1832-1859

General Land Office
Maps and Notes

1992-1997

Geographic Information System
Digital Database

Final Report

GIS Research to Digitize Maps of Iowa 1832-1859 Vegetation from General Land Office Township Plat Maps

Phase Four of Four

Includes materials from all four phases

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Phase Four of Four

I. OBJECTIVES

This report describes Phase Four of map digitizing research to prepare a vegetation data layer for Geographic Information System (GIS) data analysis. Data sources were General Land Office (GLO) surveyors' field notes and township maps completed between 1832 and 1859. (GLO is occasionally listed as the *Government* Land Office). Phase Four of the research was conducted between July 1, 1995 and June 30, 1996. Primary results of the research included digitized vegetation maps for the remaining 29 counties in western and southeast Iowa. Phase One of the research resulted in digitized vegetation maps for 14 counties in eastern Iowa. Phase Two of the research resulted in digitized vegetation maps for 25 counties in eastern and central Iowa. Phase Three of the research resulted in digitized vegetation maps for 31 counties in southwest and northeast Iowa. With the completion of Phase Four, GLO vegetation maps have been digitized for all 99 Iowa counties.

In addition to the map digitizing required by the research contract, the research team updated and expanded a Microfilm Directory Database, researched historical GLO survey methods, and researched GIS modeling procedures to analyze vegetation quantity and distribution from the vegetation map GIS files. Results of GIS spatial and statistical analysis are useful to land managers and researchers in understanding historic vegetation patterns, vegetation changes, and implications for vegetation preservation and restoration.

A. Digitize vegetation distribution from township maps

The General Land Office (GLO) conducted the original public land survey of Iowa during the period 1832 to 1859. The General Land Office later became the Bureau of Land Management in the U.S. Department of Interior in 1946. Deputy Surveyors and their assistants produced both field notes and township maps (see Appendix A) that briefly described the land and its natural resources (vegetation, water, soil, landform, and so on) at the time of the survey (Thomson 1987). These maps and survey notes are one of few data sources about vegetation distribution before much of Iowa changed to a landscape of intensive agriculture. "The field notes of the survey no longer are used to inform the public about the nature of the land. Nevertheless, they do provide a systematic inventory of the natural environment and have been used extensively in attempts to determine presettlement vegetation, especially forests. Though problems arise in interpretation of the field notes, they provide the most comprehensive data available" (Schroeder 1983, p. 5).

In accomplishing our main objective, we produced two products:

1. Digital map files of vegetation distribution in the remaining 29 counties in western and southeast Iowa
2. Expanded Microfilm Directory Database describing the surveyors' field notes and township maps

Digital map files for the remaining 29 counties were required by the research contract. The Microfilm Directory Database was not required.

B. Research GLO survey methods

Knowledge of GLO survey methods helped in preparing the township maps for digitizing. Specifically, researching the historical literature helped us interpret the surveyors' field notes and annotate the township maps before digitizing. Knowledge of GLO survey methods also helps others in interpreting the results of analyzing the digitized vegetation data using GIS software. Specifically, it helps land managers and researchers understand the quality of the vegetation data, its limitations and implications in spatial and statistical analysis.

Work on this objective resulted in two products:

1. Bibliography of literature
2. Literature review

This objective was not required by the research contract.

C. Research GIS descriptive models

GIS descriptive models use spatial, quantitative, and statistical measures to analyze the distribution of features on a data layer. GIS descriptive models are also useful for comparing distribution of features on several data layers. Results of descriptive models are useful for evaluating data quality and for making land management decisions.

Work on this objective resulted in three products:

1. Descriptive models useful for analyzing vegetation distribution
2. Descriptions of vegetation types in Fayette County
3. Analysis of witness tree data in Fayette County and Jackson County

This objective was not required by the research contract.

II. DATA SOURCES

In this research project, we did not use originals of the surveyors' field notes and maps (because they were not available for our use). Instead, we used microfilm copies of the notes and maps. In Phase One of the research (FY 92-93), we used only one set of microfilm. In Phase Two (FY 93-94), Phase Three (FY 94-95), and Phase Four (FY 95-96) of the research, we used three different sets of microfilm.

A. Secretary of State microfilm

In Phase One of the research (FY 92-93), we used only one set of microfilm. This was made available to us through DNR by arrangement with Professor Daryl Smith of the University of Northern Iowa. The microfilm was produced by the Secretary of State's office in Des Moines from records deposited there by the Surveyor General's office in Dubuque (prior to 1839, the Surveyor General's office for Iowa was in Cincinnati, Ohio (Dodds 1943, p. 262)). These 28 rolls of microfilm (on 14 double-roll spools) contained both field notes and maps. The notes were in typescript form, not in the original manuscript form. Typed originals were created during the 1930s (circa 1938) as a Works Progress Administration (WPA) project. We assumed that the typists worked from the manuscript originals or copies of the field notes handwritten in the deputy surveyors' field books. The WPA title page at the beginning of each volume included a statement similar to the following :

State Land Office
Office of the Secretary of State

Copied as part of W.P.A. Project No. 4210
which is sponsored by Mr. Earl G. Miller,
Secretary of the State of Iowa.

Superintendent.....James R. Leverett
Supervisor.....Mrs. Harriett Pugh

Copied by _____
1st proof by _____
Corrected by _____
2nd proof by _____
Final correction by _____

The maps appear to be the “rather crude sketches and plots” used as a guide to later draw refined maps at the Surveyor General's office in Dubuque (Dodds 1943, p. 11). These were considered preliminary field maps or “topographic sketches” done in the field rather than finished plat maps (National Archives 1967). The GLO

General Instructions of 1843 instructed deputy surveyors to “also make out and return with your original field notes an accurate plat or sketch of your surveys, which must exhibit the true situation of all objects noted in your field book” (Dodds 1943, p. 62). One surveyor referred to these in his field notes as “topographies” (T80N, R25W, Polk County, Joseph Moorehead, deputy surveyor, 1847). Together, topographies and field notes were considered the deputy surveyors’ “returns” to the Surveyor General. One reason we did not consider these topographies to be official plat maps was that they did not contain the surveyor general's statement and signature approving the plat as correct. Many of the original maps appeared on the microfilm to have had one fold vertically down the middle, which indicated that at one time they may have been bound in the deputy surveyors' field books. Also, many of the maps had incomplete vegetation information: lines were missing or incomplete and many vegetation labels (prairie, oak barrens, marsh, and so on) were missing.

B. National Archives microfilm

In Phase Two of the research (FY 93-94), we used National Archives microfilm from Washington, D.C. (General Land Office 1838-1846) in addition to Secretary of State microfilm. Field notes in the National Archives microfilm were the original handwritten pages (manuscript) from the deputy surveyors' field books rather than the typescript versions used in the Secretary of State microfilm. The maps were different also. Maps on the National Archives microfilm were more uniform in scale and format and graphically more refined than the maps used in the Secretary of State microfilm. They were not necessarily more complete, however. Maps from the National Archives microfilm appeared to be from one of the three sets drawn at the Surveyor General's office in Dubuque which were drawn in triplicate at a scale of 2 inches = 1 mile, using colored ink (Dodds 1943, p.11).

In Phase Two, we used a few maps from the National Archives microfilm. In the 25 counties we digitized in Phase Two, we were missing 22 township maps on the Secretary of State microfilm. We learned through our contacts in the Office of the State Archaeologist in Iowa City about the National Archives microfilm in their collection. We arranged to make prints from their National Archives set for the following townships in Phase Two:

Jackson County	T85N	R4E	T84N	R5E		
Jasper County	T78N	R18W	T78N	R17W		
Jefferson County	T71N	R10W				
Mahaska County	T77N	R14W				
Marion County	T77N	R20W	T74N	R21W	T74N	R20W
Polk County	T78N	R23W				
Van Buren County	T69N	R11W				
Warren County	T74N	R22W				

According to Fred Finney (formerly) of the Office of the State Archaeologist, their staff commonly referred to their microfilm from the National Archives as the “Blue Box Series” and their set of Secretary of State microfilm as the “White Box Series” (Perry 1993). “In this vein, the main problem in referencing GLO plat maps is that it is not always clear which of the several collections of microfilmed maps we have available is being referred to in most of the bibliographic entries I've read. This is a problem since the maps in one collection may not be the same as the maps in another collection” (Perry 1993, p. 1).

Finney indicated that the National Archives microfilm (Blue Box Series) did not contain all township plat maps for Iowa. That microfilm was missing maps for many of the townships in the northern and western counties in the state. When we obtained the township plat maps listed above from the National Archives set at the Office of the State Archaeologist, we discovered that the contents of the microfilm were limited to the townships which were surveyed before Iowa became a state in 1846. These maps covered approximately the southeast 40 percent of Iowa (approximately 670 townships). They were described as “local land office township plats” and “headquarters office township plats for the Iowa Territory” in the publication at the beginning of the microfilm (Kelsay and Pernell 1967). The publication explained the General land survey documentation process at the time:

> The first public land surveys in the area from which the Iowa Territory was formed began when the area was part of the Wisconsin Territory (1836-1838). The surveys were made by deputy surveyors and their assistants under the immediate superintendence of a surveyor general for a particular district. The deputy surveyors' returns, consisting of original field notes and a topographic sketch of the area surveyed, were

> examined and, if found to be correct, were approved. Draftsmen then prepared three plats for each township. When the plats were approved by the surveyor general, the original were filed in his office. The duplicates were sent to the local office having jurisdiction over the disposal of public lands within certain townships, and the triplicates were sent to the headquarters office in Washington (Donaldson, no date).
>
> The original set of field notes and plats of township surveys for the area now included in the State of Iowa is in the Office of the Secretary of State in Des Moines. The second set of plats, those used in the local land offices in Iowa, was sent to the General Land Office in Washington when the last local land office was closed. The plats were rebound by the General Land Office, and the 18 volumes were transferred to the National Archives in 1941. The third set of Iowa plats, known as the headquarters office plats, and copies of the original field notes remained in the General Land Office until 1959 when they were also transferred to the National Archives.

The Blue Box Series contains microfilmed copies of both the second set and the third set described above. "The local land office plats on Roll 31 were used to record entry claims, and thus have been marked up almost to the point of uselessness with respect to the location of cultural features. The headquarters office plats on Roll 32 are largely unmarked" (Perry 1993, p. 2).

Finney also indicated that the State Archaeologist's Office had a set of Secretary of State microfilm which they called the White Box Series (Office of Secretary of State 1979). "The unreliability of these plats suggests that these are copies made from the originals. We don't know who made these second generation copies or when they were made; nothing on the film indicates they were made by the WPA. SHSI has a duplicate copy of these microfilms; their card catalog references them as 'Iowa, Secretary of State, Plats' and states that the film was made in 1979" (Perry 1993, p. 3).

However, based on a brief comparison, there appeared to be some differences in the contents of the White Box Series at the State Archaeologist's Office and the set of Secretary of State microfilm at IDNR that we were using in this research. Apparently, there are at least two versions of the Secretary of State microfilm and perhaps the originals are different for each set of microfilm. A more detailed study needs to be made to describe the differences between the two sets of Secretary of State microfilm and to find out the location of the originals.

C. Historical Society microfilm

Perry (1993, p. 3) describes an additional set of microfilm available at the State Historical Society of Iowa (Office of Secretary of State 1938):

> The real WPA copies of the field notes and plats are on 16mm film at the SHSI. Apparently, these were copied from originals in the Secretary of State's collection. The field notes were typed, paginated, and assigned to volume numbers at the rate of about 4 townships per volume. Pagination is serial within volumes, and a total of 301 volumes was produced. Plat maps appear at the beginning of the notes for each township and are also paginated, but I've noticed that not all the township notes have accompanying maps, particularly in western Iowa. The reliability of the plats that are included appears to be better than the copies in the White Box Series. The WPA project was completed in 1938. The microfilms were produced as a preservation measure.

Based on this description, this set was the same as the Secretary of State microfilm that we used in Phases One through Four. However, when we visited the SHSI office in Iowa City to obtain plat maps of some additional townships, we discovered another set of microfilm. This set of three rolls apparently contained plat maps for all or most of the townships in the state. Based on a comparison of one township in Polk County (T78N, R25W), these maps appear to be virtually the same as those on the National Archives microfilm (Blue Box Series). The contents, signatures, descriptions, and drafting style were the same. However, there were minute differences in stream meanders, line width, and hatch patterns. Also, the map from the Blue Box Series contained a completed stream meander table to the right of the map.

For these reasons, we suspect that this Historical Society microfilm was filmed from one of the three sets of originals of the official plats (perhaps the first set, which as described above was originally kept at the Surveyor General's office in Dubuque, then transferred to the Secretary of State's office, then stored in the state archives of

the Historical Society). By comparison, the maps from the National Archives microfilm (Blue Box Series) were probably taken from the third set of original official plats ("headquarters plats," originally at the General Land Office in Washington, D.C., now at the National Archives).

Because some township maps missing from our Secretary of State microfilm were not on the National Archives microfilm (Blue Box Series), we obtained the following township plat maps from the Historical Society microfilm at the SHSI office in Iowa City for Phase Two townships:

Dallas County	T81N R29W, T80N R29W, T79N R29W
Polk County	T78N R25W
Warren County	T76N R25W

Also, for Phase Two we obtained the following township plat maps from the Historical Society microfilm at the SHSI library in Des Moines:

Benton County	T83N R10W
Buchanan County	T88N R8W
Delaware County	T89N R3W
Des Moines County	T71N R4W

For Phase Three, we used the following township plat maps from the Historical Society microfilm we purchased for Phase Three:

Adair County	T74N R30W, T75N R30W, T77N R30W, T74N R31W, T75N R31W, T76N R31W, T76N R32W, T77N R32W, T74N R33W, T76N R33W, T77N R33W
Adams County	T71N R35W, T72N R35W, T73N R35W
Allamakee County	T100N R3W, T100N R4W, T100N R5W, T100N R6W
Appanoose	T67N R16W, T70N R16W, T67N R18W, T67N R19W
Bremer County	T91N R13W
Butler County	T92N R17W, T93N R17W, T92N R18W, T93N R18W
Cass County	T74N R34W, T75N R34W, T76N R34W, T77N R34W, T74N R35W, T75N R35W, T76N R35W, T77N R35W, T74N R36W, T75N R36W, T76N R36W, T77N R36W, T74N R37W, T75N R37W, T76N R37W, T77N R37W
Cerro Gordo County	T94N R19W, T95N R19W, T96N R19W, T97N R19W, T94N R20W, T95N R20W, T96N R20W, T97N R20W, T94N R21W, T95N R21W, T96N R21W, T97N R21W, T94N R22W, T95N R22W, T96N R22W, T97N R22W
Chickasaw County	T97N R13W, T97N R14W
Decatur County	T67N R24W, T67N R25W, T68N R25W, T67N R26W, T68N R26W, T69N R26W, T70N R26W, T67N R27W, T68N R27W, T69N R27W
Floyd County	T97N R15W , T97N R16W, T94N R17W, T95N R17W, T96N R17W, T97N R17W, T94N R18W, T95N R18W, T96N R18W, T97N R18W
Franklin County	T91N R19W, T92N R19W, T93N R19W, T91N R20W, T92N R20W, T93N R20W, T91N R21W, T92N R21W, T93N R21W, T91N R22W, T92N R22W, T93N R22W
Hamilton County	T86N R23W, T89N R23W, T89N R24W, T88N R25W, T89N R25W, T89N R26W
Hancock County	T94N R23W, T95N R23W, T96N R23W, T97N R23W, T94N R24W, T95N R24W, T96N R24W, T97N R24W, T94N R25W, T95N R25W, T96N R25W, T97N R25W, T94N R26W, T95N R26W, T96N R26W, T97N R26W
Harrison County	T78N R41W, T78N R42W, T78N R43W, T78N R44W, T78N R45W, T78N R46W, T79N R41W, T79N R42W, T79N R43W, T79N R44W, T79N R45W, T80N R41W, T80N R42W, T80N R43W, T80N R44W, T80N R45W, T81N R41W, T81N R42W, T81N R43W, T81N R44W, T81N R45W
Howard County	T98N R11W, T99N R11W, T100N R11W, T98N R12W, T99N R12W, T100N R12W, T97N R13W, T98N R13W, T99N R13W, T100N R13W, T97N R14W, T98N R14W, T99N R14W, T100N R14W

Jones County	T83N R1W, T84N R3W, T85N R4W
Madison County	T76N R28W
Mills County	T71N R40W, T71N R41W, T71N R42W, T71N R43W, T71N R44W, T72N R40W, T72N R41W, T72N R42W, T72N R43W, T72N R44W, T73N R40W, T73N R41W, T73N R42W, T73N R43W, T73N R44W
Mitchell County	T97N R15W, T98N R15W, T99N R15W, T100N R15W, T97N R16W, T98N R16W, T99N R16W, T100N R16W, T97N R17W, T98N R17W, T99N R17W, T100N R17W, T97N R18W, T98N R18W, T99N R18W, T100N R18W
Montgomery County	T71N R36W, T72N R36W, T73N R36W, T71N R37W, T72N R37W, T73N R37W, T71N R38W, T72N R38W, T73N R38W, T71N R39W, T72N R39W, T73N R39W
Pottawattamie County	T74N R38W, T74N R39W, T74N R40W, T74N R41W, T74N R42W, T74N R43W, T74N R44W, T75N R38W, T75N R39W, T75N R40W, T75N R41W, T75N R42W, T75N R43W, T75N R44W, T76N R38W, T76N R39W, T76N R40W, T76N R41W, T76N R42W, T76N R43W, T76N R44W, T77N R38W, T77N R39W, T77N R40W, T77N R41W, T77N R42W, T77N R43W, T77N R44W, T77N R45W
Ringgold County	T67N R28W, T68N R28W, T69N R28W, T67N R29W, T68N R29W, T69N R29W, T70N R29W, T67N R30W, T68N R30W, T69N R30W, T70N R30W, T67N R31W, T68N R31W, T69N R31W, T70N R31W
Union County	T71N R29W, T72N R29W, T71N R30W, T72N R30W, T71N R31W, T72N R31W
Wayne County	T67N R20W, T67N R21W, T69N R21W, T67N R22W, T68N R22W, T67N R23W
Webster County	T89N R27W, T90N R27W, T89N R28W, T90N R28W, T86N R29W, T87N R29W, T88N R29W, T89N R29W, T90N R29W, T86N R30W, T87N R30W, T88N R30W, T89N R30W, T90N R30W
Winnebago County	T98N R23W, T99N R23W, T100N R23W, T98N R24W, T99N R24W, T100N R24W, T98N R25W, T99N R25W, T100N R25W, T98N R26W, T99N R26W, T100N R26W
Winneshiek County	T97N R7W, T98N R7W, T100N R7W, T97N R8W, T98N R8W, T100N R8W, T97N R9W, T98N R9W, T100N R9W, T99N R10W, T100N R10W
Worth County	T98N R19W, T99N R19W, T100N R19W, T98N R20W, T99N R20W, T100N R20W, T98N R21W, T99N R21W, T100N R21W, T98N R22W, T99N R22W, T100N R22W
Wright County	T90N R23W, T91N R23W, T92N R23W, T93N R23W, T90N R24W, T91N R24W, T92N R24W, T93N R24W, T90N R25W, T91N R25W, T92N R25W, T93N R25W, T90N R26W, T91N R26W, T92N R26W, T93N R26W

At the SHSI library in Des Moines, the microfilm boxes were labeled “Secretary of State Microfilm--WPA Copies.” We assume that this was a misnomer because the maps were identical to those on the microfilm at the SHSI office in Iowa City. Also, the SHSI Library in Des Moines had a set of microfilm called “Township Plats.” Apparently, all of these maps were accompanied by stream meander tables similar to the Blue Box Series described above.

In the fall of 1993, we viewed the original paper copies of some of these maps and the State Historical Society of Iowa library in Des Moines. In their archives was a set of GLO township plat maps bound in book form. The maps were a uniform scale of 2 inches per mile. The bound maps were drawn using a uniform page format and refined drafting techniques. They also were drawn using colored ink. For these reasons, we assumed that these (like the originals at the National Archives) were one of the three sets drawn at the Surveyor General's office in Dubuque. We assumed that these were the first set of original official plat maps described above, which were initially kept at the Surveyor General's office in Dubuque, then transferred to the Secretary of State's office, then placed in the state archives at the Historical Society.

Before we examined the bound books at the Historical Society library, we assumed that the set was complete. That is, we assumed that the bound books contained township plat maps for all of the approximately 1640 survey townships in Iowa. *Survey* townships are also called *Congressional* townships. *Civil* townships are a different type of township in Iowa. Civil townships were originally organized for political and governmental purposes (such as providing schools and maintaining roads and cemeteries), rather than for land survey purposes. Because there are these two types of townships in Iowa, it creates some confusion when talking about townships. Adding to the confusion is the fact that, of the 1657 civil townships in Iowa, 1158 (70 percent) cover the same area as a survey township (Anderson 1994).

However, though we did not take a complete inventory of maps in the bound books at the Historical Society library in Des Moines, we discovered some missing. There was evidence (a narrow strip of paper still bound in the book) that the missing maps were originally bound with the others, but were removed sometime after binding by tearing or cutting with a knife or razor blade.

For Phase Three, we purchased a set of Historical Society microfilm through Crest Information Technologies, 720 First Avenue NW, PO Box 73700, Cedar Rapids, IA 52407-3700, 319-366-2662, 1-800-366-0077 (Leann Hilgerson). On the invoice, Crest Technologies described the microfilm as "duplicate silver rolls, WPA original township plat maps, 3 rolls." On the box labels, they described the microfilm as "Secretary of State WPA copies of original plats, silver duplicate." Through a cursory check, we discovered that the township maps missing from the bound books at the SHSI Library in Des Moines are also missing from the Historical Society microfilm we purchased through Crest Information Technologies. Therefore, despite purchasing a second set of microfilm, we were still missing township maps.

As we completed Phase Four, we discovered that 31 township maps were missing from both sets of microfilm that contained most of the township maps we digitized. These were also missing from the books at the SHSI Library in Des Moines. It appeared that they had been carefully cut from the books using a razor blade. We later found these missing township plat maps on a copy of National Archives microfilm on file in the SHSI Library Microfilm Room in Des Moines (Newspapers Aisle, Drawer 7 "State Archives Land Survey Records"):

Carroll County	T83N R35W
Lee County	T65N R4W, T66N R4W, T67N R4W, T65N R5W, T66N R5W, T67N R5W, T65N R6W, T66N R6W, T67N R6W, T66N R7W, T67N R7W
Lyon County	T98N R45W, T99N R45W, T100N R45W
Monona County	T85N R46W, T84N R47W, T85N R47W
Plymouth County	T90N R45W, T91N R45W, T92N R45W, T93N R45W
Sioux County	T94N R45W, T95N R45W, T96N R45W, T97N R45W, T96N R43W
Woodbury County	T86N R45W, T87N R45W, T88N R45W, T89N R45W

The townships listed above for Lee County are in the southern part referred to as the "Half-Breed Tract" (Dodds 1943, p. 422, 546). The area is south of the "Sullivan Line," and was part of a boundary dispute with the state of Missouri that was settled by the U.S. Supreme Court in 1851 (Sage 1974, p. 64). Because we were missing surveyors' field notes for these townships from our Secretary of State (WPA series) microfilm, we used the field notes from the microfilm in Drawer 7 also. Surveyors' field notes were missing from our Secretary of State (WPA series) microfilm for Tier 67 of Fremont County also. We found copies of these missing field notes in a book stored in the Archives (basement) of the SHSI Historical Building in Des Moines. They were in a bound book labeled "Sec of State Survey notes" Box 30, Location 8/47, Vol. 226 (copied from Vol. 566 of *Missouri Surveys*).

D. Summary

Based on our research, there are at least 4 sets of GLO township maps:

	Map type	Original location	Later location	Current location
0.	Field maps	Surveyor Gen Dubuque	Sec of State Des Moines ?	? (unknown)
1.	Plat maps	Surveyor Gen Dubuque	Sec of State Des Moines	SHSI Library
2.	Plat maps	Local land office	GLO HQ Washington	National Archives
3.	Plat maps	GLO HQ Washington	National Archives	National Archives

Field maps (topographies) for approximately 863 townships appear on the Secretary of State microfilm. According to Miller (1995, p. 37), 887 townships were surveyed before 1850, four years after Iowa became a state in 1846. Miller also displayed a state map showing that not only were the two numbers quite similar (863 and 887), but the two township patterns were quite similar. This may indicate that the topographies were kept in a different place after statehood than before statehood. If the post-statehood topographies were kept in a different place, that may have been the reason that they weren't included with the pre-statehood topographies on the Secretary of State microfilm.

Based on our research, there are at least 4 sets of microfilm containing GLO township maps

	ISU name	Perry name	Location	Maps	Notes
1.	Sec of State		DNR/ISU & SHSI	Field maps	Typescript
1.		"real WPA copies"	SHSI Iowa City	Field maps	Typescript
2.	National Archives	Blue box series	OSA Iowa City	Set 2 / Set 3	Manuscript
3.		White box series	OSA Iowa City	"copies of originals"	? (unknown)
4.	Historical Society		SHSI Des Moines	Set 1	No notes

In addition, there are at least two sets at the National Archives. According to Brendan Shane (PhD student in geology at the University of Maryland), the new Archives II building on the Maryland campus contains microfilm of maps and manuscript notes. Brendan reported that some maps on the microfilm had owners' names handwritten and others did not. Presumably, these maps were from Set 2 (local land office copies) and Set 3 (GLO Headquarters copies).

In Phase One of our research, we used 235 township maps from the Secretary of State microfilm (WPA Series). In Phase Two, we used 385 township maps from the Secretary of State microfilm (WPA Series), 12 township maps from the National Archives microfilm (Blue Box Series), and 10 township maps from the Historical Society microfilm. In Phase Three, we used 179 township maps from the Secretary of State microfilm (WPA Series) and 318 township maps from the Historical Society microfilm. In Phase Four, we used 25 township maps from the Secretary of State microfilm (WPA Series), 445 township maps from the Historical Society microfilm, and 31 township maps from Historical Society (National Archives) microfilm.

	Microfilm source	Phase One	Phase Two	Phase Three	Phase Four	Total
1.	Secty of State (WPA series)	235	385	179	25	824
2.	Nat Archives (Blue Box series)	0	12	0	0	12
3.	Secty of State (White Box series)	0	0	0	0	0
4.	Historical Society	0	10	318	445	773
5.	Historical Society (Nat'l Archives)	0	0	0	31	31
	Total townships	235	407	497	501	1640

See Appendix B for a state index map showing the microfilm source for each township map we've digitized in Phases One, Two, Three, and Four.

Miller (1995, p. 75) used GIS and statistical techniques to compare vegetation data from Secretary of State maps (listed earlier as Map Set 0) and Historical Society maps (listed earlier as Map Set 1). Miller used a measure called Coefficient of Areal Correspondence (CAC) to compare the area of each vegetation type in Fayette County shown on the two sources. His comparisons produced a range of two percentages, representing the amount of overlap in each pair of spatial distributions. Minnick (1964) and Unwin (1981, p. 190) compute a single CAC:

	Vegetation type	CAC minimum	CAC maximum	CAC median	CAC Minnick
1.	Prairie	97.2%	97.2%	97.20%	94.55%
2.	Timber	93.5%	93.6%	93.55%	87.95%
3.	Cultural features	29.3%	54.9%	42.10%	23.62%

The CACs for prairie and timber were quite high, which indicated almost complete agreement between the field maps and plat maps in amount and location of vegetation. CACs for cultural features, such as settlements and

fields were moderate to low, which indicated less agreement between the two sets of maps. Fortunately, few cultural features (only fields and cities that are area data) were included in our digitized files, which made the differences between the two sources relatively insignificant for our purposes.

As mentioned above, more research is needed to describe and compare these known sets and perhaps to discover any additional sets. Also, research is needed to locate the paper originals of the plat maps in the Secretary of State microfilm to verify that these (1) are preliminary field maps used to make the official plats approved by the Surveyor General in Dubuque and (2) are the same as the WPA series described in Perry (1993, p. 3).

III. MICROFILM DIRECTORY DATABASE

In Phases One through Four of the research, we used township plat maps from the Secretary of State microfilm. Microfilm copies of the maps were in black and white. The exposure and clarity of the microfilm maps varied considerably from roll to roll and within each roll, though all were legible. The township maps varied in scale, date, surveyor, contents, and completeness. The township maps and field notes were contained on 28 rolls (14 double-roll spools).

A. Database purpose

The purpose of creating the Microfilm Directory Database in Phase One was to help us find specific township maps and field notes on the microfilm in a quick and efficient way. After we began looking through the microfilm, we realized that the township maps and field notes were not always present and those present were not always microfilmed in a predictable sequence (especially in the first few rolls). We discovered a general sequence:

- ordered first by range from east to west
- ordered within each range from south to north

However, there were many exceptions to this general sequence. Many township maps were not included on the microfilm (maps for 810 Iowa townships (48 percent) were missing). Also, the microfilm contained more than one map for some townships. For these reasons, we thought that a directory database would be useful in a number of ways:

1. Make our search for specific township maps and notes faster
2. Allow us to anticipate needs and problems of map digitizing
3. Help us select counties for map digitizing
4. Provide a printed list as a guide to microfilm printer operators at the ISU Parks Library
5. Make checking and verifying digitized files easier
6. Provide an aid to Michael Miller in his thesis research
7. Provide an index that other researchers, land managers, and administrators could use in the future

We realized that creation of the database would involve some extra time and effort at the beginning of the project. However, we felt that our investment would pay off in the long run through faster retrieval of the information we needed to complete the project.

B. File organization

There were a number of characteristics about the microfilm contents that were important to us in the project. We selected and organized these characteristics into database field names for data input:

1.	Rec	Record sequence number (1 to 1673)
2.	Roll	Microfilm roll number (1 to 28)
3.	Vol	Volume number (1 to 301)
4.	Bpage	Beginning page number on which the township map appears
5.	Page	Page number(s) on which the township map appears
6.	Tier	Township tier number (65 to 100)
7.	Range	Township range number (-7 to 49)
8.	County	County name(s)
9.	Month	Survey completion date

10. Day — Survey completion date
11. Year — Survey completion date
12. Exp1 — Photographic exposure, ranging from light to dark
13. Exp2 — Photographic quality, including streaks or mottled prints
14. Surveyor — Name(s) of deputy surveyor(s) for the township
15. Notes — Our comments about map condition, contents of field notes, missing information

During Phase Two of the research, we added the following data field:

Desc — Page number of deputy surveyor's township general description

For most townships, deputy surveyors wrote a paragraph summarizing the township's physical characteristics. Typically, the surveyors commented on landform, soil, water, vegetation, and wildlife. They also included assessments of the land's potential for settlement, agriculture, forestry, or other type of development. Occasionally, the surveyor included comments about settlers, politics, Native Americans, or obstacles (such as prairie fires, snow storms, large snakes, health, rations, provisions, and equipment problems). The data field contained a 0 (zero) if no page number was included on the page and a -1 if the description was missing for the township. In cases where the description was more than one page long, only the first page number was listed.

C. Data input

For data entry, we used spreadsheet software on an MS-DOS microcomputer. Microsoft Excel for MS-Windows was already available on our department computers, so we set up a spreadsheet database file with a column for each of the data fields listed above. We used each row of the spreadsheet to record information for a township (see Appendix C).

We began by printing several copies of the blank spreadsheet form. As we looked through each roll of microfilm using the microfilm reader, we wrote information on the printed form. Then we moved to the microcomputer and typed the information using the Excel spreadsheet software.

We used several checking and debugging procedures. However, some frames of the microfilm had poor image quality, which made them difficult to read. In addition, the township maps and field notes were often out of order on the microfilm. Other types of maps were included on the microfilm also. Also, the field notes were typed from the original manuscript notes in the 1930s as part of a WPA project. We detected some typos and inconsistencies in the typed version. For these reasons, we knew that the information in the database was not entirely correct, even with our thorough debugging techniques and additional review of the microfilm.

D. Data retrieval

After we entered the data in the spreadsheet file, we sorted the information by category (or combination) to print or view it on the computer monitor. For example, for each county we digitized, we printed an ordered list sorted by county, tier, and range. This helped us find and print the appropriate township maps for each county that we digitized.

From the 28 rolls of microfilm made available to us through Daryl Smith of UNI, we created a database with 1673 records (one record per map). Township plat maps were missing on the microfilm for approximately 810 townships. Approximately 50 townships had more than one version of the township plat map on the microfilm. Approximately 23 counties had all their township plat maps on the microfilm. Another 20 counties were missing only one or two township maps.

Using AutoCAD, we created a state index map from the database (see the last page of Appendix C). The map showed the microfilm roll number(s) for each of the 863 township maps. If no map was included on the microfilm, the state index map shows a diagonal line through each of the 810 townships.

E. Historical Society microfilm

In Phase Three, we purchased an additional set of microfilm (see Section II-C). This microfilm contained maps only (no field notes--field notes for these were available from the Secretary of State microfilm). For each of the 1695 maps on the Historical Society microfilm, we added a record to our Microfilm Directory Database. There

were 88 duplicates among the 1695 maps. Also, maps were missing for 28 townships (see Section II-C and the end of Appendix D). Fields used in these additional records included the following:

1.	Rec	Record sequence number (1 to 1723)
2.	Roll	Microfilm roll number (1 to 3)
3.	Tier	Township tier number (65 to 100)
4.	Range	Township range number (-7 to 49)
5.	County	County name(s)
6.	Surveyor	Name(s) of deputy surveyor(s) for the township
7.	Quarter	Survey completion date (quarter or month(s))
8.	Year	Survey completion date (year)
9.	Duplicate	Duplicate of another map on the microfilm (N, Y, D)

Appendix D contains a listing of the Microfilm Directory Database for the Historical Society microfilm. Township maps missing from the Historical Society microfilm are listed at the end of Appendix D.

IV. MAP DIGITIZING

A. Selection of counties

During Phase One of the research, two counties were selected as pilot counties: Cedar and Johnson. Our criteria for the pilot counties included the following:

1. Counties that had a complete set of township maps and field notes on the microfilm
2. Two counties for comparison purposes
3. A county that was completed at UNI by Daryl Smith
4. A county that was not completed by Daryl Smith (to compare to #3 above)
5. Two counties that had different quality township maps on the microfilm

After we digitized the two pilot counties, we selected 12 additional counties for digitizing. In addition to the five criteria above, our criteria for the 12 additional counties included the following:

6. Counties that had a complete set of township maps and field notes on the microfilm
7. Some counties along the Mississippi River for additional variety
8. Counties that were contiguous with Cedar and Johnson

We selected 12 additional counties that met all or the first two criteria. We digitized the following 14 counties in Phase One of the research project:

1.	Blackhawk	8.	Cedar
2.	Fayette	9.	Keokuk
3.	Clayton	10.	Washington
4.	Linn	11.	Muscatine
5.	Iowa	12.	Scott
6.	Johnson	13.	Henry
7.	Clinton	14.	Louisa

These 14 counties are unhatched on the accompanying map (Figure 1).

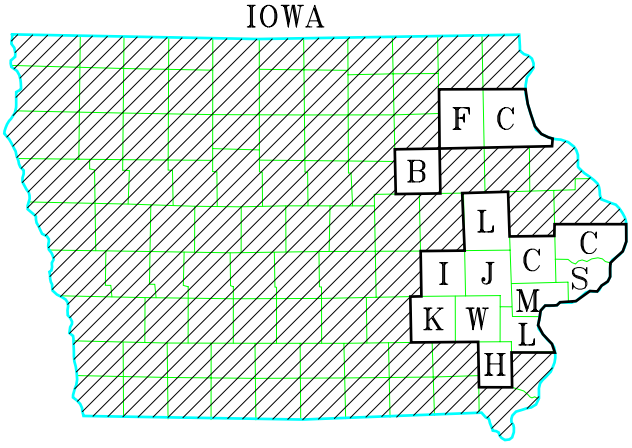
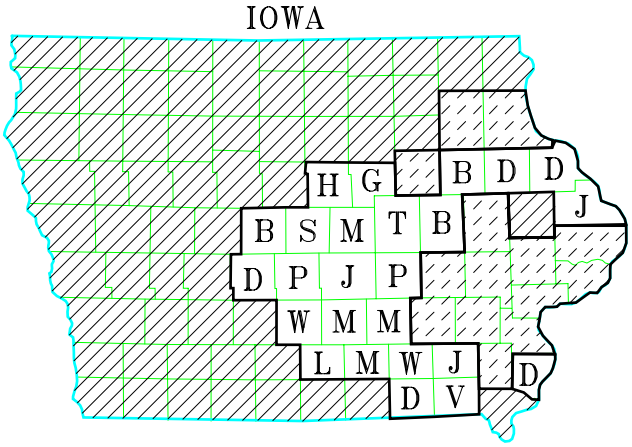


Figure 1. Phase One counties (14)

See Appendix E for an AutoCAD plot of each of the 14 county maps digitized in Phase One of the research.

For Phase Two of the research, we selected 25 additional counties that were contiguous with counties in Phase One and had complete or nearly complete coverage of township maps on the Secretary of State microfilm:

1. Hardin
2. Grundy
3. Buchanan
4. Delaware
5. Dubuque
6. Boone
7. Story
8. Marshall
9. Tama
10. Benton
11. Jackson
12. Dallas
13. Polk
14. Jasper
15. Poweshiek
16. Warren
17. Marion
18. Mahaska
19. Lucas
20. Monroe
21. Wapello
22. Jefferson
23. Des Moines
24. Davis
25. Van Buren



These 25 counties are unhatched on the accompanying map (Figure 2).

Figure 2. Phase Two counties (25)

See Appendix E for an AutoCAD plot of each of the 25 county maps digitized in Phase Two of the research.

For Phase Three of the research, we selected 31 additional counties that were contiguous with counties in Phase One and Phase Two and had complete coverage of township maps on the Secretary of State microfilm or Historical Society microfilm:

1. Winnebago
2. Worth
3. Mitchell
4. Howard
5. Winneshiek
6. Allamakee
7. Hancock
8. Cerro Gordo
9. Floyd
10. Chickasaw
11. Wright
12. Franklin
13. Butler
14. Bremer
15. Webster
16. Hamilton
17. Jones
18. Harrison
19. Pottawattamie
20. Cass
21. Adair
22. Madison
23. Mills
24. Montgomery
25. Adams
26. Union
27. Clarke
28. Ringgold
29. Decatur
30. Wayne
31. Appanoose

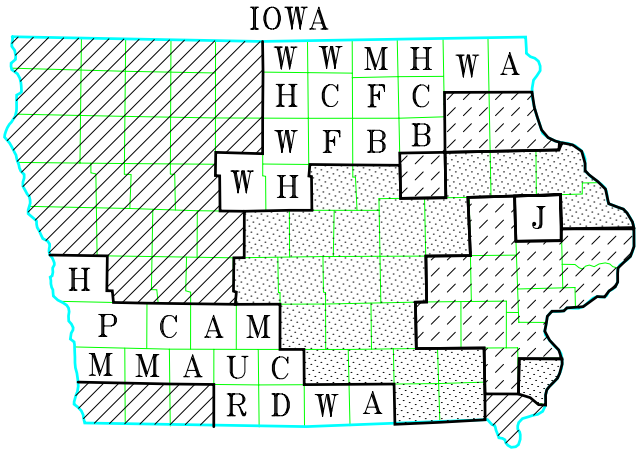


Figure 3. Phase Three counties (31)

These 31 counties are unhatched on the accompanying map (Figure 3).

See Appendix E for an AutoCAD plot of each of the 31 county maps digitized in Phase Three of the research.

For Phase Four of the research, we selected the remaining 29 counties:

1. Lyon
2. Osceola
3. Dickinson
4. Emmet
5. Kossuth
6. Sioux
7. O'Brien
8. Clay
9. Palo Alto
10. Plymouth
11. Cherokee
12. Buena Vista
13. Pocahontas
14. Humboldt
15. Woodbury
16. Ida
17. Sac
18. Calhoun
19. Monona
20. Crawford
21. Carroll
22. Green
23. Shelby
24. Audubon
25. Guthrie
26. Fremont
27. Page
28. Taylor
29. Lee

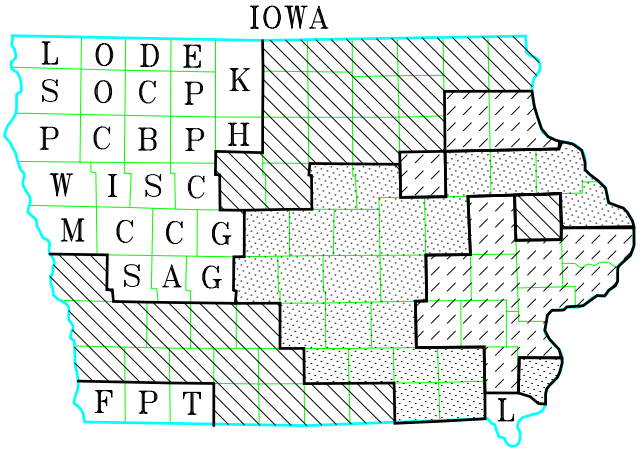


Figure 4. Phase Four counties (29)

These 29 counties are unhatched on the accompanying map (Figure 4).

See Appendix E for an AutoCAD plot of each of the 29 county maps digitized in Phase Four of the research.

B. Microfilm printing

For each county, we completed a microfilm printing order form based on a printout from the Microfilm Directory Database. The printout included all records from the Microfilm Directory Database that pertained to the county we were working on. This gave us a list with the roll number and page number of each township map we needed for the county. We brought this order form, along with the appropriate rolls of microfilm, to the Microforms Department at the ISU Parks Library. There, an operator printed a hard copy of each of the appropriate township maps using a microfilm printer. Based on our work with the hard copy, the prints appeared to be sufficient quality copies with no significant distortion.

In several cases, the microfilm contained two different versions of a township map. This occurred when the GLO resurveyed a particular township. In most of these cases, we selected the map with the later date. However, if the earlier map had more complete vegetation information, we selected it for digitizing instead.

C. Map preparation

After the maps were printed, we checked and annotated each with two types of information: vegetation lines and vegetation labels. We checked and added vegetation lines and labels with a thorough reading of the field notes. As mentioned above, some township maps (such as those in Cedar County) required very little annotation; others (such as those in Johnson County) required many hours of reading notes and annotating maps (approximately 5 hours for Cedar County and 14 hours for Johnson County).

The microfilm reader we used to read the field notes was obtained by special loan arrangement from the Parks Library Microforms Department at ISU. The other option we investigated was renting a microfilm reader from one of two microfilm reader sales companies in Des Moines. Their rental charge was approximately $40 to $50 per month for a basic model with minimal features.

Based on discussions with DNR staff members (Daryl Howell, John Pearson, and Kevin Kane), some township map features were appropriate to include in the digitized vegetation files and others were not. Map features that were appropriate for digitizing included area data that referred to vegetation and other natural land cover (such as water and sandbar). In the 99 counties, we digitized the following vegetation types:

1.	Barrens	BAR	20.	Ravine	RAV
2.	Bayou	BAY	21.	River (border)	RIV
3.	Bog	BOG	22.	Rough	ROU
4.	Brush	BRU	23.	Sandbar	SAN
5.	City	CIT	24.	Scattering trees	SCA
6.	Drain	DRA	25.	Slue [sic]	SLU
7.	Field	FIE	26.	Spring	SPR
8.	Grove	GRO	27.	Swale	ALE
9.	Indian field	IFD	28.	Swamp	SWA
10.	Island	ISL	29.	Swamp/marsh	SMR
11.	Lake	LAK	30.	Thicket	THI
12.	Marsh	MAR	31.	Timber	TIM
13.	Meadow	MEA	32.	Timber/barrens	TBR
14.	Oak barrens	OAK	33.	Timber/scattering/barrens	TSB
15.	Openings	OPE	34.	Timber/scattering/openings	TSO
16.	Part prairie/part timber	PPT	35.	Village	VIL
17.	Pond	PON	36.	Wetland	WET
18.	Pool	POO	37.	Willows	WIL
19.	Prairie	PRA	38.	Windfall	WIN

Names for these vegetation types were taken directly from the township maps and field notes. We followed the principle of keeping vegetation types separate and not aggregating vegetation types into fewer categories. In this way, others who use the data can aggregate according to their own needs. Not all vegetation types occur in every county we digitized. See Appendix F for charts that show which vegetation types occurred in each county. See Appendix G for the area of each vegetation type in each county. See Appendix H for observations about vegetation types.

Features on the township maps that were line data and point data were not digitized. Examples of line data and point data not digitized were rivers, streams, trails, cabins, floodplain edge, sand hills, mounds, and springs shown with a point symbol. In counties bordering the Mississippi River and Missouri River, river (RIV) was digitized within the state boundary as shown in the DNR Arc/Info coverage of township lines.

D. AutoLISP command file

We used AutoCAD as the digitizing software because AutoCAD (1) had powerful map digitizing capabilities, (2) was easily available at ISU, (3) was well known by members of our research team, and (4) had a powerful macro/programming language called AutoLISP. For this research project, we wrote over 150 macro commands and programs to help the digitizing process. Most of these were short AutoLISP programs which in AutoCAD performed the same type of functions as “macros” or “shortcut keys” in other software. These customized AutoLISP commands improved efficiency and productivity by reducing the number of keystrokes and digitizing commands and by speeding up the drawing setup process. They also minimized potential errors in typing commands, layer names, and vegetation labels.

E. Map digitizing

Township coverage file. Before beginning Phase One of the project, we obtained the Iowa township map coverage file from Kevin Kane at DNR. This file originated as a GIS map layer (coverage) in Arc/Info as part of the DNR database. The file contained township lines only. During the vegetation digitizing step, we added vegetation lines and label points to a copy of this file, ensuring that the new vegetation maps were properly registered when Arc/Info was used to overlay the new vegetation data layer with other existing DNR data layers. During Phase One and the first part of Phase Two, we made a copy of the township coverage file for each county. Each new file contained only the township lines in the county. During the last part of Phase Two and in Phases Three and Four, we made an Arc/Info coverage of this file, then extracted township lines for each selected county using a query in ArcCAD. This copy/extraction process typically required less than a half hour per county.

Equipment. Throughout the project period, we used AutoCAD Release 12 on three MS-DOS 486 class microcomputers. (During Phase One of the project, we used AutoCAD Release 11 on some of the counties.) We used three digitizing tablets: Hitachi 11x11, Summagraphics 12x12, and Summagraphics 12x18. In addition to using AutoCAD for digitizing vegetation lines, inserting label points, and checking the digitized files, we used

the Microsoft QuickBASIC compiler during Phase One to write several utility programs to check for open polylines and slivers.

During Phase Two we acquired three new software packages that help convert the data files from AutoCAD format to Arc/Info format. We acquired ArcCAD to speed up the conversion process. ArcCAD was an ESRI product designed to provide AutoCAD with GIS functions. It was a third party add-on to AutoCAD. Most Arc/Info functions were included in ArcCAD, including functions for building new data themes and coverages from AutoCAD files (such as cleaning, building topology, and converting file formats). We wrote an AutoLISP program which automates much of the conversion process. We also acquired PC Arc/Info and ArcView to help perform a final check on file compatibility.

Map calibration. After each township map was placed on the digitizing tablet, we calibrated (rubbersheeted) it to the township lines in the DNR township coverage file. This short but important step usually took only a minute or two for each township. AutoCAD Release 12 allowed two or more points to be used in the calibration process. Typically, we calibrated each township map to the corresponding township lines from the DNR file using four points, one in each corner of the township. Considering the lack of precision in drawing the original GLO map vegetation lines, rubbersheeting with four points gave us quite acceptable results.

This calibration process helped ensure that the digitized vegetation data layer would properly register with other DNR GIS data layers. This was true because they all used the same horizontal control provided by the UTM coordinate system used in the DNR township coverage file.

Digitizing vegetation lines and inserting label points. After each township map was calibrated on the digitizing tablet, we traced vegetation lines using the digitizer puck and AutoLISP macro commands. The AutoLISP macro commands made sure that the lines and label points for each vegetation type were digitized on a different AutoCAD drawing layer. This was the key to ensuring that each polygon was identified correctly during the importing process into Arc/Info.

Vegetation lines were recorded as a series of straight line segments: short segments of a few meters where vegetation lines were curved and long segments of several thousand meters where vegetation lines were straight. Some counties, such as Henry, had relatively few line segments (approximately 3,000) in the digitized map file; other counties (such as Linn) had relatively many line segments (approximately 10,000). Typically, this digitizing step required one to twenty hours for each county.

Edge matching township maps and closing polylines. After the vegetation lines and label points were digitized for all the townships in each county, we joined open polylines along township boundaries. Open polygons in one township that were not connected to polygons in adjacent townships were closed using a straight line along the township border. This avoided having neighboring polygons (within each county) that were the same vegetation type. This also reduced the size and complexity of the digitized vegetation map file.

Another digitizing technique used in Phases Two, Three, and Four of the research also reduced the size of the datafiles and time required for digitizing. Because we acquired ArcCAD software to import the AutoCAD drawing files ourselves, we were able to avoid having *closed* polylines around each vegetation polygon. This avoided the extra step of digitizing twice the common boundary between adjacent polygons, essentially cutting our digitizing time by a third. Typically, this digitizing step required another one to twenty hours for each county.

Checking for open polylines. In Phase One of the research, we used four procedures to check for open polylines and close them (AutoCAD JOIN command, our AutoLISP macro command to display lines and labels points for only one vegetation type at a time, our own AutoLISP macro command to examine each polyline and report on the computer screen which (if any) polylines were open, saved a DXF file that we examined with DNRDXF1, a BASIC program we wrote). In Phases Two, Three, and Four, these procedures were unnecessary because of the new importing procedure using ArcCAD.

Checking for polygon slivers. Slivers are overlaps and underlaps (gaps) produced when polyline segments cross. Slivers cause problems in vector GIS software like Arc/Info. In Phase One of the research, we used two procedures to check for slivers (a visual check and saving a DXF file which we then examined using DNRDXF2,

a BASIC program we wrote for this purpose). These procedures are now unnecessary because of the new importing procedure using ArcCAD.

Checking for unlabeled polygons. In Phase One of the research, we used a visual check to detect unlabeled polygons and polygons with more than one label was a visual check. We conducted the visual check twice: on screen and hard copy. These procedures are now unnecessary because of the new importing procedure using ArcCAD.

Checking for mislabeled and missing polygons. In all four phases of the research, we used visual checks to detect mislabeled polygons and missing polygons. We conducted visual checks four times: twice using a computer screen and twice using hard copy. The first was a color check to detect polygons whose vegetation lines, labels, and label points were not all the same color on the screen. The second was a logic check based on the vegetation patterns. The third check compared the hard copy to the township maps. The fourth was a visual color check comparing the township maps with each completed county map displayed on a computer screen using ArcView software.

F. Importing map files into ArcCAD

After we digitized all the township maps for each county and checked the digitized maps for labeling errors, we imported each AutoCAD drawing file into ArcCAD. ArcCAD is an ESRI product which can function along with AutoCAD to provide error checking and conversion to Arc/Info format. As a third-party AutoCAD accessory or add-on, ArcCAD provided additional commands needed to check or clean the digitized lines and to convert the file to an Arc/Info coverage by building topology. This procedure required approximately one hour per county.

Cleaning process. The ArcCAD CLEAN command checked for vegetation polylines whose endpoints were dangling (not connected to other polylines). Minor overshoots and undershoots (within the one meter tolerance we set) were automatically corrected during the cleaning process. Major overshoots and undershoots were flagged and required editing using AutoCAD commands. We set the dangle length and fuzzy tolerance to one meter, which seemed quite reasonable, considering that the vegetation lines on the GLO township maps were interpolated between data points that surveyors measured along the section lines. Also, this distance was reasonable given the Arc/Info guideline: MAP SCALE divided by the number of INCHES PER UNIT times the DIGITIZER ACCURACY.

Another cleaning command within ArcCAD, LABELERRORS, counted the number of label points per polygon. The command reported which polygons, if any, had no label point or more than one label point. AutoLISP commands used in the digitizing process were used, if necessary, to add or delete label points. If errors were detected using the CLEAN command and LABELERRORS command, the AutoCAD drawing file was edited to correct the errors.

Conversion process. After the AutoCAD drawing file was edited for each county, we used the ArcCAD CLEAN command and LABELERRORS command again to ensure that the errors were corrected satisfactorily. The CLEAN command converted each file to an Arc/Info coverage by creating topology. Topology described the spatial relationships between connecting and adjacent vegetation polygons (ESRI 1990). These descriptions of topology were required for the database files Arc/Info uses (such as ARC, PAT, TIC files).

AutoLISP command file. To automate the importing process in Phase One, we wrote an AutoLISP command that prompts for the county name and performs the cleaning and conversion process without the need for typing individual command names and file names. This was no longer needed in Phases Two and Three.

Comparison with Phase One. This process for checking and importing AutoCAD drawing files was faster than the process used in Phase One of the research. That process required use of separate utility programs (we wrote using Microsoft QuickBASIC) to check for open polygons, polygon slivers, and unlabeled polygons. To use these utility programs, each AutoCAD drawing file had to be converted to a DXF (Drawing eXchange File) which was an ASCII text file written by AutoCAD. The new importing procedure used in Phases Two, Three, and Four did not require saving DXF files or use of these utility programs for checking.

The new process used in Phases Two, Three, and Four of the research also eliminated the last two steps used in Phase One. One step was converting each final AutoCAD drawing file to a DXF file. The other step was importing each DXF file into Arc/Info using an AML (Arc Macro Language) program written by Kevin Kane at DNR for this purpose.

In both procedures (Phase One and Phases Two/Three/Four), there were two keys to successfully making the conversion from AutoCAD drawing files to Arc/Info coverage files: drawing layers and object snap. First, we digitized each of the almost forty vegetation types on separately named drawing layers in AutoCAD. ArcCAD then used the layer name (of the label point) as an attribute in the PAT file. Second, "snapping" new line segments to nodes of existing lines minimizes overshoots, undershoots, and the possibility of polygon slivers. These keys helped minimize editing during the checking and conversion process.

V. RELATED RESEARCH

As mentioned earlier, we conducted related research not supported by the research grant. The related research provided background for better understanding of both the township maps used as the data source and the potential uses for the new vegetation data files.

A. Research on GLO survey methods

Research on GLO survey methods consisted primarily of a literature review by Michael Miller. Miller was the senior graduate research assistant for the project. He recently completed his MLA thesis, *Analysis of Historic Vegetation Patterns in Iowa using Government Land Office Surveys and a Geographic Information System*. Miller's literature review included GLO survey methods used in Iowa and studies of presettlement vegetation in other midwest states. His bibliography contained over 90 sources and is included in Appendix I. Information from these literature sources helped in understanding the quality and limitations of the newly digitized vegetation data. Knowledge gained from these and other materials was helpful in our project in several other ways. First, Miller's literature review helped in reading and understanding the surveyors' field notes and in annotating the township maps to prepare them for digitizing.

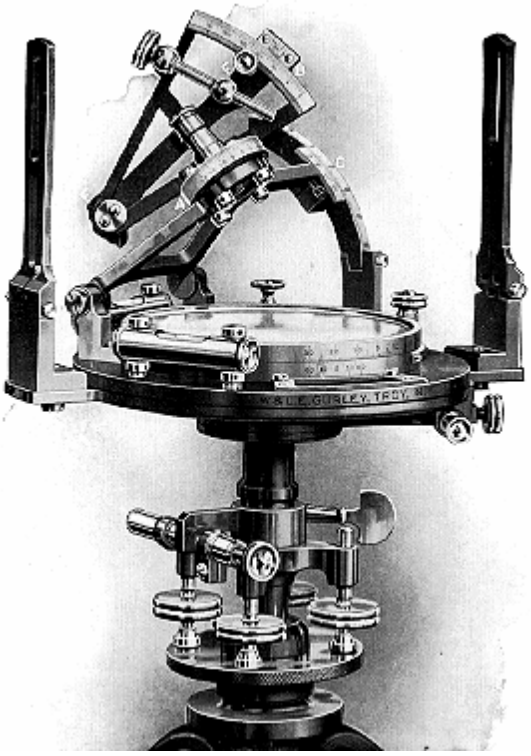


Figure 5. Burt's solar compass.

Second, Miller's literature review helped us learn from others' experiences in nearby states. Many of the sources describe similar research in states in the Midwest, including Minnesota, Wisconsin, Illinois, Michigan, Indiana, and Ohio. Though each of these states has done research on what they call presettlement vegetation, none to our knowledge has digitized the vegetation data from GLO township maps as a statewide GIS data layer. John Ebinger (1987), in *Presettlement Vegetation of Cowles County, Illinois*, says that research on presettlement vegetation is "necessary for the study of long-term ecological processes and as baseline data for the study of present day communities."

Third, Miller's literature review also helped us better understand surveying practice, technology (Figure 5), and obstacles present when the township maps were surveyed and drawn. The primary sources for information on Iowa GLO surveys were Dodds (1943) and Stewart (1935). Miller learned about survey parties and their responsibilities, equipment, compensation, schedule, and major obstacles (both cultural and natural).

- Most townships were surveyed in approximately one month
- Some counties were surveyed over a six year (or more) time span, because of the sequence in which the townships were surveyed

- High precision was not an objective of the original public land survey due to low land prices
- Speed was an objective of the original public land survey due to rapid increases in population and resultant land ownership disputes (the state's population increased from almost 11,000 in 1836 to almost 23,000 in 1838)
- Township plat maps were originally drawn at the Surveyor General's office in Dubuque by drafters based on field notes and "rather crude sketches and plots" (Dodds 1943, p. 11)
- Township plat maps were originally drawn with colored ink in triplicate at a scale of 2 inches per mile
- Deputy surveyors each led a survey party typically consisting of two chainmen, one marker (axeman/mound builder), one flagman/teamster, and a cook
- Deputy surveyors were paid $2.75 to $3.25 per mile, who then paid other members of the survey party
- Members of a survey party could make "good money" if the weather was optimal (it often wasn't)

In 1838, the first federal land offices (similar to Figure 6) in Iowa were opened in Dubuque and Burlington (Sage 1974, p. 69). In 1842, offices were opened in Fairfield and Marion. Additional districts were established around Iowa City (1843); Chariton, Fort Des Moines, and Council Bluffs (1852); Fort Dodge, Sioux City, and Decorah (1855); and Osage (1856).

These offices had a purpose similar to the surveyors' descriptions of vegetation, topography, and soil in their field notes: to aid in the "disposal" of the land. Approximately one-third was sold for cash; more than one-third given away in the form of military bounties (Sage 1974, p. 70):

Figure 6. St. Cloud, Minnesota, Land Office, circa 1860.

Percent	Purpose
33.7	Cash sales
39.7	Military bounties
0.7	Agricultural college scrip locations
2.5	Homesteads
0.1	Timber claims
0.1	Miscellaneous
3.4	State grants for swamp and saline lands
4.9	State grants for education
3.2	State grants for river improvements and public buildings
11.7	State grants for railroad construction
100.0	TOTAL

"Many of the military bounty lands found their way into the hands of speculators, sometimes by the honest purchase of the warrants from soldiers who did not want to go west to take up their lands, sometimes, no doubt, by questionable transactions. Fortunate indeed was the veteran who took his warrants and immediately came out to Iowa...to cash in on his bonus by trading in the warrants for good black land, for future use or for sale. The veteran who held on to his warrant or his land stood to gain in a time of constantly rising land values. Not all were so provident--or so lucky" (Sage 1974, p. 69-70).

Hervey Parke (1790-1879) surveyed in Michigan, Wisconsin, and Iowa (over 30 townships) through blizzards, cholera, and the Black Hawk War. "He rarely complained, although once after a protracted snow storm left drifts up to 20 feet deep, he did mention that he found surveying in prairie country discouraging under those conditions" (Cazier 1977, p. 54).

Ira Cook (Figure 7) surveyed approximately 20 townships in Iowa, primarily in the northwest part of the state in the 1850s. During four months in 1852-53, his survey party received no news from the outside world, not even who had been elected U.S. president.

William A. Burt surveyed township lines in east central Iowa. He was a judge, soldier in the War of 1812, Michigan Territory legislator, Justice of the Peace, businessman, and postmaster. In his additional role as a survey examiner, he was known for his honesty, even when resurveys of his own contract work required considerable personal time and expense (Cazier 1977, p. 62). He was author of *A Key to the Solar Compass* and *Surveyor's Companion*. In 1836, Burt invented and patented the solar compass (Figure 5) which replaced the magnetic compass in public land surveys. His son Alvin was also a surveyor in Iowa.

Figure 7. Deputy surveyor Ira Cook.

According to the field notes (Volume 4, Book 21), an iron survey chain was 28 links per mile shorter in the winter than in the summer. "These remarks are made for the information of practical surveyors." The chain was not a practical design because it snagged twigs, branches, grasses, and muck. Chainmen regularly spent time cleaning and adjusting the chain.

Apparently, creativity in spelling was considered a virtue at the time of the Iowa survey. This was most apparent to us in the words "slue," "verry," and proper names of local features (especially those of Native American origin). Because of the lack of published maps, some local feature names had several spellings. For example, we noted eight different spellings for the Wapsipinicon River:

Wabisipinicon	Wapisipinic
Wabesipinicon	Wapisipinica
Wabisipinica	Wapsipinica
Wabisipinic	Wapsippinica

Surveyors sometimes were affected by conflicts between local inhabitants. "The foregoing list of names of the settlers and the improvements and land claimed by each will show their views and difficulties and conflicting interests resulting in the settlement of a new and unsurveyed county and it seems to show the necessity of some act of Congress regulating the rights and privileges of those who may hereafter settle on the unsurveyed public lands" (T77N, R1E, Muscatine County, William A. Burt, deputy surveyor, 1837).

Some surveyor descriptions of the general characteristics of the land were poetic and some were brief. "Broken prairie, soil first rate. On the bluffs herdsgrass, hazel and redroot abounds. In the ravines rushgrass, bluegrass, and willow prevails" (T80N, R2W, Cedar County, George VanZandt, deputy surveyor, 1837). "Their [sic] is no settlers in this Township nor any improvements of any kind whatever" (T91N, R15W, Butler County, Louis V. Davis, deputy surveyor, 1849).

"There is not wood enough in the whole of it to make a fire to bake a loaf of bread; nor is there in all enough of spring water that is palatable to make a cup of coffee...every here and there scattered among the dry prairies little marshes which receive the water from the rolling prairie and being thus made full remains so till the heat of the

summer dries them up by evaporation...so soon as the dry prairies are broken the soil will naturally wash down and fill them up." (T96N, R30W, Kossuth County, G. Temple, deputy surveyor, 1855).

One of the shortest township descriptions was made by deputy surveyor E.F. Lucas: "Of this township, much could be said. But it is deemed useless to say much" (T72N, R8W, Jefferson County, 1837).

One of the longest township descriptions was almost a treatise on government settlement and land disposal policy: "Settlements are making very rapidly and some have the appearance of an invention of the settler to improve and cultivate the soil and make himself a permanent home. Others evidently have no other object than specula [sic] in the publick [sic] lands, by dubbing together and extorting money from those who wish to make an honest settlement. Such should be excluded from the benefits of a pre-emption law if any passes Congress at their next session. Mob law, which is becoming too common in the nation, should be checked by every legislative enactment that can be made to bear upon it, but the honest, industrious settler deserves the favour of the government. Let the person applying for pre-emption be required to swear that he has not sold claims or speculated in the publick [sic] lands as a condition of his right to pre-emption" (T69N, R8W, Van Buren County, Uriah Biggs, deputy surveyor, 1837).

"The town of Adel, the county site of Dallas, is located on section 29. It has now six families, a post office, tavern, store, and family grocery" (T79N, R27W, Dallas County, Wm. Henderson, deputy surveyor, 1849).

Discussions of settlement, pre-emption rights, and disputes among settlers is one reason we avoided the term "pre-settlement" vegetation that many other researchers used in the literature. The other reason related to the prior inhabitants: "...that it has been a favorite resort of the red man is proved by the many recent indications of his presence" (T83N, R18W, Marshall County, S.W. Durham, deputy surveyor, 1847). ...12 wigwams (T70N, R9W, Van Buren County, E.F. Lucas, deputy surveyor, 1837). ...grave of Chief Black Hawk (T70N, R12W, Davis County, Paul C. Jeffries, deputy surveyor, 1843). "In the southwest corner, however, there are about 15 acres of very heavily timbered land, chiefly black and white oak, and some hickory. This has been considered a favorite hunting region by the Indians and there is a band of them now on the ground" (T82N, R11W, Benton County, A.L. Brown, deputy surveyor, 1844). "But now the scene is changed, from what it was a few years ago, the rifle of the Indian hunter and the axe of the dusky maiden no longer resound through the forest...the flag still waves over the graves of the deceased warrior, but his comrades are gone to distant lands and he now sleeps on the soil of the white man, soon perhaps to be disturbed by the ploughshare of the adventurous American" (T95N, R9W, Fayette County, Hugh Treynor, deputy surveyor, 1848).

Other surveyors commented on the difficulty of classifying and mapping vegetation: "In places the timber is standing thick, then is scattering, that it is hard to distinguish between timber and prairie" (T71N, R9W, Jefferson County, E.F. Lucas, deputy surveyor, 1837). "The most of the land, returned as prairie, might perhaps with as much propriety be called barrens or openings, as there could be found upon it occasionally a scrubby oak or hickory but I have thought it would be more readily known by the description of <u>prairie</u>, and I have therefore designated it as such" (T86N, R4E, Jackson County, Moses M. Strong, deputy surveyor, 1837). "This township may be said to be a waste of Prairie--hilly or broken and totally unsuitable for agricultural purposes except grazing" (T82N, R19W, Marshall County, Wm. G. Ross, deputy surveyor, 1847) "This township is all rich rolling prairie and nothing more can be said of it worthy of notice or that would excite public curiosity" (T83N, R10W, Benton County, I. Higbee, deputy surveyor, 1843). "This township has not so many basins and sloughs as the others. They are near the dividing ground" (T81N, R27W, Dallas County, Wm. Henderson, deputy surveyor, 1849). "The whole country is covered with small ponds, sometimes the depth of 2 and 3 feet" (T79N, R26W, Dallas County, James Davis, deputy surveyor, 1847).

Other surveyors found interesting places to comment on: "I hve [sic] found myself surrounded by snakes of enormous size and concluded to back out and raise a reinforcement that being done and all well equipped with clubs we commenced the attack and soon succeeded in driving the enemy into their stronghold but not untill [sic] 11 were slain. The fight was a spirited one of short duration. The slain were piled at the entrance of the den to warn the inmates to beware of a surveying party. They were the large mountain snake in length from 4 to 5 feet, some of which had 17 rattles" (T88N, R3W, Delaware County, Milo Jones, deputy surveyor, 1837). "In the northwest corner of section 7 there is a curious spring having a rim around it some 20 inches high, sufficiently strong for men to walk upon. The rim has the colour of sand stone but has little or no grit in its composition. It

is almost as light as cork and seems to be composed of moss petrified. It is called Curiosity Spring." (T81N, R29W, Dallas County, Wm. Henderson, deputy surveyor, 1851).

Other surveyors expressed their feelings about the land in a more personal way: "The surface Rolling...but the principal as it were in Billows (not mountain high)" (T71N, R30W, Union County, W. Leffler, deputy surveyor, 1849). "Level and marshy, whole line a very fine frog pond" (T69N, R41W, Fremont County, J. Pierson, deputy surveyor, 1852). "Soil generally dry, mixed with sand, fertile, of a kind warm nature, and very productive" (T72N, R41W, Mills County, JHB. Street, deputy surveyor, 1851). "Not a stick of timber, not even a riding switch can be found growing in this township" (T73N, R31W, Union County, S. Woodworth, deputy surveyor 1849). Assistants Monroe and Delaney proved incompetent" (T71N, R37W, Montgomery County, P. Moriarty, deputy surveyor, 1851). "John Phillips Jun...left for Keokuk assigning no other reason than his wages would not keep him in pantaloons & boots" (T69N, R35W, Taylor County, W. Dunn, deputy surveyor, 1851).

B. Research on GIS descriptive models

The digitized files provide data for land managers and researchers to analyze vegetation quantity and distribution during the period 1832 to 1859. Arc/Info and other Geographic Information System (GIS) software can be used to create descriptive models for the new vegetation data alone and for combinations of data layers (for example, vegetation and soils).

In Iowa, past work in description of vegetation data from GLO township maps was carried out by Dick-Peddie (1955), Anderson (1974), and Thomson (1987). Paul Anderson's 1974 MLA thesis (*Vegetation Information in County Resource Planning*) included a discussion of vegetation history in Story County. The study incorporated early GIS technology and databases, including a time-series comparison of timber acreages from several data sources. The data sources included GLO township maps, 1875 Andreas Atlas, 1902 County Atlas, early USGS topographic quadrangles, ISU theses, and other local map sources. Though Anderson compared area measurements from these different data sources, he was not able to do descriptive models with GIS software. This was because data were digitized only for existing (1972) vegetation; other sources of vegetation data were not digitized as part of his thesis research.

Michael Miller's recent (1995) thesis research made use of Arc/Info and other GIS software, advantageous tools that past researchers did not have. Miller made arrangements to obtain GIS data layers for Fayette County that he was using for GIS descriptive models. The data layers were from the Natural Resources Geographic Information System (NRGIS), which is maintained by DNR as an FTP site on the Internet. Data layers included vegetation from GLO township maps, soil associations, transportation, streams, Public Land Survey System (PLSS) lines, existing land use, and others. Descriptive models in the research included the following:

1. Maps of vegetation types aggregated over areas larger than one county
2. Maps with vegetation types aggregated into fewer map categories
3. Maps with subsamples of points or transects along section lines
4. Quantitative measures of vegetation types (such as acres, hectares, and percent of study area)
5. Maps of vegetation distribution correlated with other land features (soils and existing land cover)
6. Maps of vegetation distribution correlated with other vegetation maps (such as 1875 Andreas Atlas, 1902 Atlas, early USGS topographic quadrangles) for comparative and time-series studies
7. Statistical measures of correlations between vegetation and other land features

Statistical measures included basic descriptive statistics (frequencies, mean, median, mode, standard deviation, and confidence intervals). They also included measures of correlation (coefficient of areal correspondence).

These map models also help in evaluating the quality, reliability, and limitations of the digitized vegetation data. In this way, the data can be used wisely in an appropriate way with the knowledge of its limitations due to survey methods of the 1832-1859 period.

VI. PROJECT EVALUATION

A. Project progress and organization

Based on our experiences in Phase One of the research, we were able to design Phases Two, Three, and Four to be more efficient. Phases Two, Three, and Four were more efficient for four reasons.

First, we were able to use the Microfilm Directory Database we created in Phase One to select counties for digitizing and prepare the maps for printing. The only work on the Database during Phase Two was the addition of a new field for surveyor descriptions of the townships. In Phase Three, we added information about the Historical Society microfilm to the Database.

Second, the new procedure for checking the AutoCAD drawing files and converting them to Arc/Info format using ArcCAD saved a estimated 14 hours per county.

Third, Michael Miller read the field notes and annotated the township maps, as he did in Phase One. His experience and the resulting consistency in interpretation added to our efficiencies in Phase Two. In Phase Three, Michael trained Robin McNeely to help with annotation. Robin did most of the annotating for Phase Three counties and all of the annotating for Phase Four counties.

Fourth, many counties selected for Phases Two, Three, and Four were located in central and western Iowa. These counties generally had less complex vegetation patterns than counties in eastern Iowa (which we did in Phase One). Also, surveyors of these counties were more consistent in map making than those of eastern counties. In Iowa, eastern counties were surveyed first, then central counties, then western counties last. Apparently, survey procedures were clarified and more explicit by the time surveyors got to central counties and western counties.

The result of these four efficiencies was digitizing 25 counties in Phase Two in approximately the same amount of time and with approximately the same amount of funding as digitizing 14 counties in Phase One. In Phase Three, we digitized 31 counties approximately in the same amount of time. In Phase Four, we digitized 29 counties in approximately the same amount of time.

An additional source of efficiency became apparent while we were researching the four sets of microfilm that we used so far. The Secretary of State microfilm that we used in all phases contains surveyors' field notes typed before 1938 as part of a WPA project. The typed field notes were much faster to read than the original handwritten (manuscript) notes from the surveyors' field books. This made the map annotation task more efficient (however, perhaps with a loss in accuracy due to typographical errors).

In Phase Three, three graduate students (Michael Miller, Robin McNeely, and Shuangyan Li) and two other student research assistants (Jane Chen and Julie Anderson) worked on the project. In Phase Four, three graduate students (Michael Miller, Robin McNeely, and Jane Chen) and two other student research assistants (Julie Anderson and Dana Watson) worked on the project. Miller's responsibilities included helping select counties for digitizing, printing township maps from microfilm, helping train other research assistants, writing AutoLISP macro commands, checking and editing completed county map files, and converting completed AutoCAD drawing files into Arc/Info format using ArcCAD. McNeely's responsibilities included reading field notes and annotating maps, digitizing township maps, and helping train other research assistants. Anderson was responsible for digitizing township maps with AutoCAD. Anderson, Chen, and Watson were responsible for visually checking digitized maps by comparing them to the township maps printed from microfilm. Anderson was also responsible for compiling and entering the additional data for the Microfilm Directory Database and for editing the final report. Three of these five students also worked on Phases One and Two. This continuity in research staff reduced training time and provided consistent data quality.

The principal investigator (Paul Anderson) was responsible for hiring and training research assistants, designing the original digitizing procedures, selecting counties for digitizing, obtaining equipment and materials, obtaining microfilm, designing the Microfilm Directory Database, writing AutoLISP macro commands, drawing Iowa index maps, checking completed county files (quality control), writing the progress report and final report, and project administration.

During most of the project period, we worked on the project part time because classes were in session. During semester break in January, spring break in March, and semester break in May and June, most of us spent most of our time working on this project. Six people working on the project seemed to be an appropriate and manageable number. Though we were constantly busy, the six of us were able to complete the project without feeling rushed. This helped in minimizing the number of mistakes and corrections while maximizing productivity.

B. Comparison with other digitizing projects

Other GIS research projects conducted in the past also prepared us for this vegetation digitizing project. Many of these other projects involved preparing large GIS databases containing ten or more data layers, each with one-quarter to one-half million data points per data layer. Projects included GIS databases for the Raccoon River Greenbelt (Dallas County Conservation Board), Guatemala Rural Development Plan (U.S. Agency for International Development), Iowa Tourism Video Database (Iowa Department of Economic Development), Protected Water Areas Inventory and Rating System (Iowa Department of Natural Resources), Zambia Rural Development Plan (U.S. Agency for International Development), Loess Hills Pioneer State Forest Database (Iowa Department of Natural Resources), and Iowa Soil Survey Information System (Iowa Department of Agriculture and Land Stewardship). Many of these projects involved the expertise of the Land Use Analysis Laboratory at Iowa State University. The Land Use Analysis Laboratory (which Paul Anderson helped found in 1972) is an interdisciplinary research group at ISU that conducts research on GIS technology and databases.

In comparison with the GIS digitizing projects listed above, this vegetation digitizing project was relatively small and uncomplicated. Frequent discussions with DNR staff helped make decision-making and project coordination easier than in many of these other projects.

C. Data quality

Several issues relating to data quality concern us. These issues should also concern land managers and researchers who use GLO township maps, surveyors' field notes, or the vegetation map files that were digitized in this project from the maps and notes.

1. Quality and consistency of the field observations by GLO surveyors
2. Quality and consistency in recording field observations in the notes by GLO surveyors
3. Quality and consistency in translating the notes into maps by GLO surveyors and drafters
4. Quality and consistency in typing the GLO field notes by WPA typists
5. Quality and consistency in creating the microfilm copies by the Secretary of State's Office
6. Quality and consistency in reading the notes and annotating the GLO maps by ISU researchers
7. Quality and consistency in understanding and interpreting the GLO maps by ISU researchers
8. Quality and consistency in digitizing the GLO maps by ISU researchers

The first five issues we had to accept and were beyond our control. We used the materials available to us on microfilm without consulting the original paper copies of the surveyors' notes and maps. Though we did read books about surveyors and their methods, we did not locate any personal journals or historical accounts that would give additional details about the counties we digitized.

One source of inconsistency in vegetation description and classification was the variability among 187 different deputy surveyors working in Iowa. Their cultural and educational backgrounds influenced their descriptions and their choice of terms (Schroeder 1983, p. 6). Another source of inconsistency was changes over time in GLO General Instructions to deputy surveyors from the Surveyor General. During the 1832 to 1859 period that Iowa was being surveyed, there were seven revisions of General Instructions (1831, 1834, 1843, 1846, 1850, 1851, and 1855) (Dodds 1943). During the period, General Instructions became more explicit, especially about data required on township maps and in field notes. General Instructions from 1831 (Dodds 1943, p. 28, 32) were relatively short and vague regarding vegetation data:

> Swamps are to be represented in the ordinary method by slightly shaded black lines and dots, and the outlines of the same should be distinctly exhibited. Prairies are to be represented by slightly shaded green lines and dots, and the outlines of the same are to be distinctly exhibited.

> Every surveyor shall note in his field book the true situation of all mines, salt licks, salt springs, and mill sites which shall come to his knowledge, all water courses over which the line he runs shall pass, also the quality of the lands.

By 1855, General Instructions (Dodds 1943, p. 129-131) were much longer and more specific regarding vegetation data:

> The field notes afford the elements from which the plats and calculations in relation to the public surveys are made. They are the sources wherefrom the description and evidence of locations and boundaries are officially delineated and set forth. They therefore must be a faithful, distinct and minute record of everything officially done and observed by the surveyor and his assistants, pursuant to instructions, in relation to running, measuring, and marking lines, establishing boundary corners, &c; and present, so far as possible, a full and complete topographical description of the country surveyed, as to every other matter of useful information, or likely to gratify public curiosity.
>
> The description of the surface, soil, minerals, timber, undergrowth, &c., on each mile of line, is to follow the notes of survey of such line, and not be mixed up with them.
>
> With the notes of the exterior lines of townships, the deputy is to submit a plat of the lines run, on a scale of two inches to the mile, on which are to be noted all the objects of topography on line necessary to illustrate the notes, viz: the distances on line at the crossings of streams, so far as such can be noted on the paper, and the direction of each by an arrowhead pointing downstream; also the intersection of line by prairies, marshes, swamps, ravines, ponds, lakes, hills, mountains, and all other matters indicated by the notes, to the fullest extent practicable.
>
> *Summary of Objects and Data Required to be Noted*
>
> 1. The precise length of every line run, noting all necessary offsets therefrom, with the reason and mode thereof.
> 2. The kind and diameter of all "bearing trees," with the course and distance of the same from their respective corner; and the precise relative position of witness corners to the true corners.
> 3. The kind of materials (earth or stone) of which mounds are constructed--the fact of their being conditioned to instructions--with the course and distance of the "pits," from the center of the mound, where necessity exists for deviating from the general rule.
> 4. Trees on line. The name, diameter, and distance on line to all trees which it intersects.
> 5. Intersections by line of land objects. The distance at which the line first intersects and then leaves every settlers claim and improvement; prairie, river, creek or other "bottom"; or swamp, marsh, grove, and windfall, with the course of the same at both points of intersection; also the distances at which you begin to ascend, arrive at the top, begin to descend and reach the foot of all remarkable hills and ridges, with their courses, and estimated height, in feet, above the level land of the surrounding country, or above the bottom lands, ravines, or waters near which they are situated.
> 6. Intersections by line of water objects. All rivers, creeks, and smaller streams of water which the line crosses; the distance on line at the points of intersection, and their widths on line. In cases of navigable streams, their width will be ascertained between the meander corners, as set forth under the proper head.
> 7. The land's Surface--Whether level, rolling, broken, or hilly.
> 8. The soil--Whether first, second, or third rate.
> 9. Timber--The several kinds of timber and undergrowth, in the order in which they predominate.
> 10. Bottom lands--To be described as wet or dry, and if the subject to inundation, state to what depth.
> 11. Springs of water--Whether fresh, saline, or mineral, with the course of the stream flowing from them.
> 12. Lakes and Ponds--Describing their banks and giving their height, and also the depth of water, and whether it be pure or stagnant.
> 13. Improvements--Towns and villages; Indian towns and wigwams; houses or cabins; fields or other improvements; sugar tree groves, sugar camps; mill seats; forges, and factories.

The list continued with seven more items concerning landforms, mines, water features, natural curiosities, and cultural features, ending with “a general description of the township in the aggregate, as respects the face of the country, its soil and geological features, timber, minerals, water, etc.” (Dodds 1943, p. 132). Surveyors were also instructed not to name features themselves, but to use only locally-given names for features on their township maps and in field notes.

After working with township maps and field notes for four years, we saw similarities in townships due to writing style, completeness of notes and maps, and drafting quality. Some surveyors and some drafters were quite meticulous and complete in their work while others were vague and incomplete. As mentioned earlier in this report, this made some counties more difficult to digitize than others.

Some of this uncertainty, vagueness, and inconsistency was understandable considering the constraints the surveyors were working under. The U.S. Government wanted to complete the survey as quickly as possible. With low land prices and development pressures, surveyors were encouraged to meet but not exceed minimum GLO standards. We realized, after we began to read some of the literature listed in Appendix I, that describing the vegetation and other natural resources of the land was secondary to land subdivision when the GLO surveyed Iowa. Many of the surveyors had little knowledge of vegetation and natural resources. “The distinction between forest and prairie and wetland may well have been more vague than we can now imagine...” (Thomson 1987, p. 120). Surveyors were instructed to describe the land as an aid to disposal and sale, not as scientific observations. “This township contains neither stone, springs, or timber and will probably none of it sell except a section or two in the southwest corner” (T72N, R5W, Henry County, Samuel Goodnow, deputy surveyor, 1837).

We also must remember that most of the GLO observations were in *transects along section lines*. Only for meandered (larger, potentially navigable) streams were surveyors instructed to walk away from section lines. In this sense, the field observations record linear samples of the vegetation, with quantitative data (distances) along section lines and qualitative data (words and map sketches) for the rest of the area that surveyors could see as they surveyed section lines. So, the deputy surveyors had little information about the interior of each section. “Sometimes the interior [section] lines of a township were run several years after the exterior lines by a different survey crew. This creates a problem in precise interpretation of survey field notes” (Schroeder 1983, p. 5).

Where the deputy surveyor's “rather crude sketches and plots” (topographies) were missing vegetation boundaries and labels, drafters at the Surveyor General's office in Dubuque may have filled in some of the missing information with help from field notes or recollections of deputy surveyors (Dodds 1943, p. 11). In many cases, they must have mapped vegetation boundaries using data points (distances) along section lines then connected them with straight-line interpolations if no other information was available to guide them. “Detailed reading of the survey notes casts considerable doubt upon both the definition of the forest then existing and the exact positioning of the forest boundary lines...there is reason to doubt that the forest boundaries drawn at the time of survey would satisfy today's ecologist, forester, farmer, tax assessor, or surveyor” (Thomson 1987, p. 120).

Where vegetation lines were missing from GLO township maps, we used the straight-line interpolation method described in the previous paragraph. On some occasions, other landform or water features shown on the maps guided us in drawing vegetation boundary lines. For example, in the absence of more definitive information from the field notes, a river or bluff line was used as a vegetation boundary. We made a concerted effort to read and reread field notes when the maps and notes were inconsistent or contained discrepancies. A common example of this was edge matching vegetation boundaries across township lines. It seems that this was seldom a concern of GLO surveyors; often, neighboring townships were surveyed by different deputy surveyors. They and the map drafters made little or no attempt to edge match adjacent townships. Our only recourse in edge-matching township maps was to connect open ends of vegetation boundaries with straight lines.

We also made a concerted effort to check the digitized vegetation files for open polygons, polygon slivers, missing or duplicate label points, and incorrect labels. As described in Section IV-E of this report, we used a variety of visual and data processing checks to detect and correct these types of errors. We performed all checks at least twice on every county we digitized. However, as with all large databases, the possibility exists that a few of these types of errors remain undetected.

As stated earlier in this report, GLO notes and maps are considered one of the best data sources about the vegetation of Iowa before the state was changed to agricultural landscape. Land managers and researchers who use this data source must also be aware of the quality and limitations of the data so they are used in an appropriate way. For these reasons, we believe that our related work on GIS descriptive modeling is important. Also, data modeling results will yield an even greater understanding of the quality of the GLO vegetation data.

D. Digitizing observations for each county

As described in Section IV-E of this report, there were several reasons why the amount of time required per county varied considerably. In some counties, the township maps were quite complete with vegetation lines and labels. Other counties had township maps with few vegetation lines and labels, requiring more intensive reading of the surveyors' field notes. Also, in some counties (particularly those with many wetlands or major rivers) the vegetation pattern was quite complex, with many vegetation types, many small polygons, and very crenulated lines. Counties without many wetlands or major rivers had a simpler vegetation pattern on the maps, requiring less time for reading field notes, annotating maps, and digitizing lines.

As we digitized each county, we recorded observations, concerns, surveyor quotes, and time in a log book. This was particularly helpful in highlighting obstacles and peculiarities specific to each county.

1. Adair County. This county took relatively little time (seven hours) to annotate and digitize because of its predominance of prairie. Narrow areas of tree cover followed stream valleys. In a number of places, what the surveyor called timber in one township was called timber/scattering/openings by the surveyor in the adjacent township. Vegetation boundaries matched fairly well across township lines. (Phase 3)

2. Adams County. There were relatively few vegetation types (seven) identified by surveyors. Tree cover consisted of small, isolated patched of timber and grove. Only one large timber area was mapped in the Adams County (T73N R33W and T73N R34W). According to the surveyor's notes there was much evidence of muskrats in Adams County. (Phase 3)

3. Allamakee County. Most of Allamakee County was mapped by the surveyors as timber/scattering/openings, although most of the southern tier or townships (and one township in the north) were mapped as timber. Two portions of the county along the Mississippi River were difficult to digitize because they contained backwater areas. These backwater areas were labeled by surveyors as river channels, sloughs, marshes, lakes, and bayous with islands in between. These areas were the most complex braided channel patterns of the river counties we digitized. The surveyor's notes described a "pressipis" and "untutored savages." In T100N R4W, surveyors found "a large fossilized slug." (Phase 3)

4. Appanoose County. Vegetation types did not match up well across township lines, causing many vegetation lines to follow township lines. Many small fields indicate a significant population before surveyors completed Appanoose County. (Phase 3)

5. Audubon County. The largest non-prairie area in Audubon County shown on the GLO maps was described as "timber/barrens" (TBR). This area is along the East Nishnabotna River in the vicinity of Exira and Brayton. In 1852, deputy surveyor J. Street said about T81N R35W "this township embraces a fine body of rolling prairie." (Phase 4)

6. Benton County. The surveyors in Benton County cited numerous instances of Native American settlement. In T82 R11W the description at the end of the township survey described a tract of ground that was considered a favorite hunting region of the Indians. Furthermore, this same township listed an area of "Indian diggings" between sections 27 and 28. (Phase 2)

7. Blackhawk County. There were eleven different vegetation types in this county (about average in Phase One). However, the vegetation pattern was not very complex. One township (T87N R13W) was a single vegetation type (prairie). Most of the GLO township maps were complete with vegetation lines and labels, so little annotating was required. We think that Blackhawk was typical of what many other counties in central and western Iowa will be like to digitize. (Phase 1)

8. Boone County. There was one large area of TIMber through the county with many MARshes and PONds on each side. A new vegetation type had to be added here, POOl. Because there were no PONds listed in that particular township, POOl could have been the deputy surveyor's name for a pond. (Phase 2)

9. Bremer County. A new vegetation type was added to the list for Bremer, Decatur, Franklin, Howard, Jones, Madison, Ringgold, Winneshiek, and Worth: TBR (timber/barrens). This represented another combination of terms used by surveyors that was different than any of the existing vegetation types on our list. Annotating and digitizing required relatively little time (five hours) because the county is smaller than average and had a predominance of prairie. (Phase 3)

10. Buchanan County. This county took relatively little time to digitize. Vegetation boundaries closely matched along township lines. The northeast corner of the county was interesting because of the large number of MARshes shown by the deputy surveyor. (Phase 2)

11. Buena Vista County. Storm Lake is clearly shown in T90N R37W. Few vegetation types other than prairie are shown in Range 38, which correlates closely with the lateral moraine of the Des Moines Lobe of the Wisconsinan glaciation. In T91N R35W, deputy surveyor J. Nowlin mentioned several mounds, "some 50 feet high." Surveyor W. Smith observed "some romantic mounds" in T92N R37W. On a different theme, surveyor G. Temple said that T93N R38W "has a variety of surface and soil, the bottoms form the luxuriant growth of grass and weeds found on them, cannot be surpassed for richness." (Phase 4)

12. Butler County. Butler contained small wetlands both on the uplands and along streams, where they were called slues [sic] or bayous. One surveyor commented in his field notes that the "left bank of the Shell Rock was high and handsome." (Phase 3)

13. Calhoun County. A high concentration of wetland vegetation types (pond, marsh, lake, slue, and swamp) are mapped in Tier 89, Ranges 31 and 32. This area contains Twin Lakes. Both townships were surveyed by G. Berry in June and July of 1854. According to deputy surveyor R. Anderson, "water fit to drink is very hard to get, that in marshes being exceedingly repulsive and unhealthy" (T89N R33W). In sections 2 and 3 of T88N R34W, surveyor J. Harlan described "ponds mostly covered with a coarse grass, forming a very strong sod. Sod frequently floats on the surface of the water." (Phase 4)

14. Carroll County. Most of the large polygons mapped in Carroll County are TIMber along the North Raccoon River and Middle Raccoon River. Two large riparian MARshes were mapped in T82N R33W and T83N R33W. In July 1851, deputy surveyor H. Waldo described a 500-acre "floating marsh" in T83N R33W in which "the sod under our weight sunk and rose about two feet." In November 1852, deputy surveyor Ira Cook said about T84N R35W "there is scarcely anything in this township worthy of notice." (Phase 4)

15. Cass County. Cass County was predominantly prairie with relatively few fields, wetlands, and timber areas. One township was mapped entirely as prairie (T75N R34W) and two townships each contained only one small timber or marsh area. (Phase 3)

16. Cedar County. This was the first county we digitized in Phase One. The GLO maps for Cedar County were, by far, the most complete and easiest to annotate. Most vegetation lines were complete and most vegetation polygons were labeled clearly. Edge matching between township maps was uncomplicated, resulting in very logical closed polygons. (Phase 1)

17. Cerro Gordo County. The vegetation pattern mapped in Cerro Gordo County was very different in the eastern half of the county than in the western half of the county. This pattern was not unexpected because the lateral moraine of the Des Moines Lobe of the Wisconsinan Glaciation was positioned through the middle of the county in a north-south orientation. Many small prairie potholes were mapped in the glaciated western portion of the county. In contrast, few wetlands were mapped in the Iowan Erosion Surface eastern portion of the county. In T95N R20W, surveyor S. Durham described "beaver dams made with ingenuity that would do credit to the human species." Clear Lake was described as "a very romantic place." On February 16, 1853, surveyor James Smith reportedly "froze his hands and feet so bad" he couldn't work. (Phase 3)

18. Cherokee County. Vegetation types containing trees are concentrated along the Little Sioux River corridor in a northeast to southwest direction. MARsh and WETland polygons are located both in the river valley and the uplands to the west. In June 1855, deputy surveyor S. Durham noted a great amount of beaver activity in T90N R39W. (Phase 4)

19. Chickasaw County. A new vegetation type was added to the list for Chickasaw, Howard, and Winneshiek: VIL (village). Another new vegetation type was added to the list for Chickasaw County: BOG. The surveyor for T94N R11W (P. Skinner) identified a small wetland area in sections 8 and 17 as bog. This was the only county we've digitized that contained what the surveyor called bog. Townships in tier 97 were split between this and Howard County. One of the largest fields we've digitized in the state was near the southwest corner of the county (T94N R14W). (Phase 3)

20. Clarke County. Clarke County had an unusually low number of different vegetation types identified by surveyors. Five different vegetation types were mapped by four different surveyors. (Phase 3)

21. Clay County. After adding the new vegetation category "meadow" (MEA) to our list for O'Brien County, we encountered it again in Clay County T97N R37W. Dan Greene Slough, Trumbull Lake, Round Lake, and Lost Island Lake were mapped by surveyor J. Pierson in T96 and 97N R35W. Because we had already used the four-letter county abbreviation CLAY for Clayton County, we used CLAW for Clay County. (Phase 4)

22. Clayton County. Townships in Range 5 and Range 6 were difficult to edge-match. One township (T91N R4W) was a single vegetation type (timber). (Phase 1)

23. Clinton County. In Tier 80 and Tier 81, the county boundary between Clinton and Scott approximates the Wapsipinicon River. Because the GLO township maps show the county boundary along the township line, we digitized complete townships rather than partial townships in Tier 81 of Clinton County. This county had the most vegetation types in Phase One (sixteen). (Phase 1)

24. Crawford County. Many non-prairie vegetation types were mapped by GLO surveyors in and near the Boyer River valley. In June 1853, surveyor J. Williams mapped a high concentration of wetland vegetation types (marsh, wetland, and "slue") in Tiers 83, 84, and 85 of Range 40. Williams described the ground in T83N R40W as "oozy and bushy" with "hossblendi rock." (Phase 4)

25. Dallas County. The deputy surveyors' notes for this county made mention of the potholes so common across the early landscape of north-central Iowa. Though only the larger ones were actually shown on the township maps, many of the descriptions mentioned small ponds (sometimes to the depth of 2 or 3 feet) covering much of the township. (Phase 2)

26. Davis County. Vegetation boundaries on the township maps in Davis County matched quite well along the township boundaries, creating logical vegetation patterns across the county. The TSO vegetation type (timber/scatterings/openings) was used in this area. TIMber in this county followed the major stream corridors, with TSO vegetation occurring far away from these corridors. (Phase 2)

27. Decatur County. A new vegetation type was added to the list for Bremer, Decatur, Franklin, Howard, Jones, Madison, Ringgold, Winneshiek, and Worth: TBR (timber/barrens). This represented another combination of terms used by surveyors that was different than any of the existing vegetation types on our list. Another new vegetation type was added to the list for Decatur, Floyd, Jones, Winneshiek, and Worth: TSB (timber/scattered trees/barrens). One of the largest fields we've digitized in the state was near the northeast corner of the county (T70N R24W). (Phase 3)

28. Delaware County. The field notes for this county had one of the most interesting comments by a deputy surveyor. In T88 R3W, the surveyor found his survey party surrounded by rattlesnakes and his description of the situation made interesting reading. "I hre [sic] found myself surrounded by snakes of enormous size and concluded to back out and raise a reinforcement that being done and all well equipped with clubs we commenced the attack and soon succeeded in driving the enemy from their stronghold but not untill [sic] 11 were slain the fight was a spirited one of short duration the slain were piled at the entrance of the den to warn the inmates to

beware of a surveying party they were the large mountain snake in length from 4 to 5 feet some of which had 17 rattles." (Phase 2)

29. Des Moines County. This was one of the more difficult counties to annotate and digitize in Phase Two. Reasons include its close proximity to the Mississippi River and the large amount of settlement before the survey was completed in 1836. These factors created high diversity (17 vegetation types) and interspersion (many small vegetation polygons, including settlers' fields). We encountered a similar situation in Dubuque County. The area in the middle of the Des Moines County that did not seem to follow the same vegetation pattern was probably due to the difficulty surveyors had in describing the vegetation influenced by settlers. (Phase 2)

30. Dickinson County. As expected, GLO township plat maps for Dickinson County included many wetland vegetation types, including larger, well-known lakes: West Okoboji, East Okoboji, Center, Spirit, Little Spirit, Swan, Minnewashta, Lower Gar, Prairie, Pleasant, Lily, Four-Mile, Diamond, Hottes, Marble, and Silver. In T99N R36W, the vegetation pattern is complicated and several vegetation boundary lines were missing in sections 11/14 and 17/18. We used straight-line interpolation to enclose TIMber in section 7 between the SLUe and the LAKe and in section 8 between the LAKe and the MARsh. (Phase 4)

31. Dubuque County. Because Dubuque County was one of the first counties we digitized in Phase Two, it presented a number of new circumstances. The first was the addition of two new vegetation types. For the first time, we ran into a major settlement (Dubuque) that was described on the map as area data and not point data (it had a hard line around it rather than just a few point symbols). This new type, CITy, was used in several other counties, but only when a hard outline or broken line was used to represent area data. In Phase Two, we classified several areas in Dubuque and Des Moines Counties as BROken. However, in Phase Four they were reclassified due to our additional research about the surveyors' use of the topographic term "broken." (Phase 2)

32. Emmet County. GLO surveyors mapped a variety of wetland and water types in a matrix of prairie, a pattern typical of the Des Moines Lobe of the Wisconsinan glaciated area of north-central Iowa. In 1859, deputy surveyor C. Estes described T98N R34W as a "prairie township with nothing worthy of particular notice." A witness tree for the quarter corner between sections 14 and 15 in the same township was described as "Balm of Gilead." Surveyor P. Harvey described a "marsh, which is a quaking bog" in sections 33 and 34 of T100N R31W. According to Harvey, sections 27 and 28 contain "fine 40 acres of swamp land" (T100N R33W). (Phase 4)

33. Fayette County. Most of the GLO township maps were easy to annotate. However, there were a few edge-matching problems, particularly in T95N R7W and T95N R8W. The pattern of small marsh areas created a strong northwest to southeast diagonal across the county. (Phase 1)

34. Floyd County. A new vegetation type was added to the list for Decatur, Floyd, Jones, Winneshiek, and Worth: TSB (timber/scattered trees/barrens). This represented another combination of terms used by surveyors that was different than any of the existing vegetation types on our list. Townships in tier 97 were split between this and Mitchell County. Vegetation boundary lines matched up fairly well across township lines. However, often surveyors described the vegetation type in slightly different terms on each side of the township lines. One deputy surveyor (L. Hodges) reported in his field notes that "John Clark froze his feet and 3 men froze fingers, toes, faces, and noses." He also commented that there were many beavers, but no other settlers. "Flood Creek was not inappropriately christened." (Phase 3)

35. Franklin County. A new vegetation type was added to the list for Bremer, Decatur, Franklin, Howard, Jones, Madison, Ringgold, Winneshiek, and Worth: TBR (timber/barrens). This represented another combination of terms used by surveyors that was different than any of the existing vegetation types on our list. As in Cerro Gordo County, the eastern half of the county had relatively few wetlands. In contrast, the western half had many small wetlands (the surveyors called marsh or pond) due to the effects of glaciation. One surveyor provided in his field notes a long description of game: buffalo (killed some), elk, coons, badgers, and beavers. (Phase 3)

36. Fremont County. A complex pattern of vegetation types was mapped by surveyors along the Missouri River (western edge of the county) and along the Loess Bluffs (primarily Range 42). An unusually crenulated vegetation boundary was mapped in T69N R43W between TIMber and PRAirie. This vegetation line followed

surveyor J. Pierson's hachure representation of the western edge of the Loess Hills. In T67N R42W, we encountered a new vegetation type, willows (WIL). This is the only place in the state that the deputy surveyor described as "willows." Other places in the state described as "willow thicket" were digitized as thicket (THI). In June 1852, deputy surveyor J. Pierson noted in T69N R41W that "mosquitoes were thick and large" and "the whole line is a fine frog pond." (Phase 4)

37. Green County. Dunbar Slough (T83N R32W) and Goose Lake (T84N R31W) appear on the GLO township plat maps. In T82N R32W, deputy surveyor H. Waldo described a mound "about 80 feet above the creek and is a conspicuous object from nearly every part of the township." In the same township, Waldo mapped a "marsh in the western part of the township that is floating in some places." Waldo described T83N R29W in which the "upland soil is mostly poor, being either gravel or else cold, wet, and sterile." While in T82N R31W, Waldo reported several changes in his survey party. He "exchanged A.L. Brown for Wm. Meyers on account of the lameness of the former." Later, Waldo also "exchanged Andrew Cosgrove for Louis Howard, the former having left the work for home." Surveyor S. Caldwell had similar problems while surveying T84N R29W. "Milton Robbins and Isaac Warner, chainmen, quit work on account of bad weather" November 4, 1852. (Phase 4)

38. Grundy County. This was one of the fastest counties to annotate and digitize in Phase Two. The relatively low amount of diversity in this county (six vegetation types) was consistent with some of the surrounding counties, but Grundy was obviously very much a prairie county. This was one of the reasons why Grundy County has one of the highest average Corn Suitability Ratings in the state. (Phase 2)

39. Guthrie County. The largest, most continuous timbered areas in the county are shown along the valley of the Middle Raccoon River. Most wetland vegetation polygons in the county are in the northeast quadrant, which corresponds to the flatter, poorly-drained landscape created by the Wisconsinan glaciation. (Phase 4)

40. Hamilton County. A typical prairie pothole pattern was mapped by surveyors, using primarily marsh, lake, and slue [sic]. Two linear stream corridors (Boone River and Skunk River) were obvious because of the pattern of timber and timber/scattering/openings. Several marsh areas mentioned in the surveyor's notes did not appear on the township maps. (Phase 3)

41. Hancock County. Large wetlands were mapped throughout the central part of the county. In the eastern half of the county surveyors mapped many small marshes and ponds. On October 6, 1854, surveyors had to stop surveying to "burn prairie and fight fire" (T96N R24W). (Phase 3)

42. Hardin County. This county took relatively little time to annotate. Most of the six vegetation types were clearly marked on the township maps. Where vegetation boundaries were missing, the field notes included enough descriptions to make drawing vegetation boundaries quite certain. The vegetation pattern in the county was relatively simple and the vegetation boundaries matched quite well along township borders. (Phase 2)

43. Harrison County. Many small wetlands were mapped by surveyors on the floodplain of the Missouri River. However, the channel of the Missouri River is much different now than in the 1850s, when GLO surveyors mapped it. DNR staff asked that we map GLO vegetation within the current state boundary as shown on the DNR section coverage from the Natural Resources Geographic Information System (NRGIS). Therefore, some areas mapped by the GLO surveyors were omitted from our digitized file because they were outside the current state boundary. Also, some areas not mapped by the GLO surveyors are within the current state boundary. These areas were digitized as RIVer. Though some parts of RIVer were shown on the GLO maps as river, other parts were not. GLO maps of townships in Nebraska from the National Archives would assist in removing the uncertainty of the areas digitized as RIV. For T79N R43W (sections 17 and 18), deputy surveyor A. Anderson said in his notes, "We crossed the NW corner of a large field belonging to a Saint." (Phase 3)

44. Henry County. This county was difficult to annotate because the GLO maps had very few vegetation boundaries. This county required more than average amount of time to read the surveyors' field notes and annotate the maps. Using the field notes, we plotted points on section lines where vegetation boundaries crossed. Then, we connected the points with straight lines. The field notes often mentioned agricultural fields but few of these fields were plotted on the maps by the GLO drafters. This county had the fewest vegetation types (six) of any county in Phase One. (Phase 1)

45. Howard County. A new vegetation type was added to the list for Chickasaw, Howard, and Winneshiek: VIL (village). Also, a new vegetation type was added to the list for Bremer, Decatur, Franklin, Howard, Jones, Madison, Ringgold, Winneshiek, and Worth: TBR (timber/barrens). This represented another combination of terms used by surveyors that was different than any of the existing vegetation types on our list. Townships in tier 97 were split between this and Chickasaw County. Vegetation lines matched up fairly well across township lines. Surveyor M. Burke commented in his field notes for T100N R14W that "Quaking Marsh is useless." (Phase 3)

46. Humboldt County. In his general description of T91N R28W, surveyor W. Smith described "the oak being what is termed barrens." However, Smith did not mention the term *barrens* in any of his notes taken along section lines. According to at least one method of measuring average slope, Humboldt County has the lowest average slope of any county in Iowa. This produced the pattern of relatively even distribution of small wetland vegetation types mapped throughout the county. Several large marshes were mapped in Range 27 by surveyors T. McCullogh and W. Smith. (Phase 4)

47. Ida County. The location of Ida Grove in T87N R40W was marked on the township plat map drawn by deputy surveyor J. Williams in July 1853. Williams also mapped a marsh in T86N R40W with an interesting and unusual (creative?) star pattern. In June 1853, deputy surveyor J. Sheller described section 3 of T87N R39W as "splendid farm land." Two years later, in nearby T89N R39W, deputy surveyor agreed, saying "as handsome a township in the state." (Phase 4)

48. Iowa County. Iowa County took the least time to digitize of any county we worked on in Phase One. However, in several townships (T79N R9W, T79N R10W, T80N R10W, and T81N R10W), there was a discrepancy between the vegetation type in the field notes and on the GLO maps (timber and oak barrens). In these cases, we digitized the vegetation type shown on the GLO map. We had to digitize Iowa County twice because the initial digital file was mistakenly replaced with an updated version of Keokuk County. Fortunately, redigitizing went quickly because Iowa County was the easiest of the fourteen counties and our new hardware and software was faster than the old. (Phase 1)

49. Jackson County. This county also borders the Mississippi River, making the vegetation pattern more diverse and complex than the other counties. For these reasons, it was similar to Des Moines County and Dubuque County. As in Phase One, the river and any land across the river but within the state boundary (as shown on the DNR township coverage file) were classified in this project as RIVer. (Phase 2)

50. Jasper County. In Jasper County, vegetation patterns seem to match up quite well between townships. However, there were many small vegetation polygons across the county, apparently along small valleys predominantly in a northwest to southeast direction. This was in contrast to other counties with larger river corridors that had more continuous linear vegetation polygons. This type of vegetation pattern analysis was quite appropriate for these data that result from this research project. (Phase 2)

51. Jefferson County. Digitizing this county was quite similar to digitizing Van Buren County because the vegetation patterns were similar (due to topography and settlement). Again, the TSO type was used to designate a combination of timber, scattering, and openings. Also, this county included areas in which the deputy surveyors described the vegetation as Part Prairie/part Timber (PPT). (Phase 2)

52. Johnson County. The surveyors seemed to have difficulty in distinguishing between timber, scattered timber, and barrens. Consistency was lacking. This made edge-matching between townships particularly troublesome. In Tier 77, the county boundary between Johnson and Washington approximates the Iowa River. Because the GLO township maps also showed the county boundary as the Iowa River, this was the boundary we followed when digitizing Johnson County. (Phase 1)

53. Jones County. A new vegetation type was added to the list for Bremer, Decatur, Franklin, Howard, Jones, Madison, Ringgold, Winneshiek, and Worth: TBR (timber/barrens). This represented another combination of terms used by surveyors that was different than any of the existing vegetation types on our list. Another new vegetation type was added to the list for Decatur, Floyd, Jones, Winneshiek, and Worth: TSB (timber/scattered trees/barrens). Though vegetation lines matched up fairly well across township lines, vegetation types did not.

The surveyor's notes mentioned numerous small marshes that were not mapped. In T86N R4W, where the prairie had been "recently burned," surveyors found buffalo horns and elk horns four and a half feet long. Surveyor's field notes for Jones County were reproduced twice in the microfilm. (Phase 3)

54. Keokuk County. The vegetation boundaries in Keokuk were quite crenulated, resulting in a complex vegetation pattern. This was especially true of the timber vegetation type. This county was one of the more difficult to digitize in Phase One, but surprisingly was one of the easier ones to edge-match. (Phase 1)

55. Kossuth County. Digitizing was quite time-consuming due to the large number of small wetlands mapped by the deputy surveyors, especially in the northern half of the county. Deputy surveyor T. McCulloch described T94N R27W as "interspersed with numerous small ponds or marshes rendering its settlement impracticable." A. Leech said of T95N R30W that "would timber be conveniently procured, it would be most excellent farming land." J. Snook described T100N R27W as "nothing worthy of note, it being entirely prairie." G. Temple described T97N R27W as "wholly prairie, not a stick of timber within the lines." Temple did find timber elsewhere in the county: T96N R29W. "There are upon the Des Moines as many as 500 acres of timber in one tract and this frequently claimed by one man to the chagrin of 100 other men." On July 19, 1855, in the same township, Temple also found "a few marshes which are marshes only in the springtime as they now are dry and I pass over them as safely as if they were solid *terra firnia* [sic]." In the same township, Temple found a spring with "enough water in it to supply a city of a population of 50,000 inhabitants. There are no cities there nor never will be." (Phase 4)

56. Lee County. The southern part of Lee County has been referred to as the "Half-Breed tract." The area is south of the "Sullivan Line," and was part of a boundary dispute with the state of Missouri that was settled by the U.S. Supreme Court in 1851 (Sage 1974, p. 64). This is the apparent reason that the township plat maps and notes for this area were not included on our microfilm rolls. We located these in the SHSI Library in Des Moines (see section II-C of this report). The GLO vegetation pattern in Lee County is influenced by the Des Moines River on the west border and Mississippi River on the east border. In July 1837, deputy surveyor P. Kent noted in T68N R5W that there were "too many mosquitos for taking notes." He also wrote that "the town of Tuscarova has a very fair prospect to die a natural death." In T65N R5W, the surveyor wrote, "On the 24 April the hands refused to work on account of an alarm as to an Indian War. May 18th, 1832, left off work in consequence of the Indian War. Returned November 3, 1832. Working for $15 a month." (Phase 4)

57. Linn County. Edge matching was easier in Linn County than in most counties in Phase One. This was the only county that contained the "windfall" vegetation category. According to evidence in the field notes, this was along the path of a tornado. It was described as a fairly good sized swath, a mile long. (Phase 1)

58. Louisa County. This was our first county next to the Mississippi River, which made it difficult to work with initially. One GLO township map (T74N R5W) had no vegetation lines; all had to be drawn by reading the field notes. Also, vegetation lines were missing from two townships (T74N R3W and T73N R2W) where areas of prairie were adjacent. Muscatine Slough was labeled in this county also, but it was spatially offset in adjacent townships after we completed edge-matching. (Phase 1)

59. Lucas County. Matching vegetation boundaries along township lines was relatively easy in Lucas County, making the vegetation patterns quite continuous across the county. (Phase 2)

60. Lyon County. TIMber, SCAttering trees, and timber/scattering/openings (TSO) were mapped along the Big Sioux River (western edge of the county). Wetland types (primarily SLUe, MARsh, and PON) were scattered in other parts of Lyon County, the SLUes mapped as riparian wetlands along the Little Rock River and its tributaries. On November 5, 1856, deputy surveyor W. Yerby's camp "burned up" in Section 3 of T98N R46W. (Phase 4)

61. Madison County. A new vegetation type was added to the list for Bremer, Decatur, Franklin, Howard, Jones, Madison, Ringgold, Winneshiek, and Worth: TBR (timber/barrens). This represented another combination of terms used by surveyors that was different than any of the existing vegetation types on our list. In many places, vegetation boundaries did not match up across township lines, creating many straight-line interpolations between measured points along section lines. (Phase 3)

62. Mahaska County. The large number of fields mapped by the surveyors in this county indicates a relatively large number of settlers at the time of the survey. As a result, many of the vegetation types were quite fragmented. Near the northwest corner of the county, the map for township T77N R16W contained many sloughs. This pattern was not repeated in any other township in the county and may be due to timing of the field survey or other factors. (Phase 2)

63. Marion County. Marion includes an area the deputy surveyor described as a WINdfall, but the field notes include no information about its origin. Matching vegetation boundaries along township lines was relatively clear with a few exceptions. (Phase 2)

64. Marshall County. There was moderately low vegetation diversity in this county (ten vegetation types). One thing to note was the vegetation pattern near the southeast corner of the county. Across the boundary between two townships (T83N R17W and T83N R18W) the vegetation changed from TIMber to SCAttering trees. This illustrates the difficulties that faced the surveyors when describing vegetation and potential inconsistencies that resulted. With further research that we and others do, perhaps the descriptions of vegetation by deputy surveyors can be interpreted and explained in a more detailed, consistent way to make the data even more useful. (Phase 2)

65. Mills County. Vegetation lines matched up across township lines better than vegetation types. WINdfall was mapped near the northwest corner of the county by GLO surveyors. Four areas along the western edge of the county were digitized as river. See the explanation in the notes above for Harrison County. Deputy surveyor J. Street described T72N R41W in 1851 as having "soil of a kind, warm nature." (Phase 3)

66. Mitchell County. Townships in tier 97 were split between this county and Floyd County. Timber and other tree cover vegetation types followed stream valleys; on the uplands, surveyors mapped prairie. In the northwest corner (T100N R18W), surveyors described a matrix of part prairie/ part timber (PPT) around a series of wetlands. (Phase 3)

67. Monona County. Along the western edge of Monona County, surveyors mapped TIMber and other vegetation types containing trees. Here they also mapped several large oxbow lakes, including Blue Lake. Other evidence of river course changes appear on the map as areas within the present boundary of the state which were mapped RIVer by the GLO surveyors. TIMber polygons mark the location of the Loess Bluffs in a north-south direction through the middle of the county. (Phase 4)

68. Monroe County. This county was typical of the southern counties we digitized in Phase Two. The vegetation patterns were quite complex with few large areas of continuous vegetation but many smaller patches. There were several instances where descriptions of TIMber, TSO, and SCAttering trees changed at township lines. (Phase 2)

69. Montgomery County. Because of a predominance of prairie, annotating and digitizing vegetation in Montgomery County required relatively little time (seven hours). The major exceptions to prairie were scattered groves and TIM and TSO along streams. Deputy surveyor P. Moriarty complained in his field notes for T71N R37W that his assistants were incompetent. (Phase 3)

70. Muscatine County. Edge matching was particularly difficult, resulting in many vegetation polygons that end abruptly at township boundaries. This was particularly true of the area called Muscatine Slough. (Phase 1)

71. O'Brien County. Surveyor W. Smith mapped two linear "slues" along the Floyd River and Little Floyd River in T97N R41W in June 1856. While annotating maps for O'Brien County, a new vegetation category "meadow" (MEA) was added to our list. This category was first encountered in five places in T95N R40W, surveyed by D. Langton in August 1857. (Phase 4)

72. Osceola County. Except for six long, narrow "slues," wetland vegetation types are located in the northeast third of the county, east of the Ocheyedan River. This is part of the relatively flat glaciated Des Moines Lobe in north-central Iowa. Deputy surveyor C. Estes noted in September 1859 that T98N R39W was "not worthy of special notice." (Phase 4)

73. Page County. GLO surveyors mapped linear bands of timber along the Middle Tarkio River and West and East branches of the Nodaway River. They also mapped many fields, especially in the eastern half of the county. (Phase 4)

74. Palo Alto County. Linear TIMber polygons were mapped along the West Fork of the Des Moines River. Fire Island Lake was mapped in T96N R32W by surveyor J. Jarrett and Lost Island Lake was mapped in Tier 96 and 97 of Range 34 by surveyor J. Pierson. In T95N R34W, deputy surveyor J. Webber described "dykes [sic], apparently formed by the waves of the lake, in some places 6 or 7 feet high...composed largely of boulders...have the appearance of an artificial work." Webber also wrote of "evidences of abundance of fish and large numbers of water fowl." According to deputy surveyor C. Estes, "SE half of section 12 is claimed as a town site. It is called Palmette City" (T95N R33W). (Phase 4)

75. Plymouth County. TIMber, SWAmp, and MARsh were mapped along the Floyd River corridor. Long, narrow SLUes were mapped in T93N Ranges 43, 46, and 47 by surveyors G. Stump and G. Trippett. (Phase 4)

76. Pocahontas County. Surveyors mapped many small wetlands (MARsh, SLUe, PONd, and WETland) throughout Pocahontas County in a matrix of PRAirie. In T90N R31W and T90N R32W, a rather extensive wetland system was mapped as swamp-marsh (SMR) by surveyor G. Berry. (Phase 4)

77. Polk County. Polk County includes an area of CITy at the confluence of the Des Moines River and Raccoon River (T78N R24W). The vegetation patterns across the county were relatively continuous. In the southeast corner of the county (T77 R22), the Des Moines River approximates the border between Polk County and Warren County; this was the line we used to divide the township among the two counties. (Phase 2)

78. Pottawattamie County. Pottawattamie required more hours of annotating and digitizing (34 hours) than any other county in Phase Three. This was not unexpected, due primarily to the larger than average size of the county (24 complete townships and 5 partial townships). As in Harrison and Mills Counties, several large areas along the western edge of Pottawattamie were digitized as RIVer. This county also contains the area which is now the community of Carter Lake, the only Iowa town west of the Missouri River. (Phase 3)

79. Poweshiek County. There were two sets of maps and notes for T78 R15W on the microfilm. One was done in 1845, the other in 1847. The notes indicated that the 1845 version was not up to the Surveyor General's expectations; therefore, it was re-surveyed in 1847. We digitized the later map, which included quite a few more fields than the earlier map. (Phase 2)

80. Ringgold County. A new vegetation type was added to the list for Bremer, Decatur, Franklin, Howard, Jones, Madison, Ringgold, Winneshiek, and Worth: TBR (timber/barrens). This represented another combination of terms used by surveyors that was different than any of the existing vegetation types on our list. In his field notes, one surveyor commented on "Indian corn cribs and grave" in sections 20 and 21 of T70N R30W. (Phase 3)

81. Sac County. Black Hawk Lake appears on the township plat map for T86N R36W. Deputy Surveyors J. Sheller and S. Durham described "splendid farming land" (T86N R38W), "soil of superior quality" (T88N R38W), and "in many places, a rich growth of weeds" (T89N R38W). (Phase 4)

82. Scott County. In Tier 80 and Tier 81, the county boundary between Scott and Clinton approximates the Wapsipinicon River. Because the GLO township maps show the county boundary along the township line, we digitized complete townships rather than partial townships in Tier 80 of Scott County. (Phase 1)

83. Shelby County. The linear marsh pattern mapped in May and June of 1854 by C. McDonald in T80N R39W and T81N R39W contrasts strongly with the remainder of Shelby County. (Phase 4)

84. Sioux County. The GLO vegetation pattern in Sioux County is dominated by MARshes and linear SLUes in a matrix of prairie. Only one polygon containing trees (SCAttering trees) is located near the Big Sioux River. In

1855, deputy surveyor G. Stump described the density of beaver activity in T95N R43W as “one beaver clan per mile.” (Phase 4)

85. Story County. There were four township maps in the northeast quarter of the county that show a high concentration of MARshes and PONds. Though these four townships were surveyed in the same year as the rest of the county (1847), they were completed by a different deputy surveyor (Horatio Waldo). This pattern was more detailed than the rest of the county but was quite typical of the prairie pothole wetlands in north-central Iowa. There was relatively little timber in this county compared to neighboring counties to the east. (Phase 2)

86. Tama County. This was the first county we digitized in Phase Two. There were several references to American Indian settlement in Tama County. In T83 R16W we included a vegetation type for the surveyor's descriptions of Indian cornfield. In that same township, the surveyor relates in his description that “...savage life existed but two years ago.” Several of the other surveyors in this county claimed in their field notes that the land could not be settled. (Phase 2)

87. Taylor County. In addition to the linear pattern of TIM and TSO along river corridors, GLO maps for Taylor County exhibit many fields, especially in the southern half of the county. In sections 22 and 27 of T68N R35W, deputy surveyor A. Carpenter described a “circular mound, 30 acres in size.” In October 1851, deputy surveyor W. Dunn wrote that a member of his survey party for T69N R35W left because “the wages wouldn’t keep him in pantaloons and boots.” (Phase 4)

88. Union County. Union County contained fewer vegetation types (seven) than average in Phase Three. Vegetation lines matched up across township lines better than vegetation types. In 1849, deputy surveyor S. Woodworth noted that in T73N R31W “not a stick of timber, not even a riding switch can be found.” (Phase 3)

89. Van Buren County. Based on the number of fields shown on the surveyors' maps, this county was one of the most densely settled in the state at the time of the survey. One new vegetation type added initially for this county (and later used in other counties) was TSO (Timber/Scattering/Openings). In some areas, the surveyors had difficulty making these distinctions, so they were designated TSO. This county also includes another instance of WINdfall. According to the surveyor's field notes, this area was created by a tornado. (Phase 2)

90. Wapello County. Though there were few occurrences of fields in this county, there was a large number of CITies shown on township maps along the banks of the Des Moines River. Also there were several places along township lines where TIMber changes to TSO which could be the result of settlement. (Phase 2)

91. Warren County. Township maps in this county were missing many vegetation boundaries in the interior of many sections. In other counties, the surveyors' field notes sometimes lacked enough detail for us to complete the vegetation boundaries with much confidence. In Warren, fortunately, the surveyors' field notes were more detailed, allowing us to complete the vegetation boundaries with more confidence. However, as described above in Section VI-C, in the absence of information in the field notes, we used a straight-line interpolation method to complete vegetation boundaries. (Phase 2)

92. Washington County. In Tier 77, the county boundary between Washington and Johnson approximates the Iowa River. Because the GLO township maps also show the county boundary as the Iowa River, this was the boundary we followed when digitizing Washington County. (Phase 1)

93. Wayne County. Wayne County contained relatively few vegetation types (seven), making it relatively painless to annotate. However, the vegetation pattern was relatively complex, due primarily to TIMber along stream valleys and a large number of small fields (primarily in the southern tier of townships--T67N). All four southern townships were surveyed by John G. Clark in 1852. In 1847, deputy surveyor H. Hendershot noted a buffalo lick in T68N R20W. (Phase 3)

94. Webster County. Eastern Webster County was easier to annotate and digitize than western Webster County because the Des Moines River valley contained so much timber and relatively few wetlands. Several large areas of WINdfall were mapped by surveyors in one township (T88N R28W). These were described by deputy surveyor

W. Neely as "timber destroyed by wind. This township has excellent advantages for farming and water power, gypsum of good quality abounds." (Phase 3)

95. Winnebago County. A new vegetation type was added to the list for Winnebago County: SMR (swamp/marsh). The surveyor for T98N R26W (O. Lyon) identified several linear wetland areas 5 to 7 miles long as a combination of swamp and marsh. This was the only county we've digitized that contained what the surveyor called swamp/marsh. This relatively small county was time-consuming to digitize because of its many small wetlands (described by surveyors as marsh, swamp, slue [sic], and swamp/marsh. Because we had already used the four-letter county abbreviation WINN for Winneshiek County, we used WBAG for Winnebago County. (Phase 3)

96. Winneshiek County. A new vegetation type was added to the list for Chickasaw, Howard, and Winneshiek: VIL (village). Also, a new vegetation type was added to the list for Bremer, Decatur, Franklin, Howard, Jones, Madison, Ringgold, Winneshiek, and Worth: TBR (timber/barrens). These represented another combination of terms used by surveyors that was different than any of the existing vegetation types on our list. Another new vegetation type was added to the list for Decatur, Floyd, Jones, Winneshiek, and Worth: TSB (timber/scattered trees/barrens). Vegetation boundaries and types did not match up well across township lines. Surveyor H. Averill commented in his field notes for T99N R10W that, through the application of labor and expense, marshes could be reclaimed and made serviceable. (Phase 3)

97. Woodbury County. Unlike Plymouth and Sioux Counties to the north, GLO surveyors mapped more trees in Woodbury County. Many oxbow LAKes and MARshes were mapped in the floodplain of the Missouri River. In 1852, deputy surveyor A. Anderson described the marsh in T87N R46W as "good for nothing." (Phase 4)

98. Worth County. A new vegetation type was added to the list for Bremer, Decatur, Franklin, Howard, Jones, Madison, Ringgold, Winneshiek, and Worth: TBR (timber/barrens). This represented another combination of terms used by surveyors that was different than any of the existing vegetation types on our list. Another new vegetation type was added to the list for Decatur, Floyd, Jones, Winneshiek, and Worth: TSB (timber/scattered trees/barrens). Worth County had an unusually high number of different vegetation types identified by surveyors. Eighteen different vegetation types were mapped by five different surveyors. The surveyors said in their field notes that T99N R21W "abounds in amfibeous [sic] animals, beaver, otter, mink, muskrat, elk." (Phase 3)

99. Wright County. In our project, this county was average in many ways: number of vegetation types, number of townships, amount of time needed to annotate township maps, and number of hours needed to digitize vegetation. In his field notes for T93N R26W, surveyor T. McCullogh mentioned evidence of a long drought which left sloughs, marshes, and ponds dry. (Phase 3)

E. Recommendations

1. Remember the data limitations As described above in Section VI-C, most vegetation boundaries on township maps were extrapolations of transect data along section lines. Most extrapolations were done by deputy surveyors in the field, but some may have been done by drafters in the Surveyor General's office in Dubuque. Also, some extrapolations were made by the research team after a careful reading of the deputy surveyors' field notes. Therefore, data quality was much better along section lines than in the interior of sections. It is more appropriate to use these data for studies of regional vegetation patterns than in detailed site-level studies. Use these digitized vegetation data with care.

2. Locate paper originals. The primary data source for this research was the Secretary of State microfilm (see Section II-A). We used the topographies (from the Secretary of State microfilm) where available (rather than the plats from the Historical Society microfilm). Research is needed to better understand the contents and accuracy of the WPA-typed field notes and the township maps. Observations suggests that the WPA project staff was careful in their typed transcriptions of the deputy surveyors' manuscript field notes, but we need more information. Also, evidence suggests that the maps were preliminary sketches done by the deputy surveyors which were later used as a basis for the official plat maps. Seeing the paper originals can help verify this assumption and explain more about how this was done.

3. Evaluate microfilm sets. We used maps from four different sets of microfilm. These were in the collections of DNR, Office of the State Archaeologist, State Historical Society of Iowa office in Iowa City, and State Historical Society of Iowa library in Des Moines. There are more sets of microfilm at the Office of the State Archaeologist in Iowa City, National Archives II in College Park, Maryland, and the National Archives regional office in Kansas City, but we have not spent time examining their contents and comparing township maps to find out which paper maps were microfilmed. Additional work is needed to evaluate and compare microfilm contents and to perhaps discover even more sets of microfilm.

4. Digitize the surveyors' field notes. On a number of occasions, we wished that the surveyors' field notes were in digital form. This would have allowed searches using software to find vegetation descriptions for particular areas we were studying. In several inquiries during the project from Brendan Shane (University of Maryland) and Joe Tiffany (Iowa State University), searching through the digital field notes using software would have been more efficient than manual searches. It may even be possible (through existing software or custom software) to create for all counties digital files of witness tree data similar to those prepared by Daryl Smith of UNI for several counties.

Because we believe that researchers and land managers would benefit from digital files of survey notes, we have begun to experiment with document digitizing using the WPA typescript transcriptions of the deputy surveyors' field notes for Dallas County. Graduate assistant Jane Chen used a desktop flatbed scanner and OmniPage Professional optical character recognition (OCR) software. Jane has developed several techniques for verifying the accuracy of the digitizing process. Further research is needed to put the digitized notes in a form that is easily accessible by researchers and is easily hyperlinked to the digital maps already digitized in this research project.

5. Compare WPA typescript with manuscript. To better understand the quality of the data contained in deputy surveyors' field notes, different forms of the notes need to be studied and compared in detail. Discrepancies between the WPA typescript versions and the original manuscript versions are to be expected. In the Surveyor General's office in Dubuque, clerks copied deputy surveyors' field notes by hand from their field books. In the late 1930s, typists copied the notes. According to Kathy Gourley (Iowa Department of Cultural Affairs), there are discrepancies; in her experience, they are few, small, and insignificant in studying vegetation. A thorough, systematic comparison could provide empirical data to support this hypothesis.

6. Make the digitized vegetation data accessible to other researchers. The Iowa Department of Natural Resources maintains an on-line database of GIS data called the *Natural Resources Geographic Information System* (NRGIS). After the GLO data prepared in this project have been thoroughly checked and accepted for distribution by IDNR, the coverages should be added to NRGIS. Information about NRGIS is available on the World Wide Web at the following URL:

http://www.igsb.uiowa.edu/htmls/nrgis/gishome.htm

7. Analyze regional and statewide vegetation patterns. Now that GLO vegetation maps have been digitized for all 99 Iowa counties, its possible to learn more from the GLO vegetation data by analyzing regional and statewide patterns. Aggregating county coverages into a state coverage permits descriptive modeling using GIS tools and a variety of geographic, spatial, and statistical measures. Using methods and measures of spatial analysis and geostatistics can also reveal relationships with surveyor characteristics, land development patterns, hydrologic characteristics, ecological regions, and so on.

8. Complete additional GIS descriptive modeling of vegetation types. Mike Miller's thesis results (Miller 1995) demonstrate how to use GIS descriptive modeling techniques to quantitatively describe GLO vegetation types. Miller spatially compared GLO vegetation patterns in Fayette County with other landscape variables (for example, slope and soil), with other historic vegetation maps, and with witness/bearing tree data from the deputy surveyor's field notes. Performing similar GIS descriptive modeling in other counties would provide a more complete description of the 38 vegetation types that deputy surveyors mapped in Iowa. More complete descriptions would, in turn, give researchers and managers additional guidance in interpreting and aggregating vegetation types described by deputy surveyors.

9. Compare digitized GLO vegetation distribution with maps by Shimek and McDonald. Thomson (1987) described and compared two Iowa maps of forest distribution, one by botanist B. Shimek and one by forester G.B. MacDonald. Both maps are widely published in books on Iowa history, in reports by government agencies, and in other publications (Miller 1995, p. 1). According to Thomson (1987, p. 116), both maps were likely based on GLO data which were aggregated into two categories: forest and non-forest. A less well-known version of one of the maps exists with three vegetation categories: forest, prairie, and wetland. These maps should be compared to the GLO vegetation data digitized in this research to empirically describe the vegetation categories aggregated by Shimek and MacDonald. We suspect that the comparison will show that the aggregation of vegetation categories on the Shimek and MacDonald maps cause misleading comparisons with the area and spatial distribution of forest as shown on more current maps published in the past several decades.

10. Continue historical research about deputy surveyors. To help researchers interpret and aggregate vegetation types, a major research effort is needed to understand the training and education that the deputy surveyors received. This includes training about surveying, formal education in public schools and college, and informal education about natural resources. Surveyors' educational, cultural, and geographic backgrounds influenced the terms and descriptions they used in the field. "Interpretation of the map requires some understanding of why surveyors would or would have not used the word 'prairie.' For example, did a New York educated surveyor have the word in his vocabulary? Would a surveyor adopt local terminology? How did a surveyor perceive the difference between prairie, barrens, open woodland, or scattering trees? Would his interpretation be the same as that of another surveyor working nearby?" (Schroeder 1983, p. 6).

Personal journals, biographies, and other literature about surveyors can help researchers better understand the vegetation data included in the GLO maps and field notes. Schroeder (1983) presents historical information and interpretations of the terms (such as prairie and barrens) that deputy surveyors used to describe vegetation. "Savanna was not used at all in early 19th century Missouri, and its use is rare today" (Schroeder 1983, p. 1). This study and others can help answer the "savanna" question being asked by resource managers in Iowa. Therefore, studying the origins and use of the vegetation terms that surveyors wrote on maps and in field notes can aid in understanding of our digitized GIS vegetation data.

11. Digitize additional features on township plat maps. GLO township plat maps contain data on topics other than vegetation. Examples include streams, trails, cabins, floodplain, topographic features, and grave sites. Scanning each township map to create a raster graphics file would be the first step. Then, additional features could be digitized to create other GIS data coverages. Researchers, such as Brandon Shane (PhD student in geology at the University of Maryland), could then use GLO streams data to study historic changes in Iowa's surface drainage system. This, in turn, helps Iowa land owners and officials manage wetlands, riparian areas, and other hydrologic features.

12. Use the GLO data to analyze topography and soils. Deputy surveyors were instructed to describe soils and topography of each township in a similar manner to vegetation. GLO map data and field notes could help land managers and scientists (such as ISU soil scientist Lee Burris) better understand historic conditions and trends leading to current conditions of natural resources.

13. Incorporate knowledge of historic vegetation into land management plans. A major benefit and use of the GLO vegetation data is informing planning and decision-making about the landscape, its history, and changes. The Iowa landscape of the 1840s and 1850s can be used as one model for landscape restoration activities, particularly if conditions of the pre-industrial agricultural landscape are desired. For example, wetland enhancement, restoration, creation, and construction can be informed by these GLO vegetation data. During the period in which the data were collected, little (if any) cultural alteration of the surface drainage system had occurred. However, it is debatable whether the Iowa landscape of the 1840s and 1850s should be used as an ecological ideal, given the common use of fire management and other techniques used for habitat control used by Native Americans. When using GLO data in vegetation management activities, perhaps the most important data limitation was mentioned above in Recommendation 1. Because of the GLO survey techniques (transects along section lines) and the variability among 187 deputy surveyors, their inventory and description of vegetation is incomplete.

14. Aggregating vegetation types. As described earlier in Section IV-C of this report, names for digitized vegetation types were taken directly from the township maps and field notes. We followed the principle of keeping vegetation types separate and not aggregating vegetation types into fewer categories. We used category names based solely on the surveyors' descriptions. In this way, others who use the data can aggregate according to their own needs. Based on advice from Miller (1995) and Thomson (1987), there is a danger of over-simplifying by aggregating into too few categories (for example, forest and prairie).

Because of inconsistencies and variability in surveyors' vegetation descriptions, it is difficult to make informed and educated decisions about aggregation. Research described above in Recommendation 10 can make aggregating more valid and useful. Knowledge of surveyor variability, map edge-matching (little to none), seasonal differences, bio-regional context, and distinctness of vegetation boundaries can help also. For example, when using GIS descriptive modeling techniques to compare GLO vegetation with current land cover, GLO vegetation types could be aggregated into six or seven categories: deep water, shallow water, prairie, prairie-timber ecotone, timber, and cultural types. When we tried assigning the 38 GLO vegetation types to these six categories based on four years of experience working with GLO maps and notes, we felt quite comfortable assigning some (such as BOG and TSO timber/scatterings/openings), and quite uncertain assigning others (such as SANdbar and MEAdow).

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VIII. APPENDICES

A. Examples of GLO township maps

B. Microfilm sources for township maps digitized

C. Secretary of State Microfilm Directory Database

D. Historical Society Microfilm Directory Database

E. Digitized vegetation maps (AutoCAD plots)

F. Counties and vegetation types digitized

G. GLO vegetation types by county

H. Observations about GLO vegetation types

I. Miller bibliography