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BATHYMETRIC AND SEDIMENT THICKNESS ANALYSIS OF SEVEN LAKES IN THE UPPER OKLAWAHA RIVER BASIN

PROJECT 90G149

Prepared for:

ST. JOHNS RIVER WATER MANAGEMENT DISTRICT
Palatka, Florida

Prepared by:

Larry J. Danek, Theresa A. Barnard,
and Michael S. Tomlinson

ECT
Environmental Consulting & Technology, Inc.
Gainesville, Florida

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EXECUTIVE SUMMARY

A bathymetric and sediment thickness survey was conducted on seven lakes in the Upper Oklawaha River Basin (UORB) in November and December 1990. The lakes that were surveyed included Lake Beauclair, Lake Dora, Lake Eustis, Lake Griffin, Lake Harris, Lake Weir, and Lake Yale. The bathymetric portion of the study was conducted using an Innerspace model 448 fathometer, a Del Norte model 540 precision microwave navigation system, and an onboard computer for data logging and navigation. For sediment thickness surveys, a second vessel was equipped with LORAN-C navigation and a sediment piston corer for measuring sediment thickness. For deeper sediments [greater than 6 to 10 feet (ft) thick] a sediment-penetrating rod was used to measure sediment thickness.

The surveys were conducted along a 1,000-ft grid on each lake. Additional depth readings between grid points were added to the database in areas where rapid changes in the depth occurred. A total of 3,093 depth readings and 2,190 sediment thickness measurements were processed. The data were calibrated, corrected for water level variations during the survey, and plotted and contoured to produce bathymetric and sediment thickness maps. The data were further processed using ARC/INFO to produce hypsographic curves relating lake water level to lake volume and surface area. The sediment data were used to produce curves relating sediment volume and surface area to sediment thickness in each lake.

The calculated lake water volumes varied from a low value in Lake Beauclair of 0.319×10^9 cubic ft (ft^3) to a high in Lake Harris of 9.781×10^9 ft^3. The average depth in the lakes varied from 18.9 ft for Lake Weir to 6.7 ft for Lake Beauclair. The deepest points observed were 31.7 ft in Lake Harris and 31.9 ft in Lake Weir. The surface areas in the lakes varied from 47.3×10^6 square ft (ft^2) for Lake Beauclair to 814.1×10^6 ft^2 for Lake Harris and Little Lake Harris. The depth values and lake volumes reported assume that the top of the flocculent layer is the lake bottom and do not account for interstitial water in the flocculent sediments.

The soft sediments were generally thickest near the central basins with a perimeter of exposed sand bottom between the soft sediments and the shoreline. The average thickness of the soft sediments varied between 4.68 ft for Lake Dora and 8.59 ft for Lake Harris. Lake Harris contained the largest volume of soft sediments with 6.797 x 10^9 ft^3 which covered 96.8 percent of the bottom. The thickest soft sediments were also recorded in Lake Harris with a sediment thickness of 29 ft. All of the lakes had areas where the sediments exceeded 15 ft thick except Lake Weir, where the maximum thickness was 12.5 ft. The total volume of soft sediment calculated for the seven lakes (excluding connecting waterways, adjacent bays, marshes, etc.) is 13.90 x 10^9 ft^3 as compared to the total water volume in the lakes of 25.77 x 10^9 ft^3.

The following table summarizes the bathymetric and sediment data collected for each of the seven lakes.

Lake	Surface Area (ft^2 x 10^9)	Water Volume (ft^3 x 10^9)	Mean Water Depth	Sediment Area (ft^2 x 10^9)	Sediment Volume (ft^3 x 10^9)	Mean Sediment Depth	% Sediment Cover
Beauclair	0.0473	0.3187	6.73	0.0353	0.1836	5.20	75.09
Dora	0.1910	1.8814	9.85	0.1623	0.7598	4.68	85.00
Eustis	0.3379	3.8337	11.34	0.3143	2.0967	6.67	93.01
Griffin	0.4100	3.1752	7.74	0.3920	2.2521	5.75	95.60
Harris	0.8141	9.7810	12.01	0.7881	6.7972	8.59	96.81
Weir	0.2449	4.6384	18.94	0.1796	0.8491	4.72	73.32
Yale	0.1751	2.1441	12.25	0.1557	0.9632	6.19	88.91

Source: ECT, 1991.

1.0 INTRODUCTION

The Upper Oklawaha River Basin (UORB) has been designated as a priority water body for the Surface Water Improvement Management (SWIM) program. One of the major environmental problems in the UORB is excessive nutrient levels in water bodies of the basin. Accurate measurements of the present bottom contours and sediment depths of the major lakes in the basin are necessary for calculating volume-stage-area relationships for the lakes, the nutrient loads and budgets for the lakes, and for developing strategies for lake restoration.

The present study investigates seven lakes of the UORB that include:

Lake	Surface Area (sq. miles)	Location (Latitude, Longitude)
Lake Beauclair	1.7	28°46′24", 81°39′44"
Lake Dora	6.9	28°47′46", 81°38′39"
Lake Eustis	12.1	28°51′06", 81°41′29"
Lake Griffin	14.7	28°51′48", 81°51′31"
Lake Harris and Little Lake Harris	29.2	28°48′14", 81°52′24"
Lake Yale	6.3	28°52′52", 81°42′21"
Lake Weir	8.8	29°02′23", 81°55′44"

These lakes all have areas with an organic flocculent substrate near the bottom and extremely soft sediments. The soft organic substrate has contributed to decreasing water quality in the lakes; various options for mitigation are being considered. An important step needed to effectively evaluate potential corrective actions is to first determine the lake volumes and the extent and distribution of sedimentation in the lakes. Consequently, the following study was conducted in November and December 1990, to provide accurate bathymetric surveys of each lake to be used to estimate lake volumes and provide relationships between lake stage, volume, and surface area. In addition, the extent of soft sediments in each lake was determined and the depths of these sediments were measured.

2.0 METHODS

The general scope of work of the study was to conduct bathymetric and sediment thickness surveys of seven UORB lakes at a 1,000-foot (ft) sampling grid. The results were used to produce bathymetric contour maps of each lake and hypsographic curves relating water elevation to lake area and volume. In addition, sediment thickness contours were developed and sediment volumes for each lake were calculated. The following sections describe the methods and materials used to complete these tasks.

2.1 FIELD METHODS

2.1.1 NAVIGATION

Two survey vessels were used to complete the field program: one equipped to conduct the bathymetric survey and a separate vessel for the sediment sampling. Navigational accuracy of ±3 meters was requested for the bathymetric survey so a Del Norte model 540 precision microwave navigation system (PMNS) was used. The system is accurate to ±1 meter and uses a vessel-mounted transceiver and at least two shore stations as shown in Figure 2-1. The navigational shore station locations were surveyed using two Trimble 4000 ST global position systems (GPSs) which (within the study area) were accurate to within 5 centimeters (cm). One GPS unit was established near a U.S. Geological Survey (USGS) monument of known coordinates. The second GPS unit was mounted at a shore station location; both locations simultaneously recorded satellite navigation signals for a minimum of 45 minutes. The procedure was repeated until 16 shore stations were surveyed in the study region as shown in Figure 2-2. The recorded satellite positioning data from the two GPS units were processed with TRIMVECT software by a Professional Land Surveyor (PLS) to provide the final coordinates for each shore station.

Two of the shore stations were established on communication towers: one on Sugarloaf Mountain and one just south of Lake Yale. These two stations provided good general coverage of the entire area. Two additional shore stations were used on each lake and relocated as needed to provide

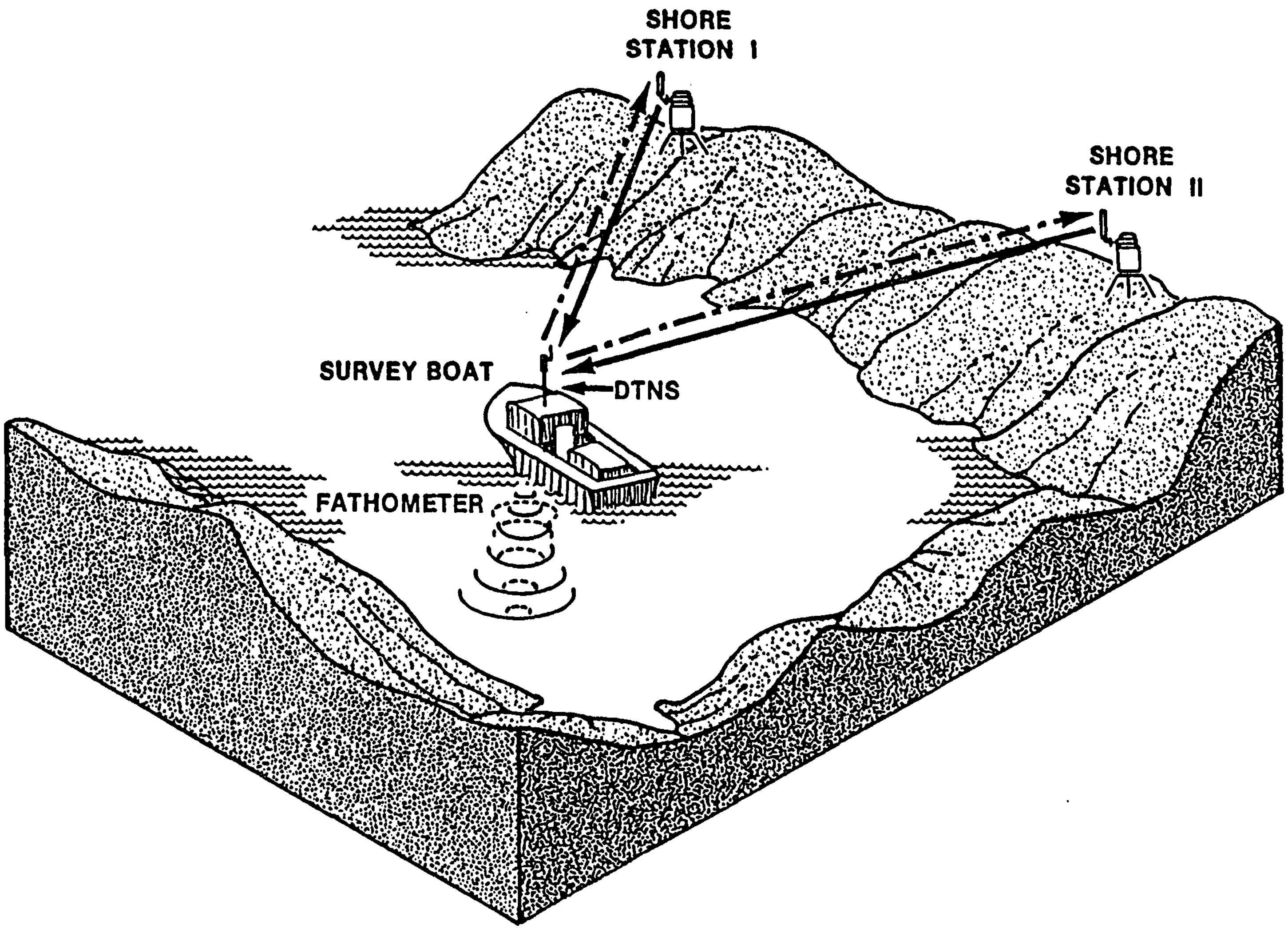

FIGURE 2-1.

PRECISION MICROWAVE NAVIGATION SYSTEM

Source: ECT, 1991.

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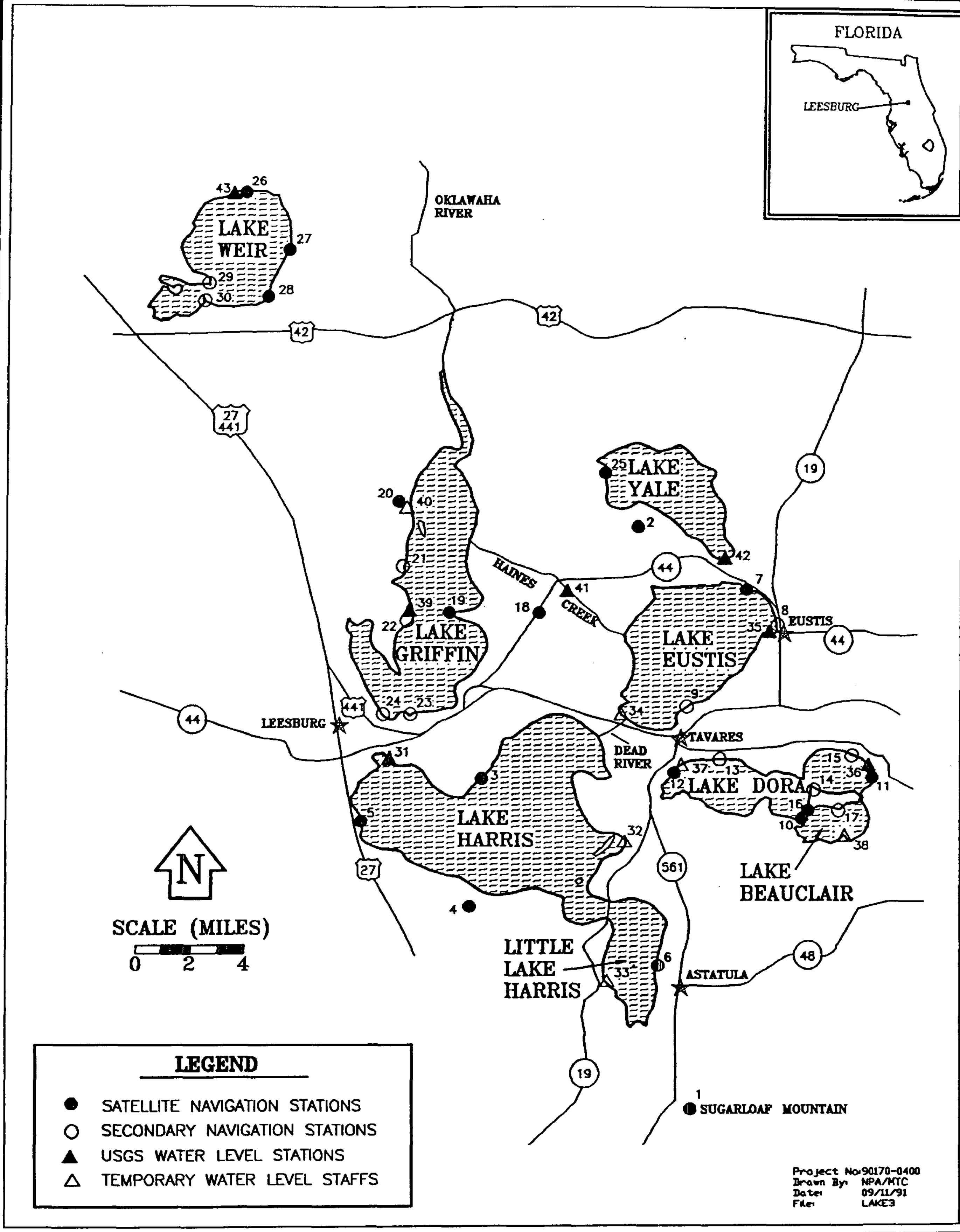

FIGURE 2-2.

BASE MAP SHOWING NAVIGATION STATIONS AND WATER LEVEL MEASUREMENT LOCATIONS

Source: ECT, 1991.

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additional coverage. The microwave system relies on *line of sight* for signal transmission; trees, hills, houses, or other obstructions will block the signals. Consequently, several shore station locations were required to provide coverage on the irregular-shaped lakes. Despite 16 established shore stations additional stations were needed because of signal blockage by trees along the shore. An additional 12 secondary shore stations were established as shown in Figure 2-2. The coordinates of the secondary stations were determined using the PMNS and previously established shore stations. The reliability of the secondary stations was diminished to ±1 meter (as compared to ±5 cm for the primary stations), but the stations still provided overall accuracy within the required ±3 meters. The shore stations and the established coordinates are provided in Table 2-1.

Despite 28 shore stations (16 primary and 12 secondary), there were still areas near shore where a minimum of two shore signals could not be received. These *blind* areas were surveyed using LORAN-C positioning (discussed below). Approximately 11 percent of the bathymetric data points were collected using LORAN-C as navigation.

The second survey vessel used for conducting the sediment thickness sampling relied on LORAN-C for navigation. LORAN-C positioning systems receive signals from permanently established stations and, consequently, no additional shore stations were required. LORAN-C, however, is only accurate to ±20 meters under optimal conditions, and frequently only accurate to ±40 meters. For the sediment sampling, an accuracy of 20 to 40 meters was acceptable. The LORAN was calibrated to a known location on each lake at the beginning of each day and checked at the end of each day to enhance the accuracy.

The bathymetric survey was completed in 5 weeks and the PMNS was dismantled. The vessel was then equipped with a LORAN-C navigation system and sediment sampling equipment, and both vessels continued sediment sampling for an additional 3 weeks.

Table 2-1. Navigation Station and Water Level Information

Location Number	Navigation Station Name	State Plane Coordinates (NAD, 1927) Northing	State Plane Coordinates (NAD, 1927) Easting	Geographic Coordinates (NAD, 1927) Lat. (N)	Geographic Coordinates (NAD, 1927) Lon. (W)
1	Sugarloaf Mountain[1]	1,569,245	264,009	28:38.93	81:44.15
2	Eichelberger Tower[1]	1,658,287	258,399	28:53.61	81:45.30
3	Biggers' Dock[1]	1,623,776	236,871	28:47.90	81:49.29
4	Deem's House[1]	1,602,067	233,859	28:44.31	81:49.83
5	Smith's Dock[1]	1,616,493	217,750	28:46.67	81:52.86
6	Richard's Dock[1]	1,595,016	260,805	28:43.18	81:44.77
7	Campbell's Dock[1]	1,649,548	276,475	28:52.19	81:41.90
8	Eustis CoC[2]	1,643,396	279,997	28:51.18	81:41.23
9	Cook's Dock[2]	1,631,975	265,773	28:49.28	81:43.89
10	Shirley Shore Offset[1]	1,615,642	284,315	28:46.60	81:40.40
11	Mt. Dora Lighthouse[1]	1,622,063	293,649	28:47.67	81:38.65
12	Tavares Homeowners, Inc.[1]	1,622,982	264,579	28:47.79	81:44.10
12	THI Offset[1]	1,622,978	264,572	28:47.79	81:44.10
13	Michels Dock[2]	1,624,698	270,594	28:48.08	81:42.98
14	Deer Island Pt.[2]	1,620,509	284,891	28:47.41	81:40.29
15	Old Page Dock[2]	1,625,836	289,677	28:48.29	81:39.18
16	Shirley Shore[2]	1,615,601	284,393	28:46.60	81:40.38
17	Beauclair N Shore[2]	1,616,350	289,300	28:46.72	81:39.46
18	Leesburg Fire Tower[1]	1,646,947	244,821	28:51.73	81:47.83
19	Treasure Island[1]	1,647,227	230,105	28:51.76	81:50.59
20	Sawyer's House[1]	1,623,749	236,848	28:47.89	81:49.30
21	Cattle Beach[2]	1,651,833	227,205	28:52.51	81:51.14
22	Fueling's Dock[2]	1,646,564	225,665	28:51.64	81:51.42
23	BG's Dock[2]	1,632,710	224,174	28:49.35	81:51.68
24	Collin's Dock[2]	1,631,720	221,350	28:49.19	81:52.21
25	Yale Baptist Retreat[1]	1,668,246	255,318	28:55.25	81:45.89
26	Moeller's Dock[1]	1,710,193	518,994	29:02.31	81:56.43
27	Ecklund's Dock[1]	1,703,648	527,649	29:01.22	81:54.81
28	Prominski's Dock[1]	1,694,457	523,929	28:59.71	81:55.51
29	Lemon Point[2]	1,696,454	515,487	29:00.04	81:57.09
30	South Point[2]	1,695,434	514,280	28:59.87	81:51.32

Location Number	Water Level Station	Gauge Type
31	Leesburg Park	USGS staff
32	Banana Cove	Temporary staff
33	Cracker's Cove	Temporary staff
34	Lake County Marina	Temporary staff
35	Eustis	USGS recording
36	Mount Dora Marina	USGS staff
37	Tavares Homeowners, Inc.	Temporary staff
38	Trimble Park	Temporary staff
39	Twin Palms Resort	USGS staff
40	Lake Griffin Resort	Temporary staff
41	Haines Creek Below Burrell Dam at Lisbon	USGS recording
42	Grand Island	USGS recording
43	Oklawaha	USGS recording

[1]Satellite navigation station.
[2]Secondary navigation station.

Source: ECT, 1991.

2.1.2 BATHYMETRIC SURVEY

The bathymetric survey of the seven UORB lakes was completed between November 1 and December 3, 1990. The data acquisition system used for the survey consisted of the PMNS (discussed in Section 2.1.1), an Innerspace model 448 fathometer, and a Toshiba 1600 lap-top personal computer (PC) with HYPACK navigational software as illustrated in Figure 2-3. The Innerspace model 448 fathometer operates at 208 kilohertz and is accurate to ±0.1 ft with 1,200 soundings per minute. The unit provides a digital signal as well as an analog graph of the depth readings. The fathometer and the PMNS were linked to the PC so that depth and position, as well as ancillary information such as time, transect, station, etc., could be automatically recorded on hard disk.

Prior to the survey on each lake, the coordinates for the 1,000-ft grid pattern were entered into the software package. The system used the positioning data and the grid system to display each transect, and the vessel's position and movement. The vessel operator used the PC display to accurately follow each transect line. The system was programmed to automatically record data at approximately 50-ft intervals to assure sufficient data were recorded. In addition, a manual record button was pushed every 1,000 ft as each grid point was reached. This recorded the depth and position on the hard disk and also imprinted a fix mark on the analog fathometer graph paper. The exact positioning data at each grid point was also manually recorded on field log sheets to assure that the ship's position could be correlated with each fix mark on the fathometer chart paper in case the data being recorded on the hard disk were lost. Consequently, each survey produced digital data recorded on the hard disk at approximately 50-ft intervals and an analog fathometer trace with fix marks at each grid point with the corresponding positioning data annotated on field log sheets.

At least twice during each day's survey a bar check was completed to assure the fathometer was adjusted and functioning properly. This was done by lowering a metal plate beneath the transducer to known depths and

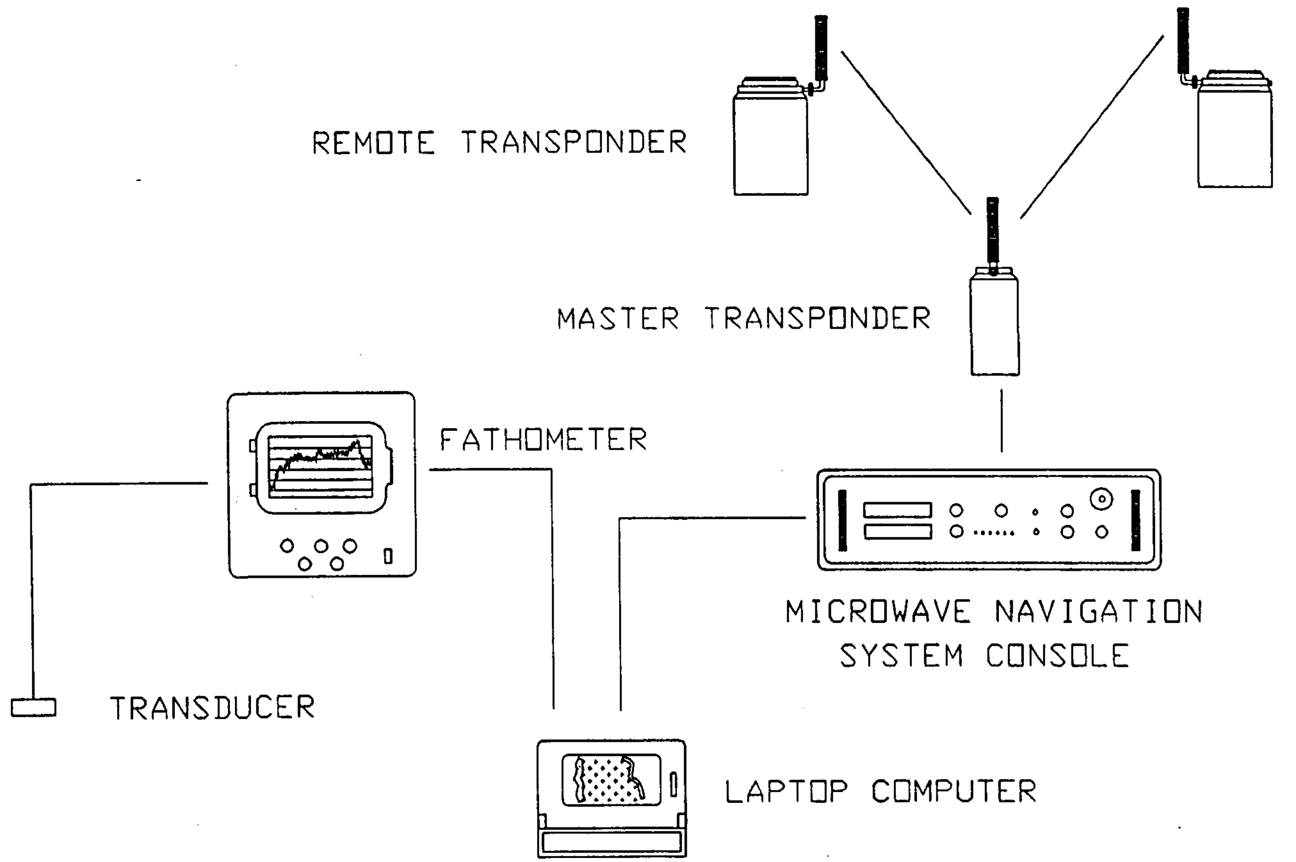

FIGURE 2-3.

PRECISION BATHYMETRIC SURVEY SYSTEM

Source: ECT, 1991.

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assuring the fathometer readouts agreed with the actual depth of the plate. Typically the plate was lowered to depths of 5 ft and 10 ft to calibrate the system. Prior to each survey the transducer's depth and the speed of sound adjustment were set to assure the readouts matched the plate depth. The instrument remained stable throughout each day's survey and adjustment was not required.

In addition to the static bar check, a dynamic calibration was completed. A dynamic calibration accounts for vertical displacement of the vessel when it is in motion as compared to the vessel draft when it is stopped. This calibration was completed by placing a float in a flat area with a known water depth. The vessel was then run at typical survey speed past the float with the fathometer recording the depth. The difference between the depth recorded while in motion and the depth recorded while the vessel was stopped at the float is called the *squat*. This difference was subtracted from each depth reading to adjust for the vertical displacement while in motion.

A photoelectric device (PD) was also used to measure the water depth and check the depth readings from the fathometer. The PD consisted of a small waterproof flashlight that was focused on a photoelectric cell. Both items were rigidly mounted and attached to a calibrated line. The wire leads from the photoelectric cell were attached to a voltmeter on the survey vessel. When the light beam contacted the photoelectric cell, the resulting voltage could be observed on the instrument readout on the vessel. As the PD was lowered into the flocculent sediment layer the light beam was interrupted and the drop in voltage was readily detectable. The depth to the top of the flocculent layer could then be read directly from the calibrated line. Twenty points in each lake were measured with the PD for comparison with the readings from the fathometer.

During the survey the small engine that was on the vessel was replaced with a larger engine. Consequently, dynamic calibrations were completed for both engines. Since a pontoon boat was used for the survey, there was very little adjustment required. The measured squat was only 0.1 ft and 0.3 ft for the small and large engine, respectively. These values were used to develop the final database.

2.1.3 WATER LEVEL MEASUREMENTS

To appropriately adjust measured water depths to a uniform reference datum, water level measurements must be made during the time of the actual survey. The water level in the lakes fluctuates because of drawdown or excessive rainfall as well as setup from winds blowing across the water. To account for these variations, water levels were measured on each lake either from established USGS gauges or from temporary water level staffs established for this survey. The temporary water level staffs were surveyed by a PLS and referenced to USGS benchmarks. Water levels were read hourly during the days that surveying was being conducted on each lake. The locations of each USGS gauge and the temporary water level staffs are shown in Figure 2-2 and Table 2-1.

The water levels on each lake did not fluctuate more than 0.26 ft during the surveys, although the water levels were all lower than the reference water level for each lake. The reference water level and the range in water levels measured during the study for each lake are provided in Table 2-2.

2.1.4 SEDIMENT SAMPLING

Two methods were used to sample the sediment thickness: a sediment coring device and a sediment penetrating rod. The coring device consisted of a 2.5-inch inner diameter clear plastic (acrylic) tube that was connected to a polyvinyl chloride (PVC) handle for operation from the boat (see Figure 2-4). Two devices were built: one with a 6-ft-long coring tube and one with a 12-ft-long coring tube for deeper sediments. A piston assembly made from a rubber stopper was positioned inside the coring tube with a cable running from the piston, inside the tube, and out the handle of the device. During sampling, the piston was set near the cutting edge of the core tube and the device was lowered to approximately 1 ft above

Table 2-2. Lake Reference Water Levels (msl) and Measured Water Levels

Lake	Reference Level (ft)	Maximum (ft)	Minimum (ft)	Range (ft)
Harris	63	62.22	62.05	0.17
Little Harris	63	62.40	62.22	0.18
Eustis	63	62.35	62.09	0.26
Dora	63	62.15	61.96	0.19
Beauclair	63	62.18	62.18	0.00
Griffin	59	58.12	57.96	0.16
Yale	59	58.90	58.80	0.10
Weir	57	54.86	54.82	0.04

Source: ECT, 1991.

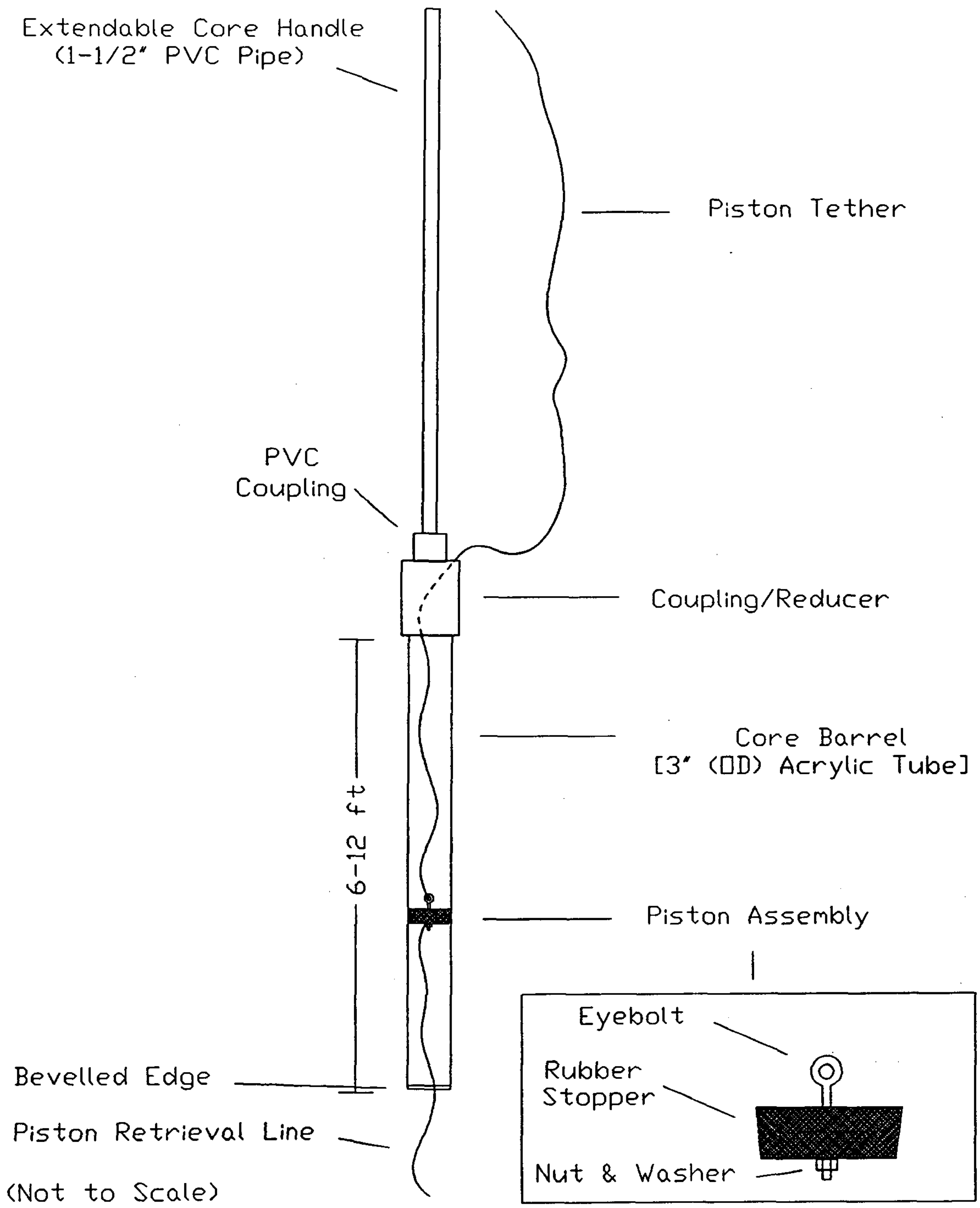

FIGURE 2-4.

SEDIMENT CORING DEVICE

Source: ECT, 1991.

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the sediment surface. The fathometer on the vessel was used to measure the water depth so that the coring device could be lowered to the proper depth. At this point, the cable leading to the piston was secured to the vessel to immobilize the piston. The sediment core was then forced into the sediment, and since the piston was immobilized, it remained stationary as the corer penetrated the sediment. Since the piston was stationary as the corer penetrated the sediment, a partial vacuum was created that allowed the soft, flocculent sediments to enter the coring tube with little disturbance. This resulted in a virtually undisturbed core that typically consisted of approximately 1 ft of water, a suspended flocculent layer, and one or more layers of sediment substrate. The corer was brought on board the vessel and the thickness of the flocculent layer and the total thickness of the black organic sediments were measured.

The original intent of the study was to measure the thickness of the organic mud overlying the sand bottom. However, it was soon discovered that there were a variety of different substrates beneath the mud layer. Examples of the deeper substrates included soft white marl, a variety of different colored and different density clays, brown organic root zones, shell layers, and several different colored sand layers. Occasionally a sand layer was encountered with additional dark organic material beneath, which made it difficult to quantify the sediment thickness. Frequently there was a 1- to 4-ft zone where the black organic material gradually transitioned into sand with increasing sand content with depth. The variety of underlying substrates and transition zones made it difficult to accurately determine the interface; however, a somewhat subjective estimate of the organic sediment thickness was recorded for each core by measuring the layer directly through the clear plastic tubing.

The sediment core could only be used for sediments less than 6 to 10 ft thick. The effective depth of the core depended on the density of the sediments (which could limit penetration), depth of water, and the weather conditions during sampling. For several hundred samples, the bottom of the muck layer could not be reached with the coring device. For these stations, a penetrating rod was used that consisted of 0.5-inch galvanized pipe. The pipe was lowered into the water and pushed into the sediment until a density interface was detected. The sediments were so soft that the rod readily penetrated the bottom. A *foot* consisting of a 2-inch reducer was installed on the end of the pipe to help the operator feel the density change in the sediments. As much as 50 ft of pipe were used at some stations to reach the bottom interface of the soft sediment layer. The total depth from the water surface to the bottom of the soft sediment was measured using graduations on the pipe, and was recorded in the field logbook. The water depth was measured using the vessel's fathometer. The sediment thickness was determined by subtracting the water depth from the total depth measured with the penetrating rod.

Both methods were effective in measuring sediment thickness, but both methods had limitations. The sediment core provided undisturbed cores which allowed for accurate measurement of sediment thickness, but could not be used for thick sediments. The penetrating rod could be used at all stations, but it was impossible to differentiate between the muck layer and similar soft underlying layers such as marl or loosely packed clay. More discussion of the accuracy and limitations of the methods is provided in Section 3.3.

2.2 <u>DATA ANALYSIS</u>

2.2.1 DATA ENTRY AND CALIBRATION

The bathymetric data collected in the field consisted of the fathometer analog strip chart, handwritten field logs of depth and position data, and the PC hard disk of digital data. The analog depth chart and the digital data file were edited jointly to develop the final data set. Since the digital data were automatically recorded every 50 ft, the extra points between the required 1,000-ft grid interval were removed. The analog chart was consulted to identify deep or shallow areas between the grid points and these additional points were added to the database to provide better detail. The analog chart was also used to verify the digital depth signals recorded on the hard disk. The depth for each grid point was read manually from the analog chart and compared to the digital value. Any discrepancies were examined and the readings from the analog chart were given priority. On several occasions the digital unit recorded the top of weeds as opposed to the lake bottom; these values were corrected using values from the analog chart. On Lake Yale the weeds were so thick that the bottom was obscured in a few areas. For approximately 10 of these grid points the depth was measured with a photoelectric device and added to the database.

The results of the initial editing was a database consisting of a depth and position value for each grid point with several additional points added to identify shoals or deep holes that were identified between the grid points. The position data are the actual positions of the vessel when the depth readings were made and do not correspond exactly with the pre-selected grid points. The data points were plotted and examined to identify any extraneous points. The field log sheets were examined, as necessary, to help explain any discrepancies in the navigation data; final corrections to the database were made. The data points were then merged with a data file containing the digitized shoreline of each lake. The shoreline of each lake was digitized from USGS quadrangle maps using the state plane coordinate system (1927) provided on the maps. The combined files were then plotted and examined to assure that the plotted data fell as expected within the lake boundary. The agreement on all lakes was very good.

The final grid patterns that identify each sampling point and the state plane coordinate system for each of the seven lakes are provided in Figure 2-5 through 2-11. The 1,000-ft grid pattern and the added sampling points can be readily identified on each lake. The sediment sampling pattern for each lake was similar except that intermediate points were not sampled, but only the required grid points.

The next step in editing the database was to apply the lake water level corrections. The water level data were used to estimate the lake water

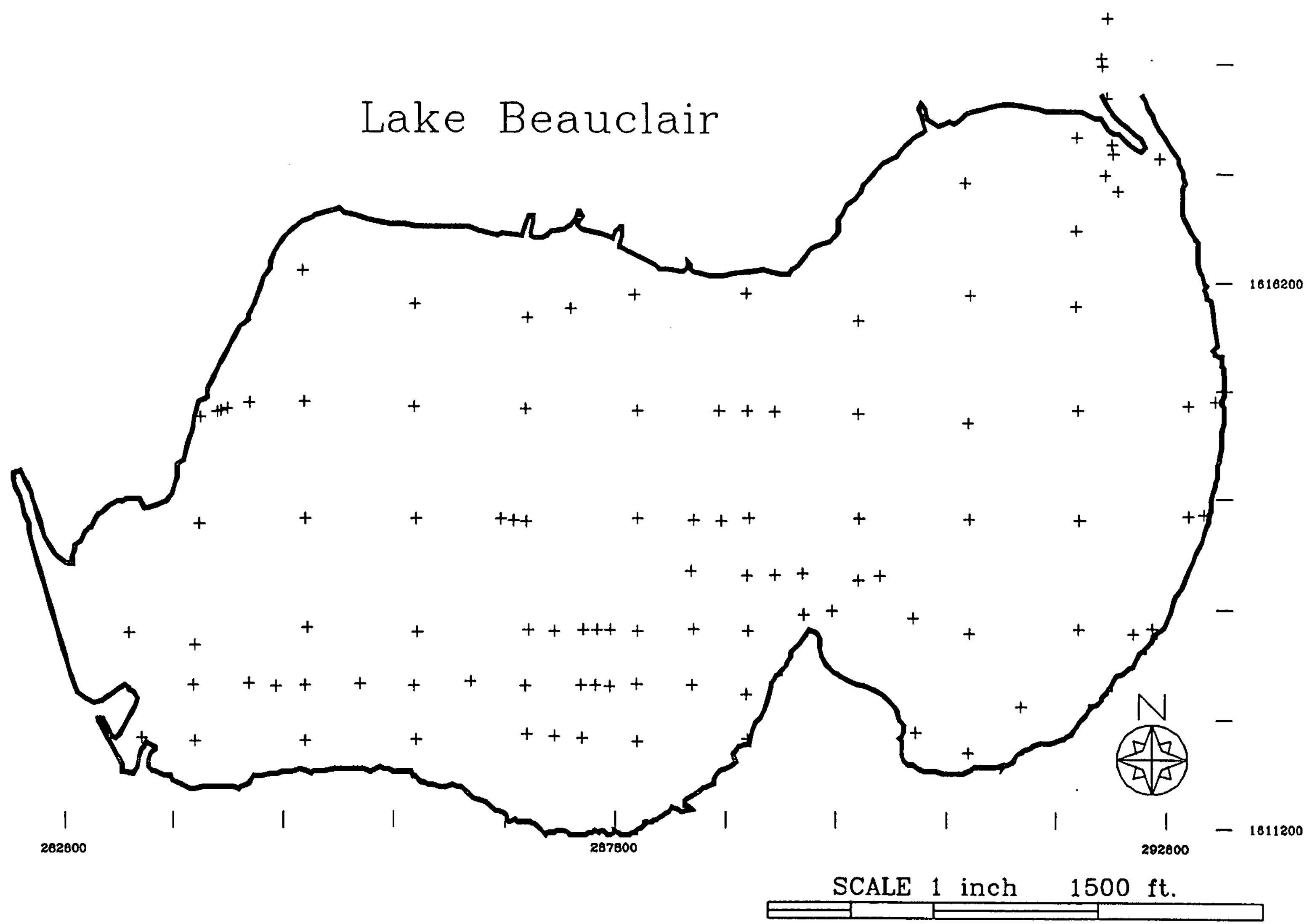

FIGURE 2-5.

BATHYMETRIC SAMPLING GRID FOR LAKE BEAUCLAIR (STATE PLANE COORDINATES ARE IN FEET)
Source: ECT, 1991.

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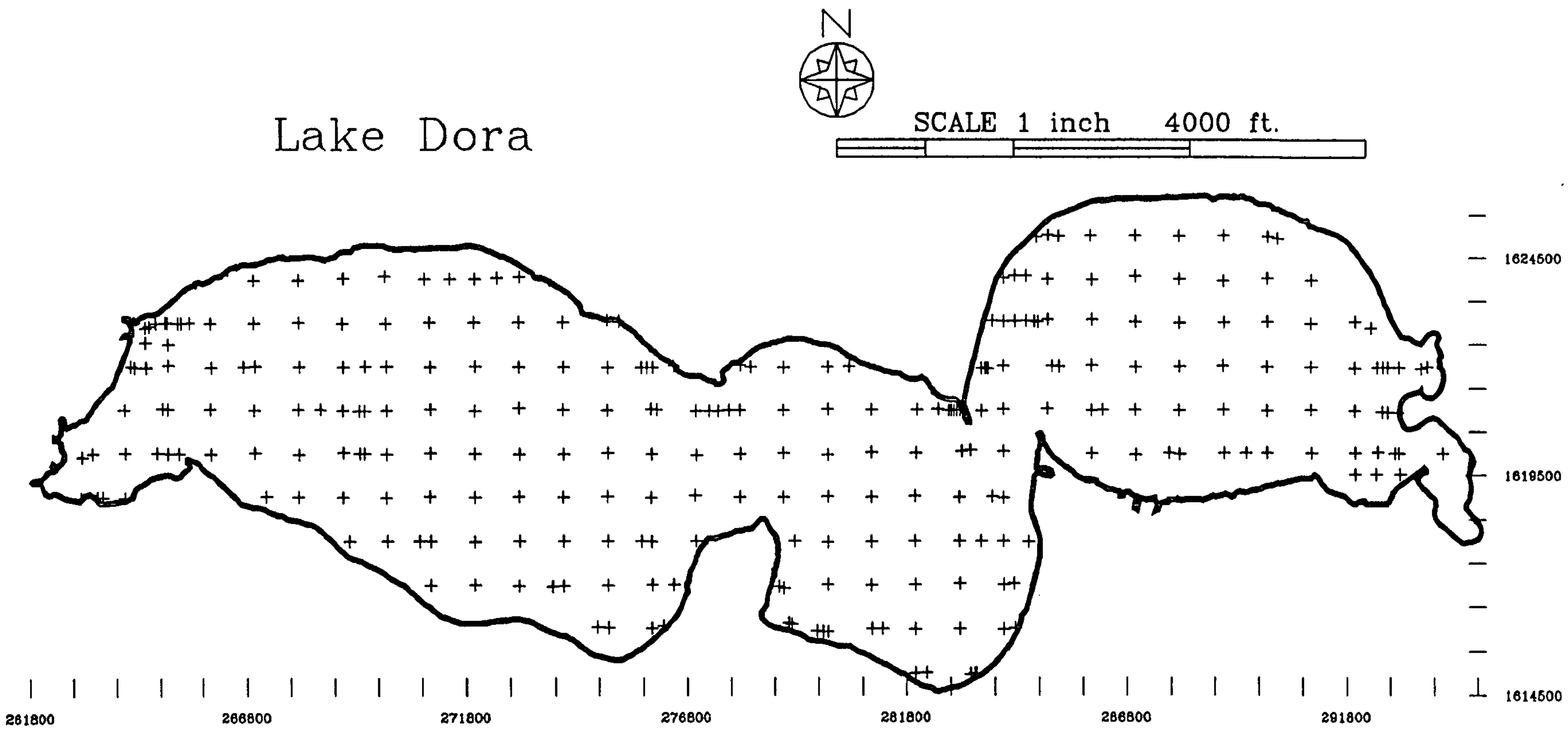

FIGURE 2-6.

BATHYMETRIC SAMPLING GRID FOR LAKE DORA (STATE PLANE COORDINATES ARE IN FEET)
Source: ECT, 1991.

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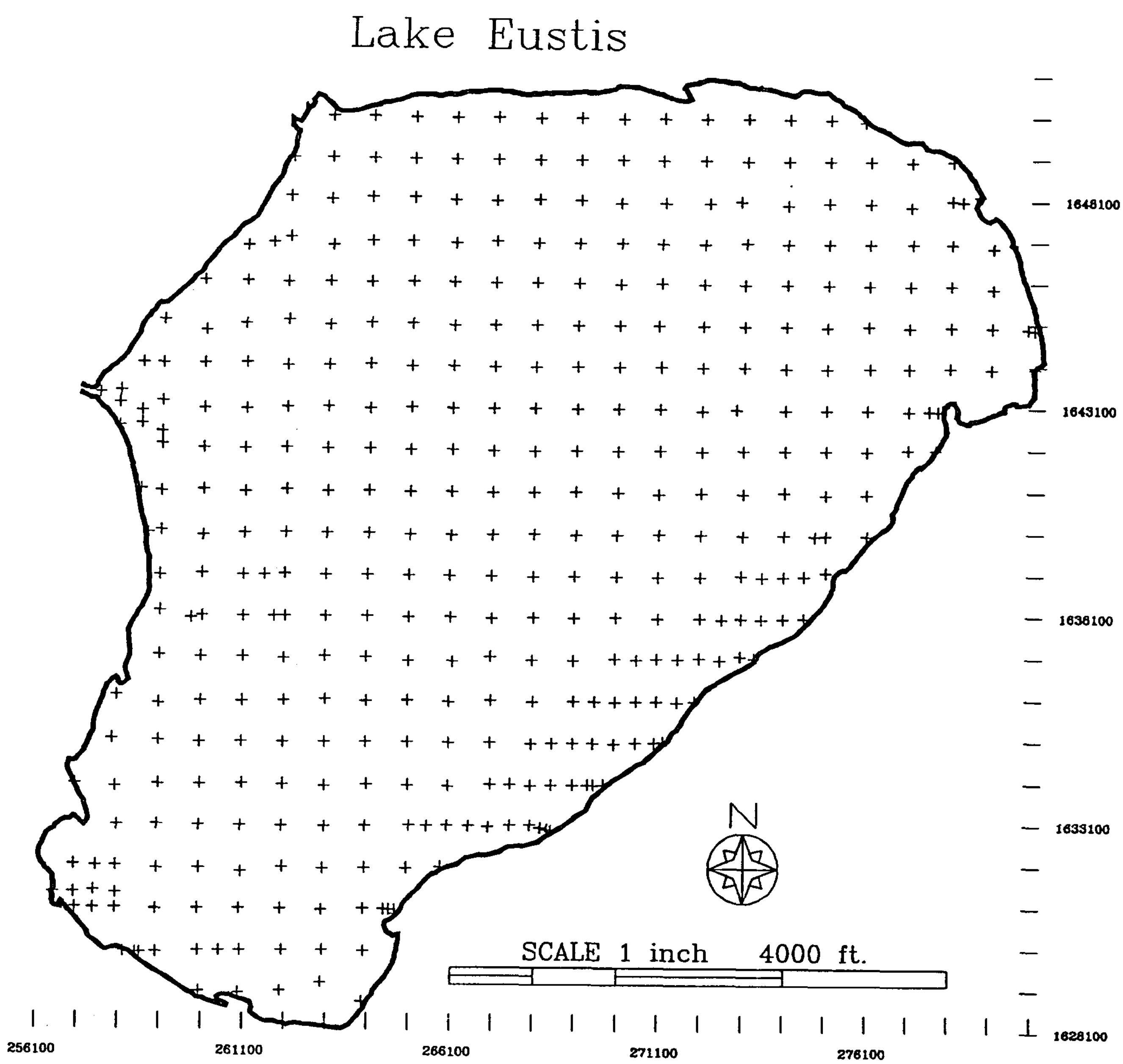

FIGURE 2-7.

BATHYMETRIC SAMPLING GRID FOR LAKE EUSTIS
(STATE PLANE COORDINATES ARE IN FEET)
Source: ECT, 1991.

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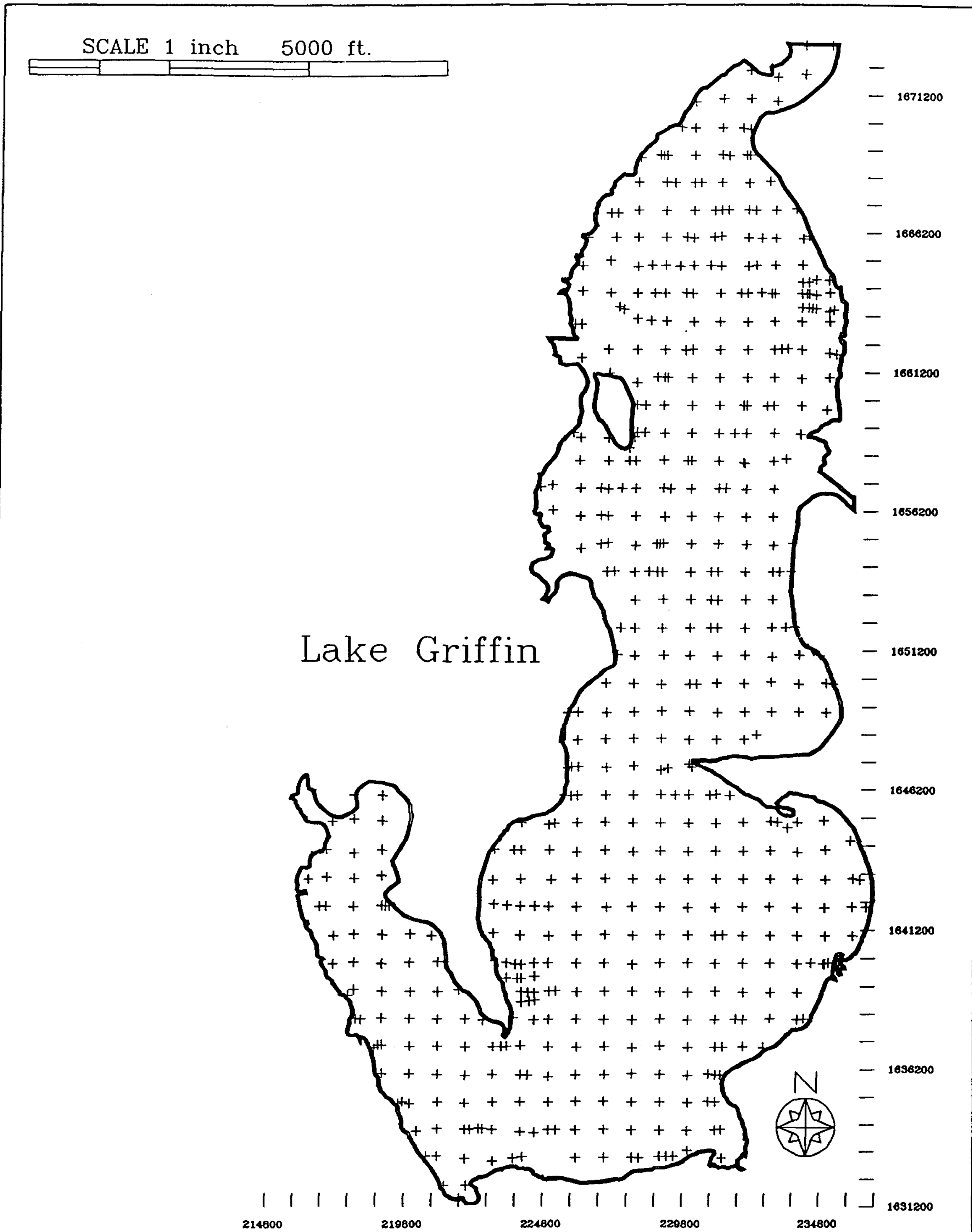

FIGURE 2-8.

BATHYMETRIC SAMPLING GRID FOR LAKE GRIFFIN
(STATE PLANE COORDINATES ARE IN FEET)
Source: ECT, 1991.

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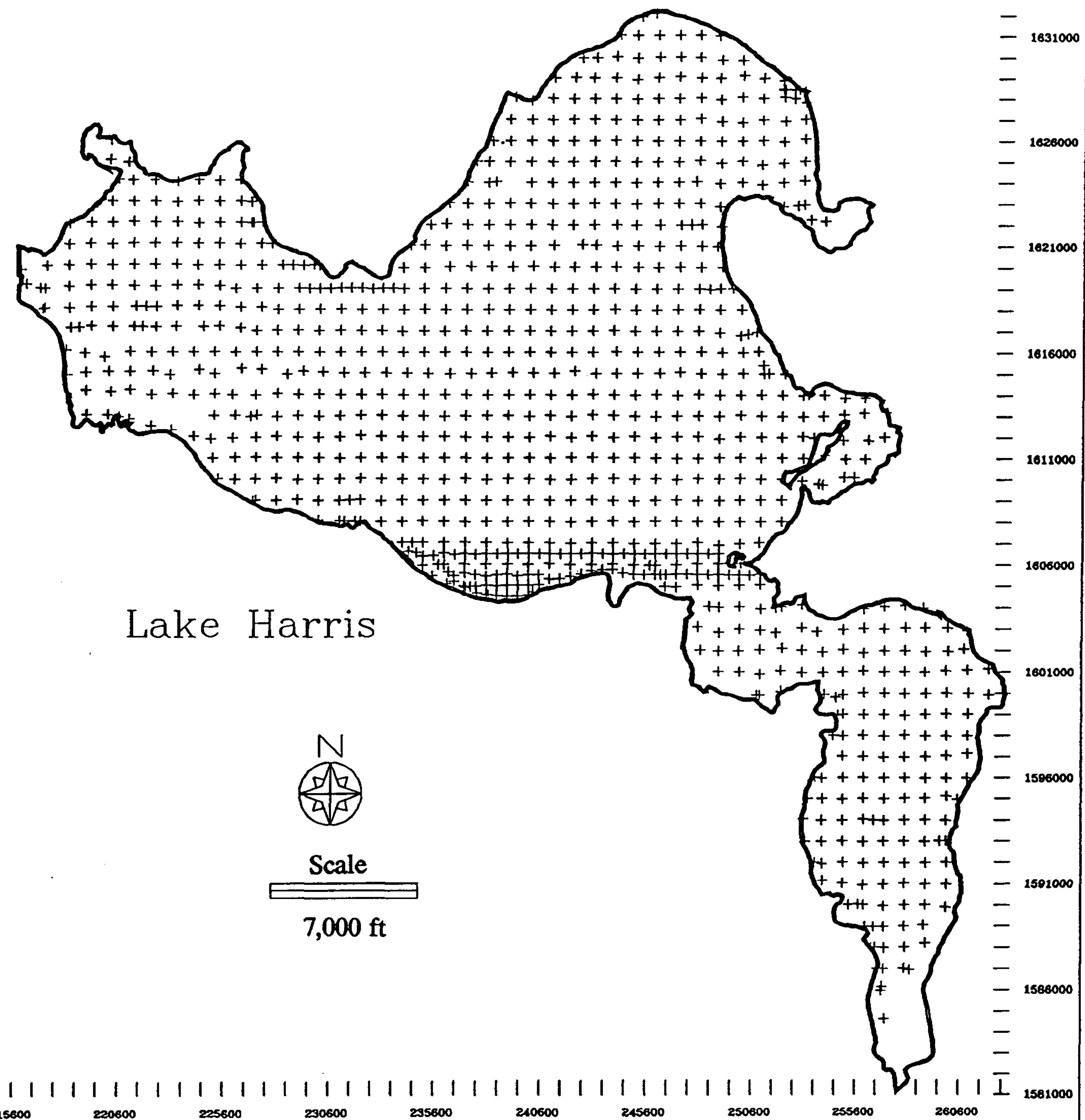

FIGURE 2-9.

BATHYMETRIC SAMPLING GRID FOR LAKE HARRIS (STATE PLANE COORDINATES ARE IN FEET)
Source: ECT, 1991.

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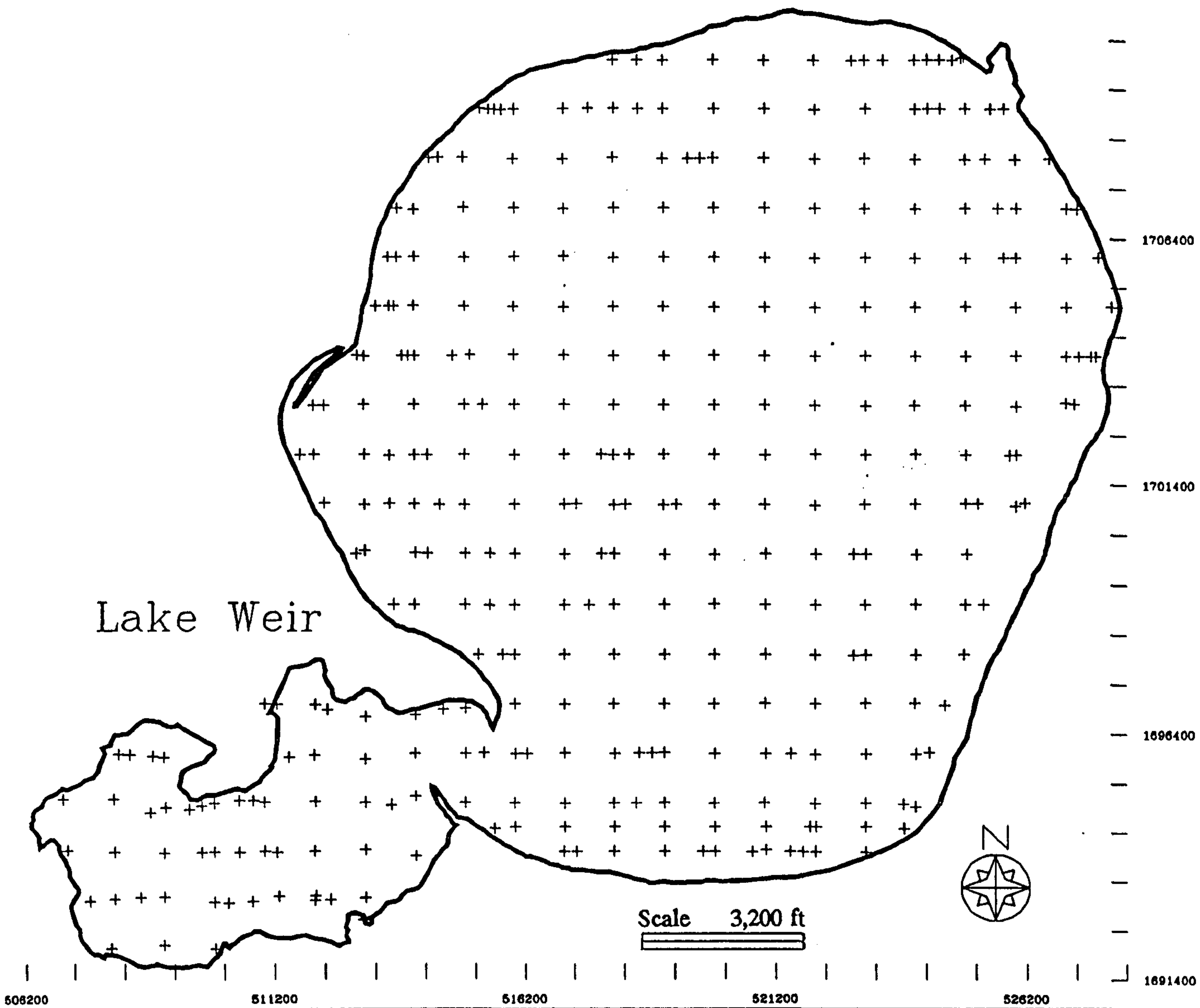

FIGURE 2-10.

BATHYMETRIC SAMPLING GRID FOR LAKE WEIR (STATE PLANE COORDINATES ARE IN FEET)

Source: ECT, 1991.

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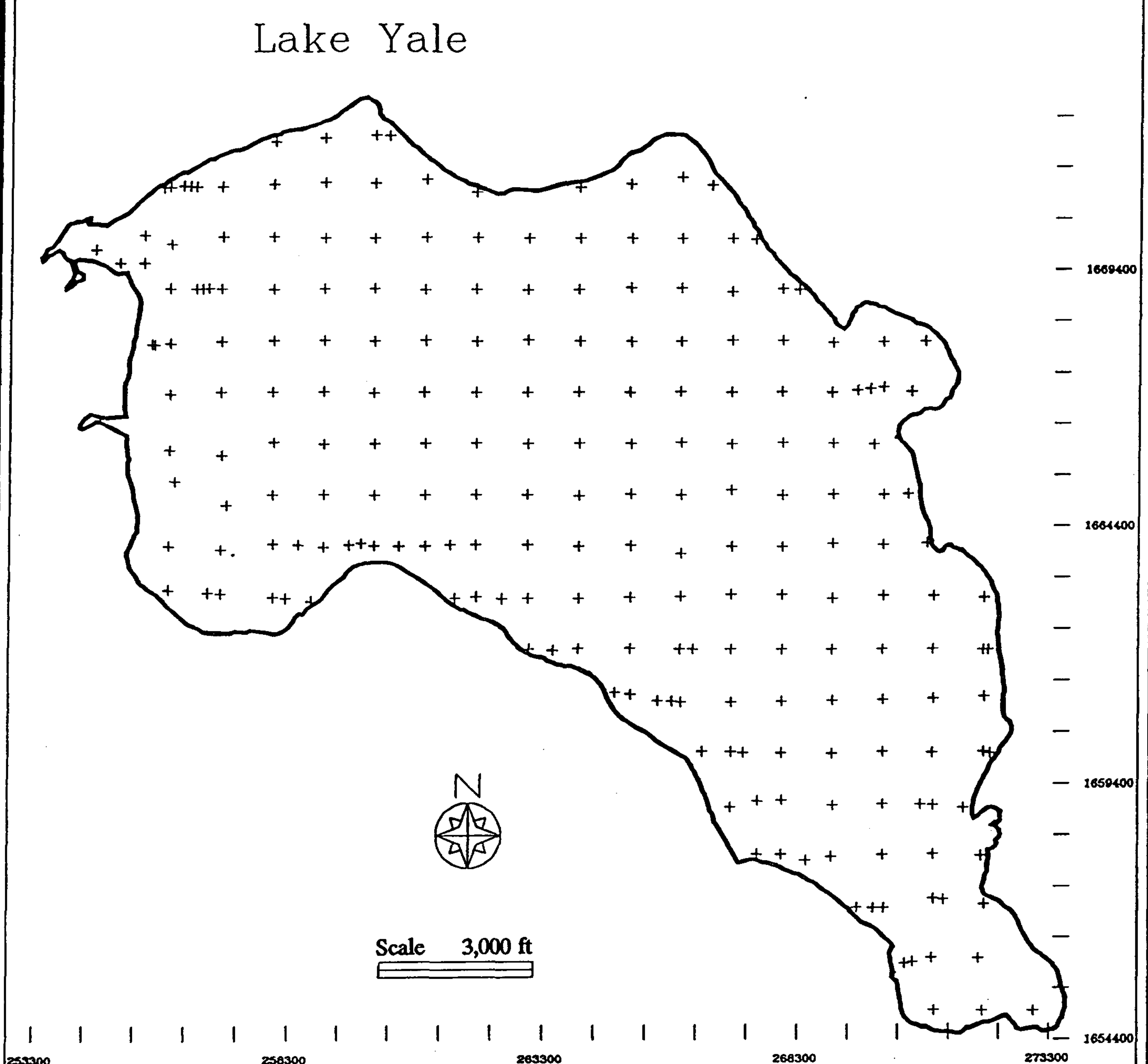

FIGURE 2-11.

BATHYMETRIC SAMPLING GRID FOR LAKE YALE
(STATE PLANE COORDINATES ARE IN FEET)
Source: ECT, 1991.

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level at the time and location of sampling for each grid point. Fortunately there was very little variation in water levels during the study and minimal interpolation was required (see Table 2-2). Since the water levels were all low during the study period an incremental value was added to each depth reading to adjust the value to the reference lake level. For example, the reference level of Lake Weir is 57 ft above mean sea level (msl) and the water level during the study varied between 54.86 and 54.82 ft msl. Therefore, approximately 2.15 ft were added to each depth reading to adjust for the low lake water level during the survey. Consequently, all recorded depth values are the depths that will be observed on each lake when it is filled to its reference level.

The final step in editing the database was to apply the squat calibration. This correction resulted in either 0.1 or 0.3 ft being subtracted from each depth reading depending on which outboard motor was used on the survey vessel at the time of sampling. Following this correction every 14th point in the database was checked by a second individual to assure that the water depth was read from the charts correctly and that all of the subsequent calibrations and adjustments were applied properly. The depth data were then contoured and examined one final time to identify any extraneous points. Only a few points required correction during this phase and the bathymetric databases for each lake were finalized.

The sediment data required less calibration and adjustments than the bathymetry data. LORAN-C was used for navigation which simplified the processing for vessel location. The LORAN-C positioning system was used to locate the vessel as close as possible (generally ±60 ft) to each pre-selected grid location. The sediment measurement was made and the sediment thickness was recorded manually on log sheets. The position of the sampling point was assumed to be that of the grid point and no navigational adjustments were made.

Data entry consisted of entering the recorded sediment thickness into the database containing the grid of sampling locations. A code identifying whether the sample was taken with a sediment core or a sediment rod was also entered. The data were plotted and the sediment thicknesses were examined to identify extraneous points (i.e., sediment thicknesses that varied considerably from adjacent points). Suspect points were evaluated by examining the field logs and reviewing the fathometer traces that were made during the bathymetry survey. Areas of exposed sand could be readily identified on the fathometer traces and verified most of the sediment thickness readings that were first thought to be anomalous. An example of an exposed sand area within a region of thick sediments is illustrated in Figure 2-12. Also in a few areas subsurface features could be recognized that verified that a thinner sediment existed in a region of thick sediments. An example of these subsurface features identified in Little Lake Harris is shown in Figure 2-13. The subsurface profile indicates the sediment thickness decreases to less than 4 ft above the features whereas the sediment at adjacent points is greater than 15 ft.

The field notes and fathometer traces were used to verify or correct most of the suspect points. However, approximately 100 points were resampled on Lake Harris in June 1991, to verify sediment measurements in the central region of the lake. In addition, there were approximately 15 suspect points within the seven-lake region that could not be verified; these few points were removed from the database and replaced with a value interpolated from adjacent points. These points were labeled as interpolated points in the final database. This was the last step in finalizing the sediment database which now consisted of the sample location, total sediment thickness, unconsolidated sediment thickness (only available when the sediment core was used), and the sampling technique (C = core, R = sediment rod, I = interpolated).

2.2.2 PLOTTING AND CONTOURING

All further analysis of the databases was performed on a variety of IBM-compatible computers, mostly 80386 and 80486 machines, networked using an Ethernet® system running LANtastic software. Data input and analysis

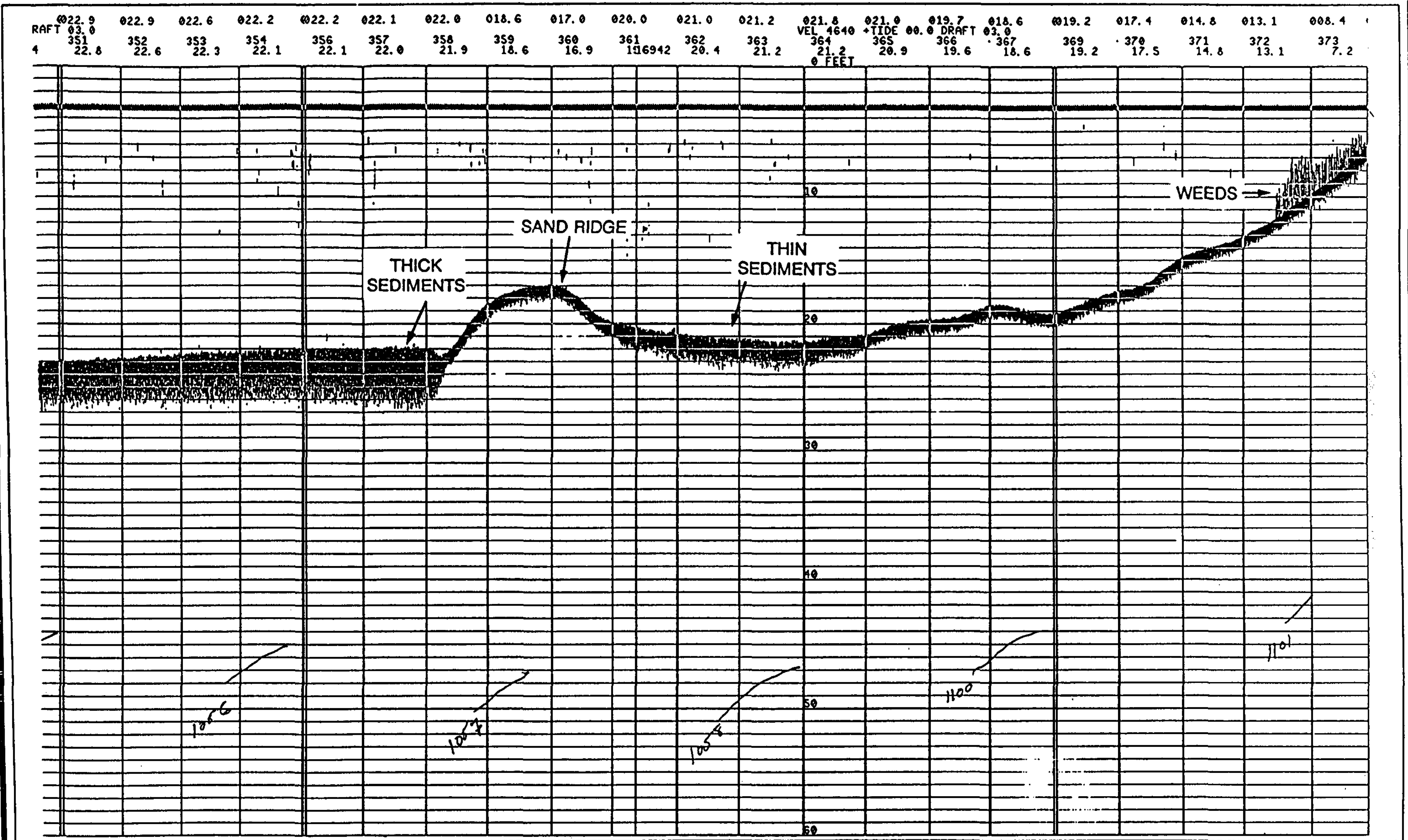

FIGURE 2-12.

FATHOMETER READING FROM LAKE WEIR

Source: ECT, 1991.

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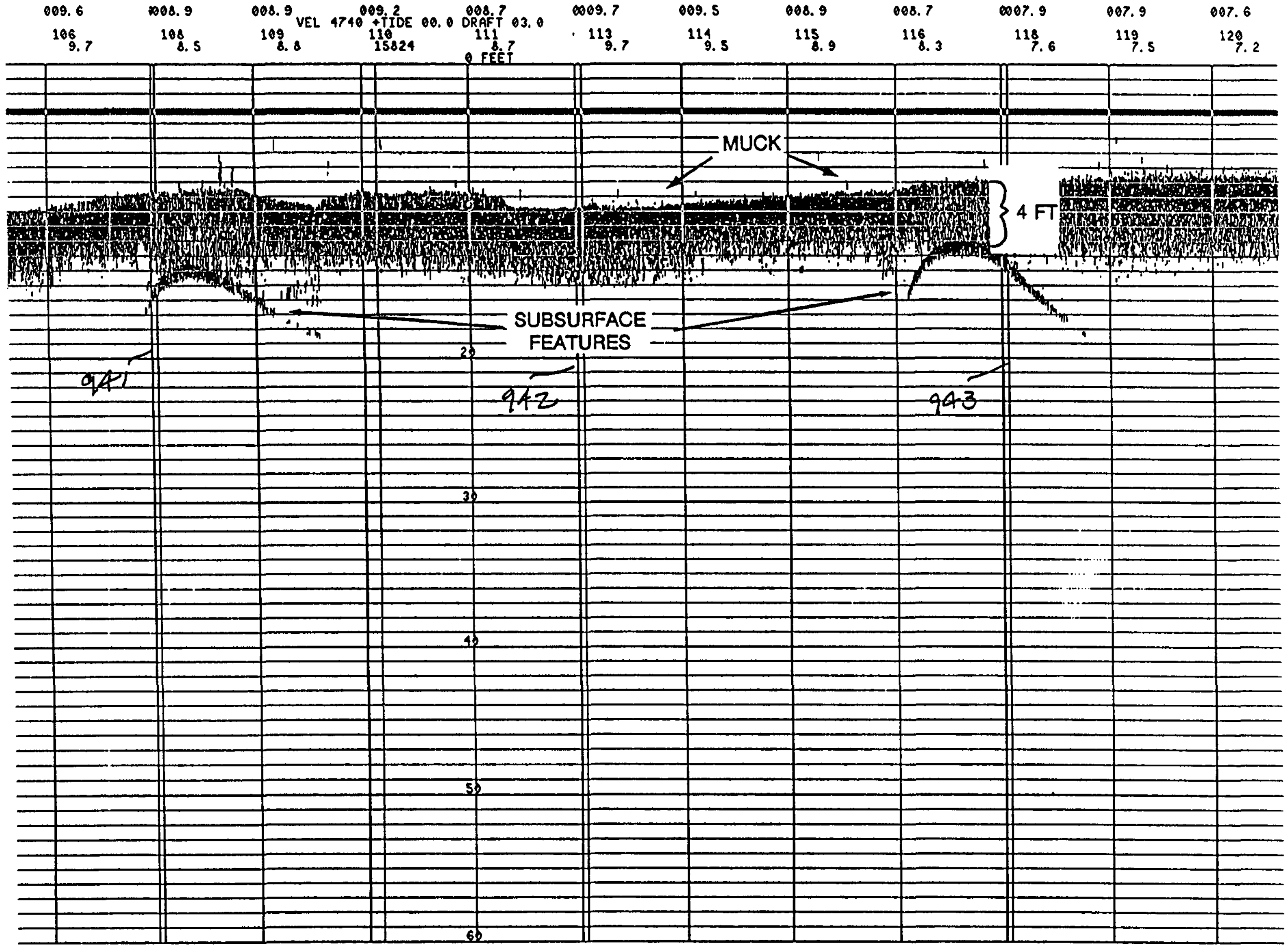

FIGURE 2-13.

FATHOMETER READING FROM LITTLE HARRIS

Source: ECT, 1991.

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utilized a variety of software packages such as ERDAS, ARC/INFO, SURFER, Lotus 123®, Generic Cadd, AutoCad®, and several user-developed programs.

The shorelines of each of the seven lakes were digitized from USGS 1:24000 topographic quad sheets using the DIGPOL routine of the ERDAS image processing/geographic information system (GIS) software. In addition to the lake margin, the first landward contour line was also digitized. Digitization was done on a GTCO tablet with a physical resolution of 0.001 inches, thus giving a scale resolution of 24 inches at 1:24000.

The individual data points were plotted with the shoreline boundaries to check for inconsistencies and typographic errors. A preliminary surfaced data set was generated using SURFER, the contouring and surfacing software from Golden Software. The preliminary maps were plotted as large as possible on a 24-inch plotter. The contour maps were then compared with the data point maps to check for further inconsistencies and errors. When all of the data points had been edited and accepted, the data were again contoured and plotted.

The shoreline boundaries were forced to be zero for both the bathymetry and sediment maps. To accomplish this, the digitized shoreline data sets were used to generate a *tie line* of data points with a value of zero with a 50-ft separation distance for the entire shore length. This acted as a boundary on the surfacing routine to force a zero value for the shoreline. Surfacing was accomplished with the GRID program of SURFER utilizing a Kriging algorithm with an octant search method, taking the nearest 2 points within 4,000 ft of the grid cell in each octant for analysis. Gridding was done on a 200-ft grid cell size for all of the lakes except Harris which required a 300-ft cell size due to its size. The Kriging algorithm calculates an interpolated value at each grid cell location while considering the interdependence expressed in the variance of the nearest sample points (Davis, 1973). The gridded data set was then taken through several steps using GIS software to force all values outside the shoreline to be zero.

Contouring was accomplished using the TOPO module of SURFER. Data editing was done in TOPO in order to fit certain assumed features such as channels and ridges more precisely to the gridded data. To minimize a scalloping effect due to the shore line zero values and the distance between collected data points, an interpolated contour line was digitized and added to the data for several lakes and then the data were regridded. After the grid database was finalized for the depth data in feet, the grid data sets were converted to meter data sets for contouring in meters. The sediment data were only contoured in feet.

Maps for each of the data sets (depth in feet, depth in meters, and sediment thickness in feet) were then plotted at an appropriate scale to fit on an 8.5- by 11-inch page. The contour data sets were plotted to a digital database at a 1-to-1 scale and converted to an ERDAS.DIG file. These polygonal data sets were then converted into ARC/INFO coverages using ERDAS, AutoCad®, and ARC/INFO software. After the polygons were converted to ARC/INFO, they were further edited to assure the polygons fit within the shoreline boundaries.

2.2.3 AREA AND VOLUME CALCULATIONS

After editing and polygon attribute assignment, the surface areas between contour lines were calculated using ARC/INFO Frequency command and exported to a text file. This surface area information was imported into Lotus 123® and the areas were combined to calculate the cumulative surface areas within each 1-ft contour level.

Lake volumes were calculated using the surface areas within each contour and computing the volumes in 1-ft layers. The water volume contained within any 1-ft interval was calculated using the truncated cone method (Wetzel, 1983) according to:

$$V = h \times \left[A1 + A2 + \sqrt{(A1 \times A2)}\right]/3$$

where: V = volume of the layer,
h = thickness of the layer,
A1 = area of the upper surface, and
A2 = area of the lower surface

These volume incremental layers were then summed for the entire depth of the lake to compute the total volume.

In addition to calculating areas and volumes from the contour polygons, the grid cell databases were used to calculate areas and volumes using SURFER to provide a comparison of the two techniques. Surface areas for this method were computed by summing all the grid cell values that fell between contour lines. For example, to calculate the incremental surface area between the 2-ft and the 3-ft contour lines simply required summing all the grid cells that were assigned a depth of any value between 2 and 3 ft. Volumes were calculated by multiplying the area represented by each grid cell by its assigned depth and summing them appropriately.

Sediment volumes and surface areas were only calculated using ARC/INFO and summation of polygons. The surface areas and volumes were calculated using the truncated cone method for sediment thickness greater than 1 ft. However, since the shoreline was forced to be the zero contour, using the truncated cone method would overestimate the surface area and volumes between the 1-ft and 0-ft contours. Consequently, these values were calculated using the values from the SURFER summation technique. These values were then added to the ARC/INFO database to complete the hypsographic curve data for the sediments.

3.0 RESULTS

3.1 BATHYMETRY

Bathymetric contour plots of the seven lakes were made on 24-inch by 36-inch format paper to provide detailed illustration of the bottom contours. In addition, bathymetry plots scaled to fit in report format were made and are provided in Figures 3-1 through 3-7. A brief description of the bathymetry of each lake is provided below.

Lake Beauclair

Lake Beauclair is the smallest of the lakes with a surface area of approximately 1.7 square miles at its reference level of 63 ft msl. The average depth of the lake is approximately 6.7 ft. The depths exceeded 10 ft near the center of the lake with a few deep areas observed near the shore. The deepest observed area was in a channel near the western shoreline where the depth reached 15.4 ft.

Lake Dora

The average water depth in Lake Dora is about 9.9 ft at its reference level of 63 ft msl. The lake covers approximately 6.9 square miles. The water depth drops off rapidly to about 10 ft along the entire shoreline and remains relatively flat near the center of the lake. The lake is divided into an east and a west basin that are outlined by the 10-ft contour lines. The basins are divided by a shallow, sandy area between the two points of land located near the eastern third of the lake. The deepest area is located in a channel along the southwestern section of the eastern basin where the depth reached 16.3 ft. There is also an isolated spot near the peninsula on the south side of the lake where the depth reached 17.2 ft.

Lake Eustis

The average depth of Lake Eustis is 11.3 ft and it covers approximately 12.1 square miles at its reference level of 63 ft msl. Similar to the other lakes, the depth increases rapidly near shore and reaches the 10-ft

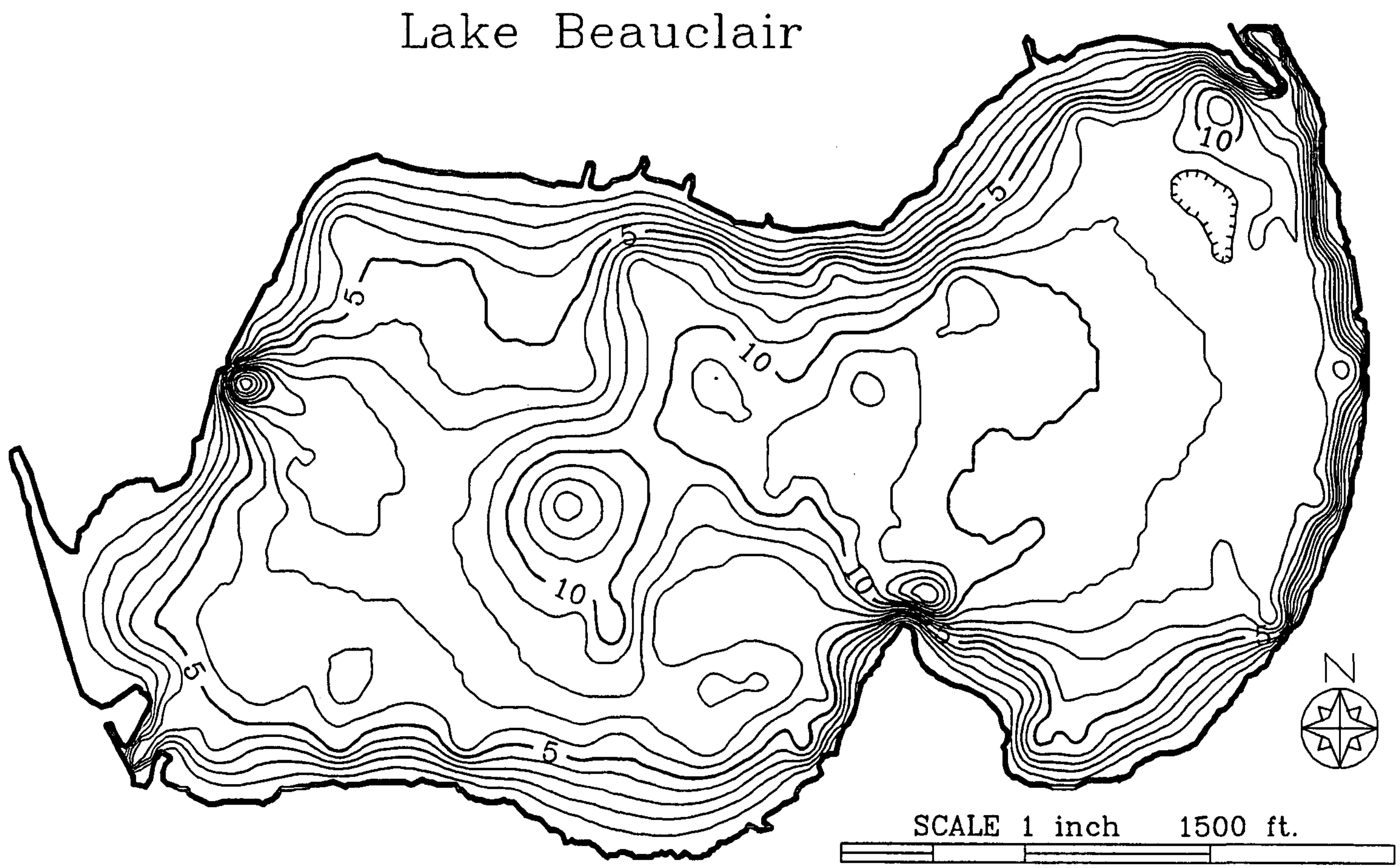

FIGURE 3-1.

BATHYMETRIC CONTOUR PLOT OF LAKE BEAUCLAIR (CONTOURS ARE IN FEET)

Source: ECT, 1991.

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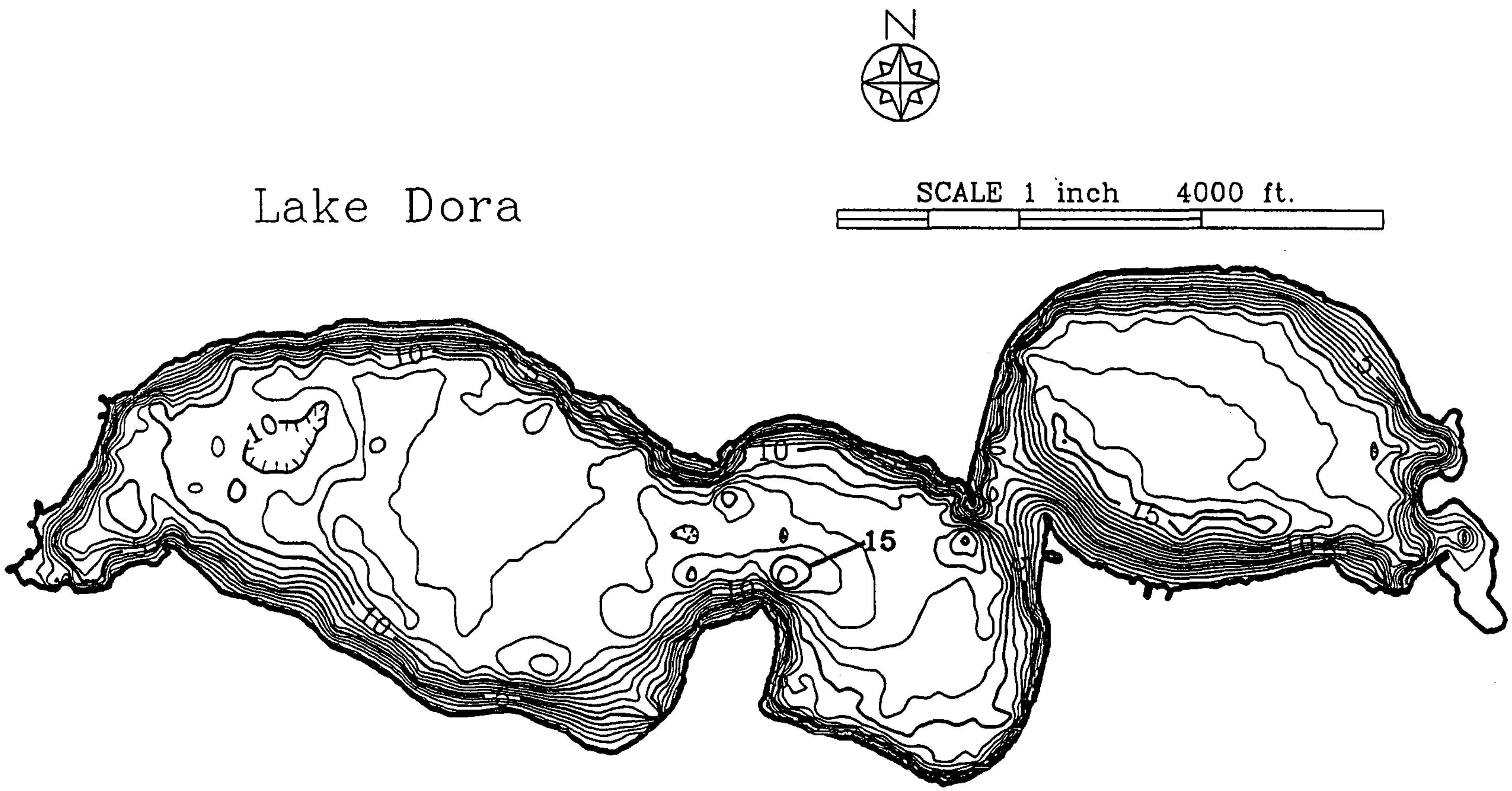

FIGURE 3-2.

BATHYMETRIC CONTOUR PLOT OF LAKE DORA (CONTOURS ARE IN FEET)

Source: ECT, 1991.

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Environmental Consulting & Technology, Inc.

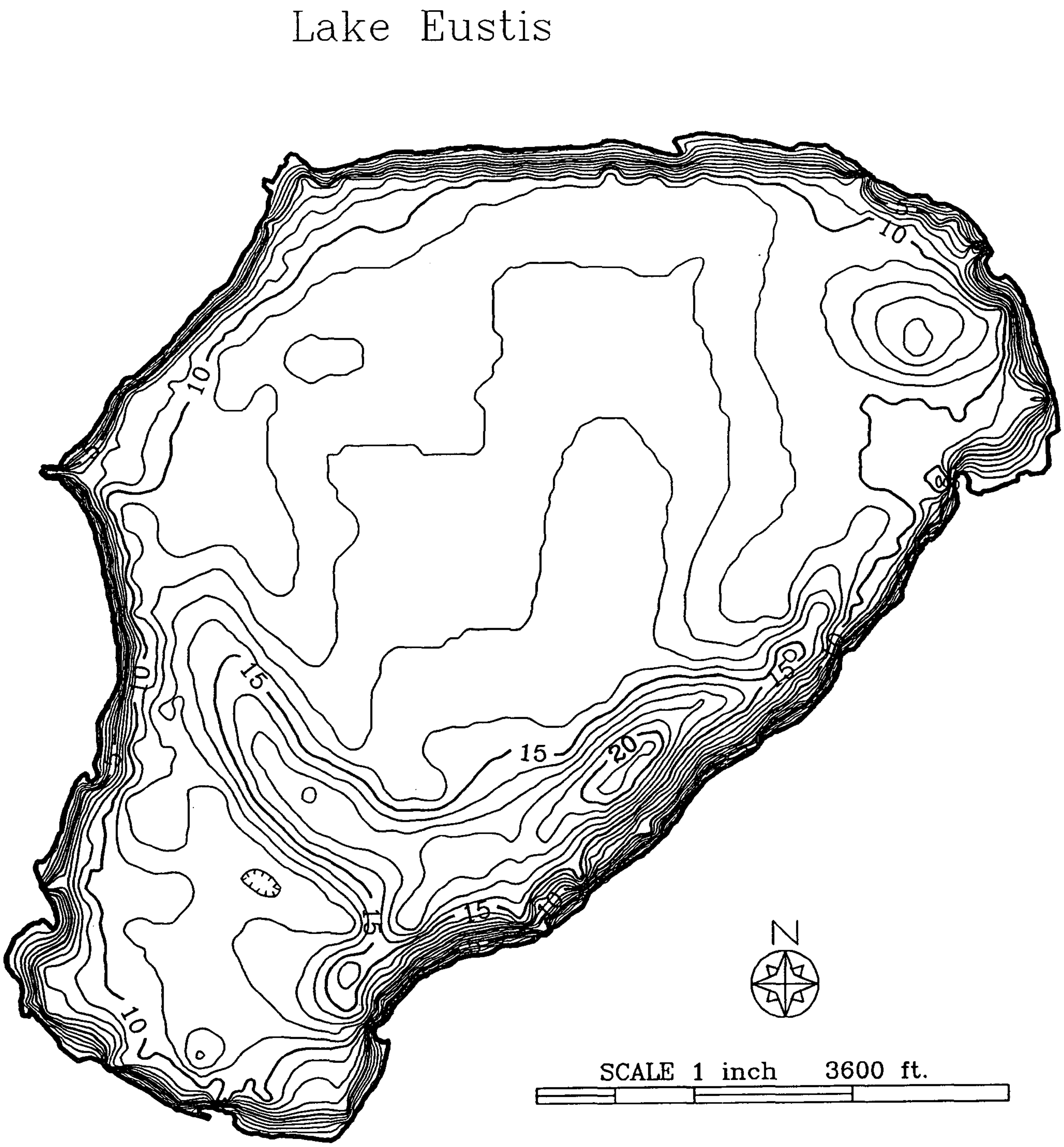

FIGURE 3-3.

BATHYMETRIC CONTOUR PLOT OF LAKE EUSTIS
(CONTOURS ARE IN FEET)
Source: ECT, 1991.

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Environmental Consulting & Technology, Inc.

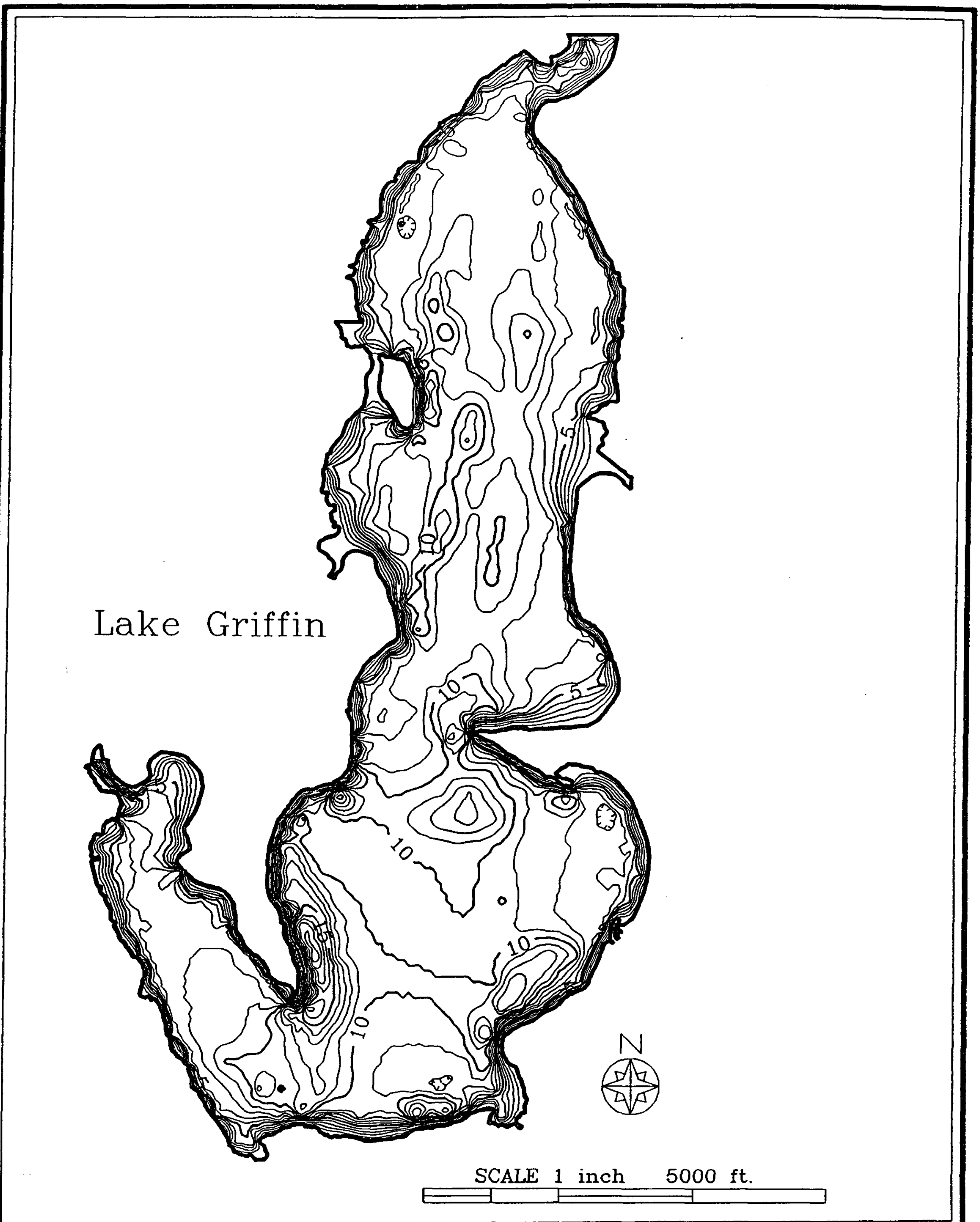

FIGURE 3-4.

BATHYMETRIC CONTOUR PLOT OF LAKE GRIFFIN
(CONTOURS ARE IN FEET)
Source: ECT, 1991.

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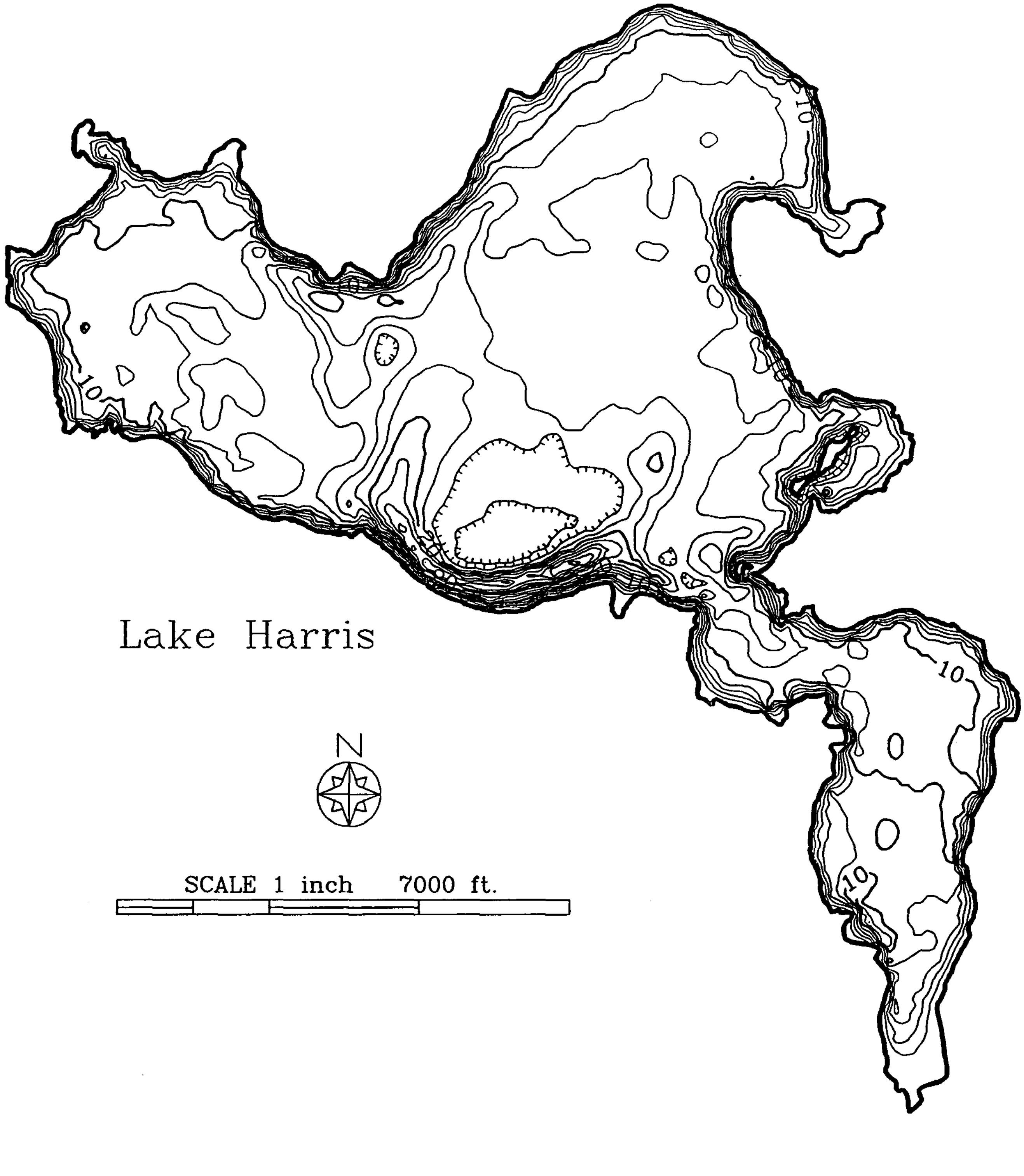
Environmental Consulting & Technology, Inc.



Note: Contours are in 2-ft intervals.

FIGURE 3-5.

BATHYMETRIC CONTOUR PLOT OF LAKE HARRIS
(CONTOURS ARE IN FEET)
Source: ECT, 1991.

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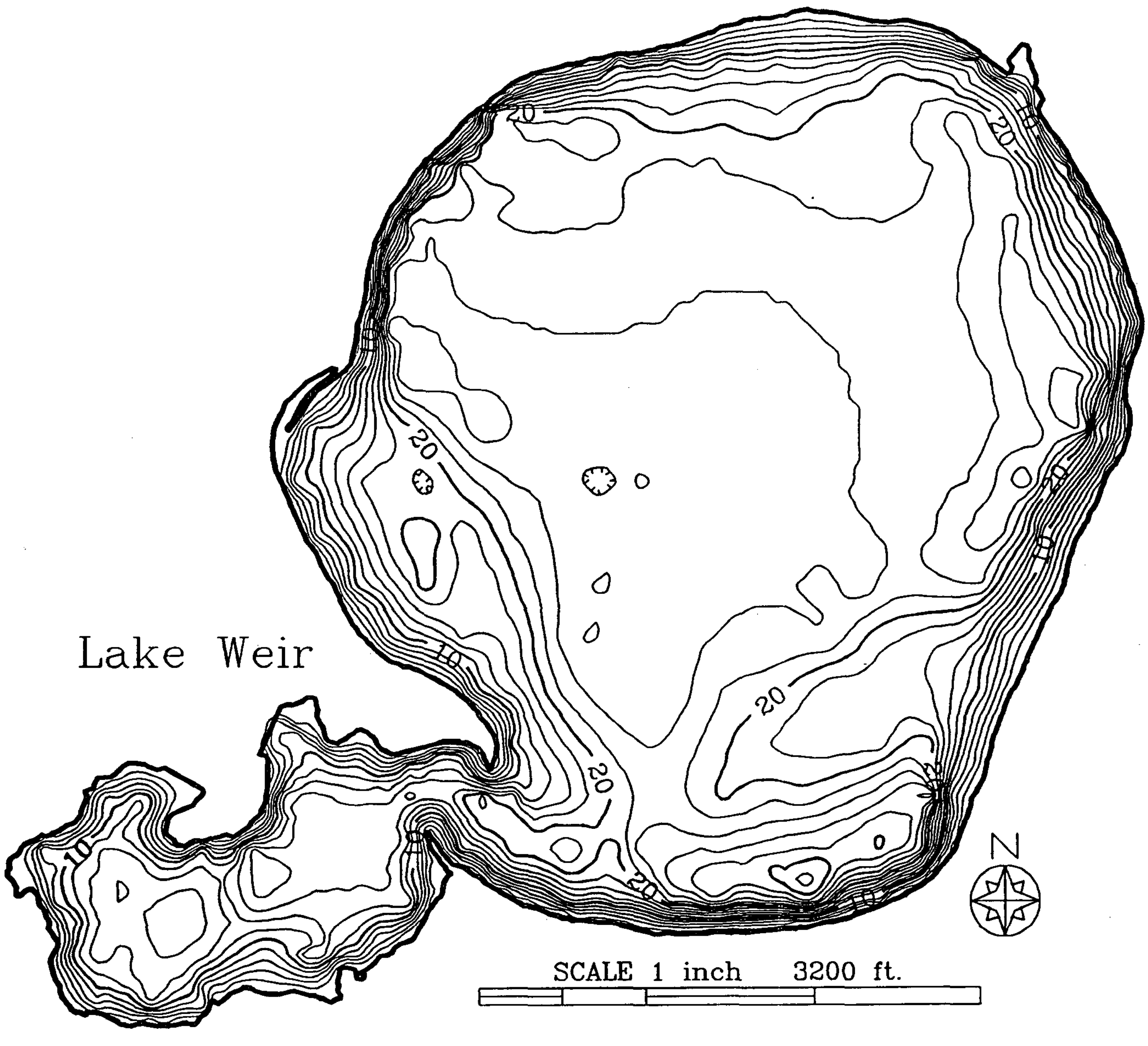
Environmental Consulting & Technology, Inc.



Note: Contours are in 2-ft intervals.

FIGURE 3-6.

BATHYMETRIC CONTOUR PLOT OF LAKE WEIR
(CONTOURS ARE IN FEET)
Source: ECT, 1991.

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Environmental Consulting & Technology, Inc.

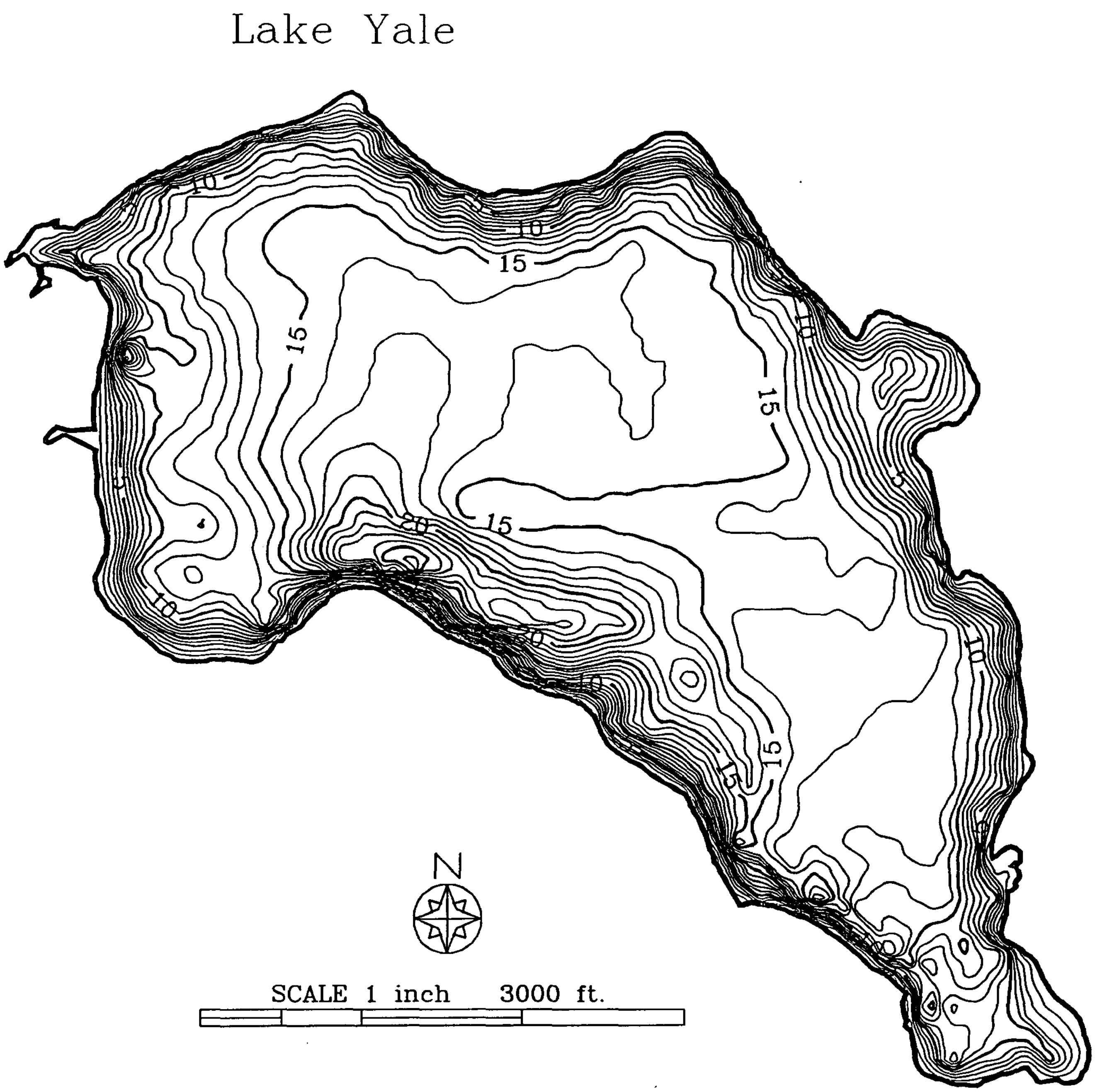

FIGURE 3-7.

BATHYMETRIC CONTOUR PLOT OF LAKE YALE
(CONTOURS ARE IN FEET)
Source: ECT, 1991.

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contour within a few hundred feet of shore. The deepest area occurs in a channel along the southeast shoreline where the depth reaches 21.7 ft. The central part of the lake is relatively flat with the depth ranging between 10 and 14 ft. The flat central portion of the lake is separated from the southwest section by a relatively deep channel that reaches 18.1 ft deep.

Lake Griffin

Lake Griffin covers approximately 14.7 square miles and averages 7.7 ft deep at its reference level of 59 ft msl. Lake Griffin is separated from Lake Eustis by the lock and dam on Haines Creek which maintains a 4-ft difference in elevation between the lakes. The estimated surface area of 14.7 square miles was calculated from USGS maps; the estimate excluded many of the fringing marsh areas noted on the map. During the survey these areas were found to be land and, consequently, were not included as part of the open water lake. Estimates of the lake surface area that include all of the fringe areas have reached as high as 16.7 square miles.

The bathymetry of the lake is characterized by relatively steep gradients near the shoreline and gently sloping bottom near the center of the lake. Deep channels were observed at several locations along the shoreline with the deepest point of 20.1 ft occurring in the channel along the eastern edge of the peninsula in the southern portion of the lake. The water depth in the central parts of the lake in general remained between 7 and 11 ft deep.

Lake Harris

Lake Harris is the largest lake and covers approximately 29.2 square miles at its reference level of 63 ft msl. The lake system consists of Lake Harris, which is the large northern portion of the system, and Little Lake Harris, which is the smaller southern portion of the lake. The average water depth of the entire system is 12.0 ft. The deepest water occurs in the channel along the southern shore of Lake Harris where the depth reaches 31.7 ft. The central portion of Lake Harris generally falls in the depth range of 11 to 16 ft with a few deeper areas in isolated regions. Little Lake Harris is somewhat shallower with the depths generally ranging between 8 and 11 ft in the central part of the lake. During the survey the extreme southwestern portion of Little Lake Harris was filled with plants which precluded access to that portion of the lake. Consequently, five grid points were not sampled in the area and the bathymetry contours were interpolated using adjacent points and the shoreline.

<u>Lake Weir</u>

Lake Weir is the deepest of the lakes with an average depth of 18.9 ft at the reference level of 57 ft msl; the lake covers an area of 8.8 square miles (excluding Little Lake Weir). The central portion of the lake was flat with depths averaging about 25 ft. The water depth increased rapidly near shore and frequently reached 20 ft deep within a few hundred feet of shore. The deepest region was a channel along the southern edge of the lake where the depth reached 31.9 ft. The deep channel along the south shore was divided by a sand ridge running north and south that shoaled to a depth of about 20 ft. The southwestern portion of the lake was more shallow than the main body of the lake with water depths generally in the range of 15 to 18 ft in the central portion of the bay.

<u>Lake Yale</u>

Lake Yale covers 6.3 square miles and averages 12.2 ft deep at its reference level of 59 ft msl. The central portions of the lake are relatively flat with depths averaging about 15 ft. There is a deep channel running along the southwest shoreline where the depth reaches a maximum of 26.0 ft. There is also a deep hole along the western shore where a depth of 20.7 ft was measured. Similar to the other lakes, the greatest change in depth occurs near shore with the water depth reaching 10 ft within a few hundred feet of the shoreline.

3.2 SURFACE AREA AND VOLUME

The bathymetric contours developed for each lake were used to produce hypsographic curves relating water level in each lake to lake surface area and volume. The hypsographic curves for each lake are presented in Figures 3-8 to 3-14. The data from ARC/INFO used to plot these curves are presented in the Appendix. The curves presented provide the results of the polygon summations of the contours using ARC/INFO and also (for comparison) the results from summing the grid points from SURFER, developed for the plotting routine (as described in Sections 2.2.2 and 2.2.3). The results from both methods agree favorably with differences typically less than 1 or 2 percent. The greatest discrepancies occur on Lake Beauclair because of relatively few grid points due to the small lake size. In addition to the standard hypsographic data, additional estimates for lake surface areas and volumes for water levels 1 ft above the lake reference levels are provided. These estimates were obtained from elevation contours on USGS quadrangle maps.

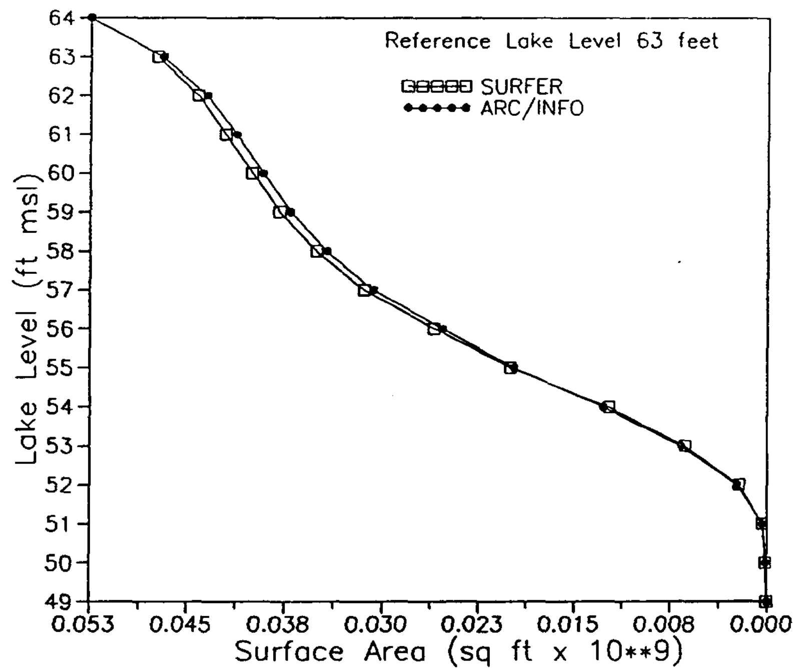
A comparison of lake volumes and surface areas for all seven lakes are presented in Figure 3-15. A brief description of the hypsographic curves for each lake is provided below (see the Appendix for data tables).

Lake Beauclair

Lake Beauclair is the smallest lake and covers 47.3 x 10^6 square ft (ft^2) and contains 318.7 x 10^6 cubic ft (ft^3) of water at its reference level of 63 ft msl. Increasing the lake level by 1 ft above the reference level would increase the lake volume by about 15.7 percent and would increase the surface area by about 12.1 percent. To reduce the volume of the lake by 50 percent would require drawing down the lake by about 3.8 ft to 59.2 ft msl. To expose 50 percent of the bottom (i.e., reduce the surface area by 50 percent) would require drawing down the lake to about 55.7 ft msl, which would require removing 272.1 x 10^6 ft^3 or 85.4 percent of the lake water.

LAKE BEAUCLAIR

Lake Level vs Surface Area



Lake Level vs Volume

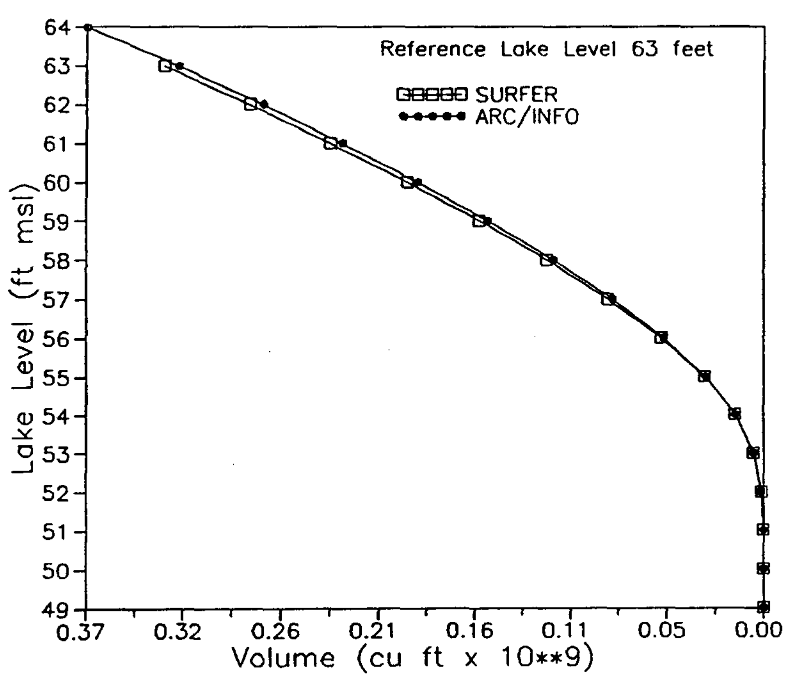


FIGURE 3-8.

HYPSOGRAPHIC CURVES FOR LAKE BEAUCLAIR

Source: ECT, 1991.

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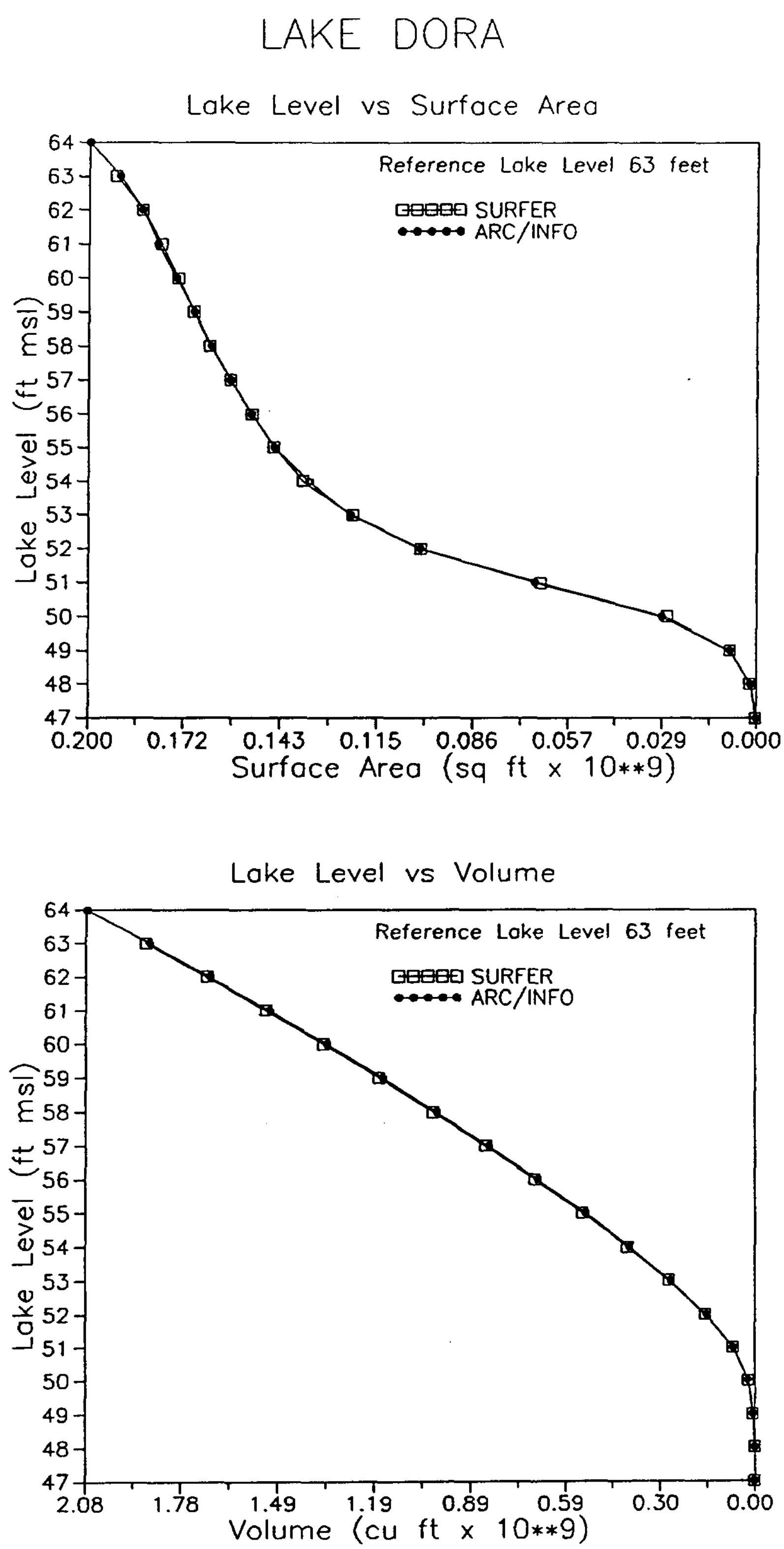

FIGURE 3-9.

HYPSOGRAPHIC CURVES FOR LAKE DORA

Source: ECT, 1991.

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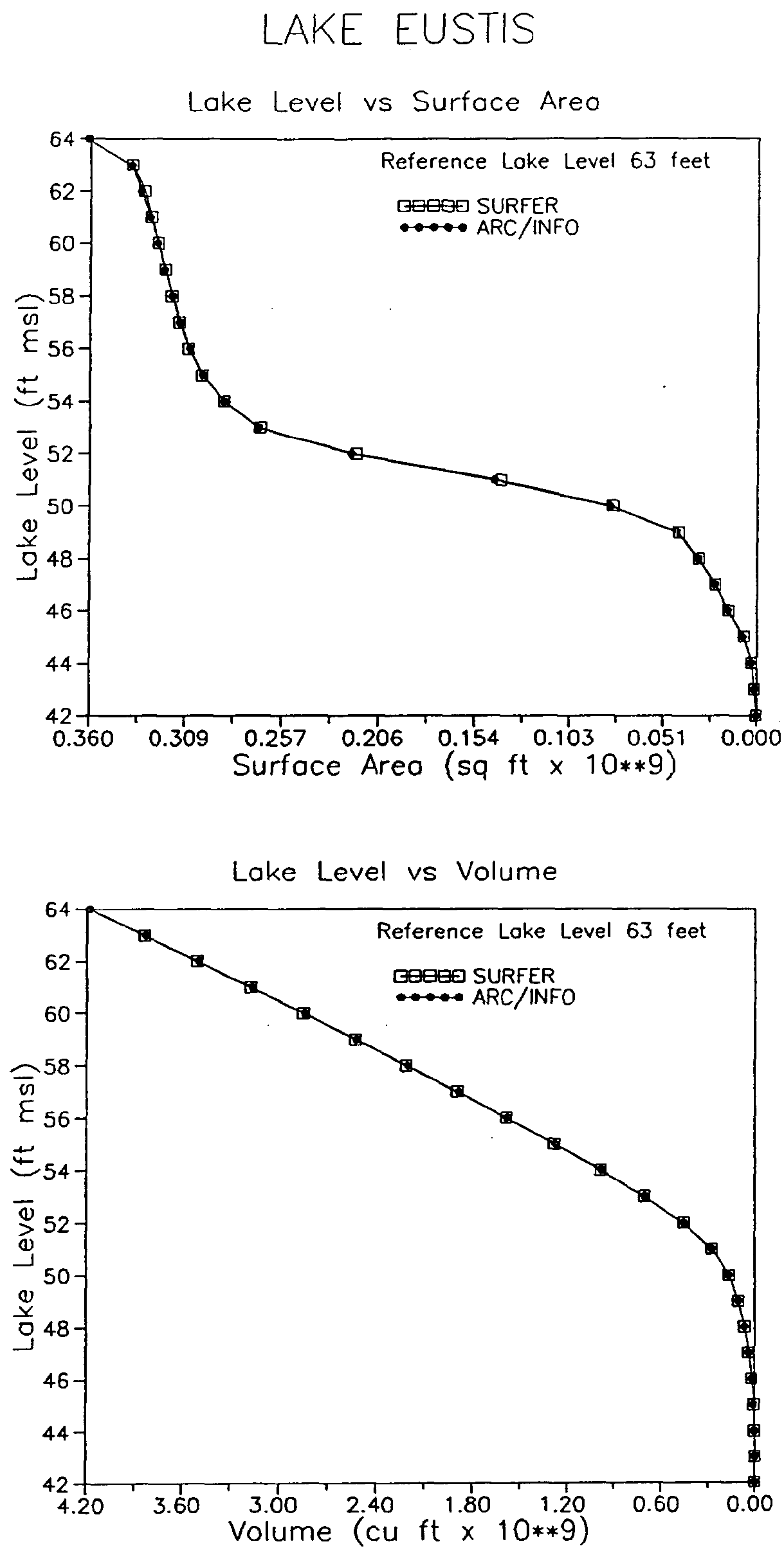

FIGURE 3-10.

HYPSOGRAPHIC CURVES FOR LAKE EUSTIS

Source: ECT, 1991.

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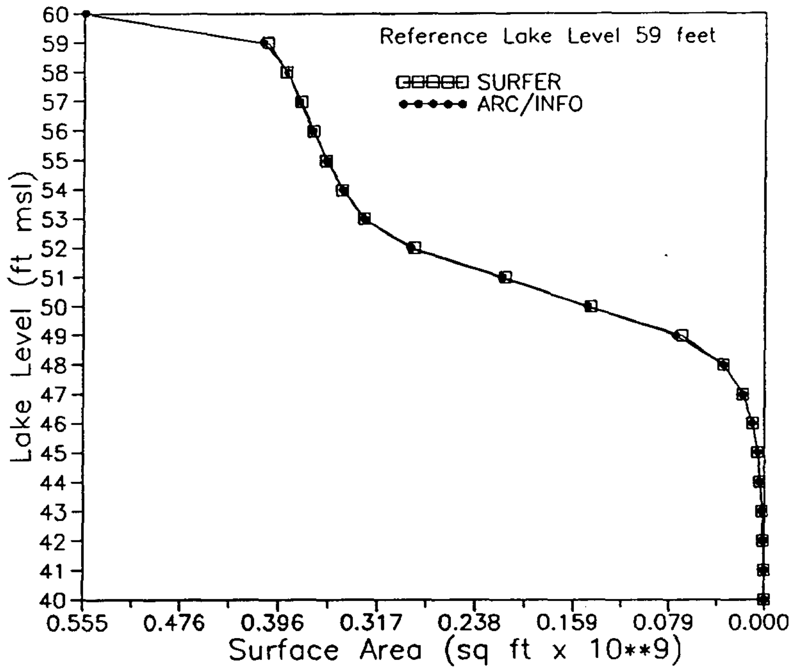
LAKE GRIFFIN

Lake Level vs Surface Area



Lake Level vs Volume

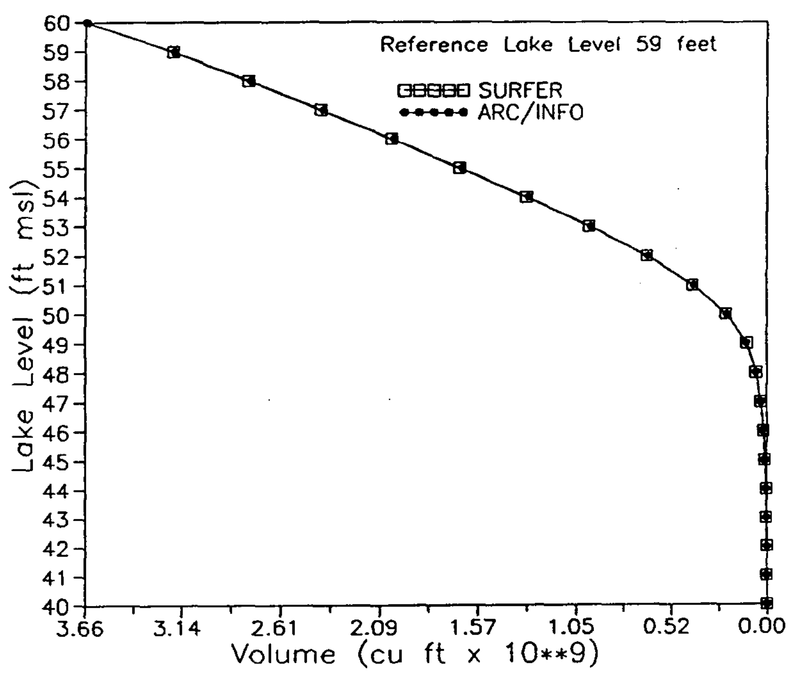


FIGURE 3-11.

HYPSOGRAPHIC CURVES FOR LAKE GRIFFIN

Source: ECT, 1991.

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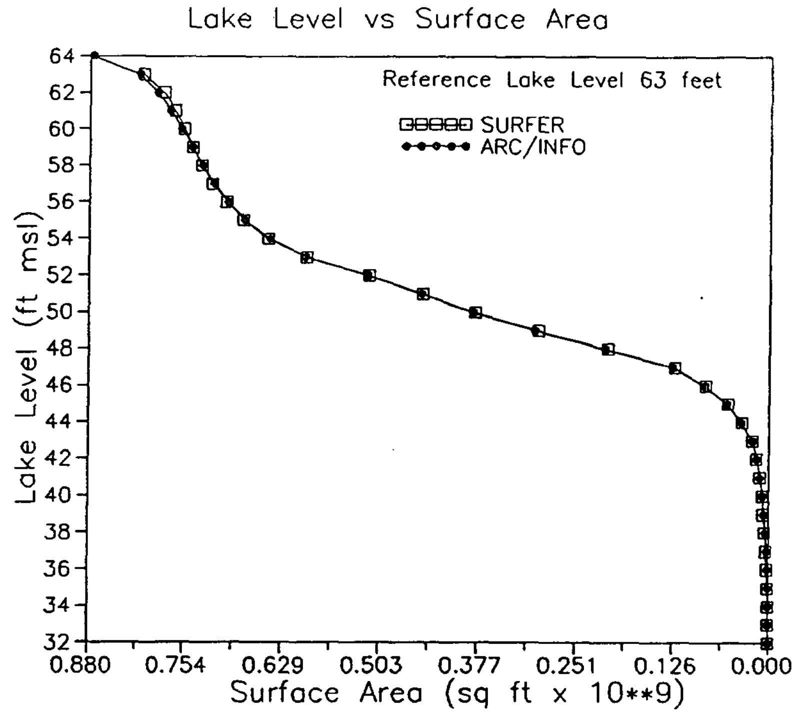
LAKE HARRIS



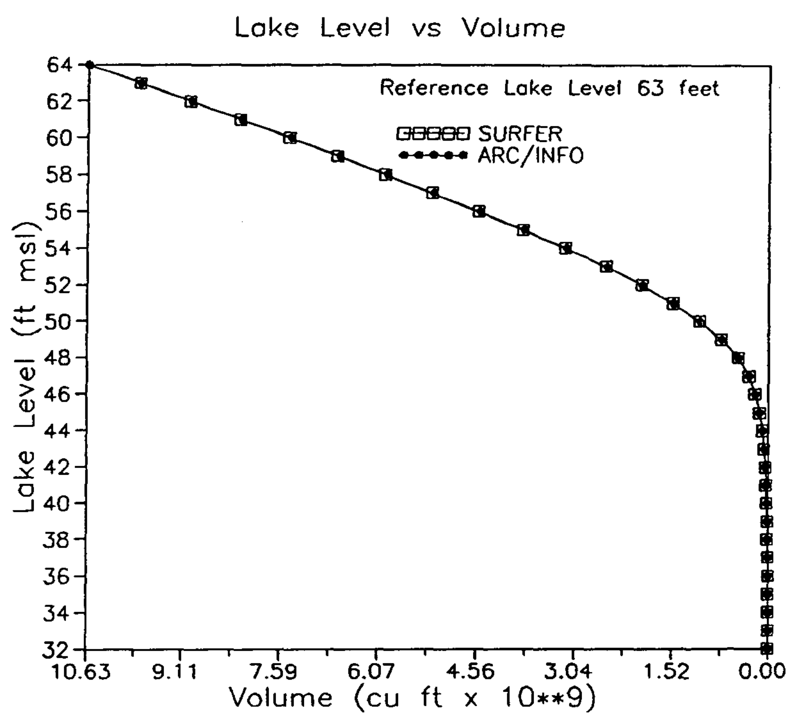


FIGURE 3-12.

HYPSOGRAPHIC CURVES FOR LAKE HARRIS

Source: ECT, 1991.

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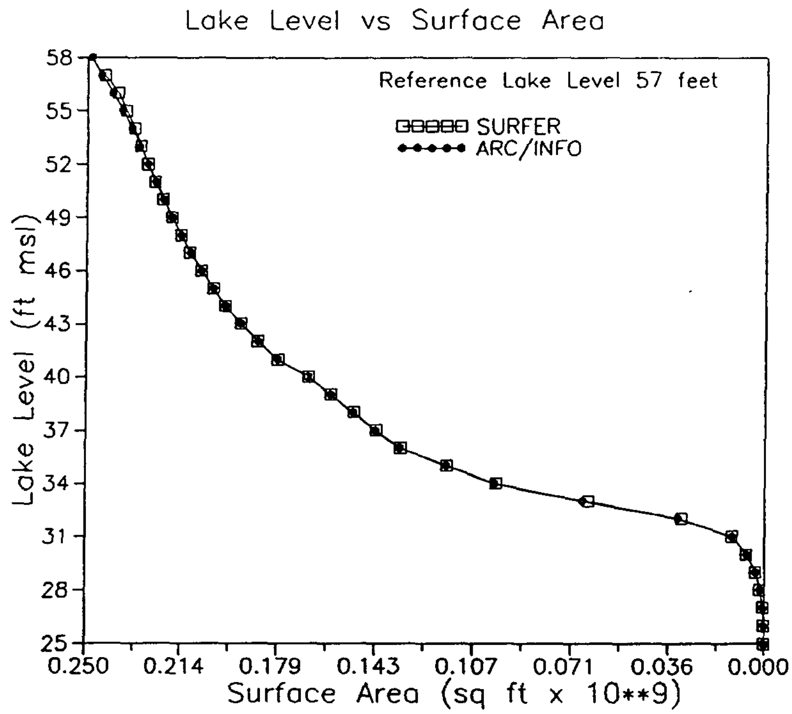
LAKE WEIR



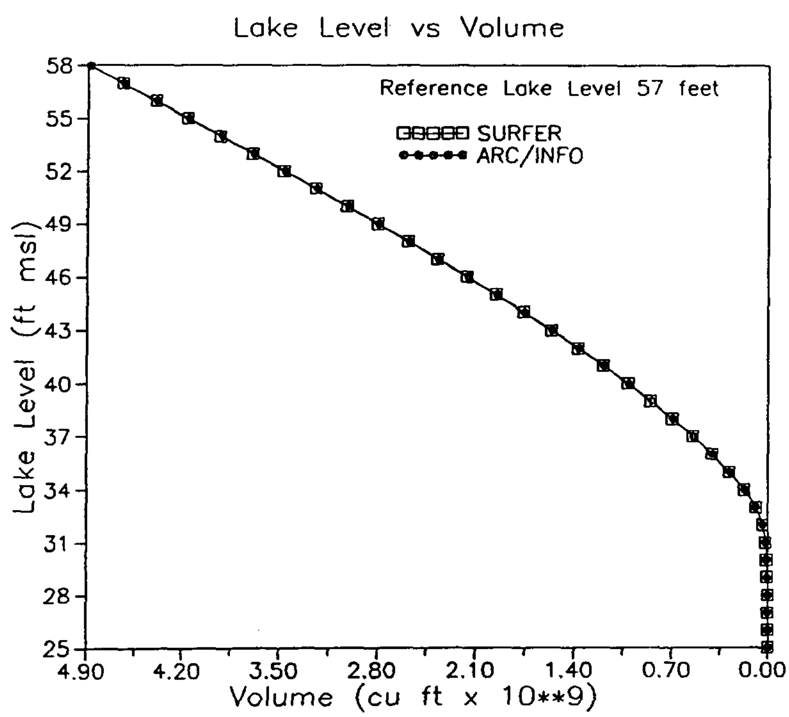


FIGURE 3-13.

HYPSOGRAPHIC CURVES FOR LAKE WEIR

Source: ECT, 1991.

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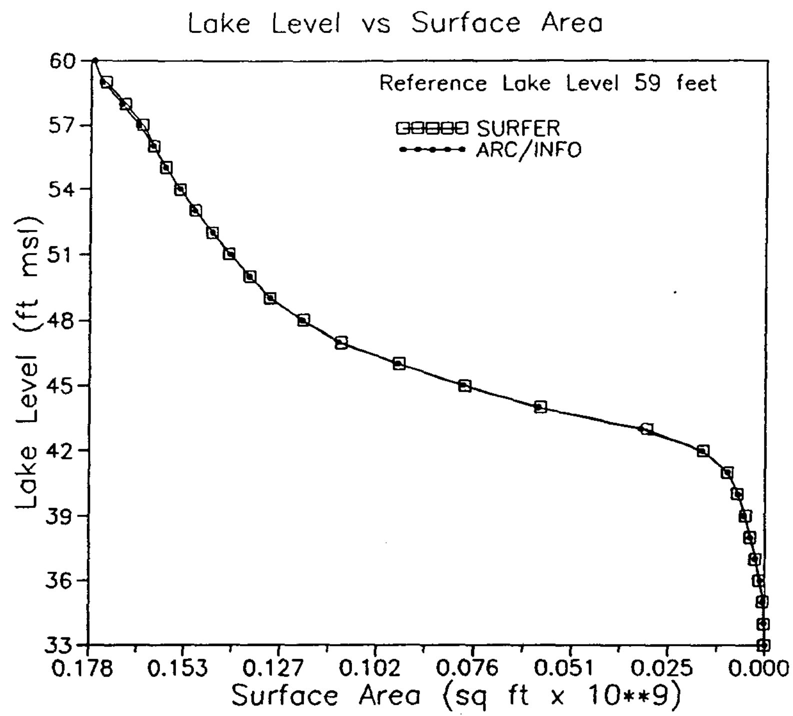
LAKE YALE



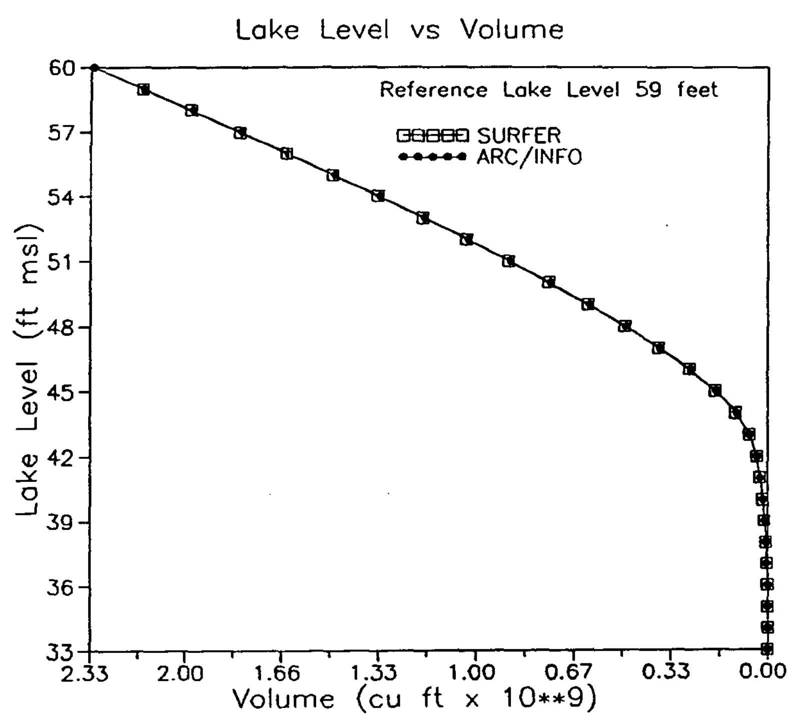


FIGURE 3-14.

HYPSOGRAPHIC CURVES FOR LAKE YALE

Source: ECT, 1991.

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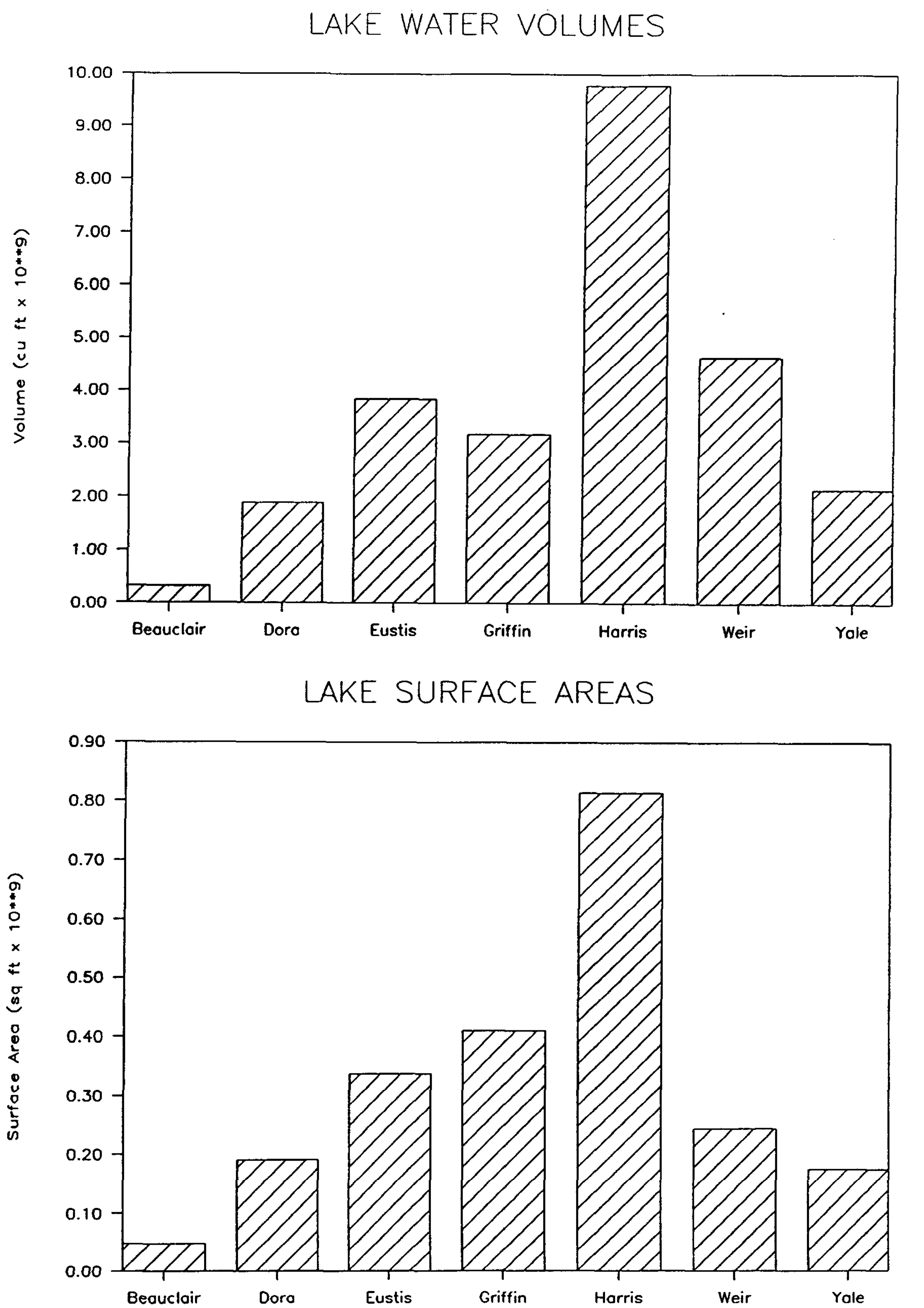

FIGURE 3-15.

COMPARISON OF LAKE WATER VOLUMES AND SURFACE AREAS

Source: ECT, 1991.

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Lake Dora

Lake Dora covers 191.0 x 10^6 ft^2 and contains 1.88 x 10^9 ft^3 of water at its reference level of 63 ft msl. Increasing the lake level by 1 ft would increase the lake volume by 10.4 percent and the surface area by 4.9 percent. To reduce the volume of the lake by 50 percent would require drawing down the lake by about 5.3 ft to 57.7 ft msl. To expose 50 percent of the lake bottom would require removing 1.73 x 10^9 ft^3 of water (92.1 percent of the lake) to lower the lake level 11.1 ft to about 51.9 ft msl.

Lake Eustis

Lake Eustis contains 3.83 x 10^9 ft^3 of water and has a surface area of 337.9 x 10^6 ft^2 at its reference level of 63 ft msl. Increasing the lake level by 1 ft would increase the volume by 9.1 percent and increase the surface area by 7.0 percent. To drain half of the lake would require lowering the water level 5.9 ft to 57.1 ft msl. To expose 50 percent of the bottom sediments would require lowering the lake level 11.7 ft to 51.3 ft msl, which would require removing 3.50 x 10^9 ft^3 or 91.2 percent of the lake water.

Lake Griffin

Lake Griffin covers a surface area of 410.0 x 10^6 ft^2 and contains a volume of 3.175 x 10^9 ft^3 at its reference level of 59 ft msl. Increasing the water level 1 ft would increase the surface area by 35.2 percent and increase the lake volume by 15.1 percent. The large increase in surface would result from inundating the large area of marsh and lowlands surrounding the lake. To reduce the volume of the lake by 50 percent would require lowering the lake level by 4.2 ft to 54.8 ft msl. To expose 50 percent of the bottom sediments would require lowering the lake level to 50.8 ft msl, which would require removing 2.81 x 10^9 ft^3 or 88.4 percent of the lake water.

Lake Harris

Lake Harris is the largest lake and contains 9.781×10^9 ft^3 and covers 814.1×10^6 ft^2 at its reference level of 63 ft msl. Raising the water level 1 ft would increase the surface area by 7.6 percent and increase the volume by 8.6 percent. To drain half of the lake would require lowering the lake level 6.5 ft to 56.5 ft msl. To reduce the surface area by 50 percent would require lowering the water level to 50.4 ft msl, which would require removing 8.55×10^9 ft^3 or 87.4 percent of the lake water.

Lake Weir

Lake Weir is the deepest lake and contains 4.638×10^9 ft^3 and covers an area of 244.9×10^6 ft^2 at its reference level of 57 ft msl. Raising the water level 1 ft would increase the surface area by only 1.0 percent and the lake volume by 5.3 percent. Reducing the lake volume by 50 percent would require lowering the lake level by 10.2 ft to 46.8 ft msl. Exposing 50 percent of the bottom sediments would require lowering the lake level to 35.3 ft msl and draining 93.1 percent of the lake, or about 4.32×10^9 ft^3 of water.

Lake Yale

Lake Yale covers 175.1×10^6 ft^2 and contains 2.144×10^9 ft^3 of water at its reference level of 59 ft msl. Increasing the water level 1 ft would increase the surface area by 1.2 percent and the volume by 8.2 percent. To drain half of the lake would require lowering the water level by 6.7 ft to 52.3 ft msl. To reduce the surface area by 50 percent would require lowering the lake level to 45.5 ft msl, which would require removing 1.92×10^9 ft^3 or 89.7 percent of the lake water.

3.3 SEDIMENT THICKNESS

The sediment thicknesses in all seven lakes were plotted and contoured; the results are presented in Figures 3-16 to 3-22. The surface area within each contour and the sediment volume as a function of sediment thickness was also computed and plotted as hypsographic curves. The results of these calculations are illustrated in Figures 3-23 to 3-29, and

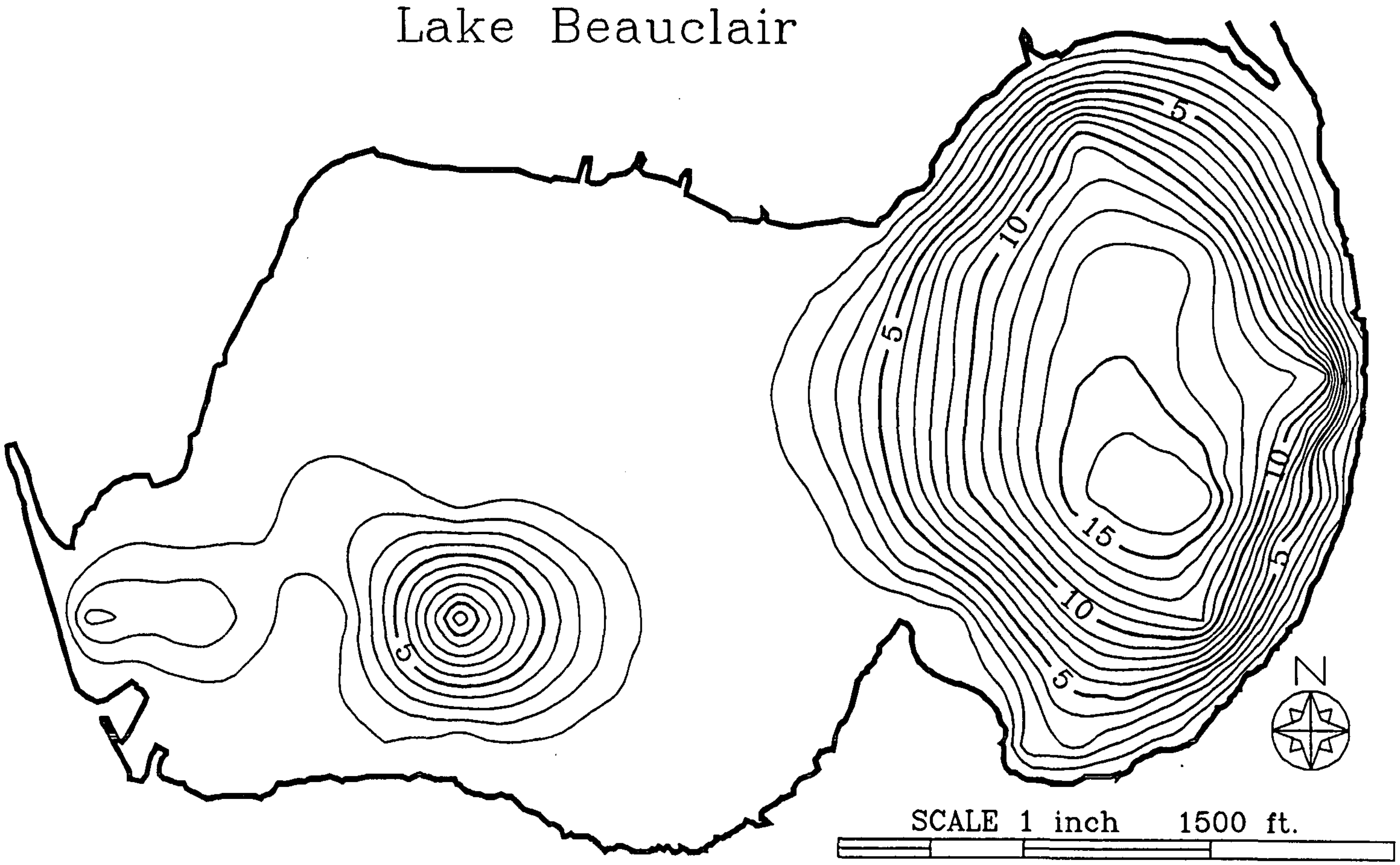

FIGURE 3-16.

SEDIMENT THICKNESS CONTOURS FOR LAKE BEAUCLAIR (CONTOURS ARE IN FEET)

Source: ECT, 1991.

ECT
Environmental Consulting & Technology, Inc.

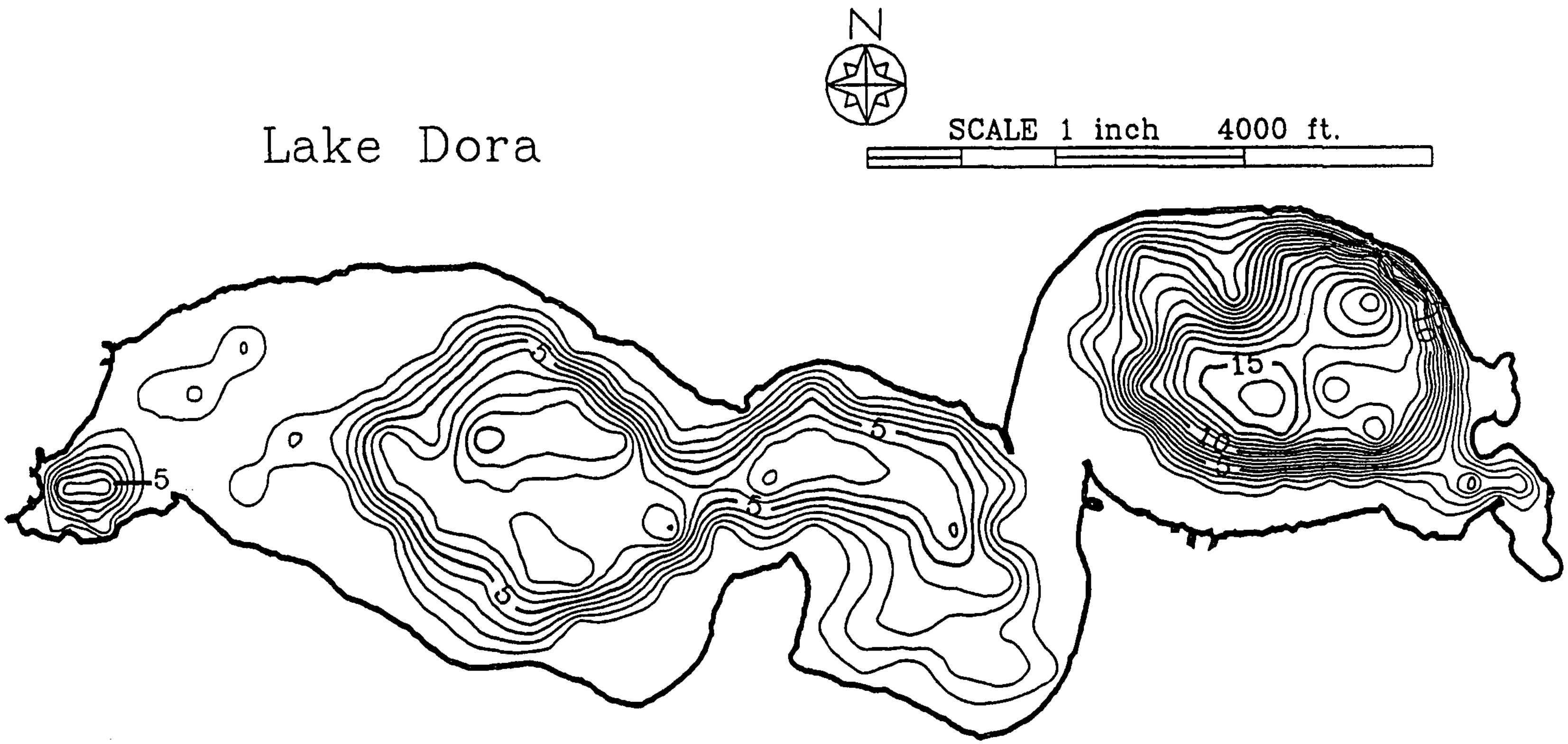

FIGURE 3-17.

SEDIMENT THICKNESS CONTOURS FOR LAKE DORA (CONTOURS ARE IN FEET)

Source: ECT, 1991.

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Environmental Consulting & Technology, Inc.

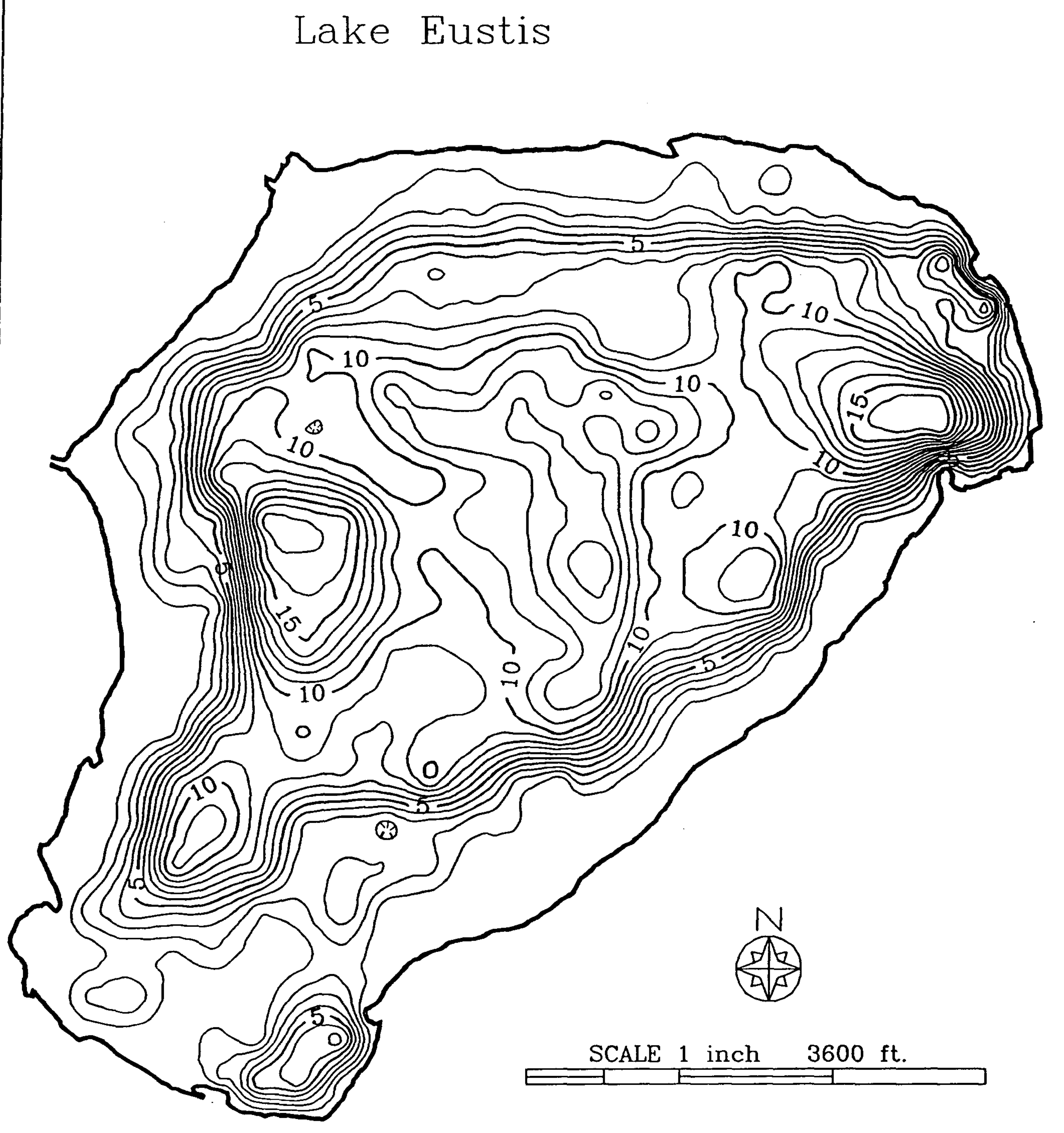


FIGURE 3-18.

SEDIMENT THICKNESS CONTOURS FOR LAKE EUSTIS (CONTOURS ARE IN FEET)

Source: ECT, 1991.

ECT

Environmental Consulting & Technology, Inc.

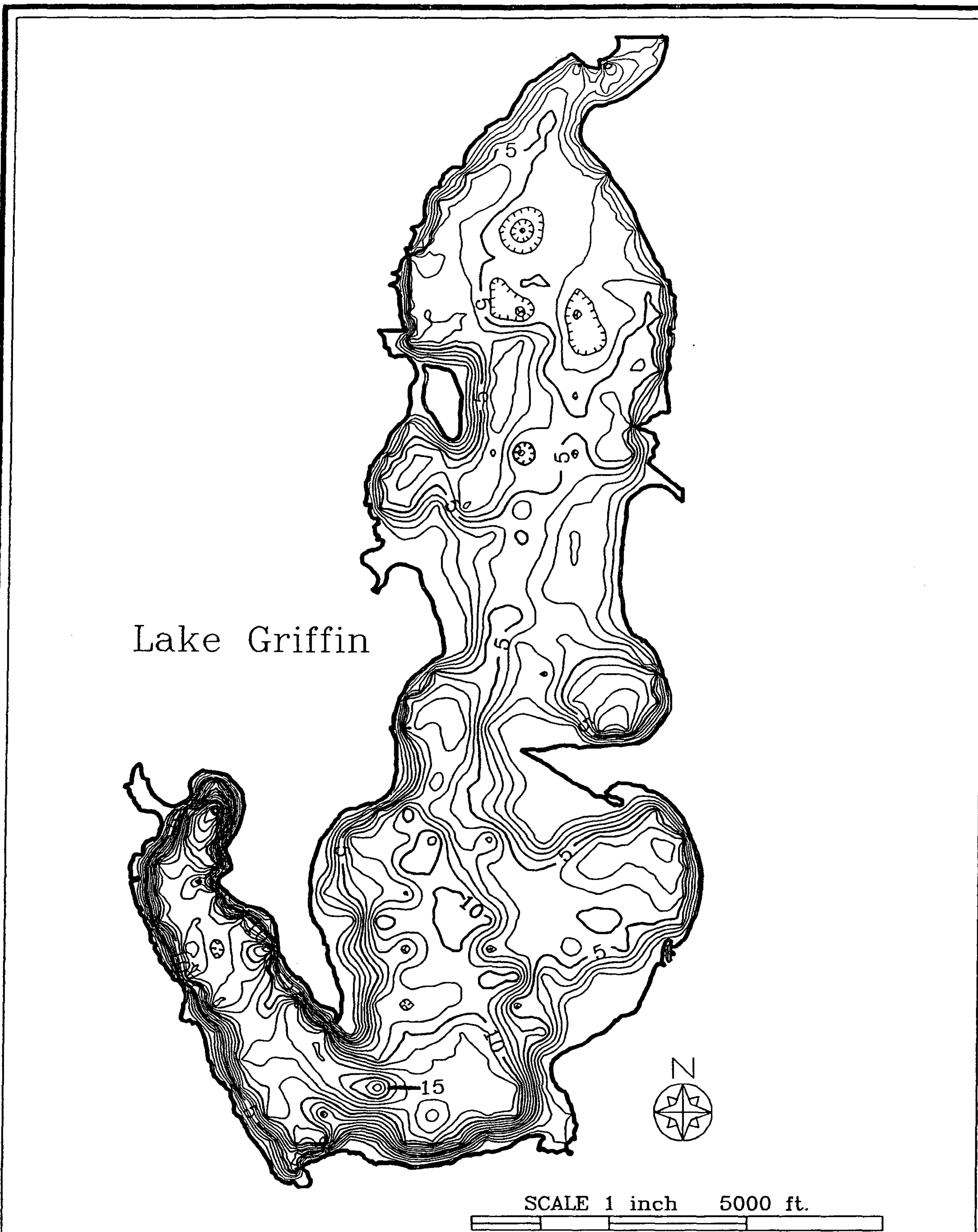
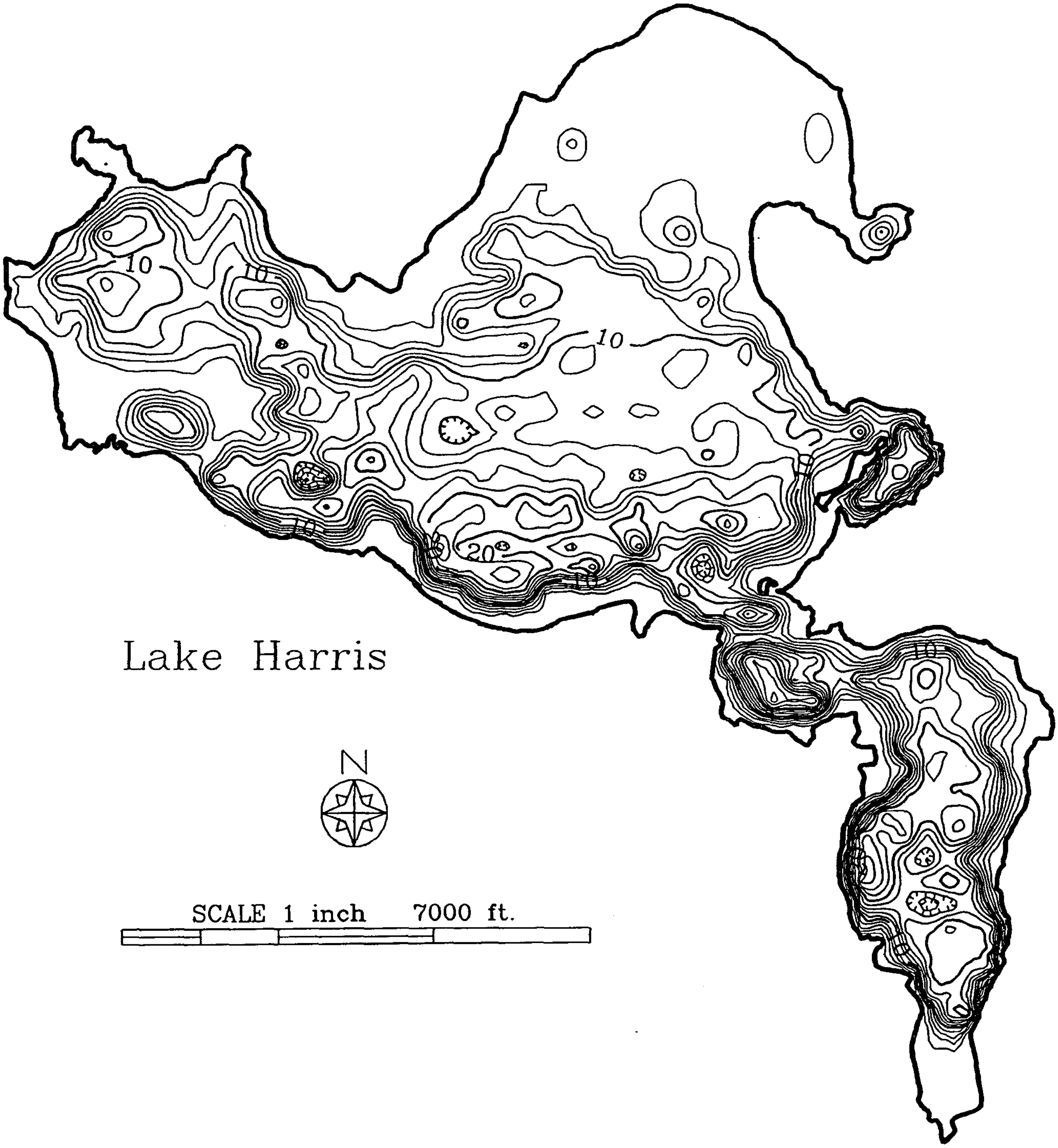


FIGURE 3-19.

SEDIMENT THICKNESS CONTOURS FOR LAKE GRIFFIN (CONTOURS ARE IN FEET)
Source: ECT, 1991.

ECT
Environmental Consulting & Technology, Inc.



Note: Contours are in 2-ft intervals.

FIGURE 3-20.

SEDIMENT THICKNESS CONTOURS FOR
LAKE HARRIS (CONTOURS ARE IN FEET)
Source: ECT, 1991.

ECT
Environmental Consulting & Technology, Inc.

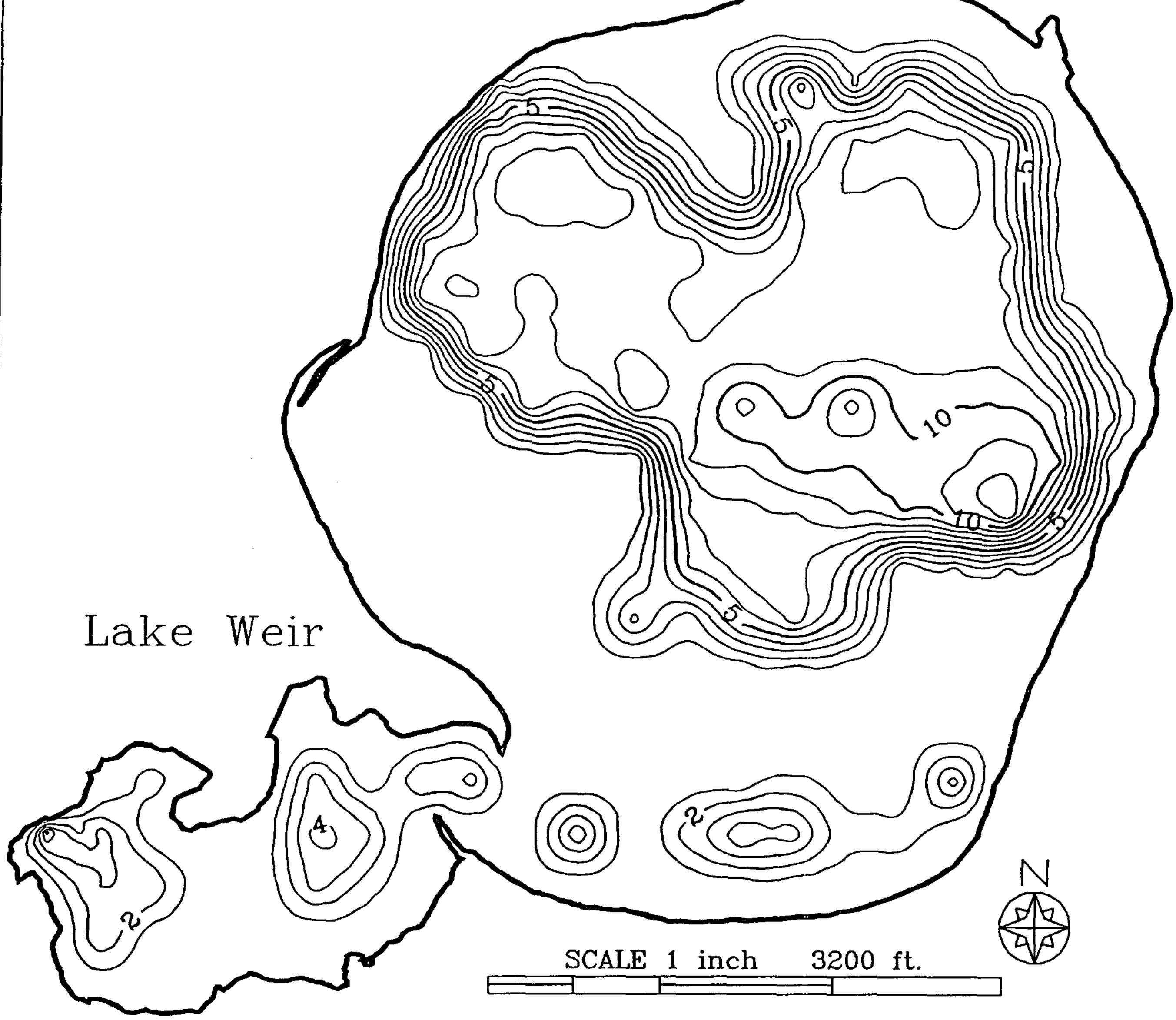


FIGURE 3-21.

SEDIMENT THICKNESS CONTOURS FOR LAKE WEIR (CONTOURS ARE IN FEET)
Source: ECT, 1991.

ECT
Environmental Consulting & Technology, Inc.

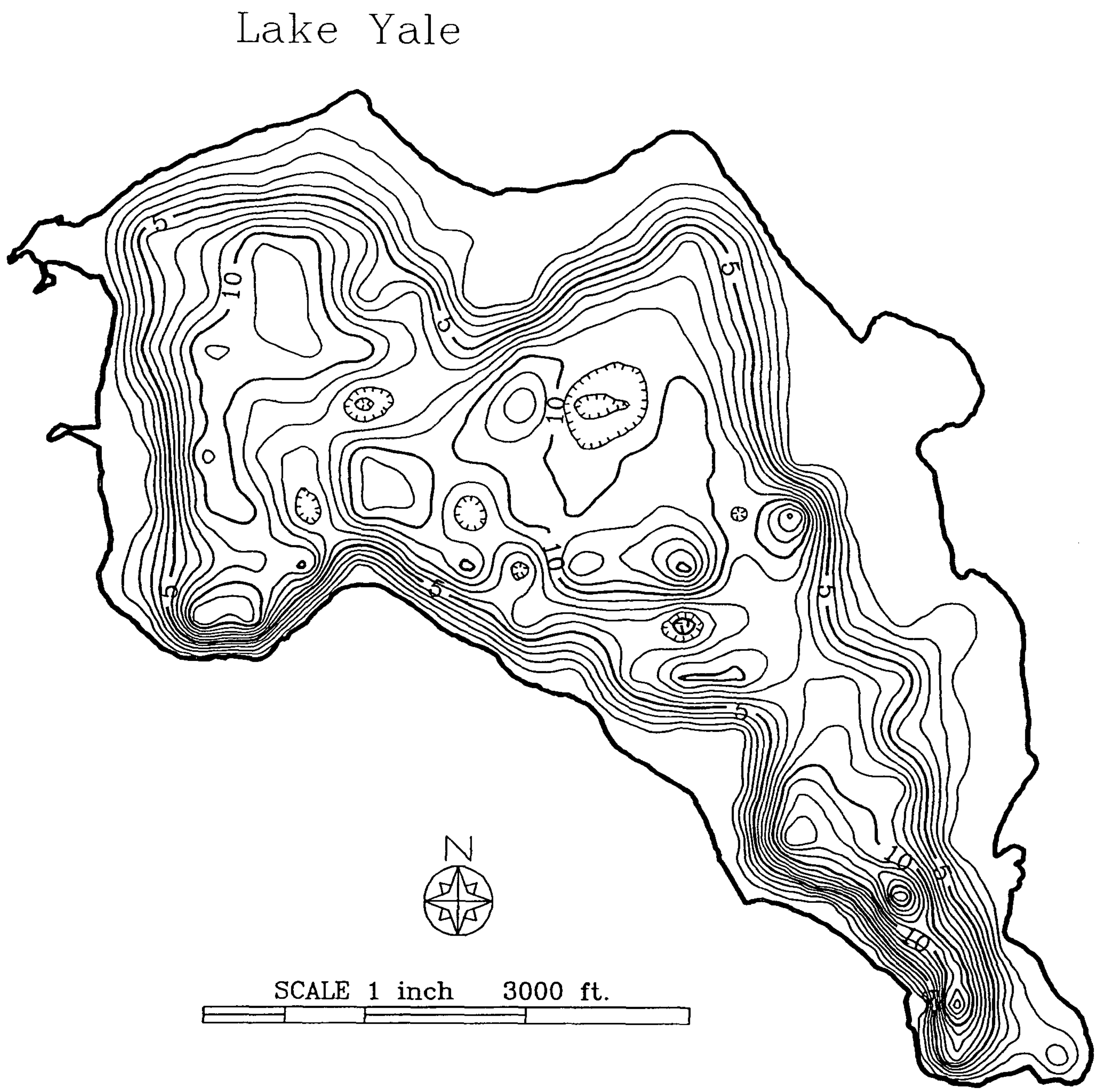
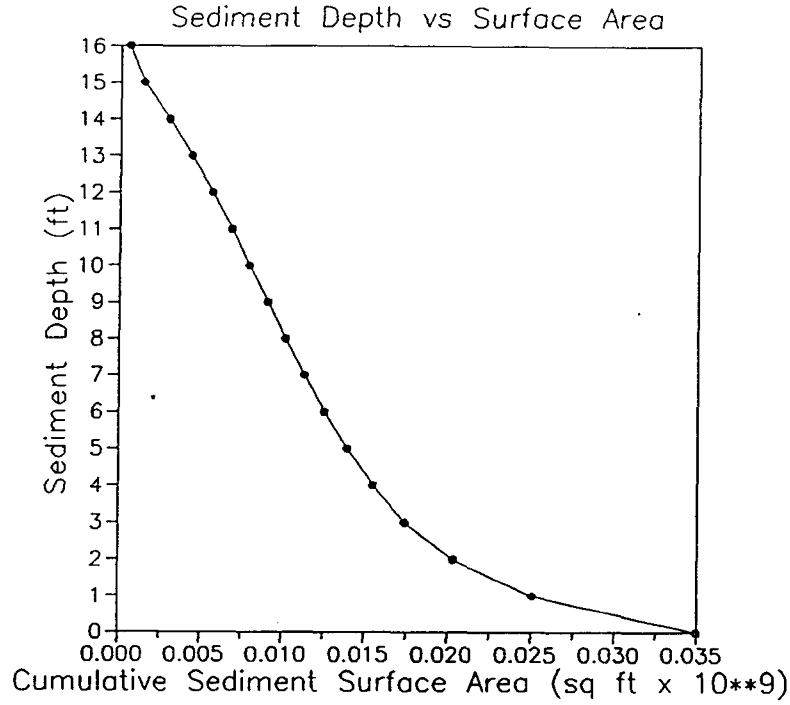


FIGURE 3-22.

SEDIMENT THICKNESS CONTOURS FOR LAKE YALE (CONTOURS ARE IN FEET)
Source: ECT, 1991.

ECT
Environmental Consulting & Technology, Inc.

LAKE BEAUCLAIR



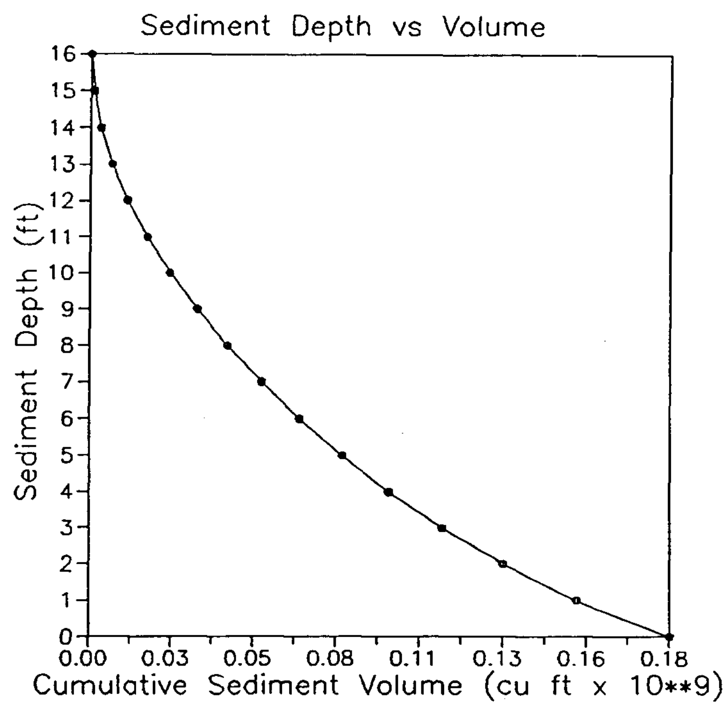


FIGURE 3-23.

SEDIMENT VOLUME AND SURFACE AREA VERSUS SEDIMENT THICKNESS FOR LAKE BEAUCLAIR

Source: ECT, 1991.

ECT
Environmental Consulting & Technology, Inc.

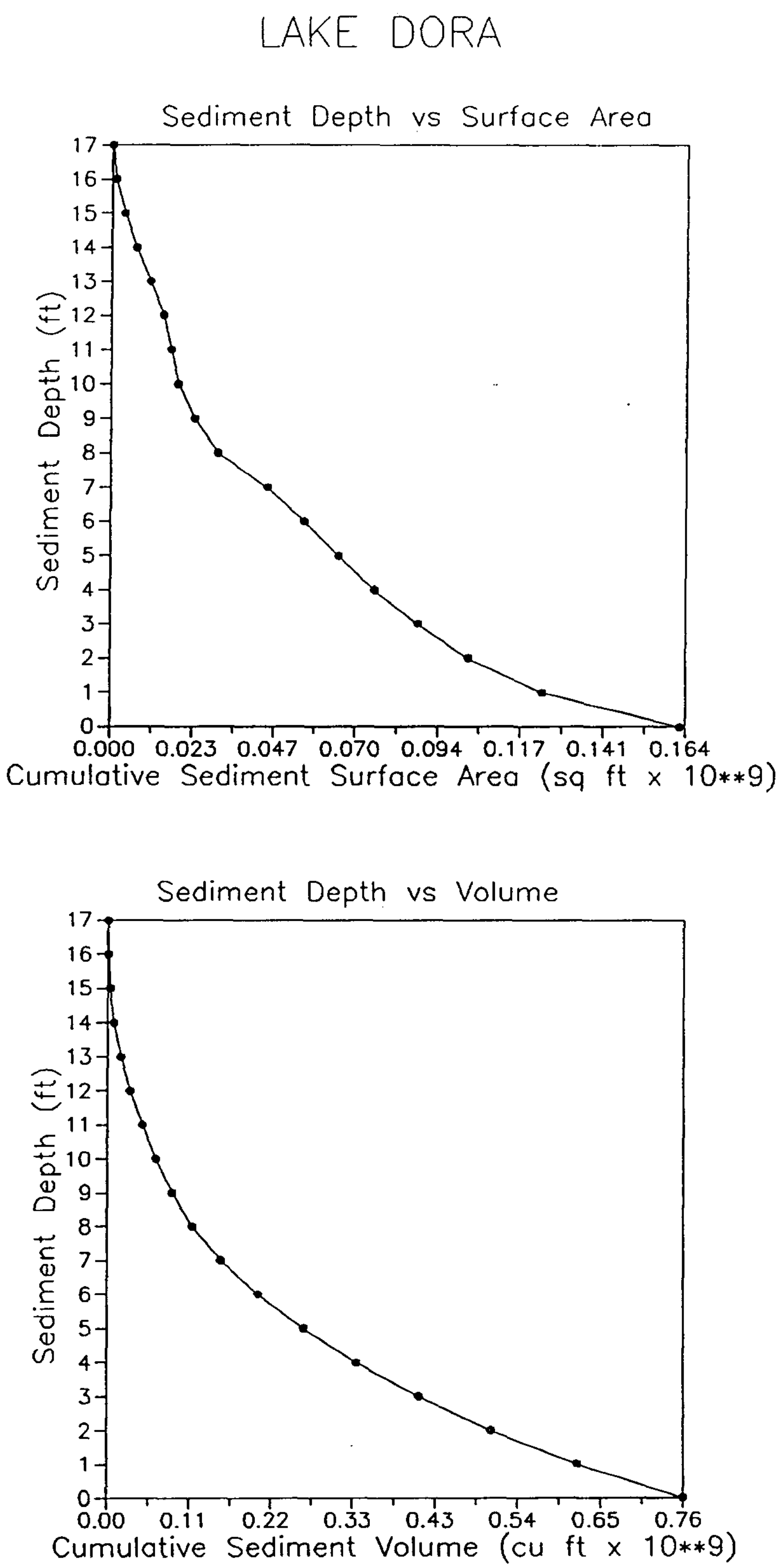


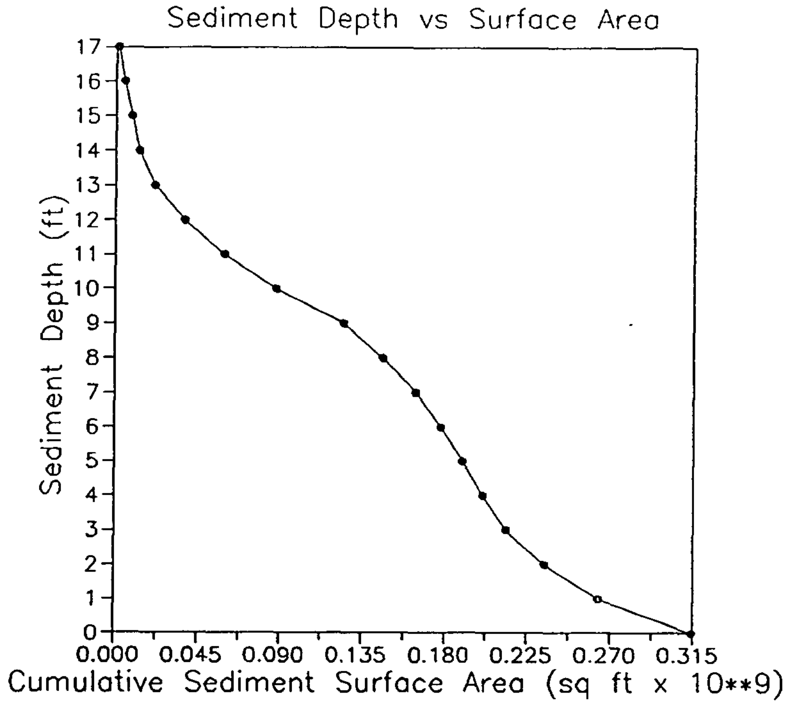
FIGURE 3-24.

SEDIMENT VOLUME AND SURFACE AREA VERSUS SEDIMENT THICKNESS FOR LAKE DORA

Source: ECT, 1991.

ECT
Environmental Consulting & Technology, Inc.

LAKE EUSTIS



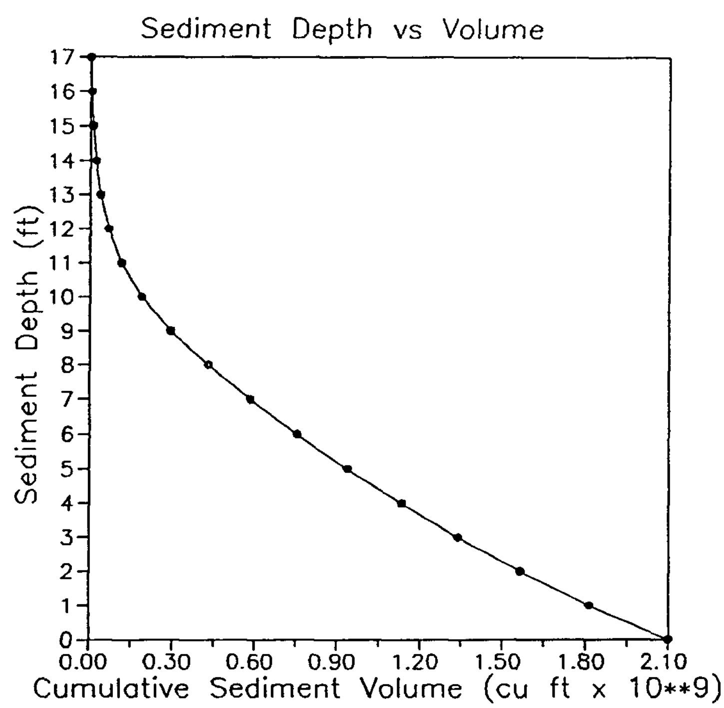


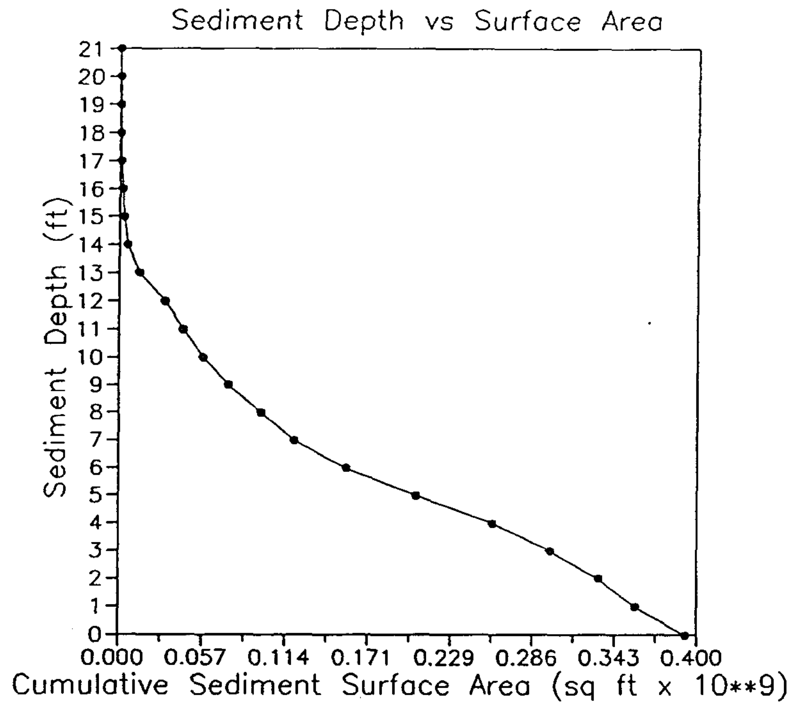
FIGURE 3-25.

SEDIMENT VOLUME AND SURFACE AREA VERSUS SEDIMENT THICKNESS FOR LAKE EUSTIS

Source: ECT, 1991.

ECT
Environmental Consulting & Technology, Inc.

LAKE GRIFFIN



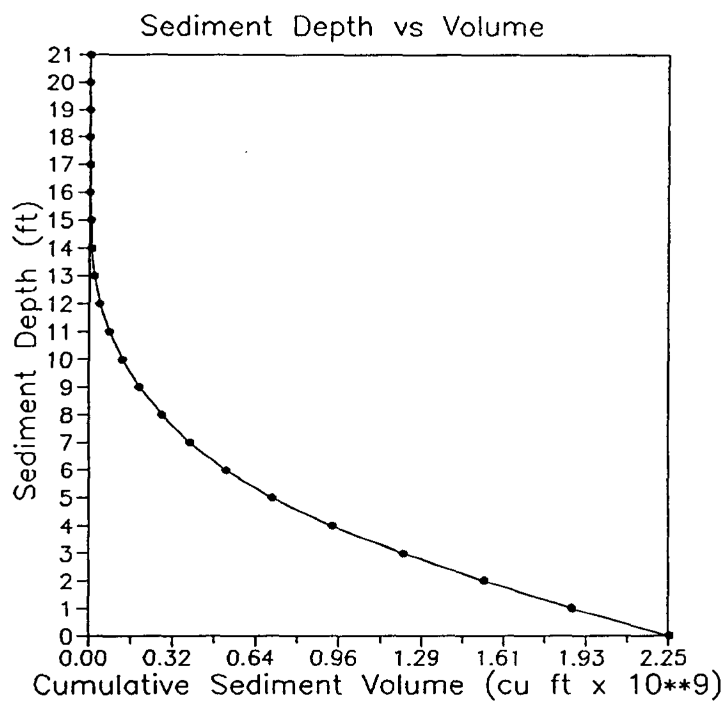


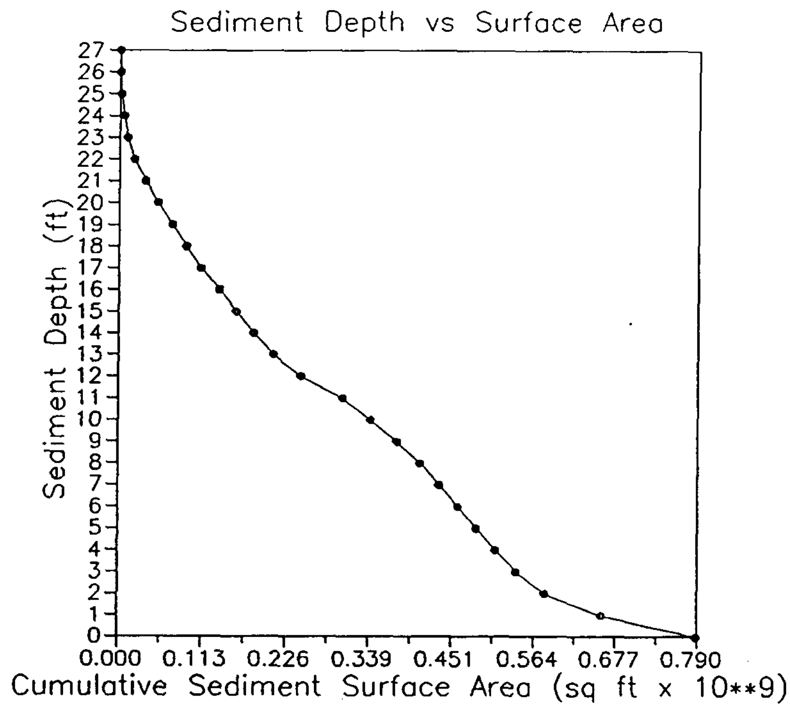
FIGURE 3-26.

SEDIMENT VOLUME AND SURFACE AREA VERSUS SEDIMENT THICKNESS FOR LAKE GRIFFIN

Source: ECT, 1991.

ECT
Environmental Consulting & Technology, Inc.

LAKE HARRIS



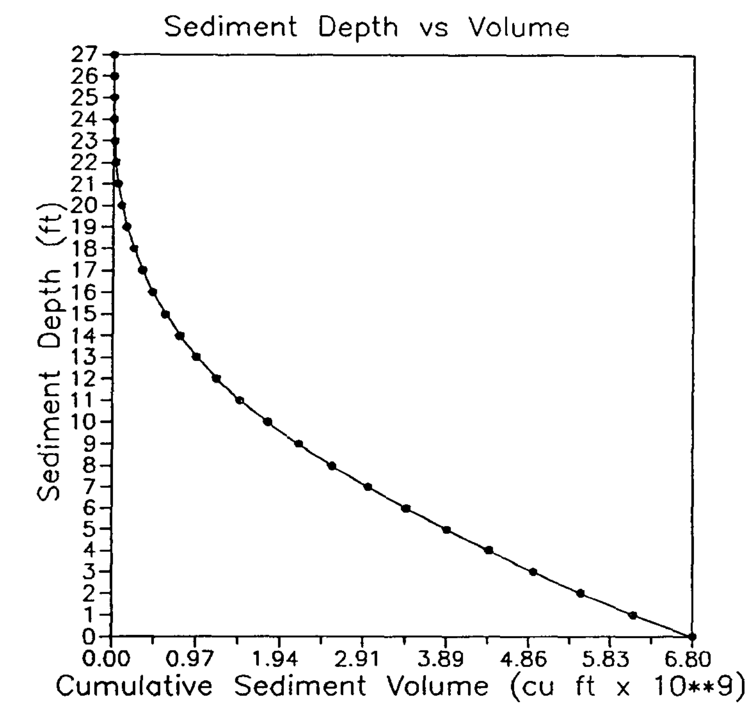


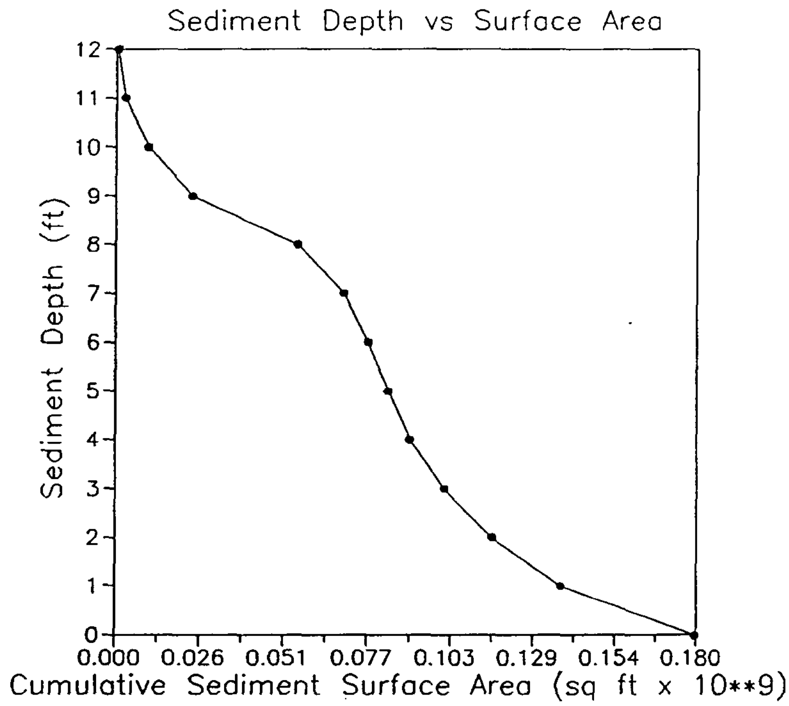
FIGURE 3-27.

SEDIMENT VOLUME AND SURFACE AREA VERSUS SEDIMENT THICKNESS FOR LAKE HARRIS

Source: ECT, 1991.

ECT
Environmental Consulting & Technology, Inc.

LAKE WEIR



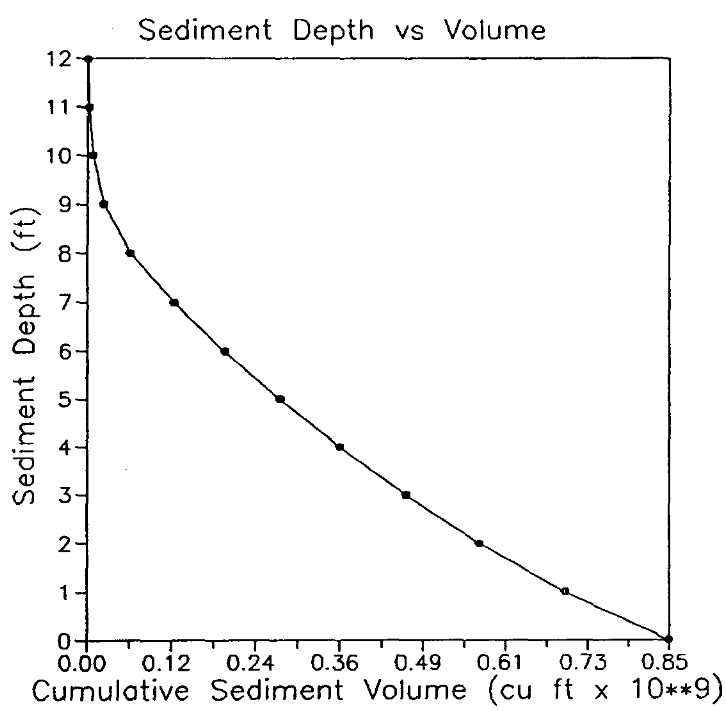


FIGURE 3-28.

SEDIMENT VOLUME AND SURFACE AREA VERSUS SEDIMENT THICKNESS FOR LAKE WEIR

Source: ECT, 1991.

ECT
Environmental Consulting & Technology, Inc.

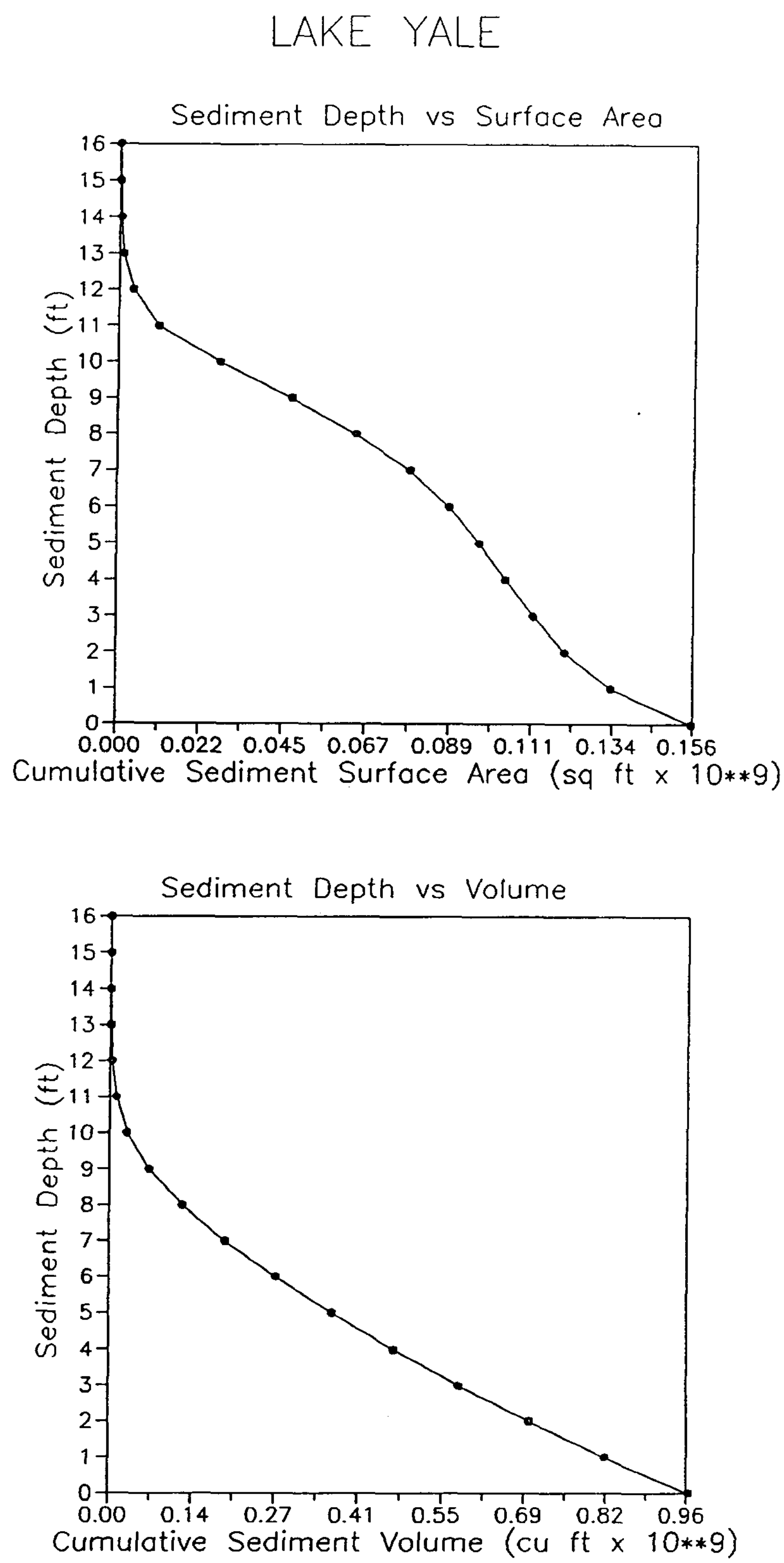


FIGURE 3-29.

SEDIMENT VOLUME AND SURFACE AREA VERSUS SEDIMENT THICKNESS FOR LAKE YALE

Source: ECT, 1991.

ECT
Environmental Consulting & Technology, Inc.

the data used to plot these curves are provided in the Appendix. A description of the sediments measured in each lake is provided below.

Lake Beauclair

Most of the soft sediments observed in Lake Beauclair occurred in the eastern end of the lake and reached a thickness of 17 ft. An additional smaller region of soft sediments occurred in the western part of the lake with one measurement recording 12 ft of sediment. There was an extensive sand bottom region between the two areas where no soft sediments were observed. The volume of soft sediments calculated for Lake Beauclair is 0.184×10^9 ft^3 and the surface area covered by soft sediments is 35.3×10^6 ft^2, which is 75.1 percent of the area of the lake. The average thickness of the soft sediments was 5.2 ft with the unconsolidated portion of the sediment (i.e., the flocculent layer) averaging 1.29 ft.

Lake Dora

The soft sediments in Lake Dora were located in the central deeper regions of both the east and west basins of the lake. An additional region of soft sediments occurred in the extreme western portion of the lake where the soft sediment thickness reached 7 ft. The thickest sediments occurred in the eastern basin with the sediments reaching a thickness of 17.8 ft. There was a border of exposed sand sediments surrounding the soft sediments in each basin and wide areas of sand separating the two basins. The total volume of soft sediments calculated for Lake Dora is 0.760×10^9 ft^3. The sediment thickness averages 4.7 ft with the unconsolidated portion of the sediments averaging 1.08 ft. The soft sediments covered a surface area of 162.3×10^6 ft^2, which is about 85.0 percent of the lake bottom.

Lake Eustis

The soft sediments in Lake Eustis covered 93.0 percent of the lake bottom with only a narrow strip of exposed sand sediments along the perimeter of the lake. Two areas of very deep sediments occurred in the lake: one area near the northeast shoreline where the sediments reached 16.2 ft thick, and one region in the west-central part of the lake where the sediments were 17.7 ft thick. The soft sediments in the central part of the lake were generally between 10 and 13 ft thick. The total volume of soft sediments calculated for Lake Eustis is 2.097 x 10^9 ft^3, which is equal to approximately half of the volume of water in the lake. The soft sediments cover about 314.3 x 10^6 ft^3, and average about 6.7 ft thick; the flocculent layer averages about 0.71 ft.

Lake Griffin

The soft sediments in Lake Griffin covered 95.6 percent of the lake with only a few areas of exposed sand occurring near shore. The deepest sediments are in the southern portion of the lake and the bay at the southwest section of the lake. A sediment thickness of 22 ft was observed at the northern tip of the southwestern bay and a thickness of 18 ft was measured in the southern part of the lake. The sediments in the northern two-thirds of the lake did not exceed 10 ft thick with many of the values being less than 5 ft. The total volume of soft sediments calculated for Lake Griffin is 2.252 x 10^9 ft^3 and the sediments cover a surface area of 392.0 x 10^6 ft^2. The average sediment thickness is 5.7 ft with 1.59 ft of that amount being flocculent sediments.

Lake Harris and Little Lake Harris

The soft sediments in Lake Harris and Little Lake Harris covered 96.8 percent of the bottom with the only exposed sand areas occurring in a few areas along the perimeter of the lake and a large area in the northeast region. The sediment thickness averaged 8.6 ft of which an average of 0.67 ft was flocculent sediments. Because of the depth of the lake and the thickness of the sediments, most of the measurements were made with the sediment rod instead of the coring device. In Lake Harris the organic sediments frequently were deposited on other soft sediments such as marl or loosely packed clay. Use of the sediment rod could not detect these subtle interfaces and, in most cases, the entire thickness of soft sediments was measured to a depth where a more firm substrate was encountered. Consequently, in the deeper regions the entire thickness of soft sediments is reported which, in most cases, will be greater than just the thickness of soft organic sediments.

The sediment thicknesses in Lake Harris were quite variable with frequent areas of deep sediments and adjacent areas of thinner sediments. The thickest sediments were observed in the southern part of Lake Harris with a maximum thickness of 29 ft. There was also an area of thick sediments in the region between the two lakes where the sediments reached 28 ft thick. The sediments in Little Lake Harris were, on the average, much thicker than observed in Lake Harris with most of the values in the central part of the lake exceeding 20 ft. The total volume of sediments calculated for the lake system is 6.797×10^9 ft^3 with a sediment coverage of 788.1×10^6 ft^2.

<u>Lake Weir</u>

The soft sediments in Lake Weir occurred in the north-central portion of the lake basin with a few patchy areas separated by sand ridges along the southern border of the lake. The total volume of soft sediments calculated for Lake Weir is 0.849×10^9 ft^3. The average sediment thickness is 4.7 ft of which about 0.84 ft is flocculent sediments. The soft sediments covered 179.6×10^6 ft^2 which is about 73.3 percent of the lake bottom. The deepest sediments occurred near the center of the lake and reached 12.5 ft thick where the water depth was about 24 ft.

<u>Lake Yale</u>

The soft sediments in Lake Yale averaged about 6.2 ft thick of which about 0.59 ft was unconsolidated organic material. The deepest sediments occurred in the southeast region where the values reached 17.9 ft. Similar to the other lakes, an exposed sand area occurred along the perimeter of the lake surrounding the soft sediments that occurred in the central region of the lake basin. The soft sediments covered 155.7×10^6 ft^2 or about 88.9 percent of the lake bottom. The total soft sediment volume calculated for Lake Yale is 0.9632×10^9 ft^3.

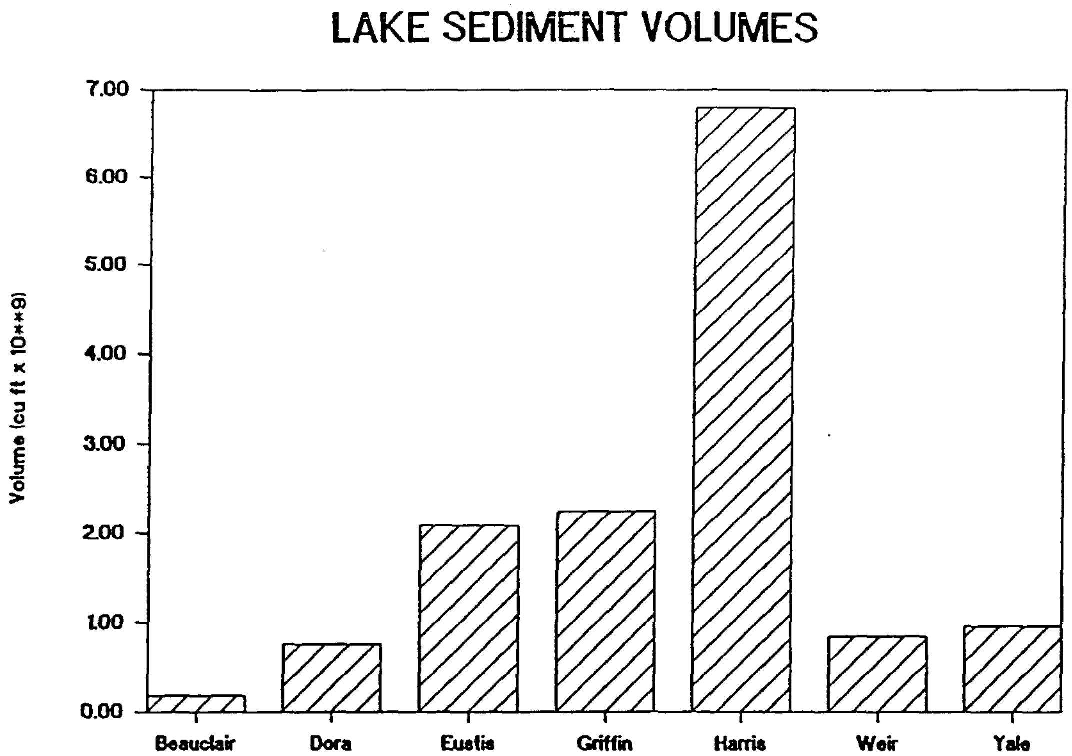
Summary

A comparison of the amount of soft sediment found in each of the lakes is provided in Figure 3-30. The sediment volumes ranged from a low value in Lake Beauclair of 0.184 x 10^9 ft^3 to a volume of 6.80 x 10^9 ft^3 in Lake Harris. A comparison of organic sediment bottom coverage is also presented in Figure 3-30. Lake Weir had the lowest bottom coverage with 73.3 percent and Lake Harris had the highest with 96.8 percent. Table 3-1 provides summary statistics of the flocculent layer measurements that include the number of stations where soft sediments were observed, the mean thickness of the flocculent layer, the number of stations where there were soft sediments but no flocculent layer, the standard deviation of the measurements, and the maximum thickness of the flocculent layer observed on each lake. Lake Yale had only 50 observations because the weeds in the lake required that the sediment rod technique be used at most stations; no observations of flocculent layer thickness at these stations were made.

3.4 ERROR ANALYSIS

Errors in completing bathymetric surveys and calculating hypsographic statistics can be introduced through several means that include: fathometer calibration, lake level slope, navigation, contouring, and digitizing. It is difficult not only to estimate the amount of error involved with each component, but also to determine the effect that error has on the final bathymetric results. For example, the navigational accuracy of the survey was about ±3 meters, but determining the effect this inaccuracy has on the final bathymetry is difficult. To complete a detailed error analysis in the strictest sense would require completing the entire survey independently several times and statistically analyzing the results to produce confidence levels. Since this was not practical, the individual components of the survey were analyzed.

An estimate of the accuracy of measuring the water depth, correcting for navigation error, calibrating the measured depth and correcting for lake level fluctuations was done by comparing the results of the survey with replicate measurements made with a photoelectric device (PD) and comparing



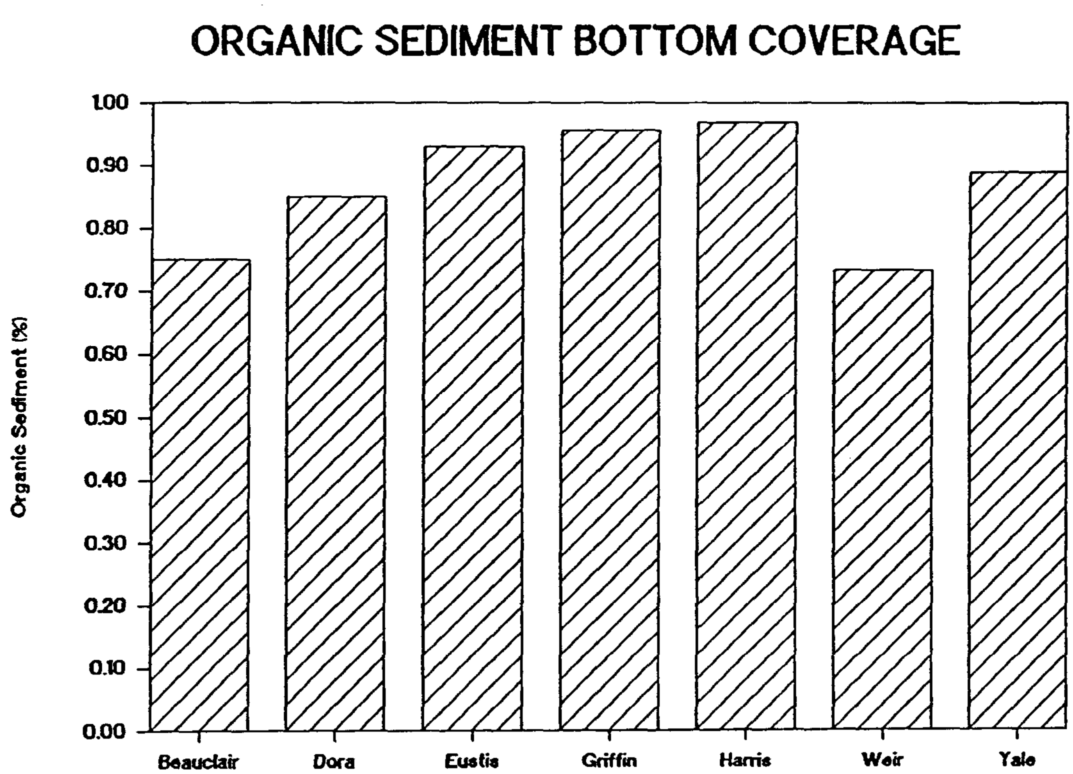


FIGURE 3-30.
COMPARISON OF LAKE SEDIMENT VOLUMES AND PERCENT OF BOTTOM COVER FOR ALL SEVEN LAKES
Source: ECT, 1991.

ECT
Environmental Consulting & Technology, Inc.

Table 3-1. Summary of Flocculent Layer Measurements

Lake	N[1]	Mean (ft)	Standard Deviation	Maximum (ft)	Nzero[2]
Beauclair	26	1.29	0.62	2.33	0
Dora	128	1.08	0.84	4.08	4
Eustis	289	0.71	0.56	2.75	6
Griffin	374	1.59	0.75	3.92	3
Harris	685	0.67	0.52	3.33	28
Weir	133	0.84	0.61	3.00	3
Yale	50	0.59	0.66	2.42	4

[1]Number of stations where soft sediments occurred and a flocculent layer measurement was available.
[2]Number of stations that contained soft sediments but no flocculent layer.

Source: ECT, 1991.

replicate sampling completed on each lake. Twenty grid points were preselected on each lake and resampled with the PD. The device did not work on sandy bottom; consequently, 11 of the preselected 140 comparison points were not usable. The results of the remaining 129 comparison points are plotted on Figure 3-31.

A second check of the method was completed by surveying four replicate transects on each lake (except Beauclair where two replicate transects were completed) which resulted in 303 replicate pairs. These points are plotted in Figure 3-31 for comparison. The agreement of both methods of replication is good with nearly all points clustering along the diagonal line. The few points that fall away from the line were from measurements taken in areas of relatively steep bottom slopes such that the observed differences were the result of slight navigational errors between sampling rather than errors in measuring the water depth.

A similar replicate sampling technique was conducted for the sediment sampling program. Five random points were selected for replicate sampling on each lake. Of the 35 points selected, 10 occurred on sand bottom such that both replicates gave readings of zero. These points were eliminated from the database; the remaining 25 points are plotted on Figure 3-32. Because of the greater inaccuracies in measuring sediment thickness than water depth there is more scatter in the replicate data. The agreement between replicates, however, is still reasonable.

An additional analysis of error was completed to determine if the difference between paired replicate samples varied with depth. This was accomplished by determining the difference between the survey value and the replicated value, and comparing the difference as a function of water depth. The resulting data from these calculations for the PD replicated pairs and the replicated survey pairs are presented in Figure 3-33. The data were further subjected to linear regression analysis to determine the coefficient of determination (r^2), slope, and intercept of the linear regression line. The results of the analysis are provided in Table 3-2.

DEPTH MEASUREMENT COMPARISONS

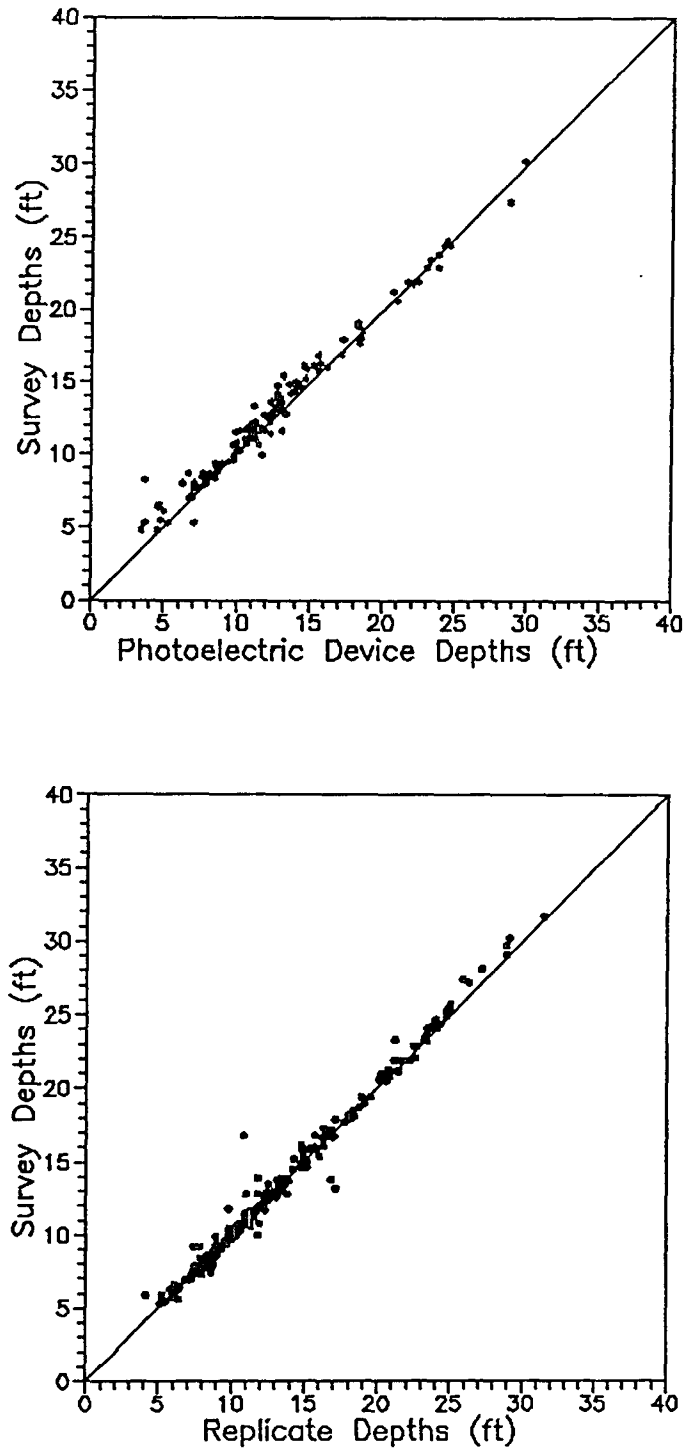


FIGURE 3-31.

COMPARISON OF REPLICATE DEPTH MEASUREMENTS

Source: ECT, 1991.

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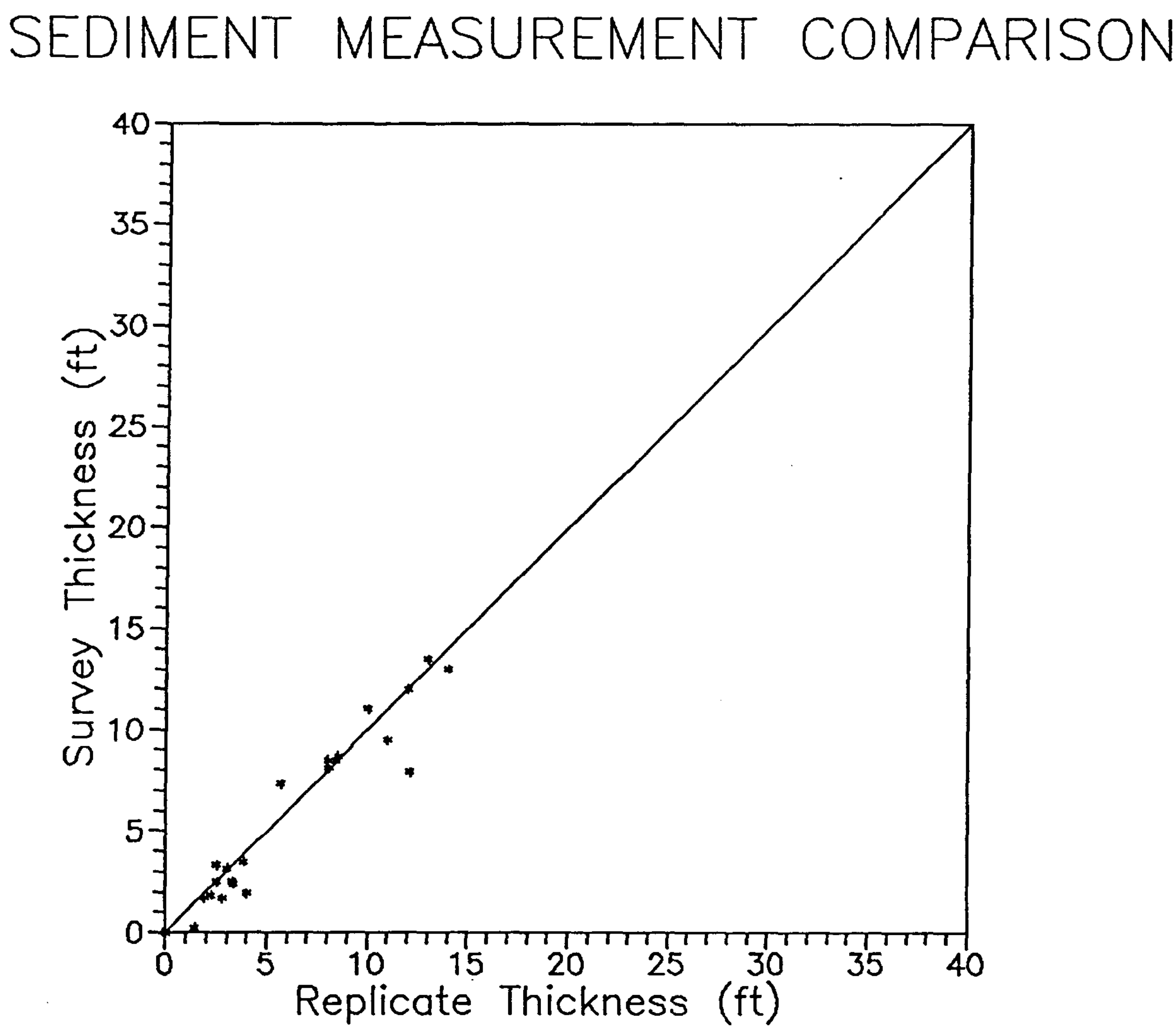

FIGURE 3-32.

COMPARISON OF REPLICATE POINTS FOR SEDIMENT THICKNESS MEASUREMENTS

Source: ECT, 1991.

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Environmental Consulting & Technology, Inc.

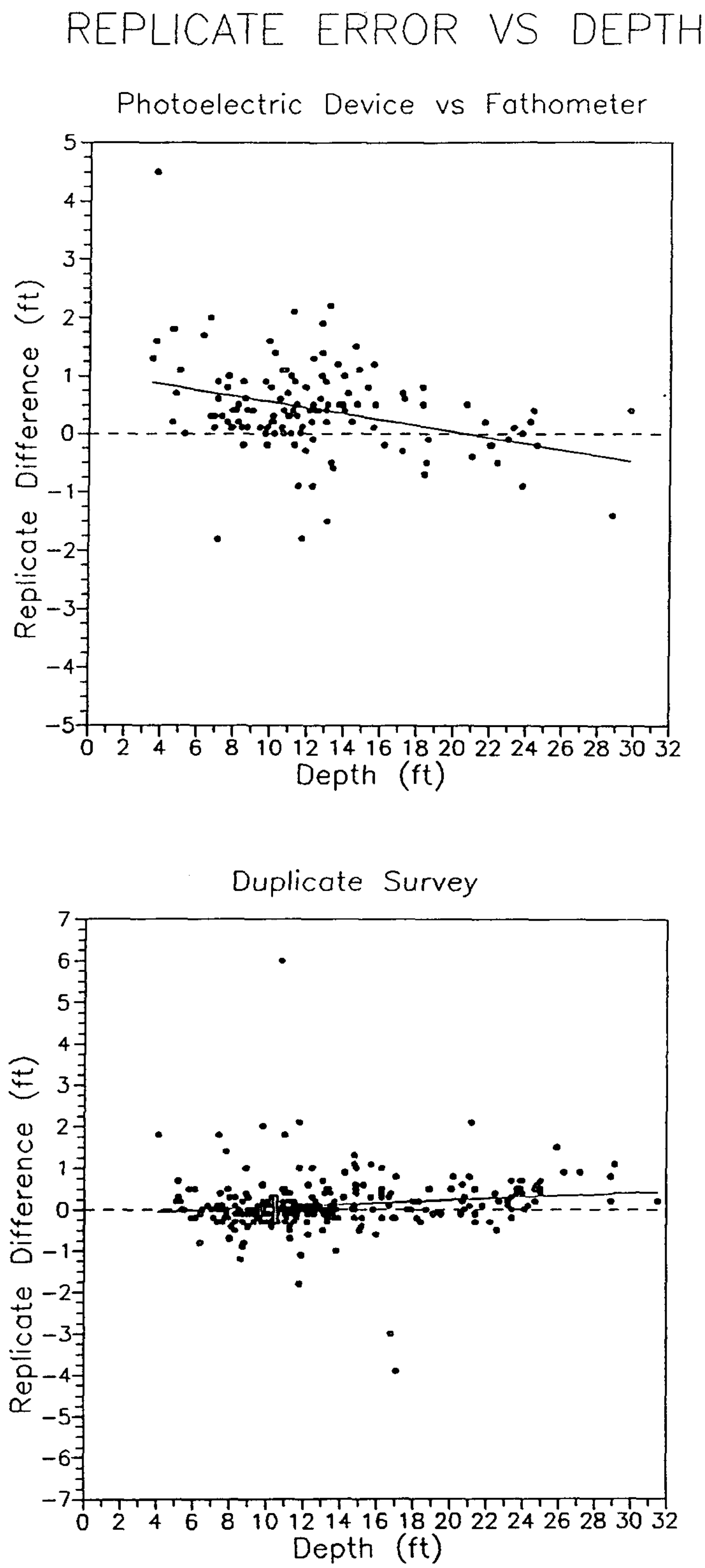

FIGURE 3-33.
COMPARISON OF THE DIFFERENCE IN PAIRED REPLICATE DEPTH MEASUREMENTS VERSUS WATER DEPTH
Source: ECT, 1991.

ECT
Environmental Consulting & Technology, Inc.

Table 3-2. Linear Regression Results from Comparison of Replicate Sampling

	PD Replicates	Replicated Transect Points	Sediment Replicates
N	129	303	25
Intercept*	1.0638	-0.1180	0.6685
Slope*	-0.0515	0.0177	-0.0625
r^2	0.1164	0.0209	0.0481

*The linear regression is of the form y = a + bx
where: a is the intercept
b is the slope, and
r^2 is the coefficient of determination.

Source: ECT, 1991.

The relatively flat slopes of -0.515 and 0.0177, as well as the low r^2 values of 0.1164 and 0.0209, indicate there is very little correlation between the error in replicates versus depth. In other words, the amount of difference observed between replicated samples did not change measurably as the water became deeper.

A similar analysis was completed for the replicated sediment samples. A plot of the difference between paired replicate samples versus sediment thickness is provided in Figure 3-34. The linear regression statistics for the data set are provided in Table 3-2. Because of differences in measurement techniques, as compared to the bathymetry, the amount of scatter in the data was greater. The slope of the linear regression equation is -0.0625 and r^2 value is 0.0481. This indicates there is virtually no correlation between the replicated sample differences and variation in sediment thickness.

As there is no systematic relationship between depth and errors in measurement, sample depth does not need to be incorporated into estimates of errors of hypsographic statistics. The mean, standard deviation, and confidence intervals were calculated for the differences between the paired observations for each of the three replicated data sets (Table 3-3). The results indicate that the PD measurements, on the average, recorded depths approximately 0.4 ft greater than with the fathometer. Because of the water depth, the PD was suspended from a line (as opposed to mounted on a rigid pole) and, despite attempts to keep the line vertical, there was a tendency to develop a slight wire angle. A slight wire angle would account for slightly greater readings with the PD. Despite this potential bias the readings were still within 0.5 ft.

A similar comparison was recently completed by Danek and Tomlinson (1989) on Lake Apopka. In the Lake Apopka study, PD measurements and fathometer measurements were made simultaneously at 18 stations. The study verified that the analog fathometer recordings accurately measured the water depth to the top of the flocculent layer. The mean value of the differences

REPLICATE ERROR VS THICKNESS

Duplicate Survey

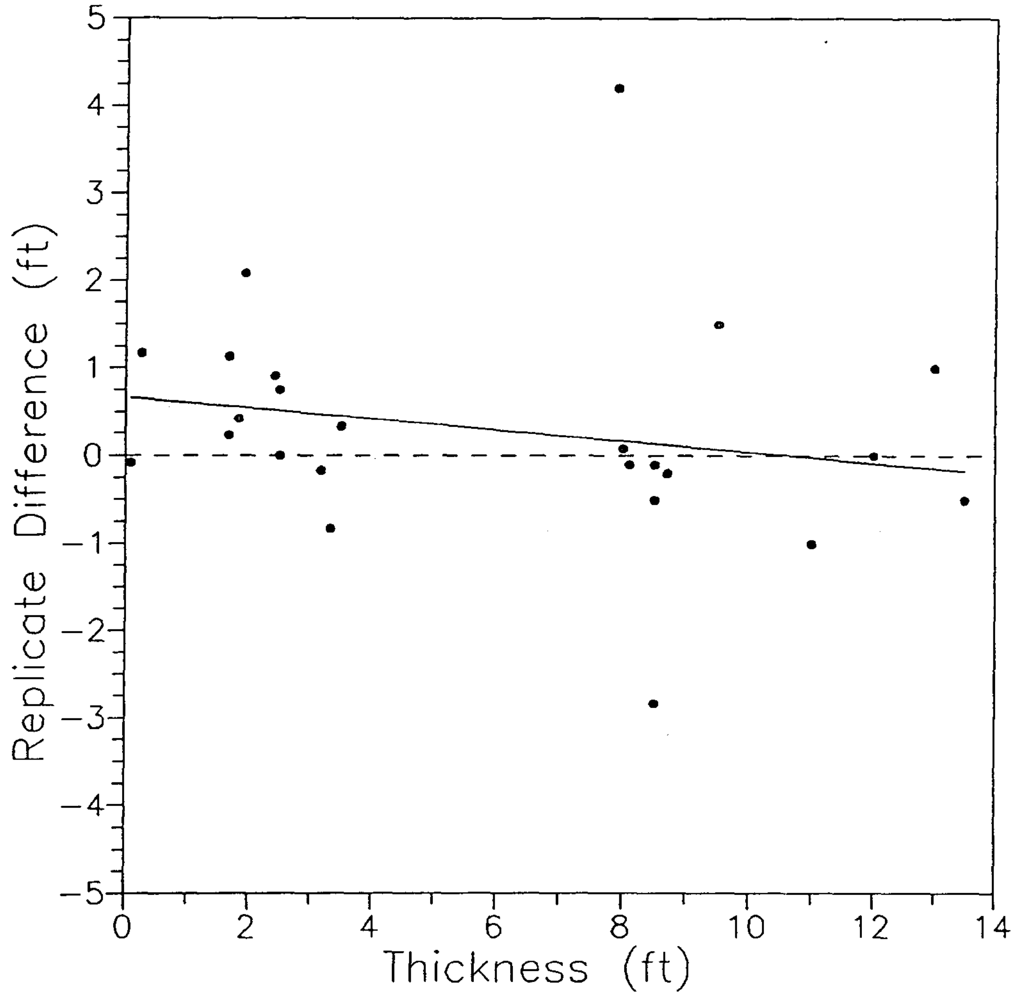

FIGURE 3-34.
COMPARISON OF THE DIFFERENCE IN PAIRED REPLICATE SEDIMENT SAMPLES VERSUS SEDIMENT THICKNESS
Source: ECT, 1991.

ECT
Environmental Consulting & Technology, Inc.

Table 3-3. Comparison Statistics for Replicate Sampling

	PD Replicates[1]	Replicated Transect Points	Sediment Replicates
N	129	303	25
Mean[2] (ft)	0.422	0.118	0.280
Standard Deviation	0.798	0.653	1.236
95 Percent Confidence Interval[3]	±.139	±.0621	±0.510

[1]Comparison of photoelectric device measurements with actual survey measurements.
[2]The arithmetic mean of the differences between the replicated survey measurements.
[3]Based on t-distribution analysis with N-1 degrees of freedom.

Source: ECT, 1991.

between the fathometer readings and the replicated PD readings was 0.02 ft, with a standard deviation of 0.15 ft. Consequently, the depth values and lake volumes reported in the Lake Apopka study and the present study define the top of the flocculent layer as the bottom and do not account for interstitial water in the flocculent sediments.

The comparison of the replicate transects was more favorable with the mean difference of the 303 paired replicated samples being 0.118 ft, with a standard deviation of 0.653 ft. This indicates that two data sets containing 303 points each that were sampled to represent the same region provided independent estimates of the mean water depth that only differed by 0.118 ft (with a 95 percent confidence interval of ±0.062 ft based on a t-distribution analysis with 302 degrees of freedom). The expected value of the mean of the differences between the paired replicates would be zero. However, the mean difference of 0.118 ft, with a 95 percent confidence interval of 0.056 and 0.180 ft, indicates a bias between the two data sets with an estimated error of up to 0.180 ft. The cause of this systematic error is unknown, but assuming that the entire data set is subject to similar bias, the maximum error expected is ±0.18 ft; or as a more conservative estimate the error for the mean depths of the lakes is within ±0.25 ft.

For the entire lake study 3,093 depth readings were made and the error for the estimated mean of the entire lake system will be less than the error estimate of the 303-point subset that was replicate sampled. The error estimates of the mean water depth would vary somewhat between lakes because the number of sample points varied from a low of 108 points on Lake Beauclair to a high of 953 points on Lake Harris. However, the conservative estimate of ±0.25 ft can be used to represent the accuracy of the survey. Considering the mean water depths measured in the seven lakes varied from a low of 6.73 ft for Lake Beauclair to a high of 18.94 ft for Lake Weir, an error of ±0.25 ft represents a potential error in the estimated mean depth of the lakes of between 3.7 and 1.3 percent. Since the volume of the lake is simply the surface area times the mean depth, an error in estimating the mean depth is translated directly to a proportionate error in estimating the lake volume. Consequently, an error of ±0.25 ft in mean depth equates to the following potential error in estimated lake volumes: Lake Beauclair, ±3.7 percent; Lake Dora, ±2.5 percent; Lake Eustis, ±2.2 percent; Lake Griffin, ±3.2 percent; Lake Harris, ±2.1 percent; Lake Weir, ±1.3 percent; and Lake Yale, ±2.0 percent.

The paired sediment replicate samples exhibited greater variation than the depth measurements with a standard deviation of 1.236 ft. Despite the large standard deviation, the mean difference was only 0.280 ft with a 95 percent confidence interval of ±0.51 ft for the 25 replicated samples compared (based on a t-distribution analysis with 24 degrees of freedom). Since 2,190 sediment samples were taken for the entire study to estimate the mean sediment thickness, a worst-case estimate of ±0.5 ft based on analysis of the 25 replicates should provide an upper limit for the expected error. The expected error for estimating the mean sediment thickness for each lake will vary because the number of samples varied between 49 for Lake Beauclair and 802 for Lake Harris. An estimated error of ±0.5 ft would translate to a maximum error of 10.7 percent for Lake Dora (the lowest mean sediment thickness of 4.68 ft) and a maximum error of 5.8 percent for Lake Harris (the highest mean sediment thickness of 8.59 ft). It should be noted that these estimates do not account for the inability of the sediment rod to differentiate between soft organic sediments and other soft sediments such as marl or loosely packed clay. For deep sediments where sampling with the sediment rod was required the entire thickness of soft sediments was reported.

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APPENDIX

Table 1. Hypsographic Data for Lake Beauclair

Depth Contour (ft)	Lake Level (ft)	Cumulative Area (sq ft x 10**9)	Layer Volume (cu ft x 10**9)	Lake Volume (cu ft x 10**9)	Lake Volume (%)
1	64	0.0530	0.0501	0.3689	115.73%
0	63	0.0473	0.0456	0.3187	100.00%
-1	62	0.0439	0.0428	0.2731	85.69%
-2	61	0.0417	0.0406	0.2304	72.27%
-3	60	0.0396	0.0385	0.1897	59.53%
-4	59	0.0374	0.0360	0.1513	47.45%
-5	58	0.0346	0.0328	0.1153	36.16%
-6	57	0.0309	0.0282	0.0825	25.88%
-7	56	0.0256	0.0226	0.0543	17.04%
-8	55	0.0199	0.0162	0.0317	9.93%
-9	54	0.0129	0.0096	0.0154	4.84%
-10	53	0.0067	0.0043	0.0058	1.83%
-11	52	0.0023	0.0012	0.0015	0.47%
-12	51	0.0004	0.0002	0.0003	0.09%
-13	50	0.0001	0.0001	0.0001	0.02%
-14	49	<0.0001	--	--	--

Note: ft = feet
cu ft = cubic feet
sq ft = square feet

Source: ECT, 1991.

Table 2. Hypsographic Data for Lake Dora

Depth Contour (ft)	Lake Level (ft)	Cumulative Area (sq ft x 10**9)	Layer Volume (cu ft x 10**9)	Lake Volume (cu ft x 10**9)	Lake Volume (%)
1	64	0.2004	0.1956	2.0771	110.40%
0	63	0.1910	0.1877	1.8814	100.00%
-1	62	0.1844	0.1821	1.6937	90.02%
-2	61	0.1797	0.1769	1.5117	80.35%
-3	60	0.1741	0.1715	1.3348	70.95%
-4	59	0.1688	0.1662	1.1633	61.83%
-5	58	0.1636	0.1608	0.9971	53.00%
-6	57	0.1580	0.1548	0.8364	44.45%
-7	56	0.1517	0.1483	0.6816	36.23%
-8	55	0.1449	0.1396	0.5333	28.35%
-9	54	0.1345	0.1284	0.3936	20.92%
-10	53	0.1223	0.1118	0.2653	14.10%
-11	52	0.1016	0.0838	0.1535	8.16%
-12	51	0.0672	0.0467	0.0697	3.71%
-13	50	0.0289	0.0174	0.0230	1.22%
-14	49	0.0081	0.0047	0.0056	0.30%
-15	48	0.0020	0.0009	0.0009	0.05%
-16	47	0.0001	--	--	--

Note: ft = feet
cu ft = cubic feet
sq ft = square feet

Source: ECT, 1991.

Table 3. Hypsographic Data for Lake Eustis

Depth Contour (ft)	Lake Level (ft)	Cumulative Area (sq ft x 10**9)	Layer Volume (cu ft x 10**9)	Lake Volume (cu ft x 10**9)	Lake Volume (%)
1	64	0.3614	0.3496	4.1833	109.12%
0	63	0.3379	0.3354	3.8337	100.00%
-1	62	0.3329	0.3305	3.4983	91.25%
-2	61	0.3280	0.3260	3.1678	82.63%
-3	60	0.3239	0.3219	2.8419	74.13%
-4	59	0.3199	0.3179	2.5200	65.73%
-5	58	0.3160	0.3138	2.2020	57.44%
-6	57	0.3116	0.3090	1.8882	49.25%
-7	56	0.3065	0.3029	1.5792	41.19%
-8	55	0.2993	0.2936	1.2763	33.29%
-9	54	0.2879	0.2787	0.9827	25.63%
-10	53	0.2697	0.2446	0.7039	18.36%
-11	52	0.2203	0.1809	0.4594	11.98%
-12	51	0.1442	0.1109	0.2785	7.26%
-13	50	0.0808	0.0618	0.1675	4.37%
-14	49	0.0445	0.0383	0.1058	2.76%
-15	48	0.0324	0.0279	0.0675	1.76%
-16	47	0.0236	0.0196	0.0396	1.03%
-17	46	0.0159	0.0116	0.0200	0.52%
-18	45	0.0078	0.0052	0.0083	0.22%
-19	44	0.0030	0.0022	0.0031	0.08%
-20	43	0.0015	0.0008	0.0010	0.02%
-21	42	0.0003	0.0001	0.0001	--

Note: ft = feet
cu ft = cubic feet
sq ft = square feet

Source: ECT, 1991.

Table 4. Hypsographic Data for Lake Griffin

Depth Contour (ft)	Lake Level (ft)	Cumulative Area (sq ft x 10**9)	Layer Volume (cu ft x 10**9)	Lake Volume (cu ft x 10**9)	Lake Volume (%)
1	60	0.5542	0.4803	3.6555	115.13%
0	59	0.4100	0.3998	3.1752	100.00%
-1	58	0.3897	0.3853	2.7754	87.41%
-2	57	0.3808	0.3752	2.3901	75.27%
-3	56	0.3697	0.3641	2.0149	63.46%
-4	55	0.3585	0.3518	1.6508	51.99%
-5	54	0.3452	0.3366	1.2990	40.91%
-6	53	0.3281	0.3090	0.9624	30.31%
-7	52	0.2904	0.2529	0.6533	20.58%
-8	51	0.2171	0.1809	0.4005	12.61%
-9	50	0.1469	0.1084	0.2196	6.92%
-10	49	0.0740	0.0529	0.1112	3.50%
-11	48	0.0342	0.0258	0.0583	1.84%
-12	47	0.0183	0.0139	0.0325	1.02%
-13	46	0.0099	0.0078	0.0186	0.59%
-14	45	0.0058	0.0047	0.0109	0.34%
-15	44	0.0037	0.0030	0.0061	0.19%
-16	43	0.0022	0.0017	0.0032	0.10%
-17	42	0.0013	0.0010	0.0014	0.05%
-18	41	0.0007	0.0004	0.0005	0.01%
-19	40	0.0002	0.0001	0.0001	--

Note: ft = feet
cu ft = cubic feet
sq ft = square feet

Source: ECT, 1991.

Table 5. Hypsographic Data for Lake Harris

Depth Contour (ft)	Lake Level (ft)	Cumulative Area (sq ft x 10**9)	Layer Volume (cu ft x 10**9)	Lake Volume (cu ft x 10**9)	Lake Volume (%)
1	64	0.8761	0.8449	10.6259	108.64%
0	63	0.8141	0.8024	9.7810	100.00%
-1	62	0.7907	0.7823	8.9786	91.80%
-2	61	0.7738	0.7665	8.1963	83.80%
-3	60	0.7591	0.7523	7.4299	75.96%
-4	59	0.7455	0.7386	6.6776	68.27%
-5	58	0.7317	0.7242	5.9390	60.72%
-6	57	0.7167	0.7076	5.2148	53.32%
-7	56	0.6985	0.6876	4.5072	46.08%
-8	55	0.6768	0.6606	3.8196	39.05%
-9	54	0.6445	0.6212	3.1591	32.30%
-10	53	0.5982	0.5576	2.5378	25.95%
-11	52	0.5180	0.4835	1.9802	20.25%
-12	51	0.4498	0.4161	1.4967	15.30%
-13	50	0.3833	0.3430	1.0806	11.05%
-14	49	0.3043	0.2578	0.7376	7.54%
-15	48	0.2140	0.1682	0.4798	4.91%
-16	47	0.1262	0.1046	0.3116	3.19%
-17	46	0.0845	0.0695	0.2070	2.12%
-18	45	0.0555	0.0456	0.1375	1.41%
-19	44	0.0364	0.0290	0.0919	0.94%
-20	43	0.0221	0.0188	0.0629	0.64%
-21	42	0.0156	0.0136	0.0441	0.45%
-22	41	0.0117	0.0101	0.0305	0.31%
-23	40	0.0086	0.0075	0.0204	0.21%
-24	39	0.0065	0.0055	0.0129	0.13%
-25	38	0.0045	0.0036	0.0075	0.08%
-26	37	0.0027	0.0021	0.0039	0.04%
-27	36	0.0015	0.0011	0.0018	0.02%
-28	35	0.0007	0.0005	0.0006	0.01%
-29	34	0.0003	0.0001	0.0002	--
-30	33	0.0001	--	--	--
-31	32	<0.0001	--	--	--

Note: ft = feet
cu ft = cubic feet
sq ft = square feet

Source: ECT, 1991.

Table 6. Hypsographic Data for Lake Weir

Depth Contour (ft)	Lake Level (ft)	Cumulative Area (sq ft x 10**9)	Layer Volume (cu ft x 10**9)	Lake Volume (cu ft x 10**9)	Lake Volume (%)
1	58	0.2473	0.2461	4.8845	105.31%
0	57	0.2449	0.2428	4.6384	100.00%
-1	56	0.2408	0.2388	4.3956	94.76%
-2	55	0.2368	0.2351	4.1568	89.62%
-3	54	0.2334	0.2318	3.9217	84.55%
-4	53	0.2303	0.2288	3.6899	79.55%
-5	52	0.2273	0.2258	3.4611	74.62%
-6	51	0.2243	0.2228	3.2353	69.75%
-7	50	0.2213	0.2197	3.0125	64.95%
-8	49	0.2181	0.2163	2.7928	60.21%
-9	48	0.2146	0.2128	2.5765	55.55%
-10	47	0.2110	0.2090	2.3637	50.96%
-11	46	0.2071	0.2049	2.1546	46.45%
-12	45	0.2027	0.2003	1.9497	42.03%
-13	44	0.1980	0.1952	1.7494	37.72%
-14	43	0.1925	0.1893	1.5542	33.51%
-15	42	0.1860	0.1824	1.3649	29.43%
-16	41	0.1787	0.1732	1.1826	25.50%
-17	40	0.1678	0.1635	1.0094	21.76%
-18	39	0.1592	0.1551	0.8459	18.24%
-19	38	0.1511	0.1470	0.6908	14.89%
-20	37	0.1430	0.1386	0.5437	11.72%
-21	36	0.1341	0.1255	0.4051	8.73%
-22	35	0.1171	0.1083	0.2796	6.03%
-23	34	0.0997	0.0830	0.1713	3.69%
-24	33	0.0673	0.0488	0.0883	1.90%
-25	32	0.0324	0.0216	0.0395	0.85%
-26	31	0.0123	0.0093	0.0180	0.39%
-27	30	0.0066	0.0048	0.0087	0.19%
-28	29	0.0033	0.0024	0.0039	0.08%
-29	28	0.0016	0.0010	0.0015	0.03%
-30	27	0.0005	0.0004	0.0005	0.01%
-31	26	0.0002	0.0001	0.0001	--
-32	25	<0.0001	--	--	--

Note: ft = feet
cu ft = cubic feet
sq ft = square feet

Source: ECT, 1991.

Table 7. Hypsographic Data for Lake Yale

Depth Contour (ft)	Lake Level (ft)	Cumulative Area (sq ft x 10**9)	Layer Volume (cu ft x 10**9)	Lake Volume (cu ft x 10**9)	Lake Volume (%)
1	60	0.1772	0.1762	2.3203	108.22%
0	59	0.1751	0.1725	2.1441	100.00%
-1	58	0.1699	0.1676	1.9716	91.95%
-2	57	0.1652	0.1633	1.8040	84.14%
-3	56	0.1614	0.1596	1.6407	76.52%
-4	55	0.1579	0.1560	1.4811	69.08%
-5	54	0.1541	0.1521	1.3251	61.80%
-6	53	0.1500	0.1477	1.1730	54.71%
-7	52	0.1453	0.1429	1.0253	47.82%
-8	51	0.1405	0.1380	0.8824	41.16%
-9	50	0.1355	0.1327	0.7444	34.72%
-10	49	0.1299	0.1257	0.6117	28.53%
-11	48	0.1215	0.1166	0.4860	22.67%
-12	47	0.1118	0.1039	0.3694	17.23%
-13	46	0.0962	0.0876	0.2655	12.38%
-14	45	0.0792	0.0692	0.1779	8.30%
-15	44	0.0596	0.0455	0.1087	5.07%
-16	43	0.0326	0.0242	0.0633	2.95%
-17	42	0.0167	0.0131	0.0391	1.82%
-18	41	0.0098	0.0085	0.0259	1.21%
-19	40	0.0072	0.0063	0.0175	0.81%
-20	39	0.0054	0.0047	0.0111	0.52%
-21	38	0.0039	0.0032	0.0065	0.30%
-22	37	0.0026	0.0019	0.0032	0.15%
-23	36	0.0013	0.0009	0.0014	0.06%
-24	35	0.0005	0.0004	0.0005	0.02%
-25	34	0.0002	0.0001	0.0001	0.01%
-26	33	<0.0001	--	--	--

Note: ft = feet
cu ft = cubic feet
sq ft = square feet

Source: ECT, 1991.

Table 8. Sediment Data for Lake Beauclair

Sediment Contour (ft)	Cumulative Area (sq ft x 10**9)	Layer Volume (cu ft x 10**9)	Sediment Volume (cu ft x 10**9)	Sediment Volume (%)
0	0.0353 *	0.0293 *	0.1836 *	100.00%
1	0.0254	0.0229	0.1541	83.97%
2	0.0206	0.0191	0.1312	71.47%
3	0.0176	0.0167	0.1121	61.07%
4	0.0157	0.0149	0.0954	51.99%
5	0.0141	0.0134	0.0806	43.88%
6	0.0127	0.0121	0.0672	36.59%
7	0.0114	0.0109	0.0551	30.02%
8	0.0103	0.0097	0.0442	24.10%
9	0.0092	0.0086	0.0345	18.79%
10	0.0081	0.0075	0.0259	14.10%
11	0.0069	0.0063	0.0184	10.02%
12	0.0057	0.0051	0.0121	6.57%
13	0.0044	0.0037	0.0070	3.82%
14	0.0030	0.0022	0.0033	1.80%
15	0.0014	0.0009	0.0011	0.61%
16	0.0005	0.0002	0.0002	0.10%

*SURFER values used in these calculations.

Note: ft = feet
cu ft = cubic feet
sq ft = square feet

Source: ECT, 1991.

Table 9. Sediment Data for Lake Dora

Sediment Contour (ft)	Cumulative Area (sq ft x 10**9)	Layer Volume (cu ft x 10**9)	Sediment Volume (cu ft x 10**9)	Sediment Volume (%)
0	0.1623 *	0.1394 *	0.7598 *	100.00%
1	0.1232	0.1127	0.6204	81.65%
2	0.1024	0.0951	0.5077	66.82%
3	0.0880	0.0818	0.4126	54.30%
4	0.0757	0.0705	0.3308	43.54%
5	0.0653	0.0604	0.2603	34.26%
6	0.0556	0.0501	0.1999	26.31%
7	0.0448	0.0375	0.1498	19.72%
8	0.0306	0.0271	0.1124	14.79%
9	0.0238	0.0214	0.0852	11.22%
10	0.0191	0.0181	0.0638	8.40%
11	0.0170	0.0159	0.0457	6.02%
12	0.0148	0.0129	0.0298	3.92%
13	0.0110	0.0089	0.0170	2.23%
14	0.0070	0.0052	0.0080	1.06%
15	0.0036	0.0023	0.0028	0.37%
16	0.0011	0.0005	0.0005	0.07%
17	0.0001	--	--	--

*SURFER values used in these calculations.

Note: ft = feet
cu ft = cubic feet
sq ft = square feet

Source: ECT, 1991.

Table 10. Sediment Data for Lake Eustis

Sediment Contour (ft)	Cumulative Area (sq ft x 10**9)		Layer Volume (cu ft x 10**9)		Sediment Volume (cu ft x 10**9)		Sediment Volume (%)
0	0.3143	*	0.2850	*	2.0967	*	100.00%
1	0.2636		0.2490		1.8118		86.41%
2	0.2347		0.2241		1.5627		74.53%
3	0.2136		0.2073		1.3387		63.85%
4	0.2010		0.1953		1.1314		53.96%
5	0.1896		0.1836		0.9361		44.65%
6	0.1778		0.1708		0.7525		35.89%
7	0.1639		0.1548		0.5818		27.75%
8	0.1460		0.1351		0.4269		20.36%
9	0.1245		0.1055		0.2918		13.92%
10	0.0876		0.0729		0.1863		8.88%
11	0.0591		0.0479		0.1134		5.41%
12	0.0376		0.0290		0.0655		3.12%
13	0.0211		0.0168		0.0365		1.74%
14	0.0128		0.0105		0.0197		0.94%
15	0.0084		0.0064		0.0092		0.44%
16	0.0046		0.0025		0.0028		0.13%
17	0.0009		0.0003		0.0003		0.01%

*SURFER values used in these calculations.

Note: ft = feet
cu ft = cubic feet
sq ft = square feet

Source: ECT, 1991.

Table 11. Sediment Data for Lake Griffin

Sediment Contour (ft)	Cumulative Area (sq ft x 10**9)	Layer Volume (cu ft x 10**9)	Sediment Volume (cu ft x 10**9)	Sediment Volume (%)
0	0.3920 *	0.3772 *	2.2521 *	100.00%
1	0.3571	0.3444	1.8749	83.25%
2	0.3319	0.3149	1.5305	67.96%
3	0.2982	0.2778	1.2156	53.98%
4	0.2579	0.2309	0.9378	41.64%
5	0.2049	0.1800	0.7069	31.39%
6	0.1562	0.1381	0.5269	23.40%
7	0.1207	0.1088	0.3889	17.27%
8	0.0973	0.0860	0.2801	12.43%
9	0.0751	0.0661	0.1941	8.62%
10	0.0574	0.0504	0.1280	5.68%
11	0.0438	0.0373	0.0776	3.45%
12	0.0312	0.0220	0.0403	1.79%
13	0.0139	0.0093	0.0183	0.81%
14	0.0054	0.0042	0.0090	0.40%
15	0.0031	0.0024	0.0048	0.21%
16	0.0017	0.0013	0.0024	0.11%
17	0.0009	0.0007	0.0011	0.05%
18	0.0004	0.0003	0.0004	0.02%
19	0.0002	0.0001	0.0001	0.01%
20	<0.0001	--	--	--
21	<0.0001	--	--	--

*SURFER values used in these calculations.

Note: ft = feet
cu ft = cubic feet
sq ft = square feet

Source: ECT, 1991.

Table 12. Sediment Data for Lake Harris

Sediment Contour (ft)	Cumulative Area (sq ft x 10**9)	Layer Volume (cu ft x 10**9)	Sediment Volume (cu ft x 10**9)	Sediment Volume (%)
0	0.7881 *	0.7039 *	6.7972 *	100.00%
1	0.6578	0.6186	6.0933	89.64%
2	0.5803	0.5601	5.4747	80.54%
3	0.5402	0.5261	4.9146	72.30%
4	0.5122	0.4990	4.3884	64.56%
5	0.4859	0.4732	3.8894	57.22%
6	0.4607	0.4478	3.4162	50.26%
7	0.4350	0.4216	2.9684	43.67%
8	0.4083	0.3924	2.5468	37.47%
9	0.3767	0.3586	2.1545	31.70%
10	0.3407	0.3211	1.7959	26.42%
11	0.3019	0.2733	1.4748	21.70%
12	0.2456	0.2265	1.2015	17.68%
13	0.2079	0.1945	0.9750	14.34%
14	0.1815	0.1699	0.7805	11.48%
15	0.1586	0.1468	0.6106	8.98%
16	0.1353	0.1227	0.4638	6.82%
17	0.1104	0.1004	0.3411	5.02%
18	0.0907	0.0811	0.2407	3.54%
19	0.0718	0.0619	0.1596	2.35%
20	0.0524	0.0433	0.0978	1.44%
21	0.0349	0.0269	0.0544	0.80%
22	0.0196	0.0149	0.0276	0.41%
23	0.0106	0.0078	0.0127	0.19%
24	0.0052	0.0035	0.0049	0.07%
25	0.0019	0.0012	0.0015	0.02%
26	0.0007	0.0002	0.0002	--
27	<0.0007	--	--	--

*SURFER values used in these calculations.

Note: ft = feet
cu ft = cubic feet
sq ft = square feet

Source: ECT, 1991.

Table 13. Sediment Data for Lake Weir

Sediment Contour (ft)	Cumulative Area (sq ft x 10**9)	Layer Volume (cu ft x 10**9)	Sediment Volume (cu ft x 10**9)	Sediment Volume (%)
0	0.1796 *	0.1548 *	0.8491 *	100.00%
1	0.1373	0.1264	0.6943	81.77%
2	0.1158	0.1082	0.5679	66.88%
3	0.1008	0.0954	0.4597	54.14%
4	0.0901	0.0867	0.3643	42.91%
5	0.0834	0.0802	0.2776	32.69%
6	0.0771	0.0733	0.1973	23.24%
7	0.0695	0.0624	0.1240	14.61%
8	0.0555	0.0383	0.0617	7.26%
9	0.0233	0.0160	0.0234	2.76%
10	0.0097	0.0058	0.0074	0.87%
11	0.0026	0.0014	0.0016	0.19%
12	0.0005	0.0002	0.0002	0.02%

*SURFER values used in these calculations.

Note: ft = feet
cu ft = cubic feet
sq ft = square feet

Source: ECT, 1991.

Table 14. Sediment Data for Lake Yale

Sediment Contour (ft)	Cumulative Area (sq ft x 10**9)	Layer Volume (cu ft x 10**9)	Sediment Volume (cu ft x 10**9)	Sediment Volume (%)
0	0.1557 *	0.1425 *	0.9632 *	100.00%
1	0.1333	0.1270	0.8207	85.21%
2	0.1207	0.1163	0.6938	72.03%
3	0.1120	0.1082	0.5775	59.95%
4	0.1044	0.1008	0.4693	48.72%
5	0.0972	0.0931	0.3686	38.26%
6	0.0890	0.0837	0.2755	28.60%
7	0.0785	0.0711	0.1918	19.91%
8	0.0640	0.0552	0.1207	12.53%
9	0.0468	0.0367	0.0655	6.80%
10	0.0274	0.0185	0.0288	3.00%
11	0.0108	0.0070	0.0104	1.08%
12	0.0038	0.0023	0.0034	0.35%
13	0.0011	0.0007	0.0010	0.11%
14	0.0004	0.0002	0.0003	0.03%
15	0.0001	0.0001	0.0001	0.01%
16	<0.0001	--	--	--

*SURFER values used in these calculations.

Note: ft = feet
cu ft = cubic feet
sq ft = square feet

Source: ECT, 1991.