ACCELERATED EROSION IN THE BAYOU PIERRE BASIN, SOUTHWEST MISSISSIPPI: CHARACTERIZATION AND CAUSES

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Introduction

Purpose and Scope: The purpose of this paper is to describe the results of on-going investigations of accelerated fluvial erosion and concomitant geomorphic change occurring in the upstream reaches of the Bayou Pierre basin of southwestern Mississippi. Erosion is accelerated when substantial geomorphic change occurs rapidly over a few years or decades, when it results in geomorphic changes in channel morphology which are more profound than changes in meander form, and when it produces general fluvial instability in a stream basin. The studies reported here are a part of basin-wide research which was initiated because of concern that erosion and related sedimentological processes are adversely affecting stream habits and the viability of the "threatened" bayou darter (Etheostoma rubrum) which is endemic to this basin (Teels 1976; Burris and Bagley 1989).

Location: The Bayou Pierre basin occupies approximately 1,070 square miles in portions of Claiborne, Copiah, Hinds, Jefferson, and Lincoln Counties. Bayou Pierre is a tributary to the Mississippi River and enters that river near Port Gibson, Mississippi; its larger tributaries are Little Bayou Pierre, White Oak Creek, Foster Creek, and Turkey Creek (Fig.1). The basin lies to the south of the Big Black River basin and to the north of the Homochitto River basin. The Pearl River basin lies to the east. Generally, agriculture and timber are the major types of land use in the region. The reach of Bayou Pierre addressed in this paper is that lying in Copiah County in the vicinity of Smyrna (on County Road 548).

Previous Investigations: In northwest Mississippi, accelerated fluvial erosion and stream instability occurring along the bluff-line streams tributary to the Mississippi River have been described by Whitten and Patrick (1981) and Grissinger and Murphey (1982). In that region, channelization has resulted in headcutting (knickpoint migration) and channel degradation on many stream channels. These processes have, in turn, produced riparian land loss by streambank erosion, destruction of bridges, and possible negative effects on stream fauna. In southwest Mississippi, accelerated erosion caused by channelization has occurred on the Homochitto River and limited descriptions have been reported by Wilson (1979), Patrick (1989), and Patrick and others (1990).

In the Bayou Pierre basin, there have been a number of articles and reports dealing with the stream fauna in the basin, of which several describe the occurrence of active erosion (Rich 1968; Hartfield 1988; and Ross et al. 1989). The studies of Ross and others. (1989) were the first to suggest a relation between knickpoint migration and the occurrence of the bayou darter. The regional geology of Copiah County has been described in a county bulletin by Bicker and others. (1969) and that of Hinds County by Moore and others. (1965).

Geologic and Hydrologic Setting: The basin lies mainly in two physiographic provinces: the upstream regions occupy the Piney Woods province, whereas the downstream areas are in the Loessial Hills province. The basin is underlain by Neogene strata consisting of clays or lutites and sands/sandstones of the Catahoula Formation (Miocene) and the lutites, sands, and gravels of the Citronelle Formation (Plio-Pleistocene?). Along the western margin of the basin, the hills are capped with wind-blown silt (loess) (Pleistocene) (Moore et al. 1965; and Bicker et al. 1969). The streams in the basin occupy wide flood plains and appear to be underfit in terms of the size of the flood plains. The field studies and examination of aerial imagery suggest that terraces are present along some stretches; however, terraces have not been studied in detail.

Methodology: Geologic and geomorphic data were collected during field studies at bridge crossing sites and by walking or wading selected reaches of the basin's streams. Geomorphic data were also taken from current and historical aerial imagery and topographic maps. The topographic data was taken from U.S. Geological Survey (USGS) topographic quadrangle maps published in 1962, 1963, 1971, 1972, and 1986. Recently, panchromatic aerial mosaics and individual photographs were obtained from the U.S. Department of Agriculture for the years 1964, 1978, and 1985, and historic imagery was purchased from the National Archives for the year 1940. Additionally, precipitation and stream discharge data were collected and reviewed as part of the larger study; however, these data have not been fully evaluated and are not discussed in this paper. Generally, the techniques employed in this investigation are similar to those described by Whitten and Patrick (1981) and Patrick and others (1982)

Data Analysis

Field Studies: Field investigations have shown that channel erosion has occurred throughout the basin, and several upstream reaches, such as Smyrna, reveal evidence for active, modern erosional activity. The field evidence for active erosion include the following: fallen trees on both sides of the channel; high, steep banks (also on both sides of the channel), failed bridges, exposed bridge pilings, and waterfalls and rapids (knickpoints). With respect to the latter, repeated field studies over a period of several years have shown knickpoint migration past (upstream) of Smyrna. These types of field evidence are often indicators of accelerated erosion caused by human activities such as channelization; however, there is little field evidence or data on imagery to suggest that channelization has been conducted in the basin. Figure 2 is a drawing made from a photograph of the bridge at Smyrna. The concrete pile liners shown by the arrows in the drawing are completely exposed; as these liners are not typically constructed to extend much above ground, we surmise that there has been approximately five (5) feet of channel degradation (deepening) at this site since the bridge was constructed during the early 1970's. We also must point out that there are a number of new bridges under construction at crossing sites on Bayou Pierre tributaries in Copiah County. During the summer of 1990, a knickpoint was located approximately 3,200 feet upstream of the Smyrna bridge; here the channel was degraded into Miocene lutites.

Analysis of Topographic Data: Stream channel morphology was determined from plots of longitudinal profiles of Bayou Pierre and its major tributaries; these profiles were developed from topographic maps and are shown in Figure 3. The topographic quadrangles used represent approximately 23 years; thus, these longitudinal profiles are composites of several years of data. The profiles show a number of knickpoints along Bayou Pierre and its tributaries. These knickpoints indicate that channel degradation processes have occurred in the basin. Even so, these data give no clue to the dynamics of knickpoint migration nor indication as to the causes of erosion in the basin. Knickpoints identified from topographic data may also be seen in the field; however, the knickpoints which are currently evident in the upstream portions of the basin are not present on the profiles. The reason for their absence is because these upstream knickpoints post-date the topographic quadrangle maps.

Analysis of Imagery: The examination and comparison of historic aerial imagery provide the best means of understanding the dynamics of knickpoint migration within the basin. Figure 4 shows line drawings of the channel taken from imagery for the years 1940, 1964, 1978, and 1985, for the reach of Bayou Pierre near the Smyrna bridge. In this illustration, one can identify the location of a suspected knickpoint (indicated by an arrow) where the stream width abruptly changes size. In the 1940 drawing, the knickpoint was located approximately 13,500 feet downstream from the Smyrna bridge; in 1964, the knickpoint had moved upstream to a point approximately 9,700 feet downstream from the bridge. In 1978 the knickpoint had migrated upstream within approximately 4,700 feet of the bridge, and by 1985 the knickpoint was located approximately 400 feet upstream of the bridge. As the knickpoint migrated, the channel widening was accompanied by decreases in channel length, decreased sinuosity (channel length divided by straight-line channel distance), and cutting off of meander bends. These data are summarized in Table 1. The numerical data given here and in the table were taken from the aerial photographs. The scales of each photograph were normalized with a zoom transfer scope; however, since there were no rectifications made to the photos, the numerical values should be considered approximations.

Discussion

Knickpoint development: Channel degradation often results when channels are straightened, resulting in increased channel dradient, or when base level is lowered. The former situation may result from some forms of channelization for flood control or navigation improvements; the latter is often associated with fall of sea level or when changes, either natural or human-induced, occur on downstream trunk streams (Simons 1979). Channel degradation may also be associated with increased water discharge without increase in

Table 1: Stream Length, Sinuousity, Knockpoint Location, and Migration Rate for that reach of Bayou Pierre channel between its confluence with Turkey Creek and Smyrna Bridge.

	Year				
	1940	1964	1978	1985	1990*
Stream length (ft)	46,200	41,450	39,070	32,740	ND
Sinuosity **	1.7	1.5	1.4	1.2	ND
Distance between knickpoint and Smyrna bridge (ft)	-13,500	-9,700	-4,700	+400	+3,200
Average knickpoint migration rate (ft/yr)	ND	158	357	728	560

ND= not determined due to lack of imagery for that year or previous year.
*= migration rate based upon ground truth.
**= length of stream channel divided by straight-line distance.
-4,700= distance downstream from bridge.
+400= distance upstream from bridge.

sediment discharge. The development of a knickpoint and its upstream migration result from a complex interaction between the materials into which the channel has eroded and the hydraulics of the channel flow. For example, a knickpoint will not form unless there is heterogeneity in erosion resistance in the channel materials. That is, interbedded or interstratified resistant layers, if present, will form a cap holding up the knickpoint at that place along the stream course where such material is present. Eventually, the less resistant material underlying the cap will be eroded out, undermining the cap, and the knickpoint will migrate upstream. In the Bayou Pierre basin, the Tertiary sediments and rocks into which the channel has eroded is highly heterogeneous and consists of erosion-resistant sandstones and less resistant clays and lutites. Generally, the hydraulic controls which define the conditions under which the undermining occurs include the thickness of the cap material, the height of water flowing over the knickpoint, and the height of tailwater. These conditions are described and explained by May (1989) and Cameron and others (1990).

The migration of a knickpoint through a stream channel produces the following sequential geomorphologic changes which begin with a deepening and widening of the channel. As the channel becomes progressively deeper, the streambanks, often on both sides of the channel, become unstable and fail by any of several slope instability mechanisms. The failed bank material, along with additional sediment introduced into the channel from upstream, often results in braided conditions within the stream channel. Subsequently, as the stream adjusts its gradient, it resumes a meandering configuration and ultimately behaves as it did prior to the knickpoint migration. However, the stream is now flowing at a lower elevation on a new floodplain. The former, higher floodplain has now been abandoned and would be called a terrace. The sequence of events previously given may not occur during a single event; rather, there may be a series of movements or waves depending upon subsurface geologic conditions and the hydraulics of flow (Whitten and Patrick 1981; Patrick and Smith 1987).

Possible Causes of Erosion: We presume that the possible causes of these erosion processes occurring in the basin may be induced by either or a combination of human-induced or natural causes. Human-induced erosion may result from channelization within or downstream of the basin (on the Mississippi River), mining of point bars, and by increased stream discharges associated with basin-wide over-extensive land use. Our preliminary studies have, however, revealed no evidence from aerial imagery that channelization was conducted in the basin after the 1940's. Also, we know of no channelization conducted in the basin prior to the 1940's. In regard to the Mississippi River, there have been three river cutoffs constructed downstream from the mouth of Bayou Pierre. These cutoffs and the years of their construction are (from north to south): Rodney (1936), Giles (1933), Glasscock (1933) (Winkley 1977). These cutoffs resulted in shortening the Mississippi River by approximately 28 miles. In the absence of evidence on the nature of Bayou Pierre prior to the cutoffs, we must conclude that these cutoffs are possible causes for knickpoint migration; however, the data are inconclusive.

The examination of imagery and review of county geological bulletins revealed several locations at which local, small-scale sand and gravel mining operations had been conducted on point bars in the channel. We believe that such mining results in minor straightening of the channel, and it may contribute to channel erosion. Also, one must suppose that the mining may result in increased sediment discharge which, in turn, may adversely affect the stream fauna. The effects of land use in the basin have not been studied in detail. Certain changes in land use since the 1940's can be seen on the historical imagery; however, we have not quantified these data and can present no conclusions. Even so, a number of investigators have suggested that the encroachment of cultivation adjacent to stream channels has resulted in increased streambank erosion and riparian land loss (Rich 1968; Hartfield 1988). No doubt, such encroachment has contributed to streambank erosion; however, no quantitative data are available.

A possible natural cause for erosion may be related to adjustments in the gradient of Bayou Pierre due to pre-1930's changes in the meander configuration of the Mississippi River. An examination of maps showing the location and configuration of the Mississippi River over the last several hundred years reveals that this river has experienced significant meandering near the mouth of Bayou Pierre (U.S. Army Corps of Engineers 1938). As the meander belt of the Mississippi River migrated, the channel of Bayou Pierre lying upon the Mississippi River floodplain may have become longer or shorter in this region which, in turn, may have resulted in channel gradient changes, knickpoint development, and headcutting. Of course, the construction of cutoffs during the 1930's may have contributed to these processes. The timing and dynamics of these possible processes are difficult to ascertain, and several possibilities may be given. For example, knickpoint migration may have begun early after the change in meander belt configuration, and only over the last few decades has headcutting reached the upstream stretches of the basin. Conversely, it is possible that the erosion is relatively recent in the basin, and it was not until a gradient threshold was reached that knickpoint migration began (Schumm 1973 and 1977).

Conclusions

Streambank and channel erosion are apparent in the field and from imagery throughout the Bayou Pierre system. Headcutting is currently operating in the upstream reaches of the basin, and it is particularly apparent in the vicinity of the Smyrna bridge where the migration rate is approximately 560 ft/yr. The probable causes of the erosion pertain to natural and constructed changes in the configuration of the Mississippi River which have contributed to changes in the gradient of Bayou Pierre. The overall effects of the erosion produced on these over-steepened channels have been to significantly modify the morphology of the main and tributary channels in the basin and, as a consequence of these processes, to cause excessive scour at a number of bridge sites in the area. Furthermore, we tentatively conclude that these geomorphologic changes are controlling the darter habitats in the basin.

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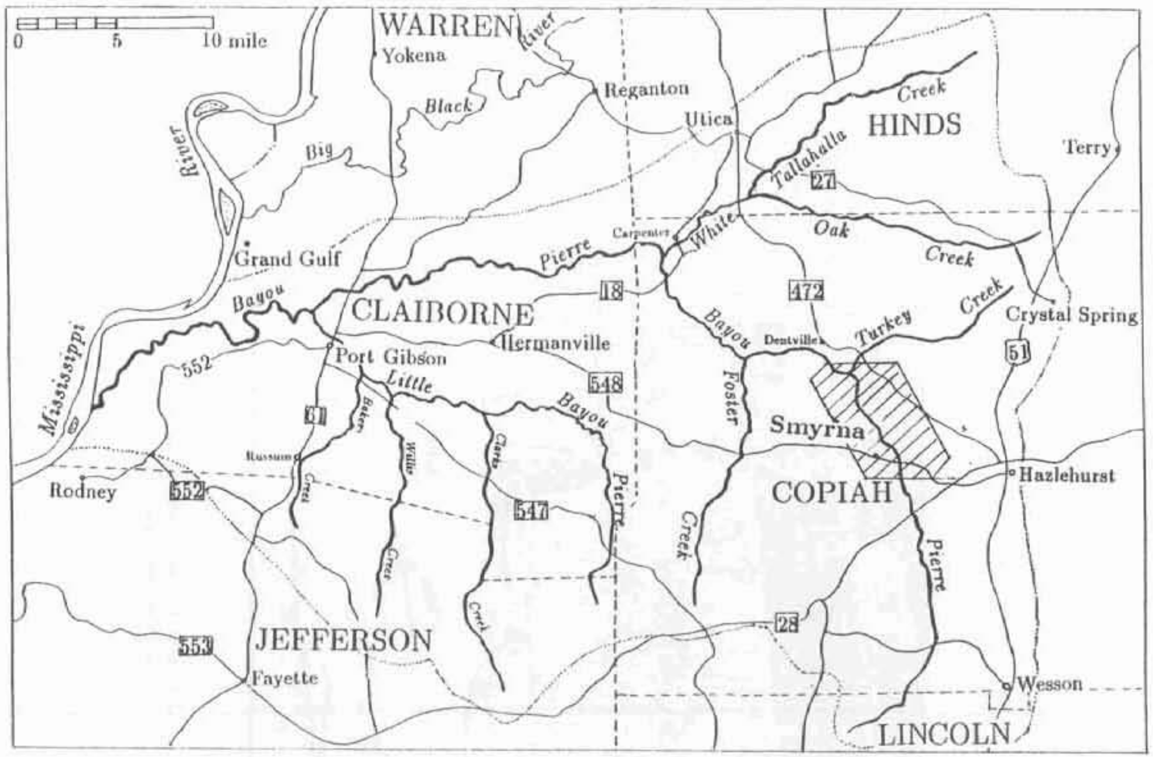

Figure 1: Bayou Pierre Basin location map showing study area (shaded).

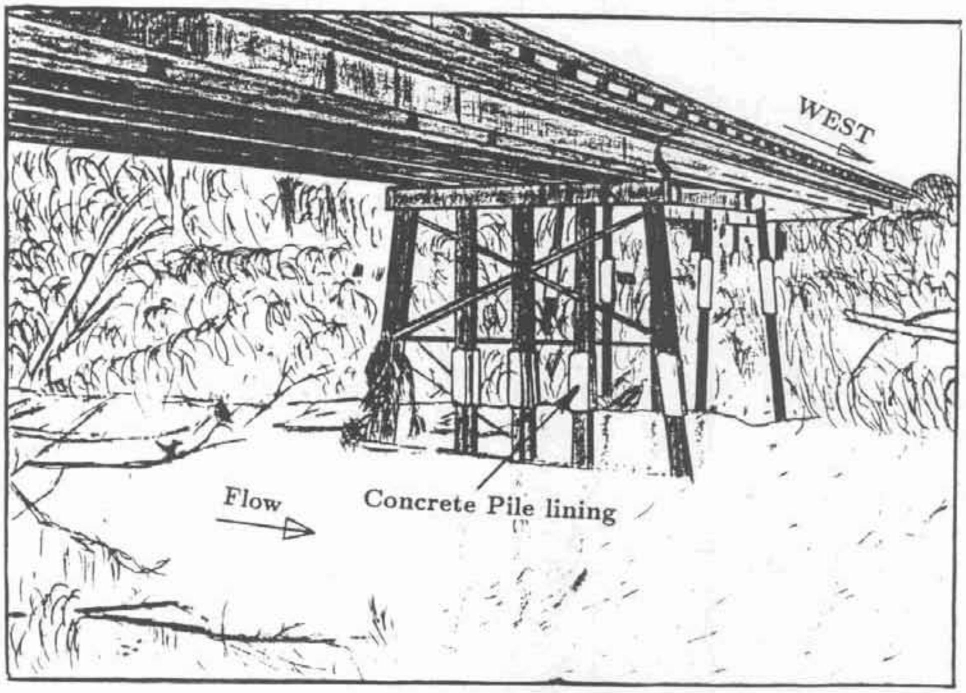

Figure 2: Illustration showing exposed concrete pile lining at the bridge at Smyrna on State Road 548, Copiah County.

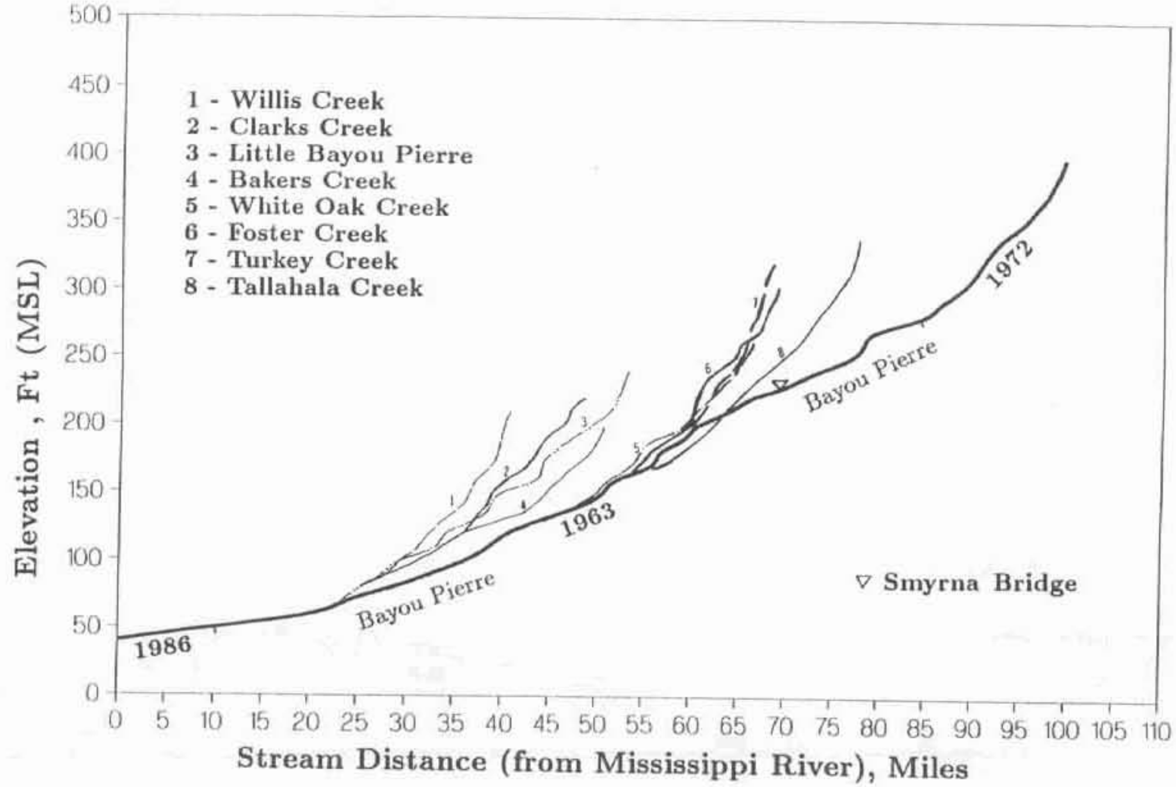

Figure 3: Longitudinal profiles plotted from topographic map data of Bayou Pierre and its major tributaries.

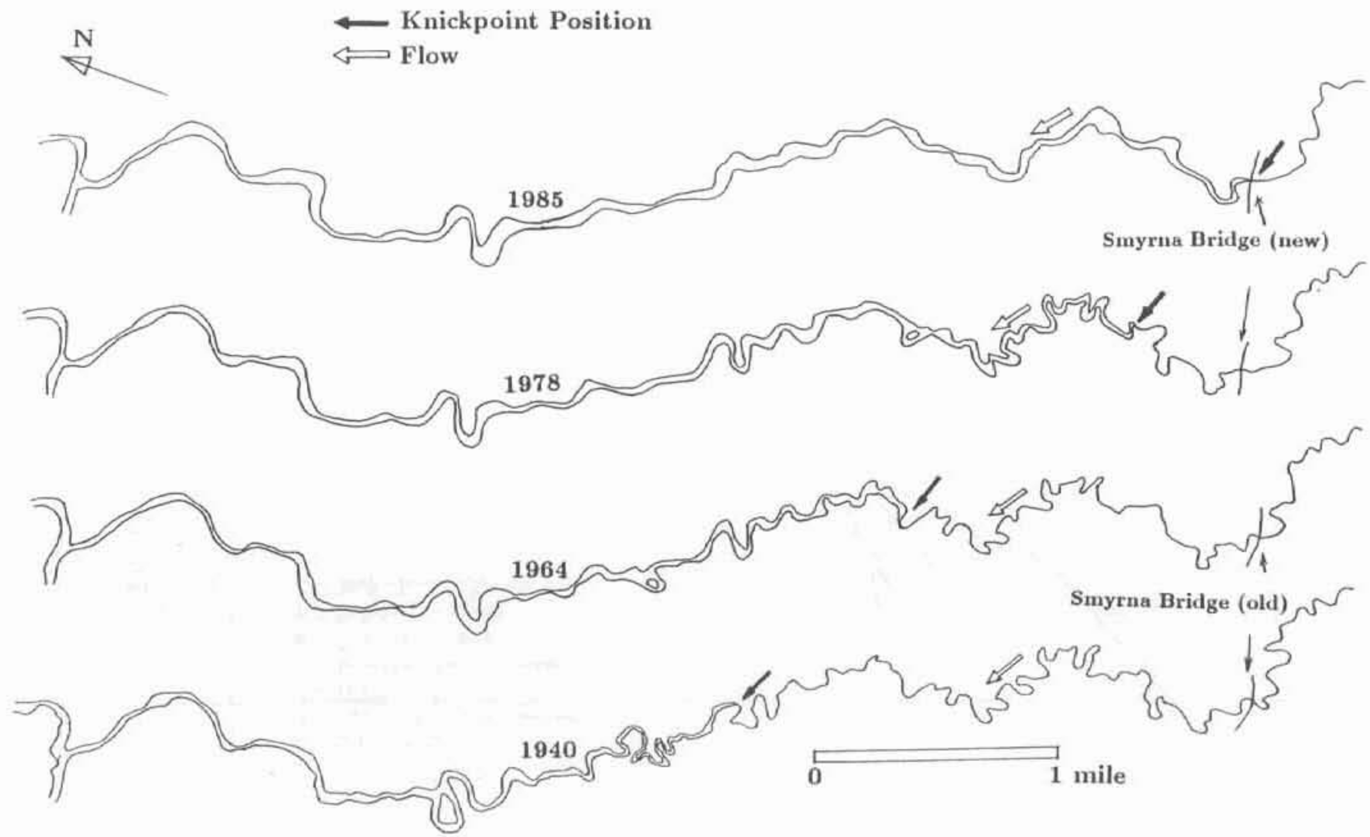

Figure 4: Line drawings developed from aerial imagery for a reach of Bayou Pierre from the confluence of Turkey Creek to the Smyrna Bridge showing knickpoint migration.