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Cooperative roles of geographic information science in identifying boundary uncertainty : a case study in The Bureau of Land Management's Manzano Wilderness Study Area

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Cooperative Roles of Geographic Information Science and Surveying in Identifying Boundary Uncertainty: A Case Study in The Bureau of Land Management's Manzano Wilderness Study Area

BY

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B.A., Visual Communications/Graphics, Kean University, 1981

THESIS

Submitted in Partial Fulfillment of the
Requirements for the Degree of

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ABSTRACT

Advances in the development and accuracy of Geographic Information Science (GIS) in concert with the rapid development of advanced microprocessors and computer software have resulted in widely available survey data. No longer held captive by the discipline of surveying, this data is currently being used by geographers, cartographers, municipal planners and realtors for display and reproduction.

Surveying provides the physical and legal basis for boundary delineation while GIS provides the tools to readily yield information from spatial data, and to economically conduct analyses enabling a more comprehensive understanding of boundary issues. A case study in the Bureau of Land Management's Manzano Wilderness Study Area is used in this thesis to illustrate some of the potential effects of boundary uncertainty and to

answer the question “What are the roles of GIS and surveying in identifying and resolving boundary uncertainty on public land?”

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CHAPTER 1:

INTRODUCTION

Boundary uncertainty and boundary location discrepancies sometimes result in encroachments or trespasses on public land. This is particularly evident in the western U.S. where large tracts of public land (Bureau of Land Management, Forest Service, Bureau of Reclamation land, etc.) interact with land originating as Spanish Land Grants, homesteads, and mining claims. Convoluted land exchanges can also cause problems. Boundary uncertainty may be identified prior to boundary conflict development with the appropriate application of modern technology.

This thesis explores management and ownership issues related to boundary uncertainty on public lands. It provides a framework for pertinent boundary location and legal information useful to landowners, surveyors, land managers and Geographic Information Science (GIS) personnel. The framework, manifested as an early warning system, will enable them to become increasingly adept at identifying potential boundary uncertainty while communicating more effectively with each other. Surveyors and GIS personnel will engage in the cross-disciplinary communication of emerging technologies required to recognize and work within the dovetail of their disciplines.

This research, focusing on public lands and centered around a case study involving a common property boundary between private and public land, has two main goals. The first is to illustrate the importance of knowing where features, especially boundaries, are located on the ground. The second is to raise landowner awareness of the risks and consequences of anthropogenic disturbances that occur near a boundary with an uncertain location. This research is important not only to the federal agencies (in this case the Bureau of Land Management) responsible for managing public land, but also to the general public for whom this area is being protected. Land managers, land owners, and the people of the United States stand to gain from the proper application of GIS and surveying in resolving boundary uncertainty. While the objectives seem fairly straightforward, there is a dearth of literature from a surveying point of view on boundary uncertainty involving GIS.

The case study involves the Bureau of Land Management's Manzano Wilderness Study Area. A land exchange involving some unsurveyed areas in the vicinity caused a lack of confidence in locating boundaries. An apparent surveying error resulted in a surface disturbance on what was thought to be private land, but is actually Bureau of Land Management (BLM) administered public land, the BLM's 881-acre Manzano Wilderness Study Area (WSA). This area is located in Torrance County, New Mexico on T6N, R5E and T7N, R5E and is approximately 16 miles east of Los Lunas. Los Lunas is located in Valencia County, New Mexico. The surface disturbance is an encroachment located along the western side of the Wilderness Study Area. The encroachment consists of a 700 ft. length of dirt road, a 2.5-acre cleared area, and a fence approximately one mile in length. This encroachment occurred during the 2001 – 2002 time period, subsequent to a 1992 land exchange. The surface disturbance was discovered by two experienced hikers familiar with the area who were using hand-held Global Positioning System devices. The hikers were diligent enough to contact the BLM at the time of discovery and report what looked like an encroachment on public land. To complicate matters even further, this particular piece of land has been managed since 1986 under the BLM's interim wilderness management policy. The BLM has three objectives for this

WSA. First, as a result of a recent BLM cadastral survey, the Manzano Wilderness Study Area boundaries will become firmly established with official boundary monuments placed in the ground. Next, with cooperation between the BLM and the private landowner, the disturbance will be actively rehabilitated. The third objective will be reached as a consequence of the second: the Manzano Wilderness Study Area will regain the wild characteristics that made it eligible to be considered for wilderness designation in the first place. The objective of this thesis is the proposed use of an early warning system to avoid boundary uncertainty such as this in the future.

With all the modern technology associated with contemporary mapping and surveying, the issue of boundary uncertainty would seem to be moot. In spite of our current ability to remove uncertainty, the legacy of past land surveying issues and the rules of boundary delineation continue to create problems. To comprehend these problems, the U.S. survey system needs to be understood.

A wooden stake placed on the western boundary of Pennsylvania and the high water line of the Ohio River on August 20th, 1785 represented the establishment of the Point of Beginning: the very first point created by and for the Rectangular Survey System, now known as the Public Land Survey System (White 1983). The enactment of the Land Ordinance of 1785 marked a turning point in the checkered history of land ownership and boundary delineation as the United States transitioned from an assembly of British colonies to an independent, self-governed nation.

Beginning in 1606 various land tenure systems were used in the British Crown's disposition of lands to the original thirteen American Colonies (Gates 1968). Grants, land sales, headrights, and other land tenure systems were the cause of many problems including overlapping claims. To further complicate matters, the old world survey method of metes and bounds was applied to establish colonial boundaries. Survey descriptions were vague and open to interpretation and even fraud. In spite of its problems this method continued to be utilized. By 1753 in the New England Towns a more orderly method of dividing rectangles into parcels based on the needs of town members was employed. It was this early model that influenced the establishment of the rectangular survey system (Gates 1968).

Prior to independence, the British attempted to bring order to the chaos on the frontier. Surveys were ordered in 1774. Limits were placed on the amount of land that the colonial settlers could acquire, attempts were made to eliminate squatting, and limits were placed on where settlement was allowed. Setting a cap on the number of acres that could be granted and restricting settlement west of a designated line on a map in 1763 may have been good land policy, but these actions served as an impetus to the American Revolution (Gates 1968). Colonists did not agree with the British Crown's limitations on their ability to settle the land. Subsequent to independence, land was ceded by the western states to the federal government, and new states were created out of this territory. This process resulted in the beginning of the public domain. The cession of land was a negotiating point required before some states would adopt the Constitution.

Once the indebted federal government became a major landowner, a system was needed to sell the land and acquire revenue. The Land Ordinance of 1785 became the foundation for that system. This 1785 ordinance implemented a methodical survey system referred to as the Rectangular Survey System (RSS), the predecessor to the Public Land Survey System (PLSS). The RSS was fairly successful at preventing fraudulent surveys such as those that had occurred during colonial times. Lands surveyed subsequent to the Point of Beginning used the RSS. This is the same survey system used initially in the vicinity of the Bureau of Land Management's Manzano Wilderness Study Area, the case study in this thesis. Unfortunately not all of the land in the U.S. was surveyed using the RSS including part of the case study location. The associated problems caused by the absence of a complete survey, will be discussed in chapter four. Boundary uncertainty issues continue to pose problems for land managers and private land owners notwithstanding the organized and straightforward Rectangular Survey System.

The central research question of this thesis is: "What roles can and should GIS and surveying play in identifying and resolving boundary uncertainty on public land?" The roles of GIS and surveying are a major component in the early warning system proposed in this thesis.

In order to answer the main question, several sources were consulted. The data for the case study was acquired from the Bureau of Land Management's Recreation and Cadastral Surveying personnel. Other data were acquired from the Valencia County GIS staff, TIGER data, and U.S. Forest Service GIS staff. U.S. Geological Survey quadrangle maps and Bureau of Land Management land status maps are used to show the location and land status for the area of interest. Survey plat images were obtained from the BLM. A copy of the private landowner's survey was provided by the Valencia County Clerk's Office. Technical and informational sources specific to the case study include the BLM's Cadastral, Realty, Engineering, Law Enforcement, and National Integrated Land System staffs. The BLM Cadastral Surveyors and Field Managers were consulted along with other federal surveyors. U.S. Forest Service Boundary Management and Lands staff were also interviewed. The following chapters provide a synthesis of the data and information to illustrate boundary uncertainty, especially as it applies to the case study, and to explain the proposed early warning system.

Chapter two focuses on boundaries and the science and systems involved in boundary delineation and demarcation. Chapter three explains land information systems used to create the Master Title Plat and all transactions related to tracts of land. These systems are supported by GIS and surveying. Data accuracy and standards used in these systems are also covered in this chapter. The case study is discussed in chapter four. Chapter four also explores boundary uncertainty, GIS, and surveying in reference to the case study. Chapter five provides a summary and discussion of the findings resulting from this research. The early warning system is proposed, explained and applied in the context of boundary uncertainty in this final chapter.

CHAPTER 2:

BOUNDARIES, PUBLIC LANDS, SURVEYING, AND THE FEDERAL LAND MANAGEMENT AGENCIES

A background of boundaries, surveying and public lands must be discussed in order to understand boundary uncertainty in the context of the case study. First, the nature and function of boundaries must be understood. Second, an integral agent in boundary formation and management, the Federal Land System, will be explored. Surveying, the third element, is the method of boundary delineation and demarcation. Finally, the goals of the major players, Federal Land Management Agencies will be discussed.

Boundaries: Their Function and Scale

One of the central focuses of political geography is boundaries and the way they function. International law defines the obligations owed between states and between the state and its citizens. A respect for the boundary itself is one of those obligations (Matthews and St. Germain 2007). According to Fred Roeder, the location of a country's "boundaries is a political matter, and politics has been called 'the science of how who gets what, when and why' " (Roeder 2006). Although boundaries in general function as a form of resource allocation, those functions and the processes related to them vary with scale (Minghi 1963).

International Boundaries

The demarcation, evolution, and function of international boundaries have been studied throughout the 20th century (Semple 1911, Brigham 1919, Boggs 1932, Jones 1943, and Minghi 1963). One can conclude that a boundary is not only defined by its spatial location, but also by its function – its effect on the surroundings. An international political boundary affects the culture, politics, and economics in its vicinity. In the early 1900s, August Lösch applied location theory to the study of the impact of a boundary and realized that boundaries affected commodity flows and their resulting spatial distributions (Lösch 1954). S. Whittemore Boggs claimed, in his international boundary studies in 1940, that boundaries have an annoying interruptive character and were barriers to economic interaction (Boggs 1940). In 1936, Stephen B. Jones studied the extent the U.S. and Canada boundary had interfered with circulation since the boundary's establishment in 1846 (Jones 1932).

Internal Political Boundaries

After World War II, political geographers increasingly began to turn their attention to the internal boundaries of countries. Internal boundaries were also studied by Jones. He suggests that political boundaries, because of their effect on the pattern of spatial distribution of phenomena, "be based on functional rather than physiographic regions" (Jones 1934). In J. R. V. Prescott's 1959 study of Nigeria's internal boundary problems, several areas had superimposed political boundaries that were not coincident with lines separating economic and ethnic entities, leading to friction among the people (Prescott 1959). Minghi's analysis of the geography of a metropolitan area supports the idea of the interruptive effect of boundaries on circulation (Minghi 1960). Boundaries have been classified by political geographers in an effort to evaluate their properties, however, "regardless of how boundaries are classified, all boundaries are artificial constructs resulting from political forces rather than any inevitable natural forces" (Glassner 1995).

Boundaries involve not only land, but also water. One of the most prevalent water boundary issues exists between the states of Oklahoma and Texas (Bowman 1923). Since its inception in the 1821 Treaty of Amity, this state boundary had been in dispute. The foundation for this boundary rests on the position of the Red River, a non-static feature. This ambulatory boundary has caused confusion and frustration among landowners and the BLM alike. In some instances, both states are trying to impose property taxes on the same tract of land. In other cases land is not being taxed at all (Jones and Smith 1997). A property dispute among two neighbors about approximately 110 acres on the river bottom resulted in a federal court decision where both landowners 'lost.' It was established that the BLM has jurisdiction over the Red River bottom lands. Ambulatory boundaries, while significantly contributing to boundary uncertainty, are beyond the scope of this thesis.

When ascertaining boundary functions, the issues of scale and type need to be addressed. Property boundaries are the finest scale and delineate ownership.

Property Boundaries

Property boundaries define the ownership interests between adjacent private land or between private and government land. In his article on designing land registration systems for developing countries, Hanstad asserts that "often, landowners will agree on the size and shape of their parcel of property, but are unable to agree on the actual boundary" (Hanstad 1998). Their cognitive boundary's ground location is uncertain. This thesis is focused on a property boundary shared by a private landowner and the federal government.

Public land boundaries in the U.S. function as physical property ownership limits, delineating where federal ownership ends and non-public ownership begins. These boundaries may be construed as 'appropriately interruptive' because they deter trespassing. However, the Property Clause, art. IV, § 3, cl. 2. of the U.S. Constitution, allows federal authority to 'bulge,' or extend jurisdiction beyond the physical property boundary as demonstrated in *Kleppe v. New Mexico*, (426 U.S. 529, 1976). The Wild Free-Roaming Horses and Burros Act of 1971 (WF-RHBA, 16 U.S.C.A §§ 1331-1340) was enacted to protect all unbranded and unclaimed horses and burros on public lands from capture, branding, harassment, or death. In this case, the New Mexico Livestock Board following New Mexico law entered upon public lands and removed wild burros, which the Board then sold at a public auction. The BLM asserted jurisdiction under the WF-RHBA and demanded that the Board recover the animals and return them to federal lands. The Board filed suit for declaratory judgment in New Mexico federal district court claiming that the Act was unconstitutional. The Supreme Court eventually decided in favor of the federal government. The Supreme Court held that the Act was a proper exercise of Congressional power under the Property Clause, and therefore Congress had the power to protect wildlife on federal lands, state law notwithstanding. The court found the burros to be federal property with protection wherever they roamed. In essence this created an ecosystem envelope around federal land extending jurisdiction into that envelope and across the boundary.

The Federal Public Lands System

Thirty states have been created out of the public domain and are sometimes referred to as 'public land states.' These states use the Public Land Survey System

(PLSS). The original 13 colonies and states created from their lands are not included. As they were initially sovereigns, Texas and Hawaii are not public land states either. A summary of the disposition of the public domain during the demand for land and government is shown in Figure 1 (Squires 1999). This diagram depicts the sequence and relationship of the components and forces at work in this process.

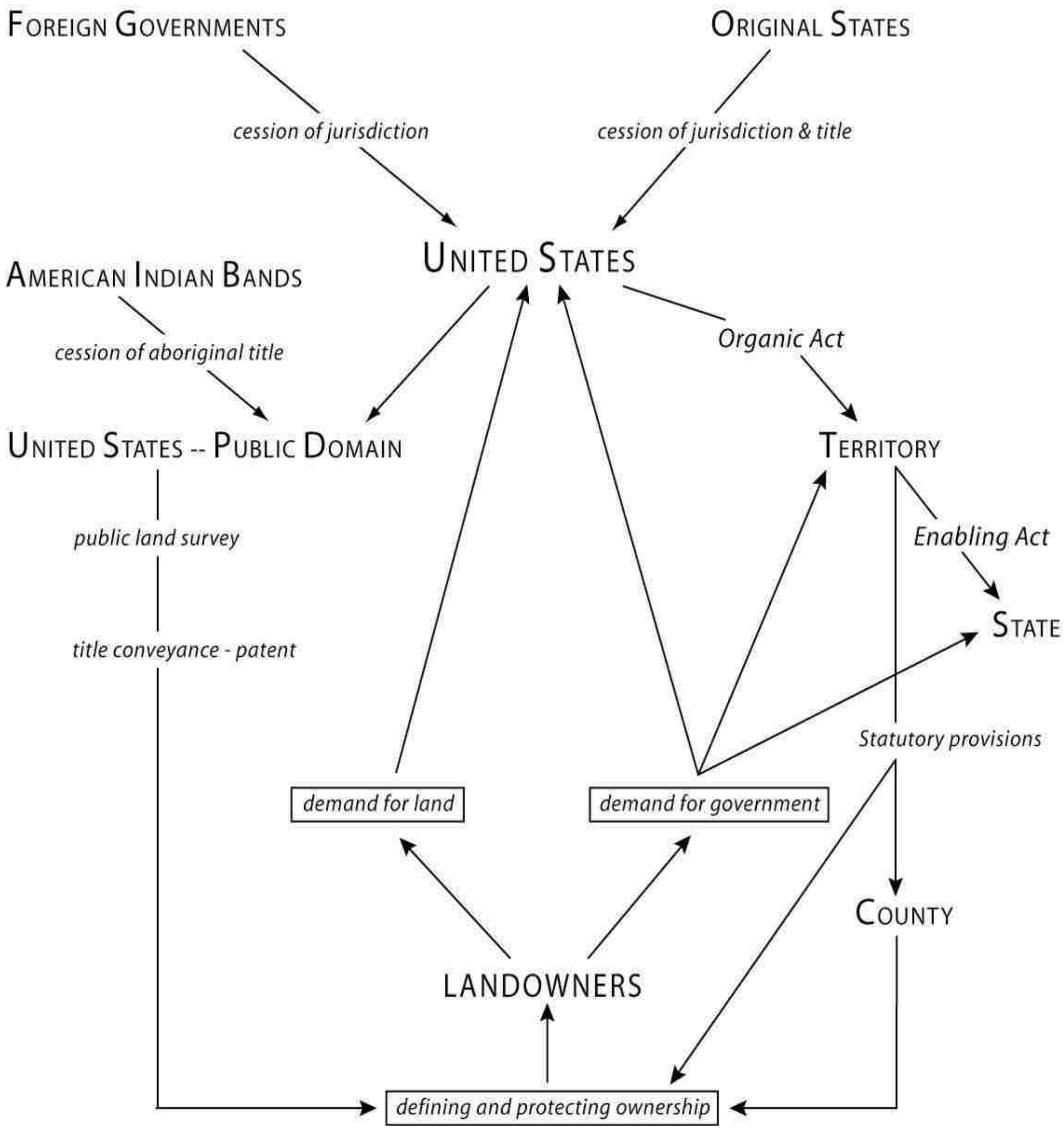


***Figure 1*. The Demand for Land and Government (Squires 1999).**

The federal agency responsible for the implementation and operation of the PLSS during western settlement was the General Land Office (GLO) which fell under the jurisdiction of the Department of the Interior (DOI) in 1849. In 1946 the GLO was absorbed by the BLM and its function taken over by Cadastral Survey, a core BLM program. This program has been in existence for approximately 222 years. The BLM's Cadastral program plays the most critical role in the establishment of the official legal record for land tracts in providing the mechanism to establish the legal record, or cadastre, for a parcel of land. As Cadastral Survey's activities lie at the heart of the case study's boundary issue, we'll explore this program more thoroughly.

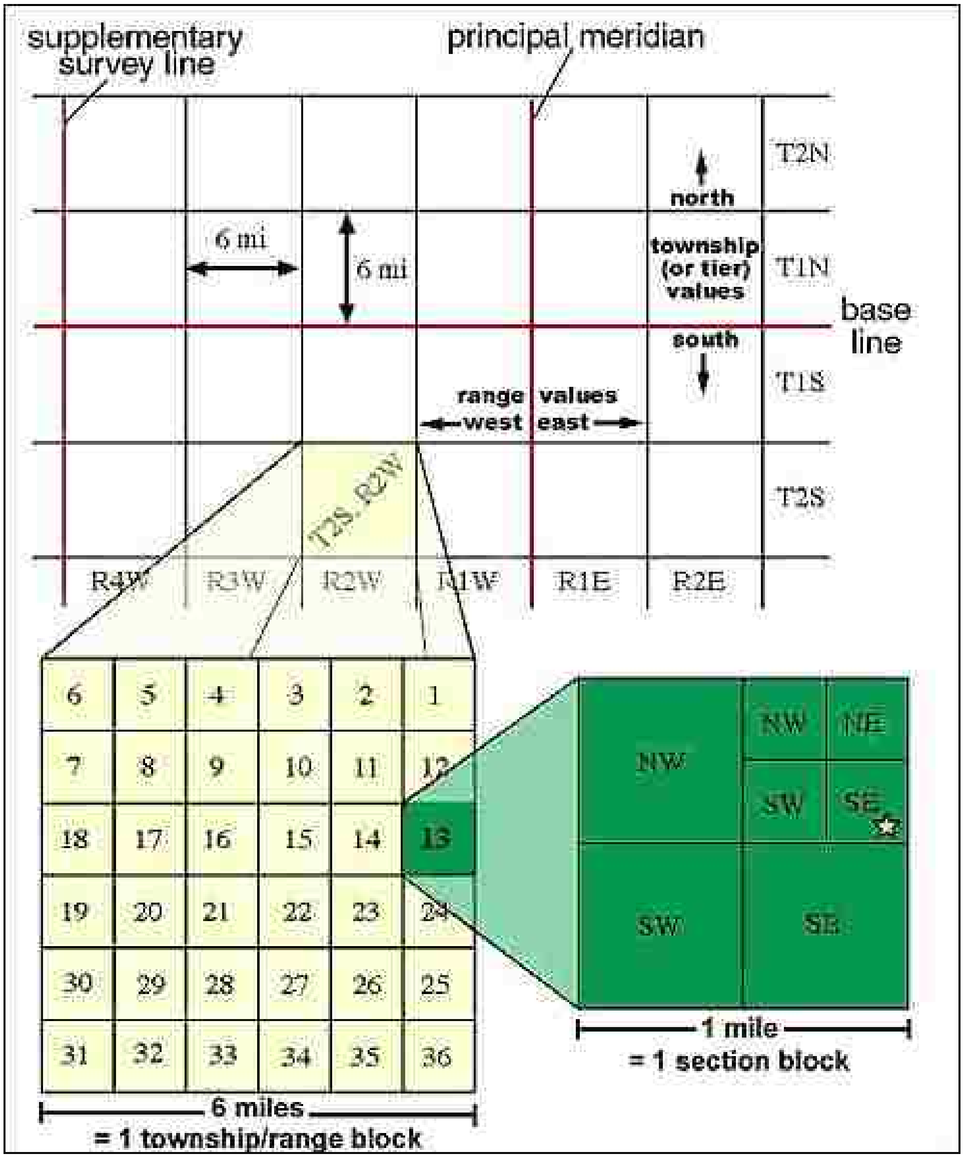
It is necessary to acknowledge the different types of land surveyors that are recognized today and the authority under which they operate. One key factor sets BLM Cadastral surveyors apart from all other surveyors. The BLM Cadastral surveyors obtain their authority from the federal government. Other surveyors obtain their authority from the state in which they are licensed. Consequently, BLM Cadastral surveys are the only surveys used in federal matters. Unlike other surveyors, BLM Cadastral surveyors have the authority to handle federal interests worldwide. BLM Cadastral surveys were the only types of surveys authorized to implement the PLSS. Forest Service surveyors follow state authority, as do county and private surveyors. The federal authority of BLM Cadastral surveyors results in their having the ultimate power to determine the location of monuments.

State surveying licensure involves the National Council of Examiners for Engineering and Surveying (NCEES) tests including a national examination, the state exam, and in most western states an additional 2 hour exam covering PLSS and the associated laws.

The Public Land Survey System

Boundary delineation and demarcation played a crucial role in the disposition of the public domain. The Point of Beginning established in Ohio in 1785 was the monument that physically and logically marked the geographic starting point of the Rectangular Survey System, now known as the Public Land Survey System (PLSS) (White 1983). Prior to this event, boundaries were established from land grants using the metes and bounds method. The rectangular method of land surveying was designed by Thomas Jefferson and has been described as "a record of the American frontier spirit blended with the concept of government for the people" (White 1983). During the settlement of the West, land reform was a major goal. The prevailing sentiment was against "land speculators and land jobbers" (White 1983). This system, while executed crudely by today's standards, cured many of the ills associated with the previously mentioned land tenure systems that were no longer being used. Figure 2 shows a visual explanation of the Public Land Survey System grid.

The foundational unit of the PLSS consists of townships. Theoretically, townships are six miles on each side containing thirty-six sections, each of which are one mile square, or 640 acres. The area of a theoretical township is 23,040 acres. Under the Homestead Act of 1862, 160 acre tracts of land (a quarter section) were given away to settlers under certain conditions. The settler had to establish residence on and cultivate the land for five years. In 1877, the Desert Lands Entry Act authorized settlers to enter on 640-acre tracts (one section) for a fee and proof of irrigation. The Public Land Survey System is organized for success in settling and irrigating the arid West.



Source: GeoSTAC 2007

Figure 2. **The Public Land Survey System grid.**

The PLSS creates a spatial hierarchy designed to reduce boundary uncertainty. During the disposition of the public domain the prevailing sentiment was against large land speculators, and this system attempted to discourage those speculators. ‘Claims Clubs’ were established by local settlers to protect their land interests and prevent bidding monopolization during land auctions. Rules of land ownership transfer and boundary creation were established. In order to transfer land from the public sector to another sector, steps had to be followed. The first step was the completion of a survey, without which the federal government would not relinquish title. The survey included the placement of monuments on the ground. The monuments on the ground will prevail in disputes, not the paper record. Thus, the rules that deal with property boundaries became 'sacrosanct' (Gates 1968). Next, the potential landowner went to the local land office handling the land transactions. The claim was registered; the requisite documentation was sent to Washington, a historic record and legal description were created. To complete the transaction, the new landowner paid for the survey and the tract of land.

A survey plat created for each survey is a major component of the Master Title Plat (MTP), the official record for a parcel of public land. The survey records were compiled into the MTP. MTP's have provided a data source for several geographic studies (Matthews 1980, McIntosh 1976).

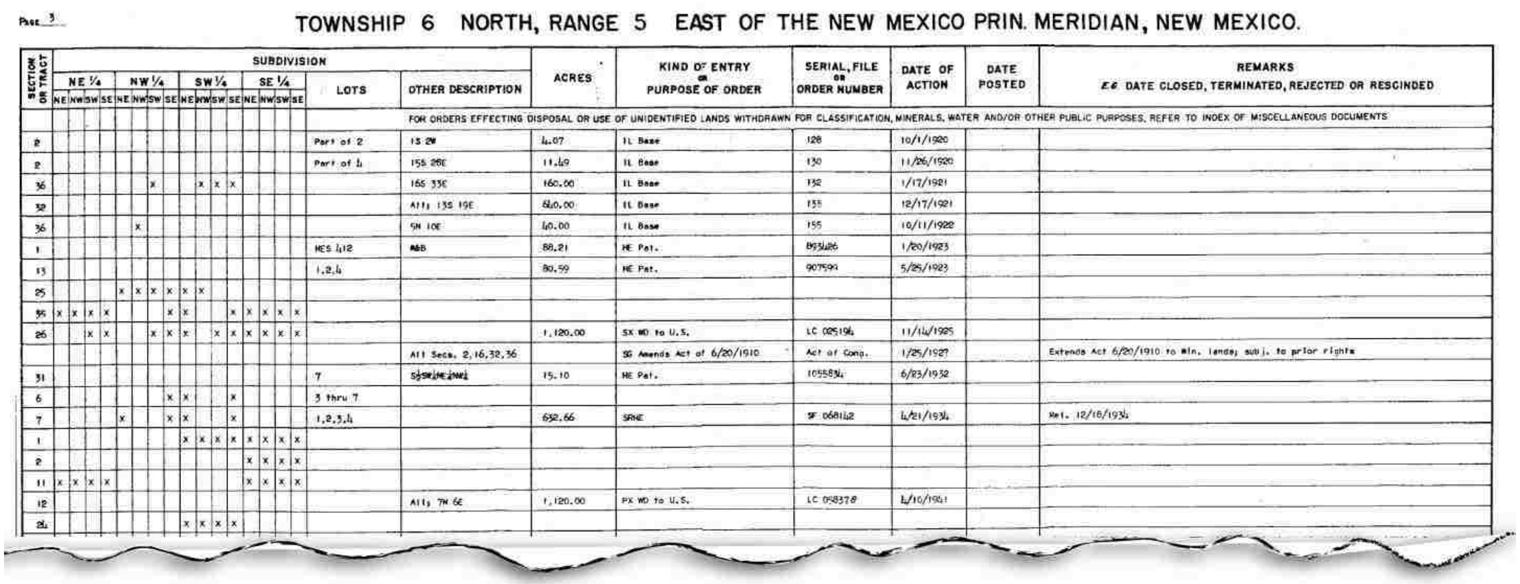
Master Title Plats are available for review by the general public at the BLM's state offices. Figure 3 depicts a portion of the parcel record, the Historic Index, obtained from the BLM's NM state office public room, for T6N R5E. This Historic Index is like all others in that it contains a record of all transactions relating to a parcel of land until that parcel is disposed of; that is, when the parcel moves from federal hands to non-federal ownership (Matthews 1980).

The original field survey notes are recognized as the authoritative survey document (BLM 1973). Shown in Figure 4 is an image of an 1882 survey plat and two pages from the accompanying field survey notes for T6N, R4E.

The system of land records was a result of the 1785 Land Ordinance. This Ordinance also set up rules describing lands and for achieving statehood. Land had to be surveyed prior to giving up federal title. A similar pattern was followed in all the western states including New Mexico.

The New Mexico State Boundary

The Territory of New Mexico was created from lands ceded to the U.S. by Texas, with lands ceded by Mexico in 1848, and the Gadsden Purchase in 1853. New Mexico was admitted into the Union in 1912. Today, the location of the New Mexico-Texas state boundary is in dispute. This boundary was supposed to coincide with the 103^{rd} Meridian according to the U.S. General Land Office (Brock 2006). A cursory review of the survey along the 103^{rd} Meridian reveals an ongoing debate. John H. Clark's erroneous 1859 survey was approved by Congress in 1891. The approval was based on an admittedly hastily-drawn map the purpose of which was simply to show the progress of the survey. The result was a loss of about 660,000 acres of New Mexico territory. The 103^{rd} Meridian is referred to as "Perhaps the most incorrect of any land line in the United States" (Roeder 2006).



Page 3

TOWNSHIP 6 NORTH, RANGE 5 EAST OF THE NEW MEXICO PRIN. MERIDIAN, NEW MEXICO.

SECTION OR TRACT	SUBDIVISION NE ¼				NW ¼				SW ¼				SE ¼				LOTS	OTHER DESCRIPTION	ACRES	KIND OF ENTRY OR PURPOSE OF ORDER	SERIAL, FILE OR ORDER NUMBER	DATE OF ACTION	DATE POSTED	REMARKS E.G. DATE CLOSED, TERMINATED, REJECTED OR RESCINDED
	NE	NW	SW	SE	NE	NW	SW	SE	NE	NW	SW	SE	NE	NW	SW	SE								
																		FOR ORDERS EFFECTING DISPOSAL OR USE OF UNIDENTIFIED LANDS WITHDRAWN FOR CLASSIFICATION, MINERALS, WATER AND/OR OTHER PUBLIC PURPOSES, REFER TO INDEX OF MISCELLANEOUS DOCUMENTS						
2																	Part of 2	1S 2W	4.07	IL Base	128	10/1/1920		
2																	Part of 4	15S 26E	11.49	IL Base	130	11/26/1920		
36							x			x	x	x						16S 33E	160.00	IL Base	132	1/17/1921		
32																		All; 13S 19E	640.00	IL Base	135	12/17/1921		
36						x												5N 10E	40.00	IL Base	155	10/11/1922		
1																	HES 412	M&B	88.21	HE Pat.	893426	1/20/1923		
13																	1,2,4		80.59	HE Pat.	907599	5/25/1923		
25					x	x	x	x	x	x														
35	x	x	x	x				x	x			x	x	x	x	x								
26			x	x			x	x	x		x	x	x	x	x	x			1,120.00	SX WD to U.S.	LC 025194	11/14/1925		
																		All Secs. 2,16,32,36		SG Amends Act of 6/20/1910	Act of Cong.	1/25/1927		Extends Act 6/20/1910 to min. lands; subj. to prior rights
31																	7	S½SW¼NE¼NW¼	15.10	HE Pat.	1055834	6/23/1932		
6								x	x			x					3 thru 7							
7					x			x	x			x					1,2,3,4		632.66	SRHE	SF 068142	4/21/1934		Rel. 12/18/1934
1									x	x	x	x	x	x	x	x								
2													x	x	x	x								
11	x	x	x	x									x	x	x	x								
12																		All; 7N 6E	1,120.00	PX WD to U.S.	LC 058378	4/10/1941		
24									x	x	x	x												

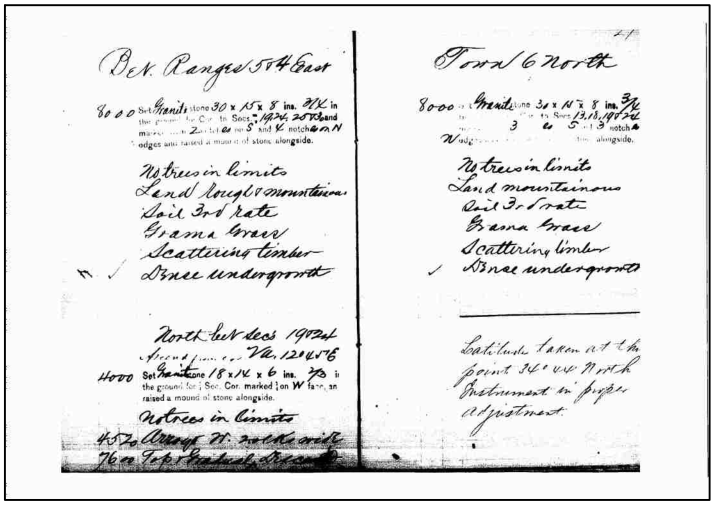
The 'subdivision' columns denote the portion of this township and range affected by certain activities.

The 'Kind of Entry' column explains the type of action taken on the parcel.

SRHE = Stock Raising Homestead Entry

Additional information such as the date of the action and 'Remarks' are recorded in the final columns.

Figure 3. **A partial image from the Historic Index for T6N, R5E in New Mexico.**



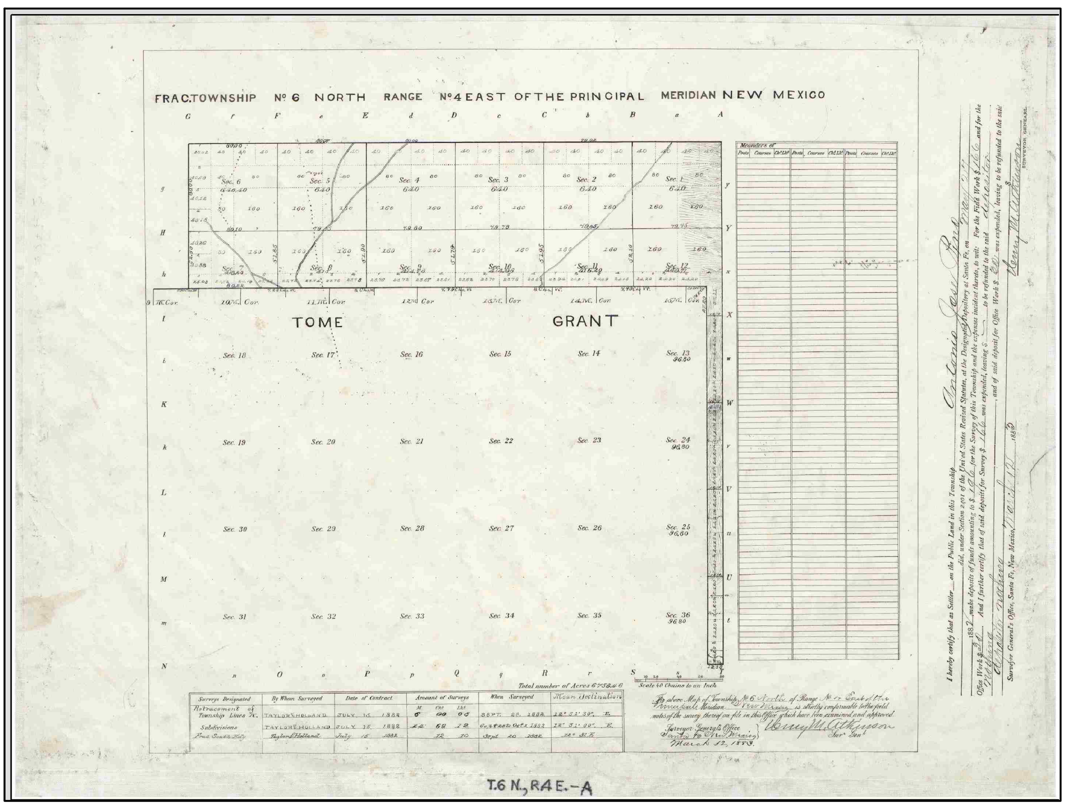


***Figure 4.* Field survey notes and accompanying 1882 survey plat generated by Deputy surveyors Taylor and Holland. At the time of this survey, Henry M. Atkinson served as the New Mexico Surveyor General.**

Lands Grants in New Mexico

Lands within New Mexico have not always been subject to the U.S. survey system and land disposal laws. Spain and Mexico, as the antecedent sovereigns of the Southwest, made many grants of land before the Treaty of Guadalupe Hidalgo (1848). Only the external boundaries of these grants were surveyed . The Treaty of Guadalupe Hidalgo ended the U.S.-Mexican War and resulted in Mexico surrendering half of its territory including California, Arizona, New Mexico and Texas, and parts of Colorado, Nevada and Utah. When the Treaty was ratified, Article X of the Treaty was deleted and title to these lands was not granted. Granting of title was later enacted by statute. As recently as the 1960s land titles made by this Treaty have been disputed. New Mexico land rights leader Reies Lopez Tijerina and his Alianza movement cited the Treaty of Guadalupe Hidalgo in their fight to regain "American-seized Mexican Land" (Urias 1995). Additions to the New Mexico lands were also done by purchases.

The Gadsden Purchase of 1853 covers 45,535 mi^2 in the southern portions of Arizona and New Mexico. The U.S. paid 10 million dollars to the Mexican government for this land. The United States' international boundary with Mexico, and the state boundaries were wrought out of this turn of events.

Surveying: A Background

Surveying the Public Domain

"The role of the survey and its function have been closely and inseparably tied to the progress of civilization" (Robillard and Bouman 1987). BLM Cadastral surveys are the foundation upon which rest title to all land that is now, or was once, part of the Public Domain of the United States. (BLM Cadastral page at http://www.blm.gov/wo/st/en/prog/more/cadastralsurvey.html). With over 1.8 billion acres of public domain lands, the young nation faced a daunting task in 1785: a complete survey of the public domain. A survey of the public domain was required for two main reasons. First, title was not transferred until a survey was completed. Second, states could not be established without it. The momentous accomplishment was made possible not only by the willingness of the government to provide guidance and support, but also due to the simplicity in the design of the PLSS. The square township is the basic figure of this system. Another element of simplicity is the network of principle meridians and baselines that defined the location of the townships, thus providing locational control (Squires 2006). Over the past 200 years, 1.5 billion acres have been surveyed into townships and sections, and monumented. 2.6 million section corners exist, placed one mile apart, across the U.S. This vast expenditure of human effort was accomplished by

Photo courtesy of the California State Library, Sacramento, CA

Figure 5. **An early California surveying crew, self-sufficient in many ways.**

the Cadastral surveyors and Deputy surveyors of the General Land Office (GLO), and later the BLM. Amazingly, the surveyors dragged heavy surveying equipment and chains across the terrain. The original survey crews were self-supporting units of 40 or more people. The photograph in Figure 5 shows a surveying crew based out of California.

A review of some of their field notes reveals that on occasion, survey crews were subject to hostile attacks, or their monuments were destroyed (White 1983). This was a difficult job with relatively low pay. These challenges resulted in poor surveys or the lack of surveys in certain areas.

The Act of May 18, 1796, provided for the appointment of a Surveyor General, Rufus Putnam, whose responsibility was to survey the public lands northwest of the Ohio River, starting from the Point of Beginning. The first Surveyor General of New Mexico was William Pelham, commissioned on August 1st, 1854. The person occupying the Office of the Surveyor General was the most powerful person in the territory of New Mexico. They took the claims submitted for Spanish and Mexican land grants and advised Congress as to whether or not the grants were valid (Westphall 1965). Pelham was succeeded by 15 others until 1925, when the Office of the Surveyor General was abolished and all equipment and records were transferred to the New Mexico Field Surveying Service (White 1983). On April 3, 1855, the initial point of the PLSS in New Mexico was established as instructed by Surveyor General William Pelham. John Garretson, deputy surveyor, surveyed the point from which the Principal Meridian and Base Lines would be generated. In 1957, Cadastral surveyors re-monumented this point at its original location of Latitude 34° 15’ 36” N., Longitude 106° 53’ 13” W., on Station Black Butte, in San Acacia (White 1983).

Surveys are triggered by original conveyance from the public domain, subsequent title conveyance, land disputes, or adjustments made as a result of lost or poorly defined boundaries (BLM 2007). In order to manage public land, one must know where that land is: this is the purpose of the BLM's Cadastral survey program, and this is how boundaries are established, monumented, and verified. "A government survey does not ascertain boundaries; it creates them" (Robillard and Bouman 1987).

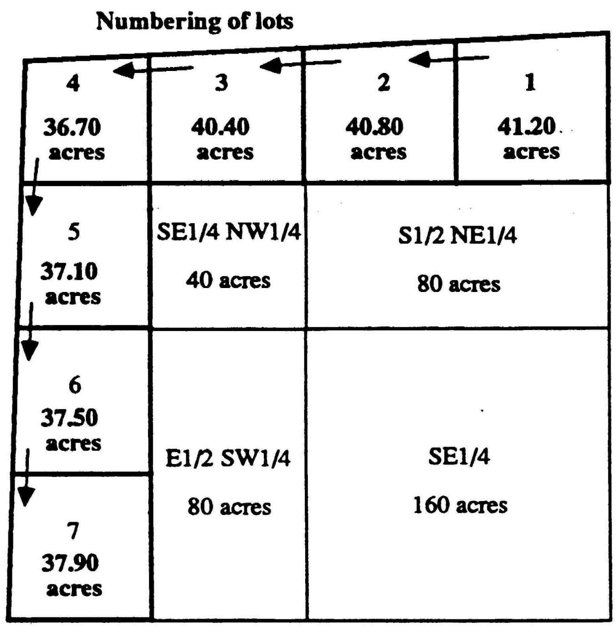
The crews received their instructions from the Surveyor General through skillful Deputy surveyors. Instructions on how to conduct surveys were at first verbally communicated. Soon thereafter, survey instructions were provided in a series of letters from the Surveyor General to the surveyors out in the field (including Deputy surveyors) and from the Commissioners of the GLO to the Surveyor General of each of the states involved. It wasn't until 1855 that the first Manual of Surveying Instructions was compiled and published by the General Land Office (White 1983). This manual and its subsequent revisions became known a the 'bible' of surveying, with instructions on monumentation, the restoration of lost or obliterated corners, plats, and laws. The most recent edition which is currently undergoing slight modification, was published in 1973 by the Department of the Interior, Bureau of Land Management.

Surveying is based on the precise science of geodesy. The geodetic position represents the absolute position of something on the earth's surface. Positional accuracy required of a Government Cadastral survey using Global Positioning System (GPS) is defined in the *Standards and Guidelines for Cadastral Surveys Using Global Positioning System Methods,* 2001. This is a joint publication of the BLM and the Forest Service. Positional accuracy is tightly controlled. All cadastral measurements are reported to the

Federal Geographic Data Committee (FGDC) Geospatial Positioning Accuracy Standards unit to show the relationship of the Cadastral survey relative to the National Spatial Reference System. The National Geodetic Survey (NGS) defines and manages the National Spatial Reference System (NSRS), the platform for cadastral measurement. Cadastral measurements represent the legal position of something on the earth's surface. The Cadastral survey is the official record and official legal description for public lands.

The proper method used to create townships and ranges involves the sequence where the township is first surveyed, then broken down. First an initial point is established at the intersection of the principal meridian and base line and the townships and ranges are surveyed from that initial point. Because townships cannot be completely uniform, corrections need to be made in the grid. Township excesses and deficiencies are 'lotted' – depicted as lots as opposed to sections or evenly divisible portions of sections called aliquot parts – to the north and west portion of the township. 'Lotting' applies to the excess or deficiency of land area resulting in a Township where sections become smaller than normal or where non-section sized portions remain outside of all of the regular sections in the Township (BLM 1973). Lotting inevitably resulted due to the convergence of different surveys started from the western states' unique principal meridians and baselines. Many survey plats refer to the lots as "L1," L2," "L3" and so forth. Aliquot parts, quarter or half divisions of a section of land, are used only for regular, complete sections. The term 'aliquot' refers to a number or quantity that divides a whole into equal parts leaving no remainder. Refer to Figures 6 and 7 for charts depicting 'lotted' areas and aliquot parts, respectively.

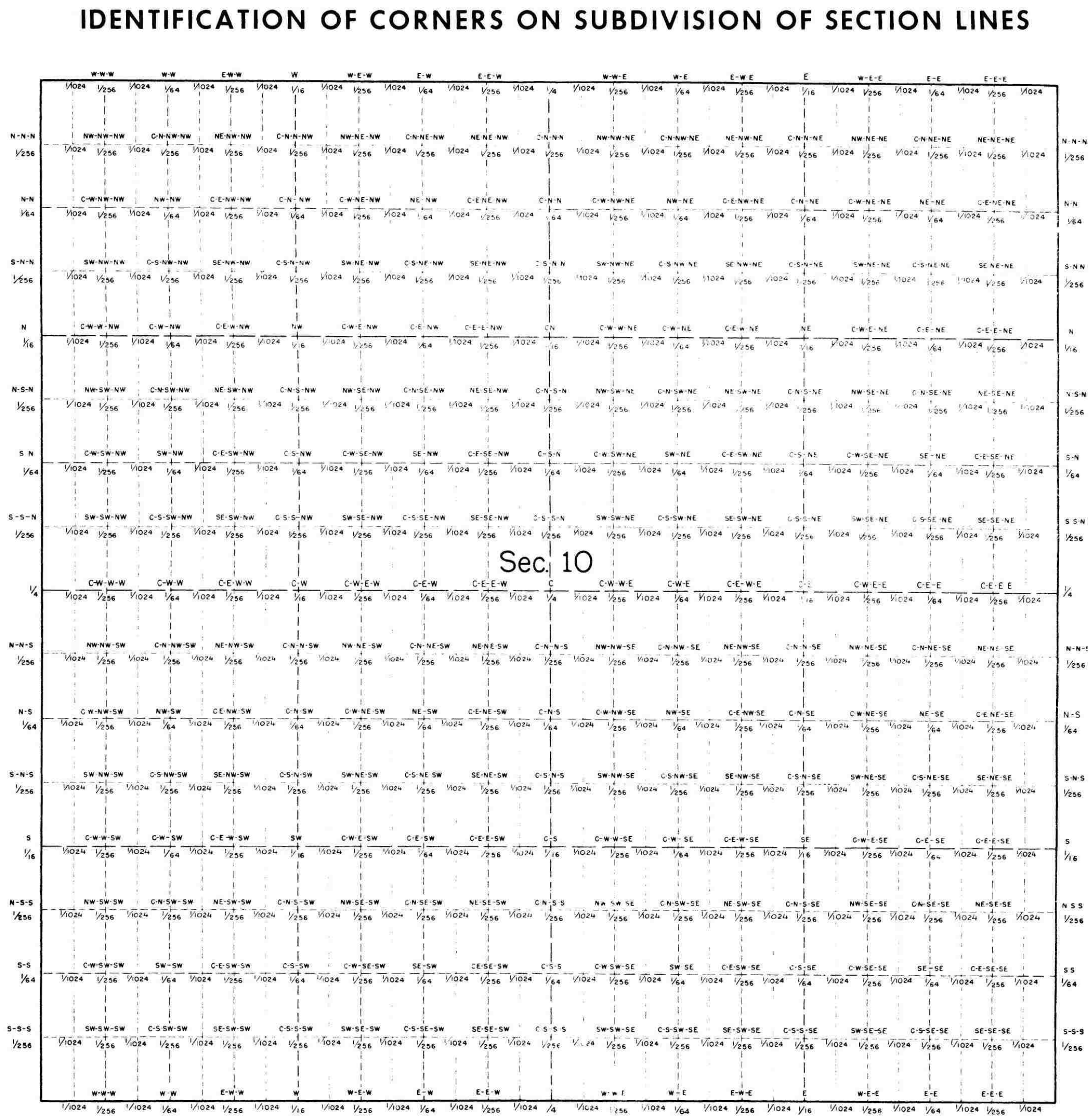
Aliquot parts are used in legal descriptions when no prominent land feature was available (Wattles 1976). This tedious method of describing land parcels allows a section to be divided evenly. The diagram in Figure 7 depicts the designations used for each aliquot part in the section being divided.



Source: Legal Description and Land Status (BLM 2000).

Figure 6. **Township Diagram showing lots.**

The township, range and section corners are monumented appropriately. Monumenting is a fundamental operation in boundary establishment. Boundary management involves a set of rules regarding monument replacement if dislocation occurs. Methods of monumenting include stones, trees, and, more recently, brass caps. Ultimately, the monuments on the ground control by preempting any legal description of the corner in question. If stones or other monumentation is found and seems questionable, the recommendation is to go to the authority for clarification. This authority is the BLM Cadastral Survey program.



Source: Corner Search, Perpetuation, & Recordation (BLM 1986).

Figure 7. **Aliquot Parts Diagram.**

Integrity is an important philosophy of Cadastral surveying. Surveying, however, was not without its temptations and challenges including fraudulent surveys, fraudulent practices in making and accepting claims, and the challenges of the outdoor frontier environment. These factors result in boundary uncertainty. A notorious example of fraud was provided by the Benson Syndicate. This unfortunate team comprised not of official

Cadastral surveyors, but of contracted surveyors, operated in California from the early 1870s to the mid 1880s and fraudulently surveyed nearly a thousand townships in that state. While punitive action was taken against the members of this syndicate, the effects of their unlawful actions of creating fictitious survey information and placing non-permanent corners are still being dealt with today (Uzes 2005). The reckless surveying practices of the Benson Syndicate have lead to boundary uncertainty (Shasta Historical Society 2007).

Similar surveying problems occurred in Florida. A number of claims made to Spanish land grants that had never been surveyed or marked on the ground were accepted by the U.S. Supreme Court between 1821 and 1845. The Florida Surveyor General, George J.F. Clarke, assumed “unusually liberal powers” (Knetsch 2005) resulting in surveys that were anomalous, confusing and very difficult to locate on the ground. Clarke admittedly changed the location of grants after actual possession without obtaining the requisite special authority from the governor. The practice of record-keeping of surveys in the territory was not only inaccurate or incomplete, it was also not done according to established rules and the presumed practice of Spanish authorities. In House Report 412 in May of 1824, Clarke’s deputy testified he was not given surveying instructions and was told that surveys were not required when they couldn’t be made (Knetsch 2005). Clarke’s tenure in office led to confusion and frustration for U.S. Deputy Surveyors who were charged with retracing the Spanish land lines for loosely defined or questionably conveyed land grants. Most of these land lines did not exist (Knetsch 2005). Consequently, people’s claims to land grants at that time only provided them ‘paper’ land, not ‘dirt.’

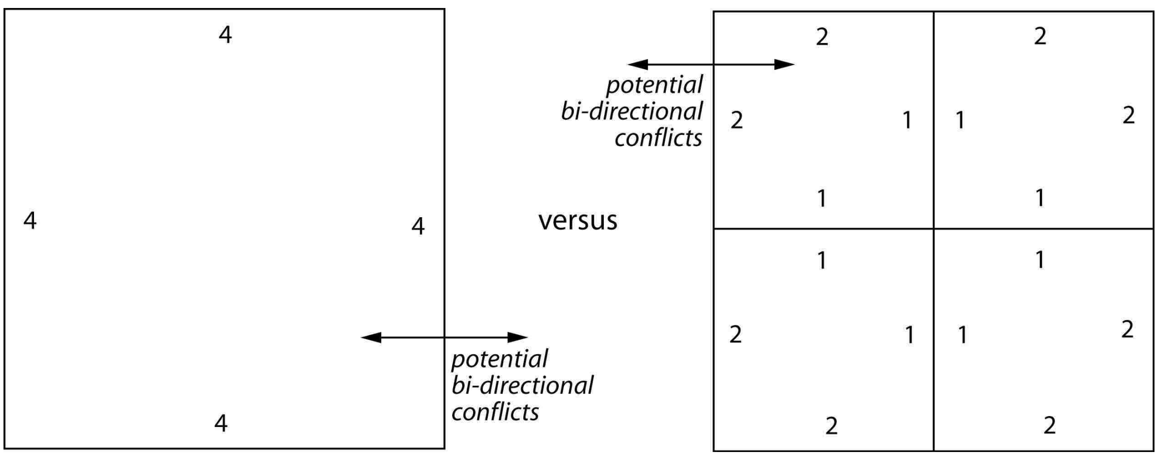
To add to the difficulties of this discipline, the Act of May 18, 1796 stipulated that the entire expense for surveying was limited to $3 per mile, an increase from the $2 per mile limit called for by the Land Ordinance of 1785. Assuming that assistant surveyors and crew members were to be paid a salary, the ability to keep the cost of surveying under this limit was questionable (White 1983). After having to purchase their equipment and pay the crews, and subsequent to the failure of some banks' ability to pay, many surveyors went deep into debt.

Out West in the New Mexico territory a certain number of settlers were residing on the land prior to surveys. They had rights to do this under preemption laws. The surveyor commissioned to survey the land boundaries conducted his survey around the land already claimed and held by people. Preemption of occupancy weighed heavily in the subsequent boundaries that were drawn. In addition, Spanish and Mexican land grants, though excluded from the PLSS, had to have their external boundaries replicated on the ground. Boundary disputes in relation to land grants were common because the records kept on the grants were often missing or inadequate in their boundary descriptions (Knetsch 2005).

New Mexico's colorful surveying history is attributed to land disposal interactions with not only the U.S. Government but also Spain and Mexico. During the time between the 1850's until the 1870's, the Surveyor General of New Mexico examined and verified the ownership of Spanish and Mexican land grants. After reviewing the land grant documentation, the Surveyor General recommended to Congress whether the grants should be rejected or confirmed. Congressional review of these recommendations ceased in the late 1870s. The Court of Private Land Claims was established in 1891 to adjudicate the outstanding Surveyor General's recommendations not yet approved by Congress. By 1904 the court completed its work. Congress and the Court of Private Land Claims ultimately issued patents for 142 of the 295 grants (GAO 2001). Property rights existing under Spanish and Mexican land grants expressed in Article X of the Treaty of Guadalupe Hidalgo (1848) were not recognized by the U.S under this treaty. This was because Article X was struck by the U.S. prior to ratifying the treaty. Later that year, the U.S. and Mexico signed the Protocol of Querétaro which provided for protection of land grant titles. The Gadsden Purchase of 1853 incorporated the property provisions of the Treaty of Guadalupe Hidalgo. Spanish and Mexican land grants are divided into two types: "individual grants" and "community land grants." A large proportion of these land grants fall into the second category. Consequently, many of these grants were rejected due to the issue of ownership of common lands (GAO 2001). Although the common lands ownership issue was decided in *United States v. Sandoval*, 167 U.S. 278 (1897), this issue has not been put to rest (Gomez 1985).

The West is becoming increasingly prone to boundary disputes due to a fairly steady rate of population growth. Population increase translates to an increase in the demand for land. Traditionally, ranches in the New Mexico territory, as well as in the western states in general, included one to several townships of public land. Actual patented ownership may have been only 40-160 acres in size – making up the strategic 'base property,' which had the 'base water,' two concepts capitalized on in the Taylor Grazing Act of 1934 (43 U.S.C.A. §§ 315-315c) (McIntosh 1976). These tracts of land were being sold to developers who then subdivide the land. The consequent edge effect is obvious. See Figures 8 and 9 for an illustration of how subdivision creates additional opportunities for boundary uncertainty and the potential disputes relating to this phenomenon.

In the event of a boundary dispute, some informal non-binding processes such as negotiation, mitigation, and arbitration may succeed in resolving the conflict. In the event an agreement cannot be reached by these means, an administrative hearing before the Interior Board of Land Appeals may be necessary for disputes with a federal land aspect (Matthews interview 2007).



Total edge units subject
to uncertainty: 16

Total edge units subject
to uncertainty: 24

Figure 8. **Single Landowner.**

Figure 9. **Figure 7's land subdivided and owned by 4 different entities.**

On each outer edge, the unit is doubled due to the two-way nature of disputes.

The focus of this thesis rests on identifying boundary uncertainty and avoiding potential conflict. Even though conflict resolution is a part of the case study, it is beyond the scope of this thesis.

In some cases, unsurveyed areas are left unsurveyed due to the high cost of Cadastral services compared with the relatively low priority for establishing certainty. In order to complete the legal description for a tract that has not been surveyed, aliquot parts are used in the description. This method can prove to be tedious, yet straightforward in a regular township. However, it becomes an onerous task when irregular boundary shapes caused by roads, streams, etc. are involved. Legal descriptions, like any other component of recording land parcel transactions, are not immune to error. Error-correction methods are explained by 'Cadastral Mapping Guidelines & Standards' (BLM Section 9.0) when a legal description is found to be erroneous. The BLM's National Integrated Land System (NILS) land parcel historical records retain all boundary information pertaining to the parcel. As a result, boundary variability of a parcel may exist. For example, a parcel may have three descriptions from different sources: a deed in 1902, a deed in 1952, and a survey in 1992. In this case the 1992 survey is accepted as the current boundary (von Meyer 2004). This situation is more common in the eastern U.S. metes and bounds states.

Surveys are more difficult in rugged terrain with issues often occurring due to the topography. For example, corners may be referred to as 'floaters' because there are several records of the same corner and each record is different. This kind of discrepancy may require a Cadastral survey to decide on what should ultimately be designated as the corner of record. This is then monumented and recorded as a legal fact (BLM 1973).

While one of the most obvious answers to any boundary uncertainty would seem to be to obtain a Cadastral survey (if the corners were in question), the issue of economics and escalating costs surfaces. In some cases the survey costs much more than the land is worth. Furthermore, when Cadastral provides an estimate of surveying costs to other agencies, that estimate, as soon as it has been transmitted, becomes a firm price.

Any unanticipated difficulties resulting in additional expenditures are absorbed by Cadastral (Cadastral Survey Team Lead interview 2007). In the past, cooperative agreements existed among federal agencies that designated shared costs of Cadastral surveys, however, budget cuts and changing economics have caused cooperative cost-sharing to disappear.

Surveying technology has advanced significantly in the last 50 years. The Electronic Distance Measurer (EDM) was a major technological advancement. It replaced the chains and tape previously used to measure distances on the ground. The pocket-sized 'Red Book,' a book containing pre-calculated trigonometric functions, was used for trigonometric computations required for accurate measurements. The portable calculator replaced the 'Red Book' in the 1960s. Consequently, measurement values are calculated more accurately. Then came GIS which provides electronic spatial data storage, display, and analysis. This was a means to save coordinates and measurements where they could easily be retrieved at a later time for review. Map displays were created from GIS data, enabling a quick visual reference for the survey data. In 1983 the National Geodetic Survey (NGS) completed its first survey using Global Positioning System (GPS) technology. This marked the beginning of the days of satellite surveying for the agency. Nearly 200 years of using metal bars, steel tapes, and electronic distance measurements was replaced by GPS technology (NOAA 2007) http://celebrating200years.noaa.gov/distance_tools/welcome.html#background. In 1995 the U.S. Air Force deployed the 24th NavStar (Navigation System by timing and ranging) satellite, completing the GPS constellation. Another technological leap occurred on May 1st, 2000, when then President Clinton announced his decision to discontinue Selective

Availability. Selective Availability involved the scrambling of GPS signals by the U.S. military thus degrading the civilian GPS signal. Overnight, civilian GPS units became ten times more accurate. This was a significant step in the ongoing effort to increase the responsiveness of civilian and commercial GPS users (White House press release, 05/03/2000). GPS has replaced the ephemera that were used to determine locations of things on the Earth's surface.

Federal land management agencies such as the Forest Service and the Bureau of Land Management rely on the emerging GIS and GPS technology to more precisely locate events and conditions on the ground. These agencies are becoming better able to implement their management strategies as a result of such technological advances.

The Federal Land Management Agencies

During the disposition of the public domain new western states were formed using enabling acts. Title conveyance and patents of land to private owners remained a federal function. Lands never conveyed to private parties or the states remained federal land. The leftover land and lands that, after private acquisition, "have been returned to public ownership [have] the status of public land by law" (BLM 1973). Not all federal land is public land by this definition. Some federal lands have been withdrawn or reserved for specific purposes. These include National Parks, National Forests and wildlife refuges. The category of federal land referred to as public land is administered by the BLM (FLPMA 43 U.S.C.A. § 1702(e)).

The area of the U.S. totals 9,826,630 km^2 or 2,428,213,155 acres. Consequently, the federal government, administering approximately 30% of the land area, is the largest single landowner in the U.S.

While several federal agencies are responsible for managing federal land, two stand out because of the volume of acres under their jurisdiction and their prominent roles in public land management. They are the Department of Agriculture U.S. Forest Service (USFS), and the Department of the Interior (DOI) Bureau of Land Management (BLM). The BLM is the result of a merger between the General Land Office (GLO) and the Grazing Service in 1946. This agency ranks the highest in land area of all federal agencies, being responsible for the management of activities on approximately 258 million acres. The BLM is also responsible for the maintenance of all public land parcel records. In 1976, the BLM's primary governing statute, the Federal Land Policy Management Act (FLPMA, 43 U.S.C.A. §§ 1701-1784) was passed. This Act establishes public land policy "to provide for the management, protection, development, and enhancement of the public lands; and for other purposes" (FLPMA 1976). This agency handled all land surveys during the disposition of the public domain (BLM 1988).

The U.S. Forest Service's main initial objectives were "the conservation of water flows and to furnish continuous supply of timber for people" (Organic Act of 1897). Today, the driving force behind the Forest Service's activities stems not only from the Organic Administration Act of 1897 (16 U.S.C.A. §§ 473-551), but also from the Multiple-Use Sustained-Yield Act (MUSYA) of 1960 (16 U.S.C.A. §§ 528-531), the National Forest Management Act (NFMA) of 1976 (16 U.S.C.A. §§ 1600-1614), and the Wilderness Act of 1964 (16 U.S.C.A. §§ 1131-1136). Essentially, the 192 million acres of Forest Service lands are to be managed based on the five MUSYA purposes: "outdoor recreation, range, timber, watershed, and wildlife and fish purposes" (Glicksman and

Coggins 2006). U.S. Forest Service land, the Manzano Forest Reserve, is adjacent to the case study's eastern and southern boundaries.

The U.S. Fish and Wildlife Service totals approximately 93 million acres. In the National Park Service there are 391 areas covering more than 84 million acres. Other government landowners include: state, county, and municipal. Outside of government land there exists the category of private land.

The path to land ownership in the U.S. is shown in the public domain disposition diagram shown earlier (Figure 1). "Public land survey" is a part of this path. Surveys provide the delineation and demarcation of the boundaries for all land parcels.

CHAPTER 3:

LAND INFORMATION SYSTEMS

This chapter will explore current land parcel information systems used by the BLM. The relationships between surveying, GIS and cartography will be discussed in regards to land information systems and boundary delineation and demarcation. An explanation of the methods and data types will be provided. Accuracy as it pertains to these disciplines will also be discussed. Issues that arise from boundary uncertainty will be introduced. Figure 10 provides a visual explanation of the relationships between elements pertaining to boundary uncertainty.

An Introduction to Data Management: the National Integrated Land System and the Geographic Coordinate Database

Land possesses two unique characteristics that set it apart from other property, such as personal property. First, it is immovable and cannot be physically moved from on location to another. Second, it cannot be increased or decreased – it is permanent. It is this permanence that makes it capable of a lasting record (Hanstad 1998).

Prior to the era of electronic data storage, land records were manually generated and maintained on paper and microfiche. Land records are composed of many parts: the legal description of the parcel, land status, survey points, coordinates, measurements, and computations, along with other components of the Master Title Plat (MTP) including survey plats and field survey notes. Over the years, a tract of BLM land may undergo several transactions such as acquired then retained, conveyance, withdrawal, exchange, etc., all of which are written and recorded on the Historic Index until that tract is disposed of which occurs when it leaves the federal public land system (Edwards 1967).

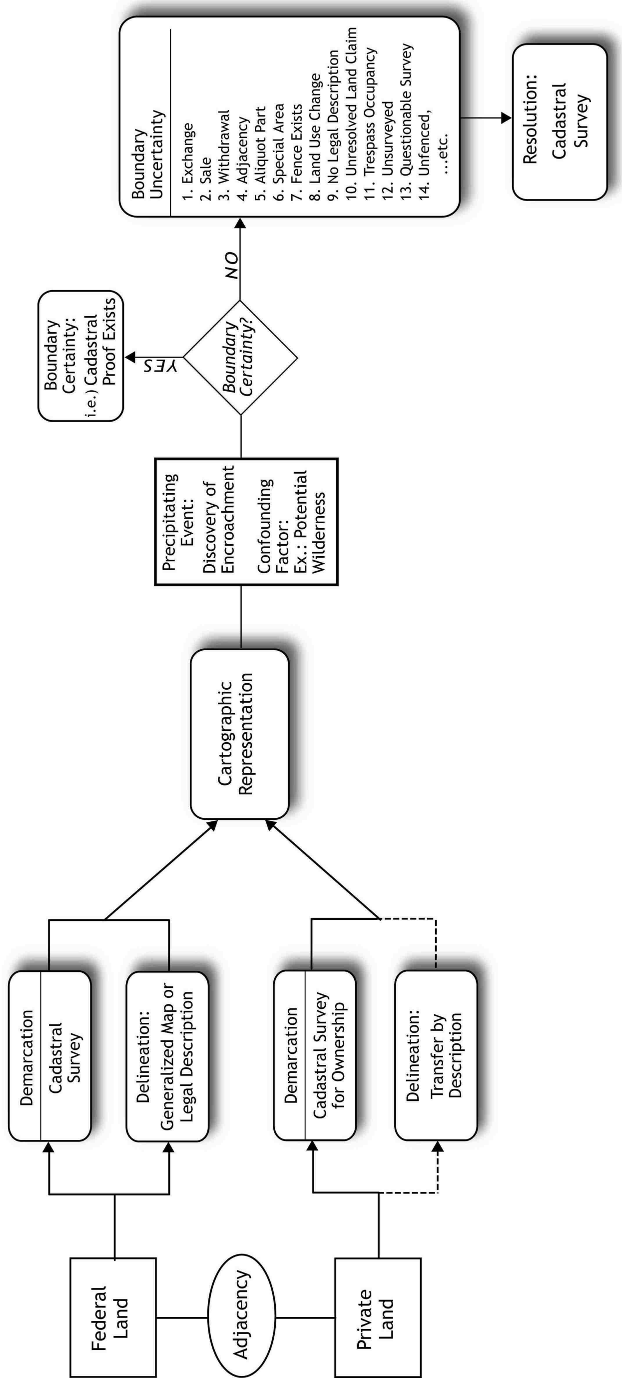


Figure 10. **A diagram of elements involved in boundary uncertainty.**

Currently, the components of the land record system are being consolidated by the BLM in a database referred to as the National Integrated Lands System (NILS). NILS is an enormous project. It encompasses all of the facets of a parcel of land. Recently, with the advent of electronic data storage and Geographic Information Science, two additional steps in the land record system process involve the Geographic Coordinate Database (GCDB) and GIS.

The National Integrated Land System and the Geographic Coordinate Database

In 1980, the Committee on Geodesy along with the National Research Foundation formed a panel on a multipurpose cadastre. Their vision involved the creation and implementation of a more unified and consistent land information system in the U.S. This effort would be aimed at improving land conveyance procedures and provide much needed information for resource management and environmental planning. Costs associated with the duplication of effort on federal, state, and local levels would be reduced (Orlin et al. 1980). While the proposal was not limited to the federal government, this thesis focuses on the activities of the federal agency responsible for land records – the BLM. NILS is a cooperative endeavor between the BLM and the Forest Service in partnership with the states, counties, and private industry including Environmental Systems Research Institute (ESRI). NILS reflects the recommendations made by the visionary multipurpose cadastre committee. This data model's main objective is to provide a process to collect, maintain, and store parcel-based land and survey information that meets the common, shared business needs of land title and land resource management in a GIS environment (Arctur and Zeiler 2004). Now, thanks to the four-module, eleven-layer NILS geodatabase, a cohesive unit for each land parcel is

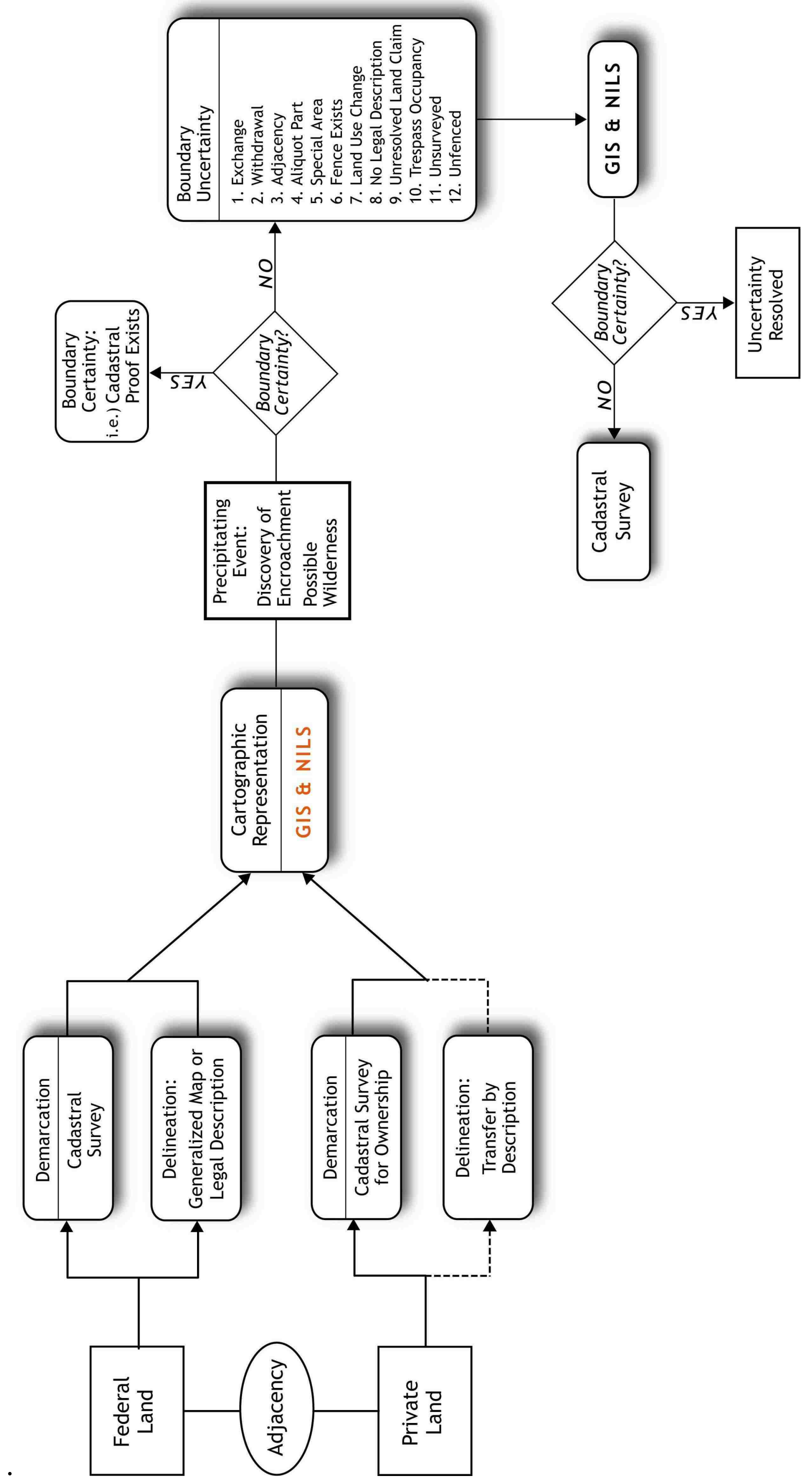


Figure 11. **Boundary Uncertainty Diagram – a more modern version incorporating GIS and NILS.**

being created. The database includes metadata and topology rules, along with everything from orthophotos to cartographic representations and legal descriptions. The four NILS modules are: Survey Management, Measurement Management, Parcel Management and GeoCommunicator. Figure 11 depicts a more modern version of the boundary uncertainty diagram. This version incorporates GIS and NILS. Records for every aspect of public land management are contained in the NILS modules. NILS uses an automated process to electronically import 80% of existing parcel information. Manual addition of 20% of the parcels is required. This is because some parcels' legal descriptions are too complex or nonexistent, or the parcel case file refers to a separate document. 500 to 1200 transactions are performed daily towards the goal of completion in the near future. A query of the NILS geodatabase may yield parcels having attributes that cause boundary uncertainty.

Land parcel management in NILS is geared toward the government professional for internal government use. However, this system makes land parcel information available to the general public by way of the internet, providing on-line access to what is currently located in and traditionally accessed by visiting the BLM's state office public rooms – large areas where the MTP's are stored in file cabinets. Historically, boundary measurements and coordinate point locations for land parcels have been depicted in hardcopy on the survey plat, which is part of the MTP (Edwards 1967). This will continue to be the case in addition to on-line methods for measurement and location, storage, and retrieval. The part of the NILS system where these data reside is called the Geographic Coordinate Database (GCDB). The GCDB grid is computed from BLM survey records (official plats and field notes), local survey records, and geodetic control information. GCDB shapefiles for a large portion of the public lands can be downloaded from the BLM's GeoCommunicator website at http://www.blm.gov/wo/st/en/prog/more/nils.html.

Geographic Information Science

GIS Data Storage and the National Integrated Land System

Geographic Information Systems provides the basis for data analysis and the compilation of maps. This cross-disciplinary system developed in the 1960s concurrently with the microprocessor (DeMers 2003). The need for a framework for generating, acquiring, accessing, analyzing and displaying spatial data was evident, and GIS provides this framework. A wide variety of systems have been developed and are currently in use. These are predominantly used for land use planning, natural resource management, and other purposes (Smith et al.1987).

Currently, the official BLM NILS publication website, GeoCommunicator, provides access to several GIS data sets. Land Records 2000 (LR2000) contains land and mineral use records and is periodically synchronized with NILS (Arctur and Zeiler 2004). The information served at this site includes case recordation, legal descriptions, mining claim recordation, land status, and dynamic mapping of data for federal land stewardship. Although BLM GIS data are also available on line, the GIS data are not yet linked to the records data. Eventually, the NILS geodatabase will provide a package of parcel data with records embedded within the spatial dataset. This system will allow electronic updates of the data while maintaining the cohesiveness of the parcel. The Forest Service PLSS data is maintained using the Automated Lands Project (ALP) which is the Forest Service's equivalent to the BLM's GCDB. When Forest Service PLSS data are formatted for ALP, they are then provided to the BLM for inclusion in the GCDB and NILS. The data management framework provided by NILS and its components allows for the retrieval and display of geographic data in the form of maps.

GIS Methodology

Maps are generated to convey locations of features and events on the ground. This process is necessary to assess locational relationships such as adjacency and proximity.

Two methods were used in the creation of the case study maps used in this thesis. First, layers in their original format and projection were imported into Environmental Systems Research Institute's (ESRI) ArcMap in one data frame. This results in the layers being projected 'on-the-fly.' Projecting on-the-fly will result in two identical datasets having different projections to display coincidentally on a map. A second method involved projecting the data. Prior to adding the layers, all layers were projected to a consistent coordinate system in ArcMap and added to a second data frame. The second data frame was overlaid on the first data frame. It is difficult to visually discern the positional shift of the data in the projected data frame compared to the data in the 'project-on-the-fly' dataframe. Either method of display is acceptable.

One of the most critical components of data acquisition in preparation for analysis and map compilation is metadata. Metadata, data about data, provides the end user with valuable information regarding when and how the data was collected and the units of measure for the data, in addition to the datum and projection. Standards are useful for creating and editing metadata, and the Federal Geographic Data Committee (FGDC) has established guidelines for compliance. Good metadata enables the map compiler to anticipate any problems that might arise from using datasets having different coordinate systems, thereby avoiding alignment problems. Data use constraints and caveats are also found in the metadata file. Differences in dataset formats require additional preparation prior to use, depending on the format. Some datasets have no metadata. This is the case in Valencia County's data for their county boundary and PLSS lines.

Scale, among other factors, will dictate level of accuracy required for generating map products using GIS data. This research is focused on a relatively small WSA, a very small surface disturbance (2.5 – 3acres), and a north-south fence built along the western side of the WSA. As a consequence of the large scale of this study, a higher degree of accuracy in the cartographic process is required. The level of accuracy required for Cadastral surveys is not subject to change, regardless of scale. (BLM 2001). Standards for accuracy of GIS data, surveying measurements and map production are described by the FGDC.

Accuracy: the Federal Geographic Data Committee Standards

The Federal Geographic Data Committee (FGDC) is charged with the definition, description, and dissemination of accuracy standards for any type of federal data. The FGDC defines map accuracy in the Cadastral Mapping Guidelines & Standards Section 3.0. Standards and their definitions for surveying, GIS, and mapping can be accessed on line at the FGDC website: http://www.fgdc.gov/, and at the USGS *National Map* website: http://geography.usgs.gov/standards/.

Accuracy and Surveying

Accuracy from a surveying viewpoint is "nearness to the truth." Precision is "repeatability" (Brown 1969). A measurement may be very precise, but not accurate, thus misplacing a feature. Historically, cadastral surveys utilized mechanical devices such as rods, chains and tapes to measure distances and locate PLSS corners. Ephemeris, tables of the positions of celestial bodies, and manual mathematical computations were also used to establish the measurements for the boundaries of tracts of land. The monuments, in the form of stones, trees, or brass caps, were set in the ground to mark these corners. These monuments can be located today – especially stones and brass caps – without a great deal of difficulty. Overall, the implementation of the PLSS was successful where land had been surveyed. Presently, global positioning satellites and electronic units used on the ground, along with the network of geodetic control base stations (HARN & CORS) allow for a much higher level of accuracy and precision compared to that achieved by historical methods. Standards for the accuracy of cadastral surveys using the Global Positioning System described above are defined by the Federal Geographic Data Committee (FGDC). The published standards can be found on and downloaded from the BLM's Cadastral website at http://www.blm.gov/nhp/efoia/wo/fy01/im2001-186attach1.pdf This publication, entitled "Standards and Guidelines for CADASTRAL SURVEYS Using Global Positioning System Methods" (BLM 2001) states that for a 95% confidence circle, the local horizontal and vertical accuracy standards for Cadastral Project Control and Cadastral Measurement are less than 0.050 meters and less than 0.100 meters, respectively. Horizontal and vertical network accuracy standards for Cadastral Project Control and Cadastral Measurement are less than 0.100 meters and less than 0.200 meters, respectively (pp 1-4). Cadastral project control represents the network of the GPS baselines tied to the National Spatial Reference System (NSRS). Network accuracy is "the absolute accuracy of the coordinates for a point at the 95% confidence level, with respect to the defined reference system" (the CORS and HARN stations on the ground) (BLM 2001). The equipment used in these surveys conforms to these accuracy standards. GPS receivers provide varying levels of accuracy depending upon their type. Coarse Acquisition (C/A code) receivers provide from 1 to 5 meter GPS positional accuracy down to 30 cm accuracy. This is adequate for many GIS applications. Carrier Phase receivers provide 10 to 30 cm accuracy required by certain GIS applications. Finally, Dual-Frequency receivers provide survey grade accuracy which is at sub-centimeter accuracy required by the FGDC for Cadastral surveys.

Accuracy and GIS Data

A core function of GIS is to provide the methodology for interim steps involved in translating survey data, especially corners, from the curved surface of the Earth in three dimensions onto the flat, two-dimensional map surface. To a certain degree, GIS accuracy depends upon the source data, and the term 'accuracy' can take on a slightly different meaning in this context. One of the methods used to ascertain the accuracy and even the validity and currentness of the data being used is to read the metadata associated with the spatial dataset being used. The FGDC has defined the standards for metadata in regards to spatial data (FGDC-STD-001-1998).

Zimmer (2005) asserts that an important role of surveyors in GIS is to certify the spatial accuracy of GIS data. He maintains that people are increasingly appreciating the importance of reliable spatial accuracy statements. Thus, surveyors will be called upon more often to certify, quantitatively or qualitatively, the accuracy of GIS data. Hardly any GIS personnel are trained in the discipline of surveying because GIS itself is a business process that is not constrained to a single discipline. Consequently, GIS personnel will work more closely with surveyors to identify the level of accuracy of GIS data used in projects.

It is possible that, at some point in the future, all registered surveyors will possess GIS expertise as GIS permeates the activities involved in surveying. Zimmer claims that "GIS and the new measurement technologies do not make the surveyor obsolete. On the contrary, these technologies reemphasize the need for expert survey analysis and evaluation of measurement data" (Zimmer 2004).

The Arizona Professional Land Surveyors Association, Geospatial Organization Committee recently published a draft outlining the use of geospatial data in that state in the monthly publication *Surface Matters*, titled "The Geospatial Debate." This debate concerns itself with ensuring that geospatial data be used for purposes appropriate for how the data was developed (Smothers and Trobia 2007). In a subsequent issue of *Surface Matters*, the widespread effects of the technological explosion on the disciplines of surveying and GIS are examined. In Oregon a task force recommended that GIS Professionals should, at a minimum, be certified by the National Council of Examiners for Engineering and Surveying (NCEES) (Smothers 2007).

Efforts to apply strict controls on the quality, generation and use of geospatial data are a result of the Brooks Act of 1972 (40 U.S.C.A. §§ 1101-1104). The Act defines the "Qualifications-Based Selection" process used by the government for selecting contractors. This Act has been amended to include surveying and mapping activities that are contracted by the federal government (Francica and Schultzberg 2007). In February of this year, the Management Association for Private Photogrammetric Surveyors

(MAPPS), etc., lost a federal case in which they tried to require GISP (GIS Professional) certification for all mapping (*Management Association for Private Photogrammetric Surveyors v. United States* , 492 F. Supp. 2d 540, E.D. Va. 2007). In spite of the results of the MAPPS case, GIS professionals may not be out of the litigation woods. In a comment on *Allnutt v. United States*, 498 F. Supp. 832, W.D. (Mo 1980) involving an aircraft crash that resulted in the deaths of a pilot and two passengers, strict liability for the defective products supplied by GIS producers was being applied. "Both the creator and distributor of GIS data, therefore, will likely be held to a strict liability standard. ...Without time to experience a few growing pains, GIS will be doomed to a strict liability standard" (Phillips 1999).

Accuracy and Maps

"Maps resemble miniature pictorial representations of the physical world" (Tufte 1997). High quality maps containing a large amount of detail and several informative data layers set standards of excellence for information design. Color is used not only as a code, but also as a natural quantifier (Tufte 1990). The proper use of typography and annotation enables efficient information transfer. Maps should be visually articulate. Otherwise, they become useless. An articulate map should tell the observer the truth. In "How to Lie with Maps," Mark Monmonier provides examples of deliberate and not-so-deliberate distortion and deception (Monmonier 1996). Our maps are only as good as the data used to prepare them, and then only as articulate as the mapmaker's skills allow. Maps of identical areas have been published. However, when compared to each other, these maps neither depict identical features nor is their symbology consistent. Consistency among maps is an issue that may never be resolved due to the preponderance of map producers and their unbounded audience. A lack of consistency in maps along with dishonest location representation can lead to boundary uncertainty.

A prime mission of the U.S. Geological Survey (USGS) is to generate primary series topographic maps, known as quadrangle maps. These products successfully convey information in reference to elevation, place names, feature names, political and PLSS boundaries, roads, and adjacent quadrangle map names. The processes involved in the production of these widely-used maps adhere to *The National Map* accuracy standards defined by the Federal Geographic Data Committee (FGDC). *The National Map* is a core component of the USGS. It is "the product of a consortium of Federal, State, and local partners who provide geospatial data to enhance America's ability to access, integrate, and apply geospatial data at global, national, and local scales" (http://nationalmap.gov/ 2007). *The National Map* accuracy standards for large-scale mapping requires that a map of scale 1:24000 must be accurate to 40 feet horizontally. All USGS quadrangle maps contain the same type of information, are produced at the same scale, and utilize consistent symbology depicting the same types of features. *The National Map* provides internet access to data and topographic map viewing. Their website also allows access to the FGDC and other geospatial partners.

Maps produced by the BLM, depending on their purpose, can be readily discerned from those even of the same genre published by the Forest Service. Each agency utilizes its own set of standards for graphic representation, so, while BLM and Forest Service products are not consistent with each other, they are consistent within their respective agencies. The case study area will be depicted using maps of scales ranging from 1: 24000 to 1:12000. These depictions conform to the national standards with a horizontal accuracy of about 33 feet. Another critical aspect of mapping relates to the data being used in the compilation of maps. Map accuracy and reliability is a consequence of the accuracy of the data used.

GIS data reliability for cartography is depicted in the GCDB's reliability diagram which can be compiled at and downloaded from the BLM's GeoCommunicator website at: http://www.geocommunicator.gov/LSIS6/map.jsp. As GCDB GIS files are suitable for cartographic representation of township and sections, this diagram is a product of interest to surveyors, GIS personnel and cartographers. A diagram can be generated from the coordinate point file for each PLSS corner from accuracy values in that file. The values are given in feet, and typically errors are approximately 40 feet (Zimmer 2004). Some areas have ample survey control and adequate supporting survey data while other areas do not. For instance, the case study area has a floating township corner at T6N & T7N, R4E & R5E on the Manzano WSA. In situations where the accuracy of the GCDB is not satisfactory, the end-user can work with the BLM to reduce the magnitude of errors. Because of their skills and knowledge of field reconnaissance, field observations, data reduction and analysis, surveyors play a key role in the process of enhancing the accuracy of the GCDB (Zimmer 2007).

The Cartographic Process

Based on the map accuracy standards discussed earlier, it would be unwise to depict a boundary on a 1:24000 scale map using a line that, in width or thickness, equates to a measure of 40 feet on the ground. These and other symbology issues are addressed in agency guidelines such as the April 2006 Cartographic Specifications and Symbols Handbook published by the Forest Service. This handbook provides explicit definitions for the depiction of map components, from color mixtures to line weights and text sizes. Map text is also discussed in "*The Art and Science of Cartographic Text Placement*," a BLM guide published in 2004 (Meszaros 2004). Meszaros also compiled the "*Cartographic Checklist*" in 2003 for the BLM as an "*Aid to Achieving Quality and Completeness in the Creation of Mapping Products*." Standards for the display of map components change depending on the map's function. Internal briefing maps used on fire incidents depict the active fire line in red. However, the color red is not allowed to be used in the maps distributed to the public.

Erroneous Boundary Location Depiction

An interesting wilderness boundary mapping issue involving cartographic representation and GIS analysis arose in June of 2007 on the Big Turnaround Complex – a fire that burned in the Okefenokee National Wildlife Reserve and Wilderness. This Reserve spans the Georgia – Florida state lines. There was more than one fire team assigned to this incident. One team was responsible for the east and south area and the other to the west and north.

The Greater Okefenokee Association of Landowners (GOAL) was involved. A major player was the timber industry. Land owned by two prominent timber companies and GOAL members, Rayonier Inc. and Toledo Manufacturing, was being threatened by this fire. Data was updated daily and maps were created to track the fire's progress. These maps provided information to the affected landowners. A dataset was created for internal purposes separating the ownership, so that the daily acreage reports of burned areas could be enumerated as well as summarized. The entire incident covered an area approximately 500,000 acres in size, roughly the size of the state of Rhode Island. The dataset containing the owner-attributed boundaries was used continuously for about two weeks. At that point, a closer examination of those boundaries revealed an erroneous section of the Wilderness boundary, showing incorrectly that it extended beyond the Reserve. That 1,500-acre parcel actually belonged to the state of Georgia, which used the acreage reports to claim Federal Emergency Management Agency (FEMA) dollars in the suppression effort. The boundary dataset was immediately corrected to reflect the proper delineation of ownership and this corrected version was used in the daily burned acres report. Not only did this incident illustrate the importance of accurate boundary representation, it also revealed the challenges and benefits of cooperative interagency management.

Many products that result from the interaction of surveying, GIS and cartography are dependent upon the proper and successful implementation of each of those disciplines. The apparent nervousness of geospatial and surveying professionals is understandable when viewed in this light. Upon each instance of compiling a map, the general question, "Will this map stand up in a court of law?" should be answered. In a perfect world, the survey and GIS data along with the cartographic representation would always be perfectly accurate, precise, and reliable. In the real world, clear documentation of the methods and processes involved, and the reasons for the decision to employ particular methods and follow particular processes are important.

With the definition of standards and a view towards cooperation, the nationwide geospatial community is pushing the limits of technology and constantly seeking to improve the quality, availability, and usefulness of geographic data (of which there is no shortage). Over the past few decades, technological advances and the interrelation of the disciplines of surveying, GIS and cartography, geospatial data and its generation, transformation, maintenance, analysis and display have occurred. These advances provide geographers with solid tools that can be used to address the ‘cognitive demands’ such as understanding “why” and “how” in addition to “what” and “where” (Golledge 2002).

The next chapter will explore these cognitive demands in relation to the case study: the BLM’s Manzano Wilderness Study Area.

CHAPTER 4: BOUNDARY UNCERTAINTY, GIS, AND SURVEYING – A CASE STUDY

The Case Study

When the 1964 Wilderness Act was passed, "little thought was given to BLM lands as potential wilderness areas. Throughout most of the early 1960's BLM lands were thought of as the residue of unappropriated and unreserved federal lands. However, when the Federal Land Policy and Management Act (FLPMA) was passed in 1976 it directed the Secretary of the Interior to review all roadless BLM lands for possible inclusion in the National Wilderness Preservation System" (Coggins and McClosky 1984). This has implications for the BLM's Manzano Wilderness Study Area because of the subsequent designation for this area.

Figure 12 is the map created for the Manzano Forest Reserve when it was initially reserved in 1906. This map was generated as a result of an 1883 survey. This area is adjacent to the case study area to the east and south. Pursuant to FLPMA the BLM began conducting wilderness studies on their lands. One of these studies was done for New Mexico in 1986. The NM Statewide Wilderness Study included the Manzano WSA. The 881-acre Manzano Wilderness Study Area was thoroughly described, and this area was deemed eligible for wilderness designation. At that time, there were no private interests in the area. This study concluded that the Manzano WSA could not only be effectively managed as wilderness, but could also be eventually transferred to the Forest Service for inclusion into the adjacent FS Manzano Mountain Wilderness (BLM 1991).

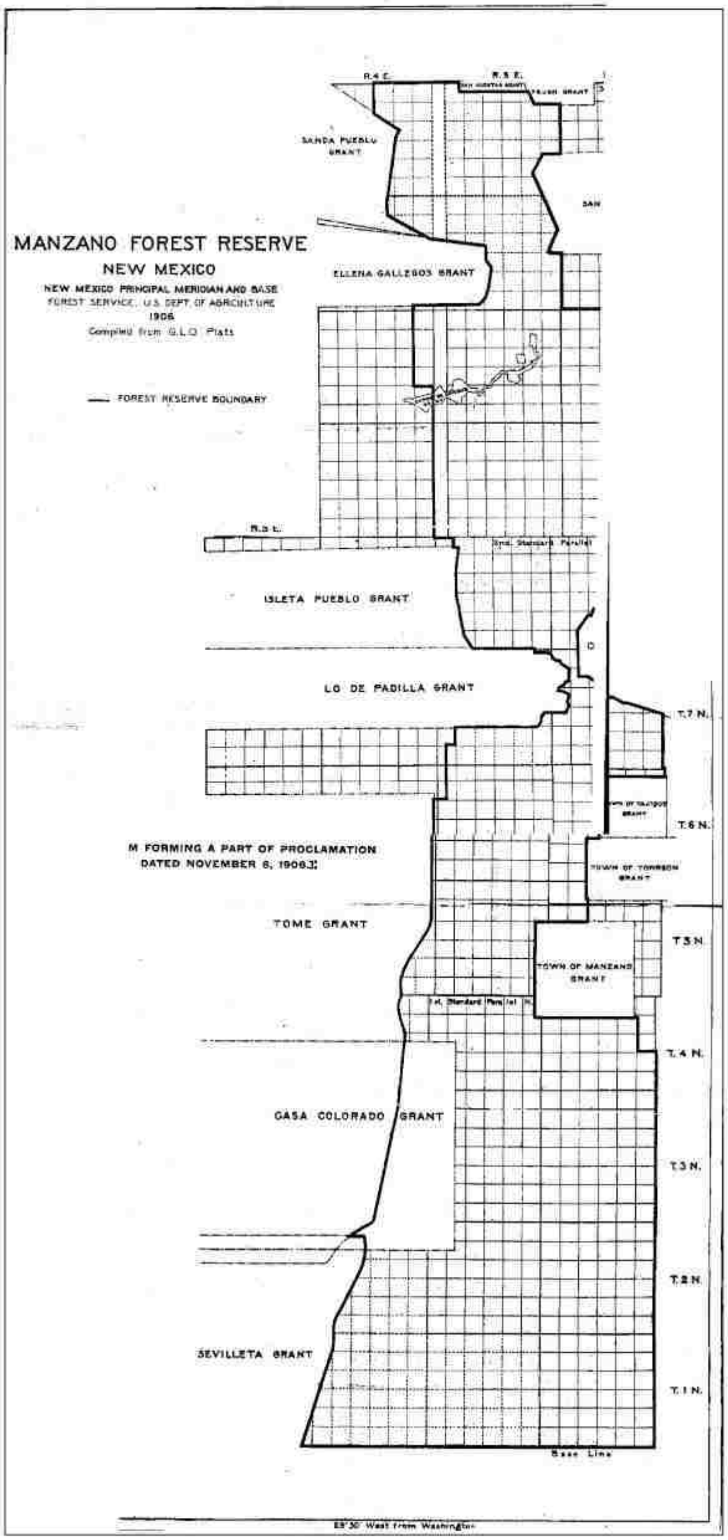


Figure 12. **The initial map generated in 1906 to depict the boundary of the Manzano Forest Reserve (adjacent to the study area).**

Prior to becoming Congressionally designated as Wilderness, the Manzano WSA was subject to the BLM's Interim Management Policy and Guidelines for Lands Under Wilderness Review. With less than the requisite 5,000 acres, the Manzano WSA was selected for study under the authority of Section 202 of FLPMA. Section 202 WSAs in this study generally followed the same process used for the other WSAs, but they depend on the lands of another agency, in this case, the Forest Service, to qualify for wilderness consideration. Therefore, the Forest Service's management plans and policies were an important factor in determining the Manzano WSA's recommendation for wilderness designation. According to the Statewide Study, the recommendation for the Manzano WSA is to "designate the entire area as wilderness and add it to the Cibola National Forest's Manzano Mountain Wilderness." The report continues: "The WSA represents a natural extension to the existing 36,785-acre Manzano Mountain Wilderness, and management by one agency will reduce overall administrative costs" (BLM 1991). Out of the 49 areas recommended in the 1986 study only two have been Congressionally designated as wilderness to date.

The level of activity allowed on an area generally becomes more restricted once it is designated as wilderness or as a wilderness study area. Mechanized vehicles, developments or improvements are usually not allowed. Practices of 'minimum tool' and 'leave no trace' are articulated and enforced. While the surface disturbance to the WSA by a dirt road, a 2.5 acre clearing and a fence, was apparently inadvertent, it does jeopardize the WSA's suitability for wilderness. Wilderness eligibility is based on the Wilderness Act of 1964.

The BLM's Manzano Wilderness Study Area

The location of the Manzano WSA in New Mexico is shown by the locator map in Figure 13. This area is covered by the U.S. Geological Survey (USGS) 'Bosque Peak'

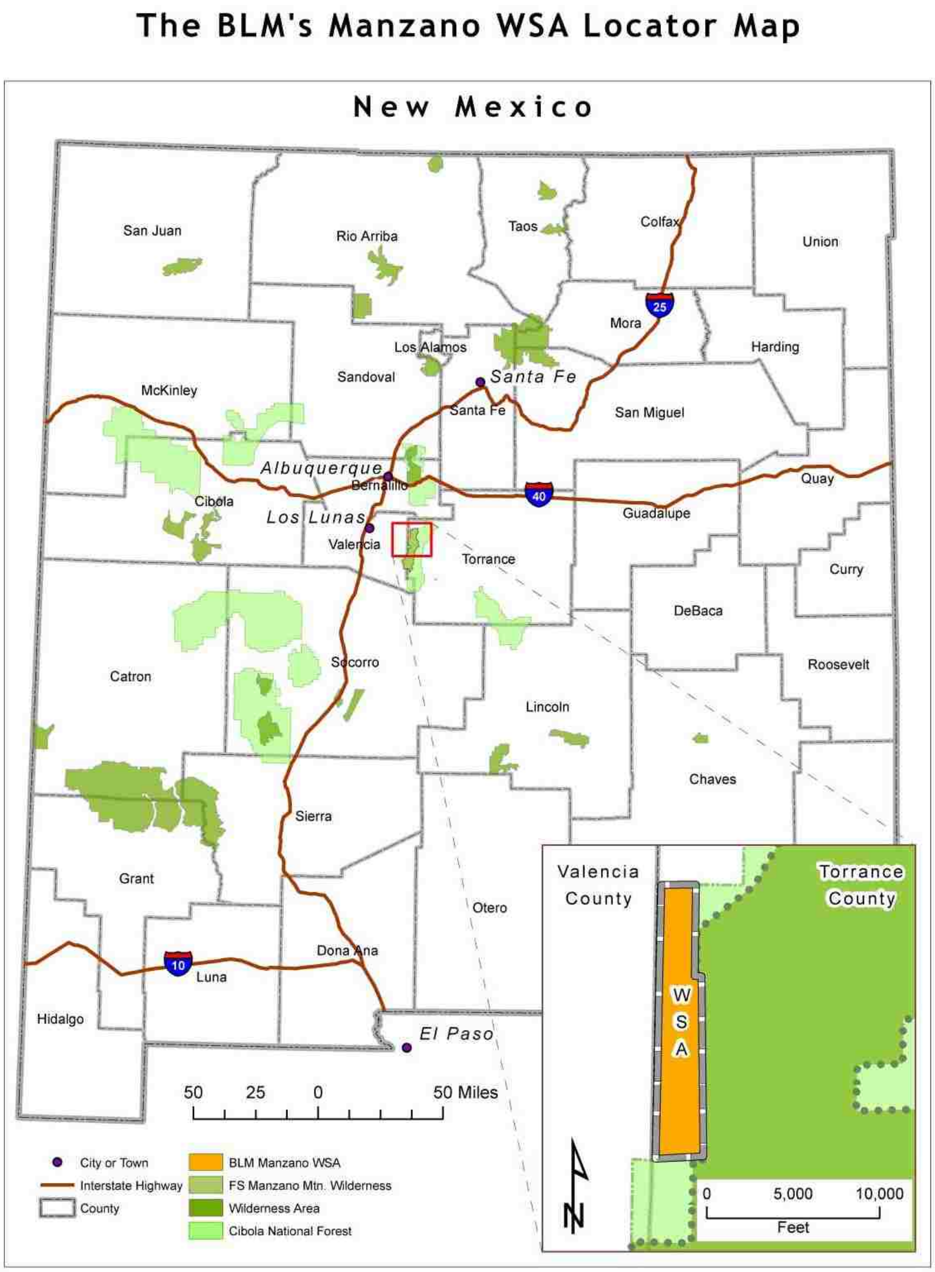


Figure 13. **The Bureau of Land Management's Wilderness Study Area in New Mexico. The WSA is situated along the eastern boundary of Valencia County and inside of the western boundary of Torrance County.**

topographic 7.5 minute quadrangle map. According to the description in the NM Statewide Wilderness Study mentioned earlier, access is gained by hiking down from the ridge in the USFS Manzano Mountain Wilderness. Alternately, from State Highway 47 turn east onto State Road 263. After about 1.5 miles, State Road 263 turns south, while another paved road continues east. A locked gate on the south side of the dirt road about one mile from this intersection gives access to a private dirt road which eventually ends at a concrete watering tank. From the watering tank the Manzano WSA can be reached by walking approximately one-quarter mile.

Figure 14 shows an image of the map that was generated for the BLM's New Mexico Statewide Wilderness Study in 1991 to depict the Manzano WSA. The WSA's location description as defined in this study follows: "The Manzano WSA (T7N, R5E, Sec. 31, W. ½; T6N, R5E, Sec. 6, W. ½, and Sec. 7, W. ½) is approximately 16 air miles east-southeast of Los Lunas in Torrance County" (BLM 1986). According to the verbal description and map of the WSA, the county, WSA, and PLSS boundaries should be coincident.

One of the most striking things about this area is its adjacency on the east and south boundaries to the 36,875 acre Forest Service Manzano Mountain Wilderness Area which was Congressionally designated in 1978 (PL 95-237). Two sections of private property indicated in Figure 14 are adjacent to the west and a section of state land is located to the northwest.

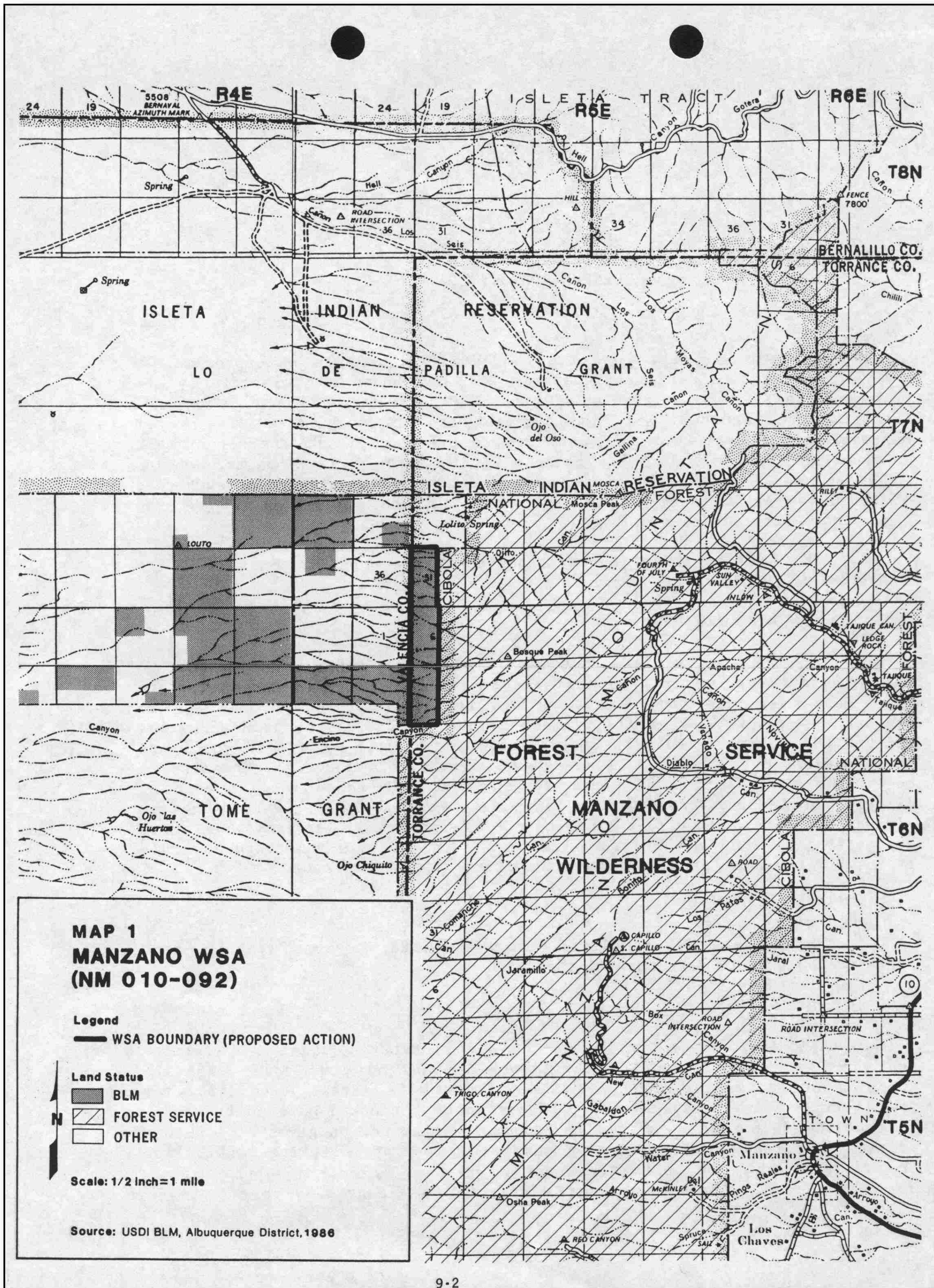


Figure 14. **This is the map used in the BLM's New Mexico Statewide Wilderness Study. Note the coincidence of the western boundary of the Wilderness Study area with the county and PLSS boundaries (BLM 1986).**

The most current PLSS data in the map shown in Figure 15 shows the GCDB shapefiles from September 2007 for the case study area.

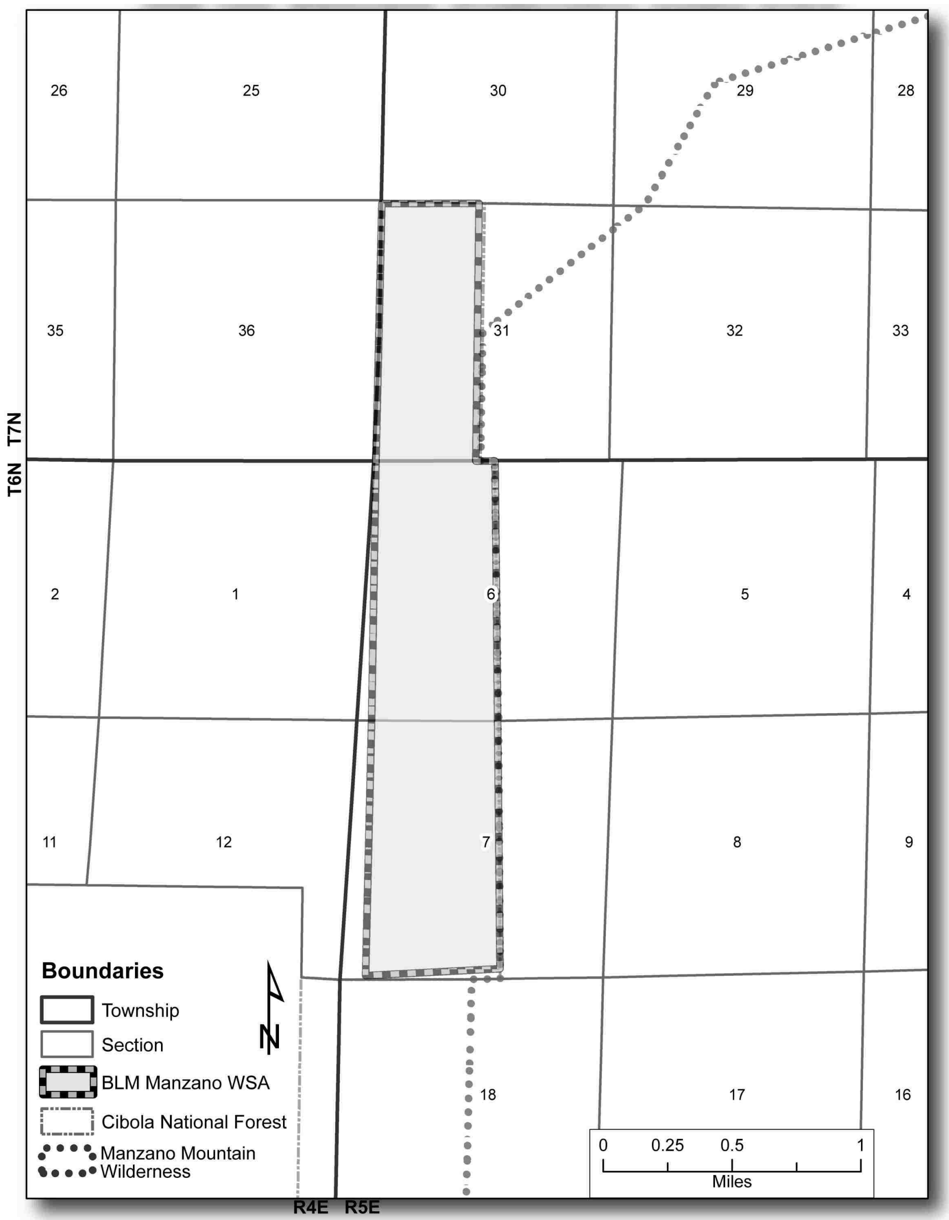


Figure 15. **Current Geographic Coordinate Database (GCDB) PLSS Data.**

The township and section boundaries shown in the map depict the most recent GCDB data along with preexisting wilderness, WSA, and forest boundaries.

The positional difference between data that was projected consistently and the data that was projected 'on-the-fly' is barely discernable. This map shows only the datasets that were projected 'on-the-fly.'

Boundary Uncertainty

Several factors are important in creating boundary uncertainty including lack of survey, moved or lost monuments on the ground, incomplete or missing legal descriptions, land exchanges, unresolved land claims, multiple corner records, etc. Uncertainty can exist for several years without harm to the public lands. A precipitating event, however, can lead to the need for certainty. In this case study uncertainty resulted from a land exchange of a land parcel with multiple corner records. The precipitating event was the discovery and report of a surface disturbance that apparently occurred on public land.

Survey and monumentation issues are major causes of uncertainty. T6N R5E on which the WSA is located was surveyed by Taylor & Holland in March of 1883. However, when the BLM Cadastral Team leader in charge of the case study recently surveyed of the area, no monumentation was located on the ground. The effects of an apparent lack of monumentation in this area on boundary uncertainty related to the case study will be explored.

Boundary uncertainty can occur as a result of incomplete map documents. During the recent fire incident in the Okefenokee Wilderness, firefighters used maps generated with best available data during fire suppression activities. These maps are used by firefighters when bulldozing areas to prevent or control the spread of fire. The maps did not show the Okefenokee Wilderness boundary. Uncertainty arose as to where the bulldozed area was in relation to the Wilderness. Fortunately, there was no damage to the Wilderness as the firefighters managed to limit their activities to outside of the boundary.

Land exchanges (FLPMA § 1716) can bring boundary management issues to the surface when public land is transferred to private ownership. Through land exchanges, the federal government, especially the BLM, acquires state and private land and inholdings with high public resource value, by trading land with higher economic development (but lesser resource) value to the state or private landowners. New Mexico BLM is a leader nationwide in land exchanges. Figures 16 and 17 are examples of land ownership status maps for the study area, dated 1979 and 2006. Since the time of the earlier published map, land exchanges have occurred.

One of the exchanges is the Rio Bonito Land Exchange. It was through this land exchange in 1992 that sections 11 and 12 on T6N R4E became the property of the developer involved in the alleged WSA encroachment, and the new ownership status is reflected on the 2006 map. The Forest Service's regional data library will be updated with the most current land status data.

The more complex land exchanges between the BLM and the USFS have taken more than five years to complete. The average time to complete this type of transaction is about 2.5 years. According to the June 15, 2005 testimony of Mark Rey, Under Secretary, Natural Resources and Environment, before the U.S. House of Representatives, "land exchange remains an effective tool in consolidating and realigning Federal lands and resources."

Land exchanges can become cumbersome, time-consuming and expensive (Lucero 2007). Furthermore, surveys are not required for each land exchange. Generally speaking, the BLM is attempting to reduce their presence in urban areas. The BLM consolidates land for management purposes, and engages in land exchanges that benefit

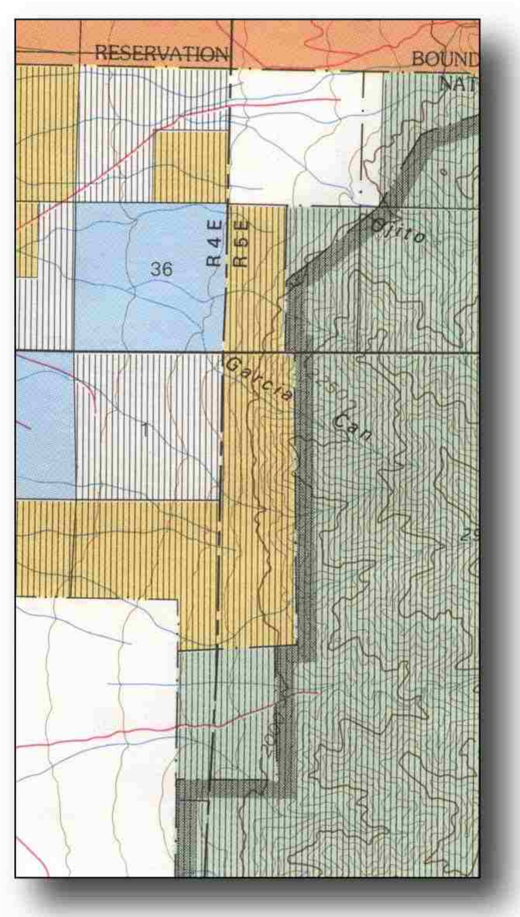


Figure 16. **BLM Lands Status (Ownership) and Minerals Maps 1979.**

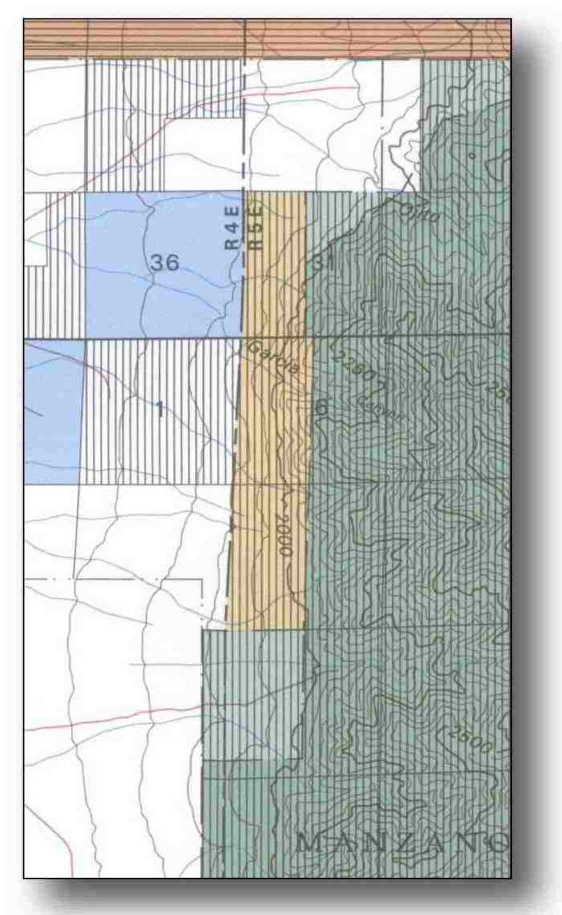
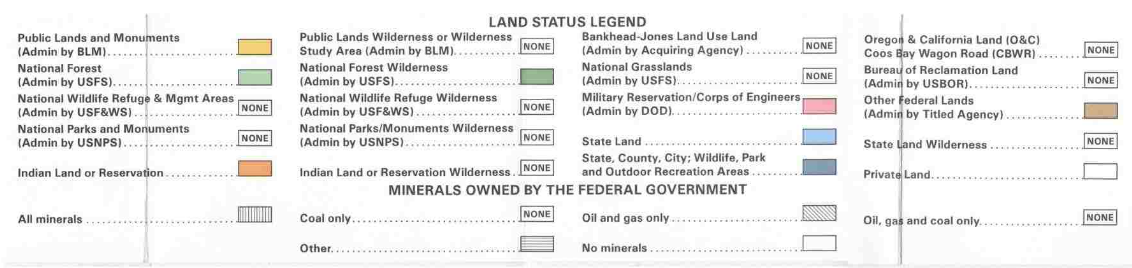


Figure 17. **BLM Lands Status (Ownership) and Minerals Map 2006.**



The two BLM land status maps for the case study area reveal a change in ownership in section 12 of T6N R4E, adjacent to the western boundary of the Manzano WSA. Also shown: BLM Land Status Legend.

the U.S. government. Another method of disposal is the sale of public lands (USDOI 1994). Public land sales may involve some of the same issues. However this thesis limits its focus to land exchanges.

The case study is adjacent to property involved in the 1992 Rio Bonito Land Exchange. In an effort to consolidate, the BLM acquired certain lands. The developer acquired section 12 of T6N, R4E bordering the western boundary of the Manzano WSA. No survey was done by the BLM at the time of the exchange. The private landowner erroneously thought the land where the surface disturbance occurred was section 12. In 2001 the private landowner who had acquired these two sections had a survey done. Figure 18 shows an image of the survey plat for this survey. Figure 19 zooms in on the southeast corner of the survey plat from figure 18. This is the area of interest. The references to 'found BLM brass cap stamped…' and 'found stone' show two corners in different locations on the ground. These two corners are supposed to be the same. It is this corner that coincides with the southwest corner of the study area. This survey begs the question, "Which corner is the actual correct corner?"

It was not until after the potential encroachment was discovered that a BLM cadastral survey was conducted. That survey was completed in September of 2007. Figure 20 shows the results of cadastral's 2007 survey. These results are preliminary and are currently involved in the BLM's review process. While seemingly on private land on the eastern boundary of the section, the boundary of this section and Section 1 to the north are uncertain. As a result of this boundary uncertainty, the disturbance was actually located not on private land, but on public BLM administered land – on the Manzano

WSA adjacent to the east. Had this land exchange not taken place, an encroachment might never have occurred.

Area of Interest

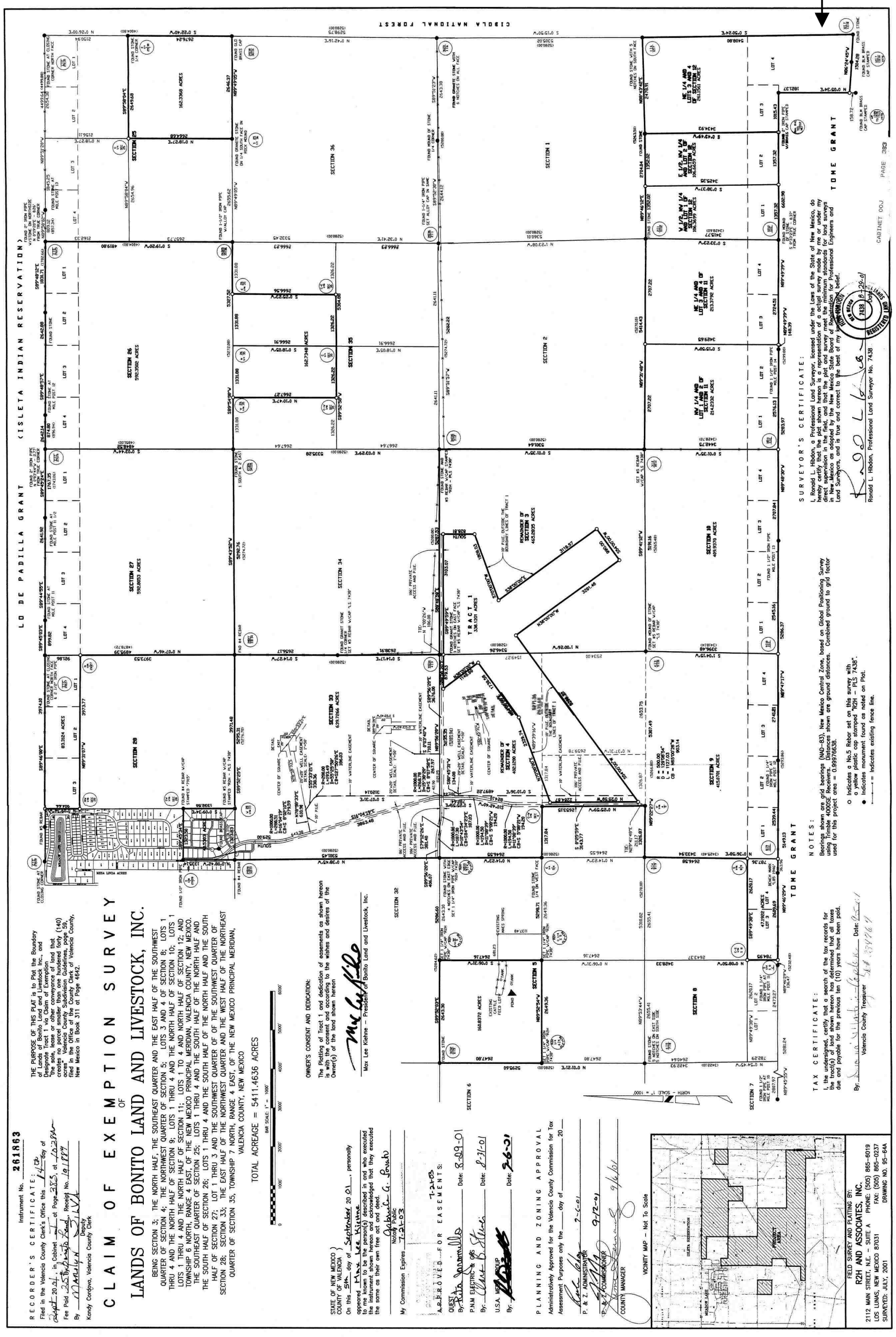
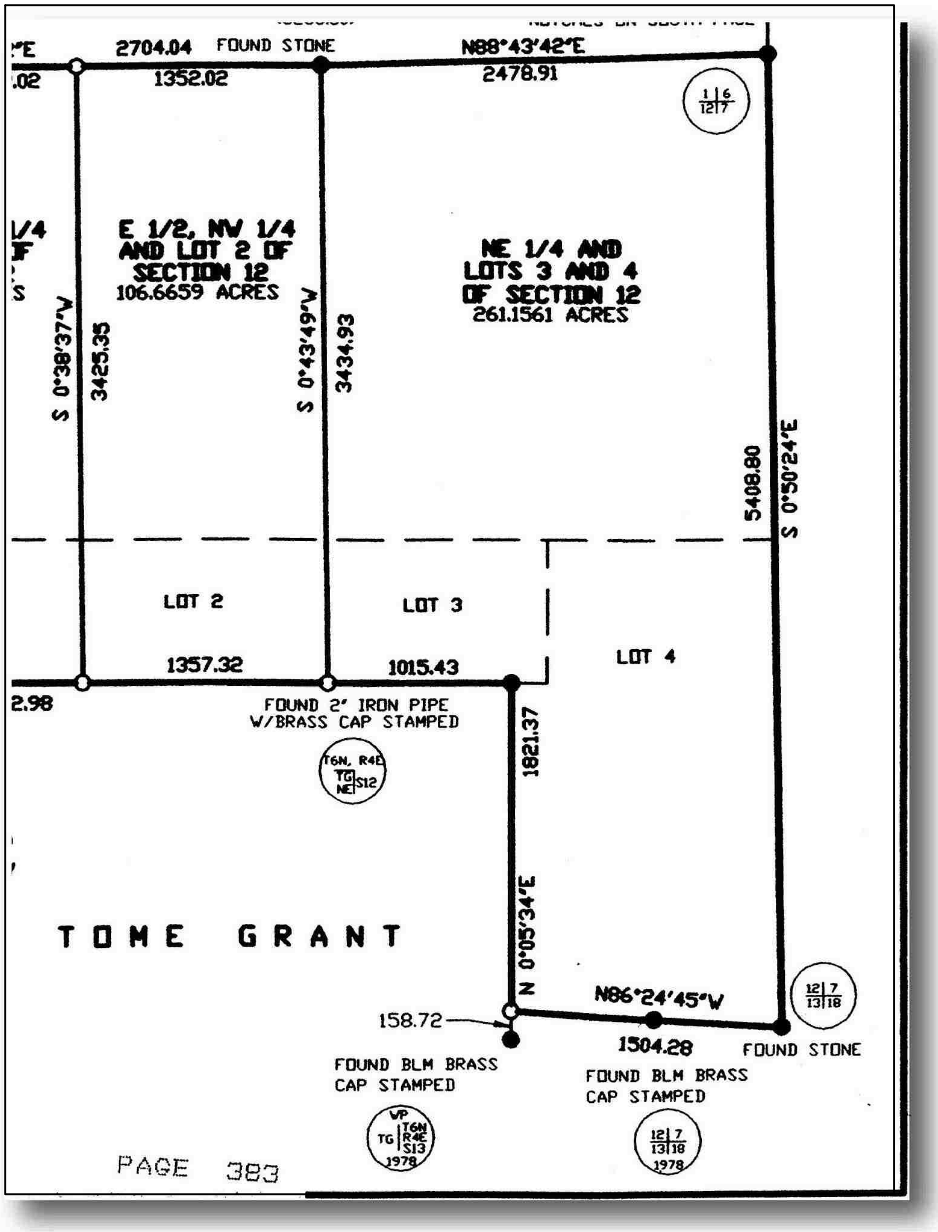


Figure 18. **Private Landowner's Survey conducted in 2001.**



Area of Interest

Figure 19. **A closer look at the southeastern area of the survey from Figure 18.**

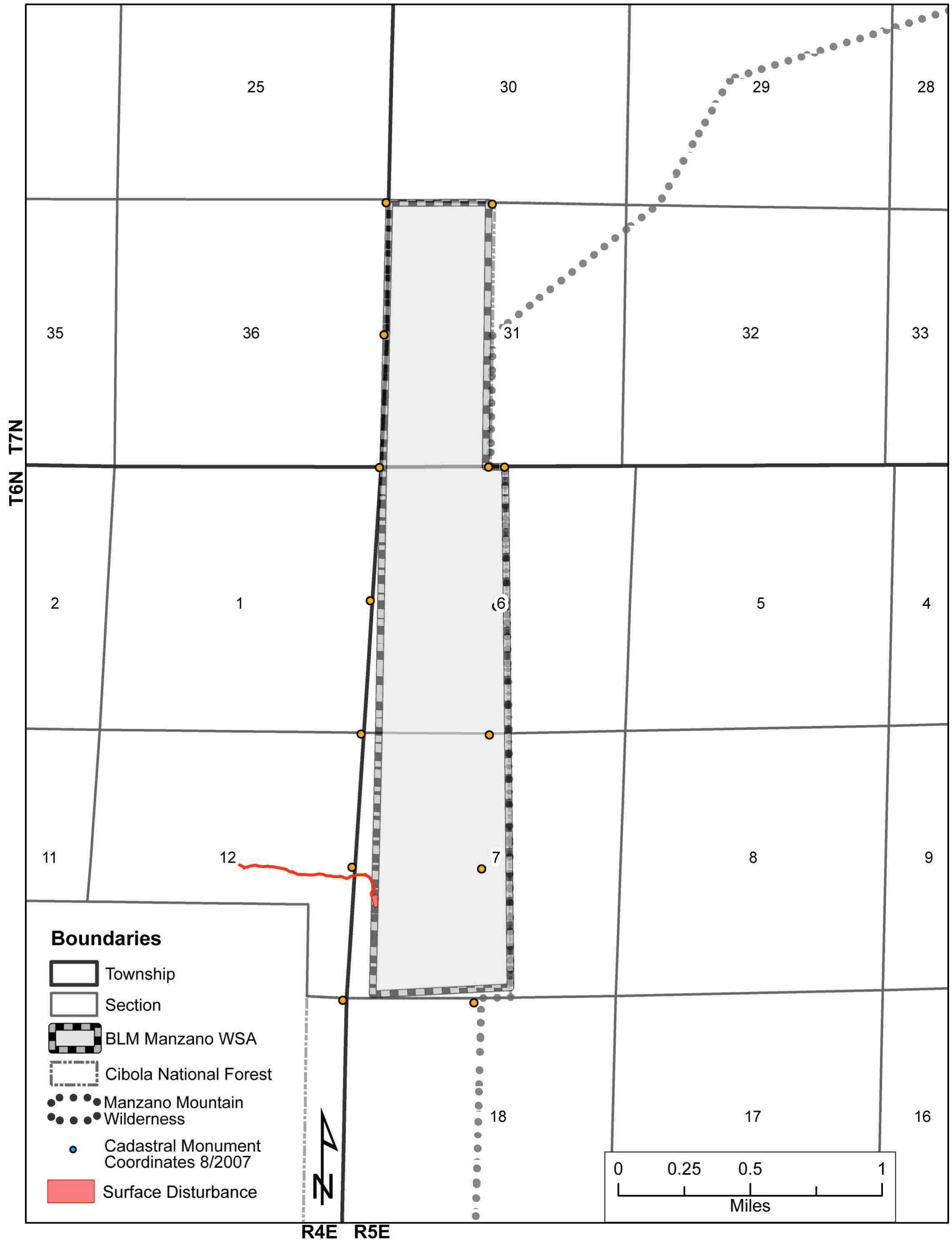


Figure 20. **Preliminary results of the BLM's Cadastral survey executed in August, 2007. New corner points are shown in orange.**

Confusion in the legal description of the case study is a factor contributing to boundary uncertainty for both the study area and the adjacent USFS Manzano Mountain Wilderness. In order to spatially represent the BLM Manzano WSA, the BLM wrote up a general description and instructed the reader to refer to a hand-drafted map. It is fairly obvious as to intent of the boundary: the eastern boundary of the WSA was to be coincident with the western boundary of the Wilderness: this line was drawn right down the center of T7N R5E Sec. 31, and T6N R5E Sec. 6 & 7, in a north-south orientation. The intent of the boundary coincidence with the rangeline is clearly shown in Figure 21. This would decidedly imply that the western boundary of the WSA should coincide with range line between R5E and R4E. In the BLM's 1986 study, the description of the location of this WSA reads as follows: "The Manzano WSA (T7N, R5E, Sec. 31, W. ½; T6N, R5E, Sec. 6, W. ½, and Sec. 7, W. ½)..." (BLM 1986). Even though lotting is involved in the western part of the WSA, the intent for the boundary has been made clear in the description above. The 1871 Tome Grant is a Spanish land grant, the northeast corner of which is located a few hundred feet east of the southwest corner of the WSA. This grant is of particular interest because a bearing and distance are made from its northeast corner as shown in the survey plat in Figure 22.

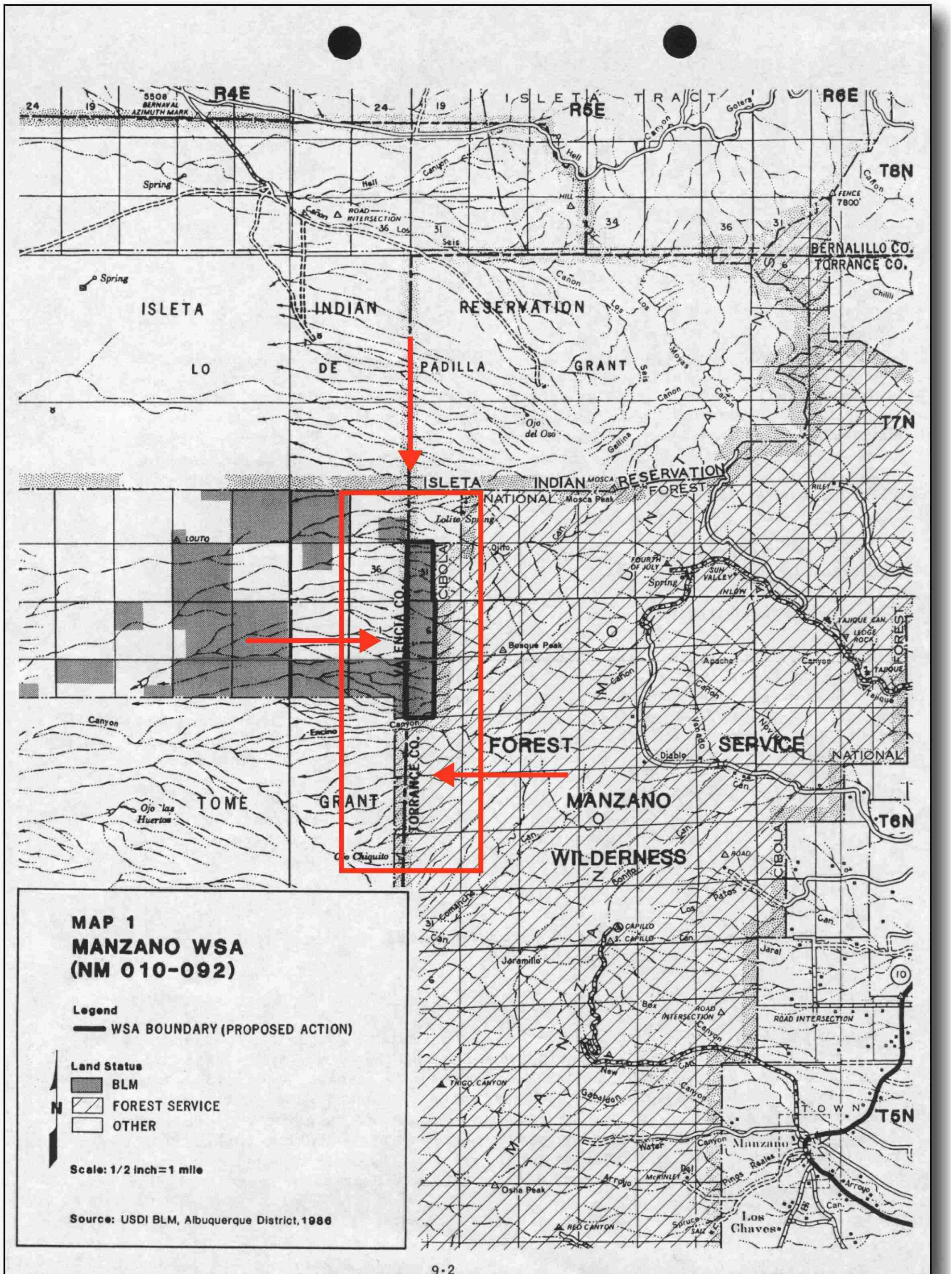


Figure 21. **Another look at the 1986 map of the Bureau of Land Management's Manzano Wilderness Study Area. Note the coincidence of the western edge of the WSA to the county line between Valencia and Torrance Counties. This county line is also the range line between R4E and R5E.**

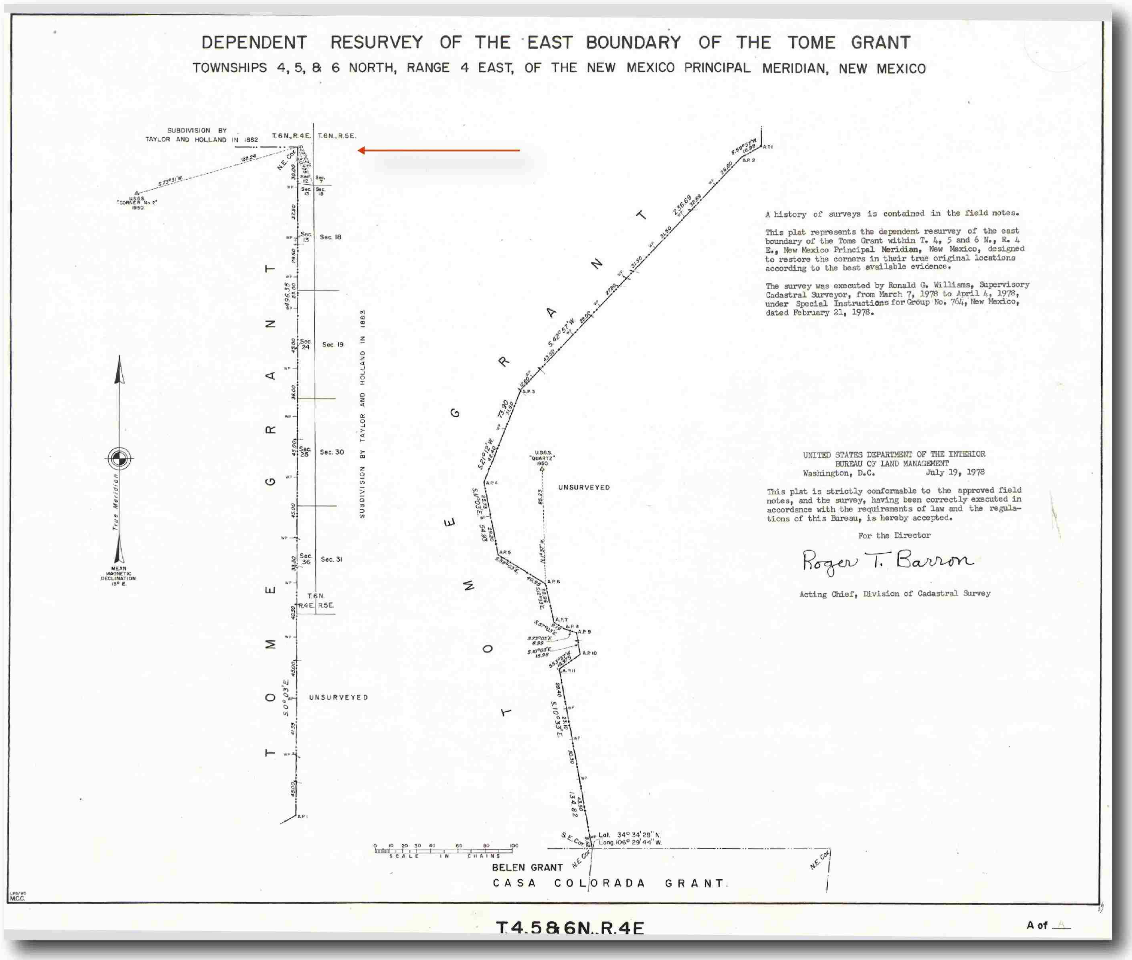


Figure 22. **1978 survey showing a bearing and distance calculated from a known monument located at the northeast corner of the Tome Grant.**

The survey plat in Figure 22 was downloaded from the BLM's GeoCommunicator website in September 2007. Historical surveying context is provided in Figure 23 showing the original 1882 Tome Grant area survey plat. The southwest corner of the Manzano WSA can be spatially located based on the Tome Grant's northeast corner. Whether or not an encroachment had occurred cannot be determined with confidence from the survey plat. Relevant boundaries can be seen on the plat, but were the monuments actually placed on the ground? Furthermore, how is the location of unsurveyed boundaries determined on the ground?

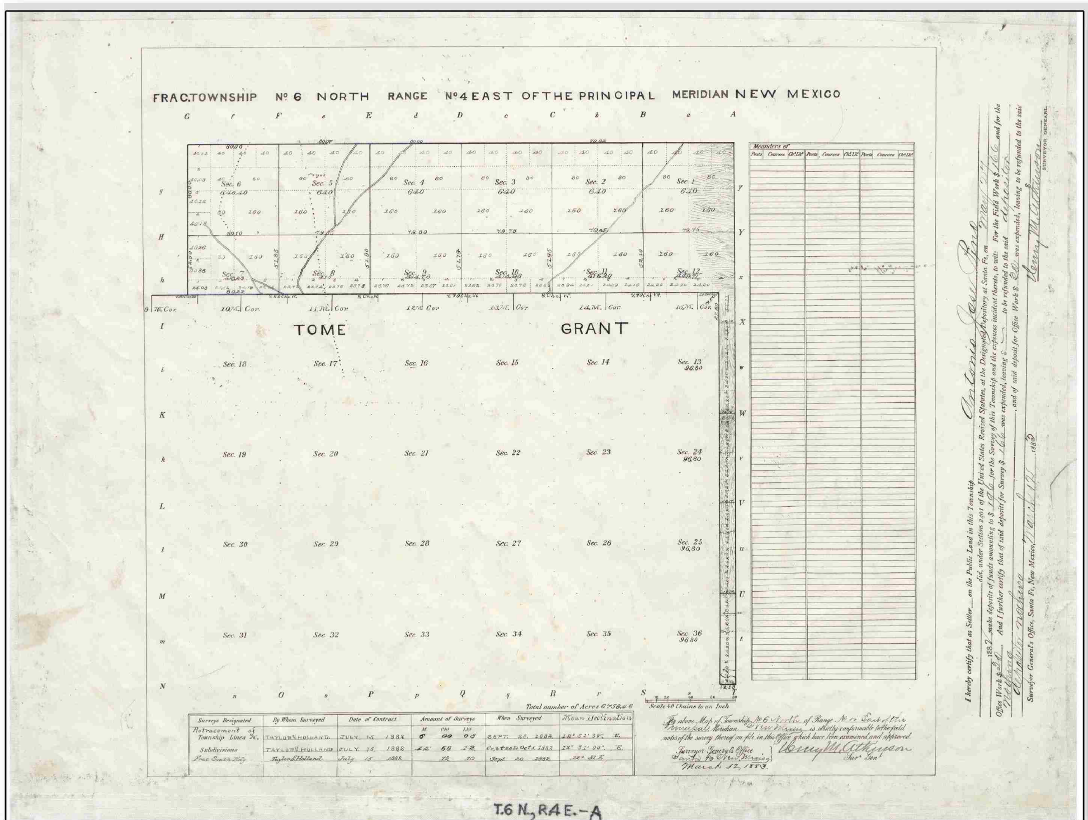


***Figure 23.* 1882 survey plat image of T6N, R4E in the vicinity of the Tome Grant.**

A map was compiled based on the data provided by the USFS, BLM, and field observers. The result was striking: a lack of boundary coincidence in the datasets obtained from the BLM, Forest Service, Valencia County, and TIGER data caused major concern. Figures 24 and 25 show the lack of boundary coincidence among boundary datasets from different agencies depicting the same boundaries. If some of these boundaries were not correct, how could the location of the WSA be known with any acceptable level of confidence? Which boundaries should be used in this case to determine the status of the disturbance? These maps are identical except for the digital orthophoto used as a base in Figure 25.

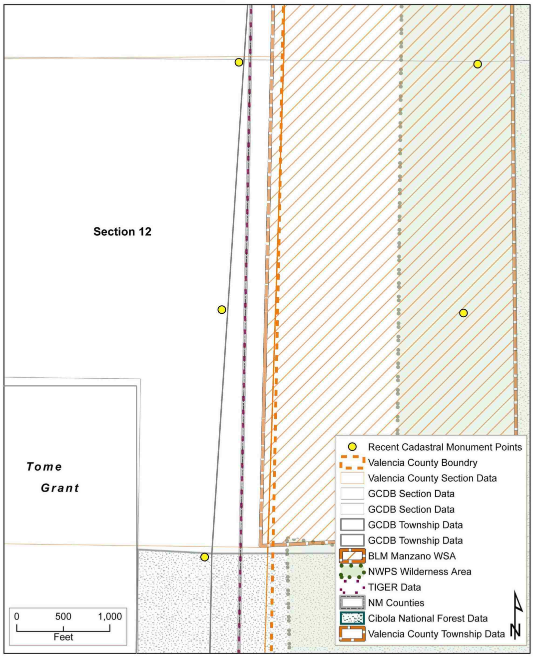


Figure 24. **Boundary uncertainty on the Manzano WSA.**

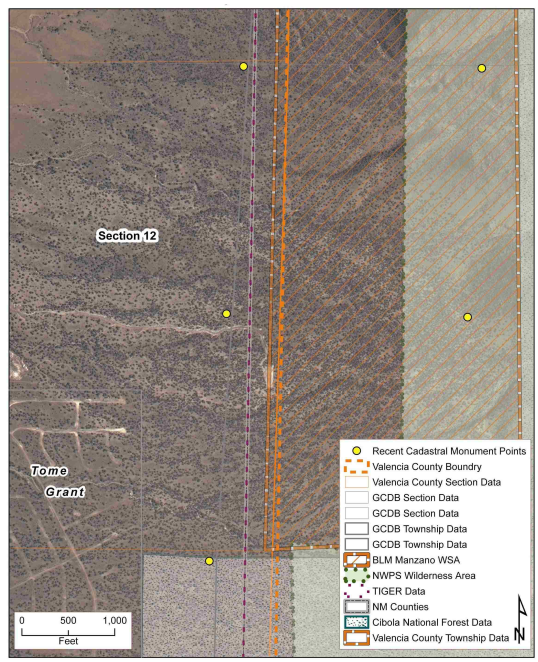


Figure 25. **Boundary data with aerial photograph (DOQQ).**

Published maps depict forest boundaries as “approximate” as does a portion of the 7.5 minute USGS Topographic Bosque Peak quadrangle map. This is due to a lack of survey information for the boundary. Figure 26 depicts the ‘approximate’ boundary on the USGS quad map.

Furthermore, a recent aerial photograph revealed the surface disturbance beyond the shadow of a doubt, as shown in Figure 25. This photograph was orthorectified to conform to the earth’s surface based on known elevation points. It is referred to as a digital orthophoto quarter-quad, or a ‘DOQQ.’ This DOQQ has a resolution of one meter, which is appropriately fine for use in this case study. Superimposing the boundaries on the aerial photograph in Figure 27 reveals the spatial position of the encroachment in relation to the Manzano WSA.

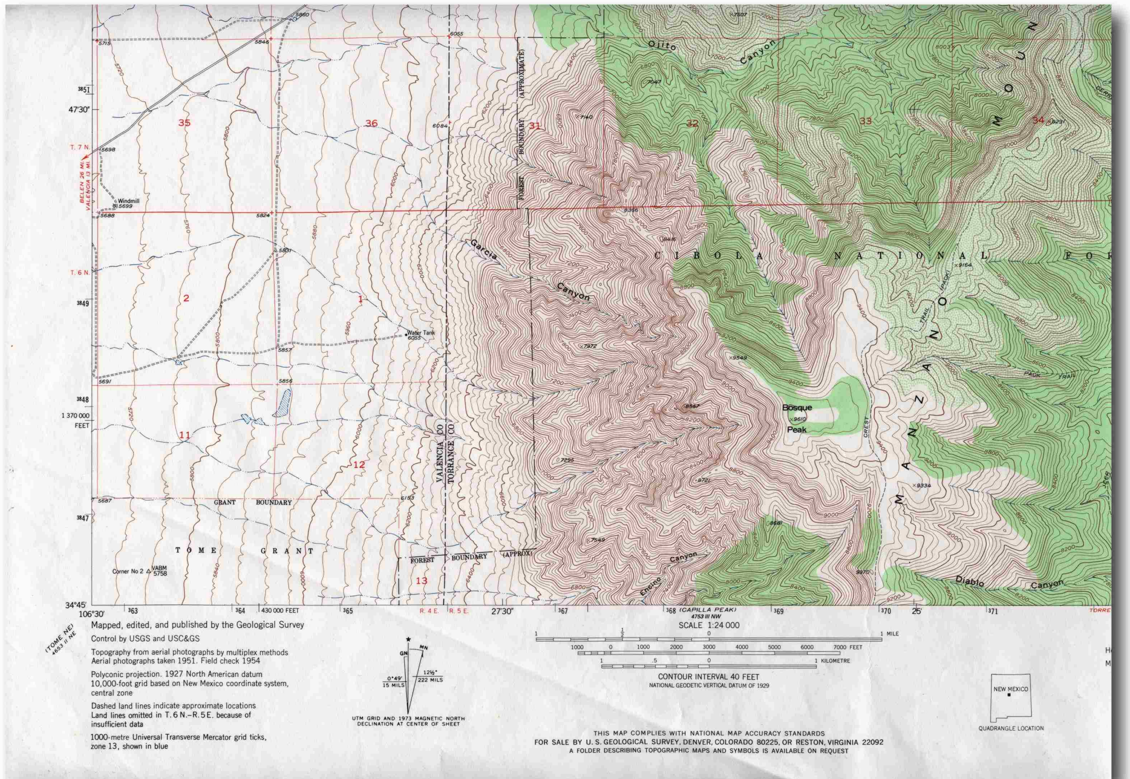


***Figure 26.* Portion of the USGS Bosque Peak quadrangle map.**
Note that "Forest Boundary Approx." is stated on this map.

Initial examination of the data pertaining to the Manzano WSA elicited a reaction of surprise and concern. An alleged encroachment issue had arisen. Which boundaries should be accepted for use in wilderness management (and for interim or WSA management) especially in light of an alleged disturbance apparently occurring on BLM land? A closer inspection of this situation confirmed that 'GIS' might very well stand for 'Get it Surveyed.' (Stone interview 2007).

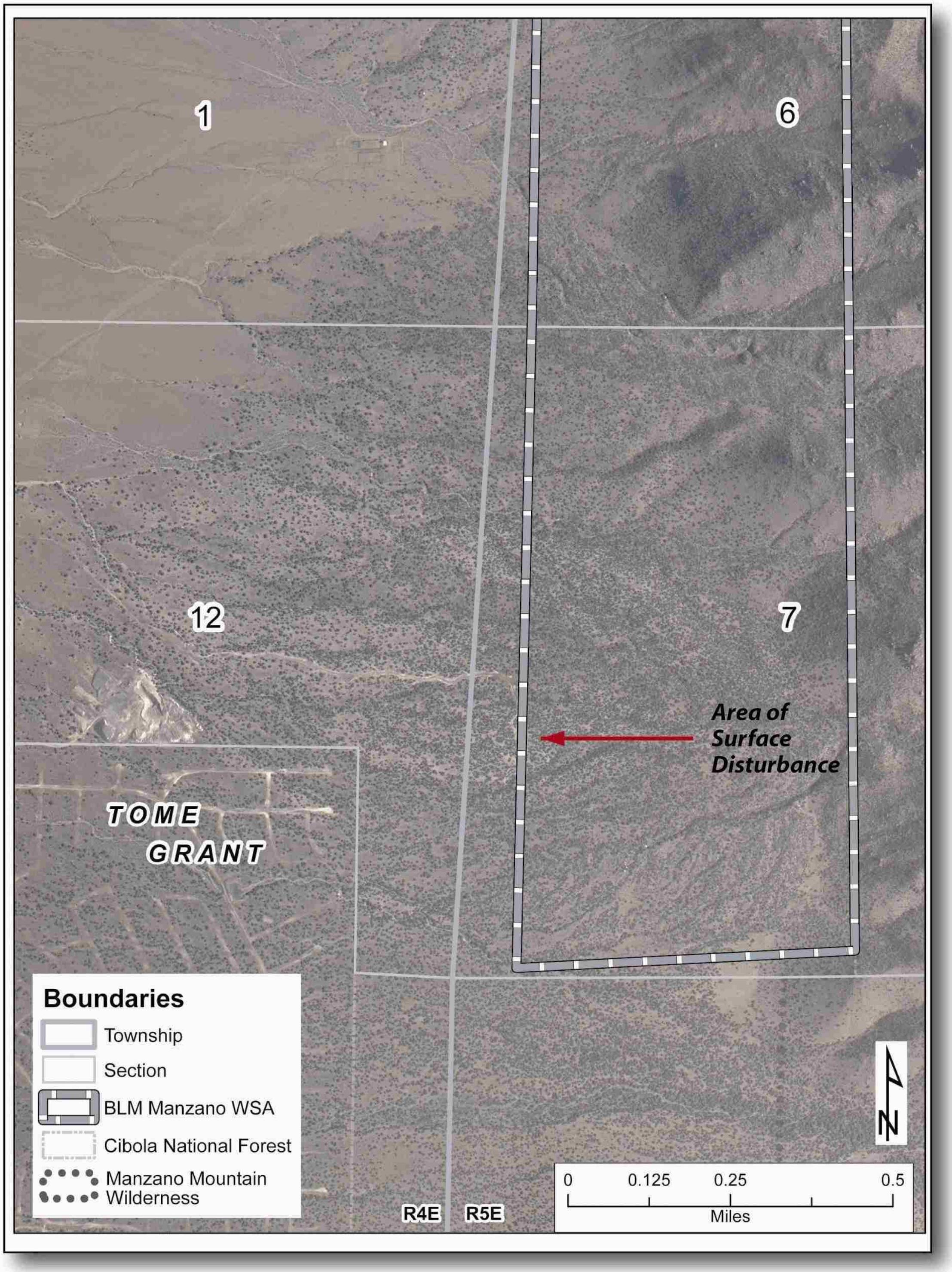


Figure 27. **Digital orthophoto showing surface disturbance and WSA boundary.**

What constitutes an encroachment? How, if this indeed is an encroachment, should this event be handled if at all? In what manner would this case be presented so as to be most descriptive and accurate without implication or bias? Should the perimeter of the disturbed area be shown in red, for instance? How should the different boundaries be portrayed to the benefit of the observer? It is at this point where mapmaking integrity comes into play.

In a recent conversation with the BLM Cadastral Survey Team Leader who was out on the ground to resolve the boundary misunderstanding at the Manzano WSA, he stated this is just one of many survey issues in this part of the state. He believes there is something strange going on with this WSA encroachment issue. In 2001 the private landowner (a developer) owning section 1 of T N R4E and section 12 of T6N R4E provided the BLM Realty staff with a survey plat created by a licensed surveyor , which triggered a Cadastral survey. Based on their knowledge of the area, the BLM Cadastral staff disagrees with the landowner's survey and asserts they encroached on BLM land as a result of this allegedly erroneous survey. It is not known where the private surveyor's corners came from. His survey has a "strange anomaly yielding strange results" (BLM Cadastral Team Lead interview 2007). In order for any survey to be legal it must be filed with the county. This survey is publicly available and can be obtained legally. This is how the results of the survey were able to be shown in Figures 18 and 19.

The corner of T6 & 7N and R4 & 5E has some problems of its own. This floating township corner, according to the Cadastral surveyor involved in resurveying the study area, has some 'real history.' It is this corner that Cadastral will soon make official. Furthermore, it appears as though the intent was for the Valencia – Torrance county lines to coincide with the range line, based on the county data and PLSS data provided by the Valencia County GIS Specialist. The range line also depicts where Valencia County ends and Torrance County begins. If the new boundary location is true, the counties' data will need to be replaced with a correct dataset and the resulting maps should reflect the correct county boundary positions.

By comparison, the BLM's Cadastral survey which is the official record, illustrates where the legal western WSA boundary exists (preliminary resolution, subject to approval). The discrepancy is obvious. Apparently, the land surveyor working on behalf of the private landowner chose to use the stone noted on the survey plat. See the lower right corner of the plat where the words "found stone" are located. This stone represents a corner approximately 700 feet to the east of what would seem to be the official corner. While rocks, among other natural items, are used as monuments to indicate a boundary, they are able to lose their permanence. When their original location cannot be found they can become "lost boundaries" (Wattles 1976). Figure 28 shows the new points representing the monuments from the cadastral survey that was completed in August of 2007.

The BLM Cadastral surveyor in charge of the project attempted to contact the landowner's surveyor to no avail. Cadastral believes this surveyor ignored their corners and instead "used corners of his own" (BLM Cadastral Team Lead interview 2007). At this time a preliminary plan has been drawn by Cadastral. The survey itself is complete: the only items that remain are some final steps that must be taken in order for the approval process to be finalized. First, the surveyors who worked out on this area will type up their field notes and draw the survey plat. These items will go to the review

New Cadastral Monument Points

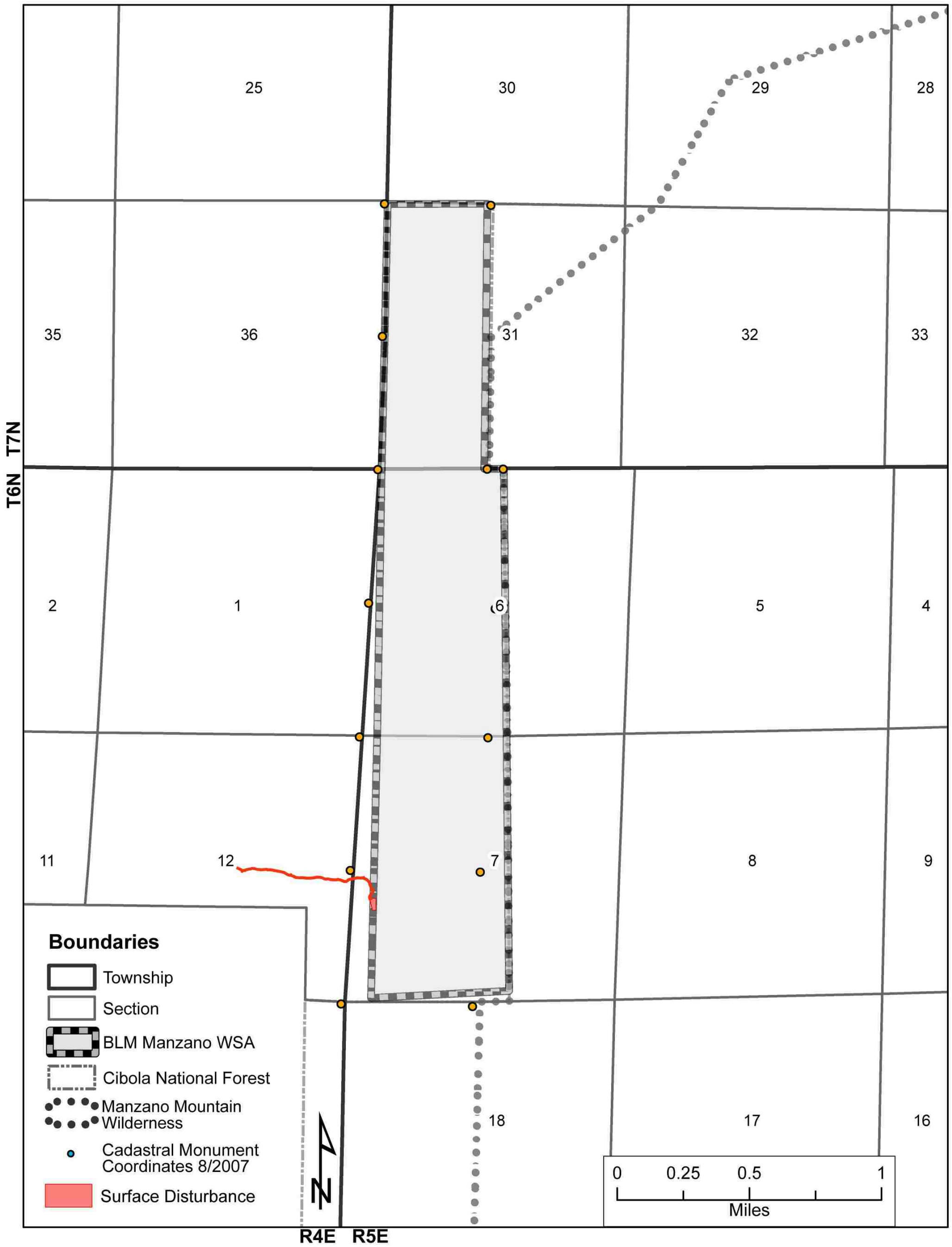


Figure 28. **Cadastral survey points representing monuments for the BLM Manzano WSA boundary.**

The BLM corner monument allegedly ignored by the private surveyor is common to sections 12 and 13 of T6N R4E and 7 and 18 of T6N R5E.

section which involves a group of senior surveyors. The senior surveyors must ensure the survey was done correctly and that the work will stand up in a court of law. Once this has been determined, the survey plat and field notes are submitted for approval before the Branch Chief for their signature on the appropriate document. After the Branch Chief's signature is obtained, the survey is published in the Federal Register. From the publishing date there is a thirty-day period during which protests can be filed. If no protest is filed, the survey approval process is legally complete. It is entirely possible that the private landowner's surveyor may file a protest. If he does so, he must either provide contradictory evidence or prove that the Cadastral surveyors did not follow their own rules (BLM 2007).

A U.S. Forest Service survey may be conducted, especially on the southeastern corner of the WSA where the WSA is adjacent to FS Wilderness. This portion of the FS boundary is depicted as "approximate," implying it had not been surveyed at the time of publication. The U.S. Forest Service survey operates under state authority and may still require a BLM Cadastral survey in the event of a boundary dispute. The only extant description of the Manzano National Forest Reserve is a one-page letter signed by President Roosevelt in November of 1906. This same letter refers to the area as the "Manzano Forest Reserve," and explicitly refers to a hand-drafted map compiled from GLO Survey Plats. An image of this letter is shown in Figure 29. The corresponding map is depicted in Figure 14. The map serves as a generalized legal description of the boundary.

This area's boundary woes negatively affect our case due to the WSA's adjacency not only to wilderness, but also to private land. Because the western and southern

MANZANO FOREST RESERVE

NEW MEXICO

By the President of the United States of America

A Proclamation

WHEREAS, the public lands in the Territory of New Mexico, which are hereinafter indicated, are in part covered with timber, and it appears that the public good would be promoted by setting apart said lands as a public reservation;

And whereas, it is provided by section twenty-four of the Act of Congress, approved March third, eighteen hundred and ninety-one, entitled, "An act to repeal timber-culture laws, and for other purposes," "That the President of the United States may, from time to time, set apart and reserve, in any State or Territory having public land bearing forests, in any part of the public lands wholly or in part covered with timber or undergrowth, whether of commercial value or not, as public reservations, and the President shall, by public proclamation, declare the establishment of such reservations and the limits thereof";

Now, therefore, I, THEODORE ROOSEVELT, President of the United States of America, by virtue of the power in me vested by section twenty-four of the aforesaid act of Congress, do proclaim that there are hereby reserved from entry or settlement and set apart as a Public Reservation, for the use and benefit of the people, all the tracts of land, in the Territory of New Mexico, shown as the Manzano Forest Reserve on the diagram forming a part hereof.

This proclamation will not take effect upon any lands withdrawn or reserved, at this date, from settlement, entry, or other appropriation, for any purpose other than forest uses, or which may be covered by any prior valid claim, so long as the withdrawal, reservation, or claim exists.

Warning is hereby given to all persons not to make settlement upon the lands reserved by this proclamation.

In Witness Whereof, I have hereunto set my hand and caused the seal of the United States to be affixt.

DONE at the City of Washington this 6th day of November, in the year of our Lord one thousand nine hundred and six, and of the Independence of the United States the one hundred and thirty-first.

[SEAL.]

THEODORE ROOSEVELT

By the President:
ROBERT BACON
Acting Secretary of State.

Figure 29. **President Roosevelt's 1906 letter creating the Manzano Forest Reserve.**

boundaries in this case follow PLSS township and range lines, the eastern boundary of the adjacent private land must be coincident with the western boundary of the WSA. Ultimately, once the range line has been confirmed by Cadastral, the western boundary of the WSA (which is described as coincident with this range line) will also be known. At that point in time, the surface disturbance will fall in a location in relation to the boundary and decisions for resolution can be initiated. Until the range line is legally and officially established, no forward movement can be made in regards to the treatment of this WSA and its wilderness eligibility. Designation hinges on the location of this range line.

The basic events summarizing this process are listed below:

1. An obvious problem is observed (this represents the precipitating event),
2. Cartographic / GIS evaluation shows boundary uncertainty,
3. Boundary certainty cannot be resolved with existing cadastral proof,
4. A new cadastral survey proves ‘encroachment,’ and, if necessary,
5. The court adjudicates. Depending upon the court’s decision, the term ‘trespass’ replaces the term ‘encroachment’ since encroachment implies a finding and trespass implies a criminal act. An encroachment will never become a trespass unless adjudicated by the court.

The judge wants the facts and will decide on what he deems is ‘fair’ when the equitable powers of the Court are invoked. What is correct and true may not be seen as fair. An example of the adjudication process is provided by the T'uf Shur Bien Preservation Trust Area Act of 2003, H.R. 222, 108th Cong. (2003). This case deals with establishing the T'uf Shur Bien Preservation Trust Area within the Cibola National Forest in the State of New Mexico in order to resolve a land claim involving the Sandia Mountain Wilderness. It was obvious to trained professional surveyors that the Cibola National Forest boundaries were clearly described and on record as such. Monuments on the ground were validated. The monuments claimed by the T'uf Shur Bien were concluded by Cadastral surveyors to be invalid. The tribe won this case against the Forest Service. The judge thought it fair to provide a place for those persons who had not dispersed but remained as a cohesive unit on the land, and the decision was ultimately handed down in their favor. The Cibola National Forest boundaries were correct and true, but not fair. (See also Michael Coleman, Sandia Dispute Comes to an End, Albuquerque J., Feb. 21, 2003, available at 2003 WL 12460652). Monuments on the ground control, except under such extenuating circumstances.

Monument location and identification are key aspects of surveying. In order to gain an understanding of the case study, preliminary research was conducted in the form of field trips. During the first field trip a key monument was located. The brass cap shown in the photograph in Figure 30 depicts the northeast corner of the Tome Grant. It is considered authentic by its markings (BLM 1973). This brass cap explains its location in reference to the PLSS and the BLM’s Manzano WSA’s southwestern corner. The brass cap alone does not provide this information. It is necessary to scour the survey plats for this corner to gain a complete understanding of the brass cap’s location in reference to other monuments.

The benchmark in Figure 30 legally marks the location of the northeast corner of the Tome Grant (discussed earlier) and its legal and spatial relation to T6N R4E section 12. The 1978 survey plat – the most recent Cadastral survey of the area – for T6N R4E

Shown at right: Location of Tome Grant NE corner brass cap in relation to the Manzano WSA boundary.

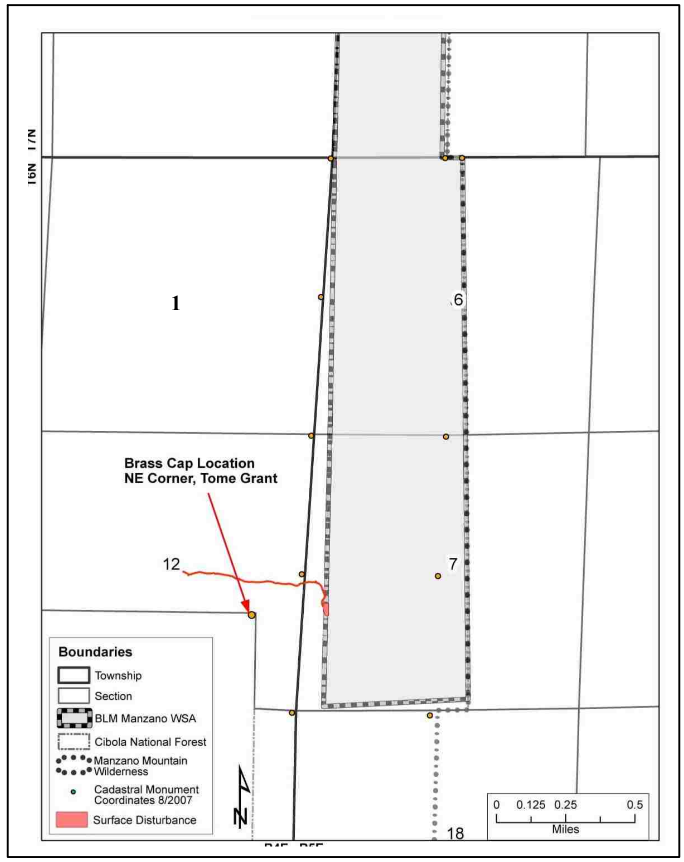


Figure 30. **NE corner Tome Grant BLM brass cap (with locator map on right).**

was consulted. This is shown on the 1978 survey plat in Figure 22. The distance and angle of the straight line to another corner from the survey were entered into Traverse in ArcMap (this is known as COGO'ing or utilizing Coordinate Geometry). At the terminus of the COGO'd line a point was added. This point could be uploaded to the Trimble Global Positioning System (GPS) unit and used to find the point out in the field. Although the Trimble GPS equipment used at this time was below survey grade, it is reasonable to anticipate locating some sort of benchmark in the general vicinity of that point. The 1978 survey also depicts two United States Geologic Survey (USGS) triangular benchmarks. These are part of the USGS's triangulation network which is associated with the Continuously Operating Reference System (CORS). CORS consists of ground control points used to differentially correct data collected by GPS processes. This process increases the positional accuracy of corners.

The First Field Trip, July 11th, 2007

In an attempt to shed some light on the issues that had been raised regarding this WSA, a field trip was conducted on Wednesday, July 11th. Access to the study area required the consent of the private landowner and a key to the locked gate. After a three mile drive from the gate the vehicle can be parked near an inactive gravel pit. At this point a half-mile walk takes the observer to the disturbed area. Obviously, access to this area is not possible for the general public without express permission from the landowner which explains at least two interesting facets of this case. First, this WSA was perceived to be ‘unthreatened’ and therefore never made it to the top of any priority lists for protection. Members of the New Mexico Wilderness Alliance stated that this area had not previously been threatened. This perspective is not without factual support. The only viable public access to this area is from the east – by making a steep off-trail hike down from the ridge of the existing Forest Service Manzano Mountain Wilderness. Anyone familiar with the area knows this takes a physical and temporal commitment not likely to be realized by the casual hiker. This fact could lead to the conclusion that the chances of a surface disturbance being discovered were minimal. As a consequence of being remote and isolated, this area did not appear as a blip on the wilderness advocates’ radar screens. There are too many other concurrent priorities demanding attention. Second, if any development took place, it would likely be known only to the developer and those involved with the project. Who else was to know exactly what was taking place in this area? Posting round-the-clock patrol guards around the perimeter of this WSA was far from the BLM's idea of a reasonable management plan. Another possibility regarding the apparent low-priority handling of this WSA could be due to the focus of the BLM at that time. A BLM assistant field manager provided a valid explanation for this. He stated that transferring this WSA to the Forest Service sounded like a good idea in some ways. However, the WSA and the U.S. Forest Service Manzano Mountain Wilderness was all federal land. As a result, there was no mechanism providing any importance for this area. The BLM's land exchange program's focus was on the transition of private to federal lands. Furthermore, the encroachment may have happened regardless of the designation of the WSA.

Photographs taken on this field trip document the disturbed area and show that no apparent additional activity has occurred since the disturbance was first discovered. See Figures 31-34. A north-south fence had been constructed, as discovered in 2004.

Figure 31. **Looking west from WSA on the cleared area.**

Figure 32. **Looking east.**

Figure 33. **Looking north, showing fence.**

Figure 34. **Looking south.**

The fence shown in Figure 33 was constructed along what the private landowner perceived as the eastern edge of section 12.

The Second Field Trip – with Cadastral Surveyors August 14th, 2007

A second field trip was made on August 14th, 2007 to set the quarter-corner for section 12 of T6N R4E. Setting the brass cap is shown in Figures 35 and 36. A map depicting the BLM Cadastral's newly-surveyed corner locations is shown in Figure 37.

***Figure 35.* Setting the newly-surveyed corner brass cap.**

***Figure 36.* Close up showing the new corner brass cap's markings.**

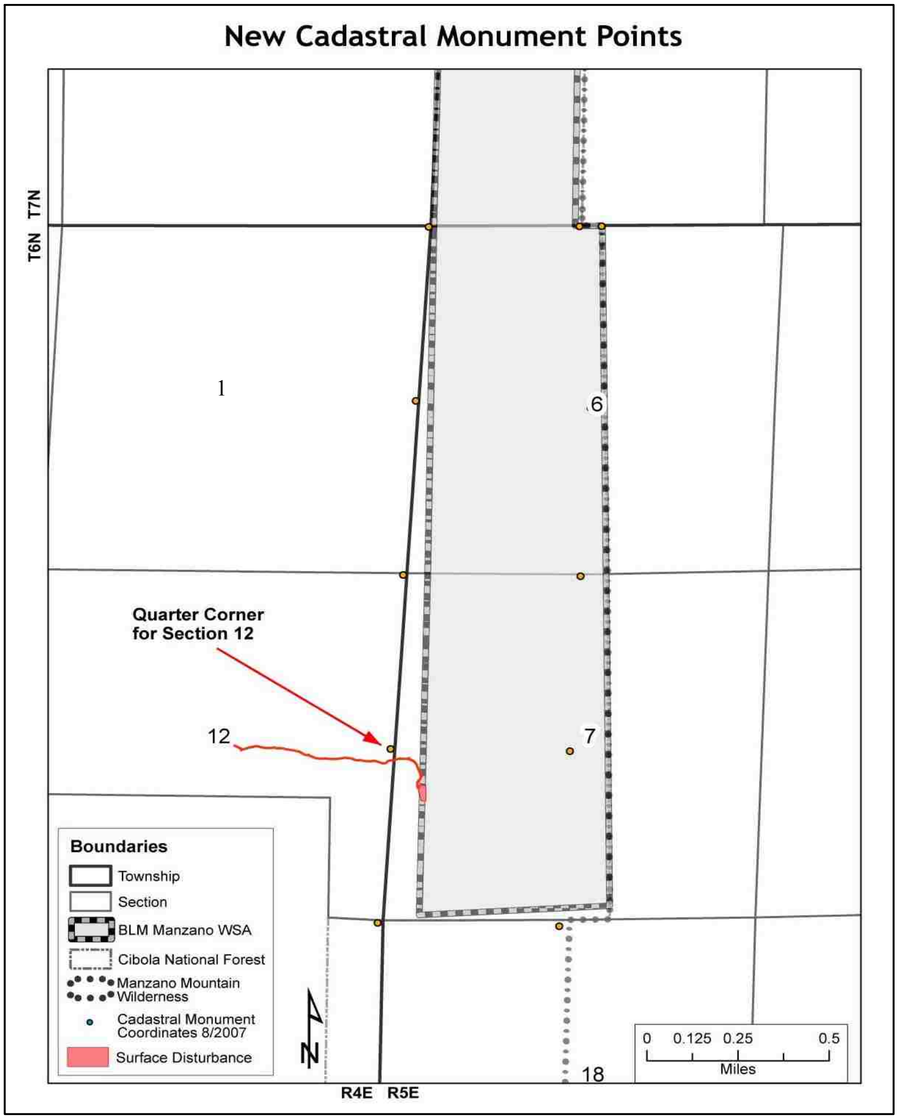


***Figure 37*. Map of BLM Cadastral's newly-surveyed corners.**

Cadastral survey teams like this one use two Real-Time Kinematic (RTK) static base stations at known coordinates for 10-minute statics (controlling measurements) that were set up and started prior to setting the pipe for the quarter corner of the eastern side of section 12. The station equipment used consisted of a Topcon FC-2000. The third component is a radio which is used for staking out the corner and is being real-time differentially corrected. Sub-centimeter accuracy is achieved with this equipment using these methods. During the week prior, this team set three witnessing points 40 chains (1/2 mile) apart along the eastern boundary of the WSA. While this boundary is completely coincident with the FS Manzano Wilderness Area, it is still necessary for the BLM to calculate the area of the WSA. Upon completing a Cadastral survey where a brass cap or other monument is set to replace the older witness stones, the stones are not removed from the site: rather, they are buried in place to facilitate relocation of the corner should the brass cap be moved (BLM 1973). In this case no stones were found.

Historically, boundary demarcation has been subject to many challenges. For instance, the Manzano Mountain area has remained mostly unsurveyed due to the steep terrain. It gains a thousand meters in a half mile heading up from west to east.
The original survey crews were paid a set amount per mile. When faced with surveying this area the crews may have simply turned around and gone home without ever doing the job.

Recent BLM Cadastral resurveys have proven that, despite some claims this area was surveyed, no trace whatsoever of corners or bearing objects could be located. No evidence of the 1882 survey for T6N R5E was found. The claim of having been surveyed in 1882 also lends itself to criticism due to the note stating the survey was completed in three weeks. This timeframe is impossibly short according to a present-day surveyor; a surveyor having access to time-saving, modern equipment.

Concluding Remarks for the BLM's Manzano Wilderness Study Area

The BLM's Interim Management Policy for Lands Under Wilderness Review states that "The BLM's goal is to immediately reclaim the impacts caused by any unauthorized action to a level ... at least to a condition that is substantially unnoticeable. The BLM will attempt to collect costs of reclamation from any and all persons responsible for causing the impacts." The statement continues: "If the person responsible for the unauthorized impacts is known but unwilling to perform the needed reclamation, BLM will undertake reclamation and initiate action to collect the costs from the responsible person(s). If the impacts in a particular case are so severe as to make it impossible or unreasonably costly to meet the requirements of the nonimpairment criteria, or if reclamation efforts would result in greater loss of wilderness values than natural reclamation, the State Director will admit written recommendations to the Director proposing an alternative reclamation strategy" (BLM 1995).

The BLM's goal is to achieve Congressional wilderness status for the BLM's Manzano WSA. Ultimately a land exchange or 'transfer' to the Forest Service could result once the Manzano WSA is restored to its original condition and Congressionally designated as wilderness.

CHAPTER 5: CONCLUSION

Discussion and Recommendations

Historical surveying led to boundary uncertainty in the area of the Manzano Wilderness Study Area. A current resurvey is about to eliminate the uncertainty. This resurvey unfortunately did not occur until after an encroachment had been committed.

The discovery of this particular encroachment would not likely have occurred without the readily available tools provided by the discipline of Geographic Information Science. GPS technology and aerial photography played an important role in locating and confirming what was discovered on the ground.

Without the discovery, years may have passed and houses may have been constructed on this public land. At that point according to many historical accounts, it would be too late to avoid harm to the potential wilderness. This begs the question: "How many other encroachments, whether deliberate or accidental, have gone undiscovered in the past, only to be revealed at a point in time that occurs beyond the window of opportunity to correct the problem?" This thesis proposes an early warning system to address this question. The Property Boundary Uncertainty Relationship Diagram is shown in Figure 38 as it relates to the case study and this early warning system.

The Early Warning System

The early warning chart in Table 1 depicts a partial hypothetical set of circumstances most likely to result in boundary uncertainty and the recommended corresponding action to identify and avoid boundary conflicts. The implementation of

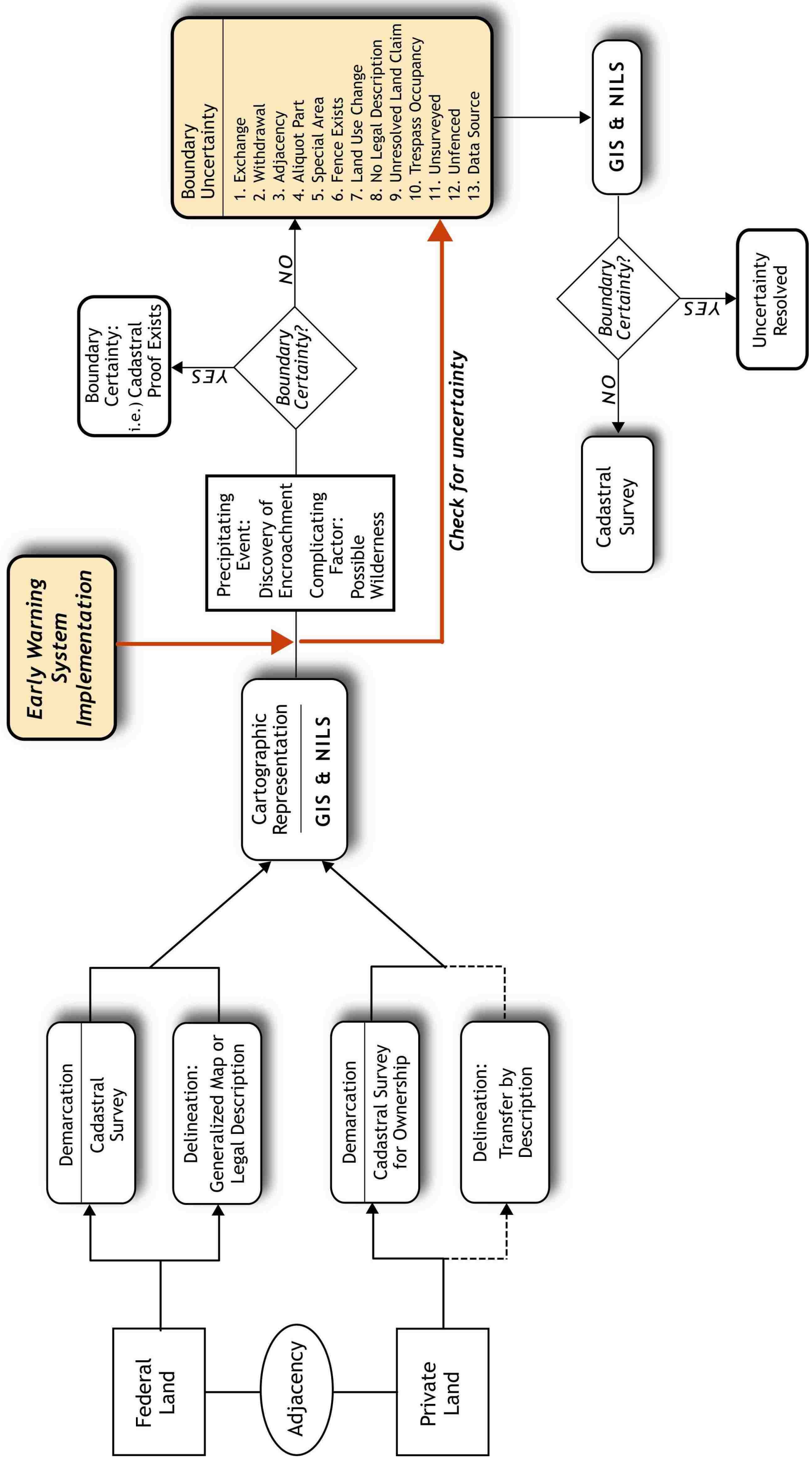


Figure 38. **Boundary Uncertainty Diagram integrated with the early warning system.**

such a decision chart in the planning stages prior to a land exchange, sale or acquisition involving public land management is proposed here.

An early warning derived from the chart in Table 1 will automatically generate a potential problem indicator with a description and possible resolutions for the parties involved. The early warning system should be implemented during or after the cartographic and GIS/NILS processes, prior to a precipitating event. This sequence is shown in the Boundary Uncertainty Diagram in Figure 38. Actions or transactions triggering early warnings should be prioritized, with the highest ranking given to conveyance, disposal, or transfer. The early warning table illustrates an organizational prioritization of early warning management. The likelihood of boundary uncertainty results in a positively correlated priority rank. Historic data collected where a boundary dispute resulted in a physical change in monumentation because of encroachments and actual trespasses may be used to achieve this. Legal factors must also be weighted in the prioritization. Subsequent to the synthesis of the available data and information, a prioritization can ultimately be determined.

Table 1. ***Boundary Uncertainty: Early Warning Ranking Decision and Action Chart.***

Priority Rank	*Variable / Event*	*Recommended Actions To Avoid Encroachment*	*Authority*
1	**Exchange: Acquisition**	Survey / Resurvey	BLM Cadastral
2	**Exchange: Disposal**	Survey / Resurvey	BLM Cadastral
3	**Sale (Disposal)**	Survey / Resurvey	BLM Cadastral
4	**Withdrawal**	Survey / Resurvey	BLM Cadastral

Table 1. Continued

Priority Rank	*Variable / Event*	*Recommended Actions To Avoid Encroachment*	*Authority*
5	**Adjacency**	Survey / Resurvey GIS Review	BLM Cadastral / GIS
6	**Aliquot Parts / Lots**	Survey / Resurvey	BLM Cadastral / Other Survey
7	**Special Area**	Survey / Resurvey	BLM Cadastral / Other Survey
8	**Fence Exists**	Survey / Resurvey	BLM Cadastral / Other Survey
9	**Land Use Change** (i.e., Grazing Allotment)	GIS Review	GIS /Resources
10	**No Legal Description**	Check MTP / Update MTP	Realty
11	**Unresolved Land Claim:** **-Spanish Land Grant** **-Aboriginal Claim** **-Legislative Directed Disposal**	Survey / Resurvey GIS Review	BLM Cadastral / GIS
12	**Trespass Occupancy**	Survey / Resurvey GIS Review	BLM Cadastral /GIS
13	**Unsurveyed**	Survey	BLM Cadastral
14	**Questionable Survey**	Check MTP / GIS Review / Cadastral Survey	Realty GIS Cadastral
15	**Unfenced Prop. Boundary - Surveyed**	Check MTP / GIS Review	Realty GIS
16	**Data Source**	GIS Review / Resource Mgmt Review	GIS / Resources
17	**Inter-agency Transfer**	GIS Review	GIS / Resources
18	**Administrative Boundary Change**	GIS Review	GIS
19	**Intra-agency (Change in Type)**	GIS Review	GIS
20	**Inter-agency Transfer**	GIS Review	GIS / Resources

Table 1 is an example of the order in which boundary uncertainty could be addressed, along with recommended actions to be taken by the appropriate authority. It should be noted that the chart is based on two classes of land ownership status: 'public,' and 'other than public.' Federal Geographic Data Committee and American Society for Photogrammetry and Remote Sensing standards for vector and raster spatial data, and survey data apply in the processes represented in this early warning system.

The Early Warning System and NILS

The NILS geodatabase shows when a special survey is required (Arctur and Zeiler 2004). Figure 39 is the schema depicting types of special surveys.

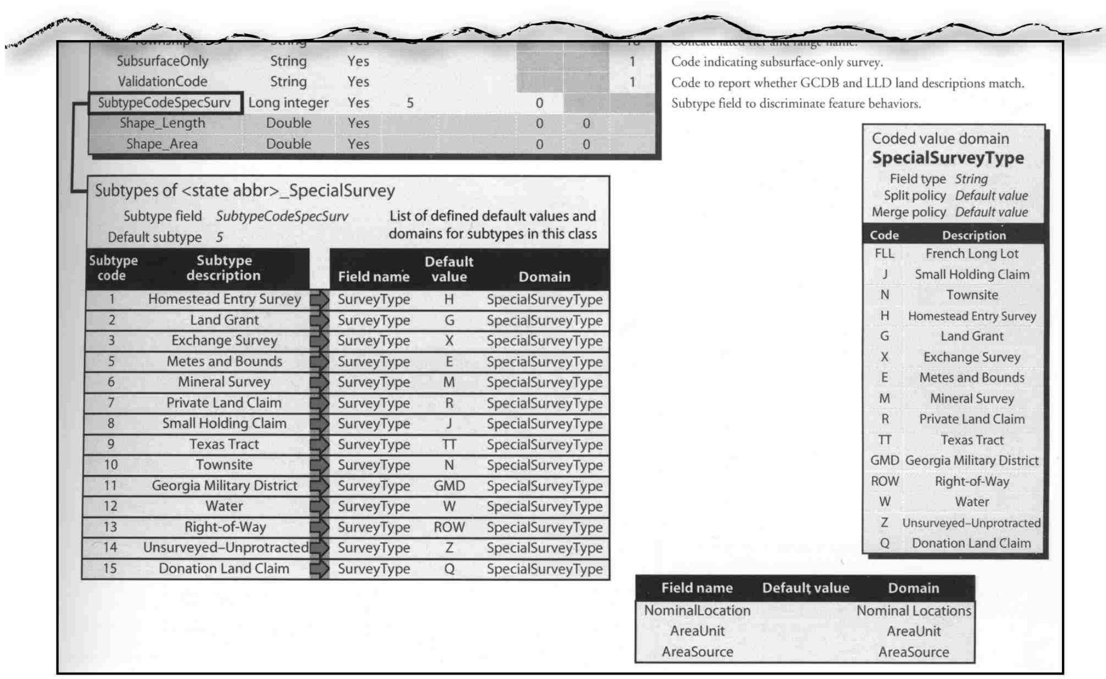


***Figure 39.* NILS Survey Schema (Arctur and Zeiler 2004).**

NILS processes do not consider the potential for boundary uncertainty. Furthermore, the geodatabase is to be used, edited, and updated internally by government professionals, not by landowners and the general public. The general public will be able to download NILS data for viewing purposes only. The proactive system that is proposed complements the functions of NILS by identifying boundary uncertainty variables and factors. Consequently, the early warning system provides for a prioritization of possible boundary uncertainty enabling an efficient, focused, and timely mobilization and deployment of resources. The early warning system may be understood and implemented not only by land management professionals, but also by consumers.

The implementation of this early warning system may be integrated with the NILS geodatabase. The recommendation is for the federal land management staff to query the NILS geodatabase for parcels having boundary uncertainty variables from Table 1, especially adjacent federal and private parcels. The results are then examined and reordered according to priority. Finally, a specific warning message is provided along with the appropriate recommended action.

Some assumptions being made include the availability of NILS for queries, timeliness of data editing in NILS, and the willingness or ability to take action based on the warning and recommendation. Regarding each event listed in Table 1, a checklist resembling the chart and the recommended action and authority, may be used and retained within the particular parcel file in hardcopy and electronic format along with all of the other corresponding documentation relevant to that parcel.

Practical Applications for the Early Warning System

Adjacent federal and private parcels in the case study provide an example for the use of this early warning system. A message would have been generated based on the following three events and variables: first, a land exchange (from public to private ownership), second, the adjacency of private property to public land, and third, unsurveyed land. These factors would have surfaced at the cartographic and GIS/NILS process in the Boundary Uncertainty Diagram. As part of the warning message, information would be disseminated to affected landowners explaining when and why a survey is needed, what to look for on a survey plat, and that planned actions, such as constructing a fence along a shared public land boundary, should be approached with caution. The flagged parcel record would reflect the fact that a warning was appropriately communicated.

The early warning system would be useful in the following resource areas:

1. Archaeology
2. Boundary Management / Surveying
3. Engineering Construction
4. Fire Science
5. Geographic Information Science
6. Lands and Minerals
7. Law Enforcement
8. Realty
9. Rangeland Management
10. Recreation
11. Soils and Vegetation
12. Timber
13. Transportation
14. Watershed Management
15. Wilderness and Special Areas
16. Wildlife and Fish

The following example of the implementation of the early warning system is in regards to archaeology. Prior to conducting field work the archaeologist would obtain a current map of the area to be surveyed. The map would show PLSS, land status and other pertinent features. In this example, private land and federal land are adjacent to one another. Their common boundary falls on a section line. The archaeologist is responsible for determining the location of sensitive cultural items and features on the entire portion along a trail on the adjacent private land, up to the federal land boundary. Using GPS, the archaeologist goes to the area and begins to collect the necessary data. During this time, a straight fence is encountered. Fence lines do not necessarily coincide with section lines or property boundaries. The archaeologist had not realized that the fence is not located on the boundary.

The scenario described above actually happened. However, the early warning system was unknown to the archaeologist. Consequently, while the archaeologist was conducting the fieldwork and the fence was encountered, it was assumed that the boundary had been reached. Upon reviewing the collected GPS data back at the office, the archaeologist realized he stopped short of the boundary. He was required to conduct a second field trip to finish collecting the missing data. Mobile GIS in the form of a laptop may have saved travel time. The early warning system would have provided useful information nonetheless.

Future study would include the acquisition and evaluation of historic data involved in encroachments. The frequency of boundary uncertainty variable occurs should be analyzed. This would help to determine probabilities for future encroachments. Four types of data and information exist that are involved in this process. The first type includes documented occurrences in court cases. Secondly, there are documented or undocumented occurrences that have been discovered and resolved. Finally, undocumented occurrences exist where a discovery is made, but not reported. The fourth category exists for encroachments that have occurred but have yet to be discovered. In the first category, data collection is straightforward. Data collection for the 2nd and 3rd categories would be difficult and may involve anecdotal information. The fourth category would require the use of aerial photography. The recommendation is to organize and analyze extant data for predictive purposes.

The cooperative activities of surveying and Geographic Information Science can result in reducing boundary uncertainty. Theoretically, the overall impact of the implementation of the proposed early warning system will result in a more efficient utilization of resources. Ultimately, environmental protection and landowner confidence will increase to the benefit of all.

Postscript

At the date of publication, the Manzano Wilderness Study Area boundary has been completely monumented on the ground (see Figure 20 showing the results of the BLM's Cadastral survey executed August, 2007). Pending approval, this boundary will be officially recorded. The coordinates of the monumented corners will be submitted to the GCDB for inclusion in their database. The location of the private landowner's encroachment will be known in relation to the WSA boundary. Encroachments, such as the one that occurred in the case study, can be avoided with the detection provided by the proposed boundary uncertainty early warning system.

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INTERVIEWS:

Steve Anderson	October 12th, 2007 (phone)
Chris Chavez	July 9th, 2007
Leslie Cone	October 31st, 2007 (phone)
John Hawkos	April 27th, 2007
Rick Hayford	August 14th, 2007
Pat Hickey	September 5th, 2007
Jay Innes	July 9th, 2007
Debby Lucero	July 2nd, 2007 (phone)
O.P. Matthews	September 18th, 2007
Kurt Menke	June 27th, 2007
Sandra Raun	September 18th, 2007
Michael Scialdone	May 9th, 2007 (phone)
Bill Stone	September 20th, 2007
Doug Williams	October 25th, 2007

ACTS OF CONGRESS:

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