SEDIMENTATION IN UNIVERSITY LAKE, ORANGE COUNTY, NORTH CAROLINA.

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ABSTRACT

University Lake, a water supply reservoir built in 1932 in the Piedmont of North Carolina, impounds water and sediment from 29.9 square miles of rural-agricultural land in the upper Cape Fear River Basin. The type, spatial distribution, and amount of sediment deposited in the reservoir were studied between 1988 and 1990.

The sediment thickness was measured in the lake, and an isopach map prepared, using core samples and a variety of sediment probes. The maximum sediment thickness is 14 feet, and the average thickness is 2.1 feet. The volume of sediment was determined from the isopach map to be 440 acre-feet, giving an average sedimentation rate over 57 years of 7.7 acre-feet per year, or 0.26 acre-feet per square mile of watershed area per year. Approximately 43% of the sediment is deposited in deltaic complexes, which cover 27% of the lake floor. Fifty-seven percent of the sediments are fine grained clay and silt bottomset deposits, which cover 38% of the floor. Thirty-five percent of the lake floor has no accumulated sediment. A bathymetric survey shows the lake to have a present water capacity of 1805 acre-feet, indicating that 20% of the original water capacity has been lost due to sedimentation.

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SUMMARY AND CONCLUSIONS

1. The water capacity in University Lake was determined by measurements from the bathymetric map surveyed in 1989. The water capacity of the lake is 1805 acre-feet to the spillway elevation of 349.5 feet. The average water depth of the lake is 9 feet.

2. Based on the topography, core stratigraphy, and sample analysis the two types of sedimentary environments in University Lake, the deltaic and lakebed environments, can be divided into distinct subenvironments. Sediments in the deltaic subenvironments fine from the tributary creek into the lake, and deposits include the following: coarse to medium sands in the distributary channel; medium to very fine sands, silts, clays, and organic debris in the distributary channel levee and the distributary mouth bar; fine sands, silts and clays in the delta front; and silt, clay, and organic debris in the prodelta. A separate marsh subenvironment, accumulating very fine sand, silt, and clay, is found on the backwater of Price Creek and Pritchards Mill Creek.

3. Outside the deltas fine silt and clay deposits cover the lakebed. These laminated, organic rich sediments have accumulated on the pre-reservoir floodplains and in the relict channels within the lakebed bottomset subenvironment. However, because of mechanical and gravitational erosion, no sediment has accumulated along the shoreline or on the steep basin slope subenvironments.

4. The areal extent of each deltaic subenvironment is controlled by the quantity of sediment transported to the lake and the topography of the backwater, especially the topographic control on the channel flow velocity. Approximately 27% of the lake is covered by deltaic deposits, with 60% of this area found on Phils Creek, 22% on Morgan Creek, and 18% on Price Creek and Pritchards Mill Creek. Of the remaining area outside the deltas, 47% is made up by the shoreline and basin slopes, and the remainder is covered by the bottomset muds.

5. The thickness of sediments in the lake range up to nearly 14 feet in the deltaic deposits on Morgan Creek. Approximately 34% of the lake bottom has zero sediment accumulation. Over the entire lake the average sediment thickness is 2.1 feet.

6. The volume of sediment could not be determined by comparison of pre-existing bathymetric maps and the map surveyed in 1989. However a sediment volume of 440 acre-feet was determined by probing the sediment thickness. Approximately 43% of the sediment volume is in the deltas, and 57% is in the lakebed deposits.

7. The average sediment accumulation rate in University Lake over 57 years is 7.7 acre-feet per year, or equivalently 11,035 tons per year. The accumulation rate per square mile of watershed is 0.26 acre-feet per year, or 370 tons per year.

8. The sediment accumulation rate has decreased 68% from the 22 acre-feet per year measured for the period 1932-1935 (Eakins, 1939). The initial accumulation rate was probably higher than the yield from the watershed because sediment was produced within the lake by shoreline and basin slope erosion.

9. Predictive equations from NVPDC-VPI (1978) and Simmons (1988) were used to estimate the amount of sediment delivered to the lake on a yearly basis. These equations underestimate the amount of sediment measured in the lake by an average of 50%. The underestimations probably reflect the high sediment transport rates which occurred early in the lake's history due to erosive farming practices.

INTRODUCTION

University Lake was formed in 1932 when the University of North Carolina constructed a 30-foot-high dam across Morgan Creek, at a point just west of Carrboro, North Carolina, and partially flooded the stream valleys of Morgan Creek and its two tributaries, Phils Creek and Price Creek (Figure 1). The purpose of this report is to describe the amount, spatial distribution, and type of sediment that has been deposited in University Lake.

During two years of study between fall 1988 and fall 1990 a bathymetric survey was conducted; 76 sediment cores were collected and analyzed; the sediment thickness in the lake was measured using a sediment spud and a variety of other sediment probes; and well over 100 hours of reconnaissance field work were spent at, on, and in University Lake and the surrounding watershed. Supplementary information includes previous topographic, bathymetric, and sedimentation surveys of University Lake; historical and current land use data from the watershed; streamflow records from Morgan Creek; unpublished lake operation records; and stream sediment transport estimates taken from the literature.

The results of the study include a detailed bathymetric map; descriptions of sediment characteristics including sedimentary structures, grain size distribution, bulk density, water content, and organic carbon content; a map showing the sedimentary environments in the lake; an isopach map of the lake sediments; and a determination of the amount of sediment deposited in University Lake. These results are used to discuss factors controlling the spatial distribution and amount of sediments found in each arm of the lake, including differences in the geology and soil in each tributary basin, the hydrologic characteristics of each entering stream, and the topography of each arm of the lake.

PREVIOUS RESERVOIR SEDIMENTATION STUDIES IN THE SOUTHEAST

Numerous sedimentation surveys have been carried out on reservoirs in the southeastern United States. Of the 129 reservoir sedimentation surveys carried out in the southeast prior to 1975 (Dendy and Champion, 1977), most were initiated by owners and managers of reservoirs to measure the loss of water storage capacity due

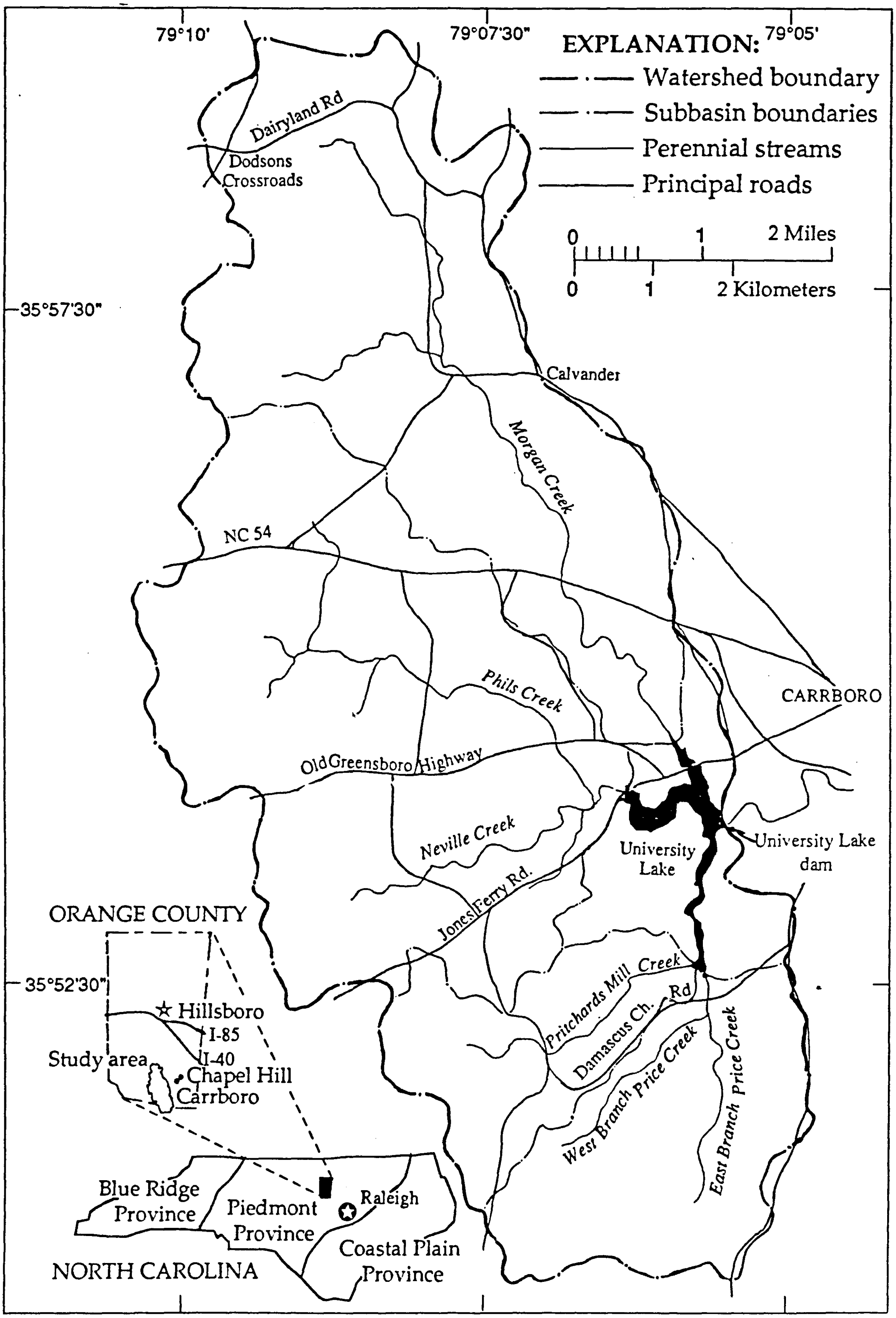


Figure 1. Geographic location map of University Lake and its watershed.

to siltation, and to estimate the remaining useful life of the impoundments (Dendy, Champion, and Wilson, 1973; United States Geological Survey, 1988; Simmons, 1988). Because of the narrow focus of most of these studies the nature of the sediment is not discussed, and in those where descriptions are made, the descriptions are usually qualitative and/or based on a few samples. The majority of the reservoir sedimentation studies referenced by Dendy and Champion (1977) are not published and the results were released only to the participating agencies or to a small number of assisting parties.

The most thorough descriptions of reservoir sedimentation in the region are found in the survey reports from the Soil Conservation Service (Eakins, 1939; Brown, 1943; Boundurant, 1955). Between 1935 and 1943 the Soil Conservation Service carried out 20 detailed reservoir sedimentation studies, made reconnaissance surveys on 8 additional reservoirs, and examined 15 former reservoirs that had been completely filled by sediment (Eakins, 1939; Brown, 1943). Eleven of the studies were released in detailed preliminary reports that contain reviews of the watershed characteristics, visual descriptions of the morphology of the exposed sediments, and graphs, charts, and photographs to illustrate the overall sediment depositional patterns. Eakins (1939) abstracted 8 of the detailed surveys and all of the reconnaissance surveys in what remains the most encompassing review of reservoir sedimentation in the Southeast.

Studies of selected groups of reservoirs have established relationships between the sedimentation rates and various watershed, hydrologic, and reservoir parameters (Eakins, 1939; Brown, 1943; Brune, 1953; Jenkins, Moak, and Okum, 1960; Dendy, Champion and Wilson, 1973; Heinemann, 1984). Jenkins et al. (1960) analyzed data from 54 reservoir studies carried out in the Southeast between 1932 and 1955. Their analysis indicates that the annual volume of sediment deposited in a reservoir is determined primarily by the area of its watershed, with an area wide average of 0.44 acre-ft per square mile of drainage per year. Because of a wide range of values, the statistical correlation of sedimentation rates to other parameters such as the capacity-watershed ratio (Brown, 1944), the retention-flow through velocities (Churchill, 1948), and the capacity-inflow ratio (Brune, 1953), was poor. Dendy (1974) summarized studies on 17 Southeastern reservoirs and concluded that the rate of sediment accumulation reflected primarily the ability of the reservoirs to trap the silt and smaller sized particles.

Since the 1970's most scientific attention to reservoir sediments has shifted from measuring or predicting water storage loss to determining the fate of various pollutants that are transported and deposited along with sediments. Studies carried out on Piedmont reservoirs have examined the transport and trapping characteristics of lead, zinc, and other toxic metals (Wu, 1989); the uptake and recycling of phosphorous through the sediment column (Kuenzler et al., 1986); the sequestering of man-made organic pollutants in lake sediment (Triangle Area Water Supply Monitoring Project, 1990); and the effects of sedimentation on benthic ecosystems (Weiss et al., 1978; Conlin, 1976). The continued interest in assessing reservoir sedimentation from all aspects has been highlighted by the United States Geological Survey which, in 1990, began a long-term reservoir sedimentation program in North Carolina (United States Geological Survey, 1988).

HISTORY OF UNIVERSITY LAKE

Construction of the Dam

University Lake was impounded in 1932 with the construction of a dam on Morgan Creek, 500 feet downstream from the mouth of Price Creek and 2000 feet downstream of the mouth of Phils Creek (Figure 1). Construction on the 800-foot-long earth fill and concrete structure dam began in September 1931, and the lake overflowed for the first time on October 3, 1932 (Chapel Hill Newspaper, 1932).

The concrete spillway over the dam is approximately 30 feet above the old stream channel, at an elevation of 347.2 feet above mean sea level, except for one 12-foot-long section at 346.2 feet (Eakins, 1939). In 1966 2-foot-high flashboards were installed across the spillway, and in 1970 3 additional feet were added (Blum, 1977). After a severe flood washed the flashboards away in 1972, a new set of flashboards was installed leaving the spillway at its present height of 349.5 feet above mean sea level.

Operation and Lake Level Record

University Lake has been operated as a water supply reservoir since it was first built. When constructed, the average draft for water supply was 12 million gallons per month (Garrin and Forester, 1940). Since that time the draft on the lake has increased, and by 1989 the average draft was over 5 million gallons per day. As the draft on the lake has increased, the frequency and magnitude of draw-downs have increased.

Draw-downs below the spillway elevation were first recorded only one year after the lake was built (Chapel Hill Newspaper, 1933), but very severe draw-downs did not become regular until the 1960's. The lowest draw-down occurred during a severe drought in October 1968, when the lake level dropped 99.5 inches below the flashboards to an elevation of 338.6 feet above mean sea level (Orange Water and Sewer Authority records). Since January 1976, a daily record of the lake level has been maintained by Orange Water and Sewer Authority, which now operates the lake. During the period of record, the lake level was below the spillway for at least one full month each year, and in most years it was at least 2 feet below the spillway for more than 3 months (Figure 2A). The lowest lake level since 1976 was 7 feet below the spillway (342.5 feet above mean sea level) during a drought in the fall of 1977. The lake level duration graph (Figure 2B) for the 13 years of record indicates that the lake was full or overflowing for 50% of the time, that 10% of the time the lake was 2.5 feet below the spillway, and for 2% of the time the water surface was more than 4.5 feet below the spillway.

OWASA can now divert up to 12 million gallons of water per day (17.8 cfs) from Cane Creek to University Lake via Phil's Creek at the Stone Quarry connection north of Highway 54. According to Mr. Edward Holland of OWASA, this occurs during seasonal dry weather, usually when University Lake is more than 12 inches below full (personal communication, 1991).

Previous Topographic and Sedimentation Surveys

The first topographic survey of the reservoir area was carried out in 1928 by G. Wallace Smith who surveyed 2 contour lines at 335 feet and 353 feet above mean sea level to determine the water holding capacity of the proposed reservoir site (North Carolina Conservation Service, 1930). In 1929 Atwood and Weeks, Surveyors (1930) prepared a more detailed topographic map of the Morgan Creek and Phils Creek valley at a scale of 1:2400 (one inch equals 200 feet), showing 5-foot contour lines up to an elevation of 353 feet above mean sea level. The following year a similar topographic map of Price Creek valley was prepared, also by Atwood and Weeks.

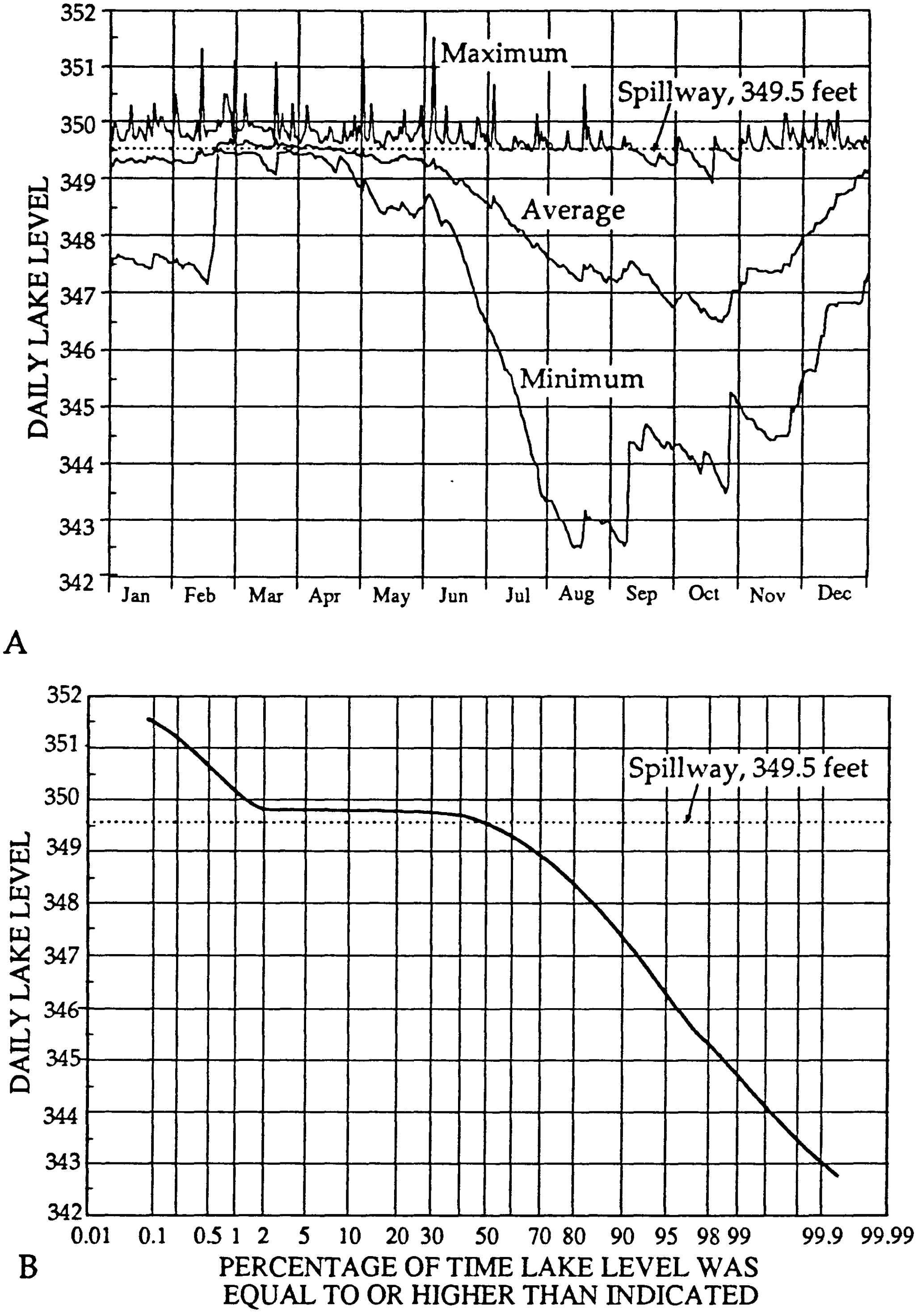


FIGURE 2. A Yearly lake level cycle: average, and extremes for each day of record. B Lake level duration graph. Period of record is January 1, 1976 to December 31, 1989. Source: Orange Water and Sewer Authority, unpublished records.

All of these maps are held in the office of the University Engineer at the University of North Carolina at Chapel Hill.

The North Carolina Department of Conservation and Development established 8 siltation ranges across the lake in 1932, with the ends marked by permanent concrete monuments (Eakins, 1939). Although at least six of their monuments were found around the lake, no record exists of measurements taken across these ranges.

Nearly three years (2.9 years) after University Lake was flooded the Soil Conservation Survey measured the water depth and the sediment thickness on 18 profiles, or ranges, across the lake (Eargle, 1935; Eakins, 1939). Using the range end method (Eakins, 1939; Heinemann and Dvorak, 1965; Rausch and Heinemann, 1984) to compute both the water capacity and the sediment volume, the Soil Conservation Service determined the water capacity to the upper spillway elevation (347.2 feet above mean sea level) to be 1870 acre-feet and reported that 64 acre-feet of sediment had accumulated in the lake, giving an accumulation rate of 22 acre-feet per year (0.74 acre-feet per square mile of watershed per year). Using an average sediment unit weight (Lara and Pemberton, 1965) of 65 pounds per cubic foot (1416 tons per acre-ft), this accumulation rate is equivalent to 31,250 tons per year, or 1,045 tons of sediment per square mile of watershed per year.

The Soil Conservation Survey Soil Erosion Division surveyed the soils, the degree of soil erosion, and the current land use in University Lake watershed in 1937 as part of a regional study designed to establish a physical basis for land use planning and soil erosion controls (Bass and Martin, 1939; Erickson and Levitte, 1939). Using the soil profile truncation method (Bass and Martin, 1939; Happ, Rittenhouse, and Dobson, 1940), they estimated that 7600 acre-feet of soil had been eroded from the watershed during the approximately 150 years of European style farming. Using the findings from the sedimentation survey, and assuming a constant rate of erosion, they calculated that about 30% of the yearly soil eroded from the watershed was deposited in the lake, while the remainder was either deposited on slopes and floodplains above the lake, or carried downstream over the dam (Bass and Martin, 1939).

In 1962 Alan Smalley prepared a bathymetric map of University Lake as part of his masters report for the Department of Environmental Science at the

University of North Carolina at Chapel Hill (Smalley, 1963). He produced a 1:1200 scale (1 inch equals 100 feet) bathymetric contour map of the lake, with 2-foot contour intervals, by taking 98 profiles across the lake with a continuous recording fathometer (Smalley, 1963). Using the contour area average-end method (Heinemann and Dvorak, 1965; Rausch and Heinemann, 1984), he made both stage-area and stage-volume curves for the lake. Smalley determined the water capacity of the lake to be 1725 acre-feet to the upper spillway elevation of 347.2 feet above mean sea level (Smalley, 1963).

The most current topographic map of University Lake was made by Piedmont Aerial Survey, from aerial photographs taken during a drought in 1968. This map shows 2-foot contour lines between 340 and 348 foot elevations, and was traced onto pre-existing base maps (the same base maps that were used by Smalley) by a draftsman at the University of North Carolina Utilities Department.

CHARACTERISTICS OF UNIVERSITY LAKE WATERSHED

University Lake is located on Morgan Creek in the upper Cape Fear River Basin in North Carolina (Figure 1). Four main creeks feed directly into the lake and together they drain an area of 29.9 square miles; of which 27.3 square miles lie in southeastern Orange County and 2.6 square miles in northern Chatham County. Morgan Creek and Phils Creek, which drain subbasins of 10.0 square miles and 11.2 square miles respectively, drain the northern and western sides of the watershed (Figure 1). Price Creek and Pritchards Mill Creek drain the southern and southwestern section of the watershed with subasins covering 3.9 square miles and 2.6 square miles. Only 2.2 square miles of the watershed drain into the lake below the backwaters of these creeks.

Topography

The topography of University Lake watershed is typical of the upland Piedmont of North Carolina with rolling hills and V-shaped valleys. About three-quarters of the watershed has slopes of 3-15%, and slopes over 15% make up 23% of the watershed (Bass and Martin, 1939). Most of the basin lies at elevations of 400 to 500 feet above mean sea level, while several small hills within the watershed, and many hills on the basin boundary, rise 200 to 300 feet higher. Bass and Martin (1939) divided the relief in the basin into 2 distinct regions. The northern two-thirds is gently to steeply rolling with a few steep-sided ridge crests, and narrow V-shaped valleys with small, laterally discontinuous floodplains. In contrast, the southern one-third is moderately to very steeply rolling with rounded, steep-sided concave hills, and generally wider, more extensive floodplains than those in the northern section.

Geology and Soils

The different relief in the northern and southern sections of the watershed can be attributed to the difference in lithologies of the underlying rocks (Figure 3). Most of the northern two-thirds of the watershed is underlain by rocks of the Carolina Slate Belt series (Mann et al., 1965). The Carolina Slate Belt series is made up of fine-grained meta-volcanics and meta-sediments which include felsic tuff (F), rhyolitic tuff (R), andesitic tuff (A), and crystal-lithic tuffs (C), and breccias and conglomerates derived from these rocks (Mann, et al. 1965; Smeds, 1972; Lyday, 1974) as in Figure 3. All of these rocks are metamorphosed to the greenschist facies, and most possess a well developed, near vertical cleavage striking northeast (Mann et al., 1965). In contrast, the southern third of the watershed, including all of Price Creek and Pritchards Mill Creek subbasins, and parts of the central area of the watershed, are underlain by igneous plutonic rocks intruded into the Carolina Slate Belt (Fleming, 1958). These rocks, which are parts of the Chapel Hill and Fearington plutons, include medium to coarse grained granites (G and cG), granodiorites (Gd), and diorites (D), (Flemming, 1958; Mann et al. 1965) as in Figure 3.

Like most areas in the Piedmont, much of the bedrock in the watershed is highly weathered and covered by a mantle of residual soil. The chemical weathering produces soils that are highly leached, acidic, and low in organic material (Bass and Martin, 1939). Most soils derived from the fine-grained Carolina Slate Belt rocks are iron stained red or orange, kaolinitic, silt loams, clay loams, or slatey clay loams (Dunn, 1977). The major soil types include Georgeville, Goldstone, Herndon, Lignum, and Tatum. Most have a compact clay subsoil, moderate surface drainage, and poor infiltration capacities (Dunn, 1977). Because of the compact subsoils and fine grain size, most of these soils are highly susceptible to runoff and surface erosion (Dunn, 1977). The soils derived from the granitic rocks are equally leached, but due to the larger grain size of the parent rock, they have less clay and

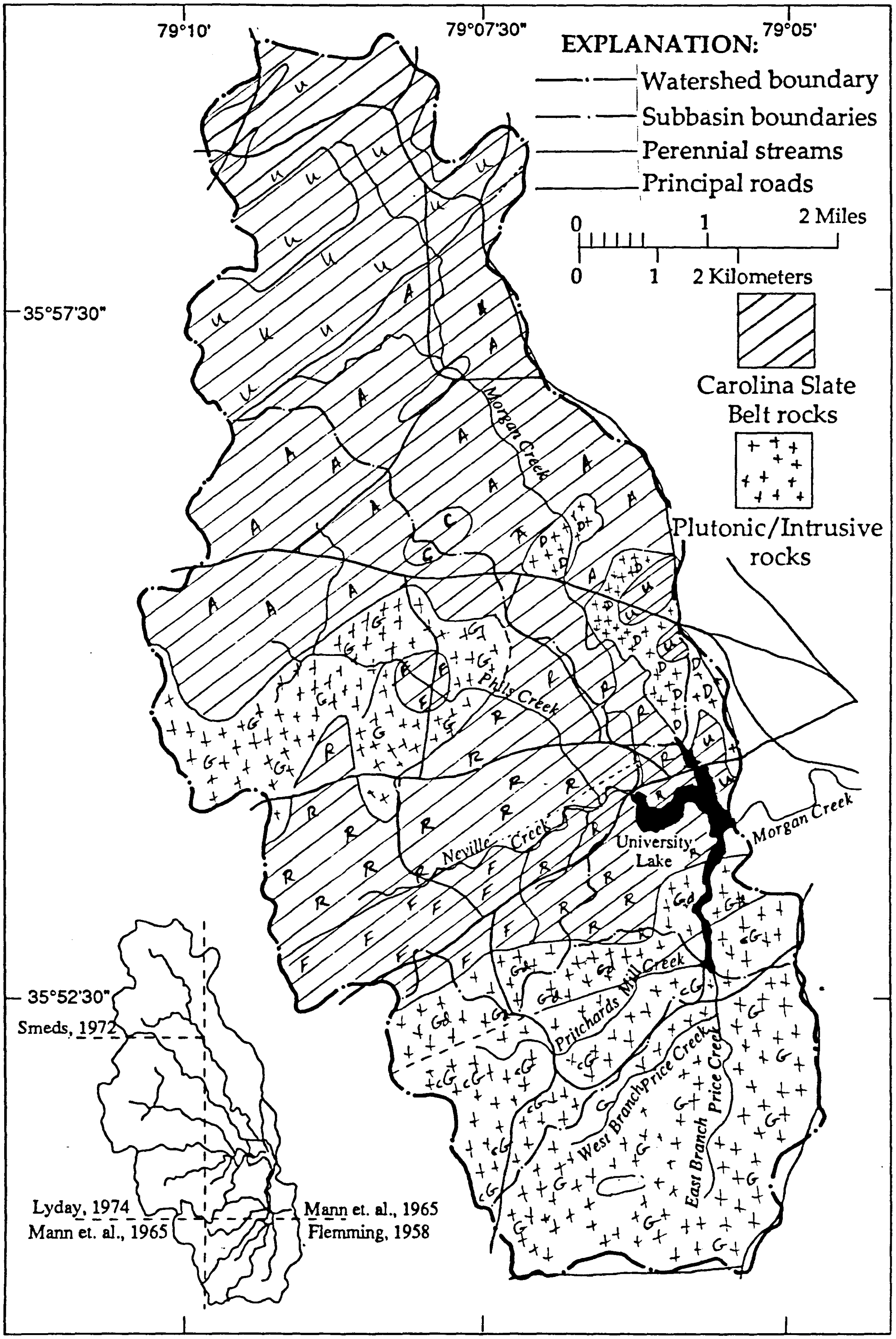


Figure 3. Geology of University Lake watershed.

are commonly sandy or sandy loam soils, rich in sand-size angular quartz and feldspar. These soil types include Appling, Cecil, Helena, Louisburg, Wedowee, and Vance (Dunn, 1977). In contrast to the soils derived from the Carolina Slate Belt rocks, the soils derived from the the granitic rocks are often well drained to excessively drained both at the surface and internally, and as a result they have a significantly lower surface runoff and erosion potential (Dunn, 1977).

Three percent of the watershed is covered by alluvial or colluvial soils deposited on floodplains (Bass and Martin, 1939). Floodplains are scattered along all the major creeks and most are narrow and discontinuous (Figure 4). Two floodplain soils, Chewacla and Conagree, are loams or fine sand loams at the surface, and have subsurfaces ranging from silt loams to stratified sandy loams (Dunn, 1977). These soils have variable to poor drainage, but due to their low slope the erosion potential of these soils is low.

Stream Morphology

Stream drainage in the watershed is mature and dendritic (Figure 4). Drainage of the northern subbasins is toward the southeast while Price Creek drains to the north into Morgan Creek. There is a slight tendency of high order streams to orient either subparallel or subperpendicular to the NE striking regional bedrock fracture (Mann et al., 1965).

On Morgan Creek and Phils Creek (above the area underlain by granitic rocks) the creek beds are armored by rounded gravel, cobbles, and boulders, and the banks are composed mostly of compact silt and clay. Sand bars cover less than a quarter of the streambed, and the streambeds are often blanketed by clay and silt during low flows. In contrast, the streambeds of Price Creek and Pritchards Mills Creek are covered by thick deposits of coarse to medium sand, and the creek banks are predominantly sand or silty sand. Cobble and boulder zones occur on Price Creek and Pritchards Mills Creek only in the upper reaches of either stream and on short stretches where the stream gradients are high.

Within the watershed there are two distinct perennial creek morphologies. Where the gradients are steep, the creeks are usually wide and shallow, with both large and small trees growing right to the waters edge. Often small levees line the low channel banks. By contrast, where the creeks pass through floodplains (Figure 4)

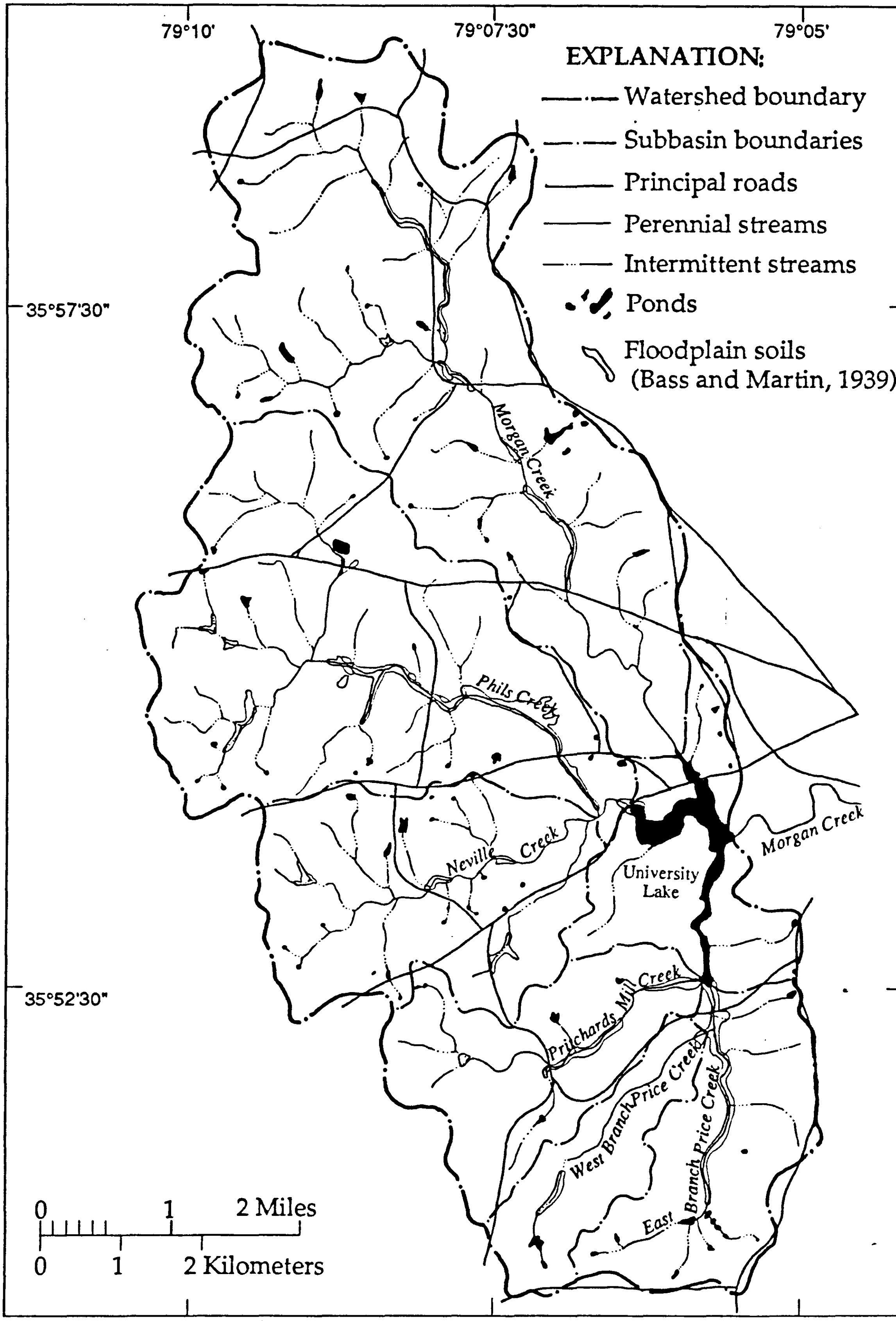


Figure 4. Hydrologic features of University Lake watershed.

they are usually deeply entrenched, with cross sectional profiles 20 to 30 feet wide and 5 to 12 feet deep. On these incised reaches there is very little vegetation along the creek banks, while undercut trees and bank gouges are common.

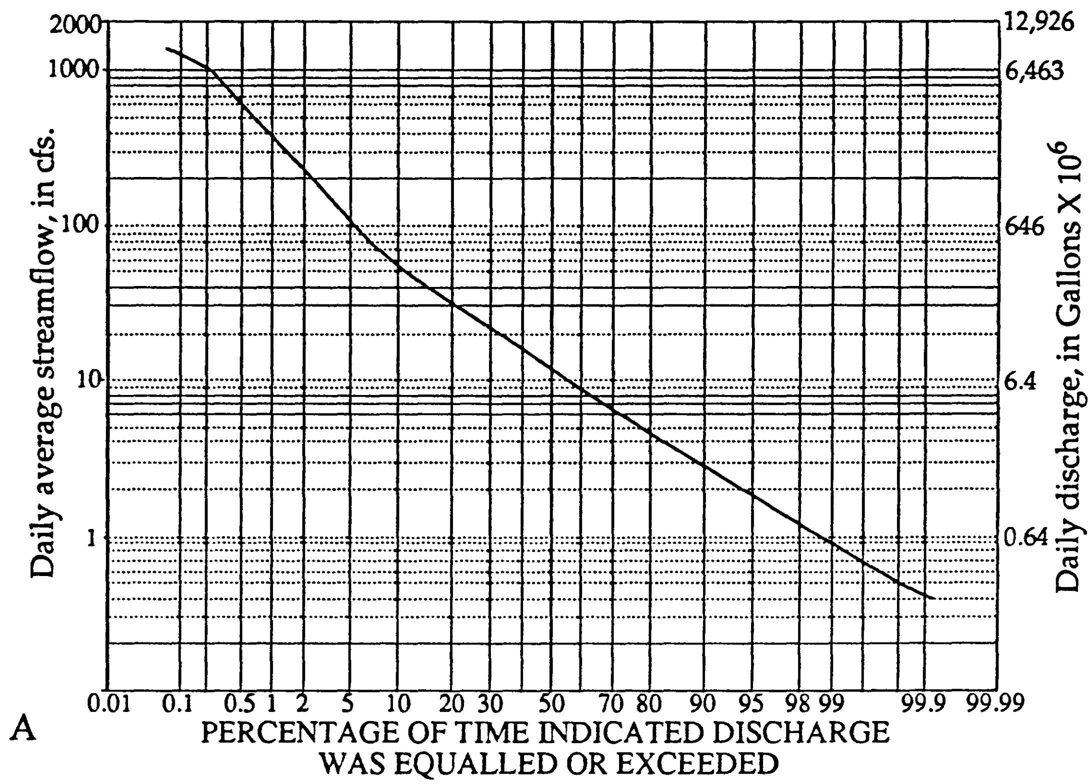
The lowest reaches of Price Creek and Pritchards Mill Creek, above the backwater of University Lake are a very important exception to the incised, eroding channels, and inactive floodplains. Both of these creeks flow through heavily vegetated, actively accreting floodplains, with shallow sandy channels. During even moderate flows the streams overflow the channels and the water moves across the floodplains in sheets flows. Thick deposits of coarse and medium sand cover these floodplains along with a large quantity of organic debris.

Precipitation and Streamflow

Precipitation in University Lake watershed is distributed throughout the year with the maximum mean monthly rainfall of 5.0 inches occurring in July, and the minimum of 3.1 inches in October. Rainfall from June to October is usually in the form of short, intense thunderstorms, and every several years heavy precipitation occurs due to tropical storms (Dunn, 1977). During the winter and spring, rains are more commonly caused by large low pressure systems which may cause heavy rainfall to occur intermittently for several days. In an average year there are 74 days with 0.1 or more inches of precipitation, 29 days with 0.5 or more inches, and 12 days with more than an inch of rain (Ruffin and Bair, 1987).

Droughts and severe floods occur during every part of the year, but both are most common during the summer and fall. One year in 10 has a monthly rainfall of less than 0.7 inches during September through November (Dunn, 1977), and of 9 years of streamflow records for Morgan Creek (1923-1932) most of the annual peak streamflows were recorded between June and October.

Between February 1923 and April 1932 streamflow records were collected on Morgan Creek by the United States Geological Survey (USGS) from a gage at the present site of the University Lake dam. During this period the average streamflow was 32.6 cubic feet per second (cfs.), and the median streamflow was 13.1 cfs. A flow duration curve (Figure 5A) prepared from the daily streamflow record, shows that the flow past the dam site was equal to or greater than the average flow only 20% of



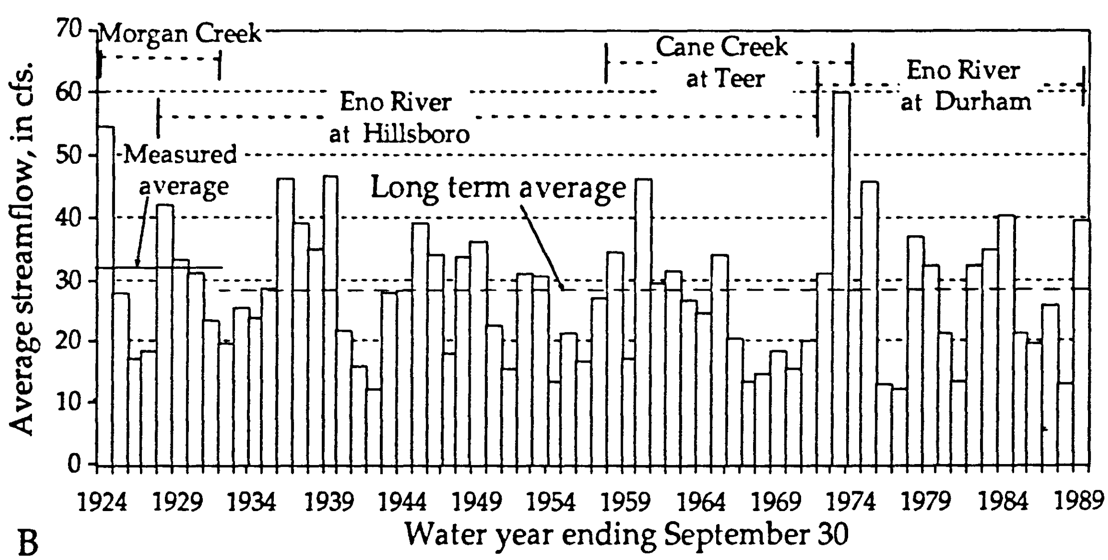


Figure 5. Morgan Creek streamflow duration and yearly streamflow
A Daily flow duration curve for Morgan Creek at the present dam site. (USGS gage #02097500). Period of record is Febuary 1923 to April 1932.
B Yearly average streamflow for Morgan Creek at the dam. Approximated using the average discharge per square mile from nearby USGS gages as shown. Measured average for period from 1924 to 1932 is 32.6 cfs. Average for 1932 to 1989 is 28.3 cfs.

the time, and flows greater than 100 cfs. occurred 5% of the time. On 7 days, or 0.2% of the time, the daily flow in Morgan Creek was more than 1000 cfs.

In general the monthly average flows are highest during the winter and lowest in the late summer and fall. This trend, which is seen throughout the Piedmont (Goddard, 1963), is due both to the decrease in base flow because of higher evaporation and evapotranspiration during the growing season, and to the large number of rainfall droughts in the summer and fall.

Flood flows are recorded during every season of the year. The maximum instantaneous stage recorded at the gage on Morgan Creek was due to a quick thunderstorm which dropped 5.3 inch of rain during just a few hours (Chapel Hill Newspaper, 1924). Within hours of the start of the storm the maximum stage reached 25 feet, and the maximum instantaneous discharge was later estimated at 30,000 cfs. (Thomas and Bonham, 1976).

The yearly average streamflow for University Lake at the dam was estimated using the streamflow records from several nearby streams (Figure 5B). This estimation indicates that the long-term (1932-1989) average streamflow into University Lake was 28.3 cfs, or 4.4 cfs less than the average measured at the dam site during the period from 1924 to 1932.

Land Use

Since University Lake was first built, land use in the watershed has remained a mixture of woodlands, rural homesites, and agriculture. However, important changes have occurred in the proportions of each type of land use, as indicated by the data from 1937 and 1988 (Table 1).

Between 1937 and 1988 there was an increase in the percent of the watershed covered by forest from 51% to 71%. This increase is due mainly to the abandonment of cropland and pasture as agriculture became less important to the local economy. Most forests in the watershed are second growth mixed hardwoods and pines, growing on lands that were farmed until the soil became exhausted and then left to reseed naturally. Forests cover almost all of the stream valleys and the floodplains, and they are distributed randomly on the upland areas. Most of the active cropland in the watershed is on the more gently sloping upland areas in Morgan Creek and Phils Creek subbasins, on large

Table 1. Land use in University Lake watershed.

Land Use, 1937[1]	%	sq. miles	Land Use 1988[3]	%	sq. miles
Forest	51.0	15.2	Forest	70.7	21.1
Cropland	19.9	5.9	Cropland	3.5	1.0
Residential[2]	4.2	1.2	Residential	16.2	4.8
Urban	0.0	0.0	Urban	1.4	0.4
Pasture/Grassland	24.2	7.2	Pasture/Grassland	7.1	2.1
Water	0.8	0.2	Water	1.1	0.3
			Total	100.0	29.9

1. Modified from Erickson and Levitte, 1939
2. Erickson and Levitte report 800 people in homes averaging 4.9 individuals. The area shown assumes 130 homes on 5 acre lots.
3. Modified from Camp, Dresser, and McKee, 1989.

farms that have been active at least since the 1930's (Erickson and Levitte, 1939). The decrease in pasture and grassland from 24.2% of the land use in 1937 to 7.1% in 1988 is a result of the decline in the number of livestock in the watershed, the abandonment to forest as discussed above, and more recently, to residential development (Camp, Dresser, and McKee, 1989). The remaining land use changes in the watershed are related to the increase in residential population in the watershed from approximately 800 people in 1937 to several thousand in 1988. The total number of houses in the watershed in 1937 was approximately 130 (Erickson and Levitte, 1939), by 1988 there were 1866 houses (Camp, Dresser, and McKee, 1989).

ESTIMATES OF STREAM SEDIMENT TRANSPORT

The relationships between land use, soil erosion, and stream sediment transport have been investigated by hydrologists, agricultural engineers, and land use planners for many years (Meade, 1982; Hadley, 1984; Back, 1980). As a result, many predictive equations have been developed to estimate the amount of soil erosion and stream sediment transport based on watershed characteristics such as climate, geology, soils, and land use conditions. Two predictive equations that have been cited by others in studies of University Lake and its watershed (Back, 1980; Camp, Dresser and McKee, 1989), are of particular use because they can be used to estimate the amount of sediment carried into University Lake using the watershed characteristics that have been described above.

The first equation comes from a detailed one-year study of stream sediment transport in 21 watersheds in the Piedmont in northern Virginia (Northern Virginia Planning District Commission and the Civil Engineering Department of Virginia Polytechnic Institute and State University, 1978). The NVPDC-VPI study produced tables of stream sediment transport rates that are determined for each of the land use classes shown in Table 1, and each of four soil textures: clay loam, silt loam, loam, and sandy loam.

The distribution of soil textures in each subbasin of University Lake watershed can be approximated from the geologic map (Figure 3) because the soil textures are largely determined by the weathering characteristics of the underlying rock (Dunn, 1977).

The following distributions are estimated for each subbasin: Morgan Creek: 50% clay loam, 50% silt loam; Phils Creek: 33% clay loam, 33% silt loam, 33% sand loam; Price Creek and Pritchards Mill Creek: 100% sand loam; and the 'Lakeshed' (the subbasin around the lake below the mouth of the 4 major inflowing creeks): 40% silt loam, 60% sand loam. The appropriate sediment transport rate for each type of land use in each subbasin (Table 2A) is then determined from the NVPDC-VPI (1978) tables. For example:

$$\text{Phils Creek rate} = 33\% \text{ clay loam rate} + 33\% \text{ silt loam rate} + 33\% \text{ sand loam rate}, \tag{1}$$

where the rate is expressed in tons per square mile per year.

Assuming that the land use in Table 1 is uniformly distributed over the watershed, the amount of sediment carried into University Lake from each subbasin is calculated by summing the contribution from each land use:

$$SEDQ = (A_1 \times R_1) + (A_2 \times R_2) + \ldots\ldots(A_N \times R_N), \tag{2}$$

where SEDQ is the suspended sediment discharged from the subbasin in tons (short)/year, A_1 is the area of land use 1 in square miles, and R_1 is the sediment transport rate for land use 1 in tons per square mile per year (Table 2A).

Table 2B gives the results of solving equation (2) using the land use in 1937 (Erickson and Levitte, 1939) and in 1988 (Camp, Dresser, and McKee, 1989). The suspended sediment predicted for each year since University Lake was built is shown in graphical form in Figure 6A. The estimated suspended sediment transported to University Lake each year has decreased 68% from 6496 tons per year in 1937 to 2065 tons per year in 1988. Most of the decrease is due to the decrease in erosion from agricultural land, which accounted for 5791 tons per year in 1937 and only 1087 tons per year in 1988. Although Phils Creek is a larger subbasin, 16% more sediment is carried into the lake from Morgan Creek than Phils Creek because of the more erosive clay soils in the Morgan Creek subbasin. Price Creek and Pritchards Mill Creek, which together drain 20% of the watershed, contribute less than 10% of the total sediment load because of the low sediment yield from the sandy loam soils.

A second equation used to estimate the annual stream sediment transported into University Lake is taken from Simmons (1988). Simmons measured over

Table 2 A. Stream sediment transport rates for each land use in each subbasin in University Lake watershed*

	tons/square mile/year					Area weighted
	Morgan	Phils	Price	Mill	Lakeshed	average
forest	42	31	6	6	19	28
cropland	1248	1025	506	506	764	968
residential	64	56	38	38	47	54
urban	141	141	141	141	141	141
pasture/grassland	42	31	6	6	19	28
water						0

B. Annual stream sediment transport to University Lake

1937^	tons/year						Percent of
	Morgan	Phils	Price	Mill	Lakeshed	Total	basin total
forest	214	177	12	8	23	434	6.7%
cropland	2496	2255	405	253	382	5791	89.1%
residential	26	22	8	4	5	65	1.0%
urban	0	0	0	0	0	0	0.0%
pasture/grassland	101	84	6	4	11	206	3.2%
Subbasin total=	2837	2538	431	269	421		
					basin total	= 6496	tons/year

1988†	tons/year						Percent of
	Morgan	Phils	Price	Mill	Lakeshed	Total	basin total
forest	298	245	17	11	30	601	29.1%
cropland	499	410	51	51	76	1087	52.6%
residential	102	101	23	15	19	260	12.6%
urban	14	28	14	0	0	56	2.7%
pasture/grassland	29	25	2	1	4	61	3.0%
Subbasin total=	942	809	107	78	129		
					basin total	= 2065	tons/year

*Modified from NVPDC-VPI, 1978

^ Land use modified from Erickson and Levitte, 1939

† Land use modified from Camp, Dresser, and McKee, 1989

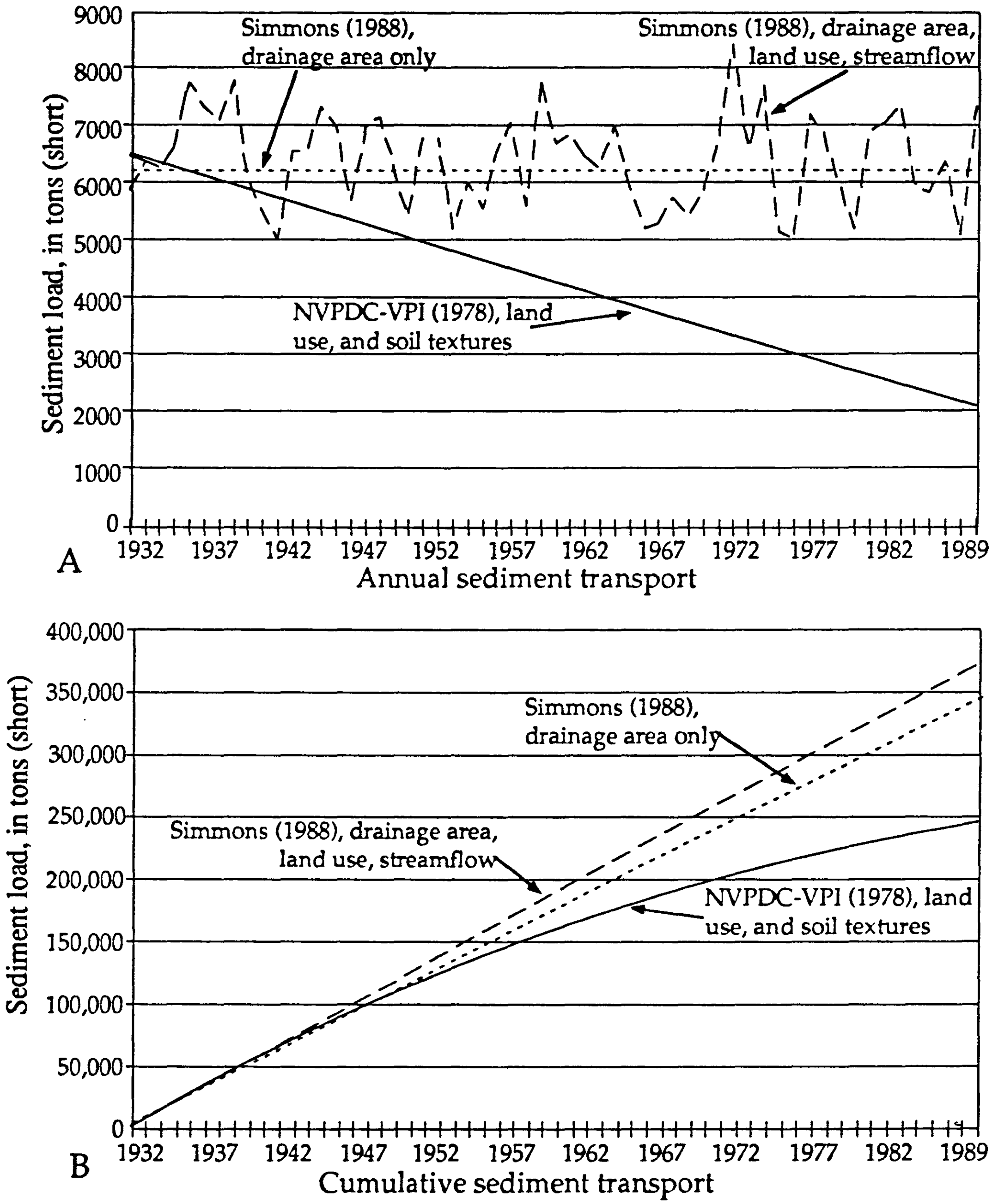


Figure 6. Estimated weight of stream sediment transported to University Lake.
A Annual transport estimated with predictive equations derived from NVPDC-VPI (1978).and Simmons (1988). Calculated with the land use from Table 1 distributed uniformly within the watershed, and using a linear change in land use between 1932 and 1989.
B Cumulative curves for the period from 1932 and 1989.

13,000 suspended sediment concentrations at 152 sampling locations in North Carolina over a nine year period (1970-1979) and developed mathematical relations to estimate the amount of suspended sediment transported in streams draining rural and agricultural areas in the Piedmont (Simmons, 1988). The two equations that are applicable to University Lake watershed are

$$SEDQ = 204 \times DA^{1.00}, \text{ and} \tag{3}$$

$$SEDQ = 203 \times DA^{.689} \times AVGQ^{1.18} \times ROW^{.0035}, \tag{4}$$

where SEDQ is the suspended sediment discharge in tons per year, DA is the drainage area in square miles, AVGQ is the yearly average streamflow in cubic feet per second, and ROW is the percentage of row crops in the basin.

Solving Equation 3 using a drainage area of 29.9 square miles, the sediment discharge to University Lake is 6100 tons per year. Equation 4, solved using the streamflow estimation shown in Figure 5 and the land use data in Table 1, varies from year to year due to the streamflow variation, with a high value of more than 8000 tons per year to a low value of 5000 tons per year in 1939 (Figure 6A). Over the period from 1932 to 1989 (calculated using a linear change in percent of row crops) the average yearly sediment load is 6514 tons per year.

Summing the annual sediment loads predicted by the two equations developed by Simmons, the net suspended sediment carried to University Lake over 57 years is 347,000 tons and 371,000 tons respectively (Figure 6B). The NVPDC-VPI (1978) study predicts a suspended sediment discharge to the lake of 248,000 tons. The accuracy of these solutions, which potentially could be used to estimate the sediment trapping efficiency of University Lake, will be discussed later by comparing the estimated suspended sediment discharged from the watershed to the amount of sediment that is measured in University Lake.

STUDY METHODS

BATHYMETRIC SURVEY

The bathymetric map of University Lake (Figure 7) was made following standardized methods (Heinemann and Dvorak, 1965; Soil Conservation Service, 1977; Rausch and Heinemann, 1984) by collecting depth measurements along survey profiles, or ranges, across the lake using a continuous recording electronic fathometer, converting the depths to elevations, plotting the elevations on a base map, and contouring points at equal elevations.

The original 1:1200 scale bathymetric maps, which were produced on five separate sheets, are held in the Department of Geology library at the University of North Carolina at Chapel Hill, and in Orange County Water and Sewer Authority records.

Seventy-two survey range ends were established along the perimeter of University Lake to serve as map control points (Figure 8). The range ends were located at approximately the same locations as those used by the Soil Conservation Survey (Eakins, 1939) and/or Smalley (1963) in order to maximize comparability with the data collected during previous surveys. Profiles were run along line of sight between range ends using a 200 kHz recording depth sounder (Raytheon Model 719-E) mounted on a 16-foot aluminum boat with a 9.9 HP outboard engine. Using a recording paper speed of 2 inches per minute, and keeping the boat at its lowest possible speed, the fathometer records have horizontal scales of 75 to 125 feet per inch. Most profiles were run in both directions between range ends to check distortions caused by variations in boat speed and course. The depths recorded by the fathometer were calibrated to elevation above mean sea level each day using OWASA's ruled gage datum located at the boat dock 200 feet from the spillway. The gage datum is zeroed on the present wooden spillway elevation of 349.5 feet above mean sea level. During the survey in June 1989 the lake level ranged from 2 to 6 inches below the spillway elevation. Theoretically the accuracy of the vertical scale recorded by the fathometer is ±3 inches at the depths encountered in University Lake (Raytheon manual). However, because the fathometer depth reading had to be calibrated by taking manual soundings using a survey pole, and then had to be calibrated to elevation, an equal additional error is assumed.

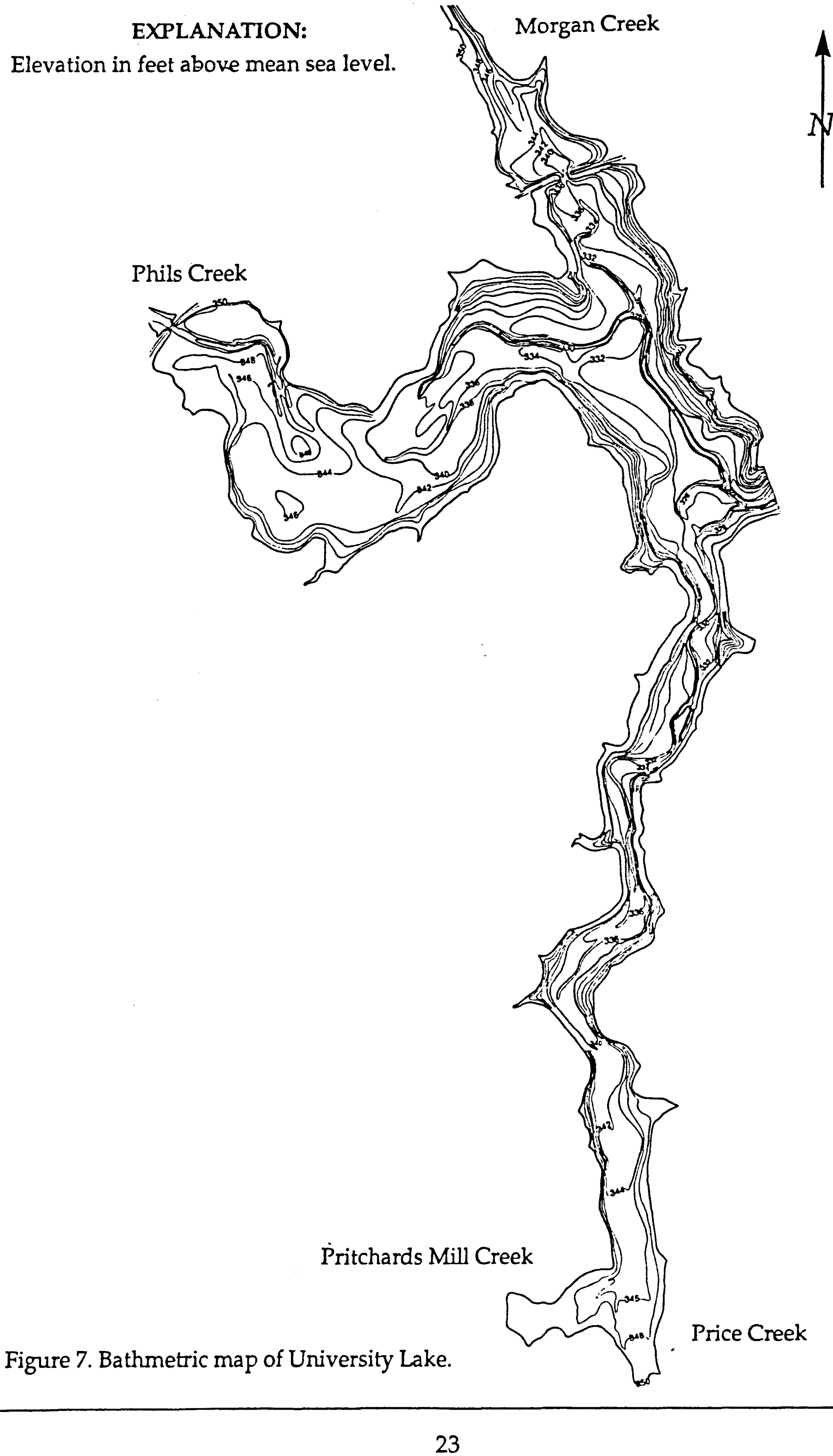


Figure 7. Bathmetric map of University Lake.

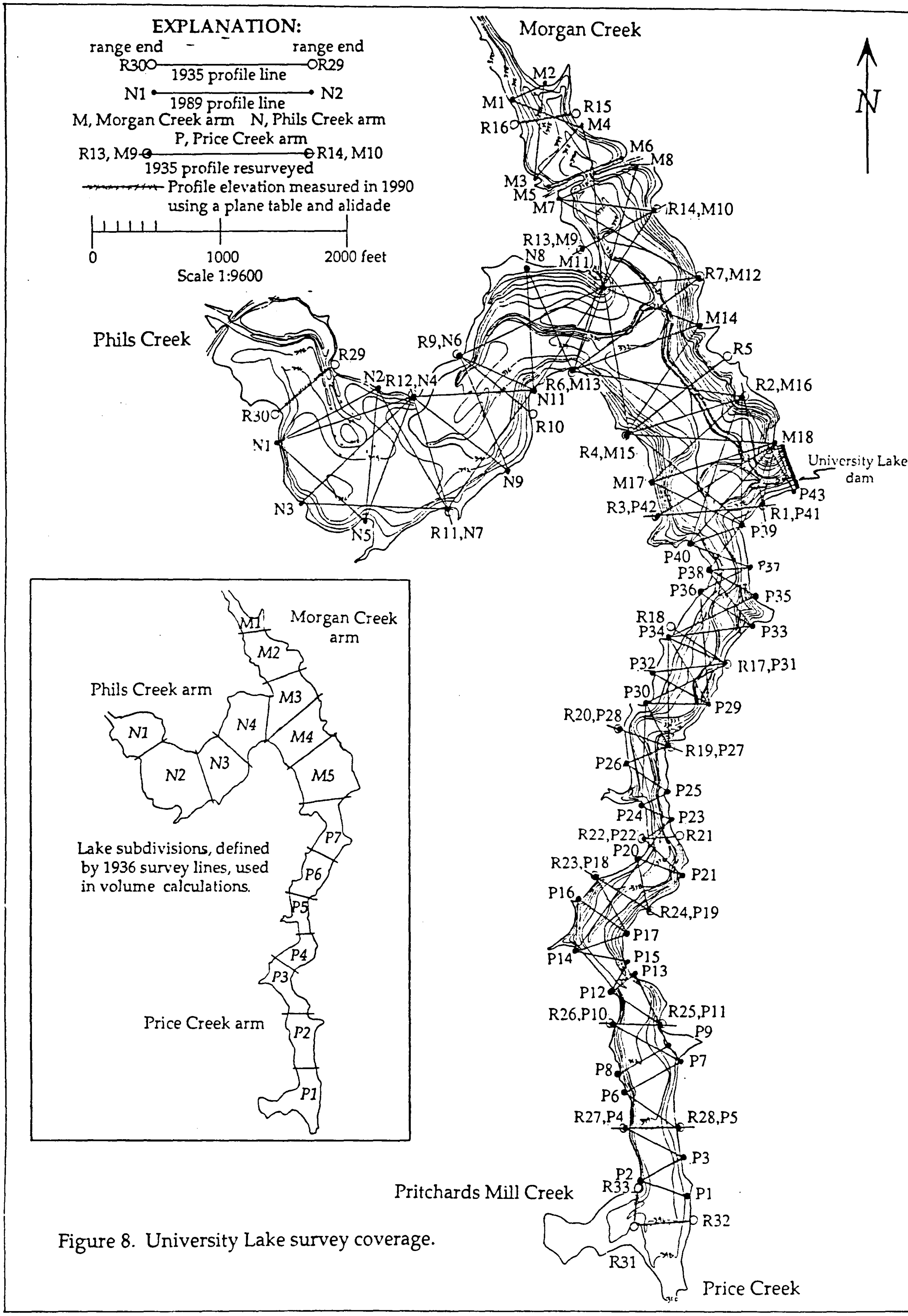


Figure 8. University Lake survey coverage.

The base map on which the fathometer records were compiled was made by Piedmont Aerial Survey during a drought in 1968 and has a scale of 1:1200 (one inch equals 100 feet), and shows two-foot contour lines down to 340 feet, or 9.5 feet below the present spillway elevation. The fathometer only recorded consistently at depths of more than 4 feet, so the profile lines were scaled to fit between the 344 foot contour lines on the base map. In all, 105 profiles (90 of which were taken in both directions) were transferred to the base map, and contour lines were drawn by hand using a two-foot contour interval.

In shallow backwater areas contour lines were determined using manual soundings and by sketch mapping when the lake level was low. In addition, the bottom elevation was measured using a plane table and alidade (Compton, 1962) along five of the profile lines that were surveyed previously in 1935 (Figure 8).

The vegetation line along the perimeter of the lake was interpreted from 1:1200 scale (one inch equals 100 feet) orthophoto maps made for Orange County in 1985. Because there were significant discrepancies in some areas between the 350 foot contour line shown on the 1985 orthophoto maps and the 350 foot line on the 1972 map, the 350 foot line from the orthophoto maps was used to make the final bathymetric map.

The stage/area and stage/capacity curves shown in Figure 9 are determined from the 1:1200 scale bathymetric maps. The map was divided into 16 segments as shown in Figure 8 to facilitate measurements, and the area enclosed by each contour (Table 3) then measured using an electronic planimeter. From these area measurements, the volume between each two-foot contour interval in each segment is determined using the contour average end method (Table 4) (Heinemann and Dvorak, 1965; Rausch and Heinemann, 1984). These measurements show the lake to have a suface area of 200 acres and a water capacity of 1805 acre-feet to the spillway elevation of 349.5 feet above mean sea level.

SEDIMENT THICKNESS MEASUREMENTS

The sediment isopach map (Figure 10) was made by compiling measurements taken with three different field survey methods. Additional information was provided by comparing the present lake bottom elevations with the elevations that were measured in 1935 (Eargle, 1935; Eakins, 1939).

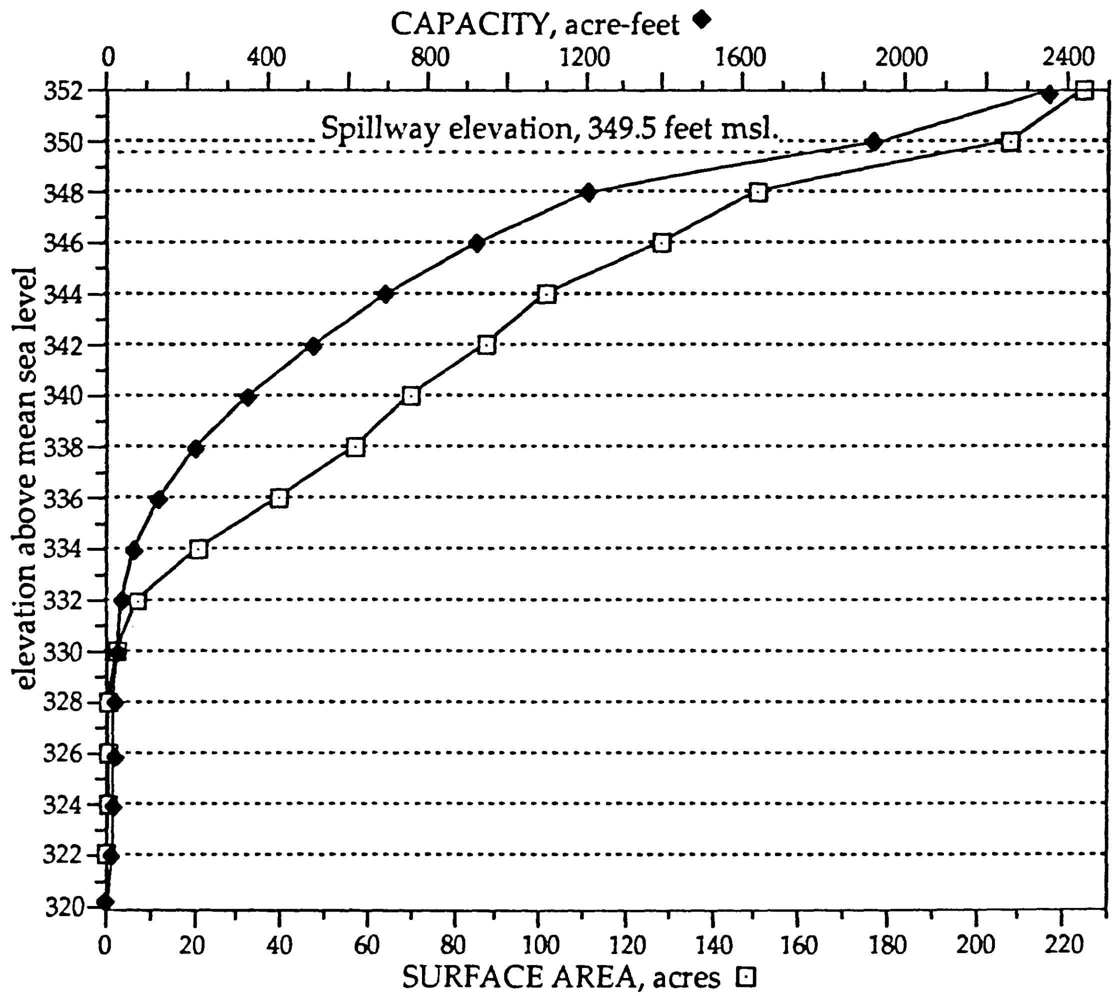


Figure 9. Stage-area and stage-capacity curves for University Lake determined from the 1989 bathymetric survey. At the spillway elevation of 349.5 feet above mean sea level the surface area of the lake a is 200 acres. The water capacity to the spillway elevation is 1805 acre-feet (588 million gallons).

Table 3. Contour areas measured from the 1989 bathymetric map. Areas are measured from 1:1200 scale map. Segment locations are shown in Figure 7. All areas in acres.

	Morgan Creek Arm						Phils Creek Arm					Price Creek Arm								
ELEV	M1	M2	M3	M4	M5	ΣM	N1	N2	N3	N4	ΣN	P1	P2	P3	P4	P5	P6	P7	ΣP	Entire Lake
352	6.3	15.9	13.6	15.7	22.5	74.0	14.5	30.0	17.8	18.1	80.4	18.7	9.4	8.9	5.6	5.6	8.3	13.0	69.6	224.0
350	5.0	14.5	13.2	14.7	21.8	69.1	13.7	29.0	17.0	17.2	76.9	13.7	8.5	8.4	5.3	5.3	8.0	12.4	61.4	207.4
348	3.1	12.6	12.4	13.4	20.0	61.5	9.3	26.8	15.4	15.3	66.8	7.9	6.9	7.4	4.4	4.4	7.4	11.2	49.6	177.9
346	1.4	11.2	12.1	12.8	19.4	56.9	1.4	22.2	14.4	14.4	52.4	3.7	5.7	6.5	4.0	4.0	6.9	10.3	41.2	150.4
344	0.3	8.9	11.7	12.3	18.7	51.9	--	15.7	13.4	13.7	42.8	--	4.4	5.7	3.7	3.7	6.4	9.5	33.5	128.2
342	--	6.1	11.3	11.9	18.1	47.4	--	2.7	11.8	12.8	27.3	--	1.0	4.8	3.4	3.3	6.0	8.7	27.2	101.9
340	--	4.6	10.8	11.3	17.6	44.3	--	0.5	9.3	11.7	21.5	--	--	2.6	3.0	2.9	5.5	8.0	22.1	87.9
338	--	3.5	10.2	10.6	15.5	39.9	--	--	2.8	10.3	13.1	--	--	0.1	2.1	2.5	5.0	7.3	16.9	70.0
336	--	2.0	9.4	9.9	14.3	35.5	--	--	0.8	7.7	8.4	--	--	--	0.5	1.8	4.2	6.5	13.0	56.9
334	--	0.3	6.9	8.8	12.5	28.4	--	--	0.1	2.6	2.7	--	--	--	--	0.4	2.8	5.5	8.7	39.7
332	--	0.1	1.6	5.0	9.2	15.8	--	--	--	0.6	0.6	--	--	--	--	--	0.5	4.3	4.8	21.2
330	--	--	0.7	0.9	3.9	5.5	--	--	--	0.2	0.2	--	--	--	--	--	0.2	1.5	1.7	7.3
328	--	--	0.3	0.4	2.0	2.6						--	--	--	--	--	--	0.3	0.3	2.8
326	--	--	--	--	1.1	1.1														1.1
324	--	--	--	--	0.5	0.5														0.5
322	--	--	--	--	0.19	0.2														0.2
320	--	--	--	--	0.02	0.0														

Lake Area at the spillway elevation 349.5 ft. = 200 acres

Table 4. Lake capacity measured from the 1989 bathymetric map. Volumes determined using the contour average end method. Segment locations are shown in Figure 7. All volumes in acre-feet.

	Morgan Creek Arm						Phils Creek Arm					Price Creek Arm									
ELEV	M1	M2	M3	M4	M5	ΣM	N1	N2	N3	N4	ΣN	P1	P2	P3	P4	P5	P6	P7	ΣP	M+N+P	CUM.
352-350	11.3	30.4	26.8	30.4	44.3	143.2	28.2	59.0	34.8	35.3	157.3	32.4	17.9	17.3	10.9	10.9	16.3	25.4	131.1	431.6	2331.7
350-348	8.1	27.1	25.6	28.1	41.8	130.7	23.0	55.7	32.4	32.5	143.6	21.6	15.4	15.8	9.7	9.7	15.4	23.6	111.2	385.5	1900.1
348-346	4.5	23.8	24.5	26.2	39.4	118.4	10.7	49.0	29.8	29.7	119.2	11.6	12.6	13.9	8.4	8.4	14.3	21.5	90.7	328.3	1514.6
346-344	1.7	20.1	23.8	25.1	38.1	108.8	1.4	37.9	27.8	28.1	95.2	3.7	10.1	12.2	7.7	7.7	13.3	19.8	74.5	278.5	1186.3
344-342	0.3	15.0	23.0	24.2	36.8	99.3	--	18.4	25.2	26.5	70.1	--	5.4	10.5	7.1	7.0	12.4	18.2	60.6	230.0	907.7
342-340	--	10.7	22.1	23.2	35.7	91.7	--	3.2	21.1	24.5	48.8	--	1.0	7.4	6.4	6.2	11.5	16.7	49.2	189.7	677.7
340-338	--	8.1	21.0	21.9	33.2	84.2	--	0.5	12.1	22.0	34.6	--	--	2.8	5.1	5.4	10.5	15.3	39.1	157.9	488.0
338-336	--	5.5	19.6	20.5	29.9	75.5	--	--	3.6	18.0	21.6	--	--	0.2	2.6	4.3	9.2	13.3	29.5	126.6	330.2
336-334	--	2.3	16.3	18.7	27.2	64.5	--	--	0.9	10.3	11.2	--	--	--	0.5	2.2	7.0	11.1	20.7	96.4	203.6
334-332	--	0.4	8.5	13.8	22.3	45.0	--	--	0.1	3.2	3.3	--	--	--	--	0.4	3.3	9.4	13.1	61.3	107.1
332-330	--	0.1	2.3	5.9	13.3	21.6	--	--	--	0.8	0.8	--	--	--	--	--	0.7	5.8	6.5	28.8	45.8
330-328	--	--	1.0	1.3	5.9	8.2	--	--	--	0.2	0.2	--	--	--	--	--	0.2	1.8	1.9	10.3	17.0
328-326	--	--	0.3	0.4	3.2	3.9	63.3	223.7	187.8	231.1		--	--	--	--	--	--	0.3	0.3	4.1	6.7
326-324	--	--	--	--	1.7	1.7	Phils Creek total= 705.9					69.3	62.4	80.0	58.3	62.1	114.0	182.1		1.7	2.6
324-322	--	--	--	--	0.7	0.7											Price Creek total= 628.3			0.7	0.9
322-320	--	--	--	--	0.21	0.2														0.2	0.2
320-318	--	--	--	--	0.02	0.0														0.0	0.0
	26.0	143.4	214.8	239.7	373.7																
	Morgan Creek total= 997.5																				

Lake capacity to 352 ft. = 2331.7 acre-feet

Lake Capacity to the spillway elevation of 349.5 ft. = 1805 acre-feet

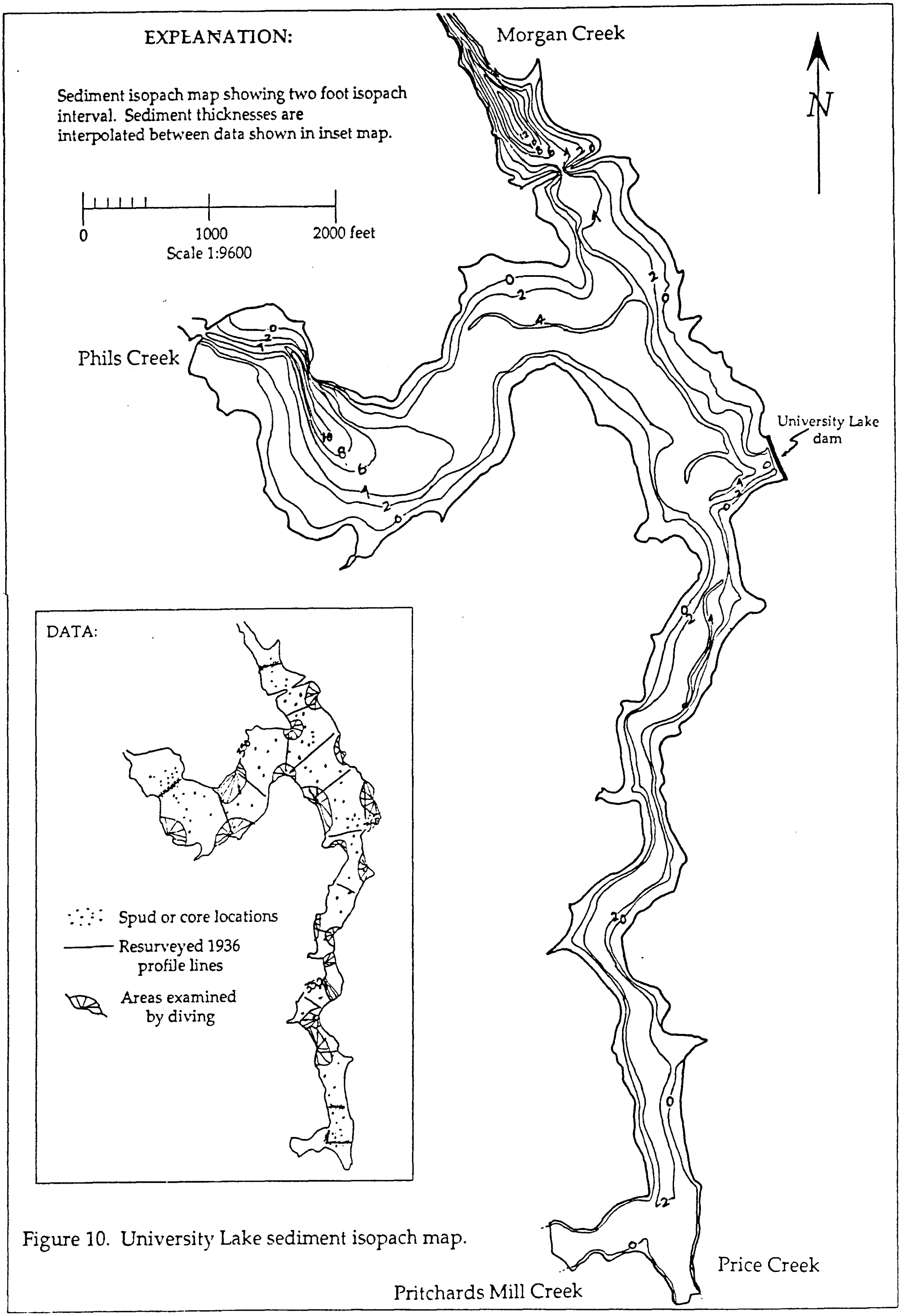


Figure 10. University Lake sediment isopach map.

The sediment thickness was measured directly at 60 points using a sediment spud (Brown, 1943; Rausch and Heinemann, 1984). The sediment spud used for this survey is an 8 foot long steel rod that has been tooled to form shallow cups at 0.1 foot intervals along its length. The spud is dropped from a boat, and the weight of the spud helps the tool penetrate the sediment. When the spud is pulled back into the boat the shallow cups usually retain some sediment. If the spud penetrates the lake deposits into the old soil, the old soil can be distinguished from the overlying mud by its contrasting color, its compactness, the presence of roots, and/or its grain size. The sediment thickness was recorded by measuring the distance along the spud from the top of the sediment to the top of the old soil.

The thickness of the lake sediments was also recorded from 55 cores that were collected in University Lake. Twenty five cores that penetrated into the old soil were used to record the total thickness, while the remaining cores provided a minimum sediment thickness (Table 5). In areas, the bottom type and sediment thickness were determined by feeling the bottom texture and/or by pushing a meter stick into the sediment. This was done by diving to the bottom without scuba gear and only areas that were less than 12-14 feet deep were explored (Figure 10).

The sediment thicknesses were determined along 13 profiles by comparing the present bottom elevations with the elevations recorded in 1935 by the Soil Conservation Survey (Eargle, 1935; Eakins, 1939) (Figure 8). Eight of these profiles were resurveyed using the fathometer and 5 were resurveyed using a plane table and alidade (Compton, 1962).

SEDIMENT SAMPLING

Field collection

Seventy-eight sediment cores were collected from University Lake (Table 5). Fifty-five cores were collected using 7.6 cm (3") diameter thin-walled aluminum core tubes which collect an essentially intact vertical section of the sediment column. Twenty-three surficial sediment cores were taken using a lightweight box corer (6"x6"x6" Wildco-Ekman Bottom Dredge). Cores were collected from throughout each arm of the lake (Figure 11), however more cores were taken in the shallow backwater areas to characterize the more variable sediments in these environments.

Table 5: Core collection.

Morgan Creek Arm (M)

Core (1)	Top of core (elevation)	Top of core depth (2)	length (cm)	lake sediment length (cm) (3)	Appendix 1 diagram pg.	Number and type of subsamples (4)	Prereservoir Geomorphic Unit	Sedimentary Environment
DCM727*3	332.5'	17.0'	59	4	A2	5A	floodplain	bottomset
HCM87*1	322.5'	27.0'	64	45	A2	1D,1E	valley slope	bottomset
HCM87*2	321.5'	28.0'	58	np.	A2	6A,1D	valley slope	bottomset
DCM817*1	332.5'	17.0'	162	51	A3	--	channel leveee	bottomset
DCM817*2	333.5'	16.0'	168	67	A3	9A,1D,5E	floodplain	bottomset
DCM817*3	331.3'	18.2'	206	51	A3	--	floodplain	bottomset
DCM821*1	319.3'	30.2'	110	90	A4	1D	channel bed	bottomset
DCM821*2	330.1'	19.4'	154	53	A4	--	floodplain	bottomset
DCM821*3	330.1'	19.4'	156	60	A4	1D	floodplain	bottomset
DCM822*1	329.5'	20.0'	130	116	--	1D	channel bed	bottomset
HCM923*1	342.0'	7.5'	41	np.	A5	1A,1C,1D	valley slope	prodelta
HCM923*2	342.5'	7.0'	83	np.	A5	1A,1C,1D	valley slope	prodelta
PCM923*3	346.5'	3.0'	129	np.	A5	3A,3C,3D	valley slope	distributary mouth bar
PCM923*4	346.0'	3.5'	70	np.	A5	4A,4C,4D	channel	distributary mouth bar
PCM923*5	345.5'	4.0'	34	np.	A5	1A,1C,1D	valley slope	channel
PCM923*6	344.5'	5.0'	114	np.	A5	1A,1C,1D	valley slope	delta front
HCM923*7	339.5'	10.0'	28	np.	A5	3A,3C,3D	channel	prodelta
HCM923*8	336.5'	13.0'	25	np.	A5	2A,2C,2D	channel bed	prodelta
BCM 122*85t	329.5'	20.0'	--	np.	--	2A,2B,2C,2D	floodplain	bottomset

Phils Creek Arm (N)

Core (1)	Top of core (elevation)	Top of core depth (2)	length (cm)	lake sediment length (cm) (3)	Appendix 1 diagram pg.	Number and type of subsamples (4)	Prereservoir Geomorphic Unit	Sedimentary Environment
VCN727*1	346.5'	3.0'	97	np.	A6	--	floodplain	distributary mouth bar
VCN727*2	346.5'	3.0'	177	np.	A6	--	floodplain	distributary mouth bar
PCN82*1	343.5'	6.0'	18	np.	A7	1A,1C,1D	trib. channel on floodplain	prodelta
HCN82*2	339.3'	10.2'	45	np.	A7	2A,2C,2D	floodplain	prodelta
HCN82*3	340.5'	9.0'	45	35	A7	2A,2C,2D	channel	prodelta
PCN82*4	344.0'	5.5'	50	np.	A7	2A,2C,2D	floodplain	prodelta

*see footnotes at end of table

Phils Creek Arm, continued

Table 5: Sheet 2 of 3

Core (1)	Top of core (elevation)	Top of core depth (2)	length (cm)	lake sediment length (cm) (3)	Appendix 1 diagram pg.	Number and type of subsamples (4)	Prereservoir Geomorphic Unit	Sedimentary Environment
PCN82*5	347.0'	2.5'	38	np.?	A7	2A,2C,2D	channel levee	distributary channel levee
PCN82*6	347.5'	2.0'	40	np.	A7	3A,3C,3D	channel levee	distributary channel levee
PCN82*7	345.5'	4.0'	42	np.	A7	2A,2C,2D	trib. channel on floodplain	prodelta
PCN82*8	347.0'	2.5'	50	np.	A7	2A,2C,2D	trib. channel on floodplain	distributary channel levee
PCN82*9	346.5'	3.0'	41	np.	A7	1A,1C,1D	trib. channel mouth	backwater trib. channel
PCN82*10	347.0'	2.5'	71	28?	A7	4A,4C,4D	channel bed	backwater trib. channel
PCN82*11	348.5'	1.0'	116	np.	A6	8A	channel levee	distributary channel levee
HCN82*12	343.5'	6.0'	70	25	A6	3A,3C,3D	floodplain	prodelta
PCN82*13	345.5'	4.0'	87	np.	A6	3A,3C,3D	floodplain	delta front
DCN822*2	341.0'	8.5'	153	49	A8	--	floodplain	prodelta
DCN822*3	330.1'	19.4'	115	105	A8	11A,11E	channel bed	bottomset
VCN829*1	349.0'	0.5'	322	np.	A9	--	channel, levee?	distributary channel levee
VCN829*2	349.0'	0.5'	324	np.	A9	--	channel, levee?	distributary channel levee
					8			
VCN97*1	349.0'	0.5'	223	50	A10	1D	channel bed	distributary channel levee
VCN97*2	345.5'	4.0'	178	23	A10	6A,1D	floodplain	prodelta
VCN98*1	346.5'	3.0'	211	np.	A11	--	channel	distributary channel
VCN98*2	346.5'	3.0'	220	np.	A11	1D	channel	distributary channel
VCN98*3	347.5'	2.0'	288	216	A8	1D	floodplain	distributary mouth bar
						--		
HCN103*1	326.7'	22.8'	50	np.	A10	--	channel	bottomset
HCN103*2	335.5'	14.0'	38	np.	A10	--	floodplain	bottomset
BCN122*52t	345.9'	3.6'	--	--	--	2A,2B,2C,2D	valley slope	prodelta
BCN122*83t	343.1'	6.4'	--	--	--	2A,2B,2C,2D	floodplain	prodelta
BCN122*73	346.5'	3.0'	--	--	--	1A,1B,1C,1D	channel bank	distributary channel
BCN122*43	347.8'	1.7'	--	--	--	1A,1B,1C,1D	channel levee?	distributary channel levee
BCN122*88	346.5'	3.0'	--	--	--	1A,1B,1C,1D	trib. channel on floodplain	backwater trib. channel
BCN122*72	345.7'	3.8'	--	--	--	1A,1B,1C,1D	channel bank	distributary channel
BCN122*151	342.7'	6.8'	--	--	--	1A,1B,1C,1D	floodplain	prodelta
BCN122*176	346.8'	2.7'	--	--	--	1A,1B,1C,1D	channel bank?	distributary mouth bar
BCN122*42	346.5'	3.0'	--	--	--	1A,1B,1C,1D	channel bank?	delta front

*see footnotes at end of table

Price Creek Arm (P)

Core (1)	Top of core (elevation)	Top of core depth (2)	length (cm)	lake sediment length (cm) (3)	Appendix 1 diagram pg.	Number and type of subsamples (4)	Prereservoir Geomorphic Unit	Sedimentary Environment
VCP728*1	346.0'	3.5'	87	8	A12	1D	floodplain	marsh
PCP728*2	346.5'	3.0'	68	np.	A12	--	floodplain	marsh
VCP728*3	346.5'	3.0'	155	13 or 70	A12	--	floodplain	marsh/relic channel
DCP728*4	343.5'	6.0'	139	35 or 60	A12	13A	channel levee?	marsh/relic channel
HCP731*1	337.0'	12.5'	35	np.	A13	2A,2C,2D	valley slope	bottomset
HCP731*2	332.5'	17.0'	30	20	A13	2A,2C,3D	channel	bottomset
HCP731*3	338.0'	11.5'	38	10	A13	2A,2C,2D	floodplain	basin slope
HCP731*4	338.5'	11.0'	39	?	A13	2A,2C,3D	channel bed	bottomset
HCP731*5	330.9'	18.6'	40	36	A13	2A,2C,2D	channel bed	bottomset
HCP731*6	340.5'	9.0'	21	15	A13	1A,1C,1D	steep trib. valley	basin slope
HCP731*7	330.1'	19.4'	50	47	A13	6A,1C,1D,6E	channel bed	bottomset
HCP731*8	343.5'	6.0'	48	?	A13	4A,4C,4D	floodplain	prodelta
DCP821*4	331.5'	18.0'	83	55	A14	--	channel bed	bottomset
PCP914*1	348.5'	1.0'	137	62	A14	13A	floodplain	prodelta
VCP103*3	346.5'	3.0'	167	30?	A14	7A	floodplain, small channel?	marsh/relic channel
VCP103*4	346.5'	3.0'	210	23?	A14	--	channel bed	marsh/relic channel
BCP122*162t1	339.5'	10.0'	--	--	--	2A,2B,2C,2D	floodplain	bottomset
BCP122*75t2	343.5'	6.0'	--	--	--	2A,2B,2C,2D	valley slope	bottomset
BCP122*40t3	341.0'	8.5'	--	--	--	2A,2B,2C,2D	floodplain	bottomset
BCP122*163t4	346.5'	3.0'	--	--	--	2A,2B,2C,2D	trib. channel	eroding soil
BCP122*179	341.3'	8.2'	--	--	--	1A,1B,1C,1D	steep trib. mouth	basin slope
BCP122*191	345.5'	4.0'	--	--	--	1A,1B,1C,1D	floodplain	marsh
BCP122*95	344.2'	5.3'	--	--	--	1A,1B,1C,1D	floodplain	prodelta
BCP122*93	339.5'	10.0'	--	--	--	1A,1B,1C,1D	floodplain (small channel?)	bottomset
BCP122*87	340.4'	9.1'	--	--	--	1A,1B,1C,1D	valley slope	basin slope
BCP122*76	341.8'	7.7'	--	--	--	1A,1B,1C,1D	floodplain	bottomset
BCP122*74	344.5'	5.0'	--	--	--	1A,1B,1C,1D	floodplain	prodelta
BCP122*186	346.4'	3.1'	--	--	--	1A,1B,1C,1D	floodplain	marsh
BCP122*94	345.9'	3.6'	--	--	--	1A,1B,1C,1D	floodplain	bottomset
BCP122*71	341.9'	7.6'	--	--	--	1A,1B,1C,1D	floodplain	bottomset

(1) First two letters denote type of core: DC, Diver core; VC, vibra-core; PC, Push core; HC, hammer core; BC, box core.
Third letter designates: M, Morgan Creek; N, Phils Creek (Nevilles); P, Price Creek, number sequence gives date and sequence of collection

(2) Depth refers to full lake, spillway height of 349.5 ft. above mean sea level (msl)

(3) Interpreted lake sediment length over prereservoir soil; np.= prereservoir soil not penetrated

(4) Number of samples of each type: A, Percent water; B, Wet bulk density; C, Percent weight loss with H202 treatment; D, Grain size; E, Percent TOC

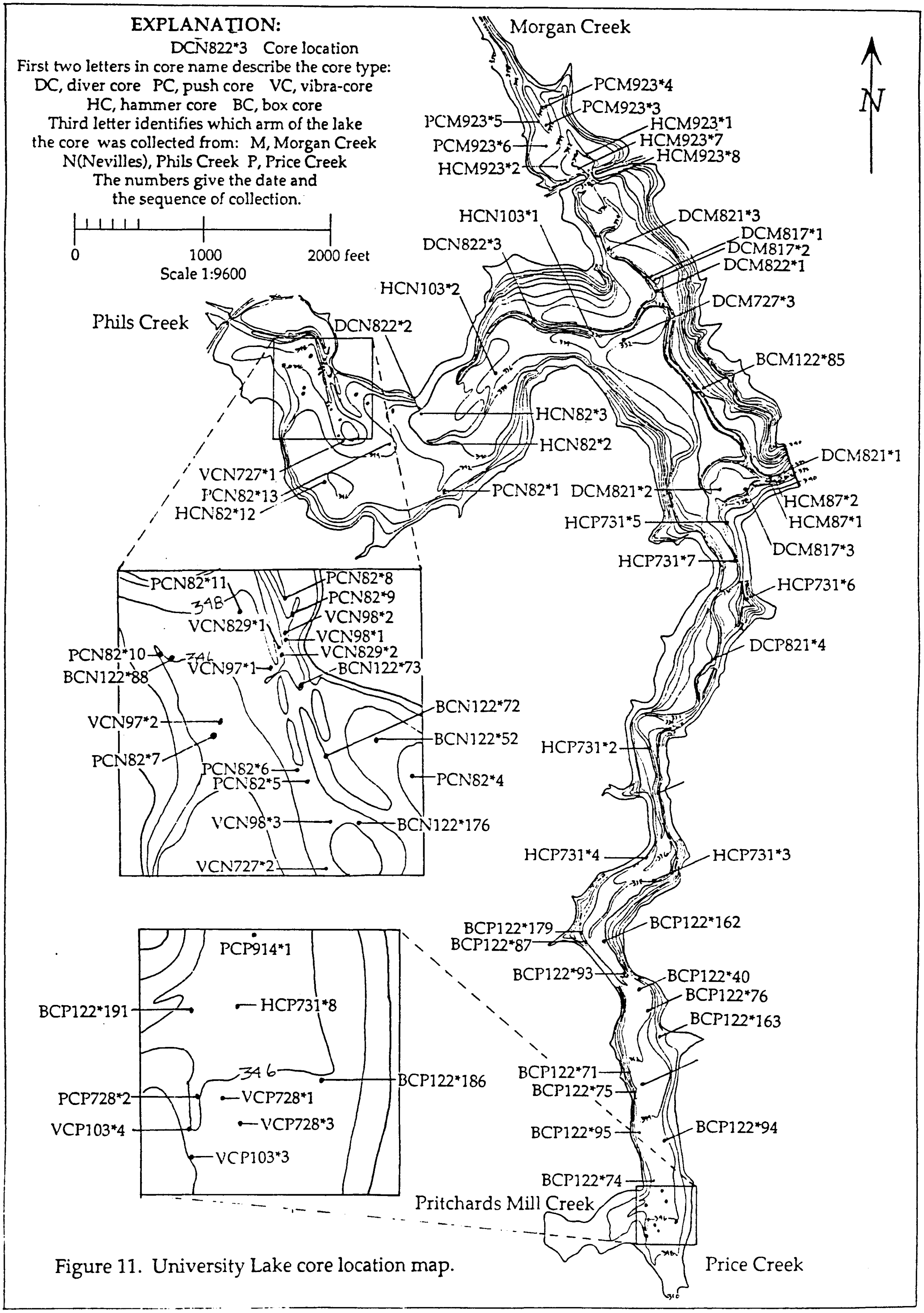


Figure 11. University Lake core location map.

Several methods were used to collect the cores. In water between 6 feet and 30 feet deep divers, wearing scuba gear, used a 15 kg slide hammer to drive a section of core tube into the sediment. Cores were taken in water less than 5 feet deep using the same slide hammer or by simply pushing a section of core tube into the sediment by hand. Thirteen cores up to 3 meters long were collected using a vibra-coring tool (Lanesky et al., 1979). Seventeen cores were collected in water over 5 feet deep using a small line mounted hammer core that was built specifically for this project.

Laboratory analysis

After storage for up to 8 months in a refrigerated locker, the aluminum core tubes were split open and the characteristic features of each core were recorded. Descriptions include the composition, texture, color, sedimentary structures, and the mean grain size of each identifiable sedimentary unit. Complete descriptions of each core are located in Appendix A. The cores remain in the refrigerated storage at the UNC-CH Geology Department.

Subsamples were removed from particular sedimentologic units in the cores to determine the percent water, the quantity of organic material in the sediments, and the grain size. Visual descriptions of each sample and the results of laboratory analysis are listed in Appendix B.

The percent water was determined by weighing 50 to 150 gm of wet sample, drying it for several days in an 80°C oven, and then reweighing after the sample had cooled at room temperature for 5 hours or more. Thirty-nine volumetric samples, including either one or two from each surficial box core, and samples from several cores of fine bottomset sediments, were used to determine the unit weight (Lara and Pemberton, 1965) of the sediments.

The grain size distribution of 103 samples was determined using either of two methods. Eighty-six samples, each containing less than 15 gm of clay, were treated with 20 ml of 30% hydrogen peroxide to remove organic matter and to reduce the number of aggregates so that the sample would pass through wire grain size sieves (Guy and Norman, 1969). The difference in sample dry weight before and after treatment was recorded to obtain a crude estimate of the percent of organic material in each sample. These organic material percents are minimums because many organic materials, such as cellulose and some humic and fluvic acids, are only partially reactive with hydrogen peroxide (Gross, 1971). After treatment the samples were placed in a 4% Calgon solution, brought to pH 10 with ammonium hydroxide, and mechanically dispersed by mixing in a blender for 1 minute at medium speed. Samples were then wet sieved through 350 μm, 150 μm, and 63 μm sieves, and the settling-pipet method was used to determine the percent of material finer than 63μm, 38 μm, 4 μm, and 1-2 μm (Galehouse, 1971).

Seventeen samples were not treated with hydrogen peroxide. These samples were dispersed using the method described above and then wet sieved through screens of 1000 μm, 500 μm, 350 μm, 150 μm, 63 μm, and 38 μm. Due to aggregates it is probable that the percentages of silt measured in these samples are slightly higher than would be measured from an equivalent treated sample.

The total carbon concentration was determined from 20 fine grained samples using a Coulometrics Model 5011 CO_2 Coulometer with a Coulometrics Model 5020 Total Carbon Apparatus. Samples of approximately 50 milligrams were burned at 760°C and the concentration of carbon in the evolved gas measured by electro-chemical titration (see Appendix B).

SEDIMENTS IN UNIVERSITY LAKE

SEDIMENTARY ENVIRONMENTS

Based on the topography, core stratigraphy, and sample analysis, two types of sedimentary environments in University Lake, the deltaic and lake-bed environments, can be divided into distinct subenvironments (Figure 12).

Deltaic Subenvironments

Deltas composed of coarse bedload and suspended sediments have formed in the backwater on the Morgan Creek and Phils Creek arms of the lake. These deltas, which cover about 20% of the lake area (Table 6), have formed where streamborne sediments are deposited as a result of the decrease in water velocity, and thus the carrying capacity, of the inflowing tributary creeks. Using the terminology for lacustrine deltaic environments modified from Tye and Coleman (1989) the deltaic subenvironments can be divided into 5 distinct subenvironments which are the distributary channel, the distributary channel levees, the distributary mouth bar, the delta front, and the prodelta. On Price Creek and Pritchards Mill Creek, extensive floodplains and wetlands just upstream from the lake trap most of the coarse bed load sediments, and very fine sand and silt accumulate in distinct marsh subenvironments, flanked by a narrow prodelta area (Figure 12).

The formation of separate deltaic subenvironments is a result of the progressive hydrologic sorting and deposition of sediments from the mouth of the tributary creek downlake to the prodelta. The areal extent of each subenvironment (Table 6) is controlled by the quantity of sediment transported to the lake and the topography of the backwater, particularly with regard to the topographic control on the velocity of the inflowing water.

Distributary channel On both Phils Creek and Morgan Creek, distributary channels extend from the head of the lake to the delta front. The streamflow characteristics and sediments in these channels are similar in most respects to those in the tributary creeks upstream from the lake. Two types of accumulation occur in the distributary channel. During periods of low flow, leaves and sticks, intermixed

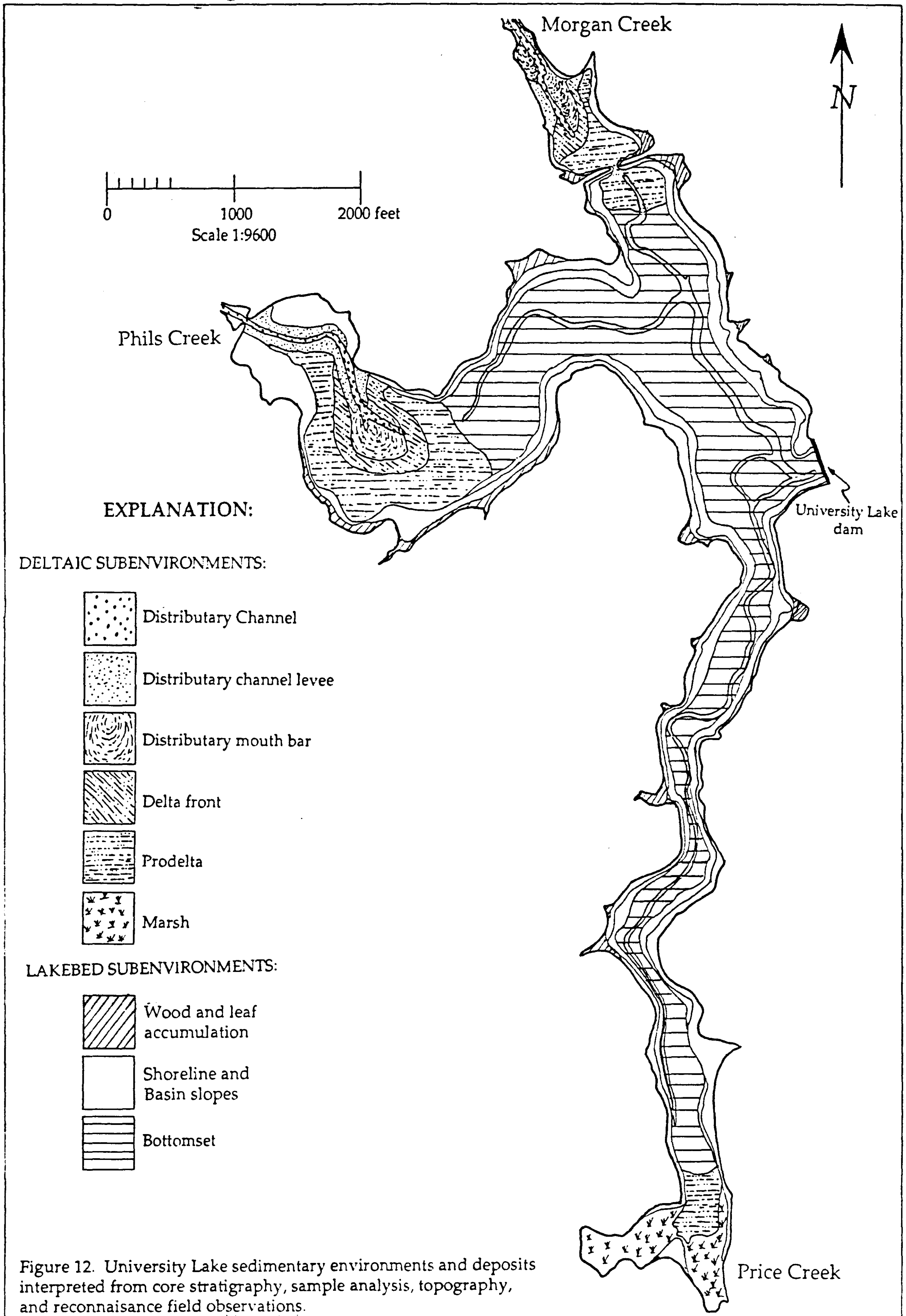


Figure 12. University Lake sedimentary environments and deposits interpreted from core stratigraphy, sample analysis, topography, and reconnaisance field observations.

Table 6. Areal extent of subenvironments measured from Figure 11. Areas in acres. Segment locations are shown in Figure 7, with numbers increasing toward the dam. M, Morgan Creek arm; N, Phils Creek arm; P, Price Creek arm.

	Area within	DELTAIC						LAKEBED		
Segment	350ft. contour	Channel	Levee	Bar	Delta front	Prodelta	Marsh	Shoreline	Basin Slope	Bottomset
M1	5.5	0.7	0.9	1.9	0.4	0.5	--	0.7	--	--
M2	14.9	0.1	0.2	0.1	1.2	6.7	--	3.6	1.6	0.9
M3	12.6	--	--	--	--	--	--	1.6	1.6	9.7
M4	15.6	--	--	--	--	--	--	2.1	2.9	10.6
M5	23.8	--	--	--	--	--	--	3.7	3.3	16.8
Total M	72.4	0.8	1.1	2.0	1.6	7.2	--	11.7	9.4	38.0
N1	14.2	1.1	3.1		0.1	2.1	--	7.0	--	--
N2	29.9	0.8	0.9	2.8	5.1	14.0	--	5.5	0.3	--
N3	16.3	--	--	--	--	3.8	--	3.5	1.5	7.5
N4	18.8	--	--	--	--	--	--	3.9	2.4	12.5
Total N	79.2	1.9	4.0	2.8	5.2	19.9	--	19.9	4.2	20.0
P1	15.7	--	--	--	--	3.1	9.1	2.5	0.3	--
P2	8.3	--	--	--	--	--	--	2.9	0.9	4.6
P3	9.6	--	--	--	--	--	--	3.2	2.2	4.2
P4	5.2	--	--	--	--	--	--	1.3	1.3	2.6
P5	4.4	--	--	--	--	--	--	1.4	1.2	1.8
P6	8.8	--	--	--	--	--	--	1.6	2.5	4.7
P7	11.6	--	--	--	--	--	--	3.0	3.2	5.4
Total P	63.6	--	--	--	--	3.1	9.1	15.9	11.6	23.2
Entire lake	215.1	2.7	5.0	4.8	6.8	30.1	9.1	47.4	25.3	81.3
% of total*	99%	1.2%	2.3%	2.2%	3.2%	14.0%	4.2%	22.0%	11.8%	37.8%

* Areas do not sum due to rounding. Area within the 350 foot contour line is within 5% of the area measured from the large scale bathymetric map.

with fine silt and clay, accumulate in the distributary channels. Because these materials are easily transported during floods they are eroded and transported downlake, and are only occasionally preserved in the channel deposits. During flood events coarse bed load, saltation load, and traction load sands are carried into the lake and deposited in the channel. In the center of the channel, deposits are predominantly very coarse to coarse sand, and toward the bank they become fine to medium sands. Silt and clay compose less than 10% of these deposits. Unlike the thin sand blankets in the tributary creek channels, the maximum thickness of the coarse distributary channel sands can be 50 cm or more (Figure 13, core VCN98*1).

The distributary channel on Phils Creek is approximately 1700 feet long. Based on both the 1930 map (Atwood and Weeks), and the 1962 maps (Smalley, 1963), this channel has prograded into the lake following the pre-reservoir channel. This regular progradation is illustrated in the cores taken from the center of the channel (Figure 13, core VCN98*1) by the gradually coarsening upward sequence from prodelta leaf and mud to delta front fine sand and silt to coarse channel sand. Cores taken from the side of the channel (Figure 13, core VCN829*1) confirm that the distributary channel has not migrated laterally a significant amount.

On Morgan Creek the distributary channel is only 1100 feet long and channel sands are found in the present distributary channel and in several cores taken across the delta (Figure 14). In contrast to Phils Creek, the pre-reservoir slope of Morgan Creek was steeper and the water depth in the lake increased more rapidly. As a result, delta accumulation occurs very close to the mouth of the creek, creating a thick wedge of sediments covering a limited area. Gradually the delta has filled the narrow pre-reservoir stream valley and has only later prograded downlake into the wider section of the lake.

Distributary Channel Levees Topographically distinct distributary channel levees (Tye and Coleman, 1989) are well developed along both sides of the channel on Phils Creek delta, but they are only weakly expressed on Morgan Creek. Levee sediments are highly variable, and range from clean fine to very fine sands deposited along the channel bank during flood events, to organic rich fine silt and clay muds deposited slowly out of the water column, to leaf debris dropped from nearby plants or carried in by the creeks (Figure 13, cores VCN829*1, VCN97*1). Distinct sedimentary units in the levees include: leaf layer/sand lens couplets; clean massive sands; dense

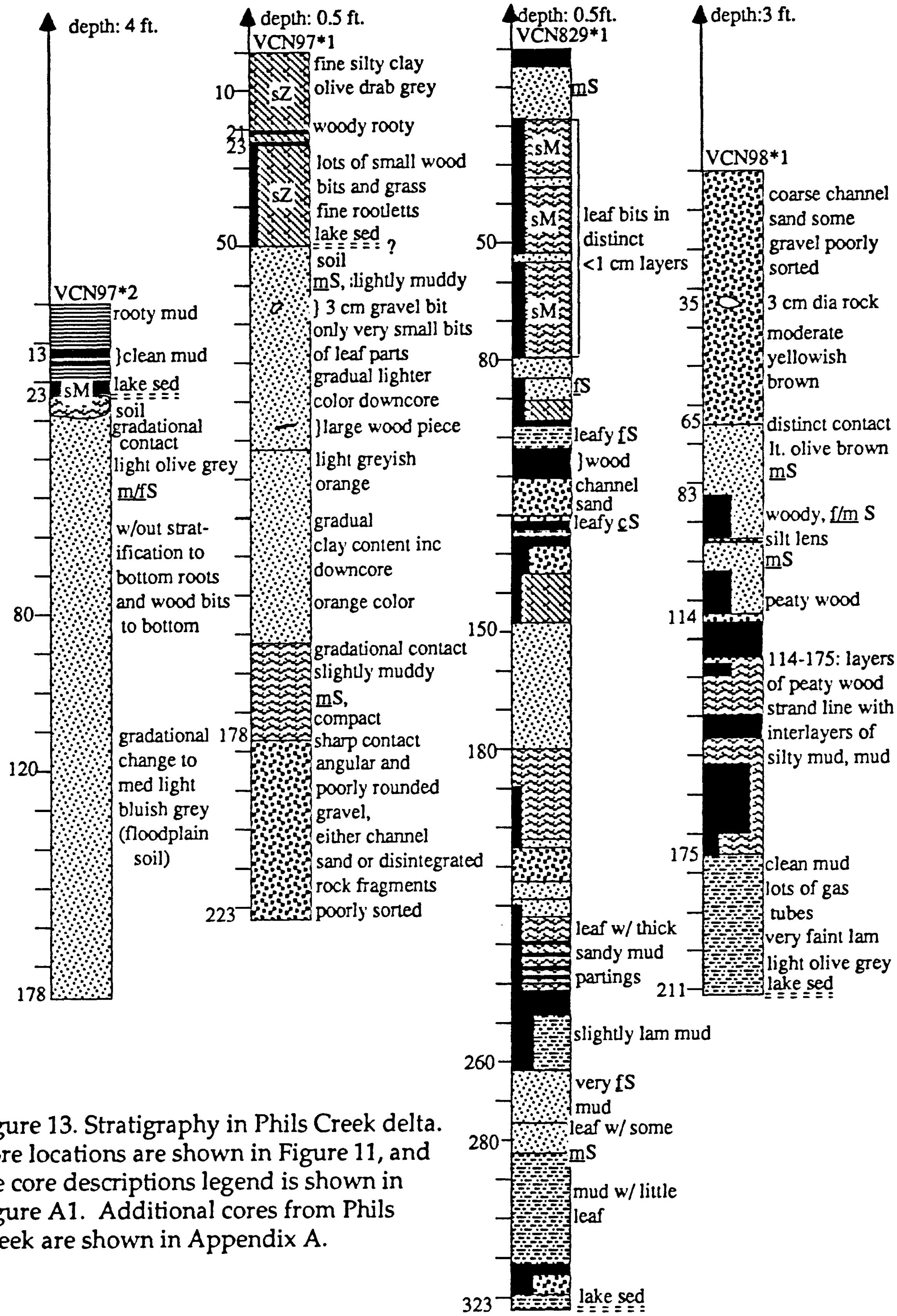


Figure 13. Stratigraphy in Phils Creek delta. Core locations are shown in Figure 11, and the core descriptions legend is shown in Figure A1. Additional cores from Phils Creek are shown in Appendix A.

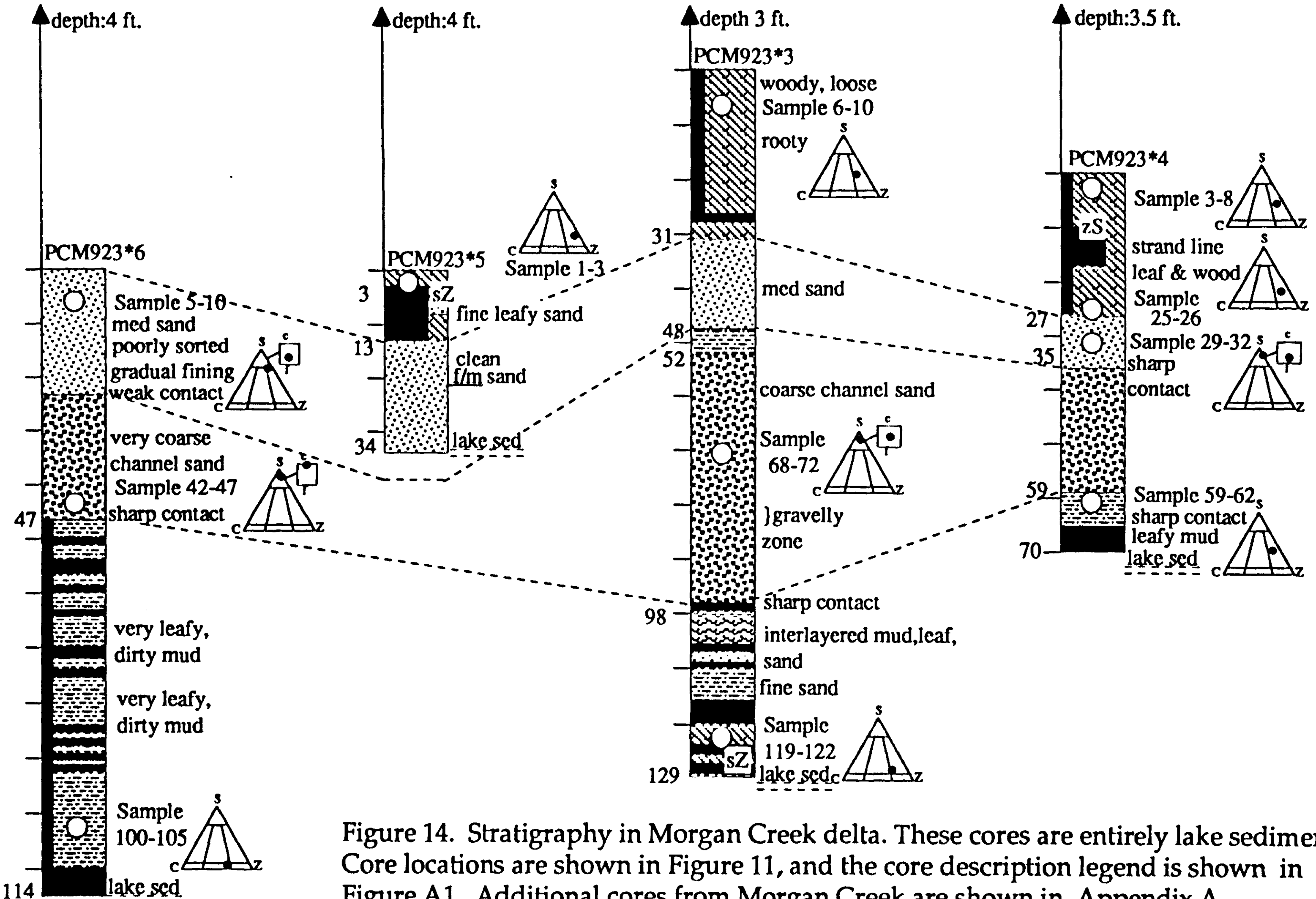


Figure 14. Stratigraphy in Morgan Creek delta. These cores are entirely lake sediments. Core locations are shown in Figure 11, and the core description legend is shown in Figure A1. Additional cores from Morgan Creek are shown in Appendix A.

macerated leaf layers which in some cores comprise up to 40% of the sediment, and root mats. Sands encountered in the subsurface never contained recognizable stratification, while levee sands deposited after flood events were often observed to contain grain size stratification. The lack of stratification in the subsurface is presumably due to intense bioturbation and rooting on the frequently exposed and heavily vegetated levees (Ferrel, 1987).

Thick deposits of macerated dark colored leaves are seen both on the surface and within many cores collected from both Morgan Creek and Phils Creek deltas (Figures 13 and 14). These leaf deposits form as the lake level drops and leaves and leaf fragments are eroded by wave action from the previously deposited sediment. Since most of these leaves are partially decomposed and waterlogged, they tend to disintegrate and accumulate below the waterline in linear strandlines up to 20 cm thick. When the lake level rises, which usually occurs rapidly following storms (Figure 2A), the leaf fragments are left behind and eventually buried.

Because the lake level is so variable, there is no clear topographic or sedimentologic break between the parts of the levees that are above or below the spillway elevation. Above the spillway elevation however, the levees are heavily vegetated by trees including willow, ironwood, and poplar, and they have a thick understory of button brush, wild rose, and other mesic and wetland plants. During the summer, the levees support a dense growth of annuals. Below the spillway elevation the only established perennials are few scattered willows and button brush; however, each year during low water periods many weeds and grasses colonize the exposed deposits.

Distributary channel levees are found on Morgan Creek at the upstream end of the delta where they have developed between the distributary channel and the upland slope into the lake. The levees on Morgan Creek have very low profiles, raised in the center and sloped evenly on either side. The low profiles indicate active overbank flooding and erosive sediment reworking on the poorly vegetated levees.

During the 1950's, beavers were reintroduced in Orange County by the North Carolina Fish and Wildlife service. Beavers are active in the deltas on both Phils Creek and Morgan Creek. Most of their activity is concentrated on the levees, where they cut trees and dig into the levees to make dens. In several places the beavers have dug trenches up to three feet deep which they use as passageways to drag wood across the levees (Eric Bernhard, OWASA Lake Warden, personal communication). Their activities may divert or impound sections of the channels, which will result in the redistribution of sediments.

Distributary Mouth Bar The distributary mouth bar makes up a large part of the coarse grained deltaic deposits. The sediments deposited in the distributary mouth bar are similar to those found in the distributary levees (Figure 13). In general, coarse sands are found at the head of the bar, and the sands fine laterally away from the main channel (Wright, 1977). Fine sands and silts, often containing leaf layers up to 20 cm thick are common along the edges of the distributary mouth bars. Roots are common in the surficial sediments but are rare in samples taken at depth below the surface roots, possibly reflecting the gradual shallowing of the bars.

The morphologies of the distributary mouth bars on Phils Creek and Morgan Creek are strikingly different. Water in Morgan Creek travels from the high gradient upland stream into relatively deep lake water over a short distance. As a result the stream enters the lake as a narrow, fast moving plume, with much of its original inertia. Coarse sediment is deposited at the head, and along the centerline of the main plume and gradually fining sands are deposited down lake and laterally (Wright, 1977). On Morgan Creek the result is a flat-topped inertia-dominated distributary mouth bar that is narrow and has a relatively steep downlake end.

In contrast, Phils Creek enters the lake through a long, very low gradient distributary channel. Much of the streamflow inertia is dissipated by friction and turbulence prior to reaching the downstream end of the distributary channel. As the streamflow reaches the end of the channel it spreads out laterally and the remaining current is dissipated. Sediments accumulate at the end of the channel in a large circular shoal. Over time this shoal became so shallow that the channel split along both sides of the shoal to form a middle-ground bar (Wright, 1977) (Figure 12).

Delta Front The delta front forms the edge of the coarse bedload and suspended sediment transport zone in the delta. Its downlake edge is recognized topographically as the narrow zone where the raised delta drops off to the more gently sloping, lower relief prodelta.

At the mouth of the distributary channel the delta front is composed primarily of fine and very fine sand, but during extreme flood events coarse channel sands can be deposited. Downslope and away from the channel, the delta front sands grade into sandy silt and silty clay muds of the prodelta. Leaves and sticks commonly make up a large part of the delta front deposits where they are found individually and occasionally in leaf lags.

Prodelta The prodelta is the transition zone from the deltaic sands and silts to the fine bottomset muds that characterize lakebed deposition in the rest of the lake. The prodelta sediments are visually distinguished from the bottomset deposits because they often contain a large amount of organic debris. In places on both Phils Creek and Morgan Creek leaves and sticks blanket the prodelta to a thickness of 10-30 cm. In laboratory analysis the prodelta deposits are distinct from the bottomset deposits because they have a high proportion of coarse silt, usually from 40-60% of the sample, and often contain 5-10% very fine sand. In several cores from the prodelta very fine graded sand and silt beds were observed in otherwise monotonous fine silt and clay muds.

Topographically the prodelta is defined on the upstream edge by the raised delta front, while downlake the prodelta slopes gently into the bottomset deposits. Because the prodelta and the bottomset deposits are very similar, the border between them is arbitrarily defined by the decrease in coarse silt to less than 30% of the sediment. The extent of the prodelta shown on the sediment facies map (Figure 12) is defined by several grain size samples and by the decrease in the amount of leaves in the bottomset deposits that was noted during diving.

Marsh None of the previously identified delta subenvironments adequately characterize the sedimentation at the backwater on Price Creek or Pritchards Mill Creek. In place of sandy deltaic sedimentation patterns seen on the other two creeks, these backwater areas are covered by relatively thin layers of organic rich clay and silt muds, deposited in heavily vegetated freshwater marshes (Figures 12 and 15). The mud layer on both marshes is between 10 and 50 cm thick and has a hummocky surface due to the mounding of decaying vegetation. Both marshes are heavily vegetated by freshwater wetland plants. The plants include arrow arum (Peltandra virginica) and cut grass in the open water and grade upstream of the lake into forests of willow and alder. Several shallow channels, 0.5 to 1 foot deep and from 2 to 4 feet wide cross each marsh. These channels, which are often covered by a thin layer of mud, have fine sand and silt beds.

The muds on Price Creek and Pritchards Mill Creek overlie fine to coarse sands and clayey sands, with no visible stratification, very little organic matter, and a distinct light blue-gray color (Goddard et al., 1948) (Figure 15). These sands appear similar to the material deposited on the floodplains upstream from the lake.

The lack of coarse deltaic accumulation can be attributed mainly to the trapping of sediments on the low gradient, heavily vegetated floodplains that extend for some distance upstream of the lake. At present beavers play an additional role in trapping sediments upstream of the marsh. There are 5 distinct dams that cross the marsh on Price Creek and 3 dams that cross Pritchards Mill Creek. Each of these dams creates small ponds that are several feet deep and heavily vegetated by aquatic and semi-aquatic plants. Overgrown relic beaver dams on these creeks date at least to the early 1970's (Eric Bernhard, OWASA Lake Warden, personal communication).

Lakebed Subenvironments

Only fine silt and clay, and some organic debris are sufficiently buoyant to be carried outside the deltas and mixed into the water column. After storms these fine sediments often leave the water a rusty red or orange color for up to several weeks. Gradually the fine sediments are either carried over the spillway or they settle to the lakebed. However, due to both erosive wave, current, and gravitational forces the fine grained sediments accumulate over only a limited area. There are three distinct lakebed subenvironments. These are (1) the eroded/non-accumulating shoreline, (2) the basin slopes, and (3) the accumulating bottomset deposits. The lakebed subenvironments cover approximately 72% of the lake, with the bottomset deposits covering 38% and the shoreline and basin slopes covering 22% and 12% respectively (Table 6).

Shoreline The shoreline is ideally recognizable as the normal, operational lake level. However, because the lake level varies (Figure 2A), the shoreline is "spread

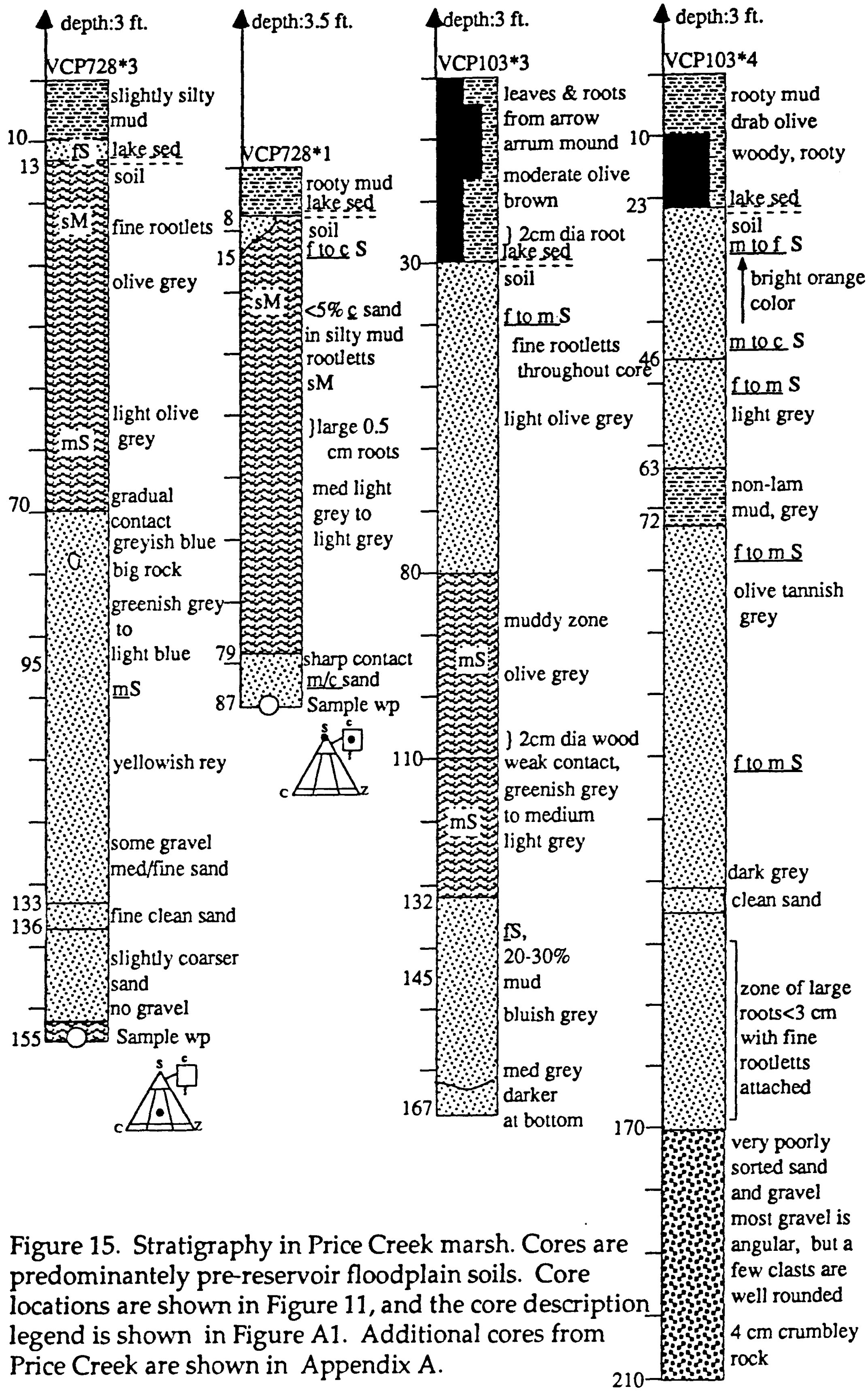


Figure 15. Stratigraphy in Price Creek marsh. Cores are predominantely pre-reservoir floodplain soils. Core locations are shown in Figure 11, and the core description legend is shown in Figure A1. Additional cores from Price Creek are shown in Appendix A.

out" to include the zone of elevations between 350 feet and approximately 345.5 feet above mean sea level, or from a half a foot over to 4 feet below the spillway. The lake level was within this zone 96% of the time (Figure 2B) prior to the current stabilization in lake level provided by the regulated additions of water from Cane Creek reservoir.

Because the shoreline is frequently exposed to wave action, rainsplash, and wind induced currents (Hakanson and Jansson, 1983), the shoreline is predominantly an erosional zone. In most areas the shoreline is characterized by exposed soils and subsoils, and rocks, gravels, and sands that remain after the finer soil materials have been winnowed away.

The depth of soil erosion (estimated by extrapolating the soil surface above the shoreline across the winnowed shoreline zone) averages about one foot. In nearly level areas the shoreline has lost little or no soil, while in steep areas, up to 1.5 to 2 feet of soil may be removed. Erosion above the shoreline takes place in only a few areas on very steep banks as a result of undercutting and slumping.

Judging from observations at Cane Creek, a nearby recently impounded reservoir, most of the initial shoreline erosion probably occurred during the first few years after the lake was filled, and again after the spillway was raised in 1966 and 1970. Due to shoreline erosion no topographical expression of the old shoreline "bench" which was drowned when the lake level was raised in 1966 and 1970, is observed within the lake.

Large pieces of wood and leaves are the only materials that accumulate in the shoreline zone. The wood and leaf accumulations are most extensive on Morgan Creek and Phils Creek arms in places where the shoreline is wide and gently sloping (Figure 12). Smaller accumulations are found in many of the small tributary valleys around the lake.

Basin Slopes The term basin slope is used to describe the areas of the lake that are below the shoreline and are part of the pre-reservoir valley slopes (Figure 12). They are distinct from the shoreline because they are deeper in the lake and have been either infrequently or never exposed. They are distinct from the bottomset areas because they have accumulated very little or no sediment.

The texture of the surface material on the basin slopes is similar to that along the shoreline (compact soil, gravel, rock, sand), but generally the basin slopes have retained more soil and are consequently less rocky. The contact between these slopes and the soft bottomset muds downslope is usually abrupt, but in places, coarse gravel and sands are found interfingered with and on top of the bottomset deposits, apparently the result of gravitational transport of erosional debris from the basin slopes.

Bottomset Organic rich clay and silty clay lacustrine sediments, here described as bottomset deposits, make up the most laterally extensive sedimentary environment in University Lake, and cover approximately 38% of the lake (Table 6). The bottomset samples range from 55 to 85 % clay (Appendix B). The sand content in the bottomset deposits varies as a function of the distance from the deltas and the basin slopes, but in general it is less than 1%. Coarse silt typically makes up 2-10% of the sediment, and the percentage of medium to fine silt ranges from 10-30%. Visible organic material found in the sediment is composed mostly of very fine leaf bits and occasionally whole leaves and small sticks. Total organic carbon analysis of 20 bottomset samples, sieved to remove leaf fragments larger than 63 μm, shows a range between samples of 3.6% to 0.62% by weight (Appendix B).

The primary sedimentary structures of the bottomset deposits consists of color banding of dark gray to black and light olive gray to orange gray (Goddard et al. 1948) (Figure 16). The thickness of the laminations varies from 1 cm to <1 mm size. The color laminations are in large part the result of the seasonal oxygen stratification which leaves the bottom water of University Lake anoxic for approximately 6 months each year (Weiss and Breedlove, 1973; Weiss and Kuenzler, 1976). During this stratified period any organic material that drops into the anoxic water is subject only to the slow degradation by anaerobic organisms. Additionally, iron and manganese, which have relatively high concentration in the inflowing surface water (Weiss and Breedlove, 1973), accumulate in reduced forms in the stagnant anoxic bottom water. The result is the accumulation during the anoxic stratification periods of reduced black, organic rich sediments (Barnes and Barnes, 1978; O'Sullivan, 1983). When the lake overturns, the iron and magnesium are oxidized giving the sediment a rust color.

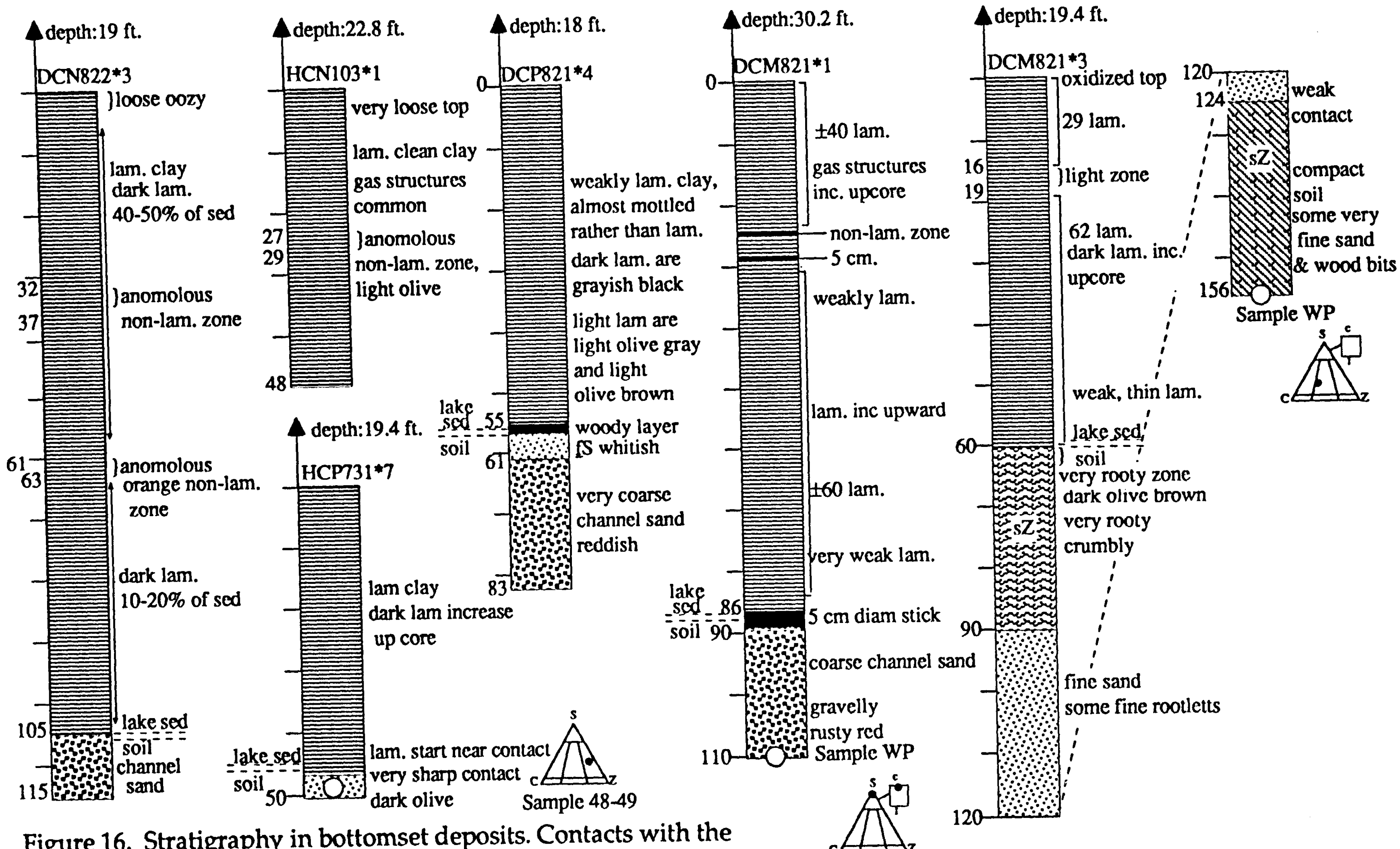


Figure 16. Stratigraphy in bottomset deposits. Contacts with the pre-reservoir soils are clear. Core locations are shown in Figure 11, and the core description legend is shown in Figure A1. Additional cores containing bottomset deposits are shown in Appendix A.

Counting the number of laminations in each core proved difficult because in parts of each core the individual laminations are clearly defined and easily measured, but in other parts the laminations are weak or so fine that the contrast between layers is indistinct. However it was determined that there are many more laminations than could be produced by a once yearly stratification. For example, in 7 cores that contained more than 80 cm of bottomset sediment there were at least 100 distinguishable laminations. The high number of laminations could be explained by the occurrence of stormflows carrying oxygenated surface water into the anoxic bottomwater as underflows, thus reflecting a short destratification event.

Laminations are seen all the way to the bottom of the sediment in cores that penetrated into the pre-reservoir soil. In 8 of the 16 cores containing bottomset deposits there is a definite trend of an increase in the proportion of dark versus light laminations from the bottom of the core to the top (Appendix A). This trend possibly reflects an increase in the length of time that the bottomwaters go anoxic each year; however, the other cores showed almost no change in the laminations upcore.

SEDIMENT VOLUME

Sediment volume measured by comparing sequential maps

The most commonly used method to determine the volume of sediment deposited in a reservoir is to calculate the reduction in water capacity measured between succesive topographic or bathymetric surveys (Heinemann and Dvorak, 1965; Soil Conservation Service, 1977; Dendy and Champion, 1977; Rausch and Heinemann, 1984). Because three sucessive maps of University Lake are available, (the pre-reservoir topographic map by Atwood and Weeks [1930], Smalley's bathymetric map prepared in 1962 [Smalley, 1963], and the bathymeteric map prepared for this study in 1989), this method could in principle be used to determine the amount of sediment deposited between 1932 and 1962, and the amount deposited between 1962 and 1989.

To measure the amount of sediment deposited in the lake from these maps, the lake was divided into 16 segments (Figure 8), and the water capacity in each segment was determined between each contour interval using the contour area average end method (Heinemman and Dvorak, 1965; Rausch and Heinemann, 1984). The sediment volumes were then determined by calculating the difference in water capacity measured from each map. The results are shown in Table 7.

Comparing the water capacity measured on the pre-reservoir topographic map (Atwood and Weeks, 1930) and the 1962 bathymetric map indicates that the water capacity increased 84 acre-feet between the two surveys. Although it is possible that shoreline erosion has slightly increased the surface area, and thus the lake's volume near the spillway elevation, field observations indicate that a net water capacity increase in the lake is not possible. The apparent water capacity increase indicated by the map comparision is most likely an artifact of the different survey techniques used in preparing these maps.

The sediment volume determined by comparing the 1962 and the 1989 bathymetric maps indicates that 370 acre-feet of sediment were deposited in the lake during this 27 year period. Averaged over 27 years this represents an accumulation rate of 13.7 acre-feet per year. This rate is 40% less than the rate of 22 acre-feet per year measured by the Soil Conservation Service between 1932 and 1935 (Eakins 1939). However there are factors that indicate that these results may not be reliable either. Field observations show (Figure 12) that no sediment has accumulated along the shoreline or on the basin slopes in many segments of the lake (M3-M5, N3-N4, P3-P6). The map comparisions of these segments show changes in water capacity at the shallow depths of the shoreline and basin slopes. Again, the change in capacity is attributed to differences in map making techniques that were used. Smalley (1963) relied entirely on fathometer records which become increasingly distorted on the shallow flanks of the lake at the ends of the survey lines. The 1989 map makes use of the aerial survey data of 1968 to constrain the shallow contours.

Another inconsistency in the 1962 and the 1989 map comparisions is the variation in sedimentation rate recorded between adjacent segments with similar sedimentary environments. For example, in segments M4 and M5, which are both near the dam and contain only fine grained bottomset muds, the apparent average sediment thickness (sediment volume divided by the area enclosed by 350 foot contour line) is 1.7 feet in segment M4 and 3.2 feet in segment M5. The isopach map, which was prepared by directly measuring the sediment thickness, indicates that the sedimentation patterns and the average sediment thickness in these two segments is uniform. Projecting the sedimentation rate indicated by the map comparision backward, M5 would have accumulated an average sediment thickness of over six feet of sediment between 1932 and 1989, although the thickest sediment measured in the segment is slightly more than 4 feet (Figure 10).

Sediment volume measured from the isopach map

The sediment volume was also measured directly from the isopach map (Figure 10). The isopach map records the thickness of sediment over the pre-reservoir surface and thus represents the total sediment deposited in University Lake between 1932 and 1989. The isopach map was divided into the same 16 segments used in comparing the bathymetric maps (Figure 8), the area enclosed by each isopach contour line was measured on a digitizing table, and the area was then multiplied by the average of the contour intervals (Table 8).

From the isopach map, 440 acre-feet of sediment were deposited in University Lake between 1932 and 1989. Forty-two percent of the sediments were deposited in Phils Creek arm, 39% in Morgan Creek arm, and 20% in the Price Creek arm (Figure 8). Deltaic sediments compromise approximately 43% of the sediment volume measured in the lake, with 61 acre-feet on Morgan Creek (segments M1 & M2), 109 acre-feet on Phils Creek (segments N1 & N2), and 17 acre-feet in the marsh on Price Creek and Pritchards Mill Creek (P1). The volume of sediment in the 11 segments of the lake which contain the fine grained bottomset deposits (Figure 12), is 256 acre-feet, or 57% of the total sediment volume.

There is considerable variation in the thicknesses of sediments in the lake, from just under 14 feet in the delta on Morgan Creek, to zero on the eroded flanks of the lake. The average sediment thickness, calculated by dividing the sediment volume by the area enclosed by 350 foot contour line, is 2.1 feet. Comparing each segment, the thickest average is in the deltas on Phils Creek and Morgan Creek (N2 and M1), and the thinnest in the marsh on Price Creek (P1).

From the isopach measurement of 440 acre-feet of sediment, the average sedimentation rate over this 57 year period is 7.7 acre-feet per year. This sedimentation rate is 68% lower than the 22 acre-feet per year measured by the Soil Conservation Service for the period from 1932-1935 (Eakins, 1939). At the 1932-1935 rate, the lake would have accumulated 1254 acre-feet of sediment by 1989, or lost 56% of its original water capacity of 2245 acre-feet (From the 1989 survey: 1805 acre-

Table 7. Sediment volumes determined by comparing bathymetric contour maps.†. All measurements are in acre-feet.

Segment	1932-1962	1962-1989	1932-1989
M1	4.3	9.9	14.2
M2	-4.3	46.5	42.2
M3	5.5	15.4	20.9
M4	-13.5	28.0	14.5
M5	6.7	71.7	77.5
Morgan Creek arm	-1.3	171.5	169.3
N1	2.5	-3.4	-0.9
N2	1.2	55.6	56.8
N3	23.0	31.7	54.7
N4	-3.9	42.3	38.5
Phils Creek arm	22.8	126.3	149.1
P1	34.9	1.1	36.0
P2	-16.3	7.4	-8.8
P3	-2.9	4.2	1.4
P4	-35.9	7.7	-28.2
P5	-18.3	6.6	-11.8
P6	-30.0	12.5	-17.5
P7	-37.0	33.2	-3.8
Price Creek arm	-105.4	72.7	-32.7
Entire lake	-84.0	370.4	285.6
Accumulation per year	-2.8	13.7	5.0

†Map sources:

1932: Atwood and Weeks (1930). 1:2400 scale, 5 foot contour interval

1962: Smalley (1963). 1:1200 scale, 2 foot contour interval

1990: Bisese. 1:1200 scale, 2 foot contour interval

Table 8. Sediment volumes measured from the isopach map (Figure 9). Segments locations are shown in Figure 7, with numbers increasing toward the dam. M, Morgan Creek arm; N, Phils Creek arm; P, Price Creek arm

	Area of each isopach unit in acres.								Sediment volume in each isopach unit in acre-feet								Acc. rate acre-ft year	Avg. thickness* in feet	Sed. rate rate cm/yr*
Segment	350-0	0-2	2-4.	4-6.	6-8.	8-10.	10-12.	Segment	0-2	2-4.	4-6.	6-8.	8-10.	10-12.	Σ	% Total			
M1	0.3	1.4	1.0	0.8	1.0	0.5	0.2	M1	1.4	3.0	4.0	7.0	4.5	2.4	22.3	5%	0.4	4.3	2.5
M2	3.6	3.5	2.7	3.3	0.7	0.4	0.2	M2	3.5	8.1	16.5	4.9	3.6	2.2	38.8	9%	0.7	2.7	2.0
M3	2.1	2.0	7.8	1.2	--	--	--	M3	2.0	23.4	6.0	--	--	--	31.4	7%	0.6	2.4	1.7
M4	3.8	3.1	7.8	0.7	--	--	--	M4	3.1	23.4	3.5	--	--	--	30.0	7%	0.5	1.9	1.3
M5	5.6	3.9	12.0	1.7	--	--	--	M5	3.9	36.0	8.5	--	--	--	48.4	11%	0.8	2.1	1.4
Total M	15.4	13.9	31.3	7.7	1.7	0.9	0.4	M	13.9	93.9	38.5	11.9	8.1	4.6	170.9	39%	3.0	2.4	1.8
N1	6.5	2.5	3.6	1.0	0.4	0.1	--	N1	2.5	10.7	4.8	3.0	0.8	--	21.8	5%	0.4	1.5	1.6
N2	5.1	8.2	4.5	6.9	2.7	1.3	--	N2	8.2	13.5	34.3	19.1	12.1	--	87.2	20%	1.5	3.0	1.9
N3	3.4	2.1	8.1	2.3	--	--	--	N3	2.1	24.2	11.6	--	--	--	37.9	9%	0.7	2.4	1.7
N4	5.1	3.3	10.0	0.6	--	--	--	N4	3.3	29.9	3.0	--	--	--	36.2	8%	0.6	1.9	1.3
Total N	20.1	16.1	26.2	10.8	3.1	1.4		N	16.1	78.3	53.7	22.1	12.9	--	183.1	42%	3.2	2.4	1.6
P1	3.3	11.8	1.8	--	--	--	--	P1	11.8	5.3	--	--	--	--	17.1	4%	0.3	1.0	0.7
P2	1.8	2.9	3.7	--	--	--	--	P2	2.9	11.2	--	--	--	--	14.1	3%	0.2	1.7	0.9
P3	3.5	2.3	3.6	--	--	--	--	P3	2.3	10.8	--	--	--	--	13.1	3%	0.2	1.4	1.0
P4	1.9	0.9	2.1	--	--	--	--	P4	0.9	6.4	--	--	--	--	7.3	2%	0.1	1.5	1.0
P5	2.7	1.2	1.3	--	--	--	--	P5	1.2	4.0	--	--	--	--	5.2	1%	0.1	1.0	1.2
P6	2.9	2.0	3.6	0.3	--	--	--	P6	2.0	10.7	1.7	--	--	--	14.4	3%	0.3	1.6	1.5
P7	5.5	2.9	3.4	0.5	--	--	--	P7	2.9	10.1	2.3	--	--	--	15.3	3%	0.3	1.2	1.3
Total P	21.6	24.0	19.5	0.8	--	--	--	P	24.0	58.5	4.0	--	--	--	86.5	20%	1.5	1.3	1.1
TOTAL	57.1	54.0	77.0	19.3	4.8	2.3	0.4	TOTAL	54.0	230.7	96.2	34.0	21.0	4.6	440.5	100%	7.7	2.1	1.5

*Sediment volume divided by the area enclosed by the 350 foot contour line.

feet water capacity + 440 acre-feet sediment volume). By comparision, the 440 acre-feet of sediment measured in the lake in 1989 represent a loss of only 20% of the original water capacity.

The decrease in sedimentation rate measured between 1935 and 1989 may reflect changes in the maturity of the lake. Since the sedimentation survey by the Soil Conservation Service was carried out just 2.6 years after the lake was impounded, their sedimentation rate included substantial imputs from within the lake basin. The loose topsoil submerged by the lake would have been eroded from the shoreline and the basin slopes and transported downslope. If 100 acres of the lake floor shed half a foot of soil this would represent 50 acre-feet of sediment and would account for a significant part of the sediment measured in the lake during the early survey. Once the soil profile eroded down to the more compact clay subsoil this sediment supply would become insignificant, and deposition would be dominated by the materials carried in from the watershed. Short term, high initial accumulation rates were documented in many of the reservoir sedimentation studies reviewed by Jenkins et al., (1960). Many of the reservoirs surveyed shortly after impoundment, and again after 10 years or more, had a decrease in the accumulation rate of 50% or more between the two surveys.

Sedimentation estimates compared to the sediment measurements

The amount of sediment deposited in University Lake can be compared with the estimates made using predictive equations (Figure 6) by converting the measured sediment volume to an equivalent dry sediment weight. The average unit weight of reservoir sediments depends on a number of factors including (1) sediment grain size; (2) length of time the sediments are exposed to drying; (3) degree of compaction; and (4) the percent of the sediment made up of leaves and wood (Lane and Koelzer, 1944; Lara and Pemberton, 1965). Reported average unit weights for reservoir deposits range from 55 pounds per cubic foot for non-dessicated clays and silts to 95 pounds per cubic foot for clean sands (Lara and Pemberton, 1965). Because of the fine grain size of most lake sediments in southeastern reservoirs, 65 pounds per cubic foot is most commonly used for the average sediment unit weight in the region (Soil Conservation Service, 1977). The sediment weights that were measured on University Lake sediments were biased toward the surface sediments which are lighter. However, the 65 pounds per cubic foot value is consistent with the values that were measured on sediments from University Lake, particularly from the slightly compacted subsurface core samples (Appendix C).

Using 65 pounds per cubic foot (1416 tons per acre-foot), the total weight of sediments deposited in University Lake is: 440 acre-feet x 1416 tons per acre-foot = 623,040 tons. Averaged over 57 years the accumulation rate is equal to 11,035 tons per year, or 370 tons per square mile of watershed per year. The sensitivity of the estimated amount of sediment in the lake to the sediment density value that is used is indicated in Figure 17.

From previous discussion, the amount of sediment delivered to University Lake over 57 years was estimated using three different predictive equations, as 347,000, 371,000, and 248,000 tons (Figure 6). Compared to the empirical measurements these equations underestimate the amount of sediment in the lake by 45%, 41%, and 61% respectively. Thus, these predictive equations cannot be used to estimate the sediment trapping efficiency (Brune, 1953; Heinemann, 1984) of University Lake.

The predictive equations from NVPDC-VPI (1978), and Simmons (1988) were derived from field sampling programs undertaken during the 1970's. Although both equations have factors to account for land use, they measure soil erosion and stream sediment from land use practices that are significantly different from those during the early history of University Lake. Judging from the descriptions of University Lake watershed given in Bass and Martin (1939) and Erickson and Levitte (1939), and more general descriptions of the farming practices and soil erosion conditions in the Piedmont region from pioneer days until the mid-1950's (Happ et al., 1940; Hall, 1948; and Trimble, 1974), the rate of erosion from farmland in the 1930's and 1940's was much higher than in the 1970's.

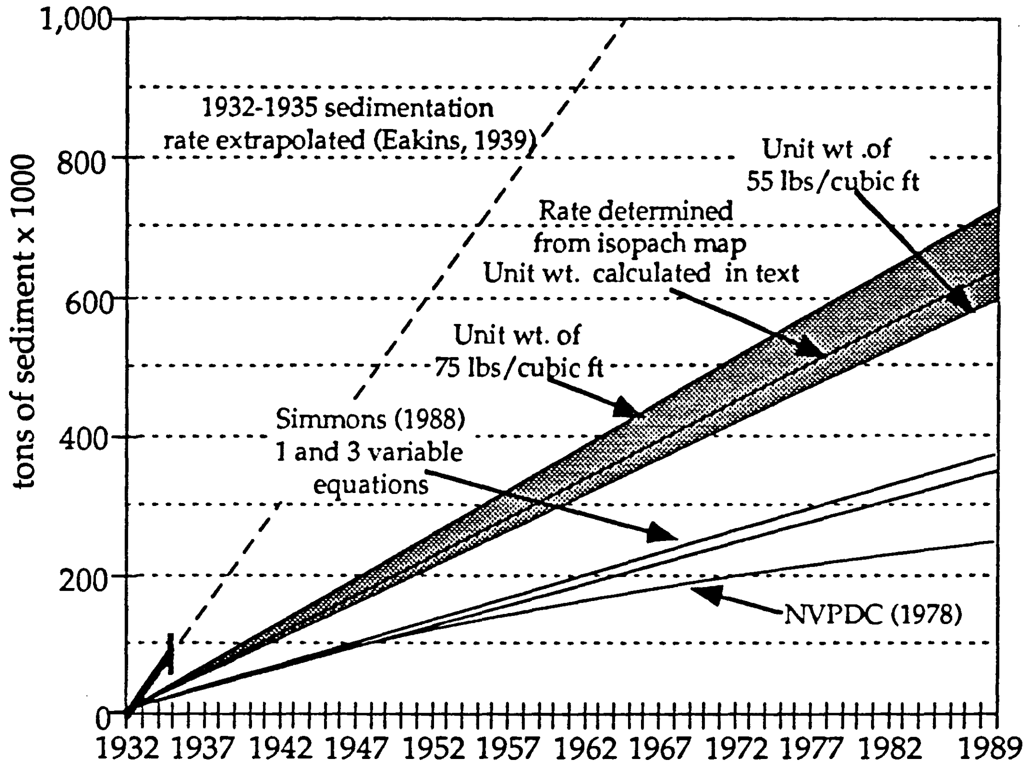


Figure 17. Comparison of estimated sediment transport to University Lake and the actual amount of sediment measured in the lake in 1989. The field for the isopach values show the range of sediment weights using the maximum and minimum sediment unit weights.

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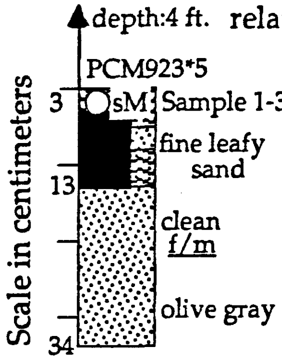
APPENDIX A: CORE DIAGRAMS

Fifty-seven cores were collected from University Lake in 3" diameter aluminum core tubes. After storage for up to eight months in a refrigerated locker the cores were split lengthwise, visually logged, sampled, and returned to the locker.

Appendix A contains diagrams of each core made from visual examination done immediately after each core was opened. Sedimentologic characteristics of each core are presented in a standardized format described in the core legend (Figure A1). The grain size distributions illustrate the visually estimated median grain size. The grain size classes are modified from Folk (1980) by extending the sand class to include samples with up to 30% silt and clay, and by eliminating the split between samples with more than or less than 50% sand.

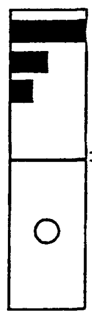
For those cores that were sampled for laboratory grain size analysis the results of these analysis are shown in a graphical form beside the core diagram. Because it proved very difficult to identify with confidence the relative percent of fine sand, silt and clay in the characteristically dark, algal rich sediments, there are significant discrepancies between the laboratory and visual estimates. These discrepencies are not corrected in the core diagrams.



The water depth to the top of the core is recorded in feet relative to the spillway elevation of 349.5 feet above msl.

The first two letters in the core name denote the type of core: [DC diver core, PC push core, HC hammer core, VC vibra-core] The third letter denotes which arm the core is collected from [M Morgan Creek, N Phils Creek, P Price Creek] The number sequence identifies the date the core was collected, while the final *# indicate the sequence of collection

Colors determined by comparision with a standard Munnsel color chart (Goddard et al., 1948)

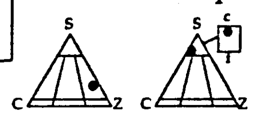


Width of black bars indicate the relative proportion of organic material (mostly leaves and sticks) seen in the

lake sed.
soil

Contact line between lake sediments and pre-reservoir soil

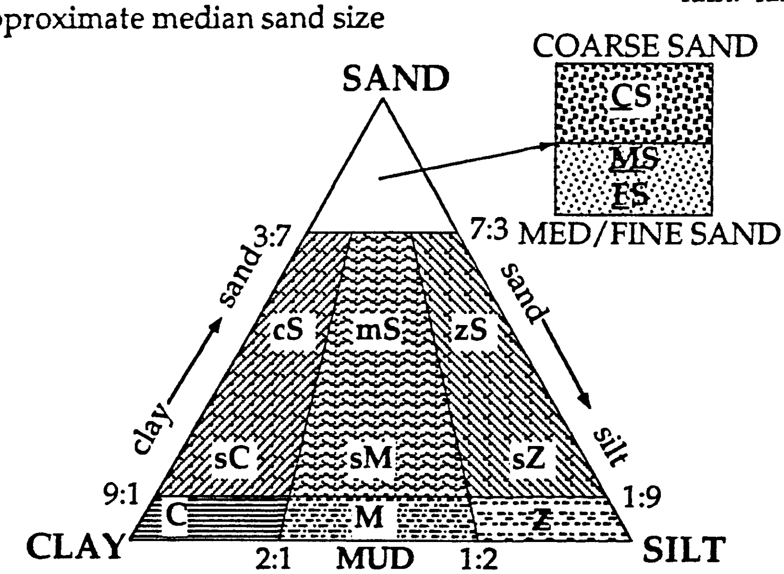
Grainsize sample



Laboratory grainsize determination. The box is used to indicate the approximate median sand size

Abbreviated composition, texture, and grain size modifiers:

G gravelly
(g) slightly gravelly
(s) slightly sandy <5%
r rooty
(r) slightly rooty
fr fine rootletts
lam. laminated



Grainsize classification scheme modified from Folk (1980).

The grainsize classifications used on the core diagrams are from the visual descriptions only. Distinctions between intermediate clay, silt, and fine sand samples are infered. There are in many cases inconsistencies with the grainsize determined in the laboratory. These inconsistencies are not corrected in the core diagrams.

Figure A1. Legend for core stratigraphy

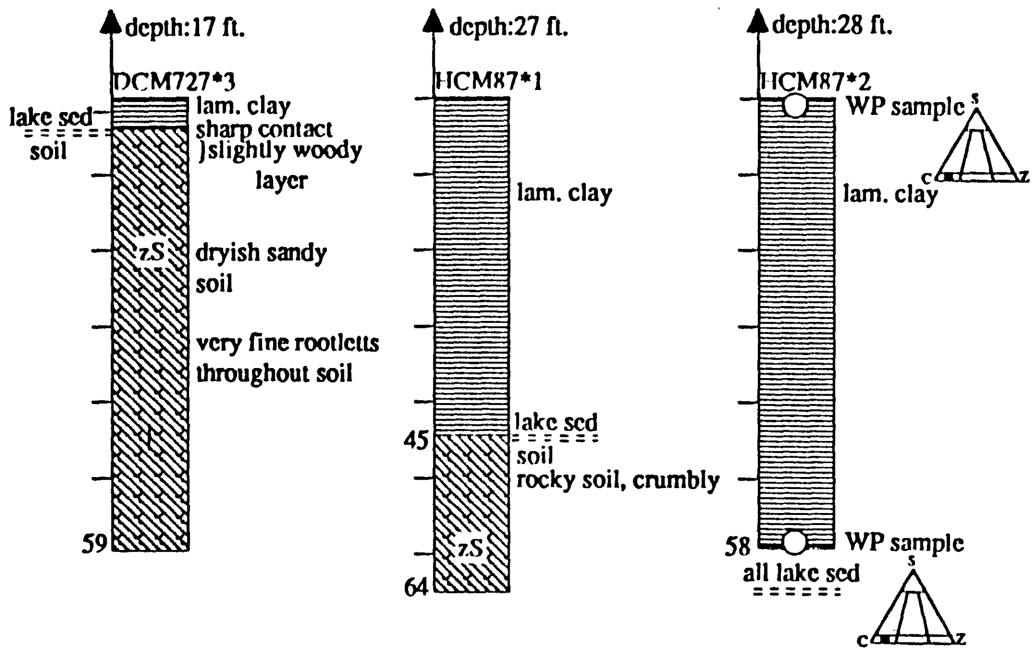


Figure A2. Visual description of core stratigraphy.

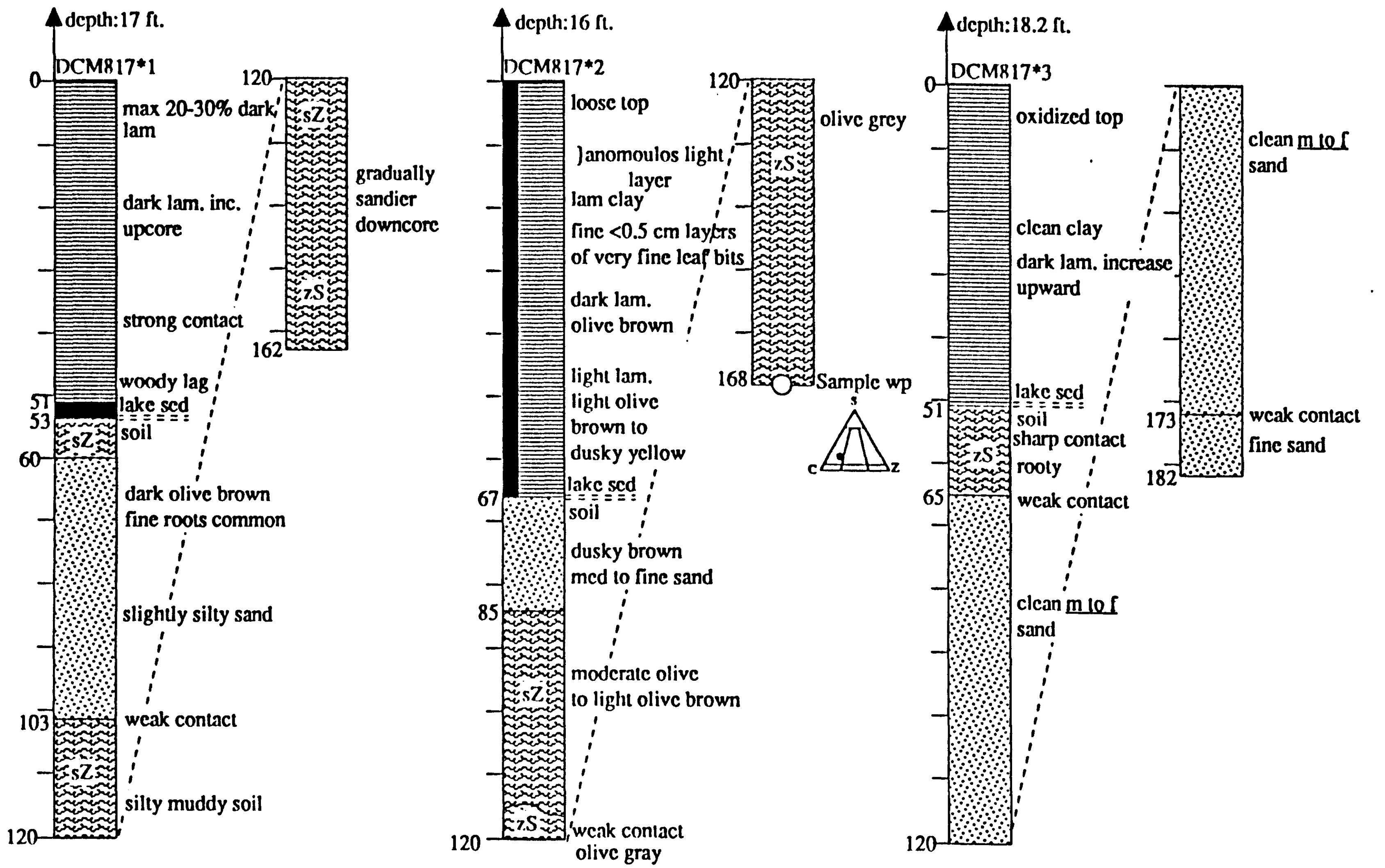


Figure A3. Visual description of core stratigraphy.

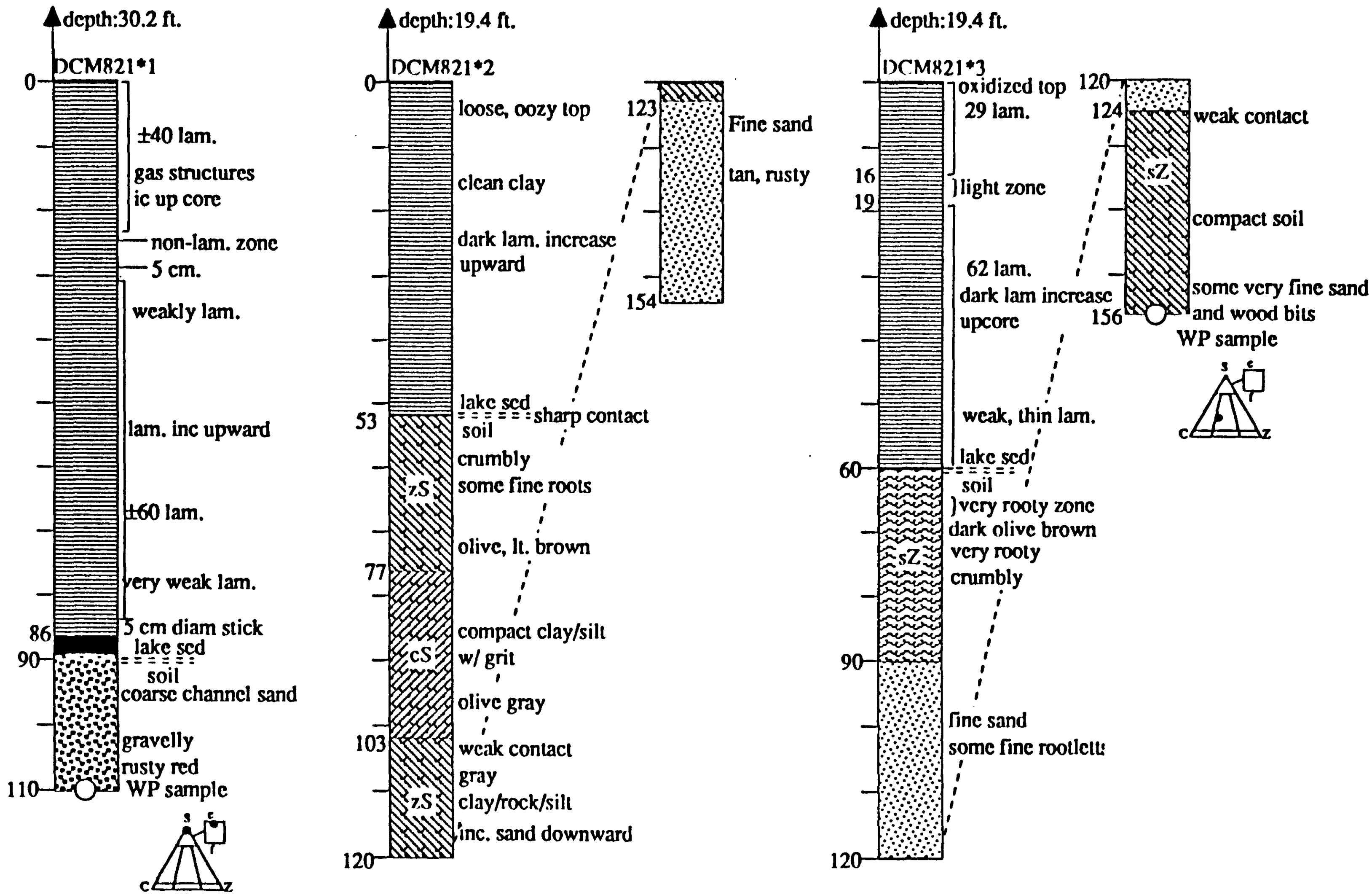


Figure A4. Visual description of core stratigraphy.

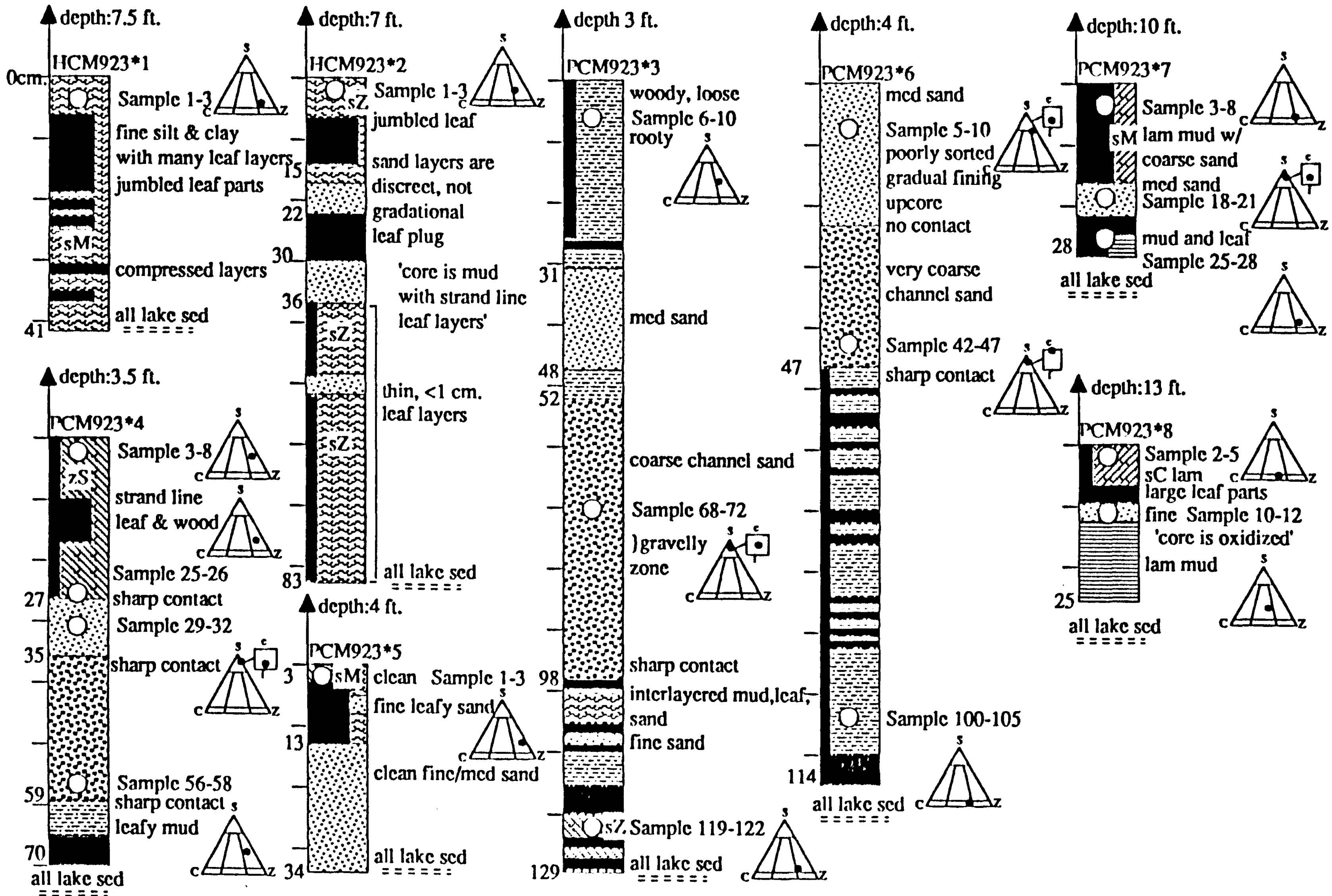


Figure A5. Visual description of core stratigraphy.

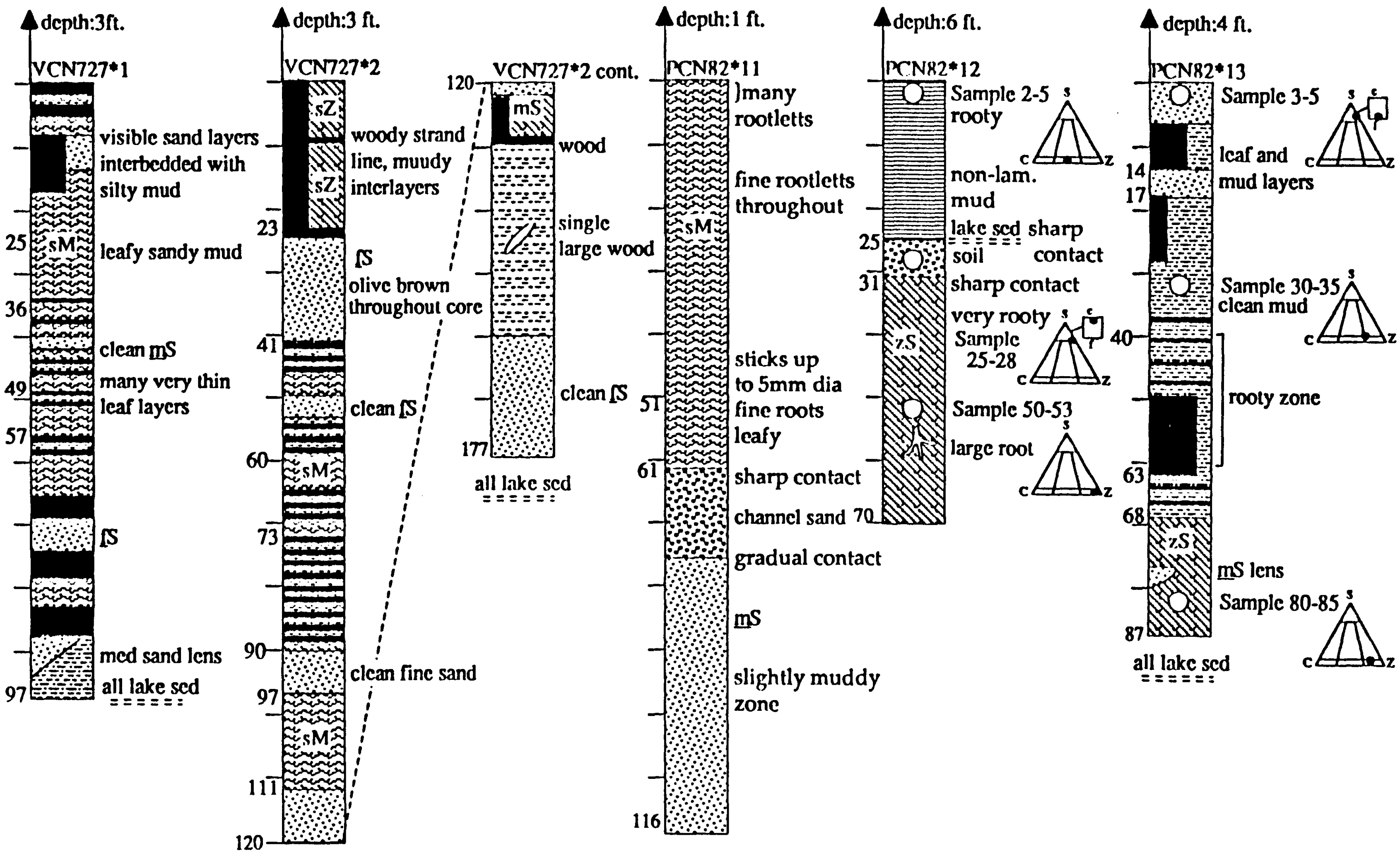


Figure A6. Visual descriptions of core stratigraphy.

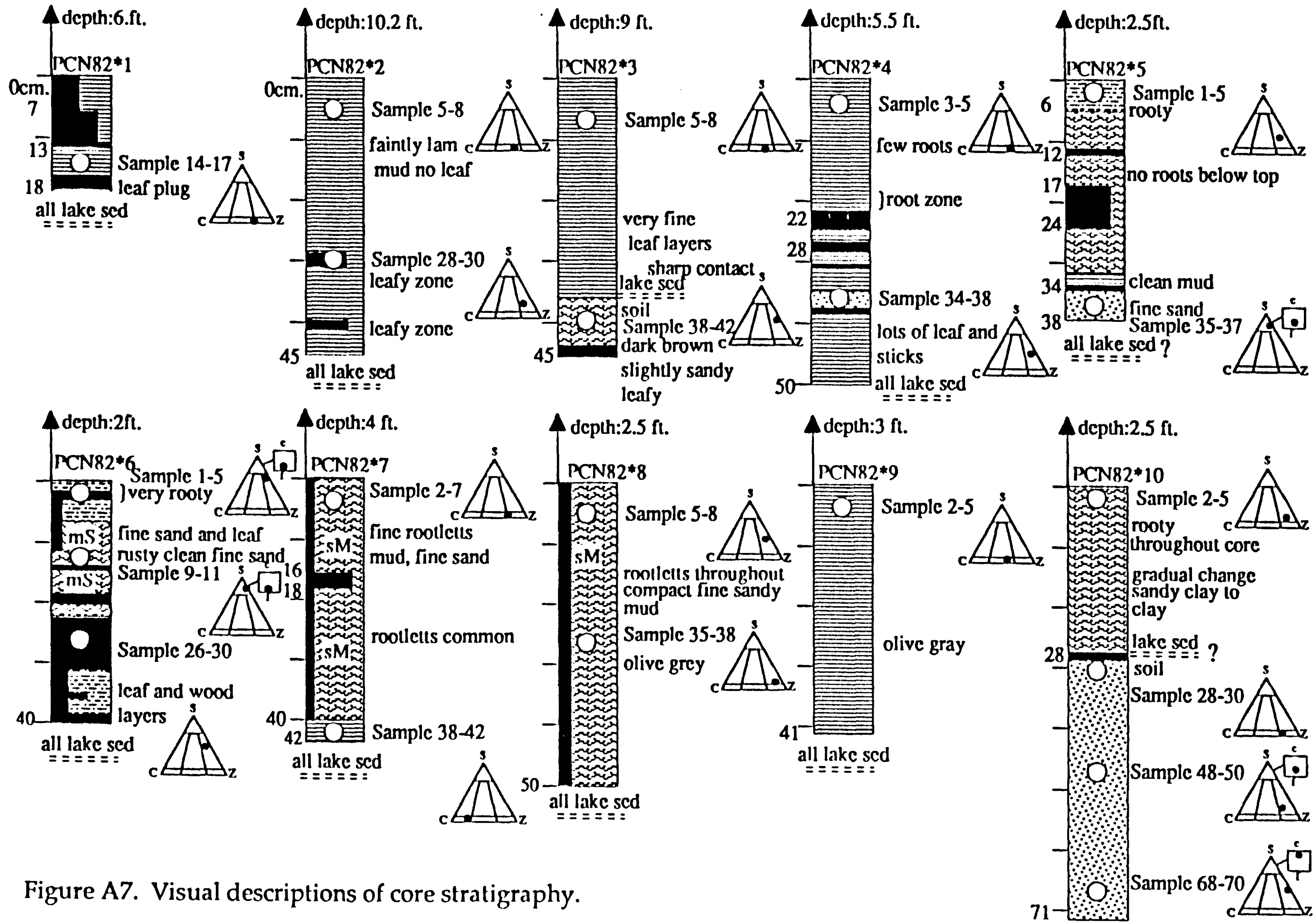


Figure A7. Visual descriptions of core stratigraphy.

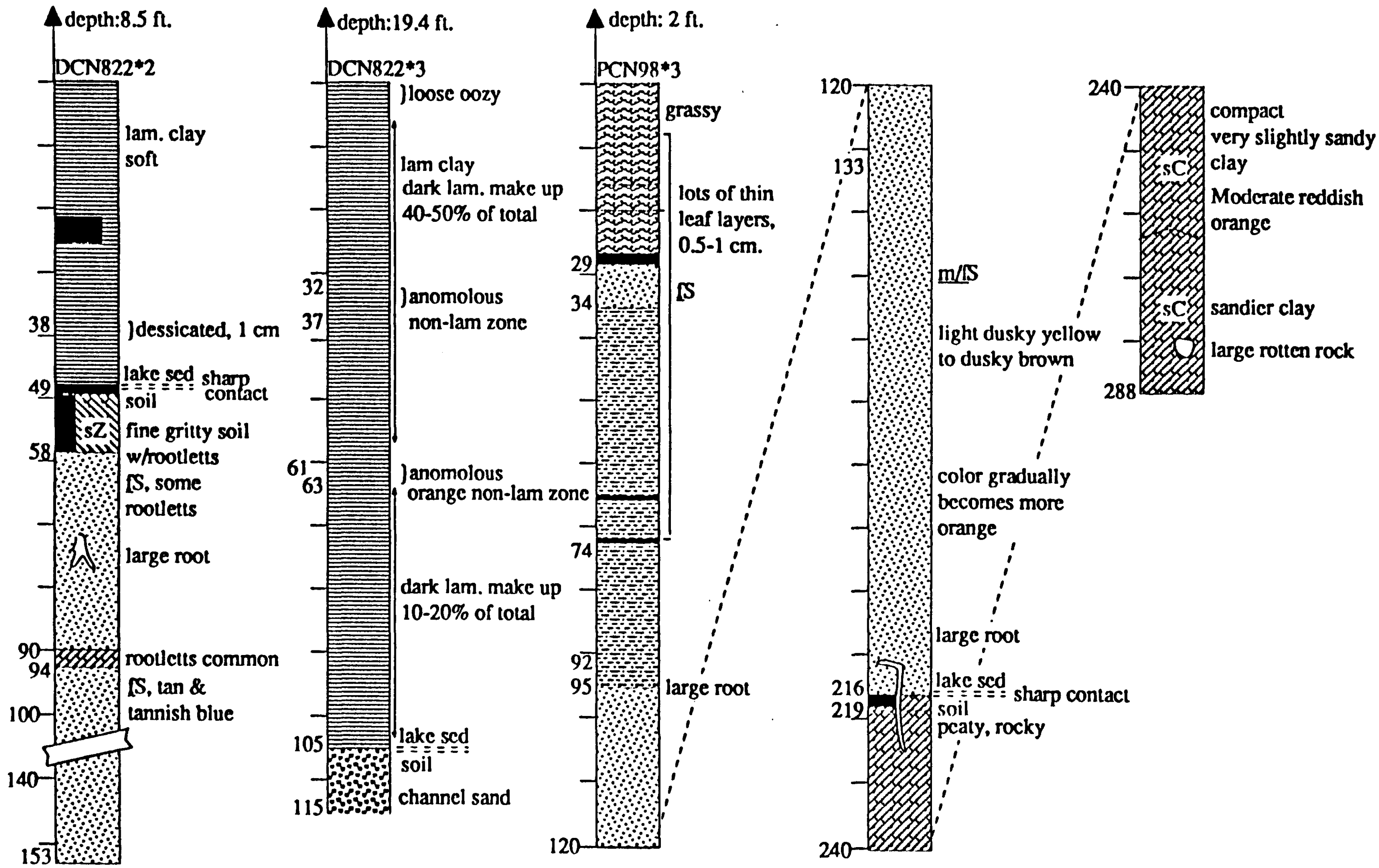


Figure A8. Visual descriptions of core stratigraphy.

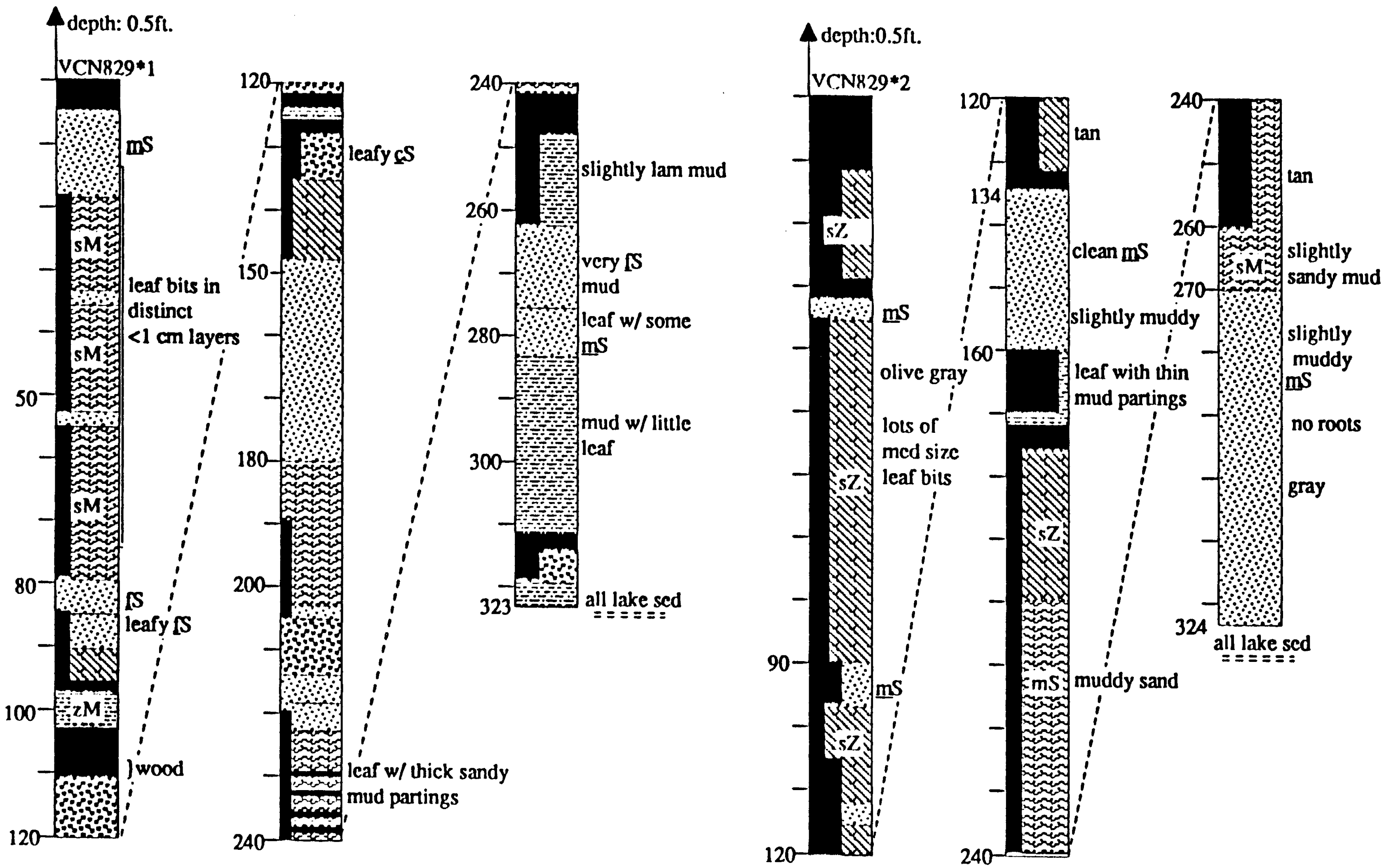


Figure A9. Visual descriptions of core stratigraphy.

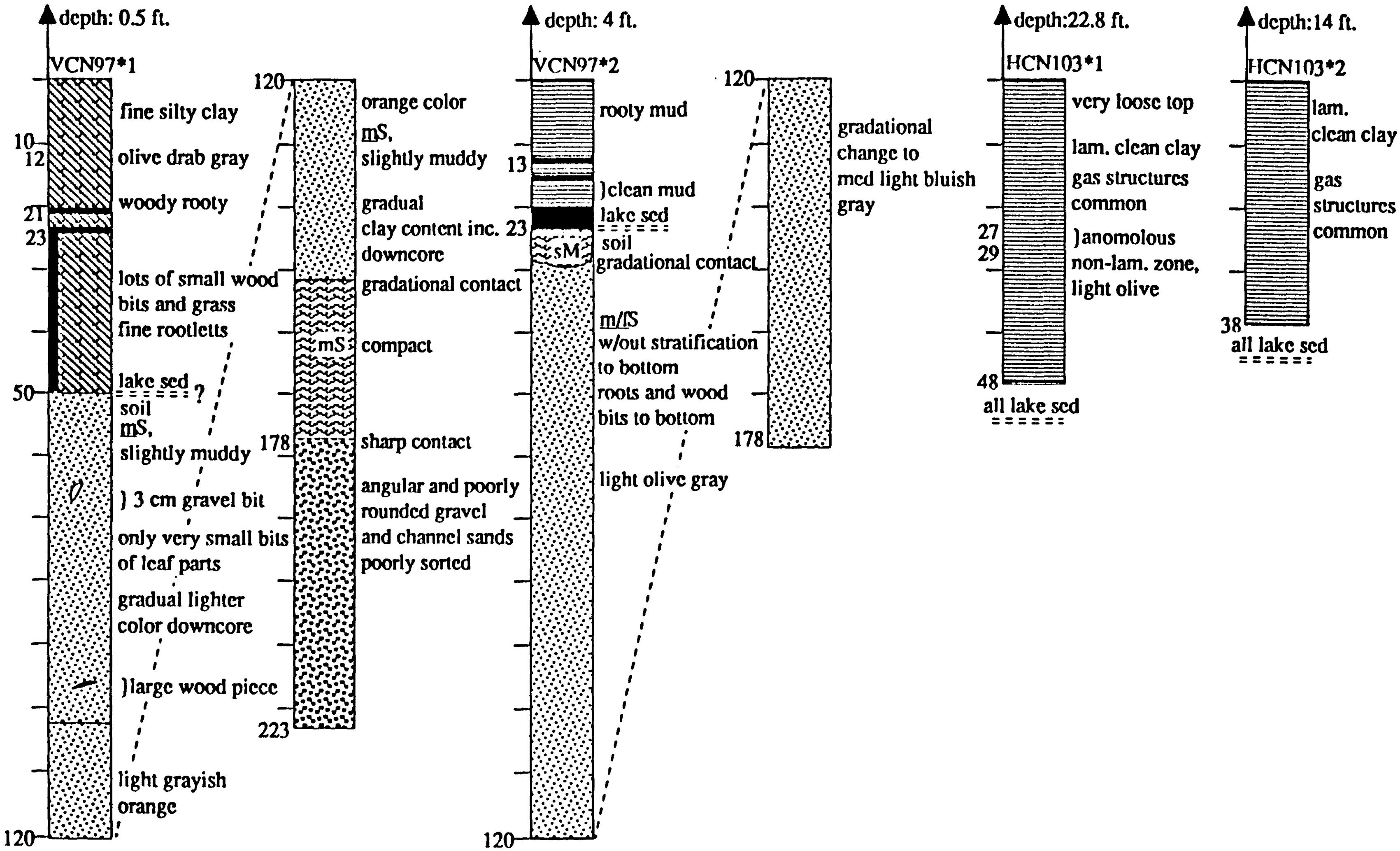


Figure A10. Visual descriptions of core stratigraphy.

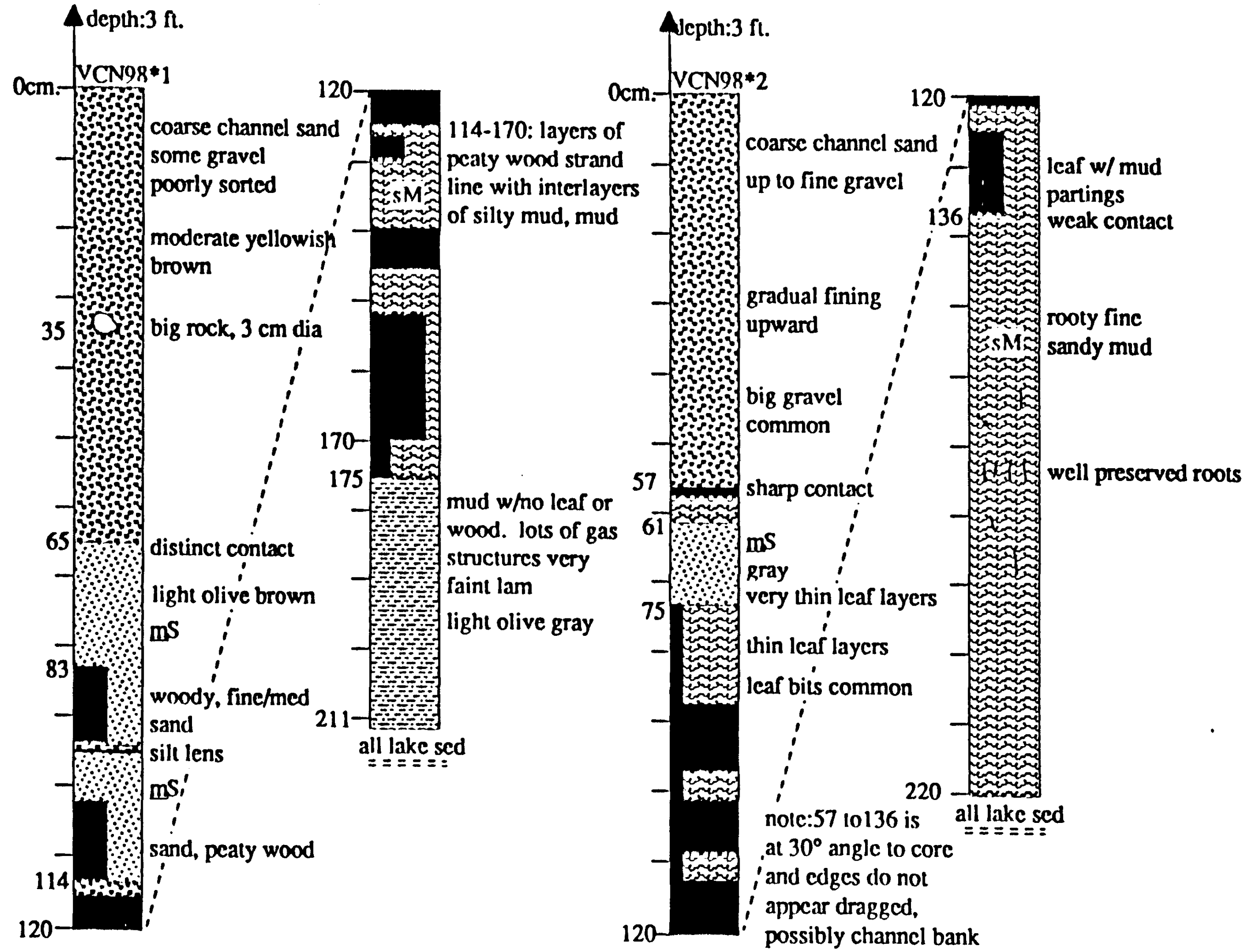


Figure A11. Visual descriptions of core stratigraphy.

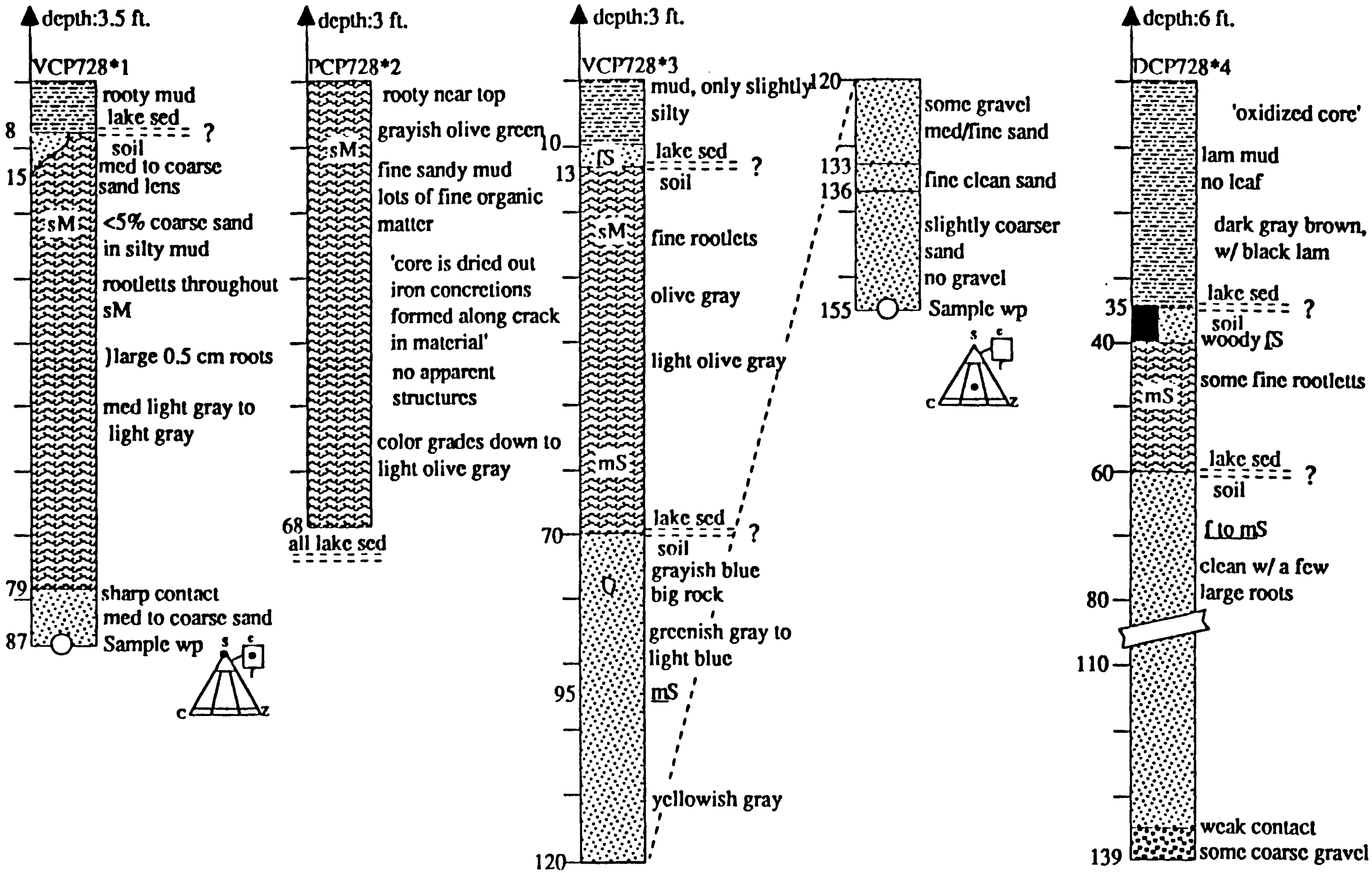


Figure A12. Visual description of core stratigraphy.

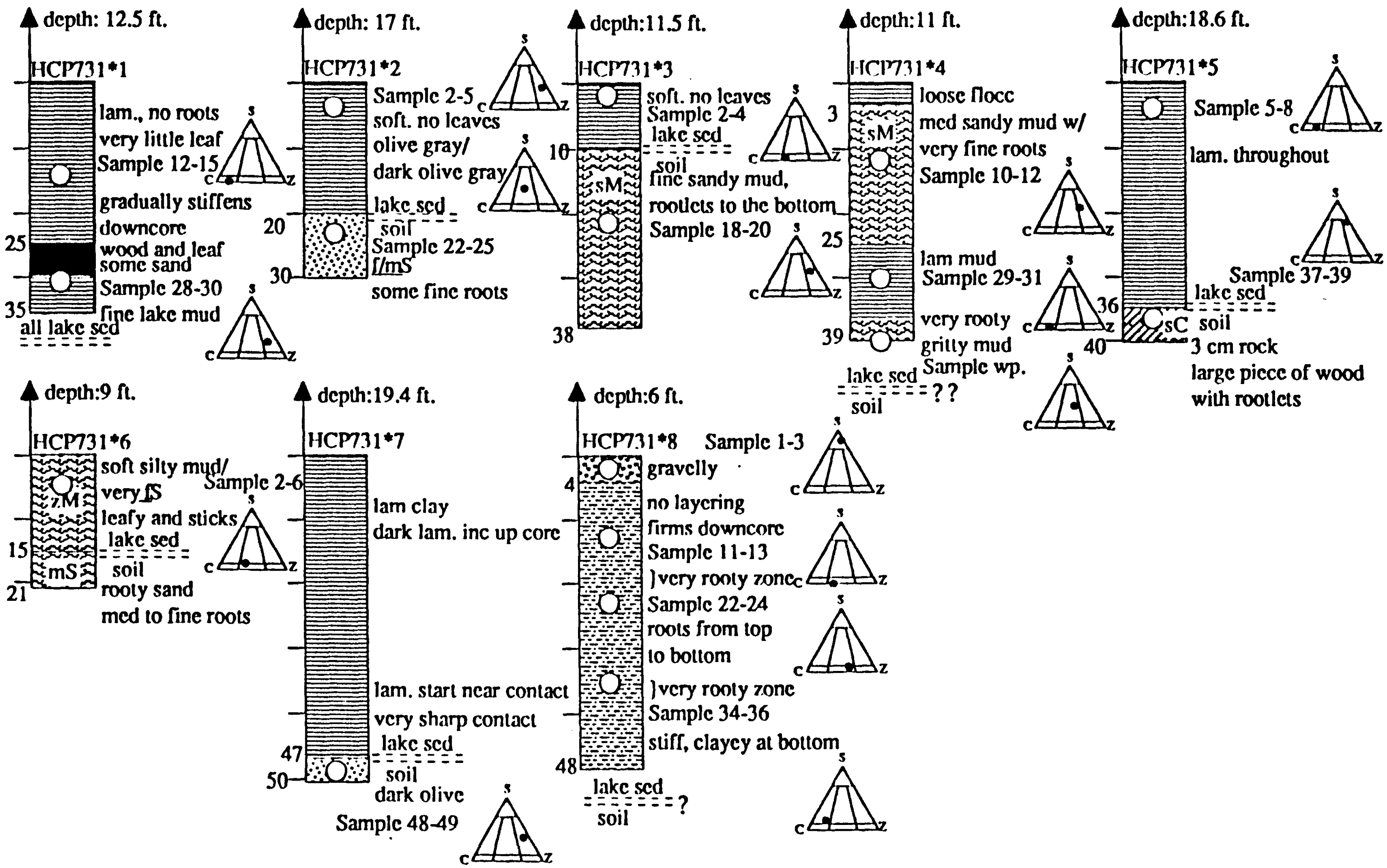


Figure A13. Visual description of core stratigraphy.

APPENDIX B: Sample analysis

Morgan Creek Arm (M)

Core type and number	Sample (1) Depth(cm)	Percent water(2)	unit weight(3)	% wt. lost H2O2 (4)	%TOC	Method used (5)	Percent finer than indicated size (in microns) 1000	350	150	63s	63p	38	4	1-2	Sample material (visual description)	Grain size Modified from Folk, 1980 (6)
DCM727*3	2-4	32	--	--	--	--	--	--	--	--	--	--	--	--	clay soil, slighty sandy, rooty	
	29-30	24	--	--	--	--	--	--	--	--	--	--	--	--	sandy clay soil, compact, rooty	
	44-46	18	--	--	--	--	--	--	--	--	--	--	--	--	sandy clay soil, compact, rooty	
	57-29	20	--	--	--	--	--	--	--	--	--	--	--	--	sandy clay soil, compact, rooty	
HCM87*1	WP top	--	--	--	3.10	A	--	--	--	100	--	99	--	--	clay	C
	WP 58	--	--	--	--	A	--	100	96	96	--	96	--	--	clay	C
HCM87*2	1-3	77	--	--	--	--	--	--	--	--	--	--	--	--	mud flocc	
	5-7	64	--	--	--	--	--	--	--	--	--	--	--	--	lam. mud	
	19-21	60	--	--	--	--	--	--	--	--	--	--	--	--	lam. mud	
	33-35	48	--	--	--	--	--	--	--	--	--	--	--	--	lam. mud	
	45-47	44	--	--	--	--	--	--	--	--	--	--	--	--	lam. mud	
	50-52	32	--	--	--	--	--	--	--	--	--	--	--	--	sandy mud	
DCM817*2	3-5	60	--	--	2.78	--	--	--	--	--	--	--	--	--	loose mud	
	13-15	49	--	--	2.86	--	--	--	--	--	--	--	--	--	silty mud, leafy, crumbly	
	35-37	47	--	--	1.46	--	--	--	--	--	--	--	--	--	lam. mud	
	48-50	42	--	--	1.45	--	--	--	--	--	--	--	--	--	fine sandy mud	
	62-64	38	--	--	1.10	--	--	--	--	--	--	--	--	--	lam. mud	
	74-76	19	--	--	--	--	--	--	--	--	--	--	--	--	med-fine sand	
	94-96	23	--	--	--	--	--	--	--	--	--	--	--	--	yellowish fine sandy clay soil	
	110-112	22	--	--	--	--	--	--	--	--	--	--	--	--	yellowish fine sandy clay soil	
	130-132	24	--	--	--	--	--	--	--	--	--	--	--	--	yellowish fine sandy clay soil	
	WP 141	--	--	--	--	A	--	--	100	79	--	69	--	--	mud	
DCM821*1	WP 110	--	--	--	--	A	59	6	6	3	--	3	--	--	gravel, mud	g coarse S
DCM821*3	156	--	--	--	--	A	100	94	81	68	--	64	--	--		M
DCM822*1	130	--	--	--	--	A	67	27	27	12	--	11	--	--		very coarse S
PCM923*1	1-3	53	--	5.0	--	B	--	--	--	86	84	77	29	18	silty mud, slightly leafy	sZ
PCM923*2	1-3	58	--	5.6	--	B	--	--	100	75	70	67	29	15	silty mud, leafy	very fine sZ
PCM923*3	6-10	55	--	3.1	--	B	--	98	--	61	61	57	24	--	silty mud, rooty	sZ
	68-70	21	--	.00	--	B	--	12	--	7	6	4	1	--	coarse channel sand	med. S
	119-122	40	--	1.7	--	B	--	--	--	82	79	73	29	--	non-lam. mud	sZ
PCM923*4	5-10	53	--	7.7	--	B	--	--	--	64	62	57	25	15	silty mud, leafy	sZ

* see footnotes at end of table

Morgan Creek Arm, continued

Core type and number	Sample (1) Depth(cm)	Percent water(2)	unit weight(3)	% wt. lost H2O2 (4)	%TOC	Method used (5)	Percent finer than indicated size (in microns) 1000	350	150	63s	63p	38	4	1-2	Sample material (visual description)	Grain size Modified from Folk, 1980 (6)
	25-26	49	--	6.5	--	B	--	--	--	71	71	64	23	15	silty mud, leaf hash	sZ
	29-32	24	--	2.6	--	B	--	20	--	10	10	8	3	--	medium sand	S
	56-58	14	--	1.2	--	B	--	12	--	7	6	5	1	1	coarse gravelly sand	(g)coarse S
PCM923*5	1-3	46	--	6.0	--	B	--	--	100	56	56	50	20	10	slightly sandy mud	very fine sZ
PCM923*6	5-10	19	--	0.3	--	B	--	57	--	35	31	22	9	--	medium sand	sZ
	42-47	13	--	.05	--	B	--	18	--	7	6	5	2	--	coarse gravelly sand	gS
	100-105	40	--	1.1	--	B	--	--	--	97	94	90	38	--	mud, very slightly leafy	M
PCM923*7	3-8	60	--	2.3	--	B	--	--	--	91	88	82	33	18	leaf, sticks, mud	Z
	18-21	28	--	0.7	--	B	--	12	--	9	9	10	3	1	clean medium sand	med. S
	25-28	47	--	3.3	--	B	--	--	--	87	84	75	25	14	muddy leaf hash	very fine sZ
PCM923*8	2-5	58	--	5.6	--	B	--	--	--	92	95	85	41	25	slightly silty lam. mud	M
	10-12	47	--	4.7	--	B	--	--	--	60	60	56	29	--	fine sand	fine sZ
BCM122*85t	1-5	75	1.09	--	--	--	--	--	--	--	--	--	--	--	loose mud	
	5-10	63	21	2.4	--	B	--	--	--	99	100	98	63	37	soft mud	C
Phils Creek Arm (N)																
PCN82*1	14-17	46	--	1.4	--	B	--	--	--	94	94	76	35	--	lam. mud, fine leaf parts	M
PCN82*2	5-8	53	--	1.6	--	B	--	--	--	94	92	85	40	--	lam. mud, fine leaf parts	M
	28-30	48	--	2.0	--	B	--	--	--	69	67	62	25	--	leaf hash	very fine sZ
	43-45	--	--	--	--	A	--	98	92	85	--	82	--	--	mud	fine sM
PCN82*3	5-8	--	--	1.6	--	B	--	--	--	99	96	91	42	--	lam. mud	M
	38-42	--	--	2.7	--	B	--	--	--	57	53	46	12	--	slightly sandy mud, rooty, leafy	sZ
PCN82*4	3-5	--	--	1.0	--	B	--	--	--	98	91	88	35	--	lam. mud	M
	34-38	--	--	2.4	--	B	--	--	--	63	60	53	19	--	fine sandy mud, leafy	fine sM
PCN82*5	1-5	45	--	3.4	--	B	--	98	--	66	64	51	20	--	silty mud, rooty	fine sZ
	35-37	38	--	0.9	--	B	--	--	--	23	21	16	7	--	muddy med-fine sand, woody	fine S
PCN82*6	1-5	50	--	2.6	--	B	--	99	--	37	36	28	12	--	mud, rooty, leafy	zS
	9-11	41	--	0.4	--	B	--		--	21	20	14	5	--	med-fine sand	fine S
	26-30	54	--	3.2	--	B	--	87	--	58	56	47	16	--	muddy sandy leaf plug	sZ
PCN82*7	2-7	28	--	2.2	--	B	--	--	--	97	96	87	32	19	silty mud, rootlets	Z
	38-40	42	--	1.3	--	B	--	--	--	96	94	90	35	20	non-lam. mud	M
PCN82*8	5-8	23	--	2.1	--	B	--	--	--	61	59	50	18	11	fine sandy mud, rootlets	sZ
	38-42	44	--	1.8	--	B	--	--	--	86	84	75	28	17	fine sandy mud, rootlets	sZ

* see footnotes at end of table

Phils Creek Arm, continued

Core type and number	Sample (1) Depth(cm)	Percent water(2)	unit weight(3)	% wt. lost H2O2 (4)	%TOC	Method used (5)	Percent finer than indicated size (in microns) 1000	350	150	63s	63p	38	4	1-2	Sample material (visual description)	Grain size Modified from Folk, 1980 (6)
PCN82*9	2- 5	46	--	3.1	--	B	--	--	--	93	89	82	39	--	non-lam. mud	M
PCN82*10	2- 5	36	--	2.0	--	B	--	--	--	79	77	54	18	12	non-lam. mud, rooty	fine sZ
	28-30	45	--	1.4	--	B	--	--	--	93	89	86	29	18	fine sandy leaf hash, rooty	Z
	48-50	36	--	0.7	--	B	--	--	--	67	67	59	22	--	med. fine sand, rooty	med. sZ
	68-70	42	--	0.4	--	B	--	--	--	52	53	42	16	--	med. sand, rooty	fine sZ
PCN82*11	2- 4	48	--	--	--	--	--	--	--	--	--	--	--	--	non-lam. mud, rootlets	
	15-17	38	--	--	--	--	--	--	--	--	--	--	--	--	non-lam. mud, rootlets	
	36-38	31	--	--	--	--	--	--	--	--	--	--	--	--	non-lam. mud, rootlets	
	50-52	35	--	--	--	--	--	--	--	--	--	--	--	--	non-lam. mud, rooty, sticks	
	62-64	19	--	--	--	--	--	--	--	--	--	--	--	--	coarse sand	
	74-76	22	--	--	--	--	--	--	--	--	--	--	--	--	muddy, med. sand	
	88-90	17	--	--	--	--	--	--	--	--	--	--	--	--	med. sand	
	110-112	14	--	--	--	--	--	--	--	--	--	--	--	--	med. sand	
PCN82*12	2- 5	19	--	1.8	--	B	--	--	--	99	98	96	49	--	coarse sand	M
	25-28	22	--	0.4	--	B	--	51	--	35	34	25	8	--	muddy, med. sand	(g) S
	50-53	17	--	1.2	--	B	--	--	--	99	96	92	18	--	med. sand	Z
	WP 70	14	--	--	--	A	99	97	92	87	--	80	--	--	med. sand	sZ
PCN82*13	3- 5	50	--	1.3	--	B	--	--	--	25	24	19	6	--	non-lam. mud	zS
	30-35	21	--	2.5	--	B	--	--	--	89	85	78	32	--	coarse sand, rooty	sZ
	80-85	27	--	1.5	--	B	--	--	--	87	85	73	27	--	silty sand very rooty	sZ
DCN822*3	2- 4	71	1.09	--	3.08	--	--	--	--	--	--	--	--	--	loose mud	
	10- 12	64	1.16	--	3.12	--	--	--	--	--	--	--	--	--	lam mud	
	20-22	56	1.23	--	2.18	--	--	--	--	--	--	--	--	--	lam mud	
	30-32	55	1.22	--	2.36	--	--	--	--	--	--	--	--	--	lam mud	
	40-42	53	1.25	--	2.20	--	--	--	--	--	--	--	--	--	lam mud	
	50-52	47	1.31	--	1.51	--	--	--	--	--	--	--	--	--	lam mud	
	60-62	43	1.38	--	1.17	--	--	--	--	--	--	--	--	--	lam mud	
	70-72	40	1.41	--	1.21	--	--	--	--	--	--	--	--	--	fainty lam. mud	
	80-82	39	1.46	--	1.18	--	--	--	--	--	--	--	--	--	fainty lam. mud	
	90-92	36	1.51	--	0.97	--	--	--	--	--	--	--	--	--	fainty lam. mud	
	100-102	34	1.52	--	0.96	--	--	--	--	--	--	--	--	--	fainty lam. mud	
VCN97*1	WP 223	--	--	--		A	78	40	26	20	--	18	--	--	med. channel sand	(g) coarse S

* see footnotes at end of table

Phils Creek Arm, continued

Core type and number	Sample (1) Depth(cm)	Percent water(2)	unit weight(3)	% wt. lost H2O2 (4)	%TOC	Method used (5)	Percent finer than indicated size (in microns) 1000	350	150	63s	63p	38	4	1-2	Sample material (visual description)	Grain size Modified from Folk, 1980 (6)
VCN97*2	8-10	39	--	--	--	--	--	--	--	--	--	--	--	--	silty mud, leafy	
	30-32	28	--	--	--	--	--	--	--	--	--	--	--	--	clayey med-fine sand, rooty	
	44-46	20	--	--	--	--	--	--	--	--	--	--	--	--	clayey med-fine sand, rooty	
	90-92	19	--	--	--	--	--	--	--	--	--	--	--	--	clayey med-fine sand, rooty	
	120-122	19	--	--	--	--	--	--	--	--	--	--	--	--	clayey med-fine sand, rooty	
	160-162	20	--	--	--	--	--	--	--	--	--	--	--	--	clayey med-fine sand, rooty	
	WP 211	--	--	--	--	A	99	92	92	66	--	63	--	--	silty mud	sZ
VCN98*2	257	--	--	--	--	A	54	35	29	24	--	23	--	--	gravelly mud	med sZ
VCN98*3	28-30	--	--	--	--	A	98	91	64	42	--	33	--	--	silty mud	zS
BCN122*52t	1-5	66	1.15	2.5	--	B	--	--	--	94	93	80	28	17	loose silty mud	Z
BCN122*52b	5-10	56	1.24	2.3	--	B	--	--	--	89	89	60	29	20	soft silty mud	very fine sZ
BCN122*83t	1-5	66	1.16	2.0	--	B	--	--	--	99	99	94	39	--	silty mud, fine leaf parts	M
BCN122*83b	5-10	59	1.22	2.0	--	B	--	--	--	99	100	94	40	19	silty mud, fine leaf parts	M
BCN122*73	1-5	46	1.33	3.9	--	B	--	22	--	12	nd	7	6	--	coarse, sandy gravel and leaves	very coarse
BCN122*43	1-5	46	1.34	2.2	--	B	--	--	--	67	68	59	21	--	silty mud, rootlets	very fine sZ
BCN122*88	1-5	48	1.29	2.2	--	B	--	--	--	86	86	72	28	13	mud, slightly leafy	sZ
BCN122*72	1-5	30	1.53	0.8	--	B	--	55	--	10	10	8	4	3	sand, leaves	med. S
BCN122*151	1-5	74	1.01	6.5	--	B	--	81	--	68	69	66	24	--	leaves, mud	sZ
BCN122*176	1-5	59	1.18	5.1	--	B	--		--	62	62	49	20	13	mud, slightly leafy	very fine sZ
BCN122*42	1-5	31	1.54	0.9	--	B	--	13	--	9	9	6	4	--	muddy sand	med. S
Price Creek Arm (P)					--											
VCP728*1	WP 87	--	--	--	--	A	36	17	9	6	--	6	--	--	grey sand	coarse S
PCP728*3	44-46	25	--	--	--	--	--	--	--	--	--	--	--	--	fine sand, silty mud	
	90-92	16	--	--	--	--	--	--	--	--	--	--	--	--	silty, sand soil, crumbly	
	100-102	21	--	--	--	--	--	--	--	--	--	--	--	--	grey sand	
	120-122	21	--	--	--	--	--	--	--	--	--	--	--	--	rusty sand	
	144-146	16	--	--	--	--	--	--	--	--	--	--	--	--	coarse sand	
	WP 154	--	--	--	--	A	99	94	86	76	--	73	--	--	silty mud	sZ
PCP731*1	12-15	52	--	3.6	--	B	--	--	--	99	102	98	77	--	lam. mud	C
	18-30	36	--	3.5	--	B	--	--	--	69	66	59	22	--	mud, rooty, leafy	g) sZ sandy sil
PCP731*2	2-5	26	--	2.7	--	B	--	--	--	47	50	44	13	--	lam. mud	med. S

* see footnotes at end of table

Price Creek Arm, continued

Core type and number	Sample (1) Depth(cm)	Percent water(2)	unit weight(3)	% wt. lost H2O2 (4)	%TOC	Method used (5)	Percent finer than indicated size (in microns) 1000	350	150	63s	63p	38	4	1-2	Sample material (visual description)	Grain size Modified from Folk, 1980 (6)
	22-25	22	--	--	--	A	99	74	55	51	--	49	--	--	muddy fine sand, leafy, rootlets	sM
PCP731*3	2- 4	64	--	3.9	--	B	--	--	--	95	97	94	62	--	soft lam. mud	M
	18-20	27	--	2.5	--	B	--	--	--	49	50	44	21	--	muddy fine sand, rootlets	med zS
PCP731*4	10- 12	25	--	2.3	--	B	--	--	--	52	50	41	22	--	muddy fine sand, rootlets	(g) zS
	29-31	63	--	1.2	--	B	--	--	--	97	93	90	69	40	lam. mud	C
	WP 39	--	--	--	--	A	80	62	57	56	--	55	--	--	(w. p.)	sM
PCP731*5	5- 8	63	--	4.2	--	B	--		--	98	94	92	71	42	lam. mud	C
	37-39	21	--	1.0	--	B	--	41	--	33	33	29	10	4	sandy, clay, compact, rooty	med S
PCP731*6	2- 6	63	--	4.9	--	B	--		--	89	84	74	45	26	fine sandy mud, leafy	sM
PCP731*7	2- 4	71	--	--	2.78	--	--	--	--	--	--	--	--	--	lam. mud	
	12- 14	68	--	--	2.14	--	--	--	--	--	--	--	--	--	lam. mud	
	22-24	60	--	--	1.60	--	--	--	--	--	--	--	--	--	lam. mud	
	32-34	54	--	--	1.40	--	--	--	--	--	--	--	--	--	lam. mud	
	42-44	51	--	--	1.28	--	--	--	--	--	--	--	--	--	lam. mud	
	48-49	30	--	--	0.61	--	--	--	--	--	--	--	--	--	medium fine sand	
	WP 50	--	--	2.2	--	B	--	--	--	46	44	38	16	6	fine sandy clay	med zS
PCP731*8	1- 3	31	--	1.9	--	B	--	--	--	15	13	12	5	2	gravelly coarse sand	S
	11- 13	57	--	3.8	--	B	--	--	--	98	97	97	59	23	non-lam. mud	M
	22-24	37	--	3.4	--	B	--	--	--	91	90	84	41	15	mud, slightly rooty	M
	34-36	27	--	2.9	--	B	--	--	--	87	94	87	67	--	clay, firm, rooty	C
DCP821*4	2	72	--	--	--	--	--	--	--	--	--	--	--	--	loose mud	
	10	64	--	--	--	--	--	--	--	--	--	--	--	--	faintly lam. mud	
	15	65	--	--	--	--	--	--	--	--	--	--	--	--	faintly lam. mud	
	20	64	--	--	--	--	--	--	--	--	--	--	--	--	faintly lam. mud	
	25	62	--	--	--	--	--	--	--	--	--	--	--	--	faintly lam. mud	
	30	60	--	--	--	--	--	--	--	--	--	--	--	--	faintly lam. mud	
	35	57	--	--	--	--	--	--	--	--	--	--	--	--	faintly lam. mud	
	40	55	--	--	--	--	--	--	--	--	--	--	--	--	faintly lam. mud	
	45	51	--	--	--	--	--	--	--	--	--	--	--	--	faintly lam. mud	
	50	48	--	--	--	--	--	--	--	--	--	--	--	--	faintly lam. mud	
	55	33	--	--	--	--	--	--	--	--	--	--	--	--	sand, woody, leafy	
	58	23	--	--	--	--	--	--	--	--	--	--	--	--	whitish sand	
	75	17	--	--	--	--	--	--	--	--	--	--	--	--	coarse gravelly sand	

* see footnotes at end of table

Price Creek Arm, continued

Core type and number	Sample (1) Depth(cm)	Percent water(2)	unit weight(3)	% wt. lost H2O2 (4)	%TOC	Method used (5)	1000	350	150	63s	63p	38	4	1-2	Sample material (visual description)	Grain size Modified from Folk, 1980 (6)
							Percent finer than indicated size (in microns)									
DCP821*4	WP 83	--	--	--		A	100	54	26	10	--	8	--	--	coarse gravelly sand	very coarse S
PCP914*1	10- 12	47	--	--	1.98	--	--	--	--	--	--	--	--	--	silty mud, rooty	
	20-22	33	--	--	1.71	--	--	--	--	--	--	--	--	--	greyish silty mud, woody	
	30-32	28	--	--	1.05	--	--	--	--	--	--	--	--	--	greyish silty mud, woody	
	40-42	25	--	--	--	--	--	--	--	--	--	--	--	--	greyish silty mud, woody	
	50-52	26	--	--	--	--	--	--	--	--	--	--	--	--	sand	
	60-62	23	--	--	--	--	--	--	--	--	--	--	--	--	soft mud	
	70-72	21	--	--	--	--	--	--	--	--	--	--	--	--	bluish clay soil, compact	
	80-82	19	--	--	--	--	--	--	--	--	--	--	--	--	bluish clay soil, compact	
	90-92	18	--	--	0.23	--	--	--	--	--	--	--	--	--	bluish clay soil, compact	
	100-102	17	--	--	--	--	--	--	--	--	--	--	--	--	bluish clay soil, compact	
	110-102	17	--	--	--	--	--	--	--	--	--	--	--	--	bluish clay soil, compact	
	120-122	17	--	--	--	--	--	--	--	--	--	--	--	--	bluish clay soil, compact	
	130-132	19	--	--	--	--	--	--	--	--	--	--	--	--	bluish clay soil, compact	
PCP103*3	8- 10	63	--	--	--	--	--	--	--	--	--	--	--	--	mud, plant parts	
	40-42	21	--	--	--	--	--	--	--	--	--	--	--	--	med-fine sand, rooty	
	60-62	19	--	--	--	--	--	--	--	--	--	--	--	--	med-fine sand, rooty	
	80-82	23	--	--	--	--	--	--	--	--	--	--	--	--	silty mud, rooty, woody	
	104-106	22	--	--	--	--	--	--	--	--	--	--	--	--	silty mud, rooty, woody	
	140-142	16	--	--	--	--	--	--	--	--	--	--	--	--	muddy sand, bluish	
	160-162	18	--	--	--	--	--	--	--	--	--	--	--	--	grey muddy sand	
BCP122*162t	1- 5	79	1.03	2.7	--	B	--	0	--	95	97	94	61	--	loose mud	C
BCP122*162b	5- 10	66	1.17	2.1	--	B	--	0	--	93	93	90	57	--	fine sandy mud	M
BCP122*75t	1- 5	76	1.04	3.0	--	B	--	--	--	90	92	83	43	22	leafy silty mud	very fine sM
BCP122*75b	5- 10	71	1.10	2.7	--	B	--	0	--	93	95	93	45	--	leaves, mud	M
BCP122*40t	1- 5	80	1.02	2.6	--	B	--	--	--	94	96	92	53	35	loose mud	M
BCP122*40b	5- 10	71	1.15	--	--	--	--	--	--	--	--	--	--	--	soft mud	
BCP122*163t	1- 5	66	1.08	--	--	--	--	--	--	--	--	--	--	--	silty mud	
BCP122*163b	5- 10	36	1.19	--	--	--	--	--	--	--	--	--	--	--	rooty mud	
BCP122*79	1- 5	42	1.40	2.1	--	B	--	--	--	52	53	43	22	--	sticky, sandy mud	fine sM
BCP122*95	1- 5	59	1.22	2.2	--	B	--	--	--	45	nd	92	55	--	silty mud	M
BCP122*93	1- 5	73	1.07	2.6	--	B	--	0	--	98	99	98	57	--	soft mud	fine sM
BCP122*87	1- 5	13	1.17	2.4	--	B	--	--	--	82	nd	69	54	--	soft mud	M

* see footnotes at end of table

Price Creek Arm, continued

Core type and number	Sample (1) Depth(cm)	Percent water(2)	unit weight(3)	% wt. lost H2O2 (4)	%TOC	Method used (5)	Percent finer than indicated size (in microns) 1000	350	150	63s	63p	38	4	1-2	Sample material (visual description)	Grain size Modified from Folk, 1980 (6)
BCP122*76	1-5	64	1.16	1.8	--	B	--	--	--	98	100	92	59	--	leaves, mud	M
BCP122*74	1-5	59	1.47	1.2	--	B	--	--	--	97	97	91	34	16	silty mud	Z
BCP122*186	1-5	64	1.15	6.1	--	B	--	--	--	96	98	95	54	--	fine sandy mud	M
BCP122*94	1-5	78	1.07	5.0	--	B	--	74	--	51	66	65	44	19	gravelly sand, rootball	sM
BCP122*71	1-5	71	1.10	2.4	--	B	--	--	--	97	nd	96	49	--	soft mud	M

(1) WP [whirl pack] samples removed from the core in the field and stored at room temperature.
(2) ((wet weight - dry weight) / wet weight) X 100.
(3) (wet weight - water weight)/ volume.
(4) Percent of original dry sample weight lost after treatment with 20 ml. of 30% hydrogen peroxide.
(5) Method A: dispersed with Calgon, wet sieved on 1000µm., 350 µm., 150 µm., 63 µm., and 38 µm. screens.
Method B: Two 10 ml. 30% hydrogen peroxide treatments, dispersed with Calgon, wet sieved on 350 µm. and 63 µm. screens, pipeted for to 63 µm., 38 µm., 4 µm., and optional 1-2 µm., measures effective settling diameter.
(6) Explanation of grain size classification scheme in Figure A1.

APPENDIX C. Unit weight of lake sediments.

Core	Depth in core (cm)	initial unit weight (gm/cc)	initial unit weight (lbs/cu ft.)	Percent water	dry unit weight (lbs/cu ft.)	dry unit weight tons/acre-foot	Sample material (visual description)
DCN822*3	3	1.09	68.0	71	23.7	516	loose mud
	10	1.16	72.4	64	32.4	707	lam mud
	20	1.23	76.8	56	41.8	911	lam mud
	30	1.22	76.2	55	41.8	911	lam mud
	40	1.25	78.0	53	44.9	979	lam mud
	50	1.31	81.8	47	52.4	1142	lam mud
	60	1.38	86.1	43	59.3	1291	lam mud
	70	1.41	88.0	40	63.0	1373	fainty lam. mud
	80	1.46	91.1	39	66.8	1455	fainty lam. mud
	90	1.51	94.3	36	71.9	1565	fainty lam. mud
	100	1.52	95.0	34	73.8	1607	fainty lam. mud
Average		1.32	83	49	52	1132	
BCM122*85t	3	1.09	68.0	75	21.2	462	loose mud
	8	1.21	75.5	63	36.2	788	soft mud
BCN122*52t	3	1.15	71.6	66	30.4	662	loose silty mud
	8	1.24	77.2	56	42.2	920	soft silty mud
BCN122*83t	3	1.16	72.1	66	30.9	673	silty mud, fine leaf parts
	8	1.22	75.8	59	39.0	849	silty mud, fine leaf parts
BCN122*73	3	1.33	82.7	46	54.0	1176	sandy gravel and leaves
BCN122*43	3	1.34	83.6	46	54.9	1196	silty mud, rootlets
BCN122*88	3	1.29	80.5	48	50.6	1101	mud, slightly leafy
BCN122*72	3	1.53	95.8	30	77.0	1678	sand, leaves
BCN122*151	3	1.01	62.7	74	16.5	360	leaves, mud
BCN122*176	3	1.18	73.5	59	36.6	798	mud, slightly leafy
BCN122*42	3	1.54	96.2	31	76.8	1673	muddy sand
BCP122*162t	3	1.03	64.3	79	15.0	326	loose mud
	8	1.17	72.8	66	31.6	689	fine sandy mud
BCP122*75t	3	1.04	64.9	76	17.5	380	leafy silty mud
	8	1.10	68.5	71	24.2	527	leaves, mud
BCP122*40t	3	1.02	63.8	80	13.8	301	loose mud
	8	1.15	71.7	71	27.4	596	soft mud
BCP122*163t	3	1.08	67.2	66	26.0	567	silty mud
	8	1.19	74.0	36	51.5	1121	rooty mud
BCP122*79	3	1.40	87.4	42	61.2	1332	sticky, sandy mud
BCP122*95	3	1.22	76.0	59	39.2	853	silty mud
BCP122*93	3	1.07	66.7	73	21.1	459	soft mud
BCP122*87	3	1.17	72.8	13	64.7	1410	soft mud
BCP122*76	3	1.16	72.6	64	32.6	711	leaves, mud
BCP122*74	3	1.47	92.0	59	55.2	1202	silty mud
BCP122*186	3	1.15	71.7	64	31.8	692	fine sandy mud
BCP122*94	3	1.07	67.0	78	18.3	398	gravelly sand, rootball
BCP122*71	3	1.10	68.9	71	24.5	534	soft mud
Average of all samples		1.26	79	54	45	973	
Standard deviation		0.15	10	16	19	403	