An Historical Examination of Water-Powered Mill Sites and Markets using Geographic Information System Analysis: Augusta County, Virginia, 1880-1885

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(ABSTRACT)

Water powered mills were a very important part of life in early America, and Augusta County, Virginia had an abundance of milling activity. Excellent records of milling activity, farm production, and road and farm locations for the period of 1880-1885 allowed a geographic information system (GIS) database to be formed so that spatial patterns could be verified and identified in the Riverheads district of the county. Service areas of 21 mills were identified by using a GIS to calculate the shortest road distance to surrounding farms. It was found that wheat, the main crop, was most likely shipped from the 369 farms to the closest mills. A correlation was also found between wheat production and distance from the mill, thus farmers closer to a mill were more likely to grow wheat. The study also demonstrates the usefulness of GIS analysis and computer cartography in historical, geographic research which has traditionally used theoretical approaches or lacked adequate data for GIS analysis.

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Chapter 1

INTRODUCTION

Background

Early dependence on waterways, forest and agricultural products heavily influenced settlement patterns in the United States. The early part of American history saw the development and use of water powered mills along the waterways of the nation. These mills were used to process grain and lumber, essentials needed by every pioneer. Water power was also harnessed for use in carding machines, iron furnaces, tanneries, distilleries and other industries. With low populations, many small communities were reliant on such labor saving devices as mills. Thus, a mill preceded the church and school in many early American towns (Hunter, 1979). Since these mills processed life sustaining agricultural products for local and distant markets, they played a prominent role in the agrarian economy of early America. These mill seats developed, grew, declined and changed due to various geographic, economic, agricultural and institutional factors. With the advent of steam power, electricity and better machines, the usefulness of water-powered mills declined in the late nineteenth and early twentieth centuries. Today, most water mill sites of the 1700's and 1800's contain only structural ruins or the remains of a dam. These salient features on the landscape today are extensions of physical and cultural conditions of the past.

Geographic Information Systems (GIS) have only recently evolved as a tool for recording and analyzing spatial characteristics of a given area or the distribution of an object. GIS applications are concentrated in the mapping and managing of lands, utilities, transportation systems and natural resources. Geographic information systems are also being used for many other applications, from the micro analysis of the atom to the macro analysis of the universe (Hall, 1992). One such application involves the use of GIS as a tool to study history. Some literature has been produced concerning historical data and GIS, but most of this writing focuses on land parcel change over time. The usefulness of GIS in the field of archaeology has also been explored through site prediction and synchronic and diachronic cultural landscape analysis applications (Savage, 1990). A GIS is an ideal tool to study the "morphology of the landscape" as Sauer defined it, because of its capabilities to integrate both physical and cultural data and perform analysis that can link many disciplines (Sauer, 1925; Peterman, 1992). However, little literature has been published about GIS applications in the discipline of Historical Geography.

With the power of computers today, we are able to analyze the spatiality of our past to obtain a greater insight into spatial relationships that no longer exist. Because human behavior is often patterned, GIS technology can be used to decode these patterns on the landscape to quantifiably and scientifically understand cultural and environmental features of the past (Peterman, 1992). As with any database, the sole usefulness of the GIS for such an undertaking depends on the availability of accurate data from archival materials or field work related to the study period.

Study Objectives

Augusta County, in the heart of the Shenandoah Valley, had an abundance of water mill activity in the 1800's. The period of 1880-1885 was chosen for the study due to the abundance of complete historical data. Good records of milling and agricultural activity can be found for the period from the Tenth Census of the United States (1880). A series of maps published by Jed Hotchkiss in 1885 in the ***Illustrated Historical Atlas of Augusta County, VA*** provides valuable locational information. Since these records exist for a period during the height of water-powered mill activity in the county, 1880-1885 was the period chosen for this study. With the aid of these archival materials, water-powered mill sites were identified and digitally mapped with crop production and transportation networks that existed for the study period. It is important to note that the development of mill seats was not strictly dependent on surrounding crop production and transportation networks alone. Physical features, such as stream gradient and water flow volume, and institutional factors such as the Virginia Mill Dam Act, influenced the placement of water-powered mills as well.

An historical examination of crop production, transportation, crop use and mill service areas was made with the aid of GIS analysis. The research had two goals, the first of which was to examine the spatial relationships between farms and grain processing mills in order to verify and identify patterns of interaction. The second goal was to demonstrate the usefulness of geographic information systems in recreating and studying the past with the sophistication of modern technology and analysis.

Study Significance

This study should reinforce the usefulness of GIS for historical and archaeological research and add to the understanding of local agricultural markets in nineteenth century Virginia. Spatial autocorrelation, cluster analysis and other similar statistical approaches have traditionally, and often unsuccessfully, been used to study the relationships of landscape archaeology (Savage, 1990). Geographic information systems have great potential for becoming valuable tools in historical studies to aid research and build theories about the spatial relationships between humans and their environment. With GIS anlaysis, an historical study of a section of Augusta County, Virginia is the topic of this Master's Degree thesis in Geography.

Chapter 2

History of Augusta County

Physical Setting

Mill site selection was based upon many physical conditions, and agriculture was obviously connected to the physical environment. Likewise, the mills were at the foundation of many communities in terms of their early development and importance in everyday life. An understanding of the basic physical and historical setting in the county is valuable in understanding mill and farm interactions in the 1800's.

Augusta County (Figure 1), the second largest county in Virginia at 631,040 acres, was first settled by Europeans in the mid 1700's. Plentiful streams, rich soil, good climate and varying topography have been instrumental in creating a sound economic and social base for over 250 years. The Shenandoah Valley, which has prime agricultural land, takes up a large portion of the county. The valley is about 12 miles wide in the southern portion of the county, and widens to 20 miles in northern Augusta County. The Blue

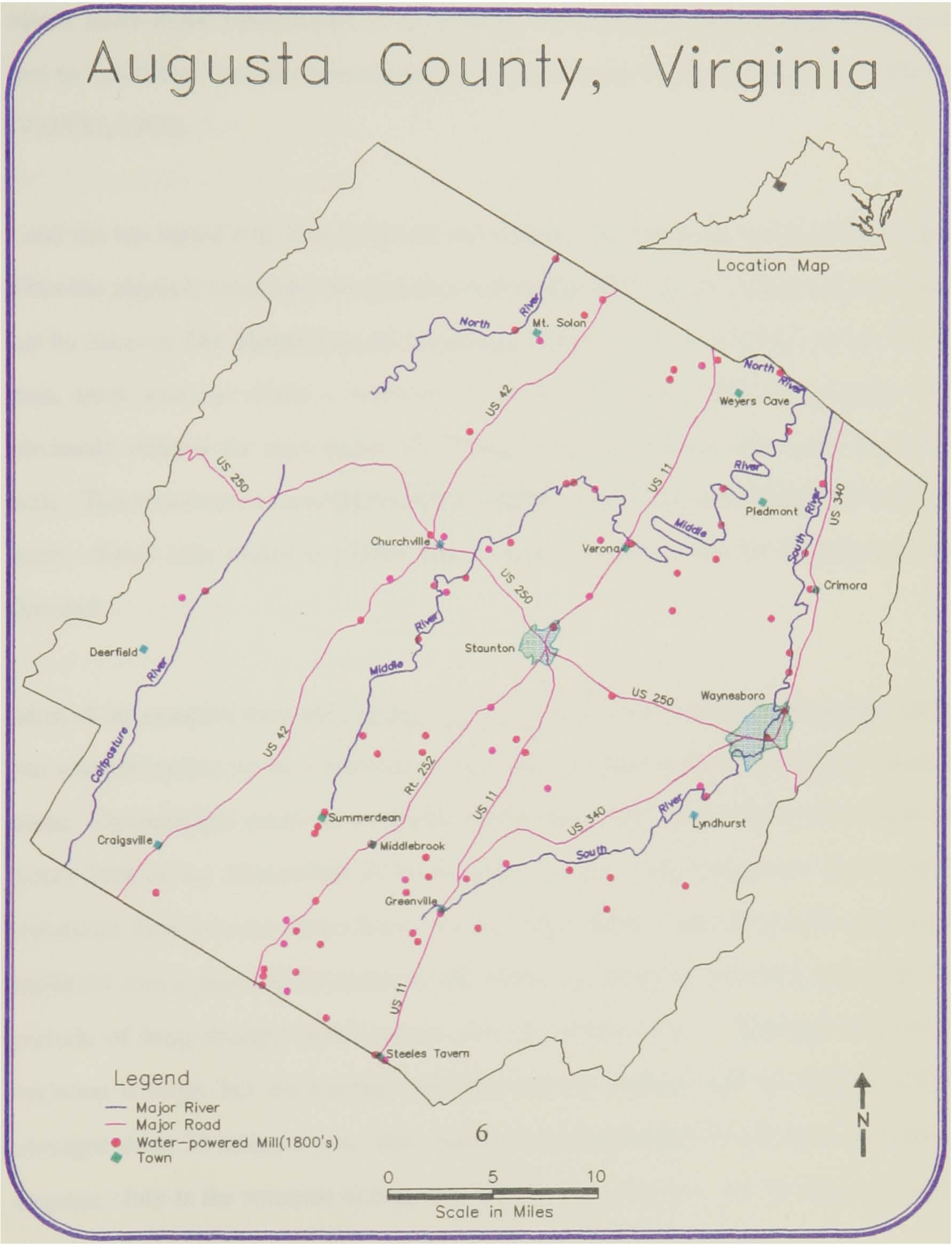


Figure 1. Augusta County, Virginia

Ridge Mountains form the eastern boundary, and the Allegheny Mountains cover 350 square miles in the western part of the county. The valley elevations range from 1,050 feet to 1,200 feet, and the mountainous elevations range from 2,100 feet to 4,458 feet (VEPCO, 1965).

Land use has varied over time as people have altered the landscape based on their needs. Thus the physical landscape has played a role along with cultural influences, as pointed out by Sauer in ***The Morphology of Landscape*** (Sauer, 1925). As settlers moved into the area, trees were no doubt a valuable resource. The valley and flood plains were obviously utilized for agriculture, and mountainous areas were sometimes farmed as well. This mountainous land has been forested and cleared several times in the past 250 years. Small hills within the valley that were too steep or rocky for farming are now forested.

Most of the complex river and stream system is part of the Potomac River drainage basin, but a small section in the southwest of the county is part of the James River drainage basin. The principal rivers are the North, Middle and South rivers which join to form the South Fork of the Shenandoah in Rockingham County. The Calfpasture River and its tributaries flow into the James River via the Maury River. The area receives about 38 inches of rain a year (40-45 inches in the 1800's according to Waddell) and rarely has periods of long drought which would prevent stream flow. Seasonal temperature variation is large, but the heaviest rainfall occurs in summer, and the winter snowfall averages about 31 inches a year. The mean annual temperature for the area is about 56 degrees. July is the warmest month, and January and February are the coldest months. The frost free growing season is just under 6 months (VEPCO, 1965).

Augusta county is underlain by several rock types. The Blue Ridge Mountains are made up of metamorphic and clastic sedimentary rocks. Most of the main rock units in the Blue Ridge are highly resistant to weathering. The valley floor is made up of sandstones, dolomites, limestones and shales. The western mountains are composed of clastic sedimentary rock. Both mountain rock groups generate clastic alluvium, which greatly influences river land forms in the valley (Sherwood, 1987).

Residual and transported soils are found in the area, with residual soils being the most common. Soils in the valley can vary from 0 to 40 feet in depth and they generally have a high clay content (Sherwood, 1987). The farming soils developed over limestones, shales and dolomites. The best farming and the thickest soils developed over limestone, which is found in much of Augusta County (Caskie, 1951). These areas of limestone are also dotted with sinkholes and other karst features. Alluvium makes up the soils along the complex river and drainage system in the valley. Flood plains and terraces, and alluvial fans in the area are made of gravel, sand, clay, silt and other alluvial deposits, which makes them well suited for agriculture.

Agriculture was traditionally the dominant industry in the county, but manufacturing is now the main source of livelihood. Poultry and dairy products now dominate the agricultural activity which was much more diverse in the past. The county has two cities, Waynesboro and Staunton, which are about ten miles apart (Figure 1), and were settled in 1736 and 1749 respectively. There are about thirty smaller villages and hamlets throughout the county.

Native Indians and European Settlement

Augusta County, when formed in 1738, extended from Virginia to the unexplored areas to the west. No Indian villages or homes were found by the first explorers, but burial mounds and artifacts in the area indicated that Indian groups did reside in the county at some point prior to European settlement. The closest Indian settlement at that time was near the town of Winchester, in the northern part of the valley.

The first Europeans, led by Alexander Spotswood, crossed the wilderness and mountains from eastern Virginia in August of 1716 to find a vast fertile valley. It is believed that they crossed into the valley at Swift Run Gap and then camped along the Shenandoah river (Waddell, 1885). The area was apparently void of large trees and was covered only with brushwood. Deer, buffalo, bears, wolves, panthers, mountain lions, foxes and rabbits were abundant in the area at the time of exploration (Waddell, 1885). The men found that the buffalo had worn a large migration path through the wilderness in an east-west direction just past the present site of Staunton. This reconnaissance trip of fifty men was followed by the migration of settlers from Pennsylvania beginning in 1732 (Peyton, 1958). Among these settlers was John Lewis, who built a stone house near the present location of Staunton, in Augusta County, and is often credited as being the first white settler in Augusta County.

Population quickly grew in the county, and Staunton was set up as the government center in 1745. Most of these initial settlers were of Irish and Scottish descent, and many had left Northern Ireland to escape religious persecution from the Church of England. Land was free for the taking, and these Presbyterians claimed whatever land they liked and built homes without any regulation from the government (Waddell, 1885). Having many settlers in the mountains helped prevent Indian movement to the eastern part of Virginia, so the colony encouraged settlement by not requiring settlers to pay colonial taxes. Since many settlers soon wanted roads and other community projects, local taxes were implemented in 1742 (Waddell, 1885). Around the time of the Revolutionary War, many settlers also began to come from Germany.

The Wars, 1750-1870

Skirmishes between Indians and settlers were common. Peyton provides detailed and graphic accounts of many of these Indian attacks. Many settlers fled east across the Blue Ridge, and the remaining settlers built many forts, some of which still stand today. After many more skirmishes and treaties, the Indian conflicts slowly simmered down and the Indians were pushed westward as their numbers diminished.

Disputes with the mother country led to the closing of Boston harbor by the British in 1774. The colonies were called upon to help the city of Boston as it suffered from lack of necessities that were normally shipped to the port. Augusta county was called upon to supply its share according the historian Brancroft:

> When the sheaves had been harvested, and the corn threshed and ground in a country as yet poorly provided with barns or mills, the backwoodsmen of Augusta county, without any pass through the mountains that could be called a road, noiselessly and modestly delivered at Frederick, 137 barrels of flour as their remittance to the poor of Boston (Waddell, 1885, p12).

On several other occasions the settlers sent flour to needy areas during the revolution. The county had also supplied hundreds of troops to help defeat the British (Waddel, 1885).

The county split up into smaller counties by 1790, leaving the present boundaries of Augusta County. Some of the original settlers moved to areas south and west, but the population of the county continued to grow (Table 1) because of appealing lifestyles and abundant resources. Agriculture remained very important, and by 1811, the Augusta Agricultural Society was formed to aid farmers and to promote good crop production (Peyton, 1953).

The War of 1812 had little impact on the residents of Augusta County, although they formed a Military Association and decided to start military schools. No battles took place in the county, and though Augusta county did train a volunteer company and sent them to Richmond, they saw no action (Peyton, 1953).

The tranquillity of the valley was interrupted again by war in 1845-1846 when the county sent a volunteer company to fight in the war against Mexico. These men went by ship, and were stationed in the northern area of Mexico. They never saw battle and returned in 1848 according to Waddell and Peyton.

The period of 1848-1855 brought many road improvements to the county. Roads were built from Buchanan to Staunton, from Nelson county to Greenville, and from Staunton to Middlebrook. The first bank in the area opened at this time, and rail service reached

Table 1. Population of Augusta County, Virginia, 1790-1890

Year	Population	State Population*	State Percentage
1790	10,886	691,737	1.57
1800	11,712	801,608	1.46
1810	14,308	869,131	1.65
1820	16,742	928,348	1.80
1830	19,926	1,034,481	1.93
1840	19,628	1,015,260	1.93
1850	24,610	1,119,348	2.20
1860	27,749	1,219,630	2.28
1870	28,763	1,225,163	2.35
1880	35,710	1,512,565	2.36
1890	37,005	1,655,980	2.23

*Using present state boundaries.

the county. Soon after all these improvements, the war between the states started and Virginia found itself at center stage.

Throughout the war, the area sent troops and provisions in the name of the Confederacy. Federal troops passed through the area on many occasions, but Augusta county was impacted the most during 1864 and 1865. The battle of Piedmont saw the engagement of troops about 12 miles from Staunton in June 1864. Following victory, Union forces marched to Staunton and destroyed some bridges, railroads, barns, mills and factories along the way. Later, in early 1865, Sheridan's troops swept through the area, burning and looting as they went. Many residents found food in short supply and the stores in Staunton could only provide basic supplies. Currency depreciation led flour to climb as high as $95 a barrel in late 1864, and to $1000 in 1865 (Waddell, 1885). Lee's surrender in April 1865 ended the war. It took weeks to establish a credible currency to do business, and months and years to rebuild what had been destroyed. By 1880 the county had the largest percentage of the state's population it would ever have (Table 1). Agriculture remained the dominant industry until well into the 1900's when manufacturing became more important because several new factories were constructed. Agriculture became less diverse, smaller scale and more specialized as states to the west began to produce more of the nation's agricultural needs. Steam power arrived in the mid 1800's, but few water-mills were converted due to the expense. The Census of 1880 reported only one steam mill, a lumber mill, in the Riverheads District.

Chapter 3

Agriculture and Water Power in Augusta County

Early Agriculture, Milling and Industry

From initial settlement until the middle of the twentieth century, agriculture met the needs of the local population. The earliest settlers, with lack of roads and wheeled vehicles, found it easier to obtain money by selling small numbers of furs and livestock instead of crops (Waddell, 1885). Most homes were built of logs and each family grew its own crops. Closely linked to this subsistence farming was the water mill, which was a labor saving device used to process agricultural and forest products. Abundant resources, lack of labor and the need for processed products, led the settlers to construct the water mills, often before churches and schools were built. These mills were tools that were as important to the settlers as the ax, plow and ox (Hunter, 1979). Every family in early America depended on bread for food, and lumber for shelter. Water-powered grist and saw mills provided for these needs, and early colonizing agencies soon promoted them in developing communities. For example, the colony of Virginia provided free milling equipment to new mills, and in 1667 extended benefits to help new settlers obtain mill seats (Hunter, 1979).

English Common Law, in effect in colonial times, applied the "natural flow" concept of riparian rights to anyone utilizing a watercourse (Walker, 1968). As early as 1795, under the Virginia Mill Act, the county court had to review a mill site proposal to be sure that it met certain state criteria. The court appointed a commission to see if a proposed dam would flood surrounding properties or obstruct river and road travel (Code of Virginia, 1950). Beyond the Mill Act, the only constraints affecting construction were physical and economic ones which will be discussed in a later section.

The earliest evidence of mills came from Augusta County Parish Order Book, Number 1 which was dated February 11, 1746. The document described two roads in the county as being "from David Davis's Mill to the top of the mountain , and the other from Benjamin Allen's Mill to North River" (Hamrick, 1982). Hamrick also found a deed that stated that Gibson Jennings had a mill prior to September 2, 1740. Hamrick goes on to cite some of the earliest mills in the County as follows:

> William King was granted permission to dig a mill race through John Trimble's land on June 18, 1746. William Long permitted to build a mill on November 19, 1746. John Pickens had a mill in June 1747 (on South River near Port Republic). Robert McCutcheon to build a mill on August 19, 1747(on Little River in Bell's Valley). James Trimble, permission to build a mill in November 1747. John Lewis had a mill prior to February 1748 (Lewis Creek). James Patton had a "Mill Place" in April 1749. John King had mills on Naked Creed and Middle River on March 20, 1767. James Givens had a mill before August 1767. James Kennerly had a mill on South River in November 1767. John Seawright had a mill at his spring before August 18, 1768. William Robertson had a sawmill before May 21 1777, probably Lewis Creek.
> (Hamrick, 1982, p6).

In 1749, a road to the east was constructed so that people in Augusta county could market produce, cattle and furs. These and other products were often traded for manufactured items that were unavailable in the valley. Flour and other grains were no doubt part of this early trade. Each family grew its own vegetables and hunted or kept a few animals. Most farmers concentrated only on providing for the needs of their families in terms of their agricultural production. Hemp was grown in many parts of the county in the 1700's for textile products such as sacks and canvas, but the hemp fields were converted to wheat in the late 1700's (MacMaster, 1988). As wheat and flour prices rose in the 1780's and 1790's the number of mills in the county doubled (MacMaster, 1988). The demands for wheat and flour came from other areas of the state, as well as from within the county. Wheat fields became abundant, and many hemp fields were replanted in the lucrative crop (MacMaster, 1988). Wheat became the main crop and the main source of income for the upper Shenandoah Valley by 1800.

The smaller settlements in the county formed near groves of trees and springs. Much of the valley land was cultivated and used for grazing and it wasn't long until only the mountains were void of farms and towns. Shops, or "stores" were established in the valley to provide for the needs of the growing population. Soon tailors, blacksmiths and other business people set up small establishments. "Butchers, bakers, brewers, carpenters, joiners, wheelwrights, plough, cart and wagon makers" were all found in the villages and towns of the county in the 1800's (Peyton, 1952). Iron, marble, coal, silver, and manganese mines, and orchards and vineyards were also operating in the 1800's (Peyton, 1952). There were attempts to establish large factories in the area, but for the most part the population relied on agriculture and small business for its livelihood. More people became involved in small business, and agricultural advances allowed the remaining farmers to grow more to meet the food needs of the split labor force. The good growing conditions and abundance of grist mills made the Shenandoah Valley well known for producing quality wheat and flour.

At the center of community life were the small town stores and the local mills. Men could meet at the mills while having their corn or wheat ground, and discuss the latest advances in crop production, politics, and local news. Wives would shop at the stores to compare prices and talk about social events. The children would often swim or fish in the mill pond (Clayton, 1983). Most of the trade in the South was done on credit. Some mills were owned by the local merchant, and accounts were settled when farmers had finished harvesting and had bought most of their supplies from the store. Clayton claims that "it was not unusual for two-thirds or more of the proceeds from a farmer's marketable crops to go to the merchant". It was often very convenient that the nearest mill was located in a small town, but this was not always the case.

It was important for the grist mills to be close to the farms since the transportation of unprocessed crops was more difficult than after milling. One acre of corn could be ground down to five barrels of corn meal, and five bushels of wheat could be ground to one barrel of flour (Clayton, 1983). Higher prices could be obtained for these processed products, thus larger farms sometimes found it economical to build their own grist mills. These larger farms would usually process the grain of surrounding farms as well. Few farmers had to travel more than few miles to the nearest mill. Those who brought their crops to the local mill were required to give the miller between one-twelfth and one-eighth of the finished product for payment. (Clayton, 1983).

Augusta County had many such grist mills. The good water power potential and the rich land in the county made grist mills a common sight along the county's roads. In 1810, Augusta County had 58 of the state's 459 mills. By the 1880's, the number of mills in the state doubled (1,065 in 1880), but the number of recorded mills in the county stayed about the same (52 in 1880). The rise in numbers at the state level indicates an increase in population, crop production and industry during the 70 year period. Many of the county's mills had been established early and it was not economical to build many new mills in the 1800's, even though population grew.

One had to consider that the risks in building a mill were often great. The cost of a mill was considerable, as a lot of machinery, belts, and gears had to be built or purchased. Sometimes a dam or long mill race had to be constructed as well. Once the mill was operating, the owner could lose money if crop yields were bad, competition was strong, or demand for cornmeal and flour was low. Floods often damaged or washed away dams and mills, and fires were also a hazard to the wooden mill structures. Heavy weights on wooden floors and friction between wooden parts could start a fire as easily as a misplaced candle or dropped lantern. The mechanical parts of a mill required a good operator, thus many owners would hire millers to do the dangerous work. The miller had to lift heavy bags of flour and meal, work in a noisy and dusty environment, fix stuck gears and change millstones that often weighed a ton (Clayton, 1983). Despite hazards, profits in the milling business could be high if nature cooperated and the machinery did not break down.

Milling Competition for Augusta County

Augusta County's wheat and grain markets were influenced by several forms of competition. Wheat production and milling activity were most abundant in New England until the mid-west was developed in the late 1800's. Virginia saw Richmond develop as the flour milling center. The mills were able to produce quality flour because of their buying power and their superior milling equipment (Kuhlmann, 1929). The canals on the James River could bring wheat from 200 miles to the west of Richmond. When these crops were poor, the mills in Richmond could buy grain from Maryland or other areas. The mills in Augusta County were reliant on local crops alone. The canal system did not reach Augusta County, thus the export of wheat to Richmond did not occur on a large scale. The mills that had been built long before the railroad and most roads, were still economical to run in the 1880's since they had been paid for years earlier. However, in the 1800's, when mills needed costly repairs or were damaged by flood or fire, they were often abandoned. When rail transportation to the midwest became more common and the Erie Canal opened, grains could be shipped longer distances at less cost.

Crop yields increased, and production of wheat increased as farmers struggled to break even after the Civil War. Prices for crops and flour fluctuated from 1870 to 1900, but by 1900, it was very difficult for a farmer to make a living by growing wheat (MacMaster, 1988). Improved transportation on a global scale influenced prices worldwide. Famines in India and poor crops in England could influence the wheat and flour prices in Augusta County (MacMaster, 1988). Likewise, new technology and cheaper production at national and international scales made wheat farming unprofitable for most in the county by 1900. As a result, small local grist mills found it difficult to sell flour or cornmeal to the public at a competitive price. Adding to this decline of the country mill were increases in the number of large commercial mills, and the widespread use of steam power. Most country mills were abandoned by the early 1900's, although some were converted to generate electricity.

Mill Site Selection

Thus far, many factors have been discussed that affected the profits of an established mill. These factors are summarized in Table 2. The success or demise of a mill depended on these social, cultural, or physical characteristics acting in many possible combinations. When their influence increased or decreased, the mill's profit margin was affected unless one factor balanced another. However, these economic factors only affected the mill's operation after it was built in a suitable location. There were also several basic physical and institutional features that were important to consider before a mill was to be built.

Water powered mills flourished in Augusta County because of many suitable locations and the low technology involved in milling. The characteristics of the stream flow were the most important aspect of mill site selection that the settlers had to study and utilize, but there were many things to be considered when selecting the optimal location to build a mill. Hunter cited a list from Swain that describes features that would make a site desirable. Table 3 describes these features.

Table 2. Influences on Mill Profit and Productivity.

1. The price of wheat/flour and corn/cornmeal set by consumer demand at the local, regional, national and world levels.
2. Improvements in road, rail and canal/river transportation.
3. Increases in efficiency by improvements in milling techniques and technology.
4. Increases in crop production, quality and yields within mill's service area.
5. Distance to nearest competing mills; size of service area.
6. Reliability and quality of the mill's gears, belts and other machinery.
7. Changing land use and its effect on the volume of wheat and corn grown in a mill's service area.
8. Mill owner's and miller's reputations among the farmers.
9. Proximity of mill to other services such as a blacksmith shop or store.
10. Fires or floods.

Table 3. Physical features that make a mill site desirable.

1. Steep stream slopes over a short distance.
2. A waterfall or series of falls that are not too small or too large to utilize for power.
3. Erosion resistant bedrock to ensure the permanence of stream slope and falls.
4. Accessability of rail road, river and canal facilities from stream fall.
5. Large average stream flow .
6. Uniform stream flow.
    a. mild winters
    b. large forests
    c. large number of lakes
    d. topography that is not steep or rocky
    e. large drainage basin
7. Proximity to resource being processed.

(1-6, Hunter, 1979)

Stream slope influences the energy potential of the stream. Many smaller streams in Augusta County had steep stream slopes over a short distance, which made it easy to construct a mill race that would carry water to the top of an overshot wheel. Small stream slopes required longer mill races and sometimes a dam. The dam would fill up to create an artificial fall and to stockpile water for mill operation during the day or in periods of low stream flow. Waterfalls were very attractive for developing water power, if they were not too small or too large to be used. Generally, the fall needed to be as high as the water wheel. The rock that made up the fall or stream bed had to be hard and resistant to erosion because a mill depended on the permanence of the stream slope or fall for many years. Transportation features needed to be close to the site, since grains and timber were shipped to the mill, and meal, flour, and lumber were marketed from the site. Streams with large volumes of water were more reliable and generated more power than smaller streams. Most of Augusta county is drained by small streams of less than 10 feet in width and 2 feet in depth and it was these streams that also had the steeper slopes. The larger mills in the county were located on the three main rivers, but most of the mills were located on the many tributaries. The uniformity of flow could be controlled temporarily by dams, but nature played the greater role. The hydrologic cycle affected both the distribution and amount of water that an area was to receive, which directly affected the stream volume and uniformity that the mills were so dependent on.

Many other factors also influenced the uniformity of stream flow. Mild winters dampened the effects of heavy snow melting in the spring. Large forests and vegetated areas slowed the effects of runoff as well. While Virginia was blessed with few natural lakes, an abundance of lakes in an area can assist in creating uniform stream flow. Steep and rocky terrain increase runoff and erosion, which in turn can cause erratic stream flow and stream sedimentation. Finally, drainage area size also plays a role in stream flow uniformity. The larger the drainage area for the stream, the more uniform the flow should be.

The Virginia State Water Control Board only keeps stream flow records for selected points on the major rivers in the county. Most of the smaller mill streams of the county have no flow records to indicate the influence that flow volume and uniformity would have had on the water-powered mills. The accuracy of estimating stream flow characteristics for these smaller streams based on drainage area, vegetation and slope would not have been adequate for purposes of this study. The time needed for such an examination would have been too long to justify, and according to the Virginia State Water Control Board, the results of such studies are often flawed.

The Milling Technology

For as long as 75,000 years, humans have ground grain into flour using a variety of techniques. Early grindstones and hand powered machines gave way to water powered mills as early as 500 AD (Storck, 1952). Hand, horse and wind powered mills were also popular and efficient in many parts of the world that lacked the resources and technology to develop water powered mills.

Early settlers in Virginia built wind-powered mills because they were easy to construct and did not require the development of dams, mill races and other complicated watercourse alterations. The lack of continuous winds and improved infrastructure and technology, led the colonists to construct more efficient water powered mills by the mid to late 1600's. Mills were classified by the type of wheel that operated the mill. The most common types found not only in Augusta County, but world wide, were the overshot, undershot, and breast mills.

The overshot was the most common wheel and mill design in Augusta County (Figure 2). This design was well suited for the upper reaches of a river system (Storck, 1952). The overshot wheel required a stream fall equal to or greater than the height of the wheel. This could be accomplished by a natural stream fall, dam, or a mill race on the lower side of the mill. The water on the overshot wheel acted over a longer distance than any of the other wheel designs. The impact of water and gravity turned the wheel. One of the two disadvantages was that the bottom of the wheel was rotating the opposite direction of stream flow. If water levels after rains or floods were high enough to submerge the bottom of the wheel, a great loss in efficiency would occur. Secondly, some water would fall out of the buckets as the wheel rotated and buckets "tilted" as they reached the lowest point of rotation.

The undershot wheel is one of the oldest wheel designs and the most inefficient. The wheel was positioned in the stream or a channel and rotated by impact alone. The advantages of the undershot wheel were that it was easy to construct and required no dam or stream course alterations. When a fall was used, water was dropped to the base of the wheel to increase its velocity upon impact. Evans (1850) recommended that the wheel rotate at two-thirds the speed of the water. Falls of less than 6 to 8 feet which were most common in lower reaches of large streams were well suited for an undershot mill (Hunter, 1979). Floating mills, in larger rivers in the United States, relied on the

Figure 2. Overshot Wheel

undershot wheel as well.

The breast wheel is a combination between the overshot and undershot wheels. The wheel moves both on impact and by gravity like the overshot, only the wheel is turning in the opposite direction and with the stream. A wooden "apron" was constructed to hold the water close to the wheel so it would not fall out of the buckets in the lower quarter of rotation (Hunter, 1979). The wheel could also be much larger than the stream fall since the water did not have to go over the top. While the wheel design offered flexibility in wheel height and was able to work in high water conditions, it never gained popularity.

Several other mill types in Early America deserve mention. The flutter mill used a small undershot wheel, crank and "pitman" to move saw blades and other similar machinery. The tub mill used a small wheel and a vertical shaft with a millstone attached at the top. The tub mill was popular in Appalachia, but was not suited for large scale production (Hunter, 1979). There were many variations of mill designs that varied from simple designs like the tub mill to complicated tidal mills in coastal areas and technologically advanced turbine mills. Augusta County primarily had overshot mills and a few undershot and breast mills.

Besides the wheel, mills operated in the basically the same way. The wheels would turn a gear or cog which would rotate the stone at a particular speed. The ideal speeds and hydraulics were often disputed until all the mill designs were thoroughly tested and documented. In 1850, Oliver Evans published The Young Mill-Wright and Miller's Guide, which documented many of the statistics. Tables 4 and 5 give examples of some of the statistics mentioned by Evans. His work, which described the laws of physics and

Table 4. Characteristics and Statistics for waterwheels (Hunter, 1979)

Wheel	Diameter (ft)	Fall (ft)	Wheel rpm	Millstone rpm	Percent Efficient
Undershot	12-18	8-20	24-26	88-106	15-30
Overshot	9-30	11-36	14-8	103-99	50-70
Breast	15	6-15	14-19	101-98	40-60
Tub	2-3.5	8-20	122	(4ft stone)122	10-15
Flutter	2.8-4.75	6-30	120	120 strokes	15-30

Table 5. Statistics for 15ft overshot wheel with 5ft stones (Evans, 1850).

Water head above impact	10 ft
Water velocity/second at impact	25.54 ft
Wheel velocity/second at full load	14.73 ft
Wheel rotation per minute	18.78
Cogs in master cog-wheel	60
Wallower rounds	25
Cogs in counter cog-wheel	44
Trundle rounds	20
Stone revolutions per minute	99
Cogs in cog-wheel (single gear)	96
Trundle rounds (single gear)	18
Stone rpm (single gear)	100
Water needed to drive stone at 97 rpm	22.89 cub.ft.
Area of water at impact	.9 sup. ft.
Area of canal needed for water with 1.5 feet velocity	15.26 sup. ft.

mechanics and gave specific instructions for mill construction, was a valuable resource for millers.

Besides the wheel, the most distinguishing characteristic of a mill was its dam. Dams served several purposes, the most important of which was to create an "artificial" fall so that water could be diverted over the top of the wheel. The dams also impounded a large amount of water that could be used to increase water flow volume during periods of peak water mill operation and periods of drought. Indirectly, the mill pond also served as a place for people, particularly, young boys, to swim and fish. The dams were constructed of local materials of stone, soil, timber, and in some cases, brush and debris. There were dozens of designs from a pile of rubble a few feet high to elaborate stone and timber dams (Figure 3). Most mills in Augusta county relied on local stone, timber and soil for their construction. Mill races were sometimes constructed instead of a dam or in conjunction with a dam. The mill races were used to divert water from the natural stream channel to a new location, and to "raise" the stream so that a fall could be created by the time the water reached the mill. For example, a stream that falls 20 feet over 200 yards could be diverted into mill race that falls only 6 inches over the 200 yards (Figure 4). A fall of 19.5 feet would then occur at the mill. If a dam were also to be constructed at the start of the mill race, the fall at the mill would then increase by the height of the dam. In general, the slope of the mill race was about 1 inch per 100 feet, but some believed that the slope could be as little as 1 inch per 500 feet without any loss of efficiency (Hunter, 1979).

Figure 3. Baylor Mill Dam

Figure 4. Baylor Mill Race

Millstones came in sizes from three to seven feet in diameter and a foot thick (Hardeman, 1981) The stones were ground to have surfaces of different roughness which would allow the grinding of different grades of flour. Many of the quartzite stones came from France by ship and the larger ones were made of smaller pieces held together by a metal band (Hardeman, 1981)

Grains and Milling

The term "grist" has been used in two ways in describing mills. Sometimes it referred only to mills that ground corn while for the most part it referred to a mill that ground any type of grain. Wheat, corn, oats, and barley were all transported to mills for processing in Augusta County.

Wheat was ground to flour to use for bread. Sometimes a certain percentage of the flour was kept by the miller for a grinding fee. Often the farmer sold his wheat to a miller instead of having it ground and then marketing himself. The wheat was ground and classified according to the fineness of the flour and sold under the label of the mill. It was shipped to cities and overseas. Other grains were also processed in this manner.

Corn was ground into cornmeal for animal consumption and many human uses. Indian corn came in many varieties and with many different harvesting times. Depending on the type of corn or stage of ripeness, settlers could process and use the corn in many ways. Hominy, or "grits", was popular and appeared as a separate category in the Census of 1880 under mill production figures. Another very popular use of corn was whisky, and many mills also operated as distilleries. Animals liked corn and it provided them the best source of energy of all grains. The ease of producing corn, low cost and abundance made it the animal feed of choice. It was fed in a wide variety of forms, from stalks and shucks, to ground cornmeal.

Rye, barley and oats were not grown as much as corn and wheat, but they were also used for human food and drink. Animals were fed these grains as well, but they were not as popular as corn among farmers (Hardeman, 1981).

Grain Transportation and Scale of Interaction

The greatest expense of grain production was transportation to the markets. The closer the mill to the farm, the more likely the farmer was to produce a profit. The census of 1880 initially tried to ascertain the cost of moving grain from farms to mills. The results of the question were so inconsistent that the government decided to leave the responses out of the census tables. The farmers' cost estimates were from 20 cents to 2 dollars per hundred bushels per mile (US Census, 1880). Based on the responses in western portions of the United States, it was not profitable for a farmer to move grain more than 18 or 20 miles over land. It was also determined that it cost more for a farmer to move 1 bushel one mile than it cost a railroad to transport a ton of grain 1 mile (US Census, 1880).

By the mid-1800's, wheat was moved from the interior part of the US to coastal areas where it was distributed and shipped overseas. This large scale movement took place by rail and water. Augusta County was less a participant in this scale of transportation since the local mills, farmers, and consumers had participated in small, local production and processing for years. Rail transportaion was often farther away from the farm than the nearest mill. Similarly, water transportation in the county had little importance due to the small size of rivers and topography. As a result, farmers most likely went to the closest mill to reduce expenses. For this reason, a local scale was chosen for purposes of this study.

Some farmers shipped their wheat outside the region to obtain better prices. Mr. Martin, who had a farm and mill on Moffet's Creek, sent some of his flour to Richmond. The grain was probably ground on the Martin property at the very small mill. Figure 5 shows a photo of the farm in the late 1880's with the mill on the left. This flour was most likely shipped by land to Lexington, and then by canal to Richmond according to Richard Byrne, the present owner of the Martin property, who was interviewed for this study.

Mills varied in size and capacity and farmers most likely used the closest large mill that would buy their grain. The exception of this would be the mills located near stores, blacksmith shops or other services. The farmer may have transported his grain to a hamlet to obtain multiple services. Because we can assume most grain would have been milled locally in 1880-1885, this study examines the local issues of transportation, mill service areas and farm-mill spatial interaction using geographic information system analysis.

Figure 5. Martin Farm and Mill

Chapter 4

HISTORICAL GEOGRAPHY AND GIS

Historical Geography

Most people are familiar with Geography and History as individual disciplines, and some may know that Historical Geography is a distinct field. Historical Geography recognizes that changing cultural and physical characteristics can be studied by examining spatial relationships. In a very general way, historians tend to examine political and social questions, while historical geographers examine human-land relationships (Guelke, 1982). All sub-disciplines of geography, such as economic, cultural, physical, social, behavioral, urban, and political geography, can be studied with an historical context and be broadly defined as historical geography. This overlap of disciplines within a spatial perspective has been a defining factor in geography as a whole in the past 50 years (Taaffe, 1974). Historical geography involves both empirical and theoretical frameworks which explore both past and changing conditions. In each case, the elements of time and space are the basic defining features of historical geography. Historical geographers have traditionally studied such things as settlement patterns, migrations, demographics and economics in terms of time and space and from theoretical viewpoints. However, history overlaps into other areas of geography as well. For example, cultural geographers such as John Fraser Hart and Fred Kniffen relied on historical information in research on cultural phenomena such as land use and housing. Their work is well known, but probably could have benefited from the use of modern techniques such as GIS analysis.

In the technological age, historical researchers have begun to use computer data analysis to verify or identify trends or practices. Spatial data had traditionally been represented using paper maps, and only recently have computers been able to perform powerful spatial analysis with ease. Specifically, the geographic information system (GIS) is a valuable tool for the historical geographer, or anyone interested in spatial analysis and modeling.

Geographic Information Systems

Maps have always been a valuable way of representing spatial information, but paper maps were not easy to update, re-draw, or analyze. The advent of computers, storage devices, and digital input and output devices during the last 30 years has allowed the development of digital mapping and the fields of computer cartography and remote sensing. Digital maps and images can be easily edited, updated, and changed using computers, and then be printed on paper for traditional viewing. Scales and features shown on these paper maps, can be easily manipulated prior to plotting. Computers have also revolutionized the way in which we keep track of tabular data. Databases and spreadsheets allow easy manipulation, storage, retrieval and analysis of great volumes of data. The merger of this database technology, computer cartography, and more recently, digital image processing has led to the development of Geographic Information Systems.

A GIS has several components of software and hardware (Table 6). Data entry can involve many devices such as a tablet digitizer, scanner, computer file or keyboard (Burrough, 1986). Data entry is the most time consuming and expensive part of setting up a GIS. Spatial data can be stored as lines, areas or points. These features are stored in a database as layers, or coverages, of similar items such as roads, streams or planning zones. The geographic database contains information on both the topology, (spatial qualities of a feature and its relation to other features), and the attributes of those features. The two parts are linked together in the database so that each entity has unique qualities and information. The information attached to each feature is limitless. For example, a line representing a road might have a value of 10 as its unique identifier in the topological database. Its length, endpoints, and other spatial information are kept in the topological database using traditional X, and Y coordinates. The attribute database may appear as listed in Table 7.

The GIS allows the user to display as much information as needed in various output forms (Table 6). For example, a transportation engineer may need to display on a monitor only the roads over which more than 200 cars per day travel. A planning council may need to see a paper map of all roads rated as "poor". However, this type of query and display does not make GIS unique.

Table 6. Software components of a GIS and related hardware (Burrough, 1986).

1. **Data input and verification;** digitizer tablet, keyboard, disk or tape drive, scanner

2. **Data storage and database management**; disk or tape drive, central processing unit (CPU)

3. **Data output and presentation;** monitor or other display device, hard copy from plotter or printer

4. **Data transformation;** CPU, keyboard

5. **Interaction with user;** input and output devices.

Table 7. Sample geographic database record.

Line 10

Name	Rolling Mill Road
Width	25 feet
Vehicles per day	325
Condition	Fair Paved 8/89
Slope	?

A key part of a GIS is its ability to generate new information from existing information (Cowan, 1988). This transformation part of a GIS (see Table 6) allows the users to maintain, utilize and transform the database (Burrough, 1986). In the previous example (Table 7), the slope of the road was not known, however the road could be "draped" over a digital map of the terrain, and the slope of each line segment computed. This overlay capability is a common feature in almost all geographic information systems. Networking, or "shortest-path" analysis can also be done with some GIS programs to aid in evaluating road features such as service areas, efficient busing or shipping routes, and emergency response time.

GIS has become extremely useful for the mapping, planning and management of spatial natural and manmade features, but GIS technology is not limited to traditional features such as roads, soils and tax parcels. Modern databases and geographic analysis techniques are being used to study atomic, genetic and cosmic features as well as traditional features on the land (Hall, 1992). GIS is most common in utilities, facilities, and land resources management. Only recently has it been used as a tool in archaeological and historical research, modeling and documentation. The possibilities and uses are only limited by the features of the GIS and the quality of information entered into the system. It has had only limited use in historical geography mainly due to the prevalence of traditional and theoretical approaches, and the lack of sufficient information for database development.

Historical data and GIS

Geographic information systems are becoming more common and powerful each year. The use of these systems for geographic research has also been increasing, especially in archaeological studies. Numerous papers have been published on the topic of "non-current" (Hunter, 1988) data and geographic information systems; however, references in mainstream journals are mainly to land parcel history in land information systems. Temporal data are valuable for identifying long term human demands on a resource, and changing natural and physical characteristics for land parcels (Vrana, 1989). Historical data in these cases are linked to current data for planning and management reasons. While a linked historical database can be useful for historical research, this is not its primary function in "non-current" databases.

Historical data not linked to current data have been used successfully for many small studies. For example, researchers in Ottawa entered land use records from 1878 to 1978 into a GIS to test theories of urban structure and development (Hunter, 1988). Non-current data have also been used in geographic databases to study social, economic, legal and environmental issues from an historical standpoint (Hunter, 1988). However, the use of GIS to study one particular period in time, or change in a portion of the past, has been practiced primarily by archaeologists, not geographers.

Archaeology and GIS

Human and land interactions have left patterns on the landscape for thousands of years, and archaeologists study such patterns and relics of the past to determine human lifestyles and characteristics. With computers and GIS analysis, archaeologists can now make complex models to study changing conditions, make predictions, or generate missing information. A geographic information system is an excellent tool for studying the past because it can analyze spatial features that represent a past condition. The source of information can be from the present landscape and current or historical data. However, the key to success is in the quality and availability of information to form a usable database.

There are many applications of GIS in archaeology that can aid researchers all sub-fields of the discipline. For example, GIS in archaeology can be used to manage cultural resources. In this application, sensitive archaeological sites are identified and managed to reduce or eliminate the impacts of development (Savage, 1990). GIS technology is also valuable for site location models. These predictive models identify independent variables and use these to "correlate with and predict site locations" (Savage, 1990). For example, a study was done to predict prehistoric site distributions in central Montana. Known sites were entered into the database and data were generated on their slope, relief, aspect, elevation, and proximity to water (Carmichael, 1990). The GIS then identified other areas that fit the description of known sites. Researchers could then concentrate further field research in the areas that would be "most likely" to contain a prehistoric site. As a research tool, using data from historical maps or documents, a GIS is very useful so long as data are adequate for database development.

This study used United States census information and historical maps to analyze spatial relationships. Archaeologists have primarily studied material remains, while geographers have studied the interactions and distribution of human and natural phenomena. Since many disciplines incorporate geography, some argue that geography should not be independent. The spatial nature of geography that links economic, cultural, physical, social, and urban studies is the defining factor of geography. While GIS has allowed many disciplines to cross traditional boundaries to incorporate spatial analysis, the use of GIS to study historical human and natural spatial interaction and distribution (Historical Geography) has had little attention.

Chapter 5

METHODOLOGY

Study Objectives

The project had two goals. The first goal was to use GIS analysis to identify spatial relationships between farms and mills when water milling of grain was still predominant. The completion of this objective would require complete production records for farm and mills, and a map of the location of mills, farms and roads for the same period. The second objective was to demonstrate the utility of GIS analysis to identify relationships that no longer exist through re-constructive modeling. Hopefully, others involved in historical and spatial research may see the usefulness of using GIS analysis and computer cartography in identifying and presenting spatial relationships that cannot be discovered or presented by manual means.

Study Area Selection

Augusta County, Virginia was chosen as the general area of study for several reasons. First, the area was well known for its good crop production, and it had more than 50 water powered mills in the late 1800's. Secondly, a series of maps, published in the Historical Atlas of Augusta County, Virginia by Jed Hotchkiss in 1885, provided excellent information on the location of all structures and roads in the county in the early 1880's. Finally, the United States Census of 1880 documented production for all farms and some mills in the county in the Census of Agriculture and Census of Manufactures. Combined together, these factors provided a wealth of statistical and spatial information.

Due to the time involved in database creation, it quickly became evident that a study of the entire county would be impractical. The population of the county in 1880 was 35,710 and there were 2,357 farms. A database of the entire county would have included the 1880 road network and multiple variables for the 2,357 farm points. Conveniently, census records and the historical atlas were divided among the county's seven minor civil divisions. The Riverheads District (Figure 6) was chosen for this study for several reasons. First, the area was small enough to have a manageable database of about 400 farms. Secondly, the area had 21 grain mills, 9 of which had census records which would provide valuable data. Finally, the area was bordered on the east and west by mountains, which would form a natural barrier to eliminate edge effects in these directions in the model. Because spatial data just outside the model were not evaluated, the model may not represent real conditions along the edge of a model and may lead to edge effects. Since no data were recorded in these two mountainous edges, few edge

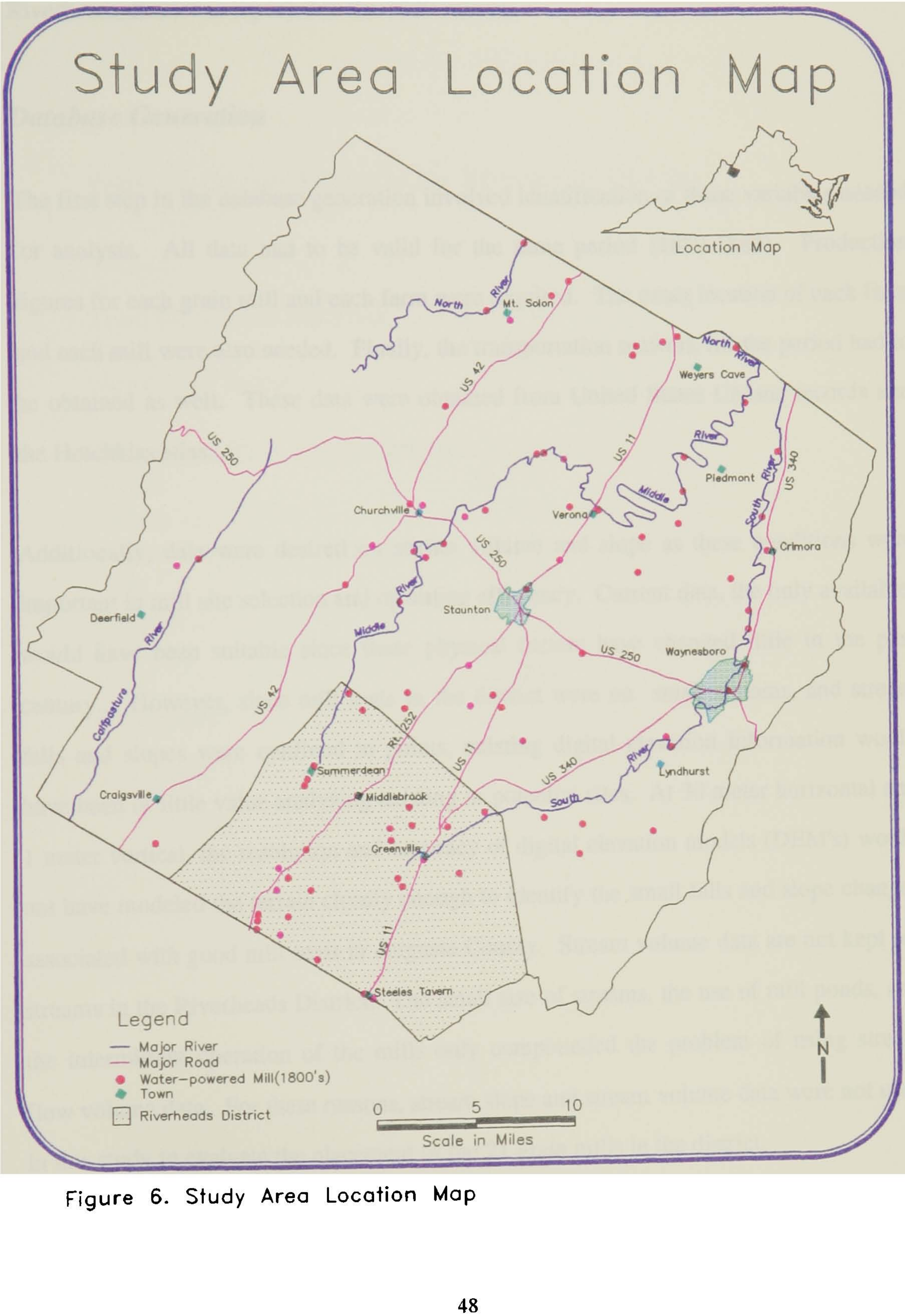


Figure 6. Study Area Location Map

effect errors were expected here. Table 8 summarizes some basic statistics about the Riverheads district as reported in the 1880 census.

Database Generation

The first step in the database generation involved identification of those variables needed for analysis. All data had to be valid for the same period (1880-1885). Production figures for each grain mill and each farm were required. The exact location of each farm and each mill were also needed. Finally, the transportation network for the period had to be obtained as well. These data were obtained from United States Census records and the Hotchkiss atlas.

Additionally, data were desired on stream volume and slope as these conditions were important in mill site selection and operating efficiency. Current data, the only available, would have been suitable since these physical factors have changed little in the past century. However, since mill seats in the district were on small streams, and stream falls and slopes were confined to points, existing digital elevation information would have been of little value analyzing existing or potential sites. At 30 meter horizontal and 1 meter vertical, the resolution and accuracy of digital elevation models (DEM's) would not have modeled the terrain closely enough to identify the small falls and slope changes associated with good mill seats in Augusta County. Stream volume data are not kept for streams in the Riverheads District. The small size of streams, the use of mill ponds, and the intermittent operation of the mills only compounded the problem of using stream flow volume data. For these reasons, stream slope and stream volume data were not used in this study to evaluate the placement of the 21 grain mills in the district.

Table 8. Census Statistics for Riverheads District

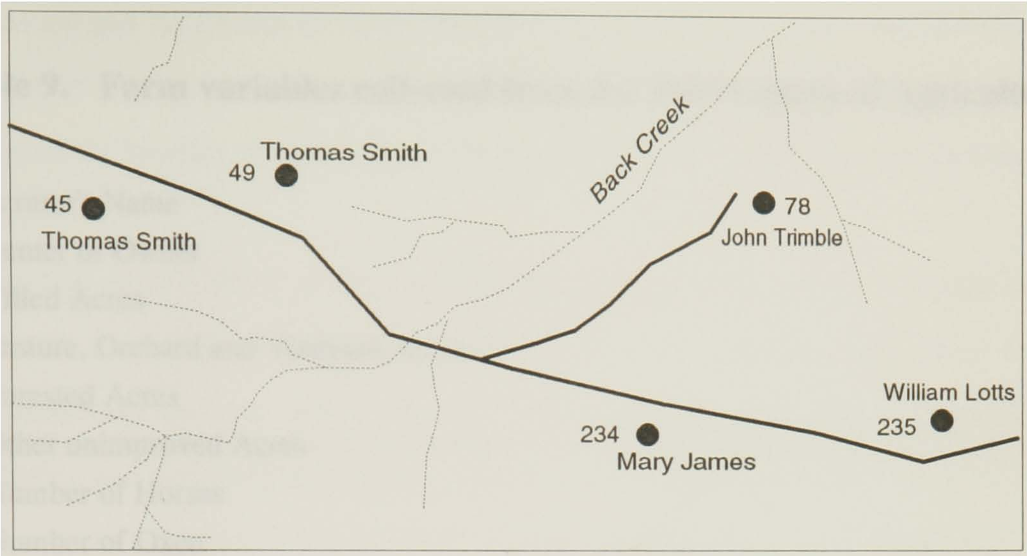
Total farm acres reported:	51,639
Total population:	4,757
Number of farms:	400

<u>Percent of farm area by land use as reported:</u>

Forest	58.7%
Wheat	16.5%
Indian Corn	12.6%
Oats	5.9%
Pasture	3.9%
Fallow	1.1%
Rye	.68%
Buckwheat	.18%

After the data were identified and collected, they were transferred to digital form. Since roads, farms, and streams were identified on the Hotchkiss map, they were all digitized using a table digitizer. The accuracy of the 1885 Hotchkiss map is not known and was not measured. Since all features came from the same map, any registration problems among the features were eliminated. Each mill and dwelling was given a unique identifier, or geocode. The owner's name for each of the 800 dwellings was identified on the Hotchkiss map and entered into a dBase file with the geocode. This process was also followed for the 37 mills that were identified on the map. When complete, this file contained the location (X,Y coordinates), geocode and owner's name of more than 800 structures.

After the Hotchkiss map was put into digital form, the 1880 Census records had to be put in digital form. Data for each farm in the study area were collected from the United States Census of Agriculture for 1880. It was decided that the additional work to add all of the agricultural data for each farm would be minimal, thus this was done to increase future research possibilities. Handwritten records for the 400 farms were entered into a second dBase file (Table 9). The two files were then merged by matching the farmers' names. The Hotchkiss map did not recognize renters, thus renters reported in the census were matched to a house based on the order of names in the census recorder's ledger (Figure 7). The census taker apparently went door to door, as neighbors appear next to each other in the census records. By process of elimination, some renter locations could be identified this way. Some names were also checked in the Census of Population which listed all 4,757 district residents (Figure 7). This was done to identify cases in which the renter or sharecropper lived with the owner of the dwelling. The Census of



Sample of Hotchkiss map with "id" numbers added.

Census of Agriculture Sample

1. Thomas Smith	Owner
2. Robert Hess	Renter
3. Frank Gibb	Renter
4. M.G. James	Owner
5. W.T Lotts	Owner

Cenus of Population Sample

1.Thomas Smith		farmer(45)
	Jane Smith	wife/homemaker
	Bobby Smith	son/at home
2.Robert Hess		farmer (49)
3.John Trimble		preacher
	Mary Trimble	wife/homemaker
	Frank Gibb	tenant farmer(78)
4.Mary James		farmer(234)
	Laura James	sister/farmer
5.William Lotts		farmer(235)
	Heather Lotts	wife/nurse

Two examples show how to find location of renters:

1. From name order in Census of Agriculture: Robert Hess most likely lived at site 49.
2. From Census of Population: Frank Gibb, a farmer lived with John Trimble, a preacher, at site 78.

Figure 7. Name matching for database generation

Table 9. Farm variables collected from the 1880 Census of Agriculture

1. Farmer's Name
2. Renter or Owner
3. Tilled Acres
4. Pasture, Orchard and Vineyard Acres
5. Forested Acres
6. Other unimproved Acres
7. Number of Horses
8. Number of Oxen
9. Number of Milk Cows
10. Number of Other Cattle
11. Number of Sheep
12. Number of Swine
13. Number of Poultry
14. Acres in Barley
15. Bushels of Barley Produced
16. Acres in Buckwheat
17. Bushels of Buckwheat Produced
18. Acres in Indian Corn
19. Bushels of Indian Corn Produced
20. Acres in Oats
21. Bushels of Oats Produced
22. Acres in Rye
23. Bushels of Rye Produced
24. Acres in Wheat
25. Bushels of Wheat Produced
26. Cords of Wood Cut

Population and the Census of Agriculture were done at the same time, thus the sequence of farmers' names were the same, which allowed cross comparisons. The final file contained the location of each farm (X,Y), a geocode and the variables listed in Table 9.

Ninety-two percent (369) of the 400 farms reported in the census were located on the Hotchkiss map. The Riverheads district had 36 water powered mills listed on the Hotchkiss map and one which was not. There were 21 grist mills, 11 sawmills, 2 distilleries and one carding machine. Census records were found for 9 of the 21 grist mills and the variables listed in Table 10 were entered into a third dBase file. One additional mill recorded in the census was not located.

Finally, each mill site was visited and interviews were conducted with landowners and long-time residents. This was done to better understand each mill site, and to obtain dates of operation and production figures for mills not recorded in the census. Interviews yielded no information on exact dates for mill operation, but some were helpful in idenfiying a mill as a saw mill, grist mill or both. In one case, a mill was "discovered", (it did not appear on the Hotchkiss map), through an interview with Richard Byrne. Mr. Byrne was also able to provide photographs (Figure 5) and shipping documents relating to the small, "unknown" Martin mill.

GIS Analysis

There were several types of software available for the GIS analysis. **IDRISI**, a raster based system developed by Clark University was chosen for this study for two reasons.

Table 10. Mill variables collected from the 1880 Census of Manufactures

1. Owner or company name
2. Investment capital
3. Number of employees
4. Months operated full time during year
5. Months operated 75% of time
6. Months operated 50% of time
7. Months idle
8. Number of stone runs
9. Maximum capacity per day in Bushels
10. Custom milling or market oriented milling?
11. Located on what stream?
12. Fall height
13. Number of wheels
14. Breadth of wheel
15. Wheel RPM
16. Wheel Horsepower
17. Bushels of wheat processed
18. Value of wheat before processing
19. Bushels of other grain processed
20. Other grain value before processing
21. Value of logs before milling
22. Value of mill supplies
23. Total value of all supplies and materials before processing
24. Board feet of lumber produced
25. Logs came from what region in county?
26. Barrels of wheat flour produced
27. Barrels of rye flour produced
28. Pounds of buckwheat flour produced
29. Pounds of barley meal produced
30. Pounds of cornmeal produced
31. Pounds of hominy produced
32. Value of all other products
33. Value of all products produced

First, the software is easy to learn and can be used on any personal computer. Secondly, the software supports network analysis which was needed to identify mill service areas

based on road distance. Two point files (farms and mills) and one line file (roads) were prepared for the **IDRISI** analysis. Before any analysis could take place, farms and mills had to be linked to the road network. A "driveway" was added from each mill and farm to the nearest road (Figure 8, Case A). In a few cases, two driveways were added when two roads were about the same distance away from the structure (Figure 8, Case B). When complete, the road layer with driveways linked every farm to every mill.

A computer routine in **IDRISI** overlaid the mills on the roads and computed the minimum distance from each road cell to the nearest mill. A second routine assigned each road cell to the nearest mill so that there was a group of roads for each mill. These road groups defined the service area for each mill under the assumption that grain was sent to the nearest mill. The road distance to the nearest mill was recorded for each farm and added to the dBase file of farm data. The techniques employed by these routines in IDRISI provided information on spatial relationships that would have been impossible to identify without the aid of the GIS. The distance and service area information added to the database by the GIS analysis provided the necessary information to perform statistical evaluations of spatial relationships between the farms and mills.

Finally, various tests and correlations were performed to identify hypothesized spatial relationships that may have existed between the farms and grist mills. The results and their explanations are discussed in Chapter 6.

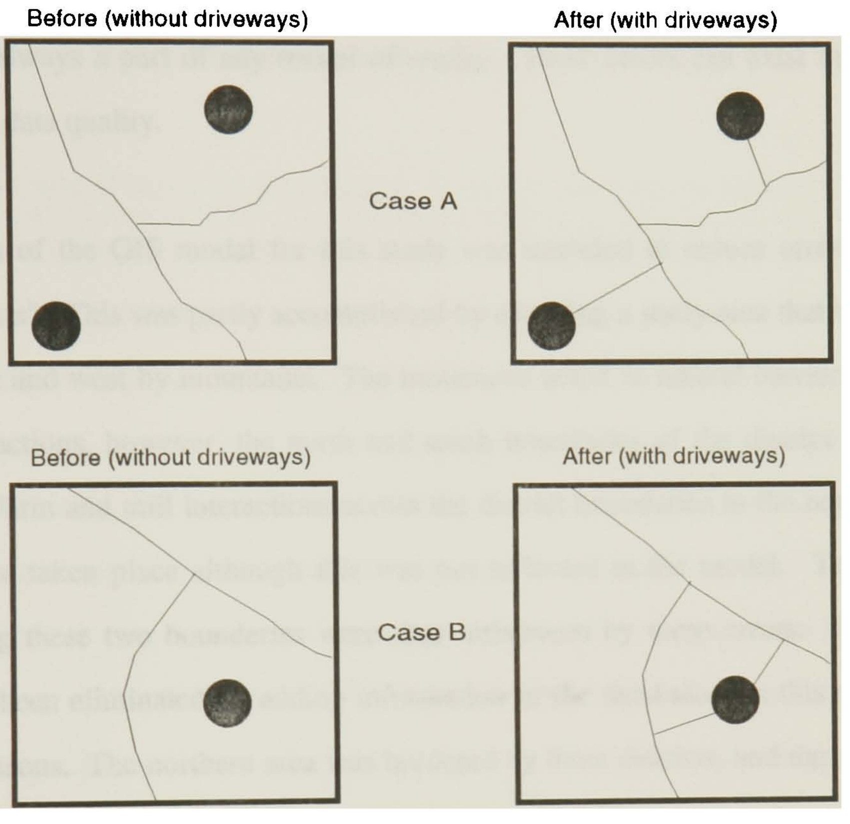


Figure 8. Examples of adding driveways to transportaion network

Error Sources in the GIS Model

A GIS database is often referred to as a model of the real world (Burrough, 1986). Spatial relationships and attributes exist in the model and in the real world, however, errors are always a part of any model of reality. These errors can exist in both model design and data quality.

The design of the GIS model for this study was intended to reduce errors created by "edge effects". This was partly accomplished by choosing a study area that was bordered on the east and west by mountains. The mountains acted as natural barriers to mill and farm interactions, however, the north and south boundaries of the district had no such barriers. Farm and mill interactions across the district boundaries in the north and south would have taken place although this was not reflected in the model. The results for areas along these two boundaries were thus influenced by these errors. This problem may have been eliminated by adding information to the database, but this was not done for two reasons. The northern area was bordered by three districts, and data collection to eliminate edge effects would have required the complete reconstruction of these three districts to be sure the border areas were correctly modeled. This would have tripled the database generation time for the project, and was not feasible. Secondly, the southern boundary was with Rockbridge county, and no map showing farm, mill and road locations in the county for the same period as the Hotchkiss map was found. A test was later done using mill service areas to determine if any edge effects were present in the model. Central areas in the district not affected by missing information were compared to the model as a whole. One would expect the unaffected service areas to have better correlations with the census data. No difference was found, either indicating the absence of edge effects or a weak model. Since edge effects to the north and south would be expected and due to many factors that could not be modeled, the most likely explanation would be a weak model. Finally, the model did not take into account a mill's size or commercial status. All mills were considered equal and not weighted to have more or less appeal based on size, capacity or price.

Data quality was affected by four factors. First, the accuracy of census takers' records depended on farmers' estimates and the census takers' ability to record information. Because all the information was handwritten over 110 years ago, some degree of error is also induced in reading the aged manuscripts. Another source of error occurred in entering the information into the computer and matching census records to map locations. Thirdly, the farm data represented areas, but in the study they represented points. It was assumed that storage and transportation network connections were near the main dwelling. It was also assumed that any grain produced would be transported out the main driveway of the dwelling, thus, representing the crops with points seemed feasible. Finally, it was impossible to determine if some mills were actually operational during the study period and should be included in the study. The impact of these sources of error in data quality and modeling on the results is not known.

Chapter 6

RESULTS AND SUMMARY

Mill Site Selection

Originally, physical data on stream flow and gradient were desired to analyze mill site selection. Lack of these data eliminated this aspect of the study. It seems that each part of the district was equally served by a mill, with the average travel distance being 1.9 miles. A few farmers located in the mountainous areas to the east and west had to travel 4 to 5.5 miles to reach a mill. From field research it was determined that most mills in the district were located on small streams, near waterfalls or steep stream slopes. It would be difficult to dermine how mill and farm development affected each other.

Service Area Analysis

Once the distance from each farm to mill was known, service areas based on each distance were identified. Service areas for the two largest crops, corn and wheat, were calculated. Most mills ground both corn and wheat, but the Bumgardner mill and distillery only ground corn. For this reason, the Bumgardner mill was eliminated from the wheat mill service area analysis. Appendix A (in rear envelope) shows the service boundaries for wheat processing mills in blue, and the service areas for the corn processing mill in green (blue lines within green area are superseded). These boundaries indicate the shortest road distance from each farm to the nearest mill.

While the GIS analysis was valid for assigning points (farms) and lines (roads) to mills based on travel distance, the service boundary map displays areas. This was done to aid in the display of the results. Since the placement of crops, and the transportation through fields are impossible to identify, the service boundaries in these areas (non-road areas) may or may not be reasonable.

It is not clear why 11 of the 21 mills were not recorded in the census. Size, commercial and operational status of the mill, were most likely considered in the census's guidelines. It was difficult to determine if mills not recorded in the census were actually in operation in the early 1880's, even though they appeared on the Hotchkiss map. Eliminating or including these questionable mills in the study could greatly influence the results. For example, it is likely that the Gilkeson grist and sawmill was not in operation for the period. This mill was located about 50 yards upstream from the McClung mill (Figure 9), which was recorded in the census. Because they were located nearly at the same point, the service area for the McClung mill could be doubled or cut in half, depending

Figure 9. McClung Mill

on the operational status of the Gilkeson mill. The present owner of the Gilkeson property believes the small mill was not in operation in the 1880's, but there is no way to verify this.

Also complicating the identification of service area boundaries was the issue of mill size. For example, the Martin mill was most likely in operation, but it was very small and may not have had a service area other than the Martin farm. This study had no way to identify the size or interactions of a mill and to thereby create a weighted model to identify more realistic service areas.

Two models were created for wheat and corn service areas. Model One includes the Gilkeson mill and Model Two does not. The hypothesis of service areas was tested by comparing the production of wheat and corn for all farms in a service area to the amount processed by its mill. (This assumes that all grain is sent to the mill, which is not the case with corn. Thus, the corn model would be expected to be weaker.) The model could only use those mills reported in the census. Table 11 displays the results for wheat, and Table 12 displays the results for corn. Predictions of production for each mill are based on the farms in the service areas identified by the GIS analysis. The mills in Tables 11 and 12 are ranked by volume processed and predicted volume processed.

The wheat predictions for Model Two (see Table 11) indicate a very strong correlation (R=.86) with actual census statistics. (A value of 1 or -1 indicates perfect positive or negative correlation while a value of 0 indicates no correlation.) This indicates that each farmer most likely went to the nearest mill. Model Two also shows that the influence of questionable data, the status of the Gilkeson mill, can affect the results greatly. Since the

Table 11. Wheat model comparisons with census data
(Bushels processed)

Model 1(Predicted)	Actual(Census of 1880)	Model 2(Predicted)*
Baylor(7661)	McClung(8000)	McClung(8855)
Smith(6052)	Baylor(6000)	Baylor(7661)
Smiley(5601)	Smith(5500)	Smith(6052)
Collins(4580)	Smiley(5000)	Smiley(5601)
McNutt(3714)	Collins(5000)	Collins(4580)
McClung(3170)	Steele(4000)	McNutt(3714)
Steele(1254)	Crawford(2200)	Steele(1254)
Crawford(485)	McNutt(2000)	Crawford(485)
R=.4701		**R=.8553**

*Gilkeson mill removed

Table 12. Corn model comparisons with census data
(Bushels and pounds processed)

Model 1(Predicted)+	Actual(Census of 1880)++	Model 2(Predicted)*+
Smith(11,980)	Bumgardner(392,000)	McClung(16,757)
Baylor(10,248)	Smith(244,000)	Smith(11,940)
Smiley(10,025)	Baylor(227,600)	Baylor(10,248)
Bumgardner(9,641)	Collins(208,000)	Smiley(10,025)
McClung(7,305)	McClung(181,800)	Bumgardner(9,641)
Collins(4,850)	Smiley(164,600)	Collins(4,850)
McNutt(4,570)	McNutt(137,000)	McNutt(4,570)
Steele(2,607)	Steele(132,700)	Steele(2,607)
Crawford(2,600)	Crawford(124,960)	Crawford(1,300)
R=.6232		**R=.4140**

+figures in bushels
++figures in pounds
*Gilkeson mill removed

models worked well, especially considering the rankings of mills based on processing volume, one would like to predict that the Gilkeson mill did not exist, or processed little wheat. While it is important to point out that other mills may also not have been operational in 1880-1885, which may have affected the results depending on their distance from competing mills, cosidering all the confounding factors, these models are very supportive of the hypothesis.

Corn service area results were less conclusive (Table 12) for two reasons. First, corn was not the largest crop, and second, some corn uses did not require corn grinding, thus not all production was sent to the mill. Distilleries processed more corn than other mills, and would have had larger service areas than grist mills. The district had two distilleries, but no census data were found for the Clemmer distillery, which was located next to the Sproul mill. These extra factors, smaller corn crops and competing mill interactions are difficult to model, and were not considered in the corn service area analysis. For these reasons, and the fact that wheat had stronger ties to the mills, the corn models were not as strong as the wheat. However, with correlation values of .86 and .41 in Model Two for wheat and corn respectively, the models show that distance was the deciding factor in choosing a mill. Therefore, it is possible to reconstruct and verify economic activity of grain milling over a century ago through GIS.

Wheat Production and Distance Analysis

While the service area analysis used the aggregate data from groups of farms, it is also possible to study spatial characteristics based on individual farms. Several tests were conducted to verify the hypothesis that crop productions were correlated with distance from the mills. The mills reported wheat, corn, buckwheat and rye processing, and each of these crops was tested. Regression analysis was done with distance from farm to mill, and bushels produced as the independent and dependent variables. Little correlation was found for corn, rye and buckwheat, and only a slight correlation was found for wheat (R=-.16). Figure 10 shows this correlation. This small negative correlation would indicate that farms closer to the mills produced more wheat, which would be expected considering the economics of wheat production. A slight negative correlation (-.10) of yield per acre and distance to mill was also found. Figure 11 shows the data from Figure 10 presented graphically in the form of a map. The proportional circle map illustrates how GIS data can be presented using computer cartography in way that may be easier to understand than a graph or table.

To examine the results in a non-linear manner, the farms were grouped into 11 classes based on their distance from the mills. When mean yield per class was examined, a correlation of -.73 was found (Table 13). The correlation coefficient for this method indicates that classes of distance are better for testing the model because they allow for the local variation in productions and yields which would be expected. It is important to point out that not all land was owned by farmers, thus the entire district was not accounted for. Since the yield was calculated based on the total farm acres in each distance class, the correlations show that the closer a farmer was to a mill, the more likely he was to grow wheat.

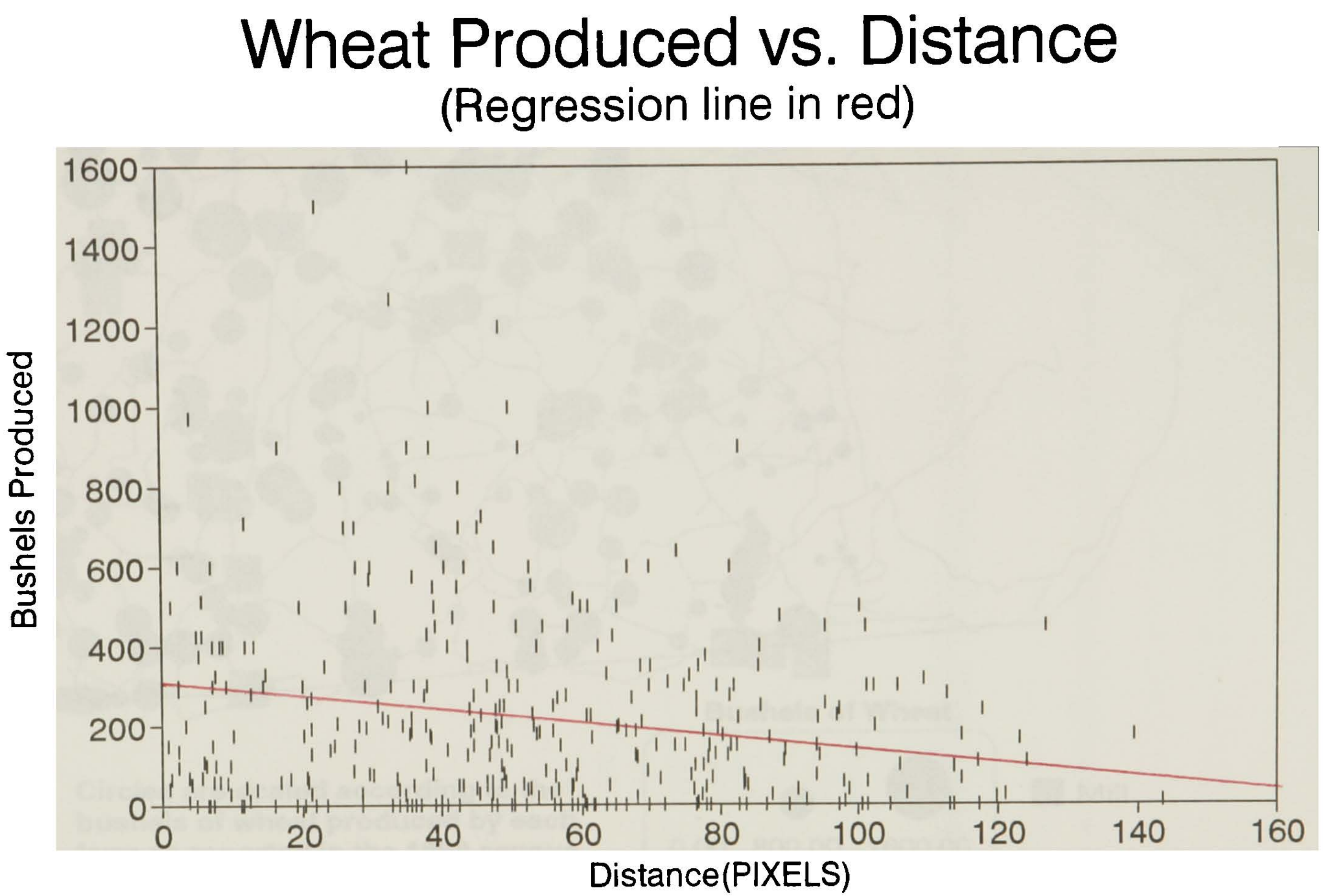


Figure 10. Graph of Wheat Production vs. Distance

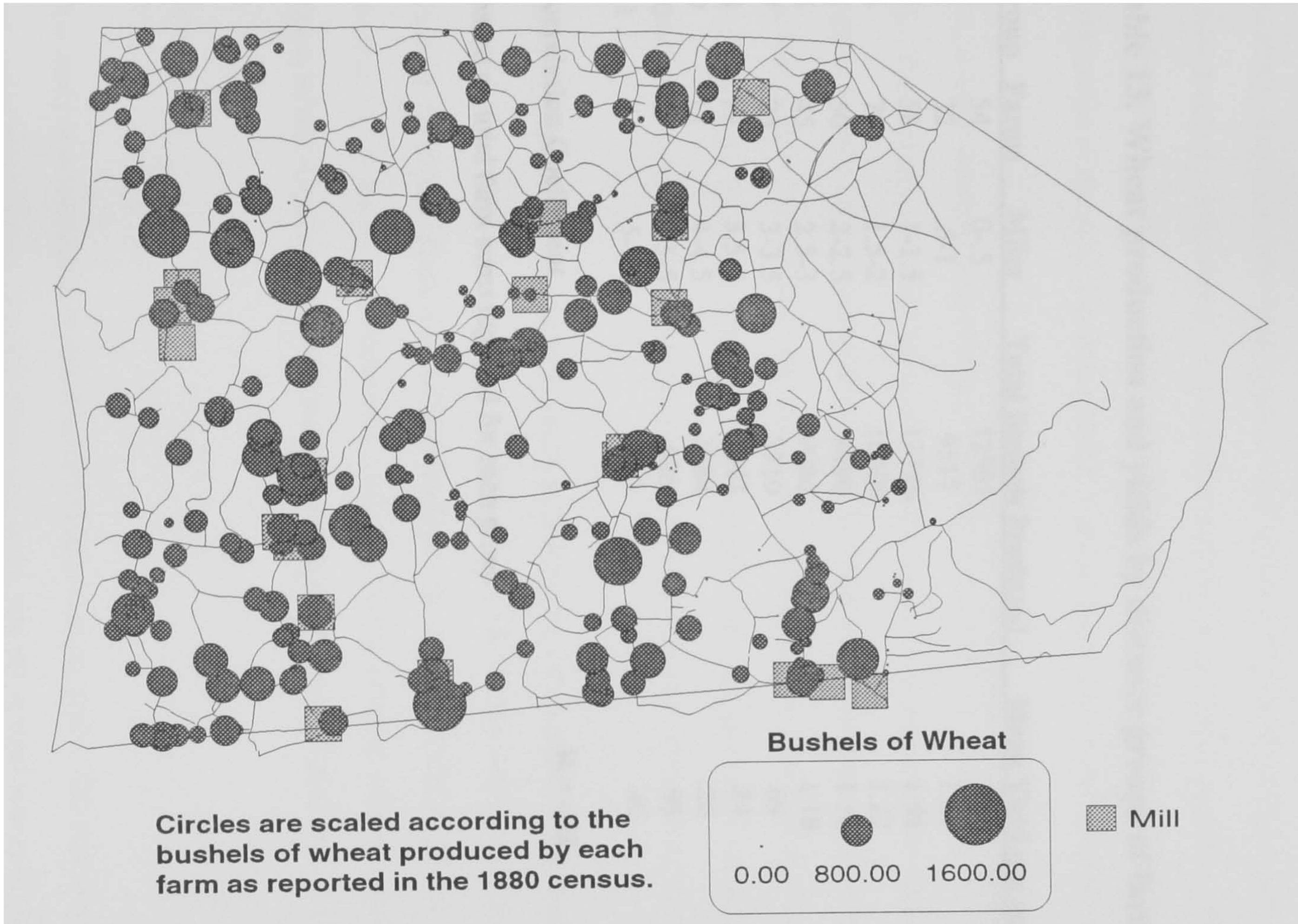


Figure 11. Proportional Circle Map of Wheat Production

Table 13. Wheat production and yields by distance groups of farms.

Group	Farms	Miles	Total Bushels Produced	Mean Yield per acre*
1	54	0-.5	12501	.90
2	32	.5-1	9517	1.61
3	58	1-1.5	17736	1.46
4	70	1.5-2	18809	1.22
5	50	2-2.5	8480	1.16
6	45	2.5-3	9086	1.18
7	25	3-3.5	3710	.69
8	19	3.5-4	3043	.84
9	13	4-4.5	1284	.26
10	2	4.5-5	626	.93
11	1	5-5.5	10	.40

Correlation Coefficient **R = -.73**

*based on total farm acres reported for each group

Suggestions for Further Study

This study identified some basic spatial relationships between wheat farms and mills, and demonstrated the importance of building a realistic model when possible. The project also demonstrated the usefulness of GIS analysis and mapping in studying spatial relationships of the past. Further research could be conducted in both of these areas.

First, a large database with multiple variables was created for this study (Tables 9 and 10). This database could be used again for research, or expanded to include all of Augusta County for a larger scale study of agriculture. The benefits of the database are that it will not go out of date, and that it contains detailed information about agriculture for the period. A database for the entire county would be useful for another historical study, but the complexity and time involved for this task may outweigh the benefits.

Secondly, historical studies have much to gain from GIS analysis. This study showed how detailed information from even 110 years ago is readily available. Further work could be done to explore how GIS technology can be specifically applied to historical research in all fields. Furthermore, methods linking existing attribute data, such as census information to spatial information such as old deeds or maps could be identified.

Summary

This study was successful in that it achieved its two main goals. The first was to identify and verify relationships between farms and mills, and the second was to demonstrate the usefulness of GIS analysis in historical research. There were several sources of error in the models, and the age and complexity of the problems made it difficult to eliminate the potential sources of error. Though the data were over 100 years old, the database created was detailed and provided coverage for 92% of the farms.

Two spatial relationships were identified in the study through GIS network analysis. The model showed that farmers most likely went to the nearest mill by the shortest road distance. This was expected since the transportation costs of grain were high. Secondly, a relationship between road distance and wheat production was found. Farmers closer to a mill were more likely to grow wheat than farmers farther away from the mill. This would also be expected since farmers closer to the mill had the economic advantage of low transportation costs. Spatial relationships based on other crops were not identified, mainly because wheat was the largest crop and the only one entirely and consistently sent to mills.

This study provides an example of how GIS analysis can be used to identify spatial patterns that no longer exist. Little literature has been produced about GIS applications in historical research other than archaeology. Historical geographers should incorporate GIS analysis when adequate data are available and there is a need to identify spatial relationships.

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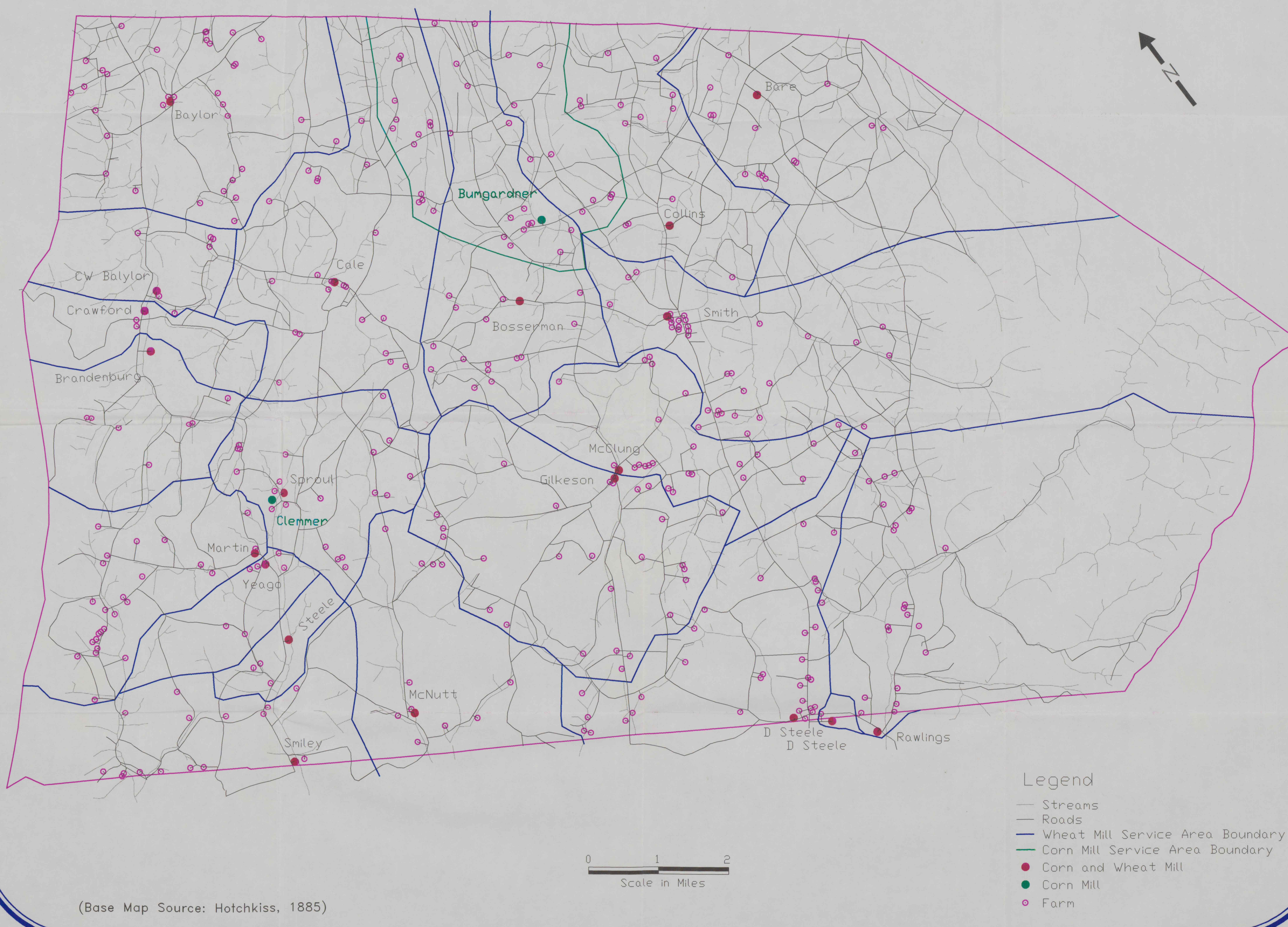
Riverheads District, 1880.



(Base Map Source: Hotchkiss, 1885)

Appendix A: Wheat and Corn Service Areas Map