Methods for Measuring Sedimentation Rates in Bottomland Hardwood (BLH) Wetlands

PURPOSE: This note describes four methods that can be used to measure sedimentation rates in BLH forests and other wetland systems. These are: a modified sediment trap method, called a sediment disk; use of a feldspar clay marker horizon; use of ^{137}cesium for dating cores; and a dendrogeomorphic method. The advantages and disadvantages of the methods are discussed and their application to wetland regulation and evaluation considered.

BACKGROUND: A comprehensive study examining the physical, chemical, and biological functions of a BLH wetland forest adjacent to the Cache River in eastern Arkansas was initiated by the U.S. Army Engineer Waterways Experiment Station in 1986. It was postulated that in highly turbid waterways such as the Cache River, one of the primary water quality functions of the wetland system involved the removal of sediments suspended in the water column and the subsequent removal of the nutrients and contaminants associated with the suspended sediments. Accordingly, a study was designed to describe the sedimentation patterns occurring within the BLH forest.

APPROACH: Four methods of measuring sedimentation were employed to determine their usefulness in evaluating sedimentation rates in wetlands and to quantify these rates. These methods range from relatively expensive and time consuming to inexpensive and quick, and also differ in the time period they are designed to assess.

- Modified Sediment Trap Method. Numerous reports are available regarding the proper way to design and install sediment traps in limnological and oceanographic research situations. Many of these reports recommend submerging into the water body a cylindrical column that is approximately five times as tall as it is wide. These 5:1 aspect ratio columns are designed to prevent any resuspension of the trapped material.

  It was decided that this design was not appropriate for a BLH system for several reasons. For example, water fluctuations can be so drastic that it would be difficult to install the cylinders at a depth where they stay submerged throughout a sampling period. The fluctuating water levels would also make it difficult to know just what portion of the water column was being sampled. Perhaps, most importantly, the resuspension of materials is a significant aspect of the sedimentation patterns of these wetland types, and high-aspect ratio sediment traps can overestimate net sedimentation.

  Therefore, "sediment plates" instead of sediment traps were designed and positioned in the field. These plates are 15-cm-diameter Plexiglas circles, with about a 1-cm hole in the middle. The upper surface of the plate is sanded so that sediments will not be washed off because of a smooth surface, but natural resuspension can occur. To anchor the disks to the surface, a 30-cm-long threaded steel rod was hammered into the ground, the disk was placed over the rod, and a washer and wing nut were used to secure the disk to the rod (see Figure 1). Minor adjustments can be made to get the disk even with the ground. Each disk was placed a known distance and direction from a PVC rod that had been securely pounded into the ground to aid in relocating the disks later.

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **JAN 1993**	2. REPORT TYPE	3. DATES COVERED **-**

4. TITLE AND SUBTITLE **Methods for Measuring Sedimentation Rates in Bottomland Hardwood (BLH) Wetlands**	5a. CONTRACT NUMBER
	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Army Engineer Waterways Experiment Station,3909 Halls Ferry Road,Vicksburg,MS,39180-6199**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT
see report

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**		**7**	

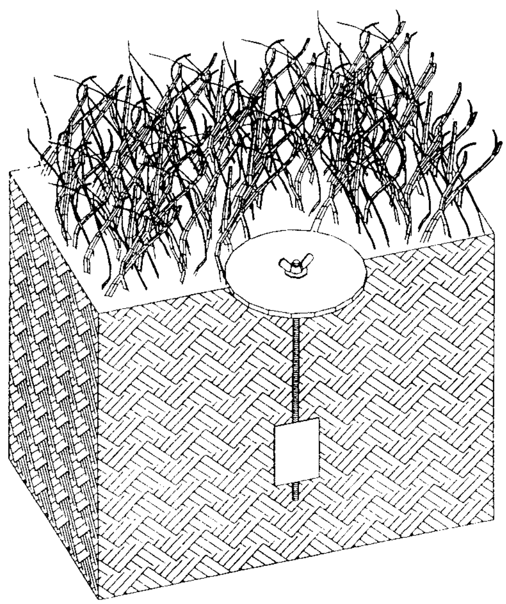

Figure 1. Schematic diagram of Plexiglas sediment disk

The sampling frequency was determined by the hydrology of the system. Annual sampling was used in a BLH system to allow the disks to collect sediment from one low-water period to the next. At sampling sites with high sedimentation rates, the disks were often completely buried (Figure 2). If sediment buried a disk, the approximate location of the disk was determined with a compass and tape measure, and then a sharp object was pushed into the sediment until Plexiglas was "hit." The accumulated material was collected by cutting around the edge of the disk with a knife and scooping the material into a zipper-lock bag with a spatula. The collected sediment was later dried and weighed in the laboratory. The depth of the ground surface above the disk surface was measured in the field, and the ground surface immediately surrounding the disk was smoothed out or the disk elevated to the new ground level so that the old deposition did not erode onto the disk.

This method is simple, provides the possibility of easy replication at each site, and provides a straightforward way of collecting annually deposited sediments for particle size analysis or chemical analysis. The sediment disks are relatively inexpensive to construct and easy to install. There is the disadvantage, however, of having to return to the sites to make repeated measurements. Additionally, while the disks seem to work very well in areas with high sedimentation, there does seem to be a tendency toward underestimation in areas with low sedimentation because small amounts of sediment can be washed off the disks during heavy rainfall.

- Feldspar Clay Marker Horizons. Researchers at Louisiana State University have used the feldspar clay method extensively in the marshes in south Louisiana (Baumann 1980; Baumann, Day, and Miller 1984; Cahoon and Turner 1989). Feldspar clay is a very white material composed of silt and clay size particles and is often used for pottery. It is very inexpensive and can be obtained in bulk.

  For this procedure, the feldspar clay is spread out on the forest floor, at a rate of approximately 2 L per 0.25 m^2, at a known distance from a PVC marker (Figure 3). Sampling consists of locating the clay pad and taking a small core of the sediments deposited above the clay and the

Figure 2. Plexiglas sedimentation disk anchored to the forest floor with about one third of the sediments scraped off

Figure 3. Researcher spreading a feldspar clay pad for a marker horizon

clay itself. A thin-walled aluminum beverage can works well as a coring device, or a chunk of the ground can be cut out with a large field knife. The amount of material deposited above the bright white marker horizon can be easily measured. As with the sediment disks, sampling frequency depends on the hydrology of the wetland system under study. In the BLH system, samples were taken during the low-water period during the fall when there was the best chance of finding all of the sampling sites exposed and out of the water. In other wetland systems, the sampling frequency should be modified to best reflect the local hydrology and to address the questions to be answered.

The clay-silt nature of the feldspar clay provides a surface for sedimentation that is very similar to the natural sediments in many wetland systems. Also, in areas that are not rapidly eroding, the clay pad stays intact for several years and allows the measurement of net sedimentation rates over a period of several years. Cahoon and Turner (1989) describe several other advantages of the feldspar methodology: (1) it is relatively inexpensive, (2) it provides an estimate of recent sediment accretion events, (3) sampling success is known at collection time because the marker is readily visible in the field, and (4) core collection and processing are relatively simple and fast.

This method can even be used in shallow standing water. Feldspar clay will sink to the bottom and create a good marker horizon. Sampling can be accomplished by pushing a clear Plexiglas tube into the ground, filling it with water, and plugging it to maintain suction while the tube is pulled out. In this manner, the white clay can be seen through the side of the tube, even if the permanently saturated sediments are too unconsolidated to be removed as an intact core.

- ^{137}Cesium Atmospheric Fallout Method. Ritchie and McHenry (1989) reviewed the use of radioactive fallout ^{137}cesium in measuring sediment accumulation rates and patterns in the environment. ^{137}Cesium is a product of nuclear fission reaction, and does not occur naturally in the environment. Widespread global dispersal of ^{137}cesium began with thermonuclear weapons testing in late 1952 (Perkins and Thomas 1980), and measurable amounts began to appear in the soil in 1954 (Wise 1980). Peak quantities occurred in 1963 and 1964 immediately before the Atmospheric Nuclear Test Ban was put into place. Figure 4 depicts a typical ^{137}cesium profile. Maximum activity occurs at the depth corresponding to 1963. The depth at which ^{137}cesium first appears is equivalent to 1954, when the isotope was first detectable. ^{137}Cesium is rapidly adsorbed by suspended particles and the clay components of sediments and soil and therefore, once deposited, establishes a fairly stable marker.

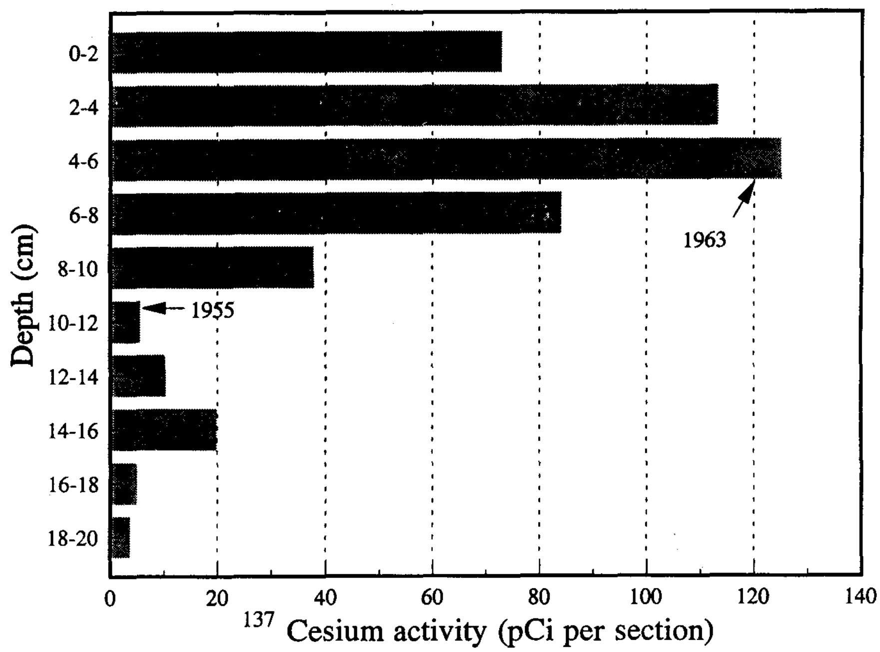

Figure 4. Typical ^{137}Cesium profile showing 1963 peak

To measure ^{137}cesium, sediment cores are taken in a wetland in a manner designed to minimize compaction. The cores are sliced in increments appropriate to the anticipated rate of sedimentation. The sections are dried, and ^{137}cesium activity is counted with a lithium-drifted germanium detector and multichannel analyzer (DeLaune et al. 1989).

DeLaune et al. (1989) have examined the accuracy of ^{137}cesium measurements in wetlands by establishing that the vertical accretion rates using ^{137}cesium were comparable to rates measured with marker horizons in Louisiana Gulf Coast marshes. ^{137}Cesium is also an excellent way to integrate sedimentation rates over a 30- to 35-year period, thereby taking into consideration periods of resuspension or erosion. Also, because estimates of sediment accumulation rates can be made from a single sediment core, repeated sampling trips are not required.

However, there are some limitations to the method. Obtaining cores from wetland locations may be a difficult task, if not impossible in some locations. In some cases, the deposited ^{137}cesium may be reworked, by either bioturbation or hydrologic events, causing the profile to be indistinct. The measuring technique, while relatively straightforward, requires specialized equipment that is available at a limited number of laboratories. The procedure is relatively expensive, and the sample processing can be time consuming.

- Dendrogeomorphic Method. The dendrogeomorphic work done in the Cache River basin was done in conjunction with the U.S. Geological Survey (Hupp and Morris 1990). Dendrogeomorphic analysis is based on both dendrochronologic and geomorphic methodologies. Sigafoos (1964) and Everitt (1968) showed that historic patterns of floodplain deposition could be described through tree-ring analysis with detailed hydrogeomorphic observation. Dendrogeomorphic analysis involves the coring or cross-sectioning of specific trees affected by the geomorphic processes.

Buried stems and associated adventitious tissues are the principal botanical evidence of high sedimentation rates. Initial tree roots form, upon germination, just below the ground surface. These first rootlets eventually form the major root trunks that radiate from the initial germination point. This basal flare or root collar and initial root zone form a distinctive marker of the original ground surface. Trees subjected to substantial sediment accretion typically have the appearance, near the ground level, of a telephone pole, and lack the normal basal flare (Figure 5).

The basic age determination of the tree is made by taking an increment core from near the base of the tree; ring counts are then made from the biological center (first year of growth) to the outside ring (last year of growth). The tree-ring counts may be made in the field or returned to the laboratory for more accurate microscopic examination and cross-dating. Generally, small measurement errors in the tree-ring counts will only have minor effects on the sedimentation calculation rates.

Several trees within the wetland area to be examined, representing a range of ages, are cored. Each sampled tree is excavated near its lateral roots. Measurements are made of the depth of burial of the lateral trunk roots, from the top of the root to the present soil surface. Depth measurements should be taken 0.5 to 1.0 meter away from the tree trunk to ensure that the measurements avoided the influence of the basal flare. Depth measurements are divided by the age of the tree to obtain a sedimentation rate near the tree. This rate is considered to be a conservative estimate of accretion, given that the initial root growth is embedded a few more centimeters into the root.

Figure 5. "Telephone pole tree." Sediment deposition has been so great around the base of this tree that the basal root flare has been completely buried

This method has the advantage of providing a "quick and dirty" means of estimating sedimentation. Only one visit to each site is required, and it is possible to get the results of the work before leaving the field. The total amount of time required is dependent upon the size of the wetland area to be characterized. Enough trees should be sampled to provide a reasonable average for each hydrologically similar portion of the wetland. The only equipment required for this technique is a tree corer and a shovel, although a calculator and a strong back are helpful. Also, differences in historic versus more recent sedimentation rates can be made by measuring trees in different age groups.

The primary disadvantage of the method is the difficulty in accounting for the variability due to differences in microtopography. Therefore, this method is probably best used where estimates of sedimentation rates are acceptable. Additionally, the method can only be used in forested wetlands, and in areas where there has been a relatively high rate of sedimentation.

- Comparison of Methods. Good success has been achieved with all of the methods discussed above in the Cache River basin in Arkansas. A graph of sedimentation rates taken with all four methods along a transect perpendicular to the Cache River is presented in Figure 6. Mass accretion, measured in kilograms per square meter per year was measured with the sedimentation disks, and vertical accretion, measured in centimeter per year was measured for the other three methods. While general trends are apparent, the actual rates of sedimentation are different for each of the methods, which gives some insight into different sedimentation rates over the time periods measured by each method. For example, the clay marker horizons measure a 3-year period, between 1988 and 1991. There has been little time for compaction of deposited sediments to occur during this period, and the measurements of sedimentation rates for the period are quite high. In contrast, depending upon the age of the trees, many of the measurements taken using the dendrogeomorphic method integrate a time period that begins during the 1930s. There has been a significant increase in agriculture in the drainage basin since that time, which may explain lower sedimentation rates in samples covering a longer time period.

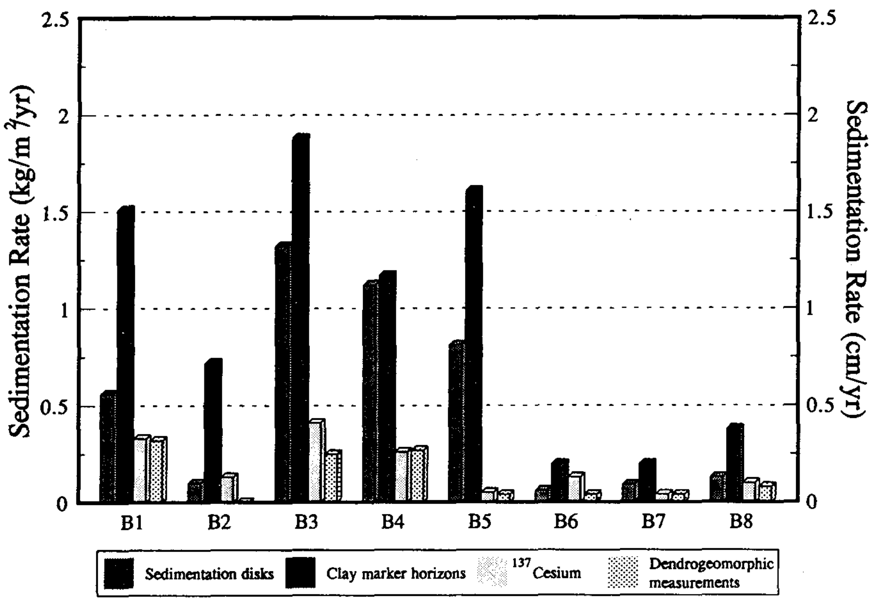

Figure 6. Comparison of results from the four methods of measuring sedimentation at one Cache River transect

Decisions concerning which method to use should be based largely on the question to be answered and the resources available. It would seem that the dendrogeomorphic method is well-suited to wetland regulatory situations in forested wetlands. In a single day, trees could be cored, root flares, uncovered and results obtained in order to estimate a wetland's sediment-trapping capacity. For longer term studies, both the feldspar clay pads and sediment disks offer inexpensive means of estimating annual sedimentation rates. The clay pads have the advantage of allowing the determination of net annual sedimentation rates over a multiple-year period, while the sediment disks are well-suited to situations in which further chemical or physical analysis of the sediments is desired. If funds are available, ^{137}cesium provides a technically respected method with which to determine sedimentation rates over a 30- to 35-year period. By using both recent and long-term sediment dating techniques simultaneously, a comparison can be made of historical and modern sedimentation patterns (Cahoon and Turner 1989).

REFERENCES

Baumann, R. H. 1980. "Mechanisms of maintaining marsh elevation in a subsiding environment," M.S. thesis, Louisiana State University, Baton Rouge, LA.

Baumann, R. H., Day, J. W., and Miller, C. A. 1984. "Mississippi deltaic wetland survival: Sedimentation versus coastal subsidence," *Science* 224, 1093-1095.

Cahoon, D. R., and Turner, R. E. 1989. "Accretion and canal impacts in a rapidly subsiding wetland; II. Feldspar marker horizon technique," *Estuaries* 12(4), 260-268.

DeLaune, R. D., Whitcomb, J. H., Patrick, W. H., Jr., Pardue, J. H., and Pezeski, S. R. 1989. "Accretion and canal impacts in a rapidly subsiding wetland; I. ^{137}Cesium and ^{210}lead techniques," *Estuaries* 12(4), 247-259.

Everitt, B. L. 1968. "Use of cottonwood in an investigation of the recent history of a floodplain," *American Journal of Science* 266, 417-439.

Hupp, C. R., and Morris, E. E. 1990. "A dendrogeomorphic approach to measurement of sedimentation in a forested wetland, Black Swamp, Arkansas," *Wetlands* 10(1), 107-124.

Perkins, R. W., and Thomas, C. W. 1980. "Worldwide fallout." *Transuranic Elements in the Environment*. W. C. Hanson, ed., USDOE/TIC-22800, 55-82.

Ritchie, J. C., and McHenry, J. R. 1989. "Application of radioactive fallout cesium-137 for measuring soil erosion and sediment accumulation rates and patterns: A review with bibliography." Hydrology Laboratory Technical Report HL-15, Agricultural Research Service, United States Department of Agriculture, Beltsville, Maryland, 67p.

Sigafoos, R. S. 1964. "Botanical evidence of floods and flood-plain deposition," U.S. Geological Survey Professional Paper 485-A, Reston, VA.

Wise, S. M. 1980. "Cesium-137 and lead-210: A review of techniques and some applications in geomorphology." *Timescales in Geomorphology*. R. A. Cullingford, D. A. Davidson, and J. Lewin, eds., John Wiley & Sons, London. 109-127.

POINT OF CONTACT FOR ADDITIONAL INFORMATION: Ms. Barbara A. Kleiss, U.S. Army Engineer Waterways Experiment Station, ATTN: CEWES-ER-W, 3909 Halls Ferry Road, Vicksburg, MS 39180-6199, Phone: (601) 634-3836.