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The Effect of Dams on Sediment Retention in Bottomland Hardwood Forests within the Upper Angelina River Basin, Texas: A Feasibility Study

FINAL REPORT

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INTRODUCTION

A research study was initiated in 1998–1999 into the effects of dams on downstream sediment retention in small, bottomland forests in East Texas. Three research sites were located in the Mud Cr drainage near Tyler, TX, preliminary site measurements were taken, and all instrumentation installed during the summer and fall of 1998. Unfortunately, this study was terminated during the winter of 1998 due to loss of access to the research sites. Because of the details behind its premature ending, little data was actually collected.

Therefore, this report examines the feasibility of doing the same or similar study in the future. It is organized into three sections: (1) a review of the background behind the study; (2) a description of the original study design; and (3) an assessment of the methodology employed. The latter part utilizes the experience gained during the initial study to suggest ways in which a future study could be improved

BACKGROUND

Recent research (Kleiss 1996) confirms that bottomland hardwood forests (BHFs) and wetlands affect where and how much sediment is retained within the area adjacent to lowland streams. Given this role, it is logical to conclude that anything that substantially changes sediment delivery to BHFs might adversely affect these ecosystems. Specifically, there is little information available at present on the effect of dams on downstream sediment retention, especially for smaller rivers. The Texas Water Development Board (TWDB) is responsible for assessing the environmental effects of proposed dam emplacement and operation on ecosystems in the state of Texas. The TWDB has identified two specific problems for which information is lacking:

1. What is the sediment impact of dams on downstream BHFs?
2. What is the effect of dams on sediment retention downstream of the confluence where the dam-affected stream joins a larger, unaffected stream?

This report assesses the feasibility of a research study to address these two problems by quantifying the effect of dam emplacement and operation on sediment retention processes in downstream BHFs in East Texas. Study methods were tested at various times from October 19, 1998 to February 15, 1999.

STUDY PLAN

Objectives

The research study had the following objectives:

- Develop annual sediment budgets for paired study sites (one downstream of a dam, the other unaffected by a dam).
- Develop annual sediment retention rates for different BHF ecosystem components within each study site.
- Determine grain-size distribution of deposited sediment for each BHF ecosystem component.
- Characterize the relationship between environmental variables and sediment retention characteristics.
- Evaluate dam effects on sediment dynamics. Compare sediment retention characteristics and relationships between sites affected by and unaffected by upstream dams.

Study Design

A paired design would be used to address Problem 1. Within a single drainage basin, one study site was located within a sub-basin that has an upstream dam; the other site was located in a sub-basin without a dam or any other significant flow diversion. Replication was achieved by using sites from two different drainage basins. The larger drainage basins were used as blocks to control variance within them. Within each sub-basin, sample sites were selected so that they are as similar as possible. The following factors were considered and, to the degree possible, kept the same between sub-basins:

- Basin area
- Land-use composition
- Lithologic material
- Physiography
- Hydrology

The study design would include several covariate factors that are described in the Methods section below. More details on statistical features of this design are described in the Data Analysis section below.

Problem 2 would be addressed by comparing predicted suspended sediment concentration (SSC) at the downstream study site to that actually measured. It would be addressed using downstream

SSC predictions based on the upstream, undisturbed site data. Predictions would be made for study sites located immediately downstream of the confluence of streams from the paired watersheds. These downstream sites would be located a minimum of four channel widths downstream of the confluence to insure complete mixing of suspended sediment (Kenworthy and Rhoads 1995). Based on recommendations of Young and Wallis (1993), upstream sites would be located as close as possible to confluence.

Tentative study sites were located in the Mud and Striker Cr basins near Tyler, TX. Their locations are shown in Figure 1. Their general spatial relationships within each of the two basins are shown diagrammatically in Figure 2. Each site was to consist of a sampling transect and an upstream sampling bridge. The Mud Cr sites were developed first and form the basis for assessing study feasibility. The Striker Cr sites were not developed before the study was terminated.

METHODS

The methods to be used for measuring sediment input, storage, output, and associated environmental factors are described below. The same methods would be used at all study sites. Sediment input to each sampling site would be determined at or near each site using a turbidity meter to measure SSC. Sediment storage measurements would be made along a transect within each site. Sediment output would be determined by subtracting sediment storage from sediment input. Environmental factors affecting sediment inputs and storage would be measured either at the upstream bridge or along the transect, as appropriate. All instrument and sampling locations would be surveyed and tied to permanent field control points.

Sediment Input

Suspended sediment would be used to characterize sediment inputs to all study sites. It is assumed to be the overwhelming source of sediment supplied from the stream to the adjacent BHF sites. Bedload was not be expected to move out of the channel onto the adjacent terrain.

Turbidity would be used to estimate SSC at each site. Its utility for this application has been demonstrated in previous studies (Gippel 1989; Lewis 1996). Its functional relationship to SSC would be determined using linear regression. Simultaneous turbidity and SSC measurements would be made at several different times and stages throughout the year at the bridge gauging station. Turbidity would then be regressed against SSC to develop a model for predicting SSC. Standard analysis methods (Myers 1990) would be used to construct the models and evaluate their predictive capabilities.

Optical backscattering (OBS) sensors would be used to measure turbidity every 15 min. These sensors would be calibrated by the manufacturer for the optical characteristics of the local sediment using samples taken from the study sites. Measurement frequency would be controlled using a programmable data logger that would also store the recorded values.

SSCs for developing the prediction models would be determined from samples taken at the bridge station associated with each sample site. SSCs would be determined from depth-integrated samples collected using standard USGS sampling methods (Edwards and Glysson 1988). They would be determined for at least six different discharge levels spread across the range of discharges occurring throughout the year. They would be collected and analyzed by TWDB staff or local collaborators. They would be measured using the filtration method (Guy 1969).

Suspended sediment grain-size distribution would also be determined from depth-integrated samples. Mechanical sieve analysis would be done on material greater than 0.0625 mm. Percent silt and clay would be determined using either VA tube or pipet analysis methods, depending on the size of the sand fraction. TWDB staff or local collaborators would perform these analyses.

Stage and Discharge

Stage would be monitored at each sample site so as to determine discharge during the period of overbank flows. Stage would be measured with a pressure transducer integrated within a Unidata Starflow doppler sensor. It would be measured every 15 min and recorded on a data logger installed at each site. It would be calibrated to discharge using data from the bridge station. Discharge would be manually gauged at least six times a year at each bridge. Sample sites would be located close enough to their respective discharge gauging sites that discharge magnitude occurring at the bridge is the same as that occurring at the sample site. A regression model would be developed between stage and discharge at each site so as to predict discharge from stage.

Sediment Storage

A transect would be located perpendicular to the general direction of channel flow at each study site. It would be located so as to include representative areas of all ecosystem components found within the surrounding BHF area. An assortment of marker beds, erosion pins, and sediment disks would be located along its length to monitor sediment processes. All sediment monitoring sites would be offset as needed from the transect to avoid disturbances along the transect caused by survey measurements. The transect would be extended to the estimated width of 100-yr stage elevation or 1500 ft, whichever is less.

Marker beds would be used to measure longer-term sediment retention along the transect. They would be made of feldspar clay and used to measure the depth of retained sediment over a multi-year period. They would be located randomly along the transect within ecosystem components judged to be relatively stable (i.e., not subject to frequent erosion). One to two marker beds per component would be used, depending on component size, with the same total number of beds being used at all sites. They would be assessed annually during low flow periods to determine whether to disturb the bed for measurement. All beds would be measured when 75% or more of beds exhibit substantial deposition.

Sediment disks would be installed at several transect locations to measure shorter-term sediment deposition. They would be located near each marker bed and at an additional number of locations along transects. The disks adjacent to marker beds would also be used to assess whether to disturb the marker bed for measurements. An equal number of disks would be used at all sites and they would be randomly located within each ecosystem component. They would be installed within those components judged to experience frequent deposition, but only infrequent erosion. Thus, they would be used at locations deemed more erosion prone than where marker beds are located, but not at sites where frequent erosion occurs.

Sediment disks would be measured twice a year: once prior to flooding season (fall) and once after flooding season (summer). The deposited sediment retained on a fabric cloth attached to the disk would be carefully removed, sealed in a plastic bag, and brought back for analysis. The following properties would be measured:

- Mass of organic material
- Mass of mineral material
- Grain-size distribution of mineral material

Erosion pins would be used to measure both erosion and deposition at sites judged to experience frequent erosion. They would be installed in active side channels, sloughs, or frequently washed components. They would be measured twice a year: once prior to flooding season (fall) and once after flooding season (summer). The total depth of erosion would be measured using the distance from the pin head to the washer. The total depth of deposited sediment would be measured using the distance from the washer to the overlying sediment surface.

Sample Coding

All sampled water, soil, sediment, and vegetative material would be coded using the following system:

Date: Month-Day-Year
Sample: Basin-Site-Station-Type-Distance-Number

where:

Month: 2 digit code with leading zeros, Jan = 01, Dec = 12.

Day: 2 digit code with leading zeros, 1st = 01, 31st = 31.

Year: 4 digit code (e.g., 1999)

Basin: 2 digit code, 1 = Mud Cr, 2 = Angelina R

Site: One digit code, 1 = No dam sub-basin, 2 = Dam sub-basin, 3 = Downstream

Transect/calibration station: One digit code, 1 = Transect 1, 2 = Transect 2, 3 = Discharge/SSC station

Sample type: One digit code, 1 = soil, 2 = sediment, 3 = water, 4 = vegetation

Distance from left-bank pin: One to five digit number to the nearest 0.1 ft

Sample number: One to four digit number, numbered sequentially, by type, if more than one sample per date, basin, site, station, type and distance.

Example: A sediment sample collected from a sediment disk on Jan 15, 1999 at the Mud Cr, No Dam sub-basin on transect 1 at 783.9 ft from the left bank pin.

Date: 01-15-1999
Sample: 1-1-1-2-783.9-1

Site Factors

Distance from channel centerline and elevation of all sediment monitoring sites would be determined from transect surveys. They have been found to be important factors in explaining sediment retention behavior (Kleiss 1996).

Surface roughness at each sediment monitoring site would be estimated using methods described in Arcement and Schneider (1989). The vegetation-density method would be used. Data necessary for using this method would be collected using the methods described next.

Surface roughness is expected to be a function of large obstructions: downed logs, coarse woody debris clumps (CWD), and vegetation. Large obstructions would be characterized along each transect. Their physical dimensions and 2D projection area in the plane of the transect would be measured. They would be classified according to type. Types to be notes are:

- Single CWD piece
- CWD clump
- Other (to be determined during initial surveys)

Vegetation would be surveyed along each transect at each marker bed site using 0.10-ac (0.04-ha) plots centered on the site. Vegetation would be quantified using different methods which depend on plant size. All stems ≥ 5 cm diameter-at-breast-height (dbh) within the entire plot be measured for dbh and categorized by species. All stems < 5 cm and ≥ 1.4 mm (i.e. , saplings) would be identified and counted using two 0.01-ac (0.004-ha) subplots within the 0.1-plot, one of which would be centered on the marker bed, the other on the nearest sediment disk. All woody seedlings (< 1.4 mm) would be identified and counted using two 0.001-ac (0.0004-ha) subplots centered on the sapling subplots. The following values would be determined from the vegetation data for each ecosystem component:

o Density (stems/area), separately for all plant-size categories and total for all vegetation.

o Basal area by plant-size category

o Percent obstruction by plant-size category

o Species composition for stems ≥ 5 cm dbh

A soil survey would be made along each transect to map the type and extent of soils at each site. Soils would be classified to the series level by either TWDB staff or local specialist. Soil bulk density, organic content, and texture would be determined for each soil type by TWDB staff from representative field samples.

Data Analysis

Specific research questions related to the study objectives would be addressed through analysis of the collected data. These questions are listed below along the with analysis procedures to be used.

Objective 1. Develop annual sediment budget for paired study sites (one downstream of a dam, the other unaffected by a dam).

Question 1.1. What is the model relating turbidity to suspended sediment concentration (SSC)?

Regression analysis would be used to develop models for predicting SSC from turbidity (Lewis 1996). It would include indicator variables to account for unique site factors.

Question 1.2. What is the suspended sediment input to all study sites?

Suspended sediment would be predicted from turbidity and integrated over time to estimate sediment input to each site.

Question 1.3. How does SSC vary over the year?

SSC over time would be plotted for each year at all sites.

Question 1.4. What are the changes in sediment storage at all study sites?

See Objective 2.

Question 1.5. What is sediment output from all study sites?

Sediment output would be measured as the difference of input and storage volumes.

Objective 2. Develop annual sediment retention rates for different ecosystem components within each study site.

Question 2.1. How does annual sediment retention (SR) vary across the study sites?

Annual SR would be estimated for each ecosystem component using marker bed, sediment disk, and erosion pin data. Location estimates of annual SR would be made for each ecosystem component at each site. Whichever statistic is appropriate to the observed sample variance and distribution characteristics would be used. It would be used in conjunction with ecosystem component area data to compute storage volumes for each component.

Question 2.1. How does SR vary throughout a water year?

Sediment disk data would be used to estimate sediment deposition over time throughout each water year. Erosion pin data would be used to estimate erosion and deposition over time throughout each water year.

Objective 3. Determine grain-size distribution of deposited sediment for each geomorphic components.

Grain-size distributions would be determined from SSC samples to estimate sediment inputs to out-channel areas. They would also be determined from sediment deposit samples taken at sediment disks in each using mechanical sieve and pipet analyses. They would be assessed to determine which distribution model best fits the sample data. Grain-size distributions would be described using both location and distribution statistics and compared using appropriate parametric or non-parametric procedures. Sediment input and storage grain sizes would be compared using the same procedures as for comparisons between ecosystem components.

Objective 4. Characterize relationship between other environmental variables and sediment retention characteristics.

Site factors would be used as independent variables in regression analysis to assess their effect on sediment retention. They would also be used as covariates in any ANOVA comparing SR characteristics between sites. They would be evaluated for how well they fit model assumptions, multicollinearity among independent variables, and the quality of model fit. The factors to be considered are:

- Distance from main channel
- Flow metrics
  - Flood duration
  - Inundation frequency
- Elevation
- Soil component of surface roughness
- Vegetation component of surface
- Soil type

Question 4.1. Are upstream pairs similar within each basin?

Question 4.2. How do upstream pairs differ between basins?

Question 4.3. How do upstream pairs differ from the downstream site within the basin?

Question 4.4. How do downstream sites differ between basins?

In each case, comparisons would be made between the sites in question using descriptive statistics, graphs, and hypothesis testing, as appropriate. Of particular interest would be how surface roughness varies with ecosystem component vegetation, soil, and location characteristics.

Objective 5. Evaluate dam effects on sediment dynamics. Compare SR characteristics and relationships between sites affected by and unaffected by upstream dams.

Comparisons would be made of SR characteristics and relationships between sites affected by and unaffected by upstream dams. They would address the following questions:

Question 5.1. What are SR rates in basins with and without dams?

Question 5.2. How do SR rates in basins with dams compare to those without?

Question 5.3. Is there a difference in sediment storage changes between dam and no-dam basins?

Question 5.4. What is the difference in SSC between dam and non-dam basins?

Comparisons would be addressed using analysis of covariance methods with the following specifications (Milliken and Johnson 1987; Mason and others 1989):

- Treatment Factor = dam/no dam
- Experimental unit = site ($n_u = 4$)
- Covariates
  - Sediment input volume
  - Sediment input size distribution
  - Flood metrics
  - Ecosystem component
  - Other site factor(s)
- Response = annual sediment retention volumes
- Blocking factor = basin ($n_b = 2$)
- Test run = 1 water year
- Replicates = number of water years during study ($r = 3$)
- Ho: Dam has no effect on annual SR in BHF sites.

The analysis would also evaluate whether there is a detectable change in sediment retention downstream of the confluence due to dam influence. Predicted downstream SSC based on output estimates from upstream sites would be compared to observed downstream SSC. It would be made using Rhoads (1996) method.

Schedule

The schedule below would be used to accomplish this study.

First year

a) At both section triplets
 1) Locate all sample sections
 2) Locate all transects
 3) Locate and install all out-channel monitoring sites
 4) Locate and install staff boards
 5) Locate all bridges for Q and C calibration

b) At one section triplet (Mud Cr)
 1) Estimate stage--Q curves for all transects
 2) Collect Q calibration data
 3) Collect C calibration data
 4) Survey all valley transects (out-channel + in-channel cross-sections)
 5) Survey all monitoring sites
 6) Install all in-channel monitoring instruments
 7) Install instrument stand
 8) Do vegetation inventory
 9) Do post-wet season measurements of sediment disks and erosion pins
 10) Do pre-wet season measurements
 11) Analyze Q and calibrate Stage-Q rating curves
 12) Analyze C data and calibrate OBS data.

2. Second year

a) At other section triplet (Striker Cr)
 1) Collect Q calibration data
 2) Collect C calibration data
 3) Survey all monitoring sites
 4) Install all monitoring instruments
 5) Install instrument stand
 6) Complete vegetation inventory

b) At both triplets
 1) Resurvey in-channel x-section at end of wet season
 2) Take pre-wet season measurements

3) Take post-wet season measurements

3. Third year
   a) Take pre-wet season measurements
   b) Take post-wet season measurements
   c) Resurvey all monitoring sites and control points

4. Sometime during study duration
   a) Soil classification and analysis
   c) Basin characterization with GIS.
      1) Use existing data (TWDB would handle)
   d) Measure marker beds (if >70% are affected by deposition)

METHODOLOGY ASSESSMENT

Sediment Inputs

OBS sensors were installed as planned with no unusual problems. Their primary installation problem was weighting the instrument so that it was oriented straight down beneath the float. They appeared to operate normally, although no judgment can be made as to their reliability or the installation success. Their primary operational concerns are biofouling of the sensors and damage or bad data resulting from stage falling below 0.3 m (depth of sensor). It seems likely that the instruments will require monthly maintenance to avoid biofouling.

Manual sampling of suspended sediment had not been initiated prior to suspension of study. However, the data collection and analysis methods are well tested, so no problems are anticipated. The main concern is personnel safety on highway bridges. The severity of this problem was not appreciated prior to field work in the Mud Cr area. Safety markers to alert drivers to presence of personnel will be required. Traffic may require an additional crew members to serve as flagpersons.

Testing by D&A Instrument Company (J. Downing, personal communication) verified that the OBS sensors were capable of measuring turbidity accurately at very high suspended sediment concentrations. They determined that the OBS turbidity readings could be used to predict SSC from 100 to 10,000 mg/L. The original plan of 6 samples per year taken across the range of stages occurring should still be sufficient.

Stage and Discharge

Starflow stage sensors have proven reliable in past studies, but these were all instances in which the sensors were continuously submerged; whereas the Mud Cr installations required the meters to be placed where they may well become exposed during low-flow periods. The effect this will have on data accuracy is unknown and should be closely monitored by correlating stage at the study sites to a nearby USGS station. Again, no data were collected due to suspension of the study, so this potential problem cannot be evaluated.

Discharge gauging involves standard, well-tested procedures and should be adequate for obtaining the data necessary to derive a stage-discharge prediction model. Gauging at SSC sampling sites will be affected by the safety concern mentioned above.

Sediment Storage

Transect plots of 3 Mud Cr sites showing marker bed, disks, and pin locations are shown in Figure x1. Each transect required 1—2 days to locate, brush out, and survey following. Surveying was done using standard methods with an auto-level and survey rod. Installing sediment monitoring devices and making a preliminary position measurements also required 1—2 days per site. Table 1 lists the devices installed at each site.

In general, device installation and operation worked as expected. The primary problem with marker beds was carrying the heavy sacks of clay while wading channels that were often chest deep. A modification had to be made to the sediment disks after their initial installation. It was discovered that the material used to collect sediment on the sediment disk became stuck to the steel plate. Installing a rubber disk between the plate and collection material to prevent the latter from sticking solved this problem. Retrofitting the disks required an additional 1-2 days to complete all three sites. Erosion pins were easily installed and appeared to operate as expected. Data collection forms designed for recording marker bed, disk, and pin measurements are listed in Appendix 1.

Site Factors

Site factors were to be measured or evaluated after all instrumentation was installed. The study was suspended prior to these measurements or evaluations being done. What follows are comments on the proposed procedures based on field observations and work experience at the Mud Cr sites.

Device Location survey
I estimate it would take 2-3 days to survey each site to determine device position and elevation using standard procedures.

Surface roughness
Based on observations at the Mud Cr sites, I believe the original procedure should be modified so that it is only applied to subsets of each transect rather than each entire transect. Thirty percent of each transect should be sufficient based on the variability observed.

Vegetation
A list of common species observed at all sites is given in Appendix 2. Estimates from area foresters are that it would take 3–5 days per site to accomplish the proposed vegetation inventory. They agreed that the proposed methods were the most appropriate given the site conditions and study objectives.

Soil Survey
This inventory uses standard procedures and should present no special problems. Estimated time to inventory all three sites is 1-2 days.

Site access
The most significant challenge to successful completion of this study is locating sites where access is conducive to its accomplishment. Three aspects of site access were found to be critical. First, physical access must be guaranteed for the life of the study so as to avoid the problem that terminated the original study. With reasonable advanced notice (say, 1-2 weeks), it must be possible to access all sites throughout the year. This makes using sites on private land difficult at best. Therefore, I recommend a better solution is to select sites on public land (after securing the written permission of the appropriate government agency).

Second, access must be such that field vehicles can be driven to within 0.25 mile or less of the research sites in order for a site to be practical. To conduct this study requires use of lots of bulky expensive equipment, which, if carried by hand over great distances, increases personnel costs and risks equipment damage.

Third, sites should be selected so that movement throughout each area can be done efficiently. The greatest problem will be crossing streams during high flows. Sites that are attractive in all other respects will often lack a nearby bridge for crossing the stream during high flow. and will be too deep to wade safely. A small raft might be safely employed to cross deep water. but this was not tested during the initial study. It may be necessary to use sites wherein measurements are only made on one side of the channel. The main problem with this approach is making sure that all sites still possess similar environmental characteristics within the sides that are selected for monitoring.

CONCLUSIONS

An evaluation of a research study into sediment retention in small bottomland forests reveals several important findings. A study such as the one described in this report is certainly possible within the budget originally proposed for this project. The study design proposed is fundamentally sound, but could be improved by subsampling for terrestrial roughness characteristics rather than sampling the entire transect. The most important concerns regarding the successful completion of this study are:

- Finding and insuring field sites have suitable access characteristics.
- Insuring personnel safety during discharge gauging and suspended sediment sampling from rural highway bridges.
- Committing to at least monthly maintenance of stage and turbidity sensors.

ACKNOWLEDGEMENTS

Greg Malstaff (TWDB) played a vital role in the conceptualization and design of this study; in installing the technical instrumentation; reviewing potential field sites, and in many other ways. Clifford Harwell, Gordon McWhirter, and Dennis Carlson (USDA Forest Service) did much of the field work and data compilation. Rand Eads (USDA Forest Service) provided useful advice on how best to employ the OBS sensors, while John Downing (D&A Instrument Company) provided valuable technical help in their calibration. Matt Lowe and Bill Goodrum (Temple-Inland Forests) gave freely of their expertise on vegetation matters. Bill Rose (Texas Forest Service) volunteered to collect data from the Mud Cr field sites.

APPENDIX 1
EXAMPLE DATA COLLECTION FORMS

Sediment Disk Data Collection Form

Process Area No.	Site No.	Date Installed	Date Sample Taken	Pre-collection Tare (gm)	Sample Mass (gm)	Notes
1	2	981030				
1	4	981030				
2	5	981030				
3	7	981030				
4	9	981030				
4	10	981030				
5	11	981030				
5	12	981030				
6	13	980723	981030	11.00		
6	14	981030				
6	16	981030				
6	17	980723	981030	10.45		
7	18	980723	981030	10.12		
8	20	980723	981030	4.14		
8	21	981030				
9	22	981030				
10	24	981030				
11	26	981030				

Erosion Pin Data Collection Form

Process Area No.	Site No.	Date Installed	Date Measure	Previous Reset Distance (mm)	Erosion Distance (mm)	Deposit Distance (mm)	New Reset Distance (mm)
1	1	980723		70			
1	3	980723		73			
3	6	980723		55			
4	8	980723		70			
8	19	980723		46			
9	23	980723		67			
10	25	980723		55			

APPENDIX 2

PRELIMINARY LIST OF VEGETATION SPECIES AT MUD CR SITES

Trees:

Species	Location
Cheerybark Oak	Overflow Area
Water Oak	Streambank, Overflow Area
White Oak	Slope
Overcup Oak	Streambank, Overflow Area
Southern Red Oak	Slope
Black Oak	Slope
White Ash	Slope
Sassafras	Slope
American Holly	Overflow Area, Slope
Bitternut Hickory	Slope
American Hornbeam	Streambank, Overflow Area, Slope
Eastern Hophornbeam	Streambank, Overflow Area, Slope
Red or Ohio Buckeye?	Slope
Carolina Basswood	Slope
Hercules Club	Slope, Upland Area
Sweetgum	Streambank, Overflow Area, Slope
Winged Elm	Overflow Area, Slope
Dogwood	Slope
River Birch	Streambank, Overflow Area
Slippery Elm	Overflow Area, Slope
Red Maple	Overflow Area, Slope
Blackgum	Overflow Area, Slope
Red Mulberry	Slope
Green Ash	Overflow Area
Eastern Redbud	Slope
Rusty Blackhaw	Slope
Mimosa	Overflow Area
Pecan/Water Hickory?	Overflow Area, Slope

Shrub and Vine:

Blackberry	Overflow Area
Peppervine	Slope
Common Greenbrier	Overflow Area
Muscadine Grape	Overflow Area

Saw Greenbrier	Overflow Area

Shrub and Vine (continued):

Crossvine	Overflow Area
Vitis spp.	Overflow Area
American Beautyberry	Overflow Area, Slope
Poison Ivy	Overflow Area, Slope
Honeysuckle	Overflow Area, Slope
Vaccinium spp.	Overflow Area, Slope
Virginia Creeper	Overflow Area, Slope

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Figures

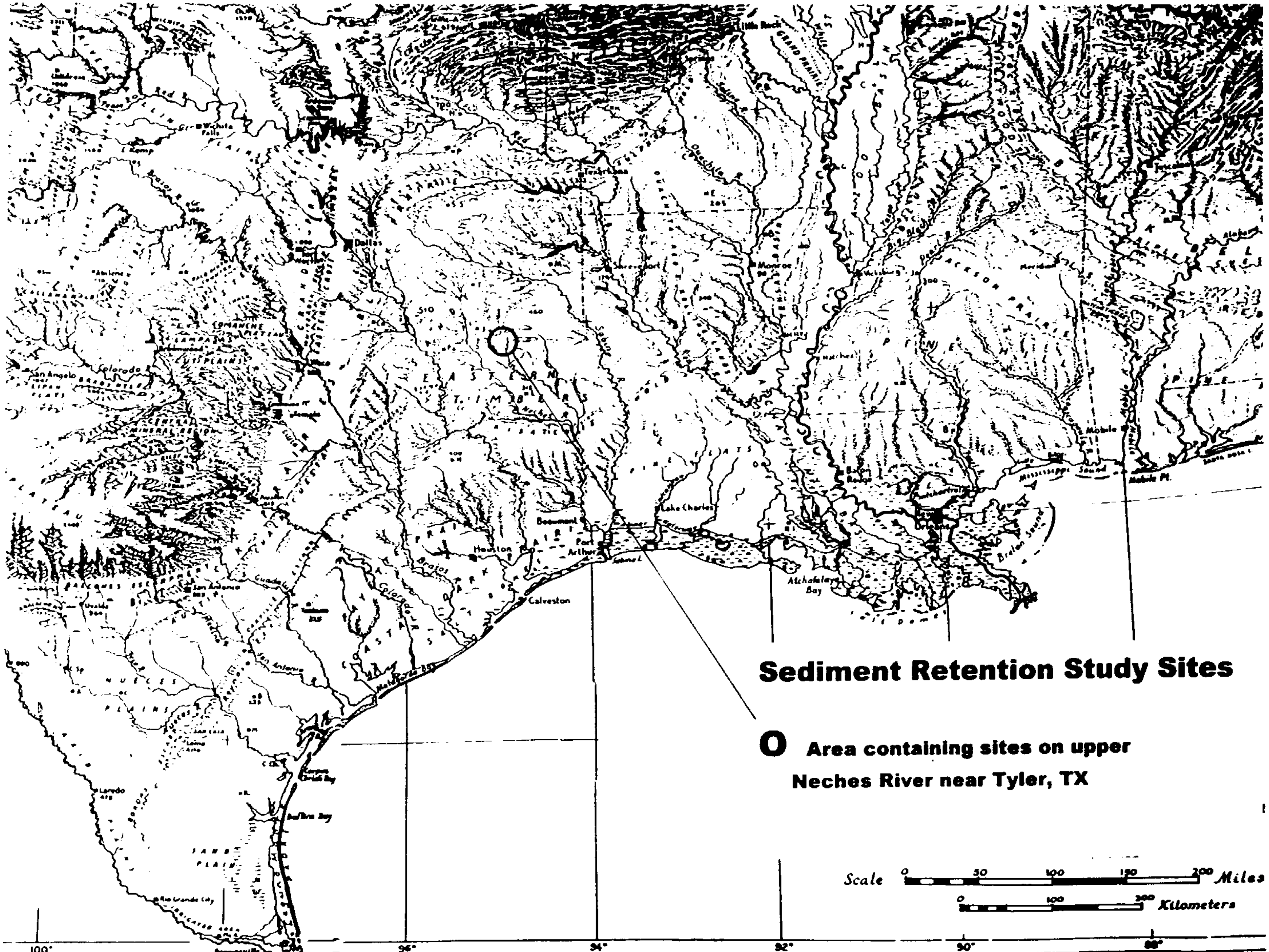

Figure 1. Tentative study site locations for assessing the effect of dams on sediment retention in East Texas bottomland hardwood forests.

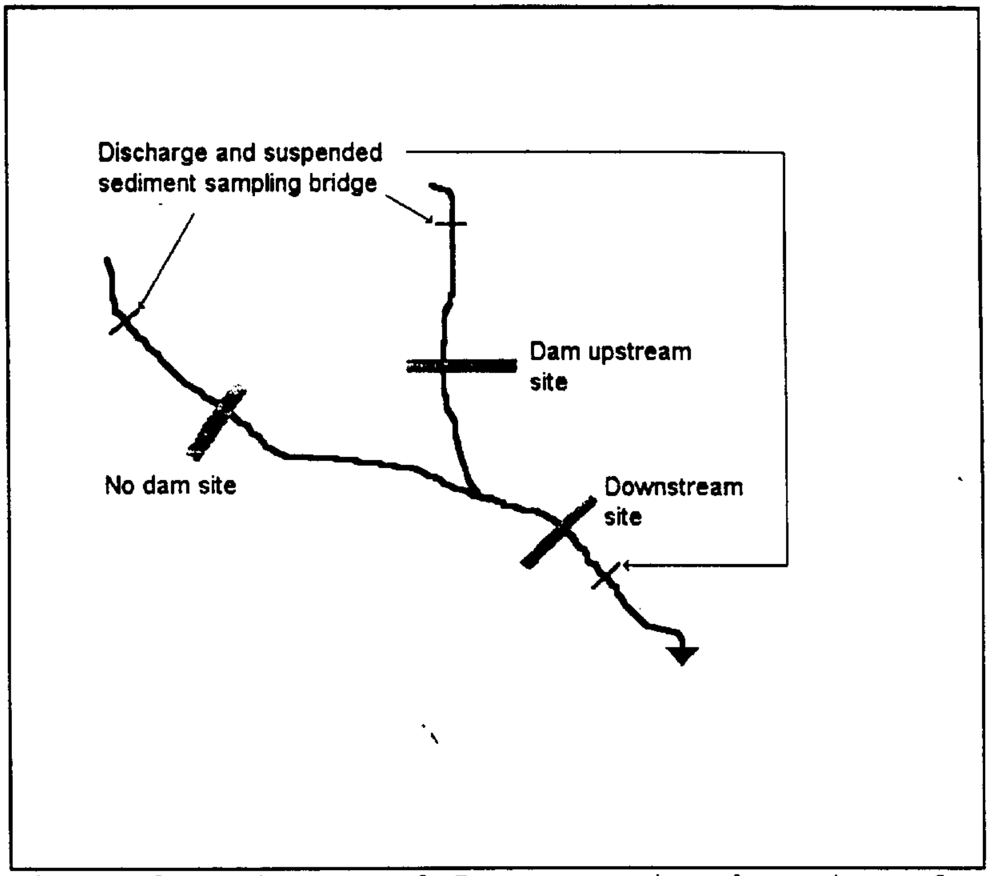

Figure 2. Diagram of Transect site locations for Sediment Retention Study.

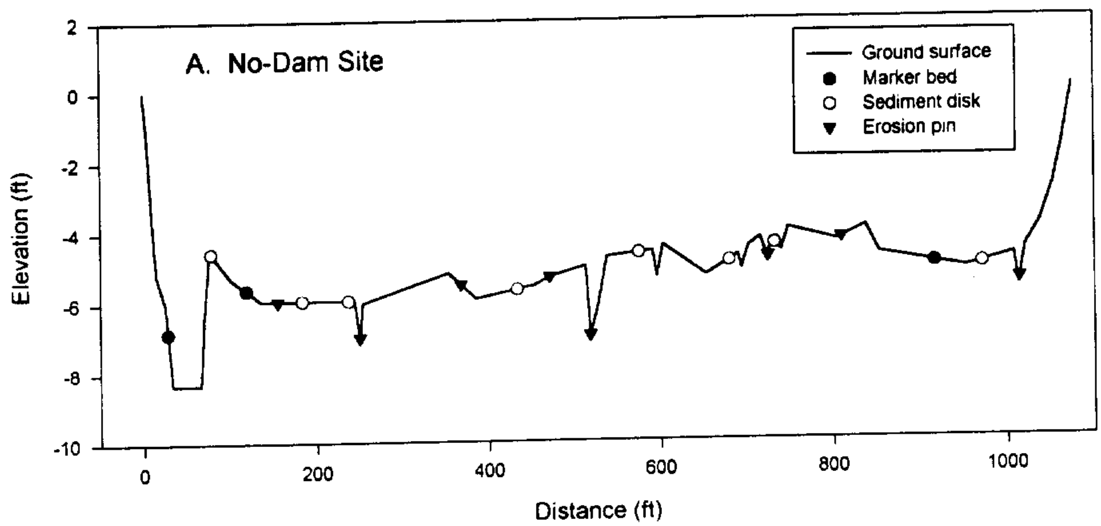

Figure 1 A. Transects perpendicular to channel at (A) the control (West Mud), (B) below dam (Upper Mud), and (C) downstream of dam (Lower Mud) study sites. Plot above does not include the 18 additional sediment disks installed after 10/26/98.

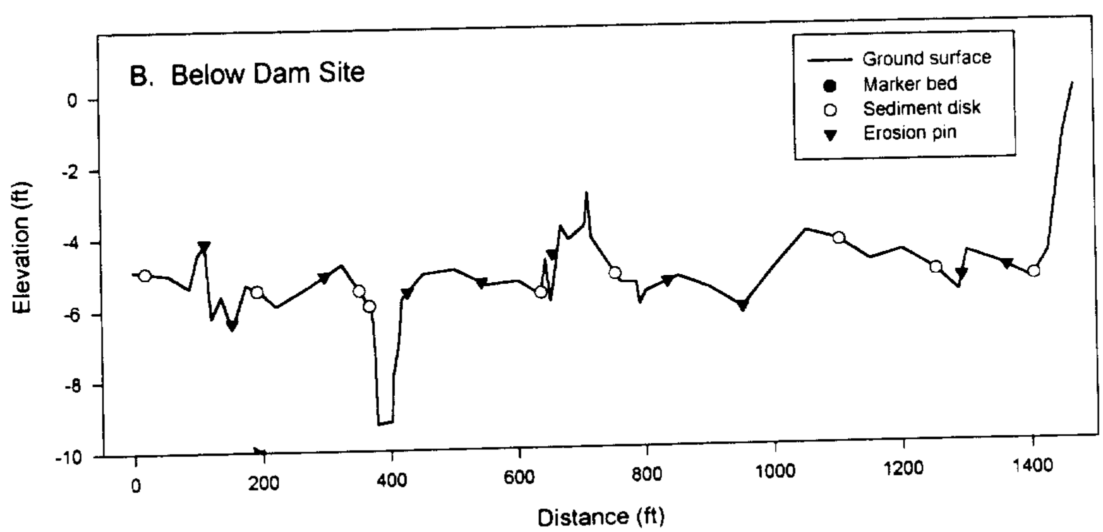

Figure 1 B. Plot does not include the one erosion marker bed and 15 sediment disks installed after 10/26/98.

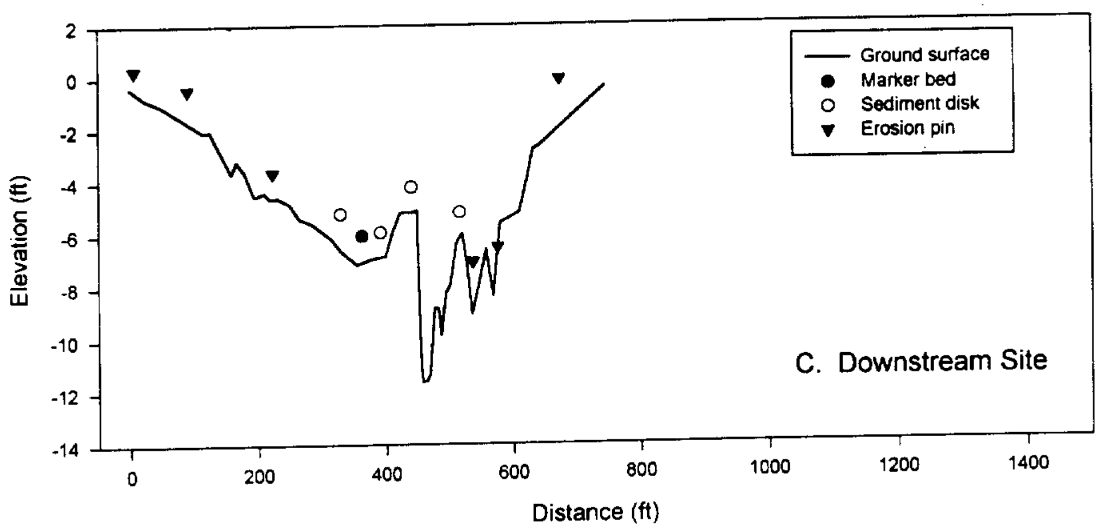

Figure 1 C. Plot does not include 14 additional sediment disks installed after 10/26/98.

Tables

1. Sediment monitoring devices installed at the three Mud Cr study sites.

Site	Marker Bed	Erosion Pin	Sediment Disk
Control (West Mud Cr)	3	8	24
Below Dam (Upper Mud Cr)	1	10	24
Downstream (Lower Mud Cr)	1	7	18