science for a changing world

National Water-Quality Assessment Program

Collection, Analysis, and Age-Dating of Sediment Cores From 56 U.S. Lakes and Reservoirs Sampled by the U.S. Geological Survey, 1992–2001

Scientific Investigations Report 2004–5184

U.S. Department of the Interior
U.S. Geological Survey

Cover:

Top left, slicing a subsample from a core for laboratory analysis;
bottom left, collecting cores on Town Lake, Austin, Texas;
right, launching a portable watercraft for sampling on a remote, mountain lake.

Collection, Analysis, and Age-Dating of Sediment Cores From 56 U.S. Lakes and Reservoirs Sampled by the U.S. Geological Survey, 1992–2001

By Peter C. Van Metre, Jennifer T. Wilson, Christopher C. Fuller,
Edward Callender, and Barbara J. Mahler

National Water-Quality Assessment Program

Scientific Investigations Report 2004–5184

U.S. Department of the Interior
U.S. Geological Survey

U.S. Department of the Interior
Gale A. Norton, Secretary

U.S. Geological Survey
Charles G. Groat, Director

U.S. Geological Survey, Reston, Virginia: 2004
For sale by U.S. Geological Survey, Information Services
Box 25286, Denver Federal Center
Denver, CO 80225

For more information about the USGS and its products:
Telephone: 1-888-ASK-USGS
World Wide Web: http://www.usgs.gov/

Information regarding the National Water-Quality Assessment (NAWQA) Program is available on the Internet via the World Wide Web. You may connect to the NAWQA Home Page using the Universal Resource Locator (URL) at:

<URL:http://wwwrvares.er.usgs.gov/nawqa/nawqa_home.html>

Suggested citation:

Van Metre, P.C., Wilson, J.T., Fuller, C.C., Callender, Edward, and Mahler, B.J., 2004, Collection, analysis, and age-dating of sediment cores from 56 U.S. lakes and reservoirs sampled by the U.S. Geological Survey, 1992–2001: U.S. Geological Survey Scientific Investigations Report 2004–5184, 180 p.

FOREWORD

The U.S. Geological Survey (USGS) is committed to providing the Nation with accurate and timely scientific information that helps enhance and protect the overall quality of life and that facilitates effective management of water, biological, energy, and mineral resources (http://www.usgs.gov/). Information on the quality of the Nation's water resources is critical to assuring the long-term availability of water that is safe for drinking and recreation and suitable for industry, irrigation, and habitat for fish and wildlife. Population growth and increasing demands for multiple water uses make water availability, now measured in terms of quantity *and* quality, even more essential to the long-term sustainability of our communities and ecosystems.

The USGS implemented the National Water-Quality Assessment (NAWQA) Program in 1991 to support national, regional, and local information needs and decisions related to water-quality management and policy (http://water.usgs.gov/nawqa). Shaped by and coordinated with ongoing efforts of other Federal, State, and local agencies, the NAWQA Program is designed to answer: What is the condition of our Nation's streams and ground water? How are the conditions changing over time? How do natural features and human activities affect the quality of streams and ground water, and where are those effects most pronounced? By combining information on water chemistry, physical characteristics, stream habitat, and aquatic life, the NAWQA Program aims to provide science-based insights for current and emerging water issues and priorities.

During 1991–2001, the NAWQA Program completed interdisciplinary assessments in 51 of the Nation's major river basins and aquifer systems, referred to as Study Units (http://water.usgs.gov/nawqa/studyu.html). Baseline conditions were established for comparison to future assessments, and long-term monitoring was initiated in many of the basins. During the next decade, 42 of the 51 Study Units will be reassessed so that 10 years of comparable monitoring data will be available to determine trends at many of the Nation's streams and aquifers. The next 10 years of study also will fill in critical gaps in characterizing water-quality conditions, enhance understanding of factors that affect water quality, and establish links between *sources* of contaminants, the *transport* of those contaminants through the hydrologic system, and the potential *effects* of contaminants on humans and aquatic ecosystems.

The USGS aims to disseminate credible, timely, and relevant science information to inform practical and effective water-resource management and strategies that protect and restore water quality. We hope this NAWQA publication will provide you with insights and information to meet your needs, and will foster increased citizen awareness and involvement in the protection and restoration of our Nation's waters.

The USGS recognizes that a national assessment by a single program cannot address all water-resource issues of interest. External coordination at all levels is critical for a fully integrated understanding of watersheds and for cost-effective management, regulation, and conservation of our Nation's water resources. The NAWQA Program, therefore, depends on advice and information from other agencies—Federal, State, interstate, Tribal, and local—as well as nongovernmental organizations, industry, academia, and other stakeholder groups. Your assistance and suggestions are greatly appreciated.

Robert M. Hirsch

Robert M. Hirsch
Associate Director for Water

Contents

Appendix

Figures

Tables

Collection, Analysis, and Age-Dating of Sediment Cores From 56 U.S. Lakes and Reservoirs Sampled by the U.S. Geological Survey, 1992–2001

By Peter C. Van Metre, Jennifer T. Wilson, Christopher C. Fuller, Edward Callender, and Barbara J. Mahler

Abstract

The U.S. Geological Survey Reconstructed Trends National Synthesis study collected sediment cores from 56 lakes and reservoirs between 1992 and 2001 across the United States. Most of the sampling was conducted as part of the National Water-Quality Assessment (NAWQA) Program. The primary objective of the study was to determine trends in particle-associated contaminants in response to urbanization; 47 of the 56 lakes are in or near one of 20 U.S. cities. Sampling was done with gravity, piston, and box corers from boats and push cores from boats or by wading, depending on the depth of water and thickness of sediment being sampled. Chemical analyses included major and trace elements, organochlorine pesticides, polychlorinated biphenyls, polycyclic aromatic hydrocarbons, cesium-137, and lead-210. Age-dating of the cores was done on the basis of radionuclide analyses and the position of the pre-reservoir land surface in the reservoir and, in a few cases, other chemical or lithologic depth-date markers. Dates were assigned in many cores on the basis of assumed constant mass accumulation between known depth-date markers. Dates assigned were supported using a variety of other date markers including first occurrence and peak concentrations of DDT and polychlorinated biphenyls and peak concentration of lead. A qualitative rating was assigned to each core on the basis of professional judgment to indicate the reliability of age assignments. A total of 122 cores were collected from the 56 lakes and age dates were assigned to 113 of them, representing 54 of the 56 lakes. Seventy-four of the 122 cores (61 percent) received a good rating for the assigned age dates, 28 cores (23 percent) a fair rating, and 11 cores (9 percent) a poor rating; nine cores (7 percent) had no dates assigned. An analysis of the influence of environmental factors on the apparent quality of age-dating of the cores concluded that the most important factor was the mass accumulation rate (MAR) of sediment: the greater the MAR, the better the temporal discretization in the samples and the less important the effects of postdepositional sediment disturbance. These age-dated sediment cores provide the basis for local-, regional-, and national-scale interpretations of water-quality trends.

Introduction

One of the three primary objectives of the U.S. Geological Survey (USGS) National Water-Quality Assessment (NAWQA) Program is to determine trends, or the lack of trends, in our Nation's water quality (Leahy and others, 1990). Water-quality trends can provide an assessment of the effectiveness of regulatory actions aimed at improving water quality, a warning of water-quality degradation, and an improved understanding of how human activities affect water quality. Many governmental agencies collect routine data for the assessment of the quality of lakes, reservoirs, and streams. Testing water-quality monitoring data for time trends has become an important exercise for water managers; however, testing historical water-quality data for trends has many limitations. These include lack of sufficient data, changing sampling and analytical methods, changing detection levels, missing values, and values below the detection level. These limitations can be particularly severe when dealing with trace elements and hydrophobic organic compounds (HOCs).

An alternative approach for evaluating water-quality trends for some constituents is paleolimnology—the use of age-dated sediment cores to reconstruct water-quality histories (Callender and Van Metre, 1997; Davis, 1980; Eisenreich and others, 1989; Hites and others, 1981; Van Metre, Callender, and Fuller, 1997). The USGS NAWQA Program is using paleolimnology to determine trends in trace elements and HOCs in river basins nationally (Van Metre and others, 2000). In the study, known as the Reconstructed Trends National Synthesis

Table 1. List of publications with interpretations of chemical trends in selected lakes presented in this report.

Reference	Lake(s) described	Report title
Van Metre and others, 2003	Lake Como, Echo Lake, Fosdic Lake	Occurrence, trends, and sources in particle-associated contaminants in selected streams and lakes in Fort Worth, Texas
Long and others, 2003	Clyde Potts Reservoir, Newbridge Pond, Orange Reservoir, Packanack Lake	Trends in chemical concentration in sediment cores from three lakes in New Jersey and one lake on Long Island, New York
Burton, 2002	R.R. Canyon Lake, Lake Hemet, West Street Basin	Effects of urbanization and long-term rainfall on the occurrence of organic compounds and trace elements in reservoir sediment cores, streambed sediment, and fish tissue from the Santa Ana River Basin, California, 1998
Van Metre and Sneck-Fahrer, 2002	Lake Houston	Water-quality trends in suburban Houston, Texas, 1954–97, as indicated by sediment cores from Lake Houston
Covay and Beck, 2001	Lake Mead	Sediment-deposition rates and organic compounds in bottom sediment at four sites in Lake Mead, Nevada, May 1998
Callender and Rice, 2000	Lake Seminole, Lake Walter F. George, Lake Harding, West Point Lake, Lake Sidney Lanier	The urban environmental gradient: Anthropogenic influences on the spatial and temporal distributions of lead and zinc in sediments
Naftz and others, 2000	Great Salt Lake (Farmington Bay), Red Butte Reservoir, Decker Lake	Reconstructing historical changes in the environmental health of watersheds by using sediment cores from lakes and reservoirs in Salt Lake Valley, Utah
Van Metre and Mahler, 1999	Town Lake	Town Lake bottom sediments: A chronicle of water-quality changes in Austin, Texas, 1960–98
Van Metre and others, 2000	Lake Anne, Lake Ballinger, Fairfax Lake, Lake Harriet, Newbridge Pond, Orange Reservoir, Packanack Lake, Palmer Lake, Town Lake, White Rock Lake	Urban sprawl leaves its PAH signature
Ging and others, 1999	Lorence Creek Lake	Bottom sediments of Lorence Creek Lake, San Antonio, Texas, reflect contaminant trends in an urbanizing watershed
Van Metre and others, 1998	Lake Anne, Lake Blackshear, Cochiti Lake, Coralville Reservoir, Elephant Butte Reservoir, Falcon International Reservoir, Lake Harding, Lorence Creek Lake, Lake Seminole, Lake Walter F. George, White Rock Lake	Similar rates of decrease of persistent, hydrophobic and particle-reactive contaminants in riverine systems
Callender and Van Metre, 1997	Coralville Reservoir, Lake Anne, Lake Harding, Lake Sidney Lanier, Lake Blackshear, White Rock Lake	Reservoir sediment cores show U.S. lead declines
Van Metre and Callender, 1997	White Rock Lake	Water-quality trends in White Rock Creek Basin from 1912–1994 identified using sediment cores from White Rock Lake reservoir, Dallas, Texas
Van Metre, Callender, Fuller, 1997	Lake Blackshear, Coralville Reservoir, Lake Harding, Lake Seminole, Lake Walter F. George, White Rock Lake	Historical trends in organochlorine compounds in river basins identified using sediment cores from reservoirs
Van Metre and Callender, 1996	Lake Livingston	Identifying water-quality trends in the Trinity River, Texas, USA, 1969–1992, using sediment cores from Lake Livingston
Van Metre and others, 1996	White Rock Lake	Water-quality trends using sediment cores from White Rock Lake, Dallas, Texas

(RTNS) study, 45 reservoirs and 11 natural lakes (hereinafter, called "lakes" except where distinction is warranted) were sampled from 1992 through 2001. The objectives were to (1) identify trends, or lack of trends, in surface water for hydrophobic and particle-reactive constituents (including trace elements and HOCs), (2) characterize relations between contaminant trends and watershed land use and regulatory changes, and (3) identify major sources of contaminants to lake sediments.

The purpose of this report is to (1) present the study design and methods of core collection, analyses, and age-dating for the RTNS; (2) present age-dating results for cores from 56 lakes; and (3) evaluate and discuss factors affecting the sampling, age-dating, and interpretation of chemical trends in lake sediment cores. Core samples were analyzed for major and trace elements, radionuclides, and major HOCs. Interpretations of chemical trends in selected cores and the associated constituent results are presented elsewhere (table 1).

Study Design

Sediment cores were collected from 45 reservoirs and 11 natural lakes, 47 of which are in or near 20 major urban areas in the United States (fig. 1, table 2). The lakes sampled represent a wide range of geographic settings, lake sizes and types, and land-use characteristics. Geographic settings represented include high-latitude or high-altitude settings, or both, in southern Alaska, the Pacific Northwest, and the Rocky Mountains; arid settings of the intermountain West and Southwest; cold grassland and forest settings in the Upper Midwest; and humid, low-altitude settings in Florida, the Atlantic Coast, and New England. Small and large lakes were sampled, with areas ranging from a few hectares (for example, Lake Anne, Newbridge Pond, and Crocker Pond) to hundreds of square kilometers (Lake Mead, Lake Washington, and the Great Salt Lake). Land use in the watersheds ranges from pristine forest to dense urban (table 2).

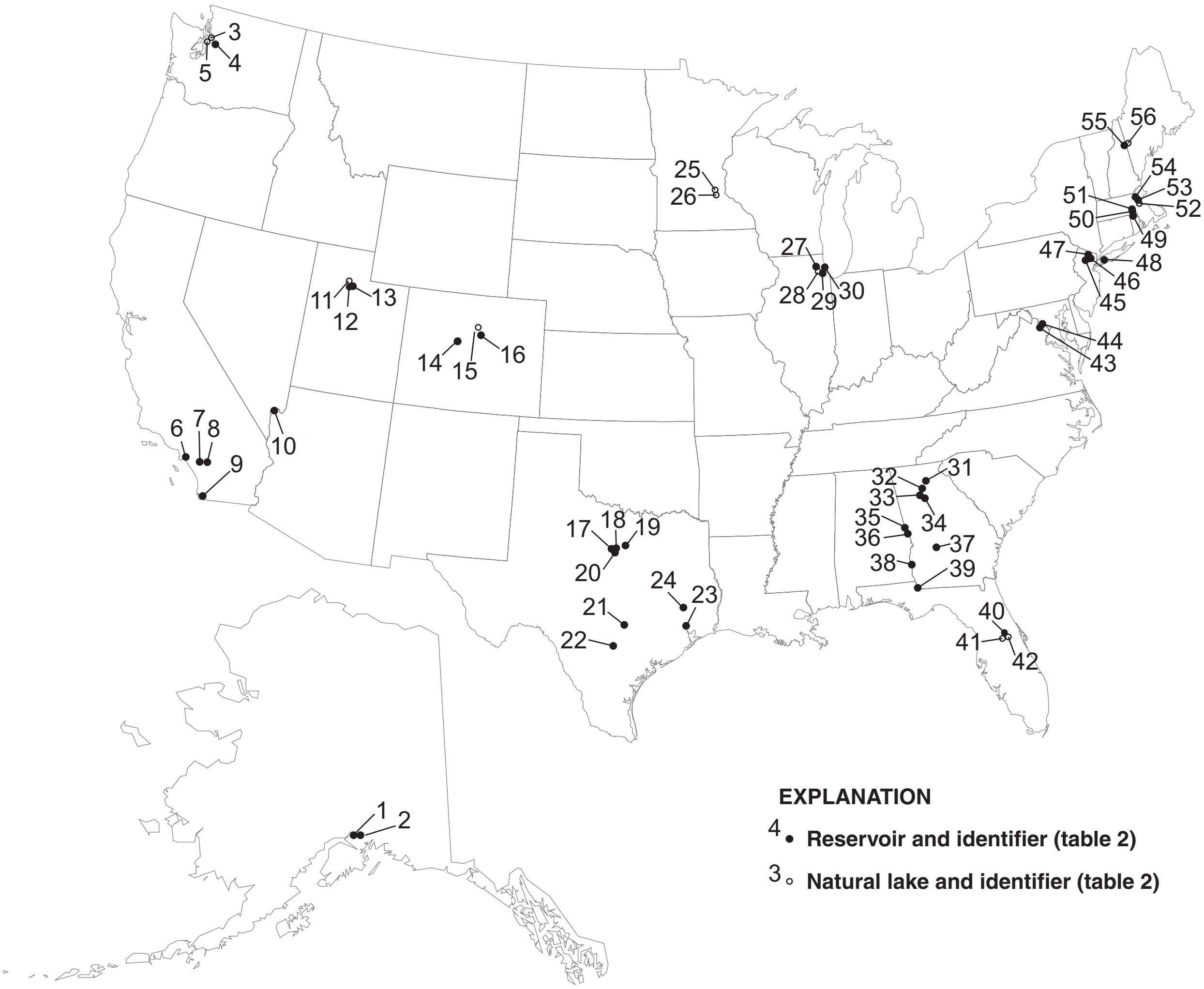
Sites were distributed across the country with the objective of sampling a variety of urban land uses in each of the major regions of the country. Residential and commercial land uses were favored; large point sources and heavily contaminated industrial areas generally were avoided, except where they contributed to large urban lakes that can be considered integrators of various land uses and contaminant sources (integrator lakes). Lakes sampled can be categorized as one of four settings on the basis of watershed land use—older urban, new urban, reference, and integrator lakes. The study design called for sampling as many as four lakes in each major urban area, one of each setting, although all four settings rarely were available.

Older urban lakes are defined as those in watersheds where most of the urban development took place before about 1950. At these sites the trend question to be answered is: How have contaminant concentrations changed over the past 50 or more years in stable urban settings? Trends in these lakes are expected in response to regulatory changes and changes in the technology and habits of the population, for example, the banning of DDT, changes in home-heating and automobile technologies, and changes in driving habits. Lake Harriet in Minneapolis, Minn., and Newbridge Pond on Long Island, N.Y., are examples of older urban lakes. New urban lakes are in watersheds that have experienced urban development, often rapid and extensive, since about 1950. The term “urban sprawl” often is used to describe this type of development. The trend question to be answered with these sites is: How do contaminant concentrations change as a watershed urbanizes, concurrent with regulatory changes and changes in human habits? White Rock Lake in Dallas, Tex., and Lake Anne in Reston, Va., are examples of new urban lakes. Reference lakes are in watersheds that have little or no development. Some reference lakes sampled by this study are in or near urban areas and some are in remote areas. Sand Lake near Orlando, Fla., and Crocker Pond in Maine are examples of reference lakes. In addition to indicating background concentrations of contaminants, reference lakes provide an indication of atmospheric fallout fluxes (mass per unit area) of contaminants that help to determine the importance of regional atmospheric fallout relative to local fluvial inputs of contaminants to aquatic systems. An integrator lake captures runoff from much or all of a large urban area and often contains appreciable percentages of other land uses such as agriculture, forest, and rangeland. Examples of integrator lakes are Lake Washington in Seattle, Wash., and Las Vegas Bay of Lake Mead in Nevada. The purpose of sampling integrator lakes was to determine trends in sediment chemistry from the combined effects of the mixture of land uses in selected major urban areas and their surroundings. One lake in an agricultural setting and one lake influenced by mining also were sampled.

In addition to the choices of urban areas and target land-use settings, several other criteria were used to guide the selection of specific lakes to sample, although because of the large variability in hydrologic settings across the country, these criteria often had to be adjusted. The NAWQA Program primarily is focused on the water quality of streams and aquifers and not explicitly on lakes; therefore, reservoirs rather than natural lakes often were chosen for paleolimnological studies. Reservoirs tend to have much larger drainage-area-to-surface-area (DA:SA) ratios and to be influenced more by fluvial inputs of contaminants than are lakes, often from one dominant stream (Marzolf, 1990; Van Metre, Callender, and Fuller, 1997; Van Metre and others, 2001). Thus, an implied assumption is that trends recorded in a reservoir core in some way reflect trends in water quality of the influent stream, an assumption recently demonstrated for trace elements and many HOCs by Van Metre and Mahler (2004).

In selecting a reservoir for sampling, the age of the reservoir, dredging history, and historical water-level fluctuations were considered. Preferably, the reservoir was constructed before about 1960, pre-dating the cesium-137 (^{137}Cs) peak in 1964 and major environmental regulations in the United States that have occurred since about 1970. The reservoir, or at least the deeper parts of it, could not have been dredged, and relatively small water-level fluctuations were preferred to minimize the chance for periodic erosion or other disturbance of sediments. Where natural lakes were common and reservoirs were not, natural lakes were sampled.

One exception to the above criteria was in the selection of reference sites. Early in this study, reference sites were selected following criteria similar to those of urban sites; however, the larger sedimentation rates of reservoirs work against the ability to detect atmospheric fallout signals in cores (Van Metre and others, 2001). Small DA:SA ratios and low sedimentation rates increase the amount of enrichment of sediment by fallout contaminants; therefore, small natural lakes with small DA:SA ratios were preferred as reference sites.



1. Hillstrand Pond, Alaska
2. Westchester Lagoon, Alaska
3. Lake Ballinger, Wash.
4. Tolt Reservoir, Wash.
5. Lake Washington, Wash.
6. West Street Basin, Calif.
7. R.R. Canyon Lake, Calif.
8. Lake Hemet, Calif.
9. Sweetwater Reservoir, Calif.
10. Lake Mead, Nev./Ariz.
11. Great Salt Lake, Utah
12. Decker Lake, Utah
13. Red Butte Reservoir, Utah
14. Dillon Reservoir, Colo.
15. Sloans Lake, Colo.
16. Cherry Creek Reservoir, Colo.
17. Lake Como, Tex.
18. Fosdic Lake, Tex.
19. White Rock Lake, Tex.
20. Echo Lake, Tex.
21. Town Lake, Tex.
22. Lorence Creek Lake, Tex.
23. Lake Houston, Tex.
24. Lake Livingston, Tex.
25. Palmer Lake, Minn.
26. Lake Harriet, Minn.
27. Lake in the Hills, Ill.
28. Shoe Factory Road Pond, Ill.
29. Busse Lake, Ill.
30. Beck Lake, Ill.
31. Lake Sidney Lanier, Ga.
32. Berkeley Lake, Ga.
33. Lakewood Park Lake, Ga.
34. Panola Lake, Ga.
35. West Point Lake, Ga.
36. Lake Harding, Ga./Ala.
37. Lake Blackshear, Ga.
38. Lake Walter F. George, Ga./Ala.
39. Lake Seminole, Ga./Fla.
40. Sand Lake, Fla.
41. Lake Orlando, Fla.
42. Lake Killarney, Fla.
43. Lake Anne, Va.
44. Fairfax Lake, Va.
45. Clyde Potts Reservoir, N.J.
46. Orange Reservoir, N.J.
47. Packanack Lake, N.J.
48. Newbridge Pond, N.Y.
49. Big Round Top Pond, R.I.
50. Maple Street Pond, Mass.
51. Harris Pond, Mass.
52. Upper Mystic Lake, Mass.
53. Charles River, Mass.
54. South Reservoir, Mass.
55. Basin Brook Pond, N.H.
56. Crocker Pond, Maine

Figure 1. Locations of National Water-Quality Assessment Program Reconstructed Trends National Synthesis study lake sediment coring sites, 1992–2001.

Table 2. Basic characteristics of lakes described in this report.

[ID, identifier; NAWQA, National Water-Quality Assessment; m, meter; km^2, square kilometer; R, reservoir; n, new; L, lake; o, old; --, not recorded]

Map ID (fig. 1)	Lake name	Site ID	Nearby major urban area	State	Date sampled	NAWQA study unit or cooperator[1]	Lake or reservoir[2]	Water depth (m)	Drainage area (km^2)	Dominant land use setting	Latitude	Longitude
1	Hillstrand Pond	HIL	Anchorage	Alaska	June 4, 1998	COOK	R	0.5	57.6	urban–n	61°11'58"	149°50'28"
2	Westchester Lagoon	WES	Anchorage	Alaska	June 4, 1998	COOK	R	1.5	71.7	urban–n	61°12'16"	149°54'28"
3	Lake Ballinger	BAL	Seattle	Wash.	June 8, 1998	PUGT	L	9.9	13.7	urban–n	47°46'54"	122°19'38"
4	Tolt Reservoir	TLT	Seattle	Wash.	June 11, 1998	PUGT	R	18.3	47.3	reference	47°42'13"	121°38'03"
5	Lake Washington	WAS	Seattle	Wash.	June 9, 1998	PUGT	L	62.5	1,471	integrator	47°39'47"	122°14'40"
6	West Street Basin	WST	Los Angeles	Calif.	Nov. 12, 1998	SANA	R	1.2	3.30	urban–o	33°47'14"	117°55'20"
7	R.R. Canyon Lake	CYN	Los Angeles	Calif.	Nov. 10, 1998	SANA	R	11.3	1,859	urban–n	33°40'53"	117°16'32"
8	Lake Hemet	HEM	Los Angeles	Calif.	Nov. 10, 1998	SANA	R	15.2	171	reference	33°39'57"	116°41'41"
9	Sweetwater Reservoir	SWT	San Diego	Calif.	Sept. 24, 1998	coop	R	16.2	470	urban–n	32°41'37"	116°59'56"
10	Lake Mead, Overton Arm	OVR	Las Vegas	Nev./Ariz.	May 13, 1998	NVBR	R	60.4	34,865	reference	36°21'56"	114°21'11"
	Lake Mead, Las Vegas Bay, Shallow	LVB-S	Las Vegas	Nev./Ariz.	May 12, 1998	NVBR	R	48.8	5,337	integrator	36°07'08"	114°50'28"
	Lake Mead, Las Vegas Bay, Deep	LVB-D	Las Vegas	Nev./Ariz.	May 11, 1998	NVBR	R	105.2	5,245	integrator	36°05'46"	114°47'56"
	Lake Mead, Colorado River Arm	MEAD	Las Vegas	Nev./Ariz.	May 14, 1998	NVBR	R	126.8	30,982	reference	36°08'45"	114°27'15"
11	Great Salt Lake, Farmington Bay	FAR	Salt Lake City	Utah	April 7, 1998	GSLB	L	1.2	10,313	urban–o	40°57'00"	111°58'00"
12	Decker Lake	DEK	Salt Lake City	Utah	April 6, 1998	GSLB	R	.9	26.7	urban–n	40°42'40"	111°57'00"
13	Red Butte Reservoir	RED	Salt Lake City	Utah	April 9, 1998	GSLB	R	7.6	19.7	reference	40°46'42"	111°48'40"
14	Dillon Reservoir	DLN	none	Colo.	Aug. 20, 1997	UCOL	R	64.9	865	mining	39°37'17"	106°03'23"
15	Sloans Lake	SLN	Denver	Colo.	Aug. 19, 1997	SPLT	L	1.1	8.24	urban–o	39°44'51"	105°02'57"
16	Cherry Creek Reservoir	CHC	Denver	Colo.	Aug. 18, 1997	SPLT	R	7.0	997	urban–n	39°38'29"	104°51'48"
17	Lake Como, Lower	CMO.1	Fort Worth	Tex.	March 8, 2001	TRIN	R	7.8	2.7	urban–o	32°43'38"	97°23'56"
	Lake Como, Middle	CMO.3	Fort Worth	Tex.	March 8, 2001	TRIN	R	5.3	2.7	urban–o	32°43'41"	97°23'57"
	Lake Como, Upper	CMO.5	Fort Worth	Tex.	March 8, 2001	TRIN	R	2.0	2.7	urban–o	32°43'44"	97°24'01"
18	Fosdic Lake, Lower	FOS.2	Fort Worth	Tex.	March 7, 2001	TRIN	R	3.6	1.2	urban–o	32°45'21"	97°15'28"
	Fosdic Lake, Middle	FOS.4	Fort Worth	Tex.	March 7, 2001	TRIN	R	2.4	1.2	urban–o	32°45'18"	97°15'32"
	Fosdic Lake, Upper	FOS.5	Fort Worth	Tex.	March 7, 2001	TRIN	R	1.4	1.2	urban–o	32°45'16"	97°15'32"
19	White Rock Lake	WRL	Dallas	Tex.	July 6, 1994	TRIN	R	4.6	264	urban–n	32°49'20"	96°43'15"
	White Rock Lake	WRL	Dallas	Tex.	June 11, 1996	TRIN	R	4.9	264	urban–n	32°49'20"	96°43'15"

Table 2. Basic characteristics of lakes described in this report—Continued.

Map ID (fig. 1)	Lake name	Site ID	Nearby major urban area	State	Date sampled	NAWQA study unit or cooperator[1]	Lake or reser-voir[2]	Water depth (m)	Drainage area (km^2)	Dominant land use setting	Latitude	Longitude
20	Echo Lake, Lower	ECO.1	Fort Worth	Tex.	March 6, 2001	TRIN	R	4.6	2.6	urban–o	32°41'56"	97°18'52"
	Echo Lake, Middle	ECO.4	Fort Worth	Tex.	March 6, 2001	TRIN	R	3.0	2.6	urban–o	32°42'00"	97°18'57"
	Echo Lake, Upper	ECO.3	Fort Worth	Tex.	March 6, 2001	TRIN	R	1.3	2.6	urban–o	32°42'01"	97°19'02"
21	Town Lake	TWN	Austin	Tex.	Aug. 26, 1998	COA	R	8.7	405	integrator	30°14'44"	97°43'04"
22	Lorence Creek Lake	LRC	San Antonio	Tex.	Aug. 23, 1996	SCTX	R	.9	5.0	urban–n	29°35'47"	98°28'34"
23	Lake Houston, East	HOE	Houston	Tex.	July 9, 1997	COH	R	6.4	2,828	reference	30°01'13"	95°07'11"
	Lake Houston, West	HOW	Houston	Tex.	July 9, 1997	COH	R	5.5	2,828	urban–n	30°01'05"	95°08'39"
	Lake Houston, South	HOS	Houston	Tex.	July 10, 1997	COH	R	13.4	2,828	integrator	29°55'25"	95°08'26"
	Lake Houston	HON	Houston	Tex.	July 10, 1997	COH	R	7.3	2,828	integrator	29°55'58"	95°09'59"
24	Lake Livingston	LIV.AC	none	Tex.	Aug. 1, 1992	TRIN	R	21.6	42,921	integrator	30°38'07"	95°01'11"
	Lake Livingston	LIV.CC	none	Tex.	Aug. 1, 1992	TRIN	R	18.0	42,921	integrator	30°41'44"	95°07'30"
	Lake Livingston	LIV.FC	none	Tex.	Aug. 1, 1992	TRIN	R	17.7	42,921	integrator	30°48'43"	95°10'40"
25	Palmer Lake, West Lobe	PLM.W	Minneapolis	Minn.	July 30, 1997	UMIS	L	.6	64.2	urban–n	45°04'55"	93°19'04"
	Palmer Lake, East Lobe	PLM.E	Minneapolis	Minn.	July 30, 1997	UMIS	L	.8	.3	reference	45°04'55"	93°18'49"
	Palmer Lake, East Lobe	PLM.E	Minneapolis	Minn.	Oct. 15, 1999	UMIS	L	.8	.3	reference	45°04'55"	93°18'49’
26	Lake Harriet	HAR	Minneapolis	Minn.	July 29, 1997	UMIS	L	21.3	6.07	urban–o	44°55'32"	93°18'20"
27	Lake in the Hills	LKH	Chicago	Ill.	July 19, 2001	UIRB	R	8.5	24.0	urban–n	42°10'49"	88°19'08"
28	Shoe Factory Road Pond	SHO	Chicago	Ill.	July 18, 2001	UIRB	L	.5	.02	reference	42°03'03"	88°11'59"
29	Busse Lake	BUS	Chicago	Ill.	July 18, 2001	UIRB	R	.3	128	urban–n	42°02'15"	88°01'00"
30	Beck Lake	BEC	Chicago	Ill.	July 17, 2001	UIRB	R	4.0	3.26	urban–n	42°04'31"	87°52'26"
31	Lake Sidney Lanier, Chattahoochee	LLCHT	none	Ga.	May 10, 1994	ACFB	R	29.0	1,517	reference	34°17'41"	83°54'51"
	Lake Sidney Lanier, Chestatee	LLCST	none	Ga.	May 10, 1994	ACFB	R	22.9	726	reference	34°19'47"	83°56'56"
32	Berkeley Lake	BRK	Atlanta	Ga.	May 19, 1999	ACFB	R	15.2	3.01	urban–n	33°59'07"	84°11'07"
33	Lakewood Park Lake	LKW	Atlanta	Ga.	May 19, 1999	ACFB	R	3.1	14.5	urban–o	33°42'04"	84°23'25"
34	Panola Lake	PAN	Atlanta	Ga.	May 18, 1999	ACFB	R	5.2	.54	reference	33°37'57"	84°10'27"
35	West Point Lake	WP.55	Atlanta	Ga.	May 7, 1994	ACFB	R	--	9,170	integrator	33°03'44"	85°07'20"
	West Point Lake	WP.99	Atlanta	Ga.	May 5, 1994	ACFB	R	3.7	9,170	integrator	33°08'52"	85°03'20"
36	Lake Harding	HRD	none	Ga./Ala.	Sept. 19, 1994	ACFB	R	21.3	12,351	integrator	32°40'33"	85°06'02"
37	Lake Blackshear	BLK	none	Ga.	May 9, 1994	ACFB	R	--	9,093	agriculture	31°55'38"	83°55'12"
38	Lake Walter F. George	WFG	none	Ga./Ala.	May 7, 1994	ACFB	R	17.7	19,721	integrator	31°54'59"	85°06'14"

Table 2. Basic characteristics of lakes described in this report—Continued.

Map ID (fig. 1)	Lake name	Site ID	Nearby major urban area	State	Date sampled	NAWQA study unit or cooperator[1]	Lake or reser-voir[2]	Water depth (m)	Drainage area (km^2)	Dominant land use setting	Latitude	Longitude
39	Lake Seminole	SEM	none	Ga./Fla.	May 11, 1994	ACFB	R	--	44,490	integrator	30°46'22"	84°50'31"
	Lake Seminole	SEM	none	Ga./Fla.	Sept. 21, 1994	ACFB	R	--	44,490	integrator	30°46'22"	84°50'31"
40	Sand Lake	SND	Orlando	Fla.	Mar. 17, 1999	GAFL	R	4.6	.85	reference	28°43'18"	81°28'20"
41	Lake Orlando	ORL	Orlando	Fla.	Mar. 17, 1999	GAFL	L	3.7	3.41	urban–n	28°35'44"	81°26'04’
42	Lake Killarney	KIL	Orlando	Fla.	Mar. 16, 1999	GAFL	L	7.5	6.34	urban–n	28°35'56"	81°22'18"
43	Lake Anne	ANB	Washington D.C.	Va.	June 24, 1996	POTA	R	8.2	2.28	urban–n	38°57'53"	77°20'05"
	Lake Anne	ANN	Washington D.C.	Va.	June 23, 1996	POTA	R	6.4	2.28	urban–n	38°57'52"	77°20'10"
	Lake Anne	AN97	Washington D.C.	Va.	Sept. 24, 1997	POTA	R	6.2	2.28	urban–n	38°57'53"	77°20'05"
44	Fairfax Lake	FFX	Washington D.C.	Va.	Sept. 24, 1997	POTA	R	3.8	10.6	urban–n	38°57'54"	77°19'07"
45	Clyde Potts Reservoir	NJCP	Newark	N.J.	Sept. 15, 1997	LINJ	R	14.0	5.38	urban–n	40°48'25"	74°34'53"
46	Orange Reservoir	NJOR	Newark	N.J.	Sept. 18, 1997	LINJ	R	--	11.7	urban–o	40°45'36"	74°17'12"
47	Packanack Lake	NJPAK	Newark	N.J.	Sept. 17, 1997	LINJ	R	2.9	4.80	urban–n	40°56'04"	74°15'22"
48	Newbridge Pond	NEW	New York City	NY	Sept. 22, 1997	LINJ	R	1.8	7.91	urban–o	40°40'00"	73°32'39"
49	Big Round Top Pond, Lower Lake	BRT.B1	Boston	R.I.	July 25, 2000	NECB	R	1.2	23.3	reference	42°00'08"	71°42'01"
	Big Round Top Pond, Mid-lake	BRT.B2	Boston	R.I.	July 25, 2000	NECB	R	2.1	23.3	reference	42°00'10"	71°42'02"
	Big Round Top Pond, Upper Lake	BRT.B3	Boston	R.I.	July 25, 2000	NECB	R	1.5	23.3	reference	42°00'15"	71°42'01"
50	Maple Street Pond	MAP	Boston	Mass.	July 27, 2000	NECB	R	1.5	54.4	urban–n	42°07'09"	71°27'16"
51	Harris Pond, Lower	HSP.1	Boston	Mass.	July 26, 2000	NECB	R	1.5	82.8	urban–n	42°01'44"	71°30'25"
	Harris Pond, Middle	HSP.B2	Boston	Mass.	July 26, 2000	NECB	R	--	82.8	urban–n	42°01'48"	71°30'20"
	Harris Pond, Upper	HSP.B3	Boston	Mass.	July 26, 2000	NECB	R	--	82.8	urban–n	42°01'56"	71°30'16"
52	Upper Mystic Lake, Upper Lake	MYS.B2	Boston	Mass.	Aug. 31, 2000	NECB	L	1.4	66.2	urban–o	42°26'37"	71°08'41"
	Upper Mystic Lake, Lower Lake	MYS.2	Boston	Mass.	Aug. 31, 2000	NECB	L	1.4	66.2	urban–o	42°26'33"	71°08'51"
53	Charles River, Lower	CHA.B1	Boston	Mass.	July 28, 2000	NECB	R	9.8	787	integrator	42°21'15"	71°05'14"
	Charles River, Upper	CHA.B2	Boston	Mass.	July 28, 2000	NECB	R	4.9	728	integrator	42°22'02"	71°07'04"
54	South Reservoir	SRV	Boston	Mass.	Sept. 1, 2000	NECB	R	13.9	1.90	reference	42°26'39"	71°06'59"
55	Basin Brook Pond	BBP	none	N.H.	Aug. 29, 2000	NECB	R	3.9	7.26	reference	44°16'12"	71°01'13"
56	Crocker Pond	CRK	none	Maine	Aug. 30, 2000	NECB	L	2.7	.81	reference	44°18'31"	70°49'27"

[1] *NAWQA Study Units:* COOK, Cook Inlet Basin; PUGT, Puget Sound Basin; SANA, Santa Ana Basin; coop, non-NAWQA study performed with a cooperator; NVBR, Nevada Basin and Range; GSLB, Great Salt Lake Basins; UCOL, Upper Colorado River Basin; SPLT, South Platte River Basin; TRIN, Trinity River Basin; SCTX, South-Central Texas; UMIS, Upper Mississippi River Basin; UIRB, Upper Illinois River Basin; ACFB, Apalachicola-Chattahoochee-Flint River Basins; GAFL, Georgia-Florida Coastal Plain; POTA, Potomac River Basin; LINJ, Long Island- New Jersey Coastal Drainages; NECB, New England Coastal Basins. *Cooperative funding agencies:* COA, City of Austin, Tex.; COH, City of Houston, Tex.

[2] Lake refers to naturally formed water body; reservoir refers to impounded stream or any other man-made lake.

Collection of Cores

Selection of Coring Sites

The lakes presented here were sampled with the primary objective of describing trends in trace elements and HOCs over a time span of several decades or more. Determining spatial variability in sediment chemistry within a lake was not usually an objective; thus, only one location was sampled in most lakes. Site selection varied somewhat depending on the lake size, type (natural lake or reservoir), sedimentation rate, and geometry. Selecting a sampling site in a typical lake is a balance between three objectives. These objectives, and a brief rationale for each, are

1. **Sample undisturbed, relatively homogeneous fine-grained sediments.** To obtain a sample adequate to describe long-term trends, the sediment must not be disturbed by near-shore wave action, periodic exposure during low-water periods, dredging, or episodic erosion by floods. The tendency of trace elements and organic carbon (OC) to positively correlate with finer grain-size particles (Horowitz and Elrick, 1987) results in higher concentrations and higher frequencies of detection in fine-grained sediments. The sorting action of a lake generally leads to homogeneous, fine-grained sediment in the middle and lower parts of the lake. This improves the confidence in the interpretation of trends in a core by reducing “natural” variability in bulk properties that can affect contaminant concentrations (for example, grain size and OC content) among subsamples of the core.
2. **In reservoirs, penetrate to the pre-reservoir land surface.** Sampling to the pre-reservoir land surface assures the longest temporal record possible and provides a reliable date marker at the bottom of the core.
3. **Obtain as thick a sequence of lacustrine sediment as possible.** Higher sedimentation rates allow for a finer temporal resolution in sampling and reduce the effects of postdepositional mixing and diagenesis on obscuring trends.

On the basis of these objectives, cores in reservoirs usually were collected in the middle or lower part of the reservoir. In natural lakes, where sediment deposition tends to be greatest in the deeper central basin of the lake, cores usually were collected from the deepest part of the lake. It is these areas where disturbance of the sediment is least likely and where sediment is more homogeneous in bulk properties.

Another consideration in selecting a sampling site is sedimentation rate. Sediment deposition in a reservoir normally is focused into the pre-reservoir stream channel and varies along the axis of the reservoir, decreasing from the river inflow to the dam (Van Metre and others, 2001; Wilson and Van Metre, 2000). Higher sedimentation rates reduce the effects of diagenesis (Callender, 2000) and postdepositional mixing (Robbins, 1986) and improve the temporal resolution of individual core intervals.

In reservoirs, reconnaissance cores were collected before selection of a sampling site, usually in the pre-reservoir stream channel in the lower or middle part of the reservoir. If lacustrine sediment there was relatively thin (less than about 50 centimeters [cm]), the sampling site was moved upstream to where the sediment was thicker or a box corer was used, or both. This was the case in eastern reservoirs (for example, Lake Sidney Lanier in Georgia) and some reference reservoirs in the West (for example, Tolt Reservoir in Washington). The tradeoff in moving upstream is that sediment deposition in the river delta at the upper end of the reservoir is more episodic and variable in bulk properties such as grain size. Also a risk is that deltaic sediment has been eroded during periods of low lake level. If sediment in the pre-reservoir channel at the first reconnaissance site was too thick to penetrate the pre-reservoir land surface, the sampling was moved downstream. If the sediment was still too thick near the dam, the sampling was moved off-channel onto the pre-reservoir flood plain. This was the case in some western reservoirs with very high sedimentation rates such as Lake Mead in Nevada and Arizona.

Selection of Boat and Coring Tools

The size of the lake dictated the size of boat used and hence the coring tools that could be used. In the larger lakes, if a boat ramp was available, a 7.5-meter- (m) long pontoon boat with a 4.5-m A-frame was used to collect cores (fig. 2a). This vessel has the advantages of allowing the use of a hydraulic winch to deploy gravity, piston, and box corers, having sufficient height for recovery of long cores (as long as about 3.5 m), and providing plenty of workspace. In addition, it has an outboard motor so it can cover the long distances necessary for coring large lakes. For smaller lakes and lakes without boat ramps, a Zodiac raft outfitted with a small crane and hand-operated winch was used (fig. 2b). The Zodiac, although less versatile in terms of coring options than the pontoon boat, has the advantage of easier launching and more portability. Outfitted with a crane and winch, the Zodiac can be used to deploy box corers and gravity and piston corers as long as about 1.5 m. It also can be used with an outboard motor. In a few very small lakes, small lightweight inflatable boats with trolling motors or oars were used. Although difficult to work from, these boats have the advantage of being transportable to sites inaccessible by vehicle. Push cores can be collected from these boats by pushing liners directly into the lake sediment by hand, and short (1 m or less) gravity cores and box cores can be collected by lowering and raising the sampler with a rope.

There are advantages and disadvantages to each coring tool that affect the selection of a tool for a given study. One consideration is the thickness of sediment to be sampled. In lakes with high sedimentation rates, for example, midwestern and western reservoirs with linear sedimentation rates of several centimeters per year or more, gravity and piston corers were used because they collect a much longer core than a box corer. These corers collect a core that is 6.7 cm in diameter and as long as 3 m that typically are sampled on a 2- to 3-cm or greater

Figure 2. (a) Pontoon boat with A-frame used to collect sediment cores in large lakes, and (b) Zodiac raft with crane and hand-operated winch used to collect sediment cores in smaller lakes.

interval to obtain sufficient material for chemical analysis. The temporal scale provided by this interval is sufficient if the sedimentation rate is on the order of 1 centimeter per year (cm/yr) or more. For lakes with lower sedimentation rates (for example, eastern lakes), 20-, 30-, and 50-cm tall box corers were used. These corers provide more material for a given interval than the tubular corers; thus, sufficient material for chemical analysis can be obtained from a 0.5-cm interval. Another important advantage of the box corers is that they collect a less-disturbed core than the gravity and piston corers because they have a larger cross-sectional area, are lowered gently into the bottom, and have jaws that close below the sample to hold it in place.

The choice between using a piston or gravity corer is influenced by several factors. The gravity corers used by the RTNS are easier to use than the piston corer and probably collect a less-disturbed core. Thus, they were used frequently, especially for reconnaissance cores. There is, however, one important limitation of gravity corers—core shortening. Core shortening is the thinning of sediment layers recovered by gravity corers relative to undisturbed sediment, and it has been attributed to friction on the walls of the liner (Emery and Hulsemann, 1964). In addition to friction, the sediment in the barrel of a gravity corer must push water out the top through the check valve, which creates backpressure inside the liner. A piston and a gravity core were collected side-by-side in White Rock Lake, Tex., in 1998. Both encountered pre-reservoir sediment, and on the basis of color banding in the cores, both appeared to represent the full sediment sequence. Age-dating of other gravity cores from White Rock Lake confirms that the full sediment sequence was sampled (Van Metre and Callender, 1997). The thickness of lacustrine sediment in the piston core was 206 cm compared with 122 cm in the gravity core, a core shortening of 41 percent. In side-by-side comparisons of box cores and gravity cores collected from Lake Anne, Va., in 1996 and 1997, shortening of about 35 percent occurred in the gravity cores, even though the lacustrine sediment was only about 20 cm thick and a slow entry with no catcher[1] or cutting head[1] was used for the gravity cores. Thus, if contaminant mass accumulation in the core is a primary

---

[1] Explained in next section.

objective (as opposed to concentration trends), either piston or box corers should be used or shortening should somehow be accounted for (Juracek, 1998).

Coring

Once a coring site was selected, basic field data were recorded and one or more cores were collected for description and for subsampling for physical properties and chemical analysis. The latitude and longitude of the coring site was obtained from a global positioning system (GPS) or, in a few cases, was estimated from a USGS topographic map. The depth of water at each site was obtained using a fathometer. Each core collected was assigned an identifier (ID) in the field and the approximate depth of sediment recovered was noted. The ID typically consists of a three-letter abbreviation of the lake name followed by the core number or by B, BC, or Box if it was a box core. For example, HAR.2 was the second gravity core collected from the sampling location in Lake Harriet, Minn., and HAR.B was the box core collected from the same location. In some cases, core numbers or location information such as a buoy number are enclosed in parentheses. The date and approximate time of core collection was recorded for each core. Individual samples from a core used the core ID plus the sampling interval, in centimeters, as identifier.

Core collection varies by coring tool type, configuration of the boat, and technique of the crew. Gravity corers used in this study have a steel barrel with a polybuterate liner. The liner has a check valve in the top that lets water out during penetration and that closes and helps retain sediment during recovery. The bottom of the liner can have a core catcher inserted to help retain sediment, and the core barrel can have a cutting head attached to help penetrate firmer sediment and protect the liner. The corer can be lowered slowly into the bottom or allowed to free-fall; recovery can vary depending on firmness and texture of the sediment. A common approach used by RTNS when cores of less than about 1.5 m were expected was to configure the gravity corer with no barrel, cutting head, or catcher (only a check valve and liner extending from the weight stand[2], held in place by a polyvinyl chloride flange and hose clamps), and ample weight on the weight stand (usually three 20-kilogram [kg] weights). The corer was lowered gently into the bottom sediment, and the bottom of the core was capped as soon as it approached the water surface during retrieval. The cap was taped on while the coring tool was suspended vertically from the A-frame, and the core was removed and stored upright until subsampling. To minimize the potential for disturbance during transport to shore, core liners were cut about 1 cm above the top of the sediment, and the top was capped and taped. When longer cores or greater penetration was needed, a core barrel (steel pipe extending from the weight stand) was added along with a cutting head and catcher, and the corer was allowed to free-fall from several meters above the bottom of the lake.

The piston corer used in this study has the same weight stand and barrel as the gravity corer and has a piston inside the core barrel connected by a cable to a trigger arm above the corer, and from there to the winch on the boat. The trigger arm holds the corer until it nears the bottom; when the trigger weight below the arm reaches the bottom, the arm releases the corer allowing it to fall past the piston into the sediment. The piston is stopped just above the top of the sediment by the cable attached to the winch (assuming the length of cable between the trigger arm and piston and the length of rope between the trigger arm and trigger weight are properly measured and the winch operator stops lowering as soon as the trigger arm releases the sampler). As the barrel falls past the piston into the sediment, a strong vacuum is created below the piston enhancing the recovery of sediment. The winch pulls the piston to the top of the barrel, if it is not there already, and then lifts the corer. The trigger arm and weight are unbolted from the cable when they reach the boat, then the barrel is raised above water level, and the core is capped and removed vertically. The piston corer works much like a syringe with the bottom cut off to create an open cylinder—the plunger is the piston and the outside of the syringe is the core barrel. The plunger (or piston) is held in place just above the sediment and the outside is pushed past it into the sediment. In fact, small cores of soft, fine-grained sediments have been collected from spring pools by the authors using plastic syringes in this way.

The third type of corer used in this study is the box corer. Four sizes have been used, all 14-cm square and 20-, 30-, 50-, and 100-cm tall. The box corers collect a larger cross-sectional area and a less-disturbed core than piston or gravity corers because they are lowered gently into the bottom sediment, have jaws that close below the sample to hold it in place, and with a larger cross-sectional area, have less friction to cause shortening. Weights can be added to achieve greater penetration, although in soft lacustrine sediment, too much penetration is just as often a problem as too little. The corers have a spring pin holding the jaws open until weight is removed by penetration into the bottom sediment allowing the pin to pop out. As the rope or cable is pulled, the arm to which it is attached pulls the jaws closed and then lifts the sampler. As manufactured, the jaws must be opened to remove the acrylic sample liner, an action that can disturb the sediments and is especially difficult with the taller corers. One 50-cm box corer was rebuilt by the RTNS to allow removal of the liner from the side of the box without opening the jaws. With this corer, a stainless steel plate is inserted below the bottom of the sediment-filled liner, and the liner is gently pulled sideways out of the sampler onto a square piston that fits into the bottom.

---

[2] The body of the corer with fins and space to hold weights.

Figure 3. U.S. Geological Survey personnel (a) describing a gravity core, (b) placing gravity core in core extrusion stand, and (c) slicing a subsample from a gravity core.

Subsampling and Description of Cores

Cores were held vertical during removal from samplers and transport and were described and subsampled on shore soon after collection. A core collected for description, always a gravity or piston core, was split lengthwise by cutting most of the way through the polybuterate liner using a circular saw, cutting the rest of the way through with a utility knife, then slicing the sediment with a Teflon or stainless steel spatula. The core was laid open next to a tape measure and described (fig. 3a).

Descriptions included color, texture, odor, and the presence or absence of biota and organic detritus or other visible debris. In cores from reservoirs, identification of the pre-reservoir land surface usually was an easy and important part of the description. Lacustrine sediments have a high water content (porosity of about 70 to 90 percent) and mostly are fine-grained particles (typically no sand and 60- to 90-percent clay-sized particles). Pre-reservoir soils are differentiated from lacustrine sediments by changes in color and texture, for example, the presence of sand- and gravel-sized grains, a drier or stickier texture, or both, and the presence of root hairs. Often the top of the pre-reservoir soil is marked by a layer of decaying leaves and sticks.

Early in this study, multiple cores frequently were collected and subsampled at a site for different groups of constituents, often at different depth intervals. For example, samples were taken for major and trace elements from one core at 1-cm intervals and for organic compounds from another core at 2-cm intervals. This approach led to considerable uncertainty in some cases in correlating information between the cores, including age estimates. It is preferable that all samples come from the same core to avoid uncertainty in extrapolating age estimates from one core to another and to aid in correlating trends in one group of constituents with another. In most lakes sampled after 1997, a single core was used to analyze all constituents for a given site.

Sampling intervals in cores varied depending on objectives, sedimentation rate in the lake, and sample mass requirements. As a general guideline, sample intervals representing from about 1 to 3 years of sediment deposition were collected. The dry mass of sediment needed for all chemical analyses is minimally about 10 grams (g) and preferably 25 g or more. A gravity or piston corer with a diameter of 6.7 cm has a volume of 35.2 cubic centimeters (cm^3) in a 1-cm slice. Box corers used in this study are 14-cm square, so a 1-cm slice has a volume of 196 cm^3. The porosity of sediment with a high OC concentration (greater than about 10 percent), typical of natural lakes in the northeastern United States and Florida, often is in the 90- to 95-percent range, and the density of the sediments can be as low as 1.2 grams per cubic centimeter (g/cm^3). Thus, a 1-cm slice of a gravity or box core can contain as little as about 2 or 10 g of sediment, respectively. With linear sedimentation rates that typically range from 0.1 to 1.0 cm/yr, the box corer, with a minimum sampling interval of 0.5 cm, is the tool of choice for sampling natural lakes. In reservoirs in the southern, central, and western United States, porosity typically is more than 90 percent at the top of the core and decreases exponentially with depth because of compaction, and porosities of about 70 percent are common in deeper sediments. OC concentrations are low, ranging from about 1 to 2.5 percent, and density of solids approaches 2.5 g/cm^3. A 1-cm slice from the top of a gravity core from one of these lakes can contain 9 g of dry sediment and a slice from deeper in the core can contain 25 g. Linear sedimentation rates are often 2 to 5 cm/yr or more, so a sampling interval of 2 to 5 cm in a gravity core can provide sufficient sediment for all analyses.

Cores collected for physical and chemical analysis were sectioned into discrete samples by vertical extrusion. An extendable piston was inserted into the bottom of the tubular core (gravity or piston), and the core was placed in a stand to hold it upright (fig. 3b). A short segment of core liner (a ring) was placed on the top of the core and the liner was pushed down onto the piston, pushing sediment up into the ring to a marked thickness (2 cm for example; fig. 3c). A thin, flat stainless steel plate was then slipped between the ring and the top of the core liner to slice off the measured interval, which then was transferred to a sample container. Each sample was labeled with the core ID followed by the depth interval of the sample in centimeters. A similar process was followed for box cores (fig. 4), except that in some cases a stainless steel screw-driven piston was used, providing more sensitive control of sampling intervals. The sampling tools were rinsed in ambient lake water or tap water, soaked and washed with a brush in water with phosphate-free detergent, and rinsed again in ambient lake water or tap water between subsamples. Samples for analysis of major and trace elements and radionuclides were placed in cleaned polypropylene jars. Samples for analysis of organic compounds were placed in baked glass jars. All samples were chilled pending shipment to the laboratory. Samples for grain-size analysis were collected from the major and trace element and radionuclides samples before drying.

Analysis of Cores

Major and Trace Elements

In the laboratory, sediment samples for elemental (and radionuclide) analyses were weighed, frozen, freeze-dried, reweighed, and then ground to a fine power. Elemental concentrations were determined on concentrated-acid digests (nitric-hydrofluoric in microwave pressure vessels) by inductively-coupled plasma-atomic emission spectrometry (ICP/AES) (Arbogast, 1996) and by graphite furnace atomic adsorption spectrometry (GF/AAS) (Aruscavage and Crock, 1987) for 40 lakes at a USGS laboratory in Reston, Va. For 15 lakes, samples were digested on a hot plate using a mixture of hydrochloric-nitric-perchloric-hydrofluoric acids and analyzed by inductively coupled plasma-mass spectrometry (ICP/MS) (Arbogast, 1996) at a USGS laboratory in Denver, Colo. Mercury was analyzed by cold vapor atomic adsorption spectrometry in both laboratories (Arbogast, 1996). No elemental analyses were performed for Cherry Creek Reservoir, Colo., as the samples were lost during shipment to the laboratory. Quality assurance was provided at both laboratories by determining the elemental concentrations for duplicate samples and a variety of soil, lake, and marine reference samples (Arbogast, 1996).

Figure 4. U.S. Geological Survey personnel subsampling a box core.

Organic Compounds

All organic compound analyses were performed at the USGS National Water Quality Laboratory (NWQL) in Denver, Colo. In several lakes sampled between 1992 and 1996, organochlorine pesticides and polychlorinated biphenyls (PCBs) were measured using the method of Wershaw and others (1987); polycyclic aromatic hydrocarbons (PAHs) were not measured. Beginning in 1996, HOCs, including organochlorine pesticides, PCBs, PAHs, and alkyl-substituted PAHs (alkyl-PAHs) were extracted, isolated, and analyzed using a variation of the procedures of Foreman and others (1995) and Furlong and others (1996) under the NWQL code LC8375. Briefly, for LC8375, wet bottom sediment is extracted overnight with dichloromethane in a Soxhlet apparatus. The extract is reduced in volume and filtered. Two aliquots of the sample extract are quantitatively injected into a polystyrene-divinylbenzene gel permeation column (GPC) and eluted with dichloromethane to remove sulfur and partially isolate the target analytes from coextracted high-molecular-weight interferences such as humic substances. The first aliquot is analyzed for PAHs and alkyl-PAHs by capillary-column gas chromatography (GC) with detection by mass spectrometry. The second aliquot is further split into two fractions by combined alumina/silica adsorption chromatography prior to determination of the organochlorine pesticides and PCBs by dual capillary-column gas chromatography with electron capture detection.

Variations on the procedures of Foreman and others (1995) for the determination of organochlorine pesticides and PCBs include the addition of a final micro-Florisil column cleanup step and instrumental analysis of a subset of analytes using a shorter GC temperature program. Most organochlorine pesticides are reported as individual compounds. Technical chlordane is estimated from concentrations of trans-nonachlor, cis-chlordane, and trans-chlordane. PCBs are reported as individual Aroclor (1016/1242, 1254, or 1260) equivalents. This method was approved in 2003 as USGS method O–5504–03 for bed sediment and O–7504–03 for suspended sediment (Noriega and others, 2003).

Variations on the procedures of Furlong and others (1996) for the determination of PAHs include the addition of a silica column cleanup step following the GPC step. Parent PAHs are identified and quantified by comparison to authentic standards. Individual alkyl-PAHs are quantified when authentic alkyl-substituted standards are available. The multiple isomeric alkyl-PAHs are quantified from mass chromatograms as the sum of all isomers at each alkylation level (C1-naphthalenes, C2-naphthalenes, and so forth). When authentic alkyl-substituted standards are unavailable, a parent PAH is used as the standard for quantitation. Nineteen parent PAHs, 10 specific alkyl-PAHs, and the homologous series of alkyl-PAHs are determined. This method was approved in 2003 as USGS method O–5505–03 (Olson and others, 2003).

Radionuclides

The primary age-dating tool used was the ^{137}Cs profile in the core; ^{137}Cs was analyzed in cores from 49 of the 56 lakes presented here. Lead-210 (^{210}Pb), another radionuclide used for age-dating cores, was analyzed in addition to ^{137}Cs in cores from 10 of the 49 lakes. Cores from seven reservoirs were not analyzed for radionuclides because the reservoirs were built after the ^{137}Cs peak in 1964 and were therefore too young to obtain ^{137}Cs results useful for age dating. ^{137}Cs analyses on the cores were performed at five different laboratories and ^{210}Pb analyses at three laboratories. Of the 49 cores analyzed for ^{137}Cs, 23 were analyzed at a USGS National Research Program (NRP) laboratory in Menlo Park, Calif. (NRP Menlo Park lab). Fourteen were analyzed for ^{137}Cs at Severn-Trent Laboratory in Richland, Wash., under contract with the USGS NWQL in Denver, Colo. (NWQL lab). Six cores were analyzed for ^{137}Cs at a USGS Geologic Discipline laboratory in Denver, Colo. (GD lab). Samples from Lake Mead were analyzed for ^{137}Cs at the University of Nevada Las Vegas laboratory in Las Vegas, Nev. (UNLV lab) (Mark Rudin, University of Nevada Las Vegas, written commun., 2001). Samples from one site, Big Round Top Pond in Massachusetts, were analyzed for ^{137}Cs at a USGS NRP laboratory in Reston, Va. (NRP Reston lab). Of the 10 lakes where cores were analyzed for ^{210}Pb in addition to ^{137}Cs, six were analyzed at the GD lab, three were analyzed at the NRP Menlo Park lab, and one at the NWQL lab. These laboratories use similar methods, described briefly below.

^{137}Cs activity was measured in all 49 lakes by counting freeze-dried sediments in fixed-geometry with a high-resolution, intrinsic germanium detector gamma-spectrometer (Robbins and Edgington, 1976). Activities of ^{210}Pb were measured in 10 lakes by high-precision gamma-ray spectrometry (Baskaran and Naidu, 1994). A high-purity germanium coaxial detector was used for gamma-ray emissions between 200 and 2,000 kiloelectron volts (keV) (including ^{137}Cs), and low-energy photon planar detector was used to detect gamma-ray emissions between 40 and 400 keV (including ^{210}Pb).

Quality Assurance

Quality assurance for major and trace element analyses was provided by analyzing several standard reference materials (SRM), an environmental duplicate, and a blank sample with each batch of as many as 20 samples. The two methods used for elements both performed well, on the basis of analyses of four of the same SRMs. Median relative percent difference (RPD) for all elements for all SRMs was 2.0 percent for ICP/AES (and GF/AAS for cadmium and arsenic) and 4.4 percent for ICP/MS (Van Metre and Mahler, 2004). Sediment samples analyzed for all major and trace elements in duplicate by both methods had a median RPD of 2.6 percent (table 3).

Quality assurance for HOC analyses using LC8375 was provided with each set of 12 environmental samples by analyzing a laboratory reagent blank sample, organochlorine compound and PAH laboratory reagent spike samples, an environmental-sample duplicate, and a certified reference material (CRM) (either CRM 354 or CRM 362) containing selected organochlorine pesticides and PAHs (Olsen and others, 2003). Surrogate compounds were added in sample preparation and analyzed to monitor the efficiency of the preparation procedure. The spike sample contains most of the individual organochlorine pesticide compounds, a mixture of PCB Aroclors 1242, 1254 and 1260, and selected PAHs. Reporting levels have been

Table 3. Summary of the relative percent difference (RPD) of duplicate analyses for selected constituents.

Constituent	Number of duplicates[1]	25th percentile of RPDs	Median RPD	75th percentile of RPDs
Organochlorine compounds				
Technical chlordane	20	11.5	17.7	31.2
Dieldrin	13	7.3	18.6	26.0
p,p'-DDE	38	5.1	7.4	18.9
p,p'-DDD	26	5.0	18.0	38.5
p,p'-DDT	16	7.0	23.8	54.9
PCB Aroclor 1242	15	3.0	8.5	16.7
PCB Aroclor 1254	25	4.0	6.5	14.3
PCB Aroclor 1260	24	3.2	8.4	26.3
All organochlorine compounds		5.1	11.8	26.0
Polycyclic aromatic hydrocarbons				
Naphthalene	39	4.6	14.6	27.3
Methylated naphthalenes	38	7.6	14.1	29.1
Acenaphthylene	33	7.7	14.8	21.4
Acenaphthene	31	4.8	11.8	27.4
9H-Fluorene	38	4.6	10.1	18.2
Phenanthrene	41	4.9	9.4	20.2
Anthracene	41	3.8	8.2	23.6
Fluoranthene	41	6.1	10.2	20.5
Pyrene	41	6.1	9.7	22.3
Benz(a)anthracene	40	3.7	11.4	19.5
Chrysene	41	6.2	15.4	21.0
Benzo(a)pyrene	39	4.5	12.6	21.2
Dibenzo(a,h)anthracene	29	7.0	14.3	30.8
All polycyclic aromatic hydrocarbons		5.2	11.9	21.6
Major and trace elements				
Organic carbon	82	.7	1.5	3.5
Aluminum	171	.7	1.9	4.6
Iron	172	1.0	1.9	4.1
Titanium	167	0	3.0	5.7
Arsenic	164	1.4	3.4	6.5
Cadmium	148	1.3	3.0	5.4
Chromium	167	2.0	3.3	6.3
Copper	167	1.1	2.2	4.3
Lead	171	1.0	2.2	5.2
Mercury	106	3.2	5.8	8.7
Nickel	167	1.1	2.3	4.8
Zinc	172	1.0	1.9	3.6
All major and trace elements		1.1	2.6	5.3

[1] Total of 41 possible; number of duplicates listed is for samples with detections for given compound.

established from method detection level determinations for the organochlorine-compound (Noriega and others, 2003) and PAH (Olson and others, 2003) methods. Forty-six of the 56 lakes had organochlorine compounds measured and 48 of the 56 lakes had PAHs measured using LC8375. The median RPD for all organochlorine compounds in 38 duplicate samples was 11.8 percent (table 3). The median RPD for all PAH compounds in 41 duplicate samples was 11.9 percent.

Each of the five laboratories that were used for radionuclide analyses has established quality assurance/quality control procedures that include analysis of environmental duplicates, blank analyses to determine background corrections, and analysis of SRMs to calibrate instruments. Two of the USGS laboratories, the NRP Menlo Park lab and the GD lab, participated in an inter-laboratory comparison in 1999 using sediment samples from White Rock Lake, Tex. The comparison, which included six different USGS laboratories, indicated similar results for these two laboratories.

Sample contamination during collection and subsampling of a core, either by smearing of sediment along the walls of the core liner or by ineffective cleaning of tools, is a potential concern but is difficult to assess directly. No standard approaches are available and no attempts were made to run sediment-based equipment blanks on core-sampling equipment. Using water as the medium will not simulate the chemical or physical processes potentially affecting sediments during coring. There is, however, evidence from field studies indicating that little if any cross-contamination of core samples is occurring using the methods described here. The most compelling evidence is nondetections of ^{137}Cs and man-made organic compounds in deeper, older sediments in cores. A core collected from White Rock Lake in Dallas, Tex., in 1994, for example, spanned deposition dates from 1912 to 1994. The first detections of ^{137}Cs occurred in the 63- to 66-cm sample; the pre-reservoir surface was at 136 cm, and ^{137}Cs was not detected in the 66- to 69-cm sample or below (Van Metre and Callender, 1997). The detection limit was approximately 0.02 picocurie per gram (pCi/g) and the peak activity, at 48 to 51 cm, was 1.34 pCi/g, 67 times greater than the detection level. The corer had to pass through ambient lake water. The bottom of the corer, where the nondetections were recorded, had to pass through all of the upper, younger sediment layers during collection and subsampling. Those younger layers were sampled first as the core was vertically extruded, meaning the tools were used for the more contaminated samples first, and the ^{137}Cs-free older sediment was pushed up through the part of the liner where the more contaminated sediments were previously in contact. Nondetection of ^{137}Cs and synthetic (non-natural) organic compounds in the deeper part of the core indicate that no detectable cross-contamination of samples occurred.

Age-Dating of Cores

Date of deposition for sediment intervals within each core was determined on the basis of a variety of depth-date markers and one of four interpolation approaches for intervening layers. Commonly used depth-date markers include the ^{137}Cs peak (in 1964), the pre-reservoir land surface (assigned the construction or impoundment date of the reservoir), and the sampling date at the top of the core. The approach used to assign dates between depth-date markers depended on the age of the lake, available chemical data for the core, results of age-dating other cores from the lake, and known changes in the watershed that could affect sedimentation or chemical inputs to the lake, for example, the construction of a reservoir upstream or the onset of urban development.

Mass Accumulation Rates

A constant or variable mass accumulation rate (MAR) was used to assign ages for samples at depth intervals between known depth-date markers. A MAR (reported here as grams per square centimeter per year) is the rate of accumulation of sediment, in dry mass, for a unit surface area of the core or the lake. Linear sedimentation rate was used in a few cases where MARs could not be computed. A linear sedimentation rate (reported here as centimeters per year) assumes a given thickness of sediment is deposited per time interval and that this does not change between depth-date markers. MARs are preferable because they automatically adjust for compaction in a core, whereas linear sedimentation rates do not. The effect of compaction on the amount of time represented by a given depth interval is quite pronounced. A 1-cm interval at a porosity of 90 percent at the top of a core will compact to only 0.33 cm at a porosity of 70 percent deeper in the core.

A MAR is computed as the mass of dry sediment per unit area of an interval of a core, divided by the time the interval represents. The mass of dry sediment is computed as the sum of the dry mass in each of the samples on a unit area basis (*DryMass*). Because the core sediment contains water, density of solids (*DS*) and porosity (*n*) are needed to estimate *DryMass*. For most samples collected before 1999, *DS* was assumed to be 2.5 g/cm^3, on the basis of 10 density measurements made on reservoir sediments collected early in the study that had densities ranging from about 2.3 to 2.6 g/cm^3. Using the assumed *DS*, *n* was computed as

$$n = (WW\text{-}DW)/([WW\text{-}DW] + [(DW\text{-}TW)/DS]), \qquad (1)$$

where

WW = wet weight (grams),
DW = dry weight (grams),
TW = tare weight of container (grams), and
DS = density of solids (grams per cubic centimeter).

The term *WW-DW* is the volume of water (V_w), in cubic centimeters, in the sample, assuming the density of water is 1 g/cm^3. The term (*DW-TW*)/*DS* represents the volume of solids in the sample, in cubic centimeters.

Beginning in 1999, *DS* was measured by weighing measured volumes of sediment before and after freeze-drying; the difference is V_w (assuming the density of water is 1 g/cm^3). Using this approach, *n* was computed as

$$n = V_w \,/\, V_T, \qquad (2)$$

where

V_T = the total volume of the sample, in cubic centimeters, and

$$DS = (DW\text{-}TW)/(V_T - V_w). \qquad (3)$$

Table 4. Comparison of *DryMass* computations using measured bulk density versus an assumed bulk density of 2.5 grams per cubic centimeter for box core BRT.B1 collected from Big Round Top Pond, R.I.

[cm, centimeters; g, grams; cm^3, cubic centimeters; g/cm^3, grams per cubic centimeters; --, not applicable; ?, not known]

Sample	Mid depth (cm)	Tare weight (*TW*) (g)	Wet weight (*WW*) (g)	Dry weight (*DW*) (g)	Water weight (*Vw*) (g)	Solids volume (*Vs*) (cm^3)	Solids density (*DS*) (g/cm^3)	Porosity (*n*)	Unit dry mass (*DryMass*) (g/cm^3)	Organic carbon (percent)	Error in unit dry mass (percent)
					Unit dry mass computed from measured bulk density						
BRT.B1 1-2	1.5	7.276	48.5	11.654	36.8	3.2	1.39	0.92	0.109	17.0	--
BRT.B1 3-4	3.5	7.108	48.7	12.097	36.6	3.4	1.47	.92	.125	15.5	--
BRT.B1 5-6	5.5	7.268	49.6	14.204	35.4	4.6	1.51	.88	.173	13.7	--
					Unit dry mass computed from wet/dry weights and assumed density of solids of 2.5 g/cm^3						
BRT.B1 1-2	1.5	7.276	48.5	11.654	36.8	?	2.5	.95	.113	17.0	3.6
BRT.B1 3-4	3.5	7.108	48.7	12.097	36.6	?	2.5	.95	.129	15.5	3.6
BRT.B1 5-6	5.5	7.268	49.6	14.204	35.4	?	2.5	.93	.182	13.7	4.8

Measured densities were computed as about 2.2 to 2.5 g/cm^3 for low-OC sediments (1 to 3 percent OC) and generally ranged from about 1.2 to 2 g/cm^3 in the high-OC sediments (10 to 35 percent OC). In a few samples very high in OC, measured density was less than 1 g/cm^3. Densities less than 1 g/cm^3 probably result from low-density, OC-dominated sediment with gas bubbles in the sample. Measurement of density by the relatively simple method described above assumes only water and solids are in the sample, which results in an underestimation of *DS* if gas pockets are present.

Once *n* and *DS* were known, *DryMass*, the mass of dry solids per unit area (grams per square centimeter) of each sample was computed as

$$DryMass = (1 - n) * DS * Th, \tag{4}$$

where *Th* = thickness of the sample interval (centimeters).

DryMass (grams per square centimeter) for each sample interval, plus interpolated dry mass of any intervals that were not measured, was summed over the length of the core to yield cumulative mass for the core and over the length between date markers for each date-bounded interval. An example of such an interval is the length of core from the top, dated as the sampling date, to the ^{137}Cs peak, dated as 1964 (^{137}Cs age-dating is discussed in the “Using Cesium-137 to Assign Dates” section). The MAR for each date-bounded interval was computed by dividing the cumulative mass (*cum*) (grams per square centimeter) by the time interval (years) to yield MAR (grams per square centimeter per year):

$$\mathrm{MAR} = cum/\text{time interval}. \tag{5}$$

The effect of using an assumed density on a core with high OC concentration is illustrated using samples from the top of core BRT.B1, a box core from Big Round Top Pond in Rhode Island. The computations of *n* and *DryMass* for three intervals near the top of the core are shown in table 4 using an assumed *DS* of 2.5 g/cm^3 and compared with the computation of *DryMass* using the measured *DS*. The OC concentration ranges from 13.7 to 17.0 percent and *DS* ranges from 1.39 to 1.51 grams per square centimeter (g/cm^2). Porosities are very high, 88 to 92 percent and estimated to be even higher, 93 to 95 percent, using the assumed *DS* of 2.5 g/cm^3. *DryMass* of the core samples, however, is only slightly changed using the measured rather than the assumed densities (less than 5 percent). Thus, the use of an assumed density causes only small error in estimating *DryMass* and, therefore, MAR in cores.

Once a MAR is computed it can be used to assign dates to intervening samples. If the date-bounded interval begins at the top of the core, the deposition date of sample *i* is computed as

$$Date_i = SampleDate - (cum_i/MAR), \tag{6}$$

where

$Date_i$ = deposition date of sample (decimal years),

$SampleDate$ = date of core collection (decimal years), and

cum_i = cumulative mass (grams per square centimeter) from the top of the core down to the midpoint of sample *i*.

In many cases, MAR changes with depth in a core; however, changes in MAR can be identified only if three or more depth-date markers are known, defining two or more zones in the core where MAR can be computed. A simple case is where different MARs are computed before and after the ^{137}Cs peak in 1964. Samples above the depth of the ^{137}Cs peak (deposited after 1964) are assigned dates using equation 6. Samples below the depth of the ^{137}Cs peak, corresponding to a zone with a different MAR, are assigned dates by

$$Date_i = DateMarker_j - ([cum_i - cum_j]/MAR_j), \qquad (7)$$

where

$DateMarker_j$ = date of the marker at the top of the zone containing sample i (decimal years),

cum_j = cumulative mass from the top of the core down to $DateMarker_j$ (grams per square centimeter), and

MAR_j = MAR for the zone containing sample i (grams per square centimeter per year).

As an example of this computation, assume that the ^{137}Cs peak is in the 48- to 50-cm interval of the core with a cum_j of 18.9 g/cm^2. The pre-reservoir surface is at 90 cm, the reservoir was built in 1930, and *cum* (for the whole core) is 42.7 g/cm^2. These values result in a MAR for the 1930 to 1964 time interval (MAR_j) of (42.7 – 18.9)/(1964 – 1930) = 0.7 gram per square centimeter per year (g/cm^2-yr). The estimated deposition date of sample i, at a depth of 60 to 62 cm with cum_i equal to 24.0 g/cm^2, is given by

$$Date_i = 1964.0 - ([24.0 - 18.9]/0.7) = 1956.7$$

Using Cesium-137 to Assign Dates

^{137}Cs was measured in cores from 49 of the 56 lakes and provided the primary basis for age-dating in 42 lakes. Depending on the penetration of a core and the age of a lake, ^{137}Cs can provide one or more date markers and can help indicate the relative amount of postdepositional mixing or sediment disturbance (Van Metre, Callender, and Fuller, 1997). Atmospheric testing of nuclear weapons by the United States began in Nevada during 1951, with much larger-scale testing beginning in 1952 (Beck and others, 1990). A peak in ^{137}Cs fallout in the United States occurred in 1957–58, caused primarily by extensive testing in Nevada (Beck and others, 1990), followed by the voluntary moratorium on nuclear-weapons testing from late 1958 to 1961. The resumption of atmospheric testing in 1961, including the largest tests ever conducted, was followed in the summer of 1963 by the Limited Test Ban Treaty, signed by the United States, Britain, and Soviet Union, which banned aboveground and ocean testing. The 1963 atmospheric fallout peak results in large peaks in ^{137}Cs activity in undisturbed sediment cores (Holmes, 1998) and is assigned a date of 1964.0 (in decimal years). The 1958 peak is sometimes seen in cores with relatively high sedimentation rates in the western and central United States and can be used as a date marker. In cores from Lake Mead in Nevada and Arizona, near the Nevada Test Site, peaks in ^{137}Cs from annual testing series in the 1950s could be discerned (see Lake Mead in the appendix). In a few lakes constructed before about 1950, the first occurrence of ^{137}Cs was assigned a date of 1953.0, consistent with the first widely detectable fallout of ^{137}Cs. The first occurrence, however, was infrequently used as a depth-date marker because it is analytically uncertain (values near detection levels), and it can easily migrate deeper in a core because of postdepositional sediment mixing or desorption and diffusion of ^{137}Cs.

^{137}Cs proved to be a very useful age-dating tool in reservoirs and in some high-sedimentation-rate natural lakes. It was not, however, always useful in some low-sedimentation-rate natural lakes, particularly those with high OC concentrations. In several of the latter, ^{137}Cs profiles followed a characteristic pattern reported for Canadian lakes (Anderson and others, 1987). The ^{137}Cs profiles had rounded peaks displaced to younger-than-expected dates (relative to ^{210}Pb age dates), or no peak at all, and long “tails” of ^{137}Cs detections at low levels to much deeper zones of the core than expected. This pattern has been attributed to the combined effects of leaching of ^{137}Cs, dispersion through pore water, postdepositional mixing of sediments, and sediment focusing (Anderson and others, 1987). In lakes sampled by the RTNS where this ^{137}Cs pattern was observed, ^{210}Pb was used as the primary age-dating tool.

Using Lead-210 to Assign Dates

The radioisotope ^{210}Pb occurs naturally in the uranium-238 decay series. Most elements in the series are heavy metals, with the exception of radon-222 (^{222}Rn), which is a noble gas. When radium-226 (^{226}Ra) in rocks and soils decays to ^{222}Rn, some of the ^{222}Rn escapes to the atmosphere where it quickly decays through two short-lived intermediaries to ^{210}Pb. The ^{210}Pb in the atmosphere falls out with precipitation and dry fall and associates with surface soils. Over geologic time in rocks, the radionuclides in a decay series will come to secular equilibrium, with activity ratios of 1. The fallout of ^{210}Pb from atmospheric ^{222}Rn, however, will result in more ^{210}Pb in surface soil than can be accounted for by decay of the ^{226}Ra in the soil. As surface sediments and soils are gradually buried and isolated from additional fallout, this “excess” or “unsupported” ^{210}Pb, the amount above secular equilibrium, decays with a half-life of 22.3 years. Thus, the relation between ^{210}Pb and other nuclides preceding it in the decay series can be used to estimate the time since deposition and burial of an interval in a sediment core on time scales of a few to about 100 years (Holmes, 1998).

^{210}Pb was used as an age-dating tool for selected cores using one of two models: the constant rate of supply (CRS) model and the constant flux, constant sedimentation rate (CF:CS) model (Appleby and Oldfield, 1992). The basic assumption of the CRS model is that the rate of supply of unsupported ^{210}Pb to the lake is constant. This implies that any change in MAR is caused by the removal or addition of

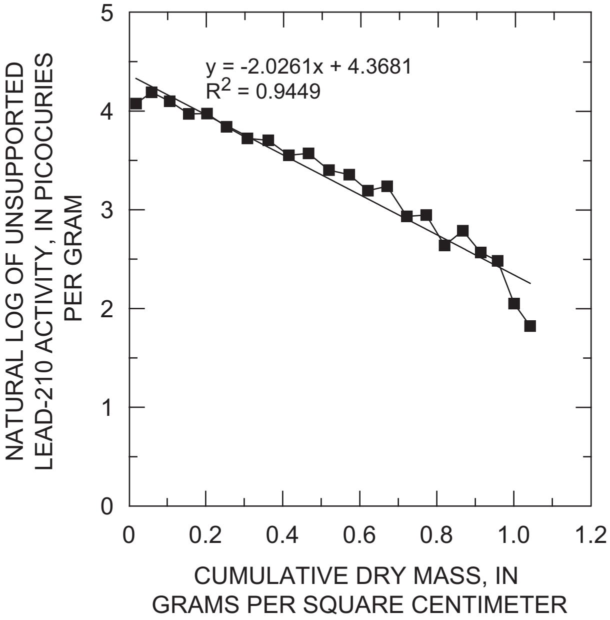


Figure 5. Example of a plot used for lead-210 age-dating using the constant flux, constant sedimentation rate (CF:CS) model.

sediment with no unsupported ^{210}Pb and, therefore, that the initial ^{210}Pb activity in surface sediment varies inversely with the MAR. In practice, this assumption rarely is met because, for example, an increase in MAR caused by land disturbance associated with urban development transports additional surficial soils and sediments into the lake. This additional erosion increases MAR and, because at least some of the additional sediment is from the land surface, increases the rate of supply of excess ^{210}Pb to the lake.

The second model used, the CF:CS model, assumes that both MAR and the flux of ^{210}Pb to the lake are constant over time (Appleby and Oldfield, 1992). It is similar to the constant input concentration (CIC) model, which assumes constant input concentration of unsupported ^{210}Pb; the simplest way for constant input to happen is for the assumptions of CF:CS to be met. In any case, both models assume that the initial unsupported ^{210}Pb activity in newly deposited sediments is constant over time, which leads to an exponential decline in ^{210}Pb activity with depth in the core. If the sedimentation rate is constant, unsupported ^{210}Pb in a core with a constant input concentration will plot as a straight line on a logarithmic scale (fig. 5).

Because unsupported ^{210}Pb is an atmospheric fallout radionuclide, it is more useful for age-dating cores from low-sedimentation-rate lakes with undisturbed watersheds where the input of contaminants is dominated by atmospheric fallout (atmospherically dominated lakes). Conversely, ^{210}Pb age-dating is less useful in high-sedimentation-rate lakes with developed watersheds where the input of contaminants is dominated by fluvial loading from one or more streams (fluvially dominated lakes). Lakes with urban or agriculture land uses usually are fluvially dominated in terms of sediment chemistry (Van Metre, Callender, and Fuller, 1997), so both the rate of supply (from the atmosphere and the watershed by way of fluvial inputs) and initial concentration of a fallout nuclide in newly deposited sediment are likely to be quite variable. In spite of these difficulties, useful age-dating information still can be obtained in some urban lakes from ^{210}Pb.

Where possible, the CRS model was used for this study. An important feature of this model is that it allows for variable sediment MARs. Ages are determined using the relation between the unsupported ^{210}Pb inventory of the whole core and the unsupported ^{210}Pb inventory below a particular interval. These inventories are computed by direct numerical integration of the ^{210}Pb profile, multiplying ^{210}Pb activities by mass of sediment for a unit area and measured thickness of each sample, then summing down the core. Ages are determined from equations 8 and 9.

$$A = A(0)e^{-\lambda_{210}t}, \tag{8}$$

where

A = the unsupported ^{210}Pb inventory below a given sample interval (picocuries per square centimeter),

$A(0)$ = the unsupported ^{210}Pb inventory of the whole core (picocuries per square centimeter) (assuming the core penetrates to the depth where unsupported ^{210}Pb is zero),

λ_{210} = the ^{210}Pb radioactive decay constant (0.03114 year^{-1}), and

t = time (decimal years).

The MAR for interval *i* is calculated from

$$MAR_i=(\lambda_{210}A)/C, \tag{9}$$

where C = unsupported ^{210}Pb activity (picocuries per gram). Once MARs are known for each interval, dates are assigned working back in time from the top of the core (and the sampling date) using the interval MAR and the mass of the interval.

In cases where the whole unsupported ^{210}Pb inventory was not measured because the core did not extend back far enough in time to capture it, the CF:CS model was used. If the assumptions of CF:CS are met, then ^{210}Pb activities are related to ages by

$$C = C(0)e^{-\lambda_{210}cum/MAR}, \tag{10}$$

where

$C(0)$ = initial unsupported ^{210}Pb activity (picocuries per gram), and

cum = cumulative dry mass per unit area above this layer (grams per square centimeter).

The terms *cum* and *MAR* can be found by plotting the unsupported ^{210}Pb activity on a logarithmic scale as a function of cumulative dry mass and fitting a least-squares regression line. If the assumptions of CF:CS are met, these data will plot as a straight line (fig. 5). The slope of the regression line equals

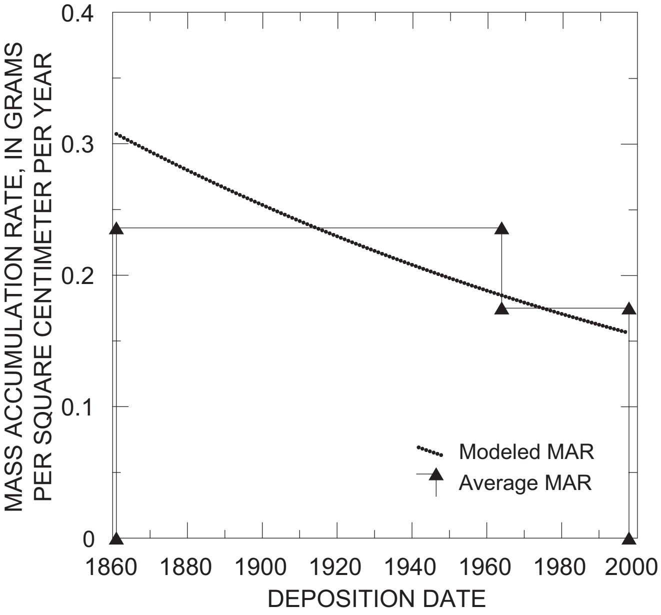


Figure 6. Comparison of average mass accumulation rate (MAR) computed using three date-depth markers to an exponentially decreasing MAR modeled using the approach of Callender and Robbins (1993).

λ_{210}/MAR (Appleby and Oldfield, 1992), and the age of a sample can be computed by dividing the *cum* by the *MAR*. In some lakes, the assumptions of CF:CS are not met for the whole core but appear to be met for two or more zones of the core defined by straight-line segments of the plot of unsupported ^{210}Pb in relation to cumulative dry mass, separated by changes in slope. Although not ideal, dates can be estimated using CF:CS by fitting regression lines to these parts of the record.

Exponentially Decreasing Mass Accumulation Rates

It is common for sedimentation rates in reservoirs to decrease over time after initial impoundment. Callender and Robbins (1993) suggested that decreases in sedimentation rates in reservoirs are caused by internal processes controlling the recruitment of sedimentary materials in newly established reservoirs. One such process is bank erosion as hillsides are converted to lake shoreline. In five reservoirs and one lake (Sloans Lake in Denver, Colo.), MAR decreased substantially (26- to 80-percent decrease) from an older part of the core to a more recent part of the core, for example, before and after the ^{137}Cs peak. There was no reason to suspect a step change in MAR in these lakes. Lacking any evidence for a step change, an exponential model was applied to estimate MARs; Callender and Robbins (1993) found that an exponential model of decreasing sedimentation rate fit reported sedimentation rate changes in 48 of 83 reservoirs evaluated. One factor here not encountered by Callender and Robbins (1993) that could cause a gradual decrease in sedimentation rate is urban development. Two of the six lakes where exponential models were applied, Sloans Lake, Colo., and Packanack Lake, N.J., are in small watersheds that experienced extensive urban development during the time period coincident with the earlier part of the core.

The exponential model is of the form

$$MAR_i = MAR(0)e^{-kt}, \tag{11}$$

where

MAR_i = MAR for a given layer (grams per square centimeter per year),
$MAR(0)$ = initial MAR at time zero,
k = time constant (year^{-1}) calibrated by fitting, and
t = time (decimal years).

The exponential model was calibrated by first assuming a *MAR(0)* equal to 1, computing MAR_is for small time intervals (one-half year, for example) from $t = 0$ to the full time interval of the core, and adjusting k to match the proportion of accumulated mass before and after a known date marker (for example, the ^{137}Cs peak). The computed MAR_is were then scaled by a constant to yield the measured cumulative mass of the core. The resulting modeled time-varying MARs match the amount of measured average accumulated mass for two or more fixed time intervals (fig. 6). These variable MARs were then used to develop a cumulative mass-to-date relation for the core by multiplying the MAR by the time step in the model to estimate accumulated mass for the time step, then summing mass from the bottom of the core to the top. Dates for sampled intervals were then assigned by comparing the modeled cumulative mass-to-date relation to cumulative mass for each sample.

Rating the Reliability of Age Dates

The reliability of age dates varies among cores. Because there is no absolute reference upon which to base a quantitative measure of reliability of age assignments in cores, professional judgment was used to assign a relative confidence in age dates for each core. Following the description of age-dating for each core, a rating is given corresponding to one of four levels of confidence in age assignments: good, fair, poor, and no dates assigned. A "good" rating means there is a well-defined ^{137}Cs profile, including a peak, or a reasonable application of a ^{210}Pb model, or both, that any other date markers present are consistent with the radionuclide-based dates, and that contaminant and radionuclide profiles indicate little or no postdepositional mixing. A pre-reservoir boundary in the core consistent with a known construction date is a particularly good date marker. The cores collected from White Rock Lake in Dallas, Tex., in 1994 received a "good" rating. Multiple cores collected there all have clear date markers that are consistent among cores, including the pre-reservoir land surface, first occurrence and peak in ^{137}Cs, first occurrence and peak in total DDT, and lead peak (Van Metre and Callender, 1997).

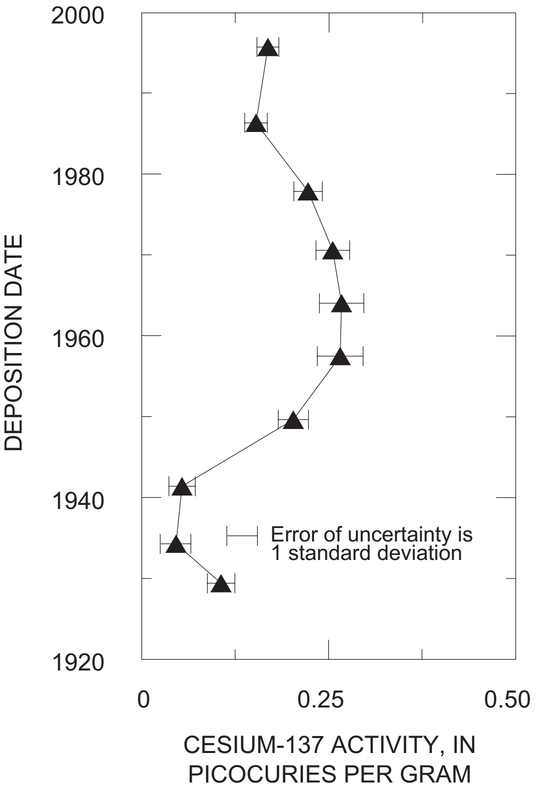


Figure 7. Example of cesium-137 profile in a sediment core (Maple Street Pond, Mass.) with postdepositional mixing or desorption and diffusion, or both.

A "fair" rating means that clear date markers were present, but that some inconsistency was noted, often an apparent difference in dates or in MARs using different date markers or among multiple cores from a site. Berkeley Lake in Atlanta, Ga., is an example of a lake with a fair rating. One box core was collected and analyzed for all constituents. The ^{137}Cs profile was inconclusive, with two anomalous values relative to a typical profile; however, use of the pre-reservoir land surface as the basis for assigning dates resulted in reasonable dates for the lead peak and total DDT profile. Thus, contaminant trends appear to be reasonable in the core, but the lack of a useful ^{137}Cs profile reduces confidence in these age assignments.

A "poor" rating means that some temporal information was preserved in the core (for example, interpretable variations in radionuclide or contaminant concentrations, or both, with depth in the core), but that age assignments were of very low reliability. Very low reliability can be caused by poor-quality date markers (for example, a broad, rounded peak in ^{137}Cs), lack of some date markers where they were expected, or large internal inconsistencies among date markers or cores. An example of a lake with a "poor" rating is Packanack Lake near Newark, N.J. One gravity core, NJPAK.6, was analyzed for ^{137}Cs and ^{210}Pb with inconsistent results. The ^{210}Pb values are highly variable and unsupported ^{210}Pb decreases to near zero at a depth of 15 cm in the core, indicating an age of 100 years for these sediments which would predate the construction of the reservoir in 1930. In contrast, ^{137}Cs does not have a clear peak and is at measurable levels at 17 cm, an interval below the disappearance of ^{210}Pb, suggesting an age in the 1950s. Thus, the radionuclides were inconsistent and provided almost no useful age-dating information. Core NJPAK.3, also a gravity core, was analyzed for major and trace elements and provides one convincing piece of dating information—a strong temporal trend in copper. Treatment of the lake with copper sulfate began in the early 1950s, which was assumed to coincide with the large increase in copper from about 50 micrograms per gram (µg/g) to more than 1,000 µg/g at a depth of 18 cm in the core. A third gravity core, NJPAK.4, was analyzed for organic compounds. NJPAK.4 has a pre-reservoir surface (1930 construction date) at 43 cm, the first occurrence of organochlorine pesticides (very roughly 1940) at 28 to 30 cm, and the highest total DDT and total PCB concentrations (mid-1960s in most cores) at 14 to 19 cm. The pre-reservoir surface and organic contaminant profiles in NJPAK.4 and the ^{137}Cs profile in NJPAK.6 indicated the MAR had decreased greatly over time; therefore, an exponential model of decreasing MAR was developed that relied on information gleaned from all three cores. The modeled relation between cumulative mass and deposition date was used to assign dates that were consistent with the timing of the copper increase and lead peak in NJPAK.3 and the total DDT and total PCB initial occurrence and peaks in NJPAK.4. It is clear, however, that there is large uncertainty in age assignments in these cores, resulting in the "poor" rating.

Two lakes from the northeastern United States with very low sedimentation rates received "poor" ratings because of substantial postdepositional mixing (Basin Brook Pond, Maine, and Maple Street Pond, Mass.). Two common causes of mixing are bioturbation and the disturbance of fine-grained sediments by water movement. Some mixing probably occurs in all cores, but its effect on obscuring trends is inversely related to the sedimentation rate (Robbins, 1986). Common indications of mixing are the rounding or flattening of the ^{137}Cs peak, the deepening of the first occurrence of ^{137}Cs (fig. 7), and a zone of constant unsupported ^{210}Pb at the top of a core with decreasing ^{210}Pb below. The ^{137}Cs profile in Maple Street Pond, Mass., also could be affected by desorption and diffusion of ^{137}Cs, as discussed by Anderson and others (1987). The only cores in which these patterns were observed were from lakes with high OC concentrations and very low sedimentation rates (less than about 4 millimeters per year). Mixing was severe enough in these lakes to raise the possibility of not dating the cores; however, they were sampled as atmospheric reference sites, and one objective was to estimate atmospheric fluxes over long time intervals. Although sediment mixing can blur trends, even decadal trends in this case, the cores still could be useful for estimating mean concentrations and fluxes of nonreactive constituents over long (multidecade) periods. Therefore, a decision was made to assign dates, primarily so a MAR could be estimated for the cores.

In a few cases, no age assignment was possible. Decker Lake, a small impoundment in Salt Lake City, Utah, is one example. The ^{137}Cs, DDT, and lead profiles were all variable and showed no clear patterns, despite the heavily urbanized setting. The impoundment is relatively shallow and is in an area with large-scale commercial and highway construction in recent years. The profiles probably result from very high sedimentation rates and extensive postdepositional sediment mixing. Without any depth-date markers on which to base dates, none were assigned. Other cases where dates were sometimes not assigned were "secondary" cores. In several lakes, cores were collected from multiple locations with many samples analyzed in one core (termed the primary core) and only a few samples analyzed in the other core or cores (secondary cores). If the secondary cores with few analyses did not offer an obvious date marker, for example a pre-reservoir surface, no dates were assigned. Only two of the 56 lakes, Decker Lake and Lake Hemet, Calif., had no dates assigned to any cores collected.

Age Assignments for Cores

One-hundred twenty-two cores were collected from the 56 lakes, and age dates were assigned to 113 of them, representing 54 of the 56 lakes. Seventy-four cores (61 percent) received a "good" rating, 28 cores (23 percent) received a "fair" rating, and 11 cores (9 percent) received a "poor" rating; nine cores (7 percent) had no dates assigned (table 5). Age-dating for each of the lakes is presented in the appendix. The discussions follow a consistent format where the basis, corroboration, and rating for each core are presented. Basis comprises the date markers, approach, and other information in the core that were used to compute age dates. Corroboration comprises any date markers and other information in the core or the watershed history that support the age assignments made. Rating is a qualitative assessment of the reliability of the age assignments. Lakes are presented in geographic order as numbered in figure 1.

Factors Affecting the Reliability of Age-Dating

To investigate the influence of environmental factors on the apparent quality of age-dating of the cores, a single core from the "primary" site in each lake was evaluated in relation to selected lake and watershed characteristics. Because three of the lakes had dated cores from two distinctly different sites representing different subwatersheds, a total of 59 primary cores was evaluated. Four factors were considered: MAR in the core, land-use setting in the watershed, watershed area, and waterbody type (lake or reservoir) (fig. 8). The clearest conclusion from the comparison shown in figure 8 is that the greater the MAR, the more likely the age-dating rating was "good." This was expected because greater MAR improves temporal resolution in core samples, reduces the effects of postdepositional mixing, and reduces the effects of diagenesis (Callender, 2000), all of which increase the preservation of trends and the ability to sample them at a finer temporal resolution. MAR might be related to the watershed size as well; the rank correlation between MAR and watershed area is significant (Spearman's rho = .495; p-value <.01). Thus, the apparent improvement in age-dating rating with increased watershed size could be an artifact of the relation between age-dating rating and MAR. Land-use setting in the watershed (integrator, reference, or urban) also appears to affect the quality of age-dating, with integrator and urban lakes faring better than reference lakes (fig. 8). The apparent relation to land-use setting, like the relation to watershed size, could be a consequence of differences in MAR. Urban lakes, although sometimes small, tend to have higher sedimentation rates than reference lakes because of land disturbance in their watersheds. Reference lakes, mostly small lakes with undeveloped watersheds, are likely to have the lowest MARs. Interestingly, no difference in age-dating rating between lakes and reservoirs is apparent. In terms of the relative amount of sediment disturbance for a given sedimentation rate and the ability to reliably collect, subsample, and age date cores, they are similar. All of these factors point to a general conclusion—sediment in lakes that have lower sedimentation rates is more difficult to sample at a given temporal resolution and is more likely to be disturbed than sediment in lakes with higher sedimentation rates.

Some "fair" and "poor" ratings can be attributed to poor sampling approaches used at some sites early in the RTNS study. An example of a poor approach is the use of multiple cores at a site with different constituents measured in each core, an approach that necessitates extrapolation of information between cores. Experience showed that sedimentation rate and sediment thickness often vary between adjacent sites, especially in reservoirs with low overall sedimentation rates. Age dates estimated for the core in which radionuclides were measured, extrapolated by depth or cumulative mass to other cores, often did not make sense when compared to profiles of anthropogenic HOCs and lead. This left the analyst with the option of basing dates for the other core or cores on contaminant profiles or using unrealistic dates. The former option was sometimes deemed the better of the two choices (see, for example, Clyde Potts Reservoir, N.J., in the appendix), even though the timing and reliability of contaminant peaks is less certain than that of the radionuclides.

Another poor approach that sometimes was used early in the study was to combine samples from box and gravity cores collected at the same site to try to create a single temporal record (see, for example, Lake Harriet, Minn., in the appendix). At some sites the two types of cores were collected side by side; samples from the upper part of the sediment (less than about 15 cm) were analyzed from the box core and deeper samples (greater than about 15 cm) were analyzed from the gravity or piston core, the assumption being that the two could be combined to make one longer record. Uncertainty in matching

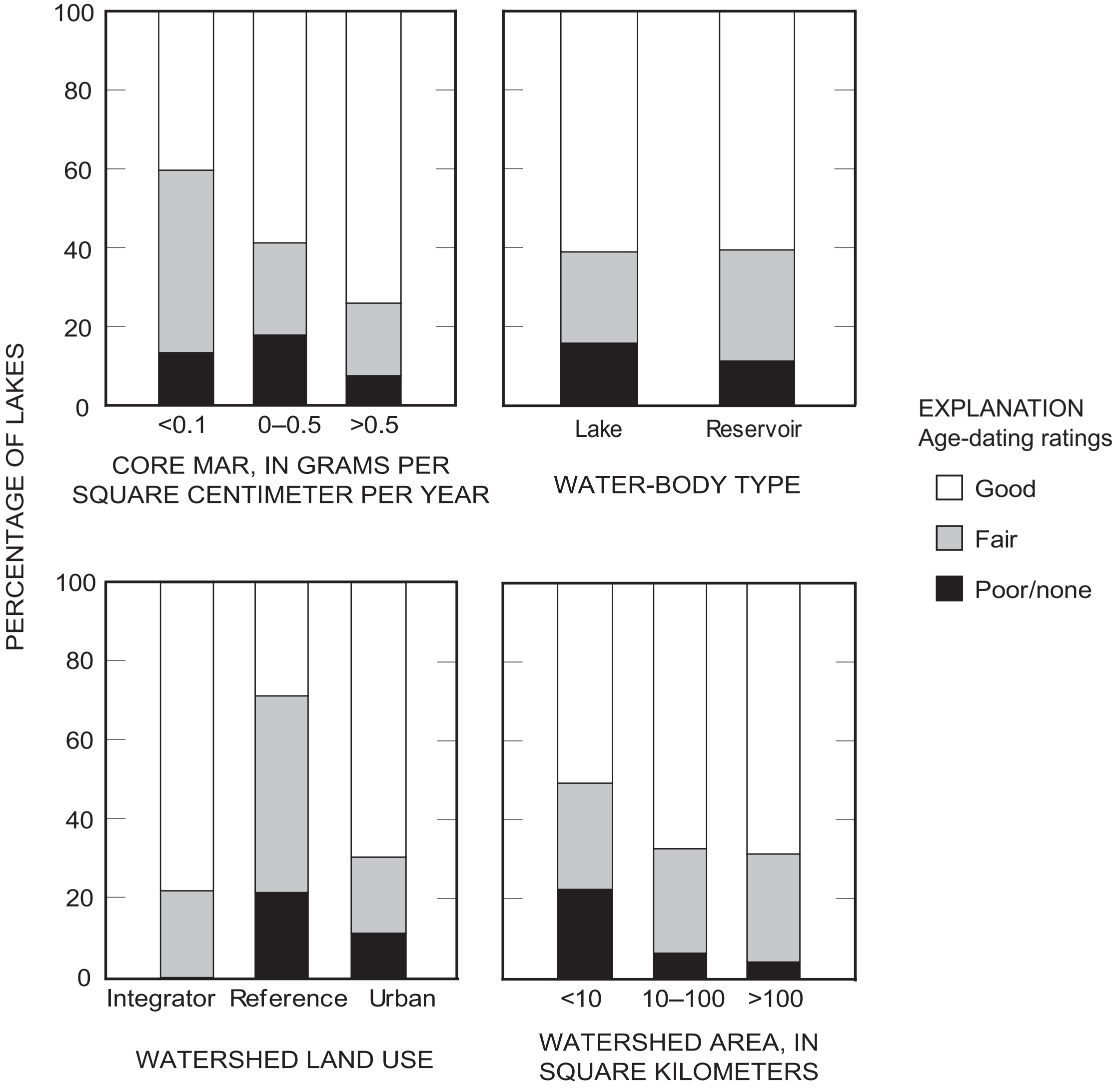


Figure 8. The percentage of lakes receiving "good," "fair," and "poor/none" age-dating ratings when grouped by core mass accumulation rate (MAR), water-body type, watershed land use, and watershed area.

samples in multiple cores and the large amount of core shortening in the gravity cores made this approach problematic. After reviewing results from sites sampled in 1996 and 1997, these approaches were discontinued. In subsequent sampling, either a single, taller box core (30 or 50 cm), gravity core, or piston core was collected for all analyses or, in lakes with unknown or intermediate sedimentation rates where the length of core to analyze was uncertain, both box and gravity (or piston) cores were collected. Analyses of contaminants and radionuclides were overlapped with depth in the two to assure development of a single, consistent temporal record. Sampling of both core types in these lakes was done to assure that the desired time interval and temporal resolution were achieved.

Interpreting Sediment Cores From Lakes and Reservoirs

Differences Between Lakes and Reservoirs and Implications for Paleolimnology

There are important differences between natural lakes and reservoirs (Thornton, 1990) that can affect the collection and interpretation of sediment cores. Of particular importance are differences in the geometry of the lake, nature of influent streams, DA:SA ratios, sedimentation rates, and sedimentation patterns. Reservoirs usually are elongated in shape and have

Table 5. Summary of age date ratings presented in this report.

[^{137}Cs, cesium-137; ^{210}Pb, lead-210]

Map ID (fig. 1)	Lake name	Date sampled	Core ID	Basis of age-dating	Age date rating
1	Hillstrand Pond	June 4, 1998	HIL.2	Lead	Good
	Hillstrand Pond	June 4, 1998	HIL.1	Extrapolated from HIL.2	Good
2	Westchester Lagoon	June 4, 1998	WES–2	Lead	Good
3	Lake Ballinger	June 8, 1998	BAL.B	^{137}Cs	Good
4	Tolt Reservoir	June 11, 1998	TLT.B	Pre-reservoir surface	Fair
5	Lake Washington	June 9, 1998	WAS–B	^{137}Cs	Good
6	West Street Basin	Nov. 12, 1998	WST.2	^{137}Cs	Good
	West Street Basin	Nov. 12, 1998	WST.3	Extrapolated from WST.2	Good
7	R.R. Canyon Lake	Nov. 10, 1998	CYN	^{137}Cs	Good
8	Lake Hemet	Nov. 10, 1998	HEM	^{137}Cs, DDE, and pre-reservoir surface	None
9	Sweetwater Reservoir	Sept. 24, 1998	SWT.4	^{137}Cs	Good
10	Lake Mead, Overton Arm	May 13, 1998	OVR–2	^{137}Cs and pre-reservoir surface	Good
	Lake Mead, Las Vegas Bay, Shallow	May 12, 1998	LVB–S4	^{137}Cs and pre-reservoir surface	Good
	Lake Mead, Las Vegas Bay, Shallow	May 12, 1998	LVB–S2	Extrapolated from LVB–S4	Good
	Lake Mead, Las Vegas Bay, Deep	May 11, 1998	LVB–D3	^{137}Cs and pre-reservoir surface	Good
	Lake Mead, Colorado River Arm	May 14, 1998	MEAD–1	^{137}Cs and pre-reservoir surface	Good
	Lake Mead, Colorado River Arm	May 14, 1998	MEAD–2	Extrapolated from MEAD–1	Good
11	Great Salt Lake	April 7, 1998	FAR.3	^{210}Pb	Fair
	Great Salt Lake	April 7, 1998	FAR.B	Grass layer	Fair
	Great Salt Lake	April 7, 1998	FAR.2	None	None
12	Decker Lake	April 6, 1998	DEK.3	None	None
	Decker Lake	April 6, 1998	DEK.2	None	None
	Decker Lake	April 6, 1998	DEK.B	None	None
13	Red Butte Reservoir	April 9, 1998	RED.1	^{137}Cs	Good
	Red Butte Reservoir	April 9, 1998	RED.3	Extrapolated from RED.1	Fair
14	Dillon Reservoir	Aug. 20, 1997	DLN.B	Pre-reservoir surface	Fair
15	Sloans Lake	Aug. 19, 1997	SLN.2	^{137}Cs and pre-lake surface	Good
	Sloans Lake	Aug. 19, 1997	SLN.3	Extrapolated from SLN.2	Good
16	Cherry Creek Reservoir	Aug. 18, 1997	CHC.4	^{137}Cs and pre-reservoir surface	Fair
	Cherry Creek Reservoir	Aug. 18, 1997	CHC.3	Extrapolated from CHC.4	Fair
17	Lake Como, Lower	March 8, 2001	CMO.1	^{137}Cs	Good
18	Fosdic Lake, Middle	March 7, 2001	FOS.4	^{137}Cs and pre-reservoir surface	Good
19	White Rock Lake	July 6, 1994	WRL(1)	^{137}Cs and pre-reservoir surface	Good
	White Rock Lake	July 6, 1994	WRL(3)	^{137}Cs and pre-reservoir surface	Good
	White Rock Lake	July 6, 1994	WRL(4)	Extrapolated from WRL(1) and WRL(3)	Good
	White Rock Lake	June 11, 1996	WRL2.2	Extrapolated from WRL(1) and WRL(3)	Fair
	White Rock Lake	June 11, 1996	WRL2.3	Extrapolated from WRL(1) and WRL(3)	Fair
20	Echo Lake, Lower	March 6, 2001	ECO.1	^{137}Cs	Good
21	Town Lake	Aug. 26, 1998	TWN	^{137}Cs and pre-reservoir surface	Good
22	Lorence Creek Lake	Aug. 23, 1996	LRC.2	^{137}Cs	Good
	Lorence Creek Lake	Aug. 23, 1996	LRC.3	Extrapolated from LRC.2	Good

Table 5. Summary of age date ratings presented in this report—Continued.

Map ID (fig. 1)	Lake name	Date sampled	Core ID	Basis of age-dating	Age date rating
23	Lake Houston, East	July 9, 1997	HOE.2	Pre-reservoir surface and ^{137}Cs	Good
	Lake Houston, East	July 9, 1997	HOE.3	Extrapolated from HOE.2	Good
	Lake Houston, West	July 9, 1997	HOW.1	Pre-reservoir surface	Good
	Lake Houston, West	July 9, 1997	HOW.3	Extrapolated from HOW.1	Good
	Lake Houston, South	July 10, 1997	HOS.1	Pre-reservoir surface	Good
	Lake Houston, South	July 10, 1997	HOS.2	Pre-reservoir surface	Good
	Lake Houston	July 10, 1997	HON	None	None
24	Lake Livingston	Aug. 1, 1992	LIV(AC–2)	Pre-reservoir surface	Good
	Lake Livingston	Aug. 1, 1992	LIV(AC–3)	Pre-reservoir surface	Good
	Lake Livingston	Aug. 1, 1992	LIV(CC–1)	Pre-reservoir surface	Good
	Lake Livingston	Aug. 1, 1992	LIV(CC–3)	Pre-reservoir surface	Good
	Lake Livingston	Aug. 1, 1992	LIV(FC)	Pre-reservoir surface	Good
25	Palmer Lake, West Lobe	July 30, 1997	PLM.W2	^{137}Cs	Good
	Palmer Lake, West Lobe	July 30, 1997	PLM.W3	Extrapolated from PLM.W2	Good
	Palmer Lake, West Lobe	July 30, 1997	PLM.WB1	Extrapolated from PLM.W2	Poor
	Palmer Lake, East Lobe	Oct. 15, 1999	PLME.2	^{137}Cs	Poor
	Palmer Lake, East Lobe	July 30, 1997	PLM.EB	Extrapolated from PLME.2	Poor
26	Lake Harriet	July 29, 1997	HAR.4	^{210}Pb	Good
	Lake Harriet	July 29, 1997	HAR.3	Extrapolated from HAR.4	Good
	Lake Harriet	July 29, 1997	HAR.1	Extrapolated from HAR.4	Good
	Lake Harriet	July 29, 1997	HAR.B	Extrapolated from HAR.4	Good
27	Lake in the Hills	July 19, 2001	LKH.1	^{137}Cs	Good
28	Shoe Factory Road Pond	July 18, 2001	SHO.2	^{210}Pb	Good
	Shoe Factory Road Pond	July 18, 2001	SHO.1	Extrapolated from SHO.2	Fair
29	Busse Lake	July 18, 2001	BUS.1	Pre-reservoir surface	Good
30	Beck Lake	July 17, 2001	BEC.1	Pre-reservoir surface	Good
31	Lake Sidney Lanier, Chattahoochee	May 10, 1994	LL.CHT.35(3)	Pre-reservoir surface	Fair
	Lake Sidney Lanier, Chestatee	May 10, 1994	LL.CST.15C(1)	Pre-reservoir surface	Fair
32	Berkeley Lake	May 19, 1999	BRK	Pre-reservoir surface	Fair
33	Lakewood Park Lake	May 19, 1999	LKW.1	^{137}Cs	Fair
	Lakewood Park Lake	May 19, 1999	LKW.2	Total-DDT	Fair
34	Panola Lake	May 18, 1999	PAN.B	^{137}Cs and pre-reservoir surface	Good
35	West Point Lake	May 7, 1994	WP.55(1)	Pre-reservoir surface	Good
	West Point Lake	May 5, 1994	WP.99–100(2)	Pre-reservoir surface	Good
	West Point Lake	May 5, 1994	WP.99–100(1)	Extrapolated from WP.99–100(2)	Good
36	Lake Harding	Sept. 19, 1994	HRD(1)	Construction of upstream reservoir, lead, and ^{137}Cs	Good
	Lake Harding	Sept. 19, 1994	HRD(3)	Extrapolated from HRD(1)	Good
37	Lake Blackshear	May 9, 1994	BLK(2)	^{137}Cs and pre-reservoir surface	Good
	Lake Blackshear	May 9, 1994	BLK(1)	Extrapolated from BLK(2)	Good
38	Lake Walter F. George	May 7, 1994	WFG.98(3)	Pre-reservoir surface	Good
	Lake Walter F. George	May 7, 1994	WFG.98(1)	Extrapolated from WFG.98(3)	Good
39	Lake Seminole	May 11, 1994	SEM.3.0(3)	^{137}Cs and pre-reservoir surface	Good
	Lake Seminole	May 11, 1994	SEM.3.0(2)	Extrapolated from SEM.3.0(3)	Good
	Lake Seminole	Sept. 21, 1994	SEM.3.0(2)	Extrapolated from SEM.3.0(3)	Fair

Table 5. Summary of age date ratings presented in this report—Continued.

Map ID (fig. 1)	Lake name	Date sampled	Core ID	Basis of age-dating	Age date rating
40	Sand Lake	Mar. 17, 1999	SND	^{137}Cs	Good
41	Lake Orlando	Mar. 17, 1999	ORL	Extrapolated from Lake Killarney	Poor
42	Lake Killarney	Mar. 16, 1999	KIL	^{137}Cs	Good
43	Lake Anne	June 24, 1996	ANB.1	Lead	Good
	Lake Anne	June 23, 1996	ANN.2	Lead	Good
	Lake Anne	June 23, 1996	ANN.1	Extrapolated from ANN.2	Good
	Lake Anne	Sept. 24, 1997	AN97	Lead	Fair
44	Fairfax Lake	Sept. 24, 1997	FFX.3	^{137}Cs and pre-reservoir surface	Fair
	Fairfax Lake	Sept. 24, 1997	FFX.2	Extrapolated from FFX.3	Poor
45	Clyde Potts Reservoir	Sept. 15, 1997	NJCP.BC4	^{137}Cs	Good
	Clyde Potts Reservoir	Sept. 15, 1997	NJCP.BC2	Lead	Fair
	Clyde Potts Reservoir	Sept. 15, 1997	NJCP.BC3	Extrapolated from NJCP.BC4	Fair
46	Orange Reservoir	Sept. 18, 1997	NJOR.1	Pre-reservoir surface, ^{137}Cs, and lead	Fair
	Orange Reservoir	Sept. 18, 1997	NJOR.4	Pre-reservoir surface, ^{137}Cs, and lead	Fair
	Orange Reservoir	Sept. 18, 1997	NJOR.5	Pre-reservoir surface, ^{137}Cs, and lead	Good
	Orange Reservoir	Sept. 18, 1997	NJOR.BC1	Extrapolated from NJOR.5	Fair
	Orange Reservoir	Sept. 18, 1997	NJOR.BC2	Extrapolated from NJOR.5	Fair
47	Packanack Lake	Sept. 17, 1997	NJPAK.6	^{137}Cs and pre-reservoir surface	Poor
	Packanack Lake	Sept. 17, 1997	NJPAK.3	Extrapolated from NJPAK.6	Poor
	Packanack Lake	Sept. 17, 1997	NJPAK.4	Extrapolated from NJPAK.6	Poor
48	Newbridge Pond	Sept. 22, 1997	NEW.2	^{137}Cs	Good
	Newbridge Pond	Sept. 22, 1997	NEW.1	Extrapolated from NEW.2	Good
	Newbridge Pond	Sept. 22, 1997	NEW.3	Extrapolated from NEW.2	Good
49	Big Round Top Pond, Lower Lake	July 25, 2000	BRT.B1	^{137}Cs	Good
	Big Round Top Pond, Mid-lake	July 25, 2000	BRT.B2	^{137}Cs	Fair
50	Maple Street Pond	July 27, 2000	MAP.1	^{137}Cs	Poor
	Maple Street Pond	July 27, 2000	MAP.B1	Extrapolated from MAP.1	Poor
51	Harris Pond, Lower	July 26, 2000	HSP.1	^{137}Cs	Good
	Harris Pond, Middle	July 26, 2000	HSP.B2	^{137}Cs	Good
	Harris Pond, Upper	July 26, 2000	HSP.B3	None	None
52	Upper Mystic Lake, Upper Lake	Aug. 31, 2000	MYS.B2	^{210}Pb and ^{137}Cs	Good
	Upper Mystic Lake, Lower Lake	Aug. 31, 2000	MYS.2	None	None
53	Charles River, Lower	July 28, 2000	CHA.B1	^{137}Cs	Fair
	Charles River, Upper	July 28, 2000	CHA.B2	None	None
54	South Reservoir	Sept. 1, 2000	SRV	^{210}Pb	Fair
55	Basin Brook Pond	Aug. 29, 2000	BBP	Pre-reservoir surface	Poor
56	Crocker Pond	Aug. 30, 2000	CRK.B1	^{210}Pb	Fair

SUMMARY OF RATINGS:

74 cores, 60.7 percent, received an age date rating of “Good”

28 cores, 23.0 percent, received an age date rating of “Fair”

11 cores, 9.0 percent, received an age date rating of “Poor”

9 cores, 7.4 percent, were not dated and received a rating of “None”

from one to only a few dominant influent streams, whereas lakes usually are more rounded in shape and often have numerous lower-order influent streams. These differences lead to differences in sedimentation patterns in reservoirs and lakes, with longitudinal gradients and greater spatial variability in reservoirs. The drainage areas of reservoirs are much larger relative to their surface areas than are the drainage areas of natural lakes (Marzolf, 1990). Many lakes are in areas of low relief and high precipitation, whereas many reservoirs are in areas of higher relief, lower precipitation, and streams with higher suspended-sediment concentrations (Thornton, 1990). These factors contribute to relatively higher sedimentation rates in reservoirs than in lakes.

Lakes sampled by the USGS encompass a wide range of DA:SA and sedimentation rates. Using data from eight reservoirs and three natural lakes, all but one of which are included in this report, Van Metre and others (2001) reported a range in DA:SA of 15 to more than 5,000 and a range in MAR of 0.11 to 2.74 g/cm^2-yr for the reservoirs. Wide ranges but smaller overall values of both were reported for the natural lakes, with DA:SA ratios of 5 to 500 and MARs of 0.07 to 0.41 g/cm^2-yr. The correlation coefficient between DA:SA ratio and sedimentation rate among these lakes and reservoirs was 0.9. The lakes and reservoirs with low sedimentation rates are in areas of high precipitation and relatively dense vegetation, such as New York, New Jersey, and Virginia. The reservoirs with the highest sedimentation rates are in semiarid areas of New Mexico and Texas.

These differences lead to several generalities that characterize sediment deposition. The dominance of one or two influent streams and elongated shape of reservoirs lead to longitudinal gradients in sedimentation rates and grain-size distributions in reservoirs. The presence of a pre-reservoir stream channel and, commonly, more pronounced bottom topography in reservoirs lead to large variations in sedimentation rates, with the greatest sedimentation typically in the pre-reservoir stream channel. A sediment core collected at a water depth of 17.7 m in the pre-reservoir stream channel of Lake Livingston in Texas encountered 138 cm of lacustrine sediment above the pre-reservoir land surface, indicating an average sedimentation rate of about 6 cm/yr. In contrast, several cores collected away from the channel in 3- to 6-m-deep water in the same part of the reservoir had lacustrine sediments of about 10 cm or less in thickness (Van Metre and Callender, 1996). Lake Livingston also showed longitudinal variation in sedimentation. The 138-cm core was collected from about the middle of the 40-kilometer (km)-long reservoir. A core from about three-quarters of the way down the reservoir had 90 cm of lacustrine sediment, and a core from near the dam had 52 cm. These patterns are typical of many of the reservoirs sampled by the USGS; much greater sedimentation in the pre-reservoir channel and decreasing sediment thickness in the down-reservoir direction (Wilson and Van Metre, 2000). Natural lakes, with generally more rounded shapes, smoother bottoms, and more distributed sediment inputs, typically have more evenly distributed sedimentation. For example, 15 cores collected from a small natural lake in Scotland had a mean MAR of 0.012 g/cm^2-yr with a standard deviation of 0.006 g/cm^2-yr (Yang and others, 2002).

Although high sedimentation rates generally lead to better temporal resolution and reduce the effects of postdepositional disturbance, very high rates can pose a challenge for sampling. Coring tools used for this study are limited to the recovery of about 3 m of core. In some lake sediments, maximum core recovery using either piston or gravity cores was limited to a little more than 1 m, probably because of physical characteristics of the sediment (texture, shear strength, water content). The goals of the RTNS study are to sample temporal records at least back into the 1960s, a very short time span compared to those of many paleolimnological studies (Davis, 1980), but corresponding to a very thick sequence of sediment in some western reservoirs. Cochiti Lake on the Rio Grande in New Mexico, for example, was constructed in the early 1970s; by 1998 as much as about 25 m of sediment had accumulated in the pre-reservoir channel (Wilson and Van Metre, 2000). Cores of about 1.5 m spanning the full lacustrine sediment sequence were obtained in the lower part of the reservoir away from the pre-reservoir stream channel where the sedimentation rate was much lower. A similar sampling strategy was used in Amistad International Reservoir, Tex., and Elephant Butte Reservoir, N.M., both of which also are on the Rio Grande (Van Metre, Mahler, and Callender, 1997) and in Lake Mead on the Colorado River in Nevada and Arizona (Covay and Beck, 2001).

One distinctive difference between reservoirs and lakes is the existence in reservoirs of a boundary between lacustrine sediment and pre-reservoir soil. This boundary provides a very reliable depth-date marker in cores in most reservoirs—a time marker designating the beginning of accumulation of sediment in the reservoir that can be matched with the date when the reservoir was filled. In most cases it can be distinguished easily in the field during sampling, which provides useful information to guide site selection and subsampling of cores. Lacustrine sediment, except near shore and near stream inflows, usually is very soft and fine grained and has a high water content. Percentage sand-sized sediment (greater than 63 micrometers [μm]) usually is near zero and percentage clay-sized sediment (less than 4 μm) often is in the 60- to 90-percent range. Porosities greater than 90 percent in the top few centimeters of cores are common, and porosities range from about 60 to 70 percent at depth. The texture and appearance of pre-reservoir material can vary greatly, from coarse sand and gravel in old streambeds, to bare rock, to well-developed soil with sand and root hairs. Often the top of the pre-reservoir soil is marked by a distinctive layer of decaying leaves and sticks. It is almost always easily distinguished from lacustrine sediment. In only a few cores collected during this study was the pre-reservoir soil difficult to visually identify in the field, usually for obvious reasons; for example, cores collected in Lake Seminole, Ga./Fla., were from a site overlying a pre-reservoir oxbow lake. Often the coring tool is inhibited from further penetration when it encounters the pre-reservoir boundary; sometimes only a small amount (1 cm or less) of the pre-reservoir material is retained in the core, but it frequently can be identified on the cutting head of a gravity or piston core or in the cap used to cover the bottom of the core.

Understanding Fluvial and Atmospheric Contaminant Inputs

Contaminants can be delivered to lakes by direct fallout on the lake surface, fallout on the watershed followed by fluvial transport to the lake, and point- and nonpoint-source releases in the watershed followed by fluvial transport to the lake. Large DA:SA ratios and high sedimentation rates will reduce the relative importance of direct atmospheric fallout on sediment chemistry and increase the relative importance of fluvial inputs; thus, the sediment chemistry of most reservoirs and many lakes is dominated by fluvial inputs of contaminants (Van Metre, Callender, and Fuller, 1997; Van Metre and others, 2001). When fluvial inputs of contaminants dominate sediment chemistry in a lake, chemical concentrations for comparable time intervals in cores are similar, regardless of differences in sedimentation rate between the cores. In such lakes, contaminant MARs (contaminant concentration multiplied by sediment MAR) correlate positively with sedimentation rates and, therefore, can vary greatly within the lake. Conversely, when contaminant inputs to lake sediment are dominated by direct atmospheric fallout on the lake, concentrations vary inversely with sedimentation rates, and contaminant MARs are relatively constant. If a contaminant is delivered only from fallout and no postdepositional transport of sediment occurs, contaminant MARs will be the same in multiple cores, regardless of differences in sedimentation rate.

In urban lakes, the importance of fluvial inputs is illustrated by comparing selected contaminant concentrations in cores with those measured at nearby atmospheric reference sites. For example, PAH concentrations (and accumulation rates) in a core from Palmer Lake in Minneapolis, Minn., increased by a factor of 80 from the 1960s, when the watershed was mostly undeveloped, to 1997, when the watershed was about 67-percent urban land use (Van Metre and others, 2000). Total-PAH in recent sediment was about 40,000 micrograms per kilogram (µg/kg) compared with about 4,000 µg/kg in the adjacent atmospheric reference site (Palmer Lake East). These data indicate that atmospheric deposition in greater Minneapolis had only a minimal effect on sediment quality compared to the effect of development in the watershed. The dominance of fluvial inputs on reservoir sediment chemistry also has been demonstrated for DDT and PCBs: Van Metre, Callender, and Fuller (1997) showed that accumulation rates of total DDT and total PCBs in six reservoirs far exceeded estimated atmospheric fallout, which indicated watershed sources and fluvial inputs as the only reasonable explanation.

In lakes with very low sedimentation rates, small DA:SA ratios, and no important point or nonpoint contaminant sources in their watersheds, atmospheric inputs dominate sediment chemistry (Heit and others, 1984; Swain and others, 1992), although even in these cases fluvial inputs of fallout contaminants from the watershed can be important (Yang and others, 2002). Therefore, if the objective of a study is to ascertain atmospheric fallout histories, then lakes with these characteristics are logical sampling choices. Even in such systems, determining fallout rates is more complicated than computing the contaminant MAR in a core. Sediment focusing, the movement of sediment and associated constituents from the watershed and from other parts of the lake to the coring site, can appreciably increase the contaminant MAR in a core (Engstrom and Swain, 1997; Yang and others, 2002). In a detailed study of a small mountain lake and watershed in Scotland, Yang and others (2002) found that 78 percent of the mercury and 91 percent of the lead being delivered to the lake are from the watershed (fluvial inputs). Therefore, only 22 percent of the mercury and 9 percent of the lead are coming from direct fallout on the lake surface. They also concluded that 77 percent of the mercury and 90 percent of the lead deposited since the 1860s and stored in watershed soils are from anthropogenic sources. Thus even for these fallout contaminants in a remote mountain setting, most of the loading to lake sediments is coming from the watershed.

Sediment focusing can be evaluated several ways. The most common approach is to compute a focusing factor (FF), the ratio of the measured radioisotope inventory to the inventory expected from direct input (Fuller and others, 1999). For ^{137}Cs, the measured inventory is the total ^{137}Cs burden in a core and the expected direct input is the total historical atmospheric fallout to the area, a value that can be estimated by the approach of Sarmiento and Gwinn (1986). This approach, used by Van Metre, Callender, and Fuller (1997) to estimate FFs for six reservoirs, yielded values ranging from 2.3 to 7.1. When a FF is greater than 1, the assumption is that the excess is from fallout elsewhere on the lake or watershed that has been transported to the coring location. Contaminant burdens or MARs can be adjusted by dividing by FF to estimate fallout burdens or rates of the contaminant, assuming no local watershed sources except fallout (Van Metre, Callender, and Fuller, 1997).

More rigorous approaches for evaluating sediment focusing and reconstructing contaminant fallout fluxes include use of multiple cores and sedimentation surveys in a lake to develop a whole-lake mass balance (Engstrom and Swain, 1997; Swain and others, 1992; Van Metre and others, 2003), and monitoring of soil cores, precipitation chemistry, and inflows and outflows from the lake (Yang and others, 2002). Swain and others (1992) showed a linear relation between whole-lake mercury accumulation rate and DA:SA ratio for seven headwater lakes in the midwestern United States. From this relation, they estimated that 25 percent of the mercury falling on the watershed was exported to the lake and that the DA:SA ratio could explain much of the variation in mercury accumulation rates among undisturbed, upper-midwestern lakes.

If the chemistry of sediment in a lake is dominated by fluvial inputs, do sediment cores record actual stream suspended-sediment concentrations? Van Metre and Mahler (2004) directly compared contaminant concentrations at the tops of cores with those of influent-stream suspended sediment in five stream-reservoir systems to determine to what extent stream chemistry was recorded in downstream cores. All five lakes (Lake Como, Echo Lake, Fosdic Lake, Harris Pond, and Upper Mystic Lake) are included in this report. In evaluating relations between suspended sediment and cores, contaminants separated into three levels of preservation in the cores: (1) influent concentrations and historical trends are preserved in cores (trace elements at all sites; some organic contaminants at some sites); (2) some loss occurred during transport and initial deposition, but relative historical trends are preserved in cores (most organic contaminants, including PAHs, PCBs, *p,p'*-DDE, total DDT, and chlordane); and (3) neither stream concentrations nor relative historical trends are preserved (dieldrin and *p,p'*-DDT). They concluded that the results support the use of sediment cores to infer stream water-quality histories for many contaminants, but suggest that reservoir bottom-sediment samples might underestimate concentrations of organic contaminants in some streams (Van Metre and Mahler, 2004).

Summary

The U.S. Geological Survey collected sediment cores from 56 lakes and reservoirs between 1992 and 2001 across the United States. Most of the sampling was conducted as part of the National Water-Quality Assessment Program. The primary objective of the study, known as the Reconstructed Trends National Synthesis study, was to determine trends in particle-associated contaminants in response to urbanization; 47 of the 56 lakes are in or near one of 20 U.S. cities. Sampling was done with gravity, piston, and box corers from boats and push cores from boats or by wading, depending on the depth of water, the thickness of sediment being sampled, and the sedimentation rate. Chemical analyses included major and trace elements, organochlorine pesticides, PCBs, PAHs, ^{210}Pb, and ^{137}Cs. Age-dating of the cores was done on the basis of radionuclide analyses and the depth of the pre-reservoir land surface in reservoir cores and, in a few cases, other chemical or lithologic depth-date markers. Dates were assigned in many lakes assuming a constant mass accumulation rate (MAR) between known depth-date markers. Dates assigned were supported using a variety of other date markers including first occurrence and peak concentrations of DDT, PCBs, and lead. A qualitative rating was assigned to each core on the basis of professional judgment to indicate the reliability of age assignments.

One-hundred twenty-two cores were collected from the 56 lakes, and age dates were assigned to 113 of them, representing 54 of the 56 lakes. Seventy-four of the 122 cores (61 percent) received a “good” rating, 28 cores (23 percent) a “fair” rating, and 11 cores (9 percent) a “poor” rating; nine cores (7 percent) had no dates assigned. An analysis of the influence of environmental factors on the apparent quality of age-dating of the cores indicated that the most important factor was the sediment MAR—the greater the MAR, the more likely the age-dating rating was “good.” Watershed area and watershed land-use setting appeared to affect age-dating quality; however, both characteristics are related to the MARs in the lakes. Greater MAR improves the temporal resolution in the core samples and reduces the effects of postdepositional sediment disturbance. Whether the water body was a lake or reservoir did not affect age-dating quality. Sampling approach also played a role in less-than-good ratings for some lakes; improvements in sampling approaches during the course of the study are discussed.

Distinctions between lakes and reservoirs and the effects of sediment MAR and drainage-area to surface-area (DA:SA) ratio on sampling and interpretation of cores are discussed. Of primary importance is the effect of DA:SA ratio on the relative contribution from fluvial sources, as opposed to atmospheric sources, of sediment-bound contaminants deposited in the lake. The larger the DA:SA ratio and the higher the MAR, the more likely it is that contaminants in bottom sediments are dominated by fluvial inputs. This is especially true in watersheds with urban land uses. These age-dated sediment cores provide the basis for interpretations of water-quality trends in these watersheds, as a function of land use, and at regional and national scales.

References

Anderson, R.F., Schiff, S.L., and Hesslein, R.H., 1987, Determining sediment accumulation and mixing rates using lead-210, cesium-137, and other tracers—Problems due to post-depositional mobility and coring artifacts: Canadian Journal of Fisheries and Aquatic Sciences, v. 44, p. 231–250.

Appleby, P.G., and Oldfield, F., 1992, Application of lead-210 to sedimentation studies, *in* Ivanovich, M., and Harmon, S., eds., Uranium-series disequilibrium—Applications to earth, marine, and environmental sciences (2d ed.): Oxford, Clarendon Press, p. 731–778.

Arbogast, B.F., ed., 1996, Analytical methods manual for the Mineral Resource Surveys Program: U.S. Geological Survey Open-File Report 96–525, 248 p.

Aruscavage, P.J., and Crock, J.G., 1987, Atomic absorption methods, *in* Baedecker, P.A., ed., Methods for geochemical analysis: U.S. Geological Survey Bulletin B 1770, p. C1–C6.

Baskaran, M., and Naidu, A.S., 1994, ^{210}Pb-derived chronology and the fluxes of ^{210}Pb and ^{137}Cs isotopes into continental shelf sediments, East Chukchi Sea, Alaskan Arctic: Geochimica et Cosmochimica Acta, v. 59, no. 21, p. 4,435–4,448.

Beck, H.L., Helfer, I.K., Bouville, Andre, and Dreicer, Mona, 1990, Estimates of fallout in the continental U.S. from Nevada weapons testing based on gummed-film monitoring data: Health Physics, v. 59, no. 5, p. 565–576.

Breault, R.F., Reisig, K.R., Barlow, L.K., and Weiskel, P.K., 2000, Distribution and potential for adverse biological effects of inorganic elements and organic compounds in bottom sediment, lower Charles River, Massachusetts: U.S. Geological Survey Water-Resources Investigations 00–4180, 70 p.

Burton, C.A., 2002, Effects of urbanization and long-term rainfall on the occurrence of organic compounds and trace elements in reservoir sediment cores, streambed sediment, and fish tissue from the Santa Ana River Basin, California, 1998: U.S. Geological Survey Water-Resources Investigations Report 02–4175, 73 p.

Callender, Edward, 2000, Geochemical effects of rapid sedimentation in aquatic systems—Minimal diagenesis and the preservation of historical metal signatures: Journal of Paleolimnology, v. 23, no. 3, p. 243–260.

Callender, Edward, and Rice, K.C., 2000, The urban environmental gradient—Anthropogenic influences on the spatial and temporal distributions of lead and zinc in sediments: Environmental Science and Technology, v. 34, no. 2, p. 232–238.

Callender, Edward, and Robbins, J.A., 1993, Transport and accumulation of radionuclides and stable elements in a Missouri River reservoir: Water Resources Research, v. 29, no. 6, p. 1,787–1,804.

Callender, Edward, and Van Metre, P.C., 1997, Reservoir sediment cores show U.S. lead declines: Environmental Science and Technology, v. 31, no. 9, p. 424A–428A.

Covay, K.J., and Beck, D.A., 2001, Sediment-deposition rates and organic compounds in bottom sediment at four sites in Lake Mead, Nevada, May 1998: U.S. Geological Survey Open-File Report 01–0282, 34 p.

Crecelius, E.A., and Piper, D.Z., 1973, Particulate lead contamination recorded in sedimentary cores from Lake Washington, Seattle: Environmental Science and Technology, v. 7, no. 8, p. 1,053–1,055.

Davis, R.B., 1980, The scope of Quaternary paleolimnology, *in* Davis, R.B., ed., Paleolimnology and the reconstruction of ancient environments: Boston, Kluwer Academic, p. 1–24.

Eisenreich, S.J., Capel, P.D., Robbins, J.A., and Boubonniere, R.A., 1989, Accumulation and diagenesis of chlorinated hydrocarbons in lacustrine sediments: Environmental Science and Technology, v. 23, no. 9, p. 1,116–1,126.

Emery, K.O., and Hulsemann, J., 1964, Shortening of sediment cores collected in open barrel gravity corers: Sedimentology, v. 3, p. 144–154.

Engstrom, D.R., and Swain, E.B., 1997, Recent declines in atmospheric mercury deposition in the Upper Midwest: Environmental Science and Technology, v. 31, no. 4, p. 960–967.

Foreman, W.T., Connor, B.F., Furlong, E.T., Vaught, D.G., and Merten, L.M., 1995, Methods of analysis by the U.S. Geological Survey National Water Quality Laboratory—Determination of organochlorine pesticides and polychlorinated biphenyls in bottom sediment by dual capillary-column gas chromatography with electron-capture detection: U.S. Geological Survey Open-File Report 95–140, 78 p.

Fuller, C.C., van Geen, A., Baskaran, M., and Anima, R., 1999, Sediment chronology in San Francisco Bay, California, defined by ^{210}Pb, ^{234}Th, ^{137}Cs, and ^{239,240}Pu: Marine Chemistry, v. 64, p. 7–27.

Furlong, E.T., Vaught, D.G., Merten, L.M., Foreman, W.T., and Gates, P.M., 1996, Methods of analysis by the U.S. Geological Survey National Water Quality Laboratory—Determination of semivolatile organic compounds in bottom sediment by solvent extraction, gel permeation chromatographic fractionation, and capillary-column gas chromatography/mass spectrometry: U.S. Geological Survey Open-File Report 95–719, 67 p.

Ging, P.B., Van Metre, P.C., and Callender, Edward, 1999, Bottom sediments of Lorence Creek Lake, San Antonio, Texas, reflect contaminant trends in an urbanizing watershed: U.S. Geological Survey Fact Sheet 149–99, 4 p.

Greve, A.I., Spahr, N.E., Van Metre, P.C., and Wilson, J.T., 2001, Identification of water-quality trends using sediment cores from Dillon Reservoir, Summit County, Colorado: U.S. Geological Survey Water-Resources Investigations Report 01–4022, 33 p.

Heit, M., Klusek, C., and Baron, J., 1984, Evidence of deposition of anthropogenic pollutants in remote Rocky Mountain lakes: Water, Air, and Soil Pollution, v. 22, p. 402–416.

Hites, R.A., LaFlamme, R.E., Windsor, J.G., Jr., Farrington, J.W., and Deuser, W.G., 1981, Polycyclic aromatic hydrocarbons in an anoxic sediment core from the Pettaquamscutt River (Rhode Island, U.S.A.): Geochimica et Cosmochimica Acta, v. 44, p. 873–878.

Holmes, C.W., 1998, Short-lived isotopic chronometers—A means of measuring decadal sedimentary dynamics: U.S. Geological Survey Fact Sheet 073–98, 2 p.

Horowitz, A.J., and Elrick, K.A., 1987, The relation of stream sediment surface area, grain size, and composition to trace element chemistry: Applied Geochemistry, v. 2, no. 4, p. 437–451.

Juracek, K.E., 1998, Analysis of lake-bottom sediment to estimate historical nonpoint-source phosphorus loads: Journal of the American Water Resources Association, v. 34, no. 6, p. 1,449–1,463.

Leahy, P.P., Rosenshein, J.S., and Knopman, D.S., 1990, Implementation plan for the National Water-Quality Assessment Program: U.S. Geological Survey Open-File Report 90–174, 10 p.

Long, G.R., Ayers, M.A., Callender, Edward, and Van Metre, P.C., 2003, Trends in chemical concentration in sediment cores from three lakes in New Jersey and one lake on Long Island, New York: U.S. Geological Survey Water-Resources Investigations Report 02–4272, 32 p.

Marzolf, G.R., 1990, Reservoirs as environments for zooplankton, *in* Thornton, K.W., Kimmel, B.L., and Payne, F.E., eds., Reservoir limnology—Ecological perspectives: New York, John Wiley, p. 195–208.

Naftz, D.L., Stephens, D.W., Callender, Edward, and Van Metre, P.C., 2000, Reconstructing historical changes in the environmental health of watersheds by using sediment cores from lakes and reservoirs in Salt Lake Valley, Utah: U.S. Geological Survey Fact Sheet 164–00, 6 p.

Noriega, M.C., Wydoski, D.S., and Foreman, W.T., 2003, Methods of analysis by the U.S. Geological Survey National Water Quality Laboratory—Determination of organochlorine pesticides and polychlorinated biphenyls in bottom and suspended sediment by gas chromatography with electron-capture detection: U.S. Geological Survey Water-Resources Investigations Report 03–4293, 46 p.

Olson, M.C., Iverson, J.L., Furlong, E.T., and Schroeder, M.P., 2003, Methods of analysis by the U.S. Geological Survey National Water Quality Laboratory—Determination of polycyclic aromatic hydrocarbon compounds in sediment by gas chromatography/mass spectrometry: U.S. Geological Survey Water-Resources Investigations Report 03–4318, 45 p.

Robbins, J.A., 1986, Model for particle-selective transport of tracers in sediments with conveyor belt deposit feeders: Journal of Geophysical Research, v. 91, no. 3, p. 8,542–8,558.

Robbins, J.A., and Edgington, D.N., 1976, Determination of recent sedimentation rates in Lake Michigan using ^{210}Pb and ^{137}Cs: Geochimica et Cosmochimica Acta, v. 39, no. 3, p. 285–304.

Sarmiento, J.L., and Gwinn, E., 1986, Strontium-90 fallout prediction: Journal of Geophysical Research, v. 91, p. 7,631–7,646.

Spliethoff, H.M., and Hemond, H.F., 1996, History of toxic metal discharge to surface waters of the Aberjona watershed: Environmental Science and Technology, v. 30, no. 1, p. 121–128.

Swain, E.B., Engstrom, D.R., Brigham, M.E., Henning, T.A., and Brezonik, P.L., 1992, Increasing rates of atmospheric mercury deposition in midcontinental North America: Science, v. 257, no. 5071, p. 784–787.

Thornton, K.W., 1990, Perspectives on reservoir limnology, *in* Thornton, K.W., Kimmel, B.L., and Payne, F.E., eds., Reservoir limnology—Ecological Perspectives: New York, John Wiley, p. 1–13.

Van Metre, P.C., and Callender, Edward, 1996, Identifying water-quality trends in the Trinity River, Texas, USA, 1969–1992, using sediment cores from Lake Livingston: Environmental Geology, v. 28, no. 4, p. 190–200.

Van Metre, P.C., and Callender, Edward, 1997, Water-quality trends in White Rock Creek Basin from 1912–94 identified using sediment cores from White Rock Lake reservoir, Dallas, Texas: Journal of Paleolimnology, v.17, p. 239–249.

Van Metre, P.C., Callender, Edward, and Fuller, C.C., 1997, Historical trends in organochlorine compounds in river basins identified using sediment cores from reservoirs: Environmental Science and Technology, v. 31, no. 8, p. 2,339–2,344.

Van Metre, P.C., Callender, Edward, Mahler, B.J., Wilson, J.T., and Dorsey, M.E., 2001, Differences in lake and reservoir sedimentation—Implications for sediment coring studies, *in* Seventh Interagency Sedimentation Conference, Reno, Nev., March 25–29, 2001, Proceedings: U.S. Department of Agriculture, Natural Resources Conservation Service, v. 2, p. IX–12–IX–19.

Van Metre, P.C., Land, L.F., and Braun, C.L., 1996, Water-quality trends using sediment cores from White Rock Lake, Dallas, Texas: U.S. Geological Survey Fact Sheet 217–96, 4 p.

Van Metre, P.C., and Mahler, B.J., 1999, Town Lake bottom sediments—A chronicle of water-quality changes in Austin, Texas, 1960–98: U.S. Geological Survey Fact Sheet 183–99, 6 p.

Van Metre, P.C., and Mahler, B.J., 2004, Contaminant trends in reservoir sediment cores as records of influent stream quality: Environmental Science and Technology, v. 38, no. 11, p. 2,978–2,986.

Van Metre, P.C., Mahler, B.J., and Callender, Edward, 1997, Water-quality trends in the Rio Grande/Rio Bravo Basin using sediment cores from reservoirs: U.S. Geological Survey Fact Sheet 221–96, 8 p.

Van Metre, P.C., Mahler, B.J., and Furlong, E.T., 2000, Urban sprawl leaves its PAH signature: Environmental Science and Technology, v. 34, no. 19, p. 4,064–4,070.

Van Metre, P.C., and Sneck-Fahrer, D.A., 2002, Water-quality trends in suburban Houston, Texas, 1954–97, as indicated by sediment cores from Lake Houston: U.S. Geological Survey Fact Sheet 040–02, 6 p.

Van Metre, P.C., Wilson, J.T., Callender, Edward, and Fuller, C.C., 1998, Similar rates of decrease of persistent, hydrophobic and particle-reactive contaminants in riverine systems: Environmental Science and Technology, v. 32, no. 21, p. 3,312–3,317.

Van Metre, P.C., Wilson, J.T., Harwell, G.R., Gary, M.O., Heitmuller, F.T., and Mahler, B.J., 2003, Occurrence, trends, and sources in particle-associated contaminants in selected streams and lakes in Fort Worth, Texas: U.S. Geological Survey Water-Resources Investigations Report 03–4169, 154 p.

Wershaw, R.L., Fishman, M.J., Grabbe, R.R., and Lowe, L.E., eds., 1987, Methods for the determination of organic substances in water and fluvial sediments: U.S. Geological Survey Techniques of Water Resources Investigations, book 5, chap. A3, 80 p.

Wilson, J.T., and Van Metre, P.C., 2000, Deposition and chemistry of bottom sediments in Cochiti Lake, north-central New Mexico: U.S. Geological Survey Water-Resources Investigations Report, 99–4258, 31 p.

Yang, Handong, Rose, N.L., Battarbee, R.W., and Boyle, J.F., 2002, Mercury and lead budgets for Lochnagar, a Scottish mountain lake and its catchment: Environmental Science and Technology, v. 36, no. 7, p. 1,383–1,388.

Appendix—Age Assignments for Cores

Appendix. Age Assignments for Cores (numbers before lake names correspond to fig. 1; lakes presented in geographic order as shown in figure 1; in all figures, "nondetection" means nondetection at the indicated laboratory reporting limit)

1. Hillstrand Pond, Alaska

Hillstrand Pond is a small reservoir located on Chester Creek in Anchorage, Alaska. Two hand-pushed cores were collected for chemical analysis near the southern shore of the pond in June 1998.

HIL.2 Push core 40 cm long analyzed for major and trace elements.

Basis A large peak in lead concentrations (hereinafter lead peak) spans two samples from 28 to 34 cm (fig. A–1a). The larger lead concentration in the 32- to 34-cm sample was assigned a date of 1973.6, resulting in a MAR of 0.92 g/cm^2-yr. Dates were assigned using this MAR.

Corroboration The following chronology was reported on the basis of repeated historical air photos (Timothy P. Brabetts, U.S. Geological Survey, written commun., 2001):

1960: The pond was a very small body of water located directly adjacent to the west side of Lake Otis Boulevard. The surrounding area was sparsely populated and undeveloped.

1965: Construction had begun on the pond—clearing and stream braiding is visible. Parks and Recreation Services was in the process of creating an outdoor ice skating rink.

1970: The pond had filled with water to about one-half the cleared area. A spillway was constructed at the outlet of the pond.

1975: The entire cleared area of the pond had filled with water. There was substantial development (condominiums) to the north, and East 20th Avenue was constructed, which included a storm drain system that drained into Hillstrand Pond. Pond size was about 3.3 acres (0.013 square kilometers [km^2]).

1980: No changes.

1985: No changes.

1990: Substantial vegetation had grown on the northeast end of the pond, and the pond area had been reduced to about 2.5 acres (0.010 km^2).

This chronology suggests that the pond was formed in its present configuration in about 1970. The core penetrated into a zone containing root hairs and some sand at 38 cm, a depth that received a date of 1970.1.

Rating Good.

HIL.1 Push core 42 cm long analyzed for organic compounds.

Basis Dates were assigned on the basis of the date-depth relation developed for core HIL.2.

Corroboration The largest total DDT concentration is in the deepest sampled analyzed (40 to 42 cm) and received a reasonable date of 1969.2 (fig. A–1b). The large total PCB peak at 32 to 34 cm received a reasonable date of 1973.6.

Rating Good.

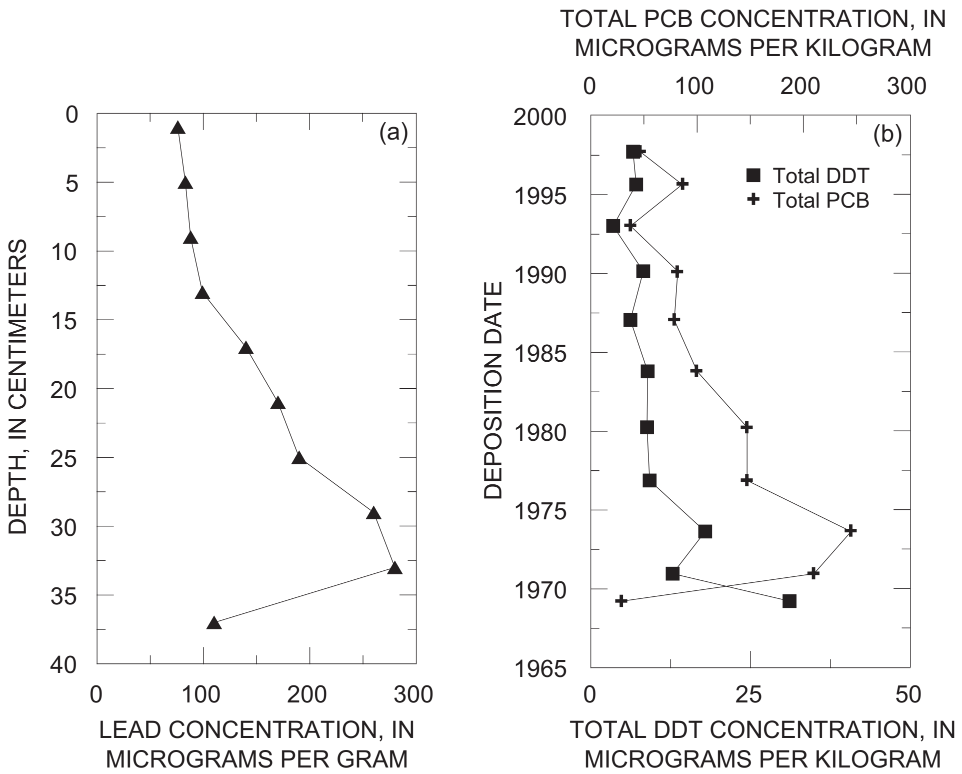


Figure A–1. Chemical constituent profiles used to estimate age dates for Hillstrand Pond, Alaska (a) HIL.2, (b) HIL.1.

Table A–1

Core HIL.2			Core HIL.1		
Sample identification	Mid-depth (centimeters)	Estimated deposition date	Sample identification	Mid-depth (centimeters)	Estimated deposition date
HIL–2 0–2	1	1997.7	HIL–1 0–2	1	1997.7
HIL–2 4–6	5	1995.6	HIL–1 4–6	5	1995.6
HIL–2 8–10	9	1993.0	HIL–1 8–10	9	1993.0
HIL–2 12–14	13	1990.1	HIL–1 12–14	13	1990.1
HIL–2 16–18	17	1987.1	HIL–1 16–18	17	1987.1
HIL–2 20–22	21	1983.8	HIL–1 20–22	21	1983.8
HIL–2 24–26	25	1980.2	HIL–1 24–26	25	1980.2
HIL–2 28–30	29	1976.9	HIL–1 28–30	29	1976.9
HIL–2 32–34	33	1973.6	HIL–1 32–34	33	1973.6
HIL–2 36–38	37	1971.0	HIL–1 36–38	37	1971.0
HIL–2 38–40	39	1969.2	HIL–1 40–42	41	1969.2

2. Westchester Lagoon, Alaska

Westchester Lagoon is a man-made impoundment constructed in 1970 on Chester Creek near the inlet of the creek to the Knik Arm of Cook Inlet in Anchorage, Alaska. One gravity core was collected for chemical analysis from the upper end of the lagoon in June 1998.

WES–2 Gravity core 68 cm long analyzed for major and trace elements and organic compounds.

Basis A very well defined lead peak at 51 to 54 cm (fig. A–2a) was assigned a date of 1975.0. The resulting MAR of 1.47 g/cm^2-yr was used to assign dates to the core.

Corroboration The causeway and roadway (Minnesota Avenue) that bisects Westchester Lagoon downstream from the coring site was constructed during 1967–69. A firm gray clay at 55 cm in the core probably marks the beginning of sedimentation soon after roadway construction. The 55-cm depth received a date of 1973.3. The largest total DDT and PCB concentrations are at 51 to 54 cm and received a reasonable date of 1975.0 (fig. A–2b). The timing of these peaks matches those in Hillstrand Pond, located upstream from Westchester Lagoon on Chester Creek.

Rating Good. Although using a contaminant profile (lead in this case) as the basis of age-dating is not as desirable as an independent marker like ^{137}Cs, the dates are well corroborated.

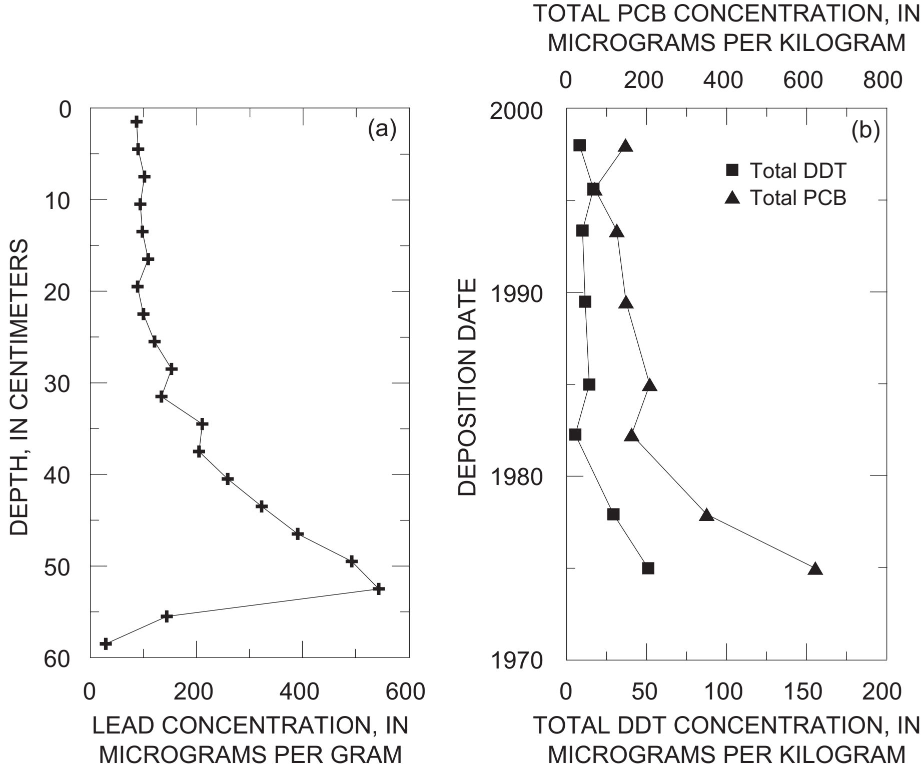


Figure A–2. Chemical constituent profiles used to estimate age dates for Westchester Lagoon, Alaska.

Table A–2

Core WES–2			Core WES–2		
Sample identification	Mid-depth (centimeters)	Estimated deposition date	Sample identification	Mid-depth (centimeters)	Estimated deposition date
WES–2 0–3	1.5	1998.0	WES–2 30–33	31.5	1985.0
WES–2 3–6	4.5	1996.9	WES–2 33–36	34.5	1983.6
WES–2 6–9	7.5	1995.6	WES–2 36–39	37.5	1982.3
WES–2 9–12	10.5	1994.5	WES–2 39–42	40.5	1980.8
WES–2 12–15	13.5	1993.4	WES–2 42–45	43.5	1979.4
WES–2 15–18	16.5	1992.1	WES–2 45–48	46.5	1977.9
WES–2 18–21	19.5	1990.8	WES–2 48–51	49.5	1976.5
WES–2 21–24	22.5	1989.5	WES–2 51–54	52.5	1975.0
WES–2 24–27	25.5	1987.9	WES–2 54–57	55.5	1973.3
WES–2 27–30	28.5	1986.3	WES–2 57–60	58.5	1971.4

3. Lake Ballinger, Wash.

Lake Ballinger is a natural lake located in the suburban area north of Seattle, Wash., known as Mountlake Terrace. One box core was collected for chemical analysis near the lake inflow in June 1998.

BAL.B Box core 28 cm deep analyzed for all constituents. Samples for organic and radionuclide analyses collected on 1-cm intervals, samples for metals on 0.5-cm intervals (all out of same core).

Basis A sharp ^{137}Cs peak occurs at 15 to 16 cm (fig. A–3a). A date of 1964.0 was assigned to the interval with a mid-depth of 15.25 cm resulting in an average MAR of 0.11 g/cm^2-yr for the core. This MAR was used to assign dates.

Corroboration A total DDT peak also occurs at 15 to 16 cm; this sample received a mid-point date of 1963.3 (fig. A–3b), which is reasonable. Chlordane is detected in the bottom sample (22 to 23 cm). Commercial production of chlordane began in 1947. This sample received a date of 1947.8, probably a little questionable, but not enough to adjust dates in the lower part of the core. A large, rounded lead peak centered at 10.25 cm received a date of 1979.6 using the average MAR, which is also reasonable.

Rating Good.

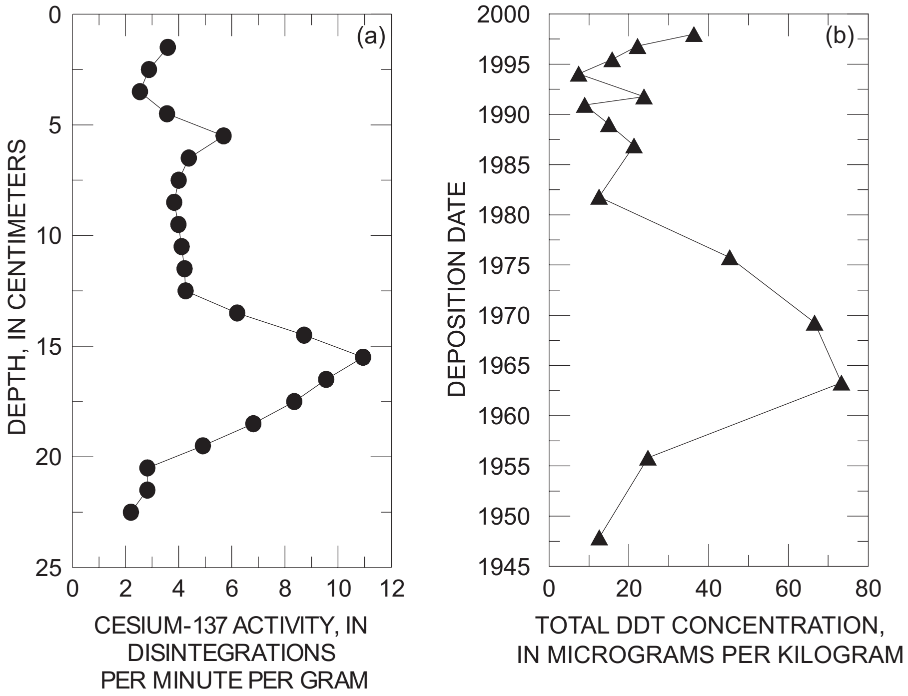


Figure A–3. Chemical constituent profiles used to estimate age dates for Lake Ballinger, Wash.

Table A–3

Core BAL.B			Core BAL.B		
Sample identification	Mid-depth (centimeters)	Estimated deposition date	Sample identification	Mid-depth (centimeters)	Estimated deposition date
BAL.B 0–0.5	0.25	1998.3	BAL.B 11.5–12	11.75	1975.0
BAL.B 0.5–1	.75	1997.7	BAL.B 12–12.5	12.25	1973.3
BAL.B 1–1.5	1.25	1997.1	BAL.B 12.5–13	12.75	1971.6
BAL.B 1.5–2	1.75	1996.5	BAL.B 13–13.5	13.25	1970.0
BAL.B 2–2.5	2.25	1995.8	BAL.B 13.5–14	13.75	1968.5
BAL.B 2.5–3	2.75	1995.1	BAL.B 14–14.5	14.25	1967.0
BAL.B 3–3.5	3.25	1994.4	BAL.B 14.5–15	14.75	1965.5
BAL.B 3.5–4	3.75	1993.7	BAL.B 15–15.5	15.25	1964.0
BAL.B 4–4.5	4.25	1992.9	BAL.B 15.5–16	15.75	1962.6
BAL.B 4.5–5	4.75	1992.2	BAL.B 16–16.5	16.25	1961.2
BAL.B 5–5.5	5.25	1991.4	BAL.B 16.5–17	16.75	1959.9
BAL.B 5.5–6	5.75	1990.5	BAL.B 17–17.5	17.25	1958.7
BAL.B 6–6.5	6.25	1989.5	BAL.B 17.5–18	17.75	1957.5
BAL.B 6.5–7	6.75	1988.5	BAL.B 18–18.5	18.25	1956.3
BAL.B 7–7.5	7.25	1987.5	BAL.B 18.5–19	18.75	1955.3
BAL.B 7.5–8	7.75	1986.3	BAL.B 19–19.5	19.25	1954.2
BAL.B 8–8.5	8.25	1985.1	BAL.B 19.5–20	19.75	1953.2
BAL.B 8.5–9	8.75	1983.8	BAL.B 20–20.5	20.25	1952.3
BAL.B 9–9.5	9.25	1982.5	BAL.B 20.5–21	20.75	1951.4
BAL.B 9.5–10	9.75	1981.1	BAL.B 21–21.5	21.25	1950.3
BAL.B 10–10.5	10.25	1979.6	BAL.B 21.5–22	21.75	1949.2
BAL.B 10.5–11	10.75	1978.1	BAL.B 22–22.5	22.25	1948.3
BAL.B 11–11.5	11.25	1976.6	BAL.B 22.5–23	22.75	1947.4

4. Tolt Reservoir, Wash.

Tolt Reservoir, also known as South Fork Tolt Reservoir, was constructed in 1964 on the South Fork Tolt River east of Seattle, Wash. The reservoir is located in the foothills of the Cascades Mountains in the Snoqualmie National Forest. Tolt Reservoir provides about 30 percent of the drinking water for the city of Seattle. One box core was collected for chemical analysis from the middle of the upper end of the reservoir in June 1998.

TLT.B Box core 14 cm deep analyzed for all constituents.

Basis Sedimentation rates are low for this protected water-supply reservoir as indicated by a total sediment thickness of 14 cm. The pre-reservoir surface at 14 cm was assigned the construction date of 1964.0, resulting in a MAR of 0.13 g/cm^2-yr. Dates were assigned on the basis of the MAR.

Corroboration As expected, the ^{137}Cs profile increases to the bottom of the core (fig. A–4). Small concentrations of contaminants in this reference lake do not provide any additional corroboration of the assigned dates.

Rating Fair.

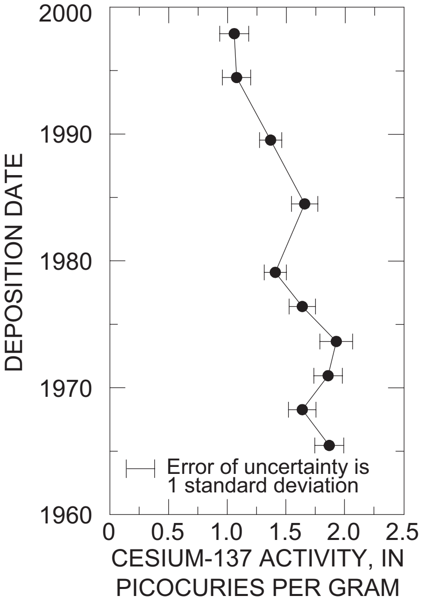


Figure A–4. Chemical constituent profile used to estimate age dates for Tolt Reservoir, Wash.

Table A–4

Core TLT.B			Core TLT.B		
Sample identification	Mid-depth (centimeters)	Estimated deposition date	Sample identification	Mid-depth (centimeters)	Estimated deposition date
TLT.B 0–1	0.5	1997.9	TLT.B 7–8	7.5	1981.8
TLT.B 1–2	1.5	1996.4	TLT.B 8–9	8.5	1979.1
TLT.B 2–3	2.5	1994.5	TLT.B 9–10	9.5	1976.4
TLT.B 3–4	3.5	1992.1	TLT.B 10–11	10.5	1973.6
TLT.B 4–5	4.5	1989.5	TLT.B 11–12	11.5	1970.9
TLT.B 5–6	5.5	1987.0	TLT.B 12–13	12.5	1968.3
TLT.B 6–7	6.5	1984.5	TLT.B 13–14	13.5	1965.4

5. Lake Washington, Wash.

Lake Washington is a large natural lake in central Seattle, Wash. One box core was collected for chemical analysis from the northern area of the lake, north of the Evergreen Point Floating Bridge, in June 1998.

WAS–B Box core 41 cm deep analyzed for all constituents.

Basis The ^{137}Cs activity peak at 10 to 11 cm (fig. A–5a) was assigned a date of 1964.0 resulting in a MAR of 0.055 g/cm^2-yr for the core. This MAR was used to assign dates to the core.

Corroboration The peak concentrations of total DDT and PCBs span two samples, 9 to 10 and 11 to 12 cm, and are reasonably dated as 1967.8 and 1960.2, respectively (fig. A–5b). Lead concentrations peak over two samples, 6 to 6.5 and 6.5 to 7 cm, reasonably dated as 1978.6 and 1977.0, respectively (fig. A–5c). Dates in the deeper, older part of the core are corroborated by increases in heavy metals, including lead and copper, beginning in about 1890 (fig. A–5c). The Asarco smelter in Tacoma began operations in 1890 as a lead smelter switching to copper smelting in 1912 (U.S. Environmental Protection Agency EPA ID# WAD980726368). Regional metal pollution, including increased metal loading to Lake Washington, has been attributed to the smelter (Crecelius and Piper, 1973).

Rating Good.

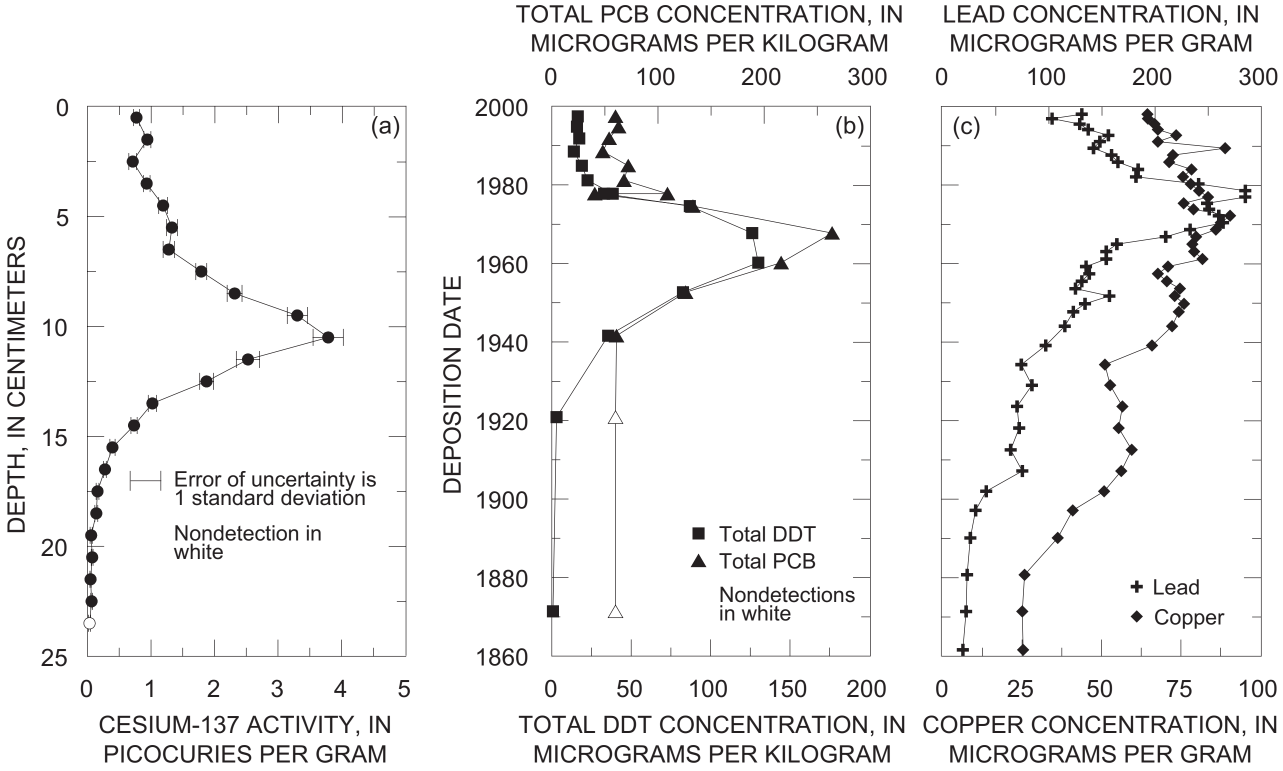


Figure A–5. Chemical constituent profiles used to estimate age dates for Lake Washington, Wash.

Table A–5

Core WAS–B			Core WAS–B		
Sample identification	Mid-depth (centimeters)	Estimated deposition date	Sample identification	Mid-depth (centimeters)	Estimated deposition date
WAS–B 0–0.5	0.25	1998.0	WAS–B 11–11.5	11.25	1961.2
WAS–B 0.5–1	0.75	1996.9	WAS–B 11.5–12	11.75	1959.2
WAS–B 1–1.5	1.25	1995.5	WAS–B 12–12.5	12.25	1957.4
WAS–B 1.5–2	1.75	1994.1	WAS–B 12.5–13	12.75	1955.5
WAS–B 2–2.5	2.25	1992.7	WAS–B 13–13.5	13.25	1953.6
WAS–B 2.5–3	2.75	1991.1	WAS–B 13.5–14	13.75	1951.7
WAS–B 3–3.5	3.25	1989.4	WAS–B 14–14.5	14.25	1949.8
WAS–B 3.5–4	3.75	1987.6	WAS–B 14.5–15	14.75	1947.7
WAS–B 4–4.5	4.25	1985.8	WAS–B 15–16	15.5	1944.1
WAS–B 4.5–5	4.75	1984.0	WAS–B 16–17	16.5	1939.1
WAS–B 5–5.5	5.25	1982.1	WAS–B 17–18	17.5	1934.3
WAS–B 5.5–6	5.75	1980.3	WAS–B 18–19	18.5	1929.0
WAS–B 6–6.5	6.25	1978.6	WAS–B 19–20	19.5	1923.6
WAS–B 6.5–7	6.75	1977.0	WAS–B 20–21	20.5	1918.1
WAS–B 7–7.5	7.25	1975.4	WAS–B 21–22	21.5	1912.6
WAS–B 7.5–8	7.75	1973.8	WAS–B 22–23	22.5	1907.2
WAS–B 8–8.5	8.25	1972.2	WAS–B 23–24	23.5	1902.0
WAS–B 8.5–9	8.75	1970.4	WAS–B 24–25	24.5	1897.2
WAS–B 9–9.5	9.25	1968.7	WAS–B 25–27	26	1890.1
WAS–B 9.5–10	9.75	1966.8	WAS–B 27–29	28	1880.7
WAS–B 10–10.5	10.25	1965.0	WAS–B 29–31	30	1871.4
WAS–B 10.5–11	10.75	1963.1	WAS–B 31–33	32	1861.6

6. West Street Basin, Calif.

West Street Basin is a retarding basin located in Garden Grove/Anaheim, Calif. The construction date of the basin could not be obtained. Two hand-pushed cores were collected for chemical analysis from the southern end of the basin in November 1998.

WST.2 Push core 40 cm long analyzed for ^{137}Cs and major and trace elements.

Basis The ^{137}Cs activity peak at 30 to 32 cm (fig. A–6a) was assigned a date of 1964.0 resulting in a MAR of 0.33 g/cm^2-yr for the core. Dates were assigned on the basis of this MAR.

Corroboration Trace element concentrations, including lead, are very large in the lower part of the core, precluding the use of lead as a date marker. Application of the date-depth relation developed for this core to the adjacent core WST.3, however, resulted in a reasonable date for the total DDT peak.

Rating Good.

WST.3 Push core 40 cm long analyzed for organic compounds.

Basis Dates were assigned on the basis of the date-depth relation developed for core WST.2.

Corroboration Total DDT peak is at 28 to 30 cm and receives a reasonable date of 1967.2 (fig. A–6b).

Rating Good.

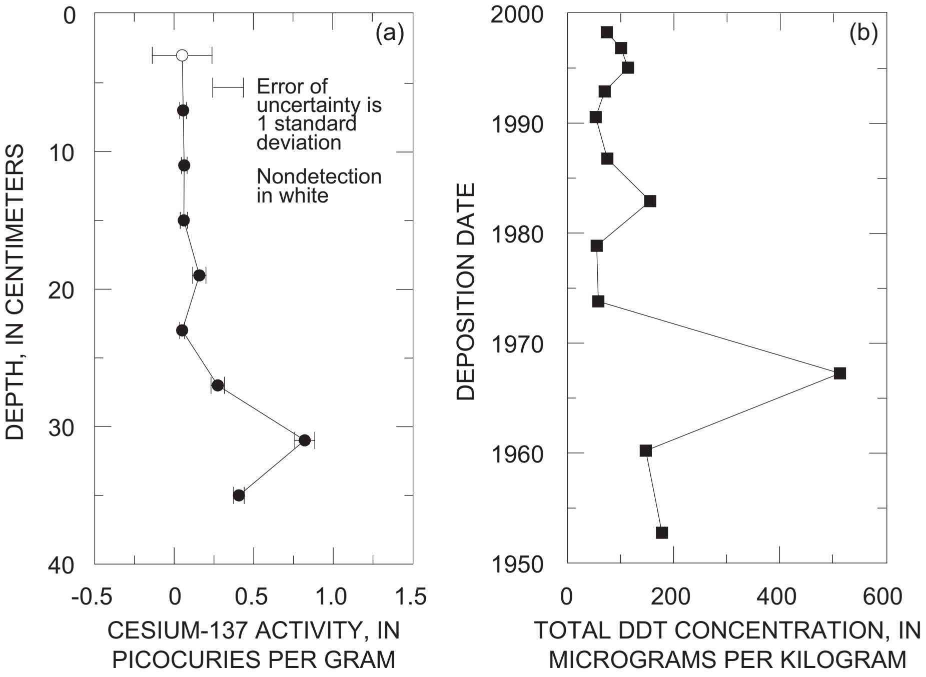


Figure A–6. Chemical constituent profiles used to estimate age dates for West Street Basin, Calif. (a) WST.2, (b) WST.3.

Table A–6

Core WST.2			Core WST.2		
Sample identification	Mid-depth (centimeters)	Estimated deposition date	Sample identification	Mid-depth (centimeters)	Estimated deposition date
WST.2 0–2	1	1998.3	WST.2 20–22	21	1978.8
WST.2 2–4	3	1996.8	WST.2 22–24	23	1976.5
WST.2 4–6	5	1995.0	WST.2 24–26	25	1973.8
WST.2 6–8	7	1992.9	WST.2 26–28	27	1970.4
WST.2 8–10	9	1990.5	WST.2 28–30	29	1967.2
WST.2 10–12	11	1988.5	WST.2 30–32	31	1964.0
WST.2 12–14	13	1986.8	WST.2 32–34	33	1960.2
WST.2 14–16	15	1984.8	WST.2 34–36	35	1956.5
WST.2 16–18	17	1982.9	WST.2 36–38	37	1952.8
WST.2 18–20	19	1981.0			

Core WST.3			Core WST.3		
Sample identification	Mid-depth (centimeters)	Estimated deposition date	Sample identification	Mid-depth (centimeters)	Estimated deposition date
WST.3 0–2	1	1998.3	WST.3 16–18	17	1982.9
WST.3 2–4	3	1996.8	WST.3 20–22	21	1978.8
WST.3 4–6	5	1995.0	WST.3 24–26	25	1973.8
WST.3 6–8	7	1992.9	WST.3 28–30	29	1967.2
WST.3 8–10	9	1990.5	WST.3 32–34	33	1960.2
WST.3 12–14	13	1986.8	WST.3 36–38	37	1952.8

7. R.R. Canyon Lake, Calif.

R.R. Canyon Lake is a reservoir, constructed in 1928, on the San Jacinto River in southern California between Los Angeles and San Diego. One gravity core was collected for chemical analysis from the lower end of the reservoir in November 1998.

CYN Gravity core 192 cm long analyzed for all constituents.

Basis The peak ^{137}Cs activity is at 118 cm (fig. A–7a). This sample was assigned a date of 1964.0, resulting in an average MAR of 1.79 g/cm^2-yr for the core. This MAR was used to assign dates.

Corroboration A well defined lead peak at 73 cm received a date of 1980.2 (fig. A–7b), a little late in time but not enough to adjust sedimentation rates. The pre-reservoir surface is at 156 cm. The deepest lacustrine sediment sample received a date of 1950.7 and has detectable concentrations of DDT, DDD, and DDE (fig. A–7b). It is concluded, therefore, that sediment deposited between 1928 and about 1950 was not preserved and that age assignments are reasonable.

Rating Good.

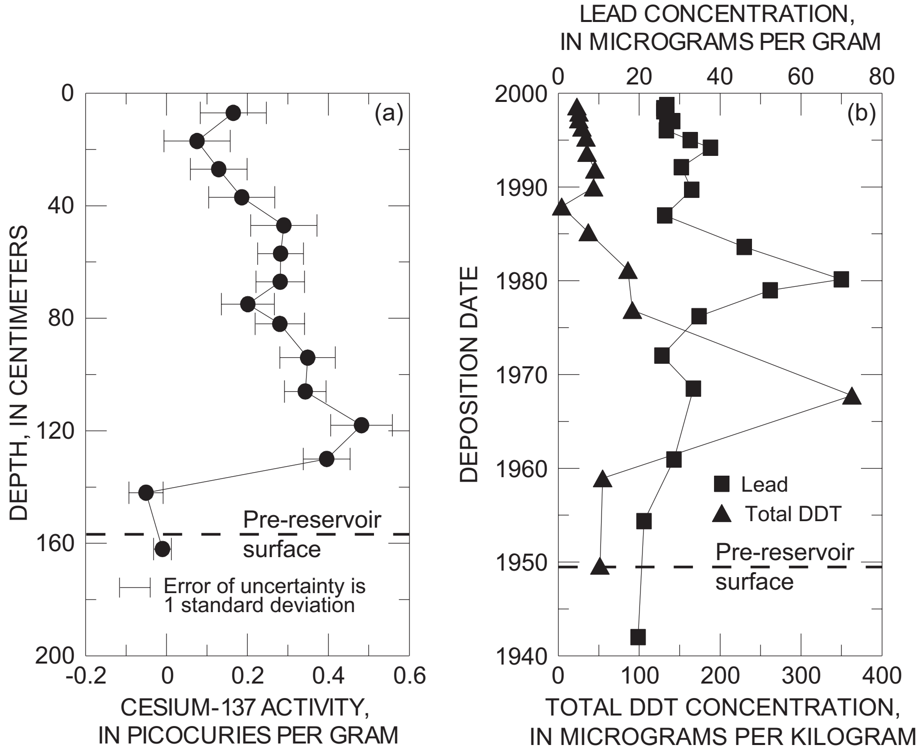


Figure A–7. Chemical constituent profiles used to estimate age dates for R.R. Canyon Lake, Calif.

Table A–7

Core CYN			Core CYN		
Sample identification	Mid-depth (centimeters)	Estimated deposition date	Sample identification	Mid-depth (centimeters)	Estimated deposition date
CYN 0–2	1	1998.7	CYN 62–64	63	1983.6
CYN 2–4	3	1998.4	CYN 64–66	65	1983.0
CYN 4–6	5	1998.1	CYN 66–68	67	1982.2
CYN 6–8	7	1997.7	CYN 68–70	69	1981.5
CYN 8–10	9	1997.4	CYN 70–72	71	1980.8
CYN 10–12	11	1997.0	CYN 72–74	73	1980.2
CYN 12–14	13	1996.6	CYN 74–76	75	1979.6
CYN 14–16	15	1996.0	CYN 76–78	77	1979.0
CYN 16–18	17	1995.5	CYN 78–80	79	1978.4
CYN 18–20	19	1995.0	CYN 80–84	82	1977.5
CYN 20–22	21	1994.5	CYN 84–88	86	1976.2
CYN 22–24	23	1994.2	CYN 88–92	90	1974.8
CYN 24–26	25	1993.8	CYN 92–96	94	1973.5
CYN 26–28	27	1993.4	CYN 96–100	98	1972.0
CYN 28–30	29	1993.0	CYN 100–104	102	1970.2
CYN 30–32	31	1992.6	CYN 104–108	106	1968.5
CYN 32–34	33	1992.1	CYN 108–112	110	1967.0
CYN 34–36	35	1991.6	CYN 112–116	114	1965.6
CYN 36–38	37	1991.0	CYN 116–120	118	1964.0
CYN 38–40	39	1990.6	CYN 120–124	122	1962.5
CYN 40–42	41	1990.2	CYN 124–128	126	1961.0
CYN 42–44	43	1989.7	CYN 128–132	130	1959.5
CYN 44–46	45	1989.2	CYN 132–136	134	1958.3
CYN 46–48	47	1988.7	CYN 136–140	138	1957.1
CYN 48–50	49	1988.2	CYN 140–144	142	1955.8
CYN 50–52	51	1987.6	CYN 144–148	146	1954.4
CYN 52–54	53	1987.0	CYN 148–152	150	1952.7
CYN 54–56	55	1986.2	CYN 152–156	154	1950.7
CYN 56–58	57	1985.5	CYN 156–160	158	Pre-reservoir
CYN 58–60	59	1984.9	CYN 160–164	162	Pre-reservoir
CYN 60–62	61	1984.2	CYN 164–168	166	Pre-reservoir

8. Lake Hemet, Calif.

Lake Hemet is a reservoir constructed about 1900 on the San Jacinto River in the San Bernadino National Forest near the San Jacinto Mountain range of southern California. One box core was collected for chemical analysis from the center of the reservoir in November 1998.

HEM One box core 45 cm deep analyzed for all constituents.

Basis The ^{137}Cs activity is greatest in the deepest sample analyzed, the 34 to 35 cm interval. The DDE concentration also is largest in the deepest sample analyzed, the 32 to 35 cm interval (fig. A–8). The reservoir was constructed about 1900, however, the cores encountered pre-reservoir sediment at 35 cm, indicating an erosional discontinuity. With no clear date markers, only one assumption could be made—the oldest 35-cm sediment was deposited about 1964. This allows computation of a minimum MAR of 0.30 g/cm^2-yr.

Corroboration None.

Rating No dates assigned; however, a minimum MAR was estimated. The minimum MAR is reasonable and can be used to estimate minimum contaminant MARs for interpretations among lakes.

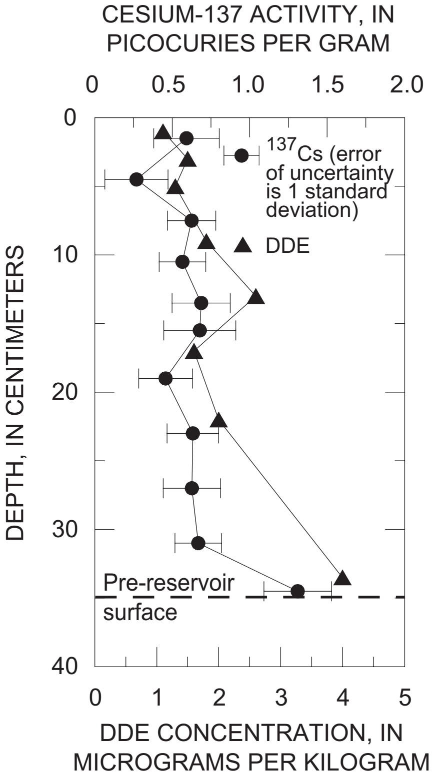


Figure A–8. Chemical constituent profiles used to estimate a minimum mass accumulation rate for Lake Hemet, Calif.

9. Sweetwater Reservoir, Calif.

Sweetwater Reservoir was constructed in 1888 on the Sweetwater River east of San Diego, Calif. One piston core was collected for analysis from the middle of the lower end of the reservoir in September 1998.

SWT.4 Piston core 193 cm long analyzed for all constituents.

Basis The ^{137}Cs activity peak at 112 to 116 cm (fig. A–9a) was assigned a date of 1964.0 resulting in a MAR of 1.27 g/cm^2-yr. The MAR was used to assign dates to the core.

Corroboration The latest nondetection of ^{137}Cs, at 152 to 156 cm, received a date of 1949.1, which correctly predates the expected first occurrence in 1952.0. The next sample analyzed, at 136 to 140 cm, had detectable ^{137}Cs and was dated as 1956.2 (fig. A–9a). The total DDT peak at 116 to 120 cm received a reasonable date of 1962.5 (fig. A–9b). The deepest lacustrine sediment sample at 180 to 184 cm received a date of 1933.8; however, the reservoir was constructed in 1888 and pre-reservoir soil was encountered below 184 cm. It therefore was concluded that the sediment deposited between 1888 and about 1934 was not preserved at the coring site.

Rating Good.

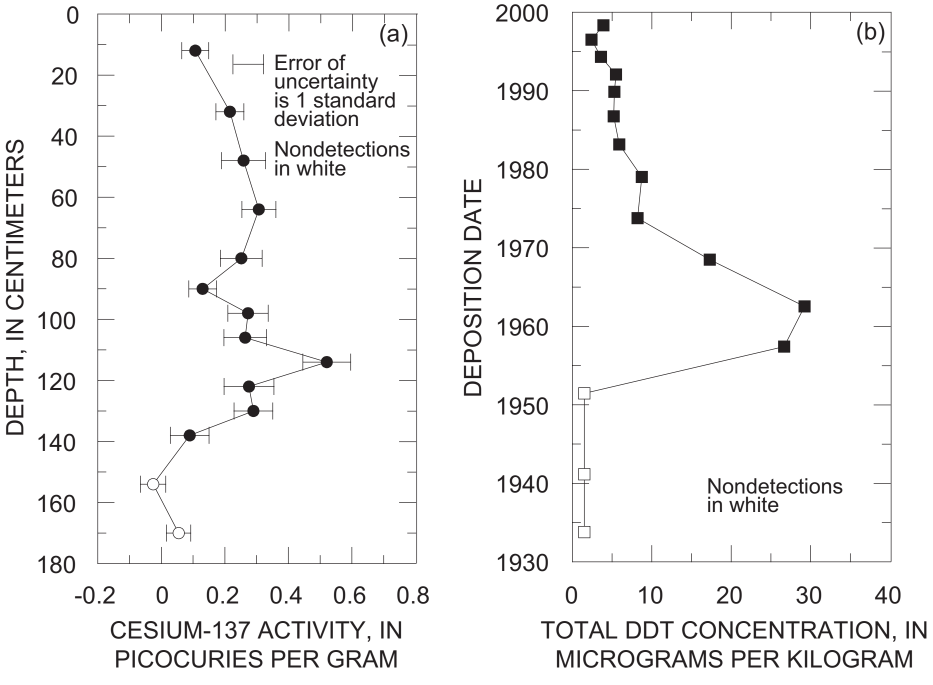


Figure A–9. Chemical constituent profiles used to estimate age dates for Sweetwater Reservoir, Calif.

Table A–8

Core SWT.4			Core SWT.4		
Sample identification	Mid-depth (centimeters)	Estimated deposition date	Sample identification	Mid-depth (centimeters)	Estimated deposition date
SWT.4 0–4	2	1998.3	SWT.4 96–100	98	1969.8
SWT.4 4–8	6	1997.5	SWT.4 100–104	102	1968.5
SWT.4 8–12	10	1996.5	SWT.4 104–108	106	1967.1
SWT.4 12–16	14	1995.5	SWT.4 108–112	110	1965.5
SWT.4 16–20	18	1994.3	SWT.4 112–116	114	1964.0
SWT.4 20–24	22	1993.2	SWT.4 116–120	118	1962.5
SWT.4 24–28	26	1992.1	SWT.4 120–124	122	1961.1
SWT.4 28–32	30	1991.0	SWT.4 124–128	126	1959.8
SWT.4 32–36	34	1989.9	SWT.4 128–132	130	1958.6
SWT.4 36–40	38	1988.8	SWT.4 132–136	134	1957.4
SWT.4 40–44	42	1987.8	SWT.4 136–140	138	1956.2
SWT.4 44–48	46	1986.7	SWT.4 140–144	142	1954.9
SWT.4 48–52	50	1985.6	SWT.4 144–148	146	1953.4
SWT.4 52–56	54	1984.5	SWT.4 148–152	150	1951.5
SWT.4 56–60	58	1983.2	SWT.4 152–156	154	1949.1
SWT.4 60–64	62	1981.8	SWT.4 156–160	158	1946.5
SWT.4 64–68	66	1980.4	SWT.4 160–164	162	1943.6
SWT.4 68–72	70	1979.0	SWT.4 164–168	166	1941.2
SWT.4 72–76	74	1977.6	SWT.4 168–172	170	1939.1
SWT.4 76–80	78	1976.3	SWT.4 172–176	174	1937.4
SWT.4 80–84	82	1975.0	SWT.4 176–180	178	1935.8
SWT.4 84–88	86	1973.8	SWT.4 180–184	182	1933.8
SWT.4 88–92	90	1972.5	SWT.4 184–188	186	Pre-reservoir
SWT.4 92–96	94	1971.2			

10. Lake Mead, Nev./Ariz.

Lake Mead, the largest reservoir sampled, is located east of Las Vegas, Nev., along the Nevada/Arizona state line. The reservoir was constructed on the Colorado River in 1935. Four locations were sampled in Lake Mead using a piston corer in May 1998: OVR (Overton Arm of Lake Mead), LVB–S (Las Vegas Bay, Shallow), LVB-D (Las Vegas Bay, Deep), and MEAD (Lake Mead, Colorado River Arm). All four cores have unique ^{137}Cs profiles that reflect their locations near the Nevada Test Site where the U.S. government conducted numerous nuclear weapons tests in the 1950s and early 1960s (Beck and others, 1990). Those tests are recorded in these sediment cores, to varying degrees, as peaks and valleys corresponding to annual testing series (OVR and possibly MEAD) or multi-year groups of testing series (LVB-D and LVB-S). Multiple peaks are evident, which the authors believe are related to the proximity of the reservoir to the Nevada Test Site. Sediment accumulation rates (MARs) appear to be larger during Nevada testing compared to those before and after testing, which implies direct (on the lake surface) and indirect (on the watershed) dust fall from testing. The resulting MARs and age-dated ^{137}Cs profiles compare well among the cores (fig. A–10). Age-dating of each core is described below.

Location OVR

OVR–2 Piston core 90 cm long analyzed for radionuclides and major and trace elements.

Basis Six clear ^{137}Cs peaks in this core (fig. A–11a) span a wide interval in the middle of the core, from about 18 to 70 cm; the pre-reservoir surface is at 75 cm. There is a rapid increase in ^{137}Cs from 75 cm to the first peak at 68.25 cm (mid-depth of a 1.5-cm sample) and a smooth exponential decrease above the upper peak at 19.5 cm to the top of the core. On the basis of this profile, it was concluded that the upper peak is the 1963–64 global ^{137}Cs peak and that the deeper peaks correspond to atmospheric testing series during 1951–58 at the Nevada Test Site, just to the west and upwind (Beck and others, 1990) (fig. A–11b). Those tests are summarized in table A–9.

Table A–9. Summary of nuclear weapons tests at the Nevada Test Site (Beck and others, 1990).

Test series	Year of test series	Total yield (kilotons)	Total ^{137}Cs produced (10^{12} becquerels)	Total ^{137}Cs deposited in continental U.S. (10^{12} becquerels)
Operations Ranger and Buster Jangle	1951	112	717	60
Operation Tumbler Snapper	1952	104	661	280
Operation Upshot Knothole	1953	252	1,604	317
Operation Teapot	1955	157	1,000	269
Operation Plumbbob	1957	343	1,947	333
Operation Hardtack II	1958	19	293	15

One implication of this interpretation of the ^{137}Cs profile in the core is that MARs during testing were much greater at this site than before or after testing. The following date markers resulted in the indicated MARs for intervening periods:

1998.4–1963.0 (top of core to 19.5-cm ^{137}Cs peak [global peak]), 0.33 g/cm^2-yr;

1963.0–1957.8 (31.5-cm ^{137}Cs peak [Operations Plumbbob and Hardtack II]), 1.43 g/cm^2-yr;

1957.8–1955.3 (45.5-cm ^{137}Cs peak [Operation Teapot]), 3.35 g/cm^2-yr;

1955.3–1952.3 (68.25-cm ^{137}Cs peak [Operation Tumbler Snapper]), 5.56 g/cm^2-yr; and

1952.3–1935 (pre-reservoir surface), 0.3 g/cm^2-yr (fig. A–10a).

The resulting dates are shown in figure A–11c along with the weapons testing series.

Corroboration Several pieces of evidence support the assigned dates. One is the ^{137}Cs peak at 56.5 cm that received a date of 1953.8 that is thought to match the Operation Upshot Knothole tests (fig. A–11c). Another is that the major elements aluminum and calcium show unusual concentration patterns during the part of the core dated as 1950s that are different from those above or below this part of the core (fig. A–11d). These variations support the conclusion of different, highly variable inputs of sediment during this time period.

Rating Good.

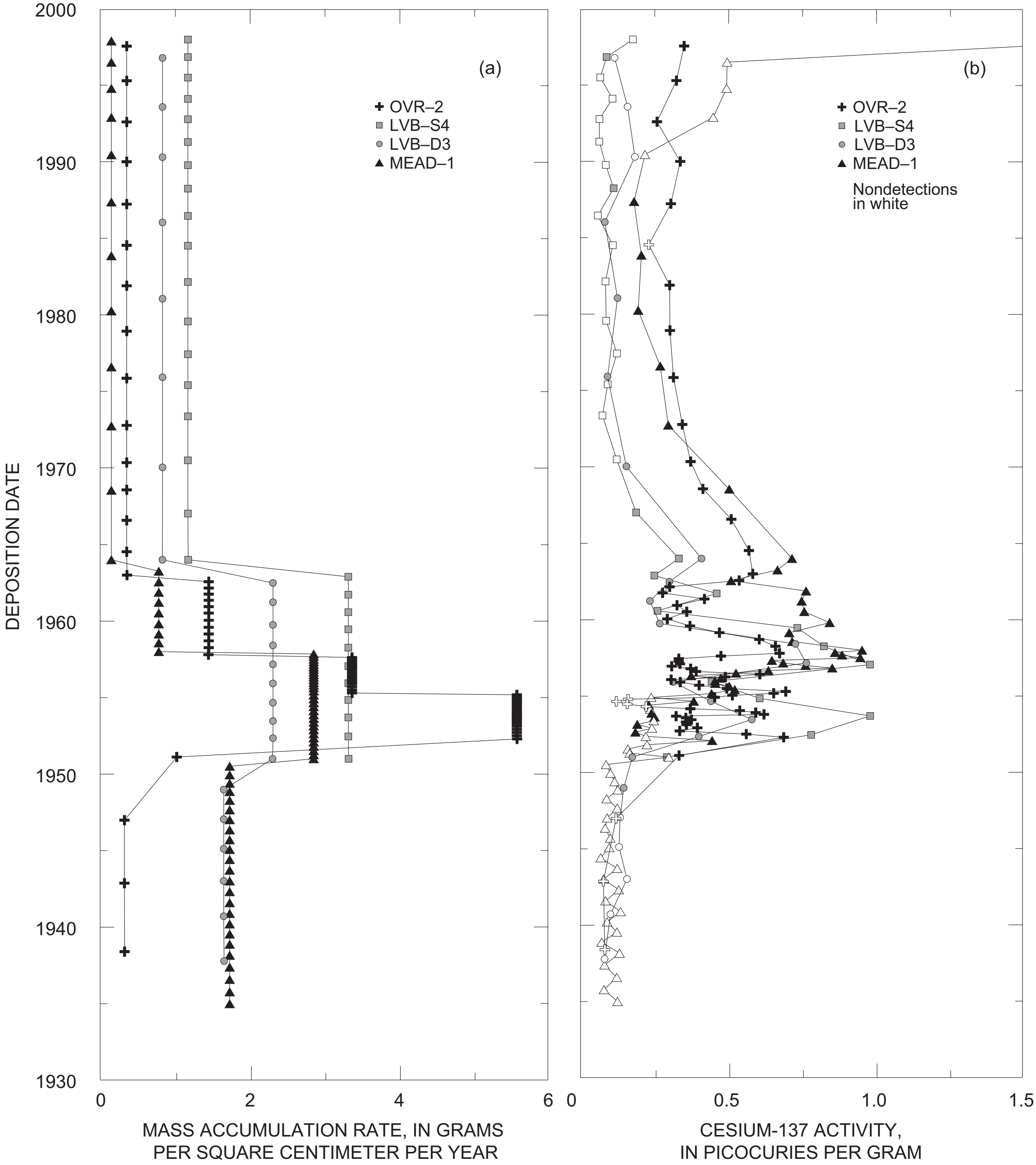


Figure A–10. Comparisons of mass accumulation rates and ^{137}Cs activities in the Lake Mead, Nev./Ariz., cores.

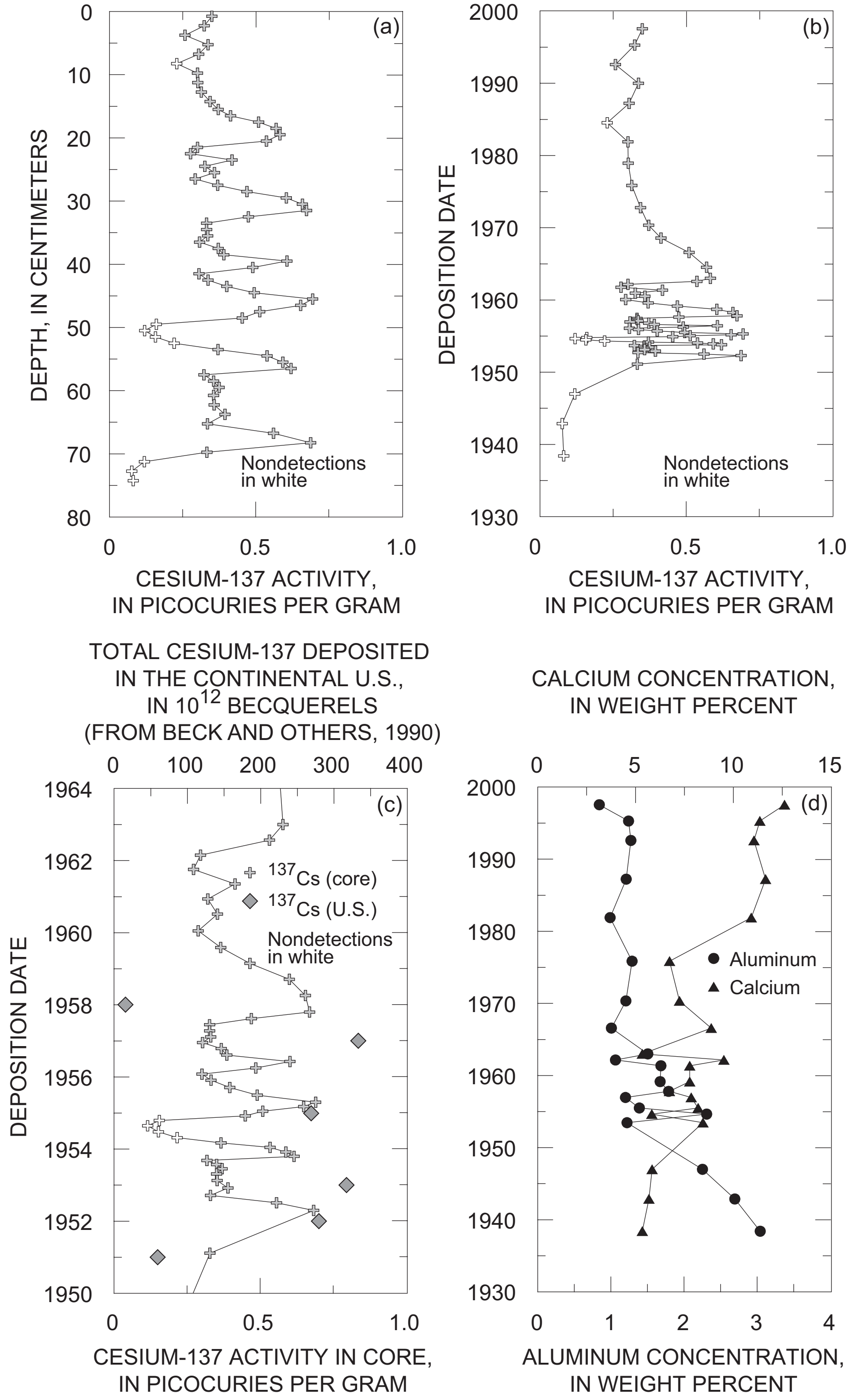


Figure A–11. Chemical constituent profiles used to estimate age dates for Overton Arm of Lake Mead, Nev./Ariz.

Location LVB-Shallow

LVB–S4 Piston core 152 cm long analyzed for radionuclides and major and trace elements.

Basis There are two large and two smaller ^{137}Cs peaks in this core (fig. A–12a). Following the conceptual model used for the OVR core, the uppermost peak centered at 57.5 cm was assumed to be the 1963–64 global peak and the other larger peaks were assumed to be from Nevada testing. The pre-reservoir surface in the core was at 114 cm, and ^{137}Cs was detected at and increased immediately above this level. This initial increase in ^{137}Cs in the 112.5-cm sample was assumed to be 1951.0 when testing in Nevada started. These date markers resulted in MARs of 1.15 g/cm^2-yr for 1964.0–1998.4 and 3.3 g/cm^2-yr for 1951.0–1964.0 (fig. A–10a). These MARs were used to assign dates.

Corroboration The two large ^{137}Cs peaks are dated as 1953.7 and 1957.1 (fig. A–12b), matching estimated ^{137}Cs deposition for the two largest testing series, Operations Upshot Knothole and Plumbbob (table A–9), respectively. The ^{137}Cs profile agrees very well with the profile at the nearby LVB–D3 core when plotted versus deposition date (fig. A–12b). Sediment overlying the pre-reservoir surface received a date of about 1950, and ^{137}Cs was detected, indicating an erosional discontinuity from 1935 to about 1950. On the basis of the assigned dates, lead concentrations peaked in 1957.1, during testing, and in 1973.4. The 1973.4 date could be the leaded gasoline peak.

Rating Good.

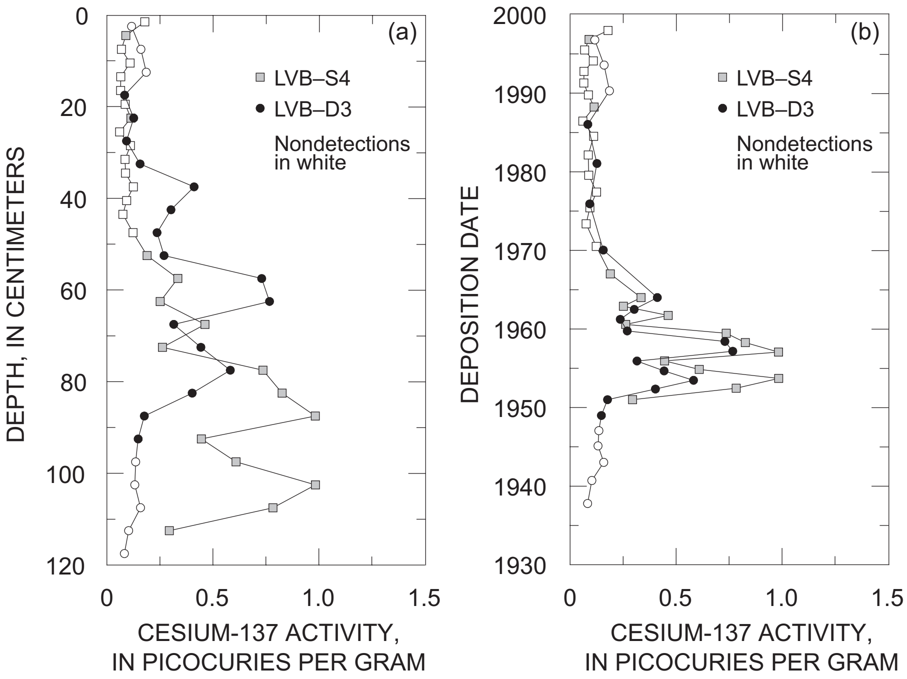


Figure A–12. Chemical constituent profiles used to estimate age dates for Las Vegas Bay of Lake Mead, Nev./Ariz.

LVB–S2 Piston core 158 cm long analyzed for organic compounds.

Basis This core penetrated the pre-reservoir surface at 116 cm, similar to the 114-cm depth in LVB–S4. Dates were extrapolated from core LVB–S2 on the basis of the date-depth relation in core LVB–S4.

Corroboration The peak total DDT concentration at 30 to 35 cm received a date of 1982.1. The DDD and DDE peaks in LVB–D3, the second location sampled in Las Vegas Bay, also are recent and received a date of about 1987. These dates are much more recent than total DDT peaks in most lake cores. The consistency of DDT and ^{137}Cs profiles in both cores, instead of drawing the age-dating into question, suggest an anomalous DDT peak.

Rating Good.

Location LVB-Deep

LVB–D3 Piston core 154 cm long analyzed for ^{137}Cs and organic compounds.

Basis The Cs profile in this core is similar to LVB–S2 but is offset with depth and shows very small concentrations (near detection levels) of ^{137}Cs below the first abrupt increase between 80 and 90 cm (fig. A–12a). Date markers used include the uppermost ^{137}Cs peak at 37.5 cm (1964.0), the initial increase in ^{137}Cs at 87.5 cm (1951.0), and the pre-reservoir surface at 120 cm (1935.0). These markers resulted in MARs of 0.81 g/cm^2-yr for 1964.0–1998.4, 2.29 g/cm^2-yr for 1951.0–1964.0, and 1.63 g/cm^2-yr for 1935.0–1951.0 (fig. A–10a). These MARs were used to assign dates.

Corroboration The ^{137}Cs profile agrees very well with the profile at the nearby LVB–S2 core when plotted in relation to deposition date (fig. A–12b). Total DDT has an unusually large peak compared with other samples in the core dated as 1981.1, similar to LVB–S2. As noted at LVB–S4, this is a very late DDT peak; however, it is not thought to contradict age assignments but, rather, suggests an anomalous DDT profile in the bay.

Rating Good.

Location MEAD

MEAD–1 Piston core 127 cm long analyzed for radionuclides and major and trace elements.

Basis The pre-reservoir surface is at 110 cm in this core and was assigned a date of 1935.0. As with the other cores, there are several ^{137}Cs peaks in this core (fig. A–13a), extending from about 11 to 62 cm. The shape of the peaks does not match that of the peaks in the other three cores; however, the location of this site on the main stem of the Colorado River could greatly affect sediment and ^{137}Cs inputs over time. One additional historical factor affecting this site and not the other three is the construction of Glen Canyon Dam upstream in 1963. The uppermost ^{137}Cs peak at 11.5 cm was assigned a date of 1964.0, and the first small ^{137}Cs peak at 61.25 cm was assigned a date of 1951.0 (fig. A–13b). The largest Cs peak at 20 to 21 cm was assigned a date of 1958.0 coinciding with the largest testing series, Operation Plumbbob. These markers plus the top (1998.4) and bottom of the core (pre-reservoir in 1935.0 at 110 cm) were used to determine MARs of 0.12 g/cm^2-yr for 1964.0–1998.4, 0.76 g/cm^2-yr for 1958.0–1964.0, 2.84 g/cm^2-yr for 1951.0–1958.0, and 1.71 g/cm^2-yr for 1935.0–1951.0 (fig. A–10a). Dates were assigned to the core on the basis of these MARs.

Corroboration The closure of Glen Canyon Dam in 1963 intercepted sediment from most of the watershed to Lake Mead, thus, it would be expected not only to reduce MARs but also to alter major and trace element concentrations. Pronounced decreases in aluminum and increases in calcium between 12 and 9 cm in the core, dated as 1963.6–1974.6, indicate a large change in sediment sources supporting the 1964.0 date at 11.5 cm (fig. A–13c).

Rating Good.

MEAD–2 Piston core 155 cm long analyzed for organochlorine compounds.

Basis The pre-reservoir surface in this core was at 85 cm compared to 110 cm in the nearby core MEAD–1; however, when coring in 125-m deep water, some difference in core location and, therefore, sediment thickness is not surprising. The date-depth relation developed for MEAD–1 was adjusted on the basis of overall sediment thickness (by the ratio of 85:110) and applied to core MEAD–2 to assign dates.

Corroboration Small concentrations of DDE and DDD are in this core. Peak total DDT concentration at 18 to 21 cm received a date of 1957.1, and the first occurrence of any of the DDTs was dated as 1954.3, both reasonable.

Rating Good.

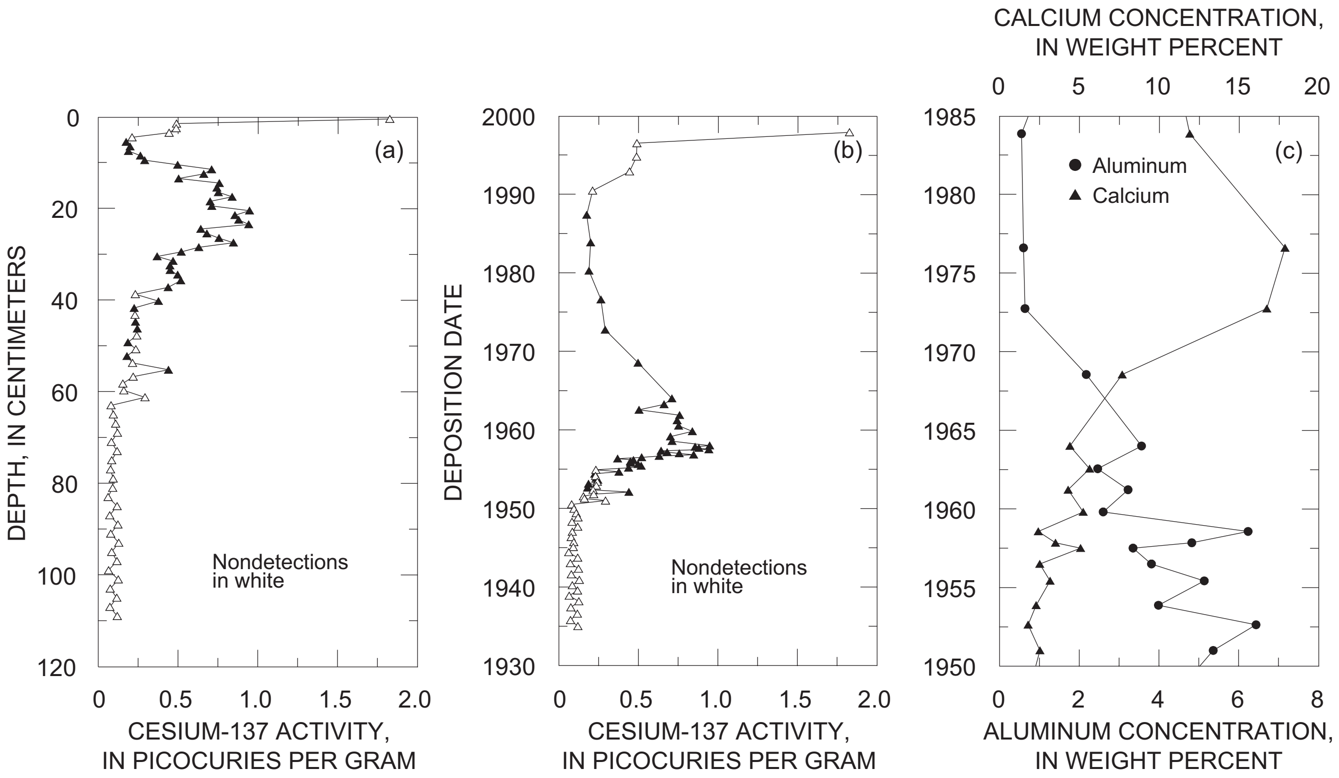


Figure A–13. Chemical constituent profiles used to estimate age dates for the Colorado River Arm of Lake Mead, Nev./Ariz.

Table A–10

Core OVR–2			Core OVR–2		
Sample identification	Mid-depth (centimeters)	Estimated deposition date	Sample identification	Mid-depth (centimeters)	Estimated deposition date
OVR–2 0–1.5	0.75	1997.6	OVR–2 38–39	38.5	1956.6
OVR–2 1.5–3.0	2.25	1995.3	OVR–2 39–40	39.5	1956.4
OVR–2 3.0–4.5	3.75	1992.6	OVR–2 40–41	40.5	1956.3
OVR–2 4.5–6.0	5.25	1990.0	OVR–2 41–42	41.5	1956.1
OVR–2 6.0–7.5	6.75	1987.2	OVR–2 42–43	42.5	1955.9
OVR–2 7.5–9.0	8.25	1984.5	OVR–2 43–44	43.5	1955.7
OVR–2 9.0–10.5	9.75	1981.9	OVR–2 44–45	44.5	1955.5
OVR–2 10.5–12.0	11.25	1978.9	OVR–2 45–46	45.5	1955.3
OVR–2 12.0–13.5	12.75	1975.9	OVR–2 46–47	46.5	1955.2
OVR–2 13.5–15.0	14.25	1972.8	OVR–2 47–48	47.5	1955.0
OVR–2 15–16	15.5	1970.3	OVR–2 48–49	48.5	1954.9
OVR–2 16–17	16.5	1968.6	OVR–2 49–50	49.5	1954.8
OVR–2 17–18	17.5	1966.6	OVR–2 50–51	50.5	1954.6
OVR–2 18–19	18.5	1964.5	OVR–2 51–52	51.5	1954.5
OVR–2 19–20	19.5	1963.0	OVR–2 52–53	52.5	1954.3
OVR–2 20–21	20.5	1962.6	OVR–2 53–54	53.5	1954.2
OVR–2 21–22	21.5	1962.2	OVR–2 54–55	54.5	1954.0
OVR–2 22–23	22.5	1961.8	OVR–2 55–56	55.5	1953.9
OVR–2 23–24	23.5	1961.4	OVR–2 56–57	56.5	1953.8
OVR–2 24–25	24.5	1960.9	OVR–2 57–58	57.5	1953.7
OVR–2 25–26	25.5	1960.5	OVR–2 58–59	58.5	1953.6
OVR–2 26–27	26.5	1960.1	OVR–2 59–60	59.5	1953.5
OVR–2 27–28	27.5	1959.6	OVR–2 60–61.5	60.75	1953.3
OVR–2 28–29	28.5	1959.2	OVR–2 61.5–63	62.25	1953.1
OVR–2 29–30	29.5	1958.7	OVR–2 63–64.5	63.75	1952.9
OVR–2 30–31	30.5	1958.3	OVR–2 64.5–66	65.25	1952.7
OVR–2 31–32	31.5	1957.8	OVR–2 66–67.5	66.75	1952.5
OVR–2 32–33	32.5	1957.6	OVR–2 67.5–69	68.25	1952.3
OVR–2 33–34	33.5	1957.4	OVR–2 69–70.5	69.75	1951.1
OVR–2 34–35	34.5	1957.3	OVR–2 70.5–72	71.25	1947.0
OVR–2 35–36	35.5	1957.1	OVR–2 72–73.5	72.75	1942.9
OVR–2 36–37	36.5	1957.0	OVR–2 73.5–75	74.25	1938.4
OVR–2 37–38	37.5	1956.8			

Table A–10 (Continued)

Core LVB–S4		
Sample identification	Mid-depth (centimeters)	Estimated deposition date
LVB–S4 0–3	1.5	1998.0
LVB–S4 3–6	4.5	1996.8
LVB–S4 6–9	7.5	1995.5
LVB–S4 9–12	10.5	1994.1
LVB–S4 12–15	13.5	1992.8
LVB–S4 15–18	16.5	1991.3
LVB–S4 18–21	19.5	1989.8
LVB–S4 21–24	22.5	1988.2
LVB–S4 24–27	25.5	1986.5
LVB–S4 27–30	28.5	1984.5
LVB–S4 30–33	31.5	1982.1
LVB–S4 33–36	34.5	1979.6
LVB–S4 36–39	37.5	1977.4
LVB–S4 39–42	40.5	1975.4
LVB–S4 42–45	43.5	1973.4
LVB–S4 45–50	46.5	1970.5
LVB–S4 50–55	52.5	1967.0
LVB–S4 55–60	57.5	1964.0
LVB–S4 60–65	62.5	1962.9
LVB–S4 65–70	67.5	1961.7
LVB–S4 70–75	72.5	1960.6
LVB–S4 75–80	77.5	1959.5
LVB–S4 80–85	82.5	1958.3
LVB–S4 85–90	87.5	1957.1
LVB–S4 90–95	92.5	1955.9
LVB–S4 95–100	97.5	1954.9
LVB–S4 100–105	102.5	1953.7
LVB–S4 105–110	107.5	1952.5
LVB–S4 110–115	112.5	1951.0
LVB–S4 115–120	117.5	Pre-reservoir
LVB–S4 120–125	122.5	Pre-reservoir

Core LVB–S2		
Sample identification	Mid-depth (centimeters)	Estimated deposition date
LVB–S2 0–5	2.5	1997.4
LVB–S2 10–15	12.5	1993.4
LVB–S2 20–25	22.5	1988.2
LVB–S2 30–35	32.5	1982.1
LVB–S2 40–45	42.5	1973.4
LVB–S2 50–55	52.5	1967.0
LVB–S2 60–65	62.5	1962.9
LVB–S2 70–75	72.5	1960.6
LVB–S2 80–85	82.5	1958.3
LVB–S2 90–95	92.5	1955.9
LVB–S2 100–105	102.5	1953.7

Table A–10 (Continued)

Core LVB–D3			Core LVB–D3		
Sample identification	Mid-depth (centimeters)	Estimated deposition date	Sample identification	Mid-depth (centimeters)	Estimated deposition date
LVB–D3 0–5	2.5	1996.8	LVB–D3 65–70	67.5	1955.9
LVB–D3 5–10	7.5	1993.6	LVB–D3 70–75	72.5	1954.7
LVB–D3 10–15	12.5	1990.3	LVB–D3 75–80	77.5	1953.5
LVB–D3 15–20	17.5	1986.0	LVB–D3 80–85	82.5	1952.4
LVB–D3 20–25	22.5	1981.1	LVB–D3 85–90	87.5	1951.0
LVB–D3 25–30	27.5	1975.9	LVB–D3 90–95	92.5	1949.0
LVB–D3 30–35	32.5	1970.0	LVB–D3 95–100	97.5	1947.1
LVB–D3 35–40	37.5	1964.0	LVB–D3 100–105	102.5	1945.1
LVB–D3 40–45	42.5	1962.5	LVB–D3 105–110	107.5	1943.0
LVB–D3 45–50	47.5	1961.2	LVB–D3 110–115	112.5	1940.7
LVB–D3 50–55	52.5	1959.7	LVB–D3 115–120	117.5	1937.8
LVB–D3 55–60	57.5	1958.4	LVB–D3 120–125	122.5	Pre-reservoir
LVB–D3 60–65	62.5	1957.2	LVB–D3 125–130	127.5	Pre-reservoir

Table A–10 (Continued)

Core MEAD–1			Core MEAD–1		
Sample identification	Mid-depth (centimeters)	Estimated deposition date	Sample identification	Mid-depth (centimeters)	Estimated deposition date
MEAD–1 0–1	0.5	1997.9	MEAD–1 42.5–44	43.25	1954.1
MEAD–1 1–2	1.5	1996.5	MEAD–1 44–45.5	44.75	1953.9
MEAD–1 2–3	2.5	1994.8	MEAD–1 45.5–47	46.25	1953.6
MEAD–1 3–4	3.5	1992.9	MEAD–1 47–48.5	47.75	1953.4
MEAD–1 4–5	4.5	1990.4	MEAD–1 48.5–50	49.25	1953.1
MEAD–1 5–6	5.5	1987.4	MEAD–1 50–51.5	50.75	1952.9
MEAD–1 6–7	6.5	1983.9	MEAD–1 51.5–53	52.25	1952.6
MEAD–1 7–8	7.5	1980.3	MEAD–1 53–54.5	53.75	1952.4
MEAD–1 8–9	8.5	1976.6	MEAD–1 54.5–56	55.25	1952.1
MEAD–1 9–10	9.5	1972.7	MEAD–1 56–57.5	56.75	1951.8
MEAD–1 10–11	10.5	1968.5	MEAD–1 57.5–59	58.25	1951.5
MEAD–1 11–12	11.5	1964.0	MEAD–1 59–60.5	59.75	1951.3
MEAD–1 12–13	12.5	1963.2	MEAD–1 60.5–62	61.25	1951.0
MEAD–1 13–14	13.5	1962.6	MEAD–1 62–64	63	1950.5
MEAD–1 14–15	14.5	1961.9	MEAD–1 64–66	65	1949.9
MEAD–1 15–16	15.5	1961.2	MEAD–1 66–68	67	1949.4
MEAD–1 16–17	16.5	1960.5	MEAD–1 68–70	69	1948.9
MEAD–1 17–18	17.5	1959.8	MEAD–1 70–72	71	1948.3
MEAD–1 18–19	18.5	1959.1	MEAD–1 72–74	73	1947.7
MEAD–1 19–20	19.5	1958.6	MEAD–1 74–76	75	1947.0
MEAD–1 20–21	20.5	1958.0	MEAD–1 76–78	77	1946.3
MEAD–1 21–22	21.5	1957.8	MEAD–1 78–80	79	1945.7
MEAD–1 22–23	22.5	1957.7	MEAD–1 80–82	81	1945.1
MEAD–1 23–24	23.5	1957.5	MEAD–1 82–84	83	1944.4
MEAD–1 24–25	24.5	1957.3	MEAD–1 84–86	85	1943.7
MEAD–1 25–26	25.5	1957.2	MEAD–1 86–88	87	1943.0
MEAD–1 26–27	26.5	1957.0	MEAD–1 88–90	89	1942.3
MEAD–1 27–28	27.5	1956.8	MEAD–1 90–92	91	1941.6
MEAD–1 28–29	28.5	1956.7	MEAD–1 92–94	93	1940.9
MEAD–1 29–30	29.5	1956.5	MEAD–1 94–96	95	1940.2
MEAD–1 30–31	30.5	1956.3	MEAD–1 96–98	97	1939.5
MEAD–1 31–32	31.5	1956.2	MEAD–1 98–100	99	1938.9
MEAD–1 32–33	32.5	1956.0	MEAD–1 100–102	101	1938.2
MEAD–1 33–34	33.5	1955.8	MEAD–1 102–104	103	1937.4
MEAD–1 34–35	34.5	1955.6	MEAD–1 104–106	105	1936.6
MEAD–1 35–36.5	35.75	1955.4	MEAD–1 106–108	107	1935.8
MEAD–1 36.5–38	37.25	1955.2	MEAD–1 108–110	109	1935.0
MEAD–1 38–39.5	38.75	1954.9	MEAD–1 110–112	111	Pre-reservoir
MEAD–1 39.5–41	40.25	1954.7	MEAD–1 112–114	113	Pre-reservoir
MEAD–1 41-42.5	41.75	1954.4			

Table A–10 (Continued)

Core MEAD–2			Core MEAD–2		
Sample identification	Mid-depth (centimeters)	Estimated deposition date	Sample identification	Mid-depth (centimeters)	Estimated deposition date
MEAD–2 0–3	1.5	1995.7	MEAD–2 30–35	32.5	1954.3
MEAD–2 6–9	7.5	1971.8	MEAD–2 40–45	42.5	1952.1
MEAD–2 12–15	13.5	1959.4	MEAD–2 50–55	52.5	1949.2
MEAD–2 18–21	19.5	1957.1	MEAD–2 60–65	62.5	1945.1
MEAD–2 24–27	25.5	1955.8	MEAD–2 75–80	77.5	1938.4

11. Great Salt Lake, Utah

The Great Salt Lake is a large natural saline lake located northwest of Salt Lake City, Utah. Two gravity cores and one box core were collected for chemical analysis from the southeast Farmington Bay of the lake in April 1998.

FAR.3 Gravity core 33 cm long analyzed for radionuclides and major and trace elements.

Basis Activities of ^{210}Pb were used to assign dates to this core using the CIC model from 0 to 7.5 cm where the top of a very distinct 2-cm-thick grass layer begins (fig. A–14a). The grass layer probably correlates with a period of low lake levels in the early 1960s. An average MAR of 0.071 g/cm^2-yr results for the interval. Unsupported ^{210}Pb is variable below the grass layer and disappears below 13.5 cm. The MAR of 0.071 g/cm^2-yr was applied to the lower part of the core assuming no change in MAR. Dates were not assigned prior to about the mid-1800s because of large uncertainty in the deeper parts of the core.

Corroboration Activities of ^{137}Cs indicate a very unusual profile in this core, with a gradual decrease in activities with depth interrupted by a single high value in the 7.5- to 9-cm sample. One possibility is that ^{137}Cs is being leached from bottom sediment in this saline environment. The grass layer begins in the core at 7.5 cm; the depth to the top of the layer was assigned a reasonable date of 1962.4. Because of differences in either bulk sediment chemistry or water chemistry corresponding to the grass layer, perhaps ^{137}Cs is not as readily leached from this layer. Lead concentrations were not measured at close enough intervals to provide much corroboration of assigned dates. The peak lead concentration at 3 to 4.5 cm was assigned a date of 1983.2 and the next largest concentration, at 6 to 7.5 cm, was dated as 1968.5. Dates below the grass layer are more uncertain and have little independent information to corroborate them. The only supporting information for the older date assignments below 9 cm are the rapid decreases in common urban heavy metals (such as cadmium, lead, and zinc) to apparent background concentrations in the 12- to 13.5-cm sample, dated as about 1900 (fig. A–14b), consistent with early development of Salt Lake City and mining in the area during the mid-1800s.

Rating Fair back to the 1960s; poor for older layers.

FAR.B Box core 12 cm deep analyzed for major and trace elements and organic compounds.

Basis The top of the grass layer in FAR.3 at 7.5 cm (dated as 1962.4) was matched with the top of the grass layer at 9 cm in this core, resulting in a MAR of 0.088 g/cm^2-yr. This MAR was used to assign dates.

Corroboration The lead peak at 4 to 5 cm received a date of 1983.6, later than expected; however, lead was at relatively high, consistent levels in all samples from 3 to 9 cm. DDT was not detected, and DDD and DDE concentrations are quite small and do not define a clear peak, thus they are only useful as an indication of post-1940s sediments. DDE and DDD were detected in the deepest sample analyzed, 10 to 11 cm, dated as 1957.3.

Rating Fair.

FAR.2 Push core 26 cm long analyzed for organic compounds.

Basis The grass layer was not present in this core. The highest concentrations of total DDT and PCBs are in the 13- to 14-cm sample, but no clear peaks are defined (only five samples were analyzed from this core). Interpolating dates (by depth) from FAR.3 results in unreasonable dates with the 13- to 14-cm sample receiving a date of about 1890, much too old for detections of DDT and PCBs. Reasonable age dates were assigned to core FAR.B which also had organic compounds analyzed, therefore, age dates were not assigned to this core.

Rating No dates assigned.

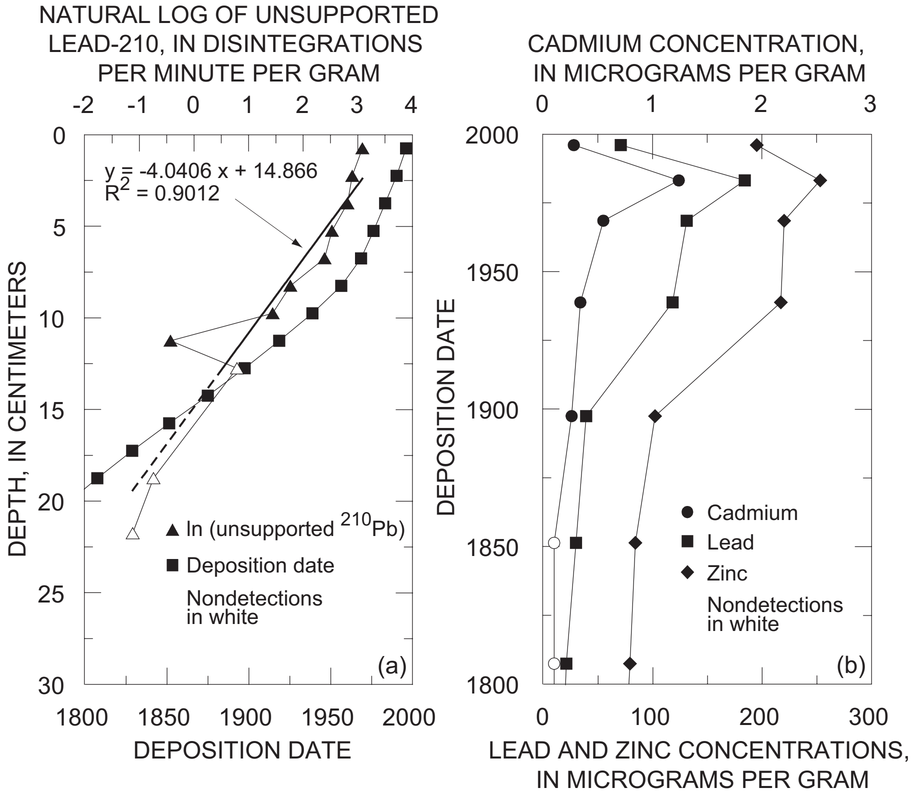


Figure A–14. (a) Regression line fit to unsupported ^{210}Pb for the top six samples of core FAR.3 used to estimate age dates for Great Salt Lake, Utah; and (b) chemical constituent profiles used to corroborate age dates for Great Salt Lake, Utah.

Table A–11

Core FAR.3			Core FAR.3		
Sample identification	Mid-depth (centimeters)	Estimated deposition date	Sample identification	Mid-depth (centimeters)	Estimated deposition date
FAR.3 0–1.5	0.75	1996.0	FAR.3 15–16.5	15.75	1851.3
FAR.3 1.5–3	2.25	1990.2	FAR.3 16.5–18	17.25	1828.7
FAR.3 3–4.5	3.75	1983.2	FAR.3 18–19.5	18.75	Not computed
FAR.3 4.5–6	5.25	1976.1	FAR.3 19.5–21	20.25	Not computed
FAR.3 6–7.5	6.75	1968.5	FAR.3 21–22.5	21.75	Not computed
FAR.3 7.5–9	8.25	1956.4	FAR.3 22.5–24	23.25	Not computed
FAR.3 9–10.5	9.75	1938.8	FAR.3 24–25.5	24.75	Not computed
FAR.3 10.5–12	11.25	1918.5	FAR.3 25.5–27	26.25	Not computed
FAR.3 12–13.5	12.75	1897.4	FAR.3 27–28.5	27.75	Not computed
FAR.3 13.5–15	14.25	1874.4	FAR.3 28.5–30	29.25	Not computed

Table A–11 (Continued)

Core FAR.B			Core FAR.B		
Sample identification	Mid-depth (centimeters)	Estimated deposition date	Sample identification	Mid-depth (centimeters)	Estimated deposition date
FAR.B 0–1	0.5	1997.1	FAR.B 6–7	6.5	1974.6
FAR.B 1–2	1.5	1994.7	FAR.B 7–8	7.5	1970.3
FAR.B 2–3	2.5	1991.5	FAR.B 8–9	8.5	1966.3
FAR.B 3–4	3.5	1987.8	FAR.B 9–10	9.5	1962.0
FAR.B 4–5	4.5	1983.6	FAR.B 10–11	10.5	1957.3
FAR.B 5–6	5.5	1979.1			

12. Decker Lake, Utah

Decker Lake is a shallow reservoir located in a suburban area called West Valley City southwest of Salt Lake City, Utah. Two gravity cores and one box core were collected for chemical analysis from the center channel connecting the two lobes of the lake in April 1998.

DEK.3 and DEK.2 Gravity cores 80 and 89 cm long, respectively, analyzed for major and trace elements and ^{137}Cs (DEK.3) and organic compounds (DEK.2).

Basis Core DEK.3 has an inconclusive ^{137}Cs profile with variable concentrations and no clear peak (fig. A–15a). Lead (DEK.3) and organochlorine compounds (total DDT, PCBs, chlordane) (DEK.2) also are variable with no clear peaks on which to base a date (fig. A–15b). This is a very shallow (about 1-m water depth) urban lake and a sediment chronology does not appear to be preserved in the sediments, possibly because of extensive postdepositional mixing.

Rating No dates assigned.

DEK.B Box core 14 cm deep analyzed for metals down to 6 cm.

Basis See above.

Rating No dates assigned.

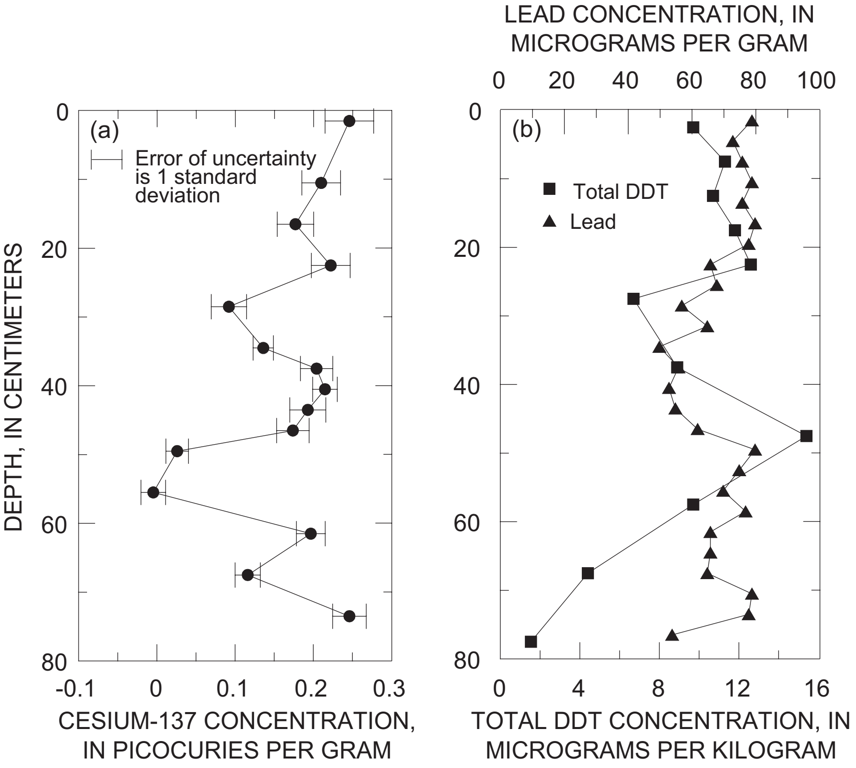


Figure A–15. Chemical constituent profiles in the gravity cores collected from Decker Lake, Utah (a) DEK.2, (b) DEK.2 (total DDT), DEK.3 (lead).

13. Red Butte Reservoir, Utah

Red Butte Reservoir was constructed in 1930 on Red Butte Creek in the Fort Douglas Military Reservation and the Wasatch-Cache National Forest northeast of Salt Lake City, Utah. Two piston cores were collected for chemical analyses from the lower end of the reservoir in April 1998.

RED.1 Piston core 110 cm long analyzed for ^{137}Cs and major and trace elements.

Basis There is a well defined ^{137}Cs peak at 94- to 96-cm and a second possible peak at 104 to 106 cm (fig. A–16a). The 94- to 96-cm peak was assigned a date of 1964.0 resulting in a MAR of 2.23 g/cm^2-yr. This MAR was used to assign dates.

Corroboration None. Contaminant concentrations in this reference lake do not show pronounced enough trends to provide support for age assignments (for example, lead [fig. A–16b]).

Rating Good.

RED.3 Piston core 95 cm long analyzed for organic compounds.

Basis Dates were assigned on the basis of the date-depth relation developed for RED.1.

Corroboration None. No organochlorine compounds were detected at this reference site.

Rating Fair.

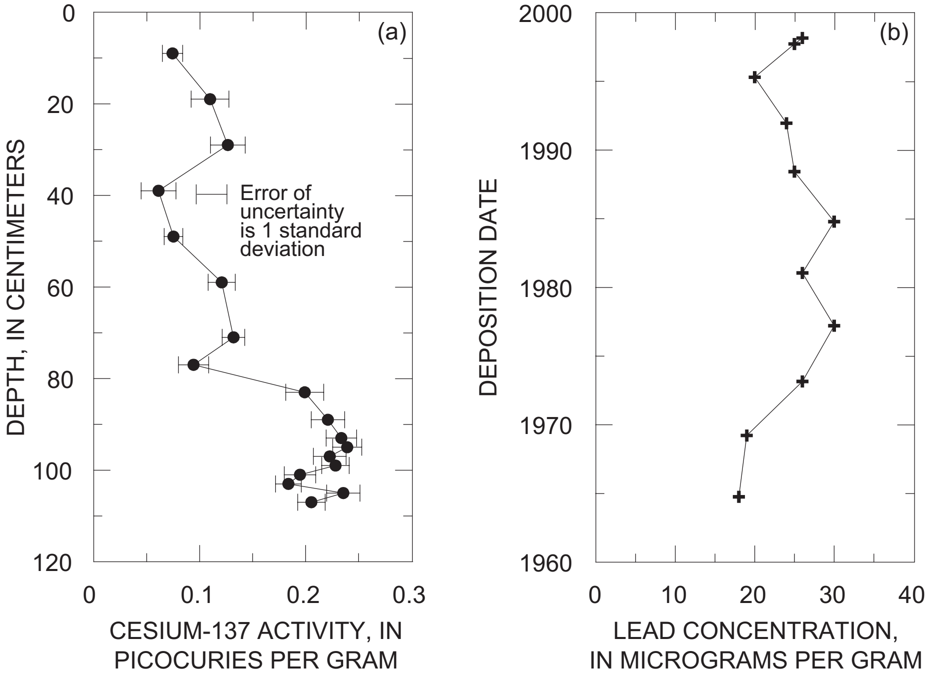


Figure A–16. Chemical constituent profiles used to estimate age dates for Red Butte Reservoir, Utah.

Table A–12

Core RED.1			Core RED.1		
Sample identification	Mid-depth (centimeters)	Estimated deposition date	Sample identification	Mid-depth (centimeters)	Estimated deposition date
RED.1 0–2	1	1998.2	RED.1 54–56	55	1979.5
RED.1 2–4	3	1997.7	RED.1 56–58	57	1978.7
RED.1 4–6	5	1997.2	RED.1 58–60	59	1978.0
RED.1 6–8	7	1996.5	RED.1 60–62	61	1977.2
RED.1 8–10	9	1995.9	RED.1 62–64	63	1976.4
RED.1 10–12	11	1995.3	RED.1 64–66	65	1975.6
RED.1 12–14	13	1994.6	RED.1 66–68	67	1974.8
RED.1 14–16	15	1994.0	RED.1 68–70	69	1974.0
RED.1 16–18	17	1993.3	RED.1 70–72	71	1973.2
RED.1 18–20	19	1992.6	RED.1 72–74	73	1972.4
RED.1 20–22	21	1992.0	RED.1 74–76	75	1971.6
RED.1 22–24	23	1991.3	RED.1 76–78	77	1970.8
RED.1 24–26	25	1990.6	RED.1 78–80	79	1970.0
RED.1 26–28	27	1989.8	RED.1 80–82	81	1969.2
RED.1 28–30	29	1989.1	RED.1 82–84	83	1968.5
RED.1 30–32	31	1988.4	RED.1 84–86	85	1967.7
RED.1 32–34	33	1987.7	RED.1 86–88	87	1967.0
RED.1 34–36	35	1987.0	RED.1 88–90	89	1966.3
RED.1 36–38	37	1986.2	RED.1 90–92	91	1965.5
RED.1 38–40	39	1985.5	RED.1 92–94	93	1964.8
RED.1 40–42	41	1984.8	RED.1 94–96	95	1964.0
RED.1 42–44	43	1984.1	RED.1 96–98	97	1963.2
RED.1 44–46	45	1983.3	RED.1 98–100	99	1962.5
RED.1 46–48	47	1982.6	RED.1 100–102	101	1961.7
RED.1 48–50	49	1981.8	RED.1 102–104	103	1961.0
RED.1 50–52	51	1981.1	RED.1 104–106	105	1960.2
RED.1 52–54	53	1980.3	RED.1 106–108	107	1959.4

Core RED.3			Core RED.3		
Sample identification	Mid-depth (centimeters)	Estimated deposition date	Sample identification	Mid-depth (centimeters)	Estimated deposition date
RED.3 0–5	2.5	1997.7	RED.3 30–35	32.5	1987.7
RED.3 5–10	7.5	1996.5	RED.3 40–45	42.5	1984.1
RED.3 10–15	12.5	1994.6	RED.3 60–70	65	1975.6
RED.3 15–20	17.5	1993.3	RED.3 90–100	95	1964.0
RED.3 20–25	22.5	1991.3			

14. Dillon Reservoir, Colo.

Dillon Reservoir, constructed in 1963, is located west of the Continental Divide in north-central Colorado. One box core was collected for chemical analysis from the lower reservoir in August 1997 (Greve and others, 2001).

DLN.B Box core 19 cm deep analyzed for major and trace elements and organic compounds.

Basis An adjacent gravity core encountered pre-reservoir material at 17 cm, and the deepest part of this box core was described as “stiffer” sediment and assumed to have reached to pre-reservoir material. ^{137}Cs was not measured because of the relatively young age of the reservoir relative to significant ^{137}Cs date markers. The 18- to 19-cm interval was given a date of 1964.0 resulting in a MAR of 0.059 g/cm^2-yr. This MAR was used to assign dates.

Corroboration Limited support for age dates is provided by DDD and DDE concentrations. Small concentrations of both compounds were detected in the deepest three samples dated between 1964.0 and 1975.0, with the largest concentrations in the deepest sample (fig. A–17).

Rating Fair.

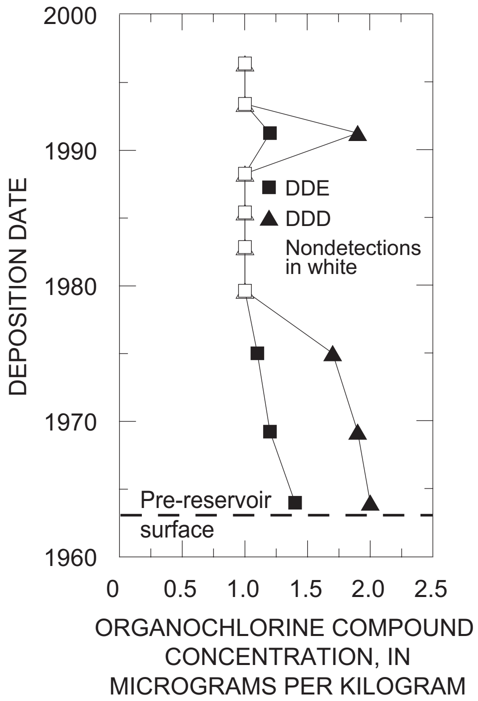


Figure A–17. Chemical constituent profiles used to estimate age dates for Dillon Reservoir, Colo.

Table A–13

Core DLN.B			Core DLN.B		
Sample identification	Mid-depth (centimeters)	Estimated deposition date	Sample identification	Mid-depth (centimeters)	Estimated deposition date
DLN.B 0–1	0.5	1997.1	DLN.B 10–11	10.5	1983.6
DLN.B 1–2	1.5	1995.7	DLN.B 11–12	11.5	1982.1
DLN.B 2–3	2.5	1994.2	DLN.B 12–13	12.5	1980.5
DLN.B 3–4	3.5	1992.6	DLN.B 13–14	13.5	1978.7
DLN.B 5–6	5.5	1990.8	DLN.B 14–15	14.5	1976.3
DLN.B 6–7	6.5	1989.1	DLN.B 15–16	15.5	1973.7
DLN.B 7–8	7.5	1987.5	DLN.B 16–17	16.5	1970.9
DLN.B 8–9	8.5	1986.1	DLN.B 17–18	17.5	1967.6
DLN.B 9–10	9.5	1984.8	DLN.B 18–19	18.5	1964.0

15. Sloans Lake, Colo.

Sloans Lake is a shallow, naturally formed lake located in west-central Denver, Colo. The lake was formed by the flooding of a low area in 1861. Two gravity cores were collected for chemical analysis from an area south of the center of Sloans Lake in August 1997.

SLN.2 Gravity core 126 cm long analyzed for major and trace elements and radionuclides.

Basis The peak ^{137}Cs activity at 24 to 26 cm (fig. A–18a) was assumed to represent 1964.0. The core penetrated a developed soil at 90 cm, and a date of 1861 was assumed for 90 cm. These two date markers plus the sampling date indicate a decrease in sedimentation rate over time. An exponentially decreasing MAR was modeled using the approach of Callender and Robbins (1993). The modeled MAR decreased from 0.30 to 0.16 g/cm^2-yr from the 1860s to the 1990s (fig. A–18b). This model was used to assign estimated deposition dates.

Corroboration The lead peak received a reasonable date of 1970.1.

Rating Good.

SLN.3 Gravity core 139 cm long analyzed for organic compounds.

Basis Assigned dates on the basis of the date-depth relation developed for core SLN.2.

Corroboration The total DDT concentration peak occurs at 24 to 27 cm and received a reasonable date of 1962.3 (fig. A–18c). The sample with the first occurrences of organochlorine pesticides received a reasonable date of 1951.0 (all nondetections in sample below with a deposition date of 1933.9).

Rating Good.

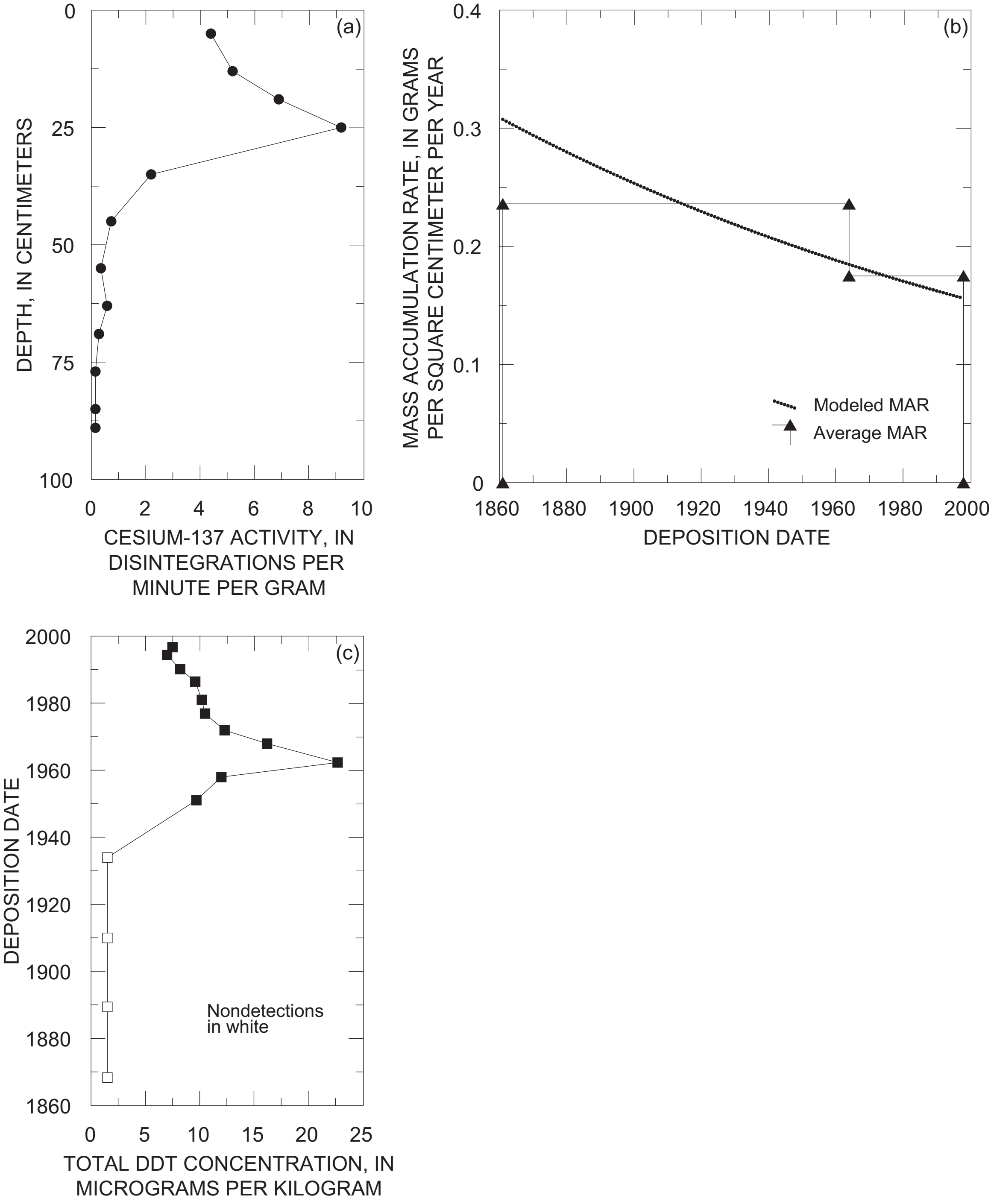


Figure A–18. Chemical constituent profiles used to estimate age dates and comparison of average mass accumulation rates (MARs) computed using date-depth markers and modeled exponentially decreasing MARs for Sloans Lake, Colo. (a) SLN.2, (b) SLN.2, (c) SLN.3.

Table A–14

Core SLN.2			Core SLN.2		
Sample identification	Mid-depth (centimeters)	Estimated deposition date	Sample identification	Mid-depth (centimeters)	Estimated deposition date
SLN.2 0–2	1	1997.2	SLN.2 46–48	47	1926.1
SLN.2 2–4	3	1996.1	SLN.2 48–50	49	1922.8
SLN.2 4–6	5	1993.6	SLN.2 50–52	51	1919.3
SLN.2 6–8	7	1991.0	SLN.2 52–54	53	1916.3
SLN.2 8–10	9	1988.7	SLN.2 54–56	55	1913.1
SLN.2 10–12	11	1985.4	SLN.2 56–58	57	1910.2
SLN.2 12–14	13	1982.2	SLN.2 58–60	59	1908.1
SLN.2 14–16	15	1979.1	SLN.2 60–62	61	1905.2
SLN.2 16–18	17	1976.1	SLN.2 62–64	63	1902.7
SLN.2 18–20	19	1973.0	SLN.2 64–66	65	1900.3
SLN.2 20–22	21	1970.1	SLN.2 66–68	67	1897.7
SLN.2 22–24	23	1967.1	SLN.2 68–70	69	1894.9
SLN.2 24–26	25	1963.6	SLN.2 70–72	71	1892.0
SLN.2 26–28	27	1960.2	SLN.2 72–74	73	1889.8
SLN.2 28–30	29	1957.1	SLN.2 74–76	75	1887.7
SLN.2 30–32	31	1953.8	SLN.2 76–78	77	1885.2
SLN.2 32–34	33	1950.4	SLN.2 78–80	79	1881.9
SLN.2 34–36	35	1946.8	SLN.2 80–82	81	1878.5
SLN.2 36–38	37	1943.2	SLN.2 82–84	83	1875.4
SLN.2 38–40	39	1940.3	SLN.2 84–86	85	1872.3
SLN.2 40–42	41	1936.8	SLN.2 86–88	87	1869.3
SLN.2 42–44	43	1933.2	SLN.2 88–90	89	1865.3
SLN.2 44–46	45	1929.6	SLN.2 90–92	91	Pre-lake

Core SLN.3			Core SLN.3		
Sample identification	Mid-depth (centimeters)	Estimated deposition date	Sample identification	Mid-depth (centimeters)	Estimated deposition date
SLN.3 0–3	1.5	1996.7	SLN.3 24–27	25.5	1962.3
SLN.3 3–6	4.5	1994.4	SLN.3 27–30	28.5	1957.9
SLN.3 6–9	7.5	1990.2	SLN.3 30–35	32.5	1951.0
SLN.3 9–12	10.5	1986.4	SLN.3 40–45	42.5	1933.9
SLN.3 12–15	13.5	1981.0	SLN.3 55–60	57.5	1909.9
SLN.3 15–18	16.5	1976.9	SLN.3 70–75	72.5	1889.4
SLN.3 18–21	19.5	1971.9	SLN.3 85–90	87.5	1868.3
SLN.3 21–24	22.5	1968.0			

16. Cherry Creek Reservoir, Colo.

Cherry Creek Reservoir, constructed in 1953, is located in a suburban area southeast of Denver, Colo. Two gravity cores were collected for chemical analysis from the lower end of the reservoir in August 1997.

CHC.4 Gravity core 165 cm long analyzed for ^{137}Cs.

Basis The pre-reservoir surface at 145 cm was assigned the construction date of 1953. The ^{137}Cs peak is at 130 to 135 cm and was assigned a date of 1964.0, although the profile is highly variable with a second, smaller peak at 80 to 90 cm (fig. A–19a). These date markers gave two MARs: 2.05 g/cm^2-yr for 0 to 135 cm and 1.85 g/cm^2-yr for 135 to 145 cm. These MARs were used to assign dates.

Corroboration None.

Rating Fair.

CHC.3 Gravity core 181 cm long analyzed for organic compounds.

Basis Dates for this core are extrapolated by depth from core CHC.4.

Corroboration The peak total DDT concentration occurs at 145 cm and received a date of 1954.4 (fig. A–19c). Pre-reservoir material is present in this same sample interval. The large DDT concentration could be from agricultural applications prior to reservoir construction.

Rating Fair. The uncertainty caused by the lack of a date marker in this core is balanced by the fair age control in the adjacent core (CHC.4) and the very high sedimentation rate at this site.

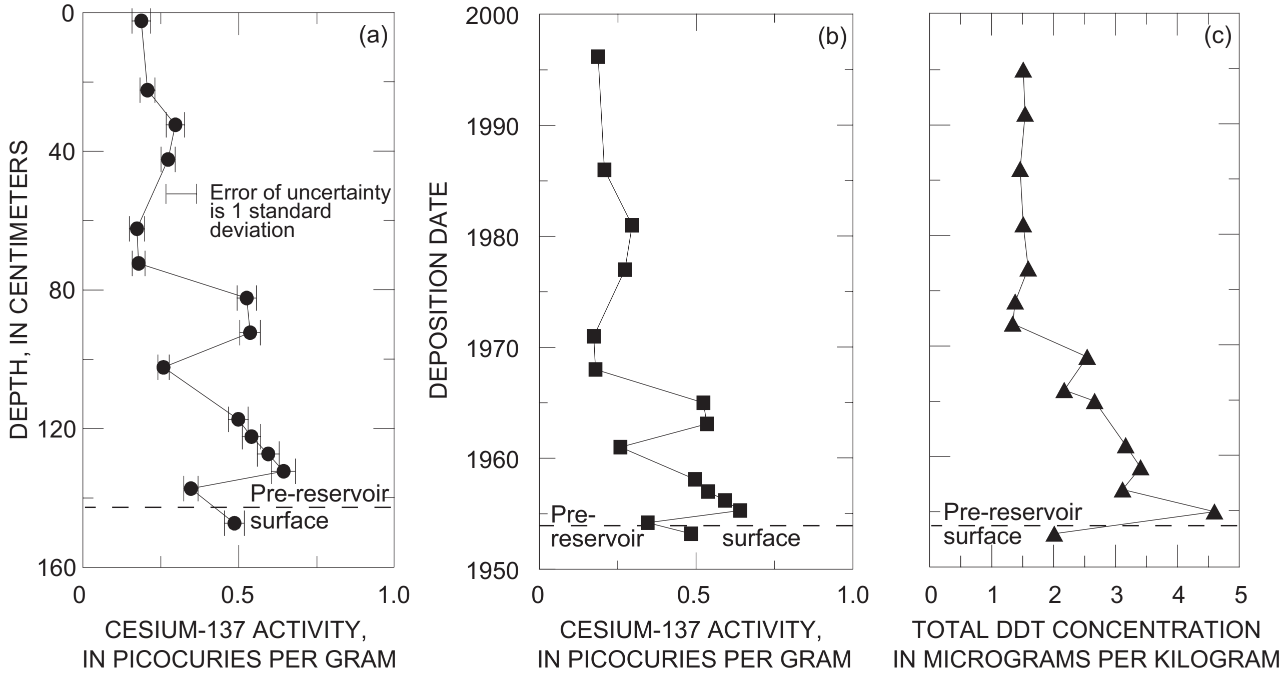


Figure A–19. Chemical constituent profiles used to estimate age dates for Cherry Creek Reservoir, Colo. (a) CHC.4, (b) CHC.4, (c) CHC.3.

Table A–15

Core CHC.4			Core CHC.4		
Sample identification	Mid-depth (centimeters)	Estimated deposition date	Sample identification	Mid-depth (centimeters)	Estimated deposition date
CHC.4 0–5	2.5	1997.2	CHC.4 80–85	82.5	1978.8
CHC.4 5–10	7.5	1996.5	CHC.4 85–90	87.5	1977.6
CHC.4 10–15	12.5	1995.7	CHC.4 90–95	92.5	1976.5
CHC.4 15–20	17.5	1994.8	CHC.4 95–100	97.5	1975.3
CHC.4 20–25	22.5	1993.9	CHC.4 100–105	102.5	1973.7
CHC.4 25–30	27.5	1992.8	CHC.4 105–110	107.5	1972.0
CHC.4 30–35	32.5	1991.6	CHC.4 110–115	112.5	1970.5
CHC.4 35–40	37.5	1990.5	CHC.4 115–120	117.5	1969.0
CHC.4 40–45	42.5	1989.4	CHC.4 120–125	122.5	1967.4
CHC.4 45–50	47.5	1988.4	CHC.4 125–130	127.5	1965.7
CHC.4 50–55	52.5	1987.4	CHC.4 130–135	132.5	1964.0
CHC.4 55–60	57.5	1986.2	CHC.4 135–140	137.5	1958.3
CHC.4 60–65	62.5	1984.9	CHC.4 140–145	142.5	1955.7
CHC.4 65–70	67.5	1983.5	CHC.4 145–150	147.5	Pre-reservoir
CHC.4 70–75	72.5	1982.0	CHC.4 150–155	152.5	Pre-reservoir
CHC.4 75–80	77.5	1980.3			

Core CHC.3			Core CHC.3		
Sample identification	Mid-depth (centimeters)	Estimated deposition date	Sample identification	Mid-depth (centimeters)	Estimated deposition date
CHC.3 0-10	5	1996.9	CHC.3 80-90	85	1978.2
CHC.3 10-20	15	1995.3	CHC.3 90-95	92.5	1976.5
CHC.3 20-30	25	1993.3	CHC.3 110-120	115	1969.7
CHC.3 30-40	35	1991.1	CHC.3 120-130	125	1966.5
CHC.3 40-50	45	1988.9	CHC.3 130-140	135	1961.1
CHC.3 50-60	55	1986.8	CHC.3 140-150	145	1954.4
CHC.3 60-70	65	1984.2	CHC.3 150-160	155	1953.0
CHC.3 70-80	75	1981.1			

17. Lake Como, Tex.

Lake Como is a small reservoir constructed in 1889 (Vicki Stokes, City of Fort Worth, oral commun., 2002) in west-central Fort Worth, Tex. The reservoir is in a low-income residential area and near Interstate Highway (IH)–30. Three locations were sampled in March 2001 in the lower (CMO.1), middle (CMO.3), and upper (CMO.5) parts of the reservoir. Only age-dating for CMO.1 is presented here; however, dates were assigned to the other two cores by Van Metre and others (2003) on the basis of limited sample analyses.

Location lower lake

CMO.1 Gravity core 96 cm long analyzed for all constituents.

Basis The bottom of CMO.1 penetrated a stiff, tan clay at 95 cm, although no root hairs or sand, common indicators of pre-reservoir soils, were found. The ^{137}Cs profile has a peak at 80 to 85 cm (fig. A–20a). The peak is sharp and activities decrease smoothly to the top of the core. The peak to top-of-core ratio of 10, even without decay correcting the older peak sample, indicates the lack of postdepositional mixing in the core. The presence of ^{137}Cs at the bottom of the core and the location of the peak activity indicate that this core penetrated only to late-1950s sediment. A MAR of 1.54 g/cm^2-yr was computed using the ^{137}Cs peak and the sampling date at the top of the core. Age dates were assigned using this MAR.

Corroboration Age assignments are generally corroborated by a very large peak in lead that was dated as 1969.1 (fig. A–20b) and maximum PCB and total DDT concentrations in the bottom sample analyzed dated as 1958.6. Although these peaks are a few years earlier than generally expected, the excellent ^{137}Cs profile takes precedence over dates suggested by the contaminant profiles.

Rating Good.

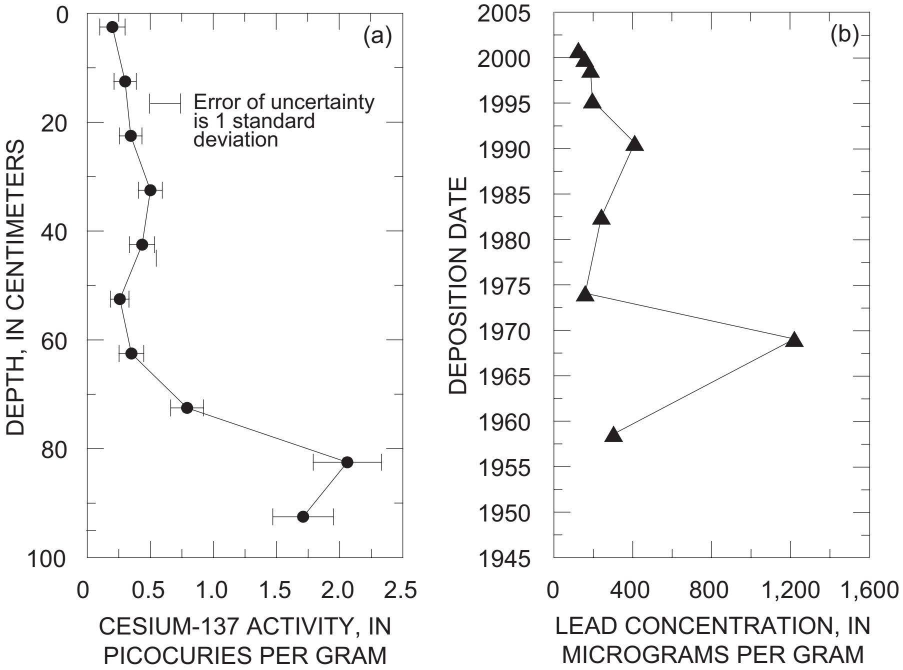


Figure A–20. Chemical constituent profiles used to estimate age dates for Lake Como, Tex.

Table A–16

Core CMO.1			Core CMO.1		
Sample identification	Mid-depth (centimeters)	Estimated deposition date	Sample identification	Mid-depth (centimeters)	Estimated deposition date
CMO.1 0–5	2.5	2000.8	CMO.1 50–55	52.5	1979.6
CMO.1 5–10	7.5	1999.9	CMO.1 55–60	57.5	1976.8
CMO.1 10–15	12.5	1998.7	CMO.1 60–65	62.5	1974.1
CMO.1 15–20	17.5	1997.2	CMO.1 65–70	67.5	1971.5
CMO.1 20–25	22.5	1995.3	CMO.1 70–75	72.5	1969.1
CMO.1 25–30	27.5	1993.1	CMO.1 75–80	77.5	1966.6
CMO.1 30–35	32.5	1990.6	CMO.1 80–85	82.5	1964.0
CMO.1 35–40	37.5	1988.0	CMO.1 85–90	87.5	1961.4
CMO.1 40–45	42.5	1985.3	CMO.1 90–95	92.5	1958.6
CMO.1 45–50	47.5	1982.5			

18. Fosdic Lake, Tex.

Fosdic Lake is a small reservoir constructed between 1909 and 1912 (Vicki Stokes, City of Fort Worth, oral commun., 2002) in east-central Fort Worth, Tex. The reservoir is in a middle-class residential area near IH–30. Three locations were sampled in March 2001 in the lower (FOS.2), middle (FOS.4), and upper (FOS.5) parts of the reservoir. Only age-dating for FOS.4 is presented here; however, dates were assigned to the two other cores by Van Metre and others (2003) on the basis of limited sample analyses.

Location mid-lake

FOS.4 Gravity core 108 cm long analyzed for all constituents.

Basis A construction date of 1910 was used in age-dating the core. The core penetrated the pre-reservoir land surface at 105 cm. The ^{137}Cs activity profile has a pronounced peak at 50 to 55 cm (fig. A–21a) and supports the assumption that the sediments represent the whole period from 1910 to 2001. Using the ^{137}Cs activity peak as a date marker of 1964.0, the pre-reservoir land surface as 1910, and the sampling date at the top of the core, MARs of 0.69 and 0.57 g/cm^2-yr were computed for 1910 to 1964 and 1964 to 2001, respectively. Age dates were assigned to the core using these MARs.

Corroboration Age assignments are generally corroborated by a very large peak in lead that was dated as 1968.9 (fig. A–21b), maximum PCB and total DDT concentrations in 1968.9, and the first occurrence of organochlorine compounds in the mid-1940s.

Rating Good.

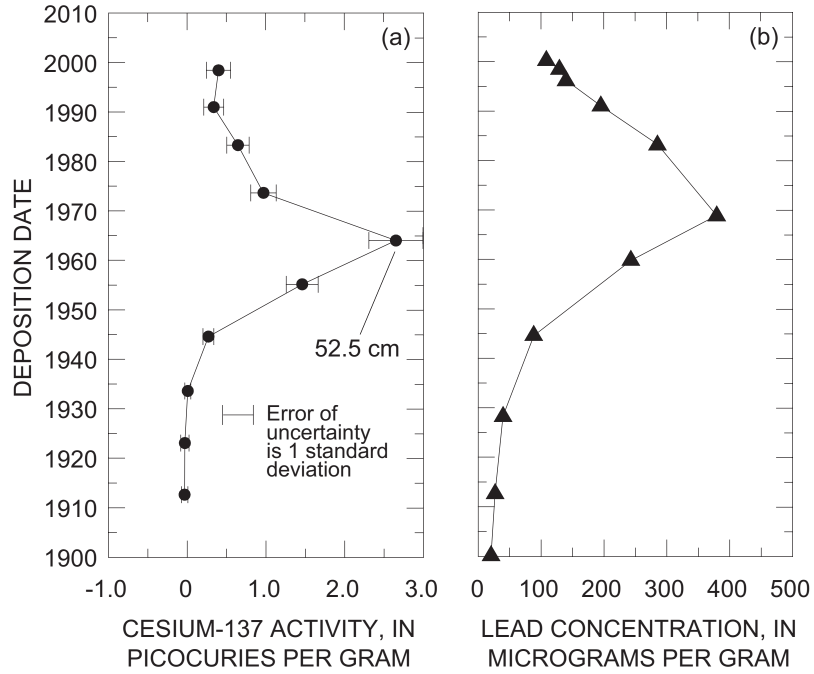


Figure A–21. Chemical constituent profiles used to estimate age dates for Fosdic Lake, Tex.

Table A–17

Core FOS.4			Core FOS.4		
Sample identification	Mid-depth (centimeters)	Estimated deposition date	Sample identification	Mid-depth (centimeters)	Estimated deposition date
FOS.4 0–5	2.5	2000.4	FOS.4 55–60	57.5	1959.8
FOS.4 5–10	7.5	1998.4	FOS.4 60–65	62.5	1955.2
FOS.4 10–15	12.5	1996.2	FOS.4 65–70	67.5	1950.1
FOS.4 15–20	17.5	1993.7	FOS.4 70–75	72.5	1944.6
FOS.4 20–25	22.5	1991.0	FOS.4 75–80	77.5	1939.0
FOS.4 25–30	27.5	1987.6	FOS.4 80–85	82.5	1933.6
FOS.4 30–35	32.5	1983.3	FOS.4 85–90	87.5	1928.3
FOS.4 35–40	37.5	1978.5	FOS.4 90–95	92.5	1923.1
FOS.4 40–45	42.5	1973.6	FOS.4 95–100	97.5	1917.8
FOS.4 45–50	47.5	1968.9	FOS.4 100–105	102.5	1912.6
FOS.4 50–55	52.5	1964.0	FOS.4 105–112	108.5	Pre-reservoir

19. White Rock Lake, Tex.

White Rock Lake is a reservoir constructed in 1912 on White Rock Creek, a tributary of the Trinity River, in northeast Dallas, Tex. The reservoir is surrounded by parkland and upper-class homes. Gravity cores were collected in July 1994 and June 1996 from the (approximate) same location at the lower end of the reservoir.

July 1994 Sampling

WRL(1) and WRL(3) Gravity cores 156 and 145 cm long analyzed for major and trace elements and ^{137}Cs, respectively.

Basis The pre-reservoir surface was encountered in all three gravity cores collected on this date at 136 cm ±1 cm. Wet and dry weights of samples were measured only on core WRL(1), thus MARs were on the basis of the combination of the mass profile in this core and ^{137}Cs date markers from WRL(3). In core WRL(3), the ^{137}Cs peak at 48 to 51 cm (fig. A–22a) was assigned the date of 1964.0, resulting in a MAR of 0.80 g/cm^2-yr for the period 1964.0–1994.5. The first occurrence of ^{137}Cs was in the 63- to 66-cm sample. Assuming a date of 1953.0 for the bottom of this interval yielded a MAR of 0.94 g/cm^2-yr for 1953.0–1964.0. The reservoir was constructed in 1912, and cores WRL(1) and WRL(3) penetrated the pre-reservoir land surface at 135 and 136 cm, respectively. The pre-reservoir surface and the first occurrence of ^{137}Cs yield a MAR of 1.09 g/cm^2-yr for 1912.0–1953.0. While not a particularly large change in MAR, the systematic decrease over time suggested an exponential model would be reasonable; therefore, the approach of Callender and Robbins (1993) was used. The resulting model (k = 0.0064) indicates a decrease in MAR from 1.23 g/cm^2-yr in 1912 to 0.73 g/cm^2-yr in 1994. The cumulative mass-date relation developed from the model was used to assign dates to all three gravity cores.

Corroboration The sharp lead peak at 28 to 30 cm in WRL(1) received a reasonable date of 1976.0 (fig. A–22b).

Rating Good.

WRL(4) Gravity core 167 cm long analyzed for organic compounds.

Basis Dates were assigned to this core using the date-depth relation indicated for cores WRL(1) and WRL(3) by the exponential model.

Corroboration The total DDT peak at 48 to 54 cm received a reasonable date of 1962.5 (fig. A–22c). The PCB peak at 42 to 48 cm received a reasonable date of 1966.5.

Rating Good.

June 1996 Sampling

WRL2.2 and WRL2.3 Gravity cores 115 and 120 cm long analyzed for major and trace elements and organic compounds, respectively. The samples from an adjacent box core, WRL2.B2 (13 cm deep), were analyzed for organic compounds, and the data were merged with data for organic compounds from gravity core WRL2.3.

Basis Radionuclides and density were not measured in these cores. They were collected from about the same location as the 1994 cores; the lacustrine sediment thickness was 105 cm compared to 136 cm in the 1994 cores. A comparison of sharp peaks in lead, total DDT, and PCBs indicated that concentrations were consistent with each other over time, but that a proportional extrapolation of dates from the 1994 exponential model would result in dates much too old for these peaks. Therefore, a constant MAR of 0.82 g/cm^2-yr was used for the upper part of these two cores resulting in about the same dates for peaks in lead, total DDT, and PCBs as determined for the 1994 cores (fig. A–22b, c, d). Differences in total DDT and PCB concentrations between the two cores are caused by a change in analytical method between the two samplings. A MAR of 0.69 g/cm^2-yr on the basis of the depth of the total DDT peak and the pre-reservoir surface was used for the lower part of these cores.

Corroboration None.

Rating Fair.

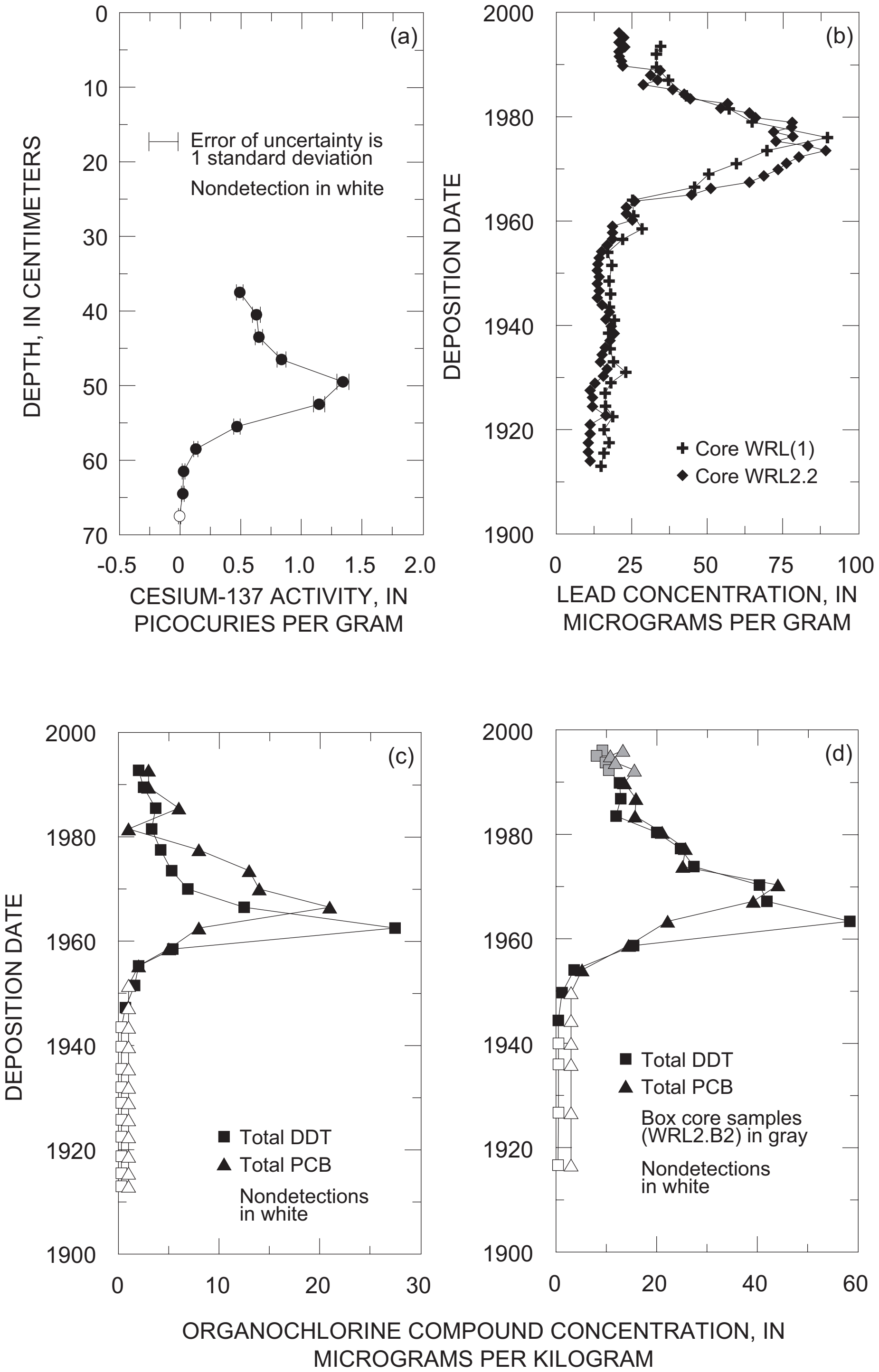


Figure A–22. Chemical constituent profiles used to estimate age dates for White Rock Lake, Tex. (a) WRL(3); (b) WRL(1), WRL2.2; (c) WRL(4); (d) WRL2.3, WRL2.B2.

Table A–18

Core WRL(1)		
Sample identification	Mid-depth (centimeters)	Estimated deposition date
WRL(1) 0–2	1	1993.5
WRL(1) 2–4	3	1993.0
WRL(1) 4–6	5	1992.0
WRL(1) 6–8	7	1990.5
WRL(1) 8–10	9	1989.5
WRL(1) 10–12	11	1988.0
WRL(1) 12–14	13	1987.0
WRL(1) 14–16	15	1985.5
WRL(1) 16–18	17	1984.0
WRL(1) 18–20	19	1983.0
WRL(1) 20–22	21	1981.5
WRL(1) 22–24	23	1980.5
WRL(1) 24–26	25	1979.0
WRL(1) 26–28	27	1977.5
WRL(1) 28–30	29	1976.0
WRL(1) 30–32	31	1975.0
WRL(1) 32–34	33	1973.5
WRL(1) 34–36	35	1972.5
WRL(1) 36–38	37	1971.0
WRL(1) 38–40	39	1970.0
WRL(1) 40–42	41	1969.0
WRL(1) 42–44	43	1967.5
WRL(1) 44–46	45	1966.5
WRL(1) 46–48	47	1965.0
WRL(1) 48–50	49	1964.0
WRL(1) 50–52	51	1962.5
WRL(1) 52–54	53	1961.0
WRL(1) 54–56	55	1960.0
WRL(1) 56–58	57	1958.5
WRL(1) 58–60	59	1957.5
WRL(1) 60–62	61	1956.5
WRL(1) 62–64	63	1955.5
WRL(1) 64–66	65	1954.0
WRL(1) 66–68	67	1952.5
WRL(1) 68–70	69	1951.5
WRL(1) 70–72	71	1950.0
WRL(1) 72–74	73	1948.5
WRL(1) 74–76	75	1947.0
WRL(1) 76–78	77	1946.0
WRL(1) 78–80	79	1944.5
WRL(1) 80–82	81	1943.5
WRL(1) 82–84	83	1942.0
WRL(1) 84–86	85	1941.0
WRL(1) 86–88	87	1940.0
WRL(1) 88–90	89	1938.5
WRL(1) 90–92	91	1937.0
WRL(1) 92–94	93	1935.5
WRL(1) 94–96	95	1934.0
WRL(1) 96–98	97	1933.0
WRL(1) 98–100	99	1932.0
WRL(1) 100–102	101	1931.0
WRL(1) 102–104	103	1930.0
WRL(1) 104–106	105	1929.0
WRL(1) 106–108	107	1928.0
WRL(1) 108–110	109	1927.0
WRL(1) 110–112	111	1926.0
WRL(1) 112–114	113	1924.5
WRL(1) 114–116	115	1923.5
WRL(1) 116–118	117	1922.5
WRL(1) 118–120	119	1921.5
WRL(1) 120–122	121	1920.0
WRL(1) 122–124	123	1919.0
WRL(1) 124–126	125	1917.5
WRL(1) 126–128	127	1916.5
WRL(1) 128–130	129	1915.5
WRL(1) 130–132	131	1914.5
WRL(1) 132–134	133	1913.0
WRL(1) 134–136	135	1912.0
WRL(1) 136–140	138	Pre-reservoir
WRL(1) 140–144	142	Pre-reservoir
WRL(1) 144–148	146	Pre-reservoir
WRL(1) 148–152	150	Pre-reservoir
WRL(1) 152–156	154	Pre-reservoir

Table A–18 (Continued)

Core WRL(3)		
Sample identification	Mid-depth (centimeters)	Estimated deposition date
WRL(3) 36–39	37.5	1973.9
WRL(3) 39–42	40.5	1971.7
WRL(3) 42–45	43.5	1969.3
WRL(3) 45–48	46.5	1966.8
WRL(3) 48–51	49.5	1964.4
WRL(3) 51–54	52.5	1962.0
WRL(3) 54–57	55.5	1959.6
WRL(3) 57–60	58.5	1957.2
WRL(3) 60–63	61.5	1954.8
WRL(3) 63–66	64.5	1952.3
WRL(3) 66–69	67.5	1949.9
WRL(3) 69–72	70.5	1947.3
WRL(3) 72–75	73.5	1944.6

Core WRL(4)		
Sample identification	Mid-depth (centimeters)	Estimated deposition date
WRL(4) 0–6	3	1992.8
WRL(4) 6–12	9	1989.5
WRL(4) 12–18	15	1985.5
WRL(4) 18–24	21	1981.5
WRL(4) 24–30	27	1977.5
WRL(4) 30–36	33	1973.5
WRL(4) 36–42	39	1970.0
WRL(4) 42–48	45	1966.5
WRL(4) 48–54	51	1962.5
WRL(4) 54–60	57	1958.5
WRL(4) 60–66	63	1955.3
WRL(4) 66–72	69	1951.5
WRL(4) 72–78	75	1947.3
WRL(4) 78–84	81	1943.5
WRL(4) 84–90	87	1939.8
WRL(4) 90–96	93	1935.5
WRL(4) 96–102	99	1932.0
WRL(4) 102–108	105	1929.0
WRL(4) 108–114	111	1925.8
WRL(4) 114–120	117	1922.5
WRL(4) 120–126	123	1918.8
WRL(4) 126–131	128.5	1915.5
WRL(4) 131–136	133.5	1913.0

Table A–18 (Continued)

Core WRL2.2		
Sample identification	Mid-depth (centimeters)	Estimated deposition date
WRL2.2 0–1.5	0.75	1996.1
WRL2.2 1.5–3	2.25	1995.2
WRL2.2 3–4.5	3.75	1994.3
WRL2.2 4.5–6	5.25	1993.4
WRL2.2 6–7.5	6.75	1992.5
WRL2.2 7.5–9	8.25	1991.6
WRL2.2 9–10.5	9.75	1990.7
WRL2.2 10.5–12	11.25	1989.8
WRL2.2 12–13.5	12.75	1988.8
WRL2.2 13.5–15	14.25	1987.9
WRL2.2 15–16.5	15.75	1987.0
WRL2.2 16.5–18	17.25	1986.1
WRL2.2 18–19.5	18.75	1985.2
WRL2.2 19.5–21	20.25	1984.3
WRL2.2 21–22.5	21.75	1983.4
WRL2.2 22.5–24	23.25	1982.5
WRL2.2 24–25.5	24.75	1981.6
WRL2.2 25.5–27	26.25	1980.7
WRL2.2 27–28.5	27.75	1979.8
WRL2.2 28.5–30	29.25	1978.9
WRL2.2 30–31.5	30.75	1978.0
WRL2.2 31.5–33	32.25	1977.1
WRL2.2 33–34.5	33.75	1976.2
WRL2.2 34.5–36	35.25	1975.3
WRL2.2 36–37.5	36.75	1974.4
WRL2.2 37.5–39	38.25	1973.5
WRL2.2 39–40.5	39.75	1972.3
WRL2.2 40.5–42	41.25	1971.1
WRL2.2 42–43.5	42.75	1969.9
WRL2.2 43.5–45	44.25	1968.7
WRL2.2 45–46.5	45.75	1967.5
WRL2.2 46.5–48	47.25	1966.2
WRL2.2 48–49.5	48.75	1965.0
WRL2.2 49.5–51	50.25	1963.8
WRL2.2 51–52.5	51.75	1962.6
WRL2.2 52.5–54	53.25	1961.4
WRL2.2 54–55.5	54.75	1960.2
WRL2.2 55.5–57	56.25	1959.0
WRL2.2 57–58.5	57.75	1957.8
WRL2.2 58.5–60	59.25	1956.6
WRL2.2 60–61.5	60.75	1955.4
WRL2.2 61.5–63	62.25	1954.1
WRL2.2 63–64.5	63.75	1952.9
WRL2.2 64.5–66	65.25	1951.7
WRL2.2 66–67.5	66.75	1950.5
WRL2.2 67.5–69	68.25	1949.3
WRL2.2 69–70.5	69.75	1948.0
WRL2.2 70.5–72	71.25	1946.6
WRL2.2 72–73.5	72.75	1945.3
WRL2.2 73.5–75	74.25	1943.9
WRL2.2 75–76.5	75.75	1942.5
WRL2.2 76.5–78	77.25	1941.2
WRL2.2 78–79.5	78.75	1939.8
WRL2.2 79.5–81	80.25	1938.5
WRL2.2 81–82.5	81.75	1937.1
WRL2.2 82.5–84	83.25	1935.7
WRL2.2 84–85.5	84.75	1934.4
WRL2.2 85.5–87	86.25	1933.0
WRL2.2 87–88.5	87.75	1931.6
WRL2.2 88.5–90	89.25	1930.3
WRL2.2 90–91.5	90.75	1928.9
WRL2.2 91.5–93	92.25	1927.5
WRL2.2 93–94.5	93.75	1926.2
WRL2.2 94.5–96	95.25	1924.5
WRL2.2 96–97.5	96.75	1922.7
WRL2.2 97.5–99	98.25	1921.0
WRL2.2 99–100.5	99.75	1919.2
WRL2.2 100.5–102	101.25	1917.5
WRL2.2 102–103.5	102.75	1915.7
WRL2.2 103.5–105	104.25	1914.0
WRL2.2 105–106.5	105.75	Pre-reservoir
WRL2.2 106.5–108	107.25	Pre-reservoir
WRL2.2 108–109.5	108.75	Pre-reservoir
WRL2.2 109.5–111	110.25	Pre-reservoir
WRL2.2 111–112.5	111.75	Pre-reservoir
WRL2.2 112.5–114	113.25	Pre-reservoir
WRL2.2 114–115.5	114.75	Pre-reservoir

20. Echo Lake, Tex.

Echo Lake is a small reservoir constructed in 1919 (Vicki Stokes, City of Fort Worth, oral commun., 2002) in south-central Fort Worth, Tex. The reservoir is in a low-income residential and industrial area and near IH–35W. Three locations were sampled in March 2001 in the lower (ECO.1), middle (ECO.4), and upper (ECO.3) parts of this small reservoir. Only age-dating for ECO.1 is presented here; however, dates were assigned to the other two cores by Van Metre and others (2003) on the basis of limited sample analyses.

Location lower lake

ECO.1 Gravity core 97 cm long analyzed for all constituents.

Basis None of the cores penetrated to the pre-reservoir land surface. Core ECO.1 was 97 cm long compared to 80 cm at the mid-lake site (core ECO.4) and 55 cm at the upper lake site (core ECO.3). The ^{137}Cs activity profile for ECO.1 contains a very pronounced peak at 70 to 75 cm (fig. A–23a). The peak is sharp and decreases smoothly to the top of the core, indicating continuous sediment deposition at the site. The peak to top-of-core ratio of about 20 indicates no substantial postdepositional mixing in this core. The presence of ^{137}Cs at the bottom of the core and the location of the peak activity indicate that this core only penetrated to early-1950s sediment. A MAR of 0.91 g/cm^2-yr was computed using the ^{137}Cs peak at 72.5 cm and the sampling date at the top of the core. Age dates were assigned using this MAR.

Corroboration Age assignments are corroborated by peaks in lead and total DDT that are dated as 1972.5 (fig. A–23b). The deepest sample received an estimated deposition date of 1951.4.

Rating Good.

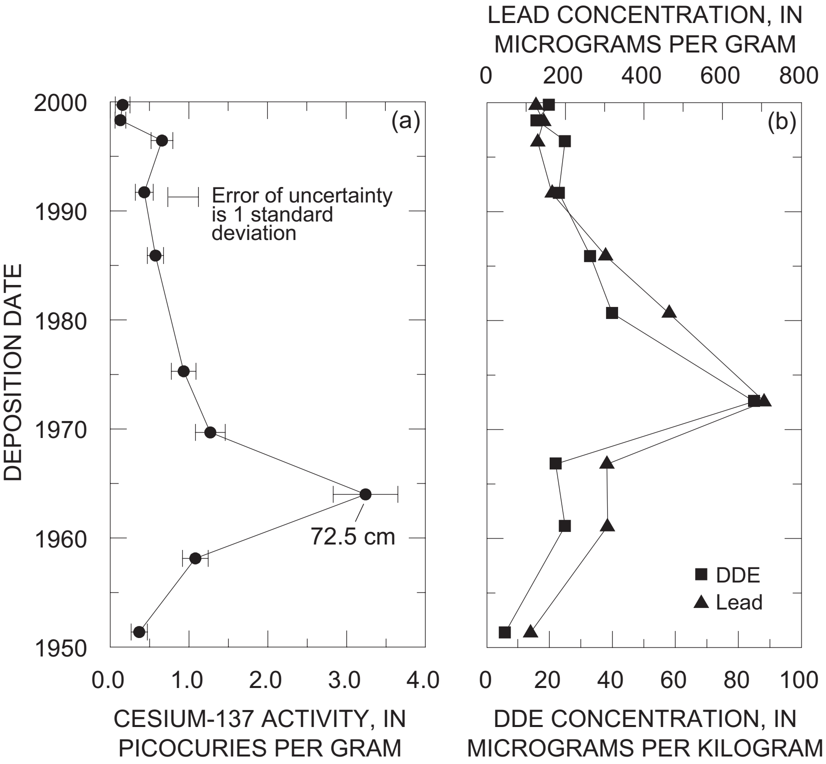


Figure A–23. Chemical constituent profiles used to estimate age dates for Echo Lake, Tex.

Table A–19

Core ECO.1			Core ECO.1		
Sample identification	Mid-depth (centimeters)	Estimated deposition date	Sample identification	Mid-depth (centimeters)	Estimated deposition date
ECO.1 0–5	2.5	1999.7	ECO.1 50–55	52.5	1975.3
ECO.1 5–10	7.5	1998.3	ECO.1 55–60	57.5	1972.5
ECO.1 10–15	12.5	1996.4	ECO.1 60–65	62.5	1969.7
ECO.1 15–20	17.5	1994.2	ECO.1 65–70	67.5	1966.8
ECO.1 20–25	22.5	1991.7	ECO.1 70–75	72.5	1964.0
ECO.1 25–30	27.5	1988.8	ECO.1 75–80	77.5	1961.1
ECO.1 30–35	32.5	1985.9	ECO.1 80–85	82.5	1958.1
ECO.1 35–40	37.5	1983.2	ECO.1 85–90	87.5	1955.1
ECO.1 40–45	42.5	1980.6	ECO.1 90–97	93.5	1951.4
ECO.1 45–50	47.5	1978.0			

21. Town Lake, Tex.

Town Lake is a reservoir constructed in 1959 on the Colorado River in central Austin, Tex. One piston core was collected for analysis from the lower end of the reservoir in August 1998.

TWN Piston core 114 cm long analyzed for all constituents.

Basis The peak ^{137}Cs activity at 90 to 95 cm (fig. A–24a) was assigned a date of 1964.0 resulting in a MAR of 1.84 g/cm^2-yr. The pre-reservoir surface at 110 cm was assigned the construction date of 1959.0 resulting in a higher MAR of 2.71 g/cm^2-yr for 1959.0–1964.0. These MARs were used to assign dates to the core.

Corroboration The total DDT peak received a reasonable date of 1962.6 (fig. A–24b). The lead peak received a date of 1968.2, which is a little early in time, but not considered conclusive enough to adjust age assignments for the core.

Rating Good.

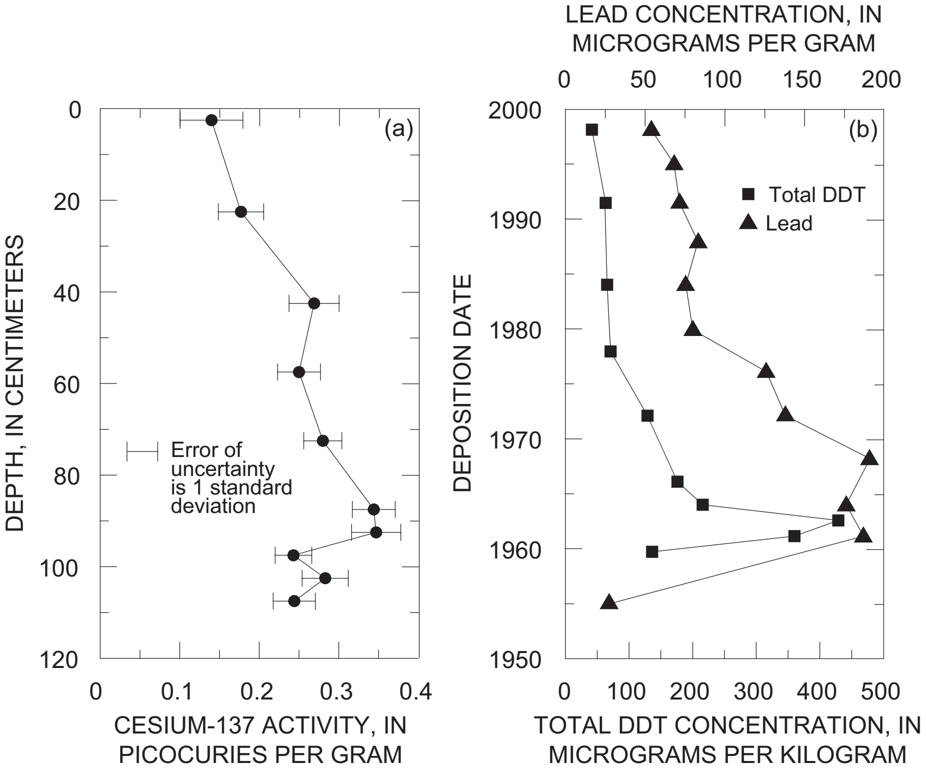


Figure A–24. Chemical constituent profiles used to estimate age dates for Town Lake, Tex.

Table A–20

Core TWN			Core TWN		
Sample identification	Mid-depth (centimeters)	Estimated deposition date	Sample identification	Mid-depth (centimeters)	Estimated deposition date
TWN 0–5	2.5	1998.1	TWN 60–65	62.5	1976.1
TWN 5–10	7.5	1996.7	TWN 65–70	67.5	1974.2
TWN 10–15	12.5	1995.0	TWN 70–75	72.5	1972.1
TWN 15–20	17.5	1993.3	TWN 75–80	77.5	1970.2
TWN 20–25	22.5	1991.5	TWN 80–85	82.5	1968.2
TWN 25–30	27.5	1989.7	TWN 85–90	87.5	1966.1
TWN 30–35	32.5	1987.9	TWN 90–95	92.5	1964.0
TWN 35–40	37.5	1986.0	TWN 95–100	97.5	1962.6
TWN 40–45	42.5	1984.0	TWN 100–105	102.5	1961.1
TWN 45–50	47.5	1982.0	TWN 105–110	107.5	1959.7
TWN 50–55	52.5	1979.9	TWN 110–116	113	Pre-reservoir
TWN 55–60	57.5	1978.0			

22. Lorence Creek Lake, Tex.

Lorence Creek Lake is a small reservoir constructed about 1962 in a suburban area known as Hollywood Park north of San Antonio, Tex. Two hand-pushed cores were collected for analysis from the lower area of the reservoir in August 1996 (Ging and others, 1999).

LRC.2 Push core 28 cm long analyzed for ^{137}Cs and major and trace elements.

Basis The ^{137}Cs peak at 25 cm (fig. A–25a) was assigned a date of 1964.0, resulting in a MAR of 0.52 g/cm^2-yr. Dates were assigned on the basis of this MAR.

Corroboration There is a distinct lead peak at 16 to 18 cm that received a reasonable date of 1973.6 (fig. A–25b). The pre-reservoir land surface is at 27 cm and the deepest sample, 26 to 28 cm, received a date of 1961.3.

Rating Good.

LRC.3 Push core 27 cm long analyzed for organic compounds.

Basis Dates were assigned on the basis of the date-depth relation in core LRC.2.

Corroboration The large total DDT concentration at 22 to 24 cm received a reasonable date of 1966.3 (fig. A–25b). The two push cores were collected near each other, and the pre-reservoir land surface was at 27 and 26.5 cm in LRC.2 and LRC.3, respectively.

Rating Good.

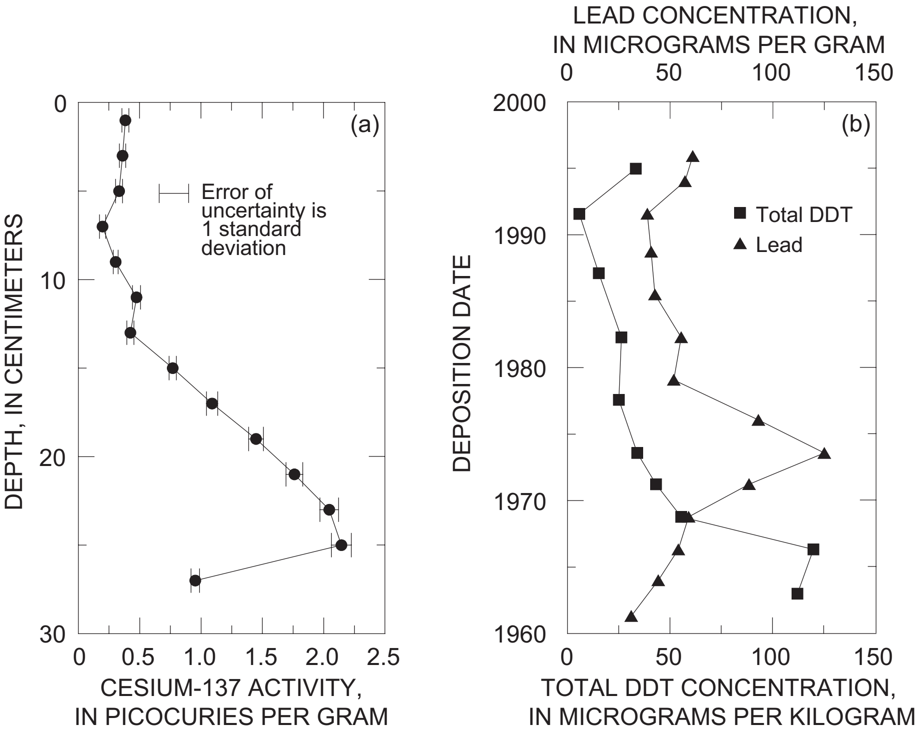


Figure A–25. Chemical constituent profiles used to estimate age dates for Lorence Creek Lake, Tex. (a) LRC.2, (b) LRC.3 (total DDT) and LRC.2 (lead).

Table A–21

Core LRC.2			Core LRC.2		
Sample identification	Mid-depth (centimeters)	Estimated deposition date	Sample identification	Mid-depth (centimeters)	Estimated deposition date
LRC.2 0–2	1	1995.9	LRC.2 14–16	15	1976.1
LRC.2 2–4	3	1994.0	LRC.2 16–18	17	1973.6
LRC.2 4–6	5	1991.6	LRC.2 18–20	19	1971.2
LRC.2 6–8	7	1988.7	LRC.2 20–22	21	1968.8
LRC.2 8–10	9	1985.5	LRC.2 22–24	23	1966.3
LRC.2 10–12	11	1982.3	LRC.2 24–26	25	1964.0
LRC.2 12–14	13	1979.1	LRC.2 26–28	27	1961.3

Core LRC.3			Core LRC.3		
Sample identification	Mid-depth (centimeters)	Estimated deposition date	Sample identification	Mid-depth (centimeters)	Estimated deposition date
LRC.3 0–4	2	1995.0	LRC.3 16–18	17	1973.6
LRC.3 4–6	5	1991.6	LRC.3 18–20	19	1971.2
LRC.3 6–10	8	1987.1	LRC.3 20–22	21	1968.8
LRC.3 10–12	11	1982.3	LRC.3 22–24	23	1966.3
LRC.3 12–16	14	1977.6	LRC.3 24–27	25.5	1963.0

23. Lake Houston, Tex.

Lake Houston is a large reservoir constructed in 1954 on the San Jacinto River northeast of Houston, Tex. The reservoir provides drinking water for the city of Houston. Three gravity cores were collected from three locations in the lake in July 1997: HOE (east) in the upper part of the lake on the eastern arm, HOW (west) in the upper part of the lake on the western arm, and HOS (south) in the main part of the lake near the dam. A single surficial sample, HON, was collected at a fourth site near HOS (Van Metre and Sneck-Fahrer, 2002) and was not dated.

Location HOE

HOE.2 Gravity core 108 cm long analyzed for ^{137}Cs and major and trace elements.

Basis Dates were assigned on the basis of the pre-reservoir surface at 107 cm (1954), the ^{137}Cs peak (fig. A–26) at 92.5 cm (1964.0), and the sampling date (1997.6), yielding a MAR of 0.95 g/cm^2-yr for 1954–1964 and 1.6 g/cm^2-yr for 1964–1997.6.

Corroboration The small lead peak at 60 to 65 cm received a reasonable date of 1975.5.

Rating Good.

HOE.3 Gravity core 110 cm long analyzed for organic compounds.

Basis Dates were assigned on the basis of the pre-reservoir surface at 110 cm and the date-depth relation developed for core HOE.2.

Corroboration The east arm of Lake Houston is mostly forested with little development. Only a few samples had detectable concentrations of organochlorine compounds, mostly from 50 to 110 cm, dated from about 1980 to the late 1950s.

Rating Good, because of the high sedimentation rates, the similar depth to pre-reservoir sediment, and the good age control in the adjacent core (HOE.2).

Location HOW

HOW.1 Gravity core 150 cm long analyzed for major and trace elements.

Basis Dates were assigned by mass on the basis of the pre-reservoir land surface at 145 cm and the reservoir construction date, yielding a MAR of 1.96 g/cm^2-yr.

Corroboration A small lead peak at 85 to 90 cm received a reasonable date of 1974.0.

Rating Good.

HOW.3 Gravity core 148 cm long analyzed for organic compounds.

Basis Dates were assigned on the basis of the pre-reservoir surface at 145 cm and the date-depth relation developed for core HOW.1.

Corroboration A small total DDT peak at 120 to 140 cm (two samples) received reasonable dates of 1960.6 and 1957.0.

Rating Good.

Location HOS

HOS.1 Gravity core 93 cm long analyzed for organic compounds.

Basis Dates were assigned by depth on the basis of the pre-reservoir land surface at 82 cm and the reservoir construction date in 1954, yielding a linear sedimentation rate of 1.9 cm/yr.

Corroboration A PCB peak and a small, rounded total DDT peak at 60 cm received a reasonable date of 1965.7.

Rating Good.

HOS.2 Gravity core 90 cm long analyzed for major and trace elements.

Basis Dates were assigned by depth on the basis of the pre-reservoir land surface at 81 cm and the construction date in 1954.

Corroboration A lead peak at 40 to 44 cm received a reasonable date of 1975.0.

Rating Good.

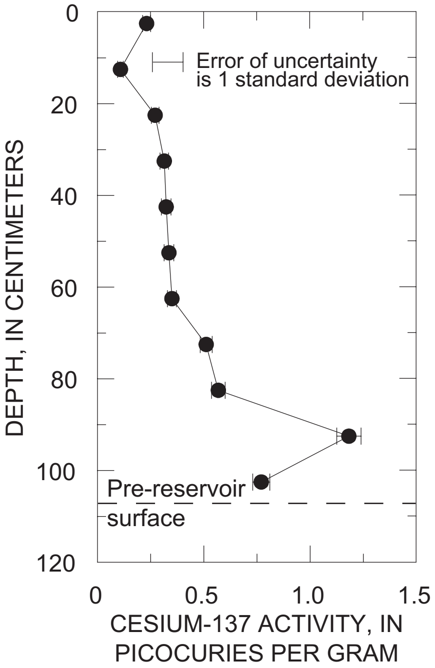


Figure A–26. Chemical constituent profile used to estimate age dates for Lake Houston, Tex.

Table A–22

Core HOE.2			Core HOE.2		
Sample identification	Mid-depth (centimeters)	Estimated deposition date	Sample identification	Mid-depth (centimeters)	Estimated deposition date
HOE.2 0–5	2.5	1996.9	HOE.2 55–60	57.5	1977.5
HOE.2 10–15	12.5	1993.3	HOE.2 60–65	62.5	1975.5
HOE.2 20–25	22.5	1988.7	HOE.2 70–75	72.5	1972.5
HOE.2 30–35	32.5	1985.9	HOE.2 80–85	82.5	1968.3
HOE.2 35–40	37.5	1984.0	HOE.2 90–95	92.5	1964.0
HOE.2 40–45	42.5	1982.4	HOE.2 100–105	102.5	1958.4
HOE.2 45–50	47.5	1980.8	HOE.2 105–107	106	1955.1
HOE.2 50–55	52.5	1979.1			

Core HOE.3			Core HOE.3		
Sample identification	Mid-depth (centimeters)	Estimated deposition date	Sample identification	Mid-depth (centimeters)	Estimated deposition date
HOE.3 0–10	5	1995.8	HOE.3 60–70	65	1974.8
HOE.3 10–20	15	1992.2	HOE.3 70–80	75	1971.2
HOE.3 20–30	25	1988.0	HOE.3 80–90	85	1967.0
HOE.3 30–40	35	1984.8	HOE.3 90–100	95	1962.8
HOE.3 40–50	45	1981.2	HOE.3 100–110	105	1956.0
HOE.3 50–60	55	1978.4			

Core HOW.1			Core HOW.1		
Sample identification	Mid-depth (centimeters)	Estimated deposition date	Sample identification	Mid-depth (centimeters)	Estimated deposition date
HOW.1 0–5	2.5	1996.7	HOW.1 75–80	77.5	1977.2
HOW.1 10–15	12.5	1994.7	HOW.1 85–90	87.5	1974.0
HOW.1 25–30	27.5	1991.4	HOW.1 95–100	97.5	1970.5
HOW.1 35–40	37.5	1988.3	HOW.1 105–110	107.5	1966.9
HOW.1 45–50	47.5	1986.0	HOW.1 115–120	117.5	1963.4
HOW.1 55–60	57.5	1983.7	HOW.1 125–130	127.5	1959.6
HOW.1 60–65	62.5	1981.8	HOW.1 135–140	137.5	1955.8
HOW.1 65–70	67.5	1980.0	HOW.1 145–150	147.5	Pre-reservoir

Table A–22 (Continued)

Core HOW.3		
Sample identification	Mid-depth (centimeters)	Estimated deposition date
HOW.3 0–10	5	1996.0
HOW.3 10–20	15	1994.0
HOW.3 20–30	25	1992.0
HOW.3 30–40	35	1989.0
HOW.3 40–50	45	1986.6
HOW.3 50–60	55	1984.2
HOW.3 60–70	65	1981.0
HOW.3 70–80	75	1977.6
HOW.3 80–90	85	1975.0
HOW.3 90–100	95	1971.2
HOW.3 100–110	105	1968.0
HOW.3 110–120	115	1964.2
HOW.3 120–130	125	1960.6
HOW.3 130–140	135	1957.0
HOW.3 140–145	142.5	1955.0

Core HOS.1		
Sample identification	Mid-depth (centimeters)	Estimated deposition date
HOS.1 0–8	4	1995.5
HOS.1 8–16	12	1991.2
HOS.1 16–24	20	1987.0
HOS.1 24–32	28	1982.7
HOS.1 32–40	36	1978.5
HOS.1 40–48	44	1974.2
HOS.1 48–56	52	1969.9
HOS.1 56–64	60	1965.7
HOS.1 64–72	68	1961.4
HOS.1 72–80	76	1957.2

Core HOS.2		
Sample identification	Mid-depth (centimeters)	Estimated deposition date
HOS.2 0–4	2	1996.5
HOS.2 4–8	6	1994.4
HOS.2 8–12	10	1992.2
HOS.2 12–16	14	1990.1
HOS.2 16–20	18	1987.9
HOS.2 20–24	22	1985.8
HOS.2 24–28	26	1983.6
HOS.2 28–32	30	1981.5
HOS.2 32–36	34	1979.3
HOS.2 36–40	38	1977.2
HOS.2 40–44	42	1975.0
HOS.2 44–48	46	1972.9
HOS.2 48–52	50	1970.7
HOS.2 52–56	54	1968.6
HOS.2 56–60	58	1966.4
HOS.2 60–64	62	1964.3
HOS.2 64–68	66	1962.1
HOS.2 68–72	70	1960.0
HOS.2 72–76	74	1957.8
HOS.2 88–92	90	Pre-reservoir

24. Lake Livingston, Tex.

Lake Livingston is a large reservoir constructed in 1969 on the Trinity River north of Houston, Tex. Gravity cores were collected for analysis from three locations along the length of the reservoir in August 1992 (Van Metre and Callender, 1996). Location AC is near the dam, location CC is in the middle area, and location FC is in the upper area of the reservoir. Total core length is not available for any of the cores discussed below.

Location AC

LIV(AC–2) and LIV(AC–3) Gravity cores analyzed for organochlorine compounds and major and trace elements, respectively.

Basis Both cores penetrated the pre-reservoir land surface at about 53 cm. Ages were assigned using a linear sedimentation rate of 2.25 cm/yr.

Corroboration None. Contaminant profiles (for example, lead) are not pronounced enough to provide convincing evidence of dates.

Rating Good. High sedimentation rates, consistent thickness of sediments at each site, and site locations in the lower and middle parts of this large reservoir all support a good rating for age assignments.

Location CC

LIV(CC–1) and LIV(CC–3) Gravity cores analyzed for major and trace elements and organochlorine compounds, respectively.

Basis Both cores penetrated the pre-reservoir land surface at about 90 cm. Ages were assigned using a linear sedimentation rate of 3.83 cm/yr.

Corroboration None. Contaminant profiles are not pronounced enough to provide convincing evidence of dates.

Rating Good.

Location FC

LIV(FC) Gravity core analyzed for major and trace elements and organochlorine compounds.

Basis The core penetrated the pre-reservoir land surface at about 138 cm. Ages were assigned using a linear sedimentation rate of 5.9 cm/yr.

Corroboration None. Contaminant profiles are not pronounced enough to provide convincing evidence of dates.

Rating Good.

Table A–23

Core LIV(AC–2)		
Sample identification	Mid-depth (centimeters)	Estimated deposition date
LIV(AC–2) 2–10	6	1989.8
LIV(AC–2) 21–27	24	1981.8
LIV(AC–2) 38–44	41	1974.3

Table A–23 (Continued)

Core LIV(AC–3)			Core LIV(AC–3)		
Sample identification	Mid-depth (centimeters)	Estimated deposition date	Sample identification	Mid-depth (centimeters)	Estimated deposition date
LIV(AC–3) 0–4	2	1991.6	LIV(AC–3) 47–50	48.5	1970.9
LIV(AC–3) 14–16	15	1985.8	LIV(AC–3) 52–53	51.5	1969.6
LIV(AC–3) 16–20	18	1984.5	LIV(AC–3) 53–55	54	1968.5
LIV(AC–3) 30–33	31.5	1978.5			

Core LIV(CC–1)			Core LIV(CC–1)		
Sample identification	Mid-depth (centimeters)	Estimated deposition date	Sample identification	Mid-depth (centimeters)	Estimated deposition date
LIV(CC–1) 1–6	3.5	1991.6	LIV(CC–1) 40–43	41.5	1981.7
LIV(CC–1) 6–8	7	1990.7	LIV(CC–1) 52–57	54.5	1978.3
LIV(CC–1) BLACK	14	1988.8	LIV(CC–1) 73–78	75.5	1972.8
LIV(CC–1) 20–24	22	1986.8	LIV(CC–1) 84–86	85	1970.3
LIV(CC–1) 39–40	39.5	1982.2			

Core LIV(CC–3)			Core LIV(CC–3)		
Sample identification	Mid-depth (centimeters)	Estimated deposition date	Sample identification	Mid-depth (centimeters)	Estimated deposition date
LIV(CC–3) 1–7	4.0	1991.5	LIV(CC–3) 39–45	42.0	1981.5
LIV(CC–3) 18–23	20.5	1987.1	LIV(CC–3) 62–67	64.5	1975.7
LIV(CC–3) 33–39	36.0	1983.1	LIV(CC–3) 80–86	83.0	1970.8

Core LIV(FC)			Core LIV(FC)		
Sample identification	Mid-depth (centimeters)	Estimated deposition date	Sample identification	Mid-depth (centimeters)	Estimated deposition date
LIV(FC) 0–5	2.5	1992.1	LIV(FC) 78–84	81.0	1978.7
LIV(FC) 15–22	18.5	1989.3	LIV(FC) 96–104	100.0	1975.5
LIV(FC) 25–33	29.0	1987.6	LIV(FC) 110–117	113.5	1973.2
LIV(FC) 38–43	40.5	1985.6	LIV(FC) 120–127	123.5	1971.5
LIV(FC) 51–57	54.0	1983.3	LIV(FC) 130–138	134.0	1969.7
LIV(FC) 62–69	65.5	1981.3			

25. Palmer Lake, Minn.

Palmer Lake is a shallow natural lake on Shingle Creek and located in a suburban area known as Brooklyn Center northeast of Minneapolis, Minn. The lake is surrounded by wetlands and has two lobes—a west lobe and an east lobe. Shingle Creek enters the west lobe, which is larger than the east lobe and has a lot of open water. The east lobe has no inflowing creek and is almost filled with aquatic vegetation. Two locations were sampled in July 1997, designated PLM.W and PLM.E (the west and east lobes of the lake, respectively); PLM.E was sampled a second time in October 1999. One hand-pushed core, one gravity core, and one box core were collected for chemical analysis from the middle of the lower end of the west lobe in July 1997. One hand-pushed core and one box core were collected for analysis near the southern shore of the east lobe in October 1999 and July 1997, respectively.

Location PLM.W

PLM.W2 Push core 57 cm long analyzed for ^{137}Cs and major and trace elements.

Basis The peak ^{137}Cs activity is at 34 to 36 cm (fig. A–27a). This sample was assigned a date of 1964.0, resulting in an average MAR of 0.41 g/cm^2-yr. This MAR was used to assign dates to the core.

Corroboration A broad lead peak from about 14 to 26 cm was dated as 1984.2 to 1974.0 (fig. A–27b). Rather than an indication of postdepositional mixing, the broad, somewhat late peak could be the result of rapid urbanization of the watershed beginning in the 1970s. Relatively little urbanization was present in the 1960s when leaded gasoline was in use and in the early 1970s when the switch to unleaded gasoline took place, thus the large increase in lead prior to the mid-1970s observed in many urban lakes (Callender and Van Metre, 1997) is not expected here. The rapid decrease in lead after the mid-1970s would likely be tempered by the lack of a large rise earlier and by increases in non-gasoline urban lead sources as the watershed developed.

Rating Good.

PLM.W3 Gravity core 42 cm long analyzed for organic compounds.

Basis Dates were assigned on the basis of the depth-date relation developed for core PLM.W2.

Corroboration The total DDT peak in the 27- to 30-cm sample (fig. A–27b) was dated as 1968.4. Total DDT drops dramatically below the peak, decreasing from 360 µg/kg at 27 to 30 cm to 1.9 µg/kg at 36 to 39 cm. The deeper sample received a date of 1960.7. In general, large increases and peak concentrations in total DDT occur earlier than this, in about the 1950s and early 1960s, respectively. However, many major and most trace element concentrations increase dramatically between about 36 and 40 cm in the adjacent core, PLM.W2, suggesting that the effects of development first began then and that the dates in PLM.W3 are reasonable.

Rating Good. The pronounced trend in total DDT indicates postdepositional mixing has not been severe at this site.

PLM.WB1 Box core 10 cm deep analyzed for organic compounds.

Basis Side by side comparisons of box and gravity cores indicate core shortening of about 40 percent is common in gravity cores. No independent date markers were suggested in this core, so 40-percent shortening of PLM.W2 was assumed, the date-depth relation was accordingly adjusted, and dates were assigned to this core.

Corroboration None, because the deepest sample, dated as 1990.7, was too young for any of the date-depth markers typically used for corroboration in sediment cores.

Rating Poor.

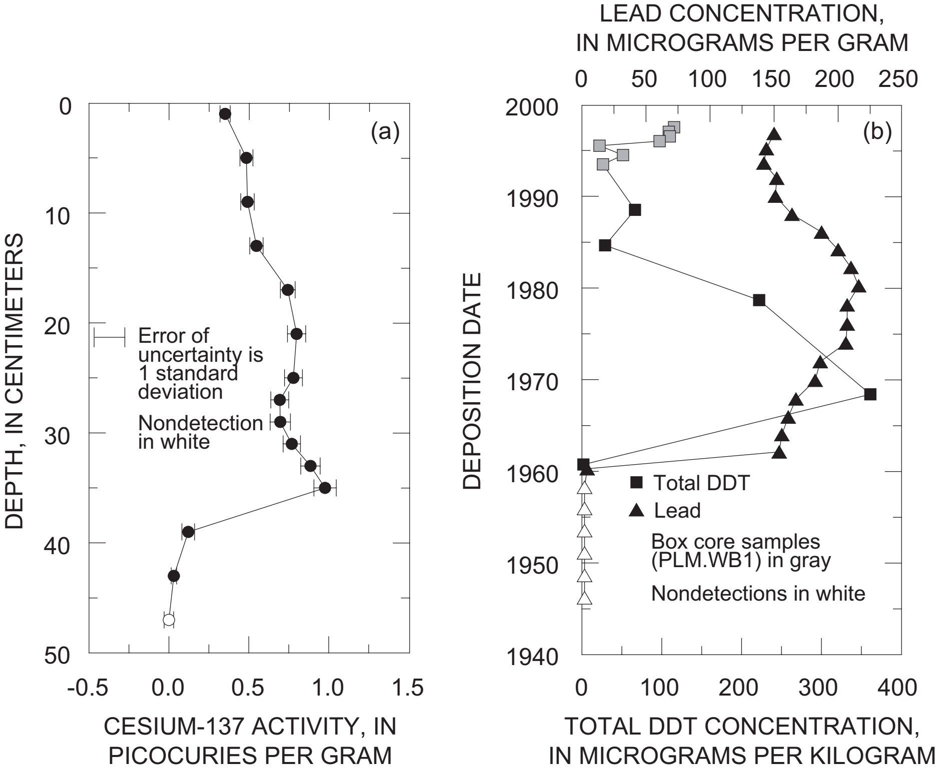


Figure A–27. Chemical constituent profiles used to estimate age dates for the west lobe of Palmer Lake, Minn. (a) PLM.W2, (b) PLM.W3 and PLM.WB1 (total DDT), PLM.W2 (lead).

Location PLM.E

PLME.2 Push core 46 cm long collected in October 1999 and analyzed for all constituents.

Basis The ^{137}Cs activity increases sharply in the 23- to 26 cm sample and is relatively constant above this interval. The 23- to 26-cm sample was assigned a date of 1964.0 resulting in a MAR of 0.27 g/cm^2-yr. Dates were assigned on the basis of this MAR.

Corroboration Lead shows a broad variable peak from the late 1950s to the early 1970s, then decreases (fig. A–28a), suggesting the age assignment of 1973.3 to the top of this peak is reasonable. Decay corrected ^{137}Cs concentrations and ^{137}Cs MARs (fig. A–28b, c) compare very well with the PLM.W2 core collected in the other lobe of the lake in 1997. Although the west lobe has a relatively large watershed and presumably much greater fluvial input of sediment than the east lobe, the similar ^{137}Cs MARs suggest a very low trap efficiency on the relatively small shallow west lobe. The good comparison between the two sites supports the age assignments in the east lobe cores.

Rating Poor. While overall age assignment seems reasonable, postdepositional mixing is indicated by ^{137}Cs and contaminant profiles in this shallow wetland lake; therefore, a poor rating is justified.

PLM.EB Box core 12 cm deep collected in July 1997 and analyzed for all constituents.

Basis Dates were assigned on the basis of date-depth relation developed for core PLME.2 and adjusted for the difference in sampling dates.

Corroboration This core extends only 12 cm deep in this apparently mixed sediment setting, thus, no independent chemical corroboration is available.

Rating Poor.

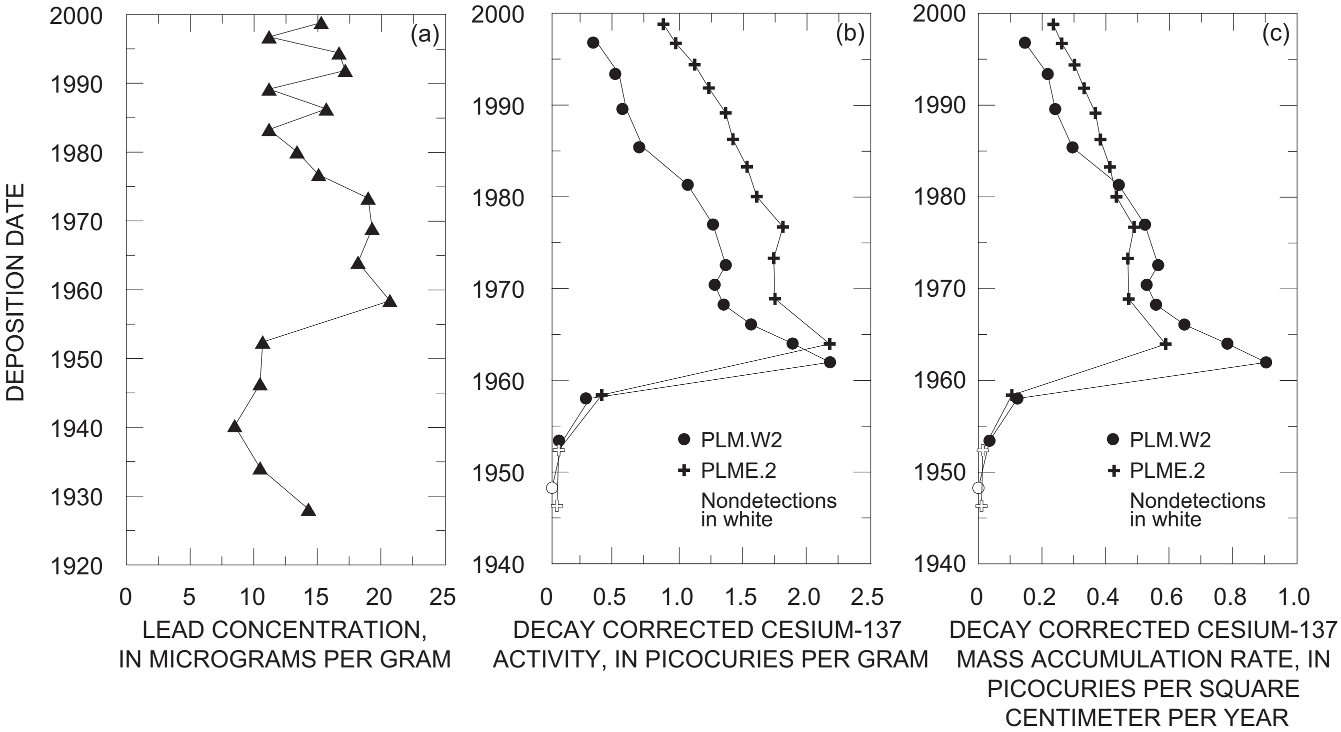


Figure A–28. Chemical constituent profiles used to estimate age dates for the east lobe of Palmer Lake, Minn.

Table A–24

Core PLM.W2		
Sample identification	Mid-depth (centimeters)	Estimated deposition date
PLM.W2 0–2	1	1996.8
PLM.W2 2–4	3	1995.2
PLM.W2 4–6	5	1993.6
PLM.W2 6–8	7	1992.0
PLM.W2 8–10	9	1990.0
PLM.W2 10–12	11	1988.0
PLM.W2 12–14	13	1986.1
PLM.W2 14–16	15	1984.2
PLM.W2 16–18	17	1982.2
PLM.W2 18–20	19	1980.2
PLM.W2 20–22	21	1978.2
PLM.W2 22–24	23	1976.1
PLM.W2 24–26	25	1974.0
PLM.W2 26–28	27	1972.0
PLM.W2 26–28	27	1972.0
PLM.W2 28–30	29	1969.9
PLM.W2 30–32	31	1967.9
PLM.W2 32–34	33	1965.9
PLM.W2 34–36	35	1964.0
PLM.W2 36–38	37	1962.1
PLM.W2 38–40	39	1960.3
PLM.W2 40–42	41	1958.3
PLM.W2 42–44	43	1955.9
PLM.W2 44–46	45	1953.5
PLM.W2 46–48	47	1951.1
PLM.W2 48–50	49	1948.7
PLM.W2 50–52	51	1946.2

Core PLM.W3		
Sample identification	Mid-depth (centimeters)	Estimated deposition date
PLM.W3 9-12	10.5	1988.5
PLM.W3 12-15	13.5	1984.7
PLM.W3 18-21	19.5	1978.7
PLM.W3 27-30	28.5	1968.4
PLM.W3 36-39	37.5	1960.7

Core PLM.WB1		
Sample identification	Mid-depth (centimeters)	Estimated deposition date
PLM.WB1 0-1	0.5	1997.5
PLM.WB1 1-2	1.5	1997.0
PLM.WB1 2-3	2.5	1996.5
PLM.WB1 3-4	3.5	1996.0
PLM.WB1 4-5	4.5	1995.5
PLM.WB1 6-7	6.5	1994.5
PLM.WB1 8-9	8.5	1993.5

Table A–24 (Continued)

Core PLME.2			Core PLME.2		
Sample identification	Mid-depth (centimeters)	Estimated deposition date	Sample identification	Mid-depth (centimeters)	Estimated deposition date
PLME.2 0–2	1	1998.8	PLME.2 18–20	19	1973.3
PLME.2 2–4	3	1996.8	PLME.2 20–23	21.5	1968.9
PLME.2 4–6	5	1994.4	PLME.2 23–26	24.5	1964.0
PLME.2 6–8	7	1991.9	PLME.2 26–29	27.5	1958.4
PLME.2 8–10	9	1989.2	PLME.2 29–32	30.5	1952.4
PLME.2 10–12	11	1986.3	PLME.2 32–35	33.5	1946.3
PLME.2 12–14	13	1983.3	PLME.2 35–38	36.5	1940.3
PLME.2 14–16	15	1980.1	PLME.2 38–41	39.5	1934.1
PLME.2 16–18	17	1976.7	PLME.2 41–44	42.5	1928.1

Core PLM.EB			Core PLM.EB		
Sample identification	Mid-depth (centimeters)	Estimated deposition date	Sample identification	Mid-depth (centimeters)	Estimated deposition date
PLM.EB 2–4	3	1994.8	PLM.EB 6–8	7	1989.9
PLM.EB 4–6	5	1992.4	PLM.EB 10–12	11	1984.3

26. Lake Harriet, Minn.

Lake Harriet is a natural lake in south Minneapolis, Minn. The lake is located in an upper-middle class residential area established in the early 1900s. Three gravity cores and one box core were collected for chemical analysis from the northern area of the lake in July 1997.

HAR.4 Gravity core 84 cm long analyzed for ^{137}Cs and ^{210}Pb.

Basis Age dates were assigned to this core using ^{210}Pb and the CRS model (Appleby and Oldfield, 1992). This approach was used because it was thought to provide the best overall representation of dates and expected variability in MARs for the core. The resulting MARs ranged from 0.024 to 0.066 g/cm^2-yr with a mean MAR of 0.044 g/cm^2-yr from about 1850 to the top of the core.

Corroboration The ^{137}Cs peak (fig. A–29a) is dated as 1965.9, however, the sample interval covers about 1963–69 indicating a good corroboration of ^{210}Pb dates. The average linear sedimentation rate since about 1930 in HAR.4 is 0.35 cm/yr, smaller than the 0.6 cm/yr rate reported for Lake Harriet by Engstrom and Swain (1997). This difference could result from the use of different coring tools; cores HAR.1, HAR.3, and HAR.4 were collected using a gravity corer, whereas Engstrom and Swain (1997) used a piston corer (D.R. Engstrom, University of Minnesota, oral commun., 2001). Gravity cores are subject to core shortening and in side-by-side trials of our gravity corer, piston corer, and box corers, we have observed about 40-percent shortening, which is expected to result in an equivalent loss of mass. Matching lead peaks from the early 1970s in gravity core HAR.3 and box core HAR.B (both discussed below) indicated core shortening of 42 percent, which when applied to the 0.6 cm/yr rate yields a rate of 0.35 cm/yr.

Rating Good.

HAR.3 Gravity core 85 cm long analyzed for major and trace elements.

Basis Dates were assigned using the date-depth relation modeled for core HAR.4.

Corroboration This core has a very pronounced lead peak at 8 to 10 cm, which received a reasonable date of 1976.5 (fig. A–29b). Support for dates deeper in the core is provided by pronounced changes in major element (silicon and titanium) and trace element (arsenic, cadmium, chromium, copper, mercury, nickel, lead, and zinc) concentrations from about 1850 to about 1930, when the watershed was initially developed for agriculture (mid-1800s) then urbanized (1920s) (fig. A–29b). These changes support ^{210}Pb age dates in older parts of the core where ^{210}Pb dates typically become less reliable.

Rating Good.

HAR.1 Gravity core 85 cm long analyzed for organic compounds.

Basis Dates were assigned using the date-depth relation modeled for core HAR.4.

Corroboration The upper 15 cm of this core was not analyzed (samples from an adjacent box core, HAR.B, were analyzed instead). The top sample analyzed in this core, 15 to 18 cm, received a date of 1954.3. PCBs, DDD, DDE, and DDT were detected in relatively small concentrations in this sample, and DDD, DDE, and DDT were detected in small concentrations in the next two deeper samples, dated as 1944.1 and 1932.8. Several samples down to the deepest sample analyzed, 63 to 66 cm and dated as pre-1800, had very low-level detections of DDD, DDE, and DDT (all are estimated values less than the method detection level). Some possible explanations for these detections include sample contamination because of smearing of sediment on the walls of the liner, minor postdepositional mixing, and analytical error. The age assignments of the larger detections seem reasonable. Further evidence of logical date assignments is provided by PAH profiles in the core. Total combustion PAH increases from small, stable concentrations of about 300 µg/kg in the 1911.4 and older samples to 1,240 µg/kg in the 1922.0 sample, then to 17,800 µg/kg in the 1932.8 sample. These increases are consistent in time with the onset of urban development of the watershed.

Rating Good.

HAR.B Box core 20 cm deep analyzed for major and trace elements on a 1-cm interval and organic compounds on a 2-cm interval.

Basis Unlike gravity cores, box cores are not susceptible to core shortening, therefore, the date-depth relation developed for core HAR.4 was adjusted using an estimated 42-percent core shortening, and dates were assigned to this box core. The 42 percent was determined by matching the lead peak in HAR.3 at 8 to 10 cm with the lead peak in HAR.B at 15 to 16 cm (fig. A–29c).

Corroboration Zinc concentrations in HAR.3 and HAR.B show a distinctive pattern from about 1970 to the present that matches well between these cores (fig. A–29d). The largest total DDT concentration in the core is in the deepest sample analyzed (14 to 16 cm), which is dated as 1977.2 and also is reasonable.

Rating Good.

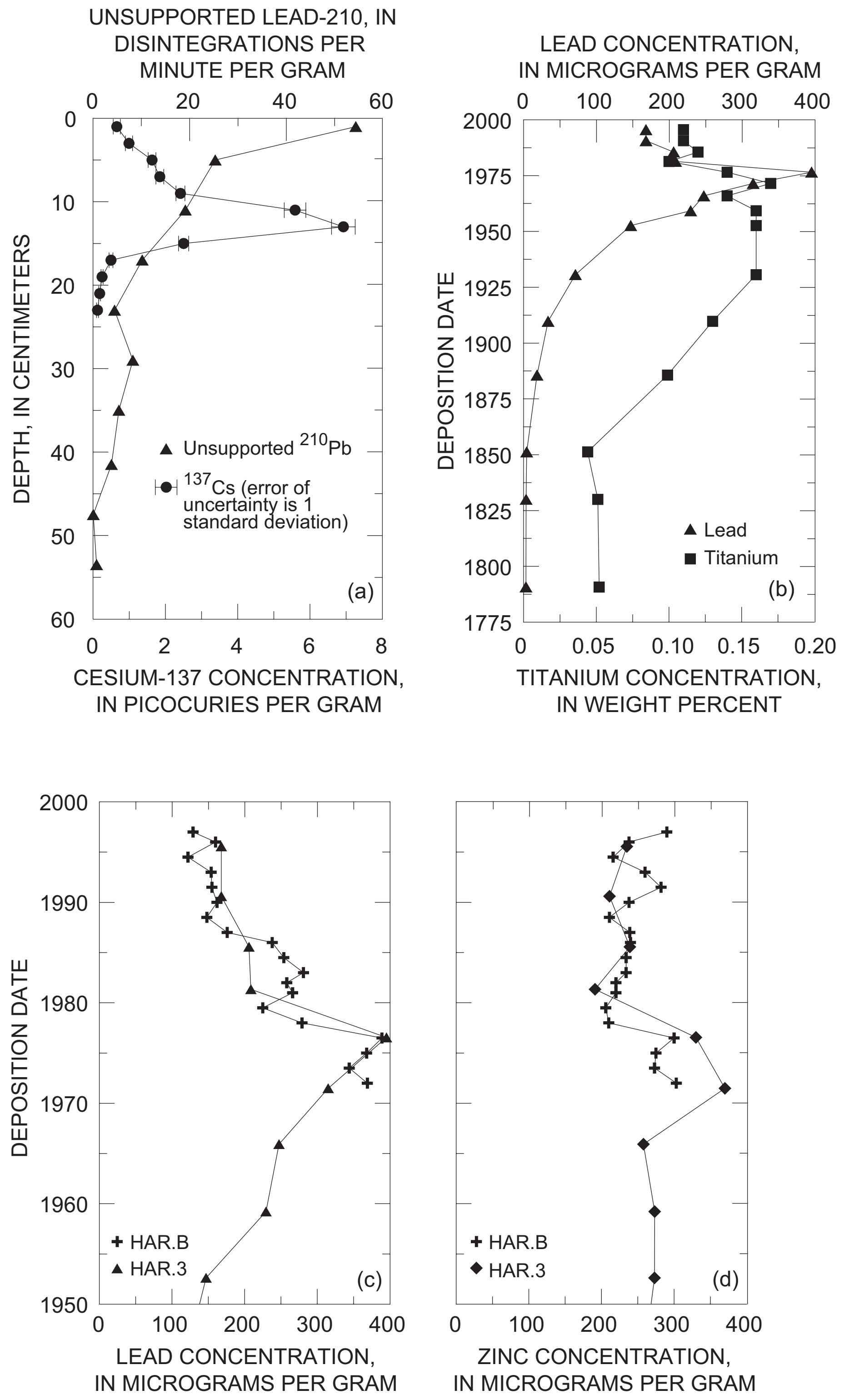


Figure A–29. Chemical constituent profiles used to estimate age dates for Lake Harriet, Minn. (a) HAR.4, (b) HAR.3, (c) HAR.B, HAR.3, (d) HAR.B, HAR.3.

Table A–25

Core HAR.4			Core HAR.4		
Sample identification	Mid-depth (centimeters)	Estimated deposition date	Sample identification	Mid-depth (centimeters)	Estimated deposition date
HAR.4 0–2	1	1995.6	HAR.4 34–36	35	Not computed
HAR.4 2–4	3	1990.6	HAR.4 36–38	37	Not computed
HAR.4 4–6	5	1985.6	HAR.4 38–40	39	Not computed
HAR.4 6–8	7	1981.3	HAR.4 40–43	41.5	Not computed
HAR.4 8–10	9	1976.5	HAR.4 43–46	44.5	Not computed
HAR.4 10–12	11	1971.5	HAR.4 46–49	47.5	Not computed
HAR.4 12–14	13	1965.9	HAR.4 49–52	50.5	Not computed
HAR.4 14–16	15	1959.2	HAR.4 52–55	53.5	Not computed
HAR.4 16–18	17	1952.6	HAR.4 55–58	56.5	Not computed
HAR.4 18–20	19	1946.4	HAR.4 58–61	59.5	Not computed
HAR.4 20–22	21	1938.4	HAR.4 61–64	62.5	Not computed
HAR.4 22–24	23	1930.6	HAR.4 64–67	65.5	Not computed
HAR.4 24–26	25	1923.8	HAR.4 67–70	68.5	Not computed
HAR.4 26–28	27	1916.8	HAR.4 70–73	71.5	Not computed
HAR.4 28–30	29	1909.7	HAR.4 73–76	74.5	Not computed
HAR.4 30–32	31	Not computed	HAR.4 76–79	77.5	Not computed
HAR.4 32–34	33	Not computed	HAR.4 79–82	80.5	Not computed

Core HAR.3			Core HAR.3		
Sample identification	Mid-depth (centimeters)	Estimated deposition date	Sample identification	Mid-depth (centimeters)	Estimated deposition date
HAR.3 0–2	1	1995.6	HAR.3 28–30	29	1909.7
HAR.3 2–4	3	1990.6	HAR.3 34–36	35	1885.6
HAR.3 4–6	5	1985.6	HAR.3 40–42	41	1851.2
HAR.3 6–8	7	1981.3	HAR.3 46–48	47	1830.0
HAR.3 8–10	9	1976.5	HAR.3 52–54	53	1790.8
HAR.3 10–12	11	1971.5	HAR.3 58–60	59	Not computed
HAR.3 12–14	13	1965.9	HAR.3 64–66	65	Not computed
HAR.3 14–16	15	1959.2	HAR.3 70–72	71	Not computed
HAR.3 16–18	17	1952.6	HAR.3 76–78	77	Not computed
HAR.3 22–24	23	1930.6	HAR.3 82–84	83	Not computed

Table A–25 (Continued)

Core HAR.1			Core HAR.1		
Sample identification	Mid-depth (centimeters)	Estimated deposition date	Sample identification	Mid-depth (centimeters)	Estimated deposition date
HAR.1 15–18	16.5	1954.3	HAR.1 30–33	31.5	1900.4
HAR.1 18–21	19.5	1944.1	HAR.1 42–45	43.5	1857.9
HAR.1 21–24	22.5	1932.8	HAR.1 51–54	52.5	1825.8
HAR.1 24–27	25.5	1922.0	HAR.1 63–66	64.5	1783.1
HAR.1 27–30	28.5	1911.4			

Core HAR.B			Core HAR.B		
Sample identification	Mid-depth (centimeters)	Estimated deposition date	Sample identification	Mid-depth (centimeters)	Estimated deposition date
HAR.B 0–1	0.5	1997.0	HAR.B 10–11	10.5	1983.0
HAR.B 1–2	1.5	1996.0	HAR.B 11–12	11.5	1982.0
HAR.B 2–3	2.5	1994.5	HAR.B 12–13	12.5	1981.0
HAR.B 3–4	3.5	1993.0	HAR.B 13–14	13.5	1979.5
HAR.B 4–5	4.5	1991.5	HAR.B 14–15	14.5	1978.0
HAR.B 5–6	5.5	1990.0	HAR.B 15–16	15.5	1976.5
HAR.B 6–7	6.5	1988.5	HAR.B 16–17	16.5	1975.0
HAR.B 7–8	7.5	1987.0	HAR.B 17–18	17.5	1973.5
HAR.B 8–9	8.5	1986.0	HAR.B 18–19	18.5	1972.0
HAR.B 9–10	9.5	1984.5			

27. Lake in the Hills, Ill.

Lake in the Hills, also known as Woods Creek Lake, is a reservoir located in a suburban area northwest of Chicago, Ill., known as Lake in the Hills. The reservoir was built in 1923 and dredged and enlarged at a later, unknown date. One gravity core was collected for chemical analysis from the lower area of the reservoir in July 2001.

LKH.1 Gravity core 89 cm long analyzed for all constituents.

Basis The peak ^{137}Cs activity is at 50 to 54 cm (fig. A–30a). This sample was assigned a date of 1964.0, resulting in an average MAR of 0.55 g/cm^2-yr for the core. This MAR was used to assign dates.

Corroboration The maximum lead concentration at the middle of a rounded lead peak received a reasonable date of 1974.4. The core encountered pre-reservoir material at 80 cm, which received a date of 1935.7. ^{137}Cs was not detected in the 66- to 70-cm sample (fig. A–30a) dated as 1950.5 and was detected in the 58- to 62-cm sample dated as 1957.9, correctly bracketing the generally accepted first occurrence of ^{137}Cs in cores in about 1953. Finally, both total DDT and PCBs peak at the reasonable dates of 1966.8 and 1974.4, respectively (fig. A–30b).

Rating Good.

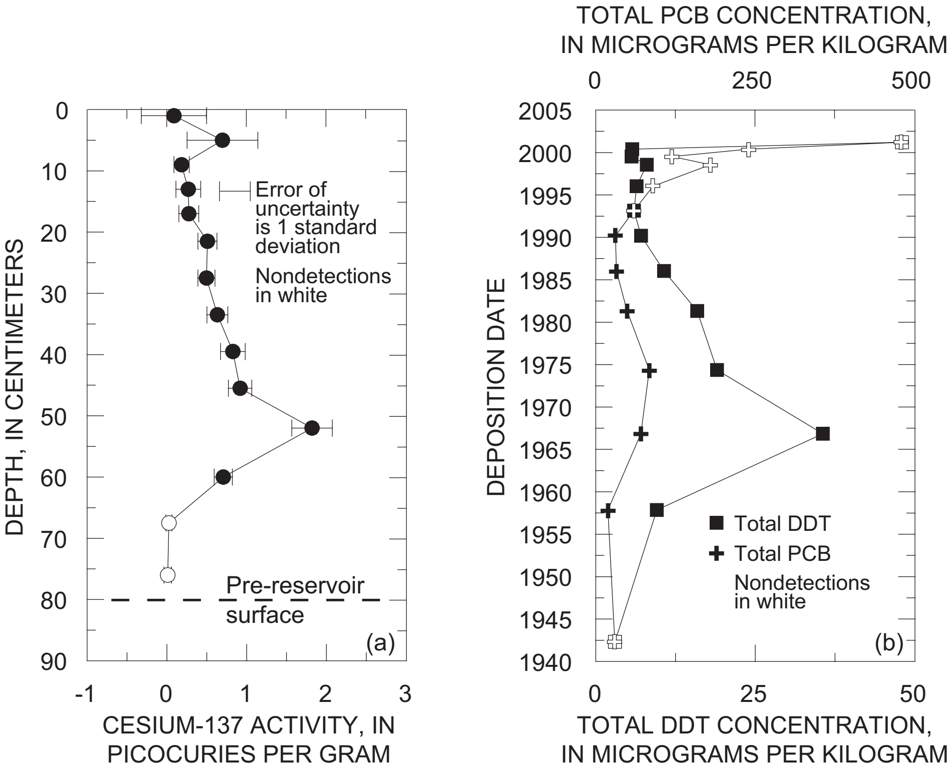


Figure A–30. Chemical constituent profiles used to estimate age dates for Lake in the Hills, Ill.

Table A–26

Core LKH.1			Core LKH.1		
Sample identification	Mid-depth (centimeters)	Estimated deposition date	Sample identification	Mid-depth (centimeters)	Estimated deposition date
LKH.1 0–2	1	2001.2	LKH.1 35–38	36.5	1976.8
LKH.1 2–4	3	2000.4	LKH.1 38–41	39.5	1974.4
LKH.1 4–6	5	1999.5	LKH.1 41–44	42.5	1971.8
LKH.1 6–8	7	1998.6	LKH.1 44–47	45.5	1969.3
LKH.1 8–10	9	1997.4	LKH.1 47–50	48.5	1966.8
LKH.1 10–12	11	1996.0	LKH.1 50–54	52	1964.0
LKH.1 12–14	13	1994.6	LKH.1 54–58	56	1960.9
LKH.1 14–16	15	1993.1	LKH.1 58–62	60	1957.9
LKH.1 16–18	17	1991.6	LKH.1 62–66	64	1954.4
LKH.1 18–20	19	1990.2	LKH.1 66–70	68	1950.5
LKH.1 20–23	21.5	1988.4	LKH.1 70–74	72	1946.5
LKH.1 23–26	24.5	1986.0	LKH.1 74–78	76	1942.3
LKH.1 26–29	27.5	1983.7	LKH.1 78–82	80	1935.7
LKH.1 29–32	30.5	1981.3	LKH.1 82–86	84	Pre-reservoir
LKH.1 32–35	33.5	1979.0			

28. Shoe Factory Road Pond, Ill.

Shoe Factory Road Pond is a small natural lake located between the suburban areas of Elgin and Hoffman Estates northwest of Chicago, Ill. Two hand-pushed cores were collected for analysis from the southern end of the pond in July 2001.

SHO.2 Push core 84 cm long analyzed for radionuclides and major and trace elements.

Basis This core was age dated using ^{210}Pb and the CRS model (Appleby and Oldfield, 1992). Radium-226, measured to account for supported ^{210}Pb, averaged 1.4 pCi/g and varied from 0.51 to 2.53 pCi/g (fig. A–31a). ^{210}Pb decreased exponentially from 10 pCi/g at the top of the core to 2.19 pCi/g at 36 to 40 cm, then flattened at a mean of 2.03 pCi/g from 44 cm to the bottom of the core at 80 cm. Because numerous core intervals were not analyzed, a regression model of natural log of unsupported ^{210}Pb in relation to cumulative mass ($r^2 = 0.99$) was used to estimate values for the entire core. The CRS model yielded a MAR from the 1930s to the top of the core with a mean of 0.59 g/cm^2-yr and range of 0.56 to 0.60 g/cm^2-yr.

Corroboration The ^{137}Cs profile suggests postdepositional mixing in this core; however, unsupported ^{210}Pb does not. The sediments have relatively large organic carbon concentrations (about 10 percent) in the upper part of the core where ^{137}Cs occurs; therefore, ^{137}Cs is suspected to be desorbing and diffusing in the sediments. The ^{137}Cs still provides some support for the ^{210}Pb dates with a rounded peak from about 1950 to 1975, centered on the historical fallout peak in 1964.0 (fig. A–31b). The lead concentration profile also supports the age assignments with an increase in concentration beginning in the mid-1800s, when Chicago began to industrialize, and a broad peak from about 1950 to 1975 (fig. A–31c).

Rating Good.

SHO.1 Push core 76 cm long analyzed for organic compounds.

Basis Dates were assigned to this core on the basis of the date-depth relation developed for core SHO.2.

Corroboration Organochlorine compounds were not detected in the 24- to 28-cm sample, dated as about 1890, and were first detected in the 14- to 16-cm sample, dated as about 1950. While providing little detailed supporting evidence of dates, these age assignments are reasonable.

Rating Fair.

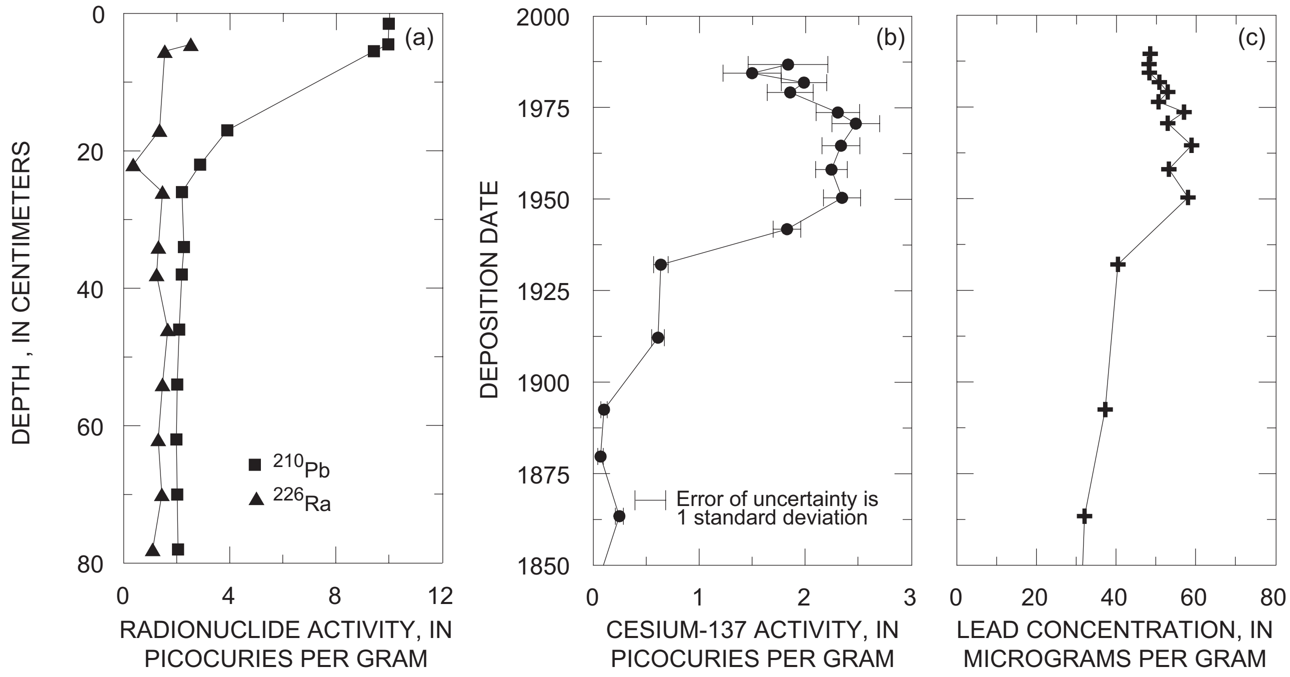


Figure A–31. Chemical constituent profiles used to estimate age dates for Shoe Factory Road Pond, Ill.

Table A–27

Core SHO.2			Core SHO.2		
Sample identification	Mid-depth (centimeters)	Estimated deposition date	Sample identification	Mid-depth (centimeters)	Estimated deposition date
SHO.2 1–2	1.5	1991.6	SHO.2 18–20	19	1932.1
SHO.2 2–3	2.5	1989.5	SHO.2 20–24	22	1912.1
SHO.2 3–4	3.5	1986.7	SHO.2 24–28	26	1892.5
SHO.2 4–5	4.5	1984.3	SHO.2 28–32	30	1879.7
SHO.2 5–6	5.5	1981.8	SHO.2 32–36	34	1863.4
SHO.2 6–7	6.5	1979.1	SHO.2 36–40	38	1841.2
SHO.2 8–9	8.5	1973.6	SHO.2 40–44	42	1801.2
SHO.2 9–10	9.5	1970.6	SHO.2 48–52	50	Not computed
SHO.2 10–12	11	1964.5	SHO.2 56–60	58	Not computed
SHO.2 12–14	13	1958.0	SHO.2 64–68	66	Not computed
SHO.2 14–16	15	1950.3	SHO.2 72–76	74	Not computed
SHO.2 16–18	17	1941.7	SHO.2 80–84	82	Not computed

Table A–27 (Continued)

Core SHO.1			Core SHO.1		
Sample identification	Mid-depth (centimeters)	Estimated deposition date	Sample identification	Mid-depth (centimeters)	Estimated deposition date
SHO.1 0–1	0.5	1993.6	SHO.1 10–12	11	1964.5
SHO.1 2–3	2.5	1989.5	SHO.1 14–16	15	1950.3
SHO.1 4–5	4.5	1984.3	SHO.1 24–28	26	1892.5
SHO.1 6–7	6.5	1979.1	SHO.1 40–44	42	1801.2
SHO.1 8–9	8.5	1973.6	SHO.1 56–60	58	Not computed

29. Busse Lake, Ill.

Busse Lake is a shallow reservoir, reconstructed in 1980, in the Ned Brown County Forest Preserve near the suburban area called Elk Grove Village northwest of Chicago, Ill. One hand-pushed core was collected for chemical analysis from the northern area of the lake near the inlet of Salt Creek in July 2001.

BUS.1 Push core 40 cm long analyzed for major and trace elements and organic compounds.

Basis The core encountered pre-reservoir material at 26 cm. A MAR of 0.83 g/cm^2-yr was computed using the 26-cm date marker and used to assign dates.

Corroboration Because of the short time span covered by the core and because only three samples were analyzed for contaminants, there is little opportunity for corroboration; however, the lead concentration profile is reasonable, decreasing from 126 to 74 to 67 µg/g from 1983.2 to 2000.2 (fig. A–32).

Rating Good.

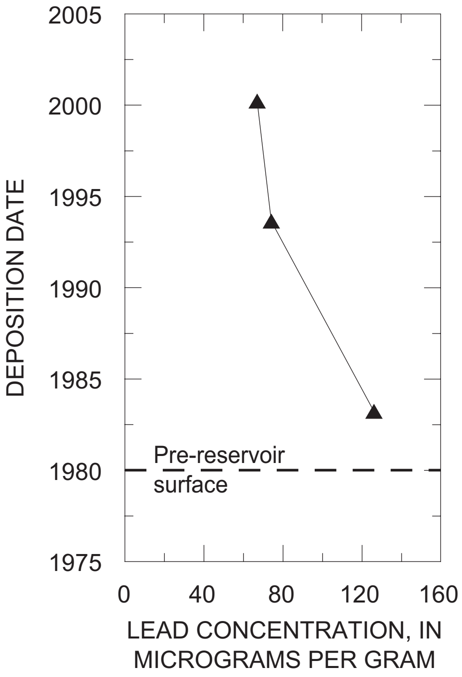


Figure A–32. Chemical constituent profile used to estimate age dates for Busse Lake, Ill.

Table A–28

Core BUS.1 Sample identification	Core BUS.1 Mid-depth (centimeters)	Core BUS.1 Estimated deposition date	Core BUS.1 Sample identification	Core BUS.1 Mid-depth (centimeters)	Core BUS.1 Estimated deposition date
BUS.1 0–4	2	2000.2	BUS.1 20–24	22	1983.2
BUS.1 4–8	6	1997.2	BUS.1 24–28	26	1980.0
BUS.1 8–12	10	1993.6	BUS.1 28–32	30	Pre-reservoir
BUS.1 12–16	14	1990.0	BUS.1 32–36	34	Pre-reservoir
BUS.1 16–20	18	1986.4			

30. Beck Lake, Ill.

Beck Lake is a small reservoir in a County Forest Preserve adjacent to IH–294 in a suburban area known as Mount Prospect northwest of Chicago, Ill. The reservoir was constructed in 1958; one box core was collected for analysis from the upper area of the reservoir in July 2001.

BEC.1 Box core 45 cm deep analyzed for all constituents.

Basis The core encountered pre-reservoir material at 44 cm. The highest ^{137}Cs activity is in the deepest sample analyzed for radionuclides (fig. A–33), 39 to 42 cm. Using the pre-reservoir surface at 44 cm as the 1958.0 date-depth marker yields a MAR of 0.41 g/cm^2-yr and a date of 1965.1 for the middle of the 39- to 42-cm interval.

Corroboration As described above, the ^{137}Cs profile provides some support for assigned dates. The lead concentration profile also supports the age dates with the largest concentration of lead in the 30- to 33-cm sample that received a reasonable date of 1976.0 (fig. A–33).

Rating Good.

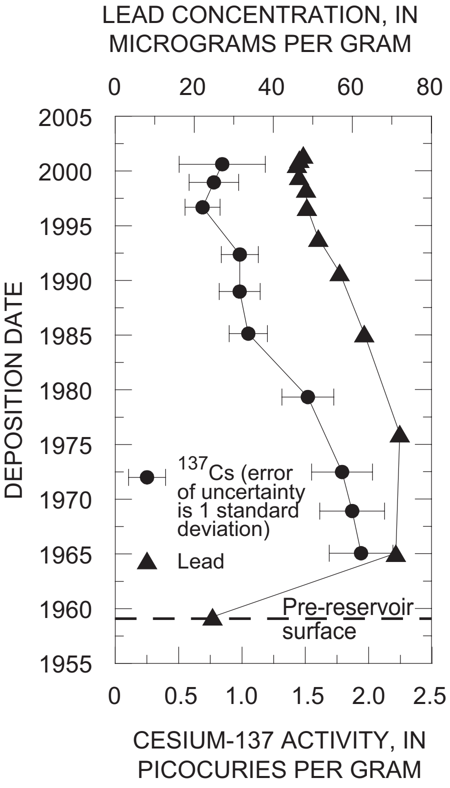


Figure A–33. Chemical constituent profiles used to estimate age dates for Beck Lake, Ill.

Table A–29

Core BEC.1			Core BEC.1		
Sample identification	Mid-depth (centimeters)	Estimated deposition date	Sample identification	Mid-depth (centimeters)	Estimated deposition date
BEC.1 0–1	0.5	2001.5	BEC.1 16–18	17	1990.7
BEC.1 1–2	1.5	2001.1	BEC.1 18–20	19	1989.0
BEC.1 2–3	2.5	2000.6	BEC.1 20–22	21	1987.1
BEC.1 3–4	3.5	2000.1	BEC.1 22–24	23	1985.1
BEC.1 4–5	4.5	1999.5	BEC.1 24–27	25.5	1982.5
BEC.1 5–6	5.5	1999.0	BEC.1 27–30	28.5	1979.3
BEC.1 6–7	6.5	1998.4	BEC.1 30–33	31.5	1976.0
BEC.1 7–8	7.5	1997.7	BEC.1 33–36	34.5	1972.5
BEC.1 8–10	9	1996.7	BEC.1 36–39	37.5	1968.9
BEC.1 10–12	11	1995.3	BEC.1 39–42	40.5	1965.1
BEC.1 12–14	13	1993.9	BEC.1 42–45	43.5	1959.3
BEC.1 14–16	15	1992.4			

31. Lake Sidney Lanier, Ga.

Lake Sidney Lanier is a large reservoir constructed in 1956 on the Chattahoochee River northeast of Atlanta, Ga. It took 2 more years for the reservoir to fill after the completion of the dam. The Chestatee River flows into the reservoir northwest of the Chattahoochee River. Two locations were sampled in May 1994, both above the confluence of the two rivers. Site LL.CHT is in the middle Chattahoochee River arm of the reservoir and just above the confluence of the two rivers. Site LL.CST is in the middle of the Chestatee River arm, well upstream from the reservoir.

Location CHT

LL.CHT.35(3) Gravity core 64 cm long analyzed for major and trace elements.

Basis The pre-reservoir surface at 25 cm was assigned a date of 1957.0 resulting in a MAR of 0.23 g/cm^2-yr. This MAR was used to assign dates.

Corroboration The lead profile has a rounded peak centered in the 1970s, consistent with lead releases and the rural setting of the lake (fig. A–34).

Rating Fair. The relatively low sedimentation rate, limited corroboration, and lack of radiochemical age-dating lead to a fair rating.

Location CST

LL.CST.15C(1) Gravity core 111.5 cm long analyzed for major and trace elements.

Basis The pre-reservoir surface at 17 cm was assigned a date of 1957.0 resulting in a MAR of 0.18 g/cm^2-yr. This MAR was used to assign dates.

Corroboration The lead profile has a rounded peak centered in the 1970s, consistent with lead releases and the rural setting of the lake (fig. A–34).

Rating Fair. The relatively low sedimentation rate, limited corroboration, and lack of radiochemical age-dating lead to a fair rating.

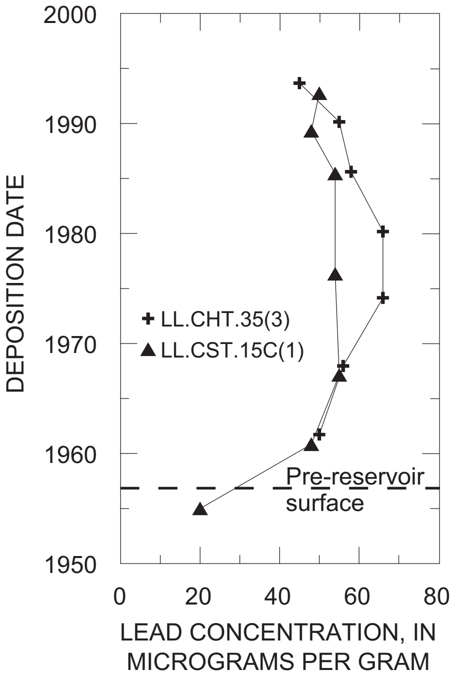


Figure A–34. Lead concentration profiles for Lake Sidney Lanier, Ga.

Table A–30

Core LL.CHT.35(3)			Core LL.CHT.35(3)		
Sample identification	Mid-depth (centimeters)	Estimated deposition date	Sample identification	Mid-depth (centimeters)	Estimated deposition date
LL.CHT.35(3) 0–2	1	1993.7	LL.CHT.35(3) 14–16	15	1977.2
LL.CHT.35(3) 2–4	3	1992.0	Ll.CHT.35(3) 16–18	17	1974.2
LL.CHT.35(3) 4–6	5	1990.1	Ll.CHT.35(3) 18–20	19	1971.0
LL.CHT.35(3) 6–8	7	1988.0	LL.CHT.35(3) 20–22	21	1968.0
LL.CHT.35(3) 8–10	9	1985.6	LL.CHT.35(3) 22–25	23.5	1961.7
LL.CHT.35(3) 10–12	11	1983.0	LL.CHT.35(3) 25–35	30	Pre-reservoir
LL.CHT.35(3) 12–14	13	1980.2			

Core LL.CST.15C(1)			Core LL.CST.15C(1)		
Sample identification	Mid-depth (centimeters)	Estimated deposition date	Sample identification	Mid-depth (centimeters)	Estimated deposition date
LL.CST.15C(1) 0–2	1	1992.7	LL.CST.15C(1) 22–27	24.5	Pre-reservoir
LL.CST.15C(1) 2–4	3	1989.3	LL.CST.15C(1) 27–37	32	Pre-reservoir
LL.CST.15C(1) 4–6	5	1985.4	LL.CST.15C(1) 37–47	42	Pre-reservoir
LL.CST.15C(1) 6–8	7	1981.0	LL.CST.15C(1) 47–57	52	Pre-reservoir
LL.CST.15C(1) 8–10	9	1976.3	LL.CST.15C(1) 57–67	62	Pre-reservoir
LL.CST.15C(1) 10–12	11	1971.8	LL.CST.15C(1) 67–77	72	Pre-reservoir
LL.CST.15C(1) 12–14	13	1967.1	LL.CST.15C(1) 77–87	82	Pre-reservoir
LL.CST.15C(1) 14–17	15.5	1960.8	LL.CST.15C(1) 87–97	92	Pre-reservoir
LL.CST.15C(1) 17–22	19.5	Pre-reservoir	LLCST15C(1)97–111.5	104.25	Pre-reservoir

32. Berkeley Lake, Ga.

Berkeley Lake is a reservoir, constructed in 1948, that drains into the Chattahoochee River. It is located in an affluent suburban area called Berkeley Lake, which is between Norcross and Duluth, northeast of Atlanta, Ga. One box core was collected for chemical analysis from the mid-to-lower area of the reservoir in May 1999.

BRK Box core 35 cm deep analyzed for all constituents.

Basis There is a single, anomalous large ^{137}Cs concentration at 14 to 15 cm and an apparently anomalous small concentration at 20 to 22 cm (fig. A–35a). While major elements show relatively large variations, suggesting variable sediment sources over time, they do not explain these anomalies. Because the ^{137}Cs profile did not conform to other age markers, it was not used. The pre-reservoir surface is well defined at 27 cm. The pre-reservoir surface was chosen as the primary date-depth marker with a reservoir construction date of 1948, and an average MAR of 0.09 g/cm^2-yr was computed for the core.

Corroboration These age assignments put 1964.0, the expected ^{137}Cs peak, at about 21 cm, matching the anomalous small ^{137}Cs concentration. Ignoring the two anomalies, the overall shape of the profile does suggest larger ^{137}Cs in that part of the core. Lead concentrations peak at 15 to 16 cm, which receives a reasonable date of 1978.2 (fig. A–35b). Total DDT and PCB concentrations increase toward the bottom of the core with the largest concentrations in the deepest sample analyzed at 22 to 24 cm, which receives a reasonable date of 1960.8 (fig. A–35b).

Rating Fair.

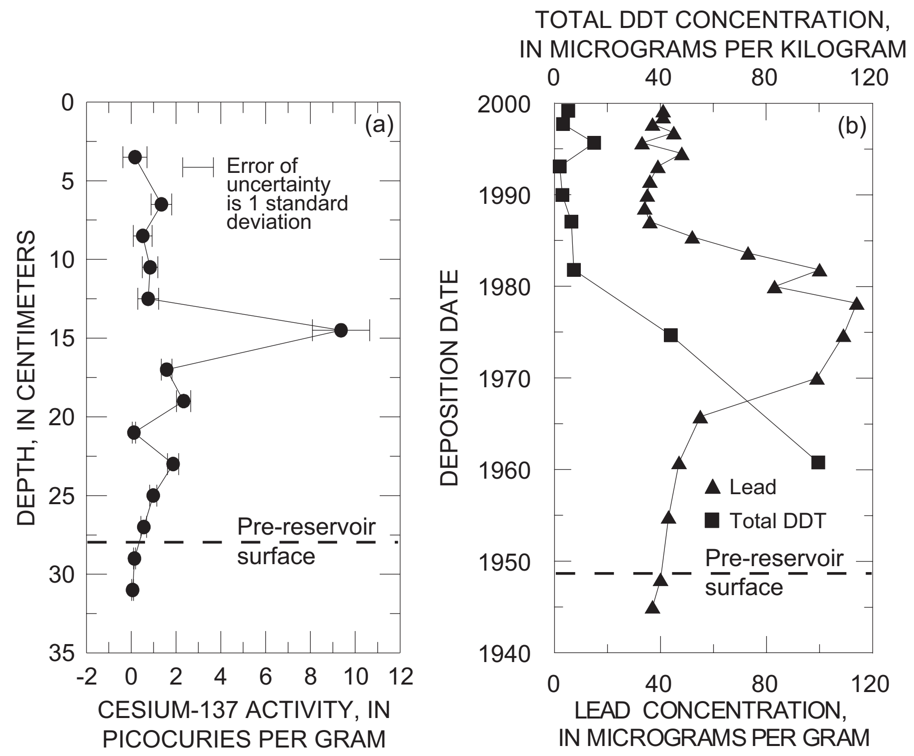


Figure A–35. Chemical constituent profiles used to estimate age dates for Berkeley Lake, Ga.

Table A–31

Core BRK			Core BRK		
Sample identification	Mid-depth (centimeters)	Estimated deposition date	Sample identification	Mid-depth (centimeters)	Estimated deposition date
BRK 0–1	0.5	1999.1	BRK 12–13	12.5	1983.6
BRK 1–2	1.5	1998.5	BRK 13–14	13.5	1981.8
BRK 2–3	2.5	1997.7	BRK 14–15	14.5	1980.0
BRK 3–4	3.5	1996.8	BRK 15–16	15.5	1978.2
BRK 4–5	4.5	1995.7	BRK 16–18	17	1974.6
BRK 5–6	5.5	1994.5	BRK 18–20	19	1970.0
BRK 6–7	6.5	1993.1	BRK 20–22	21	1965.8
BRK 7–8	7.5	1991.5	BRK 22–24	23	1960.8
BRK 8–9	8.5	1989.9	BRK 24–26	25	1954.8
BRK 9–10	9.5	1988.5	BRK 26–28	27	1948.0
BRK 10–11	10.5	1987.0	BRK 28–30	29	Pre-reservoir
BRK 11–12	11.5	1985.4	BRK 30–32	31	Pre-reservoir

33. Lakewood Park Lake, Ga.

Lakewood Park Lake is located adjacent to the Lakewood Park amphitheater and fairground in southern Atlanta, Ga. The lake is located near Lakewood Freeway and IH–75/85. Lakewood Park Lake is a reservoir, although no information on its construction could be obtained. Two gravity cores were collected for chemical analysis from the southern end of the lake in May 1999.

LKW.1 Gravity core 96 cm long analyzed for ^{137}Cs and major and trace elements.

Basis There is a zone in the middle of this core (about 42 to 54 cm) with low titanium and organic carbon and high silicon concentrations (fig. A–36a), indicating a large influx of silty or sandy material, possibly from erosion during major urban or highway construction. Concentrations of all of the trace elements and ^{137}Cs are small in this part of the core. Similar profiles were observed in Lorence Creek Lake in San Antonio, Tex. (Ging and others, 1999). Normalizing ^{137}Cs to titanium suggests the ^{137}Cs peak is at 60 to 63 cm (fig. A–36b). Age dates were assigned on the basis of the normalized ^{137}Cs peak resulting in a MAR of 1.11 g/cm^2-yr.

Corroboration There is no clear lead peak, although the relatively large concentrations just above the anomalous zone noted above date as late 1970s. Using the dates on the basis of the ^{137}Cs peak results in dates in the 1950s in the lower part of the core. Thus, the best corroboration for the dates assigned is the occurrence of ^{137}Cs in the lower part of this core.

Rating Fair.

LKW.2 Gravity core 82 cm long analyzed for organic compounds.

Basis Total DDT and organic carbon normalized total DDT concentrations peak sharply at 42 to 45 cm (fig. A–36c). Peak and first occurrence of DDT and PCBs in this core are inconsistent with the date-depth relation developed in LKW.1. Therefore, the DDT profile was used to assign dates. The total DDT peak was assigned a date of 1964.0 on the basis of the similarity of total DDT and ^{137}Cs peaks in numerous cores (Van Metre and others, 1998). Porosity was not measured in this core; therefore, the date-depth relation developed for core LKW.1 was adjusted to put the total DDT peak at 1964.0 in this core and used to assign dates. The resulting MAR is 0.064 g/cm^2-yr.

Corroboration Very small concentrations of DDD, DDE, and DDT and small concentrations of PCBs were detected in the bottom sample analyzed, 54 to 57 cm, which received a reasonable date of 1944.3. A broad high in organic carbon normalized PCBs from 36 to 51 cm is dated from 1970.5 to 1953.4 (fig. A–36c), which also is reasonable.

Rating Fair.

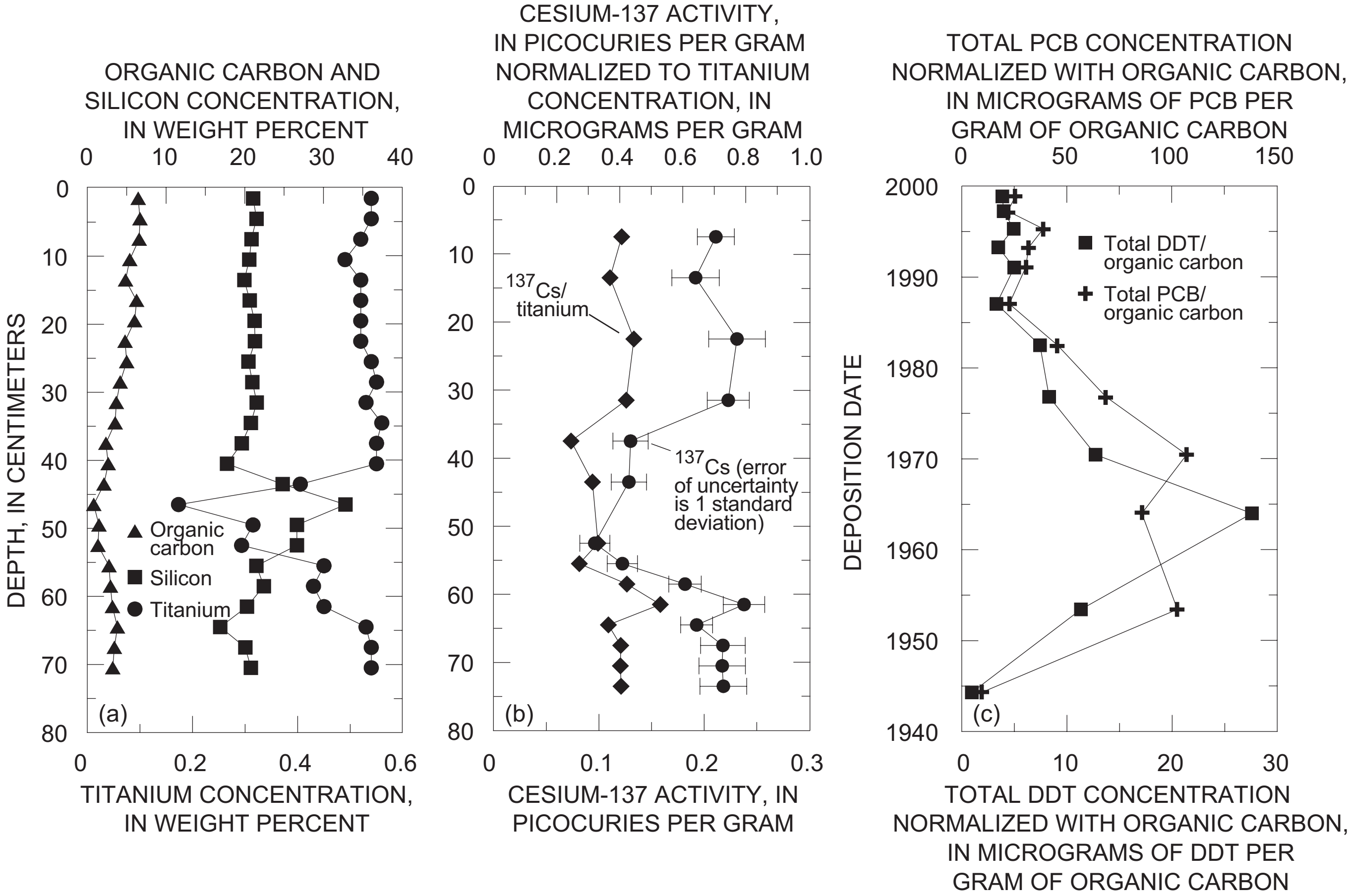


Figure A–36. Chemical constituent profiles used to estimate age dates for Lakewood Park Lake, Ga. (a) LKW.1, (b) LKW.1, (c) LKW.2.

Table A–32

Core LKW.1			Core LKW.1		
Sample identification	Mid-depth (centimeters)	Estimated deposition date	Sample identification	Mid-depth (centimeters)	Estimated deposition date
LKW.1 0–3	1.5	1999.1	LKW.1 36–39	37.5	1982.7
LKW.1 3–6	4.5	1998.2	LKW.1 39–42	40.5	1980.9
LKW.1 6–9	7.5	1997.1	LKW.1 42–45	43.5	1978.9
LKW.1 9–12	10.5	1995.9	LKW.1 45–48	46.5	1976.0
LKW.1 12–15	13.5	1994.6	LKW.1 48–51	49.5	1972.8
LKW.1 15–18	16.5	1993.4	LKW.1 51–54	52.5	1970.0
LKW.1 18–21	19.5	1992.3	LKW.1 54–57	55.5	1967.5
LKW.1 21–24	22.5	1991.0	LKW.1 57–60	58.5	1965.6
LKW.1 24–27	25.5	1989.6	LKW.1 60–63	61.5	1964.0
LKW.1 27–30	28.5	1988.1	LKW.1 63–66	64.5	1962.2
LKW.1 30–33	31.5	1986.3	LKW.1 66–69	67.5	1960.2
LKW.1 33–36	34.5	1984.4	LKW.1 69–72	70.5	1958.1

Table A–32 (Continued)

Core LKW.2		
Sample identification	Mid-depth (centimeters)	Estimated deposition date
LKW.2 0–3	1.5	1998.9
LKW.2 3–6	4.5	1997.3
LKW.2 6–9	7.5	1995.3
LKW.2 9–12	10.5	1993.3
LKW.2 12–15	13.5	1991.1
LKW.2 18–21	19.5	1987.0
LKW.2 24–27	25.5	1982.5
LKW.2 30–33	31.5	1976.8
LKW.2 36–39	37.5	1970.5
LKW.2 42–45	43.5	1964.0
LKW.2 48–51	49.5	1953.4
LKW.2 54–57	55.5	1944.3

34. Panola Lake, Ga.

Panola Lake is a small reservoir constructed in 1946 in Panola Mountain State Conservation Park southeast of Atlanta, Ga. One box core was collected for analysis from the middle of the reservoir in May 1999.

PAN.B Box core 24.5 cm deep analyzed for all constituents.

Basis The peak ^{137}Cs activity at 13 to 14 cm (fig. A–37a) was assigned a date of 1964.0 resulting in a MAR of 0.08 g/cm^2-yr for the core. Using the ^{137}Cs peak and the pre-reservoir surface at 16 cm as a date marker of 1946.0, the construction date, yields a MAR for 1946.0–1964.0 of 0.08 g/cm^2-yr, matching the MAR for 1964.0–1999.4. Dates were assigned on the basis of this MAR.

Corroboration The deepest lacustrine sample (15 to 16 cm) received a reasonable date of 1950.9. The deepest sample analyzed for organics (14 to 15 cm) has the largest total DDT concentration and received a reasonable date of 1958.6 (fig. A–37b). Peak lead concentration is at 5 to 6 cm, which received a date of 1988.8 (fig. A–37b). Because other date markers seem reasonable and sedimentation rates from before and after the ^{137}Cs peak did not change, the lead peak was not used as a date marker. An additional consideration in not using the lead peak is that this is a reference site not subject to direct urban fluvial runoff.

Rating Good.

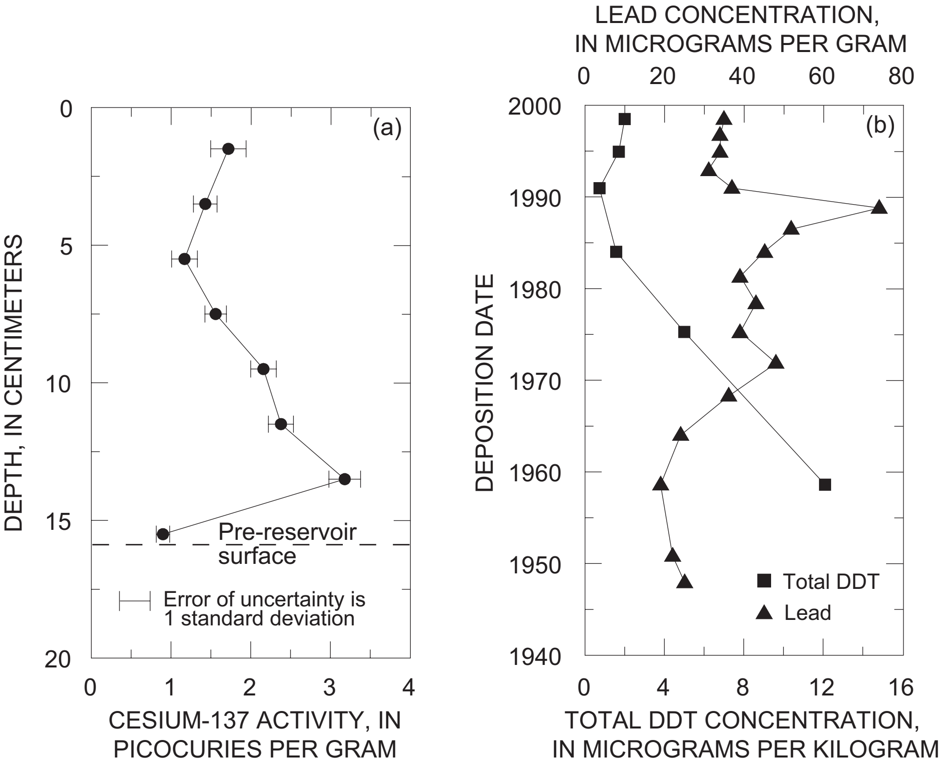


Figure A–37. Chemical constituent profiles used to estimate age dates for Panola Lake, Ga.

Table A–33

Core PAN.B			Core PAN.B		
Sample identification	Mid-depth (centimeters)	Estimated deposition date	Sample identification	Mid-depth (centimeters)	Estimated deposition date
PAN.B 0–1	0.5	1998.5	PAN.B 9–10	9.5	1978.4
PAN.B 1–2	1.5	1996.8	PAN.B 10–11	10.5	1975.3
PAN.B 2–3	2.5	1994.9	PAN.B 11–12	11.5	1971.9
PAN.B 3–4	3.5	1993.0	PAN.B 12–13	12.5	1968.2
PAN.B 4–5	4.5	1990.9	PAN.B 13–14	13.5	1964.0
PAN.B 5–6	5.5	1988.8	PAN.B 14–15	14.5	1958.6
PAN.B 6–7	6.5	1986.5	PAN.B 15–16	15.5	1950.9
PAN.B 7–8	7.5	1984.0	PAN.B 16–17	16.5	Pre-reservoir
PAN.B 8–9	8.5	1981.3			

35. West Point Lake, Ga.

West Point Lake is a large reservoir constructed in 1974 on the Chattahoochee River southwest of Atlanta, Ga. The reservoir is the farthest upstream in a chain of reservoirs on the Chattahoochee River along the Georgia/Alabama border sampled for the RTNS study. Two locations were sampled in May 1994—location 55 is located downstream from the confluence of the Chattahoochee River and Yellowjacket Creek and location 99 is located upstream from location 55 in the Chattahoochee River arm of the reservoir.

Location 55

WP.55(1) Gravity core 72 cm long analyzed for major and trace elements.

Basis The core penetrated the pre-reservoir land surface at 70 cm. The pre-reservoir surface and the sampling date yielded a MAR of 1.51 g/cm^2-yr. Dates were assigned on the basis of this MAR.

Corroboration There is a zone of large lead concentrations at the bottom of the core dated as 1974.7–1977.9 that supports the age assignments in the core (fig. A–38).

Rating Good. The high sedimentation rate and relatively short time period support a good rating.

Location 99

WP.99–100(2) Gravity core 131 cm long analyzed for major and trace elements.

Basis The core penetrated the pre-reservoir land surface at 109 cm. The pre-reservoir surface and the sampling date yielded a MAR of 3.38 g/cm^2-yr. Dates were assigned on the basis of this MAR.

Corroboration There is a zone of large lead concentrations at the bottom of the core dated as 1974.5–1976.4 that supports the age assignments in the core (fig. A–38). Differences in lead profiles between the two cores (locations 55 and 99) probably are caused by more variable, sandier sediments at this site, located in the upper reservoir, compared to location 55, located in the middle of this large reservoir.

Rating Good.

WP.99–100(1) Gravity core 123 cm long analyzed for organochlorine compounds.

Basis The core penetrated the pre-reservoir land surface at 107 cm. Ages were assigned on the basis of the date-depth relation in core WP.99–100(2).

Corroboration None. Sediment deposits in the core were too young to have recorded the DDT or PCB peaks normally used to corroborate.

Rating Good. High sedimentation rate and relatively short time period support a good rating.

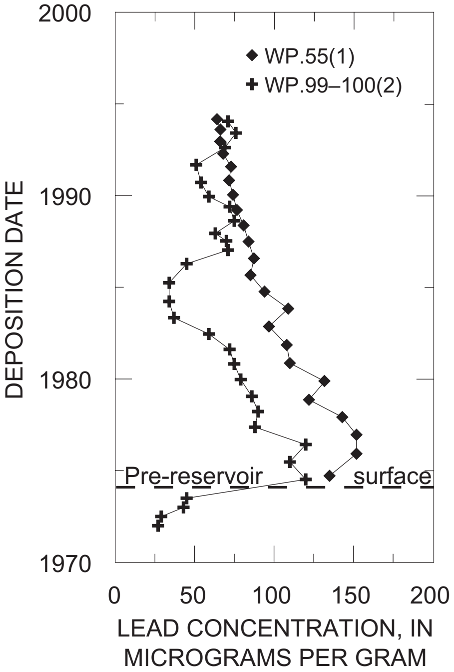


Figure A–38. Lead concentration profiles for West Point Lake, Ga.

Table A–34

Core WP.55(1)			Core WP.55(1)		
Sample identification	Mid-depth (centimeters)	Estimated deposition date	Sample identification	Mid-depth (centimeters)	Estimated deposition date
WP.55(1) 0–3	1.5	1994.2	WP.55(1) 36–39	37.5	1984.8
WP.55(1) 3–6	4.5	1993.6	WP.55(1) 39–42	40.5	1983.8
WP.55(1) 6–9	7.5	1993.0	WP.55(1) 42–45	43.5	1982.9
WP.55(1) 9–12	10.5	1992.3	WP.55(1) 45–48	46.5	1981.9
WP.55(1) 12–15	13.5	1991.6	WP.55(1) 48–51	49.5	1980.9
WP.55(1) 15–18	16.5	1990.8	WP.55(1) 51–54	52.5	1979.9
WP.55(1) 18–21	19.5	1990.0	WP.55(1) 54–57	55.5	1978.9
WP.55(1) 21–24	22.5	1989.2	WP.55(1) 57–60	58.5	1977.9
WP.55(1) 24–27	25.5	1988.4	WP.55(1) 60–63	61.5	1977.0
WP.55(1) 27–30	28.5	1987.5	WP.55(1) 63–66	64.5	1975.9
WP.55(1) 30–33	31.5	1986.6	WP.55(1) 66–70	68	1974.7
WP.55(1) 33–36	34.5	1985.7			

Core WP.99–100(1)			Core WP.99–100(1)		
Sample identification	Mid-depth (centimeters)	Estimated deposition date	Sample identification	Mid-depth (centimeters)	Estimated deposition date
WP.99–100(1) 0–9	4.5	1993.9	WP.99–100(1) 49–56	52.5	1984.8
WP.99–100(1) 9–16	12.5	1992.4	WP.99–100(1) 72–80	76	1980.4
WP.99–100(1) 25–29+34–37	30	1989.1	WP.99–100(1) 88–96	92	1977.3
WP.99–100(1) 29–34	31.5	1988.8	WP.99–100(1) 108–120	114	Pre-reservoir

Table A–34 (Continued)

Core WP.99–100(2)		
Sample identification	Mid-depth (centimeters)	Estimated deposition date
WP.99–100(2) 0–5	2.5	1994.1
WP.99–100(2) 5–9	7	1993.4
WP.99–100(2) 9–15	12	1992.6
WP.99–100(2) 15–19	17	1991.7
WP.99–100(2) 19–23	21	1990.7
WP.99–100(2) 23–27	25	1989.9
WP.99–100(2) 27–31	29	1989.4
WP.99–100(2) 31–36.5	33.75	1988.6
WP.99–100(2) 36.5–39	37.75	1987.9
WP.99–100(2) 39–42	40.5	1987.5
WP.99–100(2) 42–45	43.5	1987.0
WP.99–100(2) 45–48	46.5	1986.3
WP.99–100(2) 48–52	50	1985.2
WP.99–100(2) 52–56	54	1984.2
WP.99–100(2) 56–60	58	1983.3
WP.99–100(2) 60–65	62.5	1982.5
WP.99–100(2) 65–70	67.5	1981.6
WP.99–100(2) 70–75	72.5	1980.8
WP.99–100(2) 75–80	77.5	1980.0
WP.99–100(2) 80–85	82.5	1979.1
WP.99–100(2) 85–90	87.5	1978.2
WP.99–100(2) 90–95	92.5	1977.4
WP.99–100(2) 95–100	97.5	1976.4
WP.99–100(2) 100–105	102.5	1975.5
WP.99–100(2) 105–109.5	107.25	1974.5
WP.99–100(2) 109.5–111	110.25	Pre-reservoir
WP.99–100(2) 111–118	114.5	Pre-reservoir
WP.99–100(2) 118–125	121.5	Pre-reservoir
WP.99–100(2) 125–131	128	Pre-reservoir

36. Lake Harding, Ga./Ala.

Lake Harding is a large reservoir constructed in 1926 on the Chattahoochee River on the Georgia/Alabama border southwest of Atlanta, Ga. Lake Harding is downstream from West Point Lake and upstream from Lakes Walter F. George and Seminole; all were sampled as part of the RTNS study. Two gravity cores were collected for chemical analysis from the mid-to-lower reservoir in September 1994.

HRD(1) Gravity core 225 cm long analyzed for ^{137}Cs and major and trace elements.

Basis The peak ^{137}Cs activity is at 75 to 80 cm; ^{137}Cs first occurs at detectable levels at 120 to 125 cm (fig. A–39a). The core did not penetrate the pre-reservoir surface. West Point Lake, a large reservoir on the Chattahoochee River downstream from Atlanta, was constructed upstream from Lake Harding in 1974, presumably causing a large drop in sedimentation rate at Lake Harding. There is a lead peak at 45 to 50 cm and sizable decreases in chromium, copper, and lead concentrations between that interval and the one above it (fig. A–39b). These changes probably mark the completion of West Point Lake and the introduction of unleaded gasoline indicating a date of about 1975. A MAR of 1.18 g/cm^2-yr was computed for 1975.0–1994.3. MARs of 1.79 and 2.84 g/cm^2-yr were computed for 1964.0–1975.0 and 1953.0–1964.0, respectively, on the basis of the 1975.0 chemical marker and 1964.0 and 1953.0 ^{137}Cs markers. The lack of a pre-reservoir surface suggested the MAR for the lower part of the core prior to 1953.0 had to be at least 3.5 g/cm^2-yr. The systematic decrease in the MAR from the bottom of the core to the 1975.0 marker was modeled as an exponential decrease following the methods of Callender and Robbins (1993). The model was calibrated (k = 0.042) using the mass accumulated during 1953.0–196.04 and 1964.0–1975.0 and was used to estimate a bottom-of-core date of 1936.5. The modeled MAR decreases over time from about 7 g/cm^2-yr at the bottom of the core to 1.18 g/cm^2-yr in 1975.0. The model was used to develop a cumulative mass-date relation that was used to assign dates from the bottom of the core up to 1975.0. The constant MAR of 1.18 g/cm^2-yr was used to assign dates for 1975.0–1994.3.

Corroboration West Point Lake traps sediment in the Chattahoochee River downstream from Atlanta and upstream from Lake Harding. Several common urban heavy metals, including chromium, copper, and lead, decrease between the 45- to 50-cm and 40- to 45-cm samples, coincident with age assignment of 1975.0, to the 45- to 50-cm sample (fig. A–39b). These changes support the 1975.0 date at that depth in the core. Similar changes in organochlorine compounds occur in core HRD(3) (fig. A–39c). HRD(3) also provides evidence supporting the modeled age assignments in the lower part of this core. The first occurrence of chlordane, DDD, and DDE is at 168 to 172 cm. This interval was dated as 1943.5, a reasonable date for the first occurrence of these compounds.

Rating Good.

HRD(3) Gravity core 240 cm long analyzed for organochlorine compounds.

Basis This core was longer than the adjacent core, HRD(1), and also did not penetrate the pre-reservoir surface. Dates assigned to HRD(1) were extrapolated by depth to this core.

Corroboration Chlordane, total DDT, and PCBs have rounded peaks from about 140 to 60 cm in the core, corresponding to dates from about 1950 to 1970. These compounds first occur at detectable levels in about 1943 and drop sharply in concentration above the interval dated as 1967.5 (fig. A–39c). These patterns are reasonable considering use history and the construction of West Point Lake upstream in 1974.

Rating Good.

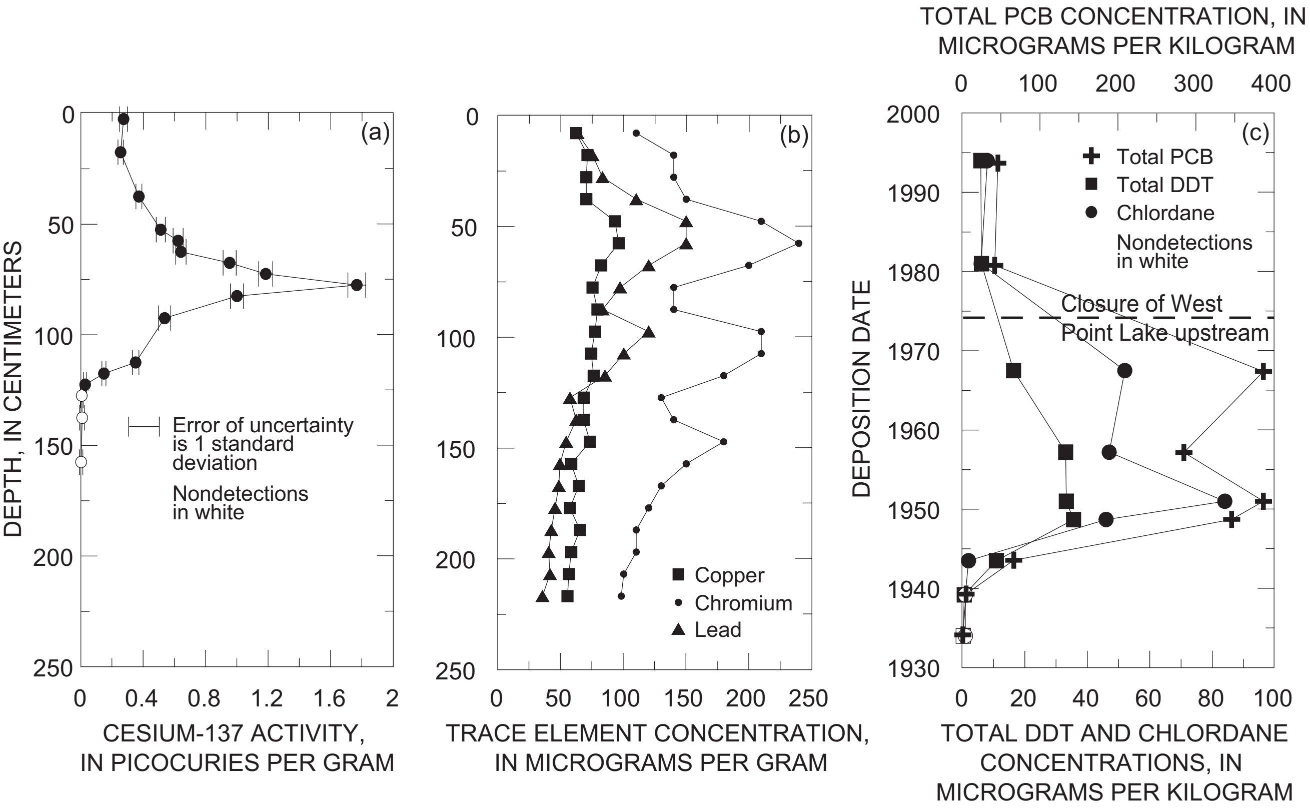


Figure A–39. Chemical constituent profiles used to estimate age dates for Lake Harding, Ga./Ala. (a) HRD(1), (b) HRD(1), (c) HRD(3).

Table A–35

Core HRD(1)		
Sample identification	Mid-depth (centimeters)	Estimated deposition date
HRD(1) 0–5	2.5	1994.3
HRD(1) 5–10	7.5	1993.1
HRD(1) 10–15	12.5	1991.5
HRD(1) 15–20	17.5	1989.6
HRD(1) 20–25	22.5	1987.3
HRD(1) 25–30	27.5	1985.0
HRD(1) 30–35	32.5	1983.0
HRD(1) 35–40	37.5	1980.7
HRD(1) 40–45	42.5	1977.9
HRD(1) 45–50	47.5	1975.0
HRD(1) 50–55	52.5	1973.0
HRD(1) 55–60	57.5	1971.2
HRD(1) 60–65	62.5	1969.5
HRD(1) 65–70	67.5	1967.5
HRD(1) 70–75	72.5	1965.7
HRD(1) 75–80	77.5	1964.0
HRD(1) 80–85	82.5	1962.5
HRD(1) 85–90	87.5	1961.0
HRD(1) 90–95	92.5	1959.7
HRD(1) 95–100	97.5	1958.5
HRD(1) 100–105	102.5	1957.2
HRD(1) 105–110	107.5	1956.0
HRD(1) 110–115	112.5	1955.0
HRD(1) 115–120	117.5	1954.0
HRD(1) 120–125	122.5	1953.0
HRD(1) 125–130	127.5	1952.0
HRD(1) 130–135	132.5	1951.0
HRD(1) 135–140	137.5	1949.7
HRD(1) 140–145	142.5	1948.7
HRD(1) 145–150	147.5	1947.7
HRD(1) 150–155	152.5	1946.7
HRD(1) 155–160	157.5	1946.0
HRD(1) 160–165	162.5	1945.0
HRD(1) 165–170	167.5	1944.5
HRD(1) 170–175	172.5	1943.5
HRD(1) 175–180	177.5	1943.0
HRD(1) 180–185	182.5	1942.0
HRD(1) 185–190	187.5	1941.2
HRD(1) 190–195	192.5	1940.5
HRD(1) 195–200	197.5	1940.0
HRD(1) 200–205	202.5	1939.2
HRD(1) 205–210	207.5	1938.5
HRD(1) 210–215	212.5	1938.0
HRD(1) 215–220	217.5	1937.2
HRD(1) 220–225	222.5	1936.5

Core HRD(3)		
Sample identification	Mid-depth (centimeters)	Estimated deposition date
HRD(3) 0–8	4	1994.0
HRD(3) 32–40	36	1981.0
HRD(3) 64–72	68	1967.5
HRD(3) 96–104	100	1957.2
HRD(3) 128–136	132	1951.0
HRD(3) 136–144	140	1948.7
HRD(3) 168–172	172	1943.5
HRD(3) 200–208	204	1939.2
HRD(3) 232–240	236	1934.0

37. Lake Blackshear, Ga.

Lake Blackshear is a large reservoir, constructed in about 1930, on the Flint River in rural southern Georgia. Two gravity cores were collected for chemical analysis from the middle section of the reservoir, south of the U.S. Highway 280 bridge, in May 1994.

BLK(2) Gravity core 79 cm long analyzed for ^{137}Cs and major and trace elements.

Basis The ^{137}Cs activity peaks at 36 to 38 cm (fig. A–40a). The pre-reservoir surface in the core was at 74 cm. These date-depth markers, plus the sampling date of 1994, were used to compute MARs of 0.54 g/cm^2-yr for the 0- to 37-cm interval and 0.48 g/cm^2-yr for the 37- to 74-cm interval. Dates were assigned using these MARs.

Corroboration A rounded lead peak defined by several samples from 24 to 34 cm is reasonably dated as about 1966 to 1974. The first occurrence of ^{137}Cs is at 52 to 54 cm, which received a somewhat early date of 1949.3.

Rating Good.

BLK(1) Gravity core 46 cm long analyzed for organochlorine compounds.

Basis Dates were directly extrapolated by depth from core BLK(2) to this core.

Corroboration A large total DDT peak at 30 to 35 cm was assigned the reasonable date of 1967.3 (fig. A–40b).

Rating Good.

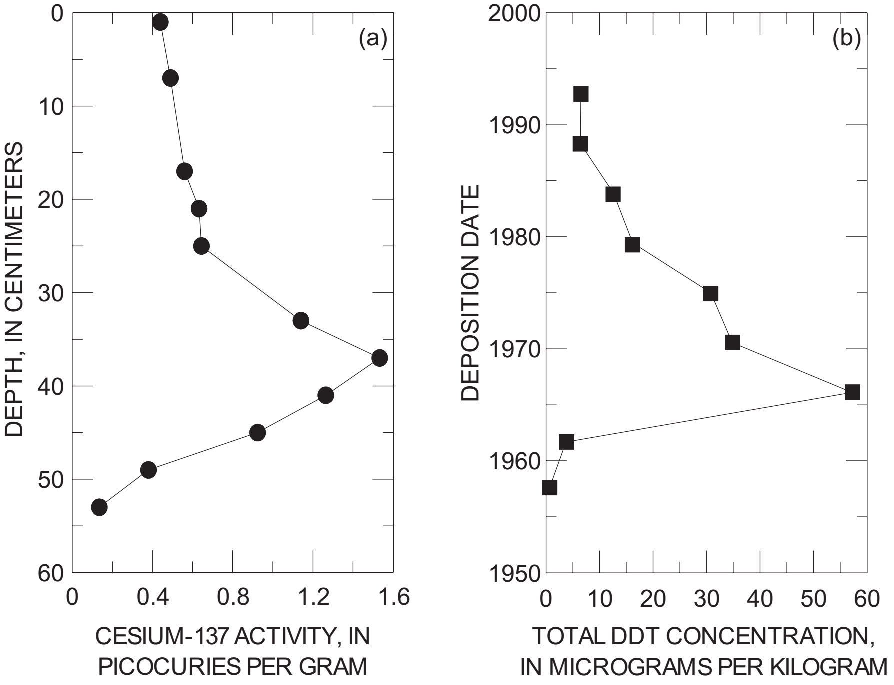


Figure A–40. Chemical constituent profiles used to estimate age dates for Lake Blackshear, Ga. (a) BLK(2), (b) BLK(1).

Table A–36

Core BLK(2)			Core BLK(2)		
Sample identification	Mid-depth (centimeters)	Estimated deposition date	Sample identification	Mid-depth (centimeters)	Estimated deposition date
BLK(2) 0–2	1	1993.6	BLK(2) 40–42	41	1960.3
BLK(2) 2–4	3	1991.9	BLK(2) 42–44	43	1958.5
BLK(2) 4–6	5	1990.3	BLK(2) 44–46	45	1956.6
BLK(2) 6–8	7	1988.6	BLK(2) 46–48	47	1954.8
BLK(2) 8–10	9	1987.0	BLK(2) 48–50	49	1953.0
BLK(2) 10–12	11	1985.4	BLK(2) 50–52	51	1951.1
BLK(2) 12–14	13	1983.7	BLK(2) 52–54	53	1949.3
BLK(2) 14–16	15	1982.1	BLK(2) 54–56	55	1947.5
BLK(2) 16–18	17	1980.4	BLK(2) 56–58	57	1945.6
BLK(2) 18–20	19	1978.8	BLK(2) 58–60	59	1943.8
BLK(2) 20–22	21	1977.1	BLK(2) 60–62	61	1941.9
BLK(2) 22–24	23	1975.5	BLK(2) 62–64	63	1940.1
BLK(2) 24–26	25	1973.9	BLK(2) 64–66	65	1938.3
BLK(2) 26–28	27	1972.2	BLK(2) 66–68	67	1936.4
BLK(2) 28–30	29	1970.6	BLK(2) 68–70	69	1934.6
BLK(2) 30–32	31	1968.9	BLK(2) 70–72	71	1932.8
BLK(2) 32–34	33	1967.3	BLK(2) 72–74	73	1930.9
BLK(2) 34–36	35	1965.6	BLK(2) 74–76	75	Pre-reservoir
BLK(2) 36–38	37	1964.0	BLK(2) 76–78	77	Pre-reservoir
BLK(2) 38–40	39	1962.2			

Core BLK(1)			Core BLK(1)		
Sample identification	Mid-depth (centimeters)	Estimated deposition date	Sample identification	Mid-depth (centimeters)	Estimated deposition date
BLK(1) 0–5	2.5	1991.9	BLK(1) 25–30	27.5	1972.2
BLK(1) 5–10	7.5	1988.6	BLK(1) 30–35	32.5	1967.3
BLK(1) 10–15	12.5	1983.7	BLK(1) 35–40	37.5	1964.0
BLK(1) 15–20	17.5	1980.4	BLK(1) 40–44	42	1958.5
BLK(1) 20–25	22.5	1975.5			

38. Lake Walter F. George, Ga./Ala.

Lake Walter F. George, also known as Lake Eufaula in Alabama, is a large reservoir constructed in 1962 on the Chattahoochee River on the Georgia/Alabama border. The reservoir is downstream from Lake Harding and upstream from Lake Seminole, which also were sampled for the RTNS study. Two gravity cores were collected for chemical analysis from the channel near the eastern shore in the upper end of the reservoir in May 1994.

WFG.98(3) Gravity core 156 cm long analyzed for ^{137}Cs and major and trace elements.

Basis The core penetrated the pre-reservoir surface at 152 cm. A MAR of 2.40 g/cm^2-yr was computed using the pre-reservoir surface and sampling date. Dates were assigned on the basis of this MAR.

Corroboration The maximum ^{137}Cs activity is in the deepest lacustrine sample, 148 to 152 cm (fig. A–41a), and received a reasonable date of 1964.0. Lead has a modest peak between about 1968 and 1972 in the core, also reasonable.

Rating Good.

WFG.98(1) Gravity core 154 cm long analyzed for organochlorine compounds.

Basis The core penetrated the pre-reservoir surface at 131 cm, indicating a slightly lower sedimentation rate than the nearby core WFG.98(3). The cumulative mass and date relation developed for core WFG.98(3) was adjusted for the difference in sediment thickness and applied to this core.

Corroboration Total DDT and PCBs peak at the reasonable date of about 1970 (fig. A–41b).

Rating Good.

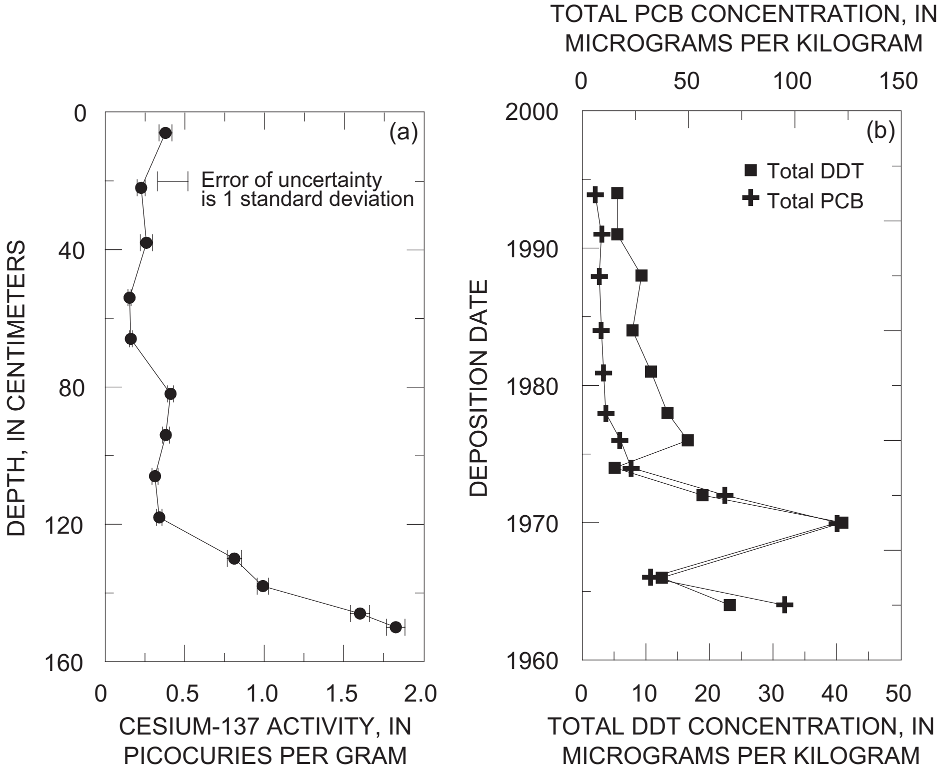


Figure A–41. Chemical constituent profiles used to estimate age dates for Lake Walter F. George, Ga./Ala. (a) WFG.98(3), (b) WFG.98(1).

Table A–37

Core WFG.98(3)		
Sample identification	Mid-depth (centimeters)	Estimated deposition date
WFG.98(3) 0–4	2	1994.2
WFG.98(3) 4–8	6	1993.7
WFG.98(3) 8–12	10	1993.1
WFG.98(3) 12–16	14	1992.6
WFG.98(3) 16–20	18	1992.0
WFG.98(3) 20–24	22	1991.3
WFG.98(3) 24–28	26	1990.7
WFG.98(3) 28–32	30	1990.1
WFG.98(3) 32–36	34	1989.4
WFG.98(3) 36–40	38	1988.8
WFG.98(3) 40–44	42	1988.1
WFG.98(3) 44–48	46	1987.4
WFG.98(3) 48–52	50	1986.7
WFG.98(3) 52–56	54	1985.9
WFG.98(3) 56–60	58	1985.2
WFG.98(3) 60–64	62	1984.4
WFG.98(3) 64–68	66	1983.6
WFG.98(3) 68–72	70	1982.7
WFG.98(3) 72–76	74	1981.8
WFG.98(3) 76–80	78	1981.0
WFG.98(3) 80–84	82	1980.2
WFG.98(3) 84–88	86	1979.6
WFG.98(3) 88–92	90	1978.9
WFG.98(3) 92–96	94	1978.0
WFG.98(3) 96–100	98	1977.1
WFG.98(3) 100–104	102	1976.2
WFG.98(3) 104–108	106	1975.2
WFG.98(3) 108–112	110	1974.2
WFG.98(3) 112–116	114	1973.2
WFG.98(3) 116–120	118	1972.1
WFG.98(3) 120–124	122	1971.1
WFG.98(3) 124–128	126	1970.2
WFG.98(3) 128–132	130	1969.2
WFG.98(3) 132–136	134	1968.2
WFG.98(3) 136–140	138	1967.2
WFG.98(3) 140–144	142	1966.2
WFG.98(3) 144–148	146	1965.2
WFG.98(3) 148–152	150	1964.0
WFG.98(3) 152–156	154	Pre-reservoir

Core WFG.98(1)		
Sample identification	Mid-depth (centimeters)	Estimated deposition date
WFG.98(1) 0–7	3.5	1993.9
WFG.98(1) 14–21	17.5	1991.6
WFG.98(1) 35–42	38.5	1987.6
WFG.98(1) 49–56	52.5	1984.5
WFG.98(1) 63–70	66.5	1981.2
WFG.98(1) 77–84	80.5	1978.2
WFG.98(1) 84–91	87.5	1976.2
WFG.98(1) 91–98	94.5	1974.3
WFG.98(1) 98–105	101.5	1972.2
WFG.98(1) 105–112	108.5	1970.2
WFG.98(1) 117–124	120.5	1966.8
WFG.98(1) 124–131	127.5	1964.6

39. Lake Seminole, Ga./Fla.

Lake Seminole is a large reservoir constructed in 1954 on the Chattahoochee River along the border between Georgia and Florida. The reservoir is downstream from Lake Walter F. George, which also was sampled for the RTNS study. Lake Seminole was sampled in May 1994 and September 1994. Three gravity cores were collected for chemical analysis near the north shore of the east arm of the reservoir.

May 1994 Sampling

SEM.3.0(3) Gravity core 130 cm long analyzed for ^{137}Cs and major and trace elements.

Basis The peak ^{137}Cs activity is at 68 to 70 cm (fig. A–42a) and the core penetrated the pre-reservoir surface at 98 cm (41.31 g/cm^2 cumulative mass). These date markers yielded MARs of 1.39 and 0.93 g/cm^2-yr for 1954.0–1964.0 and 1964.0–1994.5, respectively. The decrease in MAR over time was assumed to follow an exponential decrease and was modeled as such (Callender and Robbins, 1993). The model was calibrated (k = 0.0173) using the mass accumulated during 1954.0–1964.0 and 1964.0–1994.5. The modeled MAR decreases over time from about 1.4 g/cm^2-yr at the bottom of the core (96- to 98-cm interval) to 0.7 g/cm^2-yr at the top (0- to 102-cm interval). The model was used to develop a cumulative mass-date relation that was used to assign dates to the core.

Corroboration None. Trace element concentrations do not have pronounced enough trends to provide corroboration.

Rating Good.

SEM.3.0(2) Gravity core 129 cm long analyzed for organochlorine compounds.

Basis The core penetrated the pre-reservoir surface at 87 cm, and cumulative mass to the pre-reservoir surface was 36.6 g/cm^2, indicating a slightly lower sedimentation rate than the nearby core SEM.3.0(3). Dates were assigned using the cumulative mass-date relation developed for SEM.3.0(3), adjusted to the ratio of cumulative mass of sediment to the pre-reservoir surface in the two cores.

Corroboration Total DDT has a broad peak from about 1956 to 1962, consistent with historical agricultural use (fig. A–42b).

Rating Good.

September 1994 Sampling

SEM.3.0(2) Gravity core 112 cm long analyzed for major and trace elements, collected at same site as cores collected in May.

Basis The gravity core penetrated the pre-reservoir surface at 94 cm, compared with 98 and 87 cm, in the May cores. Depth-date relations developed for SEM.3.0(3) from the May sampling were adjusted slightly by the ratio of lacustrine sediment thicknesses (94:98) and used to assign dates to this core.

Corroboration None. Trace element concentrations do not have pronounced enough trends to provide corroboration.

Rating Fair, because of lack of radionuclide analyses and no corroboration.

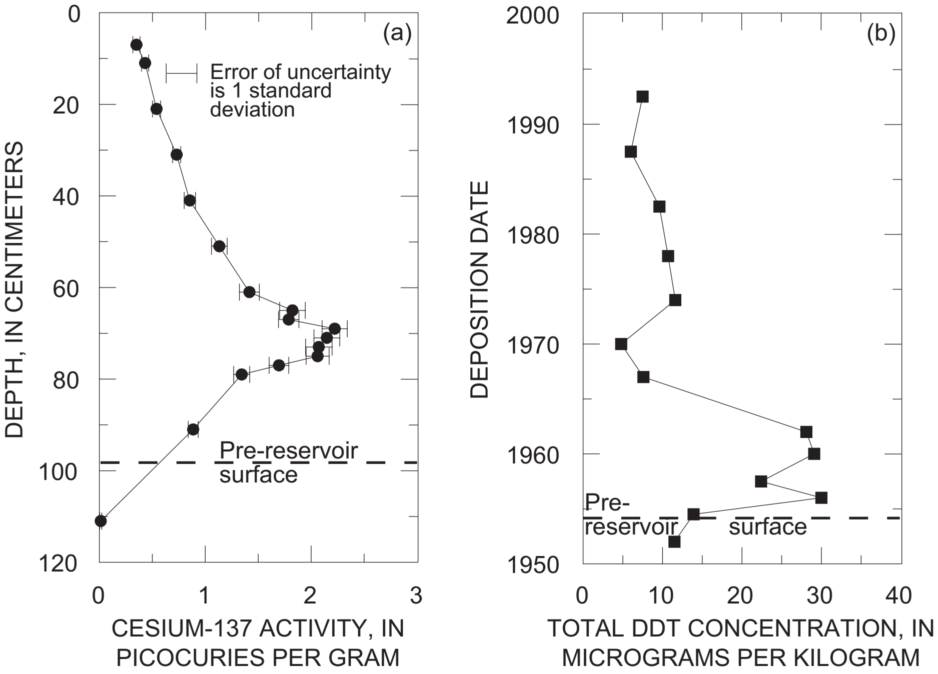


Figure A–42. Chemical constituent profiles used to estimate age dates for Lake Seminole, Ga./Fla. (a) SEM.3.0(3), (b) SEM.3.0(2).

Table A–38

Core SEM.3.0(3) – May 1994		
Sample identification	Mid-depth (centimeters)	Estimated deposition date
SEM.3.0(3) 0–2	1	1994.2
SEM.3.0(3) 2–4	3	1993.8
SEM.3.0(3) 4–6	5	1993.0
SEM.3.0(3) 6–8	7	1992.5
SEM.3.0(3) 8–10	9	1991.5
SEM.3.0(3) 10–12	11	1990.7
SEM.3.0(3) 12–14	13	1989.8
SEM.3.0(3) 14–16	15	1988.7
SEM.3.0(3) 16–18	17	1987.7
SEM.3.0(3) 18–20	19	1986.7
SEM.3.0(3) 20–22	21	1985.7
SEM.3.0(3) 22–24	23	1984.8
SEM.3.0(3) 24–26	25	1984.0
SEM.3.0(3) 26–28	27	1983.0
SEM.3.0(3) 28–30	29	1982.0
SEM.3.0(3) 30–32	31	1981.0
SEM.3.0(3) 32–34	33	1980.0
SEM.3.0(3) 34–36	35	1979.0
SEM.3.0(3) 36–38	37	1978.2
SEM.3.0(3) 38–40	39	1977.2
SEM.3.0(3) 40–42	41	1976.2
SEM.3.0(3) 42–44	43	1975.5
SEM.3.0(3) 44–46	45	1974.5
SEM.3.0(3) 46–48	47	1973.5
SEM.3.0(3) 48–50	49	1972.5
SEM.3.0(3) 50–52	51	1971.7
SEM.3.0(3) 52–54	53	1970.7
SEM.3.0(3) 54–56	55	1970.0
SEM.3.0(3) 56–58	57	1969.0
SEM.3.0(3) 58–60	59	1968.0
SEM.3.0(3) 60–62	61	1967.0
SEM.3.0(3) 62–64	63	1966.5
SEM.3.0(3) 64–66	65	1965.5
SEM.3.0(3) 66–68	67	1964.7
SEM.3.0(3) 68–70	69	1964.0
SEM.3.0(3) 70–72	71	1963.0
SEM.3.0(3) 72–74	73	1962.2
SEM.3.0(3) 74–76	75	1961.5
SEM.3.0(3) 76–78	77	1960.7
SEM.3.0(3) 78–80	79	1960.0
SEM.3.0(3) 80–82	81	1959.2
SEM.3.0(3) 82–84	83	1958.5
SEM.3.0(3) 84–86	85	1957.5
SEM.3.0(3) 86–88	87	1957.0
SEM.3.0(3) 88–90	89	1956.0
SEM.3.0(3) 90–92	91	1955.5
SEM.3.0(3) 92–94	93	1954.8
SEM.3.0(3) 94–96	95	1954.3
SEM.3.0(3) 96–98	97	1954.0
SEM.3.0(3) 98–100	99	Pre-reservoir
SEM.3.0(3) 100–102	101	Pre-reservoir
SEM.3.0(3) 102–104	103	Pre-reservoir
SEM.3.0(3) 104–106	105	Pre-reservoir
SEM.3.0(3) 106–108	107	Pre-reservoir
SEM.3.0(3) 108–110	109	Pre-reservoir
SEM.3.0(3) 110–112	111	Pre-reservoir
SEM.3.0(3) 112–114	113	Pre-reservoir
SEM.3.0(3) 114–116	115	Pre-reservoir
SEM.3.0(3) 116–118	117	Pre-reservoir
SEM.3.0(3) 118–120	119	Pre-reservoir
SEM.3.0(3) 120–122	121	Pre-reservoir
SEM.3.0(3) 122–124	123	Pre-reservoir
SEM.3.0(3) 124–126	125	Pre-reservoir
SEM.3.0(3) 126–128	127	Pre-reservoir
SEM.3.0(3) 128–130	129	Pre-reservoir

Table A–38 (Continued)

Core SEM.3.0(2) – May 1994			Core SEM.3.0(2) – May 1994		
Sample identification	Mid-depth (centimeters)	Estimated deposition date	Sample identification	Mid-depth (centimeters)	Estimated deposition date
SEM.3.0(2) 0–7	3.5	1992.5	SEM.3.0(2) 54–60	57	1964.5
SEM.3.0(2) 7–16	11.5	1987.5	SEM.3.0(2) 60–66	63	1962.0
SEM.3.0(2) 16–24	20	1982.5	SEM.3.0(2) 66–72	69	1960.0
SEM.3.0(2) 24–32	28	1978.0	SEM.3.0(2) 72–77	74.5	1957.5
SEM.3.0(2) 32–40	26	1974.0	SEM.3.0(2) 77–82	79.5	1956.0
SEM.3.0(2) 40–48	44	1970.0	SEM.3.0(2) 82–87	84.5	1954.5
SEM.3.0(2) 48–54	51	1967.0	SEM.3.0(2) 87–93	90	Pre-reservoir

Core SEM.3.0(2) – September 1994			Core SEM.3.0(2) – September 1994		
Sample identification	Mid-depth (centimeters)	Estimated deposition date	Sample identification	Mid-depth (centimeters)	Estimated deposition date
SEM.3.0(2) 6–8	7	1992.5	SEM.3.0(2) 54–56	55	1969.0
SEM.3.0(2) 12–14	13	1989.8	SEM.3.0(2) 62–64	63	1965.5
SEM.3.0(2) 18–20	19	1986.7	SEM.3.0(2) 78–80	79	1959.2
SEM.3.0(2) 24–26	25	1983.0	SEM.3.0(2) 86–88	87	1955.5
SEM.3.0(2) 30–32	31	1980.0	SEM.3.0(2) 94–96	95	Pre-reservoir
SEM.3.0(2) 36–38	37	1977.2	SEM.3.0(2) 1006	101	Pre-reservoir
SEM.3.0(2) 42–44	43	1974.5	SEM.3.0(2) 145–150	147.5	Pre-reservoir
SEM.3.0(2) 48–50	49	1971.7			

40. Sand Lake, Fla.

Sand Lake is a small lake formed in an abandoned sand quarry in Wekiwa Springs State Park located northwest of Orlando, Fla. The reservoir is not officially named, but is referred to as Sand Lake by the Florida Park Service. One box core was collected for chemical analysis from the center of the lake in March 1999.

SND Box core 47 cm deep analyzed for all constituents.

Basis The ^{137}Cs peak at 34 to 35.5 cm (fig. A–43a) was assigned a date of 1964.0 resulting in a MAR of 0.07 g/cm^2-yr. This MAR was used to assign dates.

Corroboration A zone of large lead concentrations occurs at about 36 to 22 cm in the core. This zone was dated as about 1960 to 1984 (fig. A–43b), consistent with elevated lead from gasoline use and the undeveloped nature of the Sand Lake watershed. Total DDT peaks at 31 to 34 cm received a reasonable date of 1969.4 (fig. A–43b). The total DDT concentration in the next deeper interval analyzed, 37 to 40 cm, was about one-half that of the peak concentration and was dated as 1949.5.

Rating Good.

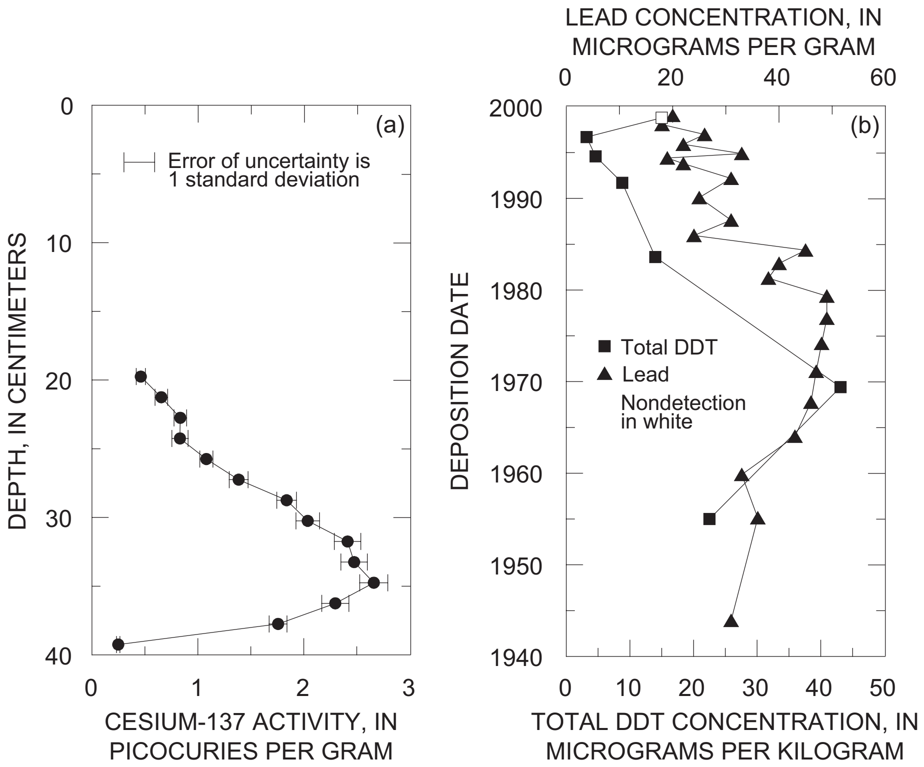


Figure A–43. Chemical constituent profiles used to estimate age dates for Sand Lake, Fla.

Table A–39

Core SND				Core SND		
Sample identification	Mid-depth (centimeters)	Estimated deposition date		Sample identification	Mid-depth (centimeters)	Estimated deposition date
SND 0–1	0.5	1999.0		SND 17.5–19	18.25	1988.9
SND 1–2	1.5	1998.6		SND 19–20.5	19.75	1987.6
SND 2–3	2.5	1998.0		SND 20.5–22	21.25	1985.9
SND 3–4	3.5	1997.5		SND 22–23.5	22.75	1984.3
SND 4–5	4.5	1996.9		SND 23.5–25	24.25	1982.9
SND 5–6	5.5	1996.4		SND 25–26.5	25.75	1981.3
SND 6–7	6.5	1995.9		SND 26.5–28	27.25	1979.3
SND 7–8	7.5	1995.4		SND 28–29.5	28.75	1976.9
SND 8–9	8.5	1994.9		SND 29.5–31	30.25	1974.1
SND 9–10	9.5	1994.4		SND 31–32.5	31.75	1971.1
SND 10–11.5	10.75	1993.8		SND 32.5–34	33.25	1967.7
SND 11.5–13	12.25	1993.0		SND 34–35.5	34.75	1964.0
SND 13–14.5	13.75	1992.2		SND 35.5–37	36.25	1959.8
SND 14.5–16	15.25	1991.2		SND 37–38.5	37.75	1955.1
SND 16–17.5	16.75	1990.1		SND 38.5–40	39.25	1943.9

41. Lake Orlando, Fla.

Lake Orlando, also known as Lake Wekiwa, is a natural lake located northwest of Orlando, Fla., between the suburban areas of Pine Hills and Lockhart, Fla. One box core was collected for chemical analysis from the southern area of the lake in March 1999.

ORL One box core 47 cm deep analyzed for all constituents.

Basis ^{137}Cs increases to the bottom of this core and does not show a peak, indicating that the core does not penetrate to 1964. Lead normalized to iron shows a small peak at 28 to 30 cm but is not conclusive, and organochlorine compounds, similar to ^{137}Cs, increase to the bottom of the core and do not have a peak. Lake Killarney, located about 5 km to the southeast, has a good rating for age-dating on the basis of a clear ^{137}Cs profile and was cored at the same time as Lake Orlando (core KIL; see 42. Lake Killarney, Fla.). ^{137}Cs in core KIL is about double that in ORL (fig. A–44a). Assuming that ^{137}Cs fallout and watershed effects are similar, these concentrations suggest that the MAR for KIL is about one-half the MAR for ORL. The MAR for ORL therefore was adjusted to arrive at a similar ^{137}Cs MAR in relation to time profile for these two lakes (fig. A–44b). The resulting MAR of 0.18 g/cm^2-yr is double the MAR of 0.091 g/cm^2-yr determined for KIL. Dates were assigned using this MAR.

Corroboration There are two pieces of corroborating evidence for dates assigned by this relatively novel approach: the iron normalized lead peak and a comparison of mercury MARs. The small normalized lead peak received a reasonable date of 1981.4 (fig. A–44c). Mercury, similar to ^{137}Cs, is delivered to lakes mostly by atmospheric fallout on the lake and its watershed. Assuming delivery of mercury fallout on these two watersheds is similar, mercury concentrations in ORL should be smaller and mercury MARs, similar to ^{137}Cs MARs, should be comparable for these two lakes. Mercury MARs are similar (fig. A–44d) and provide some independent support for the age-dating approach.

Rating Poor. Although corroborated, this novel dating approach relies on a questionable assumption of similar watershed transport processes and no single definitive date marker.

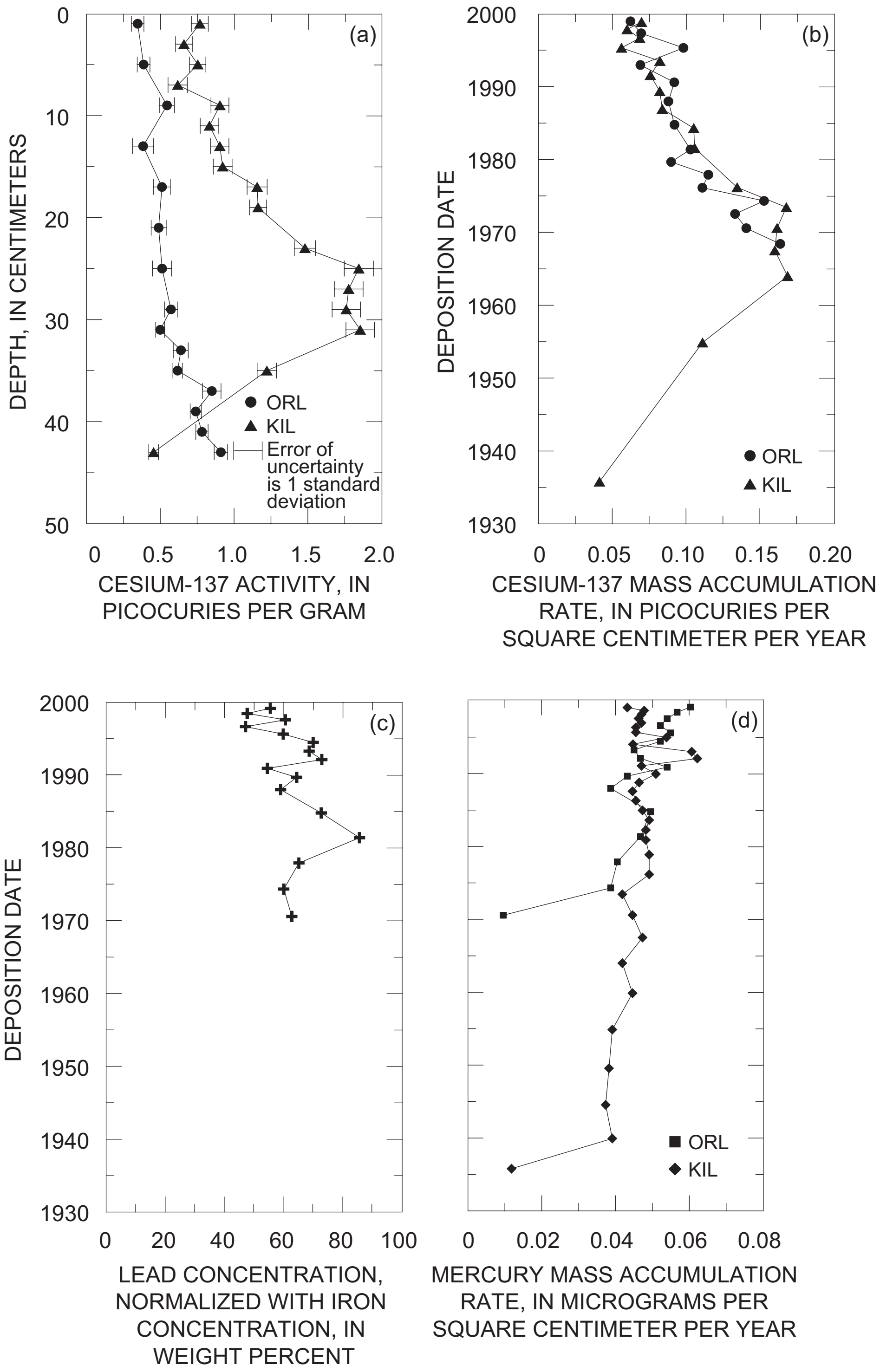


Figure A–44. Chemical constituent profiles used to estimate age dates for Lake Orlando, Fla.

Table A–40

Core ORL			Core ORL		
Sample identification	Mid-depth (centimeters)	Estimated deposition date	Sample identification	Mid-depth (centimeters)	Estimated deposition date
ORL 0–1	0.5	1999.1	ORL 16–17	16.5	1990.9
ORL 1–2	1.5	1998.8	ORL 17–18	17.5	1990.3
ORL 2–3	2.5	1998.4	ORL 18–19	18.5	1989.7
ORL 3–4	3.5	1998.0	ORL 19–20	19.5	1989.0
ORL 4–5	4.5	1997.5	ORL 20–22	21	1988.0
ORL 5–6	5.5	1997.1	ORL 22–24	23	1986.5
ORL 6–7	6.5	1996.6	ORL 24–26	25	1984.8
ORL 7–8	7.5	1996.1	ORL 26–28	27	1983.0
ORL 8–9	8.5	1995.6	ORL 28–30	29	1981.4
ORL 9–10	9.5	1995.0	ORL 30–32	31	1979.7
ORL 10–11	10.5	1994.4	ORL 32–34	33	1977.9
ORL 11–12	11.5	1993.8	ORL 34–36	35	1976.1
ORL 12–13	12.5	1993.2	ORL 36–38	37	1974.3
ORL 13–14	13.5	1992.7	ORL 38–40	39	1972.5
ORL 14–15	14.5	1992.1	ORL 40–42	41	1970.6
ORL 15–16	15.5	1991.5	ORL 42–44	43	1968.4

42. Lake Killarney, Fla.

Lake Killarney is a natural lake located adjacent to IH–4 in north-central Orlando, Fla. One box core was collected for chemical analysis from the center of the eastern lobe of the lake in March 1999.

KIL One box core 45 cm deep analyzed for all constituents.

Basis The ^{137}Cs profile has a zone of large concentrations at 24 to 32 cm, with peaks at 25 and 31 cm (fig. A–45a). The 31-cm interval was dated as 1964.0 because it resulted in better corroboration of dates by other constituents. The resulting MAR of 0.091 g/cm^2-yr was used to assign dates.

Corroboration First detections of DDD, DDE, and PCBs at 38 to 40 cm were assigned the reasonable date of 1944.6. The largest concentrations of organic carbon normalized total DDT and PCBs, both at 32 to 34 cm, received the reasonable date of 1959.9 (fig. A–45b). A broad peak in lead concentrations was dated from 1967.5 to 1973.4, which also is reasonable (fig. A–45b).

Rating Good. Although the ^{137}Cs profile is not ideal, dates assigned by it are corroborated by several other markers.

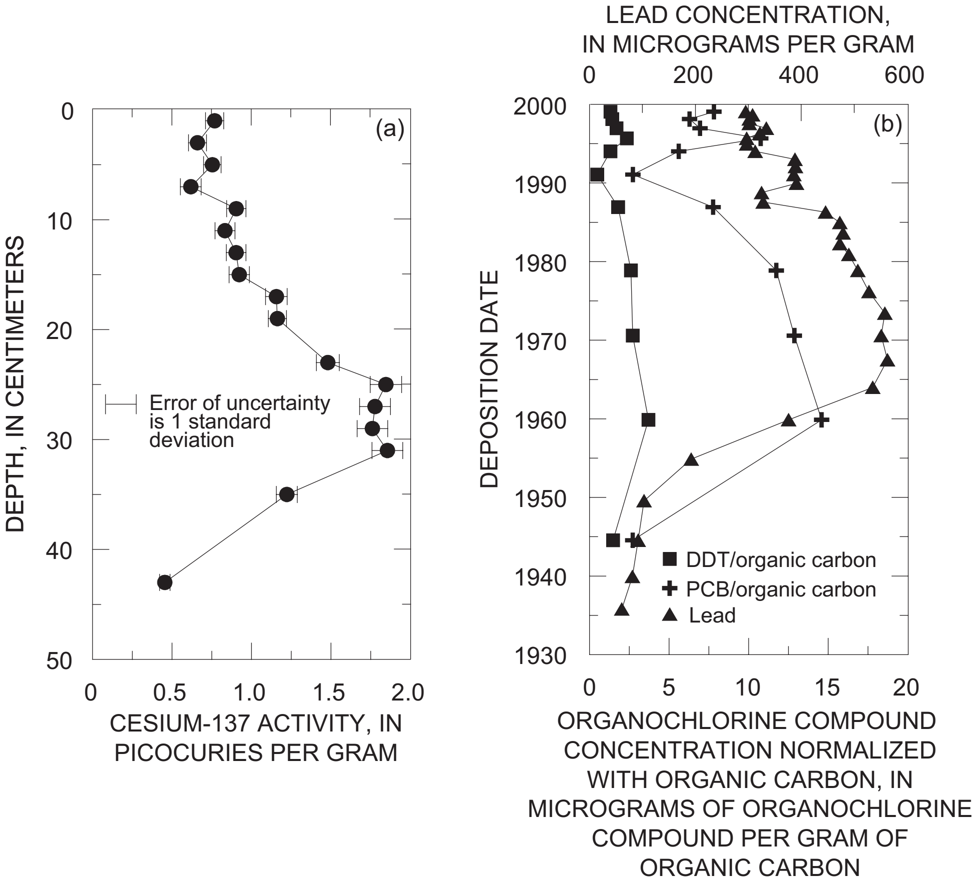


Figure A–45. Chemical constituent profiles used to estimate age dates for Lake Killarney, Fla.

Table A–41

Core KIL			Core KIL		
Sample identification	Mid-depth (centimeters)	Estimated deposition date	Sample identification	Mid-depth (centimeters)	Estimated deposition date
KIL 0–1	0.5	1999.1	KIL 16–17	16.5	1985.0
KIL 1–2	1.5	1998.7	KIL 17–18	17.5	1983.6
KIL 2–3	2.5	1998.1	KIL 18–19	18.5	1982.3
KIL 3–4	3.5	1997.6	KIL 19–20	19.5	1980.9
KIL 4–5	4.5	1997.0	KIL 20–22	21	1978.9
KIL 5–6	5.5	1996.3	KIL 22–24	23	1976.2
KIL 6–7	6.5	1995.7	KIL 24–26	25	1973.4
KIL 7–8	7.5	1995.0	KIL 26–28	27	1970.6
KIL 8–9	8.5	1994.0	KIL 28–30	29	1967.5
KIL 9–10	9.5	1993.0	KIL 30–32	31	1964.0
KIL 10–11	10.5	1992.1	KIL 32–34	33	1959.9
KIL 11–12	11.5	1991.1	KIL 34–36	35	1954.9
KIL 12–13	12.5	1990.0	KIL 36–38	37	1949.6
KIL 13–14	13.5	1988.8	KIL 38–40	39	1944.6
KIL 14–15	14.5	1987.6	KIL 40–42	41	1939.9
KIL 15–16	15.5	1986.3	KIL 42–44	43	1935.8

43. Lake Anne, Va.

Lake Anne is a small reservoir, constructed in 1962, in Reston, Va. Reston is an affluent suburban area west of Washington D.C. Lake Anne drains into another small reservoir, Fairfax Lake, which also was sampled for the RTNS study. Two locations were sampled in Lake Anne in June 1996, one gravity core (ANB.1) from a location near the lower end of the reservoir and two box cores (designated ANN.1 and ANN.2) from a location slightly up the reservoir from ANB.1. A box core designated AN97 was collected during a second sampling trip in September 1997 at the ANB.1 location.

June 1996 Sampling

Location ANB

ANB.1 Gravity core 27 cm long analyzed for ^{137}Cs and major and trace elements.

Basis The pre-reservoir surface is at 20 cm. There is a well defined lead peak at 8.5 cm and ^{137}Cs peak at 18.5 cm (fig. A–46a, b). A constant MAR of 0.28 g/cm^2-yr computed using the pre-reservoir surface puts the lead peak at the unreasonable date of 1988. Using the lead peak as a date marker of 1978.0 yields an average MAR of 0.13 g/cm^2-yr for 0 to 8.5 cm and 0.46 g/cm^2-yr for 8.5 to 20 cm. The relatively late lead concentration peak of 1978.0 was chosen because, with the increasing MAR deeper in the core, the peak in lead mass accumulation is placed at about 1970; thus, both the maximum lead mass accumulation and concentration are in the 1970s. Extensive construction around the lake in the 1960s and early 1970s supports the assumption of high sedimentation rates prior to the lead peak. Varves (dark and light layers sometimes visible in sediment cores that result from seasonal changes in water chemistry) were present in the upper 14 cm of the AN97 core and could indicate that a constant sedimentation rate from the mid-1970s to the present, including the interval containing the lead peak, was reasonable. The resulting MAR for ANB.1 gradually decreases from 0.9 g/cm^2-yr for 1962.7 to the lead peak in 1978.0 and remains constant at 0.13 g/cm^2-yr from the lead peak to the top of the core (fig. A–46c).

Corroboration The ^{137}Cs peak is at 18.5 cm and received a reasonable date of 1963.6.

Rating Good. Although the large change in sedimentation rate causes some uncertainty, there is confidence in the date-depth markers, and the sharp peaks in lead and other constituents indicate a relatively undisturbed core.

Location ANN

ANN.2 Box core 19 cm deep analyzed for major and trace elements.

Basis A well defined lead peak is at 8.25 cm, similar to the lead peak in ANB.1 (fig. A–46a), and it was assumed that the pre-reservoir surface, marking 1962, was immediately below the bottom of the core. This assumption is on the basis of the length of ANN.2 relative to an adjacent gravity core and on the characteristics of the samples. It is likely that penetration of the box corer was stopped by the firmer pre-reservoir material. MARs were adjusted similarly to ANB.1 to put the lead concentration peak at 1978.0. The MAR for the upper part of the core was 0.14 g/cm^2-yr increasing to 0.36 g/cm^2-yr in the lower part of the core (fig. A–46c).

Corroboration None in this core, however, a similar date-depth relation applied to the adjacent core ANN.1 resulted in reasonable total DDT and ^{137}Cs profiles.

Rating Good.

ANN.1 Box core 18 cm deep analyzed for organic compounds and ^{137}Cs (six samples only).

Basis Sediment thickness and cumulative mass in box core were similar to, but slightly less than, those in the adjacent box core, ANN.2; therefore, a similar but slightly smaller MAR profile was applied to this core (fig. A–46c).

Corroboration Assigned dates result in the samples with the largest total DDT and ^{137}Cs concentrations receiving reasonable dates of 1965.4 and 1964.0, respectively (fig. A–46b).

Rating Good.

September 1997 Sampling

Location ANB

AN97 Box core 20.5 cm deep analyzed for major and trace elements.

Basis This box core did not penetrate the pre-reservoir surface but thickness relative to an adjacent gravity core indicates it extends to just above the pre-reservoir surface. There is a well defined lead peak at 12.5 to 14.5 cm (fig. A–46a). The broad lead mass-accumulation peak was assumed to be centered in the 1970s and the pre-reservoir surface, marking 1962, immediately below the bottom of the core. A decreasing MAR was applied that resulted in gradually decreasing MARs from 0.22 to 0.17 g/cm^2-yr from the bottom of the core to the top (fig. A–46c).

Corroboration None in this core.

Rating Fair. Lack of corroboration and differences in trace element profiles for the 1996 cores causes some uncertainty in dates assigned to this core.

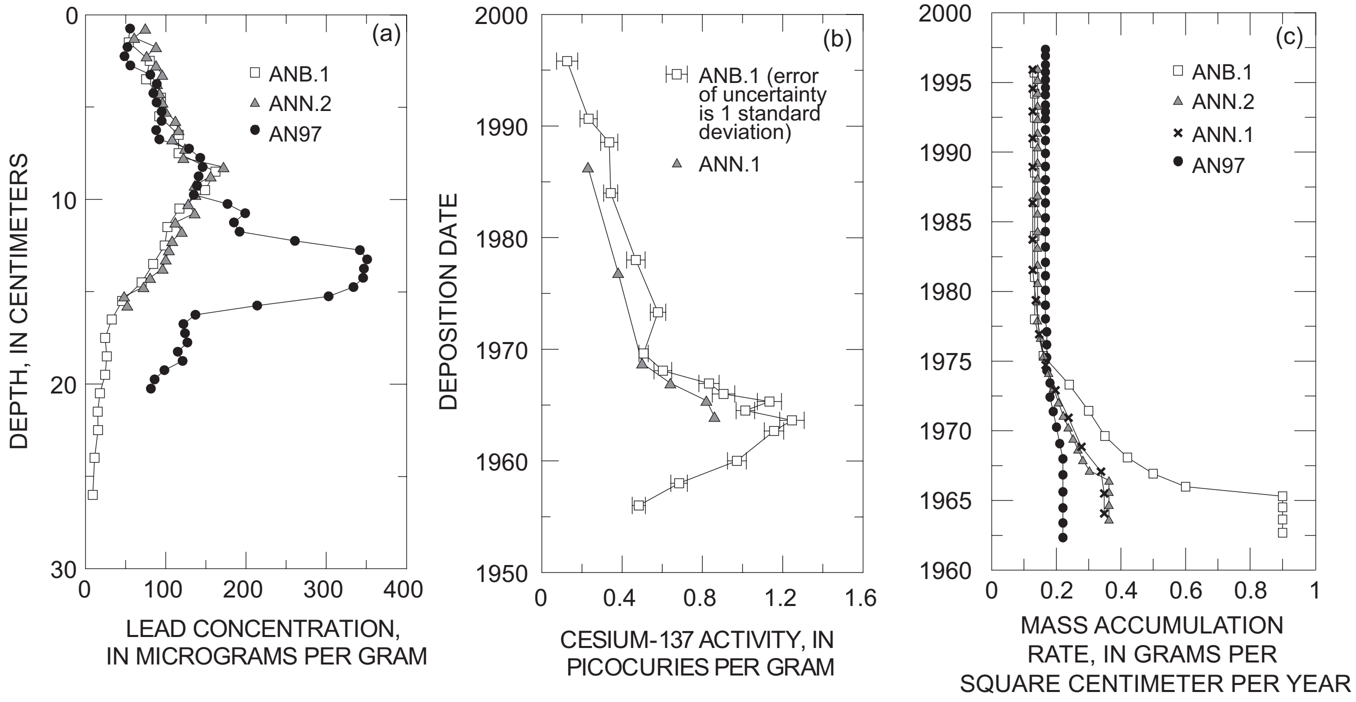


Figure A–46. Chemical constituent profiles used to estimate age dates and comparison of mass accumulation rates in cores collected from Lake Anne, Va. (a) ANB.1, ANN.2, AN97, (b) ANB.1, ANN.1, (c) ANB.1, ANN.2, ANN.1, AN97.

Table A–42

Core ANB.1			Core ANB.1		
Sample identification	Mid-depth (centimeters)	Estimated deposition date	Sample identification	Mid-depth (centimeters)	Estimated deposition date
ANB.1 0–1	0.5	1995.8	ANB.1 13–14	13.5	1968.1
ANB.1 1–2	1.5	1994.2	ANB.1 14–15	14.5	1966.9
ANB.1 2–3	2.5	1992.5	ANB.1 15–16	15.5	1966.0
ANB.1 3–4	3.5	1990.6	ANB.1 16–17	16.5	1965.3
ANB.1 4–5	4.5	1988.5	ANB.1 17–18	17.5	1964.5
ANB.1 5–6	5.5	1986.4	ANB.1 18–19	18.5	1963.6
ANB.1 6–7	6.5	1984.0	ANB.1 19–20	19.5	1962.7
ANB.1 7–8	7.5	1981.0	ANB.1 20–21	20.5	Pre-reservoir
ANB.1 8–9	8.5	1978.0	ANB.1 21–22	21.5	Pre-reservoir
ANB.1 9–10	9.5	1975.4	ANB.1 22–23	22.5	Pre-reservoir
ANB.1 10–11	10.5	1973.3	ANB.1 23–25	24.0	Pre-reservoir
ANB.1 11–12	11.5	1971.4	ANB.1 25–27	26.0	Pre-reservoir
ANB.1 12–13	12.5	1969.6			

Core ANN.2			Core ANN.2		
Sample identification	Mid-depth (centimeters)	Estimated deposition date	Sample identification	Mid-depth (centimeters)	Estimated deposition date
ANN.2 0–0.5	0.25	1996.1	ANN.2 8–8.5	8.25	1978.0
ANN.2 0.5–1	.75	1995.3	ANN.2 8.5–9	8.75	1976.8
ANN.2 1–1.5	1.25	1994.4	ANN.2 9–9.5	9.25	1975.5
ANN.2 1.5–2	1.75	1993.4	ANN.2 9.5–10	9.75	1974.2
ANN.2 2–2.5	2.25	1992.5	ANN.2 10–10.5	10.25	1973.1
ANN.2 2.5–3	2.75	1991.5	ANN.2 10.5–11	10.75	1972.1
ANN.2 3–3.5	3.25	1990.5	ANN.2 11–11.5	11.25	1971.1
ANN.2 3.5–4	3.75	1989.4	ANN.2 11.5–12	11.75	1970.3
ANN.2 4–4.5	4.25	1988.2	ANN.2 12–12.5	12.25	1969.5
ANN.2 4.5–5	4.75	1987.0	ANN.2 12.5–13	12.75	1968.7
ANN.2 5–5.5	5.25	1985.7	ANN.2 13–13.5	13.25	1967.9
ANN.2 5.5–6	5.75	1984.4	ANN.2 13.5–14	13.75	1967.2
ANN.2 6–6.5	6.25	1983.2	ANN.2 14–14.5	14.25	1966.5
ANN.2 6.5–7	6.75	1982.0	ANN.2 14.5–15	14.75	1965.7
ANN.2 7–7.5	7.25	1980.7	ANN.2 15–15.5	15.25	1964.7
ANN.2 7.5–8	7.75	1979.4	ANN.2 15.5–16	15.75	1963.7

Table A–42 (Continued)

Core ANN.1		
Sample identification	Mid-depth (centimeters)	Estimated deposition date
ANN.1 0–1	0.5	1995.9
ANN.1 1–2	1.5	1994.5
ANN.1 2–3	2.5	1992.9
ANN.1 3–4	3.5	1991.0
ANN.1 4–5	4.5	1988.9
ANN.1 5–6	5.5	1986.3
ANN.1 6–7	6.5	1983.7
ANN.1 7–8	7.5	1981.5
ANN.1 8–9	8.5	1979.3
ANN.1 9–10	9.5	1976.9
ANN.1 10–11	10.5	1974.6
ANN.1 11–12	11.5	1972.8
ANN.1 12–13	12.5	1970.8
ANN.1 13–14	13.5	1968.8
ANN.1 14–15	14.5	1967.0
ANN.1 15–16	15.5	1965.4
ANN.1 16–17	16.5	1964.0

Core AN97		
Sample identification	Mid-depth (centimeters)	Estimated deposition date
AN97 0–0.5	0.25	1997.4
AN97 0.5–1	.75	1996.9
AN97 1.5–2	1.75	1996.3
AN97 2–2.5	2.25	1995.7
AN97 2.5–3	2.75	1995.2
AN97 3–3.5	3.25	1994.6
AN97 3.5–4	3.75	1994.1
AN97 4–4.5	4.25	1993.4
AN97 4.5–5	4.75	1992.9
AN97 5–5.5	5.25	1992.4
AN97 5.5–6	5.75	1991.6
AN97 6–6.5	6.25	1990.8
AN97 6.5–7	6.75	1989.9
AN97 7–7.5	7.25	1989.0
AN97 7.5–8	7.75	1988.0
AN97 8–8.5	8.25	1987.2
AN97 8.5–9	8.75	1986.3
AN97 9–9.5	9.25	1985.3
AN97 9.5–10	9.75	1984.3
AN97 10–10.5	10.25	1983.2
AN97 10.5–11	10.75	1982.1
AN97 11–11.5	11.25	1981.1
AN97 11.5–12	11.75	1980.1
AN97 12–12.5	12.25	1979.0
AN97 12.5–13	12.75	1978.0
AN97 13–13.5	13.25	1977.1
AN97 13.5–14	13.75	1976.1
AN97 14–14.5	14.25	1975.2
AN97 14.5–15	14.75	1974.3
AN97 15–15.5	15.25	1973.4
AN97 15.5–16	15.75	1972.4
AN97 16–16.5	16.25	1971.3
AN97 16.5–17	16.75	1970.2
AN97 17–17.5	17.25	1969.0
AN97 17.5–18	17.75	1967.9
AN97 18–18.5	18.25	1966.8
AN97 18.5–19	18.75	1965.5
AN97 19–19.5	19.25	1964.4
AN97 19.5–20	19.75	1963.3
AN97 20–20.5	20.25	1962.3

44. Fairfax Lake, Va.

Fairfax Lake is a small reservoir, constructed in 1952, located east of Reston, Va., in Lake Fairfax County Park. The reservoir is downstream from Lake Anne, which also was sampled for the RTNS study. Two gravity cores were collected for chemical analysis from the lower end of the reservoir in September 1997.

FFX.3 Gravity core 59 cm long analyzed for ^{137}Cs and major and trace elements.

Basis The pre-reservoir land surface at 52 cm was assigned the reservoir construction date. ^{137}Cs is slightly elevated at 29 cm (fig. A–47a) and total DDT has a small, but well defined peak at 31.5 cm in the adjacent core FFX.2 (fig. A–47b). Using a single MAR on the basis of the pre-reservoir surface suggests the ^{137}Cs and total DDT peaks are too recent in time. Additionally, Lake Anne in Reston (also cored for this study) was built upstream from Fairfax Lake in the early 1960s, probably reducing sediment inputs to Fairfax Lake. Therefore, the pre-reservoir surface, the elevated ^{137}Cs, and the sampling date were used to compute two MARs, 1.66 g/cm^2-yr for 1952 to 1964 and 0.55 g/cm^2-yr for 1964 to 1997. These MARs were used to assign dates.

Corroboration There are no clear date markers in this core to verify the dating, however, many of the elements show clear trends (for example zinc), suggesting that postdepositional mixing is not so severe as to have obscured trends. Additionally, aluminum changes substantially above and below about 30 cm, supporting the link between the construction of Lake Anne and the change in MAR at this level in the core (fig. A–47a).

Rating Fair. Although the ^{137}Cs profile is generally inconclusive, the presence of a pre-reservoir boundary and circumstantial evidence for the early 1960s construction date for Lake Anne at 30 cm support the age model.

FFX.2 Gravity core 64 cm long analyzed for organic compounds.

Basis The pre-reservoir surface is at 61.5 cm, deeper than in FFX.3. Dates were extrapolated by depth from FFX.3 after scaling for the difference to the depth of pre-reservoir surfaces in the two cores.

Corroboration The total DDT peak in FFX.2 is at 31.5 cm and receives a reasonable date of 1967.6.

Rating Poor. Additional uncertainty of extrapolation and difference in core length results in a lower confidence than for core FFX.3.

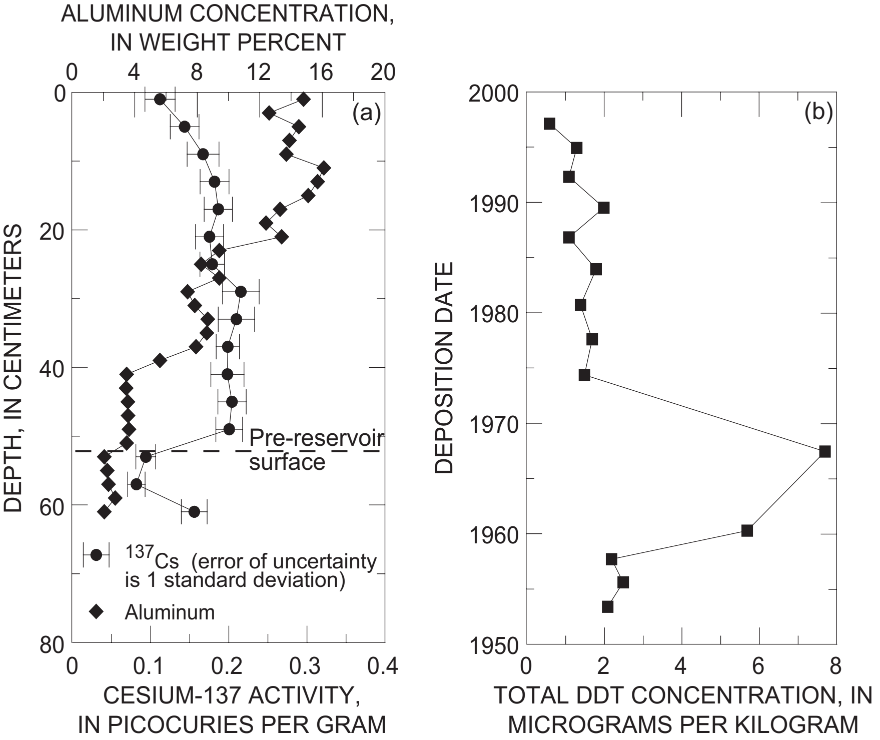


Figure A–47. Chemical constituent profiles used to estimate age dates for Fairfax Lake, Va. (a) FFX.3, (b) FFX.2.

Table A–43

Core FFX.3			Core FFX.3		
Sample identification	Mid-depth (centimeters)	Estimated deposition date	Sample identification	Mid-depth (centimeters)	Estimated deposition date
FFX.3 0–2	1	1997.2	FFX.3 32–34	33	1962.0
FFX.3 2–4	3	1995.6	FFX.3 34–36	35	1961.0
FFX.3 4–6	5	1993.7	FFX.3 36–38	37	1959.9
FFX.3 6–8	7	1991.5	FFX.3 38–40	39	1958.9
FFX.3 8–10	9	1989.3	FFX.3 40–42	41	1957.9
FFX.3 10–12	11	1987.2	FFX.3 42–44	43	1956.9
FFX.3 12–14	13	1985.1	FFX.3 44–46	45	1955.9
FFX.3 14–16	15	1982.6	FFX.3 46–48	47	1954.8
FFX.3 16–18	17	1980.0	FFX.3 48–50	49	1953.7
FFX.3 18–20	19	1977.6	FFX.3 50–52	51	1952.6
FFX.3 20–22	21	1975.2	FFX.3 52–54	53	Pre-reservoir
FFX.3 22–24	23	1972.6	FFX.3 54–56	55	Pre-reservoir
FFX.3 24–26	25	1969.9	FFX.3 56–58	57	Pre-reservoir
FFX.3 26–28	27	1967.0	FFX.3 58–60	59	Pre-reservoir
FFX.3 28–30	29	1964.0	FFX.3 60–62	61	Pre-reservoir
FFX.3 30–32	31	1963.0			

Table A–43 (Continued)

Core FFX.2			Core FFX.2		
Sample identification	Mid-depth (centimeters)	Estimated deposition date	Sample identification	Mid-depth (centimeters)	Estimated deposition date
FFX.2 0–3	1.5	1997.0	FFX.2 21–24	22.5	1977.5
FFX.2 3–6	4.5	1994.8	FFX.2 24–27	25.5	1974.4
FFX.2 6–9	7.5	1992.2	FFX.2 30–33	31.5	1967.6
FFX.2 9–12	10.5	1989.5	FFX.2 36–39	37.5	1962.6
FFX.2 12–15	13.5	1986.8	FFX.2 42–45	43.5	1960.0
FFX.2 15–18	16.5	1983.9	FFX.2 48–51	49.5	1957.5
FFX.2 18–21	19.5	1980.7	FFX.2 54–57	55.5	1954.9

45. Clyde Potts Reservoir, N.J.

Clyde Potts Reservoir is a small reservoir constructed in 1931 in a rural area of north-central New Jersey, between the towns of Brookside and Mount Freedom, N.J. Three box cores were collected for analysis from the lower end of the reservoir in September 1997.

NJCP.BC4 Box core 17 cm deep analyzed for ^{137}Cs and ^{210}Pb.

Basis The ^{137}Cs profile has a smooth, rounded peak at 11.25 cm (fig. A–48a), assumed to be the 1964.0 ^{137}Cs peak and resulting in a MAR of 0.089g/cm^2-yr. This MAR was used to assign dates.

Corroboration The unsupported ^{210}Pb profile suggests a change in sedimentation rate below about 10 cm (fig. A–48a). A regression line fit to unsupported ^{210}Pb for the top 10 samples (samples above the apparent change in slope of ^{210}Pb) (fig. A–48b) gives a date of 1964.0 at 11.25 cm, corroborating the ^{137}Cs peak.

Rating Good.

NJCP.BC2 Box core 8.5 cm deep analyzed for major and trace elements.

Basis The well defined lead peak at 3.75 cm was assigned a date of 1975.0, resulting in a MAR of 0.031 g/cm^2-yr.

Corroboration The deepest sample analyzed contained pre-reservoir material and received a date of 1926.4, approximately consistent with the reservoir construction date of 1931.

Rating Fair. The lead peak and pre-reservoir dates seem reasonable, however, the large difference in MAR and core length compared to NJCP.BC4 and NJCP.BC3 cause some concern for the reliability of this core.

NJCP.BC3 Box core 18.5 cm analyzed for organic compounds.

Basis Dates were extrapolated by depth from NJCP.BC4.

Corroboration The deepest sample analyzed, which has the largest DDT and PCB concentrations, received a reasonable date of 1959.2.

Rating Fair.

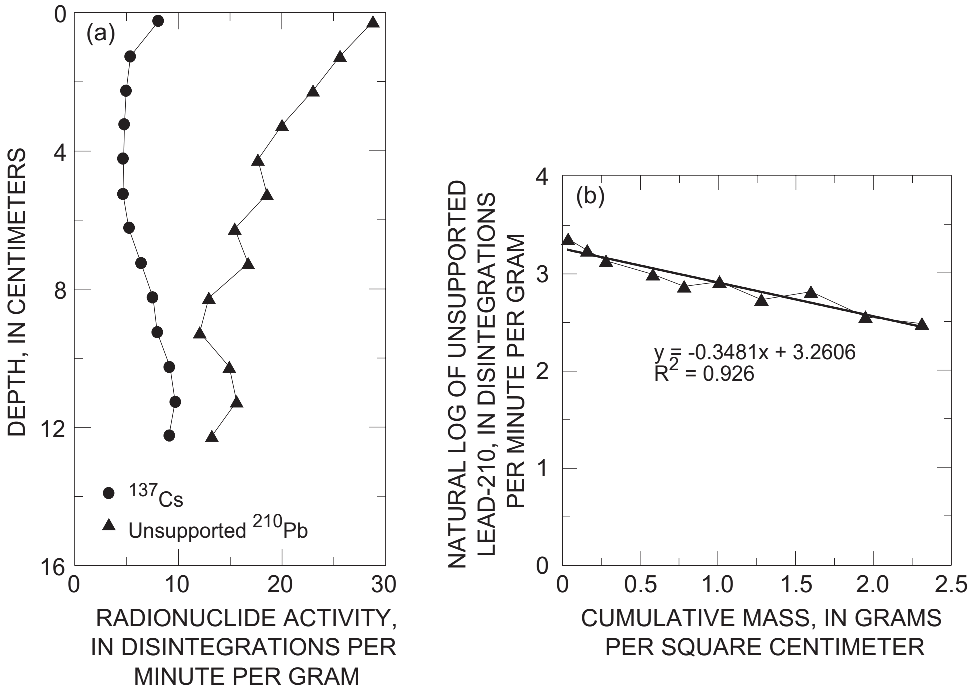


Figure A–48. (a) Chemical constituent profiles used to estimate age dates for Clyde Potts Reservoir, N.J.; and (b) regression line fit to unsupported ^{210}Pb for the top 10 samples of core NJCP.BC4 and used to estimate age dates for Clyde Potts Reservoir, N.J.

Table A–44

Core NJCP.BC4			Core NJCP.BC4		
Sample identification	Mid-depth (centimeters)	Estimated deposition date	Sample identification	Mid-depth (centimeters)	Estimated deposition date
NJCP.BC4 0.0–0.5	0.25	1997.3	NJCP.BC4 7.0–7.5	7.25	1979.8
NJCP.BC4 2.0–2.5	2.25	1994.6	NJCP.BC4 8.0–8.5	8.25	1975.9
NJCP.BC4 3.0–3.5	3.25	1991.2	NJCP.BC4 9.0–9.5	9.25	1971.8
NJCP.BC4 4.0–4.5	4.25	1989.0	NJCP.BC4 10.0–10.5	10.25	1967.8
NJCP.BC4 5.0–5.5	5.25	1986.4	NJCP.BC4 11.0–11.5	11.25	1964.0
NJCP.BC4 6.0–6.5	6.25	1983.4	NJCP.BC4 12.0–12.5	12.25	1960.2

Core NJCP.BC2			Core NJCP.BC2		
Sample identification	Mid-depth (centimeters)	Estimated deposition date	Sample identification	Mid-depth (centimeters)	Estimated deposition date
NJCP.BC2 0.0–0.5	0.25	1996.7	NJCP.BC2 4.5–5.0	4.75	1967.2
NJCP.BC2 0.5–1.0	0.75	1994.2	NJCP.BC2 5.0–5.5	5.25	1962.6
NJCP.BC2 1.0–1.5	1.25	1991.6	NJCP.BC2 5.5–6.0	5.75	1957.6
NJCP.BC2 1.5–2.0	1.75	1988.8	NJCP.BC2 6.0–6.5	6.25	1952.4
NJCP.BC2 2.0–2.5	2.25	1985.6	NJCP.BC2 6.5–7.0	6.75	1947.0
NJCP.BC2 2.5–3.0	2.75	1982.2	NJCP.BC2 7.0–7.5	7.25	1941.4
NJCP.BC2 3.0–3.5	3.25	1978.6	NJCP.BC2 7.5–8.0	7.75	1934.9
NJCP.BC2 3.5–4.0	3.75	1975.0	NJCP.BC2 8.0–8.5	8.25	1926.4
NJCP.BC2 4.0–4.5	4.25	1971.2			

Table A–44 (Continued)

Core NJCP.BC3			Core NJCP.BC3		
Sample identification	Mid-depth (centimeters)	Estimated deposition date	Sample identification	Mid-depth (centimeters)	Estimated deposition date
NJCP.BC3 0–1	0.5	1997.0	NJCP.BC3 7–8	7.5	1978.7
NJCP.BC3 1–2	1.5	1995.6	NJCP.BC3 8–9	8.5	1974.8
NJCP.BC3 2–3	2.5	1993.7	NJCP.BC3 9–10	9.5	1970.8
NJCP.BC3 3–4	3.5	1990.9	NJCP.BC3 10–11	10.5	1966.9
NJCP.BC3 4–5	4.5	1988.3	NJCP.BC3 11–12	11.5	1963.1
NJCP.BC3 5–6	5.5	1985.6	NJCP.BC3 12–13	12.5	1959.2
NJCP.BC3 6–7	6.5	1982.5			

46. Orange Reservoir, N.J.

Orange Reservoir was constructed about 1882–84 on the West Branch in the South Mountain Reservation of northeastern New Jersey near the towns of Orange and Livingston, N.J. Three gravity cores and two box cores were collected for analysis from the lower end of the reservoir in September 1997.

NJOR.1, NJOR.4, and NJOR.5 Gravity cores analyzed for major and trace elements, organic compounds, and ^{137}Cs, respectively. Gravity cores were 60 cm (NJOR.1), 56 cm (NJOR.4), and 66 cm (NJOR.5) long.

Basis Five gravity cores were collected at this site, three of which were sampled for chemical analyses. Possible individual date markers exist in each including a lead peak in NJOR.1 (fig. A–49a), a total DDT peak in NJOR.4 (fig. A–49a), and a ^{137}Cs peak in NJOR.5 (fig. A–49b). There was some indication in the core lithology that pre-reservoir material was encountered between 60 and 70 cm depth in all five cores, although the lower parts of three of the cores were lost during core recovery. These date markers are inconsistent among the cores if a constant MAR is assumed. In addition, using the probable pre-reservoir boundary as a date marker suggests that the MAR decreased in all three cores after about 1960. Therefore, for all three cores a variable MAR profile was assumed on the basis of a pre-reservoir surface at 64 cm (1883), the ^{137}Cs peak at 25 cm (1964.0), and the lead peak at 15 cm (1979.2). The resulting MAR increases from 0.34 g/cm^2-yr in the lower parts of the cores (pre-1950) to a maximum of 0.42 g/cm^2-yr at the ^{137}Cs peak, and then decreases to 0.18 g/cm^2-yr from the ^{137}Cs peak to the top of the core (fig. A–49c).

Corroboration All four of the typical date-depth indicators used by this study (reservoir construction date and ^{137}Cs, lead, and DDT peaks) are used in developing the MAR profile used to assign dates to these cores, therefore no independent corroboration exists in these cores.

Rating Fair for NJOR.1 and NJOR.4; good for NJOR.5.

NJOR.BC1 and NJOR.BC2 Box cores analyzed for major and trace elements and organic compounds, respectively. Box cores were 20 and 17.5 cm deep, respectively. Selected sample results from the upper part of these box cores were combined with the sample results from the middle and lower parts of gravity cores NJOR.1 and NJOR.4 to make a continuous temporal record.

Basis Dates were assigned to the box cores using a linear sedimentation rate determined for the upper 9 cm of core NJOR.5, adjusted for an assumed 40-percent core shortening in the gravity cores relative to the box cores.

Corroboration Very little, although the lead and total DDT profiles are consistent with the gravity cores (fig. A–49a).

Rating Fair.

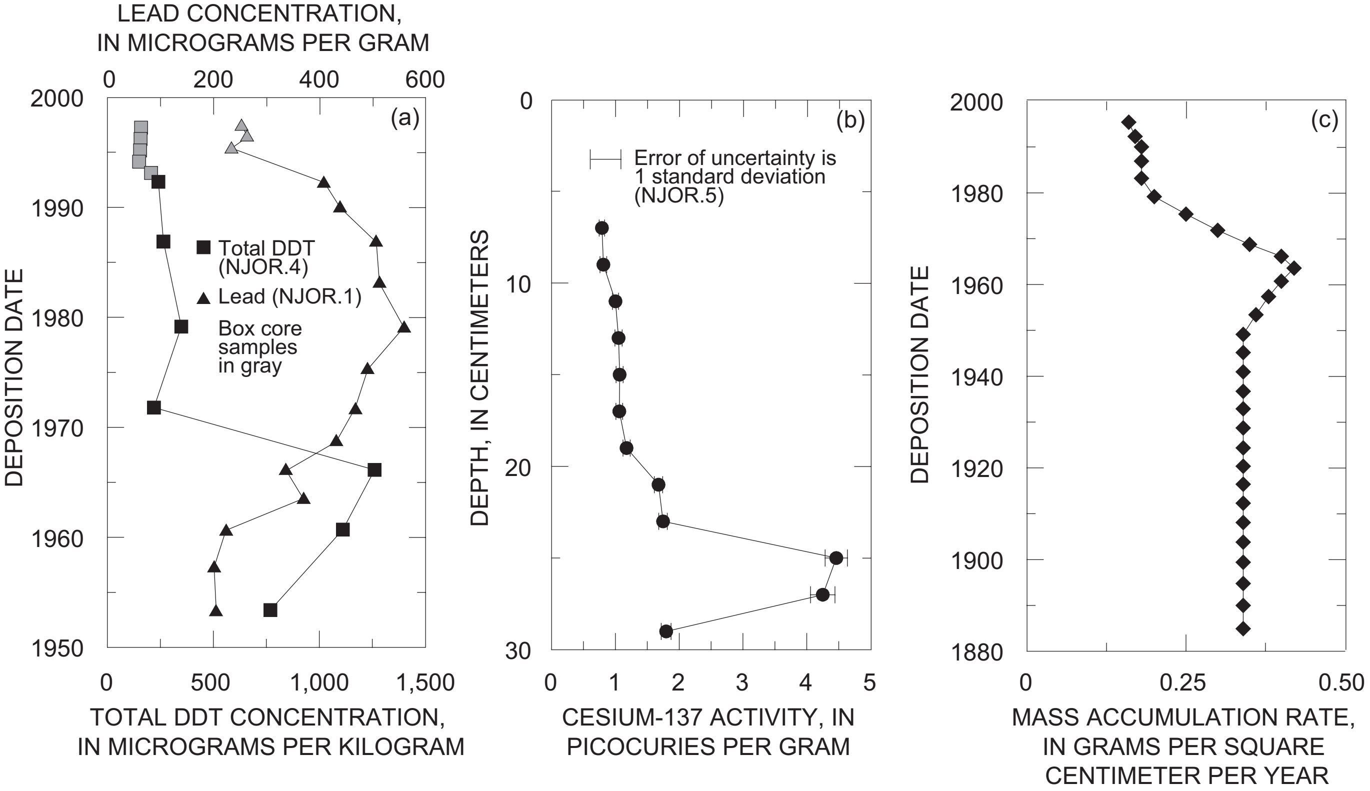


Figure A–49. Chemical constituent profiles used to estimate age dates for Orange Reservoir, N.J. (a) NJOR.1, NJOR.4, (b) NJOR.5, and (c) variations of the mass accumulation rate over time in the cores collected from Orange Reservoir, N.J.

Table A–45

Core NJOR.1			Core NJOR.1		
Sample identification	Mid-depth (centimeters)	Estimated deposition date	Sample identification	Mid-depth (centimeters)	Estimated deposition date
NJOR.1 6–8	7	1992.3	NJOR.1 20–22	21	1968.7
NJOR.1 8–10	9	1990.0	NJOR.1 22–24	23	1966.1
NJOR.1 10–12	11	1986.9	NJOR.1 24–26	25	1963.6
NJOR.1 12–14	13	1983.2	NJOR.1 26–28	27	1960.7
NJOR.1 14–16	15	1979.2	NJOR.1 28–30	29	1957.4
NJOR.1 16–18	17	1975.3	NJOR.1 30–32	31	1953.4
NJOR.1 18–20	19	1971.8			

Core NJOR.4			Core NJOR.4		
Sample identification	Mid-depth (centimeters)	Estimated deposition date	Sample identification	Mid-depth (centimeters)	Estimated deposition date
NJOR.4 6–8	7	1992.3	NJOR.4 22–24	23	1966.1
NJOR.4 10–12	11	1986.9	NJOR.4 26–28	27	1960.7
NJOR.4 14–16	15	1979.2	NJOR.4 30–32	31	1953.4
NJOR.4 18–20	19	1971.8			

Table A–45 (Continued)

Core NJOR.5			Core NJOR.5		
Sample identification	Mid-depth (centimeters)	Estimated deposition date	Sample identification	Mid-depth (centimeters)	Estimated deposition date
NJOR.5 0–6	3	1995.4	NJOR.5 36–38	37	1940.9
NJOR.5 6–8	7	1992.3	NJOR.5 38–40	39	1936.7
NJOR.5 8–10	9	1990.0	NJOR.5 40–42	41	1932.9
NJOR.5 12–14	13	1983.2	NJOR.5 42–44	43	1928.7
NJOR.5 14–16	15	1979.2	NJOR.5 44–46	45	1924.4
NJOR.5 16–18	17	1975.3	NJOR.5 46–48	47	1920.3
NJOR.5 18–20	19	1971.8	NJOR.5 48–50	49	1916.4
NJOR.5 20–22	21	1968.7	NJOR.5 50–52	51	1912.3
NJOR.5 22–24	23	1966.1	NJOR.5 52–54	53	1908.1
NJOR.5 24–26	25	1963.6	NJOR.5 54–56	55	1903.8
NJOR.5 26–28	27	1960.7	NJOR.5 56–58	57	1899.4
NJOR.5 28–30	29	1957.4	NJOR.5 58–60	59	1894.8
NJOR.5 32–34	33	1949.1	NJOR.5 60–62	61	1890.0
NJOR.5 34–36	35	1945.2	NJOR.5 62–64	63	1884.9

Core NJOR.BC1			Core NJOR.BC1		
Sample identification	Mid-depth (centimeters)	Estimated deposition date	Sample identification	Mid-depth (centimeters)	Estimated deposition date
NJOR.BC1 0–1	0.5	1997.5	NJOR.BC1 4–5	4.5	1995.4
NJOR.BC1 2–3	2.5	1996.5			

Core NJOR.BC2			Core NJOR.BC2		
Sample identification	Mid-depth (centimeters)	Estimated deposition date	Sample identification	Mid-depth (centimeters)	Estimated deposition date
NJOR.BC2 0–2	1	1997.2	NJOR.BC2 6–8	7	1994.1
NJOR.BC2 2–4	3	1996.2	NJOR.BC2 8–10	9	1993.1
NJOR.BC2 4–6	5	1995.2			

47. Packanack Lake, N.J.

Packanack Lake is a small reservoir constructed in 1930 on Packanack Brook in northeastern New Jersey, east of Paterson, N.J. Three gravity cores and one box core were collected for chemical analysis from the lower end of the reservoir in September 1997.

NJPAK.6 Gravity core 30 cm long analyzed for radionuclides.

Basis The core has a small ^{137}Cs peak at 10 to 11 cm and a profile indicative of postdepositional mixing (fig. A–50a). A small decrease in unsupported ^{210}Pb is in the top 10 cm; however, unsupported ^{210}Pb decreases to zero by 15 cm, a profile that is inconsistent with the ^{137}Cs data. With the exception of the pre-reservoir surface in core NJPAK.4, no definitive date markers occur in the other cores. Several corroborating markers were identified that, along with the ^{137}Cs and ^{210}Pb data in this core, suggest that some temporal information was preserved in these cores and that a large decrease in sedimentation rate has occurred over time. An exponentially decreasing MAR model (Callender and Robbins, 1993) therefore was used on the basis of the mass-depth profile of two cores (NJPAK.3 and NJPAK.4), the pre-reservoir surface in NJPAK.4, the ^{137}Cs peak at 10.5 cm in NJPAK.6, and the sampling date. The resulting model ($k = 0.0565$) indicates a large decrease in MAR over time, from about 1.0 g/cm^2-yr soon after reservoir construction to 0.03 g/cm^2-yr in the late 1990s. The variable MAR was used to develop a cumulative mass-date relation that was applied to all three cores.

Corroboration None in this core, but reasonable corroboration in cores NJPAK.3 and NJPAK.4.

Rating Poor. Lack of definitive date markers in these cores and profiles indicative of substantial postdepositional mixing during recent decades as MAR decreased to a very low rate leads to a poor rating.

NJPAK.3 Gravity core 33 cm long analyzed for major and trace elements from top of the core to 21 cm only.

Basis Dates were assigned on the basis of the cumulative mass-date relation developed for core NJPAK.6.

Corroboration The core did not encounter pre-reservoir material. Two date markers are available in the core—a very rounded, small lead peak at about 6 to 10 cm and a dramatic increase in copper (and lead) at about 18 cm (fig. A–50b). The lake was reportedly treated with copper sulfate to control algae beginning in the early 1950s (Gary Long, U.S. Geological Survey, oral commun., 2001). On the basis of the assigned dates, the dramatic increase in copper occurs in the mid-1950s and the high in lead is centered in the 1970s, both reasonable. The rounded lead profile in this urban setting is additional evidence of postdepositional mixing in the upper part of the core. The sharp increase in copper concentration indicates less mixing in the deeper sediments, a logical result assuming the modeled larger MAR in the early years of the reservoir is real.

Rating Poor.

NJPAK.4 Gravity core 44 cm long analyzed for organic compounds. The top two samples from an adjacent box core, NJPAK.BOX1, were analyzed for organic compounds and the data were merged with gravity core NJPAK.4.

Basis This core penetrated the pre-reservoir surface at 43 cm, a date marker used to develop the age model applied to all three cores. Dates were assigned on the basis of the mass-date relation developed for core NJPAK.6.

Corroboration Two date markers were available in this core—the first occurrence of DDTs and PCBs at 28 to 30 cm and peak total DDT and PCBs at 14 to 16 cm (fig. A–50c). The 28- to 30-cm sample received a date of 1940.5 and the 14- to 16-cm sample was dated as 1959.0, both of which are reasonable.

Rating Poor.

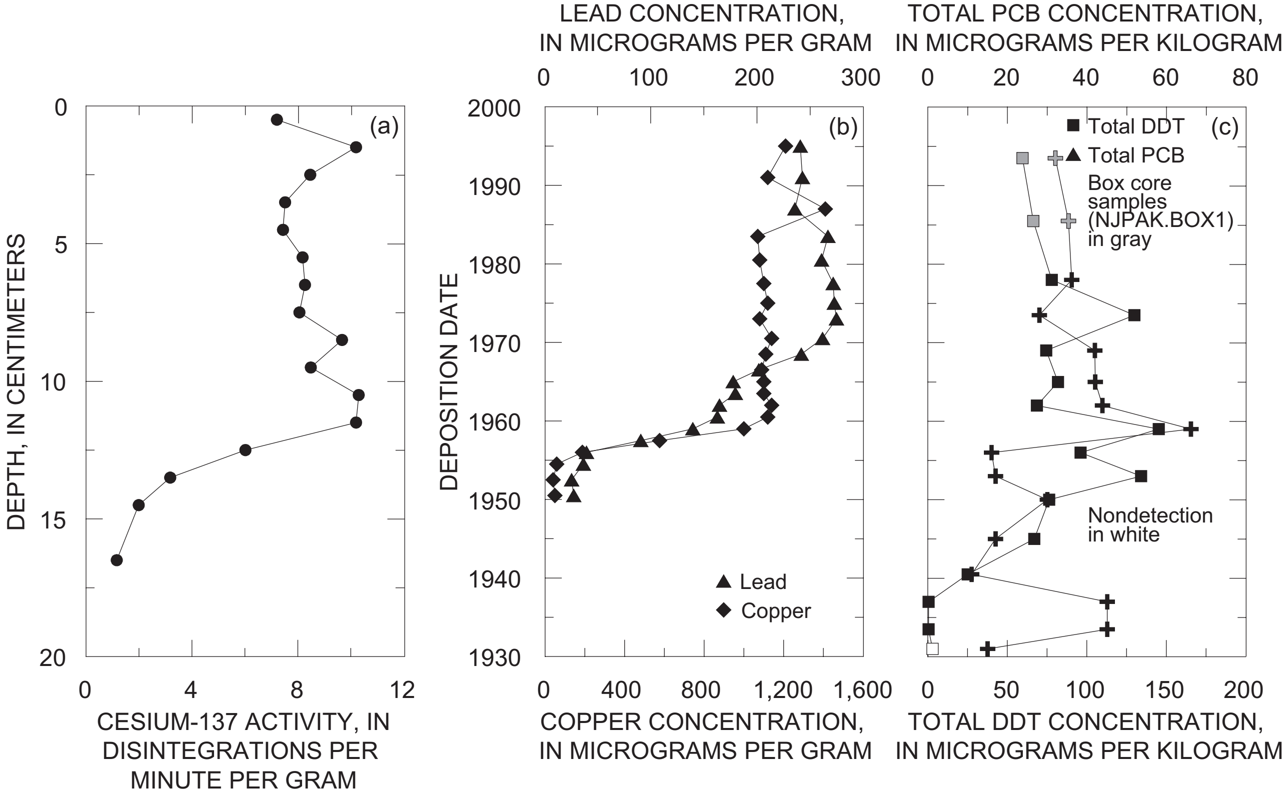


Figure A–50. Chemical constituent profiles used to estimate age dates for Packanack Lake, N.J. (a) NJPAK.6, (b) NJPAK.3, (c) NJPAK.4, NJPAK.BOX1.

Table A–46

Core NJPAK.6			Core NJPAK.6		
Sample identification	Mid-depth (centimeters)	Estimated deposition date	Sample identification	Mid-depth (centimeters)	Estimated deposition date
NJPAK.6 0–1	0.5	1996.9	NJPAK.6 12–13	12.5	1973.0
NJPAK.6 2–3	2.5	1994.1	NJPAK.6 13–14	13.5	1971.5
NJPAK.6 3–4	3.5	1991.2	NJPAK.6 14–15	14.5	1969.1
NJPAK.6 4–5	4.5	1988.9	NJPAK.6 16–17	16.5	1965.6
NJPAK.6 5–6	5.5	1986.8	NJPAK.6 18–19	18.5	1961.5
NJPAK.6 6–7	6.5	1984.9	NJPAK.6 20–21	20.5	1957.4
NJPAK.6 7–8	7.5	1983.0	NJPAK.6 22–23	22.5	1953.5
NJPAK.6 8–9	8.5	1980.8	NJPAK.6 24–25	24.5	1950.0
NJPAK.6 9–10	9.5	1978.8	NJPAK.6 26–27	26.5	1946.0
NJPAK.6 10–11	10.5	1976.9	NJPAK.6 28–29	28.5	1942.0
NJPAK.6 11–12	11.5	1975.0			

Table A–46 (Continued)

Core NJPAK.3			Core NJPAK.3		
Sample identification	Mid-depth (centimeters)	Estimated deposition date	Sample identification	Mid-depth (centimeters)	Estimated deposition date
NJPAK.3 0–1	0.5	1995.0	NJPAK.3 11–12	11.5	1965.0
NJPAK.3 1–2	1.5	1991.0	NJPAK.3 12–13	12.5	1963.5
NJPAK.3 2–3	2.5	1987.0	NJPAK.3 13–14	13.5	1962.0
NJPAK.3 3–4	3.5	1983.5	NJPAK.3 14–15	14.5	1960.5
NJPAK.3 4–5	4.5	1980.5	NJPAK.3 15–16	15.5	1959.0
NJPAK.3 5–6	5.5	1977.5	NJPAK.3 16–17	16.5	1957.5
NJPAK.3 6–7	6.5	1975.0	NJPAK.3 17–18	17.5	1956.0
NJPAK.3 7–8	7.5	1973.0	NJPAK.3 18–19	18.5	1954.5
NJPAK.3 8–9	8.5	1970.5	NJPAK.3 19–20	19.5	1952.5
NJPAK.3 9–10	9.5	1968.5	NJPAK.3 20–21	20.5	1950.5
NJPAK.3 10–11	10.5	1966.5			

Core NJPAK.4			Core NJPAK.4		
Sample identification	Mid-depth (centimeters)	Estimated deposition date	Sample identification	Mid-depth (centimeters)	Estimated deposition date
NJPAK.BOX1 0–2	1	1993.5	NJPAK.4 16–18	17	1956.0
NJPAK.BOX1 2–4	3	1985.5	NJPAK.4 18–20	19	1953.0
NJPAK.4 4–6	5	1978.0	NJPAK.4 20–22	21	1950.0
NJPAK.4 6–8	7	1973.5	NJPAK.4 24–26	25	1945.0
NJPAK.4 8–10	9	1969.0	NJPAK.4 28–30	29	1940.5
NJPAK.4 10–12	11	1965.0	NJPAK.4 32–34	33	1937.0
NJPAK.4 12–14	13	1962.0	NJPAK.4 36–38	37	1933.5
NJPAK.4 14–16	15	1959.0	NJPAK.4 40–42	41	1931.0

48. Newbridge Pond, N.Y.

Newbridge Pond is a small reservoir constructed in the early 1900s on Cedar Swamp Creek between Merrick and Bellmore, adjacent to State Highway 27, on the southwest side of Long Island, N.Y. Three gravity cores were collected for chemical analysis from the center of the pond in September 1997.

NEW.2 Gravity core 54 cm long analyzed for ^{137}Cs.

Basis The ^{137}Cs activity peak at 40 to 42 cm (fig. A–51a) was assigned a date of 1964.0 resulting in a MAR of 0.32 g/cm^2-yr. Dates were assigned using this MAR.

Corroboration The pre-reservoir land surface is at 52 cm; however, the occurrence of detectable ^{137}Cs in samples immediately above the pre-reservoir surface indicates a temporal discontinuity in the approximately 100-year old reservoir. Only ^{137}Cs was measured in this core, so no corroboration was possible; however, applying the MAR computed for NEW.2 to cores NEW.1 and NEW.3 yields reasonable dates corroborated by lead and organochlorine profiles.

Rating Good.

NEW.1 Gravity core 57 cm long analyzed for organic compounds.

Basis Dates were assigned on the basis of the date-depth relation developed for core NEW.2.

Corroboration The peak total DDT concentration received a reasonable date of 1962.2 (fig. A–51b).

Rating Good.

NEW.3 Gravity core 50 cm long analyzed for major and trace elements.

Basis The MAR of 0.32 g/cm^2-yr computed for NEW.2 was applied to this core on a mass basis to assign dates.

Corroboration The peak lead concentration at 29 to 30 cm received a reasonable date of 1976.3 (fig. A–51b).

Rating Good.

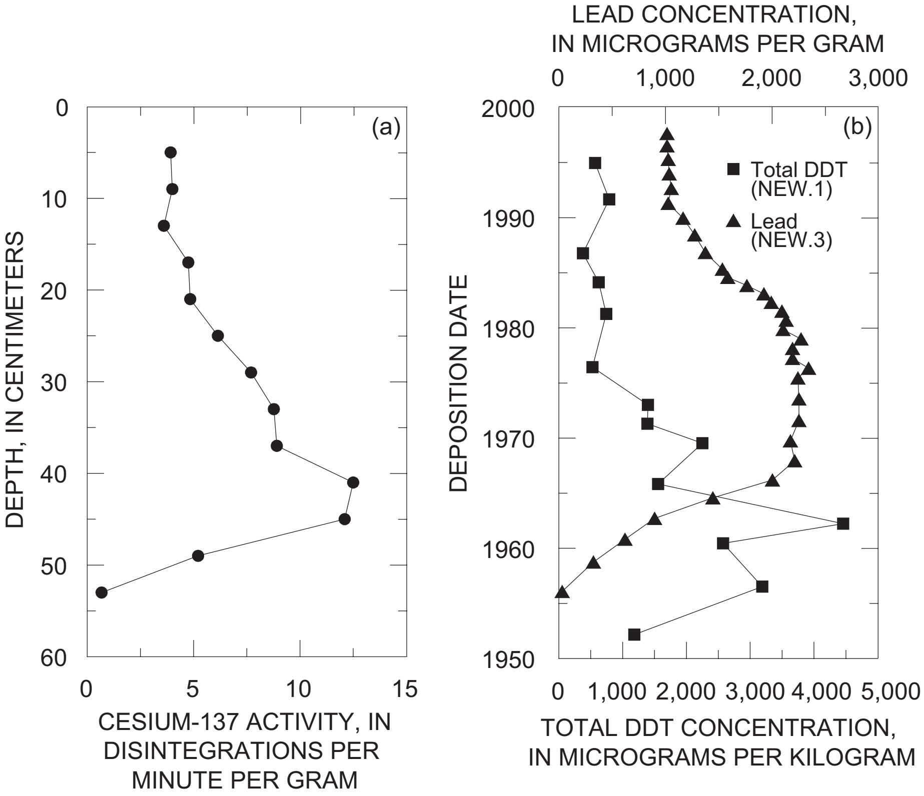


Figure A–51. Chemical constituent profiles used to estimate age dates for Newbridge Pond, N.Y. (a) NEW.2, (b) NEW.1, NEW.3.

Table A–47

Core NEW.2			Core NEW.2		
Sample identification	Mid-depth (centimeters)	Estimated deposition date	Sample identification	Mid-depth (centimeters)	Estimated deposition date
NEW.2 0–2	1	1996.9	NEW.2 28–30	29	1974.7
NEW.2 2–4	3	1995.0	NEW.2 30–32	31	1973.0
NEW.2 4–6	5	1993.1	NEW.2 32–34	33	1971.3
NEW.2 6–8	7	1991.7	NEW.2 34–36	35	1969.5
NEW.2 8–10	9	1990.5	NEW.2 36–38	37	1967.7
NEW.2 10–12	11	1988.6	NEW.2 38–40	39	1965.8
NEW.2 12–14	13	1986.8	NEW.2 40–42	41	1964.0
NEW.2 14–16	15	1985.5	NEW.2 42–44	43	1962.2
NEW.2 16–18	17	1984.1	NEW.2 44–46	45	1960.4
NEW.2 18–20	19	1982.7	NEW.2 46–48	47	1958.5
NEW.2 20–22	21	1981.3	NEW.2 48–50	49	1956.5
NEW.2 22–24	23	1979.8	NEW.2 50–52	51	1954.8
NEW.2 24–26	25	1978.1	NEW.2 52–54	53	1952.2
NEW.2 26–28	27	1976.4			

Table A–47 (Continued)

Core NEW.1			Core NEW.1		
Sample identification	Mid-depth (centimeters)	Estimated deposition date	Sample identification	Mid-depth (centimeters)	Estimated deposition date
NEW.1 2–4	3	1995.0	NEW.1 32–34	33	1971.3
NEW.1 6–8	7	1991.7	NEW.1 34–36	35	1969.5
NEW.1 12–14	13	1986.8	NEW.1 38–40	39	1965.8
NEW.1 16–18	17	1984.1	NEW.1 42–44	43	1962.2
NEW.1 20–22	21	1981.3	NEW.1 44–46	45	1960.4
NEW.1 26–28	27	1976.4	NEW.1 48–50	49	1956.5
NEW.1 30–32	31	1973.0	NEW.1 52–54	53	1952.2

Core NEW.3			Core NEW.3		
Sample identification	Mid-depth (centimeters)	Estimated deposition date	Sample identification	Mid-depth (centimeters)	Estimated deposition date
NEW.3 0–1	0.5	1997.7	NEW.3 25–26	25.5	1979.8
NEW.3 1–2	1.5	1997.2	NEW.3 26–27	26.5	1979.0
NEW.3 2–3	2.5	1996.5	NEW.3 27–28	27.5	1978.1
NEW.3 3–4	3.5	1995.9	NEW.3 28–29	28.5	1977.2
NEW.3 4–5	4.5	1995.3	NEW.3 29–30	29.5	1976.3
NEW.3 5–6	5.5	1994.7	NEW.3 30–31	30.5	1975.4
NEW.3 6–7	6.5	1994.0	NEW.3 31–32	31.5	1974.5
NEW.3 7–8	7.5	1993.3	NEW.3 32–33	32.5	1973.5
NEW.3 8–9	8.5	1992.7	NEW.3 33–34	33.5	1972.5
NEW.3 9–10	9.5	1992.0	NEW.3 34–35	34.5	1971.6
NEW.3 10–11	10.5	1991.3	NEW.3 35–36	35.5	1970.6
NEW.3 11–12	11.5	1990.7	NEW.3 36–37	36.5	1969.7
NEW.3 12–13	12.5	1990.0	NEW.3 37–38	37.5	1968.8
NEW.3 13–14	13.5	1989.1	NEW.3 38–39	38.5	1967.9
NEW.3 14–15	14.5	1988.4	NEW.3 39–40	39.5	1967.0
NEW.3 15–16	15.5	1987.8	NEW.3 40–41	40.5	1966.1
NEW.3 16–17	16.5	1986.8	NEW.3 41–42	41.5	1965.3
NEW.3 17–18	17.5	1986.1	NEW.3 42–43	42.5	1964.5
NEW.3 18–19	18.5	1985.3	NEW.3 43–44	43.5	1963.6
NEW.3 19–20	19.5	1984.6	NEW.3 44–45	44.5	1962.7
NEW.3 20–21	20.5	1983.8	NEW.3 45–46	45.5	1961.7
NEW.3 21–22	21.5	1983.1	NEW.3 46–47	46.5	1960.8
NEW.3 22–23	22.5	1982.3	NEW.3 47–48	47.5	1959.7
NEW.3 23–24	23.5	1981.5	NEW.3 48–49	48.5	1958.7
NEW.3 24–25	24.5	1980.7	NEW.3 49–50	49.5	Pre-reservoir

49. Big Round Top Pond, R.I.

Big Round Top Pond is a reservoir located in the Round Top State Fishing Area of the rural township Burrillville in far north Rhode Island. The reservoir construction date could not be obtained. Three box cores were collected for chemical analysis in July 2000 from locations in the lower (BRT.B1), middle (BRT.B2), and upper (BRT.B3) parts of this small reservoir. Age-dating of cores was attempted only on the first two locations.

Location lower lake

BRT.B1 One box core 16.5 cm deep analyzed for all constituents.

Basis The peak ^{137}Cs activity at 9.5 to 10 cm (fig. A–52a) was assigned a date of 1964. The average MAR for the 1964–2000 interval of the core of 0.036 g/cm^2-yr resulted in an age assignment of 1947 for the 13.5- to 14-cm interval where ^{137}Cs was still detected, suggesting either postdepositional mixing or that the sedimentation rate had decreased over time. The shape of the total DDT profile, with a steady increase to the deepest sample analyzed (fig. A–52b) is not a logical profile for mixing, assuming DDT peaks around 1960, and results in a date of 1951 for the highest total DDT sample (for example, Van Metre and others, 1998); therefore, a decreasing MAR was assumed. The change in MAR was modeled as an exponential decrease, a pattern reported for many reservoirs (Callender and Robbins, 1993). The model was calibrated ($k = 0.020$) using the masses accumulated during 1953.0–1964.0 and 1964.0–2000.5 and was used to estimate a bottom-of-core date of 1946.3. The modeled MAR decreases over time from 0.077 g/cm^2-yr at the bottom of the core to 0.027 g/cm^2-yr at the top. The model was used to develop a cumulative mass-date relation that was used to assign dates.

Corroboration The lead profile (fig. A–52c) was inconclusive regarding sediment age, which is not uncommon in a reference lake. Total DDT is greatest in the bottom two samples, 14 to 15 cm and 12 to 13 cm, dated as 1951.2 and 1956.2, remains relatively high in the 1960s, then decreases in the 1970s indicating a reasonable temporal profile on the basis of use and trends observed in other lake cores (fig. A–52b). The PCB peak at 8 to 9 cm was dated as 1967.8, which is consistent with national use patterns and trends in other lake cores (fig. A–52b).

Rating Good.

Location mid-lake

BRT.B2 One box core 19 cm deep analyzed for all constituents.

Basis For preliminary analysis, the peak ^{137}Cs activity at 9 to 10 cm (fig. A–52a) was assigned a date of 1964.0. The average MAR for the 1964.0–2000.5 interval of the core of 0.038 g/cm^2-yr resulted in an age assignment of 1930.8 for the 16- to 17-cm interval where ^{137}Cs was still detected, suggesting that sedimentation rate had decreased over time. As with BRT.B1, the decrease in MAR was modeled as an exponential decrease. The model was calibrated ($k = 0.053$) using the masses accumulated during 1953.0–1964.0 and 1964.0–2000.5 and was used to estimate a bottom-of-core date of 1952.6. The modeled MAR decreases over time from about 0.15 g/cm^2-yr at the bottom of the core to 0.014 g/cm^2-yr at the top. The model was used to develop a cumulative mass-date relation that was used to assign dates.

Corroboration The lead profile was inconclusive regarding sediment age; however, the lead profiles for the two cores compare well when plotted by date (fig. A–52c). Only two samples were analyzed for organic compounds in this core and they compare well with BRT.B1 when plotted by date (fig. A–52b).

Rating Fair.

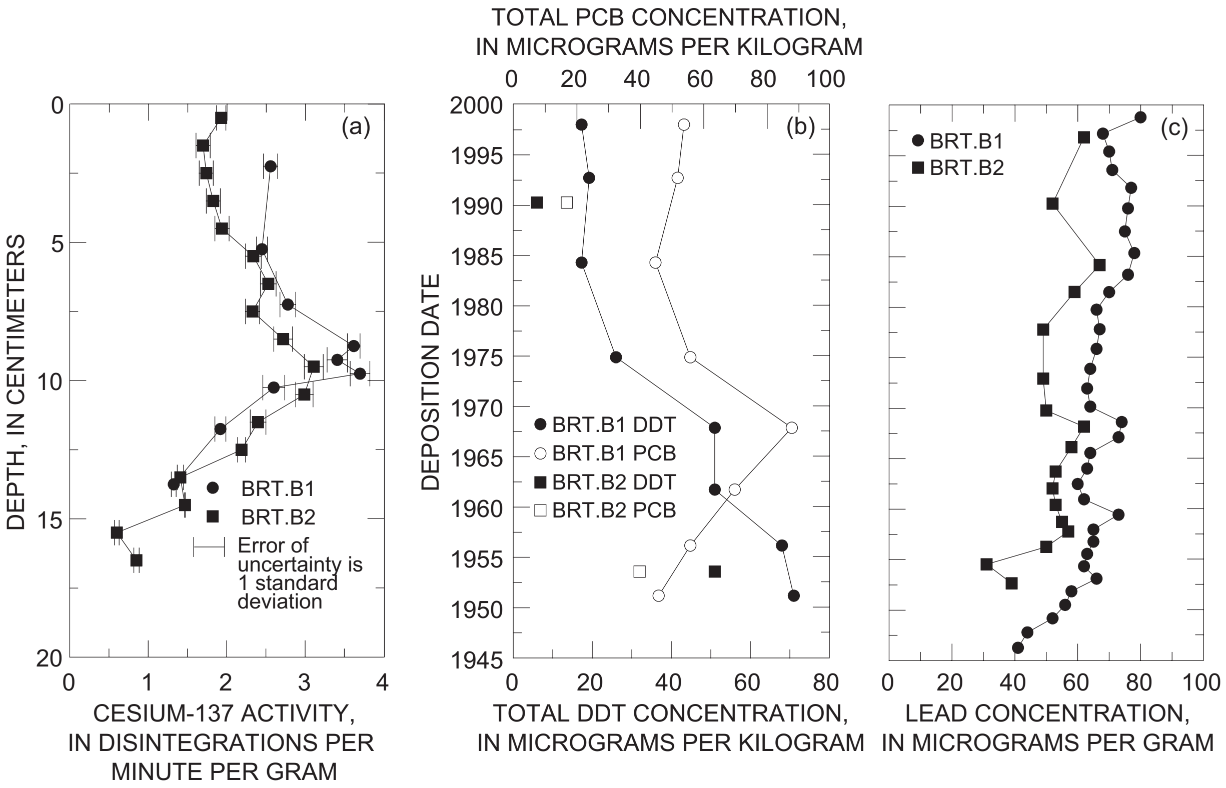


Figure A–52. Chemical constituent profiles used to estimate age dates for Big Round Top Pond, Mass.

Table A–48

Core BRT.B1			Core BRT.B1		
Sample identification	Mid-depth (centimeters)	Estimated deposition date	Sample identification	Mid-depth (centimeters)	Estimated deposition date
BRT.B1 0–0.5	0.25	1998.8	BRT.B1 8.5–9	8.75	1967.1
BRT.B1 0.5–1	.75	1997.2	BRT.B1 9–9.5	9.25	1965.6
BRT.B1 1–1.5	1.25	1995.4	BRT.B1 9.5–10	9.75	1964.0
BRT.B1 1.5–2	1.75	1993.6	BRT.B1 10–10.5	10.25	1962.5
BRT.B1 2–2.5	2.25	1991.8	BRT.B1 10.5–11	10.75	1961.0
BRT.B1 2.5–3	2.75	1989.8	BRT.B1 11–11.5	11.25	1959.4
BRT.B1 3–3.5	3.25	1987.5	BRT.B1 11.5–12	11.75	1958.0
BRT.B1 3.5–4	3.75	1985.4	BRT.B1 12–12.5	12.25	1956.8
BRT.B1 4–4.5	4.25	1983.2	BRT.B1 12.5–13	12.75	1955.6
BRT.B1 4.5–5	4.75	1981.5	BRT.B1 13–13.5	13.25	1954.3
BRT.B1 5–5.5	5.25	1979.8	BRT.B1 13.5–14	13.75	1953.1
BRT.B1 5.5–6	5.75	1977.8	BRT.B1 14–14.5	14.25	1951.9
BRT.B1 6–6.5	6.25	1975.9	BRT.B1 14.5–15	14.75	1950.5
BRT.B1 6.5–7	6.75	1973.9	BRT.B1 15–15.5	15.25	1949.2
BRT.B1 7–7.5	7.25	1972.0	BRT.B1 15.5–16	15.75	1947.8
BRT.B1 7.5–8	7.75	1970.2	BRT.B1 16–16.5	16.25	1946.3
BRT.B1 8–8.5	8.25	1968.6			

Table A–48 (Continued)

Core BRT.B2		
Sample identification	Mid-depth (centimeters)	Estimated deposition date
BRT.B2 0–1	0.5	1996.8
BRT.B2 1–2	1.5	1990.3
BRT.B2 2–3	2.5	1984.2
BRT.B2 3–4	3.5	1981.5
BRT.B2 4–5	4.5	1977.8
BRT.B2 5–6	5.5	1972.9
BRT.B2 6–7	6.5	1969.8
BRT.B2 7–8	7.5	1968.2
BRT.B2 8–9	8.5	1966.1
BRT.B2 9–10	9.5	1963.7
BRT.B2 10–11	10.5	1962.1
BRT.B2 11–12	11.5	1960.4
BRT.B2 12–13	12.5	1958.7
BRT.B2 13–14	13.5	1957.8
BRT.B2 14–15	14.5	1956.3
BRT.B2 15–16	15.5	1954.5
BRT.B2 16–17	16.5	1952.6

50. Maple Street Pond, Mass.

Maple Street Pond is a small reservoir in a swamp-like setting near the headwaters of the Charles River and the city of Bellingham in southern Massachusetts. The exact date of impoundment is not known, however USGS topographic maps show that the pond has been in existence since at least 1940. One box core and one gravity core were collected for analysis from a location in the lower end of the pond in July 2000.

MAP.1 and MAP.B1 Gravity core 28 cm long and adjacent box core 16 cm deep, both analyzed for all constituents.

Basis The center of the rounded ^{137}Cs peak in gravity core MAP.1 at 12 to 15 cm (fig. A–53a) was assigned the date of 1964.0, resulting in a MAR of 0.145 g/cm^2-yr. This MAR was used to assign dates to core MAP.1. Box core MAP.B1 was sampled to a depth of 14 cm corresponding to an approximate date of about 1964 at similar depth in core MAP.1. No clear date markers were available in MAP.B1; however, the ^{137}Cs profiles were similarly shaped but activities were somewhat larger in MAP.B1 compared to MAP.1 (fig. A–53a). Dates were estimated for core MAP.B1 by adjusting the MAR to arrive at a ^{137}Cs mass accumulation profile similar to core MAP.1 (fig. A–53b).

Corroboration The rounded ^{137}Cs profile and inconclusive lead, DDT, and PCB profiles suggest postdepositional sediment mixing has affected this core. The 21-cm deep pre-reservoir boundary in MAP.1 was dated as about 1945. The sample from 18 to 21 cm overlying the boundary had moderately high concentrations of PCBs and DDT and was dated (mid-point) as 1949.6.

Rating Poor for both cores, because of evidence of sediment mixing and lack of corroboration. While mixing and low confidence in age dates limit the use of this core for trend analysis, decadal or longer estimates of contaminant accumulations could still be useful.

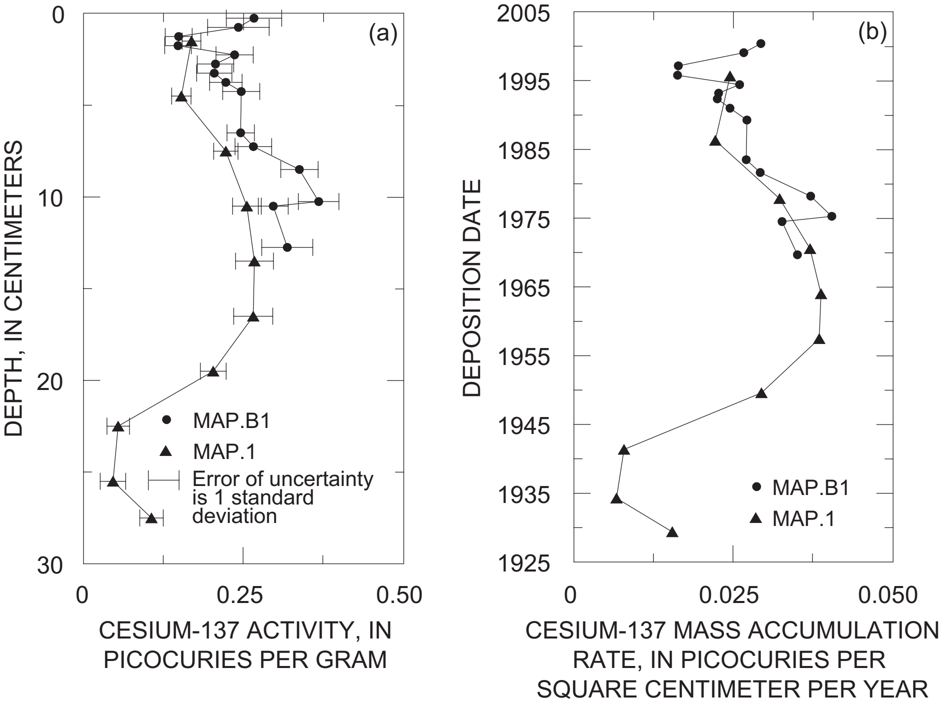


Figure A–53. Chemical constituent profiles used to estimate age dates for Maple Street Pond, Mass.

Table A–49

Core MAP.1		
Sample identification	Mid-depth (centimeters)	Estimated deposition date
MAP.1 0–3	1.5	1995.7
MAP.1 3–6	4.5	1986.3
MAP.1 6–9	7.5	1977.8
MAP.1 9–12	10.5	1970.6
MAP.1 12–15	13.5	1964.0
MAP.1 15–18	16.5	1957.5
MAP.1 18–21	19.5	1949.6
MAP.1 21–24	22.5	Pre-reservoir
MAP.1 24–27	25.5	Pre-reservoir
MAP.1 27–28	27.5	Pre-reservoir

Core MAP.B1		
Sample identification	Mid-depth (centimeters)	Estimated deposition date
MAP.B1 0.0–0.5	0.25	2000.4
MAP.B1 0.5–1.0	.75	1999.1
MAP.B1 1.0–1.5	1.25	1997.2
MAP.B1 1.5–2.0	1.75	1995.8
MAP.B1 2.0–2.5	2.25	1994.4
MAP.B1 2.5–3.0	2.75	1993.2
MAP.B1 3.0–3.5	3.25	1992.3
MAP.B1 3.5–4.0	3.75	1991.0
MAP.B1 4.0–4.5	4.25	1989.3
MAP.B1 4.5–5.0	4.75	1987.9
MAP.B1 5.0–5.5	5.25	1986.5
MAP.B1 5.5–6.0	5.75	1985.1
MAP.B1 6.0–6.5	6.25	1984.0
MAP.B1 6.5–7.0	6.75	1982.9
MAP.B1 7.0–7.5	7.25	1981.6
MAP.B1 7.5–8.0	7.75	1980.7
MAP.B1 8.0–8.5	8.25	1979.8
MAP.B1 8.5–9.0	8.75	1978.7
MAP.B1 9.0–9.5	9.25	1977.6
MAP.B1 9.5–10	9.75	1976.4
MAP.B1 10–10.5	10.25	1975.3
MAP.B1 10.5–11	10.75	1974.1
MAP.B1 11–11.5	11.25	1972.9
MAP.B1 11.5–12	11.75	1971.7
MAP.B1 12–12.5	12.25	1970.7
MAP.B1 12.5–13	12.75	1969.7
MAP.B1 13–13.5	13.25	1968.5
MAP.B1 13.5–14	13.75	1967.6

51. Harris Pond, Mass.

Harris Pond is a small reservoir located in southeastern Massachusetts north of the city of Woonsocket, R.I. Harris Pond is a supplemental water source for the city of Woonsocket, R.I. The reservoir was originally dammed in the 1880s, destroyed by a hurricane in 1954, and reconstructed in 1968. Harris Pond probably did not drain completely when the original dam was destroyed because many areas of the reservoir are poorly connected (Ann Chalmers, U.S. Geological Survey, oral commun., 2001). Three locations were sampled for chemical analysis in July 2000 in the lower (HSP.1), middle (HSP.B2), and upper (HSP.B3) parts of the reservoir.

Location lower

HSP.1 One push core 42 cm long analyzed for all constituents.

Basis The peak ^{137}Cs at 21 to 24 cm was assigned a date of 1964.0 (fig. A–54a). The average MAR for the 1964 to 2000 interval of the core of 0.18 g/cm^2-yr was used to assign dates to the core.

Corroboration The lead profile has a sharp peak that was dated as 1968.8 (fig. A–54b). Sample intervals are relatively wide in this core because of low deposition rates. The 18- to 21-cm sample covers estimated deposition from about 1966 to 1972. ^{137}Cs was detected in the deepest lacustrine sample at 24 to 27 cm, dated as 1955.6 and at the pre-reservoir surface (25 cm).

Rating Good.

Location middle

HSP.B2 One box core 29 cm deep analyzed for all constituents.

Basis The peak ^{137}Cs activity at 23 to 24 cm was assigned a date of 1964.0 (fig. A–54a). The average MAR for the 1964 to 2000 interval of the core of 0.17 g/cm^2-yr was used to assign dates to the core.

Corroboration The lead profile shows a broad high extending from the late-1950s to about 1972 (fig. A–54b). The decrease in the early 1970s is consistent with lead trends elsewhere. ^{137}Cs was detected to the deepest lacustrine sample at 27 to 28 cm and was assigned a reasonable date of 1953.4.

Rating Good.

Location upper

HSP.B3 One box core 30 cm deep analyzed for all constituents.

Basis No ^{137}Cs peak is in the ^{137}Cs activity profile, which indicates that this core does not date back to before 1964 (fig. A–54c). The lead profile has a broad high that cannot be from the 1960s and 1970s on the basis of ^{137}Cs (fig. A–54c). Lack of a clear date marker led to a decision not to assign dates to this core.

Corroboration None.

Rating No dates assigned.

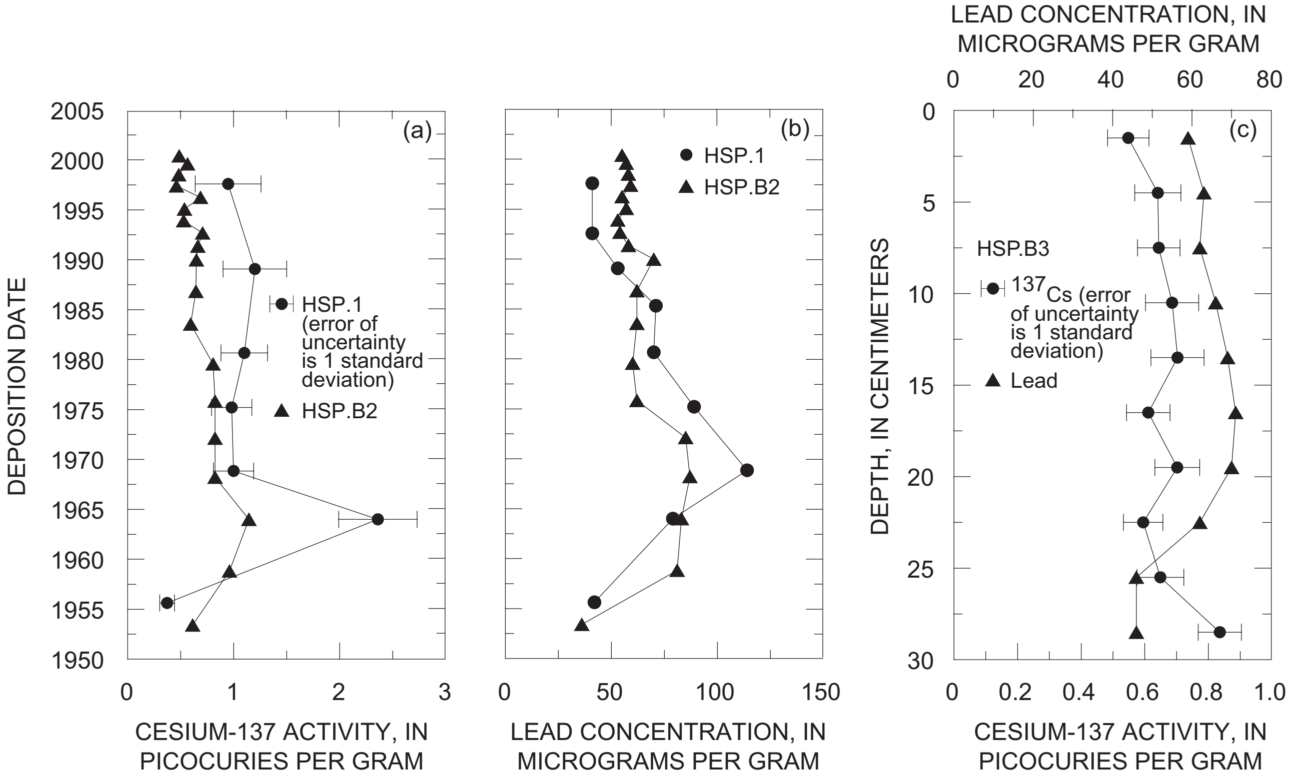


Figure A–54. Chemical constituent profiles used to estimate age dates for Harris Pond, Mass. (a) HSP.1, HSP.B2, (b) HSP.1, HSP.B2, (c) HSP.B3.

Table A–50

Core HSP.1			Core HSP.1		
Sample identification	Mid-depth (centimeters)	Estimated deposition date	Sample identification	Mid-depth (centimeters)	Estimated deposition date
HSP.1 0–3	1.5	1997.6	HSP.1 18–21	19.5	1968.8
HSP.1 3–6	4.5	1992.6	HSP.1 21–24	22.5	1964.0
HSP.1 6–9	7.5	1989.1	HSP.1 24–27	25.5	1955.6
HSP.1 9–12	10.5	1985.3	HSP.1 27–30	28.5	Pre-reservoir
HSP.1 12–15	13.5	1980.7	HSP.1 30–33	31.5	Pre-reservoir
HSP.1 15–18	16.5	1975.2	HSP.1 33–36	34.5	Pre-reservoir

Table A–50 (Continued)

Core HSP.B2			Core HSP.B2		
Sample identification	Mid-depth (centimeters)	Estimated deposition date	Sample identification	Mid-depth (centimeters)	Estimated deposition date
HSP.B2 0–1	0.5	2000.4	HSP.B2 15–16	15.5	1979.6
HSP.B2 1–2	1.5	1999.6	HSP.B2 16–17	16.5	1977.6
HSP.B2 2–3	2.5	1998.5	HSP.B2 17–18	17.5	1975.8
HSP.B2 3–4	3.5	1997.4	HSP.B2 18–19	18.5	1974.0
HSP.B2 4–5	4.5	1996.2	HSP.B2 19–20	19.5	1972.1
HSP.B2 5–6	5.5	1995.1	HSP.B2 20–21	20.5	1970.2
HSP.B2 6–7	6.5	1993.9	HSP.B2 21–22	21.5	1968.2
HSP.B2 7–8	7.5	1992.7	HSP.B2 22–23	22.5	1966.2
HSP.B2 8–9	8.5	1991.4	HSP.B2 23–24	23.5	1964.0
HSP.B2 9–10	9.5	1990.0	HSP.B2 24–25	24.5	1961.6
HSP.B2 10–11	10.5	1988.4	HSP.B2 25–26	25.5	1958.8
HSP.B2 11–12	11.5	1986.8	HSP.B2 26–27	26.5	1955.8
HSP.B2 12–13	12.5	1985.2	HSP.B2 27–28	27.5	1953.4
HSP.B2 13–14	13.5	1983.6	HSP.B2 28–29	28.5	Pre-reservoir
HSP.B2 14–15	14.5	1981.6			

52. Upper Mystic Lake, Mass.

Upper Mystic Lake is a natural lake located northwest of Boston, Mass., in the town of Winchester. The Aberjona River flows into Upper Mystic Lake and the Mystic River flows out of Lower Mystic Lake, which is immediately downstream from Upper Mystic Lake. Two locations in the northernmost lobe of the lake were sampled in August 2000—a box core was collected near the center and a gravity core was collected in the southern end of the lobe.

Location upper lake

MYS.B2 One box core 45 cm deep analyzed for all constituents.

Basis Two dating approaches were used for this core resulting in good dates for the upper part of the core but conflicting results and uncertainty for the deeper part of the core. Using the ^{137}Cs peak at 26 to 28 cm (fig. A–55a) as a marker of 1964.0 results in a MAR of 0.16 g/cm^2-yr. This MAR yields dates that are reasonably corroborated by the peak in total lead (1970–75), peaks in total DDT and PCBs (1967), and the first occurrence of chlordane, DDTs, and PCBs (1950). However, these dates are not in agreement with dates estimated using ^{210}Pb, especially in the lower part of the core (below about 30 cm). Several approaches were tried using ^{210}Pb. The unsupported ^{210}Pb profile has three breaks in slope, one at about 8 cm indicating a mixing zone to that depth, one at about 22 cm indicating a decrease in MAR below that depth, and one, defined by only two samples, suggesting a much lower MAR at the bottom of the core (36 to 40 cm) (fig. A–55a). The CRS model applied assuming the whole unsupported ^{210}Pb inventory was captured by the core resulted in a date of 1930 for the ^{137}Cs peak, an indication that the ^{210}Pb inventory is not complete. Somewhat better results were achieved using the CF:CS model, assuming the top 8 cm of the core were instantaneously mixed, and fitting two regression lines (8 to 22 cm, $r^2 = 0.974$; and 20 to 36 cm, $r^2 = 0.987$) to straight-line (on logarithmic scale) parts of the unsupported ^{210}Pb profile. The regressions yielded MARs of 0.152 and 0.089 g/cm^2-yr for the upper and lower parts of the core, respectively. These MARs, applied beginning at 8 cm (assuming a mixing zone), yield reasonable dates for the lead peak (1973–79), DDT and PCB peaks (1968), and ^{137}Cs peak (1962); however, the first (deepest) occurrence of chlordane, DDT, and PCBs was dated as 1938, several years before the synthesis of chlordane and early for the occurrence of any of the chlorinated hydrocarbons. Using the ^{137}Cs peak and assuming the same 8-cm mixing zone yields a MAR of 0.125 g/cm^2-yr and a closer match between ^{137}Cs and ^{210}Pb dates (fig. A–55b). On the basis of these interpretations, the CF:CS ^{210}Pb model was concluded to be the best choice for the upper part of the core. The range in dates estimated for the lower part of the core between the ^{137}Cs and the ^{210}Pb models was used as estimated ranges of age, and specific dates were not assigned.

Corroboration Both models yield reasonable corroborated results back into the early 1960s; however, apparent disagreement between the pre-1960 ^{210}Pb dates and occurrence of organochlorine compounds causes more uncertainty deeper in the core. Spliethoff and Hemond (1996) had somewhat similar results in dating a core from the main body of Upper Mystic Lake, south of the upper embayment of the lake where these cores were collected. Their core had a log-linear profile of ^{210}Pb to about 45 cm, then a sharp drop and increase in the variability in unsupported ^{210}Pb below that depth. They suggested that land disturbance in the watershed in the early 1900s could be the cause of the unusual ^{210}Pb profile deeper in the core. They matched trace element contaminant peaks in the lower part of the core to historical industrial activity in the watershed during 1910–20 and assigned dates that implied a much smaller sedimentation rate prior to about 1940. Even though results in this report indicate that a smaller sedimentation rate is indicated by ^{210}Pb prior to about the 1950s, there is considerable uncertainty in the estimated dates for this part of the core.

Rating Good, to about 28 cm depth and 1960; fair below that depth.

Location lower lake

MYS.2 One gravity core 49 cm long analyzed for organic compounds.

Basis Only three samples were analyzed.

Rating No dates assigned.

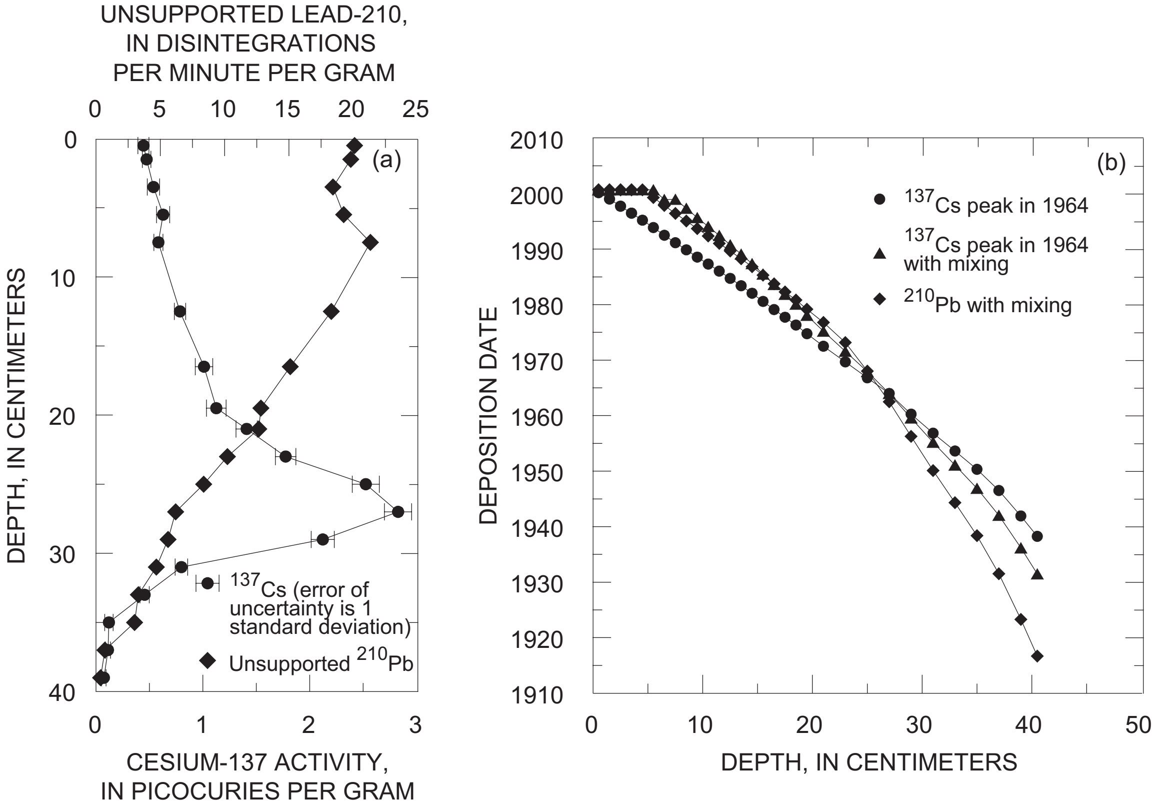


Figure A–55. (a) Chemical constituent profiles used to estimate age dates for Upper Mystic Lake, Mass.; and (b) comparison of age dates computed using three different methods for Upper Mystic Lake, Mass.

Table A–51

Core MYS.B2			Core MYS.B2		
Sample identification	Mid-depth (centimeters)	Estimated deposition date	Sample identification	Mid-depth (centimeters)	Estimated deposition date
MYS.B2 0–1	0.5	2000.7	MYS.B2 16–17	16.5	1983.8
MYS.B2 1–2	1.5	2000.7	MYS.B2 17–18	17.5	1982.3
MYS.B2 2–3	2.5	2000.7	MYS.B2 18–19	18.5	1980.8
MYS.B2 3–4	3.5	2000.7	MYS.B2 19–20	19.5	1979.2
MYS.B2 4–5	4.5	2000.7	MYS.B2 20–22	21	1976.8
MYS.B2 5–6	5.5	1999.3	MYS.B2 22–24	23	1973.2
MYS.B2 6–7	6.5	1997.8	MYS.B2 24–26	25	1968.0
MYS.B2 7–8	7.5	1996.4	MYS.B2 26–28	27	1962.5
MYS.B2 8–9	8.5	1995.1	MYS.B2 28–30	29	1956–60
MYS.B2 9–10	9.5	1993.7	MYS.B2 30–32	31	1950–55
MYS.B2 10–11	10.5	1992.4	MYS.B2 32–34	33	1944–51
MYS.B2 11–12	11.5	1991.0	MYS.B2 34–36	35	1938–47
MYS.B2 12–13	12.5	1989.7	MYS.B2 36–38	37	1932–42
MYS.B2 13–14	13.5	1988.3	MYS.B2 38–40	39	1923–36
MYS.B2 14–15	14.5	1986.8	MYS.B2 40–41	40.5	1917–32
MYS.B2 15–16	15.5	1985.3			

53. Charles River, Mass.

The Charles River begins in southern Massachusetts, flows north through the city of Boston, Mass., and empties into the Boston Harbor. The river is impounded by the Charles River dam (constructed in 1908) in central Boston, just upstream from the Boston Inner Harbor. Two box cores were collected for chemical analysis in July 2000 in the lower (CHA.B1) and upper (CHA.B2) parts of the impounded reach of the Charles River in central Boston. Location CHA.B1 is downstream from the Harvard Bridge and adjacent to the Massachusetts Institute of Technology campus. Location CHA.B2 is downstream from the John Weeks Bridge and adjacent to the Harvard University campus.

Location lower

CHA.B1 Box core 48 cm deep analyzed for all constituents.

Basis Breault and others (2000) reported the thickness of post-1908 lacustrine sediment overlying a stiff gray clay at the site to be between 1 and 1.5 m. A 70-cm gravity core collected during this study at the site did not reach the clay. The box core had detectable concentrations of ^{137}Cs and organochlorine compounds to the bottom, indicating dates of the 1950s at the oldest. A small ^{137}Cs activity peak at 30 to 32 cm (fig. A–56a) was assigned a date of 1964.0 resulting in a MAR of 0.70 g/cm^2-yr. This MAR was used to assign dates to the core.

Corroboration The variable lead profile has a rounded peak in the 1960s and early 1970s, with a decrease in lead concentrations in the late 1970s (fig. A–56b). Both PCBs and total DDT peak at 28 to 32 cm, an interval assigned a reasonable date of 1965.2 (fig. A–56b).

Rating Fair. The reasonable corroboration of dates is offset by the relatively small ^{137}Cs peak and profile that suggest postdepositional mixing.

Location upper

CHA.B2 Box core 45 cm deep analyzed for all constituents.

Basis Breault and others (2000) reported the thickness of post-1908 lacustrine sediment at the site to be about 0.5 m. The box core had detectable concentrations of ^{137}Cs and organochlorine compounds to the bottom, indicating dates of the 1950s at the oldest. The ^{137}Cs activity had a small peak at 18 to 19 cm and increasing activities in the bottom 14 cm (fig. A–56a). Lack of a clear 1964 ^{137}Cs peak or corroborative lead, DDT, or PCB peaks resulted in a decision not to assign dates to this core.

Rating No dates assigned.

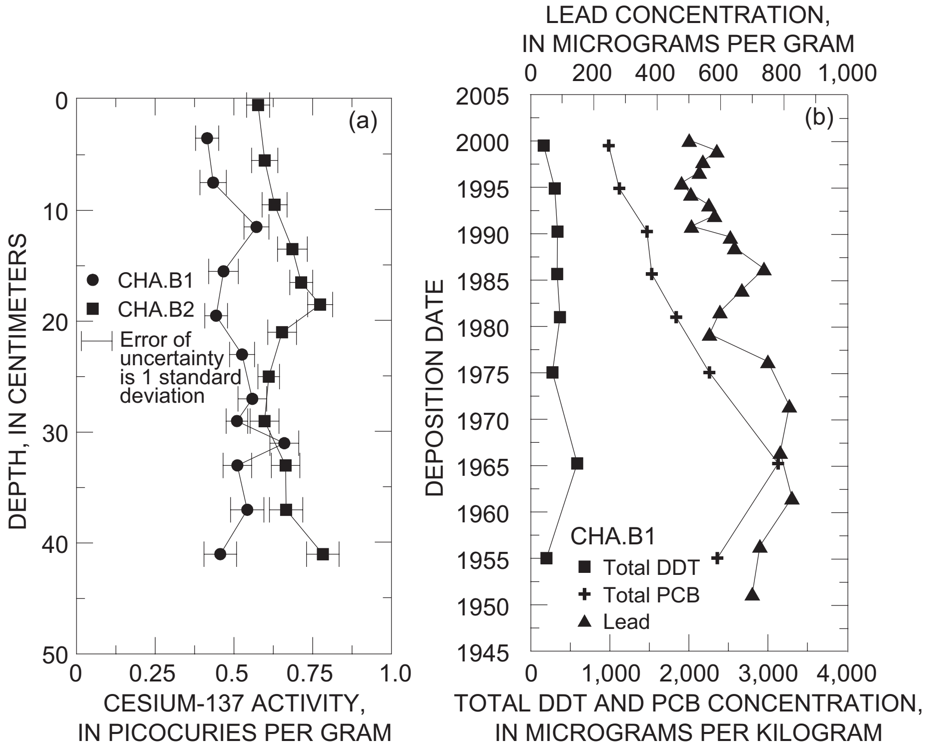


Figure A–56. Chemical constituent profiles used to estimate age dates for Charles River, Mass.

Table A–52

Core CHA.B1		
Sample identification	Mid-depth (centimeters)	Estimated deposition date
CHA.B1 0–1	0.5	2000.1
CHA.B1 1–2	1.5	1998.9
CHA.B1 2–3	2.5	1997.8
CHA.B1 3–4	3.5	1996.7
CHA.B1 4–5	4.5	1995.5
CHA.B1 5–6	5.5	1994.3
CHA.B1 6–7	6.5	1993.1
CHA.B1 7–8	7.5	1992.0
CHA.B1 8–9	8.5	1990.8
CHA.B1 9–10	9.5	1989.7
CHA.B1 10–11	10.5	1988.5
CHA.B1 11–12	11.5	1987.4
CHA.B1 12–13	12.5	1986.2
CHA.B1 13–14	13.5	1985.1
CHA.B1 14–15	14.5	1983.9
CHA.B1 15–16	15.5	1982.8
CHA.B1 16–17	16.5	1981.6
CHA.B1 17–18	17.5	1980.4
CHA.B1 18–19	18.5	1979.2
CHA.B1 19–20	19.5	1978.0
CHA.B1 20–22	21	1976.2
CHA.B1 22–24	23	1973.8
CHA.B1 24–26	25	1971.5
CHA.B1 26–28	27	1969.0
CHA.B1 28–30	29	1966.5
CHA.B1 30–32	31	1964.0
CHA.B1 32–34	33	1961.5
CHA.B1 34–36	35	1959.0
CHA.B1 36–38	37	1956.3
CHA.B1 38–40	39	1953.7
CHA.B1 40–42	41	1951.2
CHA.B1 42–44	43	1948.5

54. South Reservoir, Mass.

South Reservoir is one of three reservoirs in the Winchester Waterworks and provides drinking water for the town of Winchester, Mass., which is located on the northwestern edge of Boston, Mass. The reservoir is surrounded by public park land known as the Middlesex Fells Reservation. The exact construction date of South Reservoir could not be obtained, although it is believed to have existed since the late 1800s on the basis of historical photographs. One box core was collected for analysis from the southern end of the reservoir in September 2000.

SRV Box core 18 cm deep analyzed for all constituents.

Basis This core was age dated using ^{210}Pb and the CIC model. This model was chosen because the logarithmic plot of unsupported ^{210}Pb and cumulative mass in the core fit a straight line (fig. A–57) and the full unsupported ^{210}Pb inventory was not measured, making application of the CRS model problematic. The MAR computed from the least-squares regression fit of unsupported ^{210}Pb and mass is 0.015 g/cm^2-yr, and a date of 1931.2 was estimated for the deepest sample analyzed (10.5 to 11 cm).

Corroboration The ^{137}Cs profile suggests substantial postdepositional mixing in this core; however, unsupported ^{210}Pb does not. The sediments are dominated by organic matter and not clays; therefore, it is suspected that ^{137}Cs does not bind well to sediments and some is desorbing and diffusing in the sediments. Lead, DDT, and PCB profiles indicate mixing and provide no corroboration of specific dates.

Rating Fair, because of possible sediment mixing and lack of corroboration.

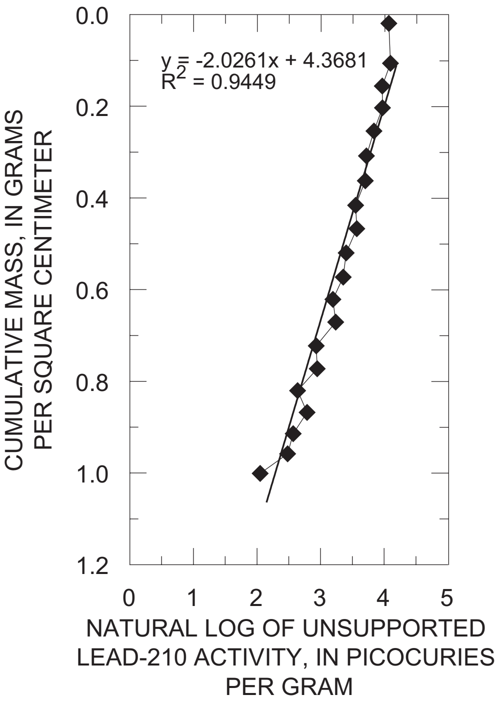


Figure A–57. Regression line fit to unsupported ^{210}Pb and used to estimate age dates for South Reservoir, Mass.

Table A–53

Core SRV			Core SRV		
Sample identification	Mid-depth (centimeters)	Estimated deposition date	Sample identification	Mid-depth (centimeters)	Estimated deposition date
SRV 0.0–0.5	0.25	1999.5	SRV 5.5–6.0	5.75	1962.6
SRV 0.5–1.0	.75	1996.8	SRV 6.0–6.5	6.25	1959.3
SRV 1.0–1.5	1.25	1993.7	SRV 6.5–7.0	6.75	1956.0
SRV 1.5–2.0	1.75	1990.3	SRV 7.0–7.5	7.25	1952.6
SRV 2.0–2.5	2.25	1987.2	SRV 7.5–8.0	7.75	1949.3
SRV 2.5–3.0	2.75	1983.8	SRV 8.0–8.5	8.25	1946.1
SRV 3.0–3.5	3.25	1980.2	SRV 8.5–9.0	8.75	1942.9
SRV 3.5–4.0	3.75	1976.6	SRV 9.0–9.5	9.25	1939.8
SRV 4.0–4.5	4.25	1973.0	SRV 9.5–10	9.75	1936.9
SRV 4.5–5.0	4.75	1969.6	SRV 10–10.5	10.25	1934.0
SRV 5.0–5.5	5.25	1966.1	SRV 10.5–11	10.75	1931.2

55. Basin Brook Pond, N.H.

Basin Brook Pond is a small reservoir, constructed in 1969 (Dale Guinn, New Hampshire Department of Environmental Services, Dam Safety Division, oral commun., 2003), in the White Mountain National Forest, N.H. One box core was collected for chemical analysis from the lower area of the reservoir in August 2000.

BBP One box core 3.5 cm deep analyzed for all constituents.

Basis There was a clear pre-reservoir boundary in this short box core at 3.0 cm. A date of 1969.0 at 3.0 cm resulted in a MAR of 0.031 g/cm^2-yr that was used to assign dates.

Corroboration This remote lake core does not have a clear lead peak, and organochlorine compounds were not measured. The ^{137}Cs activity has a small peak at 1.5 to 2.0 cm (fig. A–58) that is dated as mid-1980s that neither supports nor refutes assigned dates. The smallest ^{137}Cs activity and organic carbon concentration are in the pre-reservoir material (3.0 to 3.5 cm) and both increase between 3.5 and 2 cm. Smaller organic carbon concentrations in the 2- to 3-cm intervals suggest that the apparent ^{137}Cs peak at 1.5 to 2.0 cm is caused by mixing of pre-reservoir material and lake sediment in the 2- to 3-cm intervals.

Rating Poor, because of the short core and the lack of independent corroboration of dates.

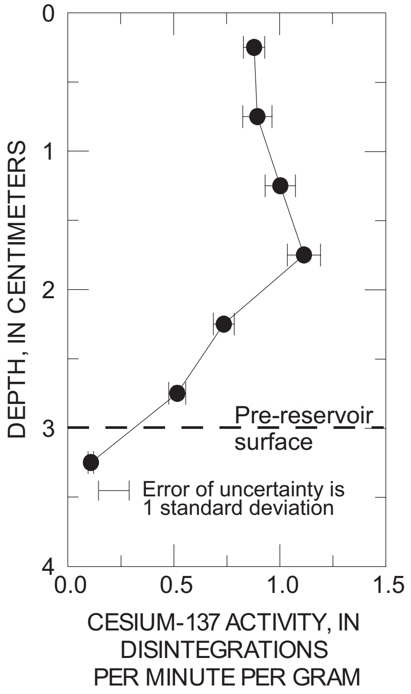


Figure A–58. Chemical constituent profile used to support age dates for Basin Brook Pond, N.H.

Table A–54

Core BBP			Core BBP		
Sample identification	Mid-depth (centimeters)	Estimated deposition date	Sample identification	Mid-depth (centimeters)	Estimated deposition date
BBP 0–0.5	0.25	1999.2	BBP 2–2.5	2.25	1981.0
BBP 0.5–1	.75	1995.8	BBP 2.5–3	2.75	1973.5
BBP 1–1.5	1.25	1991.7	BBP 3–3.5	3.25	Pre-reservoir
BBP 1.5–2	1.75	1986.9			

56. Crocker Pond, Maine

Crocker Pond is a small natural lake located in the White Mountain National Forest in southwestern Maine. One box core was collected for chemical analysis from the center of the lake in August 2000.

CRK.B1 Box core 13.5 cm deep analyzed for all constituents.

Basis The core was age dated using ^{210}Pb and the CRS model (Appleby and Oldfield, 1992). The core was sampled to a depth of 11 cm with the deepest sample dated as about 1830. ^{210}Pb dates were considered to be reliable to about 100 years old, and a date of 1905.2 was assigned to the 8- to 9-cm sample. MARs computed from the CRS model increase from about 0.003 g/cm^2-yr at the 8- to 9-cm interval to 0.017 g/cm^2-yr at the top of the core.

Corroboration The maximum ^{137}Cs activity at 4.5 to 5.0 cm received a reasonable date of 1961.0; however, the ^{137}Cs profile indicates either postdepositional sediment mixing or leaching of ^{137}Cs (fig. A–59). Some mixing over the top 2 cm also is indicated by the unsupported ^{210}Pb profile (fig. A–59).

Rating Fair, because of sediment mixing.

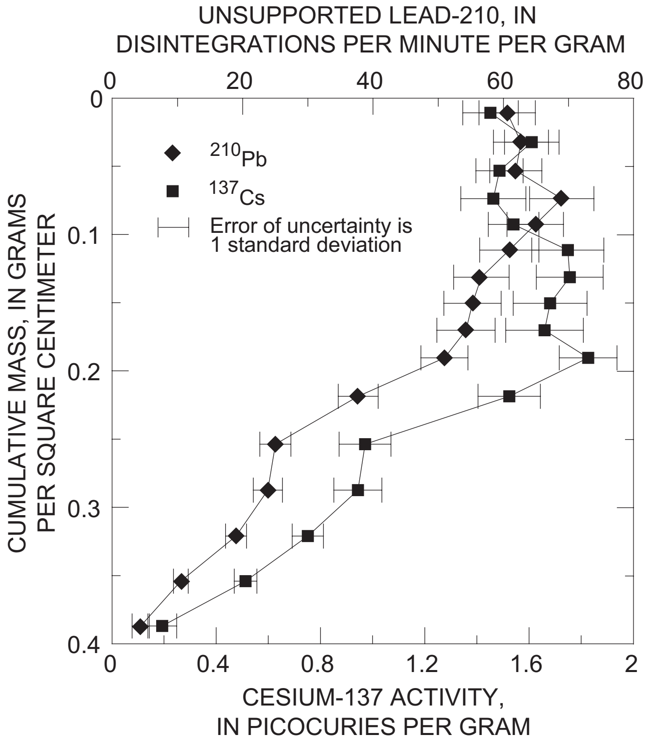


Figure A–59. Chemical constituent profiles used to estimate age dates for Crocker Pond, Maine.

Table A–55

Core CRK.B1			Core CRK.B1		
Sample identification	Mid-depth (centimeters)	Estimated deposition date	Sample identification	Mid-depth (centimeters)	Estimated deposition date
CRK.B1 0.0–0.5	0.25	1999.4	CRK.B1 4.0–4.5	4.25	1967.6
CRK.B1 0.5–1.0	.75	1996.5	CRK.B1 4.5–5.0	4.75	1961.0
CRK.B1 1.0–1.5	1.25	1993.4	CRK.B1 5–6	5.5	1951.5
CRK.B1 1.5–2.0	1.75	1989.9	CRK.B1 6–7	6.5	1939.2
CRK.B1 2.0–2.5	2.25	1986.2	CRK.B1 7–8	7.5	1925.5
CRK.B1 2.5–3.0	2.75	1982.2	CRK.B1 8–9	8.5	1905.2
CRK.B1 3.0–3.5	3.25	1977.8	CRK.B1 9–10	9.5	1875.4
CRK.B1 3.5–4.0	3.75	1973.1	CRK.B1 10–11	10.5	1829.1

Prepared by the Texas District Office:
U.S. Geological Survey
8027 Exchange Drive
Austin, TX 78754–4733

Information regarding water resources in Texas is available at URL
http: //tx.usgs.gov/