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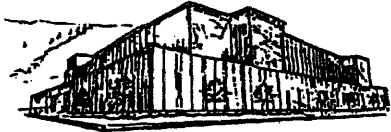
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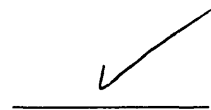
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An Assessment of the Historic Land Survey Notes and Their
Utility in Geographical Studies

by

Aron N. Langley

B.A. University of Wyoming, 1999

A thesis submitted in partial fulfillment of the

requirements for the degree of

Master of Arts


The University of Montana

2004

Approved by:



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An Assessment of the Historic Land Survey Notes and Their Utility in Geographical Studies

Chairperson: Paul B. Wilson

PW

The original land survey notes recorded by General Land Office deputy surveyors have frequently been used to characterize, interpret, evaluate, and reconstruct past landscapes throughout a large portion of the United States. The purpose of this thesis is to assess their utility in geographical and historical applications through the use of modern GIS technology.

The PLS notes contain a first hand account of the landscape from the time of settlement. They are invaluable in geographical and historical studies because they were recorded systematically for a large portion of the country.

This study found that they can be used at a variety of scales to: compare past conditions to present conditions; map the distribution of species, forest extents, and vegetation communities; relate past vegetation to ecologic, biologic, climatic, and topographic environmental factors; and to provide baselines for restoration efforts.

Small scale and large scale applications were found to differ in that the volume of data available for small scale applications allows for a more comprehensive study while large scale applications are limited. The PLS notes are often the only data available in many areas and it was determined that without the use of alternative resources, only smaller scale applications show potential to be used alone in site reconstructions.

The PLS notes showed limitations in that their generality greatly inhibited their use in comprehensive reconstructions. Other factors involved in limiting their utility include surveyor bias, fraudulent descriptions, the timing with settlement, and time consuming data entry. Inaccuracies were also apparent in the PLS surveys consulted for this study but they did not necessarily affect the utility of the notes.

The GCDB was found to be rather inaccurate for use in this thesis because of the inability to correctly locate the positions of the PLS features. This limits the ability of the GIS to test for survey accuracy but does not necessarily affect the utility of the PLS notes.

Modern GIS techniques allowed for the construction of a method to display forest densities from the time of the survey. Despite the inability in this thesis to compare these densities to present day forest densities, this method proves to add to the utility of the notes.

Similarly, the construction of the General Vegetation Map, using only the section line general descriptions in the notes, shows the ability of the PLS notes to stand alone in vegetation reconstructions.

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CHAPTER I

INTRODUCTION

The United States Public Land Survey (USPLS) is a unique rectangular land survey system that materialized out of the Land Ordinance of 1785.¹ It was designed to survey the vast amount of land in the Northwest Territory that was acquired after the Revolutionary War. It provided a method for cadastral surveying and land identification that avoided the confusion and legal disputes associated with the metes and bounds system used in the survey of the original thirteen colonies. In addition, it functioned as an effective means of preparing the public domain for settlement. The USPLS, also called the Public Land Survey System (PLSS or PLS), divided the land into townships that consisted of thirty-six square mile sections. It was a rigid geometric system that did not conform to topographic features or natural landforms inherent in the landscape.

Early surveys were conducted under the supervision of the General Land Office. The General Land Office (GLO) established offices throughout the public domain and contracted the work out to private survey teams.² Instructions were often written to the surveyors regulating the field procedure, the survey process, and required the surveyors to keep detailed field records of the survey and what they encountered. In 1855 an

¹ United States Department of Agriculture, *Land Use and its Patterns in the United States*, by F. J. Marschner, Agricultural Handbook No 153, Farm Economics Research Division, Agricultural Research Service, (Washington D.C., 1959). P 15.

² Hildegard Binder Johnson, *Order upon the land: the U.S. rectangular survey and the Upper Mississippi Country* (New York: Oxford University Press, 1976). P 56.

official manual of survey instructions was written at the direction of the commissioner of the GLO.³ The *Manual of Survey Instructions 1855* replaced all previous manuals written by the various land offices and became the official guideline for the surveys that followed.⁴ This manual ensured that the surveyors' notes were always recorded in precisely the same way. The result is an organized and consistent description of the landscape at the time of the survey.

For a large portion of the United States, the original GLO survey notes are among the only data sources that provide a standardized and systematic look at the characteristics of the land and its resources at the time of the survey. They have been used in a variety of ecological, geographical and historical studies of former forests and landscapes. They are most commonly used as an aid in qualitative or quantitative studies of these former landscapes for the purpose of comparing them to present landscapes.⁵ The notes however, were not recorded for scientific purposes and lack detail in this regard.

The GLO notes are known to consist of vague and general information about the

³ Lowell O. Stewart, *Public Land Surveys: History, Instructions, Methods* (Ames: Collegiate Press, Inc., 1935), 93.

⁴ Stewart, 91-92 & 173.

⁵ See Eric A. Bourdo Jr., "A Review of the General land Office Survey and of its Use in Quantitative Studies of Former Forests," *Ecology* 37 no 4 (October 1956); Lee C. Buffington and Carlton H. Herbel, "Vegetational Changes on a Semidesert Grassland Range From 1858 to 1963," *Ecological Monographs* 35 no. 2, (Spring 1965); Eric C. Grimm, "Fire and other Factors Controlling the Big Woods Vegetation of Minnesota in the Mid-Nineteenth Century" *Ecological Monographs*, 54 issue 3 (Sept 1984), 291-311; W. Carter Johnson, "Woodland Expansion in the Platte River, Nebraska: Patterns and Causes," *Ecological Monographs* 64 no. 1, (Feb. 1994); H. Taylor Rankin and D.E. Davis, "Woody Vegetation in the Black Belt Prairie of Montgomery County, Alabama, in 1845-46," *Ecology* 52 no. 4, (Summer 1971); Allen E. Sullivan. "The Expected Potential Natural Vegetation of the Kittitas Valley, Central Washington: A Soils Based Approach to the Reconstruction of Vegetation Landscapes" (PhD Dissertation, Oregon State University, 2000).

landscape; common names were used to represent tree species, distances to features were often estimated, and the abundance of features were described with categorical values like few, some, and many. Additionally, the notes are known to contain surveyor bias towards bearing tree selection⁶ and therefore should not be considered a true representation of vegetation cover. Early instructions ask for bearing trees to be, “the size and kind that experience tells us will be the most permanent and lasting,”⁷ allowing the surveyor to choose which trees would be blazed and marked. Bias in tree selection in the PLS notes makes quantitative studies of former landscapes difficult. Furthermore, fraud and error in the survey process is known to exist.⁸

Regardless of the limitations that are known to exist, the GLO notes are a valuable resource that can provide insight into the past. It is important to understand the limitations and the historical and geographical utility of the notes. **The purpose of this thesis is to assess the content and evaluate the utility of the original land survey notes for a portion of Boulder County, Colorado.**

To accomplish this, the first step will be to trace briefly the history of the PLSS, describe the process of the surveys, and examine the intricacies of the survey notes. The next step will be to thoroughly examine the original land survey notes for a portion of Boulder County, Colorado that were recorded from 1863 to 1883. This will be accomplished by transferring the survey notes for the study area from microfiche form

⁶ Eric A. Bourdo Jr., “A Review of the General Land Office Survey and of its Use in Quantitative Studies of Former Forests,” *Ecology* 37 no 4 (October 1956), Grimm, 291-311. Kristen L. Manies, David J. Mladenoff, and Erik V. Nordheim, “Assessing Large-Scale Surveyor Variability in the Historic Forest Data of the Original U.S. Public Land Survey” *Canadian Journal of Forest Research* 31 (2001) 1719-1730.

⁷ Stewart, 122.

⁸ Ibid, 53-58, 63-64, 66-69. S. M. Galatowitsch, “Using the Original Land Survey Notes to Reconstruct Presettlement Landscapes in the American West” *Great Basin Naturalist* 50 no 2, (1990).

into a digital database that can be used in a geographic information system (GIS). Maps, products, and findings extracted from the Boulder County PLS notes will add to the historical and geographical utility of the notes. The PLS notes for the study area will provide a sample that will show what can and cannot be accomplished when using the notes in historical and geographical studies.

A brief history of the PLSS, a discussion about many of the issues pertaining to the process of the survey and a description of survey records will be included in the next chapter along with additional background information relevant to the thesis. Chapter III will describe the methods that were used to extract information and create products from the PLS notes. Chapter IV will discuss the products and findings as they pertain to the utility of the PLS notes. Finally, the last chapter will discuss how the notes can and cannot be appropriately used in historical and geographical studies and a conclusion about the historical significance of the original land survey notes.

CHAPTER II

BACKGROUND

This chapter is intended to provide the necessary background information relevant to the topic and act as a tool for framing the research of this thesis. This requires a discussion about the history of the PLSS, the different sets of instructions that guided the surveyors, the structure and content of the surveyors' field notebooks, and additional background information about GIS, the Geographic Coordinate Database, Küchler's Potential Natural Vegetation Map, the Colorado Vegetation Model (CVM), and how they relate to the thesis. A section will also be included that discusses the known limitations inherent in using the PLS notes in historical and geographical studies. Finally, an overview of the Boulder County, Colorado study area will be included. References to previous literature will be provided throughout the chapter.

History of the Public Land Survey

The United States began as a poor and fledgling country, but knowledge and years of experience gave birth to one of the finest land survey systems in history and provided a way for the government to build its treasury. Some of the greatest minds in our history came together and devised a plan to build and settle the vast lands that were acquired following the Revolutionary War. The following section discusses the process in which

the United States Public Land Survey System was created and how the settlement of the vast western lands was accomplished.

The Period Following the Revolutionary War

The United States gained title to the lands east of the Mississippi River from the English crown in 1783.⁹ At that time, congress faced a large war debt and the newly acquired lands were quickly seen as a possible revenue producing asset. Thomas Jefferson formed a committee whose job was to draft an effective system for surveying and preparing the vast western lands for settlement.¹⁰ The draft appeared before congress in 1784, and on May 20 of the next year, congress passed the Land Ordinance of 1785.¹¹

The Land Ordinance of 1785

The Land Ordinance of 1785, officially titled “An Ordinance for Ascertaining the Mode of Disposing of Lands in the Western Territory,”¹² was a revision of the draft proposed by Jefferson.¹³ Jefferson’s plan was to divide the land into townships, or hundreds, that were ten miles squared then further divided into lots that were one mile

⁹ C. Albert White, *History of the Rectangular Survey System*, (Washington D.C., Department of the Interior, Bureau of Land Management, 1983) 10.

¹⁰ C. Albert White, 11; Johnson, 40; William D.Pattison. “Beginnings of the American Rectangular Land Survey System, 1784-1800” (PhD Dissertation, University of Chicago, 1957) 15; Stewart, 15.

¹¹ C. Albert White, 11; Johnson, 45; John G. McEntyre, *Land Survey Systems* (New York, Santa Barbara, Chichester, Brisbane, Toronto: John Wiley & Sons, 1978). P 38; Stewart, 16.

¹² C. Albert White, 11; Johnson, 43; McEntyre, 38; Stewart, 16.

¹³ Stewart, 2.

square that could be sold separately.¹⁴ The final draft, proposed by a committee headed by a Virginian named William Grayson, changed the township size to seven miles square and offered whole townships for sale rather than one-mile tracts.¹⁵ The debate over the size of the tracts to be sold and how to divide the land drew criticism from both political sides. The final plan needed to be flexible due to political pressures so in the end the townships became six miles square and could be sold individually or in one mile tracts.¹⁶

The Land Ordinance of 1785 was vague in terms of how to conduct the surveys in the field.¹⁷ Specifics were left out regarding the execution of the surveys, the requirements for the content of the field notebooks, the equipment to be used, and the basic process of conducting and recording the survey. It was a crude, effective ordinance, but it was not without its problems. The next section discusses some of those problems and issues associated with the first surveys of the public domain conducted in Ohio.

The Seven Ranges

Ohio became the proving ground for the United States Public Land Survey. Surveys began immediately following the passing of the land ordinance in 1785 at a point of beginning where the Ohio River intersected the previously established western boundary of Pennsylvania¹⁸ (Figure 2.1). These first surveys have come to be known as

¹⁴ Stewart, 2.

¹⁵ Stewart, 2.

¹⁶ Stewart, 2.

¹⁷ C. Albert White, 15.

¹⁸ Pattison, 119.

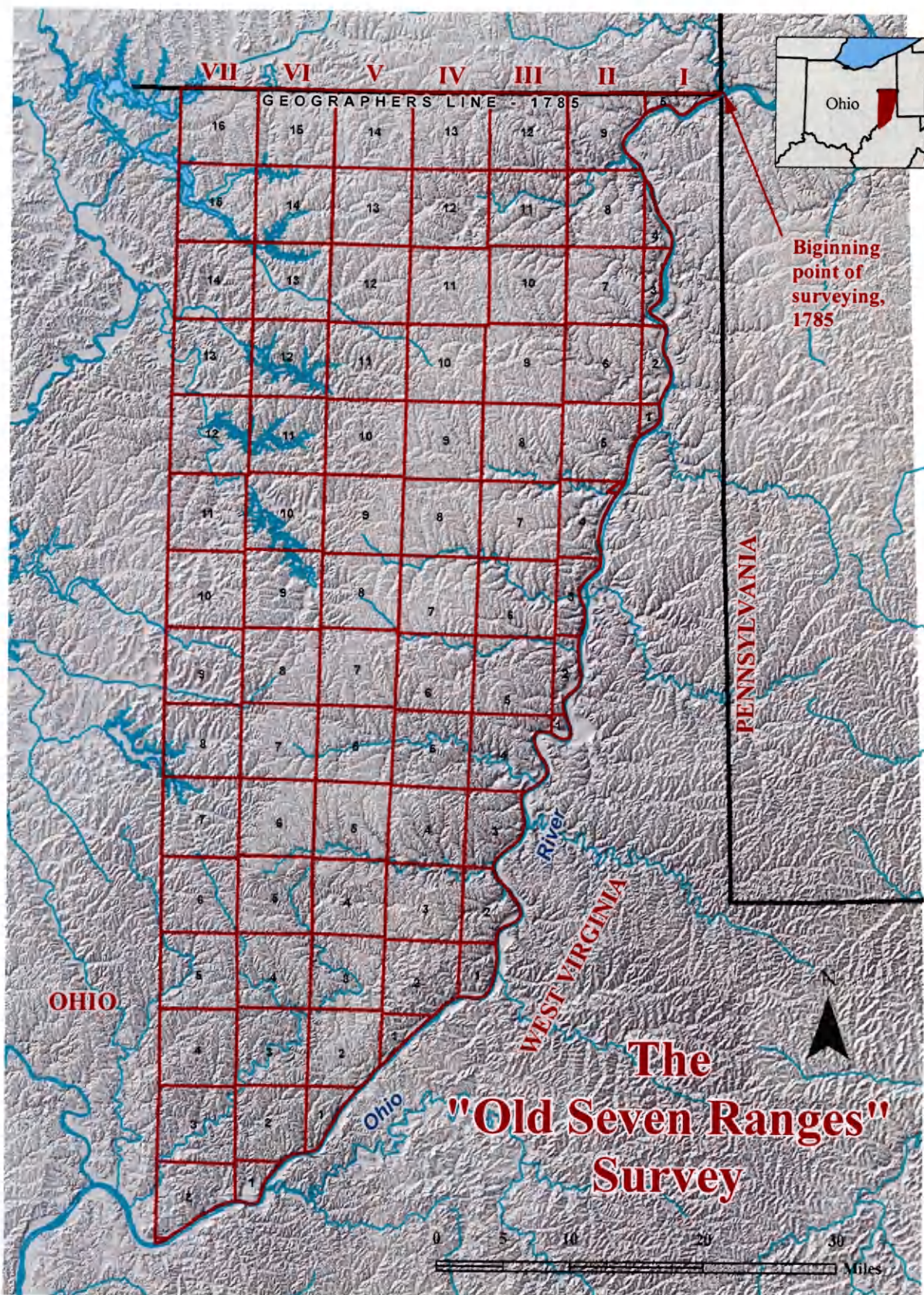


Figure 2.1 The Seven Ranges Survey. Note the beginning point of the surveys and the method of numbering sections.

the survey of the seven ranges.¹⁹ Thomas Hutchins, geographer of the United States, was the overseer of the surveys.²⁰ He led eight surveyors in the survey of the first east-west line,²¹ and then suspended the first year of surveying after just two weeks. Only four miles had been run before conflicts with local Native American tribes began to arise.²²

The following year proved more of the same with only four ranges being completed. Congress repealed a requirement that surveyors run boundary lines along the true meridian in order to speed the process,²³ and military protection from hostile tribes was obtained,²⁴ yet despite the enthusiasm and changes, the expectations of congress had not been met. Congress expected the completion of seven ranges in the first year, yet they were left with the realization that the breadth and the cost of the surveys was going to be much more than initially expected unless considerable alterations were made to the survey process. They decided to halt the surveys at that point believing that the seven ranges survey was a failure.

Eventually, the survey of the seven ranges was completed, three years after it began. Although it seen as a failure at the time, and it was poorly executed and inconsistent, today it is seen as the historically significant beginning of the American rectangular system of land surveying in which invaluable lessons had been learned.

¹⁹ Pattison, 105.

²⁰ C. Albert White, 18.

²¹ Known today as the "Geographers Line." C. Albert White, 19.

²² C. Albert White, 18.

²³ C. Albert White, 18.

²⁴ Pattison, 134.

Surveying and Legislation 1788-1796

Following the survey of the seven ranges, congress began granting large tracts of land to private companies. These companies contracted surveyors by the mile to conduct surveys of their land.²⁵ Settlers could buy land from the private companies at a lower price than what was previously offered by the government. Congress found that settlers were buying from the private companies and that no revenue was coming in from their land sales.²⁶ Alexander Hamilton devised a plan that would eventually solve the dilemma. His plan spawned the creation of the contract system and the position of the Surveyor General.²⁷

The Act of May 18, 1796 officially established the office of the Surveyor General. The duty of the surveyor general was to hire deputy surveyors and to inform, instruct, and regulate the work of those deputies and to implement the surveys that were under his direction.²⁸ This new amended land law, which was essentially a re-write of the 1785 land ordinance with a few additions, brought new direction and organization to the process and allowed the land surveys to resume. The contract system that began under this land law became the backbone of the PLSS and solved many of the issues that arose following the survey of the seven ranges.

Several things must be noted about the first surveys. First, they were completed without any formal instructions as to the survey procedure.²⁹ Surveyors worked

²⁵ C. Albert White, 24.

²⁶ C. Albert White, 28.

²⁷ C. Albert White, 28.

²⁸ C. Albert White, 29.

²⁹ McEntyre, 40.

independently and each conducted his survey differently; the process was not standardized. Second, the surveys were very time consuming. Without instructions and a standardized method of survey, mistakes were made often meaning that the surveyors had to work slowly in order to successfully complete the surveys. Further, because the procedure was not well established, it took time to work out the imminent issues. Third, congress received very little revenue from the sale of the lands.³⁰ The cost of the survey was high, and it took much longer than expected. Revenue never materialized but the benefits of the rectangular survey system outweighed the costs so the surveys continued.

Ohio saw at least six different survey systems.³¹ It was a place of experimentation for the government surveys. What may have looked like chaos was in fact a testing ground for over a hundred of years worth of knowledge (Figure 2.2). These early surveys were crude but effective in opening the public domain for settlement. They were without a doubt, far more effective than the previous methods of land identification. With this realization, congress soon began authorizing more money for the advancement of westward settlement.³²

Surveying and Legislation 1796-1812

Several acts appeared following the Act of 1796. These covered problems related to field procedures and began to standardize the survey process. The act of March 1, 1800 established the precedent that the corners set by the original surveyor, were the

³⁰ C. Albert White, 28.

³¹ Johnson, 48.

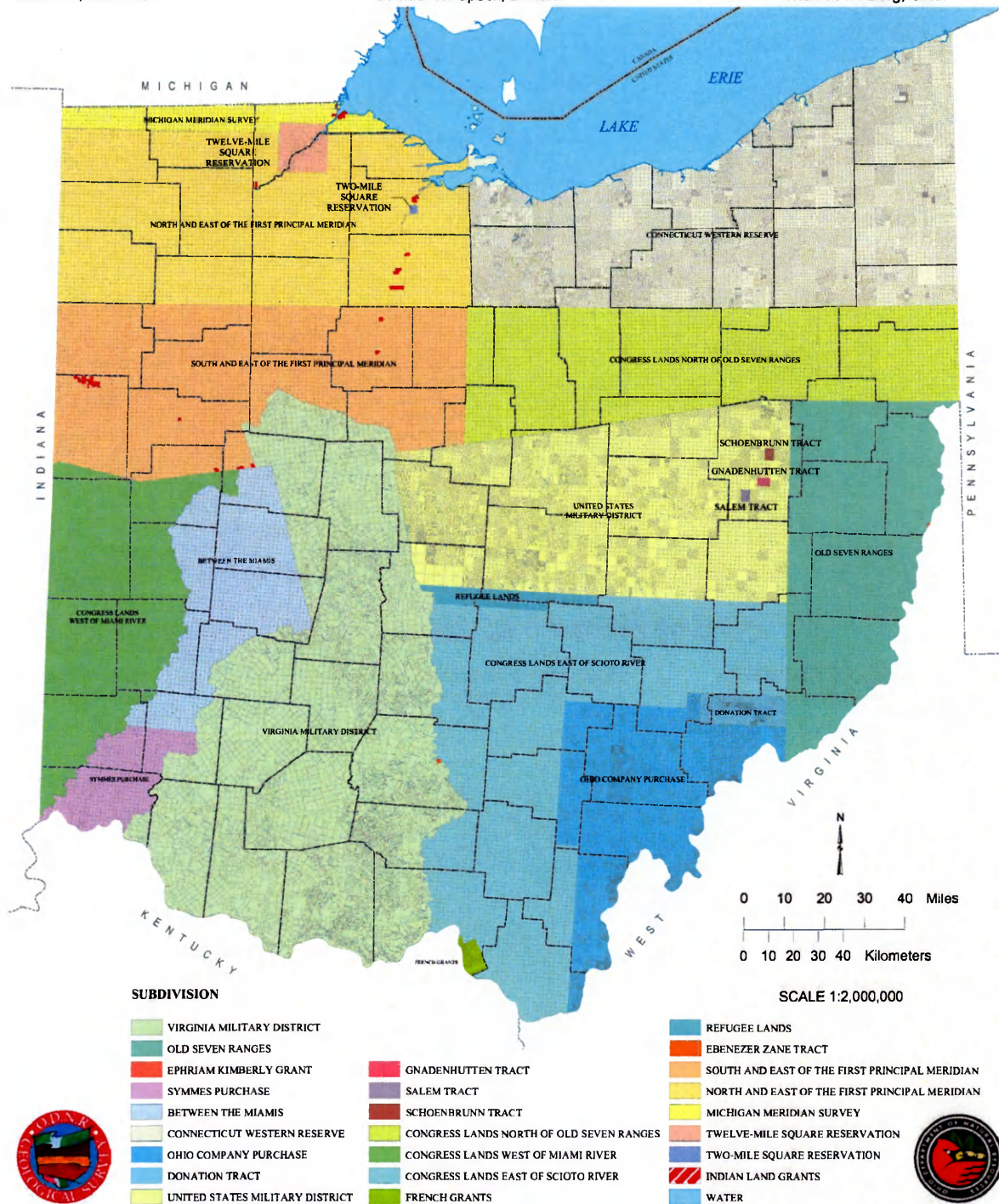
³² Johnson, 57.

ORIGINAL LAND SUBDIVISIONS OF OHIO

STATE OF OHIO
Bob Taft, Governor

DEPARTMENT OF NATURAL RESOURCES
Samuel W. Speck, Director

DIVISION OF GEOLOGICAL SURVEY
Thomas M. Berg, Chief



Generalized version of map MG-2, available as 1:500,000-scale (poster-size) print and in digital (GIS) format. To order contact Geologic Records Center (614) 265-6576

Figure 2.2 Original Land Subdivisions of Ohio. This map was created by the Ohio Department of natural Resources and can be found online at the web address below <<http://www.dnr.state.oh.us/geosurvey/gen/map/map.htm>>

legal corners for the survey, regardless of whether they were set correctly or not.³³ The Act of May 10, 1800 established that all section lines be run in the field so that the section could be easily identified when re-locating it at a later time. Furthermore, it stated that the inconsistencies resulting from convergence be corrected in the north and west portion of the township. Inconsistencies due to the convergence of north-south meridians were already known to the surveyors, but no official instructions were issued on how to correct for them at this point. Lastly, this act established the first land offices, four in Ohio, that controlled the surveys under their jurisdiction.³⁴

In 1804 the surveyor general, Jared Mansfield, ordered the use of correction lines to correct for convergence.³⁵ In later instructions these correction lines became known as standard parallels. It was a major step in the survey process and allowed for the townships to remain somewhat square. The procedure was not fully established until later instructions were issued, but it was the first attempt at correcting for convergence.

In 1812 a new government office was created called the General Land Office (GLO).³⁶ This office controlled the surveys and the sale of the lands and was headed by a chief officer who was named the Commissioner of the General Land Office.³⁷ Also by this time, numerous land offices had been established as the surveys progressed, so the GLO was tasked with administering the entire survey process.

³³ McEntyre, 44.

³⁴ Johnson, 57.

³⁵ Johnson, 57.

³⁶ Johnson, 61.

³⁷ McEntyre, 47-48.

The GLO was reorganized in 1836,³⁸ transferred from the Department of the Treasury to the new Department of the Interior in 1849,³⁹ and merged with the Grazing Service to form the Bureau of Land Management in 1946.⁴⁰

Instructions to the Surveyors

Early surveys were conducted without official instructions to the surveyors aside from what was communicated to them through their representative surveyor general, who was often in the field with them. The surveyors mostly relied on information within the congressional acts to perform the surveys. The surveyor generals were responsible for the surveys within their jurisdiction and each instructed their deputies according to their own principles. There was consistency within each jurisdiction, and none of the jurisdictions overlapped so there were no real issues at the time. Each surveyor general, however, did instruct the deputies differently and this was eventually seen as a problem. The General Land Office issued an official set of instructions in 1855 to standardize the survey procedure. This manual became the guideline for all of the surveys that followed. The following section discusses more on the history of the survey process and the evolution of the survey manuals that appeared throughout.

As the surveys progressed, the number of land offices increased as did the number of surveyors general. Each surveyor general implemented the surveys under his jurisdiction and often wrote instructions to the deputy surveyors that were hired.⁴¹ The

³⁸ Stewart, 46.

³⁹ Johnson, 61.

⁴⁰ C. Albert White, 192.

⁴¹ Stewart, 40-41.

first set of instructions came from Jared Mansfield in 1804. His instructions described instrument use, the process of marking boundary corners and bearing trees, and a plan for recording field notes and plats.⁴² They lacked however, sufficient detail and procedural information. The most well known initial set of instructions came from Edward Tiffin. Tiffin was appointed as the first Commissioner of the GLO in 1812 but wanted to work more closely with the surveys so he took the job of surveyor general for the lands north of the Ohio River in 1814.⁴³ It was here that he wrote his set of survey instructions to his deputies in 1815.⁴⁴ Tiffin's instructions were similar to Mansfield's but included more detail. He was concerned with accuracy, consistency, and procedural information; something that was left out of the acts and ordinances passed by congress. He required the deputies to test the accuracy of the instruments to ensure consistency. He also required the use of specific instruments in order to standardize the survey process.⁴⁵ Finally, he introduced a method to correct for convergence that became the standard for all of the public land surveys that followed.⁴⁶ Tiffin held this position for fifteen years.⁴⁷ While he was in office, numerous surveyor generals used Tiffin's instructions as a guideline for the surveys under their control. Tiffin left his position in 1829, and soon after, the GLO was reorganized.⁴⁸

⁴² McEntyre, 52.

⁴³ Stewart, 43.

⁴⁴ Stewart, 44.

⁴⁵ McEntyre, 62-63.

⁴⁶ Stewart, 44.

⁴⁷ Stewart, 43.

⁴⁸ C. Albert White. 88.

Between 1815, when Tiffin's instructions were first issued, and 1855 when the GLO issued the first official manual of survey instructions, nearly every surveyor general issued a set of instructions to his deputies in various forms.⁴⁹ Many of these instructions followed the same guidelines as Tiffin's instructions, but there were definitive differences among them. For this reason, and for the purpose of further standardizing the survey process and procedure, the General Land Office issued its Manual of Survey Instructions of 1855 at the direction of the Commissioner of the GLO to replace the previous manuals written by the various land offices. Officially titled *Instructions to the Surveyors General of the Public Lands of the United States for Those Surveying Districts Established in and Since the Year 1850 Containing Also, a Manual of Instructions to Regulate the Field Operations of Deputy Surveyors*,⁵⁰ it became the official guideline for all the surveys that followed.⁵¹ Subsequent manuals were issued from time to time (1871, 1881, 1890, 1894, 1902, 1930, 1947, and 1973)⁵² in order to address changes in equipment or technology but the original surveys of the public domain following 1855 were completed under one standardized and systematic set of instructions.

The manual of 1855 required the deputy surveyors to record in their field books "everything officially done and observed by the surveyor and his assistants."⁵³ These field books contain all of "the elements from which the plats and calculations...are made" and they are the "source wherefrom the description and evidence of locations and

⁴⁹ C. Albert White, 90.

⁵⁰ McEntyre 94.

⁵¹ Stewart, 91-93 & 173

⁵² McEntyre, 94.

⁵³ Stewart, 184.

boundaries are officially delineated and set forth.”⁵⁴ The survey notes were the official record of the survey. Additionally, they contained descriptive information about the landscape that was surveyed. It is this descriptive information that is of most interest to geographers and researchers because it provides an actual sample of the vegetation composition, topographic features, and patterns of settlement at the time of the survey. Additionally, it was recorded in a systematic and standardized manner, separating it from other sources of historical information, which are rare and difficult to find. The next section discusses the information required by the surveyors to be recorded in their field notebooks according to the 1855 manual of survey instructions.

The Survey Notes

The information in the notes was recorded for legal rather than scientific purposes so it is rather general in this regard. The descriptive information was recorded for two reasons; one, to describe the land to settlers who may be purchasing it, and two, to help in the re-location of the parcels at a later time.

General Descriptions

The manual states that the surveyors were to record “a full and complete topographical description of the country surveyed, as to every matter of useful information, or likely to gratify public curiosity.”⁵⁵ The surveyors were also required to record the notes in precisely the order in which the work was done on the ground. For

⁵⁴ Stewart, 184.

⁵⁵ Stewart, 184.

interior section lines, and township and range lines, features were recorded as they were crossed by the line of survey, including their distances in chains⁵⁶ from previously established corners. Following the survey of the line, a general description of the line was written describing the surface, soil, minerals, timber, and undergrowth. These general descriptions of section lines have been used in past studies to recreate the landscape at the time of the survey. Buffington and Herbel re-created the vegetation of the Jornada Plain in New Mexico using the section line general descriptions to assess vegetational changes that have occurred in the study area possibly due to grazing.⁵⁷ Their vegetation map was very detailed and may have come from multiple sources including the section line general descriptions.

Finally, at its completion, a general description of the township was required in which the surveyor would describe “any information touching any matter or thing connected with the township...and may deem useful and necessary to be known...with respects to the face of the country, its soil and geologic features, timber, minerals, waters, etc.”⁵⁸ Basic instructions are given to the surveyors as for what should be recorded in the general descriptions of the townships and the section lines, but it was left to the surveyor to decide how much detail was recorded. Some surveyors were more detailed than others. This will be discussed in Chapter IV, but it is important to note that the manual did not require the surveyors to record the general descriptions in great detail. However,

⁵⁶ Measurements were done in chains. Each chain was 66 ft. long and had 100 links. More information on the survey of the township lines, the section lines, and the chain that was used is included later in the chapter.

⁵⁷ Lee C. Buffington and Carlton H. Herbel, “Vegetational Changes on a Semidesert Grassland Range From 1858 to 1963,” *Ecological Monographs* 35 no. 2, (Spring 1965).

⁵⁸ Stewart, 186.

when surveying section lines and township lines, the instructions required the surveyors to be much more systematic in their record keeping and in doing so, the notes became more consistent between surveyors.

Township and Section Line Surveys

Outer township lines were always surveyed first in advance of the interior section lines.⁵⁹ Distance measurements were made with a chain that was sixty-six feet in length. Each chain had 100 links.⁶⁰ Chains were often checked for accuracy to ensure correct measurements.⁶¹ Township boundaries were six miles in length and corner posts were set at mile and half-mile intervals. The network that is created produces tracts of land, called sections, and quarter sections. Each section is one mile per side and contains approximately 640 acres of land. Quarter sections are one half mile per side and contain 160 acres of land. Township corners and section corners were set and marked with four bearing trees, one in each adjacent section. Quarter section corners were marked with two bearing trees, one in each section. In many cases, there were not enough trees available to be used as bearing trees. Anywhere from zero to four bearing trees were marked for section corners and zero to two were marked for quarter section corners. The species and diameter of each bearing tree was recorded including its bearing and distance

⁵⁹ Max, Hutchison. "A Guide to Understanding, Interpreting, and Using the Public Land Survey Field Notes in Illinois" *Natural Areas Journal*, 8 no 4 (1988). 246.

⁶⁰ Stewart, 174-175.

⁶¹ Stewart, 175.

in chains and links to its respective corner. Any trees intersecting the line of survey were noted in the same way.⁶²

In the process of surveying the township and section lines, surveyors noted the width and location of topographic features including; water courses, landscape changes, ravines, ridges, swamps, timber stands, lakes, and other geologic and geographic events like mineral deposits or windfalls. Patterns of settlement and improvements were also recorded including; wagon roads, railroad lines, fence lines, irrigation ditches, mining claims, cabins and trails. Following the recording of these features and the completion of the survey, the surveyor was to submit a plat map of the lines surveyed noting the locations of each of the features “to the fullest extent practicable.”⁶³

Additional Information

The features, as discussed above, recorded in the original survey notes for the study area in Boulder County, Colorado were transferred from their microfiche form into a digital form so that they could be used in a GIS. An overview of the study area is included later in this chapter and the process of transferring the notes into a digital form is discussed in Chapter III. This section outlines and defines the terminology used in the thesis in order to guide the reader in understanding the processes employed throughout. This will include the role of GIS, and descriptions of the spatial data used. Additionally, this section will discuss the role of the Geographic Coordinate Database (GCDB),

⁶² Stewart, 174-186.

⁶³ Stewart, 184-186.

Küchler's Potential Natural Vegetation map and manual, the Colorado Vegetation Model (CVM), and bias fraud and error associated with the surveys.

GIS

Geographic Information Systems (GIS) can be defined as “computer-based systems that can deal with virtually any type of information about features that can be referenced by geographical location”⁶⁴ They are tools used for the storage, analysis, communication, modeling, and display of spatially referenced data in a variety of disciplines and work environments. Two distinct data models, vector data models and raster data models, are supported and used in a GIS, and both are used in this thesis.

Vector data models consist of point, line, and polygon data. Point data is used to refer to a single location on the earth's surface, and depending on the scale of the map, can be as large as a city or as small as the location for a PLS corner. Line data refers to a continuous feature such as a road or a stream that does not enclose upon itself. Polygon data can refer to a body of water, a timber stand, or a large city, and like point data, it depends on the scale of the map.

Raster data modes are composed of pixels. Each pixel is assigned a value. The structure of raster data models are much simpler than vector data models but their file sizes are often much larger because it requires a smaller pixel to show greater detail. This thesis uses high resolution Digital Elevation Models (DEM's) to display topography over the study area and therefore, they show great detail and they are large files. The

⁶⁴ Thomas M. Lillesand, Ralph W. Kiefer. *Remote Sensing and Image Interpretation: 4th edition* (New York: John Wiley & Sons, Inc., 2000) p. 44.

DEM's used in the thesis to display topography have a resolution of 10 meters by 10 meters. This means that each pixel in the raster image represents approximately a 10 meter by 10 meter area on the ground.

Furthermore, the vegetation polygons in the General Vegetation map were built from the general descriptions of the section lines and represent an area that is approximately one mile square. This would be comparable to a low-resolution raster data set. See Chapter III. This is important because as seen later in Chapter III and in Chapter IV, the generality, or low resolution of this map restricts its utility.

The role of GIS in this thesis is mostly limited to overlay analysis of the spatial data although specific calculations are also performed. The digital files representing the PLS notes are overlaid onto recent geographic vector and raster data in order to compare the historic data to modern data sources, and forest density values are calculated using bearing tree data at the PLS corners.

This thesis utilizes two specific ESRI (Environmental Systems Research Institute) GIS software packages. ArcView 3.2 is used for digital data creation and data entry, while the ArcGIS 8.3 suite is used for data analysis, map production, and calculations including one instance of Visual Basic Editor used in ArcMap, which is part of the ArcGIS 8.3 suite. Their specific uses are detailed further in Chapter III.

The Geographic Coordinate Database

The Geographic Coordinate Database (GCDB) is a digital representation of the point locations for the PLSS corners and it represents the most accurate digital PLSS data available. The ground locations for each section corner, quarter section corner, and

quarter quarter section corner are represented by their geographic coordinates. The locations for most of the points are compiled from Bureau of Land Management (BLM) survey data, local survey data, and survey control monuments. These surveyed corners are well established and represent the actual longitude and latitude of the PLSS corners. Some of the GCDB corners are not well established and lack accurate survey data. These corners are most often located in mountainous or remote regions and may contain considerable error. They are computed or projected in the GCDB using a least squares method. The GCDB is housed by the BLM and can be continually updated with survey data as it comes in from the field.⁶⁵

The GCDB is used for this thesis to represent the PLS corners within the study area. If the original survey note data can be connected to the GCDB, information about the landscape from the time of the survey can accurately be represented in a GIS and used for analysis. This will be done with each bearing tree and all of the other information associated with the PLS survey.

Küchler's Potential Natural Vegetation

Küchler's Potential Natural Vegetation map and manual for the conterminous United States 1964 describes potential vegetation communities for the entire United States.⁶⁶ The portion of Küchler's map that covers Boulder County, and the study area shows four vegetation types in the immediate area (Figure 2.3). These vegetation types

⁶⁵ *GCDB Geographic Coordinate Database* [WWW The GCDB National Homepage, a U.S. Government Computer System] 16 April 2002 <<http://www.blm.gov/gcdb/>>

⁶⁶ A. W. Küchler, *Potential Natural Vegetation: Of the Conterminous United States*. American Geographical Society, Special Publication No 36. 1964.

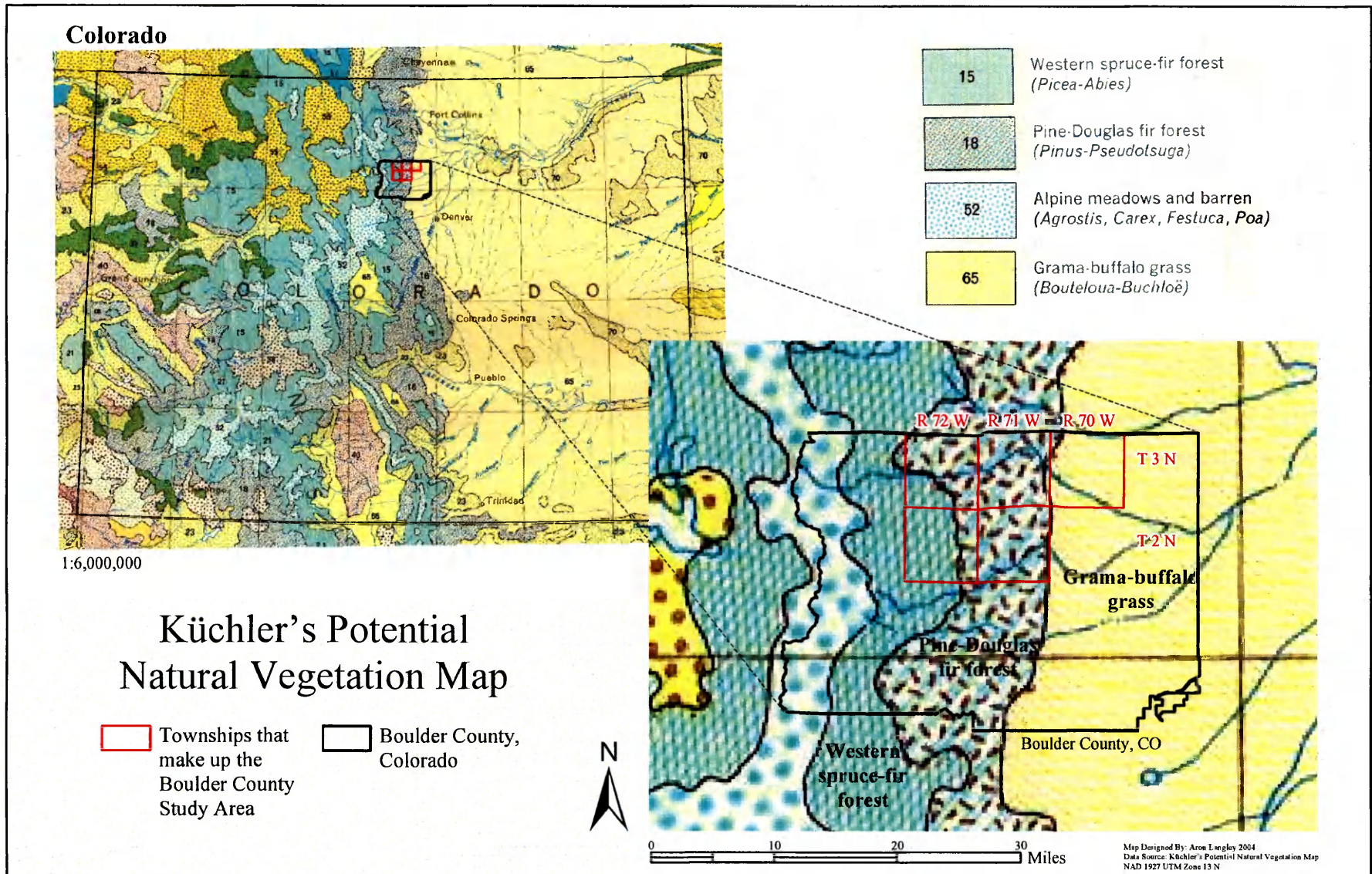


Figure 2.3 Küchler's Potential Natural Vegetation for Colorado and the Boulder County Study Area.

from east to west are: Grama-Buffalo Grass (*Bouteloua-Buchloë*) dominated by Blue Grama and Buffalo Grass, Pine-Douglas Fir Forest (*Pinus-Pseudotsuga*) dominated by Ponderosa Pine and Douglas Fir, Western Spruce-Fir Forest (*Picea Abies*) dominated by Subalpine Fir and Engleman Spruce, and Alpine Meadows and Barren (*Agrostis*, *Carex*, *Festuca*, *Poa*) dominated by Bentgrass, Sedges, Hairgrass, Fescue, Woodrush, Mountain Timothy, Bluegrass, and Spike Trisetum.⁶⁷

Gramma-Buffalo Grass is further described as “fairly dense grassland of short grass with somewhat taller grasses in the eastern sections,” and it occurs mainly in “eastern parts of New Mexico and Colorado, southeastern Wyoming, western parts of Nebraska, Kansas, Oklahoma and Texas.”⁶⁸ This is the common vegetation type in what is considered the High Plains.

Pine-Douglas Fir is further described by Küchler as “open to dense forests of tall needleleaf evergreen trees often with much undergrowth,” and it occurs mainly in the “southern rocky mountains.”⁶⁹ This is the common vegetation type for the foothills of the front range in Colorado.

Western Spruce-Fir Forest is described as “dense to open forests of low to medium tall needleleaf evergreen trees; open forests with a synusia of shrubs and herbaceous plants” occurring in “high altitudes of northern rocky mountains and Washington.”⁷⁰

Alpine Meadows and Barren vegetation is described as being “usually short

⁶⁷ Küchler, 15, 18, 52, 65.

⁶⁸ Ibid, 65.

⁶⁹ Ibid, 18.

⁷⁰ Ibid, 15.

grasses and sedges, dense to very open with extensive barren areas; many forbs” and occurs in the “rocky mountains, cascade range, and sierra nevada.”⁷¹ This type is most consistent with areas of high mountain tundra and the timberline transition.

Potential natural vegetation maps are an attempt to display the natural vegetation that would exist at the time the map is created if man were removed from influence on the area.⁷² The PLS notes were recorded at a time when man’s influence on the vegetation was as close to minimal as can be expected. A vegetation map produced following settlement would no doubt be influenced by man. Similarly, a vegetation map representing an area prior to settlement would also contain human influence due to the occupation of Native Americans in the area. This influence cannot be eliminated all together when attempting to create a map of natural vegetation for modern geographical uses. Human influence on vegetation dates back thousands of years and a map representing that time span would have to take climatic influences into consideration. The PLS notes contain vegetational information from the time of settlement and are among the only data sources that provide a standardized and systematic look at the pre-settlement characteristics of the land and its resources, thus representing vegetation information that is as close to natural as can be expected.

Küchler’s Potential Natural Vegetation Map will be compared to the General Vegetation Map, discussed in the next chapter, to evaluate the similarities and differences between what Küchler compiled and what was recorded by the surveyors as they progressed through the study area.

⁷¹ Ibid, 52.

⁷² Ibid, 2.

The Colorado Vegetation Model (CVM)

A similar comparison will be made to the Colorado Vegetation Model.⁷³ A digital representation of the CVM was obtained online from the Natural Resource Ecology Lab at Colorado State University. The CVM expands on the USGS/EPA National Land Cover Dataset (NLCD) to produce a higher resolution land cover map of the state of Colorado using additional topographic and climatic data.⁷⁴

The CVM (Figure 2.4) shows approximately twelve classes in the study area of which three are grassland categories, six are coniferous forest categories, and three are deciduous categories. These classes can be generalized into three distinct groups that will be helpful in making comparisons to the General Vegetation Map. These groups are Foothills/Shortgrass Prairie, Ponderosa Pine Montane, and Lodgepole Pine Forest. Another distinct generalization seen in the CVM is the Spruce-Fir Forest. This land cover category is not in the study area, but it may be a helpful addition when evaluating the maps later in Chapter IV. The deciduous types are diverse but limited in the study area. They may prove helpful in the thesis but not in making comparisons to the General Vegetation Map.

Bias Fraud and Error

Bias, fraud and errors are found in the original land survey notes. Bias has been

⁷³ D.M., Theobald, N. Peterson, and W. Romme. 2004. *The Colorado Vegetation Model: Using National Land Cover Data and Ancillary Spatial Data to Produce a High Resolution, Fine-Classification Map of Colorado (v8)*. 4 February. Unpublished report, Natural Resource Ecology Lab, Colorado State University.

⁷⁴ Theobald et al., 1.

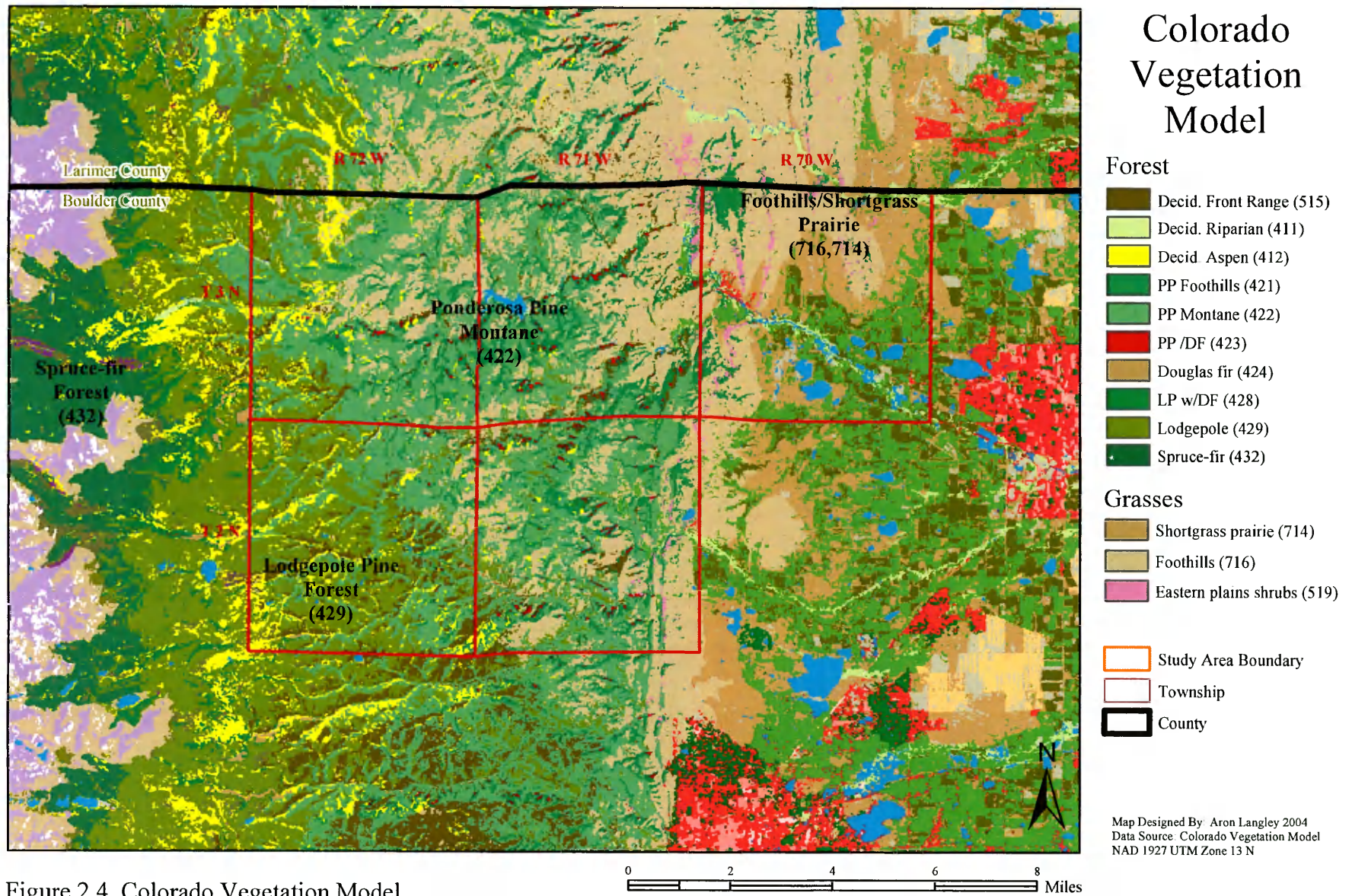


Figure 2.4 Colorado Vegetation Model.

examined in several studies⁷⁵ where conclusions all report the presence of bias in one form or another, including the size and species of trees selected as bearing trees. Bearing trees were used to witness the PLS corner and help in their relocation. Often, the closest trees to the corner were not used nor were certain species. Trees were most often selected based on their conspicuousness within a stand, their size, age, species longevity, or proximity to the corner.⁷⁶ Early instructions even state that “only the soundest and thriftiest of the trees” were to be used as bearing trees.⁷⁷ This leaves no doubt that bias existed in the selection of bearing trees and within the PLS notes.

Various accounts of fraud have been associated with the survey of the public domain. The Benson frauds of 1873-1885 involved deputy surveyors, bankers, employees of the surveyor general’s office, several hundred thousand dollars, and approximately 300 survey contracts.⁷⁸ Surveyors’ notes were faked, oaths were fictitious, and many people were involved.

Another example of fraudulent surveying occurred at times throughout the flat plains states. The wagon wheel method of surveying was conducted by tying a piece of cloth onto a wagon wheel. The circumference of the wheel was calculated and the wagon was drove until the cloth circled the wheel X number of times. The surveyor would stop the wagon and establish a corner.⁷⁹

⁷⁵ Bourdo, 761 – 764, Grimm, 291-311, Manies, et. at, 1719-1730,

⁷⁶ Grimm, 295.

⁷⁷ Stewart, 122.

⁷⁸ Stewart, 66. Lola Cazier, *Surveys and Surveyors of the Public Domain 1785-1975*, (Washington D.C., US Government Printing Office, 1976) 94.

⁷⁹ C. Albert White, 162.

A great majority of the surveys were performed to the utmost ability of the surveyors, who took an oath to perform accurate surveys.⁸⁰ Regardless, errors were a part of the survey process. The surveyors worked under extreme circumstances, and were often up against more than just the elements. They mostly worked out ahead of settlement and ran into hostile natives and squatters upset at the partitioning of their land. They worked for low wages and for long hours. These hard working conditions often resulted in erroneous surveys.

It should be noted that even though bias, fraud, and errors were a part of the survey of the public domain, they were minimal. Considering the equipment that was used and the hard working conditions, the vast majority of the surveys were performed in an unprecedented manner, to the standards set by the General Land Office, and according to the instructions established at the time.

The question still remains as to the utility of the original land survey notes and to the information that can be discerned from them for use in historical and geographical studies.

Study Area

The study area used in this thesis consists of five townships within Boulder County, Colorado; Townships 2 and 3 North and Ranges 70, 71, and 72 West of the sixth principle meridian. The area extends from the plains of Colorado west through the foothills and into the mountains (Figure 2.5). This area was chosen due to its location, size, topography, and proximity to urban areas. The surrounding region was settled

⁸⁰ Stewart, 49-50.

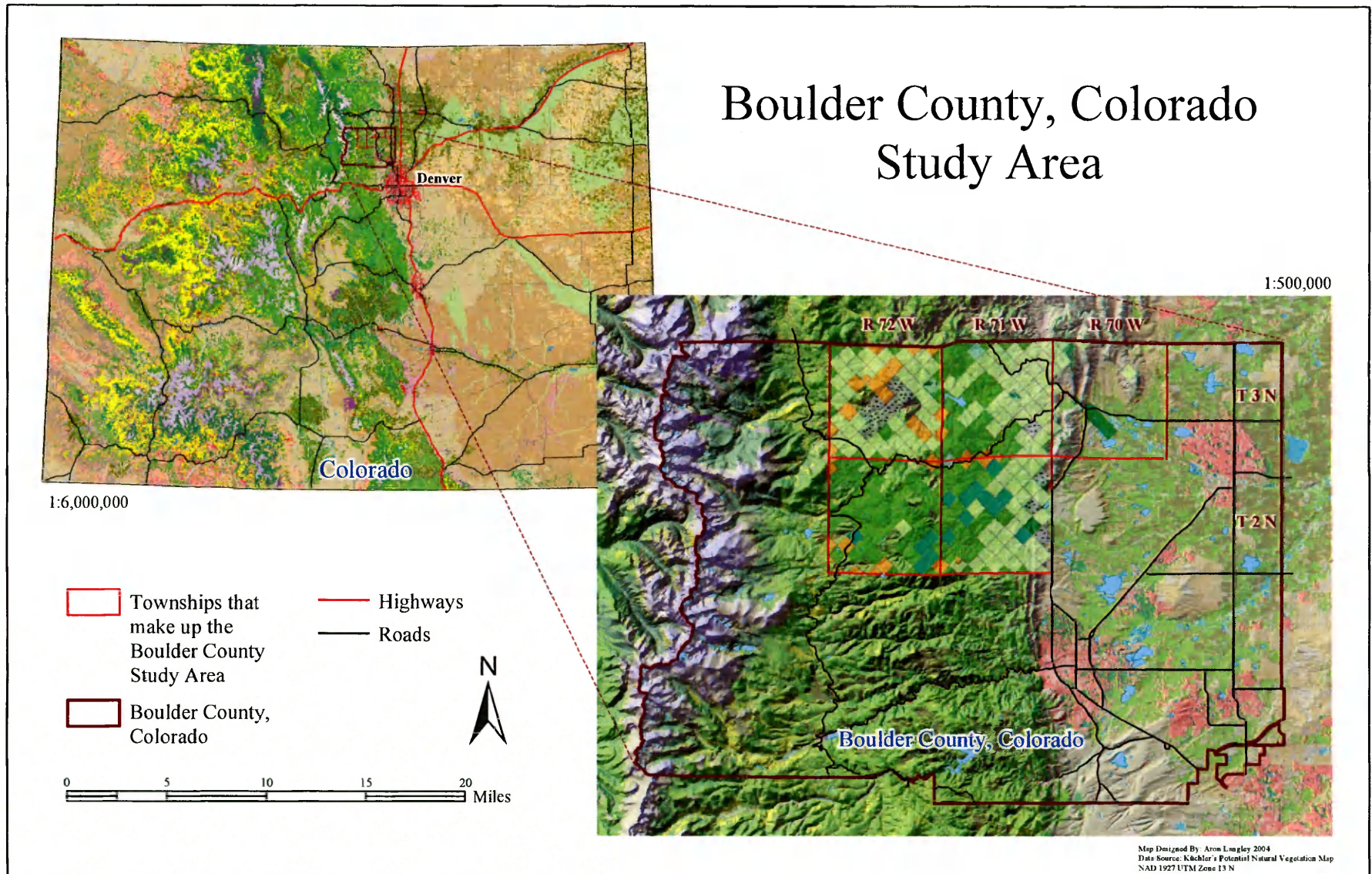


Figure 2.5 Boulder County, Colorado Study Area.

heavily beginning in 1858 following the discovery of gold in the Pikes Peak region.⁸¹ These discoveries continued north along the front range of Colorado as prospectors continued to find precious metals in the region. Towns in the immediate area began to emerge. Longmont, Colorado for example, was established in 1871.⁸² By the time the surveys within the study area were completed in 1883, settlement had reached the river valleys and began to expand into the mountains and along the river drainages.

The surveys of the townships lines were completed between 1863 and 1871 by three separate deputy surveyors, and the interior subdivisions were completed between 1864 and 1883 by five separate deputy surveyors.

Today, most of the study area is within the Roosevelt National Forest while part of it contains open space lands, state parks, and private lands. The North Saint Vrain River, the South Saint Vrain River, Lefthand Creek, along with their tributaries flow through the study area, and two towns, Lyons and Jamestown, are located within it.

This chapter is intended to provide necessary background information relevant to the thesis topic. It discusses the history behind the establishment of the public land surveys, instructions to the surveyors, and the notes that were recorded. It also provides additional information related to Geographic Information Systems, the Geographic Coordinate Database, alternative materials used in the thesis including Küchler's Potential Natural Vegetation Map and the Colorado Vegetation Model, the existence of bias, fraud, and errors in the original notes, and an overview of the study area. The next

⁸¹ Carl Ubbelohde. *A Colorado History*, (Pruett Publishing Company; Boulder Colorado, 1972) 60.

⁸² Ubbelohde, 137.

chapter details the methods and processes involved in defining the utility of the original land survey notes for use in historical and geographical studies.

CHAPTER III

METHODS

This chapter is intended to describe the methods and processes involved with defining the utility of the original survey notes for use in historical studies. This will include a description of how the PLS data was prepared for use in the thesis and the techniques that were used to create maps and products from that data. More specifically, this chapter will discuss the digitization and organization of the PLS files, the calculation of forest densities at PLS corners, the construction of the General Vegetation Map, and the extraction of additional information from the PLS records.

The Survey Note Database

Data Entry and the System Design

A system needed to be designed that could later be used in a GIS to map the features and information contained in the land survey notes. One table containing the GCDB corner data (Coords table), and a second table containing the survey note features (Features table), needed to be connected together so that the bearing tree data in the survey notes could be related to the corner for which they were associated. This required an ID field to be placed in both tables that contained identical information for each point. Each corner was given an ID, and later each record associated with that corner would be given the same ID in the Features table. This was essential for mapping purposes and

analysis in the GIS because through the ID field, features associated with the PLS corners could be selected and displayed for analysis.

Files were downloaded from the GCDB National Home Page at <http://www.blm.gov/gcdb> for all of Boulder County, Colorado. Seven GIS data coverages are included with each download. Township boundary lines, section lines, and corner data was extracted from the coverages and the remaining files were discarded. The GCDB corner data contained information for all of the section corners, quarter section corners, and quarter quarter section corners, along with additional point information for mining claim boundary information.⁸³ To prepare the GCDB data for use, all of the additional mining claim points and the quarter quarter section corner points needed to be excluded from the coverage (Figures 3.1 and 3.2). All of the editing of the shapefiles and coverages was done in ArcView 3.3.

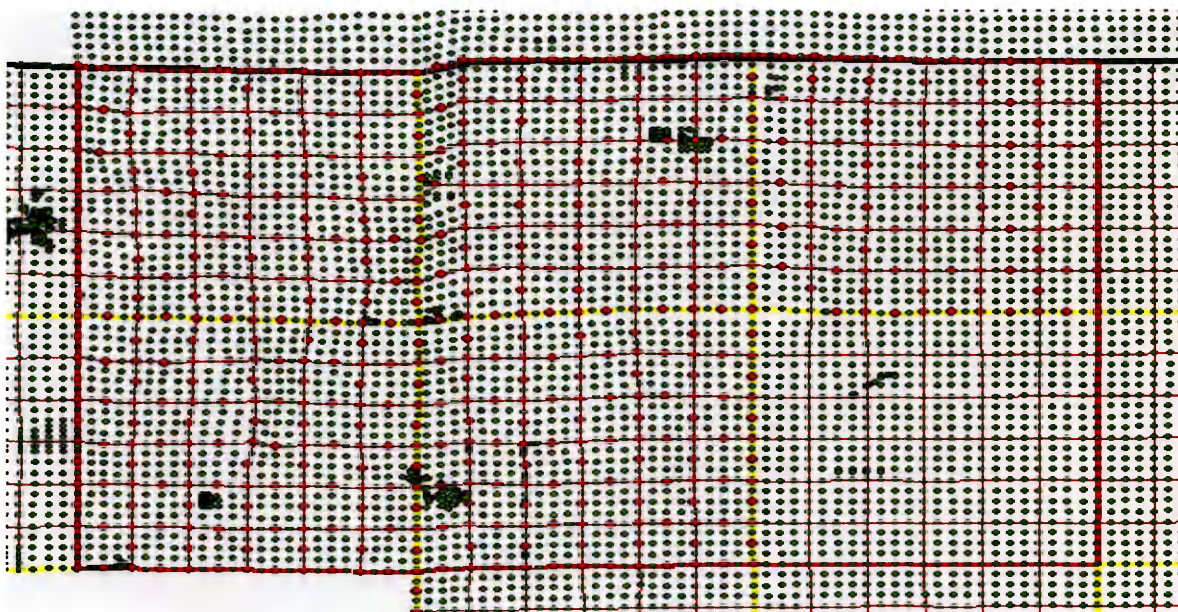


Figure 3.1 Complete GCDB Corner Data. The study area in Boulder County, Colorado is shown above with green points representing all of the points associated with the GCDB data including quarter quarter section corners and additional mining claim tract information. The green points needed to be removed before data entry began.

⁸³ Paul Lukacovic, personal communication, Bureau of Land Management, Colorado State Office, Denver, Colorado. 9 December 2003.

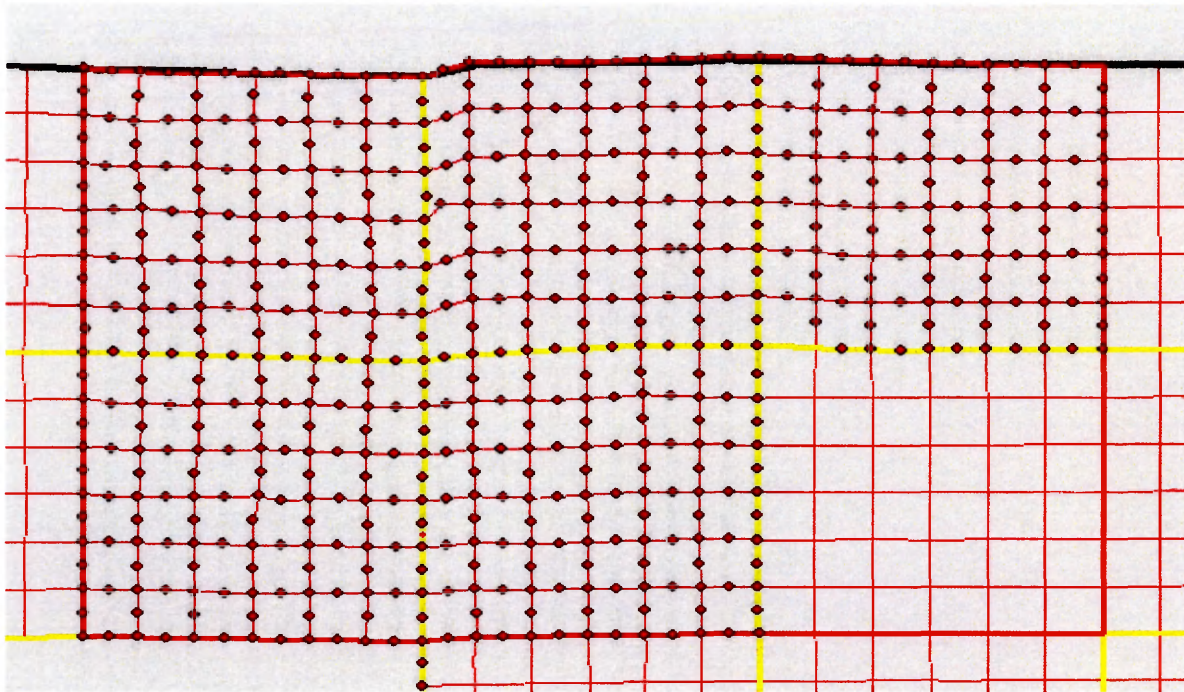


Figure 3.2 Extracted GCDB Corners and Quarter Corners. The points in red represent all of the corner points used in the study after the additional points were removed from the GCDB file.

Once the Coords file was edited, a new ID field, discussed previously, was added for the purpose of connecting it to the survey note Features Table. It was then populated with a number in beginning with 1 and ending with 601. There were 601 corners and each corner had a numerical ID from 1 to 601. A second field was added in order to enter the type of corner material that was used by the deputy surveyor to set the section corner (Table 3.1).

The Features Table was designed to accommodate all the information in the survey notes. The Type field would be populated by each feature that was encountered. Attributes for the features would then be entered in appropriate fields. A comments field was created that could be used as a back-up field for any information that did not fit into the design including information from the general descriptions of the section lines (Table 3.2).

Table 3.1**Final Coords Table and Associated Fields**

<u>Field</u>	<u>Description of the Field</u>
Lndkey	Corner identifier created for GCDB: this field was included with the GCDB files from the GCDB homepage.
North	Latitude for corner: this field was included with the GCDB files from the GCDB homepage.
East	Longitude for corner: this field was included with the GCDB files from the GCDB homepage.
Elev	Elevation of corner: this field was included with the GCDB files from the GCDB homepage.
Key	This is the ID field that is used to connect the feature to the related corner.
Cor_Typ	Type of material used by the deputy surveyor to set the corner.
Trperacre	Initial field containing trees per acre calculated by hand. Only one township has data entered in it.
Tperacre	Second field containing trees per acre. All of the values entered for quarter section corners are incorrect.
Tree_acr	Final field containing trees per acre. All townships included and calculated correctly.

Before data entry began for the study area, a trial run was performed to ensure that the design of the database was appropriate and that it could incorporate all of the things that were planned. Once a sufficient amount of information was entered into the tables, the files were brought into ArcGIS to construct several initial maps. A relate⁸⁴ was set up in ArcMap (Figure 3.3). Several corners were selected from the Cords Table and each bearing tree related to the selected corners through the Key field was extracted from the preliminary Features Table to verify whether or not the design was complete and it functioned properly.

⁸⁴ A relate is a temporary link between two themes or tables in a database based on a Key field in both tables. For example, one section corner in the Coords file has three bearing trees associated with it. The bearing trees are in one table and the section corners are in another table. The section corner has a key field value of 328. Each bearing tree in the second table with the key field value of 328 is temporarily selected from the table using the relate function.

Table 3.2

Final Features Table and Associated Fields

<u>Field</u>	<u>Description of the Field</u>
Type	Type of Feature encountered in the notes.
Species	Species of bearing tree or feature encountered.
Diam	Diameter of bearing tree.
Bearing	Bearing to bearing tree from established corner.
Twp	Township that the feature falls within.
Range	Range that the feature falls within.
Dir	Direction or course of the feature: water course, ridge line, roads etc.
Width	Width of the feature: brook, stream, gulch etc.
Lks_chns	The number of links or chains to the feature from the established Corner or location.
Key	This is the ID field that is used to connect the feature to the related corner.
Surveyor	Name of the deputy surveyor who performed the survey
Sur_date	Date that the survey was completed.
Comment	Any additional information for the features. Includes all of the information for the general descriptions of the section lines.
X_coord	Field containing Longitude values for each point entered. Created by ArcView extension.
Y_coord	Field containing Latitude values for each point entered. Created by ArcView extension.
Feet	Distance in feet from each bearing tree to its associated corner.

Several small changes were made to the design once the pretest was completed. Redundant fields were eliminated and both tables were cleaned up to allow for efficiency. The size of the study area was still undetermined at this point. The volume of the survey note data and the speed at which the data could be entered was the determining factor in selecting the size of the final study area.

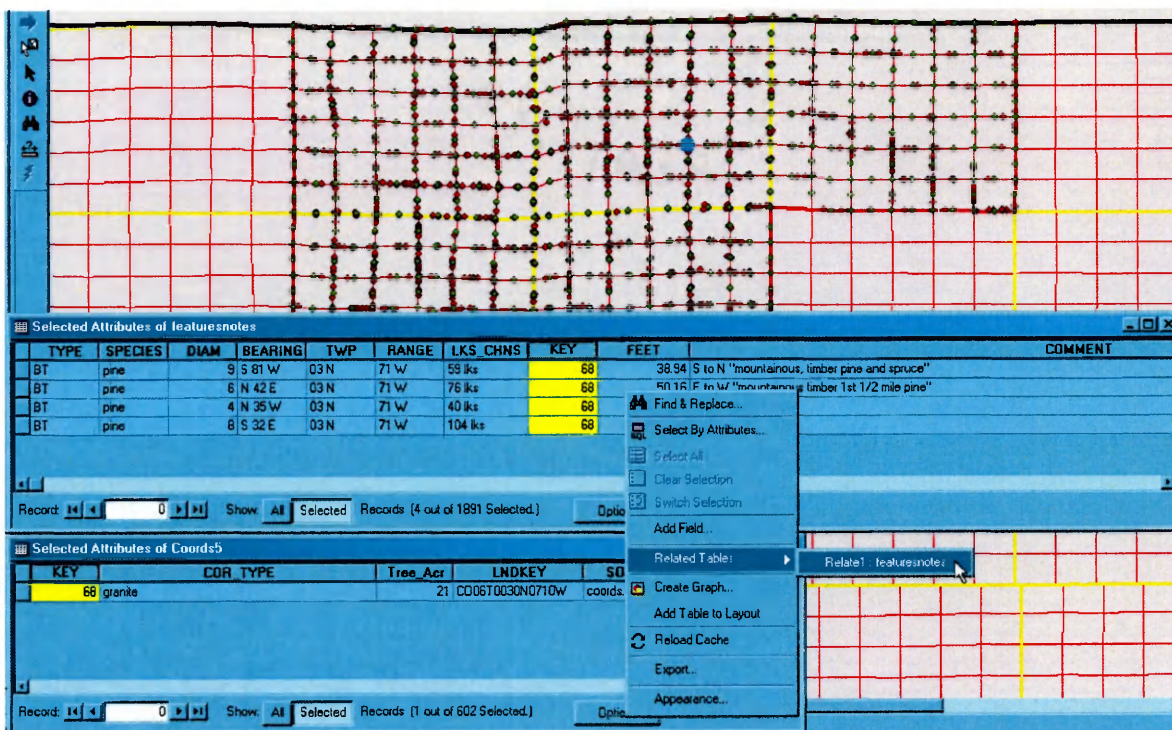


Figure 3.3 The Relate Functionality. A relate was set in ArcMap to connect the Coords table to the Features table. A corner can be selected in the Coords table and features linked to the corner are selected for display in the Feature table. The functionality of the relate was tested in a pretest prior to the development of the final Coords Table and Features Table.

Creating the Digital Survey Note Database

The original land survey notes for the state of Colorado are held at the Bureau of Land Management Colorado State Office in Denver, Colorado. The original field notebooks have been scanned and are available in microfiche form for public use.

Over the course of three months, field notes for five townships were entered into the Features shapefile using ArcView 3.2. Data was entered in the same order in which it was surveyed and recorded in the deputy surveyor's field notebook. Township boundaries were entered first, followed by the township interiors. The point location where the features in the survey notes occurred was entered into the Features shapefile in

their precise location along the section lines. The information associated with each feature was entered into the Features shapefile table and data for the type of material used by the deputy surveyor to set the section corners was entered into the Coords shapefile table. Corner ID's were added to the Features shapefile table when appropriate.

The final Features shapefile consisted of 1,891 points. An ArcView extention⁸⁵ was used to calculate the latitude and longitude of every point that was entered. Two new fields were created in the Features table to represent the precise latitude and longitude values for each feature entered.

Mapping

Maps needed to be built to show the extent of what can be extracted from the content in the original land survey notes. The Features shapefile and Coords shapefile were the data sources from which all of the maps were built. ArcGIS became the platform for data analysis and display. The following pages describe the process of creating maps and extracting products from the PLS notes using modern GIS techniques.

Basedata

GIS data from several online sources was used in the creation of a base map. The most accurate base map data available was used in order to later check the accuracy of the features from the notes when they were overlaid with the base map data. TIGER

⁸⁵ The ArcView extention used was called Add True X,Y Centroid for Preprojected Data. The about data for the extention is as follows "The X,Y coordinates for the feature true centroid are calculated and added to the themes table. Now works for multipart. Can add decimal degrees values for preprojected data. Based on code from Mark Cederholm and modifications from Zsolt Pataki."

line data (Topologically Integrated Geographic Encoding and Referencing system)⁸⁶ data was used for the roads layer for the purpose of displaying all of the roads in and around the study area.⁸⁷ The stream data was obtained from the USGS National Hydrography Dataset.⁸⁸ This is the most accurate data available for streams throughout the United States. The topography comes from ten-meter Digital Elevation Models (DEM) for the study area, that were obtained from an online data source.⁸⁹ The DEM's were downloaded as individual files. Additional processing was needed for proper display. A total of twenty-four DEM's were processed in the GIS to build the final mosaic. Aerial photographs from 1995 to 1998 covering the study area were obtained from an online source.⁹⁰ These photographs have a resolution of 1 meter and accompanied the previously mentioned data in comparing the PLS records to what is seen in the landscape today.

⁸⁶ *U.S. Census Bureau Tiger/Line* [WWW Tiger, Tiger/Line, and Tiger Related Products,] 30 September 2004 <<http://www.census.gov/geo/www/tiger/>>

⁸⁷ *Download Census 2000 TIGER/Line Data* [WWW ESRI Data Download Website] <http://arcdata.esri.com/data/tiger2000/tiger_download.cfm>

⁸⁸ *National Hydrography Dataset* [WWW The National Hydrography Dataset Homepage, a U.S. Government Computer System, U.S. Department of the Interior, U.S. Geological Survey] 23 November 2004 <<http://nhd.usgs.gov/index.html>> Select: Data, Select: Go To NHD Viewer.

⁸⁹ *GeoCommunity* [WWW The Premier Online Resource for GIS and Geospatial Data] 1995-2004 <<http://data.geocomm.com/catalog/US/61076/967/index.html>>

⁹⁰ *Downloading and Using USGS Maps and Aerial Photography from Terraserver* [WWW Rocky Mountain Mapping Center, U.S. Department of the Interior, U.S. Geologic Service] 12 December 2003 <<http://rmmcweb.cr.usgs.gov/public/outreach/terraserver.html>> This site describes the process of downloading a toolbar that can be used in ArcGIS to extract Digital Orthophoto Quads at a variety of resolutions for any study area in the United States where the imagery is available. This toolbar was downloaded and used to extract 1 meter resolution aerial imagery for the entire Boulder County study area.

Bearing Tree Densities at PLSS Corners

Method and Equation

The density of bearing trees at each section corner and quarter section corner was calculated based on a method that was used by Rankin and Davis.⁹¹ This method is a modified version of the point to plant method of calculating densities that was described by Cottam and Curtis.⁹² Essentially, at any given sample point, the density of trees per acre is equal to $43560/d^2$ where d is the average distance between the sample point and all the bearing trees associated with the sample point.

Each corner represented a sample point. Section corners were established by the deputy surveyors using four bearing trees and quarter section corners were established using two bearing trees. For a section corner, the number of trees per acre at that corner is calculated by averaging the distance to the four bearing trees (d) and plugging that number into the density equation. The equation assumes that there are four bearing trees at the corner. Many section corners were established with fewer than four bearing trees to mark them. This added a variable to the equation. The number of trees per acre at section corners is now equal to $[43560/ d^2] (n/4)$. This correction takes into consideration the case where there are less than four bearing trees used to set the corner. The same problem exists for quarter section corners. The new equation for trees per acre at quarter section corners is equal to $[43560/ d^2] (n/2)$.

⁹¹ Rankin and Davis, 716-717.

⁹² Grant Cottam and J.T. Curtis, "The Use of Distance Measures in Phytosociological Sampling," *Ecology* 37 no. 3, (July 1956) 451-460.

Problems and Issues

When the distance to bearing trees was entered in the Lks_chns field, it was entered into a text field as a value in either chains or links. For Example: the distance to one bearing tree was '18 lks.' The length of the chain that was used by the survey teams, as discussed in the previous chapter, is known to be 66 feet. There were 100 links in the chain. Each link in the chain is .66 feet, therefore, 18 links is equal to 11.88 feet. In order to calculate forest density at a corner, a new field was needed that represented the value in feet (11.88), rather the value in links or chains, (18 lks).

To do this, a field was added to the Features table and populated with the distance in feet from each bearing tree to its associated corner. The process was as follows: first, a numerical field was added to the table in ArcView. The Features.dbf file was then opened in Microsoft Excel. A new field was added in Excel that substituted all of the text in the Lks_chns field with no value. The function looked like this `SUBSTITUTE(J2,"_lks","")`. This excluded all of the text in the Lks_chns field and returned only the numerical value. The new field in the Features table, 'Feet,' was then populated by running a simple calculation using the extracted numerical values from the `SUBSTITUTE` function. The calculation looked like this, $\text{Feet} = (\text{J2} \times 66) / 100$. The Features table now had a field with all of the distance values in feet from the corner to each bearing tree that could be used to calculate density values for each corner. This process could have been avoided if the values were initially entered in feet rather than in links and chains.

Performing the Calculations

The density of trees per acre for each corner was calculated in two different manners. One township was calculated by hand and four were calculated by the use of an automated Visual Basic script added to the VB editor in ArcMap. To calculate the density values at each corner by hand, both the Coords file and the Features file needed to be in the ArcMap table of contents with a relate set up (Figure 3.3, p. 39). This allowed a corner to be selected along with each of the associated bearing trees. The distances to each bearing tree were averaged using the feet field, the appropriate equation was applied to each corner and the values were entered into the appropriate field. The remaining four townships were calculated using the VB Editor in ArcMap. The code that was written for the script systematically selected each corner and its associated bearing trees and performed the calculation using the appropriate equation. The density of trees per acre at the corners for the remaining four townships was automatically entered into the appropriate field in the Features table. The script was written by Kyler Deutmeyer of DPRA, Inc. at the Rocky Mountain Arsenal in Denver, CO.⁹³

In the process, three new fields were added to the Coords file that represented trees per acre. The final field, 'Tree_acr' was used to create a density map in ArcMap and the density of trees throughout the entire study area can be seen. The number of trees per acre at each corner was also displayed over the density grid that was produced in ArcMap (Figure 3.4). Corners with less than eleven trees per acre were grouped into one category and corners with over 120 trees per acre were grouped into another category to show low forest densities and high forest densities respectively. It should be known that

⁹³ Kyler Duetmeyer, personal communication, DPRA, Inc., Rocky Mountain Arsenal. Denver, Colorado. 26-27 February 2004.

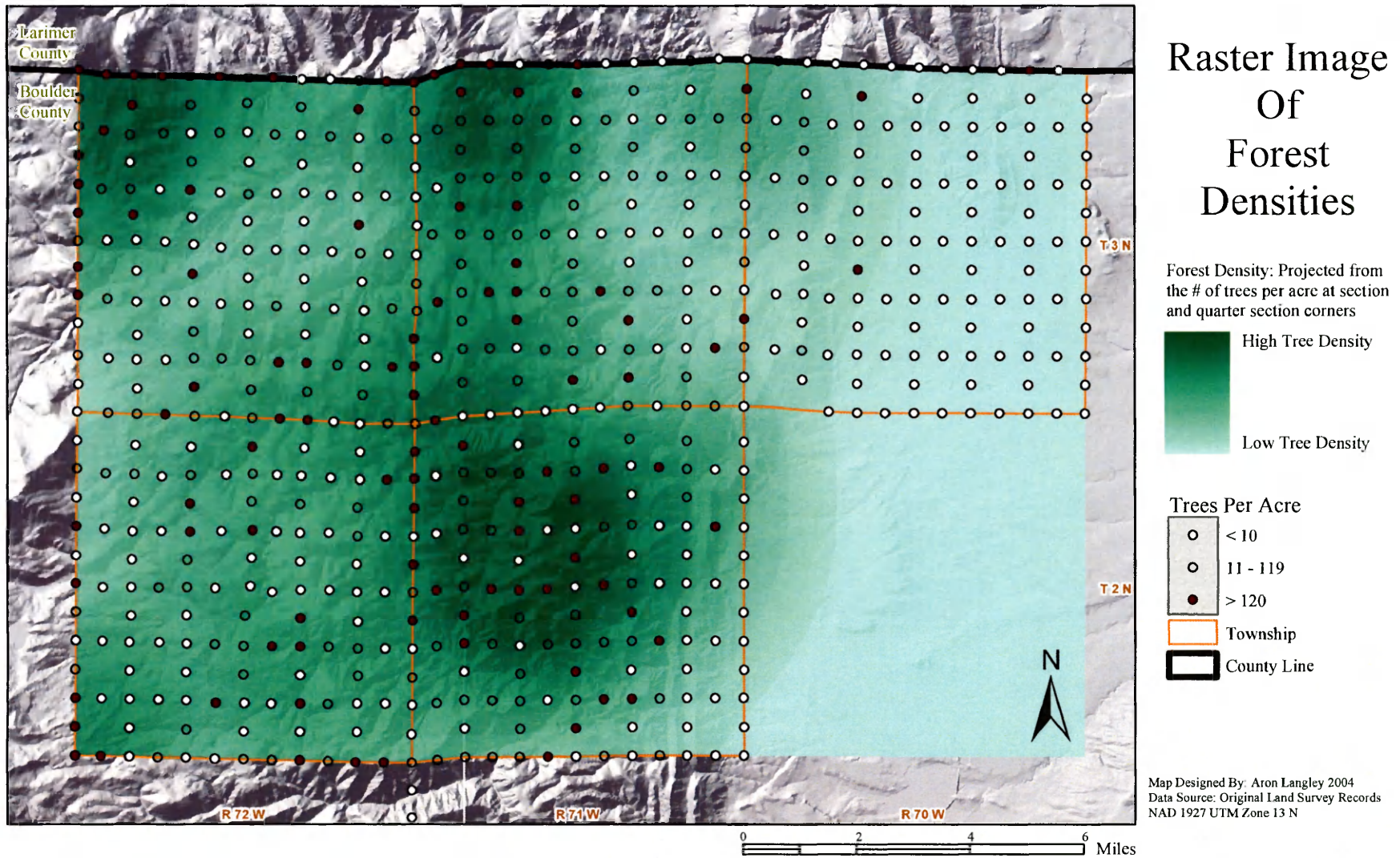


Figure 3.4 Raster Image of Forest Densities. Created from the trees per acre field in the Coords file. The number of trees per acre was calculated using the formula $43560 / d^2 \times (n/4)$ for section corners and $43560 / d^2 \times (n/2)$ for quarter section corners. Those values were used to project the density of the forests for the entire study area.

tree species were not considered in evaluating forest densities in the study area.

Calculating trees per acre is important because it is applicable in many historical studies of former forests. An evaluation of the utility of this data will be discussed in the next chapter.

General Vegetation Map

A vegetation map for the study area was created using information from the general descriptions along the section lines. A vegetation type was recorded for each section line based on the information in the general description for the section line (Figure 3.5). Several section line general descriptions did not contain vegetational information or were not surveyed in the original survey because the surveyor described them as “impassible.” These were recorded as “no data.” Similarly, some section lines were described as “barren” or “destitute of timber,” these were recorded as “barren no timber” in the vegetation type field.

It was decided that the section line vegetation information needed to be displayed as polygons for the purpose of showing land cover rather than line data that could not be displayed to the proper extent. To do this, polygons were digitized around the section lines. Each resulting polygon was similar in size to the 640 acre size of the PLSS sections (Figure 3.6).

Over thirty vegetation types were recorded directly from the general descriptions. The vegetation types were further aggregated into nine categories. The final vegetation types used for the vegetation map were Pine, Spruce, Pine and Spruce, Mixed, Deciduous, Grassland, Burnt Dead or Fallen, Barren No Timber, and No Data (Figure

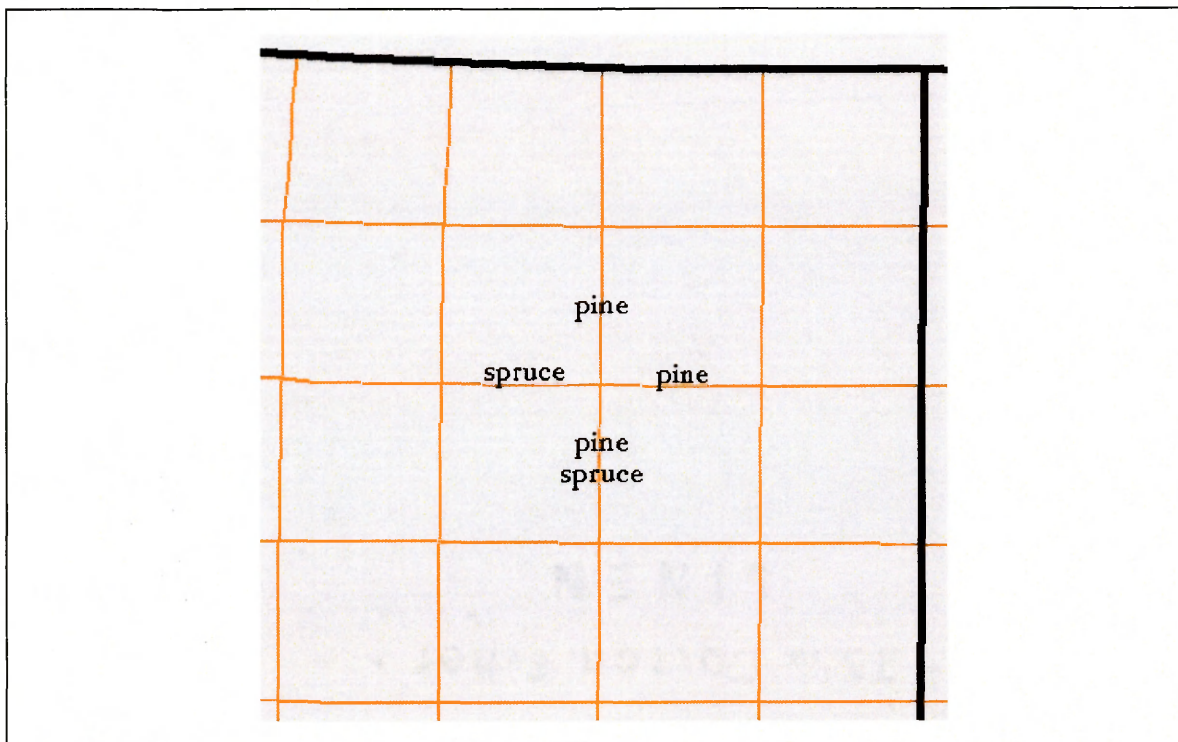


Figure 3.5 Constructing the General Vegetation Map 1. Vegetation types were recorded for each section line from the general descriptions in the original land survey notes.

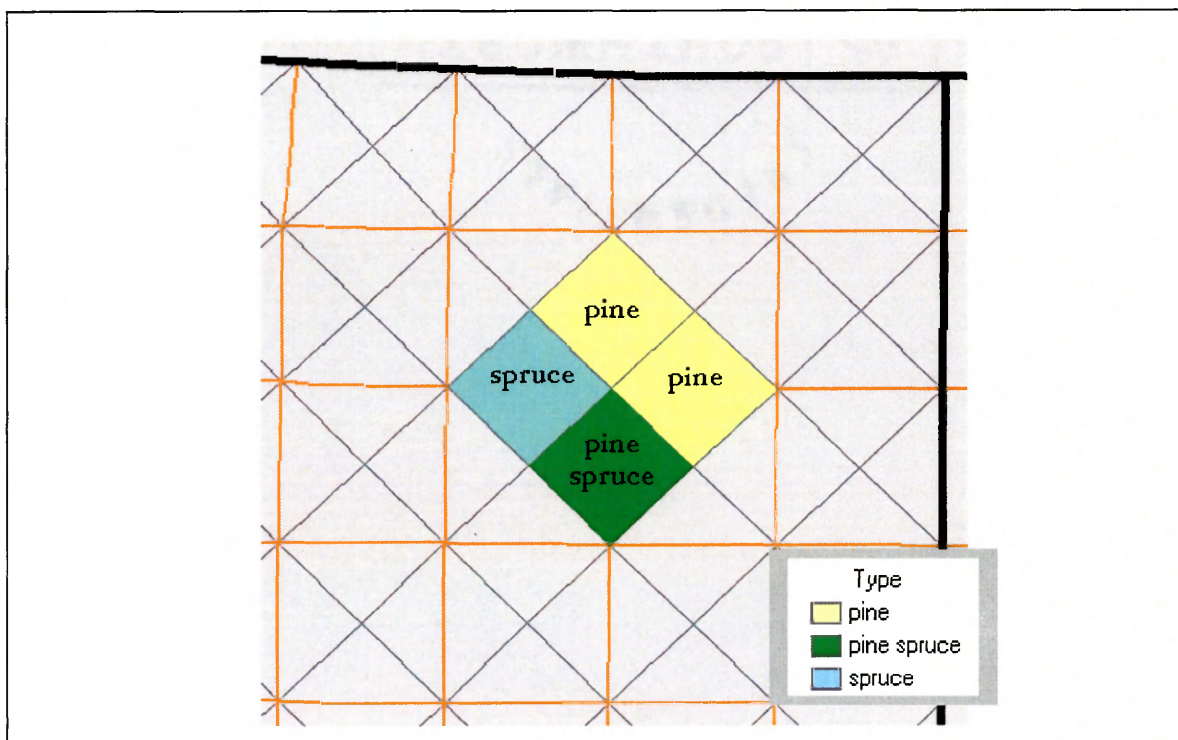


Figure 3.6 Constructing the General Vegetation Map 2. Polygons were digitized around each section line and displayed according to the vegetation type described by the surveyors in the general descriptions for the section lines.

4.5, p. 68). These categories gave no consideration to abundance. For example, timber described by the surveyors as thick pine, scattered pine, small pine and heavy pine, were all aggregated into one vegetation type named pine forest.

Extracting Additional Information

The thesis requires an in-depth look at the broad applications and the utility of the PLS notes for use in geographical and historical studies. The Features file and the Coords file were designed for the purpose of displaying and analyzing the PLS notes, and to show what applications are available. Various displays were analyzed to evaluate the records in the PLS notes that deal with topography, settlement, vegetation, the differences between surveyors, additional interesting findings; and the errors, inaccuracies, and additional limitations associated with using the PLS notes in historical and geographical studies.

The GIS was used to display the PLS features in as many ways as possible. The materials used to set corner monuments were displayed over a geologic map of the study area, bearing tree species and diameters were displayed, topographic features were displayed over modern topographic maps, and various other displays were viewed using the Features file. The purpose of developing these maps was to become familiar with the variety of applications that exist with the PLS notes once they were in a digital format.

The Features file was added to a base map to show the locations of the topographical features extracted from the survey notes. The locations of streams that were crossed, ridges, gulches, landscape changes, and wagon roads recorded in the late 1800's can be seen alongside the actual locations of those features in the topographic GIS

data. This is important because it will either show that the original notes are in fact accurate enough to be used in historical studies or they are not. When the features recorded from the time of the survey line up with the topographical features seen in the advanced technological datasets used for the study, the notes can be considered accurate.

To evaluate the topographic records in the PLS notes, the records in the Features file were displayed over the Digital Elevation Model for the study area, recent aerial photographs and the national hydrography dataset. The point locations in the Features file were compared to the topographic GIS data.

References to wagon roads, railroads, fence lines, trails, ditches, houses, and features referred to by name were draped over updated GIS data layers to look for existing evidence of those features today. References to settlement in the PLS notes can be important for historical studies. If evidence can be found, and in some cases, even if evidence cannot be found, the PLS notes would show utility in historical studies.

The General Vegetation Map was compared to Küchler's Potential Natural Vegetation Map,⁹⁴ The Colorado Vegetation Model (CVM),⁹⁵ and recent aerial photographs to evaluate the utility of the information in the section line general descriptions recorded by the surveyors, and to note the similarities and differences seen in the maps.

The differences between the surveyors were evaluated by analyzing the Features notes file, the Coords file, and the original land survey notes. Further evaluations were

⁹⁴ A. W. Küchler, *Potential Natural Vegetation: Of the Conterminous United States*. American Geographical Society, Special Publication No 36. 1964.

⁹⁵ Theobald, D.M., N. Peterson, and W. Romme. 2004. *The Colorado Vegetation Model: Using National Land Cover Data and Ancillary Spatial Data to Produce a High Resolution, Fine-Classification Map of Colorado (v8)*. 4 February. Unpublished report, Natural Resource Ecology Lab, Colorado State University.

made using documents found at the National Archives and Records Administration (NARA) in Denver, Colorado.⁹⁶

Lastly, any interesting findings in the PLS notes and in additional research materials was evaluated; including errors, inaccuracies, and additional limitations that pertain to the thesis.

This chapter describes the development of the digital survey note data files and the techniques used to create maps and calculate additional fields from the original survey note data, including the creation of a vegetation map, the calculation of forest densities at PLS corners, and the extraction of additional information from the original notes. Its purpose is to reveal and provide a platform for GIS analysis. The next chapter discusses the findings and results of the GIS analysis.

⁹⁶ Office of the U.S. Surveyor General, Colorado, RG 49, National Archives and records Administration. Denver, Colorado.

CHAPTER IV

EVALUATION AND FINDINGS

The purpose of this chapter is to outline and evaluate the contents and findings within the Boulder County, Colorado PLS notes. More specifically, it includes an outline of the recorded information in the notes and a description of the findings pertaining topography, settlement, vegetation, and the differences between the surveyors. Finally, it addresses other interesting findings, and the errors, inaccuracies and additional limitations found in the PLS records for the study area. This information will contribute to the historical and geographical utility of the original land survey notes.

The Boulder County, Colorado PLS Notes

Content

As noted earlier, the original public land surveys of the study area were completed between 1863 and 1883 by eight separate deputy surveyors. During this time three manuals were used as guidelines, the 1855 manual, the 1871 manual (which was a copy of the 1855 manual)⁹⁷, and the manual of 1881. Only slight differences exist between the 1855 manual and the 1881 manual and those differences will not be discussed. The following list gives a complete outline of the content recorded in the field notebooks by the deputy surveyors who were the first to survey the Boulder County, Colorado study area.

⁹⁷ McEntyre, 110.

I. Type of material used to set corners	
A. Granite	366 of 601 = 61%
(granite, red granite, grey granite, granite rock in place)	
B. Sandstone	127 of 601 = 21%
(sandstone, red sandstone, stone)	
C. Conglomerate	52 of 601 = 9%
(conglomerate, blended stone)	
D. Post in Mound	35 of 601 = 6%
(mound & marked stone, mound & charred stake, post in mound)	
E. Rock – named	11 of 601 = 1.8%
(mica slate, hornblende, limestone, quartz)	
F. Rock – unnamed	6 of 601 = <1%
(boulder, rock, large rock)	
G. Other	4 of 601 = <1%
1 - nook in cliff with cross	
1 - spruce tree	
1 - cottonwood tree	
1 - nothing used	

II. Noted in the Section Line General Descriptions

A. **Land** – topography and other characteristics

The land was described using various categorical terms and adjectives.

Often, two or more terms were used together; for example, the land could be described as mountainous and precipitous.

Terms Used: 1st rate, 2nd rate, 3rd rate, 4th rate, broken, mountainous, precipitous, hilly, good grazing land, barren, covered with loose rock, impassible, sloping, gently rolling, rocky, nearly all level, rough, stony, steep, of little value etc...

B. **Timber** –

The surveyors recorded timber found along the section lines in order of abundance.

Timber Types Found: Pine, Spruce, Jack Pine, Aspen, Cottonwood, Boxelder, Cedar (Juniper), lodgepole, and poles (most likely lodgepole).

Categorical Values Associated With Abundance of Timber Types: few, large, heavy, scattered, thick, heavy growth, small, fair, poor, very poor, a little, a few, young, etc...

Descriptive Terms Associated With Timber Types: destitute of timber, good lumber pine, seeding pines, thick pole timber, scrubby timber, mostly dead and fallen, dead timber, mostly burnt, no lumber, no timber, etc...

C. Soils –

Information about the soil that was traversed during the survey of the section lines was recorded using descriptive terms.

Terms Used: good, 2nd rate, 3rd rate, 1st class, very poor, stony prairie, good grazing land, rocky, swampy, covered with loose rocks, stony, and excellent pasture.

D. Other Vegetation –

Most of the vegetation information found in the Boulder County survey notes came from the timber classification. Below is a list of other terms found in the general descriptions with regard to vegetation.

stony prairie, good pasture, excellent pasture, good grazing land, rolling grassy surface, swampy, and slough.

III. Features Recorded at Section Corners and along the Section Lines During the Survey of the Boulder County Study Area.

A. Bearing Trees – see also Table 4.4, p.80

Four bearing trees were used to mark section corners and township corners. Two bearing trees were used to mark quarter section corners. Fewer bearing trees were used only when suitable trees were not found in the immediate area. Trees that were intersected by the section line were recorded in the same manner. These trees are called witness trees. Some corners were set and marked with no bearing trees at all.

Recorded Information: species, diameter, bearing from the corner, and distance from the corner in links and chains.

Tree Species Used: aspen, balsam, boxelder, cedar (juniper), cottonwood, pine, poplar, spruce, white pine, yellow pine.

B. References to Settlement –

Many references to settlement were found in the Boulder County notes. Of them, some were actual features while others were references to a place by name. For example, a field that was entered during the progression of the section line survey was referred to as Johnson's field. Recorded Settlement Features: ditch (irrigating ditch), fence, lode, road, railroad, stone wall, cabin, log cabin, house, plowed ground, cattle trail, and trail.

Examples of Named Features: Higgins park, Johnson's field, Allen's park, Brown's corral, W.H. Larrison's house, Geens field, log shaft house on the Big Blossom Lode, Golden Dipper Lode, Victoria's Crevice Lode, Last Chance Lode, Buckskin, Lode, King Phillip Lode, Elkhorn Monument, Colfax Stamp Mill, Antelope park, and Capt. Brown's house, Estes Park toll road, stream runs through east end of Springdale, Golden Age wagon road, wagon road between Jamestown and Boulder, road to Providence, wagon road from Ward to Burlington, and Stanley Gulch. Furthermore, streams were usually referred to by their common names.

C. Landscape Changes –

Changes in the landscape were noted along the township and section lines.

Examples: foot of mountain, top of hogback, leave deer park ascend mountains, enter timber, leave timber enter small park extending ¼ mile, top of divide between Lefthand and Spruce canyons, enter thick growth of small pines, leave timber and enter prairie, enter bottom land, leave bluff and enter creek bottom, leave prairie and enter cottonwood timber, leave bottom and enter high land, etc...

D. Topographic Features –

The bulk of the features encountered along the line surveys were topographic features. Surveyors recorded their location along the section lines as they crossed each feature.

Examples: bluff, brook, cliff, creek, gulch, island, lake, pond, ravine, ridge, slough, swamp, stream, and spring, limestone ridge, summit of mountain, top of hogback, rocky point, large rocks, rocky knoll, stone slide, hanging rock, ledge of rocks, and outcrop of red sandstone.

Recorded Information:

Water Courses: width in chains and links, direction of flow, common name of feature

Water Bodies: the point where the surveyor entered and left the feature, common name of feature.

Bluffs and ravines or similar: width in chains and links, direction of ridgeline, the point where the surveyor entered and left the feature, common name of feature.

Abundance:

Stream, Brook or Creek	249
Gulch, Ravine, Base of Mountain or similar	178
Ridge, Bluff, Cliff, Summit or similar	219
Slough or swamp	30
Lake, Pond or Spring	9
Island	1
Viewshed	1

The above list contains an outline of the actual content of the PLS notes for the Boulder County study area. The remainder of the chapter is devoted to evaluating this content and addressing any and all pertinent findings within the notes for the study area. It will be broken down into several sections pertaining to topography, settlement, vegetation, the differences between the surveyors, additional findings, and the errors, inaccuracies and limitations associated with the PLS notes for the study area.

Evaluation and Findings

Topography

The locations of water courses, ridges, gulches, landscape changes, water bodies, wetlands and islands that were noted in the survey records were compared to their actual locations on the ground using simple GIS overlay techniques. This was done to assess the similarities and differences between what the surveyors recorded and what is actually there (Table 4.1).

There were 249 references in the notes to a brook, stream, or a creek in the study area. Of these references, 144 were plotted on the National Hydrography Dataset's representation of water courses for the study area, and seventy nine were plotted in an obvious ravine or gulch seen in the topographic GIS data. When combined, references to water courses in the notes were plotted on an obvious water course in the GIS data 90% of the time. Additionally, eighteen, or 7% of the references in the notes were plotted in a location that was close to a water course in the GIS data. Of the remaining references, seven or less than 3% were considered out of place or in a location where a water course was not seen in the GIS data, and one fell in a reservoir.

The surveyors referred to a gulch or a ravine 178 times. Of these references, 153 or 86% were in an obvious ravine or gulch in the topographic GIS data and eleven or 6% were close. The gulches or ravines plotted from the surveyors notes were out of place or in a location where a ravine or gulch could not be seen in the GIS data fourteen times, or 8% of the time.

Table 4.1

Topography and Settlement References

Topography									
Type	Total	Accurate	% Total	Close	% Total	Error Suggested	% Total	Undetermined	% Total
Water Course	249	223	90%	18	7%	7	3%	1	0%
Gulch Ravine	178	153	86%	11	6%	14	8%	0	0%
Ridges	219	192	88%	7	3%	7	3%	13	6%
Wetlands	30	14	47%	0	0%	0	0%	16	53%
Ponds Lakes	9	7	78%	2	22%	0	0%	0	0%
Island	1	1	100%	0	0%	0	0%	0	0%
Viewshed	1	1	100%	0	0%	0	0%	0	0%
Total	687	591	86%	38	6%	28	4%	30	4%
Settlement									
Type	Total	Evidence Exists	% Total	Close	% Total	No Eviden Exists	% Total	Undetermined	% Total
Road	159	89	56%	38	24%	24	15%	1	1%
Fence-line	52	17	33%	0	0%	34	65%	1	2%
Ditch	14	10	71%	0	0%	4	29%	0	0%
Structure	10	5	50%	0	0%	4	40%	1	10%
Trail	4	3	75%	0	0%	0	0%	1	25%
RR	1	1	100%	0	0%	0	0%	0	0%
Total	233	125	54%	38	16%	66	28%	4	2%

Topographic and settlement features with respect to where they fell in relation to modern GIS data.

Ridges, bluffs, cliffs, summits, rocky points, ledges, mountain tops, or similar features were referenced 219 times. Of these references, 192 or 88% were plotted in a location where the GIS data clearly showed evidence of the feature, and seven or 3% were plotted in a location where the GIS data showed evidence of the feature close by. The GIS data showed no evidence of the feature twenty times or 9% of the time, but of those twenty references, thirteen of them were “rocky points” or “large rocks” that likely existed but were too small to be seen in the GIS data.

Thirty swamps or sloughs were referenced in the notes. Fourteen were found to be in an obvious wetland area and two references were left undetermined because the GIS data was inconclusive. Interestingly, fourteen references to swamps or sloughs were plotted in a place where settlement has since taken over the area.

Lakes or ponds were referred to nine times by the surveyors. Seven references were plotted in a lake or pond and two were plotted close to a lake or pond. Similarly, one island was referenced by the surveyors and it was plotted in a braided section of the South Saint Vrain River west of Lyons Colorado.

Most interesting was the one reference to a viewshed. The surveyor recorded in his field notebook a point along a section where “the east summit of Longs Peak bears N 44 deg 15’ W.” When finishing the section line and setting a corner monument for the section the surveyor again references Longs Peak and writes “the summit of Longs Peak bears N 45 W, making the distance by triangulation 7 miles 26 ch 40 lks.” A simple calculation knowing that a chain is sixty six feet long and a link is .66 feet long, as mentioned in the last chapter, returns this distance as 7.33 miles. Using GIS tools, the distance to the summit of Longs Peak was calculated to be 13,072 meters, or 42,876.16

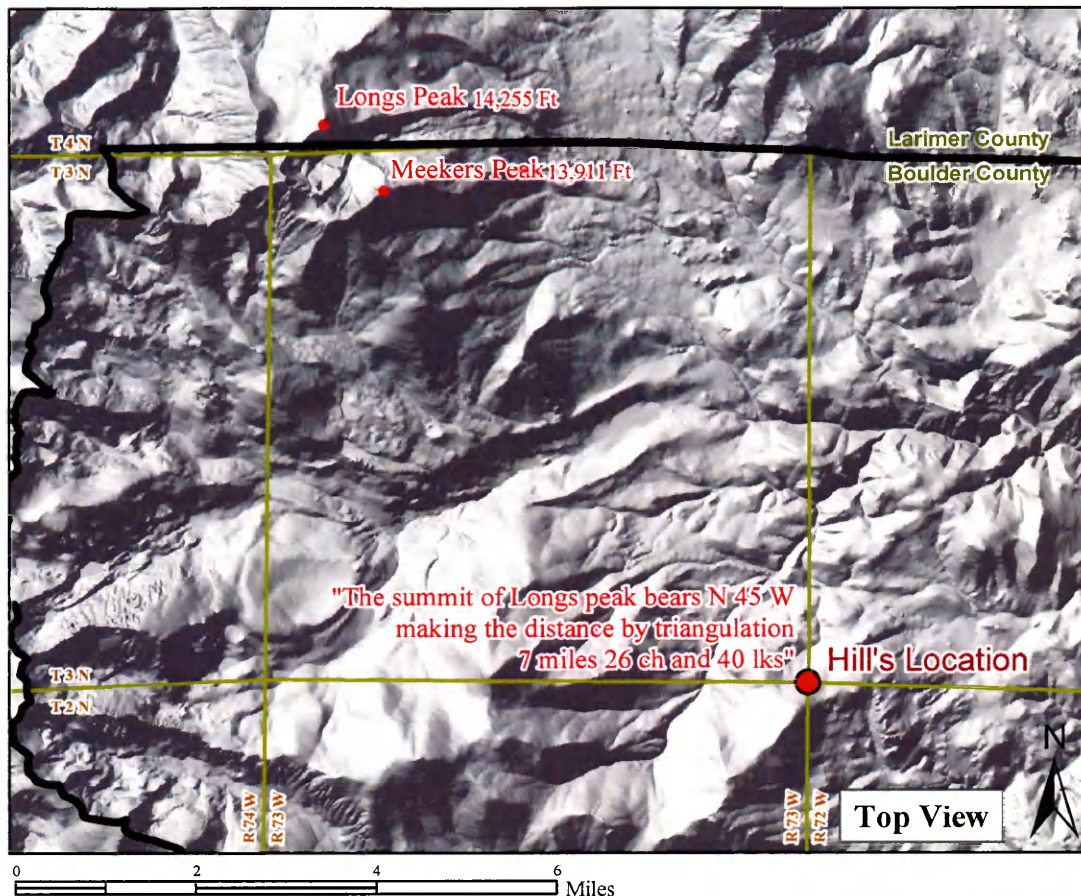
feet, or 8.12 miles. This calculation shows that the surveyor erred by .79 miles in his calculation. What is more interesting is that the surveyor was probably triangulating the distance to Meekers Peak which stands directly in front of Longs Peak from where the surveyor was viewing them (Figure 4.1). The distance in the GIS to Meekers Peak is 12,007 meters, or 39,382.96 feet, or 7.46 miles. This would make the surveyors error only .13 miles.

Overall, 687 topographic features were recorded by the surveyors in the study area. The records were plotted accurately 86% of the time and they were plotted close 6% of the time. Error is suggested in 4% of the plotted records and 4% of the records were left undetermined.

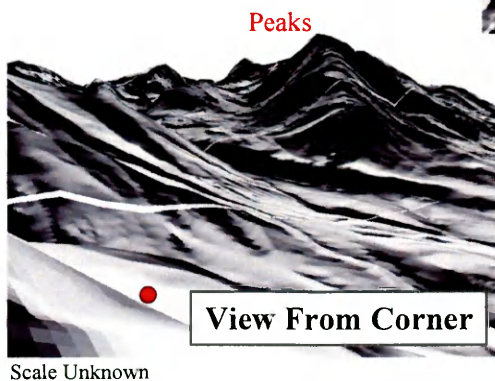
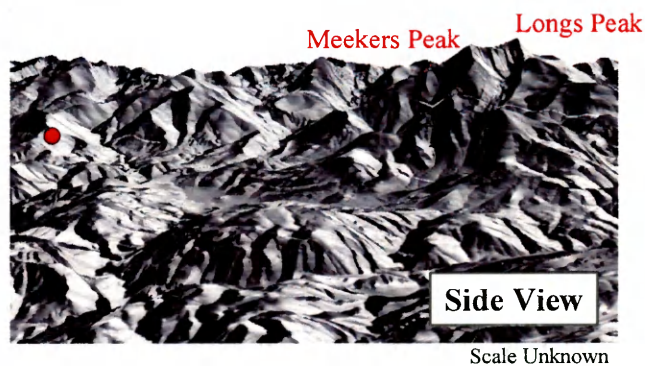
Settlement

Settlement references in the notes were compared in a similar way. References to wagon roads, railroads, fence lines, trails, ditches, houses, and features referred to by name were draped over updated GIS data layers to look for existing evidence of those features today (Table 4.1, p. 56).

The surveyors recorded a road feature in the notes for the study area 152 times. Of these references, eighty-nine or 59% of the recorded road features were plotted on an existing road or in a location where evidence in the GIS data suggests that a road once existed. For example, two references were plotted near an old railroad grade which was evidence enough to suggest that a road once existed that followed this railroad. A reference to a road in the notes was plotted thirty-eight times or 25% of the time in a location that was close to an existing road or in a location where evidence suggests that a



Longs Peak Viewshed



George H. Hill's Calculation
 Distance to Longs Peak:
 7 Miles 26 ch 40 lks = 7.33 Miles

From the section corner
 Longs Peak = 8.12 Miles
 Meekers Peak = 7.46 Miles

Figure 4.1 Longs Peak Viewshed. Viewshed Information entered by George H. Hill 1867. Note Meekers Peak directly in front of Longs Peak from where Hill made his calculation.

Map Designed By: Aron Langley 2004
 Data Source: Original Land Survey Records
 NAD 1927 UTM Zone 13 N

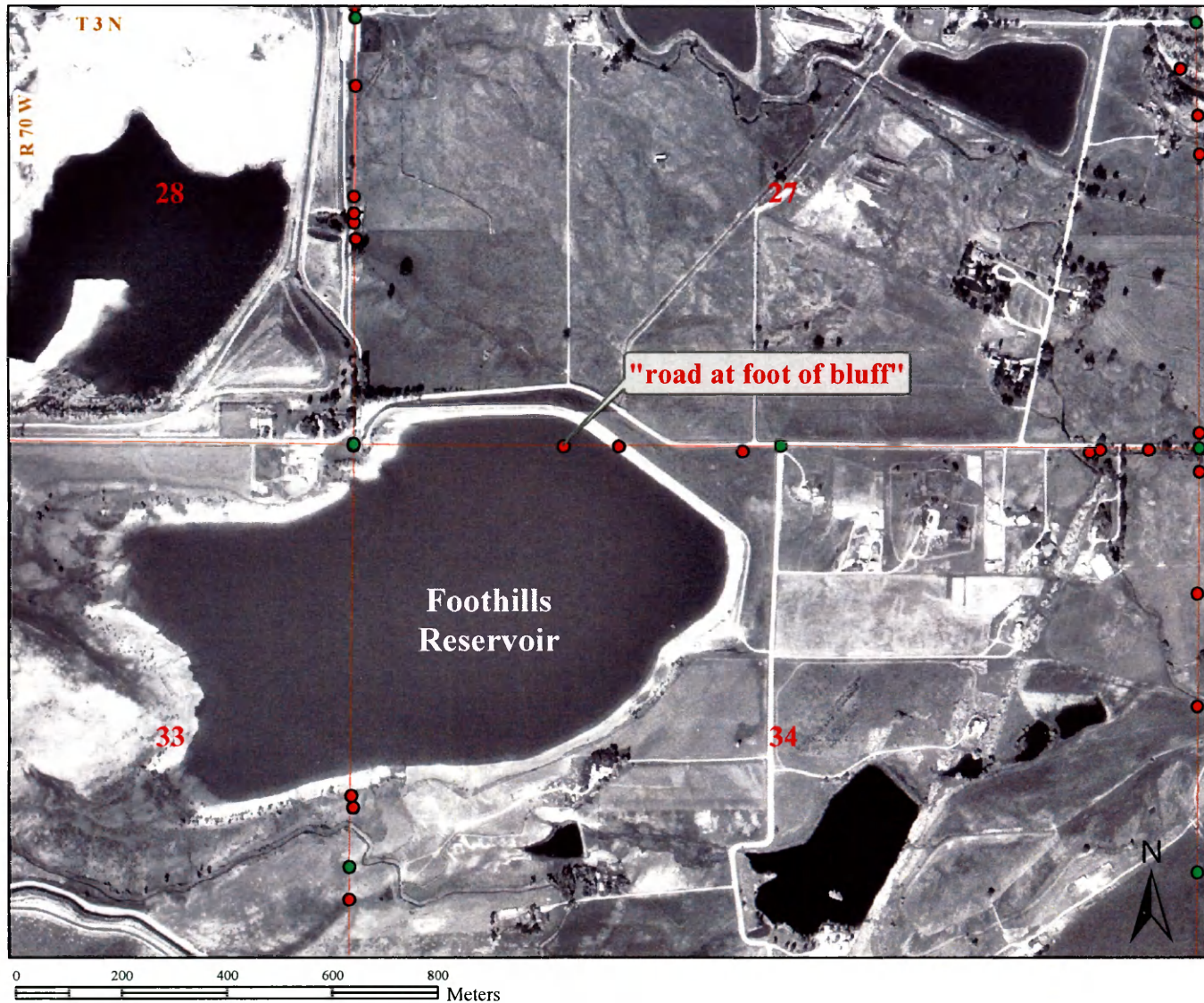
road once existed. No conclusive evidence existed twenty-four times or 16% of the time. Interestingly, seven of these roads were plotted along an existing road that followed a section line. Since section lines were being established by the survey, these roads were considered to have no evidence existing today. Finally, one road was plotted in a man-made reservoir (Figure 4.2).

Fence lines were referenced fifty-two times and none of the references were plotted in a location where conclusive evidence existed of a fence today. A fence line was plotted seventeen times or 33% of the time at a meadow or forest edge, or in a location where a fence may have existed. Although conclusive evidence was not found, there was enough evidence to say that a fence likely existed. For example, one of these fences was plotted along the same railroad grade as described above. Fence lines were plotted thirty-four times or 65% of the time in locations where no evidence is found of fences existing today, and finally, one fence was plotted in a man-made reservoir (Figure 4.3).

Ditches were referenced fourteen times. Conclusive evidence of an irrigation ditch or similar feature existed ten times. No evidence existed four times although the location suggested that an irrigation ditch possibly existed.

Structures were referenced ten times total. One was in a man-made reservoir (Figure 4.3), four lacked evidence, and five were plotted in a location where a structure was seen in an aerial photo taken between 1995 and 1998.

Trails were referenced four times. Evidence existed three times where the trail was plotted along a river or stream and one reference was left undetermined because it



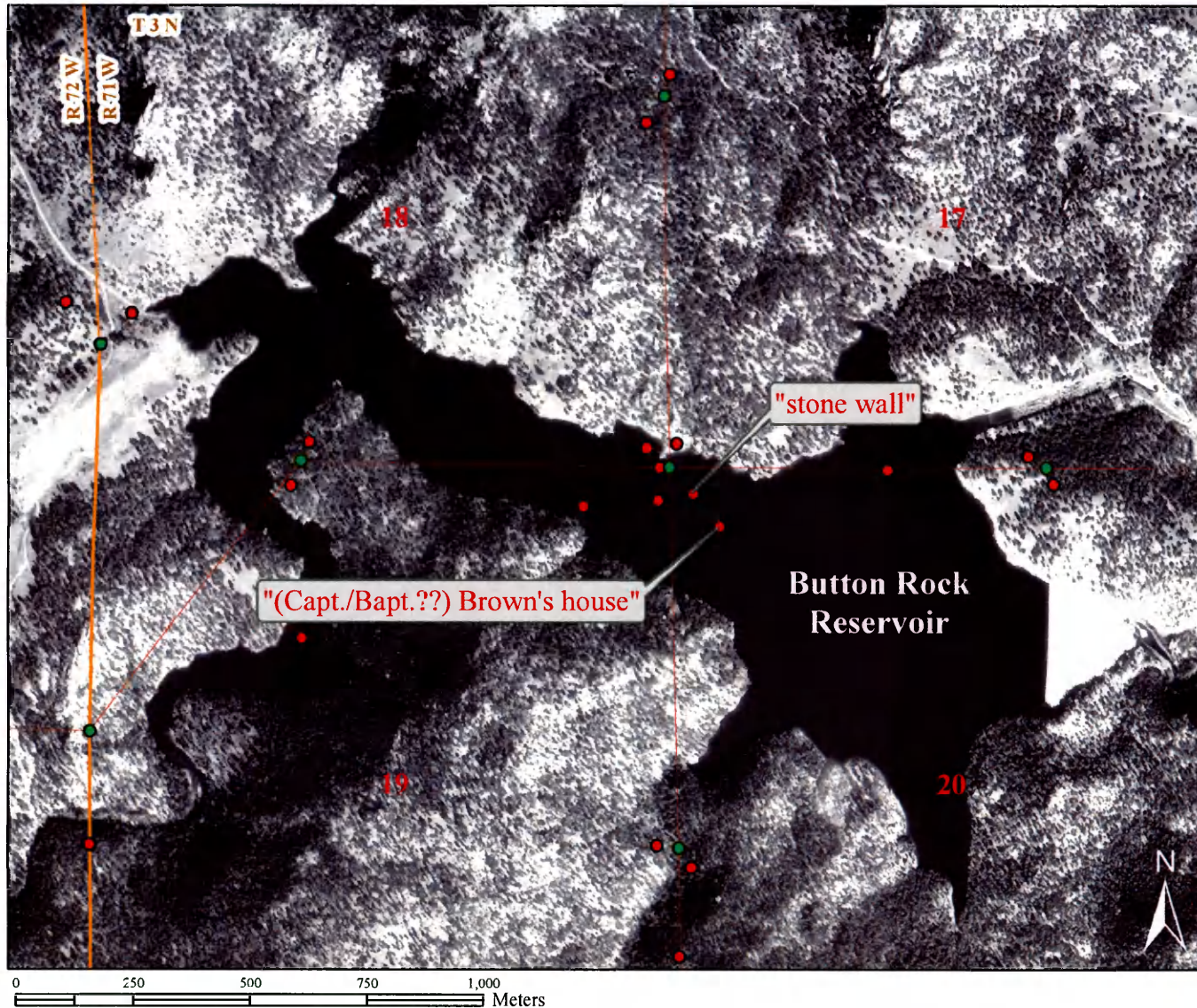
Road in Man-Made Reservoir

William Ashley, noted this road feature in 1864. Located in T3N R70W, It has since been covered by Foothills Reservoir.

- Point location for features from the original land survey notes for Boulder County, CO
- PLS Corner from GCDB
- 33** Section Number
- Section Line

Map Designed By: Aron Langley 2004
 Data Source: Original Land Survey Records
 NAD 1927 UTM Zone 13 N

Figure 4.2 Road in Man-Made Reservoir. Note the location of the road that has been covered by Foothills Reservoir.



"Capt. Browns" House

J.P. Maxwell surveyed the interior of T3N, R71W in 1877. As he surveyed the section lines he noted the location of Capt. Brown's House and a nearby stone fence. Both settlement features have since been covered by Button Rock Reservoir. It's possible that Capt. Brown may be confused with Bapt. Brown, as in Baptist Brown. The difficulty in deciphering the various handwriting styles in the notes led to this and other possible errors.

- Point location for features from the original land survey notes for Boulder County, CO
- PLS Corner from GCDB
- 33 Section Number
- Section Line

Map Designed By: Aron Langley 2004
 Data Source: Original Land Survey Records
 NAD 1927 UTM Zone 13 N

Figure 4.3 "Capt. Brown's House." The location of Capt. Browns house and a nearby stone wall has since been cover by Button Rock Reservoir.

was plotted in the town of Lyons, Colorado where any traces of a trail may have been lost in the development of the town.

Finally, one railroad was referenced in the surveyor's notes. It was recorded as the "center of RR grade" and evidence in the GIS data showed a grown over railroad grade, also referred to above, along a corridor leading into Lefthand Canyon along Lefthand Creek.

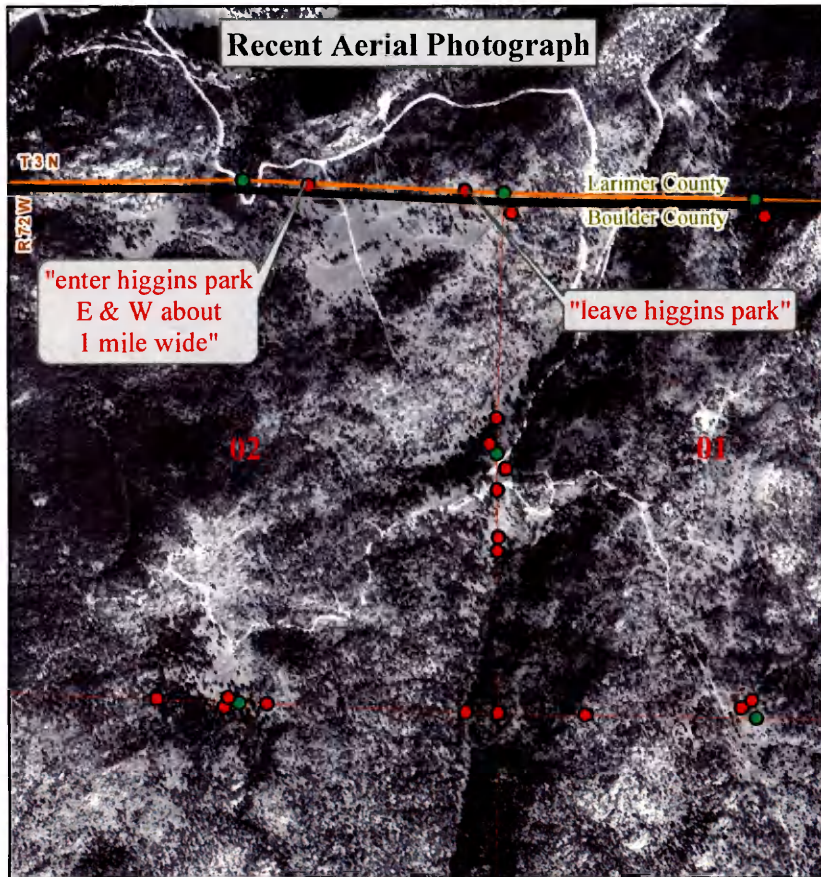
Overall, there were 233 references to settlement and evidence for those references could be found in the GIS data 54% of the time. Several features were recorded in the notes and plotted close to existing features today and this was the case 16% of the time. No evidence of the recorded settlement features existed 28% of the time and 2% of the features were left undetermined because they either fell in a man-made reservoir or in an area where settlement has covered up any evidence of the recorded feature.

Some of the records kept by the surveyors described a location or feature by name. Locations where surveyors recorded their entry into and exit out of a park were often referenced with the common name of the park. Similarly, names were recorded for a structure, mineral deposit, or field. There were twenty-one references made in this manner and each was considered a reference to settlement because a named feature suggests settlement. An example includes one surveyor's reference to the points where he enters and leaves "Higgins Park." The surveyor writes "enter Higgins Park E & W about 1 mile wide" and his following entry records where he leaves Higgins Park along the township line. Interestingly, when viewing this park on an aerial image with the surveyors plotted references overlayed on top of the image, inconsistencies can be seen

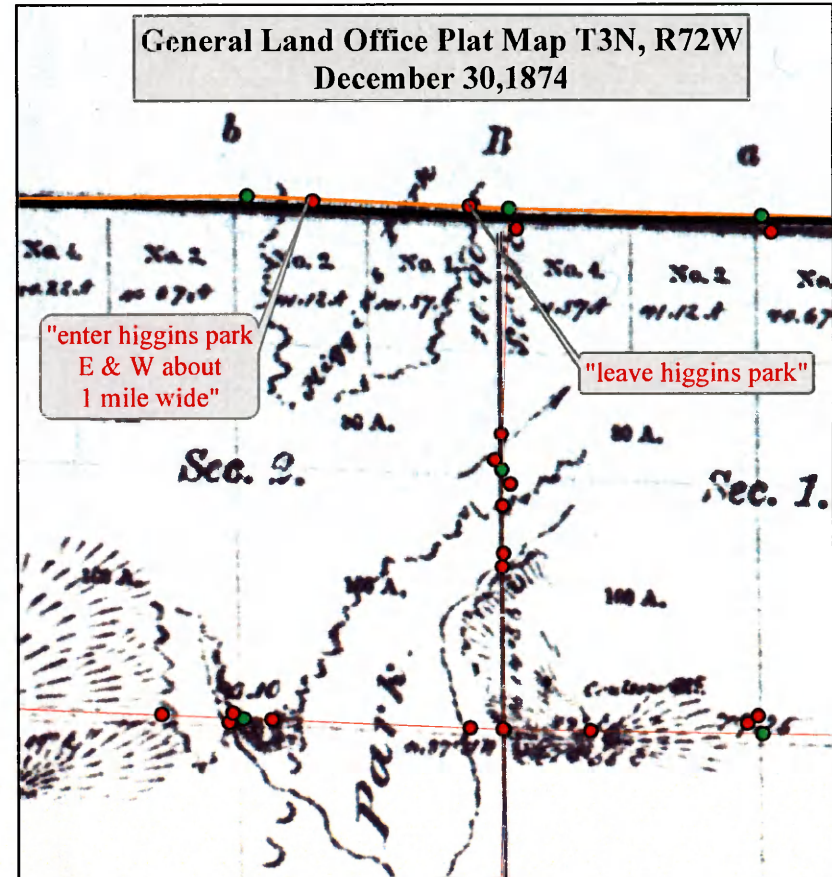
because the park is clearly not one mile wide (Figure 4.4). This is further discussed later in this chapter on page 92.

Several other examples exist of references to named features including references to “Antelope Park”, “Geens Field”, “Brown’s Corral”, “Johnson’s Field”, “Elkhorn Monument”, the “Colfax Stamp Mill”, and “Allens Park” which is in the vicinity of what is known today as the town of Allenspark, Colorado. Aerial images support the reference to four of the named features, Allens Park, Antelope Park, Geens Field, and Johnsons Field. No evidence could be found to support the references to the Colfax Stamp Mill, the Elkhorn Monument, or Brown’s Corral.

Definitive changes in the landscape can be seen in the study area when comparing the survey note records to today’s landscape. For example, records in the notes describe an area where the surveyor enters and leaves a “bottom land,” and today, this area is home to a large sandstone quarry as seen in recent aerial photos. One surveyor describes the location and extent of “allen’s park” as it existed during the time of the survey. The surveyor seems to be describing the extent of an open park void of timber and makes no reference to any structures or settlement. Today, the town of Allenspark, Colorado is located in and around these extents and the open park has either been invaded by forests or the surveyor erroneously recorded these extents at the time of the survey. What is seen today are the remnants of the open park with its boundaries being more confined than what was recorded by the surveyor and the variable extents of the small mountain town. It is also possible that the surveyor was recording the extents of the park along with the extents of the early settlement that had already begun but no evidence was found to suggest this.



Map Designed By: Aron Langley 2004
 Data Source: Original Land Survey Records
 NAD 1927 UTM Zone 13 N



The Extent of Higgins Park

- Point location for features from the original land survey notes for Boulder County, CO
- PLS Corner from GCDB
- 33 Section Number
- Section Line

1:24,000

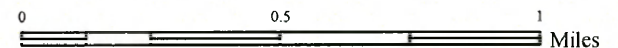


Figure 4.4 The Extent of Higgins Park. Francis F. Brune surveyed this township line in 1871. He notes the extent of higgins park to be '1 mile wide.' Clearly, the park is not 1 mile wide. Either Brune's estimation of one mile is grossly in error, or the forest has invaded the park.

Similarly, another example is the town of Lyons, Colorado, which is located at the intersection of the plains and the foothills at the confluence of the north and south branch of the Saint Vrain River. This is a prime location for a settlement yet there was only sparse mention of settlement in the area and no mention of the town of Lyons in the surveyors' records. Settlement references in the area include two houses in a nearby canyon, two roads on nearby ridge tops, a stone wall outside of today's town limits, good grazing land nearby, and mention of the "Estes Park Toll Road."

Interestingly, there was a reference to a road on the outskirts of what is today the town of Lyons, where the surveyor writes, there is a "major rd from Burlington to Estes Park." It is possible that the town of "Burlington," referenced several times in the notes, is now the town of Lyons, Colorado. No evidence of the town of Burlington was found in the study area. However, there is an elementary school in the town of Longmont, which is several miles east of Lyons, named Burlington Elementary. Additionally, there is a town named Burlington on the eastern plains of Colorado. US Highway 36 runs from Estes Park, Colorado, that was first settled in 1859, across the plains and close to the town of Burlington, that was first settled in 1886.⁹⁸ It is possible that the surveyor was referring to this town and this road. The notes show geographical and historical utility in this regard because landscape changes since the time of the survey can be documented.

Vegetation

Vegetation information in the PLS notes can be found in the section line general descriptions and in the bearing tree data. The section line general descriptions were

⁹⁸ William Bright. *Colorado Place Names*, (Johnson Printing Company; Boulder Colorado, 1993) 22, 50.

compiled and displayed in the General Vegetation Map (Figure 4.5). This section address how this map compared to Kuchler's Potential Natural Vegetation Map and the Colorado Vegetation Model. Additionally, this section reveals what was found in this map in terms of the differences between the surveyors, the generality of the information in the notes, and the potential for its use in historical and geographical studies.

General Vegetation Map

The General Vegetation Map shows a transition from grassland to pine forest to pine spruce forest when traveling from east to west from the plains through the foothills and into the mountains. This same transition occurs in Kuchler's Potential Natural Vegetation map (Figure 2.3, p. 24), although the transition does not occur in the same place. Kuchler's transition from pine forest, which he calls Pine-Douglas Fir Forest, into the pine spruce forest, which he calls the Western Spruce-Fir Forest, occurs further west. Regardless, this transition between grasslands into pine forest, and further into spruce fir forest can be seen occurring in the study area. This is evidence that the General Vegetation Map and the vegetation seen by the surveyors at the time of the survey, is very similar to what Kuchler considers the potential natural vegetation for the study area.

This same transition can also be seen in the Colorado Vegetation Model (Figure 2.4, p. 28), but it occurs further west than both the General Vegetation map and Kuchler's map. The CVM shows four distinct vegetation types when traveling east to west. These vegetation types are Foothills/Shortgrass Prairie, Ponderosa Pine Montane, Lodgepole Pine, and Spruce-Fir Forest. The CVM shows similar transition zones to what Kuchler's map shows but the vegetation types are different. What Kuchler calls a

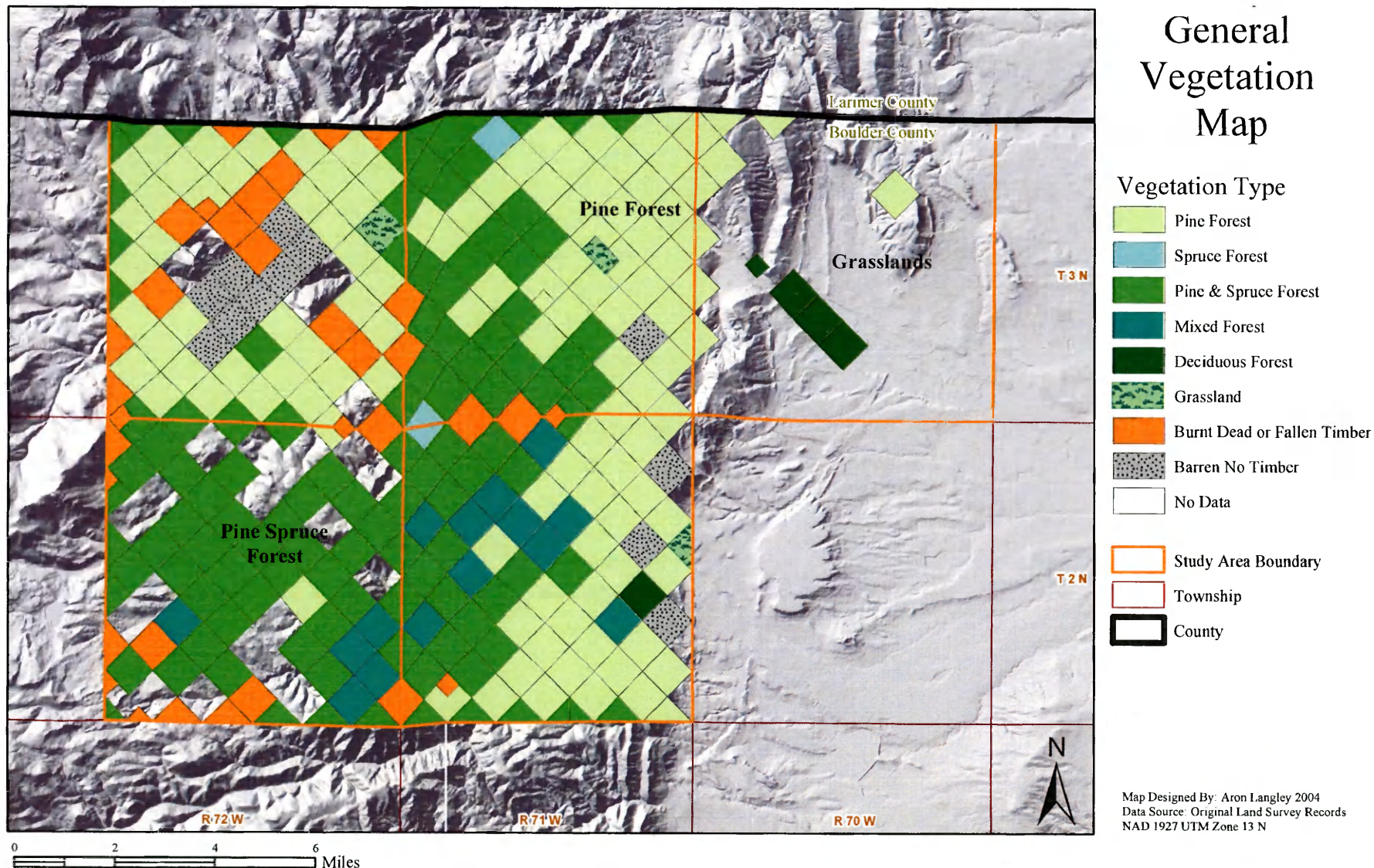


Figure 4.5 General Vegetation Map. Derived from the section line general descriptions in the original land survey records.

Western Spruce Forest, the CVM calls Lodgepole Forest. What Kuchler calls Pine Douglas-Fir Forest, the CVM calls Ponderosa Pine Montane. What Kuchler calls Gramma Buffalo Grass, the CVM calls Foothills/Shortgrass Prairie. Finally, the CVM shows a Spruce-Fir Forest further west than Kuchler, in fact, Kuchler calls this area on his map Alpine Meadows and barren.

If the Lodgepole Pine forest and the Ponderosa Pine Montane forest were combined in the CVM, a transition from grassland into pine forest, and further west into Spruce-Fir forest would be seen, but it would be occurring further west than what both Kuchler shows in his Potential Natural Vegetation map and what is seen in the General Vegetation Map. This would suggest that the pine forests have replaced the Spruce-Fir forests at lower elevations and pushed them further west into the higher elevations. Even more interesting is the suggestion that Lodgepole Pine has replaced the Spruce-Fir forests. Evidence for this replacement comes from the fact that the transition zone seen in all three maps occurs in the same area. In both the General Vegetation Map and Kuchler's map, pine transitions into Spruce forests at the same spot. At this same spot in the CVM, Ponderosa Pine Montana transitions into Lodgepole Pine while the Spruce-Fir forest occurs further west and out of the study area (Figure 2.3 p. 24, Figure 2.4 p. 28, and Figure 4.5 p. 68).

Differences between surveyors can also be seen in the General Vegetation Map. When looking at Township 3 North Range 72 W (T3N R72W), it is clear that the surveyor of the township lines was different than the surveyor of the interior of the township. The interior surveyor recorded a more general description of the vegetation along the section lines than the surveyor of the township lines. The interior surveyor

almost always recorded what he saw as “scattered pine” while the township surveyor recorded his findings to be variables of “pine spruce forest.”

The interior surveyor’s descriptions also stand out when viewing all of the townships collectively. The interior surveyor for T3N R72W described the township as being dominated by “scattered pine,” while the township directly south was described as being dominated by “pine spruce” by another surveyor. This difference is difficult to explain considering the townships are very similar in location, elevation, and topography. It may simply be a case where one surveyor considered all of the trees to be conifers, or “pines” in his eyes, while the other surveyor considered the conifers to be ponderosa pine and spruce. What is evident though is that a third surveyor extended his descriptions to include even more detail by adding categorical values like few, heavy, fair, small, good, burnt, or poor timber.

Three evident differences are seen between these three surveyors in terms of how much detail they recorded in their vegetation descriptions. Instructions did not specify how much detail was to be recorded, it was at the discretion of the surveyors.

Further findings in the General Vegetation Map include descriptions of burnt, dead or fallen timber. This could indicate the presence of wildfires, diseased timber, and even meteorological events like blow downs. The PLS notes have potential to be used to better log these historic events. Additionally, the PLS notes show a potential for use in mapping historic forest extents and forest structure but this would likely require a sizeable study area. The descriptions are probably too general to be effective in providing this type of information for a small study area.

However, potential does exist for the general descriptions to provide utility in localized research. Several descriptions mention a change of vegetation along creek bottoms where the timber was described as “pine timber” and mention was then given to “aspen and cottonwood along creek bottoms.” This allows a researcher to perform a more localized study on the changes in a creek bottom landscape. Similarly, mention was sometimes given to locations where “good lumber pine” or “excellent pastures” existed. Mention was also given to “seeding pines”, “good grazing land”, and areas that were “not fit for cultivation.” Localized research may be performed on these areas with this unique knowledge when supported by additional resources.

Bearing Tree Data

Bearing tree data is the most sought after information in the original survey notes. Limitations exist in using this data due to the way it was collected. The sample is not random and therefore spoils conclusions drawn from statistical review of the bearing tree data. Bias is known to exist in the selection of the trees although no bias was tested for or found in the records used in this thesis. Regardless, the data exists and can be utilized in several ways.

The number of trees per acre was calculated for each corner and quarter corner to show how dense the forest was at those corners during the time of the survey. See Chapter III. This was done in concurrence with the research done by Cottam and Curtis.⁹⁹ Any corner that returned a value that was greater than 120 trees per acre was considered to be a high tree density corner. Corners that returned a value of less than 10 trees per acre were considered low tree density corners. Corners returning a value

⁹⁹ Cottam and Curtis, 453

between 11 and 119 were considered too close to call. There were a total of 601 corners that were calculated. Of these corners, 17% returned a high density value, 55% returned a low density value, and the remaining corners were considered too close to call (Table 4.2).

The utility of the density values is seen when comparing them to the aspect values for all the slopes in the study area. Questions as to what aspect the high forest density corners fall, or what aspect certain species occur, can be evaluated using the density values. First, the aspect was calculated for all of the slopes in the study area (Figure 4.6). The density values were then displayed over this file and a count was taken for each density class in terms of the aspect in which the corner fell (Table 4.2).

Of the 102 high forest density corners, 52% were found on a north facing slope while only 19% were found on a south facing slope. Similarly, 32% of the low forest density corners were on a south facing slope while 40% were on a north facing slope. This is evidence that a north facing slope, with its wetter, cooler climate, has a higher density of trees.

Similarly, the location of each species of bearing tree can be made with respect to the aspect in which it fell. Table 4.3 shows that pine, as recorded by the surveyors, occurs somewhat equally on all slope aspects. Pine occurred 35% of the time on north facing slopes, 38% of the time on south facing slopes and 27% of the time on east or west facing slopes. However, spruce, as recorded by the surveyors, occurred more frequently on north facing slopes than on any other. Spruce was found on north facing slopes 54% of the time, 20 % of the time on south facing slopes, and 26% of the time on east or west facing slopes. The fact that pine occurred evenly and spruce occurred more often on

Table 4.2

Forest Density and Aspect

<u>Corner Density</u>	<u>Total</u>	<u>%</u>	<u>N Slope</u>	<u>%</u>	<u>S Slope</u>	<u>%</u>	<u>EW Slope</u>	<u>%</u>
High Tree Density (trees per Acre = 120+)	102	17	53	52	19	19	30	29
Low Tree Density (trees per acre = 0 – 10)	333	55	107	32	134	40	92	28
Average Tree Density (trees per acre = 11 – 119)	166	-	43	26	82	49	41	25

Equation for Section Corners: $[43560/ d^2] (n/4)$

Equation for Quarter Section Corners: $[43560/ d^2] (n/2)$

d = average distance to all bearing trees

n = number of bearing trees marked

The number of trees per acre was calculated for each section and quarter section corner using the number of bearing trees recorded for the corner and how far each tree was from the corner to determine if the corner had a high tree density, a low tree density, or an average tree density. Each corner was then checked to determine its location with respect to the aspect of the slope in which it fell.

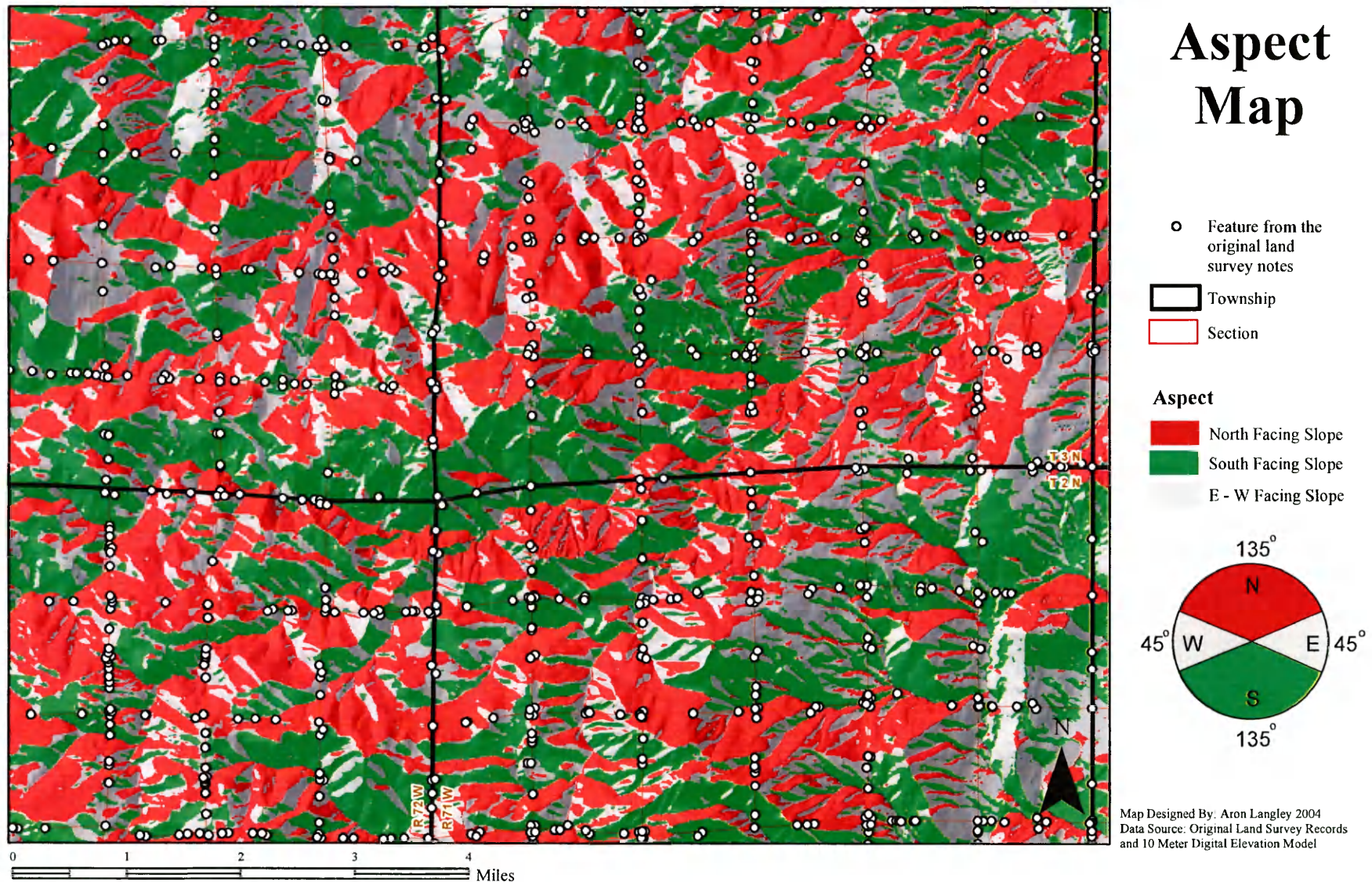


Figure 4.6 Aspect Map. The location of each feature from the original notes, with respect to the aspect of the slope in which it falls, can be derived.

Table 4.3

Bearing Trees and Aspect

<u>Bearing Tree</u>	<u>N Slope</u>	<u>S Slope</u>	<u>EW Slope</u>	<u>Total</u>	<u>% N Slope</u>	<u>%S Slope</u>	<u>%EW Slope</u>
Pine	210	225	158	593	35	38	27
Spruce	45	17	22	84	54	20	26
Cottonwood	5	9	0	14	-	-	-
Aspen	3	2	1	6	-	-	-
Yellow Pine	1	0	2	3	-	-	-
Balsam	0	3	0	3	-	-	-
White Pine	0	0	1	1	-	-	-
Poplar	0	0	1	1	-	-	-
Cedar	0	0	1	1	-	-	-
Boxelder	1	0	0	1	-	-	-
Total	265	256	186	707	37	36	26

Bearing trees were subdivided into species and then checked to determine the aspect of the slope in which each of the trees fell.

north facing slopes would suggest that spruce is a shade tolerant species and would prefer a wetter, cooler climate, while pine is more adaptable. Other species were not considered because of the low sample numbers. Finally, the table shows that all bearing trees, when not subdivided into species, occurred evenly on both north facing slopes and south facing slopes.

Looking at the number of bearing trees on a north facing slope versus the number of bearing trees on a south facing slope is arbitrary because the results should be close to identical. Aspect numbers for bearing trees are only valid when calculating which species may occur more often on which aspect because this determination is normalized by species. Likewise, when looking at forest densities, the determinations are valid because they are normalized by density values.

The density values were also overlaid onto aerial photos from 1995 to 1998 to see where the corners fell in relation to the forests seen in the photos. Of the 102 high density corners, 95% of them fell in a wooded area seen in the photos. Interestingly, only 58% of the low density corners fell in an area that was seen as low density in the aerial photos. An overwhelming number of them fell in a high density area or an area where it was definitely not low density. This was the case for 42% of the 333 low density corners. This could be the result of several factors. One, the density numbers and calculations are not reliable; two, the forest extents have grown since the time of the survey; or three, the surveyors may have failed to record bearing trees as instructed.

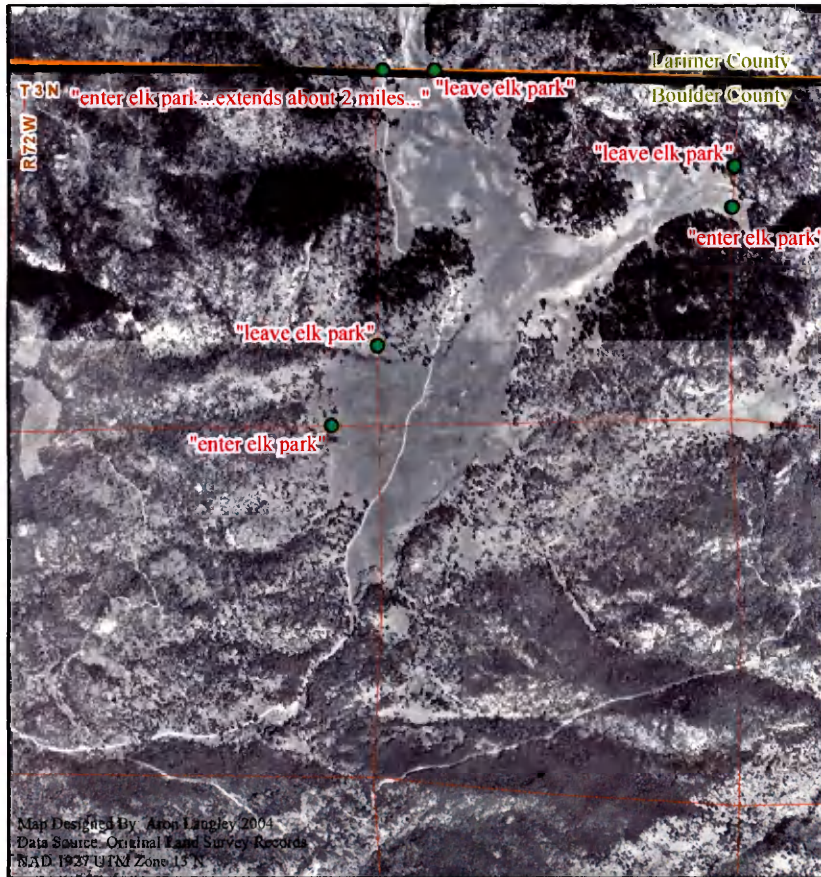
No evidence was found that would suggest that the density numbers and calculations were unreliable other than the fact that there were a high number of low density corners that fell in a wooded location in recent aerial photographs. The

possibility of surveyor error will be discussed later. Evidence was found however, that would suggest that the extents of the forests have not grown since the time of the survey.

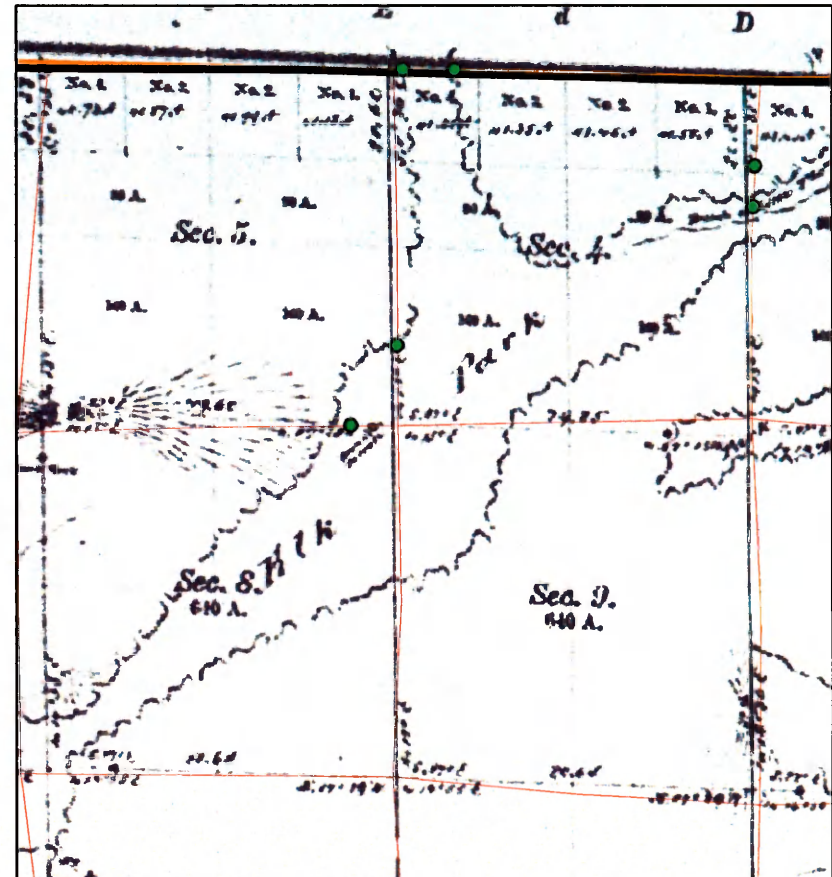
This evidence comes from intermittent references in the notes to landscape changes encountered by the surveyors. As the surveyor entered a field, meadow, or park, he made reference to it in his notes. The same was done for the point at which he left the park and entered timber. These points, where the surveyor encountered landscape changes, were plotted over recent aerial photos for evaluation. Figure 4.7 shows the points where the surveyor entered and left “Elk Park” during the survey. These points clearly show that the surveyor accurately recorded the extent of this meadow, and that the extent of the meadow has not changed dramatically since the survey. Similar evidence is found in several locations suggesting that the forests have not encroached upon the various mountain landscapes.

A digital representation of the plat map for T3N R72W was also added to the GIS for analysis. The plat map was drawn from the original notes from the surveyors after they came in from the field. In general, plat maps contained limited amounts of information. When looking at the extents of elk park in the plat map, the PLS notes contradicted the plat map and more closely resembled the parks’ extents in recent aerial photos. This would suggest that the plat map was a poor representation of the topographic data collected by the surveyors.

A raster image of forest density (Figure 3.4, p. 45) was created in the GIS using the trees per acre field in the Coords file. This field was calculated using the data obtained from the bearing tree information. The raster image of forest densities was draped over vegetation maps and land cover maps for the study area and no results were



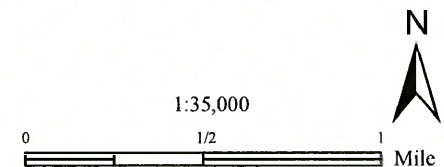
Recent Aerial Photograph



General Land Office Plat Map T3N, R72W
 December 30, 1874

The Extent Of "Elk Park"

Figure 4.7 The Extent of Elk Park. Note the points where the surveyor entered and left the park in both the aerial photograph and the 1874 GLO plat map. Also note the difference between the plat map and the photograph.



found. It was hoped that the density map would show the extent and location of the forested areas in the study area. It did not. It appeared to show areas of higher forest density and areas of low forest density but these findings were not corroborated by any of the supporting GIS data. The size of the study may have played a role in the lack of results obtained from this raster image. A larger study area would likely show discernable results.

The bearing tree data did produce some interesting results when creative analysis was performed in the GIS. Table 4.4 contains data for all of the trees recorded in the survey, including bearing trees, trees intersected by the line of the survey, and witness trees. The surveyors recorded the diameter, species, and distance to the each tree, as required by instructions. This data was used to calculate some basic tree statistics for the study area, which can be found in the table.

Differences Between Surveyors

It is important to understand before using the original land survey notes that differences exist between each surveyor in terms of how detailed his descriptions were and the terminology used by each individual. What one surveyor calls a brook, another may call a creek. The same is true for ridges, cliffs, gulches, ravines, etc. Surveyors were also inconsistent in their terminology used to record features. The next section discusses these differences.

Of the 249 references to water courses in the study area, the surveyors recorded 10 as 'streams,' 69 as 'brooks,' and 170 were recorded as 'creeks.'

Table 4.4**Bearing Trees**

<u>Bearing Tree</u>	<u>% Total</u>	<u>Count</u>	<u>Ave Dia (in)</u>	<u>Min Dia</u>	<u>Max Dia</u>	<u>Ave Dist (ft)</u>	<u>Min Dist</u>	<u>Max Dist</u>
Pine	84	598	10.8	3	36	30.7	0	261.4
Spruce	12	85	10.9	4	30	18	0	118.8
Cottonwood	02	14	5.7	3	10	41.4	0	166
Aspen	<01	6	5.8	2	14	21.7	8.6	35.6
Yellow Pine	<01	3	15.7	8	27	10.7	2.6	21.1
Balsam	<01	3	6.7	5	8	7.0	5.9	8.6
White Pine	<01	1	9	-	-	13.9	-	-
Poplar	<01	1	10	-	-	136.6	-	-
Cedar	<01	1	5	-	-	50.2	-	-
Box elder	<01	1	6	-	-	161.7	-	-
All	100	713	10.7	2	36	29.5	0	261.4

Only one surveyor recorded water courses as streams. This surveyor recorded ten streams ranging from 5 links wide to 70 links wide. This same surveyor recorded fifteen creeks ranging from 4 links wide to 78 links wide, and six brooks ranging from 5 links wide to 24 links wide. This shows variable and inconsistent ranges in widths for each term used for a water course by this surveyor alone.

Another surveyor recorded every creek as 50 links wide while he recorded brooks ranging from 3 links wide to 6 links wide. This shows a consistency in terminology but an inconsistent record of creek widths.

A third surveyor records creeks ranging from 100 links wide to 220 links wide and often left the width unrecorded.

A fourth surveyor recorded creeks ranging from 1 to 50 links in width, and brooks ranging from 1 to 6 links in width. Further evidence exists with the remaining surveyors as to their inconsistencies in terming water courses. This shows an overall lack of utility in the survey records when relying on the terminology used by the surveyors and in some cases, it shows obvious inaccuracy, as is the case where every creek recorded by one surveyor was 50 links wide, which was most likely an estimation.

As discussed, the surveys were performed for legal reasons and not meant to be a scientific survey of the landscape. This can be seen when considering the amount of detail recorded between surveyors.

George H. Hill surveyed a portion of the 9th guide meridian in the study area in 1867. George E. Pierce surveyed township exteriors in the study area in 1863. When compared to one another, Hill is much more descriptive than Pierce. Pierce performed his surveys as per instruction yet his notes fail to provide anything in excess. He set all

but one corner with a “mound and charred stake,” a method that lacked permanence. He also marked no bearing trees, and was redundant with his descriptive terminology. Hill provided more detail in his general descriptions, recorded various species of bearing trees and set corners using a more permanent marker.

Francis F. Brune, who surveyed township exteriors for the study area in 1871, recorded his notes with the same amount of descriptiveness as Hill. All three surveyors met the standards set at the time for surveying township boundaries, but only Pierce lacked detail in his records and showed no attention to permanence. In fact, Brune failed to relocate several corners set by Pierce eight years previous, when he was completing an intersecting township boundary.

Pierce completed his surveys to the standards set by instructions but he basically did only what was asked of him while the others went beyond.

Elijah James Hall surveyed the interior of T3N R72W in 1874. He was very consistent with his record keeping and recorded more data on landscape changes than the other surveyors, but he had trouble with a few section lines that he called “impassible.” His township general description stated that the “surface is very rough and broken ground, mostly barren rocks.” Interestingly, Hall marked fewer bearing trees than anyone but Pierce even though the interior of the township showed ample timber in recent aerial photos. Hall also referenced in his township general description “different parks among which are: allens park, deer park and elk park that contain in the aggregate about 2500 acres which is susceptible of cultivation.” He also stated that the township “is well watered with good mountain springs in convenient locations.”

William Ashley surveyed a portion of T3N R70W in 1864. His descriptions were different only because this township is mostly flat and borders the other mountainous townships in the study area. He marked his corners with a variety of materials, sandstone being the most common. This is interesting because the sandstone most likely had to be transported from the foothills to their corner locations. Unlike Pierce, his corners were set with more permanence in mind. He marked no bearing trees on the plains, but where trees were seen in recent aerial photos, he marked them, including Box elder, Poplar, Pine and Cottonwood trees. He set two granite stones as corners in the middle of the prairie, both in locations where the GIS data showed possible evidence that granite obtrusions may exist. This would suggest that he performed his surveys with an attention to detail that was not seen in the Pierce surveys. Furthermore, his township general descriptions showed similar detail. He stated that the “twp contains some good farming land but is more valuable for its pasture lands, it being covered with good grass the entire year.” Hal Sayr surveyed the remaining portion of this township in 1875.

J.P. Maxwell surveyed the interior of T3N R71W in 1877. Both the north and south branch of the Saint Vrain River run through this township. Maxwell crossed these rivers eighteen times during the survey and he calculated the width of the rivers to be 50 links wide every time he crossed them. This is an obvious estimation of the width of the rivers. George S. Oliver surveyed two township interiors, T3N R71 and 72W, he crossed the south branch of the Saint Vrain River eleven times and his calculations ranged from 20 to 50 links in width. When Hall surveyed his township interior he calculated the width of the North Saint Vrain River to range from 23 to 60 links wide when he crossed it

fourteen times. These differences between the surveyors need to be considered when working with other aspects of the survey records.

Interestingly, Maxwell was the third surveyor to make reference in his township general description to the land being valuable as a commodity. He states that the “E half of the twp affords good grazing land and will support 400 to 500 head of stock the year round.” This is evidence that the surveys were performed for legal reasons and not for scientific purposes. The surveyors likely saw their job as a process for which they were to document the land and its resources so it could be sold, settled and used as a commodity, rather than a scientific sample of the land and its resources. The other surveyors who made similar references were William Ashley and Elijah James Hall.

Overall, every surveyor performed his duty to the standards set by the instructions. The systematic documentation of the land and its resources contained in the survey notes cannot be found in other sources. Only the Pierce surveys, which were incidentally the first surveys conducted on any portion of the study area, lacked diversity in their descriptions. This can lead to an unexpected void for researchers. The surveyor did nothing wrong, he only did what was asked, while the others showed a commitment to providing a more diverse and more detailed record of what they encountered.

Additional Interesting findings

When working with the PLS notes, historically interesting or geographically interesting things were often encountered. These interesting findings show historical significance and add to the utility of the PLS records. Coupled with previous findings

discussed above, they help in the assessment of the utility of the survey notes for use in historical and geographical studies.

As the surveys progressed from the plains into the mountains, where the geology changes from sedimentary rock into igneous rock, the materials used to set corners also changed from sedimentary rock to igneous rock. This is an interesting, if not unexpected, finding. Even more interesting is the few cases where the surveys progressed through “sandstone cliffs,” and “hogbacks,” but corners were set with granite stones (Figure 4.8).

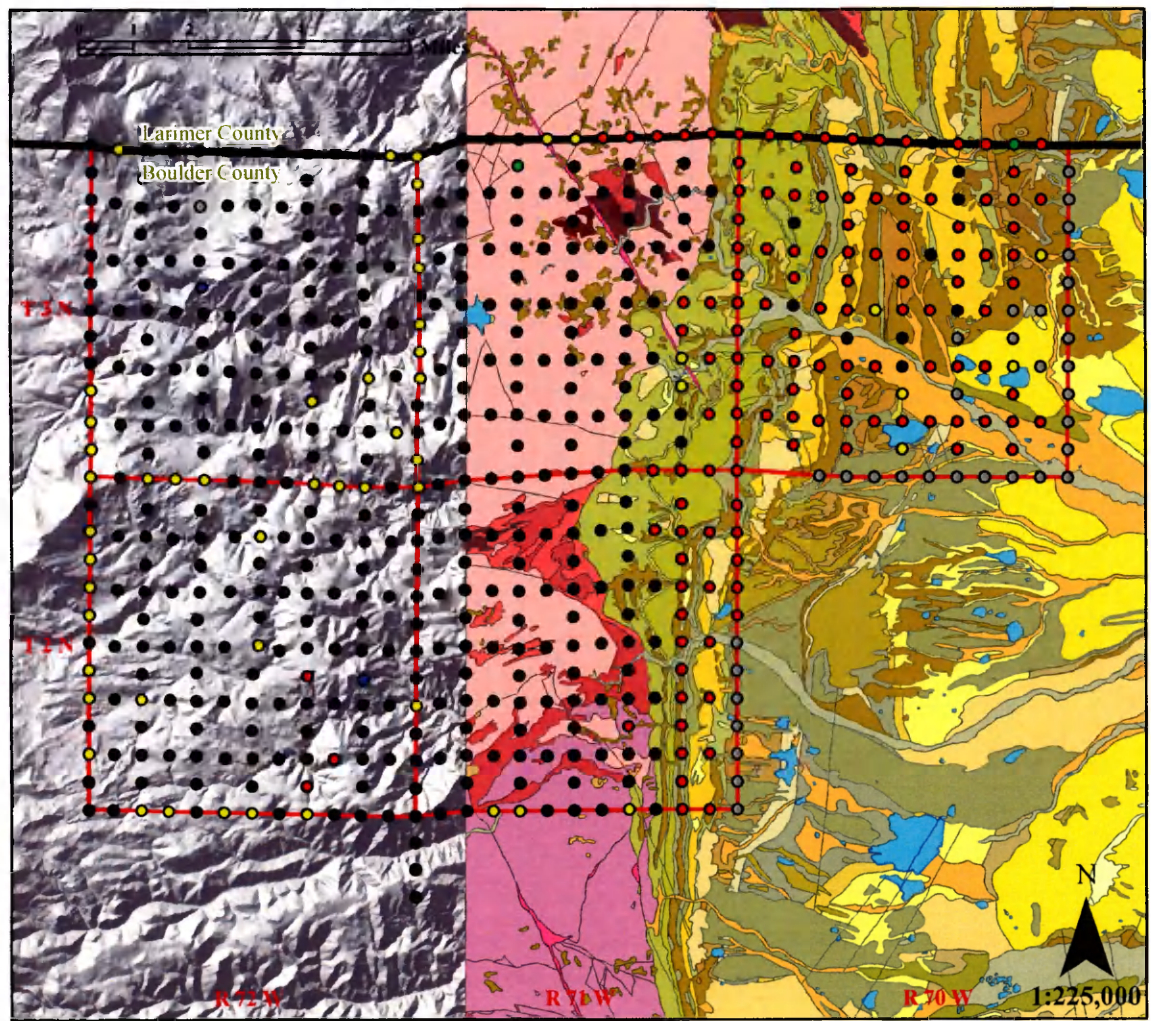
The town of “Burlington” was referenced several times while recording the location of a road, or railroad grade. This is interesting because there is no evidence of this town existing today other than what was discussed above when speaking about the lack of settlement references in and around the town of Lyons, Colorado.¹⁰⁰

One Bearing tree was recorded as a cedar. At the time of the survey, cedar was the common name for juniper.¹⁰¹ It is interesting to see the different plant names used by the surveyors from this time period and these differences should be recognized by the researcher when working with the PLS records. Not only did the surveyors use different terminology than what is used today, but their handwriting styles were different, which created problems when interpreting what was recorded. Some handwriting styles were sloppy while others were a strong cursive, making most of the handwriting styles hard to decipher without prolonged exposure.

George S. Oliver recorded one feature that stood out in the evaluation of the notes because of how accurate it was. Oliver recorded in T2N R72W the location where he encountered the “top of a large rock.” When seen in a recent aerial photo, the reference

¹⁰⁰ Refer back to page 66.

¹⁰¹ Galatowitsch, 187.



- Corner Material**
- Igneous
 - Sedimentary
 - Conglomerate
 - Post in Mound
 - Other
 - Tree
- Study Area Townships
County Line

- Geology**
- Sedimentary Rock**
- Artificial fill
 - Post-Piney Creek Alluvium (upper Holocene)
 - Talus (upper Holocene to Pleistocene)
 - Colluvium (upper Holocene to Pleistocene)
 - Eolium (windblown clay, silt (loess), sand, and granules) (upper Holocene to Bull Lake Glaciation)
 - Landslide deposits (Holocene to Pleistocene)
 - Piney Creek Alluvium (upper Holocene)
 - Broadway Alluvium (Pinedale Glaciation, Pleistocene)
 - Louviers Alluvium (Bull Lake Glaciation, Pleistocene)
 - Slocum Alluvium (Sangamon Interglaciation or Illinoian Glaciation, Pleistocene)
 - Verdos Alluvium (Yarmouth Interglaciation or Kansan Glaciation, Pleistocene)
 - Rocky Flats Alluvium (Altonian Interglaciation or Nebraskan Glaciation, Pleistocene)
 - Pre-Rocky Flats Alluvium (Nebraskan(?) Glaciation, Pleistocene)
 - Boulder deposits (Pliocene?)
 - Quartz monzonite (Eocene)
 - Rhyodacite and basalt (Paleocene)
 - Denver (Paleocene and Upper Cretaceous) and Arapahoe (Upper Cretaceous) Formations
 - Laramie Formation (Upper Cretaceous)
 - Fox Hills Sandstone (Upper Cretaceous)
 - Upper transition member of Pierre Shale (Upper Cretaceous)
 - Upper shale member of Pierre Shale (Upper Cretaceous)
 - Richard, Larimer & Rocky Ridge Sandstone Member of Pierre Shale (Upper Cretaceous)
 - Middle shale member of Pierre Shale (Upper Cretaceous)
 - Hygiene Sandstone Member of Pierre Shale (Upper Cretaceous)
 - Lower shale member of Pierre Shale (Upper Cretaceous)
 - Niobrara Formation (Upper Cretaceous)
 - Carlile Shale (Upper Cretaceous), Greenhorn Limestone (Upper Cretaceous), and Graneros Shale (Upper and Lower Cretaceous)
 - Dakota Group (Lower Cretaceous)
 - Morrison Formation (Upper Jurassic), Canyon Springs Member of Sundance Formation (Upper Jurassic), and Jelm Formation (Upper Triassic)
 - Lykins Formation (Triassic and Permian)
 - Lyons Sandstone (Permian)
 - Satanka and Ingleside Formations (Permian)
 - Ingleside Formation (Permian)
 - Fountain Formation (Permian and Pennsylvanian)
- Igneous Rock**
- Silver Plume Quartz Monzonite (Precambrian Y)
 - Pegmatite (Precambrian Y or X)
 - Boulder Creek Granodiorite (Precambrian X)
 - Tonalite (Precambrian X)
 - Quartzofeldspathic schist and gneiss interbedded with mica schist and gneiss (Precambrian X)
 - Knotted mica schist (Precambrian X)
 - Porphyroblastic biotite schist (Precambrian X)
 - Amphibolite (Precambrian X)
 - Brecciated rock
 - Open water

Corner Material And Front Range Geology

Figure 4.8 Corner Material and Front Range Geology. Material used by the surveyors to set corners seen alongside the geology of the front range. Note the abrupt change from sedimentary rock into igneous rock (from east to west) in both maps.

Map Designed By: Aron Langley 2004
Data Source: Original Land Survey Notes
United States Geological Survey USGS
NAD 1927 UTM Zone 13 N

was plotted directly on the top of a large granite obtrusion along the section line (Figure 4.9).

There were also numerous references to previous mining surveys in the notes. They were referenced by calculating the bearing and distance from a point on the line to a corner of a previous mining survey. These references were not added to the survey note database for the project, but it is important to note that numerous references existed.

Time was spent in the National Archives and Records Administration in Denver, Colorado looking for information about the various surveyors who surveyed the study area.¹⁰² A few interesting facts were obtained about the surveyors. Francis F. Brune, who executed PLS surveys in 1867, 1869, 1871, and 1873, was suspended by the General Land Office in 1881 for “non-compliance with instructions” as was Hal Sayr in 1880.¹⁰³ No evidence of this was found in any of the Brune surveys, but interestingly, Hal Sayr did make a mistake that will be discussed shortly. William Ashley and his relatives performed a large number of surveys as did George Hill. Pay rates were also recorded showing that surveying guide meridians and standard parallels paid the most while interior township surveys paid the least. Finally, Colorado surveying took place very rapidly between 1863 and 1876 when finally in October of 1876 the first month went by without any contracts being awarded since their beginning.¹⁰⁴

¹⁰² National Archives and Records Administration, RG 49.

¹⁰³ National Archives and Records Administration, RG 49.

¹⁰⁴ National Archives and Records Administration, RG 49.



Top Of Large Rock

George S. Oliver noted this feature in 1883 in his interior survey of T2N R72W. As he surveyed the section line from south to north, he encountered & noted the "top of large rock." Also note the locations of the points where he encountered the swamp in the lower left portion of the image.

- Point location for features from the original land survey notes for Boulder County, CO
- PLS Corner from GCDB
- 33** Section Number
- Section Line

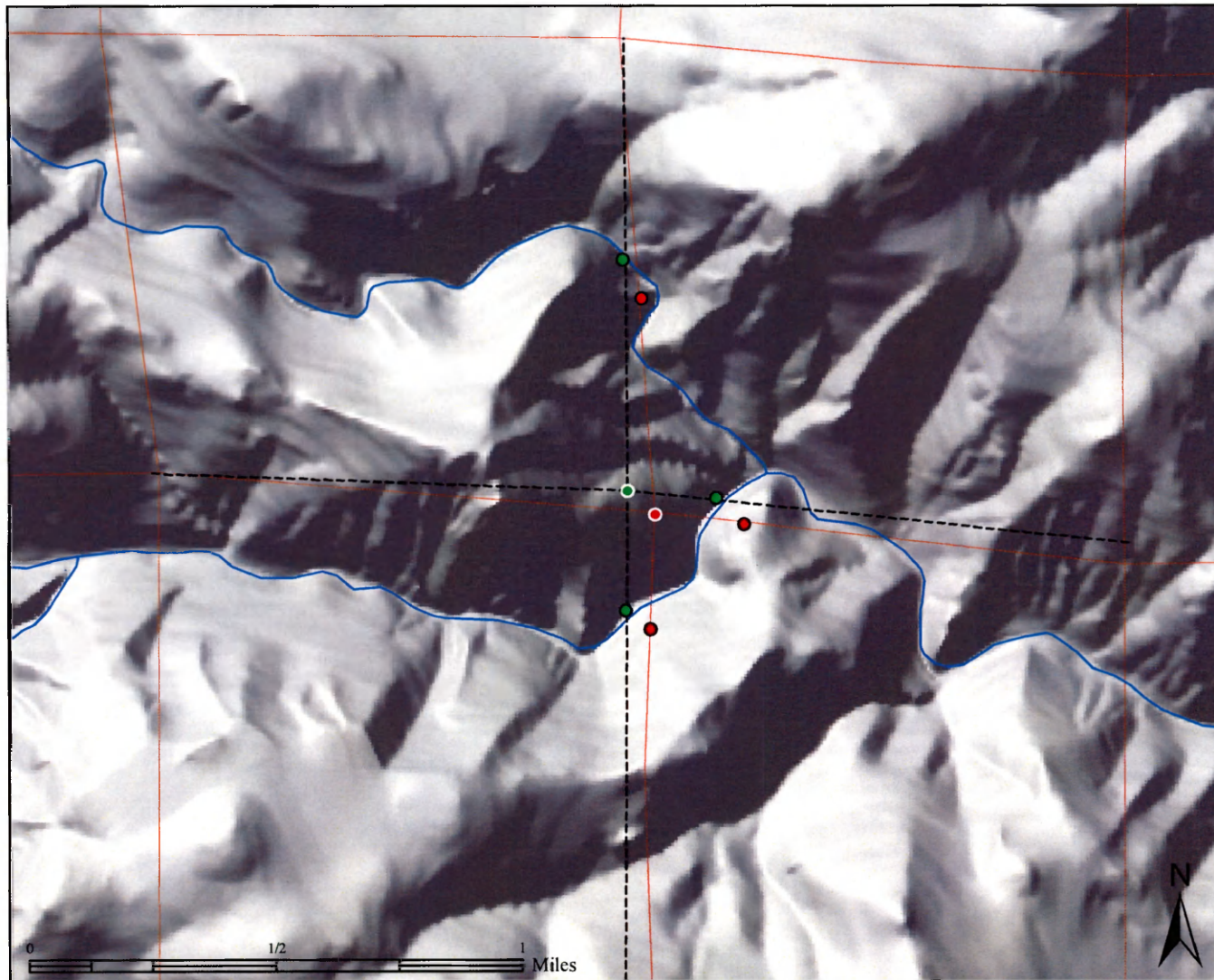
Map Designed By: Aron Langley 2004
 Data Source: Original Land Survey Records
 NAD 1927 UTM Zone 13 N

Figure 4.9 "Top of Large Rock." Note the accuracy in which the feature is recorded by the surveyor when plotted over the GCDB.

Errors, Inaccuracies and Additional Limitations

In addition to the errors and inaccuracies discussed previously, further evidence was found that would suggest that the surveys were possibly erroneous in certain instances. Furthermore, additional limitations exist in using the notes in historical and geographical studies and they will be discussed here.

The accuracy of the GCDB in the mountainous regions of the study area came into question several times. Because the survey note features were plotted along the GCDB PLSS data, they are only as accurate as the GCDB data. For this reason, when the topographical data in the notes did not line up with the Digital Elevation Models, the accuracy of the GCDB from which they were plotted came into question. The evidence for this is difficult to display but it does question the GCDB accuracy. If the GCDB corners are accurate, then the section lines which connect them should traverse the same topography as the surveyors did during the time of the survey when they set the PLSS corners. At times, this was not seen in the GIS display. It was often possible to conceptualize a traverse line followed by the surveyors that was different from what the GCDB section lines were inferring. The evidence for this comes from the location of the features as they were plotted on the GCDB with respect to where the features existed in the topography (Figure 4.10). The possibility of error existing in the GCDB was evident in several locations within the study area. This is a concern because the GCDB is the most accurate digital representation of the PLSS that is available. Furthermore, The GCDB merely attempts to show where the corners are located today and the accuracy of some of the corners is ambiguous. Some corners and corner monuments may have been lost and replacements set inaccurately with respect to their original locations, and others



GCDB Inaccuracy

The PLS records were plotted on the GCDB data. Often, what the surveyors traversed, could be conceptualized on the topographic data while the GCDB data seemed to follow a separate traverse.

- Likely course traversed by the surveyor
- GCDB
- Where the surveyors likely encountered the feature
- Where the feature was plotted on the GCDB
- Likely location of the original corner
- Corner location in the GCDB

Map Designed By: Aron Langley 2004
NAD 1927 UTM Zone 13 N

Figure 4.10 GCDB Inaccuracy. Note the likely location of the feature compared to where the feature is plotted on the GCDB. Similar inconsistencies occurred several times suggesting that inaccuracies exist in the GCDB data.

may have been moved on purpose. The GCDB, as a result, does not accurately represent the locations of the original PLS corners or the traverse lines of the original surveys.

The methodology, using the GCDB to represent the actual ground locations for the original section corners and quarter corners, would then be flawed, and any accuracy references with respect to the PLS notes are invalid using this methodology. With respect to the topographic numbers on pages 50-52, the features that were plotted in a location where the topographic feature is evident, and the features that were plotted close to an evident topographic feature should thus be considered one and the same.

These inaccuracies, whether valid or not, can be eliminated. The GCDB uses a least squares method to project a grid from known corner coordinates. In mountainous regions, there are fewer known corner coordinates. Therefore, many of the corner coordinates are estimates. If one were to spend the time to GPS the actual ground location for every corner and quarter corner in their study area, these inaccuracies can be at least partly eliminated.

Surveyors often made mistakes. These mistakes became a part of the survey. The original survey, whether accurate or not, became the official legal record of the survey and remains that way today. Essentially, the Act of March 1, 1800 established the fact that the original corners set by the surveyors became the legal record even if they were found inaccurate at a later time.¹⁰⁵ When the surveyor made a mistake that went unnoticed, this mistake became a part of the legal record. Hal Sayr made a mistake in his survey when running a random line west from an established corner. It was practice for the surveyor to run a random line, set a temporary quarter section marker, and proceed until he intersected an already established line. From there he would return to the

¹⁰⁵ McEntyre, 43.

previous corner using the corrected bearing and set the permanent quarter section marker. Sayr's mistake was in setting a permanent marker rather than a temporary marker on his random line, instead of setting the permanent marker upon his return, as instructed. This is a small mistake but if it had occurred earlier in the survey of the township interior, it would have introduced an error into all of the corner markers that followed because it was not set on the corrected bearing. It was the only time that this type of mistake was found in the study area and the only error found in the Sayr surveys.

Another possible surveyor error was found when plotting park extents from the Brune surveys. As discussed earlier in the chapter on pages 63-64, inconsistencies were apparent when plotting the extent of "Higgins Park." Brune estimates the park to be one mile wide, yet the distance between where he entered and left the park is hardly one quarter mile wide. Recent aerial photos are consistent with the plotted entry and exit points, but they show no evidence of the park being one mile wide in any direction, and neither does the 1874 GLO plat map (Figure 4.4, p. 65). Either Brune's estimation of one mile is grossly in error, or the forest has invaded the park since the survey. The most likely presumption is the former, which introduces inconsistency into the Brune surveys.

This chapter has described the content of the Boulder County, Colorado PLS notes for the study area and the GIS analysis that was performed on the data pertaining to topography, settlement, vegetation, and the differences between the surveyors. It also has addressed additional interesting findings, and the errors, inaccuracies and additional limitations found in the PLS records for the study area. The next chapter addresses the conclusions reached throughout the completion of the thesis paper in terms of the historical and geographical utility of the original land survey notes.

CHAPTER V

CONCLUSIONS

This final chapter addresses the conclusions reached throughout the completion of the thesis paper. It is divided into three sections that help in defining the utility of the original notes for use in historical and geographical studies. This will include a section on the generality of the PLS notes, a section on utility that deals with what worked, what did not work, and the potential applications of the notes, and finally, a section discussing the limitations of the notes.

Generality

The United States Public Land Survey was one of the greatest accomplishments in the history of land surveying. With its unique design and method of land identification, it functioned as an effective means of preparing the public lands of the United States for settlement. The PLS notes, recorded by the surveyors at the time of the survey, provide a systematic sample of the landscape for a large portion of the country. Inherent in the notes is a generality that has in many cases detracted from their utility for use in historical and geographical studies, yet they still provide a significant amount of information about the landscape from the time of the survey that cannot be found in alternative resources.

Section Line General Descriptions

Most of the data obtained from the section line general descriptions in the PLS notes for the study area consisted of general references to vegetation, topography, and in some cases, soils. An example from the general descriptions of the section lines read “timber small pine and spruce, land mountainous.” Similarly, another read “surface mountainous, soil 3rd rate, scattered pine timber.” When this information is compiled, it is possible to display each section line as a polygon representing a specific trait.

The General Vegetation Map, created for this thesis, does just this (Figure 4.5, p. 68). However, the map is very general. First, the descriptions from which this map is derived come from samples taken at one mile intervals. Second, instructions called for the surveyor to list the most common vegetation type or the most abundant species encountered along the section line. On some occasions, more than one species was recorded, as was the case for the pine spruce vegetation type. In these cases, it was assumed that both pine and spruce showed a relatively similar abundance along the section line. Regardless, the vegetation descriptions lacked depth and the resulting vegetation type categories were general. Third, only categorical abundance values, such as ‘few,’ ‘some,’ or ‘many,’ were associated with the recorded species, and these values were only recorded intermittently by some surveyors. However, the vegetation information in the section line general descriptions did result in a useful product that, when compared to alternative resources, added to the utility of the PLS notes.

It would also be possible to create a similar product from the soil descriptions. The notes for the Boulder County study area did not provide enough soil descriptions to do this, but it could be done for example, with a study area on the plains.

Bearing Tree Data

The bearing tree data also contains general information. Trees were recorded by their common names, often being referred to as pine, spruce or cottonwood rather than the type of pine or type of spruce. Additionally, the bearing trees were recorded at section and quarter section corners, leaving a large portion of the landscape between these points un-sampled.

Compiled bearing tree data was analyzed in the GIS to address its utility and several interesting products resulted. The most useful results come from the trees per acre field. The values in this field represent forest density at each corner, and through GIS analysis, were projected to show the density of the forest throughout the study area (Figure 3.4, p. 45). When compared to alternative resources, however, results were inconclusive. No similarities were seen between the raster image of forest densities and any other GIS data other than the general location of the forested areas. The bearing tree data and the forest density values are likely too general to aid in interpreting the forest densities from the time of settlement. Interpreting forest densities at settlement using the PLS notes and comparing them to present forest densities would greatly enhance the utility of the notes, but the generality of the bearing tree data, most importantly the inherently large distance between sample points, detracts from their utility.

However, the bearing tree data and the density values can be used in both large scale studies and in small scale studies. Potential applications of both the section line general descriptions and the bearing tree data will be discussed later in this chapter.

Plat Maps

Only one GLO plat map was obtained from the BLM and used in this study, and it proved useful in several instances. When comparing the extents of 'Elk Park' in a recent aerial photo and the December 30, 1874 General Land Office Plat Map for T3N R72W, the plat showed inconsistent and exaggerated extents of the park (Figure 4.7, p. 78). Where the aerial photo corroborated the PLS notes, the plat was lacking. A second instance of utility came when looking at the extents of 'Higgins Park' (Figure 4.4, p. 65). The plat, PLS notes, and aerial photo showed similar extents while the surveyor recorded an uncorroborated extent in his notes. The plat, when combined with the aerial photo, helped to show that the surveyor may have mistakenly described the extents of the park. The plats show the greatest utility when used alongside the PLS notes. When used alone, however, the plat was far too general and would likely have little utility in interpreting the landscape from the time of the survey. The information in the plat, mostly topography, has not changed since the survey and therefore would not be useful in geographical studies. However, the plats do have historical significance.

Utility

The utility of the original land survey notes for use in historical and geographical studies can be defined by what can be done with them, what cannot be done, and their potential applications. This section gives an overview of what was tried and worked, what was tried and did not work, and how the notes can be used in historical and geographical studies.

What Worked

The PLS notes are commonly used in vegetation reconstructions. The General Vegetation Map shows that a reconstruction is possible. It was compiled using the section line general descriptions and provides an account of the vegetation types encountered by the land surveyors as they surveyed the Boulder County study area. The vegetation type polygons represent the most abundant species encountered by the surveyors. When this information is compiled, it can be used to represent the vegetation that existed at the time of the survey. Furthermore, it can be compiled for a large portion of the United States. This data can then be compared to recent data showing what is there now to assess and interpret land cover changes that have occurred since the survey. When making this type of comparison, the PLS notes show great utility for use in historical and geographical studies because they contain a systematic sample of information that cannot be found in other resources.

The General Vegetation Map showed similarities to Kùchler's Potential Natural Vegetation Map. It was believed that Kùchler's map would be too general for comparison to the PLS data for the study area because it covered the entire country, but this was not the case. Both Kùchler's map and the General Vegetation Map showed a similar generality that allowed for comparisons to be made. It was also believed that the Colorado Vegetation Model would have limited use in the study because it was too detailed. This too was not the case. Once it was generalized, the Colorado Vegetation Model showed similarities to both Kùchler's map and the General Vegetation Map. When comparing all three maps, one can argue that vegetation changes since the survey can be seen.

The section line general descriptions can be used alone, with bearing tree data, or alongside other historic resources in a variety of studies. Most importantly, these descriptions have the potential to provide a baseline for restoration efforts at a variety of scales.

Bearing tree data, including the species and diameter of every tree, can be used in a broad range of studies including the calculation of forest densities, forest extents, and forest structure. Additionally, each tree species can be mapped to show its range with respect to slope and aspect, or other biologic, ecologic, or climatic data like moisture availability. Similar to the section line general descriptions, the bearing tree data has potential to stand alone or with other historic resources when interpreting an area, and can provide an important baseline for restoration efforts.

When displayed in the GIS, the corner materials used by the surveyors to set corners showed a transition from sedimentary rock, on and near the plains, into igneous rock in the mountainous areas. A geologic map of the front range of Colorado shows this same transition (Figure 4.8, p. 86). Similarly, a display of settlement features from the PLS notes shows that the extent of settlement had reached far into the study area by the time the original surveys were conducted. It was possible to display each of the settlement references comparing them to existing settlement features in modern maps, and to compare the corner materials to a modern geologic map of the front range of Colorado. Both displays showed that the PLS notes have a utility for use in additional studies.

What Did Not Work

A raster image of forest densities was created in the GIS using the trees per acre field in the cords file (Figure 3.4, p. 45). This field was calculated using the data obtained from the bearing tree information. The product was draped over vegetation maps and land cover maps for the study area. The greatest densities of forest occurring in the study area at the time of the survey can be seen, but there is nothing to compare it to. It could be compared to a similar product if bearing tree data could be obtained for the corners today. Collecting this data was beyond the scale of this project but not out of question is one was so inclined. This could be an important platform for interpreting change in forest densities for forest restoration efforts.

Because the raster image of forest densities could not be used in any comparison for this project, it was considered to be something that did not work. As discussed, however, it does show utility for use in a variety of studies.

An attempt was made to find information on expected vegetation or actual vegetation for the study area from the time of the survey including, information of forest structure or expected climax species. This data was to be compared to the vegetation information in the PLS notes to look for similarities or differences. No information of this kind could be found. Kuchler's map and similar national maps were the only source of information of this kind that was available. If the data exists, it was not found, if it does not exist, the significance and utility of the vegetation information in the PLS notes is increased for this area because it may be the only information available on vegetation from this time period.

The plat maps, created from the original surveyors' notes as they came in from the field, showed little utility in this study. The information in the map is very general and often inaccurate, as was the case with the references to elk park (Figure 4.7, p. 78). Furthermore, the plat map used in this study displays topographic features and little else. Because topography has not changed since the survey, the plat used in this thesis has no geographical utility, but other plats often display settlement features like roads and houses in conjunction with topography and can be useful in historical studies. It was interesting to see the plat that was created exclusively from the original notes at the time of the survey, but its lack of content, aside from topography, limited its use in this study.

Unlike a vegetation reconstruction, a full landscape reconstruction that can be used in geographical studies is not a likely product that can be extracted from the PLS notes. The result would be similar to the plat map created in 1874. The PLS notes contain only vague information about the landscape. The section line general descriptions contain information about the topography, soils, vegetation and little else, and the features recorded along the section lines can do no more than represent a point. In a historical sense, one could compare what the landscape actually looks like to what it was thought to have looked like, similar to work done in this thesis, but in a geographical sense, the topographic features have not changed.

Potential Applications

There are large scale and small scale applications for the PLS notes ranging from site-specific studies up to county-size studies or larger. Large scale or site-specific studies show less potential than smaller scale studies because the range of descriptive

information is more limited. However, as the size of the study area increases, so does the amount of descriptive information available from the PLS notes. This section discusses the potential applications of the PLS notes in terms of how they should be used and what can be done with them.

Depending on the nature of the study, the PLS notes can be used to characterize, reconstruct, evaluate or interpret an area from the time of the survey. This can be useful in comparing past conditions to present conditions; mapping species distribution, forest extents, and vegetation communities; relating vegetation to ecologic, biologic, climatic and physical environmental factors; and providing a baseline for restoration efforts and natural resource management.

Potential large scale applications include restorations of native plant communities following long periods of livestock grazing in riparian habitats, historic studies of settlement features inundated by man-made town sites or reservoirs, studying the after effects of reservoir construction on downstream habitats, or studying landscape evolution following settlement. More often than not, large scale studies are dependent on the value of the information in the notes. One may or may not find the notes useful; only by consulting them would one know if the information would prove valuable.

Small scale studies, on the other hand, have a much greater chance of proving valuable because there is a greater volume of data available and patterns would show up better. Potential studies include quantitative studies of the structure of former forests, relating controlling environmental factors like fire history to past and present forest structure, analyzing the degree of change forest extents, structure, or densities, performing an analysis on the movement of sandbars or braided river channels in a river

ecosystem, or when supporting data is available, conducting time series studies to interpret change. Small scale studies do not depend as much on the value or amount of data available in the notes. Because the surveys were standardized, the value of the data is consistent, and because of the size of the study area, there is a sufficient amount of data available.

Alternative resources play a major role in defining the utility of the PLS notes. In large scale study areas, it is essential that alternative resources be used in conjunction with the PLS notes when defining an area. There is just not enough information in the notes for them to stand alone when working in a small study area at a large scale. This is true because a study area that is approx four miles square would have twenty one sample points and a maximum of sixty bearing trees. Of those bearing trees, forty eight would lie on the outside boundary of the study area and only twelve would be inside the study area. A one mile square study area would contain a maximum of twenty four bearing trees, each of them lying on the boundary of the section. This is assuming that all four bearing trees were marked at section corners and two bearing trees were marked at quarter section corners, which was very rare in the forested Boulder County study area used in this thesis. Even when combined with the section line general descriptions, this is a poor sample in a small study area. Alternative information about the study area would be necessary when defining the area. In this case, the PLS notes would be most useful in a supporting role. At a small scale, the PLS notes show the potential to stand alone in defining an area, but alternative resources, when combined with this data, would greatly improve the utility of the notes.

The study area used in this thesis exemplifies a small scale study area although the most useful product, the General Vegetation Map, would benefit from covering a larger area. Time constraints limited the size of the study area. The PLS notes for the Boulder County study area would likely show more utility if the study area was expanded into a county-sized study area or larger. However, it was of sufficient size to show utility for use in historical and geographical studies because it was able to reveal possible changes that have occurred in the landscape without the use of supporting material.

Interestingly, the General Vegetation Map was similar to Kùchler's Potential Natural Vegetation Map. This suggests that the map has great utility in additional studies because it has the potential to show the researcher 'what was there' at the time of the survey while Kùchler's map only shows 'what is supposed to be there' based on other environmental factors. The Colorado Vegetation Map attempts to show 'what is there,' so when compared to the General Vegetation Map, one can potentially reveal any changes that have occurred in the landscape since the time of the survey. The General Vegetation Map uses only the section line general descriptions to make these determinations.

Because of the high data volume in a small scale study area, data entry is considered to be a major limiting factor in using the PLS notes in historic and geographic studies. Other limiting factors including bias, fraud, errors, and the timing with settlement will be discussed in the next section.

Limitations

The limitations inherent in using the PLS notes come primarily from the generality in the notes, although other factors are involved in effecting their utility including surveyor bias, fraudulent descriptions, the timing with settlement, time consuming data entry, and their accuracy.

Bias Fraud and Errors

Bias, fraud and errors exist in the PLS notes that can be a limiting factor in their utility. It is hard to assess when and if they are occurring in a study area. No particular bias was found in the Boulder County PLS notes, but no testing was performed on the data. Likewise, no fraud was found. Errors, on the other hand, existed in some of the records consulted but were few. All of the errors that were found were simple mistakes and mental errors, where the surveyor failed to record a tree species or set a permanent corner where a temporary corner was required. Any incorrectly located lines or corners introduce error in the plats, but the actual ground locations are official.

These problems were probably more wide spread than what was detailed in the study. As the data was entered into the table for the first time, inconsistencies were apparent but could not be completely corroborated (Figure 4.10, p. 90). To some extent, they should be expected and do not necessarily affect the utility of the notes.

The difference in the amount of detail recorded by the surveyors can also be a limiting factor in the utility of the notes. Certain study areas may have been surveyed by several surveyors. Inconsistent amounts of detail or a lack of detail throughout the study area may be a factor that limits utility.

Settlement

The original notes had more references to settlement than was expected. Because the PLS notes have often been considered to reflect the lay of the land prior to settlement, a high number of settlement references would seem to limit their utility when evaluating pre-settlement conditions. In this study, the Boulder County PLS notes have a limited utility in evaluating pre-settlement conditions because of the high number of settlement references. In other words, the Boulder County PLS notes can not be considered to represent pre-settlement conditions. For the most part, however, the surveys preceded settlement and its effects on the landscape and the notes can be considered to have utility for use in used in historical or geographical studies.

Time Consuming

Transferring the PLS records from their original form to a digital form that can be used in a GIS proved to be very time consuming, although there are workarounds. Creating a vegetation map similar to the General Vegetation Map would not require every record to be entered into a table. One could go through the original records and only extract the section line general descriptions. This would allow for a larger study area than the one used in this thesis. The difficulty in deciphering the various handwriting styles of the surveyors and their terminology would be the only limiting factor. Similarly, extracting the bearing tree data could be done in a similar manner with similar limitations. Extracting topographic data, settlement data, and other landscape changes would not be as easy although it could be done in the same manner. Every page would still have to be reviewed, and each reference would have to be recorded.

Regardless of the workarounds, this process is still very time consuming. The volume of data entry involved with a small scale study area is enormous, but the results are potentially invaluable because of the exclusiveness of the PLS data. Each reference would have to be plotted where it occurs, either on an existing PLSS map or similar to what was done for this thesis. Regardless of the potential results, data entry is a major limiting factor in using the original PLS notes in historical and geographical studies.

Accuracy

A major initial goal of the thesis was to show how accurate the original survey was. It was believed that the PLSS notes could be plotted over the GCDB to show the accuracy of the survey. However, evidence of inaccuracies within the GCDB in the mountainous study area was found. This eliminated any accuracy testing of the plotted PLS note records. Despite this, it was found that the accuracy of the original survey does not necessarily affect the utility of the notes. However, if one were trying to plot the exact locations of the bearing trees or other features for use in a detailed GIS analysis, actual locations of the corners would have to be logged in the field prior to the study. This would provide a more accurate base for which the PLS data could be plotted and viewed against the topographic GIS data. Further analysis of the accuracy of the GCDB in mountainous or remote locations would therefore be a valuable study.

Because the PLS data was plotted on the GCDB, entries considered 'close' and entries considered 'accurate' had to be combined when comparing actual ground locations of topographic and settlement references with their plotted references (see Chapter IV pp. 55-63). If the GCDB corners represented the actual locations of the

original PLSS corners, this data would likely be more revealing and contribute more to the utility of the notes.

Summary

The utility of the PLS notes can be seen in several products extracted for this thesis. The General Vegetation Map became a central product due to its ability to display vegetational information for the study area that could not be found in any other consulted resources.

The bearing tree data was used to calculate the density of trees per acre at each section and quarter section corner and stored in a 'Tree_Acr' field in the Cords file. This field can be used in a variety of ways including density mapping for a large or small study area and the mapping of tree species with respect to slope, aspect, moisture availability or other biologic, ecologic, or climatic data.

The Features file housed all of the original PLS data for the study area and was used in a variety of ways to assess the utility of the PLS notes for use in historical and geographical studies. When related to the Coords file, all the features associated with any particular PLSS corner or group of corners can be displayed and mapped in the GIS. This is essential in calculating tree density at corners and displaying data associated with corners.

There are large scale and small scale applications for the PLS notes ranging from site-specific studies up to county size studies or larger. Small scale studies are the most common due to the generality of the information in the notes. Large scale site-specific studies are more common when alternative resources exist for the study area. Depending

on the nature of the study, the PLS notes can be used to characterize, reconstruct, evaluate or interpret an area from the time of the survey

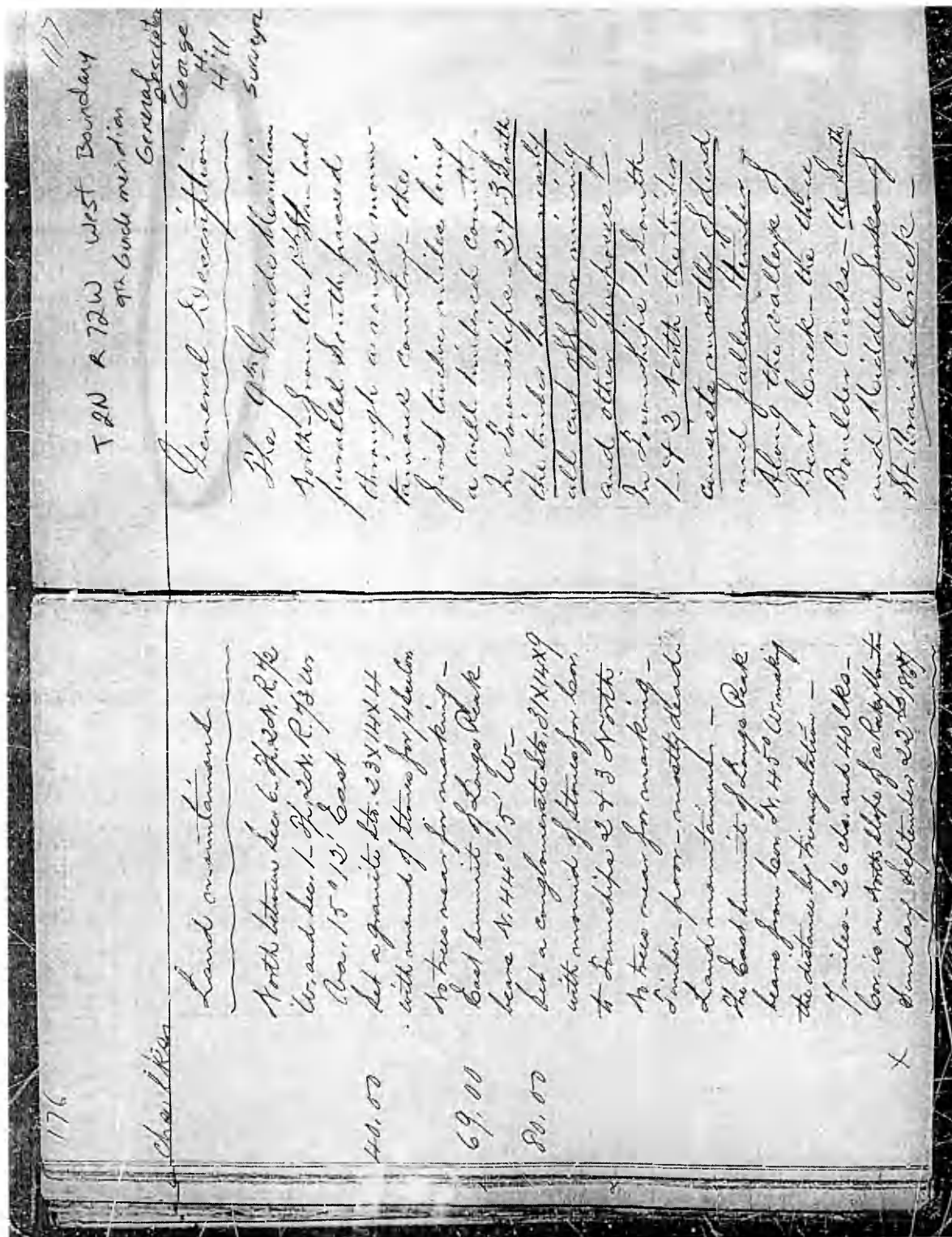
The original notes for the Boulder County study area contain a valuable amount of topographic, settlement, vegetational, and interesting records associated with the time period in which they were recorded. These records are significant in the fact that they were recorded in a systematic way for a large portion of the country. They are valuable in a supporting role in most historic landscape studies and in some cases they can stand alone in defining an area as it existed at the time of the survey.

The General Land Office survey notes provide valuable insight into the characteristics of the land at settlement. They have been used in a variety of ecological, geographical and historical studies of former forests and landscapes. This paper reveals how the notes can be utilized in those studies and how they can potentially be used in modern GIS analysis.

Additional studies might include the development of descriptive models for vegetation types recorded by the surveyors in the section line general descriptions. This would be most beneficial in areas like the Colorado Front Range where humans have had a significant influence on vegetation communities and the landscape since settlement. Additionally, many states, Colorado in particular, could benefit from an in-depth report on the history of the PLS surveys in the state. Additional studies may also include the development of online applications that allow for the easy collection and analysis of the PLS records. The original records for each PLS state are housed in different locations and are often difficult to interact with. Online access to the records would significantly increase their availability and their ease of use. Finally, another apparent study would be

an assessment of the accuracy of the GCDB in mountainous and remote areas. Areas of increased settlement have seen numerous surveys and the geographic coordinates of the PLS corners in those areas have been well established. In contrast, mountainous and remote areas have not.

APPENDIX



George H. Hill Surveyed the 9th guide meridian in 1867. Two pages from his notes describe his distance calculation to the summit of Longs Peak (Figure 4.1, p. 59), and his general description of the 9th guide meridian.

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