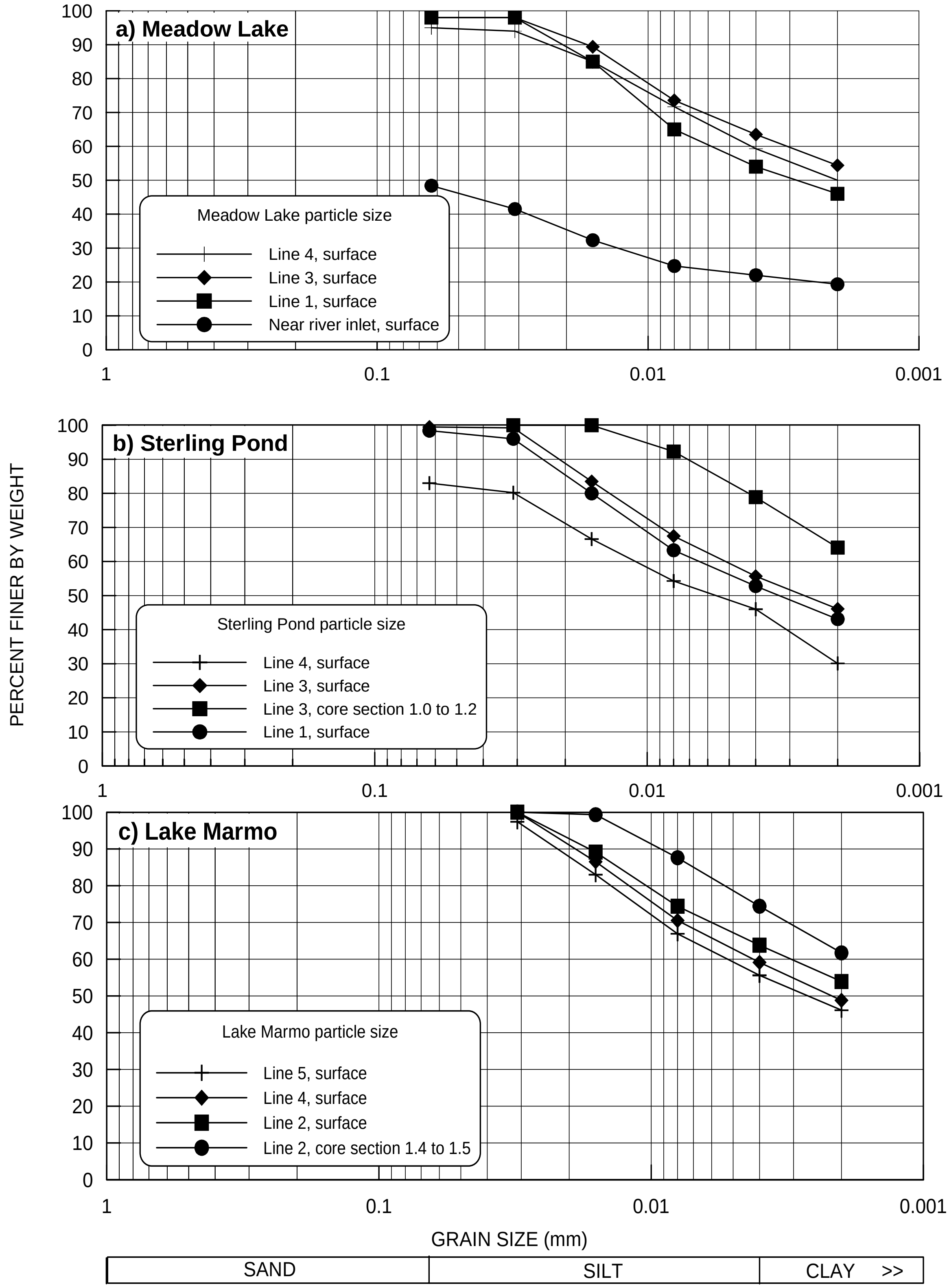


Figure 6. Sediment particle size analyses

Table 4. Comparison of The Morton Arboretum Lakes and Other Illinois Lakes

Lake	*County*	*As-built capacity (ac-ft)*	*Surveyed capacity (ac-ft)*	*Age (years)*	*Annual rate of volume loss (percent)*
Astoria Reservoir	Fulton	67.2	33.1	38	1.34
Farina Lake	Fayette	16.4	13.4	30	0.61
Maynard Lake	Champaign	6.15 feet	4.97 feet	25	0.77
Indian Lake	Cook	26.4	25.2	21	0.24
Meadow Lake	Du Page	40.9	36.8	39	0.26
Sterling Pond	Du Page	20.6	10.1	36	1.41
Lake Marmo	Du Page	27.8	19.9	77	0.37

Note: The Maynard Lake survey was not a volumetric survey. Survey results and all analyses were given in terms of the average of all measured depths.

of the other lakes but the rates for Meadow Lake and Lake Marmo are slightly lower than for most other lakes.

Both the Astoria and the Farina watersheds are rural watersheds, and the Maynard Lake watershed is an urban subdivision watershed. The Astoria and Farina surveys were conducted around 1960 and the Maynard Lake survey in 1985. Indian Lake is on the grounds of Brookfield Zoo, and the survey results were presented by Kirschner et al., 1997.

Future sedimentation rates will be dependant on potential land use changes in the watershed. Additional urban development in the watershed will impact Sterling Pond, in particular, during active construction periods. The county forest preserve and existing subdivisions will generally provide stable, low soil loss surfaces.

Summary

The Illinois State Water Survey conducted sedimentation surveys of three lakes at The Morton Arboretum in Lisle, Illinois. The lakes surveyed were Meadow Lake, constructed in 1960; Sterling Pond, constructed in 1963; and Lake Marmo, constructed in 1922. The lakes serve as visual accent points for the grounds.

Sedimentation has reduced the capacity of Meadow Lake by 10 percent, Sterling Pond by 51 percent, and Lake Marmo by 29 percent. The sediment accumulation rates in the lakes averaged 0.10 acre-feet per year for Meadow Lake, 0.29 acre-feet per year for Sterling Pond, and 0.10 acre-feet per year for Lake Marmo.

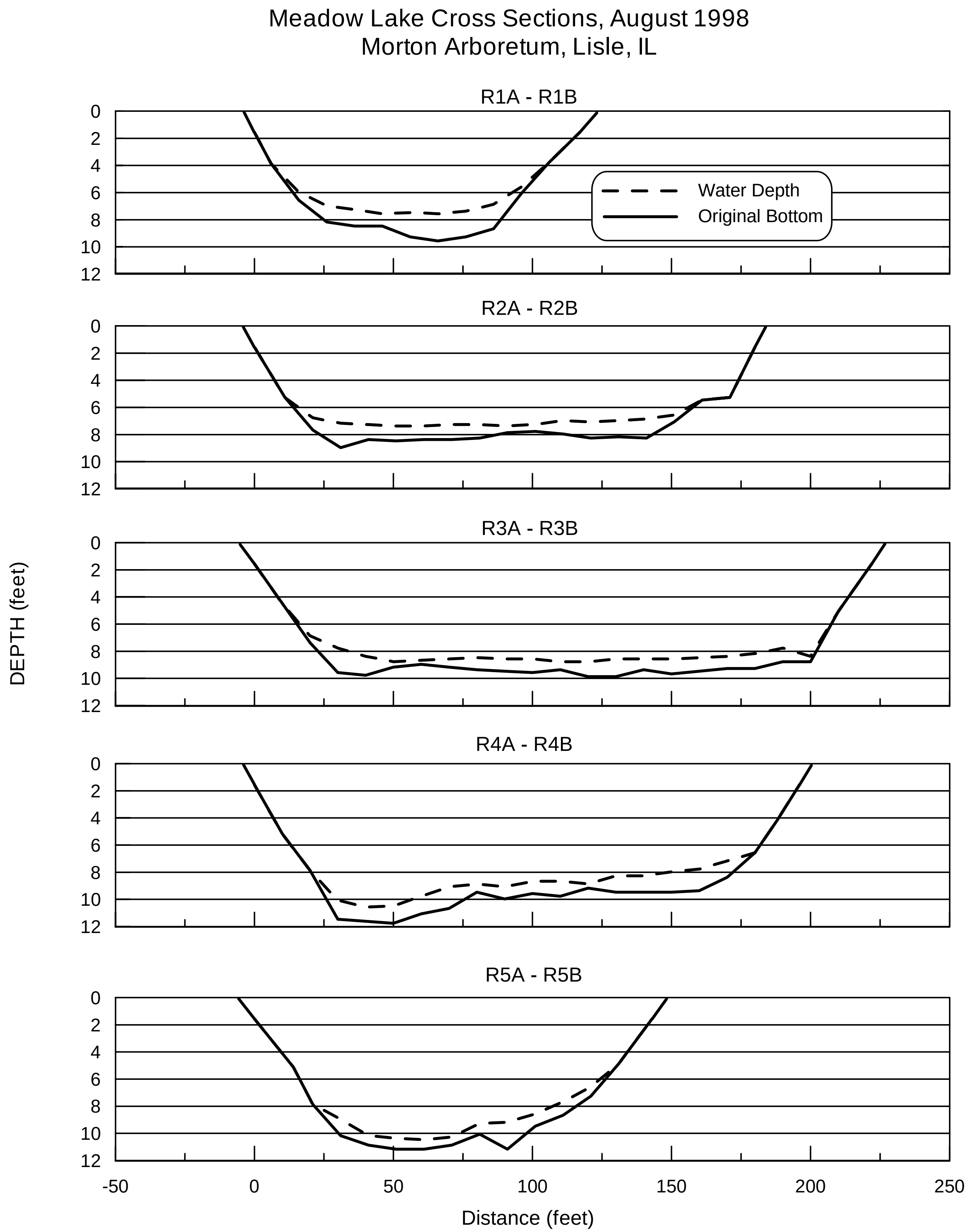
References

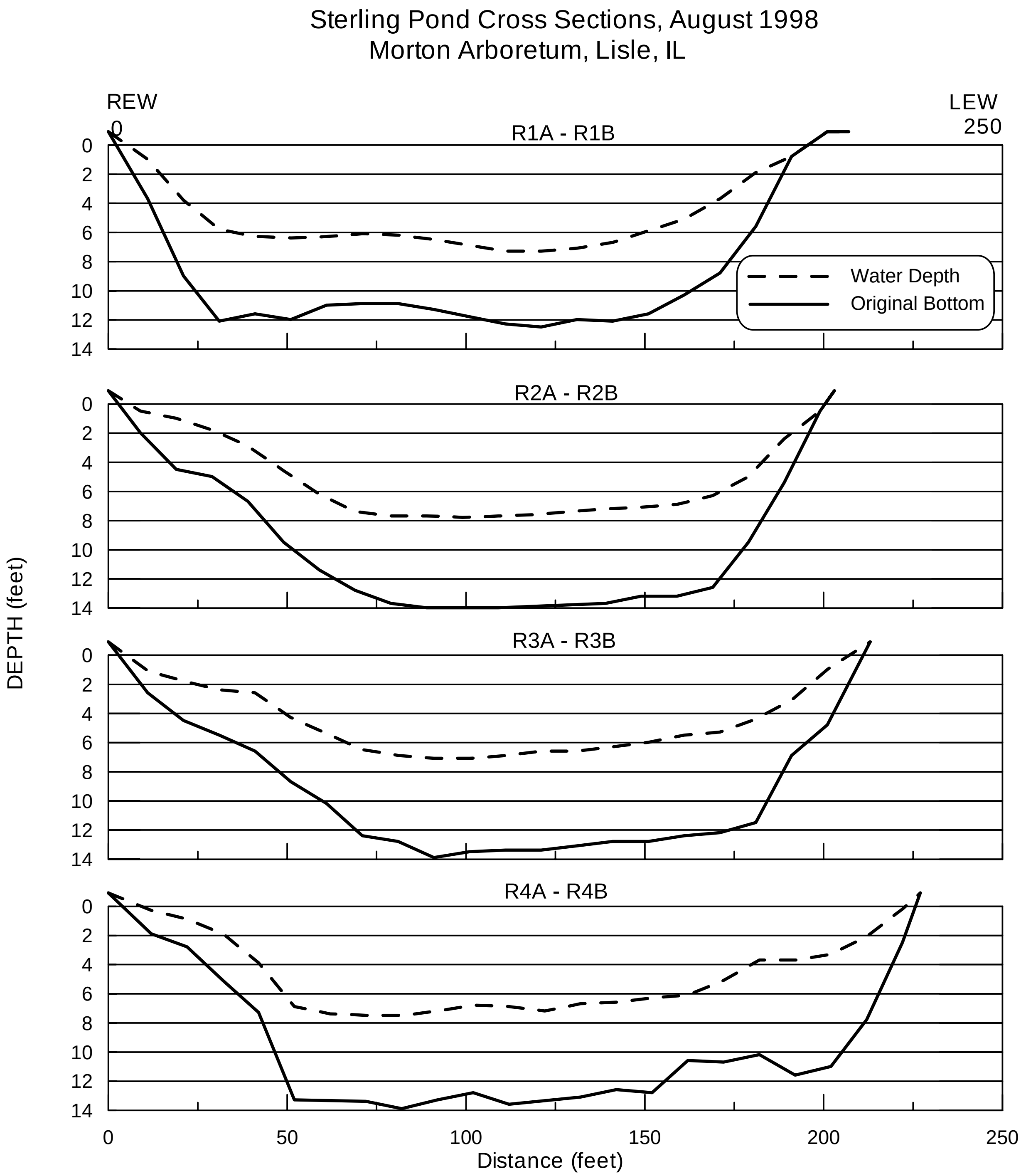
Kirschner, R.J., H.L. Hudson, M.M. Murphy, and T.H. Price. 1997. *Phase 1 Diagnostic/ Feasibility Study of Indian Lake, Brookfield Zoo, Cook County, Illinois.* Report prepared by the Northeast Illinois Planning Commission.

Morton Arboretum web page: http://www.mortonarb.org/

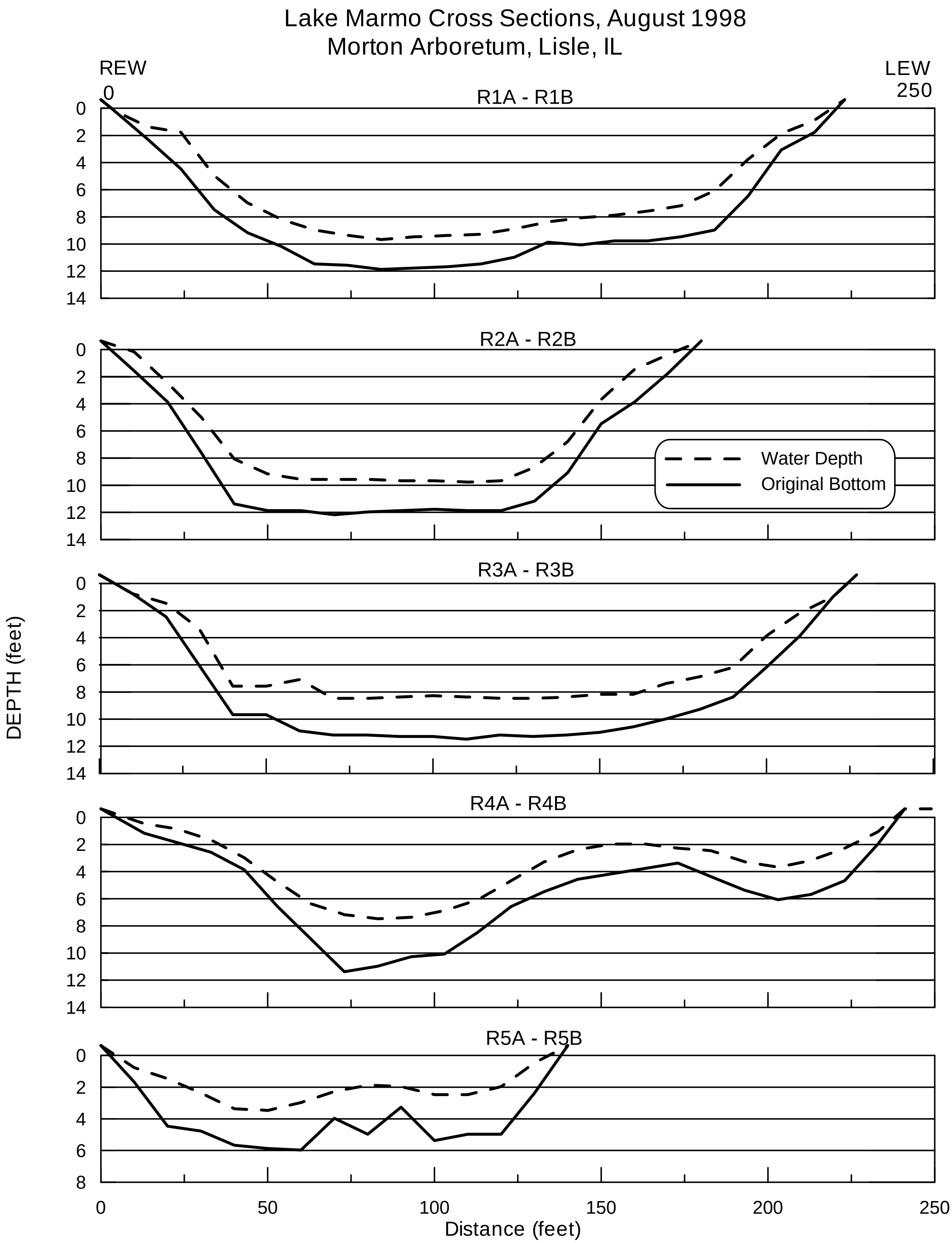
U.S. Geological Survey, 1993. Wheaton, Ill., 7.5-minute quadrangle map

Appendix I. Cross Section Plots for The Morton Arboretum Lakes


Meadow Lake Cross Sections, August 1998
Morton Arboretum, Lisle, IL
R1A - R1B
R2A - R2B
R3A - R3B
R4A - R4B
R5A - R5B
Water Depth
Original Bottom
DEPTH (feet)
Distance (feet)
0
2
4
6
8
10
12
-50
0
50
100
150
200
250



Sterling Pond Cross Sections, August 1998
Morton Arboretum, Lisle, IL
REW
0
LEW
250
R1A - R1B
R2A - R2B
R3A - R3B
R4A - R4B
Water Depth
Original Bottom
DEPTH (feet)
0
2
4
6
8
10
12
14
0
50
100
150
200
250
Distance (feet)


Lake Marmo Cross Sections, August 1998
Morton Arboretum, Lisle, IL
REW
0
LEW
250
R1A - R1B
R2A - R2B
Water Depth
Original Bottom
R3A - R3B
R4A - R4B
R5A - R5B
DEPTH (feet)
0
2
4
6
8
10
12
14
0
50
100
150
200
250
Distance (feet)

Appendix II. Laboratory Analysis of Unit Weight Samples for Lake Marmo and Sterling Pond

Sample	*Unit weight (pounds per cubic foot)*
Lake Marmo	
Unit weight 2	39.4
Unit weight 4	30.4
Unit weight 6	31.6
Unit weight 7	39.4
Sterling Pond	
Unit weight 10	40.7
Unit weight 12	41.7
Unit weight 15	45.3

Note: No samples were collected for Meadow Lake

Appendix III. Sediment Particle Size Distribution Sample Results for Meadow Lake, Sterling Pond, and Lake Marmo

Particle size (millimeters)	*Meadow 1*	*Meadow 2*	*Meadow 3*	*Meadow 4*
		Percent of sample finer		
0.063	95.0	98.0	98.0	48.4
0.031	94.0	98.0	98.0	41.5
0.016	85.0	89.4	85.0	32.3
0.008	71.7	73.6	65.0	24.7
0.004	59.3	63.5	54.0	22.0
0.002	50.0	54.4	46.0	19.3

Particle size (millimeters)	*Sterling 9*	*Sterling 11*	*Sterling 13*	*Sterling 14*
		Percent of sample finer		
0.063	83.0	99.5		98.4
0.031	80.2	99.2	100.0	96.0
0.016	66.6	83.5	100.0	80.0
0.008	54.3	67.5	92.3	63.3
0.004	46.0	55.7	78.9	52.8
0.002	30.1	46.1	64.1	43.1

Particle size (millimeters)	*Marmo 1*	*Marmo 3*	*Marmo 5*	*Marmo 8*
		Percent of sample finer		
0.063				
0.031	97.4	100.0	100.0	100.0
0.016	83.0	86.5	89.1	99.3
0.008	66.9	70.5	74.4	87.6
0.004	55.6	59.1	63.8	74.4
0.002	46.1	48.8	53.9	61.7

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