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

Water-Quality Trends Using Sediment Cores from White Rock Lake, Dallas, Texas

Introduction

The U.S. Geological Survey National Water-Quality Assessment (NAWQA) Program has three objectives, one of which is "to define trends (or lack of trends) in water quality" (Leahy and others, 1990). Water-quality trends are of interest for at least three reasons: First, trends can improve our understanding of the influence of human activities on water-quality conditions; second, trends can indicate the effectiveness of environmental regulations; and third, trends can provide a warning of additional degradation of water quality in the future. A common approach for determining water-quality trends in streams is to apply statistical tests to historical data; however, historical water-quality data have several limitations. These include lack of data, inconsistent sampling and analytical methods, numerous measurements below detection levels, and questionable accuracy. If historical data are lacking or are inappropriate for statistical trend testing, water-quality records can be partly reconstructed using sediment cores from receiving water bodies such as reservoirs.

The purpose of this fact sheet is to summarize the principal findings documented in a report on water-quality trends in White Rock Creek Basin using dated sediment cores from White Rock Lake (Van Metre and Callender, in press). The study used dated sediment cores to reconstruct water-quality conditions. More specifically, the changes in water quality associated with the watershed's change from agricultural to urban land use and with the implementation of environmental regulations were identified.

Figure 1. White Rock Lake, downtown Dallas, and Trinity River, Sept. 25, 1991. In the foreground, sediment-laden water from the previous day's rain is concentrated in the pre-reservoir stream channel and diffuses through the shallow zones to the sides. The boundary separating the sediment-laden water and the clear water in the lower one-half of the lake is believed to be caused by a difference in density related to water-temperature differences between lake water and stream water.

Setting

White Rock Lake (fig. 1) is located on White Rock Creek, which is in the northeastern part of Dallas, Tex. White Rock Creek flows approximately south and is a tributary to the Trinity River. The reservoir was constructed in 1912 for water supply and was used for this purpose until 1964. Since then, it has been used primarily for recreation. The original capacity of White Rock Lake was 18,000 acre-feet, but sedimentation had reduced the capacity to 9,000 acre-feet by 1994. The lake has a drainage area of about 100 square miles and an original surface area of 2.0 square miles at normal pool elevation. Parts of White Rock Lake have been dredged four times in its history, most recently in 1974.

The White Rock Creek watershed in 1990 was dominated by urban land use (fig. 2). When White Rock Lake was constructed, land use in the watershed was dominated by agriculture, as can be inferred from a 1920 Soil Conservation Service map (fig. 3). During the agricultural era that ended in the mid-1950s, soil-conservation practices were uncommon; so, by the late-1930s, soil erosion had adversely affected more than 90 percent of the watershed. Intensive growth in population and the associated shift in land use followed World War II (fig. 4).

Sediment is washed off the land surface into streams during rain storms. Much of it is deposited in White Rock Lake. Over time, sediments have accumulated to form a thick layer on the bottom of White Rock Lake (more than 8 feet thick in the deepest part of the lake).

The chemistry of discrete slices of the sediment can provide historical information on water-quality conditions (Charles and Hites, 1987) just as tree rings can provide insight to historical climatic conditions.

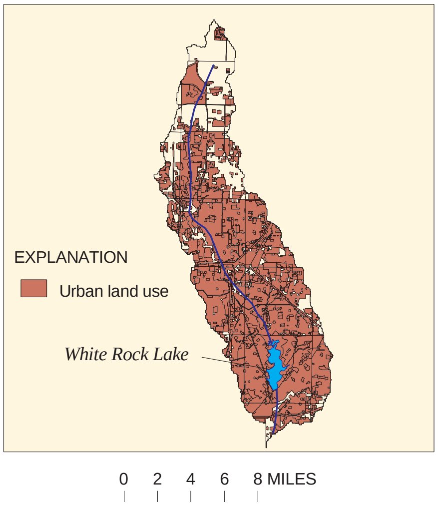

Figure 2. A 1990 land-use map of White Rock Creek Basin prepared by the North Central Texas Council of Governments.

Collecting and Analyzing Sediment Cores

Cores penetrating the whole sequence of reservoir sediment (fig. 5) were collected in July 1994 approximately 0.25 mile north of the dam and in the prereservoir flood plain west of the old White Rock Creek streambed. The sediment cores were collected by a gravity corer and a box corer from a custom-built coring boat. The boat is a 24-foot aluminum-decked pontoon boat with a 15-foot A-frame extending over a cut-out in the front deck. The coring tools are lowered and raised with a hydraulic winch. The gravity corer is 2.5 inches in diameter and can take cores as long as 13 feet. The box corer is 6 inches square and 8 inches tall.

Several cores had to be collected to provide sufficient material for the laboratory analyses. One core was split and its physical characteristics were described on site (fig. 6). Discrete horizontal slices of sediment cores were analyzed for organochlorine insecticides and industrial compounds, cesium-137, major and minor elements, grain size, diatoms, and pollen.

Age Dating

The top of the core was assigned the sampling date (July 1994), and the bottom of the lake sediments was assigned the reservoir construction date (1912). The sediments deposited during 1952–64 were identified by concentrations of radioactive cesium-137, which is a by-product of nuclear weapons testing. Measurable concentrations of this isotope first appeared in the atmosphere in about 1952, with the advent of large-scale weapons testing, and peaked during 1963–64 (fig. 7).

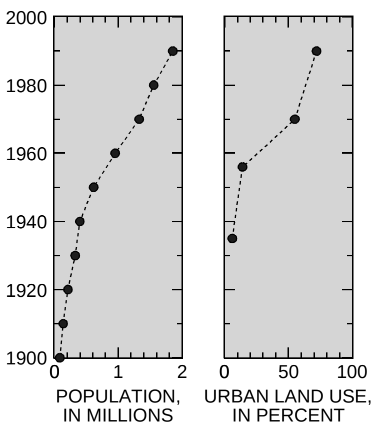

Figure 4. Population in Dallas County and percent urban land use in White Rock Creek watershed.

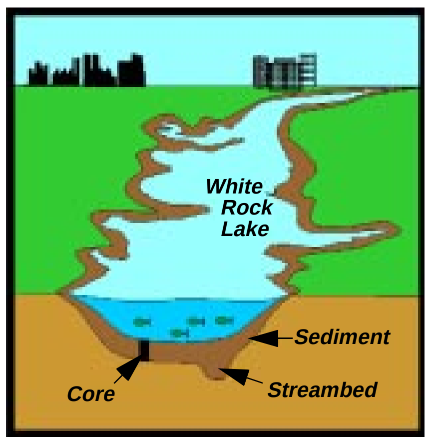

Figure 5. Schematic showing the accumulation of sediment on the bottom of White Rock Lake.

Figure 6. Photo of a sediment core that has been split and readied for sampling.

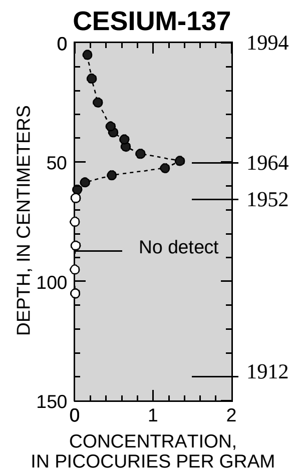

Figure 7. Cesium-137 was used for age dating.

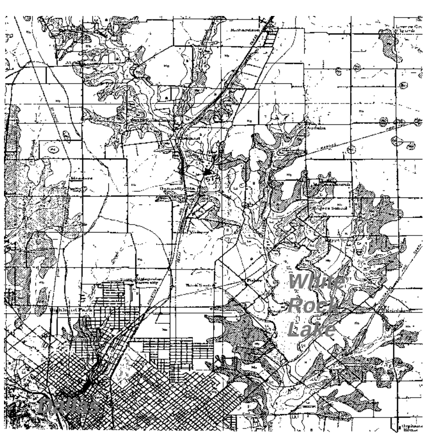

Figure 3. A 1920 map prepared by the U.S. Department of Agriculture, Soil Conservation Service. (Shaded areas indicate riparian vegetation.)

Sedimentation

A change in erosional processes coinciding with urban development is indicated by decreasing sedimentation rates, decreasing vertical variations in particle size, and changes in concentrations of major elements. Using measured porosities and an assumed density of solids of 2.5 grams per cubic centimeter, average sedimentation rates are 1.1, 0.66, and 0.76 grams per square centimeter per year for the periods 1912–52, 1953–63, and 1964–94, respectively. Sedimentation rates and major element concentrations suggest (1) rapid, episodic soil erosion during the agricultural land-use era (1912 to mid-1950s), which is indicated by higher sedimentation rates, generally lower concentrations of calcium, higher concentrations of aluminum, and larger variability in major-ion concentrations and clay content; and (2) a reduction in soil erosion since the onset of urbanization in the mid-1950s, with newer sediments containing progressively less clay, which correlates with a decrease in aluminum and an increase in calcium.

Trace Elements

Concentrations of three trace elements (arsenic, lead, and zinc) were normalized with respect to aluminum by dividing concentration of the element by the concentration of aluminum. Because aluminum is a major element of rock-forming minerals, normalization "corrects" trace metal data for variations in geologic source and allows the highlighting of concentrations that might be related to human activities.

After remaining relatively constant from 1912 to about 1952, normalized concentrations of arsenic, lead, and zinc began to increase (fig. 8). From 1952 to 1994, normalized arsenic concentrations increased by about 75 percent and zinc concentrations increased by about 65 percent. Normalized lead concentrations increased by a factor of about six from 1952 to about 1976, coinciding with rapid urbanization and economic growth in the White Rock Creek watershed and the accompanying increase in use of leaded gasoline. After about 1976, normalized lead concentrations decreased about 60 percent, coinciding with the replacement of leaded gasoline with unleaded gasoline, and reached a relatively constant level in the mid-1980s.

Organochlorine Compounds

DDT, DDE, and DDD

Organochlorine compounds generally are characterized by great persistence and toxicity in the environment.

Use of the organochlorine insecticide DDT began in 1939. Its use peaked in the 1960s and widespread use continued until about 1970, just before its use was banned in 1972. DDT breaks down to DDE and DDD, which also are toxic and are very resistant to further chemical decomposition. DDD was detected in White Rock Lake sediments that were deposited as early as about 1942. DDE was detected in all sediment samples deposited since about 1945. Concentrations of total DDT (sum of DDT, DDE, and DDD) peak in White Rock Lake sediments deposited in about 1963 and decrease by more than a factor of 10 from 1963 to 1994 (fig. 9). Detection of DDD and DDE in the upper parts of the core indicates that DDT metabolites continue to enter White Rock Lake, presumably associated with soils eroded from the basin.

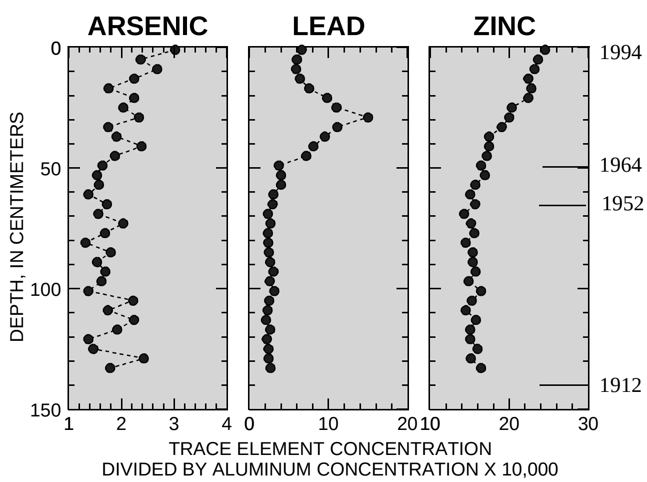

Figure 8. Concentrations of arsenic, lead, and zinc that have been normalized with aluminum.

Chlordane

Chlordane, an insecticide, was introduced in 1947. Environmental concerns resulted in a series of U.S. Environmental Protection Agency restrictions beginning with agricultural use in the 1970s and the cancellation of virtually all uses in April 1988. Chlordane was detected in White Rock Lake sediments deposited as early as about 1964. Concentrations continually increase in sediments deposited from about 1970 to a maximum concentration in sediments deposited in about 1990. A slight decline was noted in the most recent (1994) sample. The predominance of urban land use in the basin and the permitted applications indicate that chlordane in White Rock Lake mainly results from applications in urban areas.

PCBs

Polychlorinated biphenyls (PCBs) have been used as plasticizers, as hydraulic lubricants in gas turbines and vacuum pumps, in heat-transfer systems, and as dielectric fluids in electrical transformers and capacitors since the early 1930s. Annual sales peaked in 1970. Following the voluntary ban on PCBs in open systems in 1971, use declined by about 50 percent by 1973. In 1979, all new uses of PCBs were banned. PCBs in the sediment core from White Rock Lake were not detected in sediment deposited before the mid-1940s. Concentrations increase sharply in sediments deposited after about 1950, peak in sediments deposited in the late-1960s, then decrease to about 15 percent of the peak concentration in sediments deposited in about 1994. Changes in PCB concentrations in White Rock Lake sediments

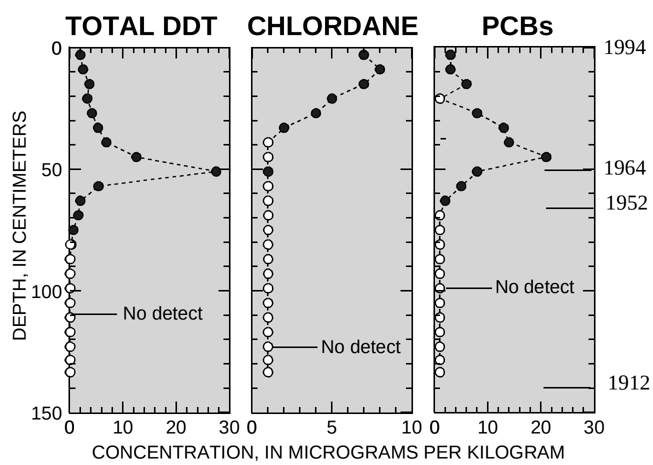

Figure 9. Concentrations of total DDT, chlordane, and PCBs show the use and persistence of organochlorine compounds.

appear to correlate well with sales and regulation of PCBs in the United States.

Implications for Water Quality

The chemical quality of streams and ground water is the result of many natural and human factors. Two human factors that affect the occurrence of contaminants are use and regulation. Intensive use of naturally occurring elements or synthetic chemicals leads to releases of these potential contaminants into the environment and can cause a variety of environmental hazards. Control of the entry of these contaminants into the environment through regulation of their use can greatly reduce the amount of these potential contaminants in the environment; or over time, eliminate them altogether.

The study of the sediment cores from White Rock Lake and a review of the use of the elements and compounds and governmental regulations indicate that:

- Environmental regulations can be successful at eliminating or reducing the entry of some toxic contaminants into aquatic systems. This conclusion is supported by the large decreases in concentrations of lead, DDT, and PCBs in White Rock Lake sediments since restriction of their use. However, the environmental response to regulation can be slow, and in some cases might take decades to complete.
- If a metal such as lead, pesticides such as DDT and chlordane, or industrial organic compounds such as PCBs are in widespread use, the elements or compounds will eventually reach streams. The amount reaching the streams appears to be in proportion to its use.
- Environmentally persistent toxic organic compounds, such as DDT, chlordane, and PCBs, will remain in the environment, often in the sediment of streams and reservoirs, long after uses have been restricted.

Summary

White Rock Lake is a 2.0-square-mile reservoir in Dallas, Tex., and has a drainage area of 100 square miles. The watershed was predominantly agricultural before about 1950. Since then, it has undergone urban development, which dominated land use by 1990.

Cores of sediment deposited from 1912 to 1994 were dated using an isotope of cesium. Sedimentation rates and the percentage of clay-sized particles in sediments have decreased since the early 1950s. Trace-element concentrations also have changed in response to changing land use. About a six-fold increase in normalized lead concentrations occurs in sediments deposited from 1952 to about 1976, followed by about a 60-percent decline in sediments deposited since the advent of unleaded gasoline. Zinc increases by about 65 percent in sediments deposited from about 1952 to 1994. No organochlorine compounds were detected in sediments deposited before about 1942. The DDT metabolites DDD and DDE were detected in all sediment samples deposited after about 1945. Total DDT peaks in sediments deposited in about 1963, about the time the use of DDT peaked. Concentration of total DDT in the most recent sample (1994) has decreased by more than a factor of 10 from the peak concentration. Chlordane concentrations increase in sediments deposited during the 1970s and 1980s and peak in sediments deposited in about 1990. Agricultural use of chlordane was restricted in the 1970s; however, urban use continued until virtually all uses were cancelled in 1988. Concentrations of PCBs first appear in sediments deposited in about 1950 and peak in sediments deposited in the late-1960s, followed by a decrease to about 15 percent of the peak concentration in the sample of 1994 sediments.

References

Charles, M.J., and Hites, R.A., 1987, Sediments as archives of environmental pollution trends, *in* Hites, R.A., and Eisenreich, S.J., eds., Advances in chemistry series 216—Sources and fates of aquatic pollutants: Washington, D.C., American Chemical Society, 558 p.

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.

Van Metre, P.C., and Callender, E., in press, 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.

—P.C. Van Metre, L.F. Land, and C.L. Braun

Information on technical reports and hydrologic data related to the NAWQA Program can be obtained from:

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Austin, Texas 78754–3898

The National Water-Quality Assessment Program

The U.S. Geological Survey began the NAWQA Program in 1991 to assess the status and trends in the quality of the Nation's streams and aquifers. The program is designed to enhance understanding of natural and human factors that influence water quality, and consists of studies in 60 major river basins and aquifers of the United States. Together, the 60 studies compose about one-half of the land area of the United States and 60 to 70 percent of the water use and population served by public water supplies. The similar design of each study and use of consistent methods allow comparisons at regional and national scales. This information is being used to guide policy and to manage water resources at the national, State, and local levels.