HISTORICAL LAND-USE CHANGES AND POTENTIAL EFFECTS ON STREAM DISTURBANCE IN THE OZARK PLATEAUS, MISSOURI

U.S. GEOLOGICAL SURVEY
Open-File Report 94-333

Prepared in cooperation with the
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By ROBERT B. JACOBSON *and* ALEXANDER T. PRIMM

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Rolla, Missouri
1994

U.S. DEPARTMENT OF THE INTERIOR

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CONVERSION FACTORS AND VERTICAL DATUM

Multiply	By	To obtain
inch	25.4	millimeter
foot	0.3048	meter
mile	1.609	kilometer
acre	0.4047	hectare
cubic foot per second	0.02832	cubic meter per second
millimeter	0.03937	inch
meter	3.281	foot
kilometer	0.6214	mile
square kilometer	0.3861	square mile
meter per second	3.281	foot per second

Temperature in degrees Celsius (°C) can be converted to degrees Fahrenheit (°F) as follows:

$$°F = (1.8 \times °C) + 32$$

Sea Level: In this report "sea level" refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929)--a geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called Sea Level Datum of 1929.

HISTORICAL LAND-USE CHANGES AND POTENTIAL EFFECTS ON STREAM DISTURBANCE IN THE OZARK PLATEAUS, MISSOURI

By Robert B. Jacobson[1] *and* Alexander T. Primm[2]

ABSTRACT

Land-use changes have been blamed for creating disturbance in the morphology of streams in the Ozark Plateaus, Missouri (hereafter referred to as the Ozarks). Historical evidence and stratigraphic observations document that streams have been aggraded by substantial quantities of gravel beginning sometime at or near the time of European settlement of the Ozarks. Before European settlement, streams were depositing a mixed sediment load of gravel bedload and silty overbank sediment. Observations of early explorers conspicuously lack descriptions of extensive gravel bars; observations of geologists working during the middle to late 1800's before significant land-use disturbance, however, include descriptions of large quantities of gravel in stream banks and beds.

The first change in land cover as settlement progressed from the early 1800's to approximately 1880 was replacement of valley-bottom forest with cultivated fields and pastures. At the same time, suppression of wildfires in the uplands caused an increase of woodland with woody understory at the expense of grassland and oak savannah. Valley-bottom clearing probably initiated some direct disturbance of stream channels, but fire suppression would have decreased runoff and sediment yield from uplands.

Beginning sometime during 1870 to 1880 and continuing until 1920, commercial timber companies began large operations in the Ozarks harvesting shortleaf pine for sawlogs and oak for railroad ties. Selective cutting of large timber, use of livestock for skidding logs from the forest, and avoidance of the steeper slopes minimized the effect of this phase of logging on runoff and sediment supply of uplands and valley-side slopes. Continued decreases in the erosional resistance of valley bottoms through clearing and road building, and the incidence of extreme regional floods from 1895 to 1915, probably caused initiation of moderate stream disturbance. This hypothesis is supported by historical and oral-historical observations that stream instability began before the peak of upland destabilization from 1920 to 1960.

The post-Timber-boom period (1920 to 1960) included the institution of annual burning of uplands and cut-over valley-side slopes, increased grazing on open range, and increased use of marginal land for cultivated crops. Models for land-use controls on annual runoff, storm runoff, and soil erosion indicate this period should have been the most effective in creating stream disturbance. Written historical sources and oral-historical accounts indicate that erosion was notable mainly on lands in row-crop cultivation. Oral-history respondents consistently recall that smaller streams had more discharge for longer periods during 1920 to 1960 than during 1960 to 1993; many additionally observed that floods are "flashier" under present-day (1993) conditions. Changes in the timing of hydrographs probably relate to changes in upland and riparian zone vegetation that decreased storage and flow resistance. Probably the most destabilizing effect on Ozarks stream channels during this period was

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caused by livestock on the open range that concentrated in valley bottoms and destroyed riparian vegetation in the channels and on banks. Destruction of riparian vegetation in small valleys may have encouraged headward migration of channels, resulting in extension of the drainage network and accelerated release of gravel from storage in the small valleys. This hypothesis is supported by lack of other sources for the large quantity of gravel in Ozarks streams and oral-historical observations that gravel came out of the runs, rather than from slopes.

From 1960 to 1993, cultivated fields and total improved land in farms decreased, but cattle populations continued to increase. This increase in grazing density has the potential to maintain runoff and sediment delivery to streams at rates higher than natural background rates. Whereas some riparian zones have been allowed to grow up into bottom-land forest, this stabilizing effect occurs on only a small part of valley-bottom land. Recovery processes aided by riparian vegetation are limited by channel instability and frequent, large floods.

INTRODUCTION

Many stream channels in the Ozark Plateaus physiographic province (known locally, and hereafter referred to in this report, as the Ozarks; fig. 1) are perceived to be aggrading with gravel and sand at greater than natural rates, and that aggradation is accompanied by increased incidence of channel instability (Saucier, 1983). Aggradation and instability are thought to alter physical habitat in Ozarks streams, resulting in an overall decrease in habitat quality (Jacobson and Pugh, 1992; Rabeni and Jacobson, 1993).

Disturbance to a stream channel exists when channel characteristics are outside of an accepted range of variability. The bounds on the range of variability, however, are dependent on a reference frame of the time and spatial scales of interest. For example, 100 percent channel widening during 1 year in a stream reach 100 m (meters) long would be a significant disturbance if the reference frame of interest was on the order of several years and several hundred meters. However, such a disturbance could be considered acceptable natural variability on time scales of centuries and spatial scales of hundreds of kilometers. For the purposes of this report, a channel is considered disturbed if geomorphic features or alluvial processes are outside of the range of variability that would be expected over scales of several kilometers and multiple decades to several centuries.

Stream disturbance in the Ozarks has been linked to land-use changes that have occurred since European settlement (Hall, 1958; Kohler, 1984; Gough, 1990; Love, 1990). However, the hypothesis of land-use-induced disturbance has never been tested rigorously. Testing of this hypothesis requires, at minimum, definition of the bounds of natural spatial and temporal variability of stream disturbance, establishment that post-settlement disturbance was outside these bounds, and definition of the processes responsible for disturbance.

Purpose and Scope

The purpose of this report is to present historical evidence of land-use changes and stream disturbance in the Ozarks from the period before European settlement to the present (1993) and to evaluate possible cause and effect relations between land-use changes and stream disturbance. This evaluation will add to ongoing studies intended to test the hypothesis that post-settlement period land-use changes are responsible for stream disturbance, to evaluate the consequent effects on stream ecology, and to develop a predictive understanding of how these streams will change in the future with continued land-use and climate change. These studies by the U.S. Geological Survey are in cooperation with the Missouri Department of Conservation.

The specific objectives of this report are to evaluate:

- upland and riparian vegetation conditions before European settlement;
- conditions of Ozarks streams before settlement;
- the magnitude of upland and riparian land-use changes that occurred after settlement; and
- the potential for increased magnitude or frequency of stream disturbance as a result of post-settlement land-use changes.

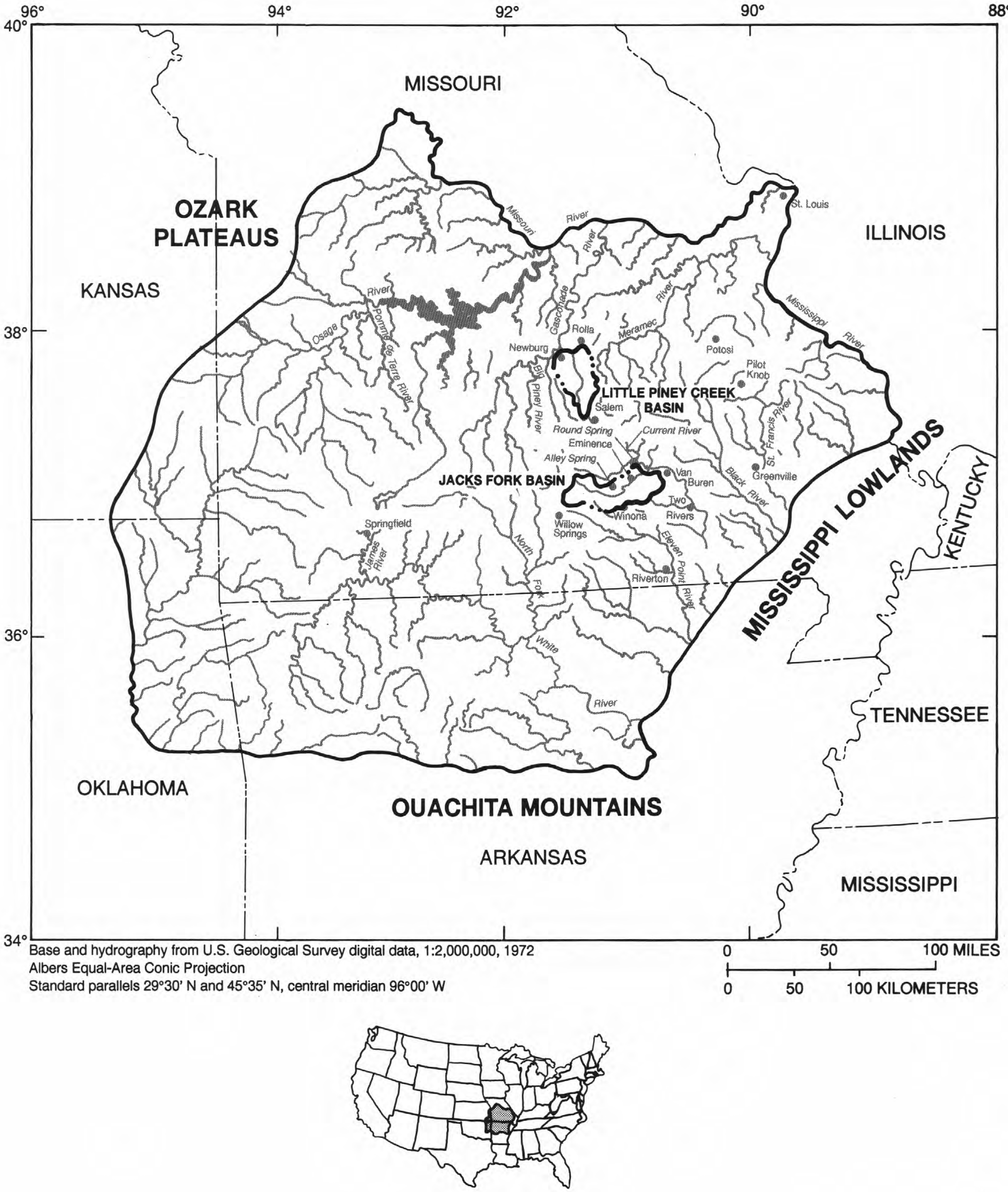


Figure 1. Ozark Plateaus physiographic province, rivers, and drainage areas of the Jacks Fork and Little Piney Creek Basins.

The general objective of this report is to increase understanding of the processes by which landscape disturbances are propagated through drainage basins.

To accomplish these objectives, this report compiles various sources of information including stratigraphic studies, archeological studies, historical documents, land-use statistics, historical photography, and oral-historical accounts. The historical information is then used with simple runoff, soil erosion, and hydraulic models to discuss the probable cause and effect relations between land use and stream disturbance in the Ozarks.

The geographic scope of this report is the Ozarks of Missouri, with emphasis on two representative drainage basins, Jacks Fork and Little Piney Creek. These basins were selected because of their long hydrologic record [1921 to present (1993) for Jacks Fork and 1929 to present (1993) for Little Piney Creek] and representative land-use histories and physiographies. The land-use history compiled applies in general to the entire Ozarks; however, emphasis is placed on the steeper land of the Salem Plateau, which has been subjected to timber cutting as well as agricultural land uses.

Background

Previous studies have described features of Ozarks stream morphology that are indicative of aggradation and instability (Saucier, 1983; Jacobson and Pugh, 1992); collectively, these features fit within the definition of disturbance used in this report. Saucier (1983) described disturbance zones in Ozarks streams consisting of bar/island complexes, large, unstable gravel bars, and eroding cutbanks (fig. 2). He attributed these features to upland land-use changes, principally timber cutting during the turn of the century followed by grazing. Jacobson and Pugh (1992) presented preliminary stratigraphic observations that established the existence of pre-settlement period episodes of stream aggradation and instability and documented that the most recent, post-settlement period of aggradation involved much greater volumes of gravel and sand than the previous episodes.

Jacobson and Pugh (1992) also reviewed changes in streambed elevation at four U.S. Geological Survey stream gaging stations from 1921 to 1990 and determined (1) a trend of streambed degradation after 1930 in two smaller basins [512 and 1,019 km^2 (square kilometers) area; fig. 3]; (2) multiple episodes of aggradation and degradation in two larger basins (2,030 and 4,268 km^2); and (3) an apparent correlation of episodes

Figure 2. Oblique aerial photograph of unstable channel zone, the Current River between Two Rivers and Van Buren, Missouri (flow is from right to left: field of view is approximately 600 meters).

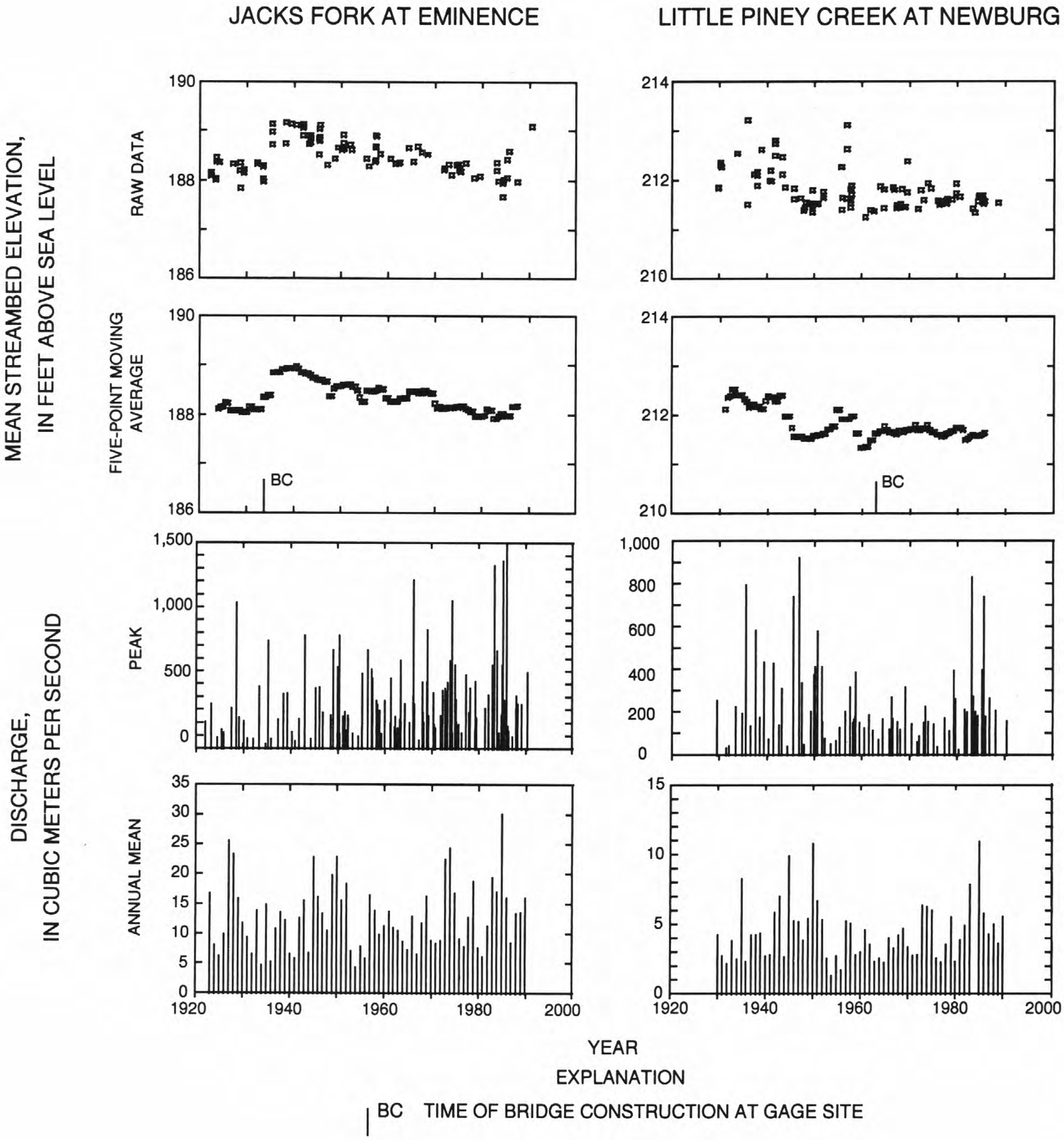


Figure 3. Streambed elevation changes and annual mean and peak discharges, Jacks Fork and Little Piney Creek, Missouri.

of aggradation and degradation with multiple-year climatic shifts. Jacobson and Pugh concluded from these observations that there is potential for aggradation and instability in Ozarks streams because of climatic effects in the absence of post-settlement land-use changes; climatically induced effects have interacted with a wave of land-use-derived sediment in complex ways related to timing of the two sources of disturbance, routing of disturbance-induced sediment through a basin and other non-systematic factors, such as geomorphic thresholds, timelags, and internal geomorphic adjustments.

Conceptually, disturbance to a channel can occur as a result of changes imposed to basin-scale factors, such as runoff characteristics and sediment supply, or channel-scale factors, such as altered roughness or resistance to erosion in channels and on banks. Channels also may be disturbed as a result of adjustments that are internal to the basin system (Schumm, 1973), but these disturbances can be considered part of the normal variability of the system. In the Ozarks any of these factors may have operated to induce channel disturbance. The main hypotheses are listed below.

(1) There has been no disturbance; all features indicative of disturbance are within variation expected under natural conditions.
(2) Disturbance is the result of a discrete climatic shift or extreme hydrometeorological events (floods or droughts) that have altered runoff or sediment supply, whereas land-use changes have been insignificant.
(3) Upland land-use changes have increased quantity or timing of runoff and quantity of sediment supply.
(4) Valley-bottom land-use changes to channels and vegetation have increased erodibility of banks and streambeds or erosivity of floods.
(5) Rare hydrometeorological events have combined with land-use-induced changes that have lowered geomorphic thresholds, producing a complex response.

Morphological and stratigraphic evidence of significant disturbance during the last 100 years indicates that natural variability alone (hypothesis 1) is unlikely to have created the present (1993) state of Ozarks streams (Saucier, 1983, 1987; Jacobson and Pugh, 1992). Radiocarbon dates supporting the existence of pre-settlement period episodes of channel instability indicate the possibility that hypothesis 2 can be a contributing factor, but changes in streambed elevations during the last 50 years support hypotheses 3 and 4, that land-use changes have created a wave of land-use-derived sediment (Jacobson and Pugh, 1992). Existing observations are consistent with hypothesis 5, but data are insufficient to separate the effects of rare hydrometeorological events and thresholds lowered by land-use changes. Although most of the evidence is consistent with land-use-induced disturbance of streams, the evidence does not constitute a rigorous test. In particular, previous studies have not provided detailed characterizations of how recent stream disturbance compares to natural variation or of the processes that link cause and effect.

The historical data that are presented in this report are inadequate for rigorous testing of the hypotheses outlined above. However, these data provide essential observations for constraining hydrologic models of cause and effect and additionally indicate new hypotheses to explain observed phenomena.

Location, Geology, and Physiography

Historical information collected in this study is for the entire Ozarks of Missouri (figs. 1 and 4). Land-use statistics are presented for 14 counties representative of the Salem Plateau. Oral history and additional detailed data are presented for the Jacks Fork and Little Piney Creek Basins (fig. 1).

The Ozarks are a broad geologic uplift with its medial axis oriented approximately southwest-northeast (fig. 4). They are approximately bounded by the Mississippi River valley and lowlands on the east and southeast, the Missouri River on the north, the Ouachita Mountains on the south, and the outcrop of Mississippian rocks on the west (figs. 1 and 4; Fenneman, 1938; Hunt, 1974). Most of the area is underlain by nearly flat-lying Paleozoic sedimentary rocks of Cambrian, Ordovician, and Mississippian age. The sedimentary rocks are dominated by cherty limestone and dolomite, with smaller contributions of sandstone and shale. A small area of igneous rocks defines the St. Francois Mountains.

Weathering of the carbonate rocks has produced a variable thickness of residuum. On areas of low slope and chert-rich rocks, clay- and gravel-rich residuum and colluvium can accumulate to as much as 6 to 7 m thick. Areas of steeper slopes have thin, clay-rich soils or no soil at all.

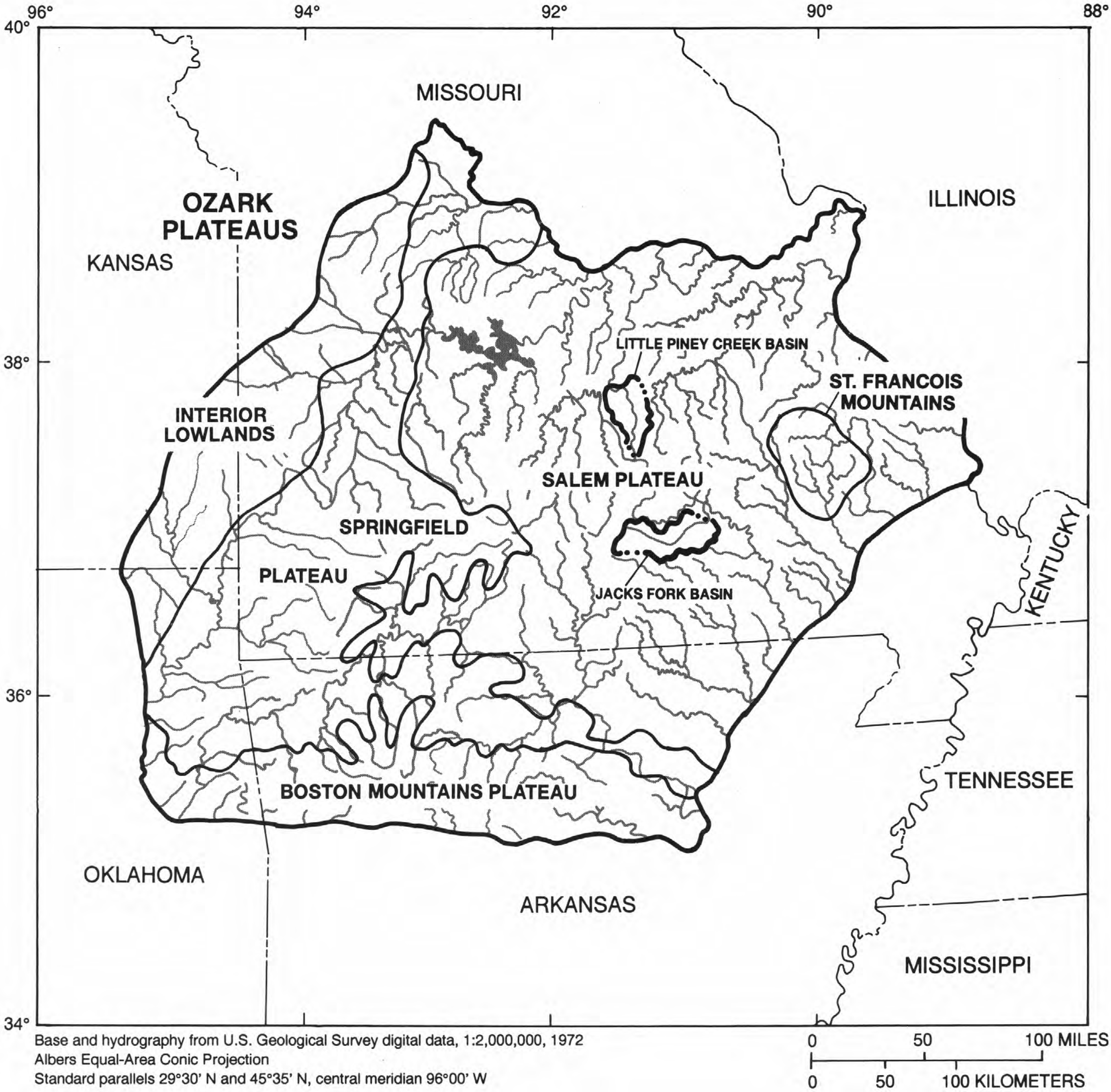


Figure 4. Physiographic subdivisions of the Ozark Plateaus, drainage network, and location of Jacks Fork and Little Piney Creek Basins, Missouri.

A karst drainage system has developed in the carbonate rocks over most of the Ozarks (Vineyard and Feder, 1974). Much of the upland precipitation that is not extracted in evapotranspiration infiltrates into the subsurface karst drainage system to emerge in springs in the valley bottoms. Under natural land-use conditions, runoff is restricted to unusually intense rainfall events so that many upland streams are dry most of the year.

The Osage, Gasconade, and Meramec are the dominant rivers draining the north and west sides of the Ozarks (fig. 1). The south and east sides mostly are drained by tributaries of the White River, including the James, North Fork, Eleven Point, Current, and Black Rivers. The part of the Ozarks underlain mainly by rocks of Ordovician age and older is called the Salem Plateau, whereas the part underlain mainly by rocks of Mississippian age is called the Springfield Plateau (fig. 4). The Boston Mountains Plateau is underlain by resistant clastic rocks of Pennsylvanian age; the St. Francois Mountains are an area of uplifted Precambrian igneous rocks. Elevations in the Ozarks range from approximately 150 m above sea level in the north along the Mississippi River to slightly more than 720 m above sea level in the Boston Mountains Plateau on the southern border. In Missouri, the upland elevations commonly are less than 500 m above sea level except in the St. Francois Mountains.

River valleys of third order and greater in the Ozarks have an entrenched appearance with steep valley walls and local relief as much as 200 m (fig. 5). Uplands between the valleys, however, have a rolling topography with local relief typically of only a few tens of meters. Valleys in the upper parts of basins are wide with gradual slopes extending from the stream channel to the valley wall; many of these streams are ephemeral with flow only during periods with large quantities of rainfall. Downstream, valleys become narrower and canyon-like. In these valley reaches, there are little valley-bottom sediment and many bedrock bluffs. Springs are abundant along valley margins of the canyon-like reaches and provide a relatively steady base flow. Still farther downstream, valleys are wider and have extensive valley-bottom deposits consisting of floodplain and alluvial terraces bounded by steep valley walls.

Climate

The Ozarks have a continental climate affected by prevailing east-moving storm systems, Gulf-coast moisture sources, and occasional incursions of the polar front. The climate record at Rolla (period of record is 80 years; fig. 1) is representative of the central Ozarks. Mean annual temperature ranges from 15 to 18 °C (degrees Celsius) and mean annual precipitation ranges from 1,000 to 1,200 mm (millimeters; Jacobson and Pugh, 1992). On average, May and June generally receive greater rainfall than other months (fig. 6); however, the seasonality of rainfall and annual rainfall have varied significantly by multiple-year periods during the last 80 years (Pugh, 1992)

Acknowledgments

The authors acknowledge the extremely valuable contribution of the oral-history respondents who took part in this study. We also thank the staff of the Ozark National Scenic Riverways for historical information and logistical support.

METHODS

Systematic, detailed data bases for direct evaluation of land-use changes from pre-settlement period to the present (1993) do not exist. For this reason, many types of data sources were addressed for this study in an attempt to use all available indirect information that would apply.

Historical Sources

Prehistoric land-use data were compiled from interpretive reports of archeology, palynology, dendrochronology, and geomorphology (Knox, 1972, 1983; King and Allen, 1977; Barrett, 1980; Brakenridge, 1981; Guyette and McGinnes, 1982; Chapman and Chapman, 1983; Smith, 1984; Haynes, 1985; Huber, 1987; Saucer, 1987; Cleaveland and Stahle, 1989; Ladd, 1991; Royall and others, 1991; Mink, 1992; Miller and others, 1993). Descriptions of the pre- and Early-settlement period landscape were given in accounts of travelers and explorers and some diaries of early settlers (Schoolcraft, 1819, 1821; Featherston-

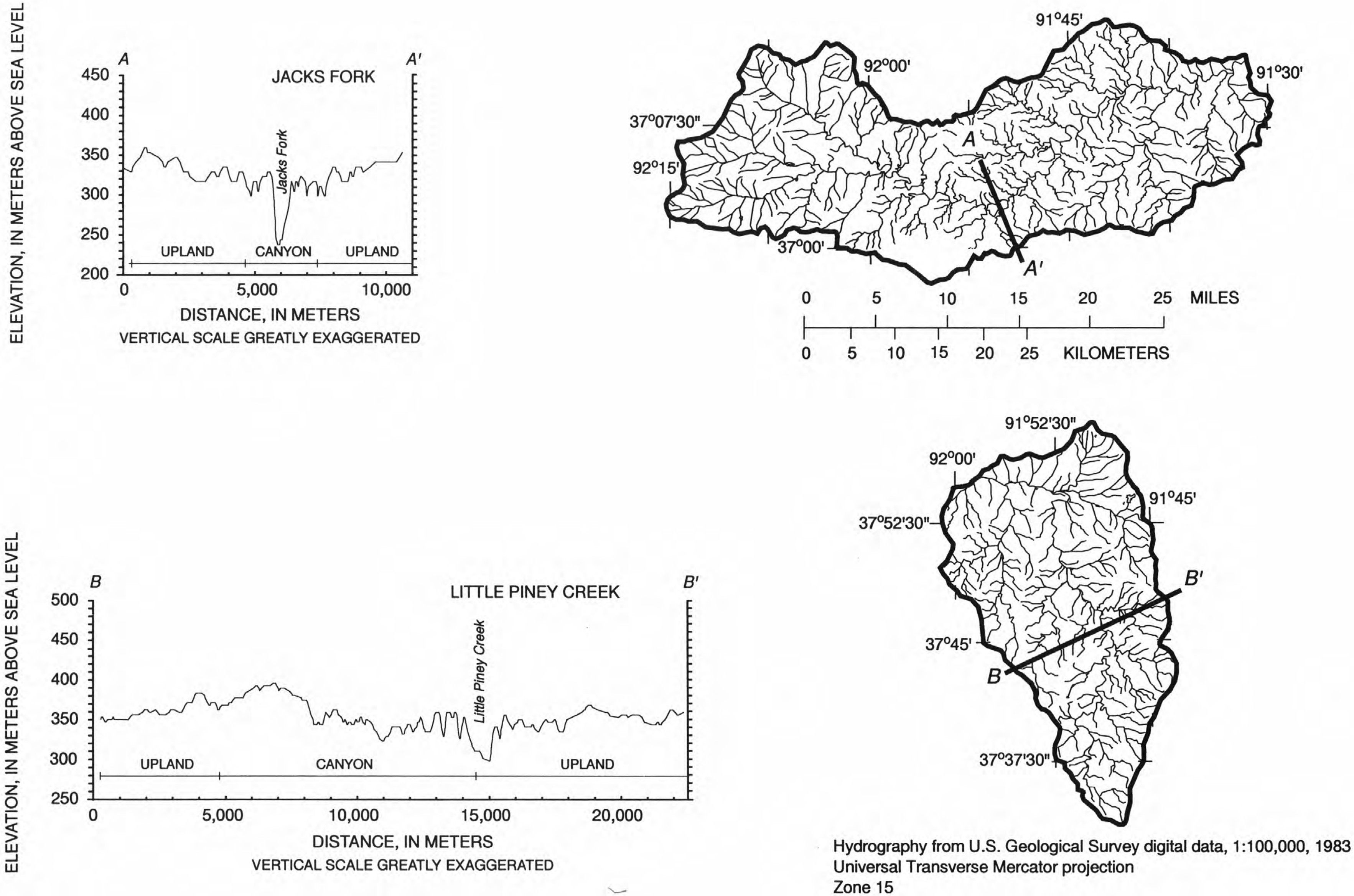


Figure 5. Representative topographic profiles across Jacks Fork and Little Piney Creek Basins, Missouri.

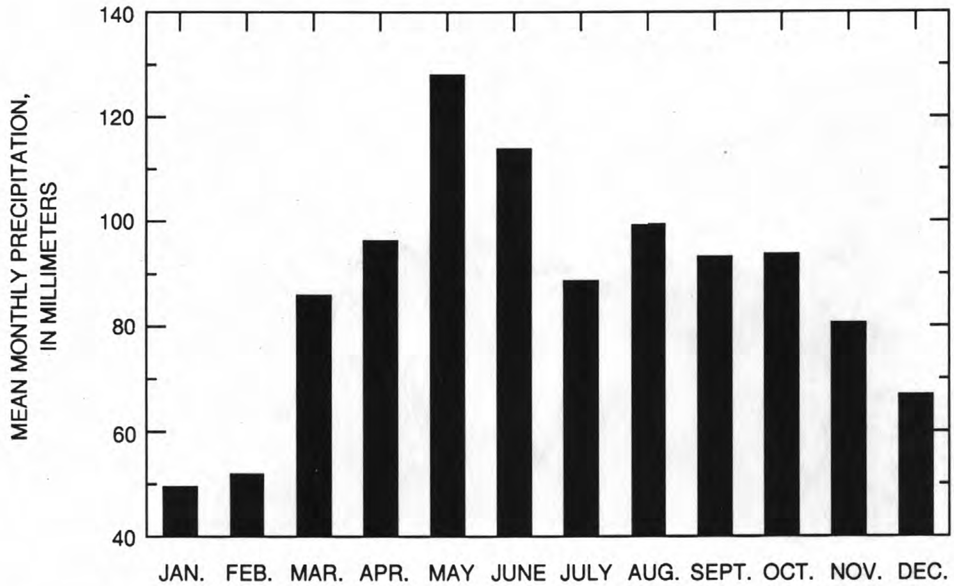


Figure 6. Mean monthly precipitation, Rolla, Missouri, 1900-90.

haugh, 1844; Goodspeed Publishing Company, 1889; Goodrich and Oster, 1986). Both original documents and historical compilations were consulted.

Geologists, foresters, and soil scientists began to study the Ozarks beginning in the mid-1800's. Geologic reports provided detailed descriptions of gravel resources that provide some insight into stream disturbance (King, 1839; Swallow, 1855, 1859; Williams, 1877; Keyes, 1895; Marbut, 1896, 1914; Lee, 1913; Dake, 1918; Bridge, 1930; Hendriks, 1954). With increased national interest in soil conservation in the 1930's, professional accounts of the Ozarks landscape increased. A series of reports on Ozarks timber and soil occur in publications of the U.S. Department of Agriculture, Bureau of Soils and Agricultural Stabilization and Conservation Service (ASCS), and Agricultural Experiment Station of the University of Missouri-Columbia. These reports were considered to be highly reliable and objective accounts of land-use and erosion conditions during 1900 to 1950 (Krusekopf and others, 1918; Miller and Krusekopf, 1918; Watkins and others, 1919; Helm, 1925; Auten, 1934; Baver, 1935; Bennitt and Nagel, 1937; Krusekopf, 1937; Arend, 1941). Historical photographs of streams and land-use practices also were consulted and some are reproduced to show qualitative aspects of stream changes.

Land-use Data

The Government Land Office (GLO) performed systematic boundary surveys of the Ozarks from the 1810's to the 1840's. Surveyors noted vegetation and soil characteristics along the lines of survey and measured the distances to witness trees at section corners and the widths of channels crossed along the line of survey (table 1). These types of GLO data have been used in previous studies to document historical land-use and geomorphic changes (Trewartha, 1940; Schumm and Lichty, 1963; Knox, 1972). In this study, pre-settlement period land-use maps were compiled from interpretations of unpublished GLO survey data on file at the Missouri Division of Geology and Land Survey, Rolla, Missouri. Survey notes also were used as general observations of vegetative conditions. Surveyors' descriptions were classified into six categories (table 2) based on their descriptions [which usually were averaged for the 1-mi (mile) section line] and distances measured to the witness trees. These categories were noted on a map of the basins, contiguous areas were combined into polygons, and the data were digitized into a digital geographic information system.

Changes in land-use patterns from pre-settlement period to the late 1970's were assessed by digitally overlaying the GLO maps of pre-settlement period

Table 1. Typical Government Land Office survey notes for an upland and a valley bottom area in the Little Piney Creek Basin, Missouri (from unpublished survey notes on file at Missouri Division of Geology and Land Survey, Rolla, Missouri)

[Original spelling and notations are preserved; distances are given in chains and links; E, east; N, north; W, west; S, south; N°, number; T, township; R, range; B oak, black oak; Dia, diameter; lks, links; W oak, white oak; In, inch; Tim, timber; B walnut, black walnut; under, undergrowth]

North along the E Side of Section N° 25 T36N of RN°9W

Chains		
15	23	a B oak 8 in Dia
37	25	a Brook 15 lks wide runs NE
40	00	Set 1/4 Section post from which a W oak 8 In Dia bears N26°W 213 lks
65	81	a B oak 8 in Dia
80	00	Set post corner of Section N° 24 & 25 from which a W oak 18 In Dia bears N54 1/2°W 145 lks and a W oak 18 In Dia bears S30°W 128 lks Land hilly and Stoney not fit for cultivation barrens B & W oak bushes
		March the 24th 1822

East Between Sections N° 25 and 36 T 37 N R 9 W on a random line

Chains		
10	00	a creek 100 lk wide runs NE
40	00	Set Temporary 1/4 Section post
80	30	intersected the NS line 3 lks North of the Section corner Land this mile level good Soil Tim oak Elm B walnut & under redbud hazel Spice etc

Table 2. Pre-settlement period land-use categories and Government Land Office survey note equivalent descriptions

[Classification categories are from U.S. Geological Survey (1990)]

Category	Survey note equivalent descriptions
Herbaceous rangeland (pasture and cropland)	Prairie
Shrub and brush rangeland (oak savannah)	Thin timber with understory open, grass understory, and long distances between witness trees
Deciduous forest land	Timber with oak, elm, walnut, and hickory as major species and understory the same or hazel, spicebush, vines, or other brushy plants
Evergreen forest land	Pines
Mixed forest land	Mixture of deciduous trees and pines, understory grassy, open, or brushy
Mixed barren land (barrens)	Barrens with no timber or stunted, extremely thin timber

land cover in the Jacks Fork and Little Piney Creek Basins with land-use maps derived from high-altitude aerial photography (U.S. Geological Survey, 1990). Level two land-use classes were simplified and matched to corresponding classes derived from GLO survey notes (table 2).

Official U.S. Census data for Missouri began during 1850 (U.S. Bureau of the Census, 1850-1982). These data were used in this report for a statistical view of land use, timber harvest, and population changes. A subset of 14 Ozarks counties was selected as being representative of land-use trends on the Salem Plateau.

Aerial photography of the Ozarks was started by the ASCS during 1938. These photographs were compared to later photographs to assess qualitatively upland and valley-bottom land-use changes and evidence of gullying.

Oral History

To gain a more detailed understanding of land use and erosional processes that existed from the turn of the century to the present (1993), oral-historical accounts were collected from elderly inhabitants of the Jacks Fork and Little Piney Creek Basins. Potential respondents were identified by recommendations of initial contacts in the area. During the interviews, respondents were asked to identify additional people to contact. In this way most of the older, long-term inhabitants in the two basins were identified and contacted. Respondents were chosen for interviews on the basis of length of time they had lived in the area, strength of memory, and whether they had spent substantial time in activities that would make them knowledgable about landscape changes. The oral-historical accounts were obtained by interviewing respondents in their homes, establishing a relaxed rapport, and asking questions designed to draw out recollections of past land-use practices and landscape changes without bias. Oral-history respondents specifically were asked about the history of timber harvesting, tie and log drives, open-range grazing, upland and valley-bottom crops, stream changes, and fishing changes.

Oral-historical accounts provide detail and first-hand observations of landscape processes. If the accounts are interpreted with care to avoid common sources of biased memory, they are considered to be more specific and frequently less biased than many written sources of historical information (Thompson, 1978). With the lack of long-term, conventional scientific observation, oral-historical accounts become a significant basic data source.

PRE-SETTLEMENT PERIOD LANDSCAPE OF THE OZARK PLATEAUS

The landscape encountered by settlers moving into the Ozarks in the early 1800's was not static. Under natural conditions, a landscape is subject to episodic erosion and deposition, varying with time and space within some bounds. The extremes of this variation, such as extended drought or large floods, can produce geomorphic changes that are far in excess of that associated with human activities (Nolan and Marron, 1985; Osterkamp and Costa, 1987; Miller, 1990). Settlers possibly encountered the Ozarks during a time of naturally changing climate, either as a gradual trend or a discrete shift. Variability and trends in the pre-settlement period landscape processes must be evaluated to assess whether changes induced by settlement were significantly different.

Indirect Observations

Indirect observations of the late Holocene climate, vegetation, and geomorphology are present in stratigraphic, palynologic, dendrochronologic, and archeologic studies. A stratigraphic study along the Pomme de Terre River in western Missouri encountered valley-bottom strata ranging in age from 190 to 48,900 ^{14}C yr B.P. (radiocarbon years before present; Brakenridge, 1981; Haynes, 1985). Brakenridge's interpretation of the Pomme de Terre data indicated a period of stability and floodplain formation from 7,500 to 5,000 ^{14}C yr B.P., followed by at least five episodes of floodplain formation and intervening periods of erosion during the last 5,000 years. He interpreted this episodic record as the result of shifting continent-scale climate, an idea developed by Knox (1976) to explain the Holocene alluvial record of the upper Mississippi River valley. This model proposes that streams deposited floodplain sediments during periods of few or smaller floods when atmospheric circulation was dominated by east-west flow, and streams eroded floodplains during periods of increased flooding when the atmospheric circulation was dominated by north-south flow. In contrast to Brakenridge's (1981) interpretation of the stratigraphic record of the Pomme de Terre River, Haynes (1985) maintained that periods of floodplain formation were periods of basin-wide instability when the river was vertically aggrading its floodplain, and gaps in the stratigraphic record were created during periods of stability when aggradation ceased. Preliminary stratigraphic data presented in a report by Jacobson and Pugh (1992) support a model of episodic deposition of floodplain strata during the last 5,000 years.

Palynologic data for the Ozarks are scarce and, because pollen records are subject to stratigraphic mixing, they resolve climatic variability only on time scales of 1,000 years or longer. In an alluvial pollen record from southeastern Missouri, King and Allen (1977) interpreted a transition from swamp to marsh plants from 8,700 to 5,000 ^{14}C yr B.P. as the result of drier and warmer conditions during the continental Hypsithermal Interval. The last 5,000 years were characterized by relatively wetter conditions. Smith (1984) described the pollen stratigraphy of a core from the sediments of Cupola Pond in the southeast Missouri Ozarks uplands. He concluded that the Hypsithermal Interval lasted until approximately 4,500 ^{14}C yr B.P., after which conditions became noticeably wetter and the oak parkland or savannah vegetation was replaced by pine and wetter species. Smith interpreted the climate of the last 4,000 years to be essentially the same as the modern climate. Huber (1987) identified three pollen zones in a 3,100-year stratigraphic sequence in a bog in Shannon County, Missouri. The older two zones documented a minor succession of oak-pine forest by oak-pine-hickory, and the youngest zone showed a distinct rise in ragweed, indicative of clearing associated with European settlement. Correlations of vegetation changes between the Mississippi lowlands and the Ozarks indicate regional climate changes from wet to dry at about 8,500 yr B.P. and dry to wet at about 4,500 yr B.P. (Royall and others, 1991).

Dendrochronological reconstructions of pre-settlement period climate in the Ozarks extend back to 1700 A.D. (Cleaveland and Stahle, 1989). These data indicate that the mean annual runoff from the White River Basin (fig. 1) has not varied significantly from 1700 to the late 1980's, but the record is characterized by episodic, multiple-year periods of persistent drought and flood. Trees also provide information on pre-settlement period forest-fire frequency in the Ozarks. Guyette and McGinnes (1982) determined that fires recurred on the average every 3.2 years from 1730 to settlement in the 1830's. They showed that fire frequency dramatically decreased to an average of one fire every 22 years after settlement. Fire incidence was correlated somewhat with periods of drought as deduced from tree-ring widths, but the authors also concluded that pre-settlement period fire frequency was largely controlled by Native Americans, starting fires for game management.

The archeological record of pre-settlement period history of the Ozarks depicts a gradual transition of tribal groups from nomads to foragers to village farmers from 7000 B.C. to A.D. 900 (Chapman and Chapman, 1983). During the Archaic period (7000 to 1000 B.C.), the Ozarks were inhabited by semi-nomadic tribes who lived in small, transient camps and subsisted mainly on animal food (Stevens, 1991). In the late Archaic period (3000 to 1000 B.C.), tribes on the fringes of the Ozarks had begun to settle in larger villages and use more plant food, while tribes in the Ozarks continued to rely on hunting. During the Woodland period (1000 B.C. to A.D. 900), Native American cultures based on ceramics and agriculture flourished around the Ozarks, but the tribal groups living in the Ozarks remained hunters and gatherers. During the early Mississippian period (A.D. 900 to 1200), tribal groups created larger and more elaborate villages and mixed more agriculture with hunting. From A.D. 1200 to approximately A.D. 1500, Mississippian culture disappeared from the southern Ozarks as large agricultural villages grew along the Mississippi River along the eastern margin of the Ozarks; during this period, the Ozarks mainly were used for seasonal hunting and collection of flint and chalcedony for tools (Chapman and Chapman, 1983; Stevens, 1991). One of the largest Mississippian sites, Cahokia Mounds in western Illinois, was a thriving village of as many as 20,000 inhabitants. Abrupt abandonment of Cahokia Mounds and other Mississippian villages around A.D. 1200 has been hypothesized to be related to a climate shift to cooler, drier summers that resulted in failure of the maize crops on which the population depended (Mink, 1992). After the decline of the Mississippian culture, remnants apparently reassembled as the Osage tribe that existed in the Ozarks during the subsequent European settlement.

Except for fire, the effect of Native Americans on the Ozarks landscape probably was minimal. Native Americans used caves and rock overhangs and built small villages on alluvial terraces. In the late Woodland and Mississippian periods, they cultivated small garden plots, but subsisted mainly on hunting and foraging for wild plants. Forest fires set by Native Americans, however, are thought to have been a significant factor in determining vegetation distributions (Ladd, 1991) and may have affected runoff and erosion. Many historical accounts exist of fires set by Native Americans, and many anthropologists think the fires were set purposefully for reasons such as improvement of grasslands for grazing by large game, aid in hunting, and harassment of enemies (Barrett, 1980). In 1833 Featherstonhaugh (1844, p. 50) described another motivation for Native Americans to set fires:

> The soil was always prone to produce a lofty wild grass; and as this prevented the Indians from seeing and pursuing their game, they were in the habit of annually setting fire to it, and thus kept the undergrowth down.

It is not known when Native Americans began to use fire for these purposes, or whether fires were set more frequently during some parts of the pre-settlement period history of the Ozarks. Ladd (1991) argued that the pre-settlement period Ozarks landscape was virtually equilibrated to a regime of wildfire at multiyear intervals.

Pre-settlement Period Vegetation

Historical accounts of travelers and explorers from the early- to mid-1800's describe a different vegetation distribution from that which exists today (1993) in the Ozarks. Detailed analysis of early historical accounts of vegetation are given in Steyermark (1959) and Ladd (1991). These two authors present evidence from the same sources, but they disagree on the interpretation. Steyermark argued that early descriptions of forest indicated that the Ozarks always have been forested and have not been undergoing rapid, recent change. In contrast, Ladd concluded that early accounts described abundant prairie and savannah in the now-forested Ozarks; Ladd used many descriptions of fires set by Native Americans as evidence that fire was a significant factor in maintaining prairie and savannah communities. In this section, historical accounts are used to indicate that, during pre-settlement period conditions, the Ozarks uplands primarily were prairie and oak savannah, whereas steep valley slopes and valley bottoms were dominated by thick deciduous and pine forest.

One of the earliest and most detailed descriptions of the Ozarks landscape was the account by Schoolcraft (1821) of his 1818 to 1819 trip from Potosi, southwest to the White River, then northwest to the present location of Springfield (fig. 1). Schoolcraft's descriptions are similar to most of the historical descriptions detailed in Ladd (1991), which consistently described uplands as a mosaic of grassland; savannah; oak forest with open, grass undergrowth; and barrens (areas with thin grass, scattered and small cedar trees, and large areas of bare soil and rock). Schoolcraft (1821) described dense growth of timber with thin to thick undergrowth present on steep slopes; valley bottoms were described as being densely wooded with a few patches of grassland. In an earlier publication, Schoolcraft (1819, p. 154-155) summarized his views of the Ozarks:

> There is very little land of an intermediate quality. It is either very rich, or very poor; it is either bottom land, or cliff, prairie or barren.***It is deep black marl, or a high bluff rock, and the transition is often so sudden as to produce scenes of the most picturesque beauty. Hence the traveller in the interior, is often surprised to behold at one view, cliffs and prairies, bottoms and barrens, naked hills, heavy forest, rocks, streams, and plains, all succeeding each other with rapidity, and mingled with the most pleasing harmony.

From Potosi west to the Meramec River (fig. 1), Schoolcraft (1821) described sterile ridges with a thin growth of oaks and hilly barren areas of tall grass with clumps of trees. Valley bottoms were described as being well-wooded except for one creek, which was described as having extensive prairies along its banks. Proceeding across the divide between the Meramec and Current River Basins, he described the upland as mostly open prairie with scarce oak trees and no wood available for campfires. On nearing the Current River, he described "forests of lofty pine" and abundant timber along the banks. Southwest of the Current River, the steeper slopes were described as having thin shortleaf pine, shrubby oaks, and thick underbrush; extensive grassland prairie was described on the uplands: "Now and then an oak stood in our path; sometimes a cluster of bushes crowned the summit of a sloping hill***."

In the valley of the North Fork River (fig. 1), the timber was extremely thick and dominated by deciduous trees. The report by Schoolcraft (1821) described the valley bottoms as being choked with vegetation, including cane, greenbriar, and grape vines. To avoid the thick vegetation, Schoolcraft climbed over a ridge and encountered shortleaf pine on the slopes, brush in the ravines, and open grassland on the uplands, an area "destitute of wood". Near Beaver Creek in what is now Taney County, Missouri, Schoolcraft described a thick growth of oak, ash, maple, walnut, mulberry, sycamore, and cane in the valley bottom whereas the uplands had "***a feeble growth of oaks***and covered with coarse wild grass; and sometimes we crossed patches of ground of considerable extent, without trees or brush of any kind, and resembling the Illinois prairies in appearance, but lacking their fertility and extent." On the uplands near Springfield, he described a wooded area with patches of grasslands. Near the James River (fig. 1) he encountered the edge of the extensive western prairies: "They are covered by a coarse wild grass, which attains so great a height that it completely hides a man on horseback in riding through it." In the James River Valley, he described a patchy distribution of grasslands mixed with forest:

> Along the margins of the river, and to a width of from one to two miles each way, is found a vigorous growth of forest trees.***Little prairies of a mile or two in extent are sometimes seen in the midst of a heavy forest, resembling some old cultivated field, which has been suffered to run into grass.

The condition of pre-settlement period vegetation in the Ozarks was summarized by Marbut (1914, p. 1,737):

> The greater part of the Ozark dome and large areas of the rest of the region***was up to the middle of the nineteenth century a region of open woods, large areas being almost treeless. Except on the roughest land, the thoroughly dissected portions of the Clarksville soils, the rough stony land, the Decatur soils, and the more hilly portions of the Boston Mountain Plateau, the timber growth was not dense enough to hinder in anyway the growth of grass. The whole region in its vegetation was more closely allied to the western prairies than to the timber-covered Appalachians. There were however, no large areas of country so entirely bare of trees as to interfere with the settlement of the country. Along all the permanent streams, occupying usually the whole of the alluvial belts, there was commonly a heavy growth of timber.

The GLO records of public-land surveys comprise a systematic data base for assessing pre-settlement period vegetation conditions. The Ozarks were surveyed during the early 1800's, mostly before 1830. Surveyors would lay out chains 33 or 66 ft (feet) long along the section boundaries that were nominally 1 mi long. Distances were recorded in terms of the 66 ft chains and the 0.67 ft links of which they were made. In a typical entry, the surveyor would note the section, township, range, and bearing of the side he was surveying, the width of any streams crossed along the line of survey, and an averaged description of the topography, soil, and vegetation. Quarter-section posts were set at 40 chains and section posts were set at 80 chains. For these posts, distances and bearings to witness trees were recorded. A representative entry from the Little Piney Creek Basin is given in table 1.

The pre-settlement period vegetation for the Jacks Fork and Little Piney Creek Basins was compiled from reproductions of the original GLO survey notes. Vegetation descriptions and distances and species of witness trees were used to classify the vegetation into the general categories given in table 2 to compare with land-use data from the 1970's. Maps of the pre-settlement period vegetation distributions are shown in figure 7. These maps resolve the broad spatial distribution of vegetation communities, but because descriptions were averaged over mile-long transects, they do not include details and specifically do not resolve completely the differences in upland and valley-bottom vegetation. The eastern part of the Jacks Fork Basin was dominantly mixed deciduous and evergreen forest and the western one-half was deciduous forest usually described as thin. An area of shrub and brush rangeland (oak savannah) and barrens occurred in the southernmost part of the basin. The Little Piney Creek Basin was dominantly deciduous forest with thin woody understory, shrub and brush rangeland with grass understory and patchy areas of barrens.

Maps of land use in the two basins from the 1970's are shown in figure 7, and changes between the pre-settlement period vegetation and 1970's land use are given in table 3. The most substantial change between the two periods has been the net conversion of shrub and brush rangeland to deciduous forest.

Descriptions of Streams

Historical accounts rarely described pre- or Early-settlement period streams other than noting the clearness of the water and the fertility of the adjoining floodplains. The consistent lack of description of extensive gravel and sand deposits seems to be an indication that streams were different from their present (1993) condition (fig. 2).

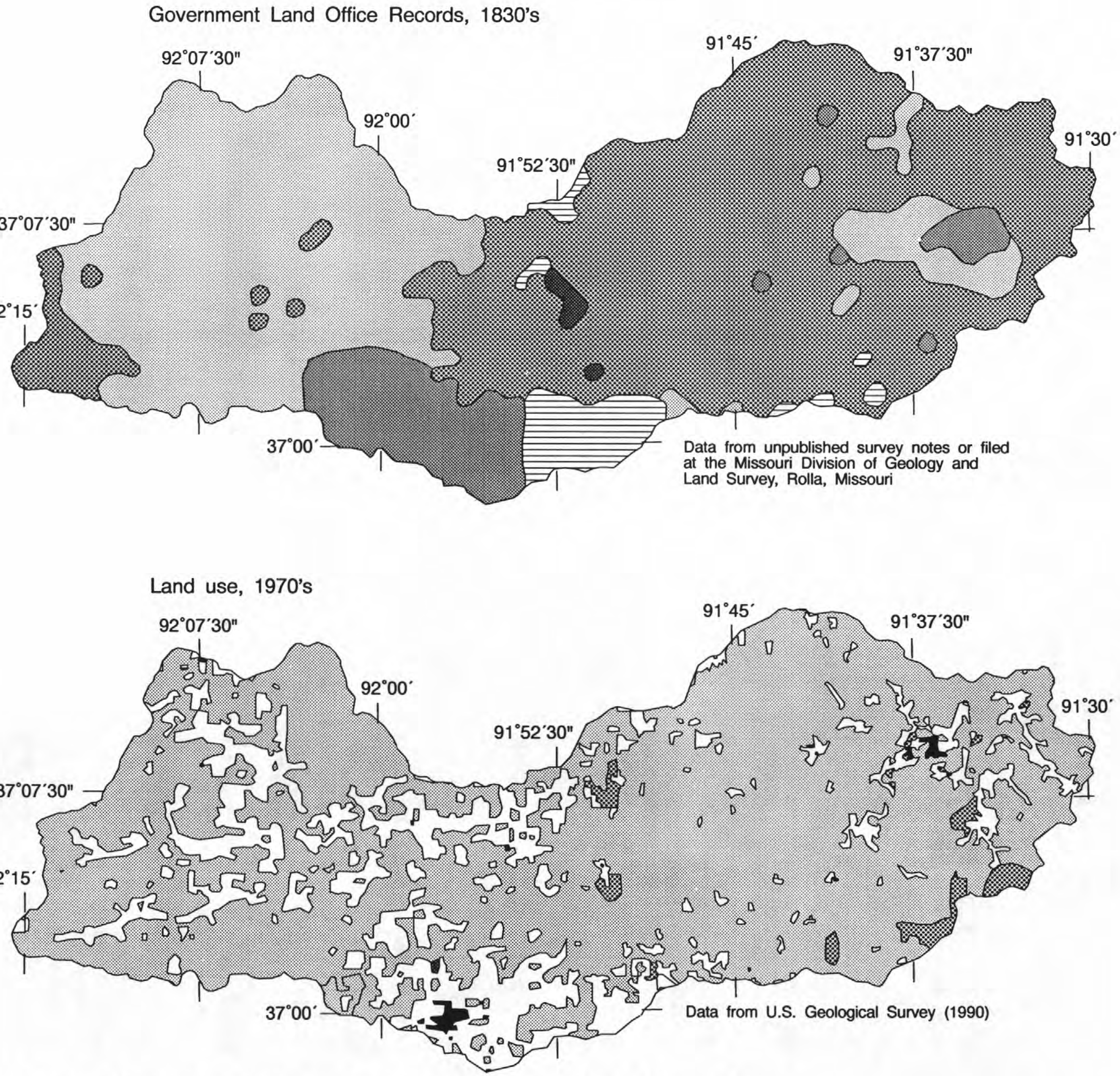


Figure 7. Land-use changes, Jacks Fork and Little Piney Creek Basins, Missouri.

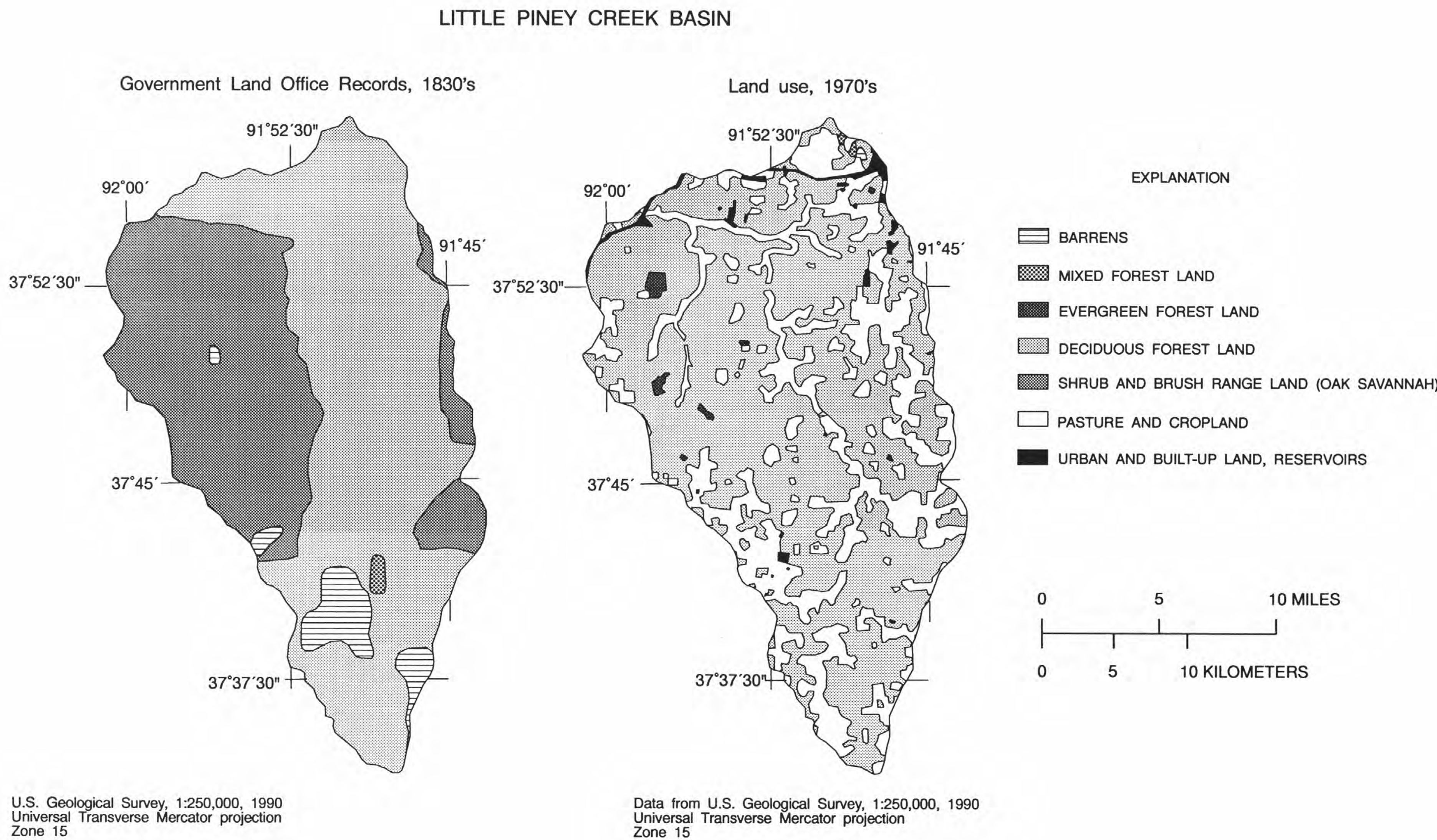


Figure 7. Land-use changes, Jacks Fork and Little Piney Creek Basins, Missouri–Continued.

Table 3. Net change in land use from pre-settlement period conditions to the 1970's in the Jacks Fork and Little Piney Creek Basins, Missouri

[Pre-settlement period land cover was mapped from Government Land Office Records (Missouri Division of Geology and Land Survey files, Rolla, Missouri) and 1970's land-use data are from U.S. Geological Survey digital land-use maps compiled from high-altitude photography (U.S. Geological Survey, 1990); the two digital map data sets were overlain in a geographic information system to calculate net changes between the two periods]

Category		Area in 1970's, in square kilometers	Percent change from 1820's
1820's	1970's		
	Jacks Fork		
Shrub and brush rangeland	Urban and built-up land	2.6	3
	Pasture and cropland	42.6	48
	Deciduous forest land	43.9	49
Deciduous forest land	Pasture and cropland	96.4	25
	Deciduous forest land	287.4	75
Evergreen forest land	Deciduous forest land	5.7	100
Mixed forest land	Pasture and cropland	55.5	11
	Deciduous forest land	453.2	87
	Mixed forest land	11.3	2
Barrens	Pasture and cropland	24.9	53
	Deciduous forest land	22.1	47
	Little Piney Creek		
Shrub and brush rangeland (oak savannah)	Urban and built-up land	1.4	0
	Reservoirs	0	0
	Pasture and cropland	58.5	22
	Deciduous forest land	198.5	76
	Evergreen forest land	3.9	1
	Mixed forest land	.1	0
Deciduous forest land	Urban and built-up land	6.9	2
	Reservoirs	.7	0
	Pasture and cropland	133.2	35
	Deciduous forest land	242.9	63
	Evergreen forest land	.2	0
	Mixed forest land	.7	0
	Barrens	.7	0
Mixed forest land	Deciduous forest land	2.6	100
Barrens	Urban and built-up land	0	0
	Pasture and cropland	12.3	39
	Deciduous forest land	19.1	61

Most early historical accounts make no mention of gravel or any other geomorphic features that might indicate channel instability or aggradation. King (1839) described the valley of the Osage River (fig. 1) as "***broad, level, and fertile bottom covered with a heavy growth of timber." Schoolcraft (1819, p. 28) emphasized the fertility and agricultural potential of the valley bottom:

> The vallies have always a Stratum of alluvial soil, which is more or less deep, according to their extent, but there are few which are not adapted for cultivation, and the *bottoms* on the streams, and lowland *prairies*, consist of several strata of black alluvial earth, affording some of the richest farming lands in the western country. The strong quality of the soil is shown in the heavy growth of trees with which it is covered.

As a general description of a variety of Ozarks stream valleys, Schoolcraft (1819, p. 31) stated:

> These streams with their tributary waters, afford farming lands of an excellent quality, both bottoms and uplands, and present a pleasing contrast to the sterile mineral hills which they border.***The traveller is alternately presented with poor flinty hills, rich alluvial bottoms, barren plains, towering cliffs, and level *prairies****.

Of the Black River (fig. 1), Schoolcraft (1819) states: "The banks of Black River and of all its tributaries afford strips of rich alluvial land of more or less extent." His description of the White River, a "beautifully clear and transparent" river, is similar; the lack of gravel bars in his description is conspicuous:

> The immediate margin of the river, uniformly presents a strip of the richest alluvial bottom land from a quarter of a mile to a mile and a half in width***tributaries***invariably afford, however small, strips of the most fertile lands, covered with a heavy growth of forest trees and underbrush. The cane is also most common to this stream in its whole course*** (p. 248).

Schoolcraft (1819) makes special mention of the lack of beaver in northeastern Ozarks streams, indicating that by 1819 the beaver had already been crowded out: "The Beaver has been driven off. This shy animal is the first to abandon a country on the approach of man" (p. 36). He also describes the White River Basin, however, as "***a region remarkable for the abundance of beaver found in its streams" (p. 252). Schoolcraft does not describe any features of the valley bottom or stream that were left from the former beaver population.

One of the few direct mentions of gravel bars is in Schoolcraft (1821), where he describes a campsite on a bar along the White River near Beaver Creek: "We now found ourselves on a gravelly barren point of land, encompassed on both sides by water, without wood, and exposed to a keen air blowing down the river." Gravel bars must not have been too common along the White River, however, because when he encountered impenetrable vegetation along one section of the White River, he chose to climb the bluff and proceed along the ridge rather than walk along the stream.

George Featherstonhaugh was another early traveller through the Ozarks during 1834 to 1835. He wrote a general travelogue (Featherstonhaugh, 1844) about his trip from St. Louis (fig. 1) through the lead-mining region around Potosi, to the Oklahoma border, and then south to New Orleans. He had a special interest and formal training in geology and his observations of geology, soils, and vegetation were fairly detailed; however, his descriptions of Ozarks rivers concentrated on the clearness of the water and the fertility of the valley bottoms. The waters of the Meramec, St. Francis, Black, Current, Eleven Point, and White Rivers (fig. 1) were described as beautiful, transparent, and pellucid. His comments on the valley of the St. Francis River near Greenville, were typical:

> The settlement, however, is beautifully situated on a rich bottom of land on the east bank of the St. Francis, a fine clear stream about eight yards broad, running thirty feet lower than the banks at this time, but which often during the floods overflows them.

His allusions to gravel in the channel are vague. He described the St. Francis River with "The bed of this stream contains great quantities of siliceous gravel***." He spent one night camping on a "beach" of the Black River and he wrote that the White River had "***a great margin of beach on each side."

Several geologic reports from the mid-1800's gave more detailed descriptions of Ozarks streams. Because there had been little chance for settlement and land-use change by this time, these reports presumably describe near pre-settlement period conditions. The reports tend to indicate a greater quantity of gravel than the earlier accounts, although they vary. Some of the variability in the reports may be because of differing scientific perspectives, because the reports were intended for different audiences, or because the authors were looking at different streams. Swallow (1855) described abundant gravel in Ozarks streams and noted its importance for construction and development:

> Many of our streams abound in water-worn pebbles, which constitute their beds, and form bars along their margins and channels.***The economic value of these pebbles for roads and streets, and the obstruction they often present to navigation, as in the Osage, give them unusual importance in our Geology (p. 66).
>
> Good pebbles are abundant in streams of Maries, Boone, Cooper, and Moniteau. The Osage and its tributaries can supply any needed quantity. And there can be no doubt that the Gasconade and the Meramec have a good supply of them in localities nearer to St. Louis (p. 169).

However, in a report describing the geology of the country along the proposed route of the southwestern branch of the Pacific Railroad, Swallow (1859) described fertile floodplains with relatively little emphasis on extensive gravel aggradation:

> Almost every acre of the alluvial bottoms throughout this entire region, has a rich, durable soil, which is usually well adapted to the culture of corn, wheat, tobacco, oats, and the grasses; some would yield good hemp (p. 9).
>
> The valleys of Little Piney, Spring and Dry Fork of Meramec and Bourbeuse, have a width varying from a hundred yards to a half of a mile, and their soils are remarkable for their productiveness, throughout nearly their whole extent (p. 24).
>
> Gravel and pebbles of good quality for roads and streets occur in great abundance (p. 28).

These descriptions together indicate that gravel was plentiful in Ozarks streams under pre-settlement period conditions, but it did not form the extensive, conspicuous bars and islands that presently (1993) exist.

LAND-USE CHANGES FROM EUROPEAN SETTLEMENT

European settlement of the fringes of the Ozarks began in the early 1700's, first under French political control, followed by Spanish and American control. Early settlements were along the Mississippi and Missouri Rivers and were mainly involved in trade or farming on the fertile lowlands of the Mississippi River valley. After the United States gained control of the Ozarks with the Louisiana Purchase of 1803, American settlers began to settle in some of the former French and Spanish settlements along the Mississippi and Missouri Rivers. Greater migration occurred after the War of 1812, and migration spread to the mining areas around Potosi in the eastern Ozarks and the prairie areas of the Springfield Plateau to the west (Stevens, 1991). The population of the rugged interior of the Ozarks grew more slowly with immigrants of different ethnic groups. Population growth and land use can be divided into four generalized and somewhat overlapping time intervals of Early-settlement period (1800 to 1880), Timber-boom period (1880 to 1920), post-Timber-boom period (1920 to 1960), and Recent period (1960 to 1993; table 4). Details of the settlement history of the Ozarks are given in Sauer (1920), Rafferty (1980), and Stevens (1991).

During the Early-settlement period, the populations of Native Americans were in flux. Westward expansion of the United States caused the settlement of eastern Indian tribes in the Ozarks. The Osage tribes were moved west out of the Ozarks by the terms of two treaties during 1808 and 1825. Shawnee and Delaware tribes originally had moved into the Ozarks under Spanish direction in the late 1700's. By the early 1800's Kickapoo and Cherokee tribes also had migrated into the area. These tribes established transient villages in the James, Gasconade, and Current River Basins (fig. 1) and had moved westward out of the Ozarks by 1830. The changing populations of Native Americans during the Early-settlement period may have affected wildfire frequency.

U.S. Census Data

U.S. Census data for Missouri are available from 1850 to the present (1993). Population data from a sample of counties representative of the Salem Plateau (figs. 4 and 8) are shown in figure 9, which depicts slow growth during the Early-settlement period and a first peak during the Timber-boom period. Population then declined in rural, southern Ozarks counties during the post-Timber-boom period but continued to increase in northern border counties. A rapid increase in the population of Pulaski County after 1960 was caused by

Table 4. Sequence of land-use changes on parts of the rural Ozarks landscape

Period	Uplands	Valley slopes	Valley bottoms
Pre-settlement before 1800	Patchy prairie and oak savannah	Thick oak-hickory and yellow pine forest	Thick deciduous forest
Early-settlement 1800-1880	Patchy prairie, used for grazing and minor row crops	Thick oak-hickory with minor cutting	Cleared for pasture and row crops
Timber-boom 1880-1920	Cutover, fire suppression	Cut over	Cleared for pasture and row crops
Post-Timber-boom 1920-1960	Increasing pasture, row crops	Woodland grazing, seasonal burning	Cleared for pasture and row crops, open-range grazing
Recent 1960-present (1993)	Increased grazing and row crops	Woodland grazing, managed timber little burning	Cleared for pasture and row crops with some reversion to forest

Figure 8. Index of counties for which U.S. Census data have been collected for this report.

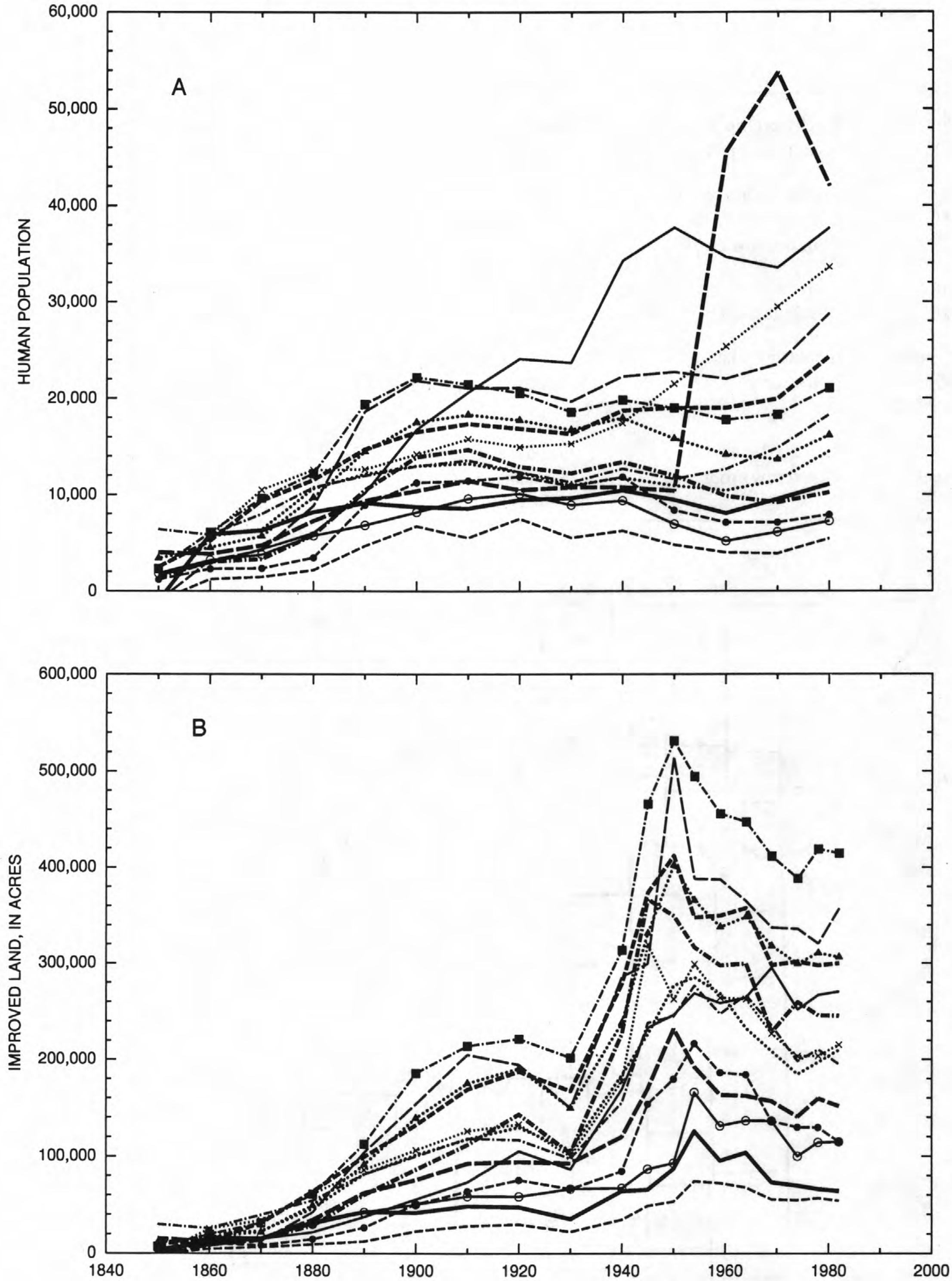


Figure 9. Human population (A), acres in improved land (B), and percentage of land in culivated crops (C) for selected counties in Missouri.

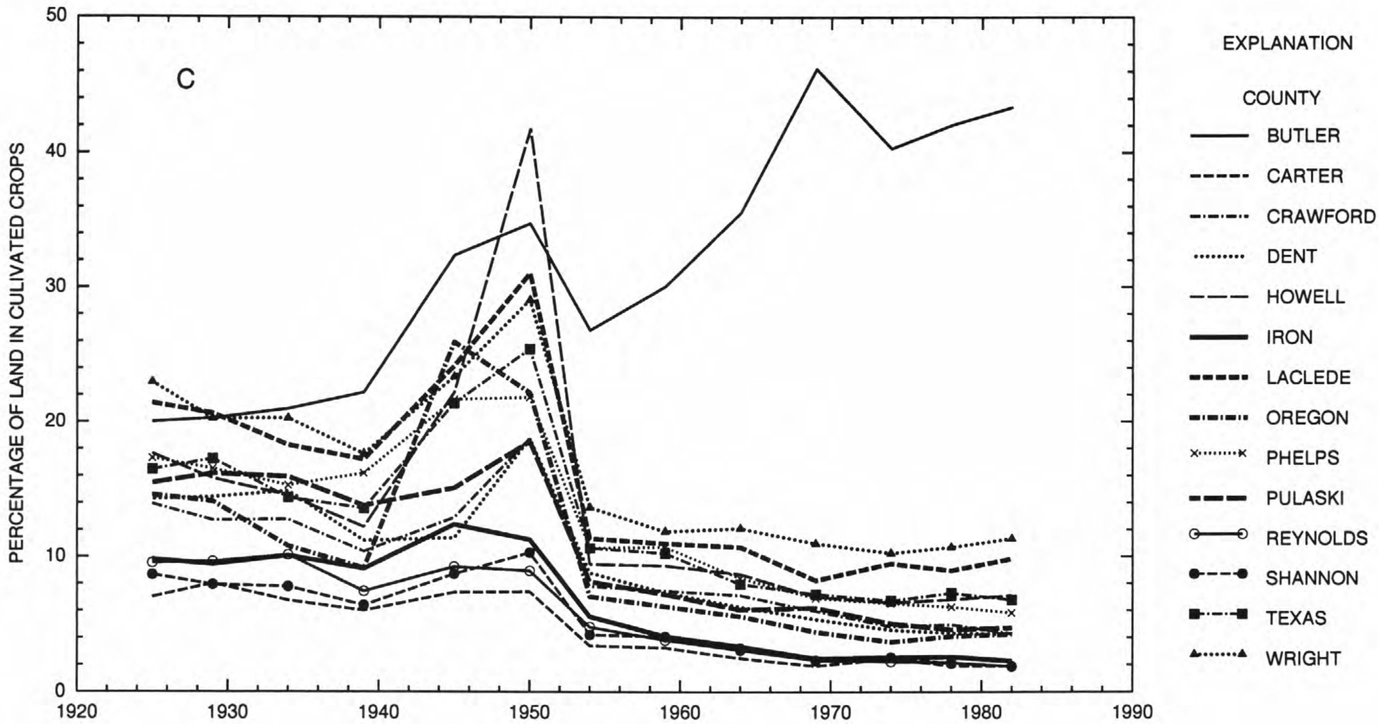


Figure 9. Human population (A), acres in improved land (B), and precentage of land in culivated crops (C) for selected counties in Missouri--Continued.

growth of the Fort Leonard Wood Military Reservation.

Early settlers used valley-bottom land for gardens and row crops, and they used the wooded slopes and natural grass of the uplands for grazing cattle, hogs, horses, and other livestock. Because U.S. Census land-use classification categories have changed over the years, agricultural land use categories is combined into the broadest category of improved land from 1850 to 1982 (fig. 9). After 1925, the land in cultivated crops could be extracted from the statistical data (fig. 9). Improved land includes land cleared for pasture, fenced land, orchards, and land in cultivated crops or fallow fields. Land in cultivated crops includes all land undergoing intense tillage, including harvested cropland, failed cropland, and fallow cropland. Improved land trends follow those of the human population through the Early-settlement and Timber-boom periods (fig. 9). From 1940 to the late 1950's, however, the total area in improved land rapidly increased because of a general increase in the quantity of stock being grazed and the closure of open range that occurred throughout the Ozarks county by county during this time. After the open range was closed, more land had to be fenced. From the 1960's to 1982 the quantity of improved land generally decreased. Land in cultivated crops follows a similar trend with a peak during 1940 to 1950 and decreasing from 1950 to 1982; Butler County is an exception because the southeastern two-thirds of the county is in the agriculturally productive Mississippi Lowlands. Data for land in cultivated crops are summarized in table 5.

Cattle and hogs have been the primary livestock grazed in the Ozarks. In the Early-settlement period and through most of the Timber-boom period, hogs were the dominant livestock (fig. 10). Cattle populations increased substantially about 1920 and again after 1940. With the advent of the closed range and improvements of beef markets, areal densities of cattle on pasture increased markedly.

Timber production data for the Ozarks are not available, but the statewide figures (fig. 11) are reasonable estimates because most of the statewide timber production has been from the Ozarks (U.S. Bureau of the Census, 1850-1982). Some timber production undoubtedly predates the earliest figures for 1868; Schoolcraft (1821) mentions a sawmill that was operating on a tributary to the Gasconade River during 1818. However, these mills probably were small operations that supplied lumber locally to small communities.

Table 5. Percentage of land in cultivated crops for selected counties in Missouri, 1925-82

[Data from U.S. Bureau of the Census, 1925-82]

County	1925	1929	1934	1939	1945	1950	1954	1959	1964	1969	1974	1978	1982
Butler	20.01	20.27	20.94	22.17	32.34	34.72	26.80	30.04	35.54	46.20	40.29	42.03	43.35
Carter	7.00	8.00	6.74	5.99	7.33	7.37	3.39	3.24	2.47	1.90	2.43	1.90	1.88
Crawford	13.92	12.72	12.77	10.37	12.90	18.76	7.76	7.44	7.11	5.94	4.80	4.95	4.28
Dent	14.29	14.43	14.87	11.20	11.39	18.74	8.78	7.32	6.26	5.34	0.45	4.32	4.22
Howell	17.65	15.80	14.54	12.21	22.16	41.77	9.42	9.31	8.68	7.01	6.58	6.79	7.10
Iron	9.79	9.43	10.08	9.09	12.39	11.26	5.53	4.08	3.33	2.44	2.53	2.58	2.26
Laclede	21.40	20.62	18.26	17.20	24.15	31.02	11.34	10.97	10.70	8.22	9.47	8.95	9.82
Oregon	14.59	14.10	10.78	9.14	25.92	22.14	7.02	6.29	5.55	4.41	3.67	4.08	4.24
Phelps	17.30	16.53	15.28	16.17	21.65	21.80	10.64	10.69	8.38	6.90	6.51	6.25	5.81
Pulaski	15.47	16.16	15.92	13.78	15.08	18.51	8.13	7.18	6.05	6.19	5.01	4.58	4.71
Reynolds	9.53	9.64	10.12	7.42	9.23	8.92	4.77	3.80	3.06	2.31	2.22	2.15	1.86
Shannon	8.65	7.92	7.76	6.38	8.68	10.28	4.20	4.05	3.21	2.30	2.54	2.08	1.87
Texas	16.47	17.25	14.37	13.58	21.36	25.41	10.62	10.23	7.95	7.20	6.72	7.28	6.78
Wright	22.96	20.24	20.26	17.61	23.35	29.04	13.65	11.87	12.10	10.97	10.25	10.69	11.34
Average of all counties[1]	14.93	14.60	13.76	12.26	17.71	21.41	9.46	9.03	8.60	8.38	7.39	7.71	7.82
Average of all counties excluding Butler County[1]	14.69	14.20	13.23	11.55	16.93	21.13	8.22	7.58	6.64	5.56	5.26	5.25	5.19

[1] Averages are calculated from total cropland in all counties divided by total area in all counties; these values do not equal the average percentage of cropland in individual counties because of rounding.

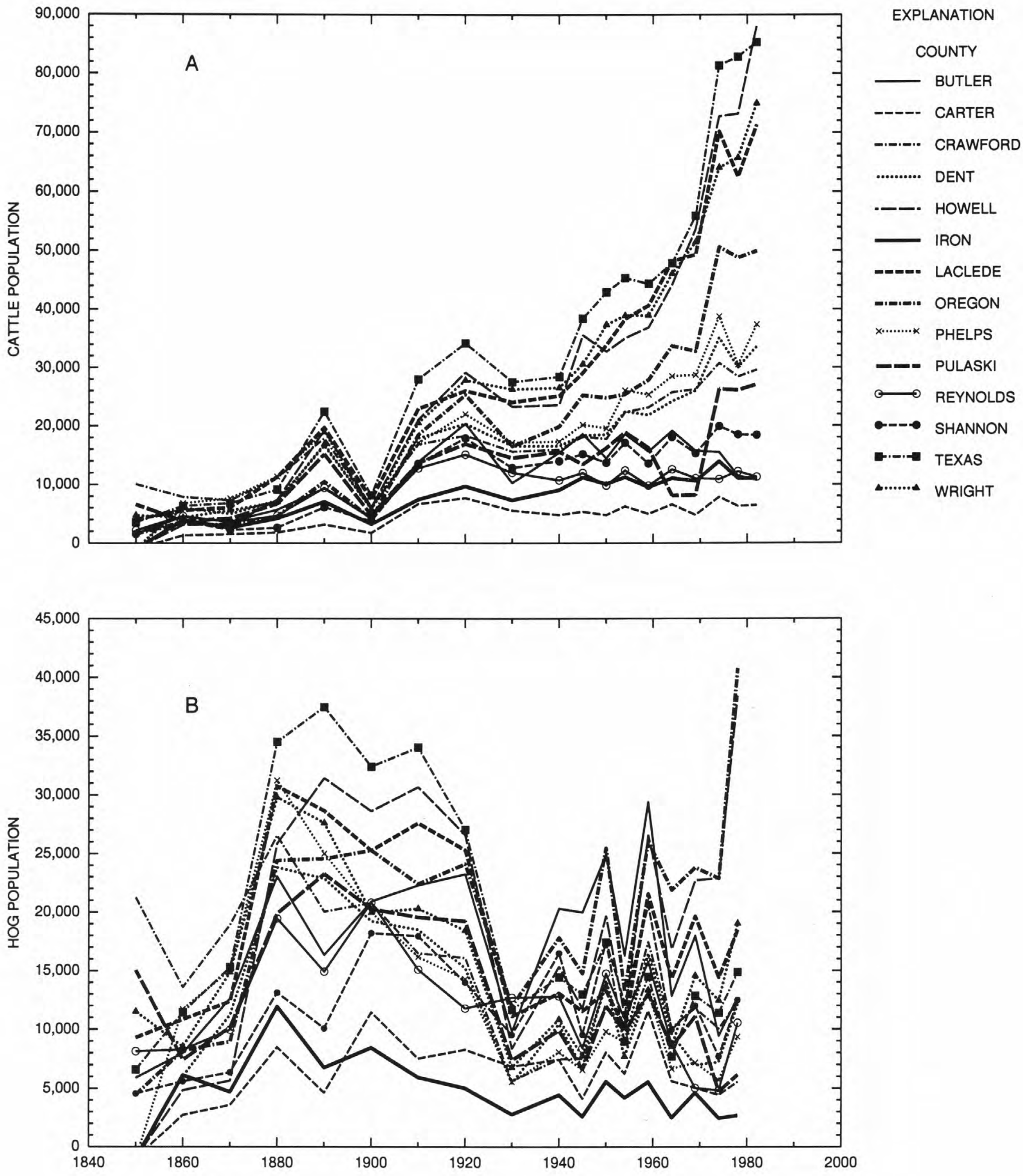


Figure 10. Cattle (A) and hog (B) populations and cattle and hog average density (C) for selected counties in Missouri.

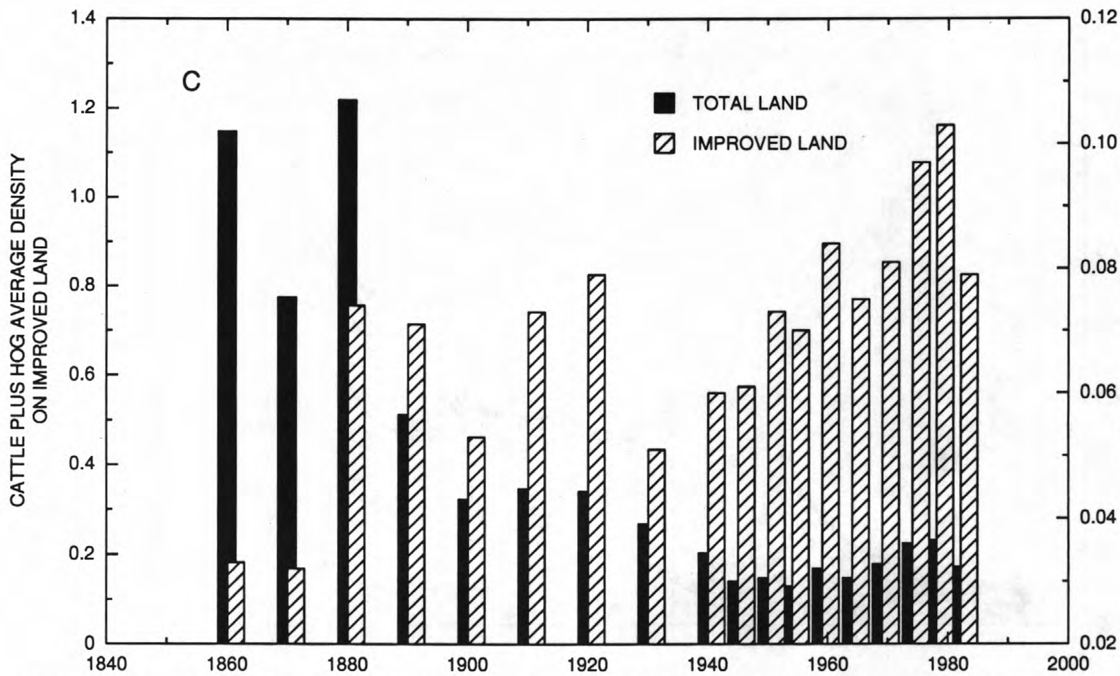


Figure 10. Cattle (A) and hog (B) populations and cattle and and hog average density (C) for selected counties in Missouri--Continued.

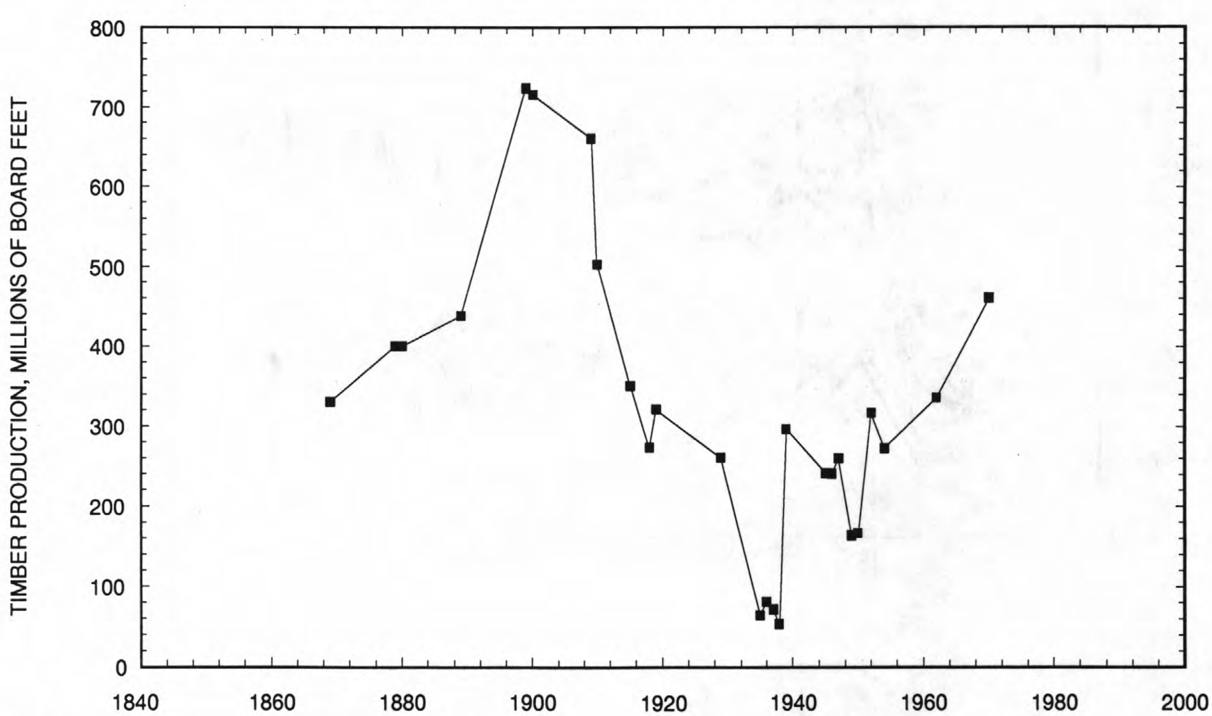


Figure 11. Timber production in Missouri.

Most of the large-scale timber operations in the Ozarks began in the 1870's when railroads were constructed into the area (Stevens, 1991). The peak of timber production occurred from approximately 1880 to 1920 (fig. 11). At the end of the Timber-boom period (1920), most of the marketable shortleaf pine was depleted (Cunningham and Hauser, 1989; Stevens, 1991). Production then shifted to smaller companies that made railroad ties, stave bolts, firewood, and charcoal. Increases in timber production from the mid-1950's to the early 1970's represent renewed cutting of second growth forests (Cunningham and Hauser, 1989).

Historical Accounts

Historical accounts of inhabitants and scientists in the Ozarks add necessary detail to the statistical data. Of particular importance are accounts stating where different land uses occurred, what processes were involved, and whether any direct effects on stream disturbance were recorded.

Early-settlement Period

The accounts of Schoolcraft (1819, 1821), King (1839), Featherstonhaugh (1844), and Swallow (1855, 1859) depict a landscape with little change from the pre-settlement period conditions to the mid-1800's. Settlers were living a subsistence life style. They had cleared small plots for wheat, corn, and oats in the fertile soils of the valley bottoms while their livestock grazed on the slopes and uplands. Schoolcraft (1819, p. 34-35) noted:

> The farmer here encloses no meadow--cuts no hay.--The luxuriant growth of grass in the woods afford ample range for his cattle and horses, and they are constantly kept fat. Hogs also are suffered to run at large, and in the fall are killed from the woods; I have seen no fatter pork than what has been killed in this way. There is, perhaps, no country in the world, where cattle and hogs can be raised with so little trouble and expense as here; and this is an advantage this country possesses which is likely to be permanent.***Horses are raised in considerable numbers by the inhabitants generally, and with little labour. They subsist themselves in the woods, both summer and winter***.

Featherstonhaugh's (1844, p. 85) recollections of farming practices were similar but more negative in his description of the effects of wildfire on Ozarks farms:

> Fires of this kind are much dreaded by the agricultural settler. If his building and fences are burnt, his cattle and swine destroy what little crop he has, and at any rate, the advancing fire destroys the mast about the country, upon which many depend for the subsistence of their stock, which often have nothing else to eat: for the small settlers have no fields, with the exception of one or two in which they raise their Indian corn; they raise no wheat, no rye, no oats; they have no meadow, and, of course, no hay or straw; the little fodder they have they save from the leaves of their corn-stalks; and there being nothing for the cattle at the homestead, they roam about the country to pick up the mast; the which if it fails, they get so little to eat at the farm that few of them survive the winter.

In a trip from Pilot Knob to Salem (fig. 1), during 1867, Daniel Fogel wrote of a more positive view of mid-1800's agriculture (Goodrich and Oster, 1986): "***the very few vallies which we crossed contain a very rich soil washed off the surrounding hills, and which are all improved, and bear beautiful orchards and good crops." He describes the uplands around Salem as:

> The country on this side of Salem for 10 miles is very broken and gravelly***from here to Current River the country is what might be called an undulating plain, covered with a variety of timber***with an undergrowth of grass & weeds.

During the Early-settlement period, the frequency of wild fires decreased (Guyette and McGinnes, 1982), presumably because of fire suppression by settlers anxious to save their fences and crops. As of 1835, Featherstonhaugh (1844) thought that setting of wild fires primarily was a Native American activity, but that it also had been adapted by some settlers to help their hunting:

> The hunters, too, sometimes, with the intention of driving the game to a particular quarter, will purposely fire the country in various places, indifferent to the devastation and inconvenience they cause; and all this merely to get a few deer with greater dispatch than they would do by going a little farther into the country.

Marbut (1914, p. 1,740) described the effects of fire suppression on upland vegetation:

> The change began to take place on an important scale immediately after the Civil War. Within 30 years the growth had spread to such an extent that no large areas of treeless grassy plains existed in the region.

Early timber cutting before 1870 was concentrated in the Gasconade and Osage River valleys (fig. 1) where shortleaf pine provided timber for small mills and oaks provided railroad ties (Sauer, 1920; Hawker, 1992). Several small, family-owned operations supplied lumber for transport down the Gasconade River until sometime during the 1850's. Timber also was cut to supply charcoal for local iron smelters in Phelps and Crawford Counties (fig. 8) from the 1820's to the 1860's.

Early-settlement period accounts do not contain any specific references to upland erosion associated with burning, clearing, crops, grazing, or limited timber cutting. Two sources on timber cutting activities, however, relate the effects of logs and lumber that were being floated downstream. A history of Texas County from 1889 recalls that cutting the pine woods along the Big Piney River had been started as early as 1816, and that by spring of 1820 "The Piney was filled with rafts of sawn or hewed lumber and floating logs" (Goodspeed Publishing Company, 1889). On the Current River, floating timber was associated with channel changes that were noted by a GLO surveyor during 1844 who was connecting his 1844 survey with an 1822 survey just to the north:

> This country along river bottom & especially along this line has undergone a very considerable change since the old survey - the river here is much wider, composed of logs pine planks from saw mills above, slues [sloughs], islands and an extensive raft.

Timber-boom and post-Timber-boom Periods

During the Timber-boom period, many more settlers migrated to the Ozarks for jobs in the forest and mills. Improved land and cattle and hog populations also increased (figs. 9 and 10). At the end of the Timber-boom period, loggers emigrated from the Ozarks. The loss of jobs during the Great Depression forced many inhabitants into a subsistence agricultural pattern for several decades. Rafferty (1980) and Stevens (1991) provide detailed overviews of the history of Ozarks timber exploitation and the following post-Timber-boom period.

Effects on Uplands

The distribution of extensive commercial timber cutting in the Ozarks was controlled by the distribution of shortleaf pine and transportation routes provided by rivers and railroads (Cunningham and Hauser, 1989). These factors led to establishment of large corporate pine timber and milling operations in the Ozarks of southeastern Missouri. Pine logs were cut in the forests with cross-cut saws and transported by mule skidding or horse- or ox-drawn wagons to either a river bank or a tram railroad line. Cutting was selective; typically, only pine trees greater than 30.5 cm diameter were cut (Cunningham and Hauser, 1989). Historical photography of cut-over landscapes of the Timber-boom period is rare; the existing photography, like that shown in figure 12, shows no evidence of accelerated erosion associated with timber cutting.

Log drives could be quite large, and until 1909, lumber floated down rivers was not tied into rafts. A typical log drive was one-half million board feet of loose logs spread out over 25 km of river. Often, large floods would break up the log drives (Stevens, 1991), or logs would become jammed and require blasting to break them up (Rafferty, 1980). By 1920 most of the large holdings of pine had been cut and the larger mills had shut down (Sauer, 1920).

In areas of the Ozarks where pine was lacking, hardwoods were used for a variety of products. The primary product was railroad ties, followed by flooring, barrel staves, tool handles, and fuel (Stevens, 1991). Most of the tie cutting was carried out by smaller companies, and as timber declined in abundance, many inhabitants hacked oak railroad ties for a living or supplemental income. Ties were cut from white or post oaks large enough for the 15 to 20 cm required size. Typically, ties were hauled by wagon or skid to a river landing or tie slide (fig. 13) and then rafted downstream during high water (fig. 14). Concerns about the dangers of loose ties and the effects on stream banks prompted Missouri to regulate tie drives. The size of drives was limited to 50,000 loose ties during 1909, and legislation during 1919 required that ties be nailed into rafts.

Whereas saw logs and railroad ties required selective cutting of large or high-quality timber, specialty products, stave bolts, and charcoal production used a much greater range of sizes and quality of hardwood; land cut over for charcoal, for example, was cleared of almost all trees (Cunningham and Hauser, 1989). The

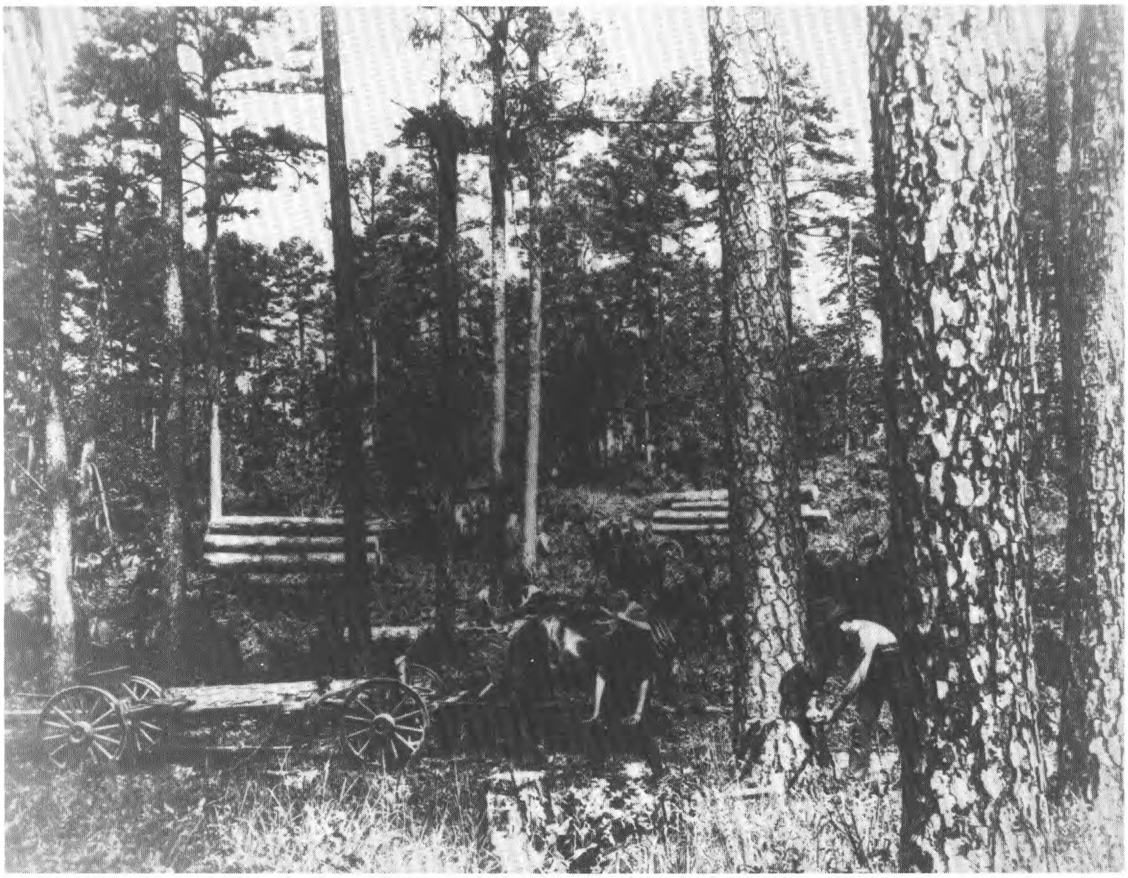


Figure 12. Harvesting yellow pine, southeast Missouri, about 1900 (photographer unknown; Ozark National Scenic Riverways collection).

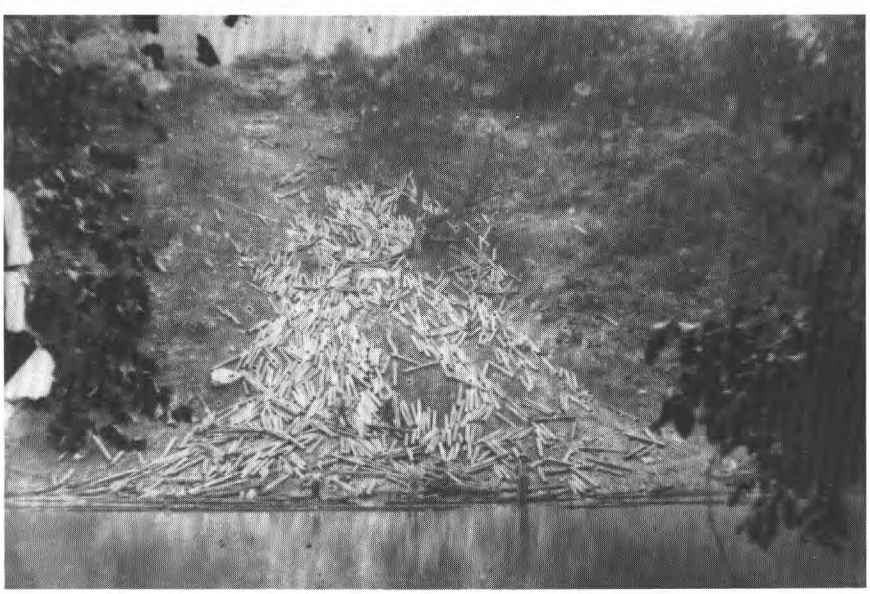


Figure 13. Railroad tie slide on the Big Piney River, Missouri, 1910-14 (photographer unknown; Missouri State Archives collection).

Figure 14. Tie drive on the Current River, Missouri, about 1920 (photographer unknown; Ozark National Scenic Riverways collection).

cutting by charcoal producers in Iron and Crawford Counties was described as clean cutting (Sauer, 1920).

The sociological and economic effects of the decline of the timber industry in the Ozarks were severe and had a substantial effect on subsequent land-use decisions. When the timber companies left, and as the national economy deteriorated with the Great Depression, many of the former timber company employees were left without jobs. While many people emigrated from the Ozarks, the population remained substantially greater than before the Timber-boom period. The cutover land was the one inexpensive resource available to the inhabitants, and much of it began to be reused for subsistence-level agriculture (Rafferty, 1980). In contrast to the Early-settlement period, however, wild game was depleted, increasing the difficulty of a subsistence life-style.

Because of suppression of wild fires, the open range also offered much less grassland than in the Early-settlement period. Writing of observations made during the 1910's, Sauer (1920) described the condition of the grazing lands that were mostly in open range:

> Most of the range is very poor, especially for cattle. The grass-covered hills of the early days have been replaced for the most part by a dense growth of oak sprouts. The ceasing of grass fires, the clearing of smooth land, and the overgrazing of the remaining area have caused the famous bluestem pasture grass of the early days to become nearly extinct.

Watkins and others (1919, p. 11-13) description of open-range grazing in Texas County (fig. 8) is typical:

> Both cattle and hogs graze to a large extent upon the limited open range which exists mainly in the rougher sections of the county. The cattle feed upon the wild grasses, of which lespedeza is the most important. ***Hogs are raised in considerable numbers. They are allowed to run on the range. In some years there is such an abundance of acorns that little or no feeding is required to fatten the hogs.

During the post-Timber-boom period, annual burning of woodland became an established activity throughout the Ozarks as inhabitants attempted to increase grass production on the cut-over land (Cunningham and Hauser, 1989). Inhabitants also justified burning in the belief that fire killed ticks and snakes. Soil scientists of the early 1900's encouraged burning for management of grasslands but discouraged burning of timberland because of the great potential for erosion once the litter layer was removed (Krusekopf and others, 1918).

Historical accounts of the effects of the Timber-boom and the post-Timber-boom periods on the landscape include a considerable variety of opinion and observation. Much of what has been written about soil erosion on the Ozarks upland from 1900 to the present (1993) lacks documentation or measurement. Accounts from soil scientists and geologists who worked in the Ozarks in the late 1800's to the mid-1900's provide the most objective observations.

Marbut's (1914) "Soil Reconnoissance of the Ozark Region of Missouri and Arkansas" describes soil erosion as a problem only in the northern Ozarks border areas where row crops were being grown on rolling land; no mention was made of soil erosion in the steeper cut-over lands to the south. In contrast, Krusekopf and others' (1918) soil survey of Reynolds County attributed stream erosion to land-use practices that increased runoff, but the report does not mention hillside soil erosion:

> The uplands of Reynolds County under forest conditions are subject to relatively little erosion, but, owing to the cutting of the timber and the practice of annually burning over the timberland, destructive stream erosion is taking place in all parts of the area. In the interest of the future agriculture of the county these practices can not be too strongly condemned (p. 1,309).

In a report about meadow and pasture management in the Ozarks, Helm (1925) notes: "If put under cultivation, however, the soil is washed away in a few years, leaving a mass of rocks which will not permit further cultivation" and "Such land is usually rugged, with steep rock slopes. It is easily affected by drought and if cleared will wash badly."

Bridge (1930) mapped the geology of the Eminence and Cardareva 15-minute quadrangles in Shannon and Reynolds Counties (fig. 8) from 1922 to 1927 and included these observations about the land-use history:

> Most of the lumbering has been carried on in a most wasteful manner. The cut-over country on the plateau has been in part reclaimed as farmland, but in the rougher portions have been burned over repeatedly and the present second growth is an almost worthless variety of scrub oak (p. 25).

In an assessment of soil erosion on steep soils of the Ozarks, Baver (1935, p. 61-62) concluded that antecedent land use had resulted in moderate to severe erosion on these soils depending on their history:

> Throughout most of the Ozarks a major portion of the total woodland is woodland pasture. Most of these timber tracts have been burned over more or less regularly and appreciable erosion has taken place. Where the land has been cultivated serious sheet erosion has taken place. About two-thirds of the original surface soil has been lost. Farmers have complained about the stones coming to the surface without realizing that in addition to the heaving effects of freezing and thawing erosion has been washing the surface soil away from the stones. Gullying has been moderate because of the stony nature of the soil. Erosion has been moderate where the percentage of woodland has been high; probably slightly more than one-fourth of the surface soil has been lost. The other areas have undergone serious sheet erosion and have lost about one-half of their original surface soil.

Krusekopf (1937, p. 15) deemphasized the extent of soil erosion in the Ozarks uplands and echoed Baver's suggestion that because the chert-rich soil of the Ozarks resists formation of deep gullies, erosion had been minimized:

> Soil erosion as a physical factor in land use is of minor importance in the Ozark Region.***The forest cover and the stone content in the soils have been protecting agencies from more serious erosion. The utilization of the hill land for either cultivated crops or pasture would quickly result in the hopeless destruction of the land.

Krusekopf (1937) also considered the effect of annual burning on increasing runoff. He noted that runoff in the Ozarks was twice that of northern Missouri and he attributed the high runoff to destruction of the litter and humus soil layers because of burning.

Sauer (1920) observed that steep roads on valley-side slopes in the Ozarks tended to be gullied, especially in areas with non-cherty soils (fig. 15). Bridge (1930, p. 27) also noted that abandoned wagon roads were prone to gully on steep slopes:

Figure 15. Gullied road on the Ozarks uplands, about 1900 (reprinted from Sauer, 1920; courtesy of University of Chicago Press).

> The logging operators of the past few decades have covered the wooded areas, and particularly the ridge tops with a network of old wagon trails, some of which are now used as roads.***On steep slopes these roads gully badly and unless regularly maintained are soon destroyed. On the level ridgetops the fine residual chert gravels which cover much of the country soon pack down, and if the traffic is not too heavy form a good road which last for many years.

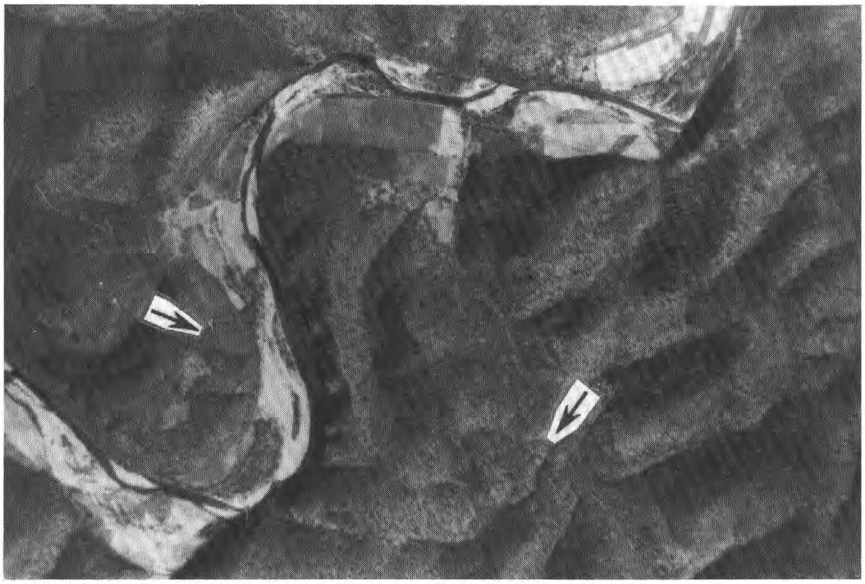
Aerial photography of the Ozarks from 1939 to the present (1993) illustrates the magnitude of apparent aggradation and instability in stream channels but does not show a large number of gullies that would be indicative of extensive destabilization of upland soils (fig. 16). A representative area along the Jacks Fork from 1939, 1964, and 1992 is shown in the photographs in figure 16. Some steep-sided gullies are apparent on valley-side slopes in the 1939 photo but they are well covered with trees. If these gullies had been caused by land use, they had healed by 1939. Alternatively, they may be natural features. Onsite reconnaissance in the area could not determine the age of the gullies. In either case, it is significant that an extensive upland gully network does not exist in this area where timber was cut during the Timber-boom period and then was subjected to open-range grazing for 40 to 50 years.

A large selection of ground photographs of the Ozarks uplands between 1890 and 1950 also was examined for this report. The selection of photographs available through various sources cannot be considered a scientific sample of the Ozarks landscape. Nevertheless, no photograph was located that showed upland gullies associated with any land-use practice except cultivated fields and roads.

Effects on River Valleys and Streams

Soil scientists and geologists working in the Ozarks during the Timber-boom and post-Timber-boom periods described valley-bottom landforms, alluvial soils, and gravel resources as part of their studies. These observations can provide an indirect basis for assessment of stream conditions during these periods. Historical photographs from these periods, some of which have been replicated during 1992, provide an additional basis for assessing change.

Similar to the descriptions of streams by pre- and Early-settlement period travelers, many of the descriptions of streams in the Timber-boom and post-Timber-boom periods are significant for their lack of information of the extensive gravel and sand deposits that are now (1993) so prevalent. In general, descriptions by soil scientists tended to minimize gravel, perhaps because of a bias toward agricultural resources. In contrast, descriptions by geologists give more detailed



Agricultural Stabilization and Conservation Service, Salt Lake City, Utah

NOTE: Flow is from lower left to upper right. River length is approximately 4 kilometers

1939

Arrows indicate examples of steep-side gullies.

U.S. Geological Survey, EROS Data Center, Souix Falls, South Dakota

1964

National Biological Survey, University of Missouri-Columbia

1992

Figure 16. Vertical aerial photographs of part of the Jacks Fork Basin, Missouri, 1939, 1964, and 1992, showing changes in valley-side slope and valley-bottom land use.

descriptions of gravel, probably because geologists viewed the gravel as a resource. In both cases, the descriptions do not seem to match the magnitude of the present (1993) gravel aggradation.

Williams (1877) described the Current River, Jacks Fork, and Barren Fork (a small tributary to the Current River) as "***rapid-flowing and clean, with narrow fertile valleys***" and other smaller streams were described as "***smaller streams and brooks, along the narrow bottoms of which excellent farming land is found" (Williams, 1877, p. 159). This description contrasts with the present (1993) condition of these rivers (fig. 17). Similarly, Keyes (1895) described the geologic and geomorphic characteristics of the Ozark mountains, including a model of recent uplift and vigorous erosion, without mentioning extensive gravel deposits that might have been used as support of that model.

A report by Marbut (1896) on the physical features of Missouri gives detailed descriptions of many of the geomorphic and topographic features of Ozarks stream valleys, but rarely mentions gravel. In describing a small, dry valley near Winona (fig. 1) in Shannon County, he states:

> The floor of the valley was perfectly free from visible streams and only an occasional bar of angular chert fragments and an irregular rocky depression two or three feet beneath the level of the floor of the valley showed any indication that there ever had been any flowing water in it (p. 88).

Although it is unclear which stream valley near Winona Marbut was describing, all streams that flow through the town today (1993) have well-developed channels with conspicuous gravel bars. In a report by Marbut (1914) on soils of the Ozarks, detailed descriptions of alluvial soils are included that the author considered the most productive and valuable soils of the area. Similarly, he made no mention that these valuable soils were subject to erosion or burial by gravel.

In a general report on the soils of Missouri, Miller and Krusekopf (1918) described the Huntington Loam, an alluvial soil that occurs in the Ozarks valley bottoms in association with the Clarksville soil of the valley-side slopes. Their description mentions gravel in the stream but emphasizes the loamy soil next to it. They concluded that flooding in these streams regenerates the fertility of the soil rather than affecting it adversely:

> In the region of the Clarksville stony loam and along many of the smaller streams, it is more or less gravelly. The gravel consists wholly of chert. Bordering the streams, the soil is almost universally a loam or fine sandy loam.***The frequent overflows supply fertility and make the need of crop rotation less than on upland soils (p. 99-100).

The soil survey report of Reynolds County (Krusekopf and others, 1918) described a soil unit called river wash in association with the Huntington Loam; the river wash was not mapped in Texas County (Watkins and others, 1919), implying that it was not areally extensive. The description of the river wash unit (Krusekopf and others, 1918) is identical to extensive gravel bars seen today, and the authors explain its origin as the result of land-use-induced stream aggradation:

> This low, recently placed streamwash has practically no agricultural value. It represents the lowest part of the stream flood plain. The higher adjacent alluvial soils support forest, and, where farmed, rank as good agricultural land (caption to fig. 2, plate XV).

> The belts of loose gravel, sand, and stones bordering the larger streams have been mapped as Riverwash.***The material is like the gravel beds in the stream channels, and is saturated with water a few feet below the surface. At every rise of the stream the materials are reworked, and in many places built up as long ridges paralleling the stream channel. Riverwash occurs mainly along Black River and the lower courses of West Fork and East Fork. With the aggradation of the streams in this region this wash material is gradually encroaching upon the unoccupied areas of the bottoms as well as extending up the stream valleys as they are deepened. It is only a matter of time until the valleys of all the larger creeks, excepting the coves and other protected places, will be covered by a mass of gravel, and their value for agriculture permanently reduced (p. 1,331).

Although the river wash unit received emphasis in the 1918 report, it was not mentioned in two subsequent reports on soil erosion problems that were published in the 1930's (Baver, 1935; Krusekopf, 1937). A connection between upland land-use practices and stream aggradation was inferred, however, in a report on game and fish habitats (Bennitt and Nagel, 1937) in which degradation of fish habitat was caused by "***fire, lumbering without reforestation, overgrazing, too-clean farming, and other practices, followed by excessive erosion and a run-off that has washed away the

Jacks Fork--extensive gravel aggradation on top of a once-productive field (November 1990).

Barren Fork--unstable channels and extensive gravel deposition (November 1990).

Figure 17. Oblique aerial photographs of Jacks Fork upstream from Alley Spring and Barren Fork, Shannon County, Missouri.

topsoil and filled the streams." The emphasis on top soil may indicate that the authors perceived aggradation with fines as more adverse to fish habitat than aggradation with gravel.

A report by Lee (1913) on the geology of the Rolla quadrangle indicates that gravel was in large supply in that area: "Gravel is obtained in abundance in Little Piney Creek at Newburg; in the Gasconade River at Jerome; and in Love branch near Rolla." Dake (1918) evaluated sand and gravel resources statewide in Missouri. His report indicates that extensive gravel deposits were common along Ozarks rivers in the 1910's:

> From the mouth of Big Dry Fork near Meramec Springs to Valley Park extensive gravel bars of the best quality are abundant (p. 226).

> Black River carries much excellent gravel (p. 231).

> Little Piney Creek in Phelps County carries extensive gravel and sand bars (p. 234).

> [There is extensive gravel deposits]***at the junction of the Little Piney and the Gasconade, but most of the gravel is furnished by the former. The bar is from 4 to 8 feet deep, 20 rods wide, and over a mile long (p. 235).

A treatise by Sauer (1920) on the geography of the Ozarks is a comprehensive assessment of how physiography and soils affected settlement and land use in the Ozarks. Sauer noted the presence of thin, erodible soils in the Ozarks but made no mention of accelerated erosion because of land use. Although he observed the abundance of chert gravel in streams and included illustrative photographs (fig. 18), he did not interpret the gravel to be the result of detrimental land use. In fact, in a discussion of valley-bottom roads, he explicitly states that the gravel was highly stable:

> Streams are crossed most commonly by means of fords, which are located at broad shallows, formed by gravel bars.***Many of these bars are probably residual rather than transported, and do not change their positions. Because of the stability of these bars, the fords may remain at the same place for many years. In some cases they have not changed appreciably since the first settlement of the region (p. 224).

A report by Bridge (1930) on the geology of the Eminence (fig. 1) area described fertile alluvial soils in most of the valleys, but he also described the presence of gravel deposits in places along the rivers:

> [Valley bottoms]***are floored with a mantle of boulders, gravel, sand, and silt,***The deposit varies from a few inches in thickness up to as much as 20 or 30 feet.***The coarser materials are to be found along the smaller creeks. In such places large boulders and coarse gravel make up the bulk of the deposit, and the soils are thin and stony. Along the large streams the sorting is much more perfect, and the gravels, sands, and silts are fairly well stratified (p. 133).

> The valleys of the rivers and larger creeks contain moderately large deposits of sand and gravel, which constitute an important, but as yet slightly developed resource (p. 183).

In his travelogue of float trips during the early 1930's, Dorrance (1935) described the large number of hogs on the open range that he encountered near the Current River. His description implies that hogs may have directly affected the stream channel:

> The number of swine at large is therefore incredible.***At every bend in the stream there stands haunch-deep a band of shoats, grubbing for shellfish.

The description of the Steelville quadrangle in Crawford County (fig. 8; Hendricks, 1954, p. 52) also includes fine, alluvial sediments in larger valleys and coarser gravel in smaller valleys:

> The broad flood plains and terraces in the quadrangle are covered with silt and sand, whereas the narrow valleys and ravines are floored with chert gravel and scattered boulders, which came from the adjacent hillsides.

During the Timber-boom period, many roads were constructed in the valley bottoms for transport of forest products and access to farms. Road builders took advantage of the level ground provided by valley bottoms and often constructed road beds on gravel bars and in the channels of ephemeral streams. Sauer (1920) noted:

> If the valleys are sufficiently large they are followed usually by secondary public roads. Roads in the valleys are impassable at times because of freshets. The road commonly follows gravel bars marginal to the stream or, if the stream is not large, even the stream bed itself. After a freshet the valley roads usually need to be cleared of the driftwood that has lodged in them, and also must be relocated here and there to avoid quicksands, undercut banks, and washed-out fords.

About 1900 (photograph originally from Frisco Line promotional literature; reprinted from Sauer, 1920; courtesy of University of Chicago Press).

Figure 18. Replicate photographs of Little Piney Creek upstream from Newburg, Missouri, about 1900 and 1992.

By the mid-1940's it was popularly accepted that stream aggradation and instability were caused by upland land-use changes (Bauman, 1944). Popular literature on the Ozarks accepted the connection between land-use and stream conditions. For example, based on his experience living in the Ozarks, Hall (1958) stated that:

> All in all, the picture of land use in the Current River country for the past hundred years has not been a happy one. It has been largely a picture of land going down hill. Over-logging, overgrazing, poor farming, and erosion have combined to seriously reduce the life-carrying capacity of the region. As the good timber and forage plants disappeared, their places were taken by others less commercially valuable and less palatable. Wildlife largely disappeared, and fewer game fish grew in gravel-choked streams (p. 43).

> A deep layer of humus is created in a forest by decaying matter and by the annual fall of leaves. On the burned-out land this of course soon disappeared. The thin topsoil washed away down the hollows until there was little left but rocky chert, and the mountain streams became choked with gravel (p. 50).

Oral-Historical Accounts of Land Use and Effects on Streams

U.S. Census data and historical descriptions of land-use and landscape changes provide a framework for understanding how land-use changes may have affected streams. Oral-historical accounts add detail to this framework because respondents (table 6) can be asked about specific issues bearing on the hypotheses for the origin of stream disturbance. These issues include the extent of upland and slope gullying, effects of burning, timing of stream disturbance as compared to land-use changes, relative effects of timber cutting, burning, open range, and row crops, and the relative effects of land-use changes on uplands, valley-side slopes, and valley bottoms.

Upland and Valley-side Land Use

During the latter one-half of the 19th century, uplands and valley-side slopes were subjected to timber cutting, followed by conversions of cut-over and prairie land to pasture and row crops. Wagon roads, skid trails, and tram railroad lines were constructed to haul timber to mills and for agricultural business. Oral-historical accounts of upland and valley-side slope land-use changes began in the latter part of the Timber-boom period and continue to the present (1993). They include recollections of timber cutting practices, open-range grazing and burning, and the effects of row crops.

Timber Cutting

Most oral-history respondents described the commercially valuable upland forests before timber cutting as consisting of open stands of large oak and pine trees with grassy understory. Their accounts minimize the effectiveness of turn-of-the-century timber-cutting methods in destabilizing upland slopes and causing increased runoff or sediment delivery to streams.

Lillian Dowler's father was a timber man involved in cutting virgin pine in the Jacks Fork and Eleven Point Basins. His description was of large trees with open understory:

> He did tell how the virgin pine, there was nothing underneath it and you could see so far, see the deer.

Ab Detwiler described the upper Jacks Fork Basin when he was a boy during the 1910's and 1920's. He stated that cutting of the virgin pine forest left little timber cover until oak growth replaced the pines:

> There was a lot of timber. You see, they got--people got the wrong impression of this country. You see, this country when I was a boy, before they cut this big timber off it, it was just big timber. Shoot, there were pines here that were 4 and 5 foot through. My granddad, my grandfather left here in [19] '13 and they had just about finished cutting the native timber off***They didn't leave anything; they just cut it. Everything. The oak wasn't big enough to cut. Oak come up since that.***Half post oak and half white oak.

Bill Gates also recalled the big, virgin pine trees and his remarks emphasized that early timber cutting was selective for large trees:

> In them days, I can remember when between Alley and Summersville, that was all big pine. There wasn't hardly any oak at all.***They would just pick down to a certain size, I'd say 12 inches. They left the small timber. They cut what you call the virgin timber, they cut that clean***.

Table 6. Names and background information of oral-history respondents, Jacks Fork and Little Piney Creek Basins, Missouri

Name	Background information
Jacks Fork Basin	
Alan and Virginia Anderson	Mr. Anderson was born in Illinois in 1932 and moved to the upper Jacks Fork Basin in 1951. Mrs. Anderson was born in 1935 and spent all her life on farms in the upper Jacks Fork Basin.
Roy Baugh	Mr. Baugh was born in 1908 in the upper Jacks Fork Basin and has farmed and logged in the area all his life.
Oliver and Sylvia Beavers	Mr. Beavers was born in 1916 and logged timber in the upper Jacks Fork Basin. Mr. and Mrs. Beavers both worked at Rhymer's Ranch along the Jacks Fork in the 1930's and farmed in the upper Jacks Fork Basin.
Willa Pearl Cowan	Ms. Cowan moved with her family to the upper Jacks Fork Basin in 1911 and lived in the area all her life.
Ab Detwiler	Mr. Detwiler was born in 1904 on a farm in the upper Jacks Fork Basin and has lived in the area most of his life.
Paul and Lillian Dowler	Mr. Dowler was born in 1908, grew up in the Jacks Fork and Eleven Point River Basins, cut timber in Oregon after graduating from high school, and returned to Shannon County in the 1930's. After his return, he operated a sawmill and logged timber until the 1980's. Mrs. Dowler's father was a timber man, and she has spent her entire life in Shannon County.
Alden Duncan	Mr. Duncan was born in 1915 and grew up in the upper Jacks Fork Basin. He has farmed in the area since 1935.
Gurn and Sadie Garrison	The Garrisons owned a 280-acre farm on the North Prong of Jacks Fork. Mr. Garrison was born in 1912 and was raised on an upland farm. Mrs. Garrison was born and raised on a 280-acre farm on the Jacks Fork.
Bill Gates	Mr. Gates was born at Alley Spring in 1907. He spent much of his life farming and running a portable sawmill in the Jacks Fork Basin.
Thelma Harmon	Ms. Harmon was born in 1917 and moved to a farm on the North Prong of Jacks Fork in the 1920's. She farmed there until 1989.
Tom and Minnie Martin	Mr. Martin was born in 1910 and his family moved to a farm on the Current River near the junction with Jacks Fork in 1915. In 1935 he married Minnie and moved to a farm on the upper Jacks Fork Basin.
Will McVicker	Mr. McVicker was born in 1926 and grew up on the Jacks Fork. He has logged and farmed in the upper Jacks Fork Basin all his life.
Wayne Miller	Mr. Miller was born in 1919 and raised near Sargeant, Missouri, and has spent his life roaming around the Big Piney River and Jacks Fork Basins.

Table 6. Names and background information of oral-history respondents, Jacks Fork and Little Piney Creek Basins--Continued

Name	Background information
Jacks Fork Basin (continued)	
Jess and Charlene Plowman	Mrs. Plowman grew up downstream from Alley Spring on the Jacks Fork and Mr. Plowman grew up in the uplands west of Alley Spring, near Bay Creek; he was born in 1914. They lived near Bay Creek for the last 46 years. Mr. Plowman worked mostly as a sawyer.
Elvis Thomas	Mr. Thomas was born in Shannon County in 1909. He worked as a tie cutter in the Jacks Fork and Current River Basins.
Jack Toll	Mr. Toll was born in 1927 and his family moved to the upper Jacks Fork Basin in 1932. He grew up on the Jacks Fork, worked for the U.S. Fish and Wildlife Service, and has owned a farm on the Jacks Fork since 1960.
Jewel Wagner	Ms. Wagner was born and raised in rural Texas County in the headwaters of the Jacks Fork. She and her husband farmed on the South Prong of Jacks Fork beginning in the 1930's.
Little Piney Creek Basin	
Alva Brown	Mr. Brown was born in 1909 and has spent his entire life farming Little Piney Creek bottomland.
William Burns	Mr. Burns was born in 1909, grew up on a farm on the Gasconade River near Jerome (near the junction with Little Piney Creek), and purchased his present home on Little Piney Creek in 1938.
Jack Fore	Mr. Fore was born in 1909 and lived in the upper reaches of the Little Piney Creek Basin until 1928 and returned after World War II.
Clyde Huskey	Mr. Huskey was born in 1912 and has lived all his life on Little Piney Creek.
Cecil King	Rev. King was born in 1922 downstream from Yancy Mill on Little Piney Creek and has lived in the area all his life.
Cora King	Mrs. King was born in 1890 and has lived most of her life on a farm on Little Piney Creek.
Frank Widener	Mr. Widener was born in 1905 and was raised in the upper Little Piney Creek Basin.

Oliver Beavers described the upper Jacks Fork Basin during the late 1910's and 1920's as being fairly heavily wooded. "At that time there was still a lot of timber, private-owned timber mostly, black oak and pine." Tom Martin's recollections of timber cutting during the 1920's emphasized big trees that no longer exist:

Back when I was a kid there was virgin timber here. Lots of big pine and oak. And they cut this and skid it with mules and stuff like that.***Now they're trying to save the timber, but now when they cut, they clear-cut, cut everything small***[In the old days] they just cut your best timber. They selected timber using those big old white oaks, they busted good and they sawed good, but now the oaks you got are tough you can hardly bust them at all.***They had a mill there at Doniphan when my dad was a boy and they hauled in logs, at that time it was with oxen. They skidded them to the wagons and loaded them with oxen and hauled them on in.

Tom Martin also observed that during the 1920's to 1930's loggers always left the small trees to grow up and continue the seed source:

They wouldn't allow clear-cutting. Now you see lots of little white oak trees that come up from the seeds, it's about that big around. I'd rather have one of these than a garden of these that come up from the stump. You'll have a sprout that comes up from the side of that stump, and if it grows up there will always be a rotten place where it attaches to the stump.

Mr. Martin observed that the methods of hauling logs out of the woods changed depending on the product. Mules and horses were used to skid the big virgin timber, but the stave-bolt industry that began in the post-Timber-boom period required different handling of the timber:

Well, they had horses and mules and they skidded them and hauled them to the saw mills.***I never saw them use any tractors. Now, they did on the stave bolts. They would drive one of these hills, and if you skid them logs with your stave bolts, you got to bark them or the rocks lept into them and ruined your logs. Yea, they used tractors for stave bolts and they used dozers, too some. The tractors could pull a trailer loaded with them bolts. They had a two-wheeled trailer and then they hooked that trailer on the back of the tractor and hauled it up on top of the hill.

After the land was cut for the first time, small parts were used for row crops, but large areas were allowed to grow up into second growth that provided for subsequent timber cutting. Roy Baugh described timber cutting when he was a boy during the 1910's. His family's method was to cut timber on some land, farm it for a few years, and then move on to another plot. The only land that was clear cut was for farming:

If we cut it, we farmed it. We cut our wood, we'd cut an acre, two or three, we cut our wood, and then we farmed that.***This place I bought in [19] '45 and since I bought it I cut the timber off it four times.

Willa Cowan described the open condition of patches of uncut forest that existed in areas during the 1920's:

Yes, it was fairly open. After they cut it down, then the blackjack, black oak came in. We didn't have any problem with the multiflora roses, now we have that, it's really a pest in our Ozarks, but we had it pretty open. You could ride through the forest and see quite a ways.

Willa Cowan also recalled erosion did occur on cut land, but it was not as bad as she remembered from examples from northern Missouri where she lived as a young girl. She contrasted lumbering methods during the 1920's to 1930's with those used today; during the 1930's they skidded the timber with horses and mules:

Mules mostly. You could see where they were skidding them, it looked just like a little round rut. It marked up the ground pretty much.***Yes, but it wasn't as bad as it is in the areas where it is not rocky. When they were harvesting the timber, they were pretty primitive. They didn't have tractors and things, and when they put trucks in there and tractors and pulled the logs up, it did make gullies.***No country roads is left if the loggers ever went over it; you can hardly get through***I remember as a child in north Missouri, the gullies were like miniature canyons, but we didn't have anything like that in our Ozarks. If we had a little ditch where there would be some wash, it would be knee deep.

Alden Duncan commented on the sequence of timber cutting in the upper Jacks Fork Basin:

They just cut everything***cut most of the big pine around here. Then a fellow***come in and he cut part of the oak and some of the pine that they couldn't get out of these hollows. Now a lot of these pines in the gulches and these hollows, they couldn't get it out of there with these oxen and horses; now that's where they left, if there was any virgin timber, now they left it there, see. But now they're going down there with these tree farmers [mechanized skidders] and stuff and getting it all out.

Paul Dowler described his farm on the Jacks Fork-Eleven Point River divide during the 1920's after the big pine had been cut:

It was mostly scrub oak stuff, blackjack, post oak, some red oak and some pine, yellow pine. I don't remember any virgin pine at all.***Some of the land that I owned eroded bad after I first started farming it until I got it sowed down in fescue or some kind of a crop like that.

Oliver Beaver's experience in managing his own timber land during the 1940's was typical. Mr.

Beavers cut pine and oak off of his farm during 1941 and 1942 using a cross-cut saw and a mule for skidding. The cutting was selective for larger trees, and a second harvest was taken off the same land about 30 years later during the 1970's:

A lot of it has been cut a second time since that. I didn't cut it too close. Yeah, mine was selective cutting by my own choice. I didn't like getting that forester man out there.***Anything that wouldn't make a tie, I wouldn't cut it.

He did not recall seeing any erosion associated with his timber cutting during the 1940's to 1960's:

Not near like it does now when these skidders come. That's terrible. You ever seen one of these hills that they've logged with one of these skidders? They drag down young timber and drag out holes in the ground.***I never used no skidders; used a mule.

Jack Toll also described the upland forest and selective cutting during the late 1930's and 1940's:

When I was a young man you had two kinds of trees in the forest: great big, "wolf" trees, and then you had younger stuff. And what people were cutting was the younger stuff that got big enough to make a tie***I don't recall much pine, I mean I recall young pine, but I don't recall big, mature pine.***[On his farm] Dad would probably say "don't cut anything smaller than so and so." So that's what they would cut. They wouldn't cut any deformed trees or any big trees, because all the cutting was being done with a cross-cut saw.***It was selective, but it might not have been good timber management but it was selective cutting. It isn't what people who talk about timber today talk about selective cutting as opposed to clear cutting. When you do a good job of selective cutting you're taking out some of the deformed trees that would remain under the old type of selective cutting. They selective cut because it was worth money to cut and you could harvest it and you didn't waste your time with a cross-cut saw***.

Between 20 and 40 percent was cleared***I know there was a lot more in timber then than there is now. When I was a kid, things were going in reverse actually. There was a lot of old abandoned places everywhere that had been cleared and productive, but places had been abandoned and they were coming up in various things depending on where they were in the successional stage. But there were an awful lot of fields that had sassafras, persimmons, blackberries, and a lot of them, like our place where we moved back in 1933 had 6 to 8 inch trees all over it that had been cleared before. That's what we had to clear up to put it back into production. In the same general area, there's 75 percent more land cleared now than there was then. Back then, the fields was little islands amongst the timber; today, the timber is little islands amongst the fields, in that particular area.

Jess Plowman's observations of timber cutting emphasized that little erosion occurred, especially before the advent of mechanized skidders and even now (1993), the effects of skidders do not last long:

Now that was after these log skidders. After they got them why they went down in the rough. Them things'll go anywhere and get out somehow or another, and get every tree. Before when they had horses they logged with and mules, why that rough country they just left it in there; it wasn't worth bringing out but these skidders went down in there and if they couldn't do no better they'd pull that cable down there and just winch 'em out. It's a different type work any more, logging is, it's nothing like it used to be***.

I don't know what happens but you go in there where they logged and it looks like they tore stuff all to pieces. And you go back in three or four years and it's not the same place. If you're not careful.***Now I do a lot of root digging and I've walked, tracked these hills. And you run across stuff and you're wondering now what caused this? But you get studying it and you'll see there was a logging operation there at one time, but it's almost gone away. If it's left alone it will almost disappear.

Sadie Garrison's brothers were tie hackers. Her recollections of how the white and black oak were cut into ties during the 1930's indicate that the cutting was selective for the large trees.

They hewed ties and took to town when I was a kid. But that just helped the timber really because the timber growed back better.***After awhile it'll just rot anyway if you just leave the timber there.

Gurn Garrison cut ties in the 1930's and 1940's immediately upstream from the North and South Prongs of Jacks Fork. Cutting was selective for larger trees: "If it wouldn't make a tie, they wouldn't cut it." He contrasted this with practices since the 1960's in which more timber is cut because large quantities of cord wood are cut after the saw logs and stave bolts are taken. In the 1930's and 1940's, he noted no erosion during timber cutting.

Elvis Thomas also recalled selective cutting of ties during the 1930's:

I cut lumber for***in Winona. They would come out and spot the trees for me to cut. Put red paint on the ones they wanted out. There were alot of ones I'd like to cut–they were nice trees--but they weren't spotted.

Jewel Wagner described clearing in the divide area between the Jacks Fork and Big Piney River Basins:

It's always been timbered. Until these people with bulldozers came in and started taking it out.***In the late [19] '40's and '50's that I remember most of it was done. But that was to clear the hilltops, not the sides or in the valleys, because the soil just washes down and that takes these rocks and gravel with it.***You can farm the hilltops for pasture. It's not really good to put in crops to plow.

Virginia Anderson described the state of the upland forests in the Jacks Fork Basin during the 1940's: "There was a lot of brush, but there wasn't a lot of huge timber either." Their family would cut railroad ties on a regular basis from the second growth forest:

You would cut, like Dad and Mom and another family that we was neighbors, we would cut a load of ties maybe twice a week and they would be hauled to Sargeant to the railroad***.

Alva Brown's description of timber cutting in the Little Piney Creek Basin during the 1920's was similar to those of respondents in the Jacks Fork Basin with the exception that, because of a lack of extensive pine woods, large commercial logging businesses did not operate in the Little Piney Creek Basin area. Mr. Brown recalled selective cutting and limited row cropping that produced a mosaic of cleared and partially cleared fields:

There was a lot of it. Making ties, railroad ties. They took the best trees they could get. Ones they could work, you know, and they hewed them with an old broad axe.***There wasn't much clear cutting done. Sometimes a new family would move in and they would clear a bunch of land, you know. It was kind of a slow process; they had the old cross-cut saws and they didn't have chain saws. There wasn't no sale for cordwood much, and the tops usually laid there and rot after they cut the tie out of it.

Mr. Brown estimated that during the 1920's one-half of the Little Piney Creek valley bottoms were cleared and the rest was grown up with sycamores and elms. On the ridge, there was not much open land: "Each farmer had enough to farm, and a lot of it was blackjack and hickory and stuff that was no good except for fire wood."

Jack Fore recollected that timber cutting in the Little Piney Creek Basin during the 1920's was mainly by farmers and small tie-hacking companies:

Back then we had lots of larger trees and all and they've been cut out. And new trees would come in. And in all that vicinity out in that part of the country, anyone would go out and cut wherever they found something they wanted to cut. Nobody thought anything about whose land it belonged to. Most of them called it speculator's land.***And they made ties***and they would haul these ties to Newburg, a lot of them, and then a lot of them would sell them over here [Yancy Mill, Missouri], and then they would raft them down the Little Piney to Newburg. They didn't fool with black oak back then. They made white oak ties, but later on in years, timber began to get slack and then they went to black oak too. Not too much pine, not in this part of the country. You get on farther south and you get into pine. They would cut it [oak forest] for ties. And a lot time they would leave the tops, you know. All that could have been utilized for [fuel] wood and stuff, but they didn't do that. And it was a shame. A lot of that timber they cut, they just cut what they wanted out of it and make ties out of it or take it to a sawmill somewhere.

Frank Widener observed that in the upper reaches of the Little Piney Creek Basin, timber stocks had been depleted by the late 1930's: "Good timber was coming pretty scare then." Subsequent regrowth allowed additional cutting, however, beginning during the 1940's.

Rev. Cecil King's description of the timber cutting practices from 1900 to the 1940's in the Little Piney Creek Basin included the observation that with changing logging methods, more timber was cut during the 1940's and 1950's than when he was a boy during the 1930's:

There wasn't much timber cutting when I was a boy. Later on, they began to do that, see, and they still are. When I was a boy, they didn't cut much timber. There was a lot of timber left.***When I was a boy, they didn't have the means to get out into the timber like they do now. You used a horse, mule, and dragged them out. You had no way to haul them a distance. Your mill would have to be close by. I remember steam engine mills. I guess you could say they were portable because you could move them, but it wasn't easy to move them.

It was random cutting.***They cut these ties on almost anybody's land. A lot of the land hadn't been surveyed. It was called mostly speculator's land. A lot of speculators out of St. Louis, Chicago, New York, wherever, would buy land down here in blocks. And they didn't seem to mind people cutting on them. Maybe they didn't know about it. I don't know. But they cut ties almost anywhere.***There was some logging [for saw logs] but not all that much.***I remember logging by our farm down there. An operation came in and they used a big old steam engine.***It was about 1935.***It was for their own use, mostly. They was just after the better trees. They would take just the better trees. There was no clear-cutting on the hills; there might have been down in the bottom where they wanted to farm it.

At what Rev. King considered the peak of stream instability and aggradation during the 1940's, much of the Little Piney Creek Basin was still in forest:

There was more forest than there is now. Because they hadn't come in with the bulldozers, and they sprayed with the aerial spraying and killed a lot of timber. And there was much more, I would almost guess there was twice as much. But it seems to have not affected the flow of the river or the streams or branches.

Respondents on the Jacks Fork consistently observed that little or no timber was transported downstream by floating on the Jacks Fork because it was considered to be too shallow and flood prone. Instead, the timber on the Jacks Fork was transported to neighboring towns on unimproved wagon roads and small tram railroads (fig. 12). These roads later provided access to open range and the rivers. Bill Gates described the roads:

There was log roads, you might say. On the Current River that's about all you's say they was, was log roads. Of course, up and down the river, they went up and down the river.

Alan Anderson described little gullying of logging roads he was familiar with, including a part of the White River Trace, a pre-settlement period trade route and major wagon road used until the mid-20th century:

They may be a foot wide and 4 or 5 inches deep, but there weren't huge gullies. It's got washed places in it a foot deeper than the surrounding area.

Rev. Cecil King observed that logging roads would wash out to "some degree":

I've seen some roads back over here above Yancy Spring and different spots and I've found them where they've washed out to some degree. But not all that much.

Rev. King described how logs were taken to the portable steam mills in the Little Piney Creek Basin during the 1930's:

We hauled them on a wagon. But most people would usually haul them on a wagon or with mules, horses; horses mostly.***You didn't have your trucks and bulldozers and this that and the other way back then, so you didn't have what you would call roads. But they would have paths, more or less.

Open-Range Burning and Grazing

After the large commercial timber interests left the Ozarks, inhabitants became more dependent on raising cattle, hogs, and sheep on the open range (Rafferty, 1980). In an attempt to improve and maintain the range, fire suppression was replaced by active seasonal burning.

Ab Detwiler described the open range in the Jacks Fork Basin from 1920 to 1930. He assumed that there was some erosion associated with burning, but "***there was enough stuff on the ground that it didn't wash through":

You see, they used to burn this woods off every year. Why them old pine stumps would burn out there, man, I'm atelling you, there'd be those old pitch hearts clear through.***We used to always burn every spring. You had to burn every spring because, you see, there wasn't no stock law. People just turned their stock out on what they call the free range. Over there at the old home place where this house is, well we'd milk the old cows and just kick them out the gate. They'd go out and roam the woods and then we'd have to go hunt them up when we needed them.***You could go back out north out there and there'd be as high as 50 bells. You could just hear cow bells, horses, horse and cows***and they all had bells on them.

These observations were echoed by Tom Martin:

Yea, they'd burn. You would see people going, bunches of them going together and rake around their farms and they would burn around one man's farm. If somebody else's farm was close to it they would burn it. They would always burn about every spring. It didn't kill the timber then because there wasn't that many leaves. If you let these leaves get knee-deep and

Lord, it will kill everything that could burn. No, it wasn't a big fire, it would burn, you could see the fire burn, but it wasn't nothing like it is now.

Bill Gates described spring burning from the point of view of a timber man:

That was bad. The bad part of it was the farmer would burn the woods, and of course it didn't hurt oak too bad. But pine, it would hit them little pines, and they'd burn up. Of course, for grazing and all that, that didn't hurt it. The farmers, they'd burn the woods every year. In the spring they had this old grass, bluestem I call it, and it would sprout up and that made good grazing. And then in a little while it got too big and tough and the stock wouldn't eat it. And they'd graze on these, where there would be some little field that somebody had cleared up at some time or another. A lot of cattle would be on that and that grass wouldn't be an inch or higher. And they would all try to live on that and they would get poor. And then the beggar lice would come on and they'd fatten up then.

Oliver Beavers indicated that spring burning was common during the 1940's:

Pretty near everybody [burned].***When I bought the farm over there, we had one man that had section of land over there and he always lived in town. And he'd come out there and burn that, when things were dried up to burn. And he'd just set the thing afire and go back to town.***The old timers did, they liked to burn because it did make more pasture for their cattle.

Alan Anderson described typical burning methods during the 1940's:

And every spring, especially on Easter Sunday, the woods were always burnt. I mean, there were fires ***Easter Sunday was the big day for burning, which I don't know why. [They burned] they said to get rid of the ticks. We had one neighbor who would just get out and start walking to the store and if he had a match in his pocket and saw a pile of leaves, he would just set it on fire. Take off and let it burn.***Only time you got into trouble was if you burnt someone's fence posts up.

Jess Plowman stated that the annual burning was not practiced much in his neighborhood because people feared that they would ruin their hog range:

The people didn't burn the woods much right in this area because they didn't want to spoil their hog feed, burn them acorns***far as I know acorns need to sprout. If they don't sprout they dry rot.

Alden Duncan concluded that burning led to increased erosion and bigger floods from spring rains that occurred soon after burning:

Every spring, we would have big rains, you know, they would burn the woods to graze the livestock, and we didn't have the ticks we have now. Yes they had erosion, yes, yes, yes. We had a lot, we had big floods.

Sadie Garrison's observations on open range emphasized that open-range stock roamed over wide areas:

They [cattle and hogs] were just all over. There was alot of this ground wasn't even fenced then. Seeded fields, and things like this, they went all over. In a way hogs did [cause trouble] you know, they were sometimes, my dad had to fence with woven wire. Which we went to barb wire when the open range was over.

Two years after we were married they voted the stock law in***I think it was better than what it was worse***I mean for the people around. A lot of people hated this because they didn't have but small farms, know what I mean, in those days. And they didn't know what they was going to do hardly because they had more cattle than what their little farm would take care of. Most people just had 80 acres.

The Garrisons were not in favor of the stock law that repealed open range, but now (1993) they approve of the closed range. Methods of farming have changed and there is now much more emphasis on soil fertility:

I much would rather have the way things are now. Since we have the bigger farms. And Gurn went to GI school and learned how to fertilize and, you know, I mean, a lot of things we used to didn't have, and they wore down the land a lot, our dads did, because corn and everything, and we didn't know about fertilizer, something like that.

Willa Cowan characterized her family's use of open range for hogs:

Well, you see, the hogs ran on the range and we had the oak leaf system, they called it, mast, the acorn crop. And when you wanted to fatten your hogs up to sell them, you penned them and fed them corn, otherwise the meat, the fat was real soft. I just loved acorn meat, myself, it had a wild taste, but they wouldn't put on weight.

Jewel Wagner felt that open range during the 1930's and 1940's was not hard on the land because there were not enough cattle. She never saw the ground torn up because of cattle on open range.

> The thing that's wrong with free range is you have to fence to keep things out. You don't fence to keep them in***and it was bad if you had to fence against hogs.

Thelma Harmon remembered her mother burning pastures and woods in the spring:

> My mother used to burn the ridge and stuff in the spring. She used to burn the pastures off so that there'd be fresh grass. She'd burn the pastures and she'd go down the crick and burn all the leaves and clean it up.

Roy Baugh described the effects of burning and open range in the upper Jacks Fork Basin:

> Last of February, first of March, burn it off. You could see a horse up there on that hill; you had open timber. Nowadays, you can't walk through that. It's all briars and brush.

He continued to say that when it was burned, bluestem grass came back naturally. He was in support of open range and burning, and he did not observe erosion associated with open range:

> You had to [burn] with that open range. We didn't have no pasture. We had that open range; we couldn't farm it.

Jack Toll described burning and its effect on litter and undergrowth in the woods:

> Every spring you could depend on burning all over the country.***My dad wasn't particularly for burning; in fact he wouldn't go out and light fires, but to keep it from getting into your hay fields and one thing and another***you almost had to burn to keep from losing your fences and losing some of your fields. We didn't actually burn our woods, but we burned around our place to protect against incoming fire.

> They would burn it because it would take the litter off, stimulated the grass to grow, and of course a lot of silly old-timers said it would kill the ticks. I don't remember any fall burning; I think it was spring burning. I know the burning must have had an effect. I don't remember walking out through leaves like you do now. You would walk out and it was rocks and bare and there was a lot of plants underneath the trees***.

He also described some of the effects hogs could have on open range:

> I can tell you for sure that if you go out into the woods where hogs have rooted and browsed for acorns and grubs and that sort of thing, they can literally tear--it looks like they've plowed. It has to be a very erosive thing for the soil.

Willa Cowan described what happened to the farm her family formerly owned after they sold it in the mid-1930's:

> It was really after we left there some saw mills came in there and began to cut that beautiful timber. It was hardwoods, white oaks and some pine, some of the big pines.***What they did, they cut all of that beautiful timber off, and what they didn't sell, they dozed it off and tried to make it look like Texas.***And they stocked it with a lot of cattle, stayed there probably 10, 15 years.***He just wasted the timber, he just cut it. And he'd make these beautiful ridges of forest that we kids enjoyed so, and all the whole community, they just cut it, slaughtered that timber, sold what they could haul off, and then come in with dozers and dozed it off and made it into pasture. A lot of it was burned. Most of the time they just dozed it off into large mounds.***It was amazing, he was going to fence it all.***It didn't work because if somebody wanted to go hunting or cut a load of logs, they would cut his wire.

Large cattle or hog operations were rare on the Jacks Fork from 1920 to 1960. Virginia Anderson recalled the typical family livestock operation. She observed that the effects of hogs on the forest floor were intense, but limited areally; much of the time the stock concentrated in the valley bottoms:

> Usually a family would turn out a sow or maybe two sows and get them in the fall. And they would have their litters and stuff, and they would notch their ears so they would know which ones were theirs, and they would get them in the fall and if they come with your sow, they were yours. They didn't do a whole lot of rooting in the fall when the acorns was out, but after the acorns fell you got your hogs in and butchered them or sold them. There might be one hillside where all of them would sleep and it would be rooted around.

> When you went to get them at night to bring them in they would be down along the creeks somewhere, and they stayed down there especially in hot weather. There would be some big, deep ditches down there where they walked and where they went down into the creeks.

Bill Gates also recalled fewer total numbers of livestock during the 1920's to 1950's:

> There wasn't as much stock as they are now, not near as much. But a lot of people run out--they run their stock out all the time. I've seen hogs all over the woods, you know, eating acorns. And the cattle, there would be bunches everywhere, especially on the river.

As the open range was repealed township by township during the 1940's to 1960's, more inhabitants attempted to improve grazing by fencing, clearing, seeding, and fertilizing. The biggest challenge faced by farmers was controlling hardwoods that would sprout from roots and stumps. Will McVicker described a typical process of clearing the land:

> Used to, they would deaden some trees as they were clearing the land. Then they would throw a fence around it, put some goats in and goat it off. Get the sprouts. They didn't have bulldozers back in those days. Chopping axes, us kids' job. Kill the sprouts after the land was cleared. We'd have to come three times a summer and it had to be once in August. It was real hot. If there was goats in there, it [the ground surface] was pretty bare because they eat everything, but there wasn't no erosion.

Cora King recalled that during her early childhood during the 1890's there was little burning of the woods in the Little Piney Creek Basin because inhabitants valued the wild fruit and nuts:

> People used to burn, but not too much, because we had all kinds of wild grapes and things, you know, and huckleberries that we would get out and pick, you know, and blackberries.***They didn't burn the woods too much then; they got to burning the woods later.

Cora King also recollected that livestock were sparse on the open range when she was a child but increased in population until the open range was closed:

> I never saw them when I was a kid. They did run wild, of course; when they passed the law to keep them from running out, a lot of people got mad about it. It was good, though, because on the farm we was on, a bottom farm, hogs would come from off of them hills and the high lands and on down into the bottoms. And they would break into the fields, and mow down fences, and tear your corn up and everything.

During the later 1910's and 1920's, however, the history of grazing and burning on the open range in the Little Piney Creek Basin was quite similar to that of the Jacks Fork Basin. Alva Brown talked about the grazing history of his father's farm during the 1910's. Their 160-acre ridge farm had cattle and row crops:

> He had cattle, not a big bunch, but a few. He run them on what they called free range.***We had sheep, a few hogs. There was pretty good demand for lamb and for wool, and there wasn't no coyotes or wolves at that time. It was pretty safe. Then the coyotes began moving in, and a timber wolf, a few now and then, and they got to killing sheep, you know. And a lot of people went out of business because of that.

Mr. Brown recollected that burning of open range occurred mostly in the spring in the Little Piney Creek Basin:

> It was mostly in the spring. They would get all them dead leaves burned off and the grass would grow better. It would kill a lot of bugs and insects. I don't know if it was good or bad; some people yet today say it was a good thing***.

Rev. Cecil King's recollections of upland pasture management in the Little Piney Creek Basin were similar. Selective cutting of upland forests left thinned woods where grass was maintained by annual spring burning. He recalled that there was always some erosion after the spring burning, and he compared floods during the 1940's with a recent flood on Little Piney Creek [May 13, 1991, 21,300 ft^3/s (cubic feet per second), approximate 10-year recurrence interval]:

> A fire would come along and damage some of it. But if you burned every year, then the leaves would not be deep and it didn't damage as bad. When your leaves are deep, and the fire gets big then the fire damages things. It would always kill some of them [trees].
>
> It would green up but it would never green up enough to keep it from washing. There was nothing there to hold it, you know. So, if you had a big flood like we had two days ago, you would have had a hundred times as much washing, depositing silt, sand, and gravel down there on the Piney, than you had the last few days. Because now you don't burn anything off, and you have a lot of ponds, so you don't have as much washing.***They would burn the woods. Of course, you had to back fire.***[The point of burning was] to encourage the growth of grass and get rid of ticks, and snakes, and this, that, and the other. But there was no grass, really, then, though there was a little growth in the woods.***Everybody burned, and if you didn't burn,

you ended up burning because you had to backfire to keep from burning your houses, barns and stuff down.

The bulldozers didn't come into much prominence in the [19] '30's. They just barely started. They were pretty rare. They were doing some but not much even in the [19] '40's. It was not until after World War II that we really started having the bulldozers pushing down trees and this, that, and the other. Now that didn't make all that much difference as far as the flow of the water was concerned. Once they stopped burning the timber, you see, it made a difference in the flow of the water. In other words, you don't have the big flood like you used to have. You haven't had for years.

In considering the effects of open range on the landscape, Rev. King recalled that sheep were the hardest on the land:

Sheep was always the worst, on any kind of pasture. They eat it down so close. They didn't have open range down here [on the Little Piney Creek valley bottom] when I was a kid; this was all fenced. They did have open range around Salem, south of there. ***[Hogs] didn't hurt the woods; they'd be rough on the pasture. A cleared pasture, they would root that up.

Row Crops

Although respondents' recollections were mixed concerning how much erosion was associated with timber cutting and burning of open range, all recalled instances of substantial erosion associated with row cropping on uplands. Roy Baugh's observations of gullies that resulted from row cropping of corn in the uplands of the upper Jacks Fork Basin were typical. Gullies were fairly common when he was a young man during the 1930's:

Where folks plowed up a hill and didn't get it seeded down good enough. Then when it rained on it, it started to wash. We had one go across our field and we picked probably 40 wagon loads of rocks to fill that thing up. It's all fairly common, and when you planted your corn, if that soil was loose, it'd run right down your corn row, you see. And then all that dirt would get washed out.

Oliver Beavers described only a little of upland erosion on his farm:

On my farm there were a gully or two***I was about to put in some new fence and I took that old wire and put it in them gullies and they just about filled up.

Alden Duncan observed that accelerated soil erosion was common while he was growing up during the 1920's until the 1940's:

Our rivers were, at that time, we had bigger floods, you know, there would be more silt and stuff go into our rivers. When it would erode, you know. Farmers were plowing up ground they had no business of plowing, you know [during the (19) '30's and '40's]. They are still doing some of that, and bulldozing.

Mr. Duncan also described his efforts to rehabilitate land that had been row-cropped by previous owners:

Well, now, a lot of people overgrazed their land in order to clear it up so they could grass it. We married in [19] '35 and I bought an old dilapidated house and rebuilt it, and cleared all that ground. It had been run over and farmed for years and they just killed it out, you know, corned it and caned it. And I bought that and I rebuilt that. About 400 and some acres. I rebuilt it by seeding it to grass, putting in grass, permanent grass. Fertilized it. Grazed it with goats; didn't put no row crops on it. There was [row crops] before I bought it. They wore that out. There was ditch running across that farm that I could stand up in and you couldn't see my head. It's all filled in since I got it. All them places in time, back a hundred years and better, have been abused.

Paul Dowler's farm had been cut, cleared, and row cropped before he started farming it during the mid-1930's. The previous land use had left some gullies, but the depth of incision apparently was limited by the stone content of the soil:

It didn't erode here like it did in some places. It eroded bad of course, and took the topsoil off, but the topsoil was so shallow you were down to hardpan soon after it washed 6 or 8 inches deep. And of course, if it washed any deeper it ruined it for farming. I had 40 acres up here and 20 acres of it was just ruined. I farmed it every year, plowed it up every year. I got a tractor and worked the ditches in best I could. And now I don't run any machinery on it, I just leave it in grass.

He recalled that almost everyone had some row crops, generally corn, and that the accepted practice during the 1930's was to plow up and down the hill:

Oh, yea, up and down hill. Everybody. You had to have a patch of corn or you weren't in business at all. Wheat wouldn't wash as bad as corn.

Willa Cowan's father had an upland farm from 1919 to 1930 in the upper Jacks Fork Basin. His farming effort was typical with about 25 acres in grains and about the same in hay:

> He stayed up on the ridge.***He would have, oh, I'd say 10 or 15 acres of corn, and he'd raise oats. He tried to do like the northern Missouri farmers did. Which was hard. He raised enough grain to fatten the livestock; he would run the hogs on the range.***Everybody had a patch of corn, everyone put up enough grain to mix with their hay. And later on during, we had some droughts following that depression, and then they began planting sorghum crops.

Jack Toll also recalled growth of sorghum during the 1940's:

> Almost the only row crop that anybody tried to plant was sorghum. Almost everybody tried to grow enough sorghum to make molasses. In addition to that what we did, when we cleared off this land and it had a lot of stumps in it we would plant one year of some type of cane, not necessarily sorghum, and then the following year, we would plant oats and some type of grass.

Virginia Anderson recalled sheetwash erosion from row-crop land rather than deep gullying:

> It washed more all of it, instead of just cutting gullies and stuff; it was more like sheetwash. If a field washed it would be the whole field, you know, would be washed down more so than cutting the big gullies. The creeks would be muddy for only half a day and then they would run clear.They wouldn't be muddy for 2 or 3 days at a time like these are now.

Alva Brown described his experience with row-crop farming as a boy in the 1920's in the Little Piney Creek Basin; his father owned 160 acres of ridge land, but no bottom land:

> I plowed with a team of horses. Cut sprouts. Helped Dad haul rocks off the land.***We raised corn up there; corn, oats, and wheat***[Erosion], that ruined a lot of the ridge land.

When erosion ruined the land, they would abandon it and let it grow up:

> It would grow back up, maybe sprouts and wheat and things, and eventually, it would grow back, after several years it would get back to where it would produce a little. But back then there was no such thing as fertilizer, just barnyard manure was about all we had for fertilizer.

Jack Fore described the typical upland farms of the Little Piney Creek Basin. Ridge farms were not considered the best land because of the risk of drought conditions:

> What we called ridge farms then, that is up at higher elevations--if you got a rainy season it would raise quite a bit of stuff, but you got a drought or half-way drought, stuff would burn up. But down around Little Piney bottom, down in there, they raised pretty good stuff.

Rev. Cecil King recalled that row cropping in the Little Piney Creek uplands produced gullies and erosion of topsoil:

> We lived on the Piney, see, so we had semi-level fields. But there were people who didn't live on the Piney who had to try to raise corn on land that was somewhat rolling. It washed. I think they were aware about it [the problem of erosion] but they never seemed to do anything about it much, so nothing was done. In a lot of fields there were gullies. Ordinarily they would farm a field for awhile until the topsoil was gone, and then they would go on to farm another field someplace.***If you were living up on the hills and ridges, and you didn't have fertilizer, you couldn't farm very long and you ruined your land. So soon, all the topsoil on the ridges was gone.

Rev. King also described the transition of the land after it was row cropped:

> Most of the time it would just sit there, but a lot of times they would use it for pasture. Sometimes it would heal back; sometimes the gullies would fill up, and it would reclaim itself to some degree. Most of the time, though, all those gullies and stuff would remain there until you got bulldozers and things of that nature, and people would fill them up, making terraces and all that. That is what happened in the latter part of the [19] '30's and the '40's; they began the terracing. And that made a big difference.

Present (1993) Upland Conditions

Some seasonal burning still occurs on the upper Jacks Fork Basin, although it is not as extensive as it used to be. The effects of the more recent burnings have been described as more severe, probably because less-frequent burning has allowed more fuel to accumulate. Will McVicker described a recent incident:

I had one in [19] '80 down there. Boys burning on their own land, got to drinking, and it get out and a south wind took it across my place. Cooked everything, killed everything, big trees and all.

Alan Anderson remarked that cattle concentrations are now much higher with the end of open range and the subsistence style of farming:

The cattle and everything weren't as concentrated, though as they are now, either. Now they concentrate huge herds and they all water in a smaller area. At that time they were scattered out a lot more.

Thelma Harmon, Jewel Wagner, and Wayne Miller all commented at length on a present-day (1993) cattle operation in the upper Jacks Fork Basin. This land is being clear-cut, bulldozed, and seeded, and many inhabitants blame the operation for increased flooding, erosion, and aggradation downstream. Jack Toll described the operation and recalled that these clearing methods have been used before:

They cleared stuff that I know is on a 1 to 1 slope. They didn't leave any trees. They cleared everything. It's already washing. I don't know how in the world they will ever stabilize it.***That's a recent thing but that has been going on for years especially back in that part of the country, in the headwaters [of the Jacks Fork]. And particularly on the South Prong.

Many respondents contrasted present (1993) timber-harvesting methods with those that existed from 1930 to 1960. Most observations indicated that mechanization and increased cutting of more of the timber for a wider variety of timber products has produced greater potential for erosion. Elvis Thomas commented:

Now they're just gutting, they're cleaning it***clean it up, boy and quit. All this land they're coming in now. They bring in skidders in here and they won't leave nothing. What little saplings they do leave, they run over with the skidders and tear them all down.

Valley-bottom Land Use

Early settlement of the Ozarks was concentrated in the valley bottoms because of the availability of fertile soil and water. Oral-historical accounts of changes in valley-bottom land use emphasize that valley bottoms primarily were used for timber, crops, grazing, and gravel mining. In addition, owners of valley-bottom land frequently attempted to rechannelize the stream to optimize pasture or cropland. It also was common to remove riparian vegetation to maintain a "clean" streambank.

Timber Cutting, Channel Mitigation, and Gravel Mining

Respondents on the Jacks Fork described a range of approaches to riparian forestry. Because the narrow valley bottoms of the upper Jacks Fork Basin were difficult to access and not productive for row crops, riparian forests were left relatively intact. Willa Cowan described parts of the Jacks Fork where she played as a child during the 1920's:

The amazing thing, I would say that the reason the river sides were not eroded was the trees were holding, controlling the river, and the big trees along the river, they couldn't get them out. Because they had to go down maybe in a canyon or they didn't have cables and things to get the timber out like they have in the western country.

Other respondents described the cutting of riparian timber in areas of wider valley bottoms and more prosperous farms, which was common. Thelma Harmon's recollections of living on the North Prong of Jacks Fork reflected the tendency of many landowners to devegetate riparian corridors in trying to minimize inundation by floods and create an orderly pastoral setting:

When I was growing up, the Jacks Fork went right through our place. And my parents kept the stream clean and kept all the debris and branches and everything cleaned out. We had no problem with it flooding out and cutting different channels. It kept in its channel.

Mrs. Harmon, referring to her farm, also on the North Prong, stated that she had no problem with the stream until the mid-1960's. When an upstream neighbor cut his timber, she then attributed gravel aggradation on her farm to channel instability propagated directly from the effects of timber harvesting:

The Jacks Fork went right through the middle of my place and until people above me went to cutting trees and falling them in the crick and just leaving them and everything, I had no problem.***Then when the crick got up it washed it down on me, and then if I didn't clean it up, which I wasn't man enough to keep it all cleaned out, it would go down on the other feller. And it just kept changing 'til it spread it out, 'til it***it lost its depth, there wasn't no swimming holes.***It would wash out, wash around the tree roots, cut a new channel, spread out.***It would form new gravel bars, and wash out holes. Then the next time the channel would change a little bit and there'd be another hole and gravel bar. Time after time it got worse.

Virginia Anderson stated that riparian trees usually would not be cut along the Jacks Fork, unless they were a fairly valuable species like walnut. Jack Toll's observations from the Jacks Fork indicate that removal of riparian forests has the potential to cause instability and aggradation:

I know one place on the South Prong just below Gatons [?] hole where somebody came in and cleared 5 acres right in the bottom, in the flood-plain area, and disked it up and planted it in something, I'm not sure what. And the next year there was nothing there but just a big old gravel bar. And that was all trees before.

William Burns described his experiences on the Little Piney Creek during the late 1930's and early 1940's. He always maintained a dense growth of timber, 15 to 45 m wide, along his section of the river, but his neighbors upstream did not:

I left it growed up for water protection. I know a place right above me here where they cut everything on the bank. Every time the creek gets up it takes off a slab of it and washes it away.

Rev. King recalled that most all the virgin timber in the Little Piney Creek valley bottom had been cut by the time he was a boy:

We had about the last piece of virgin timber down on the George Lane place. Which is now part of the Lane Spring area. And my dad never would cut it. Then he moved up here where I'm living now and when he sold it folks came in and they cut it all down***there were some enormous trees. Sycamores were, I guess, twice bigger than anything you see down at the Lane Spring area now. They were all cut. Just enormous things.

Rev. King's father tried to maintain a strip of trees along the channel for a buffer:

There was always a buffer strip of trees he would try to leave. But the way the Piney always worked it kept eating and working and eating and pretty soon the buffer strip of trees was gone.***Most all [neighbors along the river] tried to leave a buffer strip.

Oliver Beavers recalled a family farm near Alley Spring on the Jacks Fork where the owners planted row crops up to the edge of the river and attempted to stop erosion of their land by moving channel gravel and piling brush on the banks:

Down near Alley, when I was guiding down there, they'd clean out the main channel***to keep the river from making a rain channel. And they even would cut a lot of brush, like the river would come around a bend and cutting into their land. They'd cut saplings and brush and bank in against the bank there to keep it from washing out.***Some of that bottom land along the river there is rich ground and they'd just hate to lose it.

Jewel Wagner recalled how her father-in-law attempted to manage the channel of the South Prong of Jacks Fork during the 1920's:

He thought it would be better to have the creek going up the side of the field instead of meandering across then he would have more bottom land to farm.***Instead of that, why, it would overflow and create gravel bars and it just took the holes out.

On the Little Piney Creek, Jack Fore recalled that only a few farmers tried to change the channel on the Little Piney Creek:

It would be a losing situation, then. Now of course, you have big equipment, heavy stuff, you could probably do a lot of changes. But it is not necessary now because you don't get enough floods to really affect the river.***They would clean out some obstruction if they figured that if they cleaned that out it wouldn't keep cutting on them.

Rev. King's recollections were similar, but he added the observation that attempts to control the channel increased during the 1940's when bulldozers became more prevalent:

Once and a while they would fall some trees into the stream to keep the stream from eating their banks out. I know they did that, sometimes, but very little of that.***There wasn't much you could do with it. You would just sit and watch the creek ruin your land.***There wasn't much they did do. The river is pretty hard to fight. When the bulldozers came along, they could do a lot more. They could clean out the stream.***What he [a neighbor] would do is, he would come down through here and push the gravel on one side or the other to make the creek straighten out.

My grandfather, George Black, built a rock dam right at the end of this field [near Piney Spring]***to keep the Little Piney from washing down through a field.*** But most people did not do anything***.

Jewel Wagner commented on the prevailing method of taking gravel directly out of streams for road maintenance:

The only time this [taking gravel directly from the stream] happened is when they put in a new road when they would gravel the road. Like [State Route] 137 probably 25 years ago, 30 years ago was a gravel highway. And they had to take the gravel from these creeks then to keep the potholes filled.

Roy Baugh recalled that it was common practice to haul gravel out of the Jacks Fork for use on farm roads and county roads. He estimated that in a given year during the 1930's, the county road crew would take about 100 truckloads of gravel from his farm:

We got all our gravel for our roads out of the Jacks Fork.***If we needed some gravel for anything, we'd just take a team of wagons down there, down to one of the gravel bars and take it off. It's clean gravel.***We'd grade a road down there in the spring so we could get in there and get gravel, and we could all go down there go swimming***, until the Scenic Riverways got it; they wouldn't let us grade that road. And they said we couldn't get no gravel.

Jack Toll confirmed that a substantial quantity of the gravel for roads throughout the basin was supplied from the Jacks Fork. His observations of present (1993) gravel operations led him to believe that gravel mining did not have a significant effect on the river:

There is no way in the world that you could haul enough gravel out of this river basin to make any effect whatsoever.***[When he was a kid] everybody went to the river and did it. The WPA hauled truckload after truckload from right at the forks of the river***and gravelled the roads around here.***Well, the most extensive gravel operation we have got is on the South Prong, just above the bridge. And it goes up, they have gone into gravel deposits for a mile. Now, that part of the river is really in bad shape, but I don't think that in itself is what did it. It probably contributed, but I don't think that is the primary reason.

Bill Gates also described extensive gravel operations on the Jacks Fork:

The gravel, they used to get the gravel out of the river for the highways, and things like that. They kept it cleaned out pretty well. Now like down here at the bridge [State Route 17] they used to go in there every year. The river would get up and put in more gravel and then they would come and set up their gravel plant down there***.

Tie Rafting

Railroad ties and some saw logs commonly were floated to railroad terminals and mills (fig. 14). Individual ties, rafts, and jams composed of escaped lumber had the potential to aid in physical erosion of the streambed and banks and cause destabilizing diversions to flow. Places where ties were hauled to the river for nailing into rafts also had the potential to cause significant local disturbance (fig. 13).

Ties and lumber routinely were floated on the Current River. Tom Martin, who lived near the junction of the Jacks Fork and Current River, recalled participating in tie rafting and setting ties into the Current River during the 1920's:

They rafted all times, all months of the year. Just every 2 or 3 days there would be a tie raft come around.***Now, when they used to raft these ties, they used to haul them to the river and stack them on these high banks where they wouldn't wash away until they dried out. And we always took a 12-inch board, nailed two 2 by 4's on that to where the ties go down this, then we always wet them or greased them with grease, and then you'd take a sled and haul 10 or 12 of them up to this slide and put them on cross ways. And all you had to do was lift them up and they'd go down to the river.

Jack Fore's description of tie-rafting down the Little Piney Creek emphasized how conditions on the river have changed. Ties were rafted from Yancy Mills [20 km (kilometers) upstream from Newburg] to Newburg until approximately 1918. The rafts consisted of up to 100 ties, nailed in groups of 8 to 10 per block. Blocks were nailed together by a pole down the center so that the raft could bend around curves in the river:

Then they would put a guy on the front end, two or three in the middle and a guy on the back. They would leave a space on the back so big and have a big pole, and if they gave him a signal to slow it down if the front end got tangled up, he'd run that thing down into the ground and snub that down and stop the raft. Now in the middle, when they go around a curve they just hold against the bank and just walk the bank.***When they would get all those ties nailed in, get ready to go, they would open the gate on the mill pond and let that water down and that would give them a send-off.***This was usually in the fall, not too much in the spring; usually from mid-summer on to before cold weather.***They would raft two or three rafts in a month's time. They would have no problem, they would go right down. They would have a problem occasionally, getting hung up. You see, that's a thing of the past, out there now it couldn't be done. Well, the river doesn't have enough water in it now.

Alva Brown's description was similar:

Well, the tie buyers up at Yancy Mills, there, they bought ties. The buyer would buy up a lot of them, you know. Then he would hire these rafters to raft them to Newburg. Usually the Henson boys got the job of rafting them. John and Jim Henson, some of their in-laws or children***I don't think there was any special time, except real dry weather when the water was low, you know, they couldn't get over the shallow places very quick. As long as the river was up fairly good, why, they ran stuff down. I remember you could hear them whooping and hollering for miles, you know, up the river coming. And when the river made a bend, one had to steer that with a pole to keep it pushed off from the inside of that bend. You would hear them hollering back and forth.***If the front part hung up or hit something, it would just keep folding up; it would come to pieces. They would have 45, 50, or 60 ties on a raft; maybe as many as 100. It was nearly a quarter of a mile long.

Mr. Brown also described his family's tie operation, which was typical of farmers who had small farms. They would cut 12 to 15 ties at a time and spend the day hauling them to Newburg by wagon where they got $.50 a piece for them. The ties weighed as much as 200 pounds.

Grazing

Unfenced fields in the bottomland were subjected to grazing by livestock that were loose on the open range. Oral-historical accounts describe how livestock ate vegetation on gravel bars and kept bottomland pasture cleared of woody understory vegetation. Jess Plowman recalled how livestock used to congregate near the river:

They had trails now that they kept open [by the river] and I think they'd keep it open, well I know they'd have to keep the brush down by the river. They'd go there for water, and they'd bed down there. They'd like to lay on level ground. And they'd go into them bottom lands***.

The Beavers' farm was diversified with hay, a big garden, a little corn, and hogs and cattle. Oliver Beavers recalled that his cattle spread over long distance in open range along Jacks Fork:

I ran my cattle out on the river. Most of the time ***running 40, 50 head. I put my salt out down at Rymers, down there in the mouth of Johnny Holler and I'd go down there about once a week***and they ran from there to Alley. And the funny part was there was a guy by the name of Jones had turned his cattle out down there near Alley and they come back up here and mine all go down there.***I never kept my hogs on the river. There were a lot of hogs, some of them were wild hogs.

Oliver Beavers observed substantial changes in valley-bottom vegetation along the Jacks Fork valley from Rymers Ranch to Alley Spring after the land was incorporated into the Ozark National Scenic Riverways during 1965. Although the National Park Service maintains land in the Scenic Riverways corridor in accord with the land use that existed when the Riverways was created, much of the valley-bottom land has been allowed to revert to forest:

Since the riverways, that river bottom and all has growed up and you can't hardly walk through a lot of it. Back in them days the cattle kept it opened up right along the river***.

Bill Gates described the valley-bottom vegetation along the Jacks Fork near Alley Spring during the 1930's and the common practice of keeping the riparian zone "clean":

It [valley bottom] was clean. You could walk up and down the river; there was paths all up through the bottom; the cattle you know run out. There wasn't any brush, not near like it is now. Along the river, that was always damper, see, and the grass would be good. And then, they was close to water.

They kept the stock in there and they kept it cleaner, and the river could get away, you know. And now, they don't never clear out everything; they don't clear a tree. They used to, you know, the farmer he would keep his run cleaned out so the water could run down and it didn't accumulate gravel, but as sycamore brush grows up***and, first thing you know, you got a big gravel bar there. A bunch of that sycamore grow in

> there and catches that gravel. And it just keeps building in, building in.

Tom Martin's recollections of valley-bottom grazing near the junction of the Jacks Fork and Current River were similar to Bill Gates' description:

> There is so much underbrush and stuff like that, that the cattle now, you hardly ever see them. If there was any brush along the river, the cattle would eat it. And in the spring of the year when things got green, why they would just take that birch and everything right off; they killed alot of that stuff. [The livestock]***they used to stay along the rivers and in these creeks.***It was nothing to see 40 or 50 head of cattle in the river.***In the spring of the year when these leaves get full grown or past full grown, the cattle will eat a lot of the leaves. Those buds, they go crazy after them in the spring.

Alden Duncan commented that large numbers of livestock congregated in the Jacks Fork and tributaries near Blue Spring in the period of open range:

> Oh, yes, the livestock were in the creek, of course they were. The hollows were full of them, the people running their livestock free range and all. Yes, yes.

Clyde Huskey had similar observations from when he was growing up along the Little Piney Creek during the 1920's and 1930's:

> The cattle used to run up and down the creek. They'd eat it out. Used to be open range. I guess the whole county was at one time, before they had the stock law.

Row Crops

In general, the wider valley bottoms were favored for row crops, grains, and gardens. The upper Jacks Fork has a narrow valley bottom with few areas wide enough for extensive cultivation. Crops were more common downstream from immediately above Alley Spring where the valley begins to widen (fig. 16). Pearl Cowan described the typical bottomland corn patch in the Jacks Fork valley bottom during the 1930's:

> There was generally a strip of timber [left along the fields] because when we had a heavy spring or fall rains, the Jacks Fork would be a wild river.***They left a strip of timber because these spring floods would come up over them. And they were smart enough guys, they wouldn't exceed an acre or two along the river. They were little fields: a vegetable garden and a field of corn. Corn seemed to be the main thing these old gentlemen planted.

Virginia Anderson gave a similar description for the upper Jacks Fork during the 1940's:

> Everybody used to have a patch of corn, you know, maybe a half an acre or as much as five acres. There might be as much as three or four feet [between the field and the stream] but they wouldn't be big trees, or anything.

William F. Burns described his family's farm on the Little Piney Creek valley bottom during the late 1930's:

> We had a garden, pasture, potato patches, and things. Corn, we had corn; that was our main go down on the river; we had a corn field.

Alva Brown described row cropping on the valley bottom of the Little Piney Creek. His observations of channel changes suggest that where bottom-land soil was eroded by channel migration, the sediment that filled in the former channel position was silt, which made good, tillable soil:

> There wasn't nothing you could do. Just let it happen. Try to keep it cleaned out a little, like big tree tops get in it, or something, and cause it to build up and run out over the fields. I didn't mess with the creek much or farm close to it. The banks sometimes washed pretty bad and eroded. Maybe a tree fall in, and that kinda pushed against the other bank, and washed the other bank. But there's an old saying about the Little Piney, what it washes off of one side it will put back on the other. And that's pretty much true. There's places where it used to run, it looked like years ago, just a little old gravel branch there. And now it's filled in, you know, and there's good land there.

Jack Fore recalled that prosperous farmers along the Little Piney Creek valley bottom during the 1920's had a constant struggle against the river, but the productive soil made it worthwhile:

> There were a few farms up and down the Little Piney River. Like I said, the creek changed on them you know, and took out a lot of their fields. And they would go back. And they had that problem. But what ground they had was rich soil that they could raise good crops on.

He also observed that most farmers along Little Piney Creek grew crops right to the edge of the water:

They went pretty well up to the bank of the river.***A good percentage of them farmed right up to the edge. In some cases they didn't because they would have to do away with too many trees. But as a rule, they farmed, when they could, up to the bank.

Floods during the 1920's to 1940's often were beneficial to farmers because of silt deposited in the bottomland fields:

It really helped the farmers. Maybe next time it would take it away from them; maybe next time it would be to their benefit.

Frank Widener recalled one flood on Little Piney Creek that washed off the plowed layer of his father's field that had just been planted with wheat:

***and it washed the ground down to where it had been plowed in the spring. You could see where the plow slid along the ground to turn the furrow.

Present (1993) Conditions

As bottomland farms were abandoned on the Jacks Fork after the Great Depression and because of incorporation into the Ozark National Scenic Riverways, valley-bottom vegetation has begun to grow up in old fields. Many respondents commented on how different this condition is from what existed from 1920 to the 1960's. As Tom Martin observed:

Another thing since they bought this, the Scenic River bought it, it's closed up. You can't even find the farms.

The Little Piney Creek valley bottom is more typical of Ozarks streams, with only a small part in Federal ownership by the U.S. Forest Service. With the closing of open range, increased awareness of conservation practices, and institution of riparian buffer areas on bottomland owned by the U.S. Forest Service, there has been a modest increase in riparian vegetation, especially adjacent to the stream. Clyde Huskey observed the difference between the Little Piney Creek valley bottom now and during 1930 to 1960:

Yea, it's lots different, it's all growed up. And it ain't got no place to go to. Why you had just a little nice stream, it used to be deep holes, and a lot wider. See all that timber there. Back behind there, it's the same way. It's all the way up, all the way down.***There might have been some [trees] along the bank, but it wasn't all out in the gravel, in the bottom.

Effects on Streams

Oral-history respondents observed consistently two changes in the Jacks Fork and Little Piney Creek during the past 80 years. The first observation is that in the first one-half of the century there used to be more springs that discharged for longer periods during the year and that river stages were higher for longer intervals during the year. These hydrologic changes could be explained by land-use changes that altered annual and storm runoff, climatic changes that altered runoff independent of land-use changes, increased flow of water through aggrading channel gravel, or a combination of these mechanisms. The second change consistently noted was a trend toward shallower channel depths and aggradation of pools.

Hydrologic Changes

Most respondents commented on changes in flooding magnitude or frequency, and most agreed that as springs had dried up from 1920 to 1992, streamflow was "flashier" with less water in the river during low-flow periods and larger flood peaks. Will McVicker described changes on the upper Jacks Fork:

The water runs on down and don't come out in the springs like it used to when I was a kid. Up on Leatherwood, when I was a kid, up above, where I used to fish all the time, now there isn't much water.

Roy Baugh described springs on his farm that started to dry up during the 1940's:

The river is getting narrower and shallower.***Well, we've had some droughts. I had a spring on the west end of my place, a little spring, run year round. And I had one on the east. And neither one of them runs anymore. They ran dry in dry years and they never did come back. Probably in the [19] '40's.

Bill Gates described springs that have gone dry since the 1930's:

Springs that used to run big, don't even run no more; I guess it's the water level. I know places where we had a sawmill, the whole camp--of course, in those days you had to have a camp, people didn't have cars, they had to have a place to live and they had to have a little store and stuff like that, because they didn't have a way to get to town. And those springs that the camp used; I know one spring down there run an inch of water, and then that didn't take care of it, and it ran out. Now, you can't see no sign of no spring.

Willa Cowan's recollections of the Jacks Fork emphasized the relative lack of water during low-flow periods:

If it has changed any at all, it just doesn't have the volume of water, outside of the floods***.

This observation was echoed by Jess Plowman, who compared recent hydrology of the Jacks Fork to his recollections of the 1920's and 1930's:

There's less water I think. There was a lot of bays along the river, that the water come up but there wasn't no current through it. That was the main thing that I saw and pretty much dirt not a lot of gravel in it.***When they lost the drifts out of the river had a lot to do with that [loss of bays].***Those old big sycamores, now they cut some of them but the majority of them sycamores died.***And they used to make alot of big drifts but people just burned them, alot of them.***They cut some sycamore but most of them fell down.***The river gets bigger than it used too. You know, there's too much runoff.

We was talking about that [19] '26, '27 flood [actually, June 15, 1928, 40,000 ft^3/s at Eminence, approximate 10-year recurrence interval]. There was farms along these little creeks--you know that real good soil. And that year it come and most everyone had just plowed, and you know the topsoil was real loose. And the creek got all over the bottom in each of these valleys and it wash every bit of that dirt off and then a lot of them had to leave***it just got rid of them little old fields that they depended on***yeah, it just washed everything off.

Tom Martin described differences he observed between how the Jacks Fork was during the 1930's to 1940's and how it is during the 1990's:

I want to tell you, I've seen that river get up and stay up for 30, 90 days at a time***you couldn't cross that river, I'll tell you, it was deep all the time. But now you can cross it pretty near anyplace***.

Virginia Anderson's recollections also include more floods now than during her childhood during the 1940's:

I don't know if there has been more rainfall or not, but when I was walking to school I used to have to cross two or three cricks. Oh, maybe once or twice a year they would be so high that we couldn't wade cross it. Now then, about every time you turn around they are flooded.

Willa Cowan described the upper Jacks Fork as having more water and, consequently, having greater depth and velocity. She remembered that there were few places you could cross with a horse:

I think there was more water flowing then than there is now.***It was a narrow river. Several places you could cross with a team of horses.***It was nothing like a wide stream. It was very swift and it had deep holes. And they would be against these bluffs, what they called Catfish Bluff and Loader Ford had deep holes. And that's where people fished a lot.

Jack Toll also commented that, compared to the 1940's, low-flow discharges seem to be smaller, especially on the smaller streams,

The thing I've noticed about these little streams is that they don't carry as much water. I mean, except in flood time, they are not running as much as they were.

Thelma Harmon described recent flooding on the South Prong of Jacks Fork since extensive clearing upstream in the last 5 years:

After they begin to cut off the timber and everything, the river just spread all over everything. Sometimes my house was just an island and the water was bank to bank. Clear across the whole.***I had a little garden field and it'd be just all over. In fact, I had my cattle washed in several times and that never happened before.

Jack Fore felt that the Little Piney Creek had bigger floods in the past, particularly during the late 1920's:

It used to rain and the Little Piney would get up; it would be unbelievable how high it would get. You just don't hear of any floods like that in recent years.***I think back to several years ago in the fall, we would have rain and rain and rain, you know what I mean, and all the cricks would be up. And when I was a kid, in the fall, when it would rain like that, we could go around at our place and on the hillsides we had what we called wet-weather springs. There would be a gusher running out maybe a spring the size of an 8-inch pipe, a spring that would run maybe for 30 days or two weeks. We called them wet-weather springs. We had them. But you don't have them any more; that's a thing of the past.***They floated ties down there from that old Yancy Mill. They had them stacked there and they would float ties down there. You couldn't float a canoe down there I don't suppose now without dragging it over some of those shoals.

Cora King echoed the recollection that floods on the Little Piney Creek used to be bigger around the turn of the century to approximately 1920:

> Lots of water in the Little Piney. Back then we had floods so many times and our crops washed away. Little Piney would raise 20 feet sometimes.

In fact, the maximum stage recorded at Newburg (before installation of the recording streamgage) occurred during 1915 (Reed and others, 1992). Clyde Huskey also observed that floods aren't as big as they used to be, but he attributed that to a simple fact: "It just don't rain as much."

Morphological Changes

Most respondents observed substantial changes in the morphology of the rivers. The most common observation was that the rivers are filling up with gravel, especially the deep pools that provided swimming holes and fish habitat. Jewel Wagner characterized the disappearance of the deep holes in the Jacks Fork as a gradual process from the 1930's to the present (1993):

> Yes, I would say that it was a gradual thing that they disappeared. It wasn't anything that happened suddenly.

Sadie Garrison describes a swimming hole on the Jacks Fork that has filled up with gravel and cleaned out several times in her experience:

> Sometimes it'd come down and there would be gravel even in our swimming hole down there***sometimes it'd be real deep and sometimes it would put gravel in there alright. But it would come a big rain and wash it out again.***Sometimes it's filled up and sometimes it's cleaned out again.

Oliver Beavers described some of the changes he witnessed along the Jacks Fork upstream of and near Alley Spring:

> I've seen the river eats out quite a bit, you know on some of those turns. The river is straightened out a lot from what it used to be. And one thing, where them curves is, that's what made the deep holes. Where it straightens out is where it filled up more.

From his experience guiding fishing trips on the Jacks Fork, Mr. Beavers believes that the river has changed substantially and that a lot of holes have filled with gravel:

> Down below Bunker Hill, there's Dark Hollow hole***in there where it used to be 15 foot deep, now they say you can wade in there. You can wade in there now!***It's filled up with gravel***.

Virginia Anderson described gravel aggradation in a small tributary to the Jacks Fork near Willow Springs (fig. 1):

> There was one about a half a mile from our place that was a real nice swimming hole. It had solid rock on the bottom of it. And it was about waist deep when I was 13, 14, somewhere in there. But, now then it's full of gravel, it's knee deep now, probably. It's been cut, the banks have been all cut into it; they've been all cut in to where they eventually fall into the crick and wash away.***They made it [the channel] a lot wider. The banks are more cut back in where the roots and all are now.

Wayne Miller emphasized that the source of gravel in the Jacks Fork has been new channels that are cut into the floodplains when water flows around debris obstructions:

> The gravel was there but it had dirt on it. But the dirt gets washed off of it and then it washed the gravel out.

Jack Toll has been fishing the upper Jacks Fork intensively since the mid-1930's. His recollections are unusually detailed and consistent:

> That's a place I've known since I was probably 8 or 9 years old. We would go there several times every summer and we would fish in that hole of water alone.***Well, there is no water there now. I can wade, I was just up there the other day and the deepest place in the hole is not over my head. And most of it, when the water level gets down to a normal summer flow is probably going to be only a foot or two deep, full of gravel. It was 6 to probably 8 feet deep in the deepest parts.

> On the lower end the hole extended completely across; it got deep on the off-rock or the off-current side and there were lily-pads growing along there. These lily-pads were probably in 4 feet of water. Well, there's nothing there now, except gravel***.

There is a large hole there called the Hiker Hole. The Hiker Hole, as long as I can remember--and I bought the land in 1960 but I fished it before that--that hole was always a big, deep hole and it was always deep at the upper end and it was deep throughout--there was a bluff on one side--and that hole has filled, half of the hole has filled up. With gravel. And the gravel bar has just extended and extended until there used to be just a little bitty edge of gravel over there and now it's fit itself way the heck out in that deep hole.

But, there's no question in my mind that the overall trend in the river--the area from where I live right now at the Veterans of Foreign Wars camp (VFW), that area completely all the way up both the South and North Prong for at least two miles on each side, which I have walked and fished many times over the years and very frequently in the last 6 years since I retired --all of those areas are filling up and you're getting hole after hole after hole.***Once in a while you'll get a new hole created that wasn't there before. And sometimes they'll fill a hole one year and maybe the next year flush it out.***I can tell you there just isn't the kind of water in these holes that there used to be even 15 years ago. And in my mind a lot of this has happened in the last 20 or 25 years.

The thing I know about the flooding now that I sure as heck don't remember--it might have occurred, but I don't think it did--was the way that when the water gets up it would knock out these large timbered areas at the lower ends of these big holes. I can tell you in particular the big Blue Hole down here which used to have a lot of timber, the VFW campground used to have a lot of timber on it.***I don't recall those things before. Same thing with Hattie Hole. Hattie is gone--that's on the South Prong. And there's wide expanses that it just looks like the water gets up and just tears everything in front of it. And I don't recall that. I remember the floods; I know there were floods but I don't remember seeing the damage. I think there is a lot more movement of gravel; it appears to me that it is piled higher and it fills in the holes.

There are old fields on the South Prong that I can think of that they have hayed for years and years and in a lot of them, the water has cut through, cut channels through those fields, and absolutely destroyed the fields.

I think that you see more bare banks, just bare banks with no vegetation on them, where they have been scoured. I can think of a lot of areas that for years and years and years never showed any erosion and those areas now are eroding; and it is a continual eroding process; it doesn't seem to be healing.

Ab Detwiler also observed gravel aggradation in the holes:

Last time I ever floated the river, why good gosh, you'd have to get out and pull the boat right over, right on where used to be deep holes.***Mostly, it wasn't the gravel. The gravel was already in the river. It just washed in the deep holes. There used to be holes you could swim a horse in. Well, there ain't no hole in Jacks Fork I think where you could swim a horse. It just washed them gravel bars into the big holes. And made the holes just one big continuous riffle now***.

Tom Martin's comments were similar:

Well, the Jacks Fork now is almost filled up with gravel. In the summer time, alot of times you can walk across it without getting your feet wet on the shoals on account of all the gravel.

Willa Cowan described changes in places on the upper Jacks Fork that had occurred since she was a child during the 1920's and 1930's, including filling of the holes and shallowing of the rapids:

Going back to the old swimming hole and the old places where we played as children, you can wade it most any of the places, its just the deep places against the bluffs where they fish.***You see there was no canoe floating, just the john boats, I've seen the canoes coming down and even the canoes can't float over the rapids; they have to get out and guide them along.

Another common observation by respondents is that the areas where they used to cross the river--the riffles--used to be deeper and faster. Ab Detwiler observed:

[In the old days] it was just swifter, deeper, deep riffles. That's what it was***used to be you couldn't wade the riffles. A riffle was usually about waist deep and swift enough that you couldn't stand up in it.

Respondents in the Little Piney Creek Basin had similar observations about morphological changes. Jack Fore described Little Piney Creek as a bigger stream with more water, better fishing, and an active channel during the early 1920's and 1930's:

I can remember when the Little Piney used to be what you might call a small river or a medium-sized river. It had lots of water in it. And you could fish and catch fish in it. And we used to have some tremendous floods. And it would really get up there, I mean bank to bank. There was quite a few gravel bars after what we would term a flood. And there were a lot of gravel bars. And next time we would have another flood it would change that; it would wash that out and put another channel in***it would change its course quite a bit. Not real far apart just maybe 50 feet or maybe 100 feet. Used to be it would get up, you know, and after it would go down it had what we would call eddies, you know, kind of a pond-like area. We would fish out of them, catch perch, what not.

Back when we used to have them floods, it would leave an island here, an island there, and leave a big pond or a big lake--we called them sloughs and we would fish out of them. Maybe the next time it would take out the island on this side and the channel would go down that side. And that went on time after time. It would depend on what obstruction had accumulated in the channel below, and the water would go around; it couldn't go through, it would go around. And it cut and eroded.

He recalled that after a decrease in flooding during the late 1930's, the river began to be affected by large organic debris:

But we had a lot of drifts. Logs and trees and limbs piled up and they check the water, and then it would try to go around that see, and cut channels and cut out into the fields.

Rev. King believed that aggradation in Little Piney Creek had begun somewhat before his memory, probably during the late 1920's or early 1930's, an observation that is consistent with streambed elevation data from the streamgage at Newburg (fig. 3):

evidently the washing and erosion had started before I remember the river beginning to fill up. I remember the stream had been a beautiful stream, a lot of beautiful eddies, a lot of fish, a lot of deep holes.I suppose by 1940 it was all filled up and it was beginning then to overflow into the fields. The fields we had began to be covered with sand and gravel and things of that nature.***It's not filling up now like it was.***I think it's normalized to some extent, with all the gravel and sand that's there. I think [a gravel extraction operation upstream from Rev. King's farm] has helped some, down below Piney, because they have been trapping some sand and gravel up there in their operation. So it does not wash down as much now.

Rev. King recalled the big floods during the 1930's, during a decade-long period of regional drought, were especially effective in eroding banks and depositing sand and gravel on the valley bottom:

I recall that the [19] '30's, we had some very big floods. I believe it was after we had the drought, I think it would be in [19] '34 and '35, so somewhere around [19] '36 and '37 we had some great big floods. Around Yancy Spring down here in the Mill Pond, I can remember when it was literally hill to hill.***[River-banks] washed awfully, awfully bad. Our field, we had beautiful fields, we grew some good crops, but when it started to flood like that and that gravel started coming down, it ruined a lot of our fields.***It deposited sand and gravel deep on the fields.***You would get some mud and silt mixed in with the sand and gravel, but most of the mud would just keep going down.

He also recalled that most of the gravel came from tributary valleys rather than being traceable directly to hillsides: "There was always some that came off the side of the hills, but most of it came in from the branches. They would bring in sand, silt, gravel." Rev. King emphasized that Little Piney Creek aggraded with sand and silt during the 1930's and 1940's rather than gravel, which was more common on the Jacks Fork:

The Little Piney is not the size it used to be when I was a boy. When I was a boy, before I went to Washington, and the silt filled up the channel, it was a beautiful stream. Wide, deep. That's the way it was when we were rafting ties. Then along comes all this silt and sand, and fills up the Little Piney.

Clyde Huskey commented on changes in the Little Piney Creek during his lifetime. He observed that the riparian vegetation has increased substantially and the channel has narrowed. He commented that there is more gravel now in the stream than there used to be and he concluded that growth of timber in the riparian zone was the cause:

You didn't see nothing like that much. Lots a deep holes, swim horses and everything else in them. But they all filled up.***I guess it growed up. See, all that timber and stuff holds it [the gravel].***Well, you know to raft them ties it had to be deep. You couldn't get 300, all them ties***how would you get a raft of ties down that thing?***The banks were a lot higher then than they are now. It's grown up from the bottom, see.

Sediment Changes

Oral-history respondents also were asked about their observations on changes in channel and bank sediment. Willa Cowan described the Jacks Fork bed material during the 1920's and 1930's:

> It was beautiful, round stones***and except for the periwinkles, the stones were, the pebbles were smooth and best to walk along. It wasn't muddy or silty. Once in a while we would get in a place where it was dark and muddy.***The water was so swift, it kept the river bed clean.

At the same time, however, overbank flows were depositing fine sediment on the valley bottom. Alden Duncan observed greater deposition of fine sediment on the Jacks Fork valley bottom during the 1920's and 1930's compared to the early 1990's:

> And I don't know***I feel the river has filled up some. It's changing its channels. Yes, yes, this river has always had some gravel. They are stopping so much silt and stuff from running off into it. We don't have the muddy overflows that we had when I was a kid. They come from peoples fields and places where they plowed up hillsides that had no business being plowed up.

Tom Martin's recollections from the lower Jacks Fork and Current River, where the valley is much wider, emphasize that a large quantity of silt was deposited during floods, especially on the inside bends or point bars. Mr. Martin remembered that the 1915 flood carried off their shocked corn, but did not erode the valley-bottom fields:

> It just cleaned off everything that we had. We didn't lose no soil. It took what we raised. Most of the time in the bottom like that if you have a flood like that it will leave the settlings, the rich dirt. [Near Alley Spring] every time the Jacks Fork got up a ways, it would leave a lot of silt there. It built that ground up there so high, into a nice little farm. If you've not got no bends in your river, it will wash your ground. And if you've got those bends in the river, like I said, you will get silt deposited. It makes fine ground.

> Back then there was a lot of ground that wasn't cleared up along this river. And it would pick all these leaves and silt and everything up and wherever there was a crooked place in the river, it would follow the bank around and it would drop out on the bottom.

Wayne Miller's observations of stream sediment during the 1930's and 1940's indicate little change as compared to sediment in the early 1990's:

> Well, they've got wider. First they started filling up with chat [gravel] and so they had to move somewhere and so they spread out wide. And they made new channels. It'd fill up here, why it'd back them up and make a pond and it'd spread out and cut over here.***I don't think the particle size has changed, it's just the gravel that's all over this country***there might be a little more sand.

Virginia Anderson's memories of river sediment during the 1940's suggest a change from mixed sediment load to a coarser, well-sorted sediment load during the 1990's:

> Used to be what we called gravel was more or less a sand with mud mixed in. Now then, it's just rock, large gravel. Back then when you found a gravel bank it was more a sand with mud mixed in; now then the size is bigger rocks with very little sand***After a really heavy rain there would be more of a mud and a sand along the sides like where a crick would turn, that would catch back in that turn place, there. But it would be more like a sand and a mud. Nowadays, it is just gravel. You don't see the fine clay, sand and stuff anymore.

Jewel Wagner observed that during the past 5 to 10 years, there is less clean white sand and more silt:

> Right now, I can't think in my mind where you could go to find some clean sand. There's too much silt. Used to be you could find sand bars on the Jacks Fork, clean white sand, clean enough to make cement.

Jack Toll described an incident during 1991 when a flood left an anomalous blanket of silt on the Jacks Fork bed:

> Well, I see silt, in fact we had a phenomena last year***where we had the river come up and when it went down there was a quarter inch of mud all over the gravel from all the way down from 17 [State Route 17] bridge all the way up the North Prong.***I don't know whether it was up the South Prong or not.***It was like mud and if you would walk through the gravel it was like walking in an old muddy pond and the mud would just boil up behind you.

Recent Water-Quality Changes

Many respondents on the Jacks Fork described increasing frequency of algae blooms approximately during 1985 to 1992. Will McVicker's description was typical:

> The last time I floated it, the upper river, here below [State Route 17] bridge, seemed like it was green. Mossy and green. Looks different. It used to be clear. It's been in the last 5 or 6 years. From the bridge to way below Blue Spring. Most of them holes was greenish, mossy or something.

Roy Baugh has observed that recent water-quality changes in the Jacks Fork are evident from algae growth on the rocks as compared to conditions during the 1920's:

> Oh, you'd walk out there about hip deep, look down and see your feet on the bottom, watch the minnows play around. And them rocks was white. Now when you go down there they're green with slime on them.

Ab Detwiler observed the same changes on the Jacks Fork:

> [The bottom of the river] used to be just nice clear, clean gravel. Now it's just a nasty and dirty old slimey river.***Used to be the gravel was just as clean as it could be. When you waded the river, you didn't see no mud going down the river. It was just clean old water.

Jack Toll agreed with Mr. Detwiler's observations:

> We never had algae in the river before. Now you get huge algae blooms. I mean big ones. They occur all up and down the river on both prongs. And they get so bad in the summer that when they die and float to the top, you just can't fish. They kind of peter out as you get on down below the prongs.***Huge algae blooms. And they were not there 20 years ago. Seems like it starts in late July and then they bloom and there's just this green stuff that's everywhere. And it comes off the bottom, and when you try to fish you get it all over your lures and everything.

Respondents on Little Piney Creek did not emphasize degradation in water quality from the early 1900's to the present (1993). Rev. King's recollection was unusual:

> Pollution is bad.***When I was a boy we used to drink out of the Little Piney. It was good, clear, beautiful water. I wouldn't drink out of it for anything now.

Fishing Changes

All respondents on the Jacks Fork and Little Piney Creek remarked on how good the fishing used to be. Tom Martin's observation of fishing on the upper Jacks Fork was typical:

> And there was lots of fish. I never seen so many fish in my life as there was in the Jacks Fork. Bass, striped bass, goggle-eye, perch, blue-gill: I never saw so many fish in my life. Now you don't see so much because they fish it to death. [The fishing] went down because we got so many people anymore, catch these here little fish and keeping them.***I've seen them kill them and just throw them out on the bank. [In the old days] there was more suckers.

Minnie Martin agreed:

> Shovel bill. Lot of people call them spoon bills. Now, used to, the river was full of them. Hardly ever see them anymore. Jack Salmon, you don't see them any more. We had lots of them. They killed every one of them. You don't see them anymore. We used to have channel cats and flathead cats, they call them. You never see one of them anymore either.

In contrast to Tom Martin, many respondents on the Jacks Fork observed that the fishing had not changed much even with substantial changes in channel morphology and water quality. Ab Detwiler's comments on fishing were typical: "Oh, there's all kinds of fish in the Jacks Fork. I think there's more [than there used to be]." Wayne Miller described fishing on tributaries to the Jacks Fork and Big Piney River: "We had catfish, bass, smallmouths, but once in a while you'd find a largemouth, too."

Thelma Harmon described her brothers' fishing experience during the 1930's on the upper Jacks Fork and concluded that fishing couldn't be as good now (1993) because of gravel aggradation in the streams:

> When we lived down there at Mom's place, my brothers they'd go fishing about any time they got ready and catch fish out of that blue hole***and now that's about filled up until it's not even much to wade in.

Jack Toll's experience with fishing the Jacks Fork has been that the species composition and number of fish has not changed substantially since the 1940's, despite aggradation:

> I don't see much change. For a while, we had carp but that's been some years back and they never did

> reproduce. But they would come up the river from someplace. Those have kind of disappeared. We were catching long-ear sunfish, green sunfish, smallmouth bass, and largemouth bass when I was a kid and that's what we are catching now. The thing that I have noticed is that you catch more, larger smallmouth, and I think that's strictly because of the regulation of 12-inch length which I think has really been good for the fish. You can still go catch fish. Even where you have lost these holes***you have these little pockets along the side. Somehow or another these smallmouth bass seem to be able to survive and get by; but I can't believe that the total number of fish can be as much with what is to me an obvious decrease in the total volume of standing water.

In the Little Piney Creek Basin, most respondents felt that fish populations had definitely decreased. Jack Fore's observations were typical:

> The fishing used to be pretty good in the Little Piney years ago. Back then there was lots of fish, especially perch and goggle-eye, and lots of suckers, hog suckers.***Folks used to just go by foot, fish off the bank or they waded. It would be worthless to go down and fish in Little Piney now. You might catch a perch or something in one of these holes, but they've filled up. I don't know if there are trout in there or not--it's cold water. I haven't fished in the Little Piney for years, but back when I was a kid I used to fish all the time.

Rev. King perceived that the species composition of the fish in the Little Piney Creek has changed considerably since he was a boy during the 1930's:

> It makes a good fishing stream as far as trout are concerned. But the other fish such as suckers, catfish, bass, things like that. It is not much of a stream for that anymore. It used to be a long time ago. But it is just a trout stream now.***We used to have those long, deep holes that contained a lot of fish.

> Fish was good, but as I said, it was good all the time I was a boy, because it hadn't yet filled up like it is now. But it's filled up all those nice big eddies and the deep holes, so you hardly have any suckers, bass, and big trout like we used to have. We used to get black suckers and hog mollies and reds. No gar. No eels. There was always plenty of fish for everybody. Now, when I was a boy, if you couldn't catch them, why you'd take a little stick of dynamite, and blew you up a hole. It didn't hurt anything. You'd get a tub or two, or two or three sacks***.

Interpretation of oral-historical accounts

Oral-historical accounts provide some insights to land-use changes that are not available from any other source. However, these accounts also may contain subjective biases and interpretations that could be misleading or erroneous. This section is an interpretation of the oral-historical accounts, with the objective of summarizing, synthesizing, and reconciling the observations.

Observations of the condition of the remaining upland virgin forest from 1900 to 1920 are consistent with GLO records and historical documentation. Oral-historical accounts emphasized the open understory and large trees. Observations on timber-cutting methods indicate that selective cutting and animal-powered transportation of logs during the Timber-boom period resulted in minimal increases to runoff and sediment load from upland and valley-side forests. Many respondents contrasted the gullying associated with modern logging practices with the lack of gullying during the Timber-boom period.

Recollections of widespread burning of the open range in the post-Timber-boom period were common to all respondents. Observations show a considerable range of opinion on the value of burning. There also was a considerable range of opinion on whether burning and grazing caused erosion. Some respondents indicated shallow washing, or sheetwash erosion, accompanied burning of hillslopes. Erosion was not associated with upland grazing except for grazing by hogs, which caused substantial erosion in limited areas. There was a general consensus among respondents in the upper Jacks Fork Basin that clearing of land for pasture and cattle densities per unit area had increased during the last 10 years.

Observations on the effects of upland cultivation of row crops were more consistent. Almost all respondents noted that cultivation caused sheetwash and, to a lesser extent, gullying. The extent of upland cultivation was limited by a lack of power equipment, stony soils, risk of drought, and limited fertilization. Hence, although cultivated fields were observed to erode, they were never extensive (fig. 9).

According to the earliest memories of oral-history respondents, valley bottoms were mostly cleared for hay, pasture, and row crops in the early part of the 20th century. The wider valley bottoms were the most productive and valuable agricultural land that existed in the Ozarks. Some landowners maintained riparian corridors just along the bank, but others were just as likely to remove all riparian vegetation in an attempt to maintain a "clean" pastoral setting and maximize crop and forage production. Respondents noted that channelization and bank stabilization efforts were largely futile, especially before the availability of heavy equipment, and that the seemingly endless supply of gravel was used for local road construction with no apparent adverse effects.

One of the most often-repeated observations was the effect of livestock on riparian vegetation. Under open-range conditions, livestock usually had free access to the rivers. Cattle browsed heavily on young sycamores and willows on gravel bars, thus maintaining a "clean" appearance and preventing or slowing stabilization of the gravel bars. After the closing of open range and during the last 20 to 30 years as more valley-bottom land has come under State and Federal management, respondents noted that the valley bottoms have become much more heavily vegetated.

Oral-historical accounts about hydrologic changes were especially subject to biases and interpretation. Many respondents observed that, as compared to discharge from springs during the early part of the century, the discharge has decreased and less water, on average, is apparent in stream channels. Perceptions of how floods have changed are more inconsistent, presumably because of the high variability in climatic conditions during the period of memory (for example, fig. 3). Some respondents perceived that floods used to be much greater from 1920 to 1940 and rivers stayed up longer than they do now. Other respondents perceived that floods were more frequent and "flashy" now than floods during the first one-half of the century.

Taken as a group, oral-historical accounts about channel changes support the idea that there has been, and continues to be, net aggradation of gravel in the rivers, resulting in a shallower and wider channel. However, the accounts also indicate great spatial variability. Most respondents recall pools (or "holes") that have filled up; a few respondents noted episodic filling and re-excavation of pools. Several respondents noted that large pools ("sloughs" or "eddies") were created by big floods, and some were associated with large, organic debris jams.

Observations on water-quality changes in the Jacks Fork were consistent; there was general agreement that algae blooms are much more common now than in the past. However, there was no agreement on a trend in water quality in Little Piney Creek. Observations on changes in fish populations were similarly mixed. Overall, changes in fish populations perceived by the respondents were remarkably minor as compared to the perceived changes in habitat.

Historical Photographic Evidence

Replicated historical photography of Ozarks rivers presents some qualitative information about how streams have changed. The photographs were chosen based on availability and ability to relocate the exact spot where the photographs were first taken. Although it is impossible to determine how representative this selection is of stream changes, these photographs show trends that are consistent with other historical information. Mainly, the photographs underscore the great spatial variability that exists in the Ozarks rivers.

Three replicate photographs from Little Piney Creek indicate that gravel aggradation and instability apparently were more prevalent at the turn of the century than during 1992. Upstream from Newburg, the morphology of Little Piney Creek during 1992 has not changed substantially from that of the turn of the century (fig. 18). The 1992 view seems to have somewhat less gravel. Downstream from Newburg, Little Piney Creek had similar morphology about 1900 to its condition during 1992 (fig. 19). The earlier photo shows somewhat more gravel and wood in the channel. At the junction of Little Piney Creek and the Gasconade River, the quantity of gravel during the 1910's was conspicuously greater than during 1992 (fig. 20). These photographs indicate less net instability and gravel aggradation at the present (1993) as compared with conditions from 1900 to 1920, and they are consistent with the geological descriptions of Lee (1913) and Dake (1918).

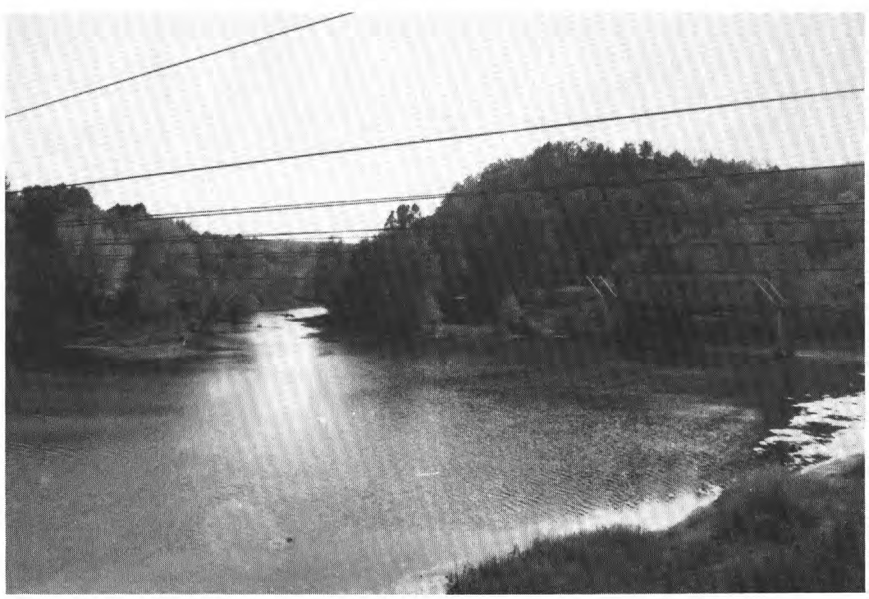
A series of four photographs from about 1900, 1936, 1952, and 1992 show growth and disappearance of islands in the Gasconade River at the mouth of Little Piney Creek (fig. 21). Little Piney Creek flows into the Gasconade River from the right between the two bridges. The series of photographs show the growth of islands upstream and downstream from the railroad bridge (downstream from Little Piney Creek) and progradation of the downstream island toward the right bank. The 1992 photograph shows that the upstream island has been removed, and the channel has migrated so the larger channel is along the right bank. Between the 1952 and 1992 photos, the railroad bridge was re-

About 1900 (photographer unknown; Clare V. Mann collection, University of Missouri-Rolla archives).

1992

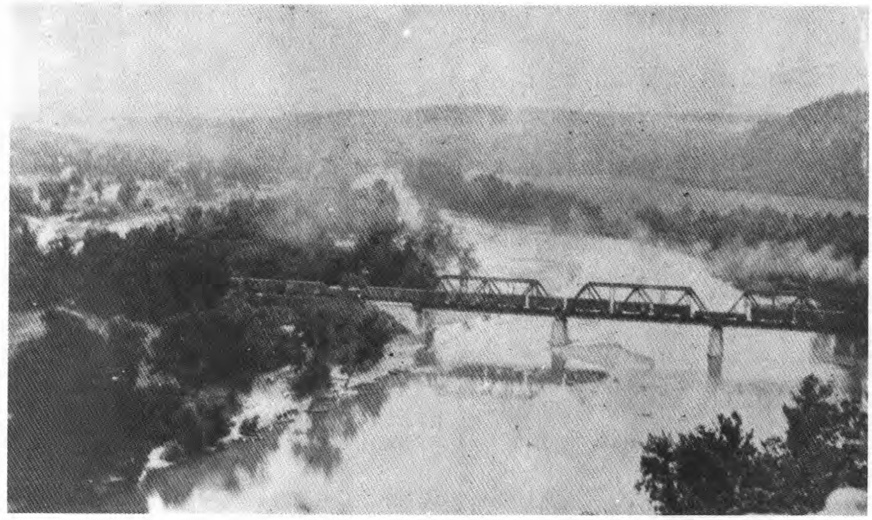
Figure 19. Replicate photographs of Little Piney Creek downstream from Newburg, Missouri, about 1900 and 1992.

About 1910 (photographer unknown; Clare V. Mann collection, University of Missouri-Rolla archives).

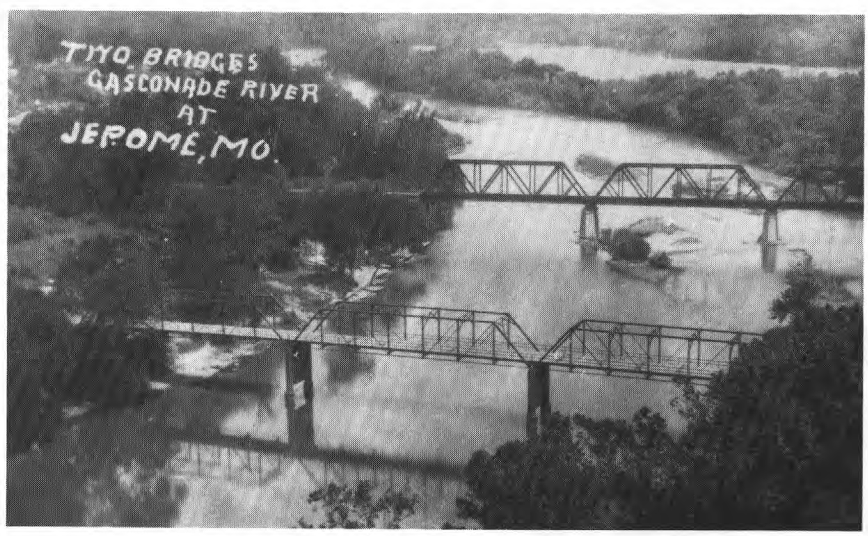


1992

Figure 20. Replicate photographs of the junction of Little Piney Creek with the Gasconade River, Missouri, about 1910 and 1992.



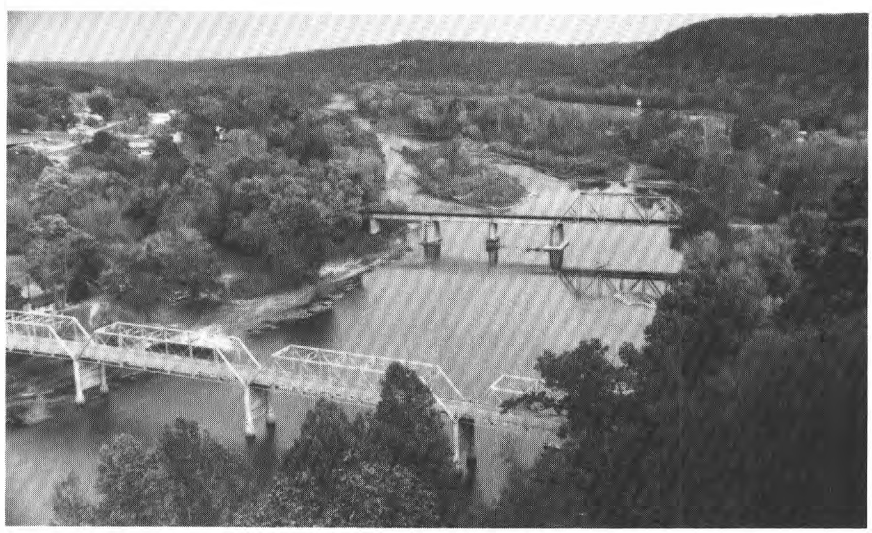
About 1900 (photographer unknown; Phelps County Historical Society postcard collection).



About 1936 (photographer unknown; Phelps County Historical Society postcard collection).

Figure 21. Replicate photographs of the Gasconade River at Jerome, Missouri, about 1900, about 1936, about 1952, and 1992.

About 1952 (photographer unknown; Phelps County Historical Society postcard collection).



1992

Figure 21. Replicate photographs of the Gasconade River at Jerome, Missouri, about 1900, about 1936, about 1952, and 1992--Continued.

built and the Gasconade River had its greatest flow on record (136,000 ft^3/s during 1983; Waite and others, 1984).

The mouth of Big Piney River at its junction with the Gasconade River also shows much greater gravel accumulation during the 1910's than during 1992 (fig. 22). A reach upstream on the Big Piney River at Ross Bridge southwest of Rolla shows little change between 1936 and 1992, except for greater development of riparian forest in the later photograph (fig. 23).

A photograph from the Jacks Fork near Alley Spring about 1925 shows a wide, stable, and vegetated channel in an area in the 1992 photograph occupied by an extensive gravel bar (fig. 24). Downstream approximately 10 km at Cane Bluff, the Jacks Fork now had less gravel and more stable, vegetated banks during 1992 than it did about 1910 (fig. 25).

A series of stereo-optician photographs are available from a 1908 float trip down the Current River (figs. 26 to 29). Three of the four photographs replicated during 1992 show modest increases in bare gravel bars. The fourth (fig. 29) doesn't show an obvious increase, but during 1908 the photographer was standing on a gravel bar, and the photograph had to be taken from a boat during 1992. The Eleven Point River at Riverton (fig. 30) was similar in appearance during 1992 to its condition during 1937.

POTENTIAL EFFECTS ON STREAM DISTURBANCE

The history of land-use changes in the Ozarks has been complex. Many of the land-use changes documented in this report potentially could have altered runoff, sediment supply, or stream-bank resistance to erosion sufficiently to create channel disturbance. This discussion is intended to constrain the probable cause and effect relations of stream instability based on documented land-use changes and models for how those changes may have affected the Ozarks landscape. For each of the major land-use transitions (table 7), the probable effects on magnitude and trend of runoff quantity and timing, upland sediment yield, and valley-bottom resistance to erosion will be evaluated.

Disturbance Mechanisms

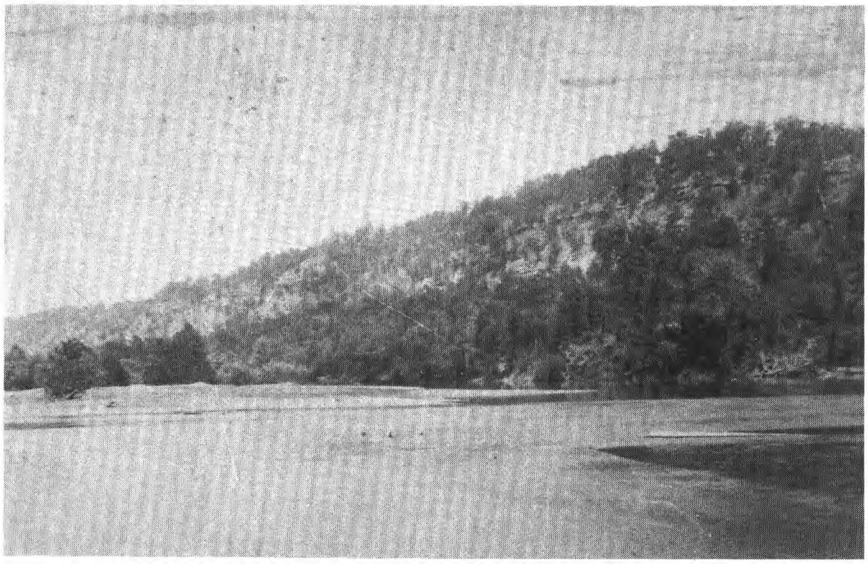
Land-use effects on annual runoff, storm runoff, upland sediment yield, and riparian erosional resistance can be evaluated by using simple empirical and theoretical models. The following sections introduce simple models to provide semi-quantitative and relative estimates of the effects of each of the major land-use transitions in the recent Ozarks landscape history.

Annual Runoff

Changes in vegetation can affect the annual hydrologic balance of a basin primarily by altering evapotranspiration. Forested areas generally have lower annual runoff than grasslands because lower albedo, greater aerodynamic roughness, somewhat greater rainfall interception, and greater rooting depth in forests all increase actual evapotranspiration (Hibbert, 1967; Bache and MacAskill, 1984). Lee (1980) presented data showing pasture and cropland annual runoff was 10 to 101 mm per year greater than annual runoff for mixed deciduous forest and 17 to 62 mm per year greater than annual runoff for oak-hickory forest. Also, evapotranspiration from grasslands and pastures tends to be greater than that from row crops and small grains (McGowan and others, 1980). However, most of the vegetative effects on annual runoff occur from April to October during the growing season, and so effects on runoff also are dependent on the seasonal distribution of precipitation. Forest and grassland burning also can augment runoff by decreasing evapotranspiration. Depending on the severity of the burn, the effect could be short-term (several weeks) or long term (several years) if canopy trees are destroyed.

Storm Runoff

Runoff from a storm or a series of storms largely depends on the intensity and duration of the rainfall, and how much of the rainfall is abstracted by interception, evaporation, or infiltrated into the soil. Vegetation changes can alter infiltration rates, interception of rainfall by the forest canopy, and antecedent moisture conditions (by altering evapotranspiration efficiency). When runoff arises from generally saturated conditions throughout a basin as the result of long, low-intensity rainfall, differences in vegetation would have little effect. When runoff arises from intense rainfall, however,



About 1900 (photographer unknown; Clare V. Mann collection, University of Missouri-Rolla archives).

1992

Figure 22. Replicate photographs of the junction of the Big Piney River and the Gasconade River, Missouri, about 1900 and 1992.

About 1935 (U.S. Geological Survey collection, Rolla).

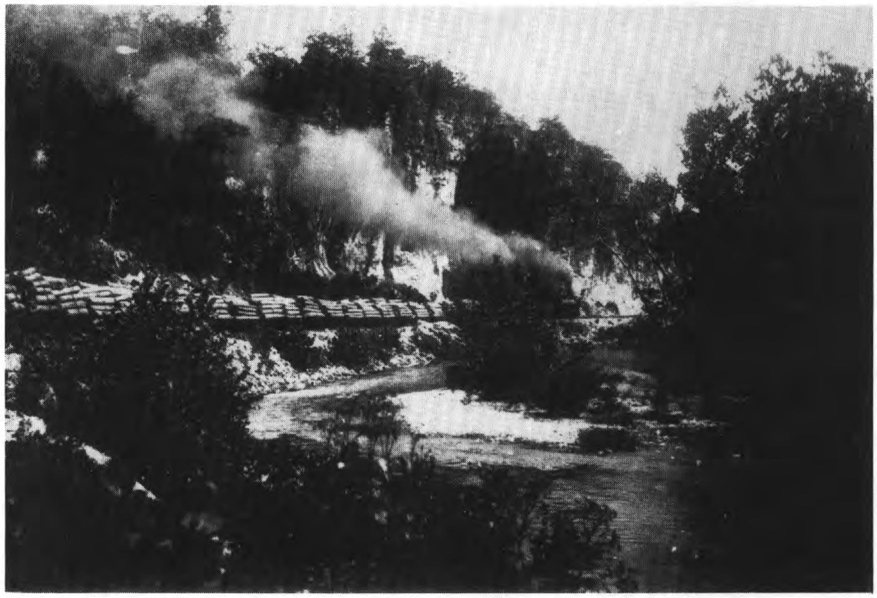
1992

Figure 23. Replicate photographs of the Big Piney River at Ross Bridge, southwest of Rolla, Missouri, about 1935 and 1992.

About 1925 (photographer unknown; Betty Hicock collection, Ozark National Scenic Riverways).

1992

Figure 24. Replicate photographs of the Jacks Fork upstream from Alley Spring, Missouri, about 1925 and 1992.

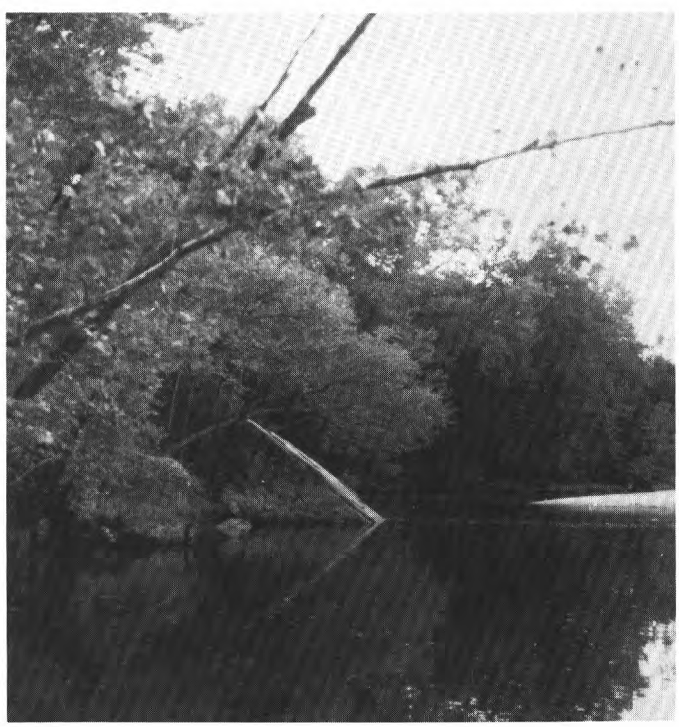


About 1910 (photographer unknown; Ozark National Scenic Riverways).

1992

Figure 25. Replicate photographs of the Jacks Fork at Cane Bluff near Eminence, Missouri, about 1910 and 1992.

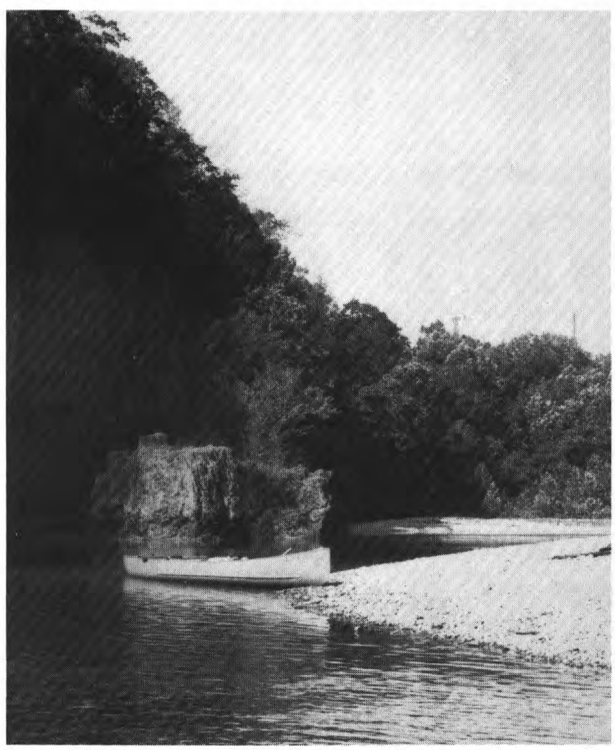
1908 (from the Governor Hadley expedition; James E. Price collection, Ozark National Scenic Riverways).



1992

Figure 26. Replicate photographs of the Current River upstream from Round Spring, Missouri, 1908 and 1992.

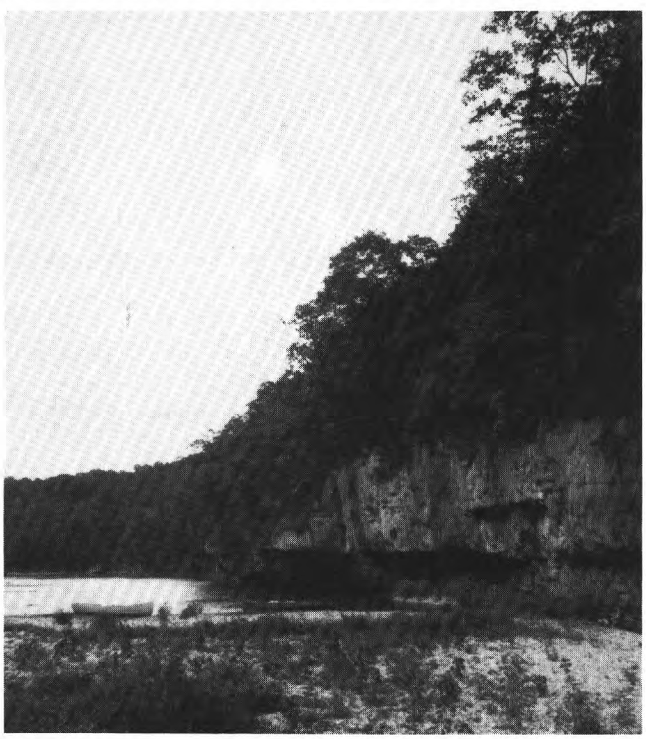
1908 (from the Governor Hadley expedition; James E. Price collection, Ozark National Scenic Riverways).



1992

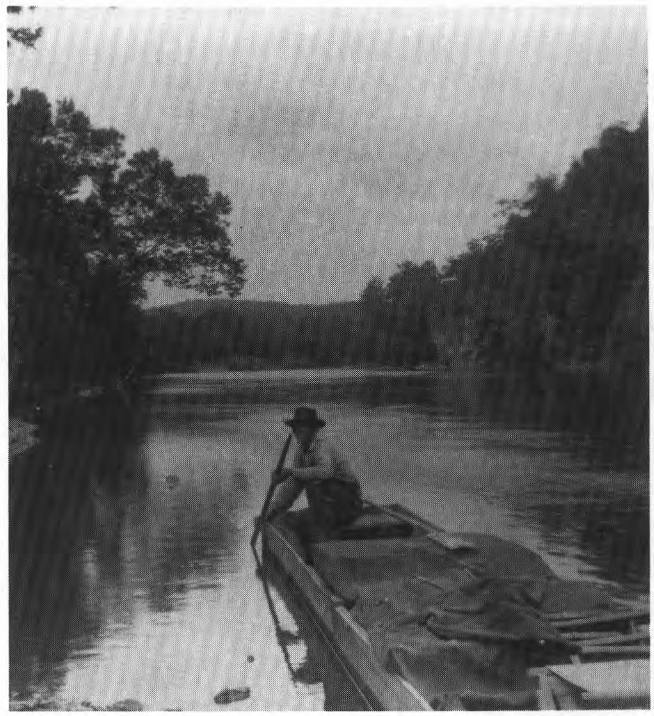
Figure 27. Replicate photographs of the Current River between Round Spring and Two Rivers, Missouri, 1908 and 1992, upstream site.

1908 (from the Governor Hadley expedition; James E. Price collection, Ozark National Scenic Riverways).



1992

Figure 28. Replicate photographs of the Current River between Round Spring and Two Rivers, Missouri, 1908 and 1992, downstream site.



1908 (from the Governor Hadley expedition; James E. Price collection, Ozark National Scenic Riverways).

1992

Figure 29. Replicate photographs of the Current River between Two Rivers and Van Buren, Missouri, 1908 and 1992.

1937 (U.S. Geological Survey collection, Rolla, Missouri).

1992

Figure 30. Replicate photographs of the Eleven Point River near Riverton, Missouri, 1937 and 1992.

Table 7. Summary of probable, qualitative changes to runoff, soil erosion, and riparian erosional resistance on parts of the Ozarks landscape relative to pre-settlement period conditions

[N/A, not applicable]

Period	Uplands	Valley slopes	Valley bottoms
Pre-settlement	Baseline	Baseline	Baseline
Early settlement			
Annual runoff	Decrease	Slight increase	N/A
Storm runoff	Decrease	Slight increase	N/A
Upland sediment yield	Decrease	Slight increase	N/A
Riparian erosional resistance	N/A	N/A	Moderate decrease
Timber-boom			
Annual runoff	Slight increase	Slight increase	N/A
Storm runoff	Slight increase	Moderate increase	N/A
Upland sediment yield	Slight increase	Moderate increase	N/A
Riparian erosional resistance	N/A	N/A	Decrease
Post-Timber-boom			
Annual runoff	Moderate increase	Increase	N/A
Storm runoff	Moderate increase	Increase	N/A
Upland sediment yield	Moderate increase	Increase	N/A
Riparian erosional resistance	N/A	N/A	Substantial decrease
Recent			
Annual runoff	Slight increase	Slight increase	N/A
Storm runoff	Slight increase	Moderate increase	N/A
Upland sediment yield	Slight increase	Slight increase	N/A
Riparian erosional resistance	N/A	N/A	Decrease

changes in infiltration rates, antecedent moisture, and canopy interception because of varying vegetative cover can have a substantial effect (Bache and MacAskill, 1984).

Generally, infiltration rates increase with vegetative cover on soils with similar particle-size distributions and physical characteristics (Hibbert, 1978). Addition of vegetative cover nearly doubles infiltration rates on clay and clay loam soils like those of the Ozarks (Lee, 1980). Infiltration rates are nearly the same under healthy grassland and woodland but decrease considerably under many other land-use practices with decreasing root density, decreasing litter depth, and greater soil compaction (Glymph and Holtan, 1969). For example, Stoeckler (1959) documented decreases in limiting infiltration rates in southeastern Wisconsin from 190 mm per hour under ungrazed oak forest to about 1 mm per hour under grazed oak forest.

Woodland and grassland burning generally decreases infiltration rates and increases runoff. This can be a short-term effect because of water repellency induced in the soil by long-chain organic compounds produced during burning or a longer-term effect produced by removal of organic litter and changes in soil structure (McNabb and Swanson, 1990). Auten (1934) determined that infiltration rates on unburned forest soils in the Ozarks were two to eight times greater than burned soils and Arend (1941) determined that the limiting infiltration rate of an unburned Ozarks forest soil was 53 mm per hour whereas that of an area subjected to annual burning for 5 to 6 years was only 33 mm per hour.

Rainfall interception by tree canopies can be as great as 0.4 to 2.0 mm (Rutter, 1975), but this quantity is not significant for long, high-intensity rainfall. Trees generally have a slightly greater storage capacity than grass.

Probably the most important effect of trees on storm runoff is the increased efficiency of evapotranspiration in decreasing antecedent soil moisture from greater depths than accomplished by other vegetation. This effect can be seen in representative maximum soil-moisture deficits, which are 125 to 250 mm under woodland, 125 mm under permanent grass, and as low as 50 mm under grazing (Bache and MacAskill, 1984). For rainfall intensities that are less than limiting infiltration rates, greater soil-moisture deficits translate to greater total infiltration capacity.

Empirical models for runoff generation can provide some estimates of the magnitude of changes in runoff that would accompany changes in vegetation on the Ozarks landscape. For simplicity in making semiquantitative comparisons, the Soil Conservation Service (SCS) curve number method is used in this report (Soil Conservation Service, 1972). In this method, direct runoff from a storm event is calculated based on curve numbers defined by land-use practice and hydrologic soil group and a value assumed for initial rainfall abstraction. Soils in the Ozarks uplands valley slopes are clay loams and silty clay loams with varying stoniness and moderate to low infiltration rates; they usually are assigned to hydrologic soil groups B and C (Gott, 1975). Estimated percentages of direct runoff for two soil groups and a range of land-use practices and storm rainfall are given in table 8. Vegetation has greater effects during smaller rainstorms than during larger rainstorms when rainfall intensity and duration overwhelm infiltration capacities. Burning effects would be similar to those from bare or fallow ground.

In addition to volume of runoff generated from storms, the rate of runoff may be altered by vegetation changes that alter infiltration rates, depression storage, and overland-flow roughness. Runoff rates can be measured by the time to peak, the time between the center of mass of rainfall and the peak of the hydrograph (fig. 31). Decreased vegetation density often has been associated with a decreased time to peak (Dunne and Leopold, 1978). In a regression study of hydrologic response of small basins, Bell and om Kar (1969) determined that significant decreases in time to peak could be associated with increased area in grassland relative to woodland. Their model is shown in figure 32A. Heerdegen and Reich (1974) also detected substantial increases in base length and recession length of hydrographs (fig. 31) with increasing forest cover in the basin (fig. 32B, C). These models are intended to indicate trends that would be expected in the Ozarks, not to predict actual values for these parameters.

In addition to affecting the rate of runoff from slopes and channels, decreases in riparian vegetation may begin a positive-feedback effect in small streams wherein decreased flow resistance allows channel incision, followed by upstream migration of knickpoints. As the channel network is extended upstream into previously unchanneled, first- and second-order valleys, efficiency of the channel network is increased and time to peak and base length and recession length would be expected to decrease (Gregory and Gurnell, 1988).

Upland Sediment Yield

Changes in vegetation can have substantial effects on soil erosion and delivery of sediment to streams. Vegetation decreases soil erosion by decreasing overland flow and by binding soil particles. The universal soil loss equation (Wischmeier and Smith, 1978) provides an empirical framework for evaluating the extent of erosion changes that probably accompanied land-use changes in the Ozarks. Similar to the preceding discussion of changes in hydrologic response, this evaluation is meant to provide broad constraints on the relative effects of different land-use transitions, not to produce predictions, actual rates, or quantities.

The universal soil loss equation is an empirical model of soil erosion on a hillside and predicts long-term erosion rates by rain splash, sheetwash, and rilling processes as a function of rainfall energy and soil resistance. Soil erosion per unit area is expressed as the product of a rainfall-intensity index, a soil physical-characteristic index, a slope length and steepness index, a conservation practice index, and a cover factor (C-factor; Wischmeier and Smith, 1978). For the purpose of analyzing changes in soil-erosion potential with changing vegetation, it is possible to focus on the C-factor; if all other factors are constant, soil erosion rate will vary directly with the C-factor.

Values of C-factor for various vegetation types and ratios of predicted erosion rates to rates that would occur under natural forest conditions are given in table 9. Considerable variation exists between two sources of C-factors for forested areas, especially in estimates for C-factors associated with burned or grazed woodland. The C-factors from the Soil Conservation Service (1975) for burned or grazed woodland are 20 to 100 times greater than those calculated by Dissmeyer and Stump (1978). These differences arise from a general lack of calibration data for woodland situations, the considerable variety of conditions that can exist, and different methods for estimating C-factors when data are lacking.

Whereas the universal soil loss equation provides an index for evaluating how much soil erosion will occur at a site under various vegetative types, it does not predict delivery of sediment to channels. Sed-

Table 8. Percentage of runoff from 24-hour rainfall ranging from 12.5 to 127 millimeters using the curve number method for various land-use conditions

[Runoff estimated from curve number method (Soil Conservation Service, 1972) for B and C soil hydrologic groups under varying land use and rainfall quantities; low refers to a low-range estimate for the curve number corresponding to less runoff; high refers to the converse; the meadow designation corresponds to natural prairie or range; N/A, not available]

			24-hour precipitation, in millimeters											
	Curve number		12.5		25.4		50.8		76.3		101.6		127	
Land use	Low	High	Low	High	Low	High	Low	High	Low	High	Low	High	Low	High
B soil group														
Dirt road	82	N/A	82	N/A	90	N/A	95	N/A	96	N/A	97	N/A	98	N/A
Fallow	86	N/A	86	N/A	92	N/A	96	N/A	97	N/A	98	N/A	98	N/A
Row crop	78	81	77	80	87	89	93	94	95	96	96	97	97	97
Grain	75	76	74	75	85	86	92	93	95	95	96	96	97	97
Pasture	61	79	57	78	75	88	86	94	90	96	92	97	94	97
Meadow	58	N/A	54	N/A	72	N/A	84	N/A	89	N/A	92	N/A	93	N/A
Woods	55	66	50	63	69	79	83	88	88	92	91	94	92	95
C soil group														
Dirt road	87	N/A	87	N/A	93	N/A	96	N/A	97	N/A	98	N/A	98	N/A
Fallow	91	N/A	91	N/A	95	N/A	97	N/A	98	N/A	98	N/A	99	N/A
Row crop	85	88	85	88	92	93	96	96	97	98	98	98	98	98
Grain	83	84	83	84	91	91	95	95	96	97	97	97	98	98
Pasture	74	86	73	86	85	92	92	96	94	97	96	98	96	98
Meadow	71	N/A	69	N/A	83	N/A	91	N/A	93	N/A	95	N/A	96	N/A
Woods	70	77	68	76	82	87	90	93	93	95	95	96	96	97

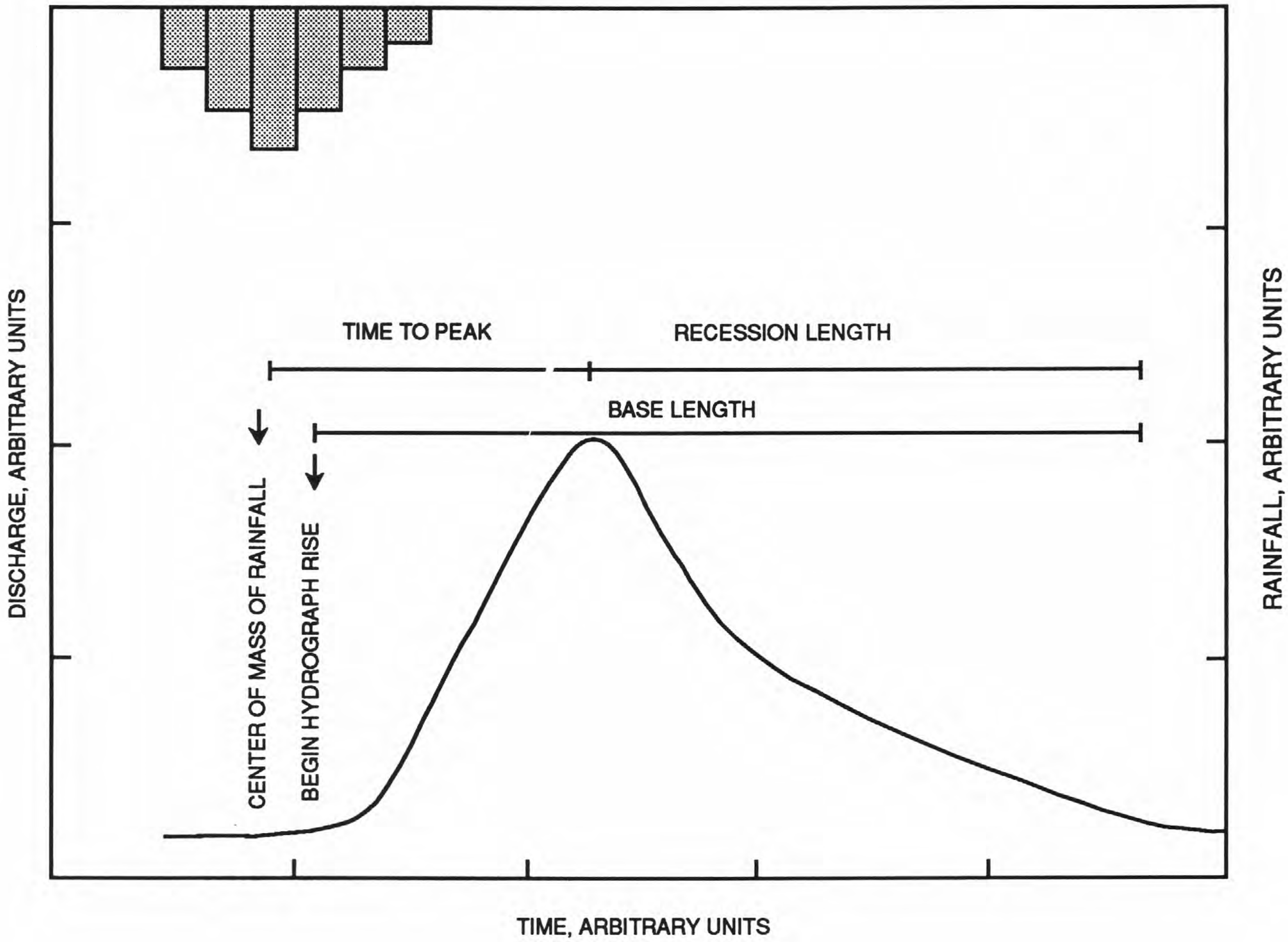
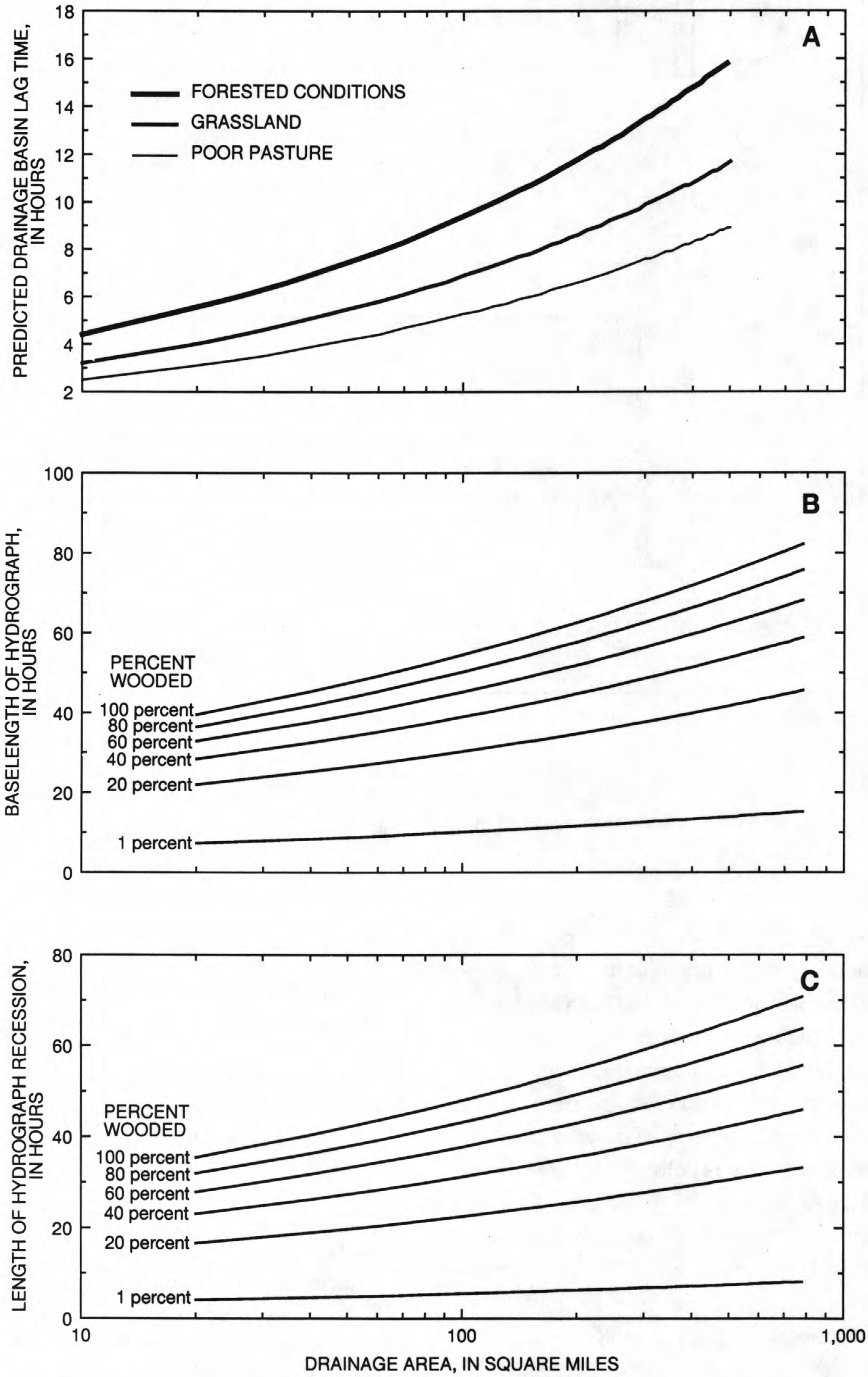


Figure 31. Definition of time parameters for hydrograph models.

iment delivery to channels usually is expressed as the sediment delivery ratio, or ratio of sediment transported by the channel to that which has been eroded upslope. Sediment delivery decreases systematically with increasing drainage area. Because sediment delivery pathways are longer at larger drainage areas and more sites exist where sediment may be stored temporarily, a smaller part of sediment is delivered to larger streams (Roehl, 1962; American Society of Civil Engineers, 1975). Sediment delivery ratios are interdependent with runoff and erosion processes, however, and processes that increase runoff and promote gully formation tend to increase sediment delivery ratios for a given drainage area.

Riparian Erosional Resistance

Changes in upland runoff and sediment supply ultimately affect areas downstream. Changes in runoff volume and lag time can alter the magnitude and frequency of shear stresses applied to the riparian zone, thus altering streambank erosion rates. Changes in the quantity of sediment delivered from upstream can cause degradation or aggradation of the bed, with associated changes in channel morphology and migration. These basin-wide changes can be accompanied by land-use changes in the valley bottoms that alter the resistance of riparian areas to erosion. Because the Ozarks dominantly are rural, this analysis will not include evaluation of in-channel disturbance such as gravel mining, dredging, and road crossings. Instead,



Figue 32. Models for change in hydrograph time parameters with changing basin vegetation (A from Bell and om Kar, 1969; B and C from Heerdegen and Reich, 1974).

Table 9. Universal soil loss equation, cover factors, and ratios of estimated erosion rates to an average minimum rate defined by thick woodland conditions

Category	Cover factor	Ratio of estimated erosion to an average minimum rate on thick woodland
Woodland[1]		
Thick woodland	0.001	1
Thick woodland, burned/grazed	.011	11
Medium woodland	.003	3
Medium woodland, burned/grazed	.04	40
Thin woodland	.006	6
Thin woodland, burned/grazed	.09	90
Natural grassland[1]	.003	3
Woods with grass understory[1]		
60 percent ground cover, 75 percent canopy	0.039	39
60 percent ground cover, 50 percent canopy	.04	40
60 percent ground cover, 25 percent canopy	.077	77
60 percent ground cover, no canopy	.042	42
20 percent ground cover, 75 percent canopy	.17	170
20 percent ground cover, 50 percent canopy	.18	180
20 percent ground cover, 25 percent canopy	.17	170
20 percent ground cover, no canopy	.2	200
0 percent ground cover, 75 percent canopy	.36	360
0 percent ground cover, 50 percent canopy	.39	390
0 percent ground cover, 25 percent canopy	.42	420
0 percent ground cover, no canopy	.45	450
Bare soil[1]	1	1,000
Ozarks forest estimates[2]		
Natural forest	0.0004- 0.001	0.4 - 1
Grazed	.004 - .047	4 - 47
Logged	.002 - .0068	2 - 6.8
Burned	.0001 - .002	.1 - 2
Skid trails	.0025 - .047	2.5 - 47

[1] Cover-factor data compiled from Soil Conservation Service (1975), Wischmeier and Smith (1978), and Bache and MacAskill (1984).
[2] Cover-factor data compiled from Dissmeyer and Stump (1978).

the analysis will focus on the function of riparian vegetation.

Vegetation can stabilize non-cohesive and cohesive valley-bottom sediments. Non-cohesive sediments generally erode particle by particle, and roots of woody vegetation can impart shear strengths as much as 20,000 times greater than sediment without roots (Smith, 1976). Alluvial banks with cohesion, which are much more common, usually erode by processes that include mass failure. In these cases, bank stability is determined by root strength in addition to other factors, such as height of the bank and soil moisture (Thorne and Tovely, 1981; Greenway, 1987; Thorne, 1990). In slope failures where the failure plane is in the rooting zone, the contribution of roots to cohesive strength has been estimated to be as much as 1.1 kPa (kilopascals) from grass roots (Selby, 1982) and greater than 20 kPa from tree roots (Greenway, 1987). Depending on the materials and failure geometry, roots can contribute as much as 90 percent of the total shear strength. As bank height increases, the part of the failure plane in a sliding or toppling failure that intersects the root zone decreases. Hence, the contribution of roots to bank strength generally decreases with increasing drainage area.

Besides adding erosional resistance directly, vegetation also adds shear resistance to flowing water by increasing roughness. The Manning equation provides a simple means of evaluating the effect of vegetation:

$$V = (1/n)R^{0.66}S^{0.5}, \quad (1)$$

where V is average cross-sectional velocity in meters per second, R is the hydraulic radius (area divided by cross-section perimeter) in meters, S is the water-surface slope, and n is the roughness coefficient, which measures the resistance to flow. The value of n is a function of many factors, including bank and bed material size, channel geometry, and vegetation. For a given discharge, increased roughness decreases velocity and increases energy losses, thereby decreasing the capability of the flow to erode. Roughness added by vegetation also can vary during a flood as different parts of the vegetation are submerged and as the vegetation bends. The relative contributions of different riparian vegetation situations to flow resistance in a typical, medium-size Ozarks stream are tabulated in table 10 using n values taken from Chow (1959) and Bache and MacAskill (1984).

The effect of vegetation on channel morphology has been noted by numerous authors. At small drainage areas where channel widths are not much greater than the height of riparian trees, vegetation can have the maximum effect by providing bank stability, roughness on the floodplain, and channel roughness when trees fall into the channel (for example, Swanson and others, 1976; Keller and Swanson, 1979). In larger streams, bank stability added by trees results in steeper banks and smaller width/depth ratios as compared to the stability of streams of comparable size with grassed banks (Maddock, 1972). A study of gravel-bed rivers in Britain [Bache and MacAskill (1984)] established a statistical relation between channel width (b) and bank-full discharge (Q):

$$b = 3.75kQ^{0.45}, \quad (2)$$

with k ranging from 0.9 and 1.3 for grass banks and 0.7 and 1.1 for wooded banks. In addition to having wider channels, decreased resistance to erosion of grass banks allows for higher lateral migration rates, a process noted by Hickin and Nanson (1984).

Pre-Settlement to Early-Settlement Period Transition, About 1800

During the pre-settlement period, the Ozarks landscape was a mosaic of vegetation communities. Valley bottoms mainly were occupied by dense deciduous forest. Valley walls were occupied by oak, hickory, and pine forests. Uplands were covered with prairie, oak savannah, oak woods with open undergrowth, glades, or barrens. The upland vegetation apparently was controlled to a large extent by fires that thinned trees and maintained grasses. Whether started by lightning strikes or set by Native Americans, fire was an integral part in determining upland vegetation, and by extension, in affecting runoff and sediment supply. Steeper, canyon-section slopes and valley bottoms were not subject to fire as frequently as the uplands be-

Table 10. Typical values of Manning's n roughness coefficient for land-use types that apply to Ozarks valley bottoms

[Data from Chow (1959) and Bache and MacAskill (1984)]

Morphological unit	Land use	Range of n values
Channel	Gravel channel	0.03 - 0.05
Floodplain	Short grass	.025 - .035
	High grass	.03 - .05
	Fallow field	.02 - .03
	Row crops	.025 - .045
	Small grains	.03 - .05
	Brush and trees, winter	.035 - .06
	Brush and trees, summer	.04 - .08
	Dense brush, winter	.045 - .110
	Dense brush, summer	.07 - .160
	Dense willows, summer	.110 - .2
	Cleared, tree stumps	.03 - .05
	Timber, low stage	.08 - .12
	Timber, high stage	.1 - .16

cause forest and prairie fires tend not to burn downhill and because slopes and valley bottoms usually would be wetter than uplands. Relative lack of fire on steep slopes and in the valley bottoms allowed more vigorous growth of trees and woody understory plants.

The most substantive landscape change in the pre- to Early-settlement period transition was an inversion of the distribution of grassland and forestland. Settlers sharply curtailed fire frequency on the uplands, allowing the upland mosaic of woods and grassland to increase in total area covered by woodland with woody undergrowth. Simultaneously, the thick deciduous forest that formerly covered most of the valley bottoms began to be logged, plowed, and pastured, because this was the most productive agricultural land.

An increase in woodland on uplands at the expense of grassland would tend to decrease annual runoff, storm runoff, and soil erosion by slight to moderate amounts (tables 8 and 9). Hogs maintained on open range in the oak forests on valley slopes might have had substantial effects on increasing runoff and soil erosion in limited areas if groups were concentrated, but average areal density of hogs was only 0.03 hog per square kilometer from 1860 to 1870. Clearing of bottomlands for pasture and cultivated crops would be expected to have a greater and immediate effect by lowering erosional resistance of streambanks. Perhaps the greatest potential local effect during the Early-settlement period would be from logging debris in stream channels, as noted in 1820 on Big Piney River and by 1844 on the Current River.

According to early accounts, substantial quantities of gravel existed in Ozarks streams under pre-settlement period conditions before significant disturbance from land-use changes. The lack of observations of gravel accumulations and channel instability, such as those noted today (1993), however, is interpreted as evidence for a trend or shift toward increased aggradation and channel instability.

Early-Settlement to Timber-Boom Period Changes, About 1880

From the Early-settlement period to the Timber-boom period, the primary land-use transition was logging of pine and oak forests. This change was accompanied to a smaller extent by expansion of valley-bottom farms and free-range grazing of cattle and hogs to feed the increased human population. Conversion of upland grasslands to woodland also continued.

Written and oral-historical accounts indicate that logging was selective, that few if any areas were clear-cut, and that because logs had to be skidded from the slopes using mules and oxen, logging was not attempted on the steeper slopes. The hydrologic effect of logging on valley slopes probably was minor. Whereas substantial increases in annual and storm runoff are recorded from areas logged using mechanized skidders and trucks, especially in clear-cut areas, this effect lasts only 2 to 4 years (Hibbert, 1967; Bache and MacAskill, 1984). In the case of the early logging in the Ozarks where canopy trees and grassy understory remained after the cutting and skidding methods that had low potential to compact soils, evapotranspiration and infiltration probably were affected minimally.

Soil erosion was undoubtedly accelerated to some extent on access roads; logged land without roads probably had no appreciable acceleration of erosion rates. With the limited road-building capability at the time, most of the wagon roads were either on level uplands or valley bottoms; steeper slopes were avoided (Sauer, 1920). Sauer's descriptions and oral-historical accounts of valley-bottom roads indicate that development of the valley-bottom road network had potential for substantial decreases in riparian vegetation and streambank stability.

Increased human populations promoted greater local production of meat and grain, as indicated in increases in cattle, hogs, and improved land (figs. 9 and 10). Livestock densities averaged over the area were still quite low, only 0.014 to 0.043 cow per square kilometer and 0.036 to 0.055 hog per square kilometer. However, historical accounts that livestock on open range tended to concentrate in the valley bottoms indicate that actual densities in valley bottoms may have been considerably higher. Oral-historical accounts that cattle and hogs frequently preferred to stand directly in the channel and that cattle browsed heavily on immature riparian vegetation on gravel bars indicate significant direct disturbance of riparian areas. Extreme regional floods during 1895, 1897, 1904, and 1915 (Reed and others, 1992), when riparian erosional resistance was quite low, could have been extremely effective in destabilizing channels.

Railroad ties and timber floating downstream also had the potential to disturb channels and banks directly by abrasion and by creating channel obstructions that diverted flow. This would have been a greater problem before legislation requiring ties be nailed together into rafts. However, the existence of channel disturbance on streams like the upper Jacks Fork that were not used for floating timber indicates that it was not a necessary mechanism.

Written and oral-historical accounts of stream erosion and gravel aggradation during the latter part of the Timber-boom period support the hypothesis that channel instability began during this time. Of the land-use changes that had occurred to this point, decreases in riparian erosional resistance because of clearing, grazing, and road construction were the most significant. Therefore, riparian conditions probably defined the threshold of instability for Ozarks streams.

Timber-Boom to Post-Timber-Boom Period Changes, About 1920

The transition from the Timber-boom period to the post-Timber-boom period involved extensive changes in timber management, exodus of a large part of the Ozarks population, and increased reliance of those who remained on agricultural land use. The most significant land-use changes that occurred in this transition were the institution of annual burning of woodland to maintain open range and the expansion of crops onto marginally productive land on valley slopes and uplands. In addition, productive valley-bottom land probably was cleared to the greatest extent during this period, the number of livestock on open range was at a maximum, and, toward the end of the post-Timber-boom period, timber management began to include more intensive cutting methods and use of mechanized skidders. Annual runoff probably increased during this transition because of additions of storm runoff (table 8) and somewhat diminished evapotranspiration resulting from the woody understory vegetation being replaced with grasses.

Runoff from individual storms also should have increased during this transition because increases in plowed fields, grazing, and burning would decrease infiltration capacities, and burning would decrease soil moisture deficits. Effects would vary considerably by time of year, however. Spring burning, as practiced by most inhabitants of the Ozarks, would be expected to produce substantial increases in runoff when spring rains fell on bare forest floors following burning. The decreased evapotranspiration, moisture deficits, and interception caused by burning would not last long after spring burning because of natural regrowth. Fall burning, which was not as common, could produce longer-lasting effects on the forest floor, but because fall and winter months average less mean rainfall, the effect on storm runoff would not have been as severe.

The relative effects of converting upland forest and grassland to plowed fields and the effects of burning can be compared using the ratios of predicted runoff given in table 8. For example, burning natural forest (going from the low curve number range for woods to the high curve number range) could result in an increase in runoff from a 76-mm storm of 88 to 92 percent for the B soil group. Conversion of natural forest (woods) to a fallow field would result in an increase from 88 to 97 percent for the B soils, using low curve numbers. However, during 1925 only 15 percent of the sample Ozarks counties were in cultivated fields (table 5), while burning was ubiquitous. If burning affected only 35 percent of the area, the two effects would be of comparable magnitude in producing runoff on similar parts of the landscape.

Burning, grazing, and plowing also would be expected to decrease hydrograph time to peak, base length, and recession time (figs. 31 and 32), thereby producing greater peak discharges at the expense of more moderate flows. This trend is consistent with the oral-historical accounts that floods during the 1930's were larger and more effective in destabilizing stream channels than those that occurred during the Recent period. The model of changing hydrograph timing parameters also is consistent with oral-historical accounts that during the 1920's and early 1930's, floods were longer. Alternatively, changes in hydrograph shape may relate to changing seasonality of precipitation for the same time interval (Jacobson and Pugh, 1992). In a study in southwestern Wisconsin, Knox (1977) concluded that upland land use had a significant effect on peak discharge. He estimated that during the most adverse land-use practices (1880 to 1940), peak discharge increased five times over pre-settlement period conditions; peak discharges in the 1970's were estimated to be three times pre-settlement period values.

As log-skidding and transport became more mechanized during the latter part of the post-Timber-boom period, compacted skid trails and roads also had the potential to produce greater runoff of the same order of magnitude of conversion of forest to fallow fields (table 8). Although statistics on the densities of log roads and skid trails are not available, roads and trails were certainly of less total area than plowed fields and so contributed relatively little to storm runoff increases.

Generally, erosion rates are more sensitive to land-use changes than runoff. The C-factors for the universal soil loss equation show the magnitude of change likely from burning, conversion to plowed fields, and roads (table 9). When all other factors are unchanged (rainfall index, soil erodibility index, slope-length index, and conservation practice index), soil erosion per unit area relates linearly to the C-factor. Conservative C-factors from Dissmeyer and Stump (1978) predict only 0.1 to 2 times the erosion on burned woodland as compared to the erosion on unburned woodland, and 4 to 47 times the erosion on grazed woodland as compared to ungrazed woodland. The C-factors from Soil Conservation Service (1975) predict increased erosion by as much as a factor of 90 when woodland is burned or grazed, and by as much as a factor of 450 when ground cover is decreased to zero in woods with grass understory. Plowed land with no cover has, by definition, a C-factor of 1, resulting in predicted erosion rates of as much as 1,000 times the rates occurring on natural woodland. Oral-history respondents consistently remarked that soil erosion observed on burned woodland was minor sheetwash, whereas cultivated fields eroded extensively by rills and gullies. The net effect of cultivated fields on soil erosion rates, therefore, probably was significant and much greater than burned woodland.

The effects of logging, burning, and agriculture on the uplands of the Ozarks was minimized by the stony, infertile soils. High stone content of these soils limited the depth of gullies that could form and, with the absence of chemical fertilizers, the thin, infertile soils were rapidly depleted and abandoned. Gullying was much more severe in the Ozarks border regions where loess deposits, glacial drift, and bedrock with less chert content produced fertile soils that were cultivated more intensely and could erode to greater depths (Krusekopf, 1937). An example of accelerated hillslope erosion and the effects on streams in an Ozarks border region in southern Illinois is given by Miller and others (1993).

The extent to which soil eroded during this period was delivered to streams is unknown. Sediment produced by accelerated soil erosion frequently is temporarily stored on slopes before it is delivered to channels (Happ and others, 1940; Roehl, 1962; Meade and others, 1990). Soil eroded on rolling uplands, far from active channels, would be much less likely to be delivered directly to streams than soil eroded on steep valley slopes adjacent to a river. Soil erosion rates and sediment delivery probably were at a maximum because much of the land that was subject to burning, renewed logging, and agricultural development in this time period was steep, cutover land of marginal productivity (Rafferty, 1980).

Agricultural development of valley bottoms peaked during the last one-half of the post-Timber-boom period. More pasture, hay fields, and cropland, and more livestock grazing on open range would have maintained the open, "clean" aspect of valley bottoms noted by many oral-history respondents. This minimum of erosional resistance in the valley bottoms occurred simultaneously with the peak of storm runoff and sediment supply from uplands and valley-side slopes. Clearing of riparian vegetation in first- and second-order valleys would be expected to promote headward expansion of the channel network. Incision into non-channeled areas, like the valley described near Winona by Marbut (1896), would deliver gravel from storage to streams at an accelerated rate and simultaneously increase conveyance of the channel network, thereby increasing flood peaks downstream. This effect would be accentuated, of course, by increases in runoff from upland areas. The hypothesis that first- and second-order valleys were, and continue to be, significant sources of gravel is supported by the lack of gullied upland and valley-side-slope source areas and observations by oral-history respondents that gravel came from the runs and valley-bottom sediments, not from hillslopes.

Post-Timber-Boom to Recent Period Changes, About 1960

Two opposing land-use trends have been occurring since about 1933. Conservation land management has been encouraged by State and Federal agencies, and much land in the Ozarks has been purchased by these agencies for recreation and timber production, beginning during the 1930's. Approximately 15 percent of the Ozarks of Missouri currently (1993) is under State or Federal ownership (U.S. Bureau of the Census, 1990). The effects of increased area of land managed for soil, water, and timber conservation has been countered, however, by more intensive logging and agricultural practices on some private land. The trend of increasing land-use intensity is indicated by recent increases in livestock populations (fig. 10) and timber production (fig. 11). Furthermore, with the advent of mechanized equipment and broader wood-product markets, logging is more intense and the effects potentially more severe.

Creating more woodland area would tend to increase evapotranspiration and decrease annual and storm runoff (table 8). This hypothesis should be testable with rainfall and streamgage data from the Ozarks. However, rainfall and runoff data are not available for this period for smaller basins that would have suitably uniform land use and physiography. For larger basins like Little Piney Creek Basin (512 km^2), spatial variability in land use and physiography and year-to-year variability in climate obscure any obvious trends (fig. 33). During 1930 to 1988, growing-season runoff correlates well with growing-season precipitation for the Little Piney Creek Basin, indicating most control of runoff at this scale is by rainfall intensity and quantity rather than by obstruction of rainfall by vegetation. Residuals (actual minus predicted runoff) from the regression of runoff with precipitation also show no clear trend with time, except for a slight minimum during 1950 to 1970, a time of regional drought. Although land-use-induced changes in runoff cannot be demonstrated at this spatial scale, they may operate at the scale of smaller (zero- to second-order) basins. Conversely, increased grazing intensity of some areas with accompanying decreases in evapotranspiration and infiltration capacity would have the opposite effect of increasing annual runoff, in addition to decreasing base-flow recharge. Oral-historical accounts that hillside springs have dried up could be explained locally by either mechanism. Increased logging intensity would be expected to produce modest increases in annual and storm runoff, but these increases would last only 3 or 4 years after cutting, in areas not subjected to disturbance and compaction by skidders.

Decreased area in improved land from the mid-1940's to the late 1980's in most counties in the Ozarks (fig. 9) also would be expected to alter the timing of storm runoff, increasing time to peak, base length, and recession time. Testing of these hypotheses is beyond the scope of this report.

Upland soil erosion rates would have been expected to decrease as cropland decreased (fig. 9). A decrease in cultivated cropland would have resulted in significant local decreases in sediment production because of the extremely high relative rates of soil erosion associated with plowed fields. The effect on sediment delivery to streams, however, is much more difficult to predict because sediment eroded from fields during the previous period may be delivered to channels from intermediate storage sites long after erosion from the field (Jacobson and Coleman, 1986; Meade and others, 1990). Soil erosion and sediment delivery would be increased locally in areas of high logging traffic, but this would represent a small overall change in sediment budget because of the limited area affected by logging roads and trails.

Erosional resistance of bottomland has increased markedly on State- and Federal-owned land where buffer strips are maintained between stream channels and grazing land and in other areas where the valley bottom has been allowed to grow up completely into forest. However, unstable channels and high aggradation rates have the potential to prevent establishment of a stable riparian corridor. Because valley-bottom land continues to be the most productive agricultural land in the area, much of the privately owned land is kept cleared for pasture and crops. Popular concepts of stream management and pastoral aesthetics promote continued clearing and cleaning of riparian areas, as described by many oral-history respondents.

According to oral-history respondents, during the post-Timber-boom and Recent periods, Ozarks streams have exhibited the greatest rates of accelerated aggradation and channel instability. The net effect has been to decrease area and depth of pools, decrease depth in riffles, increase channel widths, and increase lateral movement of the channel. During the same period, the streamgage record of streambed elevation changes on small streams like Little Piney Creek and Jacks Fork indicate a net decrease in streambed elevations, rather than aggradation (Jacobson and Pugh, 1992; fig. 3). The streambed elevation data have been interpreted as the recessional limb of a passing wave of land-use-induced sediment that began before gage construction (1921-28). Observations that channels have been getting shallower are supported by weak relations indicating widening (Jacobson and Pugh, 1992). Most oral-history respondents believe that, despite observed changes in channel morphology, there has not been a significant effect on fish populations.

Decreases in improved land and increases in valley-bottom riparian forest may indicate a trend toward less disturbance of stream channels in the future. However, Ozarks basins can be expected to have considerable lags between changes in upland and valley-bottom conditions and recovery of stream

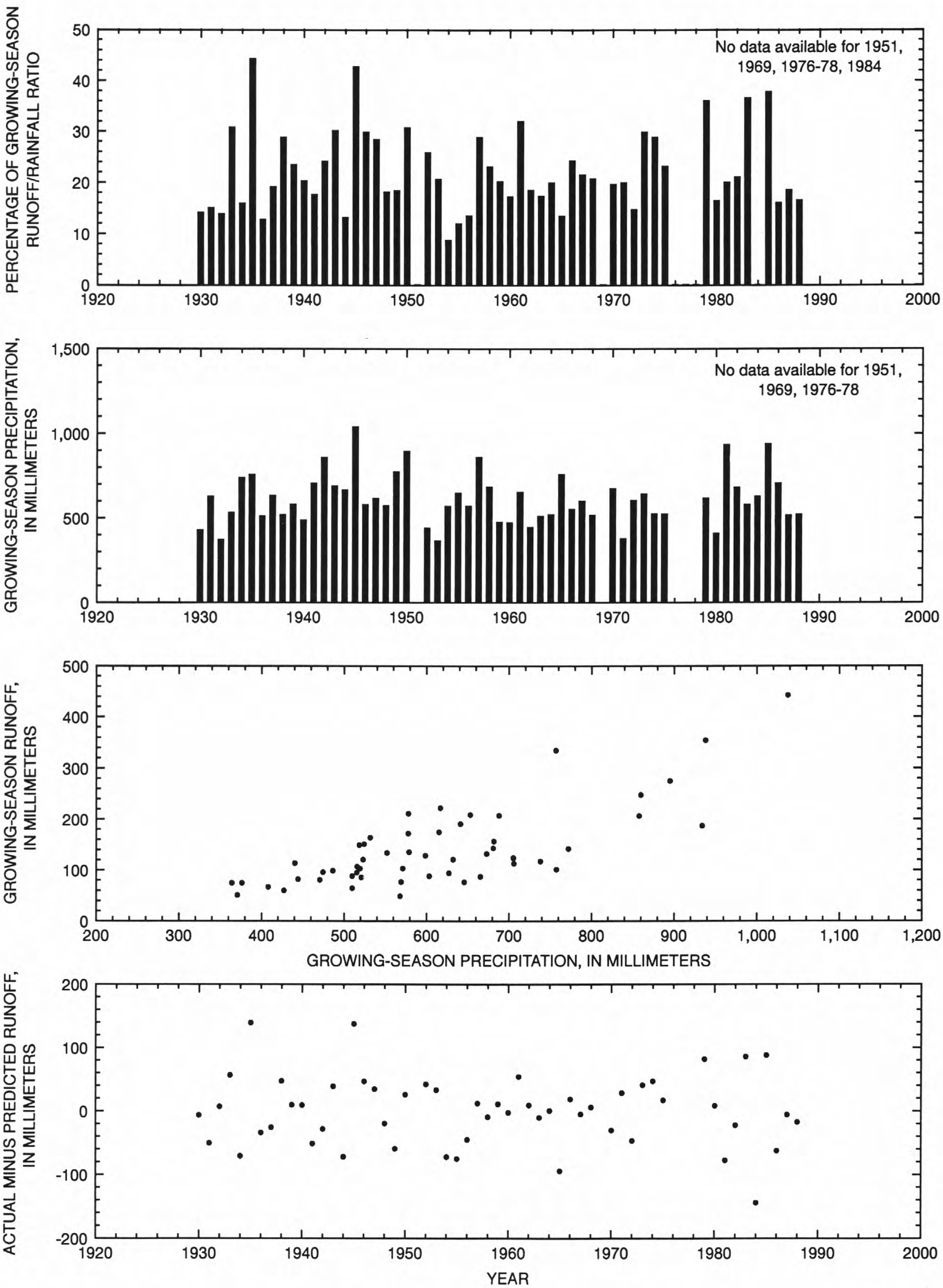


Figure 33. Changes in runoff and precipitation, Little Piney Creek Basin, Missouri.

channels. The cumulative effects of changes in runoff, sediment supply, and riparian erosional resistance, occurring at different times and in different places in the basins, can be expected to have complex and persistent effects. Sediment eroded during one phase of land-use history may take decades or more to move from hillslopes to valley bottoms and through the alluvial system (Meade, 1982). Because of these lags between upland causes of disturbance and valley-bottom effects, Ozarks streams can be expected to be in a continued state of adjustment to sediment derived from earlier land-use changes. Even if hydrologic conditions of uplands are improved to decrease runoff and sediment supply, it is likely that the overload of sediment already in transit through stream channels will work counter to riparian recovery processes. Under these conditions, the stabilizing role of riparian vegetation becomes critical.

Summary and Conclusions

The variance between present (1993) conditions of Ozarks streams and pre-settlement period historical descriptions, stratigraphic observations, and accounts of oral-history respondents of river changes during the last 90 years, establish that Ozarks streams are disturbed from their natural conditions. Disturbance has been characterized by accelerated aggradation of gravel, especially in formerly deep pools, accelerated channel migration and avulsion, and growth of gravel point bars. Streamgage data from the mid-1920's record the passing of one or more waves of gravel through the gaged reaches. However, these data indicate that channels also have been disturbed by extreme floods, and they do not indicate when land-use disturbance began. Historical photographs from around 1900 to the 1940's show great variability in stream-channel changes. Some reaches look similar to the present (1993) channel, whereas others are quite different; some show greater instability, some less. These observations indicate the great spatial and temporal variability common to Ozarks streams. Oral-historical accounts, however, are consistent in their observations that natural channels of Ozarks streams have been severely affected by aggradation by coarse sediment, and that aggradation and instability continue to the present.

The primary hypothesis to explain aggradation and instability is that land-use changes have disturbed parts of the hydrologic or sediment budgets, or both. Land use and land cover have changed markedly in the Ozarks since European settlement. Different types of land use have taken place on different parts of the landscape, and at different times, resulting in a complex series of potential disturbances. Uplands have been subjected to suppression of a natural regime of wildfire, followed by logging, annual burning to support open range, patchy and transient attempts at cropping, a second wave of timber cutting, and most recently, increased grazing intensity. Valley-side slopes have been subjected to logging, annual burning, and a second wave of logging. Valley bottoms were the first areas to be settled, cleared, and farmed; removal of riparian vegetation decreased the erosional resistance of the bottomlands. More recently, some areas of bottomland have been allowed to grow back into forest.

The net effects of this complex series of land-use changes are difficult to determine and separate from natural variability. Understanding is complicated by a physical system in which geomorphic effects are subject to thresholds and lags, and stochastically varying meteorological conditions produce additional spatial and temporal variability. However, in addition to suggesting new hypotheses for testing, the historical observations reported here provide constraints to the understanding of how land-use changes may have affected Ozarks stream channels:

- Initial settlement of the Ozarks may have initiated moderate channel disturbance because of decreased erosional resistance of cleared bottomlands. This trend would have been countered by decreased annual runoff and storm runoff that accompanied fire suppression in the uplands.
- Because of low-impact skidding methods and selective cutting during initial logging for pine during the Timber-boom period, logging would have had minimal effects on runoff and soil erosion. Low-impact methods and selective cutting continued to be the norm in timber harvesting of hardwoods until the late 1940's, when mechanization and diversified markets for wood products promoted more intensive cutting. Locally, log and tie jams, tie slides, and logging debris may have added to channel instability by diverting flow, but because aggradation and instability also occurred on streams not used for floating timber, these factors were not necessary to

timber, these factors were not necessary to create channel disturbance.

Significant channel disturbance probably began in the Timber-boom period because of continued clearing of bottomland forest and road building in the riparian zone. This hypothesis is supported by evidence that significant stream disturbance began before the peak of upland destabilization in the post-Timber-boom period. Extreme floods during 1895 to 1915 may have combined with lowered erosional thresholds on bottomlands to produce the initial channel disturbance.

The regional practice of annual burning to maintain open range had the most potential to increase annual and storm runoff and soil erosion because of its considerable areal extent and repeated occurrence. Burning would have been most effective in increasing runoff and erosion on the steep slopes that had been recently cutover during the timber boom. Generally, accelerated soil erosion was not observed after burning, and relict gullies presently (1993) are not apparent on valley-side slopes and uplands. These observations support the hypothesis that burning did not produce substantial quantities of sediment.

The greatest potential for soil erosion on valley slopes and upland areas occurred during the post-Timber-boom period when marginal upland areas were cultivated for crops. Accelerated erosion of plowed fields was observed and noted by oral-history respondents and by soil scientists working in the Ozarks during the post-Timber-boom period.

Valley bottoms have the longest history of disturbance from their natural condition because they were the first to be settled, cleared, and farmed. The lowered resistance to stream erosion that results from removing or thinning riparian woodland would have been a significant factor, especially on small- to medium-sized streams for which bank stability and roughness provided by trees are not overwhelmed by discharge. Disturbance of bottomland riparian forest increased as free-range grazing, crop production, and use of valley bottoms for transportation expanded and reached a peak in the post-Timber-boom period. Headward extension of the channel network because of loss of riparian vegetation may have increased conveyance of the channel network (and hence flood peaks downstream) and removed gravel from storage in first- and second-order valleys at accelerated rates. This hypothesis is supported by a lack of other source areas for gravel and by observations that gravel came from small stream valleys, not off the slopes.

- During present (1993) conditions, channel instability seems somewhat decreased in areas where the riparian woodland has recovered, but stability is hampered by high sedimentation rates because of large quantities of gravel already in transport and effects of instability in upstream reaches that lack a riparian corridor.
- Land-use statistics indicate that the present trend in the rural Ozarks is toward increased populations of cattle and increased grazing density. This trend has the potential to continue the historical stream-channel disturbance by increasing storm runoff and sediment supply with consequent remobilization of sediment already in transit.

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