Palo Alto Battlefield National Historical Park Landscape Classification and Historic Analysis

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Overview and general description. The Palo Alto Battlefield National Historical Park (PAAL) as part of the National Park Service (NPS) was established in 1978 by the U.S. Congress.

The NPS plan for the PAAL was to restore the landscape appearance to that present at the time of the 1846 battle between the United States and Mexico. The PAAL includes about 1372 ha (3400 acres) (14,163,997 m^2) of *Spartina spartinae* (gulf cordgrass) prairie, tamaulipan and mesquite forests, and resacas. Resacas are former channels of the Rio Grande found in the southern half of Cameron County (The Handbook of Texas Online. http://www.tshaonline.org/handbook/online/articles/RR/rbrnp.html). Since 1846, alterations to the landscape have included road construction (unpaved), water control features such as the large drainage ditch just to the north of the battlefield and damming of the resacas for water storage (cattle tanks), intermittent cultivation and ranching activities, and predevelopment construction (Fig. 1).

The NPS recreation of the 1846 PAAL landscape required multiple steps. First, the earliest photographic coverage of the PAAL portrays the landscape at some hopefully distant point in the past; hopefully before major landscape alterations. The NPS historians would then use this spatial portrayal and ancillary data to accurately recreate the 1846 PAAL landscape. Second, a key component of the NPS restoration plan included determining what alterations to the landscape had occurred; especially regarding the resaca's and cordgrass prairie, pivotal components of the battle outcome. To detail landscape changes, the NPS restoration plan included documenting the current landscape status.

Photographic coverages. Overall, the NPS requires mapping to be at a minimum mapping unit of 0.5 hectare and georeferenced to USGS 1:24,000 topographic maps. To be useful for resource management and for recreation of historic landscape features and conditions of the PAAL, these NPS mapping mandates were too coarse; a much finer spatial resolution was necessary. In response to this need for higher spatial resolution maps, the NPS and U.S. Geological Survey's (USGS) National Wetlands Research Center (NWRC) jointly organized a project to prepare a current landcover map and a historic comparison of the PAAL at a 1-m spatial resolution. To fulfill this request, current color infrared (CIR) photographic coverages of the PAAL were collected in 19 July 1999 and 2 February 2000 at an approximate 1:6,000 scale. These coverages were kindly provided by Mr. James Everitt the Project Leader of Range Science and Remote Sensing Research of the U.S.D.A. ARS IFNRRU at 2413 E. U.S. HWY 83, Weslaco, Texas 78596-8344.

As part of the historic comparison and in addition to the 1999 and 2000 images, we collected historic photographic coverages of the PAAL from many sources. In our original proposal to NPS, we recommended historic photography in 1968, 1954, and 1938 be acquired and entered into the GIS for comparative landscape change analyses. Because of the availability of complementary photography, however, we were able to enhance the historic photographic analysis by encompassing the years from 1993 to 1934. In addition to the 1999 and 2000 photography, we acquired photographic scenes covering the PAAL in (1) 03-08-1993, (2) 03-05-1989, (3) 10-05-1977, (4) 09-22-1977, (5) 02-09-1962, (6) 11-04-1950, (7) 12-10-1939, and (8) 11-04-1934. In total, 10 separate photographic coverages were acquired with photographic scales ranging from 1:40,000 to 1:6,000. The project area included the authorized site boundary extended to the nearest road or natural boundary. As part of the rectification and mosaicing procedures, all photographic coverages were standardized to a 0.5 m spatial resolution.

Landscape classification protocol. As mandated by the NPS, the landcover and landuse classification protocols followed the National Vegetation Classification Standard (NVCS) (e.g., VCS 1997, Ramsey et al. 2002)[1]. Methods used to classify and interpret the accuracy of the classified map are based on protocols we developed for the National Park Service following the National Vegetation Classification Standard (NVCS) established by the Federal Geographic Data Committee (http://www.fgdc.gov). NVCS landcover classes pertinent to the PAAL were based on a report by Mr. Normal Richard and Dr. Alfred

[1]The lack of a Federal standard for vegetation classification and reporting of vegetation statistics has hindered the ability to create timely and consistent synoptic views of all vegetation resources within the United States and worldwide. Natural resource and regulatory agencies document, map, analyze, and report vegetation data in different ways according to their mandates and jurisdictions. This has led to different classification and reporting definitions that are generally divided by broad vegetation and landuse types (e.g., forest, rangelands, wetlands, agricultural lands) or by mission and jurisdiction (e.g., National Forests, Public Lands, National Parks, National Refuges) (VCS 1997). In response to these differences and the need for national synoptic views of vegetation resources, in 1997, the Federal Geographic Data Committee (FGDC) developed the National Vegetation and Classification Standard (NVCS). The NVCS is based on work of United Nations Educational Scientific and Cultural Organization (UNESCO 1973) and Driscoll et al (1984), and it is being considered as a model for a global standard to characterize earth's land covers (Young 1994, UNEP/FAO 1995, Di Gregoiro and Jansen 1995).

The NVCS provides a basis for consistent national classification and statistics in vegetation resources. It facilitates the compilation of regional and national summaries, and in turn, provides a detailed, quantitative, and georeferenced data base for vegetation cover modeling, mapping, and analysis. The standard requires all vegetation classification efforts financed in whole or in part by Federal funds to include NVCS core components. In cases where the NVCS overlaps other classification standards (e.g., the Wetlands standard used in wetland and emergent aquatic regions), the standard should be used to complement alternate approaches in the overall analysis of a geographic area.

The NVCS is hierarchical, the higher the level the less numerous and more generalized. The highest level is the Division followed by Order, five physiognomic levels that describe the structure and life form of the plant community, and two floristic levels that mainly describe the dominant species. The Division divides the earth into non-vegetated and vegetated levels, and the Order further divides the vegetated Division into tree, shrub, dwarf shrub, herbaceous, and non-vascular life forms. Physiognomic class defines the relative percent canopy cover of each Order at the peak of the growing season. Subclass describes the predominant leaf phenology of woody plants (evergreen, deciduous, mixed evergreen-deciduous) and the leaf type and periodicity of herbaceous plants. Group relates to a combination of climate, leaf morphology, and leaf phenologic factors. Subgroup divides the physiognomic group level into natural/semi-natural and planted/cultivated categories. The final physiognomic level, formation divides the physiognomic subgroup into common environmental and additional physiognomic factors (e.g., upland, seasonally flooded, pavement [sparsely vegetated]). The floristic levels, alliance and association, currently are not required as part of the NVCS, but they are a required part of all NPS classifications. Alliance represents an aggregation of associations. Association, as the finest floristic level in the NVCS, describes a diagnostic species that is shared by a physiognomically uniform group of vegetation stands that are generally found in similar habitat conditions. A complete overview and detailed explanation of the hierarchy can be found at http://www.fgdc.gov/.

Richardson (Biology Department, University of Texas, Brownsville, Texas 78520) titled, "Biological inventory, natural history, and human impact of Palo Alto National Battlefield," submitted to the PAAL on 28 October 1993. The NVCS classes contained in the report were used by Ms. Karen Weaver (PAAL Park Ranger) to classify the PAAL landscape. Landcover classes that included *Colubrina texensis* and *Sonchus asper* (Table 1) in a disturbed area adjacent to the PAAL were added to the original classes after field surveys and discussions with Ms. Karen Weaver and Mr. Louis Krug (Park Rangers) from 15 to 19 March 2001.

Rectification and mosaicing. On our first field trip to the PAAL (24 to 28 April, 2000), we collected 40 ground control points (GCP) that allowed accurate scene mosaicing and georeferencing to an international projection system, in this case, the Universal Transverse Mercator projection. In all current to historic coverages, from 1 to 11 photographic scenes were used to produce the PAAL continuous coverages. A base photographic coverage was separately rectified to the collected GCPs by using nearest neighbor resampling, and all remaining scenes were registered to the base coverage. After registration, the individual scenes were color matched to the dominant scene illumination and then stitched into an overall coverage of the PAAL. Figure 2 illustrates how each scene was separately rectified, color matched, and entered into the PAAL image. In all final mosaics, the reported root-mean-square error indicated less than a ±0.25 m positional accuracy and a 0.5-m spatial resolution. These mosaiced coverages are shown in Figures 3 to 9.

Field surveys and GIS creation. We also collected 46 field sites throughout the PAAL by recording vegetation occurrences and coverages, and documenting these occurrences with 35-mm slide photography. All field site data were assigned to a physiognomic level (class, subclass, group, subgroup, formation) and a floristic level (alliance, association) as required by the NVCS convention. An additional 92 field site locations were added in our second field trip from 15 to 19 March 2001, resulting in a total of 138 field sites distributed throughout the PAAL. Field site locations and descriptive data including 35-mm photography were entered into a geographic information system (GIS). The GIS included a visual portrayal of field site and GCP locations that were hotlinked to map identifiers overlain on 1999 mosaic photography coverage (Fig. 10). Clicking on a map identifier retrieved a tabular and visual display of all data and photography available for each field site and GCP location. The GIS project that contained GCP locations and descriptions (some with photography), field site locations and descriptions including photography was delivered to the PAAL personnel on October 11, 2000.

Landscape classification logistics and results

Scanning, mosaicing, and classification. The 1999 CIR scenes were scanned and subsequently mosaiced to create a continuous coverage of PAAL and adjacent lands at a <1-m spatial resolution (Fig. 11). The spatial resolution or image element (pixel) was determined by the original photographic scale and scanning resolution. Color infrared photography was scanned in the blue, green, and red wavelength ranges creating three image planes related to the green, red, and near infrared landscape components. All three image planes were entered into the classification. All landscape classifications employed a widely used and documented progressive clustering technique driven by an unsupervised K-means clustering algorithm (PCI Geomatics 1998, Ramsey and Laine 1997, Ramsey et al. 1998, Ramsey et al. 2002). In the classifications, the spectral values associated with each image element (pixel) were combined into spectrally similar clusters. These clusters were then associated with identifiable earth landscape features.

Failure of the 1999 photographic coverage. Attempts to classify the 1999 CIR mosaic were not successful. Severe illumination differences among photography scenes could not be normalized well enough for accurate landscape classification. Even though illumination problems still existed, in 15 to 19 March 2001 meetings with the PAAL personnel, Mr. Luis Krug and Ms. Karen Weaver, the mosaiced 2000 CIR coverage was deemed adequate for creation of the current PAAL landscape classification at a spatial resolution of 0.5 m. This spatial resolution surpassed the proposed 1-m resolution. As in all mosaiced photographic coverages, the spatial coverage of the 2000 CIR photography extended well beyond current PAAL landholdings (Fig. 12). The produced photographic coverage greatly exceeded the proposed spatial coverage extents and the NPS requested spatial coverages.

2000 photographic coverage. Our first attempt to classify the 2000 CIR photographic coverage used an earlier vegetation coverage map to guide our classification (Fig. 13). Vegetation classes, nonexistent for this mixture of semi arid and wetland landscape features, followed NVCS guidelines (VCS, 1997). The vegetation map was created for the NPS ensuring the created classes fulfilled the requirements of resource management. The identifiable features generated during the classifications were the land covers described by physiognomic and floristic level documented during the site reconnaissance. The georeferenced photographic spectral data were then transformed into landcover information. All field site data were assigned to a physiognomic level (class, subclass, group, subgroup, formation) and a floristic level (alliance, association) as required by the NVCS convention.

Failure of initial landscape classification. In our second field trip from 15 to19 March 2001, we discovered our 2000 classification based on the 1993 (Richard, 1993) vegetation classification was highly incompatible with the actual vegetation distribution, and therefore, highly inaccurate. The inconsistency between mapped and actual landcovers was based on two main factors. First, the 1993 vegetation map was spatially too generalized, allowing numerous miss classification errors. Second, the vegetation classification was not entirely conducive to mapping with optical remote sensing systems. This incompatibility was especially apparent in mapping the mixed vegetation class, for example, tamaulipan forest.

Creating a useable 2000 landscape classification. Our solution was to disregard the earlier vegetation classification (Richard, 1993) and to build an entirely new landscape classification based on the 2000 CIR photographic data base, the NVCS protocols determined in the earlier classification, our field site data and descriptions, and our classification methods (Ramsey et al. 2001). To overcome problems in classification of mixed vegetation associations with remote sensing image data, we first estimated the spatial extent of these classes, and refined these extents by classification iteration based on producing spectral similarity and a lack of abrupt spectral changes along spatial transects. The final map (Fig. 14) included 10 land cover classes and one land use class (i.e., water tanks, roads) (Table 1).

An accuracy assessment of the classification was performed. The technique followed a class-stratified, random-sample design (e.g., Van Genderen and Lock 1977, Congalton 1991). The assessment of accuracy was based on the collected field site data and was >89% per class and over the entire classification (Table 2). The final classification accuracies exceeded the proposed 85% accuracy limit. Landcover coverage per class was summarized in Table 3.

Historic photographic analyses. On the 15 to 19 March 2001 meetings with the PAAL personnel, Mr. Luis Krug and Ms. Karen Weaver, we supplied hardcopies of scanned and mosaiced photography from 07-19-2000 and 02-10-1999, and from (located and purchased by us) 03-08-1993, 03-05-1989, 10-05-1977, 09-22-1977, 02-09-1962, 11-04-1950, 12-10-1939, and 11-04-1934. After inspection of the photographic coverages and discussion, we decided that full classifications would be generated for and limited to the 07-19-2000, 10-05-1977, 11-04-1950, and 11-04-1934 mosaiced. The scanned, mosaiced, and registered photography of the remaining years would be included in the final GIS without direct comparison to the 1934 or 2000 classifications.

A new discovery. A surprising development since our creation and transference from 15 to 19 March 2001 of the 1934 photographic mosaic to PAAL personnel was the discovery of the historic "wet" roadway by inspection of the mosaic (as depicted on Fig. 15). The roadway was critical to the development and strategies of the 1846 battle. All signs of the historic roadway had been obliterated, and it was thought the actual roadway location would never be recovered. This discovery was not envisioned during the project design but added a critical element to the successful recreation of the battlefield landscape.

Historic comparisons

<u>2000 landcover and land use vectorization</u>. Our first step in the historical comparison was to transform the 2000 photographic landscape classification to a classification more amenable to a vector depiction (i.e., polygons, lines, points). For the most part, conversion of the 2000 classification raster image to vector coverage was accomplished with image processing software (PCI Geomatics 1998). In some cases, the software was not capable of creating a workable vector coverage. In one case, this unworkability was associated with landcover classes that were highly spatially mixed and spectrally nonuniform (e.g., the tamaulipan forest). In the case of mesquite and grassland classes, the vector coverage encompassed numerous polygons as small as trees, in effect, creating a landscape with severe heterogeneity that would be of little use to resource management or historic

comparisons. To create a workable class while still representing the natural variability of the PAAL landscape, the mesquite and grasslands classes were combined and regrouped into mesquite-grassland and mesquite classes. In another case, the software did not adequately isolate and define features, such as water tanks, roads, and buildings. Other features that were important to NPS plans at recreating the historic PAAL landscape, the resacas, were also delineated on the 2000 vector classification. The reference resaca is highlighted in the classifications (Figs. 16A and 16B).

The 2000 vector landscape coverage linked to the 1934 landscape. Our guidelines for linking the current to historic landscapes were stated in our proposal to NPS: "Historic class definitions are dependent on the scope of landscape alterations since the time of the battle, available photography, and the condition and information content of the historic photography. Historic classifications must also be conducive to consistent classification through time and to simulating battle conditions." ("Palo Alto Battlefield National Historical Park Landcover Classification," USGS proposal to NPS, page 3, section 3. Proposed Classification Scheme and Accuracy Assessment). To fulfill this objective, we followed the proposed procedure by first attempting to classify the 1934 landscape with methods used to classify the 2000 photographic coverage. Inspection of the 1934 black and white photographic coverage suggested the point classification method would not produce a detailed landscape similar to the 2000 vector classification, or even produce an accurate classification. The latter point is particularly pertinent to historic classifications where no ground-based observations exist.

To retain most of the classification detail produced in the 2000 vector classification and to insure the highest possible classification consistency and accuracy, we devised a method that (1) minimized subjective or interpretive decisions, (2) emphasized solely landscape change, specifically changes in landscape trends, and finally, (3) accentuated the use of brightness and texture in the black and white photographs in the absence of multiple spectral information. First, we overlaid the 2000 vector classification onto the 1934 black and white photographic mosaic. Second, we altered class polygons to reflect brightness and texture or changes in tonal pattern. Tonal pattern referred to uniform texture patterns in the back and white photography that represented a particular landcover. For instance, the tamaulipan forest was associated with a unique tonal texture on the 1934 photographic mosaic that was recognized when the 2000 tamaulipan forest polygon was overlain on the 1934 photographic mosaic (Fig. 17, example of 2000 polygon overlay on the tamaulipan forest 1934). In the same way, all 2000 class polygons were overlain on the 1934 photographic mosaic and then adjusted to represent any change in their spatial extent or locations. In addition, cultural features such as cattle tanks were visually identified on the screen and added to the 1934 land use classification by heads-up, onscreen digitization (Figs. 18A and 18B). Landcover coverage per class are summarized in Table 3.

Landcover and landuse changes from 1934 to 2000. The greatest alteration affecting the PAAL occurred prior to the earliest photography collected in 1934. Although not completely shown on the photographic mosaics, a very large drainage canal had been constructed prior to 1934. Outside the drainage canal to the north, the most striking change from 1934 to 2000 was increased landscape complexity (Figs. 19A and 19B). Major landscape changes that caused the striking increase in complexity were mesquite expansion into cordgrass creating a bimodal vegetation mix, cordgrass reduction accompanied by *Borrichia frutescens*, dead and sparse grasses, and bare soils expansion, and drainage impediments primarily associated with resaca alterations by cattle tank construction. Conversely, except for notable losses within D6 to D7 and E7 (refer to Fig 14 for quadrant locations), the most stable landcover class was the tamaulipan forest followed by the huisachal class associated with resacas in the north of the PAAL.

Large losses of mesquite stands and mesquite grasslands occurred from 1934 to 2000 in the battlefield core area (E4, D5, F4, E5, G5, H5, I5, J5, G6, H6) and in the southwest of the study area (Figs. 20A and 20B, see Fig. 14 for quadrant locations). In these areas, losses were dominantly replaced by cordgrass, *Borrichia frutescens*, and bare to sparse grasslands. From 1934 to 2000, mesquite stands in the north expanded into cordgrass grasslands creating an extensive area of mesquite grassland (F9 to F13, E11 to E14, G9 to G13, D14 to D15) to the south and to the east (A15, B15, and C15) (Figs. 21A and 21B). A secondary expansion occurred in the south east of the study area (H7, M3 to M4, and O3). A closely aligned landcover class, tamaulipan forest (please see Table 1, NVCS descriptors) coverage decreased slightly from 1934 to 2000 (D6, D7 and E7). Conversely, tamaulipan forest coverage increased in the northwest (B2 to B3, C2 to C3, and G2 to G3 and H1 to H3) (Figs. 22A and 22B).

Widely and fairly contiguously distributed in the south and in the northwest corner in 1934, *Borrichia frutescens* expanded somewhat from these established coverages. *Borrichia frutescens* was newly established in the core battlefield area (G4 to G6, H4 to H7, I4 to I7, and J4 to J6), an area adjacent to the lake (D6 and D7, E6 and E7, and F6 and F7), and in the north central (G8 to G11 and H8 to H13), and northern (B4 to B10 and C4 to C8) regions of the study area (Figs. 23A and 23B). Accompanying the expansion and new establishments of *Borrichia frutescens* were smaller expansions of sparse vegetation and bare ground areas in the south and a new area in the core battlefield area.

Notably the largest landcover losses were associated with cordgrass (Table 4 summarizes polygon areas per class). This loss is especially apparent from H5 to H7 and

J5 to J7 encompassing the core battlefield area (Figs. 23C and 23D). Other notable cordgrass losses were in the northwest quadrangle and south of the PAAL, with a smaller area to the east that had been extensively invaded by mesquite. Conversely, in 2000, some of the densest and visually healthiest cordgrass (visually assessed) was found to the east and very slightly south of this area. It was believed, the area had been ditched for drainage in preparation for development (Figs. 24A, 24B, 24C and 24D). Another conspicuous change was the disappearance of the lake located in the northwest quadrangle of the PAAL (E5 and F5 and and E6 and F6). The lake was lost because of the construction of a cattle tank between 1934 and 1950 (Fig. 25A and 25B).

Numerous cattle tanks were constructed from 1934 to 2000. In resacas, cattle tanks were constructed by damming the resaca flow. Markedly, the reference resaca (around Q11) appeared to be largely unaltered despite the dirt roadway construction between 1950 to 1977 (Fig. 26A and 26B). Similarly, the northwest resaca portion (D3, E2 and F3) seemed to be largely undisturbed. The greatest change in resaca character between 1934 to 2000 was the normally bare ground of the main channel becoming vegetated, as illustrated within the reference and northwest resaca's from 1934 to 2000 (Fig. 27A and 27B**)**. As illustrated, encroaching vegetation into the resaca channel and subsequent classification and polygon creation creates an artificial perception of resaca channel migration. Outside of resaca damming subsequent tank creation, cattle tanks were constructed to drain the solitary lake in the north central of PAAL (Fig. 25B, E5 and F5), and others away from visible drainage channels or topographic depressions accumulating water (around J7, K7, L5, L6 and E15).

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Hardcopy and digital products transferred to the National Park Service

1. Photography coverages

   Color infrared photographic scenes

      19 July 2000
      11 scenes (1:6000) unrectified
      11 scenes rectified at a 0.5 m spatial resolution
      a mosaiced coverage of the PAAL at a 0.5 m spatial resolution

      10 February 1999
      11 scenes (1:6000) unrectified
      11 scenes rectified at a 0.5 m spatial resolution
      a mosaiced coverage of the PAAL at a 0.5 m spatial resolution

   Black and White photographic scenes

      8 March 1993
      2 scenes (1:20,000) unrectified
      2 scenes registered to the 2000 coverage at a 0.5 m spatial resolution
      a mosaiced coverage of the PAAL at a 0.5 m spatial resolution

      5 March 1989
      1 scene (1:40,000) unrectified
      1 scene registered to the 2000 coverage at a 0.5 m spatial resolution
      a mosaiced coverage of the PAAL at a 0.5 m spatial resolution

      5 October 1977
      2 scenes (1:24,000) unrectified
      2 scenes registered to the 2000 coverage at a 0.5 m spatial resolution
      a mosaiced coverage of the PAAL at a 0.5 m spatial resolution

      22 September 1977
      1 scene (1:24,000) unrectified
      1 scene registered to the 2000 coverage at a 0.5 m spatial resolution
      a mosaiced coverage of the PAAL at a 0.5 m spatial resolution

      9 February 1962
      3 scenes (1:20,000) unrectified
      3 scenes registered to the 2000 coverage at a 0.5 m spatial resolution
      a mosaiced coverage of the PAAL at a 0.5 m spatial resolution

      4 November 1950
      4 scenes (1:20,000) unrectified
      4 scenes registered to the 2000 coverage at a 0.5 m spatial resolution
      a mosaiced coverage of the PAAL at a 0.5 m spatial resolution

10 December 1939
1 scene (1:24,000) unrectified
1 scene registered to the 2000 coverage at a 0.5 m spatial resolution
a mosaiced coverage of the PAAL at a 0.5 m spatial resolution

4 November 1934
8 scenes (1:18,000) unrectified
8 scenes registered to the 2000 coverage at a 0.5 m spatial resolution
a mosaiced coverage of the PAAL at a 0.5 m spatial resolution

2. Site-specific field data

Tabular data
40 Ground control point locations (GCP) and site descriptions
138 Field site locations and site description
100 Scanned 35-mm photography collected and GCP and field sites

Geographic Information System
A comprehensive and interactive database overlain on the 2000 photographic CIR mosaic
1. GCP locations
2. Field site locations
3. Hot links to tabular, electronic site descriptions and field notes
4. Scanned 35-mm photography collected at the GCP and field site locations

Landcover and land use class descriptions
National Vegetation Classification Standard descriptors of landcover classes used in the PAAL classifications. Determination of the PAAL NVCS classes and descriptions were created and kindly provided to NWRC by Ms. Karen Weaver (Park Ranger) of the PAAL

Landcover and land use changes from 1934 to 2000
1934 mosaic with grid overlain
2000 mosaic with grid overlain
Tabular itemization of changes between 1934 to 2000 per grid location
Tabular changes include 1977 and 1950 landcover and land use information

Accuracy assessment results per class and for the overall 2000 classification

Aerial estimates of each class within the PAAL for 1934 and 2000 (digital and vector)

3. Classified PAAL databases—an interactive GIS contains the following databases

2000 classified map of the PAAL
Following NVCS protocols
At a 0.5 m spatial resolution
Cattle tanks and resacas specifically designated on the classified map

2000 vector classification of the PAAL
Following NVCS protocols
Cattle tanks and resacas specifically designated on the classified map
Mesquite and grassland classes combined as the mesquite-grassland class

1934 vector classification of the PAAL
Following NVCS protocols
Cattle tanks and resacas specifically designated on the classified map
Mesquite and grassland classes combined as the mesquite-grassland class

1934 vector classification overlain on the 1950 photographic mosaic

2000 vector classification overlain on the 1977 photographic mosaic

4. A final report—hardcopy and CD
   - Metadata required by the Federal Geographic Data Committee mandates
     - All original files and final raster files
     - All GIS files within ArcView 3 projects

5. Descriptive posters

   Historical Analyses of the Palo Alto Battlefield Vegetation Landscape from 1934 – 2000

   Landcover Classification of 07-19-00 Aerial Photography

Table 1. The National Vegetation Classification System crosswalk

1. **Tamaulipan Brush*****
2. **Mesquital Forest:** III.B.3.N.a – 4 *Prosopis glandulosa* shrubland
3. **Huisacatal:** III.B.3.N.a – 4 *Acacia farnesiana* shrubland
4. **Borrichia frutescens Prairie:** III.B.2.N.h. – 4 *Borrichia frutescens* tidal shrubland
5. **Spartina spartinae Prairie:** V.A.5.N.n. – 13 *Spartina spartinae* tidal herbaceous
6. **Dead and Sparse Grasses*****
7. **Bare Soils:** VII.C.4.N.c – 1 non-tidal mud flat seasonally/temporarily flooded sparse vegetation
8. **Sonchus asper Prairie***
9. **Texas Colubrina Prairie****
10. **Mesquital Prairie:** V.A.7.N.m – 3 *Prosopis glandulosa* shrub herbaceous
11. **Southern Cattail (Water):** V.A.5.N.k. – 31 *Typha domingensis* seasonally flooded temperate herbaceous
12. **Needle Spikerush (Water):** V.A.5.N.k. – 61 *Eleocharis acicularis* seasonally flooded herbaceous

*****This "prairie" occurs in an extremely disturbed area. The area is an abadoned sorghum field. Many species – predominantly sunflowers (*Helianthus annuus*) – grow in this area. One of many species that grows in this area is *Sonchus asper*. Therefore, the classification "Sonchus asper Prairie" is false.

** This "prairie" occurs in an extremely disturbed area. The area is an abadoned sorghum field. In 1997 this field was replanted with many different species. Several of these species are native to Cameron County but are not found at Palo Alto. Texas Colubrina (*Colubrina texensis*) is one of these species. Therefore, the classification "Texas Colubrina Prairie" is false.

***These vegetation classes could not be crosswalked into the NVCS. At this time, there are no comparable classes in the NVCS.

Table 2. Classification accuracy assessment.

IMAGE CLASSIFIED	FIELD OBSERVED CLASSES										
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	Total
Tamaulipan Brush	**1**	**6**	0	0	0	0	0	0	0	0	6
Mesquital Forest	**2**	0	**9**	2	0	0	0	0	0	0	11
Huisachal	**3**	0	0	**1**	0	0	0	0	0	0	1
Borrichia Prairie	**4**	0	0	0	**60**	0	12	0	0	0	72
Spartina Prairie	**5**	0	0	0	0	**32**	0	0	0	0	32
Dead/Sparse Grasses	**6**	0	0	0	0	0	**13**	0	0	0	13
Bare Soils	**7**	0	0	0	0	0	0	**0**	0	0	0
Sonchus Asper	**8**	0	0	0	0	0	0	0	**1**	0	1
Texas Colubrina Prairie	**9**	0	0	0	0	0	0	0	0	**1**	1
	Total	6	9	3	60	32	25	0	1	1	137

Overall Accuracy For All Classes Combined (Percent) 89.78

Table 3. Spatial coverage of each landcover class from 2000 classification.

LANDCOVER	HECTARES[1]
Taumilipan	149.38
Mesquite	31.3
Husachial	2.66
Borrichia	497.06
Spartina	453.1
Dead/Sparse	167.72
Bare Land	47.69
Texas colubrina	6.79
Sonchus asper	16.99

[1]Above spatial coverages based on the 2000 raster based classification (<1 m spatial resolution).

Table 4. Modeled spatial coverage of landcover classes in 1934 and 2000

	1934 Total Area Sq. Meters
Tamaulipan	1584482
Mesquite Forest	755741.8
Huisachal	246606.4
Borrichia	2502442
Spartina	6862324
Dead/Sparse	1562844
Bare Soils	266862.5
Mesquite Plain	133555.9
Water	15687.64

	2000 Total Area Sq. Meters
Tamaulipan	1637733
Mesquite Forest	417586.1
Huisachal	49395.3
Borrichia	4999008
Spartina	3968954
Dead/Sparse	1067207
Bare Soils	268563.4
Texas Colubrina	70652.2
Sonchus Asper	174805.9
Mesquite Plain	1061994

Figure 1. Year 2000 CIR photography. Man made cattle tanks are highlighted, and numerous roadways and cultivated areas are visible. North is indicated, and is applicable to all future images.

Figure 2. Examples showing how the general mosaic is made up of different frames. Here, 4 different sub frames are depicted in different colors showing their locations and where they were stitched together.

Figures 3 – 9. Final mosaics of the years 2000, 1989, 1977, 1962, 1950, 1939, and 1934.

Figure 10. A representation of the interactive clickable map. The user of the interactive map can click on the different points to retrieve location information and pictures where available.

Figure 11. The 1999 CIR mosaic that was not used due to scene problems.

Figure 12. The final 2000 CIR image with the park boundary shown in blue.

Figure 13. The initial vegetation cover map that was available prior to our analysis.

Figure 14. The final land cover classification map with a quadrant overlay shown. These quadrants are used for reference in future figures.

Figure 15. A scanned copy of a historic map with the location of the historic roadway emphasized.

Figure 16A: The 2000 polygon coverage that was derived from the raster image, with a blowup showing detail.

Figure 16B: The 1934 polygon coverage that was modified from the 2000 polygon coverage, with a blowup showing detail.

Figure 17: The year 2000 polygon outlines overlain on the 1934 imagery.

Figures 18A & B: The 1934 photography shown with and without the hand digitized manmade features.

Figures 19A and B: The final 2000 and 1934 photo mosaics showing dramatic changes between 1934 and 2000 in complexity of the landscape.used.

Figures 20A and B: Blowups showing the loss of mesquite stands between 1934 and 2000.

Figures 21A and B: Blowups showing expansion of mesquite grassland.

Figures 22A and B: Blowups showing increasing tamaulipan coverages.

Figures 23A and B: Showing the expansion of Borrichia into the core battlefield area.

Figures 23C and D: Showing the loss of cordgrass in the core battlefield area.

Figures 24A thru D: Showing areas of healthy cordgrass.

Figures 25A and B: Showing the cattle tank that resulted in the loss of the lake.

Figures 26A and B: Showing the reference Resaca relatively unchanged except for this roadways.

Figures 27A and B: Showing the Resaca becoming vegetated.

Figure 1

Figure 2

Figure 3

Figure 4

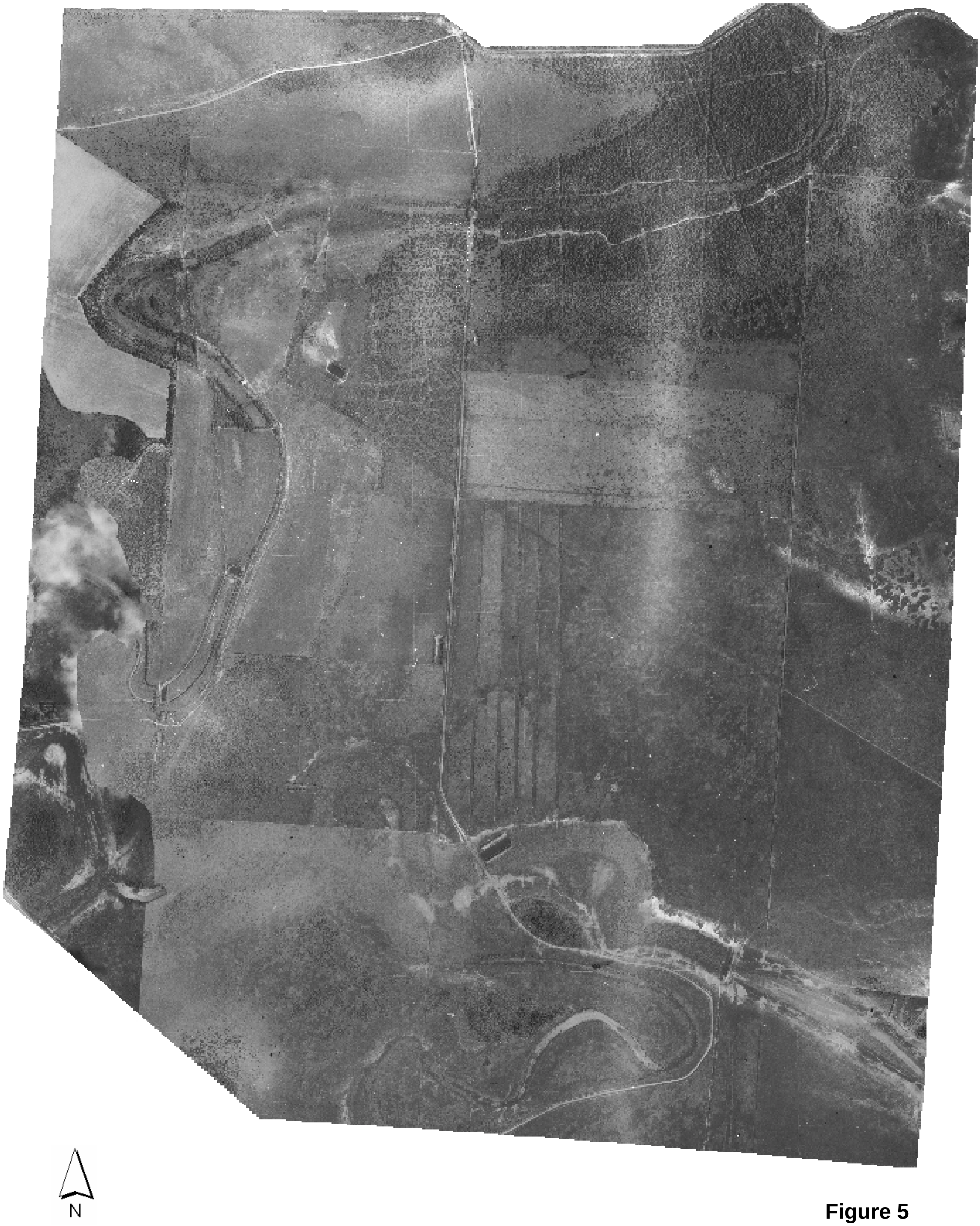


Figure 5

Figure 6

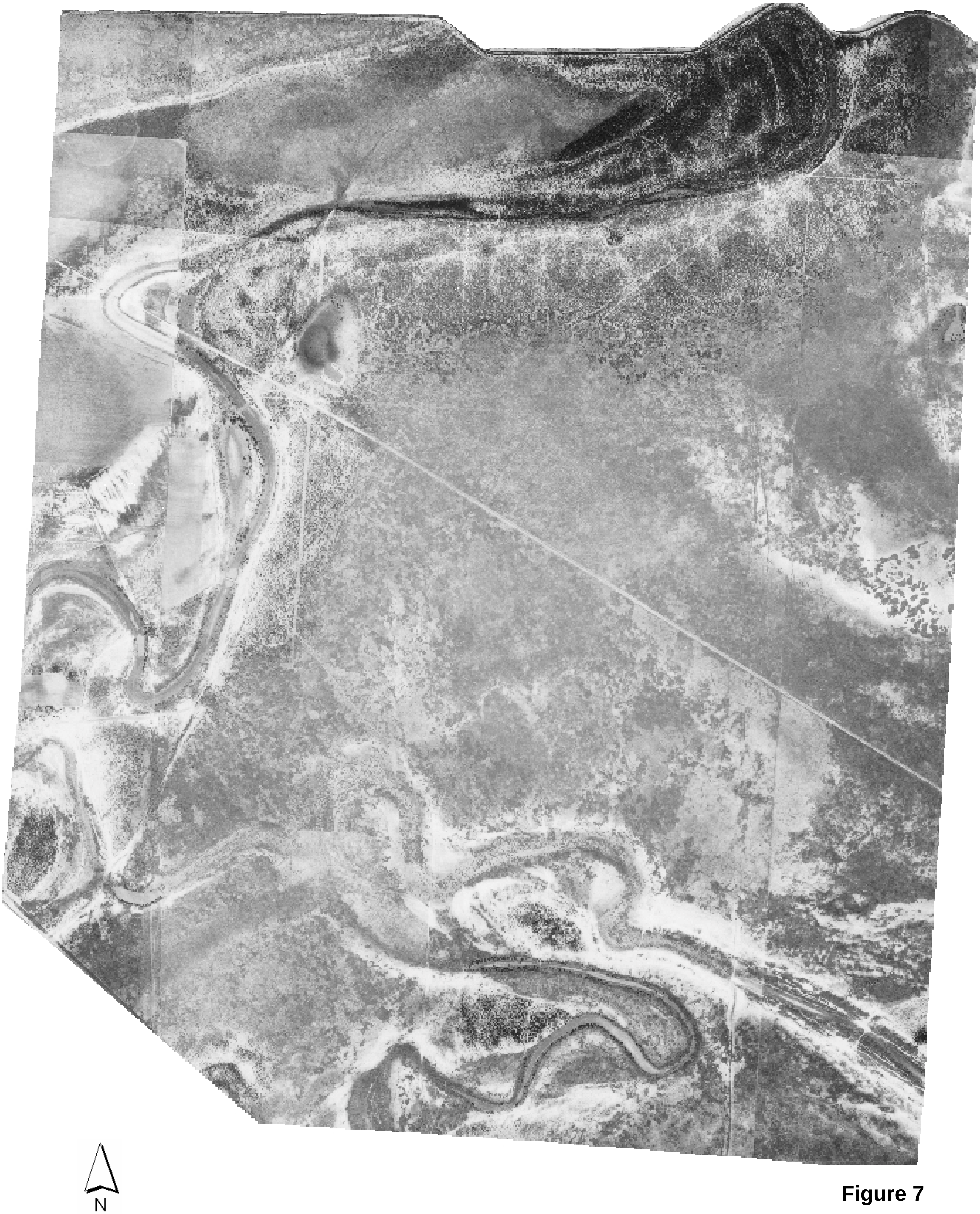


Figure 7

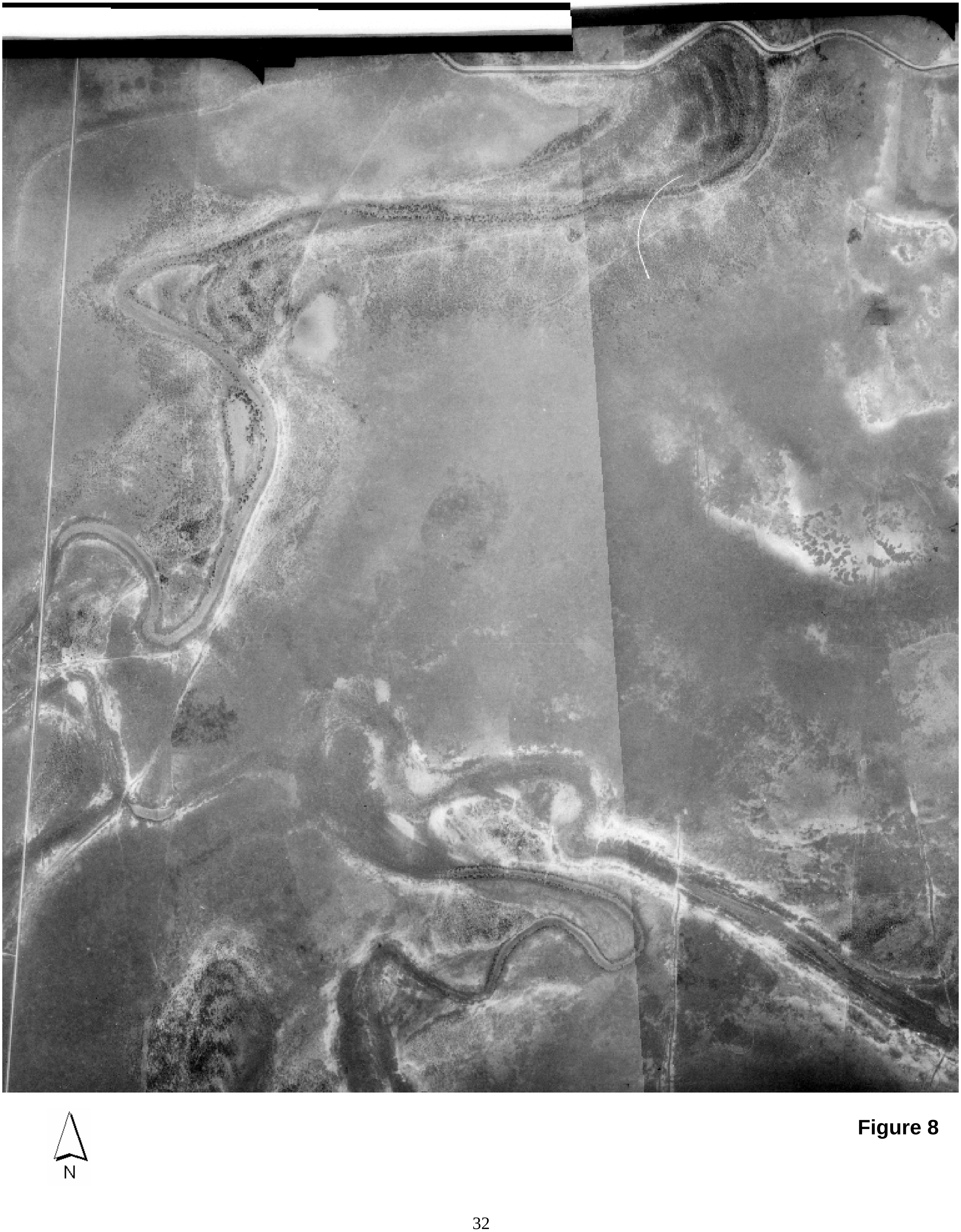


Figure 8

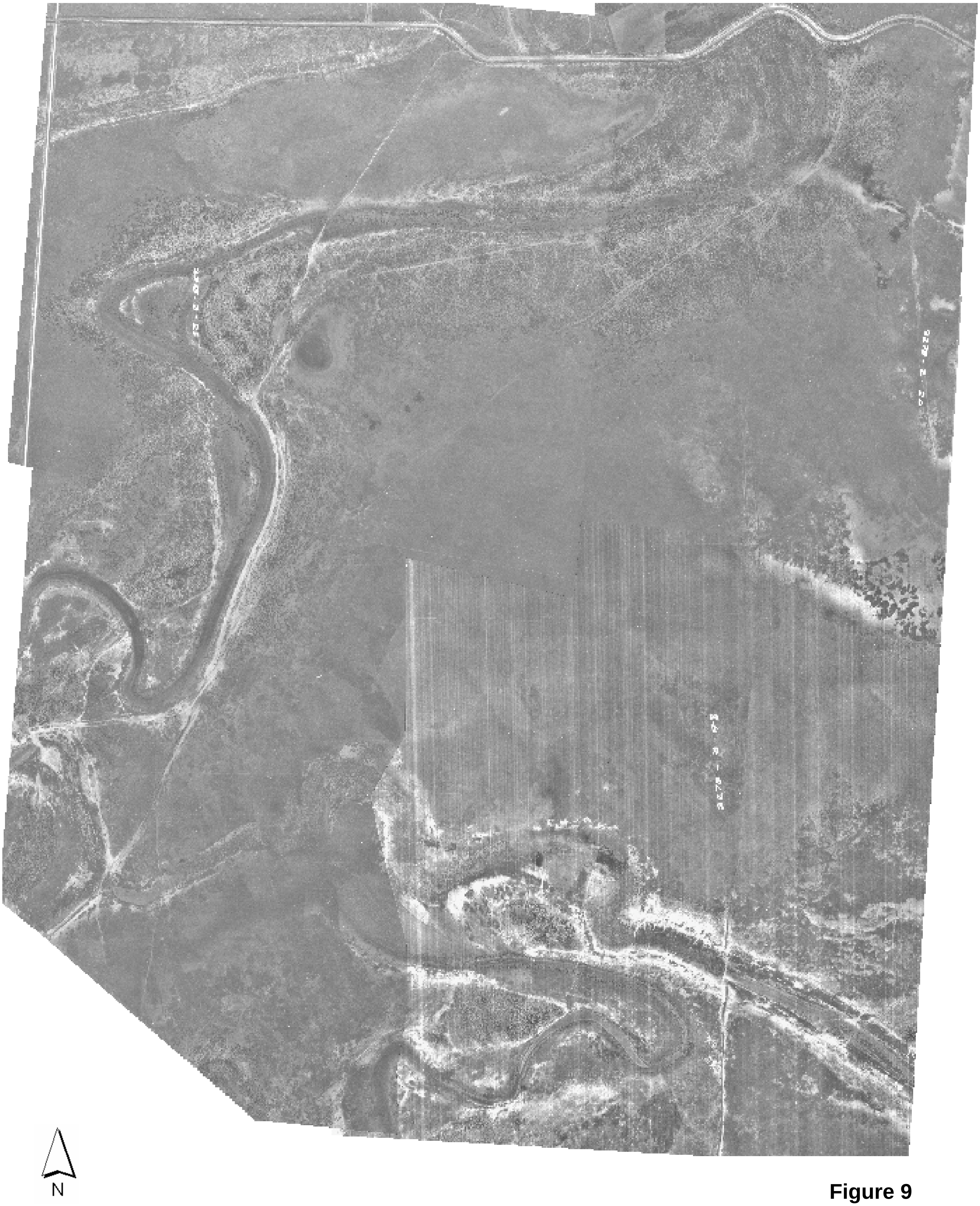
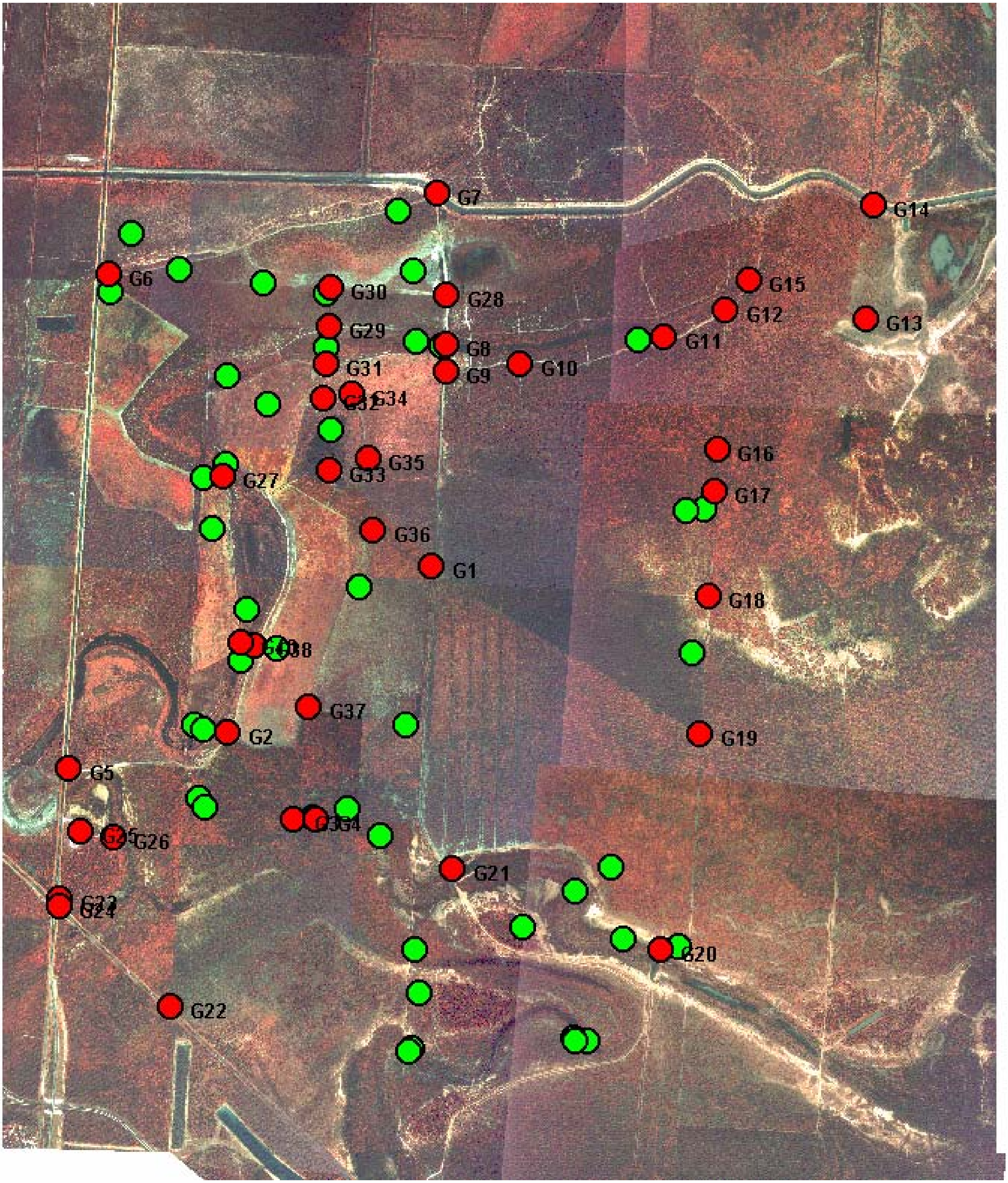


Figure 9



N

Ground Control Point Location Vegetation Sample Location **Figure 10**

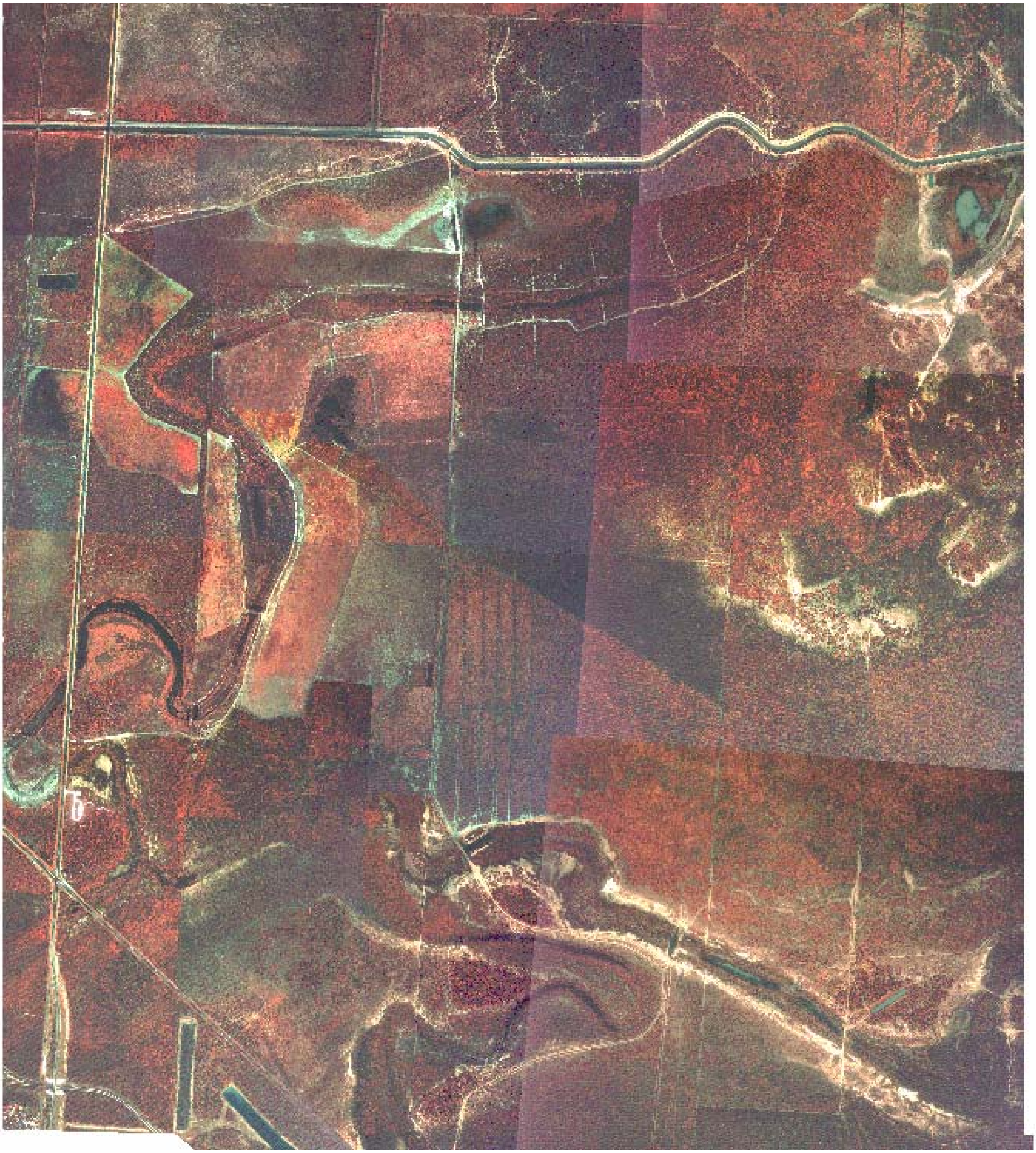


Figure 11

Figure 12

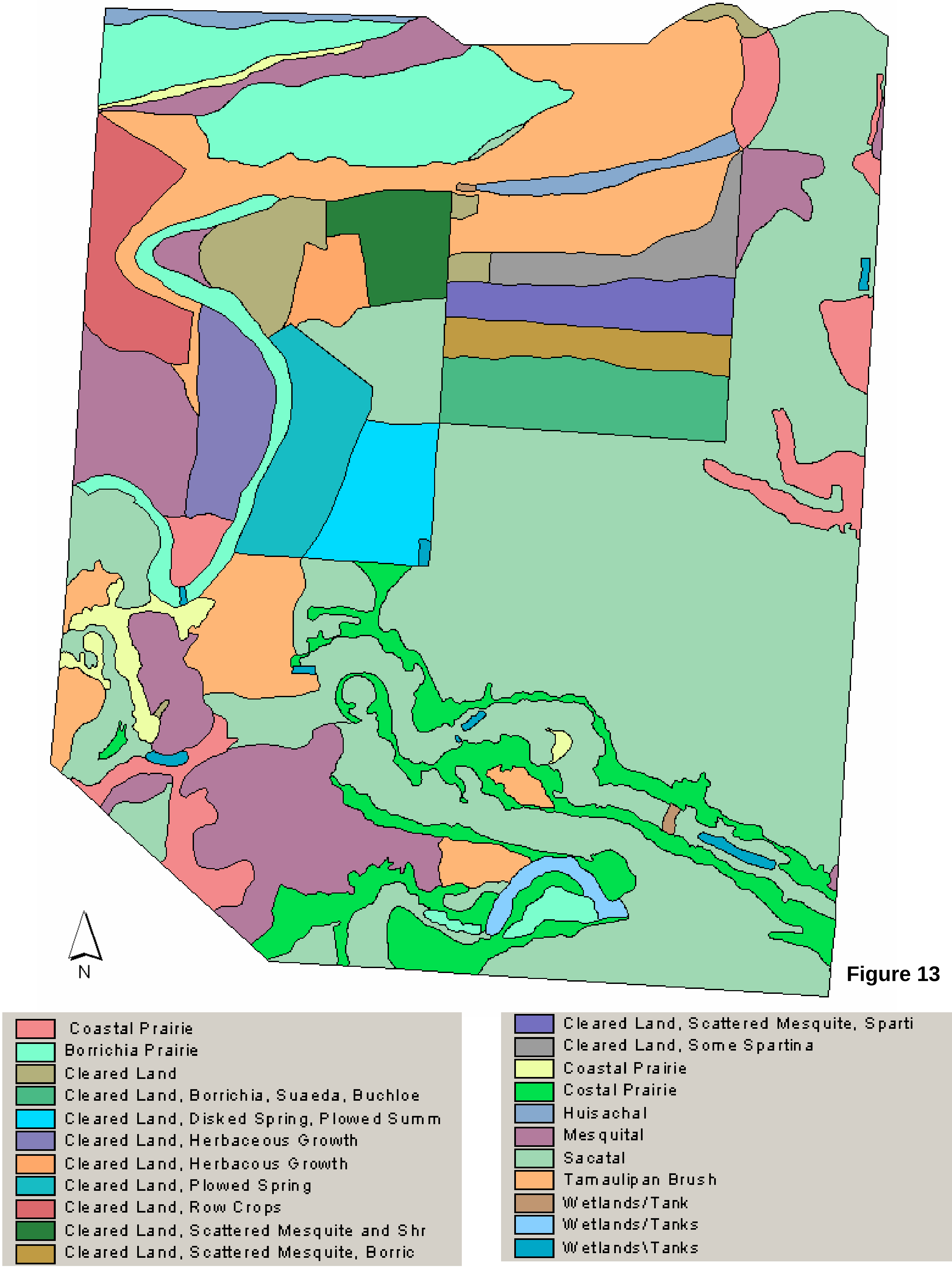

N
Coastal Prairie
Borrichia Prairie
Cleared Land
Cleared Land, Borrichia, Suaeda, Buchloe
Cleared Land, Disked Spring, Plowed Summ
Cleared Land, Herbaceous Growth
Cleared Land, Herbacous Growth
Cleared Land, Plowed Spring
Cleared Land, Row Crops
Cleared Land, Scattered Mesquite and Shr
Cleared Land, Scattered Mesquite, Borric
Cleared Land, Scattered Mesquite, Sparti
Cleared Land, Some Spartina
Coastal Prairie
Costal Prairie
Huisachal
Mesquital
Sacatal
Tamaulipan Brush
Wetlands/Tank
Wetlands/Tanks
Wetlands\Tanks

Figure 13

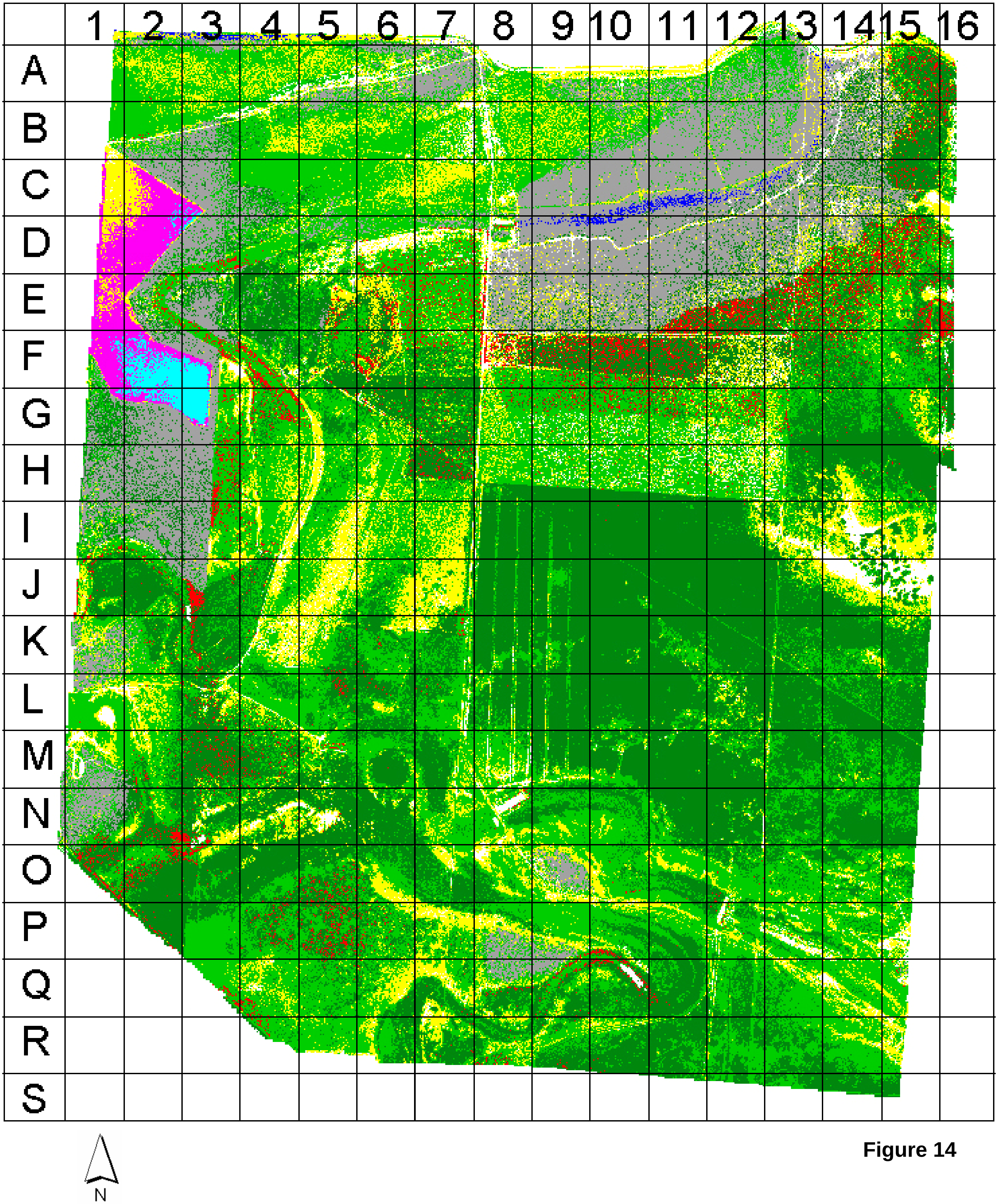


Figure 14

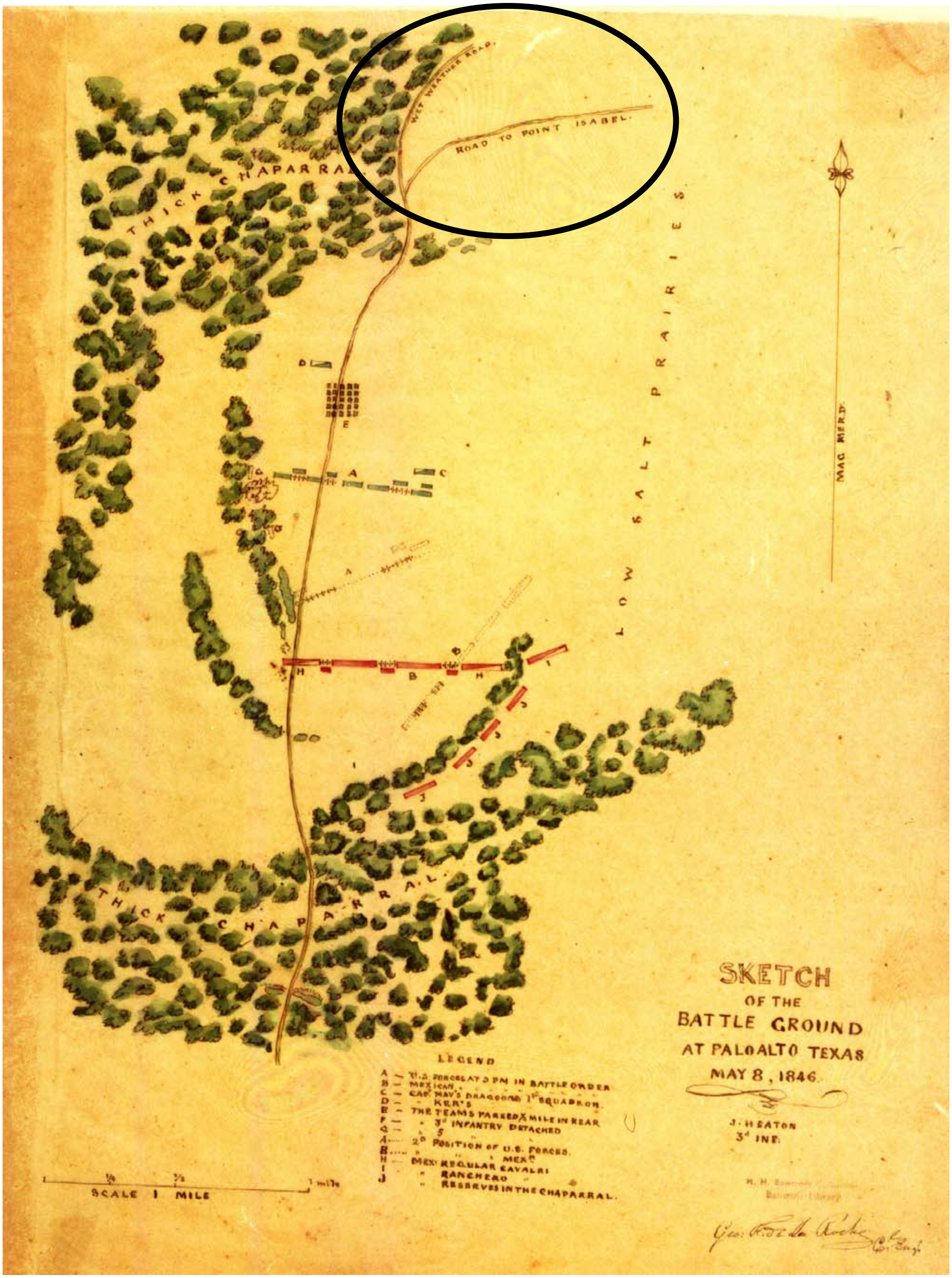

WET WEATHER ROAD.
ROAD TO POINT ISABEL.
THICK CHAPARRAL
LOW SALT PRAIRIES
MAG MERD.
THICK CHAPARRAL.
SKETCH
OF THE
BATTLE GROUND
AT PALOALTO TEXAS
MAY 8, 1846.
J. H EATON
3d INF.
LEGEND
A — U.S. FORCES AT 3 PM IN BATTLE ORDER
B — MEXICAN
C — CAPT MAY'S DRAGOONS 1st SQUADRON.
D — KER'S
E — THE TEAMS PARKED ¾ MILE IN REAR
F — 3d INFANTRY DETACHED
G — 5
A.... 2D POSITION OF U.S. FORCES.
B.... MEXN
H — MEX: REGULAR CAVALRI
I — RANCHERO
J — RESERVES IN THE CHAPARRAL.
SCALE 1 MILE
1 mile

Figure 15

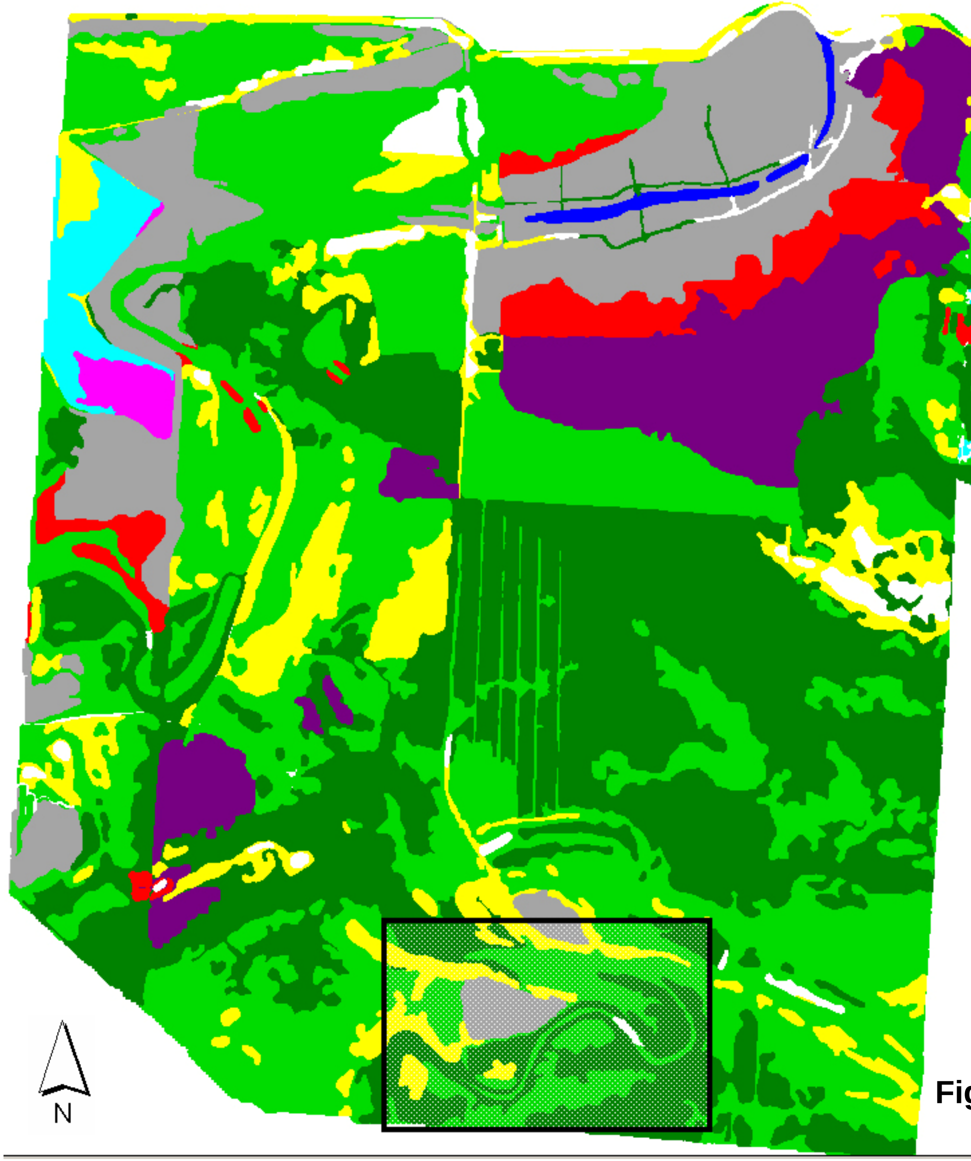
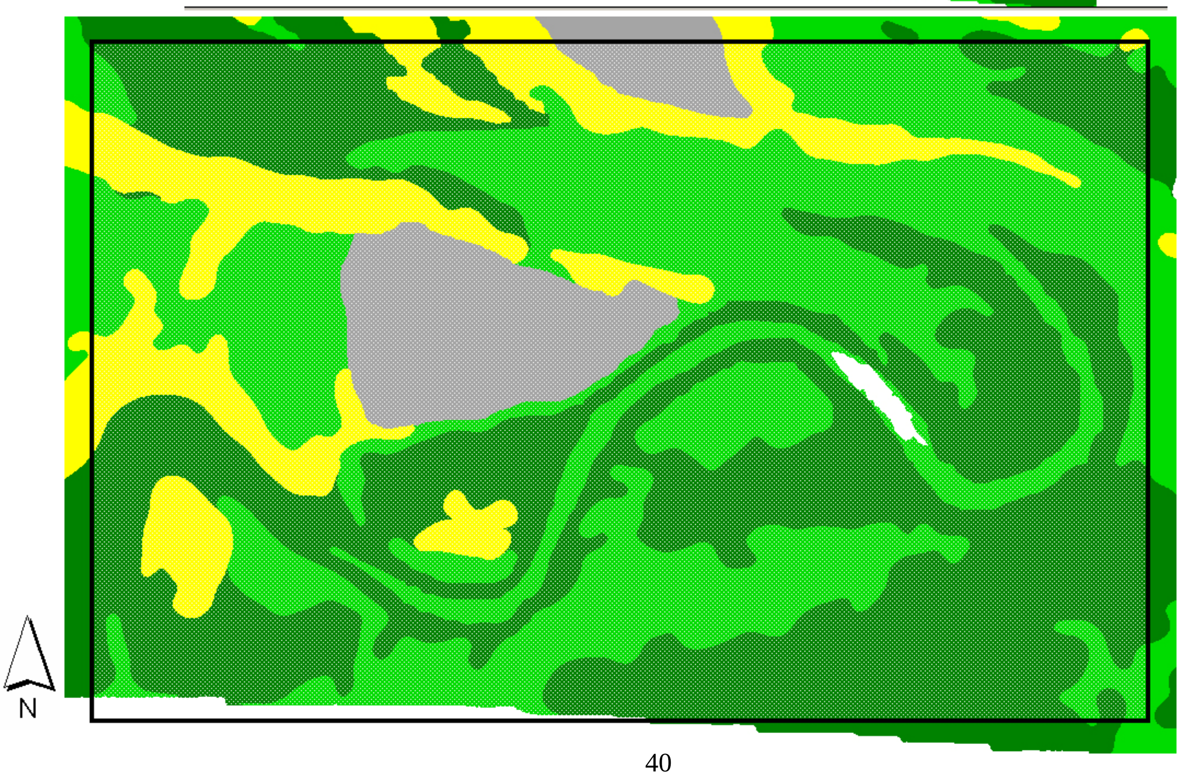


Figure 16A



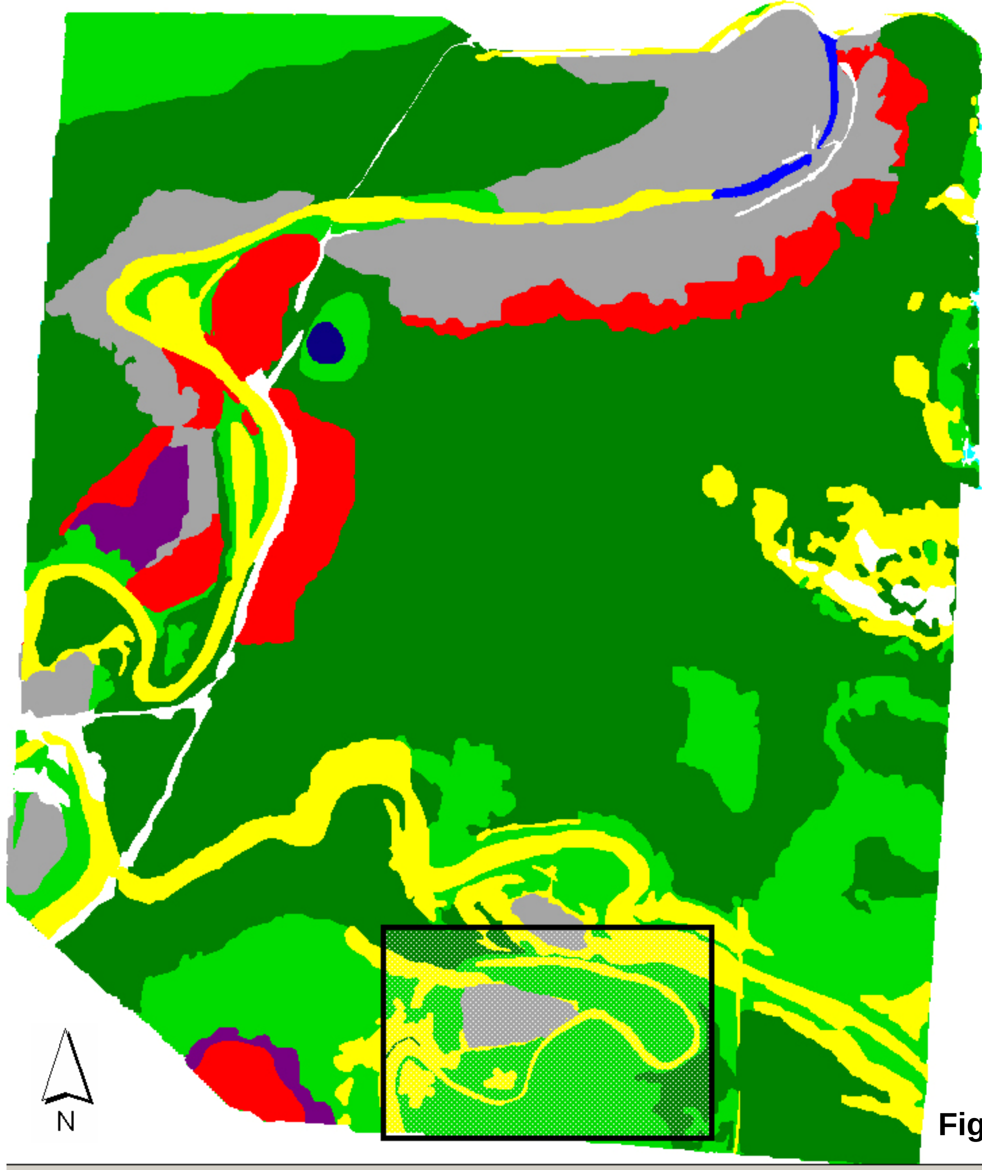
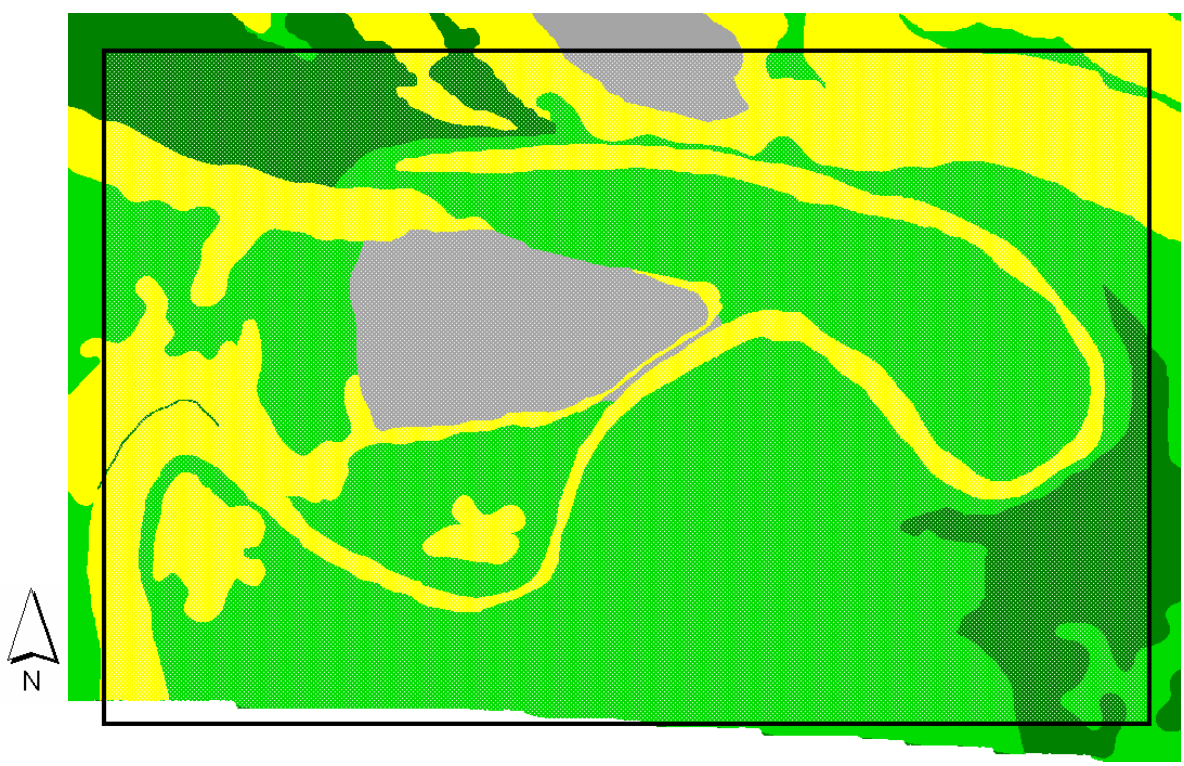


Figure 16B



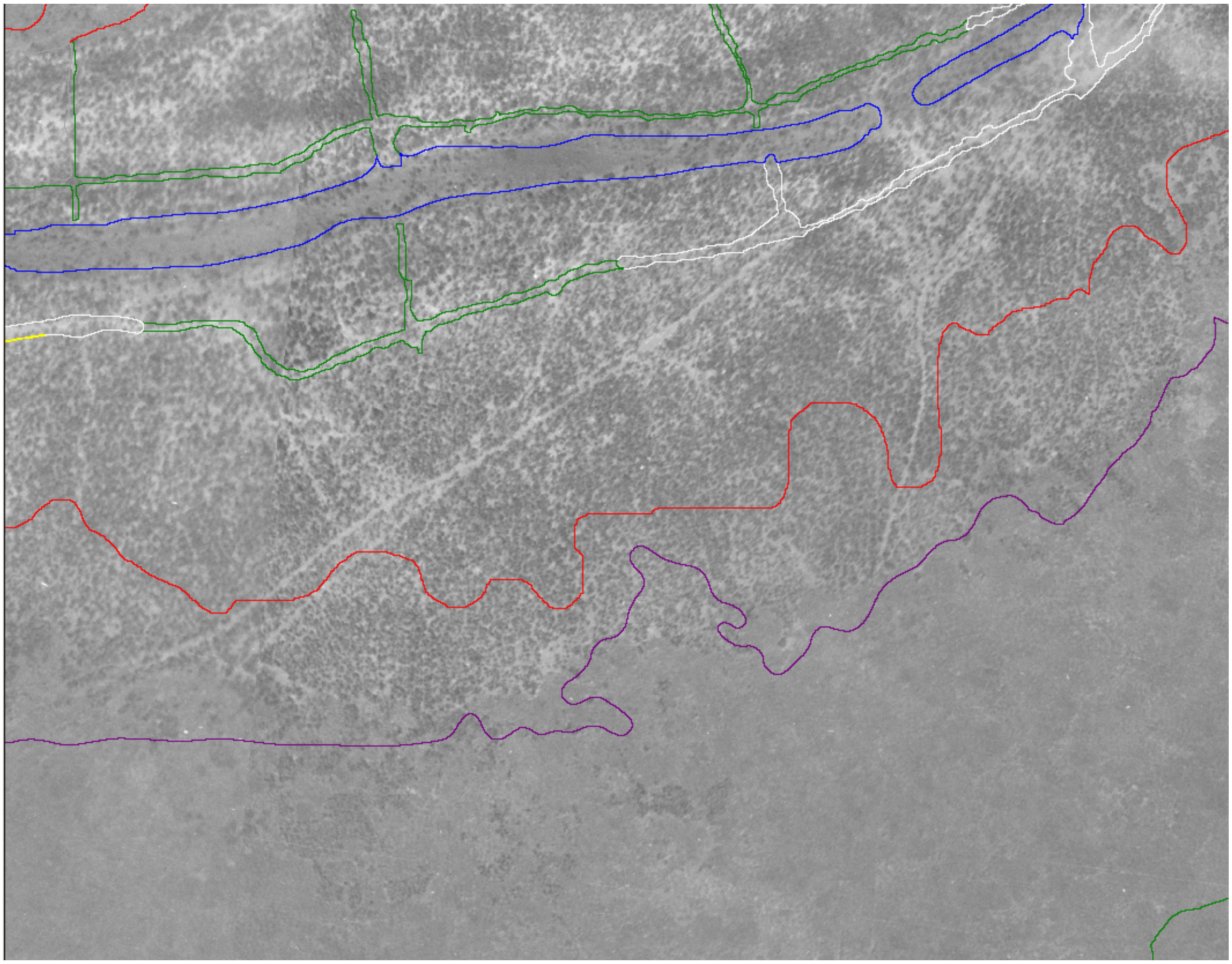


Figure 17

Figure 18A

Figure 18B

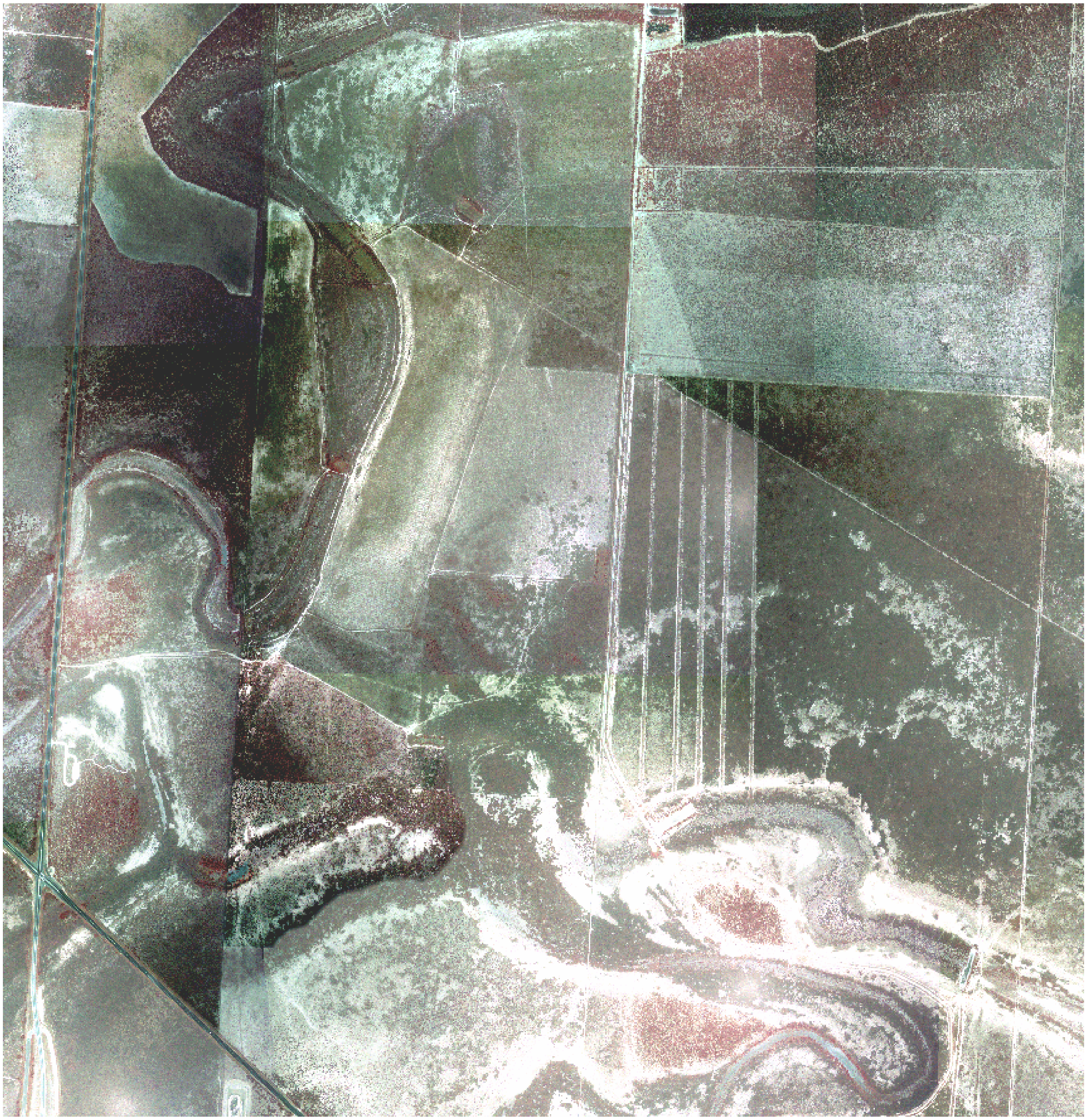


Figure 19A

Figure 19B

Figure 20A

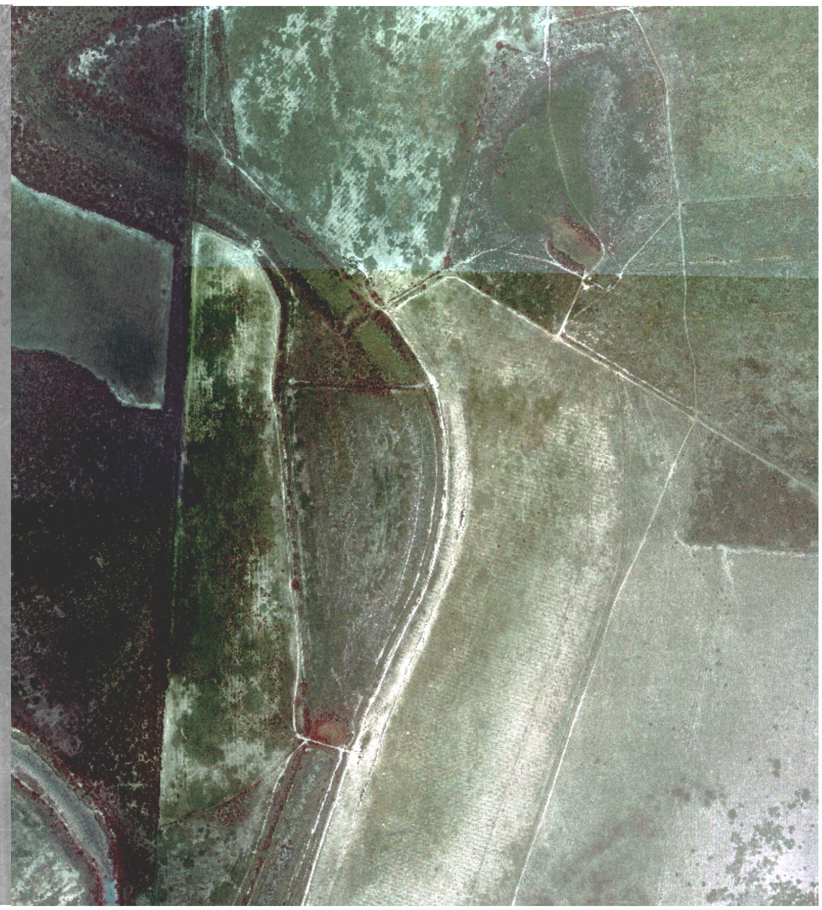


Figure 20B

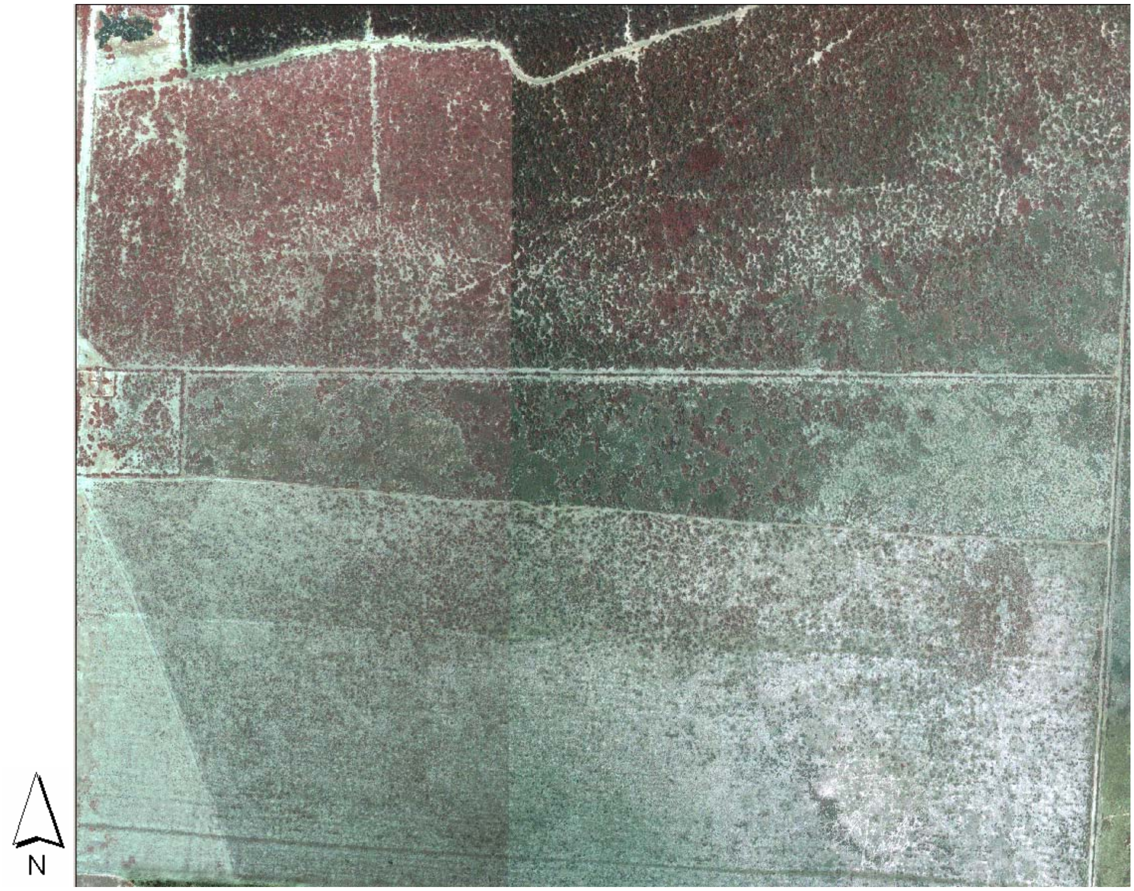


Figure 21A

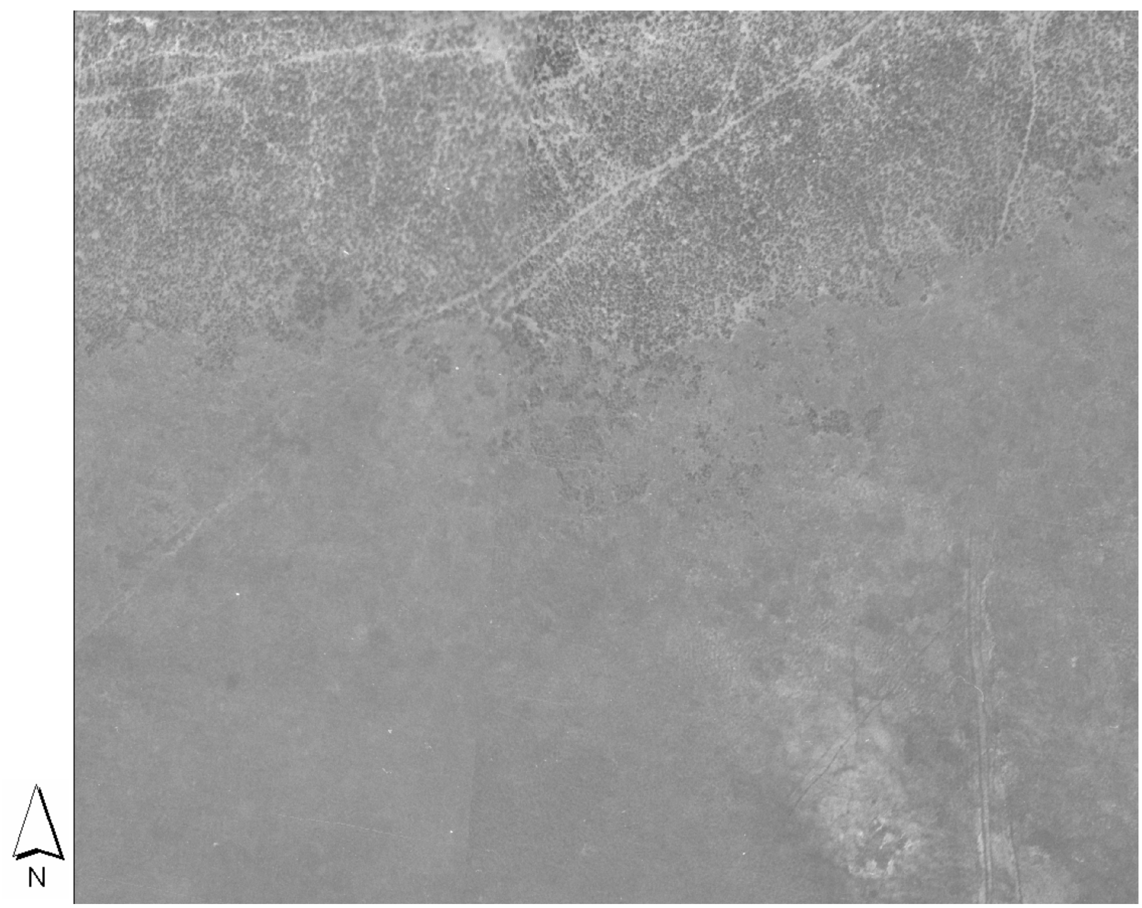


Figure 21B

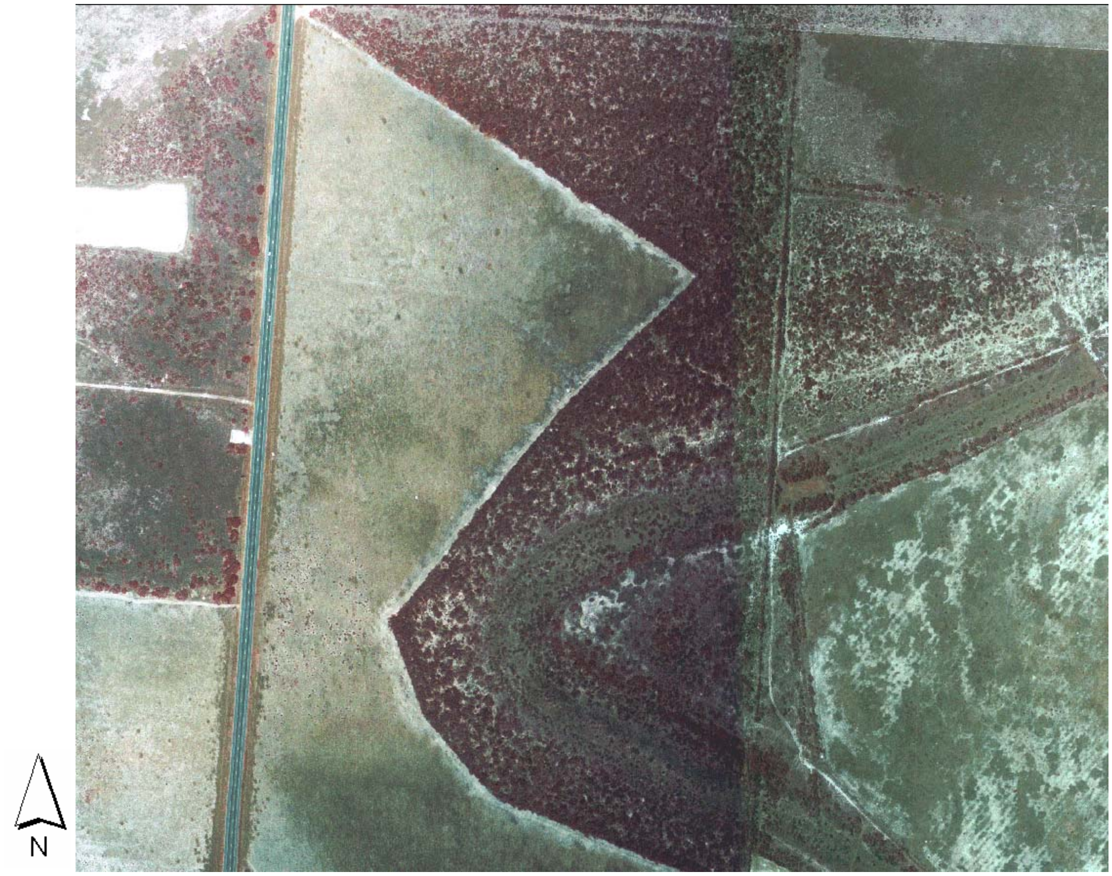


Figure 22A

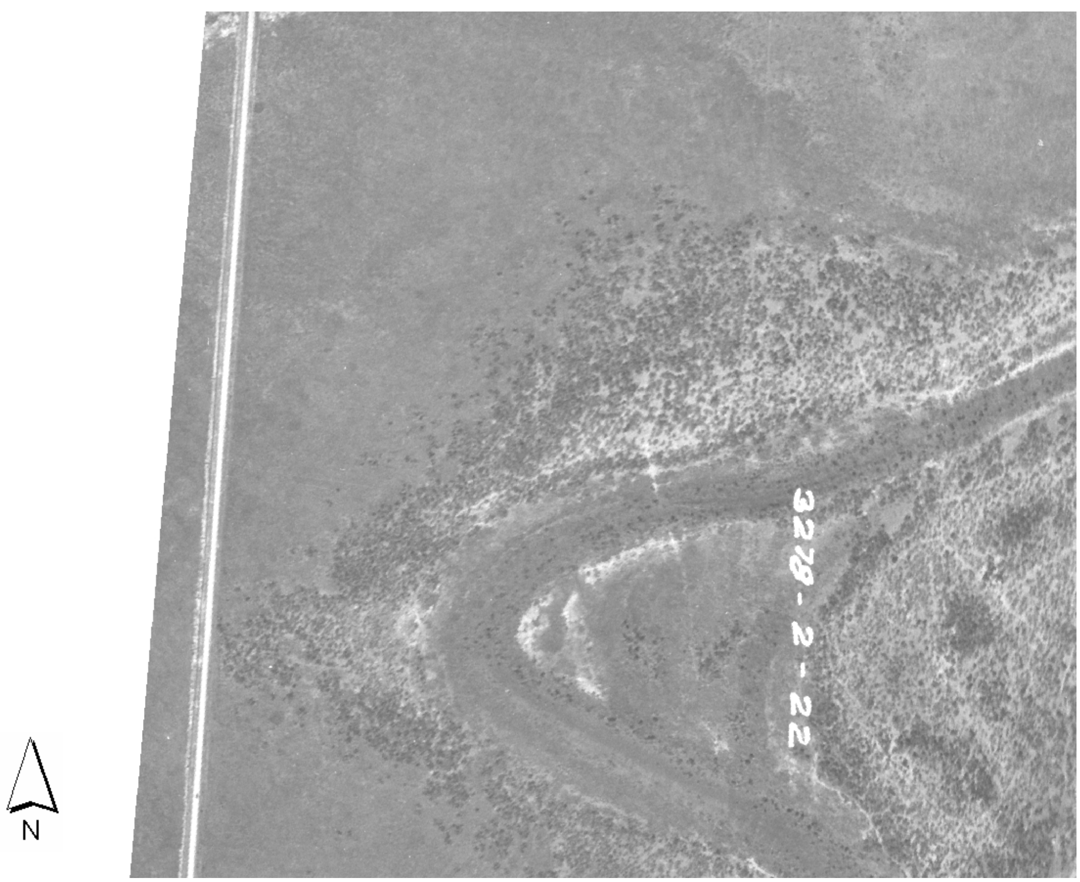


Figure 22B

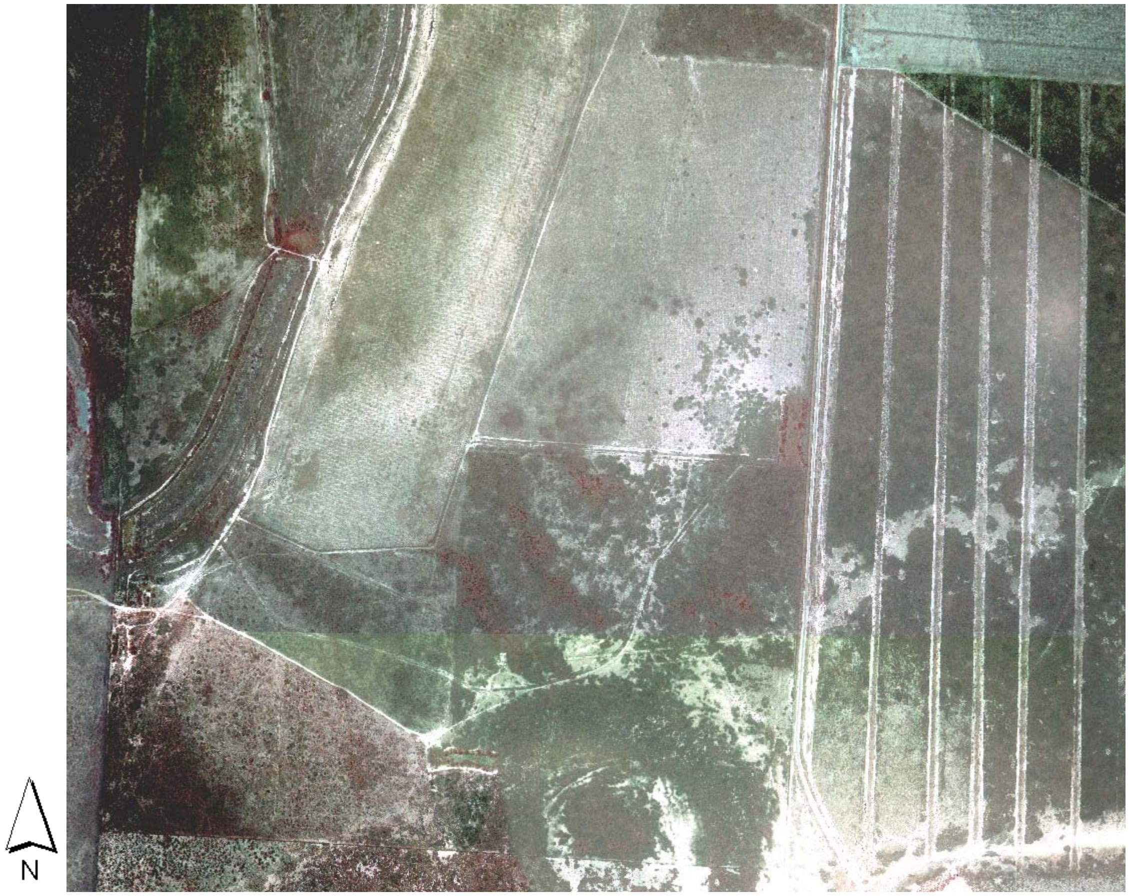


Figure 23A

Figure 23B

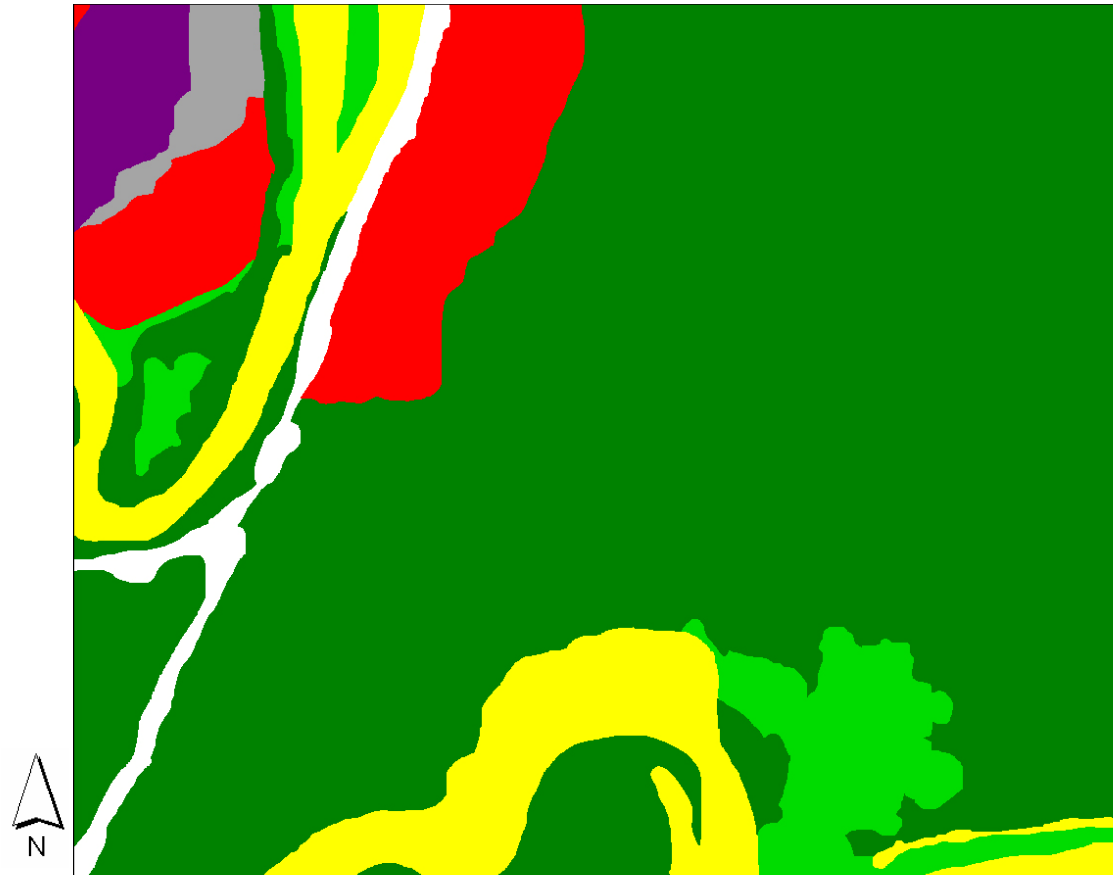


Figure 23C

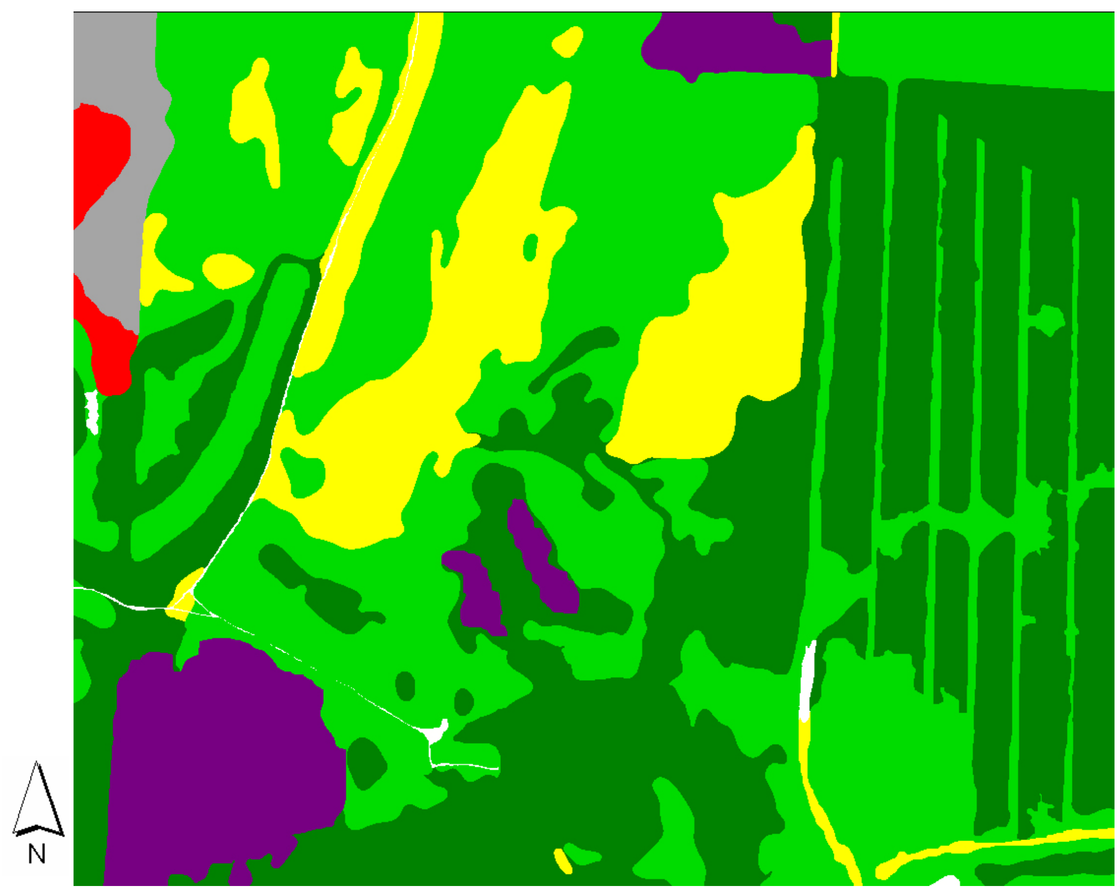


Figure 23D

Figure 24A

Figure 24B

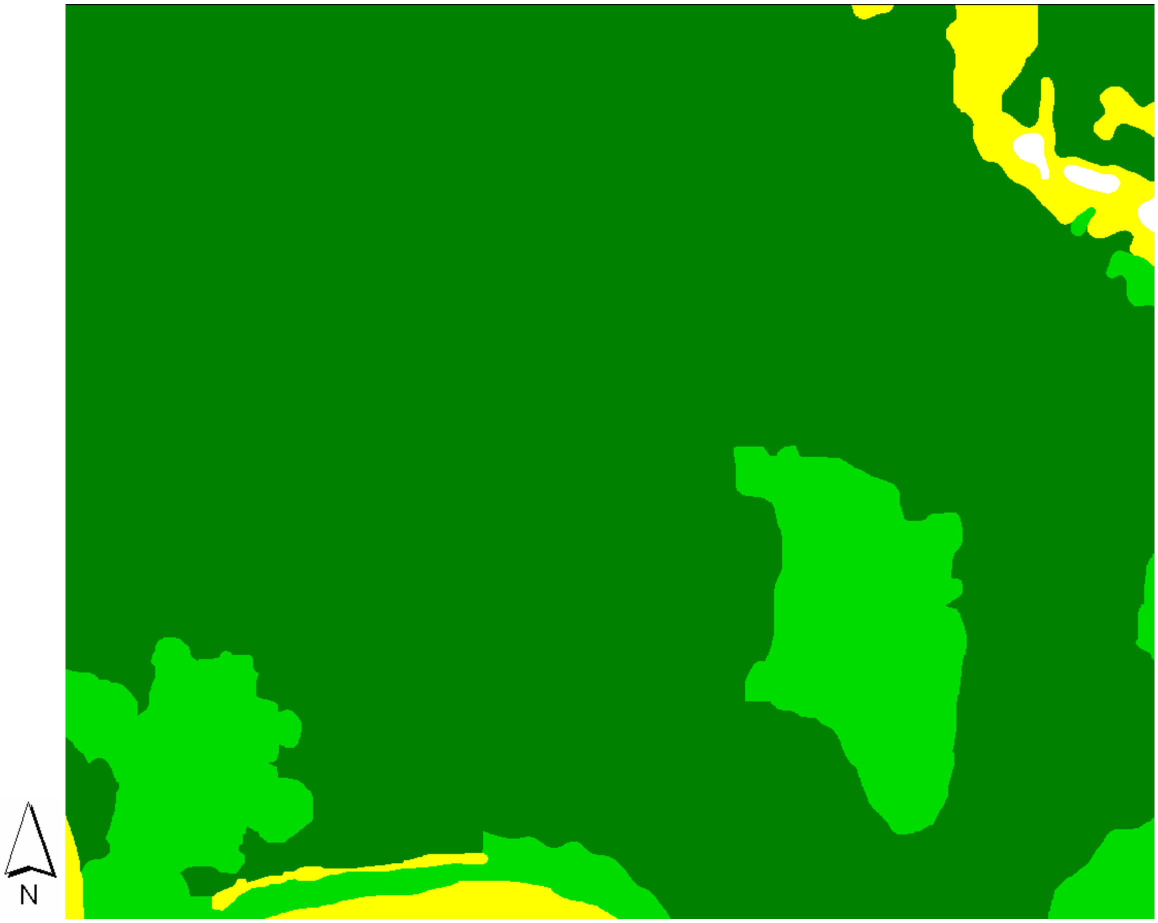


Figure 24C

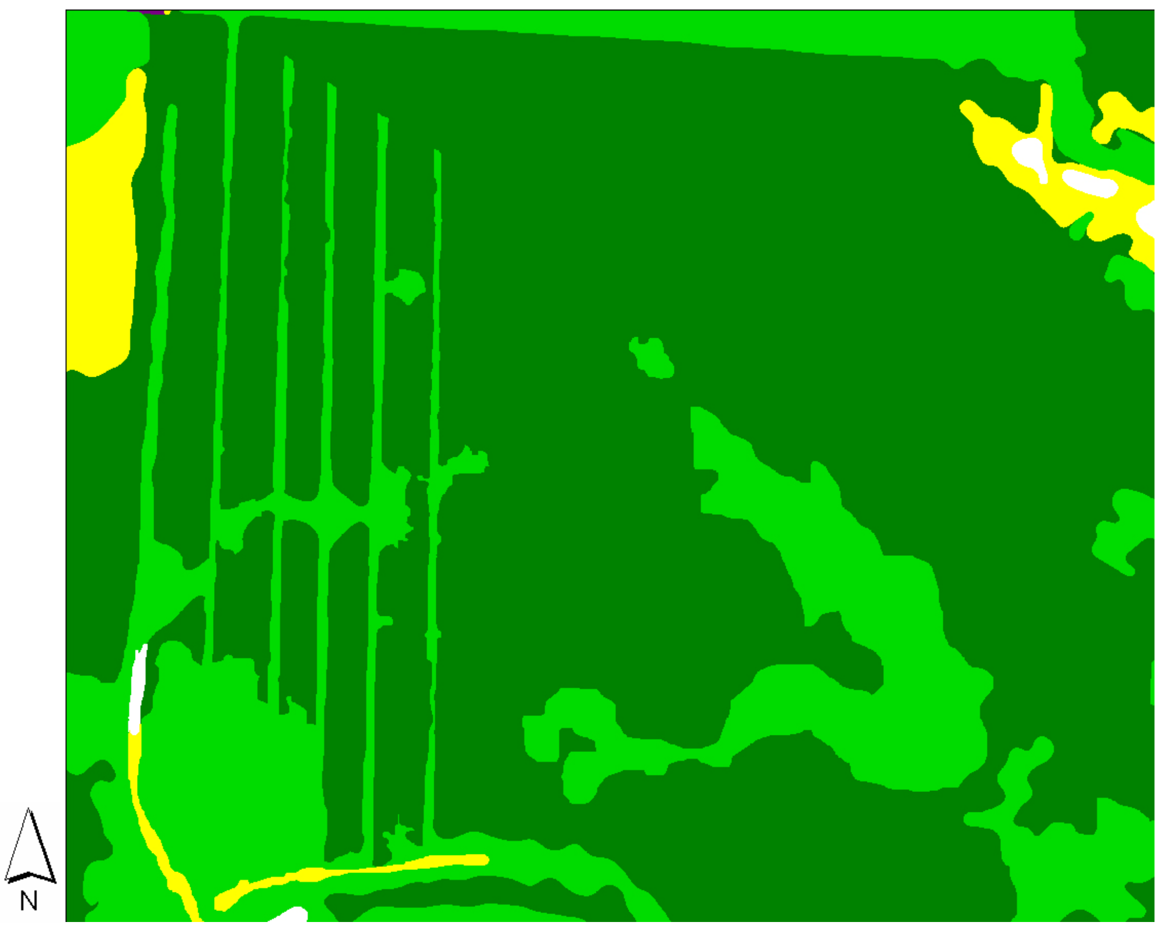


Figure 24D

Figure 25A

Figure 25B

Figure 26A

Figure 26B

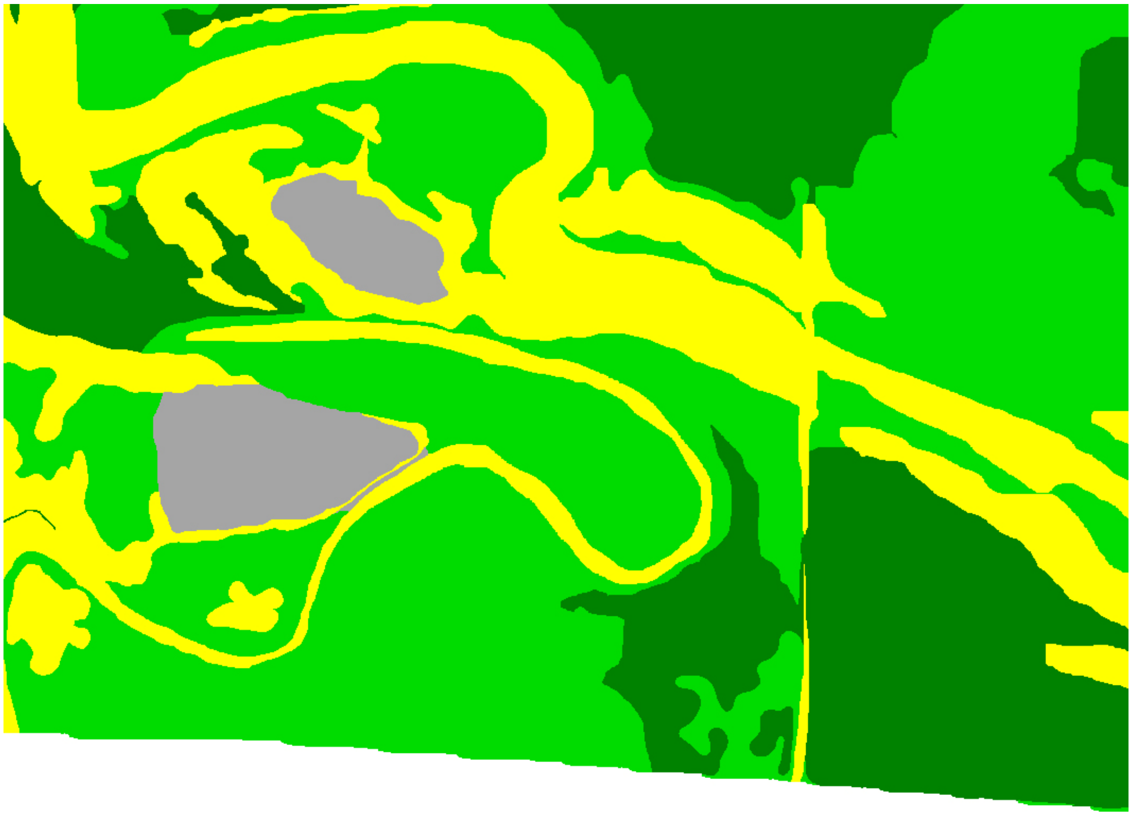


Figure 27A

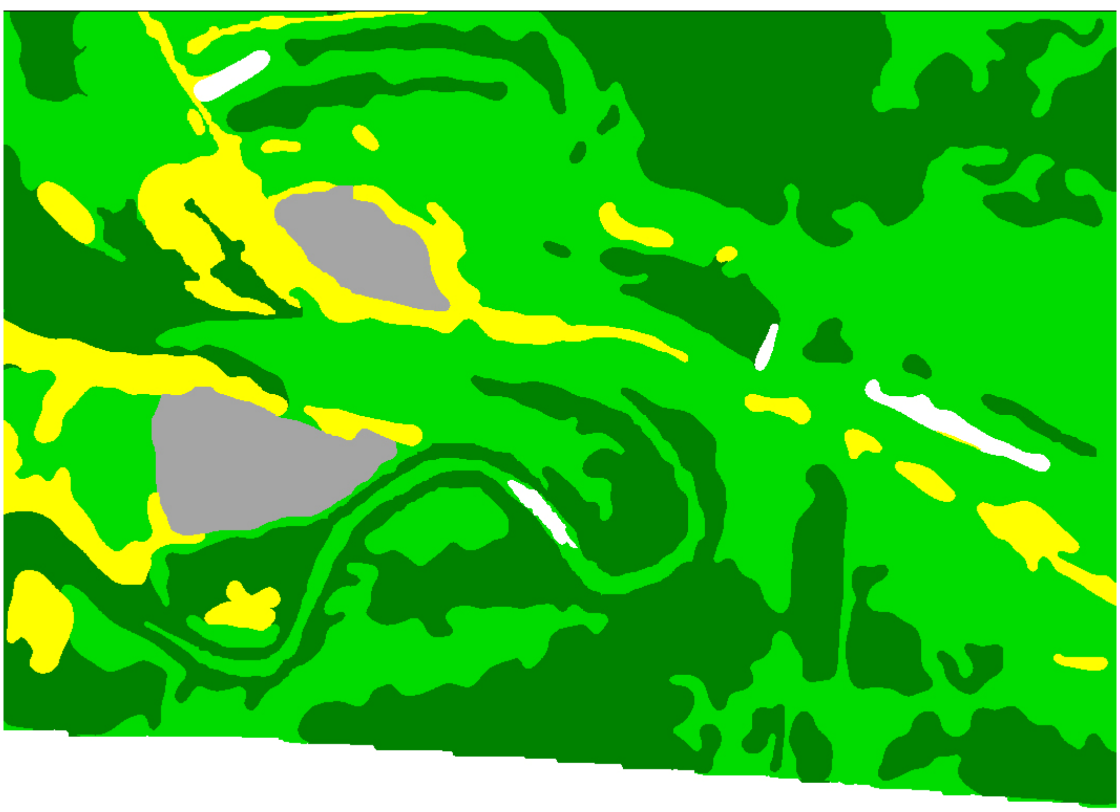
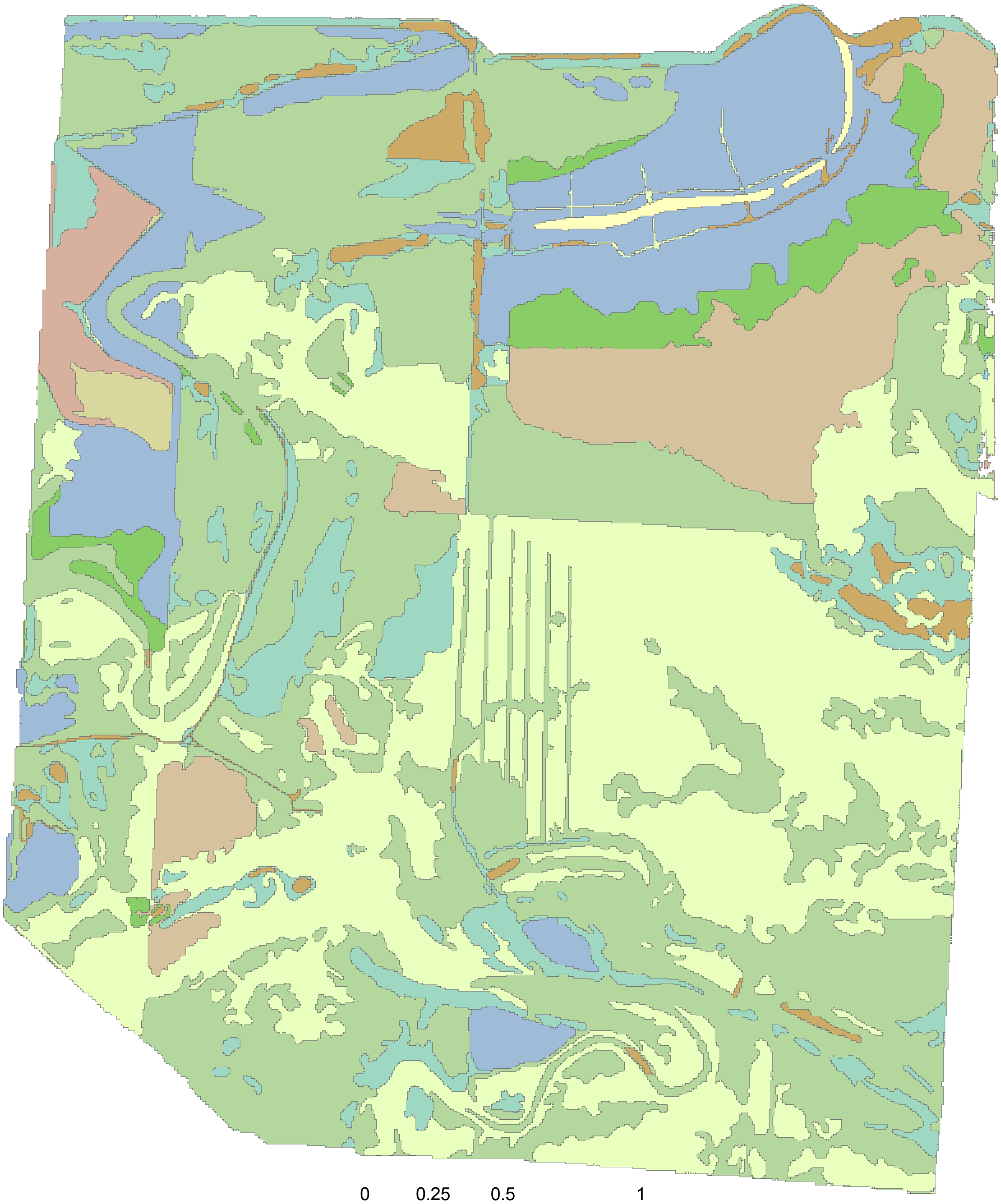


Figure 27B

Palo Alto Battlefield National Historical Park
Texas

National Park Service
U.S. Department of the Interior

Vegetation Map



0 0.25 0.5 1 Kilometers

Projection UTM Zone 14, Datum NAD83

Legend

Map Class

- Tamaulipan Brush
- Mesquital Forest
- Huisacatal
- Seaside Oxeye Prairie
- Gulf Cordgrass Prairie
- Dead and Sparse Grasses
- Bare Soil
- Spiny Sowthistle Prairie
- Texas Colubrina Prairie
- Mesquital Prairie
- Water

N

Produced by USGS

July 2010