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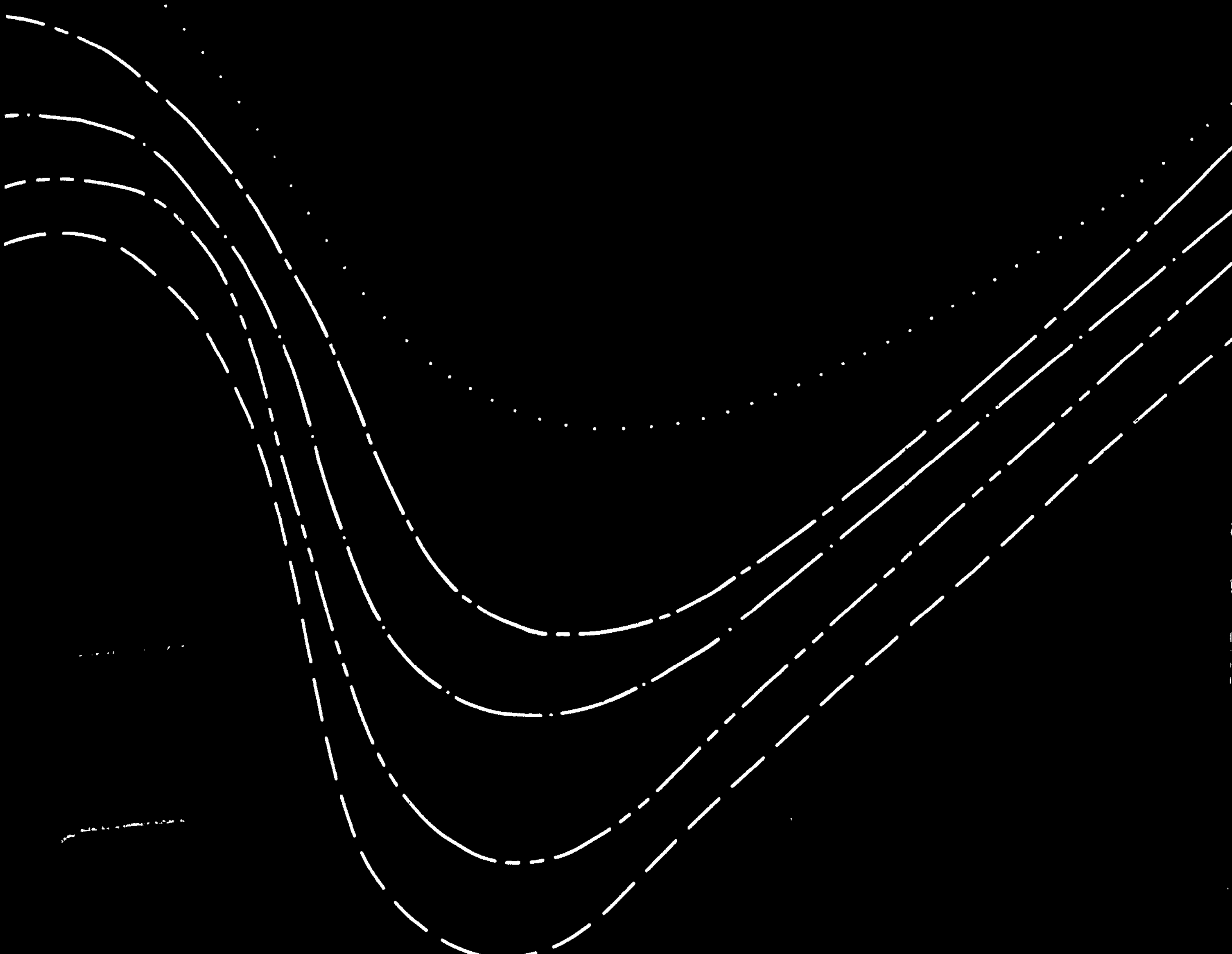
GEOMORPHIC AND VEGETATIVE RECOVERY PROCESSES ALONG MODIFIED STREAM CHANNELS OF WEST TENNESSEE



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TENNESSEE DEPARTMENT OF TRANSPORTATION

Hoosier and Pond Creeks

These loess-bed creeks have strikingly similar material properties (Simon, in press) and show different projected widening trends because of dissimilar modifications. Whereas Hoosier Creek was channelized from its confluence with the North Fork Obion River, Pond Creek (tributary to the North Fork Forked Deer River) was locally dredged by landowners and cleared throughout its length. Like Cane Creek, the banks of Hoosier Creek have been dominated by deep-seated rotational failures since construction of the channel in the mid-1960's. The most downstream reaches of this creek are protected by backwater and, in places where bank angles have been reduced considerably, slough-line surfaces have developed above an inner channel. Top-bank widening has for the most part ceased, after roughly 20 years of widening (fig. 45a).

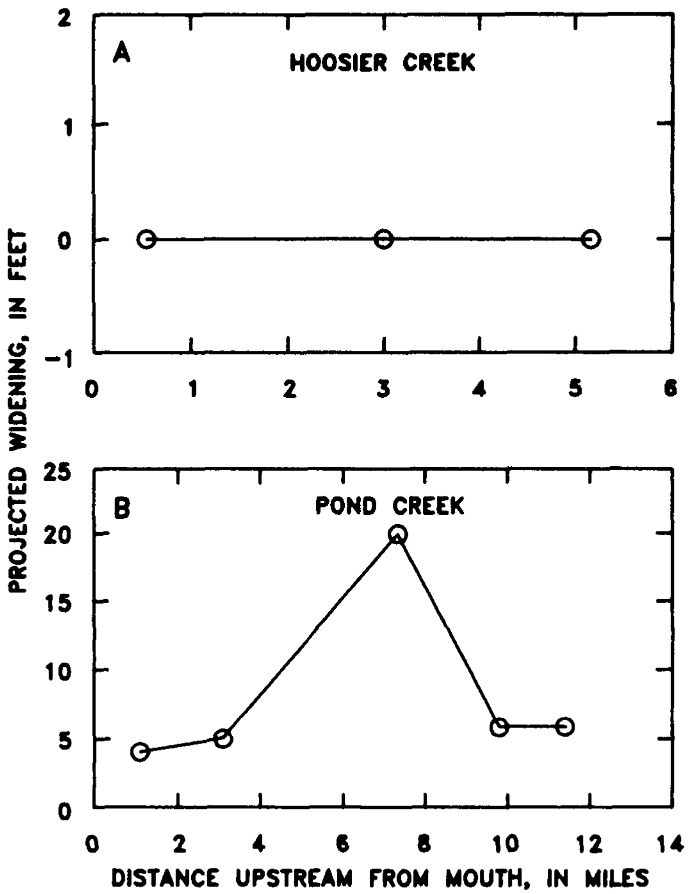

Figure 45.--Projected widening along (A) Hoosier and (B) Pond Creeks.

Pond Creek, also affected by backwater (from the North Fork Forked Deer River) has degraded upstream of some localized disturbances, creating moderately unstable banks. Planar failures appear to be more common than rotational failures. Projected widening ranges from 5 to 20 feet (fig. 45b).

System-Wide Channel Recovery--From Dendrogeomorphic and Plant Ecological Evidence

Systematic trends of channel adjustment begin immediately after modifications to reduce channel gradient and stream power (Simon and Robbins, 1987). Channel bed, bank, and vegetative processes vary through the course of fluvial adjustment and are diagnostic in determining the stage of channel evolution (table 5). The relative roles of channel-bed degradation, channel widening, and shear strength on morphologic changes have been addressed in previous sections. These processes and variables have been shown to vary according to the stage of adjustment, and to yield quantitative information regarding present and future channel changes. Dendrogeomorphic and plant ecological variables such as tree age and species numbers (richness), percent vegetative cover, and rates of sediment accretion can be similarly used to discern present-bank processes at a site. These data can be further used to determine the timing of initial stability and therefore, the number of years required for the channel banks to adjust to a stable configuration. Restabilization of the banks is closely tied to the amount of channel-bed degradation (over 10 to 15 years) and the presence-absence of aggradation.

Plant ecological variables such as vegetative cover, species richness, and species presence vary systematically with stage along all study streams. These variations are distinct and may be used to characterize each stage botanically. Areas characterized by high widening rates (stage IV) typically lack substantial vegetative cover. Only species with broad ecological amplitudes (adapted to a wide range of environmental conditions) like black willow, river birch, and silver maple may germinate. Areas having stable banks (stage I) typically support a relatively wide array of species in a dense riparian zone. Stages V and VI are intermediate between I and IV in terms of bank stability and reflect the onset of aggradation and a trend towards increasing bank stability. Species particularly tolerant of high accretion rates achieve their greatest dominance during these stages. From stage IV through VI, the vegetation reflects a trend of riparian-zone recovery after channel modification. Stage I reaches represent natural-bank conditions unaffected by channel modification. Stage III reaches are a specific variation of stage I reaches, where bed levels have been lowered, but active mass wasting has yet to begin and the old riparian stand is still largely intact.

Plots of dendrogeomorphic and plant ecological data (fig. 46) sorted by stage represent an integration of all streams studied, irrespective of the size of the drainage basin and the dominant geologic formations (table 1). As expected, vegetative cover, species age and numbers, and rate of sediment accretion are inversely related to channel-widening rates (fig. 46). More specifically, these variables display a logical quantitative variation by stage. Minimas of mean vegetative cover (21 percent), age (2 years), and numbers (2), occur during stage IV, when widening rates are greatest (fig. 46a and b). Woody vegetation is most limited during stage IV and increases in vegetative cover and richness from stage V through stage VI, reflecting channel recovery and decreased widening rates (fig. 46a and b).

The greatest values of mean vegetative cover (90 to 100 percent) and species numbers (5 to 8) are attained on banks during stages I, III, and VI, when widening rates are minimal (fig. 46a). These stages reflect the longest periods of time since the last episode of channel modification and therefore have vegetative characteristics corresponding to either natural banks or banks that have been allowed to recover. Banks of stage I and III reaches consequently support the oldest trees (median age 33 and 41 years, respectively). The absolute tree ages for stages I and III are more reflective of past land use [logging and (or) clearing] than they are of recovery time. The oldest riparian trees range in age from 25 to 65 years. Tree ages along stage VI reaches are low (14 years) relative to stages I and III and

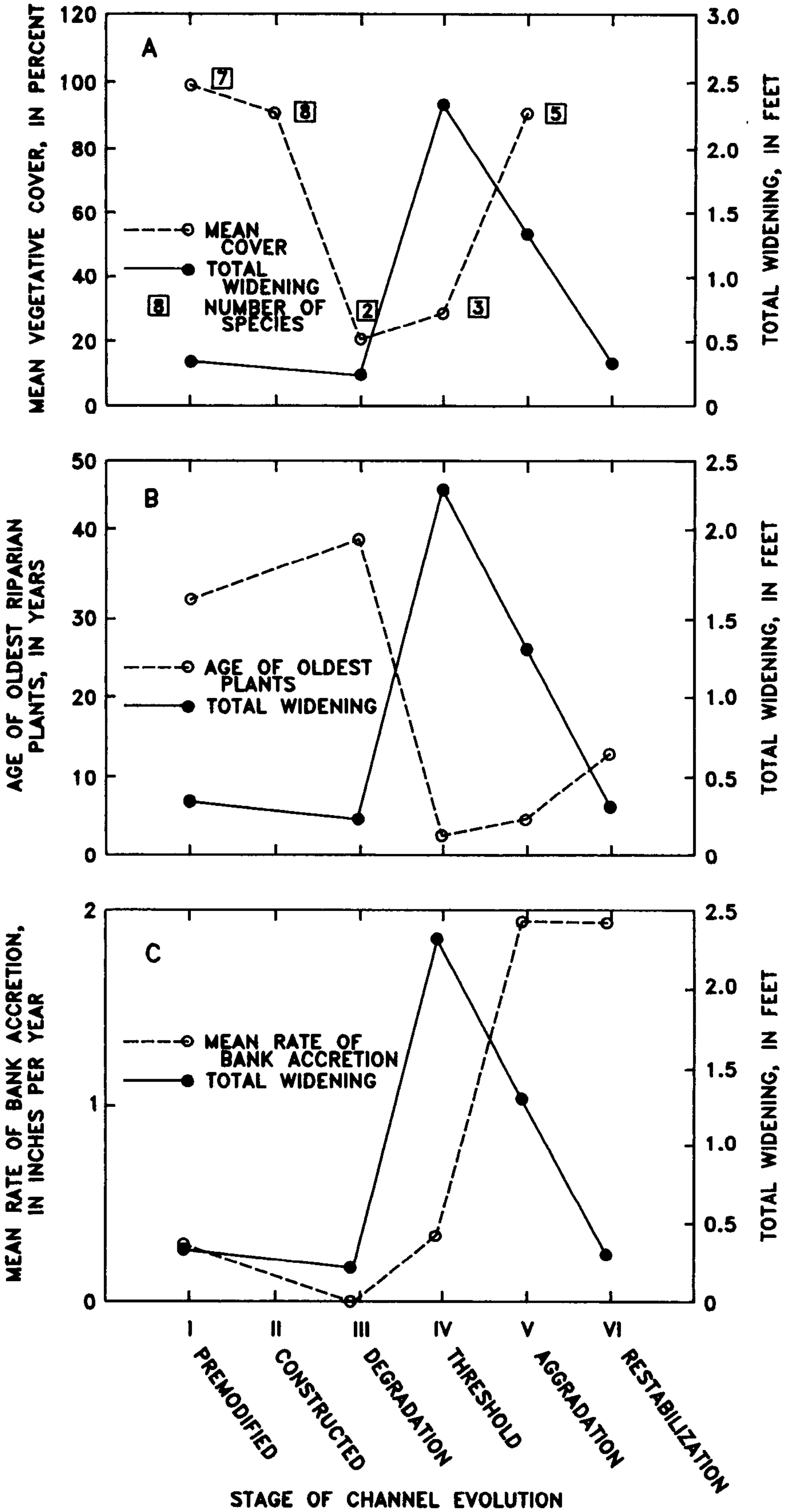

Figure 46.--Trends of dendrogeomorphic variables with stage of channel evolution reflecting the effect of bank instabilities on (A) vegetative cover, (B) maximum tree age, and (C) bank-accretion rate.

denote a trend towards restabilization of the channel banks (fig. 46a). The absolute mean age of trees along stage VI reaches is a function of the recovery period as well as the timing of sampling relative to past channel work (for instance, the 1940's).

Due to active mass wasting, banks of stage IV reaches support trees whose mean age is only 2 years and only then, in protected areas. Successful establishment and initial bank recovery does not occur until stage V, during which time channel-bed aggradation, bank accretion, and bank-angle reduction occur (table 4). The shift from degradational processes to aggradational processes is shown by the sharp increase in mean accretion rates during stage V to 1.9 inches per year (fig. 46c).

The ages of trees along stage V reaches reflect the period of time that geomorphic recovery processes (bed aggradation and bank accretion) have operated at a site (since the cessation of stage IV). Maximum pioneer-tree ages along stage V reaches are 14 years on the forks of the Obion River, 11 years on the South Fork Forked Deer and Wolf Rivers, and 7 years on the North Fork Forked Deer River (table 22). These time periods for the sand-bed streams do not represent complete restabilization of the channel banks, but only the period to low- and mid-bank stability. Because top-bank widening may still be prevalent during stage V, the 7- to 14-year range for recovery is conservative. This is particularly true considering that the low value for the North Fork Forked Deer River is attributable to the input of large quantities of bed sediment from the Middle Fork Forked Deer River. As previously discussed, this resulted in a suppressed tendency for channel deepening, widening, and therefore, the time period required to achieve low-bank stability. Conversely, backwater encroachment up the most downstream (stage V) reaches of Cane Creek resulted in an initial-recovery periods of 17 years.

Excluding the North Fork Forked Deer River, sand-bed channels may require approximately 10 to 15 years of stage V recovery processes to achieve low- and mid-bank stability. Degraded loess-bed streams may take considerably longer time. The range of timeframes specified for the sand-bed channels to begin to recover is supported by the mean age of stage VI riparian trees (14 years), and represent reaches that have only recently regained bank stability.

The Obion River main stem receives large volumes of both suspended and tractive sediments from its forks. Since 1967, almost 215 Mft^3 of channel materials have been delivered to the main stem (tables 10 and 19), causing high rates of bank accretion and channel-bed aggradation, and necessitating repeated dredging. Rates of bank accretion are among the highest along the banks of the Obion River (table 22), but tree ages are low considering that aggradation has occurred for more than 20 years. A few plant species can tolerate high-accretion rates (black willow, cottonwood, and boxelder). However, even these species become severely limited along many reaches of the Obion River main stem. It may be that the accretion rate is so rapid that even these species cannot elongate their stems and produce new roots fast enough to avoid burial or suffocation. Thus, the main stem Obion River generally lacks the vegetative cover values and tree ages normally associated with stage V reaches.

Table 22.--*Dendrogeomorphic data for all sites*

[--, no data available]

Stream	Station number	River mile	Percent vegetative cover	Mean number of species	Maximum tree age (years)	Mean rate of accretion (inches per year)
Cane Creek	1	0.61	20	4.0	13	2.48
	2	1.95	63	6.0	0	1.97
	3	2.52	88	4.0	7	1.97
	4	3.64	70	3.0	7	.00
	5	4.06	75	5.0	5	2.36
	6	5.71	63	2.0	5	.00
	7	6.19	50	3.0	6	.00
	8	7.06	50	6.0	5	5.90
	9	7.99	40	2.0	7	.00
	10	8.98	35	3.0	4	3.15
	11	9.92	35	3.0	5	1.97
	12	10.26	15	2.0	4	.79
	13	11.05	25	4.0	3	1.46
	14	11.31	25	2.0	3	1.97
	15	11.84	20	3.0	4	.00
	16	12.59	15	2.0	2	1.38
	17	13.39	10	1.0	3	.00
	18	14.05	15	1.0	3	.79
	19	14.83	10	5.0	7	.00
	20	15.36	5	1.0	0	.00
	22	15.95	10	6.0	4	.00
Cub Creek	07029447	6.9	25	4.5	7	.29
	07029448	5.7	12	5.0	12	.59
	07029449	2.2	36	3.5	11	2.75
	07029450	1.5	74	11.0	8	3.97
Hatchie River	07029400	182.0	100	5.0	22	.29
	07029430	162.0	100	12.0	50	.59
	07029500	135.0	100	10.0	40	.19
	07029650	121.0	100	7.0	50	.19
	07029900	80.8	100	16.0	50	.59
	07030000	68.4	97	10.0	29	.29
	07030025	49.5	97	10.0	30	.19
Middle Fork Forked Deer River	07028900	44.9	95	11.0	50	.39
	07028910	37.0	85	12.0	26	.00
	07028960	30.5	95	9.0	46	.78
	07028990	21.5	95	3.0	21	.39
	07029000	14.6	0	0.0	0	.00
	07029020	5.2	12	1.0	6	.00
North Fork Forked Deer River	07028410	41.6	97	5.0	25	2.95
	07028500	34.6	18	5.0	19	.29
	07028820	23.9	0	0.0	0	.00
	07028835	20.2	0	0.0	0	.39
	07028840	18.8	17	3.0	3	.59
	07029040	13.6	1	2.0	1	.00
	07029100	5.1	75	3.0	4	3.42
	07029105	3.8	90	4.0	6	3.94
North Fork Obion River	07025320	34.9	75	6.0	45	.00
	07025340	26.4	87	10.0	40	.00
	07025375	21.1	75	2.0	4	.00
	07025400	18.0	50	6.0	5	.59
	07025500	10.0	19	0.0	0	3.94
	07025600	5.6	0	0.0	0	.00

Table 22.--*Dendrogeomorphic data for all sites*--Continued

Stream	Station number	River mile	Percent vegetative cover	Mean number of species	Maximum tree age (years)	Mean rate of accretion (inches per year)
Obion River	07024800	68.5	49	6.0	4	0.68
	07025900	62.2	41	4.3	5	2.16
	07026000	53.7	1	1.5	1	3.15
	07026250	42.4	40	2.0	4	2.56
	07026300	34.2	22	1.0	4	2.95
	07027180	25.6	15	2.0	2	.19
	07027200	20.8	18	2.5	2	1.77
Pond Creek	07029060	11.4	20	0.5	1	2.95
	07029065	9.8	81	2.0	5	3.74
	07029070	7.3	20	0.5	2	2.56
	07029075	3.1	1	1.0	2	.39
	07029080	1.1	75	2.0	5	.39
Porters Creek	07029437	17.1	75	6.0	11	1.49
	07029438	13.9	95	6.0	12	.98
	07029439	11.2	47	4.5	6	.98
	07029440	8.9	67	6.0	9	2.10
	07029445	4.5	35	9.0	5	4.72
Rutherford Fork Obion River	07024880	43.3	75	7.0	20	.47
	07024888	39.4	100	5.0	40	0.31
	07024900	29.9	87	4.0	30	.78
	07025000	17.9	28	5.0	3	2.08
	07025001	24.5	81	3.0	41	.59
	07025020	17.1	5	1.0	5	--
	07025025	15.2	35	3.0	6	1.57
	07025050	10.4	11	2.0	3	1.57
	07025100	4.9	55	5.0	5	1.18
South Fork Forked Deer River	07027680	33.7	100	8.0	65	.00
	07027720	27.6	0	.0	0	.49
	07027800	16.3	0	.0	0	.00
	07028000	13.3	6	.5	1	.98
	07028050	11.9	0	.0	0	.00
	07028100	7.9	0	.0	0	.00
	07028150	5.6	55	6.0	7	.00
	07028200	3.3	2	1.0	3	.47
South Fork Obion River	07024350	33.8	100	2.5	--	--
	07024430	28.5	80	10.0	15	2.95
	07024460	23.2	55	2.0	2	.00
	07024500	19.2	37	3.0	2	.00
	07024525	16.8	1	.0	2	.00
	07024550	11.4	19	3.0	2	.39
	07024800	5.8	49	6.0	4	.68
Wolf River	07030392	69.9	95	7.0	35	.19
	07030395	57.5	52	9.5	40	.19
	07030500	44.4	50	6.0	16	1.18
	07030600	31.2	50	6.5	16	1.97
	07030610	23.6	32	3.5	5	1.57
	07031650	18.9	50	8.0	11	3.94
	07031700	9.1	47	6.5	7	.39

Dendrogeomorphic and plant ecological variables such as percent vegetative cover, number of species, tree ages, widening rates, and bank-accretion rates reflect varying channel conditions, processes, and the stage of channel evolution (fig. 46). Values of these characteristics, associated with a given stage of bank-slope development or channel evolution, can be diagnostic in determining the stability of a particular channel reach. Relatively stable reaches will generally support high vegetative cover values, species numbers, tree ages, and accretion rates. Conversely, unstable sites have very low values of these variables because young riparian plants cannot survive active mass wasting of the banks.

Bank-Stability Index

Bank-widening rates (table 18), vegetative cover of woody riparian species, and rates of bank accretion are important indicators of bank stability. These three site variables were used to develop a simple bank-stability index (I_S). This index permits rapid interpretation of relative bank stability and comparison among sites using dendrogeomorphic data (table 22). The three site variables are categorized for use here, and in the following section on plant ecology; details on the categorization are given in the subsequent section. Site variable categories and I_s weights are provided in table 23.

The computation of I_s is performed by the addition of numerical weights given to the various variable categories:

$$I_s = W_w + W_c + W_a \tag{13}$$

where W_w = weighted total-widening rate, in feet per year;
W_c = weighted mean vegetative cover, in percent; and
W_a = weighted mean accretion rate, in inches per year.

The most stable conditions, such as very low widening, medium accretion, and very high vegetative cover are given the lowest weights (table 23). Conversely, the most unstable conditions are given the highest weights. Weights range from one to five (one value for each of the variable categories) for total-widening rate and vegetative cover. The lowest weight for accretion is two because high accretion frequently leads to secondary-bank failures, although moderate rates of accretion are commonly associated with stable, aggrading-channel conditions. Thus, a given site could have an I_s value from 4 (most stable) to 15 (least stable). I_s values and weights for individual categories are listed for 98 sites in table 24.

I_s values below 7 suggest stable conditions with little mass wasting, high vegetative cover, and moderate accretion rates. I_s values above 10 are distinctly unstable and suggest high widening rates, low vegetative cover, and low to no accretion. Thus, there are three I_s ranges; (1) stable (I_s = 4 to 7);

Table 23.--*Site-variable categories, abbreviations, and bank-stability index (I_S) weights*

[n, number of sites; ft/yr, foot per year; in/yr, inches per year; %, percent cover; >, greater than]

Abbreviation	Site-variable category	Range	n	I_S weights
		Channel-bank widening		
VW	Very low widening	0.00-0.49 ft/yr	16	1
LW	Low widening	0.50-0.99 ft/yr	14	2
MW	Medium widening	1.00-2.99 ft/yr	17	3
HW	High widening	3.00-3.99 ft/yr	13	4
XW	Very high widening	>4.00 ft/yr	18	5
		Channel-bank accretion		
OA	Zero accretion	0 in/yr	17	5
VA	Very low accretion	0.01-0.49 in/yr	21	4
LA	Low accretion	0.60-0.99 in/yr	12	3
MA	Medium accretion	1.00-2.49 in/yr	11	2
HA	High accretion	>2.50 in/yr	15	2
		Vegetative cover		
VC	Very low cover	0-9 %	15	5
LC	Low cover	10-24 %	14	4
MC	Medium cover	25-49 %	16	3
HC	High cover	50-74 %	11	2
XC	Very high cover	75-100 %	22	1

(2) at risk (I_S = 8 to 10); and (3) unstable (I_S = 11 to 15). This breakdown of relative bank stability is analogous to those described in the critical-bank conditions section. Relative to critical-bank conditions (fig. 35), it can be inferred that on the average; at stable sites no significant mass wasting occurs, at sites at risk any point along a bank fails once every 2 to 5 years, and at unstable sites, any point along a bank can fail annually.

When grouped by stage of bank-slope development, the study sites reveal expected low (stable) mean I_S values at stages I and VI, with relatively high (unstable) mean I_S values at stages IV and V (fig. 47). The trend displayed in figure 47 represents the integration of the individual dendro-geomorphic variables plotted in figure 46.

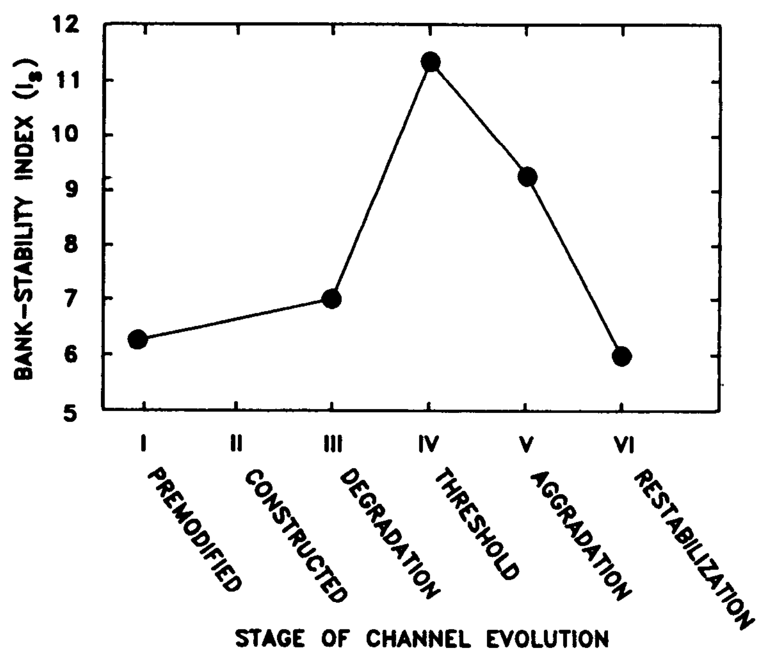

Figure 47.--Mean bank-stability index (I_S) reflecting variation in relative stability over the course of channel evolution.

Table 24.--*Bank-stability index for all sites based on classes of dendrogeomorphic data*

[W_w=weighted widening; W_a= weighted accretion; W_c= weighted vegetative cover; I_s=stability index; stage I=premodified; stage II=constructed; stage III=degradation; stage IV=threshold; stage V=aggradation; stage VI=restabilization; --=no data]

Stream	Station number	River mile	W_w	W_a	W_c	I_s	Stage
Obion River	07027200	20.8	1	2	4	7	V
	07027180	25.6	1	4	4	9	II
	07026300	34.2	4	2	4	10	V
	07026250	42.4	2	2	3	7	V
	07026000	53.7	5	2	5	12	V
	07025900	62.2	2	2	3	7	V
	07024800	68.5	4	3	3	10	V
North Fork Obion River	07025600	5.6	5	5	5	15	IV
	07025500	10.0	5	2	4	11	V
	07025400	18.0	4	3	2	9	IV
	07025375	21.1	4	5	1	10	IV
	07025340	26.4	2	5	1	8	III
	07025320	34.9	3	5	1	9	I
Rutherford Fork Obion River	07025100	4.9	3	2	2	7	V
	07025050	10.4	3	2	4	9	V
	07025025	15.2	3	2	3	8	IV
	07025001	24.5	2	3	1	6	III
	07025000	17.9	4	2	3	9	IV
	07024900	29.9	2	3	1	6	VI
	07024888	39.4	1	4	1	6	VI
	07024880	43.3	2	4	1	7	VI
South Fork Obion River	07024800	5.8	4	3	3	10	V
	07024550	11.4	5	4	4	13	V
	07024525	16.8	5	5	5	15	IV
	07024500	19.2	5	5	3	13	IV
	07024460	23.2	5	5	2	12	IV
	07024430	28.5	1	2	1	4	VI
Middle Fork Forked Deer River	07029020	5.2	2	5	4	11	VI
	07029000	14.6	5	5	5	15	--
	07028990	21.5	2	4	1	7	--
	07028960	30.5	1	3	1	5	--
	07028910	37.0	3	5	1	9	--
	07028900	44.9	1	4	1	6	--
North Fork Forked Deer River	07029105	3.8	1	2	1	4	VI
	07029100	5.1	4	2	1	7	V
	07029040	13.6	5	5	5	15	IV
	07028840	18.8	3	3	4	10	V
	07028835	20.2	5	4	5	14	IV
	07028820	23.9	5	5	5	15	IV
	07028500	34.6	1	4	4	9	I
	07028410	41.6	1	2	1	4	I
South Fork Forked Deer River	07028200	3.3	3	4	4	11	V
	07028150	5.6	5	5	2	12	V
	07028100	7.9	5	5	5	15	V
	07028050	11.9	5	5	5	15	V
	07028000	13.3	5	3	5	13	IV
	07027800	16.3	4	5	5	14	IV
	07027720	27.6	5	4	5	14	IV
	07027780	33.7	1	5	1	7	III
Hatchie River	07030025	49.5	1	4	1	6	I
	07030000	68.4	1	4	1	6	I
	07029900	80.8	1	3	1	5	I
	07029650	121.0	1	4	1	6	I
	07029500	135.0	1	4	1	6	I
	07029430	162.0	1	3	1	5	I
	07029400	182.0	1	4	1	6	I

Table 24.--*Bank-stability index for all sites based on classes of dendrogeomorphic data--Continued*

Stream	Station number	River mile	W_w	W_a	W_c	I_s	Stage
Wolf River	07031700	9.1	4	4	3	11	IV
	07031650	18.9	4	2	2	8	IV
	07030610	23.6	3	2	3	8	IV
	07030600	31.2	1	2	2	5	I
	07030500	44.4	2	2	2	6	I
	07030395	57.5	3	4	2	9	I
	07030392	69.9	2	4	1	7	I
Pond Creek	07029080	1.1	3	4	1	8	IV
	07029075	3.1	4	4	5	13	IV
	07029070	7.3	4	2	4	10	IV
	07029065	9.8	3	2	1	6	IV
	07029060	11.4	4	2	4	10	IV
Porters Creek	07029445	4.5	3	2	3	8	V
	07029440	8.9	1	2	2	5	V
	07029439	11.2	3	3	3	9	IV
	07029438	13.9	2	3	1	6	VI
	07029437	17.1	5	2	1	8	IV
Cub Creek	07029450	1.5	3	2	2	7	VI
	07029449	2.2	3	2	3	8	VI
	07029448	5.7	5	3	4	12	V
	07029447	6.9	3	4	3	10	IV
Cane Creek	1	.61	1	2	4	7	IV
	2	1.95	3	2	1	6	IV
	3	2.52	2	2	1	5	IV
	4	3.64	1	5	2	8	IV
	5	4.06	3	2	1	6	IV
	6	5.71	1	5	2	8	IV
	7	6.19	1	5	2	8	IV
	8	7.06	5	2	2	9	IV
	9	7.99	1	5	3	9	IV
	10	8.98	4	2	3	9	IV
	11	9.92	3	2	3	8	IV
	12	10.26	2	3	4	9	IV
	13	11.05	3	2	3	8	IV
	14	11.31	3	3	4	9	IV
	15	11.84	1	2	3	8	IV
	16	12.59	3	2	3	8	IV
	17	13.39	1	5	4	10	IV
	18	14.05	2	3	4	9	IV
	19	14.83	1	5	4	10	IV
	20	15.36	1	5	5	11	IV
	22	15.95	1	5	4	10	IV

I_S values generally tend to decrease upstream or with distance from the most recent channel work, indicating greater bank stability. I_S values by river mile for the Obion River basin, the Forked Deer River basin, Cane Creek, Wolf River, and Hatchie River (table 24) are illustrated in figure 48. Exceptions to this relation of decreasing I_S with distance upstream are the Obion River main stem, Cane Creek, and one seemingly anomalous site on the Wolf River. The Wolf River site (07030395, table 6) has been affected by local channel modifications unrelated to downstream modifications; this localized work has mildly affected the site just upstream and has a relatively high I_S value (fig. 48d). Most of the Obion River main stem maintains low vegetative cover values due to rapid accretion. Continued dredging and the subsequent maintenance of bank heights, largely beyond the critical limit, serve to keep I_S values high (fig. 48a).

Cane Creek was channelized from its mouth to near its upstream limit during two operations in 1970 and 1978. Sites downstream from river mile 6 (fig. 48c) are relatively stable owing to backwater control provided by the Hatchie River. Stability generally decreases upstream of river mile 10 (fig. 48c) due to severe degradation. Overall, the I_S values are lower (more stable) than would be expected. This is due largely to the considerable amount of bank-surface area relative to any of the other studied streams. Large bank-surface areas are created by rotational failures. This large amount of area allows vegetation to establish on low-bank locations away from the actively failing vertical faces and above erosive streamflow. Thus, the widening weight (W_w) is offset by the vegetative-cover weight (W_c) in the calculation of I_S values. In this case, the slope-stability calculations (fig. 35) provide a more accurate estimate of bank stability.

The forks of the Obion River show clear stability differences among the streams at all sites except a site on the South Fork (07024430), which is a bottomland marsh. In order of increasing stability the streams rank: South Fork, North Fork, and Rutherford Fork Obion River (fig. 48a). The Forked Deer River forks clearly show a tendency for resumption of stability downstream, with their middle reaches being quite unstable, and their upstream reaches showing the typical trend towards stability (fig. 48b). The only anomalous site (fig. 48b) is a relatively stable site on the North Fork (07028840), which is influenced by the confluence with the Middle Fork as explained elsewhere.

The Hatchie River is uniformly stable (fig. 48d) with no I_S value above 6, and serves as a comparison for the other studied streams. The mean I_S value for the Hatchie River is 5.71 (n=7, standard deviation=0.49) and is shown as a dashed line in figure 48 (a through c) for comparative purposes. Mean I_S values of other study streams are indicated on figure 48.

Accretion and Channel Pattern

Detailed accretion analyses were conducted along reaches from late stage IV through stage VI. Variations in bank form, sediment accretion, and therefore the character of the vegetation that may proliferate along a reach during a given stage occur largely because of bends in the channel or thalweg. The bends may represent incipient meanders characteristic of late stage V, as in the lower reaches of the Obion River forks, or true meanders (stage I), as along the Hatchie River and upper reaches of the

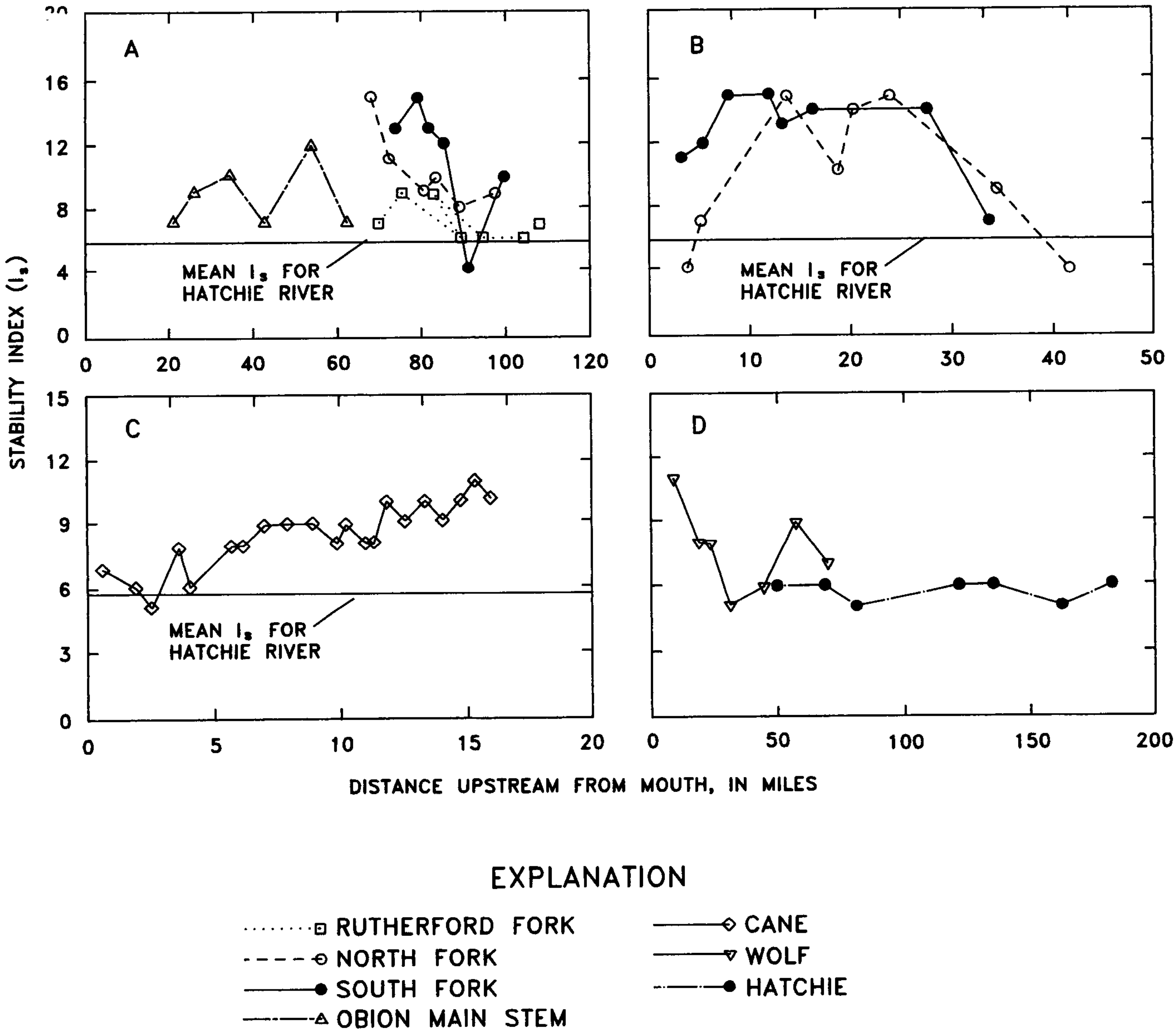

Figure 48.--Bank-stability index (I_s) along adjusting stream channels in the (A) Obion River system, (B) Forked Deer River system, (C) Cane Creek, and (D) Hatchie River and Wolf River. (Hatchie River mean I_s is included for contrast with a natural channel.)

Wolf River. For example, a stage V reach with a bend or incipient meander in the channel may have heightened accretion rates, substantial vegetation establishment, and point-bar development along the inside bank. In contrast, the opposite, outside bank with an impinging thalweg and pronounced toe cutting will have generally steep banks, little or no net accretion, poor vegetation establishment, and accelerated lateral erosion. Differences between inside and outside banks are most pronounced in late stage IV and stage V when the establishment of the slough line may be compromised by an outside bend. Although these differences have been generalized in the overall discussion of channel recovery by stage, the topic warrants special treatment, because of the sometimes striking variation in bank forms along a reach.

Examples of differences between inside- and outside-bend configurations are provided in figure 49. Outside bends (fig. 49a) tend to maintain a concave profile in cross section due to mass wasting from the vertical face and upper bank, and removal of failed material by fluvial action. Failed material may remain on the upper bank (fig. 49a) in over-widened and protected areas, but it is still subject to secondary failures that help maintain the concave shape of the outside bank. Lower parts of the upper bank and the slough line may have some localized accretion. However, outside bends tend to be erosional surfaces due to heightened shear velocities that extend meander loops and retard vegetation establishment.

Inside bends (fig. 49b) have substantial accretion that transforms the slough line into a pronounced depositional surface during stage V. Exceptions occur in the loess tributaries such as Cane, Hoosier, and Pond Creeks where little accretion takes place due to a lack of coarse (sand) materials. In these cases, the slough line consists almost entirely of previously failed colluvium.

The depositional surface is a composite of all preceding depositional episodes that expands vertically and laterally with time. This surface takes a convex profile; and over time, it may extend up to, and attach to the flood plain (fig. 49b) depending on bank heights and flow-duration characteristics. These surfaces are generally stable. However, shallow secondary failures of saturated, previously failed materials and accreted sediments may occur low on the depositional surface. Stabilizing depositional processes expand upslope as mass wasting diminishes and channel-bed elevations rise. Characteristic flow durations for the depositional surface (slough line) range from 10 to 50 percent.

Channel shelves (or benches; fig. 49b) commonly occur below the depositional surfaces. Shelf areas are usually depositional, occur at much flatter angles, and appear to be related to point-bar development. Shelves may have a steep profile at the low-water surface where they are truncated by flows, or they may grade into channel bars that extend well into the active channel.

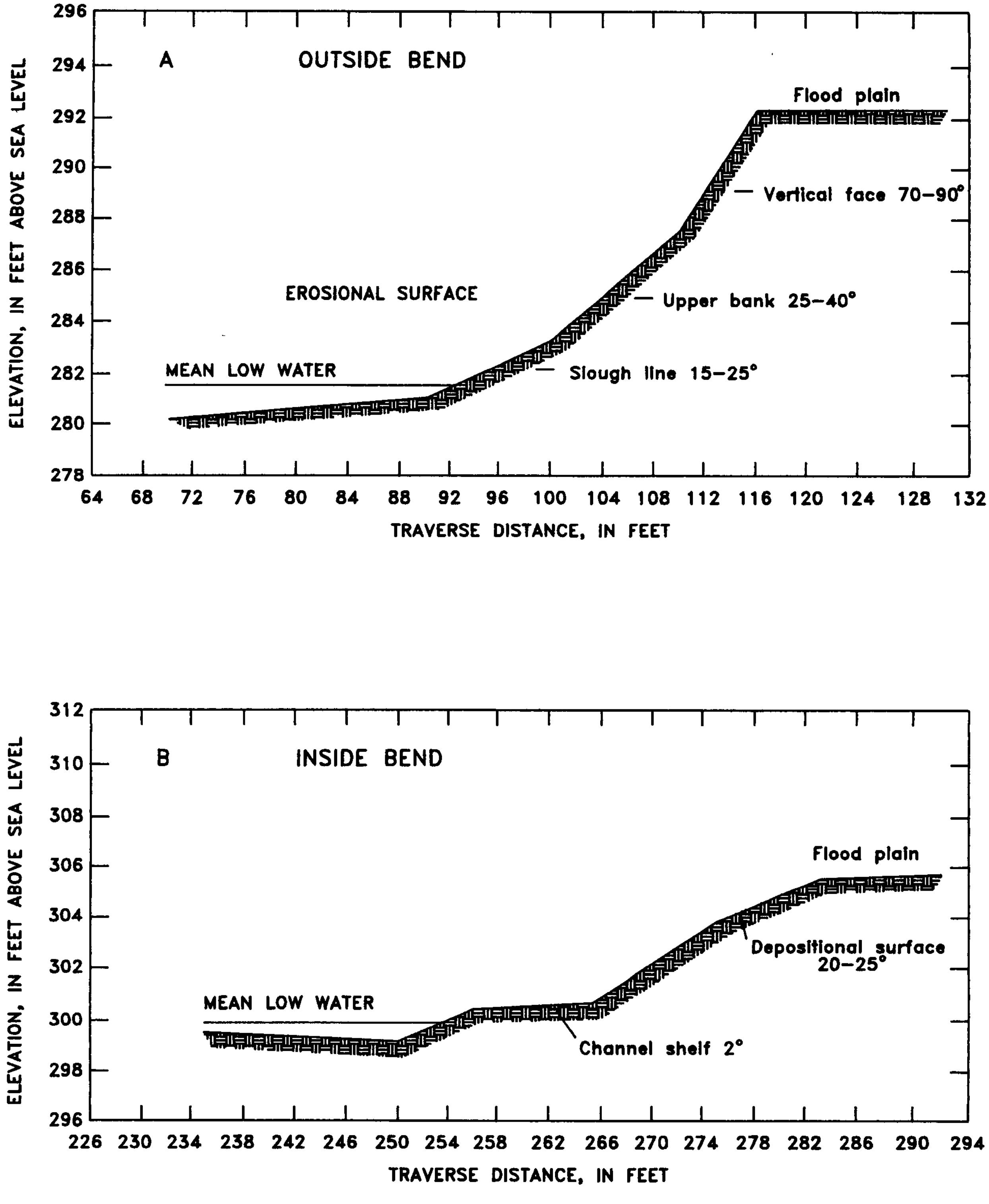

Figure 49.—Typical (A) bank on outside bend in channel and (B) bank on inside bend in channel for aggradation stage reaches (stage V).

Alternating outside- and inside-bend conditions may exist along predominantly straight reaches and are related to a meandering low-flow thalweg that further reduces channel gradients during late stage V (fig. 50). Straight, stage V reaches with no meandering thalweg typically have depositional surfaces, upper banks, and vertical faces on both banks, although bank features are not as pronounced as they are on inside or outside bends (fig. 49).

Figure 50.--Point-bar development along a reach during late aggradation stage (stage V), Porters Creek at Hebron, Tenn. (station number 07029445).

As described above, inside- and outside-bend sections show large relative differences in widening, accretion, and vegetative-cover values, while straight reaches maintain intermediate values. A summary of inside-outside differences for stages IV and V reaches is given in table 25. Accretion along straight reaches during late stage IV is much less than along stage IV inside bends, attesting to the lower shear stresses that exist in areas away from the thalweg. During stage V however, the shift to a generally depositional environment increases accretion rates for both straight reaches and inside bends (tables 4 and 25).

Table 25.--Variation in dendrogeomorphic variables as a function of reach type

[n=number of sites]

Reach type	Widening (feet per year)	Accretion (inches per year)	Vegetative cover (percent)	n
		Stage IV--Threshold		
Inside	0.41	2.44	38.5	8
Outside	3.05	0	1.3	8
Straight	2.31	.65	12.9	22
		Stage V--Aggradation		
Inside	0	2.32	51.2	8
Outside	1.68	.92	9.4	8
Straight	1.60	1.98	24.3	18

These data, and the descriptions provided previously, indicate that lateral migration of the thalweg plays an important role in the development of bank features from late stage IV through stage V. These results also suggest a general shift from channel processes dominated by degradation and mass wasting, during stages III and IV, to channel processes dominated by aggradation and fluvial action during stage V and beyond. The greater accretion and vegetation establishment on inside bends provides a natural, physical explanation for increased flow deflection towards the opposite bank. This in turn leads to further point-bar growth on the inside bend, accelerated bank retreat on the outside bend, and consequently, an increase in channel sinuosity as meanders develop.

Woody-riparian vegetation readily establishes and grows on most inside bends during stage V from the shelf to the top of the bank. Initial establishment occurs on the slough line (Simon and Hupp, 1986b). This band of vegetation then spreads somewhat downslope, and to a greater degree, upslope through vegetative runners or "recruitment". Riparian vegetation increases channel roughness, which dissipates flow energy, promotes sediment accretion and aids in bank stability through root-mass development.

Detailed bank-accretion analyses done on vegetated and highly depositional banks, supply information about the increasing influence exerted by role of fluvial processes in determining bank form during stage V. The depositional surface typically occurs between 32 and 79 percent of the total bank elevation (0 percent being the elevation of the channel bed, and 100 percent being the elevation of the flood plain; fig. 51). The typical median location of the depositional surface is about 56 percent. Depth of accretion tends to decrease downslope in depositional areas from a mean of 14.5 inches, through 12.8 inches in middle depositional surfaces, to 9.0 inches on low depositional surfaces.

Typical angles for depositional surfaces are rather constant on middle and upper areas--about 23 degrees, steepening slightly on low depositional surfaces to about 28 degrees (fig. 52). The former value holds important implications towards interpretations of dominant bank-forming processes and long-term changes in channel width. With the depositional surface being an accreted and fluvially reworked slough line, and representing a newly stabilized condition, it is reasonable to assume that the angle of this surface should approximate the angle of the original slough line (as determined by the temporary angle of stability; eq. 11). The fluvial processes that place further sediments on the slough line (described herein as accretion) are the same processes that rework the colluvial material that formed the original slough line. The mean,

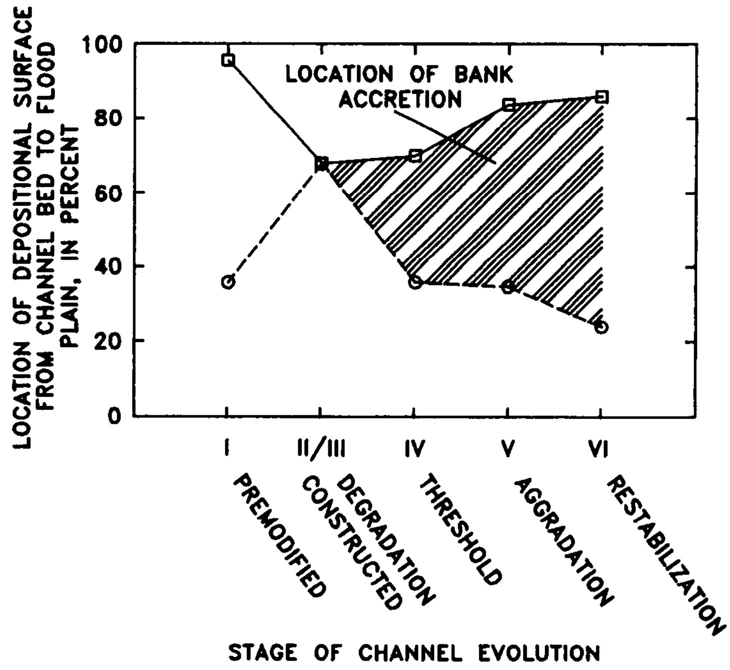

Figure 51.--Variation in location of depositional surface by stage of channel evolution.

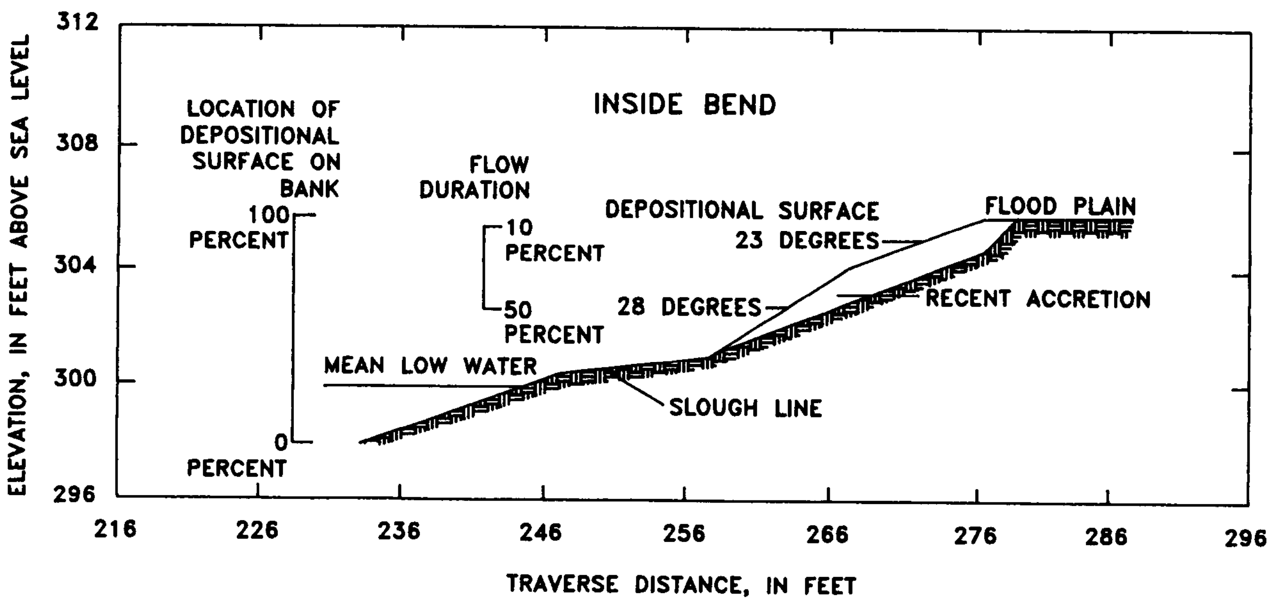

Figure 52.--Channel-bank accretion characteristics for site 07026000 along the Obion River main stem.

temporary angle of stability for 76 sites (table 20) is 24 degrees (standard deviation=4.7) and supports this argument, by being independently substantiated through the dendrogeomorphic analyses. Angles of depositional surfaces are derived from dendrogeomorphic data, whereas temporary angles of stability are based on shear-strength data and Mohr-Coloumb failure envelopes. The angle of the slough line influences the subsequent angle of the depositional surface, which is partly a function of contrasting grain sizes and permeabilities of the sediments comprising these features. Accreted sediments are sand sized (Simon, in press) and allow water to drain down into the silty, colluvial material of the buried slough line. Shallow secondary failures can then occur in the saturated silt. The accreted sand remains on the surface and can reflect the angle determined by the subsurface movement.

The greater mean angle of the low depositional surface (28 degrees) is explained by lateral truncation through stream action. The resulting convex bank shape is therefore a function of previous mass-wasting processes and subsequent lateral-fluvial processes. This sequence is applicable to straight and inside, stage V reaches. Outside bends may show some accretion during stage V (table 25), but their shapes are still determined by fluvial undercutting and mass-wasting processes.

The quantitative characteristics of the depositional surface are shown graphically in figure 52--a generalization based on the cross section of site 07026000 on the Obion River. Note the flow durations for parts of the depositional surface.

The depositional surface (fig. 52) typically ranges from the flood-plain surface (100 percent bank location) down to about the 35-percent bank location along 'natural' West Tennessee streams. During channel construction (stage II), which can be considered an instantaneous condition, the depositional surface is absent. The same is true during stage III (degradation), as high stream power keeps sediment in transport.

Initial development of the depositional surface occurs during late stage IV relatively low on the bank, and corresponds to the position of the slough line (fig. 51). As previously noted, the slough line is the first part of the bank to become stable after a period of active mass wasting. During stage V, the depositional surface expands upslope from 70 to 80 percent of the total bank height (fig. 51). Thus initial accretion occurs low on the bank slope with later expansion upslope. This coincides with trends of spreading vegetation that initially began growing on the slough line. By stage VI, the lower boundary of the depositional surface extends downslope to nearly the 20-percent location, which is substantially lower than the lower boundary for "natural" streams (fig. 51). Continued expansion of the upper depositional boundary during stage VI is also observed and is related to continued aggradation of the streambed. Initial low-bank stability determined in this study supports Thorne and Osman's (1988) suggestion that bank stability is largely controlled at the base of the bank ("basal endpoint control") and provides a link between bed processes and bank processes.

Assuming that channel incision during stages III and IV was not so severe as to render the flood plain a terrace (Simon, in press), it is expected that the upper depositional boundary will attach to the flood plain with time. The pattern of depositional-surface locations through stages of bank-slope development are most pronounced along inside bends. However, straight reaches also follow this same general pattern, albeit at a slower pace. The vertical growth of this surface and its attachment to the flood plain represents flood-plain growth. Patterns of pioneer-vegetation establishment by stage typically coincide with those of depositional-surface location.

Depositional bank angles rapidly flatten to about 23 degrees once accretion begins in late stage IV. Stages V and VI indicate increasing amounts of accreted material and mean depositional surface angles around 23 degrees (fig. 53). Accretion depths were determined through the excavation of buried trees and shrubs. The amount of accretion is related to the age of the plants, and accretion prior to vegetation establishment is not included in accretion estimates. Thus, the accretion estimates include only relatively recent deposition and recent rates of accretion. This limitation is not problematic along modified channels or reaches that have been affected by channel modification, because rates of accretion in depositional reaches of disturbed streams are greatly accelerated. However, along natural streams (stage I), accretion as a natural-channel process has occurred at slow rates for millennia.

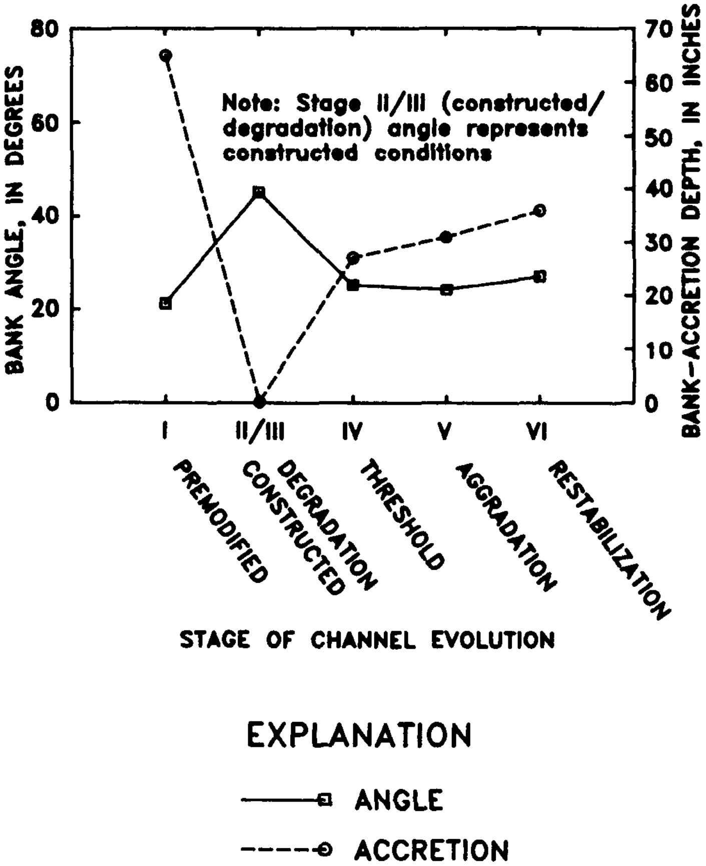

Figure 53.—Variation in bank angles and depths of bank accretion on the depositional surface through stages of channel evolution.

Development of Long-Term Channel Geometry

Previous sections of this report describe adjustment processes and trends throughout a number of fluvial systems in West Tennessee. A bed-level model has been used to estimate future degradation and aggradation along modified channels. Shear-strength determinations and slope-stability analyses have been used to describe thresholds of mass wasting on the channel banks and for differentiating between stable and unstable banks. Factors of safety and probabilities of failure have been found to vary according to the stage of adjustment as described in conceptual models of bank-slope development and channel evolution (Simon, 1989; and tables 4 and 5). Furthermore, accurate rates of channel widening by mass-wasting processes have been obtained through dendrogeomorphic techniques. This section uses these previous analyses for the purpose of estimating long-term (25 to 100 years) channel geometry throughout the studied stream systems.

Changes in the elevation of the channel bed at a site have been described by equation 2 and used to estimate future degradation and aggradation at 5-year intervals to the year 2000 (figs. 20-22, tables 9 and 12). With channel-bed degradation lasting for 10 to 15 years at a site and followed by secondary aggradation, long-term channel depths can be estimated. Projection of future channel depths in this manner is based on the concepts of complex response (Schumm, 1973) and oscillatory channel response (Alexander, 1981; Simon, 1989). The fundamental component of these concepts is that within a trend of bed-level response such as downcutting, there can be alternating periods of deposition and erosion of the channel bed with each episode being of lesser magnitude. This has been shown in the experimental work of Schumm and Parker (1973) and from the empirical data of Simon (in press). In the latter case, only two such episodes were observed and monitored: an initial downcutting phase followed by a phase of secondary aggradation at rates approximately 78-percent less than the initial rate of incision (Simon and Hupp, 1986a). This percentage was derived from comparing rates of degradation and aggradation at 14 sites in West Tennessee (Simon, in press). An idealized representation of this phenomenon, showing a 78-percent reduction in the rate of bed-level change for each episode is shown in figure 54b and 54c.

The difference between complex response and oscillatory-(episodic) channel response seems one of scale. Alternating phases of aggradation and degradation within a larger trend of gradient reduction represent episodic responses as local thresholds are exceeded. These phases may last for a number of years. Conversely, secondary aggradation, which follows the 10 to 15 year period of degradation represents the complex response of the drainage network, and may last 25 to 40 years (based on channel-bed elevation and tree-ring data), or up to about 100 years (based on post-settlement adjustments). Thus, episodic phases of aggradation within the larger trend of channel-bed lowering (episodic response) should not be confused with the subsequent, larger aggradation trend characteristic of stages V and VI of the channel-evolution model (table 5). Estimated channel geometries based on 100 years of aggradation, therefore, represent minimum channel depths. However, error margins should be small because extrapolation occurs in the very flat part of the curve generated by equation 2.

For the purposes of this study, long-term channel depths are calculated from equation 2 using a 15-year period of degradation (b-value from table 3) followed by aggradation (b-value from table 3 or calculated by $|-b|$ x 0.22) periods of 25 and 100 years. Calculated channel depths after 15 years of

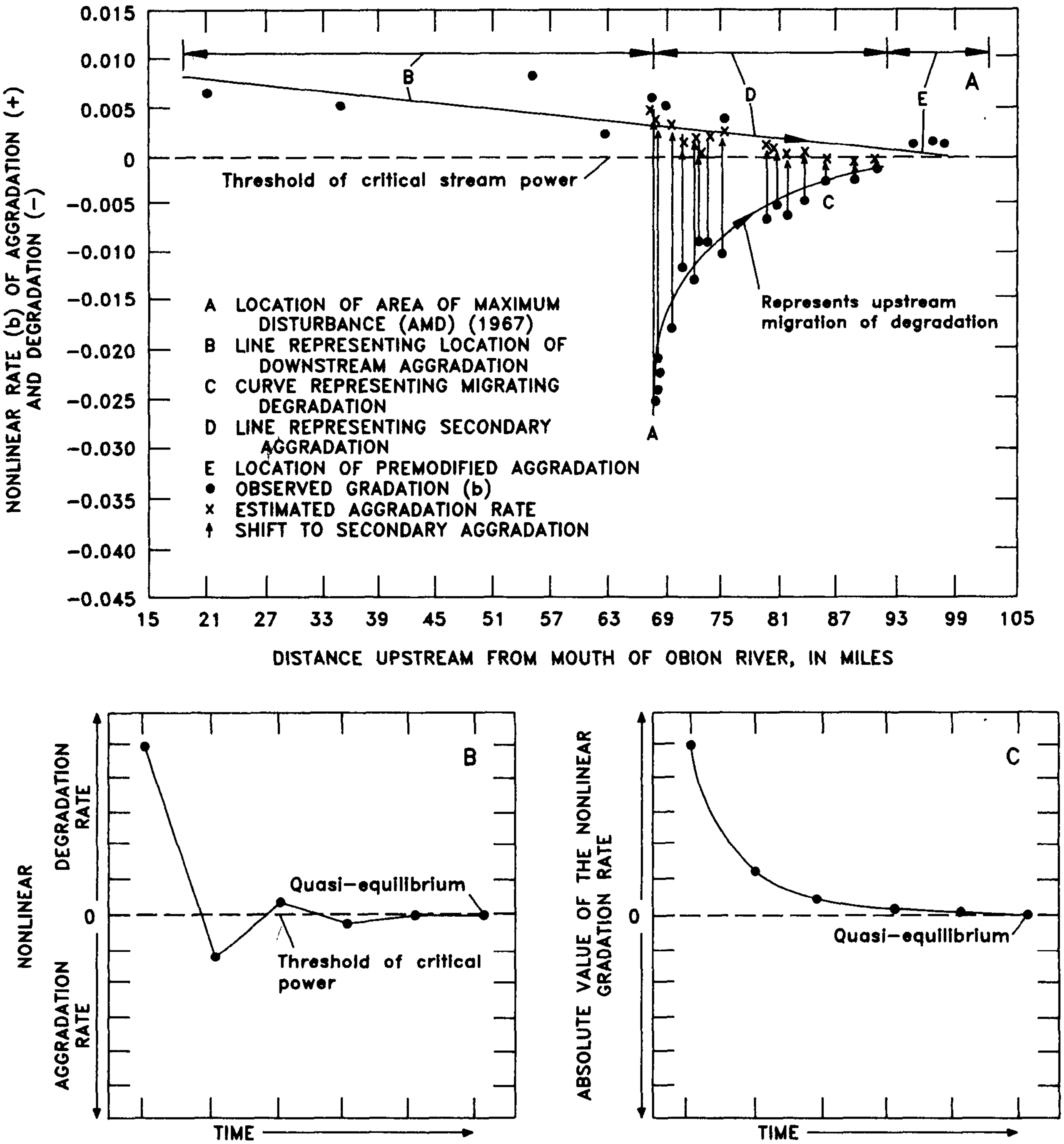

Figure 54.−−Representation of (A) channel−bed response to channel disturbance including secondary aggradation and (B and C) idealized oscillatory channel response. (Modified from Simon, in press.)

degradation and 25 years of aggradation, and after 15 years of degradation and 100 years of aggradation, are given in table 26. Thus the total amount of time represented for each of these estimates is 40 and 115 years, respectively.

Long-term channel widths are calculated using present (1987) channel widths and estimates of projected-channel widening (table 20). The values for long-term channel widths presented in table 27 are based on the assumption that there is no renewed phase of significant channel incision. The projection of long-term channel widths is based on values for a given cross section; using mean values of bank height, bank angle, and material properties between the left and right banks. If the site is in a straight reach, differences are generally minimal and the assumption of a trapezoidal shape is realistic. However, some differences between banks can exist for those reaches which exhibit incipient meandering of the thalweg. Estimates of long-term channel widths (top-bank width) do not account for channel narrowing which may take place in stage VI as the depositional surface attaches to the flood plain. In all cases, estimates in table 27 represent mean conditions for the entire cross section.

Long-term channel depths (table 26) and channel widths (table 27) should represent stable, stage VI conditions. This can be checked by taking the temporary stability angle (table 20) for a given site, and then selecting a channel depth for that site from table 26. Applying these values to a bank-stability chart for each site, it is found that most sites fall into the stable, or the lower part (more stable) of the at-risk category. This indicates bank stability and a general lack of mass-wasting processes.

Exceptions to this long-term stability are along Cane Creek. Throughout this report, Cane Creek has been used as the example of worst-case conditions in the region. Bank-stability charts developed for this stream indicate that a number of sites will still not be stable after 115 years of adjustment. This finding agrees with previous discussions of channel-adjustment trends in the Cane Creek channel and, potentially, of other severely degraded loess tributary streams.

A convenient means of discerning differences in controlling channel processes and channel morphology is the width-depth ratio. Low width-depth ratios indicate that bed degradation is dominant, whereas high values indicate mass wasting is dominant on the channel banks and (or) rapid infilling of the channel. Width-depth ratios for the studied sites are calculated by dividing the estimates of long-term channel widths by the estimates of long-term channel depths, after either 40 or 115 years of adjustment processes (table 28).

The minor differences between estimates of long-term width-depth ratios after 25 and 100 years of aggradation can be explained in terms of the time-dependent nature of channel adjustments. As with degradation, rates of change on the channel bed are relatively rapid at first as the aggradation threshold is crossed (due to low gradients and high tractive loads from upstream). The aggradation process

Table 26.--*Estimated mean channel depths after 15 years of degradation and 25 and 100 years of aggradation*

[PDDH = Predisturbed depth; DH15 = Depth after 15 years of degradation; DHA25 = Depth after 15 years of degradation and 25 years of aggradation; DHA100 = Depth after 15 years of degradation and 100 years of aggradation]

Stream and station No.	River mile	PDDH	DHA15	DHA25	DHA100
Cane Creek					
1	0.61	13.1	17.7	16.3	15.7
2	1.95	9.7	19.2	16.4	15.2
3	2.52	18.8	29.5	26.4	25.0
4	3.64	15.8	33.6	28.5	26.2
5	4.02	17.6	35.9	30.6	28.3
6	5.72	17.1	36.5	30.9	28.5
7	6.27	12.3	32.6	26.7	24.2
8	7.06	16.2	37.8	31.6	28.8
10	8.99	15.3	31.4	26.7	24.7
12	10.25	22.4	39.5	34.5	32.4
16	12.58	10.9	22.9	19.5	17.9
18	13.98	12.7	24.4	20.9	19.5
19	14.85	16.7	25.4	22.9	21.7
20	15.34	10.8	15.5	14.1	13.5
Cub Creek					
7029447	6.90	3.9	6.7	5.9	5.5
7029448	5.70	5.3	9.0	7.9	7.5
7029450	1.50	2.8	11.5	8.9	7.8
Hoosier Creek					
7025660	5.15	16.0	22.8	20.8	19.9
7025666	2.99	14.9	23.8	21.2	20.0
7025690	.55	13.9	29.6	25.0	23.0
Hyde Creek					
7030002	1.20	6.6	18.1	14.7	13.3
7030004	1.90	9.3	18.5	15.8	14.6
North Fork Forked Deer River					
7028820	23.97	7.6	13.0	11.4	10.7
7028835	20.33	6.8	14.5	12.3	11.3
7028840	18.82	7.3	13.3	11.5	10.8
7029100	5.71	5.8	17.6	14.2	12.8
7029105	4.04	17.7	32.4	28.1	26.3
North Fork Obion River					
7025320	34.90	8.4	--	7.1	6.5
7025340	26.40	14.0	15.8	15.3	15.1
7025375	21.10	16.9	21.1	19.9	19.3
7025400	18.00	13.6	16.7	15.8	15.4
7025500	10.00	6.1	15.8	12.9	11.7
7025600	5.90	12.0	30.3	24.9	22.6

Stream and station No.	River mile	PDDH	DH15	DHA25	DHA100
Obion River					
7024800	68.5	4.0	20.6	15.8	13.7
7025900	62.2	22.8	--	20.8	19.9
7026000	53.7	22.3	--	14.8	11.5
7026300	34.2	27.0	--	23.0	21.3
7027200	20.8	25.1	--	20.7	18.8
Pond Creek					
7029060	11.4	7.9	14.1	12.3	11.5
7029065	9.8	7.8	13.6	11.9	11.2
7029070	7.3	5.7	14.6	11.9	10.9
7029075	3.1	--	--	--	--
7029080	1.1	6.6	12.8	11.0	10.2
Porters Creek					
7029437	17.1	3.9	17.2	13.3	11.6
7029439	11.2	7.0	21.5	17.2	15.4
7029440	8.9	7.8	13.9	12.1	11.3
Rutherford Fork Obion River					
7024900	29.9	10.7	--	8.9	8.2
7025000	17.9	10.8	13.5	12.7	12.4
7025020	17.1	--	--	--	--
7025025	15.2	11.0	15.1	13.9	13.4
7025050	10.4	13.3	21.2	18.9	17.9
7025100	4.9	9.6	22.8	18.9	17.3
South Fork Forked Deer River					
7027720	27.6	11.9	18.7	16.7	15.8
7027800	16.3	7.1	13.9	11.9	11.0
7028000	13.3	11.9	18.9	16.7	15.9
7028050	11.9	15.1	23.9	21.3	20.2
7028100	7.9	15.1	26.1	22.9	21.5
7028200	3.3	30.9	--	21.9	17.9
South Fork Obion River					
7024430	28.5	11.7	12.2	12.0	11.9
7024460	23.2	8.2	10.2	9.6	9.4
7024500	19.2	9.5	14.9	13.3	12.6
7024525	16.8	10.5	15.1	13.8	13.2
7024550	11.4	7.6	14.9	12.7	11.8
7024800	5.8	4.0	22.2	16.9	14.6

Table 27.--*Present (1987) and estimated mean long-term channel widths*

Stream and station number	River mile	1987 width	Long-term width
Cane Creek			
1	0.61	91	94
2	1.95	109	112
3	2.52	155	161
4	3.64	162	178
5	4.02	160	171
6	5.72	148	158
7	6.27	160	204
8	7.06	152	197
10	8.99	141	179
12	10.25	165	210
16	12.58	109	112
18	13.98	143	152
19	14.85	124	134
20	15.34	114	114
Cub Creek			
07029447	6.90	25	30
07029448	5.70	29	36
07029450	1.50	62	72
Hoosier Creek			
07025660	5.15	109	109
07025666	2.99	118	118
07025690	.55	146	146
Hyde Creek			
07030001	.15	66	88
07030002	1.20	36	47
07030004	1.90	75	75
North Fork Forked Deer			
07028500	34.60	43	74
07028820	23.97	55	65
07028835	20.33	56	64
07028840	18.82	77	85
07029040	13.69	81	95
07029100	5.71	124	147
07029105	4.04	156	156
North Fork Obion River			
07025320	34.90	50	78
07025340	26.40	104	155
07025375	21.10	110	121
07025400	18.00	124	147
07025500	10.00	158	178
07025600	5.90	166	185
Obion River			
07024800	68.50	158	160
07025900	62.20	237	237
07026000	53.70	214	224
07026250	42.40	205	205
07026300	34.20	170	170
07027180	25.60	248	252
07027200	20.80	271	271
Pond Creek			
07029060	11.40	46	52
07029065	9.80	48	54
07029070	7.30	60	80
07029075	3.10	64	69
07029080	1.10	46	50
Porters Creek			
07029437	17.10	78	120
07029439	11.20	78	103
07029440	8.90	79	90
07029445	4.50	91	96
Rutherford Fork Obion River			
07024900	29.90	59	64
07025000	17.90	111	111
07025020	17.1	100	113
07025025	15.2	106	142
07025050	10.4	90	151
07025100	4.9	113	129
South Fork Forked Deer River			
07027680	33.7	115	115
07027720	27.6	94	107
07027800	16.3	109	123
07028000	13.3	105	124
07028050	11.9	117	161
07028100	7.9	146	146
07028200	3.3	112	112
South Fork Obion			
07024430	28.5	97	119
07024460	23.2	86	94
07024500	19.2	96	112
07024525	16.8	90	151
07024550	11.4	105	167
07024800	5.8	158	160
Wolf River			
07030395	57.5	100	100
07030500	44.4	105	107
07030600	31.2	115	122
07030610	23.6	142	163
07031650	18.9	170	178

Table 28.--*Estimated width-depth ratios after 15 years of degradation and 25 (WD25) and 100 (WD100) years of aggradation*

Stream and station number	River mile	WD25	WD100	Stream and station number	River mile	WD25	WD100
Cane Creek				Obion River			
1	0.61	5.75	5.97	07024800	68.5	10.13	11.69
2	1.95	6.81	7.35	07025900	62.2	11.38	11.87
3	2.52	6.10	6.43	07026000	53.7	15.10	19.41
4	3.64	6.25	6.79	07026300	34.2	7.38	7.99
5	4.02	5.59	6.04	07027200	20.8	13.09	14.44
6	5.72	5.11	5.55				
7	6.27	7.64	8.44	Pond Creek			
8	7.06	6.24	6.83	07029060	11.4	4.24	4.53
10	8.99	6.70	7.25	07029065	9.8	4.53	4.83
12	10.25	6.08	6.49	07029070	7.3	6.67	7.37
16	12.58	5.76	6.25	07029080	1.1	4.54	4.89
18	13.98	7.26	7.81				
19	14.85	5.86	6.16	Porters Creek			
20	15.34	8.07	8.42	07029437	17.1	9.01	10.33
				07029439	11.2	5.97	6.69
Cub Creek				07029440	8.9	7.44	7.95
07029447	6.90	5.08	5.41				
07029448	5.70	4.54	4.83	Rutherford Fork Obion River			
07029450	1.50	8.06	9.19	07024900	29.9	7.13	7.78
				07025000	17.9	8.71	8.96
Hoosier Creek				07025025	15.2	10.20	10.60
07025660	5.15	5.23	5.46	07025050	10.4	7.99	8.44
07025666	2.99	5.57	5.88	07025100	4.9	6.80	7.46
07025690	.55	5.84	6.34				
				South Fork Forked Deer River			
Hyde Creek				07027720	27.6	6.40	6.75
07030002	1.20	3.19	3.54	07027800	16.3	10.33	11.15
07030004	1.90	4.76	5.13	07028000	13.3	7.40	7.81
				07028050	11.9	7.56	7.98
North Fork Forked Deer River				07028100	7.9	6.37	6.79
07028820	23.97	5.68	6.04	07028200	3.3	5.12	6.26
07028835	20.33	5.22	5.67				
07028840	18.82	7.36	7.89	South Fork Obion River			
07029100	5.71	10.38	11.61	07024430	28.5	9.88	9.93
07029105	4.04	5.54	5.93	07024460	23.2	9.76	10.03
				07024500	19.2	8.41	8.87
North Fork Obion River				07024525	16.8	10.97	11.46
07025320	34.90	10.98	11.92	07024550	11.4	13.09	14.13
07025340	26.40	10.13	10.28	07024800	5.8	9.47	10.97
07025375	21.10	6.09	6.26				
07025400	18.00	9.31	9.55				
07025500	10.00	13.75	15.20				
07025600	5.90	7.41	8.17				

attenuates with time to a minimum and, in conjunction with reduced rates of channel widening, results in small variations in the width-depth ratio.

Variations in projected width-depth ratios also occur due to gross differences in the character of the channel alluvium. As indicated by Schumm (1960), channels cut through silt-clay alluvium tend to be narrower and deeper than those in sediments that contain greater percentages of coarse material. Although Schumm's "M" (percentage of silt-clay in the channel perimeter) was not calculated in this study, those channels that have been described as the "loess tributaries" display generally lower width-depth ratios than the sand-bed streams over the long term. Projected mean width-depth ratios for the loess tributaries and the sand-bed streams after 40 years of adjustment range from 4.0 to 6.4, and from 6.8 to 11.4, respectively. Similarly, after 115 years of adjustment, the estimated width-depth ratios for the fine-grained channels range from 4.3 to 6.8, and for the sand-bed channels, from 7.4 to 13.1. The discrete ranges given above are more a function of the lack of channel bed-level recovery along the loess tributaries (which keeps the channels deep) than of differences in widening rates due to greater cohesion in the channel banks. Furthermore, the loess tributaries have some of the greatest widening rates recorded during the study, and this is attributed to substantial amounts of channel bed-level lowering.

There are many uncertainties involved in projecting natural processes and forms 100 years into the future. Data presented in this section and tables 26 through 28 are estimates of the long-term channel geometry along adjusting channels in West Tennessee. The attenuation of processes such as bed-level change and channel widening have been accounted for through time and location within the general framework of the models of channel evolution and bank-slope development. However, variables such as further direct human intervention, land-use changes and low-frequency climatic events cannot be incorporated into this analysis and therefore create a degree of unreliability.

Riparian-Vegetation Recovery

The most apparent characteristic of unstable bank conditions is a general lack of woody-riparian vegetation. The rate of bank widening is perhaps the most influential factor determining the type and abundance of riparian species. Bank accretion also affects species presence; high accretion rates appear to limit the presence of many species through suffocation of the root zone. Together, bank widening and accretion exert a pervasive influence on the riparian-vegetation community. The unstable banks are typically unshaded, which might also affect the early stages of revegetation; many stable-site species are relatively shade tolerant.

Natural or man-induced disturbance in vegetation systems have received considerable attention recently among students of plant ecology (White, 1979). Channel-bank responses to channelization