RECENT GEOMORPHIC EVOLUTION OF THE LITTLE PINEY CREEK, PHELPS COUNTY, MISSOURI

by

AARON LEWIS PUGH, 1960-

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Approved by

John D. Rockaway, Ph.D., Advisor

David J. Barr, Ph.D.

Jerome A. Westphal, Ph.D.
ABSTRACT

During the past 75 years, many residents of the Ozark plateau have become concerned that the Ozark streams were becoming choked with gravel. This study was conducted to assess the timing and possible causes of gravel aggradation on Little Piney Creek.

Surficial stratigraphy of Little Piney Creek valley bottoms indicates four distinct periods of deposition since the mid to late Holocene. The first three depositional units consist of relatively large amounts of fine grained material being deposited in typically fining upward sequences, with the first unit being deposited more than 4000 years BP (before present, 1992). The latest period seems to have begun nearly 200 years ago, at approximately the same time as European settlement of the basin, and consist almost entirely of coarse grained material.

Analysis of census data, historical aerial photography, and recollections of local residents indicate that land-use disturbance of uplands has contributed to the aggradation of Little Piney Creek. However, analysis of historical precipitation and discharge data also indicates a strong correlation between precipitation and stream fluvial morphologic parameters. Morphologic parameters examined included; channel cross sections, the stage-discharge relationship, mean streambed elevations and the hydraulic geometry.

Two factors are theorized to have acted simultaneously to produce changes in the recent fluvial morphology of Little Piney Creek. One factor has been the a wave of sand and gravel derived from the drainage basin. This wave was created mostly from an influx of land-use-derived sediment from the basins uplands. The other factor has been the presence of multiple-year climatic anomalies. Discrete multiple-year periods of wet and dry weather have created discrete periods of channel stability and instability superimposed on the wave of land-use-derived sediments.
for purposes of illustration the surficial material has been grouped into eight categories: 1) weathering profile, 2) sandy-loam, 3) silty-clay, 4) clay, 5) sand & gravel, 6) sand; 7) gravel; and 8) bedrock (figure 5).

The radiocarbon dating of the three samples taken from the backhoe pits was performed by Beta Analytic Inc., Coral Gables, Florida. Before the samples were sent, all visible rootlets were removed. Beta Analytic Inc. further prepared the three samples by first examining for rootlets, then administering a hot acid wash to eliminate carbonates, followed by repeated rinsing to neutrality. The samples were then given a hot alkali soaking to remove humic acids and again repeatedly rinsed to neutrality. Finally the samples were given a second acid wash and rinsed to neutrality. The samples were then dated using C-14 radiocarbon dating methods. The results of the radiocarbon dating are given in Table II.

Table II.—Radiocarbon dates for surficial material of the Little Piney Creek, site 1, pits 1 & 2.

<table>
<thead>
<tr>
<th>LOCATION</th>
<th>DATE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pit 1 (charcoal)</td>
<td>460 +/- 70 Years BP</td>
</tr>
<tr>
<td>Pit 2 (wood &amp; leaf mat)</td>
<td>20 +/- 50 Years BP</td>
</tr>
<tr>
<td>Pit 2 (wood &amp; leaf mat)</td>
<td>60 +/- 60 Years BP</td>
</tr>
<tr>
<td>BP: Before Present (1991)</td>
<td></td>
</tr>
</tbody>
</table>

B. FLUVIAL MORPHOLOGY

Channel cross-sections, stage-discharge data pairs, mean streambed elevations, and stream geometry relationships were obtained from U.S. Geological Survey discharge measurement notes, station #06932000 at Newburg, Mo. (U.S. Geol. Survey Water-Supply Papers). Sixtythree data sets were selected based on the following two requirements: 1) the measurement must have been made at the highway T bridge, at Newburg, Mo., and 2) the stage must have been at or below bankfull (Appendix B). By choosing only those measurements made at the bridge guarantees that all measurements were made at the same location, thus maintaining vertical and horizontal control. To calculate the mean stream depth required the assumption of a rectangular cross-sectional area. For this reason only those measurements made at a stage of bank
full or less were chosen.

Fourteen representative channel cross-sections are presented in figure 6. The cross sections were plotted from soundings made during the collection of discharge measurements at the highway T bridge between 1929 and 1989. Cross sections were aligned horizontally using pier locations, while the bridge provided vertical control. Channel cross-sections reveal relations between channel morphology and bed position.

Stage-discharge data pairs provide an independent means of assessing changes in channel morphology. Figure 7(a) is a plot of the stage-discharge pairs with stage expressed as a power function of discharge. Figure 7(b) is a plot of the residuals of the stage-discharge regression. Regression residuals were defined as the actual value minus the calculated value. Stage-discharge residual plots may identify periods of channel aggradation and degradation. Stage depends not only on discharge and bed elevation, but integrates the effects of several hydraulic variables over the entire channel boundary, including channel slope, roughness, cross-sectional area, and flow velocity (Hey, 1978; Hey and Thorne, 1986). When used in conjunction with other observations, long-term changes in the stage of a given discharge can reveal channel scouring or filling.

By assuming a rectangular channel cross-section, the mean stream depth may be calculated by dividing channel area by the width. For the selected discharge measurements, the mean streambed elevation was calculated by adding the gage height to the datum elevation (resulting in the water surface elevation) and then subtracting the mean depth. A plot of the running average (J=5) of the mean streambed elevations and the mean streambed elevation data is presented in figure 8. Mean streambed elevations augment information from channel cross-sections or stage-discharge relationships by revealing the average depths of scour and fill.

Hydraulic geometry data may indicate long-term changes in channel shape. Leopold and Maddock (1953) noted that width, depth, and velocity vary with discharge by the following power functions:

\[ w = a \times Q^b \]  \hspace{1cm} (1)

\[ d = c \times Q^d \]  \hspace{1cm} (2)

\[ v = k \times Q^v \]  \hspace{1cm} (3)

Note: \( Q = \text{Area} \times \text{Velocity} = w \times d \times v \)
Figure 6.--Channel cross sections, gage at Newburg.
Figure 7.--Stage-discharge relationship, gage at Newburg. (a) Stage (relative to gage datum) as a power regression of discharge. (b) Time series of regression residuals.

Figure 8.--Mean streambed elevations, gage at Newburg.
\[ Q = (a \times Q^b) \times (c \times Q^f) \times (k \times Q^m) \]

Thus: \[ b + f + m = 1 \]
\[ a \times c \times k = 1 \]

where \( w \) is width in feet, \( d \) is mean depth in feet, \( v \) is mean velocity in feet per second, \( Q \) is discharge in cubic feet per second, \( a, c \) and \( k \) are the \( y \) intercepts, and \( b, f, \) and \( m \) are the slopes.

The Little Piney’s hydraulic geometry data and the corresponding power functions (figure 9) produced values for \( b, f, \) and \( m \) which sum to 1.000; and values for \( a, c, \) and \( k \) which have a product of 1.087. Deviation of the product of \( a, c, \) and \( k \) from 1.000 was a result of computer rounding of these values.

The values obtained from the Little Piney Creek for depth (\( f \)) correlate well with the values obtained by Leopold and Maddock (1953) and with the values obtained by Carlson (1969) (Table III). The Little Piney’s values for width (\( b \)) and velocity (\( m \)) appear to have been interchanged when compared to the values obtained by Leopold and Maddock and by Carlson. This is due to the fact that the Little Piney data were collected from the Highway T bridge at Newburg which offers a constricted opening to higher flows, limiting width adjustment. Leopold and Maddock’s observations were from ten river basins across the country including: the Mobile River, the Scioto River, the Tennessee River, the St. Lawrence River, the Yellowstone River, the Velle Fourche River, the Kansas River, the Missouri River, the Mississippi River, and a combination of the Missouri and Mississippi Rivers. Carlson’s observations were from 46 stations in the Yellowstone River basin, representing a large segment of the western plains country to the eastern Rocky Mountain front.

Table III.—Stream geometry relation to discharge.

<table>
<thead>
<tr>
<th>SLOPE</th>
<th>LITTLE PINEY CREEK</th>
<th>LEOPOLD AND MADDOCK</th>
<th>CARLSTON</th>
</tr>
</thead>
<tbody>
<tr>
<td>Width (( b ))</td>
<td>0.179</td>
<td>0.461</td>
<td>0.499</td>
</tr>
<tr>
<td>Depth (( f ))</td>
<td>0.346</td>
<td>0.383</td>
<td>0.320</td>
</tr>
<tr>
<td>Velocity (( m ))</td>
<td>0.475</td>
<td>0.155</td>
<td>0.180</td>
</tr>
<tr>
<td>SUM</td>
<td>1.000</td>
<td>0.999</td>
<td>0.999</td>
</tr>
</tbody>
</table>

Residuals from the width, mean depth and velocity regressions indicates how the
Figure 9. -- Hydraulic geometry, gage at Newburg.
Figure 10.--Time series of the hydraulic geometry regression residuals, gage at Newburg.
Little Piney stream geometry has adjusted over the period of record (figure 10).

The Little Piney Creek's width/depth ratio decreases with discharge (figure 9) due to containment of floods within the stream banks, and the spreading out of low-flows over the relatively flat bed. Width/depth ratios of overbank flows would increase with discharge, however only discharge measurements made within streambank flows were selected for this analysis. Residuals from the width/depth regression (figure 10), along with the hydraulic geometry and channel cross-sections indicate the morphological evolution of the Little Piney Creek over the period of record.

C. CLIMATE

Discharge measurements and stream basin characteristics were obtained from the U.S. Geological Survey, station at Newburg (U.S. Geol. Survey Water-Supply Papers). Precipitation measurements from the National Oceanic and Atmospheric Administration (NOAA), station at Rolla-University of Missouri (NOAA Climatological Data for Missouri), were used to investigate climatic trends for the Little Piney Creek basin (Appendix C).

The annual maximum flood series indicates long term trends in maximum discharge. The Little Piney Creek's annual maximum flood series is characterized by three distinct regions. The first, from 1929 through 1951, is dominated by moderate and large floods, the second, from 1952 through 1981, consist of small and moderate floods, while the third region, from 1982 through 1988, is principally moderate and large floods (figure 11).

Figure 12(a) depicts the relationship between precipitation and discharge. The residuals of this relationship over time may indicate basic changes in the basin water budget with respect to precipitation and discharge (figure 12(b)).

The basin's water budget may be broken into two components: the surface budget, which includes precipitation, surface flow in and out, groundwater flow into the stream, infiltration, evaporation and transpiration; and the groundwater budget, which includes infiltration, groundwater flow into and out of the basin, evaporation and transpiration (Bras, 1990). Any variation in the precipitation-discharge relationship would be a direct result of changes in one or more of the components of the basin's water