RECLAMATION
Managing Water in the West

Technical Memorandum No. 86-68260-07-01

Lake Meredith National Recreation Area, Alibates Flint Quarries National Monument, Texas
2004-2006 VEGETATION CLASSIFICATION AND MAPPING

Remote Sensing and GIS Group, Technical Service Center

A view of Lake Meredith from a steep slope below Fritch Fortress.

U.S. Department of the Interior
Bureau of Reclamation

April, 2007

This report was prepared for the U.S. National Park Service and the U.S. Geological Survey's Center for Biological Informatics by the Remote Sensing and Geographic Information Group of the Bureau of Reclamation's Technical Service Center, Denver, Colorado in cooperation with NatureServe.

Technical Memorandum No. 86-68260-07-01.

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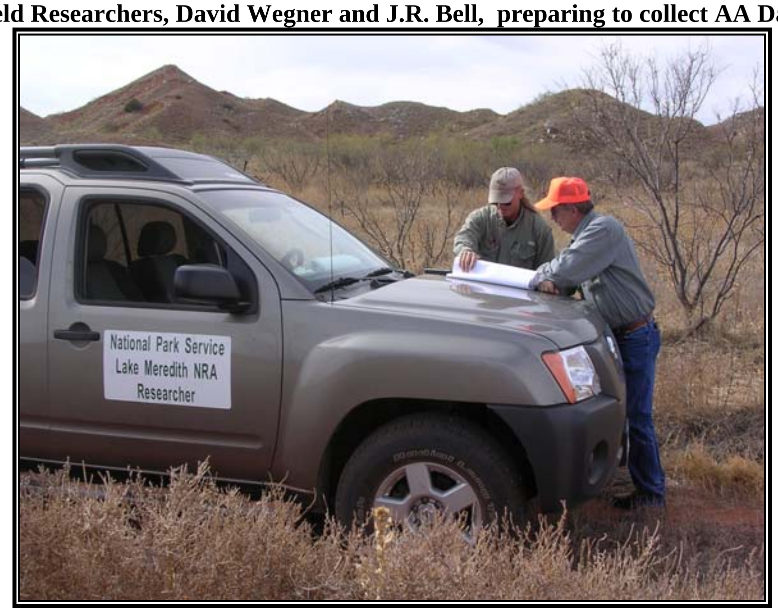
We would like to thank the personnel at Lake Meredith National Recreation Area/Alibates Flint Quarries National Monument in Fritch, Texas for being so supportive and helpful throughout the project from planning to field effort to analysis of the accuracy assessment. We thank both Jim Rancier (now retired) and Paul Eubank, Chief of Resource Management. Paul was always there to help us with logistics and provided us with office space at the Park ranger station. We can only hope that this map and GIS database are useful to the Park and that it, in some way, help make their job easier.

The collaboration with NatureServe for development of the NVC classification was a very positive one. Shannon Menard and Jim Drake of the Minneapolis office were also instrumental in providing training in standard NVC vegetation sampling methods for the field crew. Their expertise and help were greatly appreciated.

Finally, we were able to put together a small but talented crew to collect the field data. The expertise and athletic stamina of Dave Wegner was appreciated and enabled us to get to places that we might not have otherwise sampled. Finally, this project was immeasurably improved by having the talents and expertise of J.R. Bell on board to characterize the vegetation at Lake Meredith. Having a local native of the area to negotiate our movement on and through the private ranches that surround Lake Meredith was a great benefit to the project.

Field Researchers, David Wegner and J.R. Bell, preparing to collect AA Data.



LIST OF ABBREVIATIONS AND ACRONYMS

AA	Accuracy Assessment
ALFL	Alibates Flint Quarries National Monument
AML	Arc Macro Language
BOR	Bureau of Reclamation (also USBR)
BRD	Biological Resource Division (of the USGS)
CBI	Center for Biological Informatics (of the USGS/BRD)
CIR	Color Infrared Photography
CRMWA	Canadian River Municipal Water Authority
DEM	Digital Elevation Model
DLG	Digital Line Graph
DRG	Digital Raster Graphic
DOQQ	Digital Orthophoto Quarter Quadrangle
FGDC	Federal Geographic Data Committee
GIS	Geographic Information System(s)
GPS	Global Positioning System
IMU	Inertial Measurement Unit
LAMR	Lake Meredith National Recreation Area
MMU	Minimum Mapping Unit
NPS	U.S. National Park Service
NAD	North American Datum
NBII	National Biological Information Infrastructure
NRCS	Natural Resources Conservation Service (formerly SCS)
NREL	Natural Resource Ecology Lab, Colorado State University, Fort Collins.
NVC	National Vegetation Classification
NVCS	National Vegetation Classification Standard
NWI	National Wetland Inventory
PARK	LAMR
RMS	Root Mean square
RSGIG	Remote Sensing and Geographic Information Group
TNC	The Nature Conservancy
USBR	United States Bureau Of Reclamation (also BOR)
USDA-SCS	U.S. Dept. Of Agriculture – Soil Conservation Service
USFS	United States Forest Service
USGS	United States Geological Survey
UTM	Universal Transverse Mercator

EXECUTIVE SUMMARY

Lake Meredith National Recreation Area (LAMR) encompasses 67 square miles in north central Texas, an area known as the Texas Panhandle within the Canadian River Breaks land resource area. This mapping effort is part of the National Park Services' National Inventory and Monitoring (I&M) Program and will provide core or 'baseline' information that park managers need to effectively manage and protect park resources. The LAMR vegetation inventory was conducted in accordance with the following USGS-NPS Vegetation Mapping Program specified protocols and standards:

Nationally defined standards:
- National Vegetation Classification Standard
- Spatial Data Transfer Standard
- Metadata Standard
- Positional Accuracy
- Taxonomy

Additional Program Defined Standards
- Classification Accuracy
- Minimum Mapping Unit

A multi-year approach was utilized to effectively classify and map the wide range of vegetation at LAMR consisting of several linked phases: (1) vegetation classification using the National Vegetation Classification (NVC), (2) digital vegetation map production, and (3) map accuracy assessment. To classify the vegetation, we sampled 182 representative plots located throughout the 46,000-acre (18,200 ha) park and surrounding environs during the summer of 2004. Analysis of the plot data using ordination and clustering techniques produced 29 vegetation communities, composed of one alliance (Cottonwood Temporarily Flooded Woodland Alliance), 18 existing associations and 10 additional associations that were newly described for this area.

To produce the digital map, we used both the 2002 1:12,000-scale color infrared aerial photography and the 2002 1:40,000-scale color infrared ortho-rectified imagery reproduced at 1:12,000-scale, and 2 years of ground-truthing and data collection to interpret the complex patterns of vegetation and landuse at LAMR. In the end, 34 map units were developed and cross-walked or matched to corresponding plant associations and land use classes. All of the interpreted and remotely sensed data were converted to Geographic Information System (GIS) databases using ArcInfo© software. Draft maps created from the vegetation classification were field-tested and revised before independent ecologists conducted an assessment of the map's accuracy during 2005.

Products developed for LAMR are described and presented in this report and are stored on the accompanying DVD, these include:

- A Final Report that includes a vegetation key, accuracy assessment information, and a map unit visual guide;
- A Spatial Database containing digital vegetation map, plots, accuracy assessment, and flight line index layers;

- Digital Photos of each vegetation type along with representative ground photos and miscellaneous Park views;
- Field key for association identification and a list of associations present in the mapping area;
- Federal Geographic Data Committee-compliant metadata for all spatial database coverages and field data.

In addition, LAMR received copies of:

- 9x9 inch Aerial Photos;
- Uncompressed individual Digital Orthophotos and a compressed MrSid© compilation of Digital Orthophotos;
- Digital data files and hard copy data sheets of the vegetation field plots, and accuracy assessment sites;
- Hardcopy, paper vegetation maps.

The DVD attached to this report contains text and metadata files, keys, lists, field data, spatial data, the vegetation map, graphics, and ground photos. The USGS will post this project on its website: http://biology.usgs.gov/npsveg/index.html

For more information on the NVC standards, please go to the FGDC (Federal Geographic Data Committee), National Vegetation Classification Standard website: http://www.fgdc.gov/standards/projects/FGDC-standards-projects/vegetation . For more information on NVC associations in the U.S., please go to NatureServe's website: http://www.natureserve.org. BOR has numerous services and programs and may be visited at http://www.usbr.gov.

INTRODUCTION

Background

USGS-NPS Park Vegetation Mapping Program

In 1994, the U.S. Geological Survey (USGS) and National Park Service (NPS) formed a partnership to map National Parks in the United States using the National Vegetation Classification (NVC). The goals of the USGS-NPS Vegetation Mapping Program are to provide baseline ecological data for park resource managers, create data in a regional and national context, and provide opportunities for future inventory, monitoring, and research activities (FGDC 1997, Grossman et al. 1998, http://biology.usgs.gov/npsveg/index.html).

Central to fulfilling the goals of this national program is the use of the NVC as the standard vegetation classification. This classification:

- is based upon current vegetation;
- uses a systematic approach to classify a continuum;
- emphasizes natural and existing vegetation;
- uses a combined physiognomic-floristic hierarchy;
- identifies vegetation units based on both qualitative and quantitative data;
- is appropriate for mapping at multiple scales.

The use of standard national vegetation classification and mapping protocols facilitate effective resource stewardship by ensuring compatibility and widespread use of the information throughout the NPS as well as by other federal and state agencies. These vegetation maps and associated information support a wide variety of resource assessment, park management, and planning needs, and provide a structure for framing and answering critical scientific questions about vegetation communities and their relationship to environmental processes across the landscape.

The NVC has primarily been developed and implemented by The Nature Conservancy (TNC) and the network of Natural Heritage Programs over the past twenty years in collaboration with the NPS (Grossman et al. 1998). Refinements to the classification occur in the application process, leading to ongoing proposed revisions that are reviewed both locally and nationally. The FGDC Vegetation Subcommittee works to keep this standard current, Federal Geographic Data Committee (FGDC) - Vegetation Subcommittee Home Page. NatureServe has made available a 2-volume publication presenting the standardized classification. This document provides a thorough introduction to the classification, its structure, and the list of vegetation types found across the United States as of April 1997 (Grossman et al. 1998). This publication can be found on the Internet at: http://www.natureserve.org/publications/library.jsp. NatureServe has since superseded Volume II (the classification listing) with an online database server that provides regular updates to ecological communities in the United States and Canada. NatureServe Explorer®, can also be found on the Internet at: http://www.natureserve.org/explorer.

Lake Meredith National Recreation Area Mapping Project

The specific decision to map the vegetation at LAMR as part of the U.S. Vegetation Mapping Program was made in response to the NPS Natural Resources Inventory and Monitoring Guidelines issued in 1992. Under these guidelines, LAMR was viewed as a priority Park based on its need for the program's vegetation map products. LAMR is the first full scale park to be undertaken in the state of Texas. Driving this need was the Park's desire to spatially analyze the vegetation at a fine enough scale to accurately predict various management issues. The project includes three separate but contiguous properties, Lake Meredith National Recreation Area, Alibates Flint Quarries National Monument and an additional 800-acre BOR-owned property that now houses the Canadian River Municipal Water Authority Headquarters.

In 2004 the USGS Center for Biological Informatics (CBI) kicked-off this project by asking the U.S. Bureau of Reclamation's Remote Sensing and Geographic Information Group (RSGIG) to undertake the mapping portion of this project. At this same time, NatureServe was contracted to develop the initial classification and to provide training for the plot collection and accuracy assessment efforts.

Our objectives were to produce final products consistent with the USGS-NPS National Vegetation Mapping Program mandated standards as follows:

- National Vegetation Classification Standard (FGDC 1997)
- Spatial Data Transfer Standard (FGDC 1998a)
- Content Standard for Digital Geospatial Metadata (FGDC 1998b)
- United States National Map Accuracy Standards (USGS 1999)
- Integrated Taxonomic Information System
- NPS-USGS Program-defined standards for map attribute accuracy and MMU

The products derived from these efforts include:

Spatial Data

- Aerial photography
- Map classification/descriptions
- Spatial database of vegetation communities
- Hardcopy maps of vegetation communities
- Metadata for spatial databases
- Complete accuracy assessment of spatial data

Vegetation Information

- Vegetation classification
- Dichotomous field key of vegetation classes
- Formal description for each vegetation class
- Ground photos of vegetation classes
- Field data in database format

Previous Vegetation Studies

Several previous efforts have been completed for the vegetation of Lake Meredith NRA and Alibates Flint Quarries National Monument. Two of these studies were used to provide background information when setting up this mapping effort. A study by Wright and Meador (ca.1981) delineated five plant associations: bottomland, steep slope, gravelly slope, mesatop, and sandhill. A second study, "Vascular Plants of Lake Meredith National Recreation Area and Alibates Flint Quarries National Monument" by Nesom and O'Kennon (2005) was also consulted. Although the objective of this study was primarily to provide an account of all vascular plant species, the previous work was thorough, current and yielded a useful list of major plant communities. The Nesom and O'Kennon communities consisted of sandhills and sand flats, sandy valley bottoms, gravelly slopes, dolomite caprock, red slopes, gypsum outcrops, river and creek sides (includes: riparian areas of larger tributaries, sedge meadows and corridors, cottonwood gallery forest, hackberry-soapberry dry woodland), lakeshore, marsh, borrow area, lawn and mowed roadsides, and old homesites. Since the purpose of Nesom and O'Kennon's work was a floristic survey, the plant community descriptions were qualitative and no standardized sampling methods were conducted.

Other useful studies included the Landcover Classification for Lake Meredith National Recreation Area by (Nelson et al, 1999), a T & E plant species survey for Alibates Flint Quarry National Monument (Bell, Budd and Coffman, 2000), and the 2002 Oil and Gas Management Plan (NPS, 2002).

Scope of Work

Vegetation at LAMR was mapped and classified by the U.S. Bureau of Reclamation, RSGIG with the help of NatureServe personnel, Jim Drake and Shannon Menard. The protocols and standards used are described in the NPS/USGS program documents. Existing 1:12,000 color infrared stereo-pair aerial photographs and 1:12,000 scale CIR digital ortho-photography (1 meter pixels) created to USGS DOQQ specifications were used for the aerial imagery and basemap for this project. This imagery was acquired in 2002 for a separate BOR project in support of a salt cedar mapping of the Lake Meredith NRA floodplain (Fenton and Bell, 2003).

Vegetation mapping for LAMR encompassed both the official boundary, as provided by the NPS, of Lake Meredith National Recreation Area, Alibates Flint Quarries National Monument and a small piece of Bureau of Reclamation-owned property on which the Canadian River Municipal Water Authority headquarters is located, as well as a 1-mile buffer around these properties (Figure 1). The 1-mile buffer was common for many park mapping projects. More recently, the standard buffer has been reduced to ¼ mile or 100 meters in an effort to reduce the overall costs of each mapping project. For the purposes of this project all three properties were treated as one study although the data can be extracted by individual property if needed.

The project was initiated in the fall of 2003 with project planning and scoping meetings. Project planning and logistics were completed during the winter and spring of 2003-2004. After a training session at Lake Meredith in April 2004, the vegetation plot data were

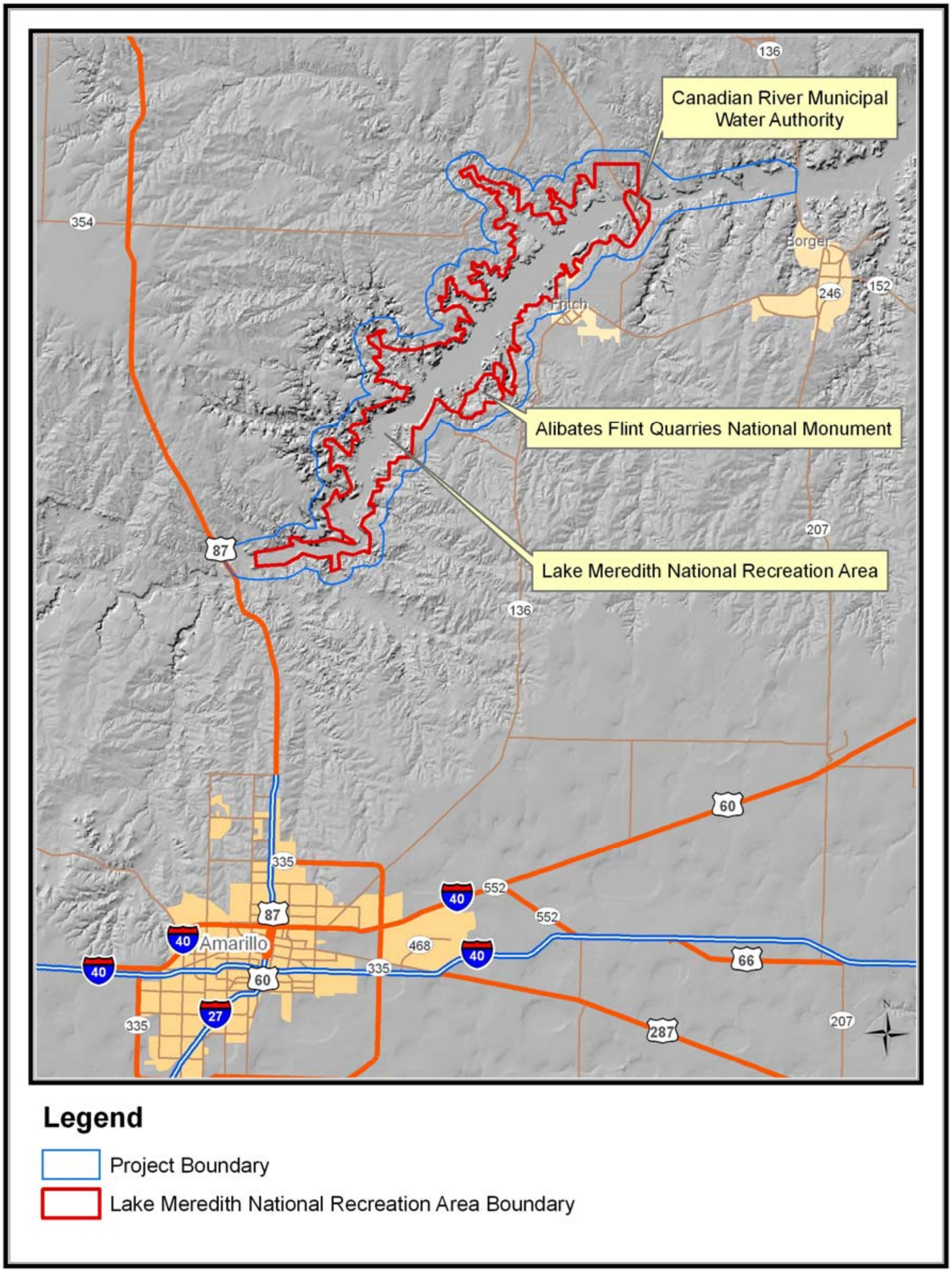


Figure 1. Vegetation Mapping - Project and Map boundaries.

collected during the summer of 2004. After entry into the Access database software, the plot data were turned over to NatureServe for analysis and creation of the vegetation classification, field key, and local association descriptions during the fall of 2004 and spring of 2005. Planning for the accuracy assessment was conducted during the spring of 2005. After a training session at Lake Meredith National Recreation Area in the summer of 2005, the AA data collection was started in July and completed in the fall of 2005. The assessment of the map accuracy was completed during the winter of 2005 and spring of 2006.

Introduction to the National Vegetation Classification (NVC) and Standard (NVCS)

The USGS-NPS Vegetation Mapping Program uses the US National Vegetation Classification (NVC) as the standard to identify and describe vegetation types within the map boundaries. The National Vegetation Classification (NVC) was begun in the early 1990's by ecologists in the Science Division of The Nature Conservancy and state Natural Heritage Programs and Conservation Data Centers in collaboration with partners from the academic, conservation, and government sectors. This classification was designed to allow description of plant assemblages based on existing vegetation rather than on potential natural vegetation, climax vegetation, or physical habitats. The US NVC is part of the International Vegetation Classification System (IVC) which currently includes the USA, Canada, and several Caribbean, Central and South American countries. Its application is rapidly expanding and may soon include other countries as well.

The NVC uses a hierarchical system of 7 levels; the lower levels are nested into the higher levels. The two lowest levels (most specific), Alliance and Association, are based entirely on the floristics, while the upper five levels are based on physiognomy (structural and morphological characteristics of the vegetation type e.g. forest, grassland, evergreen, deciduous, broad-leaved, needle-leaved), natural and cultural characteristics, and flood regime.

Table 1 identifies the 7 levels of the NVC and depicts their placement in the hierarchical relationship (Maybury 1999). While the classification currently includes more than 5000 vegetation associations and 1,800 Alliances, the NVC has been adopted by the Federal Geographic Data Committee to the level of Formation for use by all U.S. federal agencies. Mapping to greater detail than Formation is left to the discretion of each park and their particular data needs.

Table 1. Summary of the National Vegetation Classification System Hierarchal Approach (Maybury 1999).

LEVEL	PRIMARY BASIS FOR CLASSIFICATION	EXAMPLE
Class	Structure of vegetation	Woodland
Subclass	Leaf phenology	Evergreen Woodland
Group	Leaf types, corresponding to climate	Temperate or Subpolar Needle-Leaved Evergreen Woodland
Subgroup	Relative human impact (natural/semi-natural, or cultural)	Natural/Semi-natural
Formation	Additional physiognomic and environmental factors, including hydrology	Saturated Temperate or Subpolar Needle-Leaved Evergreen Woodland
Alliance	Dominant/diagnostic species of the uppermost or dominant stratum	Longleaf Pine -- (Slash Pine, Pond Pine) Saturated Woodland Alliance
Association	Additional dominant/diagnostic species from any strata	Longleaf Pine / Little Gallberry / Carolina Wiregrass Woodland

Alliances and Associations are based on both the dominant (greatest canopy cover) species in the upper strata of a stand as well as on diagnostic species (those consistently found in some types but not others). Associations are the most specific classification and are hierarchically subsumed in the Alliances. Each Association is included in only one Alliance, while each Alliance typically includes many Associations. Alliance names are generally based on the dominant/diagnostic species in the uppermost stratum of the vegetation, though up to four species may be used if necessary to define the type. Associations define a distinct plant composition which repeats across the landscape and are generally named using both the dominant species in the uppermost stratum of the vegetation and one or more dominant species in lower strata, or a diagnostic species in any stratum. A table listing all the dominant species is included in Appendix 1. The species nomenclature for all Alliances and Associations follows that of Kartesz (1999). Documentation from NatureServe (2005) describes the naming and syntax for all NVC names:

- A hyphen ("-") separates names of species occurring in the same stratum.
- A slash ("/") separates names of species occurring in different strata.
- Species that occur in the uppermost stratum are listed first, followed successively by those in lower strata.
- Order of species names generally reflects decreasing levels of dominance, constancy, or indicator value.
- Parentheses around a species name indicates the species is less consistently found either in all associations of an alliance, or in all occurrences of an association.
- Association names include the dominant species of the significant strata, followed by the class in which they are classified (e.g., "Forest," "Woodland," or "Herbaceous Vegetation").
- Alliance names also include the class in which they are classified (e.g., "Forest," "Woodland," "Herbaceous"), but are followed by the word "Alliance" to distinguish them from Associations.

Examples of alliance names from LAMR:

- *Prosopis glandulosa* Shrubland Alliance
- *Populus deltoides* Woodland Alliance

Examples of association names from LAMR:

- *Populus deltoides / Panicum virgatum – Schizachyrium scoparium* Woodland
- *Andropogon hallii – Calamovilfa gigantean* Herbaceous Vegetation

For more information on the NVC see Grossman et al. (1998) and FGDC (1997).

PROJECT AREA

Location and Regional Setting

The Lake Meredith project area includes Lake Meredith National Recreation Area (LAMR), Alibates Flint Quarries National Monument (ALFL) and a minimum one-mile buffer that was extended on the east to State Highway 207, approximately three miles north of Fritch, Texas and on the west to U.S. Route 287. The project area is located in the geographic center of the Texas Panhandle, about 40 miles northeast of Amarillo, Texas. LAMR and ALFL cover parts of three counties, Hutchinson, Moore and Potter with ALFL occurring totally within Potter County. The Park is accessible on the west from the U.S. Route 287 bridge over the Canadian River, from the north and northwest off of Ranch Roads 1913, 1319 and 3395 (Town of Bugbee), from the east off of State Route 136, the town of Fritch, and on the east via Ranch Road 687. Fritch, Sanford and Bugbee border the Park. The largest nearby town is Borger, located 8 miles northeast of Sanford Dam (Figure 2. Location Map and Figure 3. Detail Map).

Much of the Park is accessible only by crossing private property. All areas outside of LAMR, ALFL and the headquarters of the CRWB property are private, including several large ranches. Permission to cross private property to reach the Park is required. During the course of the project, permission to enter private land either to reach park property or to collect vegetation data was arranged by Mr. J. R. Bell of Amarillo, Texas. Mr Bell is a native Texan who has worked extensively in the project area and was hired to work on the LAMR vegetation mapping project due to his expertise in the local vegetation.

Juniper woodland seen from the LX Ranch.

Figure 2. Location Map - Lake Meredith National Recreation Area.

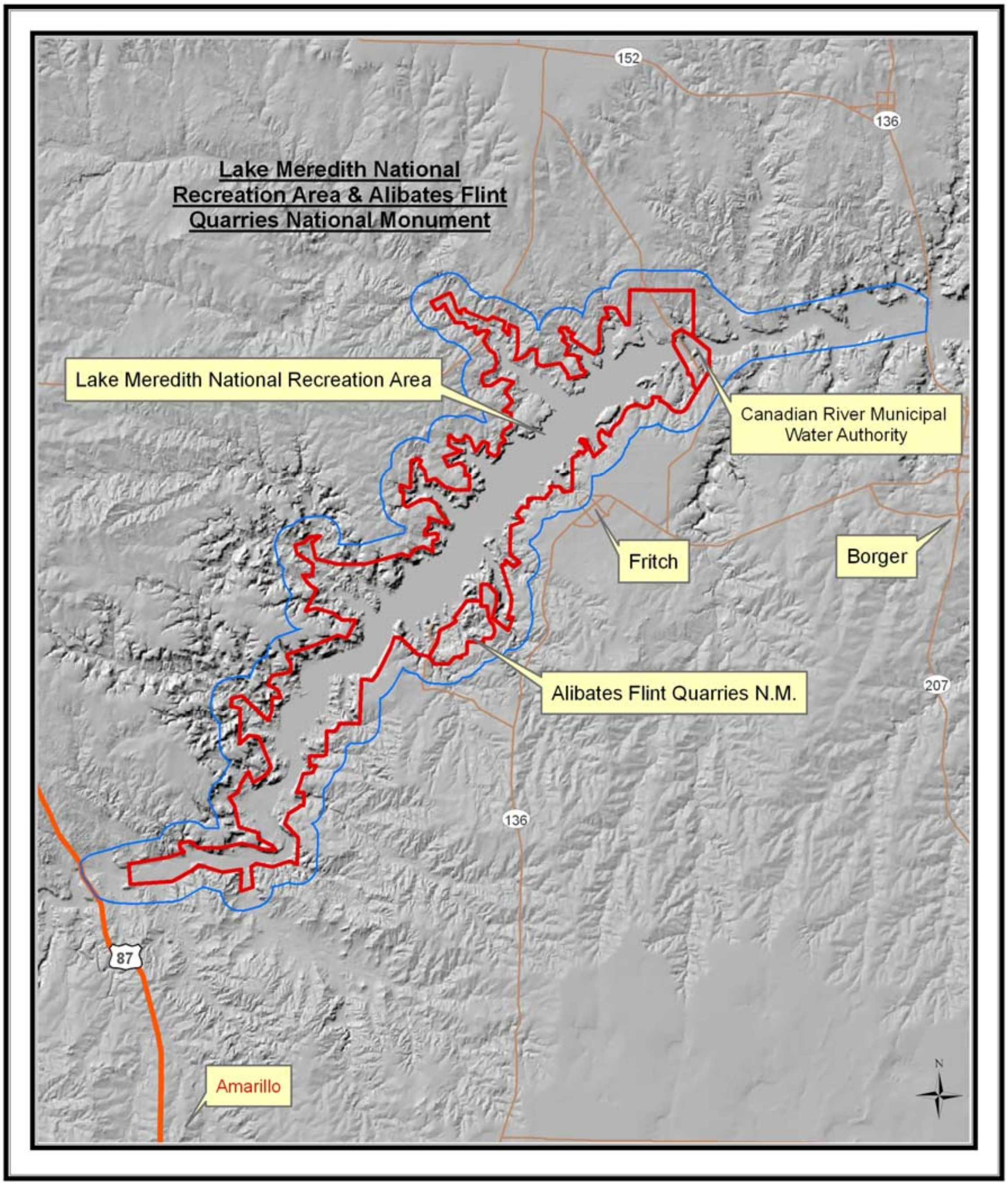


Figure 3. Detail Map - Lake Meredith National Recreation Area.

Climate and Weather

The climate in and around LAMR is described as a temperate semi arid steppe (Bailey R.G. 1995). It is within the Continental Steppe climate zone of Texas. This climate type is typical of interiors of continents and is characterized by large variations in the magnitude of ranges of daily temperature extremes, low relative humidity, and irregularly spaced rainfall of moderate amounts. In Texas, this climate is characterized by semi-arid conditions and mild winters.

Precipitation varies considerably with a mean annual precipitation of 20 inches. Precipitation reaches the highest levels in late spring and early summer while the winters are typically dry. With this type of climate, there can be a wide variation in the mean from year to year and the area is prone to drought cycles. This variation is mirrored in the vegetation with large fluctuations in vegetation production. The summer of 2004, when plot data were collected at LAMR, corresponded to a season of record rainfall. The following summer, 2005 was a more average season for rainfall although the area appears to be headed back into the drought cycle. Record fires occurred in the area in the summer of 2005.

Topography

LAMR occupies an area of transition between the High Plains and the Rolling Plains. As such, it includes areas of relatively flat terrain, rolling or dissected terrain and the 200 to 300 foot cliffs that make up what are called the Canadian River Breaks, formed by the carving action of the Canadian River and its many tributary streams. The project boundary includes elevations ranging from about 2700 feet to 3600 feet.

Numerous prominent drainages feed into the Canadian River and Lake Meredith including Bonita, Mullinaw, Coetas, Chicken, Alibates, South Turkey and Short Creeks on the south and east side of the recreation area and Plum, Evans, Martin’s, Big Blue and North Turkey Creeks on the west and north of the park. Many of these creeks are dry or nearly so for parts of the year.

Geology

There are five ages of sediment outcrops in the vicinity of the LAMR project. These are Permian Quartermaster Formation, Triassic Dockum Group, Tertiary (Miocene-Pliocene) Ogallala Group, Pleistocene terrace deposits, and Holocene alluvium. The age varies from the Permian redbeds at 245 million years old to the present-day fluvial sediments deposits.

Permian Quartermaster Formation: <u>Age-250 to 286 million years B.P.</u>

This formation is noted by the persistent ledge of dolomite where exposed. It is white and massive and forms the caprock of the conspicuous ledges, bluffs and cliffs along the river. In some locations, the dolomite outcrops have become agatized, known as the colorful Alibates chert. This chert has been used by Native Americans for the last 12,000 years for making projectile points and other implements.

Triassic Dockum Group: Age-225 to 208 million years B.P.

These deposits are found in upstream areas in the southwestern part of the Park and consist of different colored (yellow, maroon and lavender) shales and sandstones. The group was deposited in the area during the Upper Triassic Period.

Tertiary (Miocene-Pliocene) Ogallala Group: Age-12 to 1.9 million years B.P.

This group consists of silts, sands and gravels that were deposited by meandering streams. They form the underground aquifer that underlies much of the Texas Panhandle.

Pleistocene terrace deposits, and Holocene alluvium: Age-1.9 million years ago to present

Gravels, sands and silts of the Pleistocene age are deposited along the canyon walls near the southern edge of Lake Meredith. Holocene-aged sediments are found in the upper canyons and along the southern edge of the lake.

Soils

Soils play an important role in determining the types of vegetation that might inhabit a site. The soils in the Lake Meredith area are characterized as moderately deep to very deep and nearly level to strongly sloped, and fine sandy loams to clay loams (USDA, SCS, Soil Surveys 1975, 1976, and 1980). On steeper slopes, the soils tend to be shallow (10-20 inches), well-drained, calcareous loamy to gravelly soils with differing amounts of rock fragments. A good description of the soils of the area can be found in the report, Alibates National Monument Threatened and Endangered Plant Species Survey, Bell, et al., 2000 report to U.S. Dept. of the Interior. (Figure 4. Soils of the Lake Meredith project area)

Wildlife

Lake Meredith is home to approximately 60 species of mammals, 15 fish species, 32 reptile species, 11 amphibian species and over 200 bird species. Common large mammals include mule deer, white-tailed deer, and coyote. Smaller mammals such as porcupine, raccoon, skunks, ground squirrels, rabbits, pocket gophers, mole, bats, and several species of rats and mice are common here.

Wild turkey, bobwhite, scaled quail, mourning dove, roadrunner, and redwing blackbird are birds common to Lake Meredith.

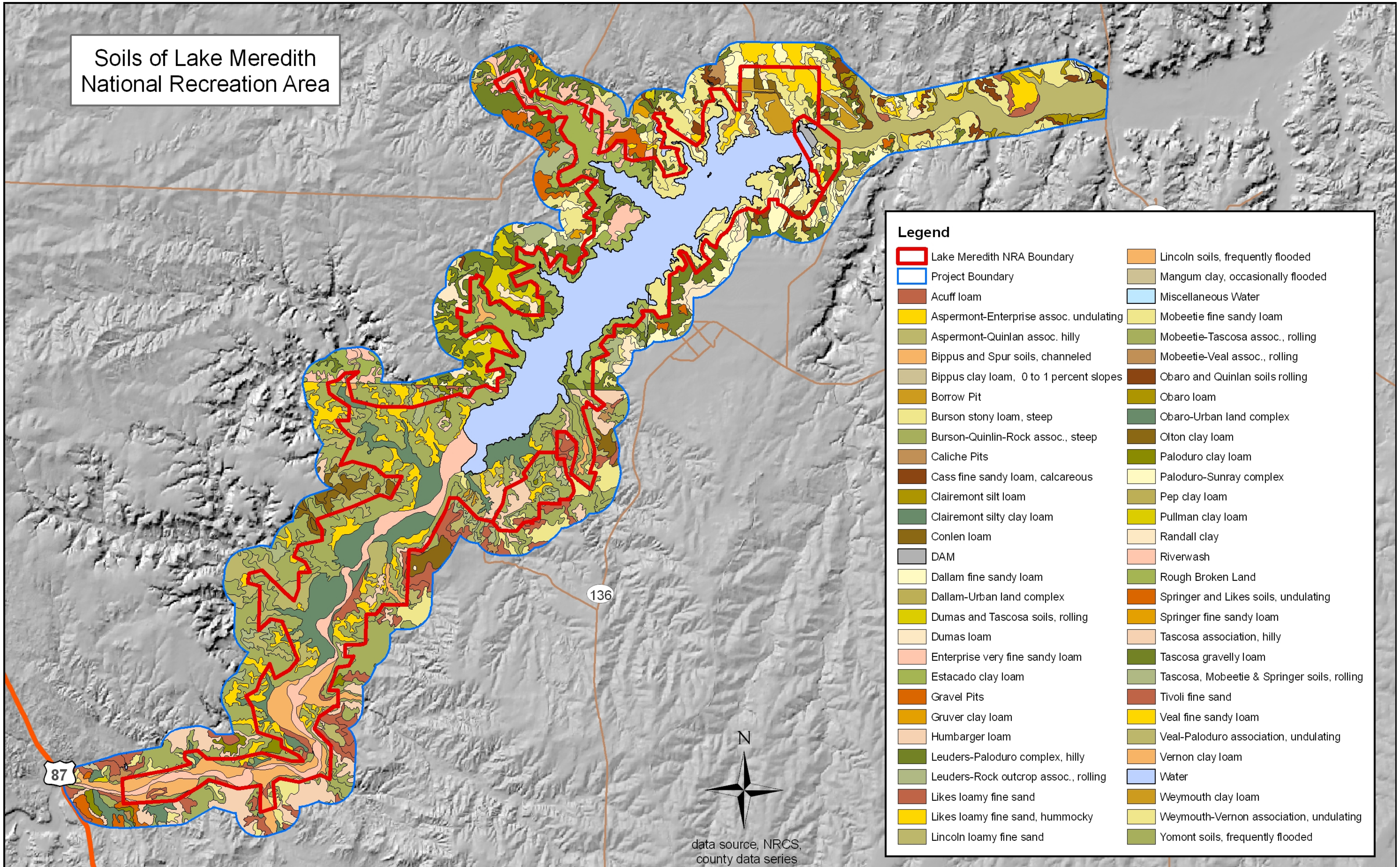


Figure 4. Soils of the LAMR & ALFL Vegetation Classification and Mapping Project.

Hydrology

The hydrology of LAMR centers around the Canadian River, Lake Meredith, some tributary creeks, local springs and shallow groundwater areas as well as the deep underground aquifers. All of these influence the vegetation of the project area (Figure 5).

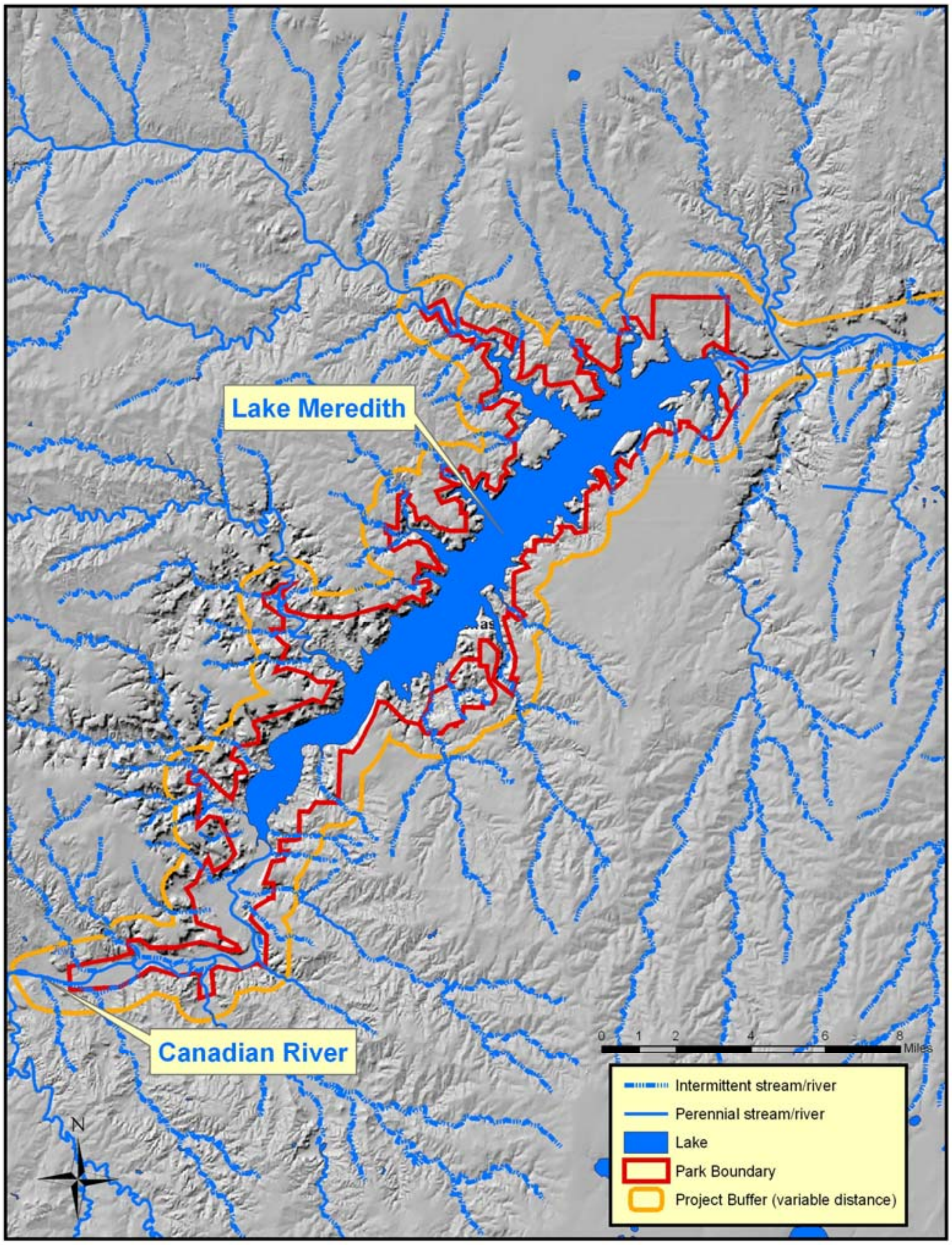


Figure 5. Lake Meredith Regional Rivers and Lakes.

Vegetation

LAMR lies within the Dry Domain, Tropical/Subtropical Steppe Division, Southwest Plateau and Plains Dry Steppe and Shrub Province, Texas High Plains Section as described by Bailey (1995). This ecoregion is characterized by arid grasslands and the presence of open stands of mesquite among the grasses. The land-surface form consists of flat to rolling plains as well as a mesa-and-butte landscape in some areas.

LAMR resides in two of the major plant zones of Texas, the Rolling Plains and High Plains, as mapped in various forms by several authors including V.L. Cory and H. B. Parks (1937) and more recently by F.W. Gould (1962).

Tallgrasses in Canadian River floodplain

Cottownwood Alliance stand near mouth of Bonita Creek

METHODS

The methods to produce a vegetation map for Lake Meredith National Recreation Area follow the guidelines established for large parks. However, unlike many larger parks, the small staff and support in this park create unique circumstances. The project was divided into six major steps.

1 - Planning and Scoping

The LAMR and ALFL Vegetation Classification and Mapping Project incorporated the combined expertise and oversight of several organizations. The roles for each partner included the following:

CBI, NPS, and LAMR Responsibilities:

- CBI & NPS provided cooperative management at the national level, as well as, oversight and programmatic considerations
- LAMR provided park specific logistical support and safety oversite

BOR Responsibilities and Deliverables:

BOR assumed the primary responsibility for the majority of the tasks for this project:

- Overall project facilitation and coordination
- Provide the 2002 acquired 1:12,000 scale CIR aerial photography and orthorectified imagery;
- Develop map units linked to the NVC at the Alliance and Association level;
- Provide field maps and GIS support to the field crews;
- Interpret aerial photographs;
- Transfer interpreted information to a digital spatial database and produce hard copy (paper) vegetation maps;
- Create digital vegetation coverages including relevant attribute information;
- Produce Arc/Info export file of vegetation plot, observation point, and accuracy assessment locations;
- Create a contingency table comparing the mapped classes with the AA classes in order to determine map accuracy;
- Document and record digital FGDC compliant metadata files (*.html, .xml & .txt) for all created spatial data; and
- Produce the final report and CD-ROM describing procedures used in preparing all products.

NatureServe Responsibilities and Deliverables:

- Assist in project scoping and planning activities;
- Develop a preliminary vegetation classification for the study area from secondary sources;
- Assist in training field crews in standard NPS vegetation sampling methods for classification and accuracy assessment;
- Be available for consultation in data management and vegetation classification;
- Assist in developing mapping units;
- Review and finalize draft classification, local community descriptions, and field key to community types.

LAMR Project Meetings

Initial Planning Meeting:

The project participants met at Lake Meredith park headquarters in Fritch, Texas on February 11-12, 2004. Representatives from LAMR, BOR and NatureServe met to discuss and plan the project. The goals of the meeting were to (1) learn about Park concerns and management issues, (2) assign responsibilities, (3) establish a schedule, (4) tour the park with LAMR officials, and (5) determine project boundary.

Field Preparation Meetings:

NatureServe conducted a training session at Lake Meredith NRA the week of April 24, 2004 to demonstrate the proper technique for collecting plot data to BOR personal. Final planning for the plot data collection field season were finalized at this time.

Interim Status Meeting:

A progress meeting was held on Feb 28, 2005 with USGS, NPS and BOR personnel to establish that the project was on schedule or to identify any problems.

Map Unit Meeting:

The map unit meeting was held in March 2005 via conference call between BOR RSGIG, NatureServe personnel and J. R. Bell. Based on analysis of the draft vegetation associations and discussion of potential map units, a preliminary map class scheme was developed.

AA Field Preparation Meeting:

The field ecologists and BOR RSGIG met at Lake Meredith in July 2005 for training in AA data collection led by Jim Drake of NatureServe. Two days were spent testing the vegetation key for the plant associations of Lake Meredith.

Accuracy Assessment Meeting:

After analysis of the AA data, a meeting was held in April 2006 to discuss the initial results of the map AA. This meeting was attended by some of the field ecologists who collected both plot data and AA data, as well as Mr. Paul Eubank, Chief of Resource Management at LAMR. The focus of this meeting was the consideration of those AA points that initially were considered mismatches.

2 - Field Survey

Sampling Design: Stratified Random Gradsect

Our ultimate goal at LAMR was to obtain a thorough description for the range of plant communities, both the common/extensive and the rare/unique. To this end we felt that an unbiased census of all

the vegetation (*i.e.* a complete enumeration of the population) would not be achievable or practical for such a large, remote Park. As a result, to cost-effectively capture the full spectrum of vegetation, we felt it necessary to optimally locate sampling plots using "Gradsect Sampling" (GRADient-directed tranSECTs) (Gillison and Brewer 1985). Gradsects are a survey method that addresses 1) the need for representative sampling based on environmental stratification, 2) the need for a compromise between statistical sampling, practical logistical problems, and costs, and 3) the value of replicated and randomized sampling (Austin and Heyligers 1989, Gillison and Brewer 1985). We determined that a
modified Gradsect methodology would allow field crews to visit the full spectrum of physical environments and thus most of the vegetation types.

For LAMR, we decided that a spatial-historical model coupled to a 30-meter digital elevation model (DEM) of the Park would be more predictive of vegetative diversity and more efficient than a linear transect approach. Using only existing digital resources, LAMR personnel and local vegetation expert, J.R. Bell were asked to select the driving variables thought to influence vegetation response. For LAMR's modified gradsect, slope and aspect, were chosen as the key abiotic factors (Table 2.). In addition, we modified a digital land cover classification (Nelson et al., 1999) to reflect the major vegetation land cover classes that were known at Lake Meredith. We then split each gradsect variable into logical classes to best reflect the vegetation distribution and created digital map layers using ArcView GIS. These GIS layers were then added together to generate a map coverage of all combinations occurring in LAMR, with each unique combination representing a Biophysical Unit (BPU).

At LAMR there were 60 BPU types within the mapping boundary resulting in a total of 7709 polygons. The project area was divided into map segments and hard copy plots depicting the biophysical units, maps sized 11X17 were provided to the field crews (Figure 6). These plots were intended to be used as guidelines for the plot data collection.

The crew response to field visits to the selected BPU's was mixed to poor. The small size of the map plots made it difficult to pinpoint their location on the ground and determine which specific BPU polygon was being sampled. It was felt that the most important strategy for ensuring the sampling of the full range of plant communities was a familiarity with the vegetation of the park and knowledge of the roads and access. In the end, the field crews used the general land cover classes and the slope combined with access to collect plot data in the full range of plant communities. The plot locations were entered into a digital database and categorized by land cover class and slope as well as by preliminary vegetation association. Map plots and tallies of how many plots had been collected in each category were given to the field crews regularly. Using these as guidelines, additional plots were collected in as many areas of the park as practical until it was determined that sufficient sampling had been completed.

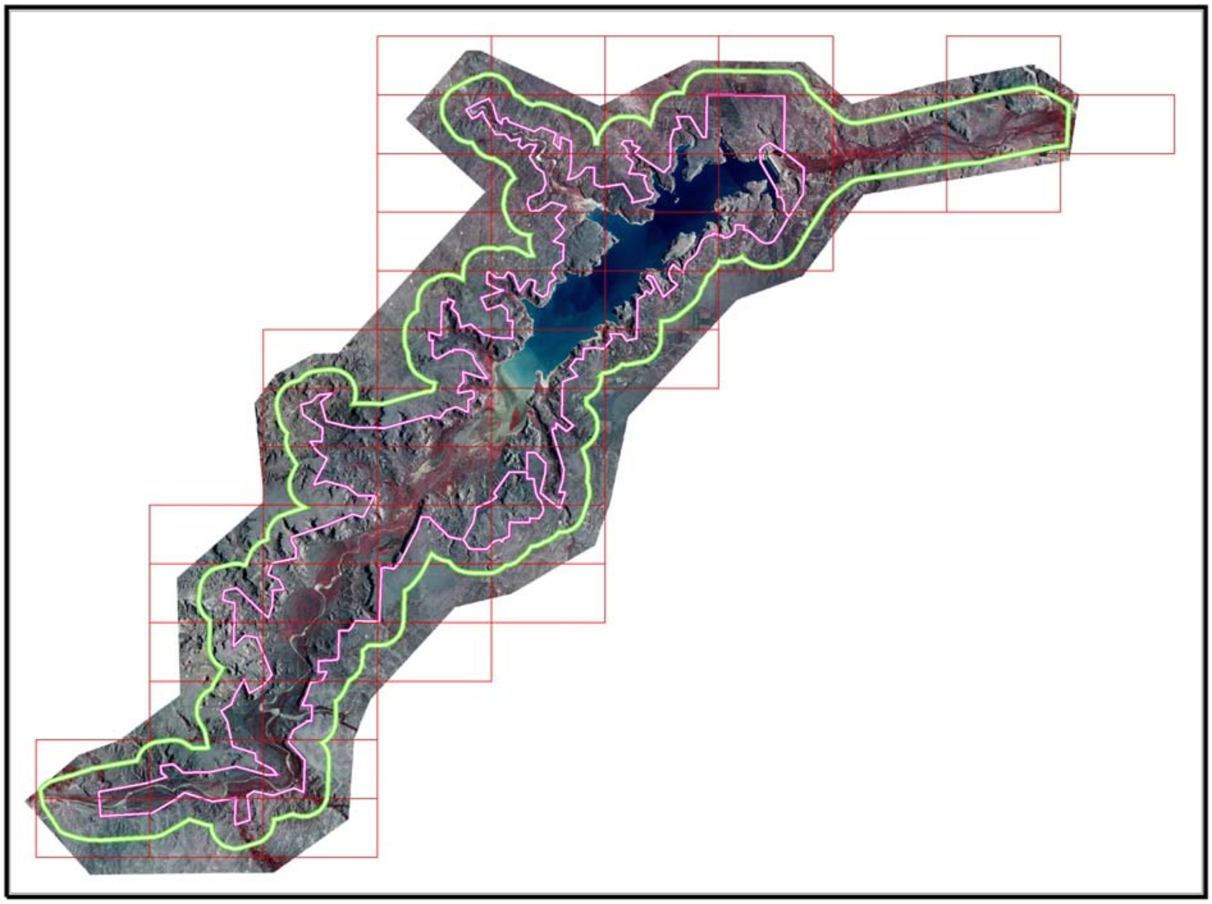


Figure 6. Gradsect Map Sections

Table 2. Environmental variables and classes used in the modified gradsect analysis for LAMR

LAND COVER	SLOPE	ASPECT
Upland Grassland	0 to 3 / flat	flat
Vegetated Cliffs	3 to 5 / gentle	N/E (0-125, 270-360)
Disturbed Grassland	5 to 12 / rolling	S/W (125-270)
Riverine Grassland	12 to 25 / moderate	S/W (125-270)
Emergent/Shore Vegetation	25 to 90 /steep	
Mixed Forest		
Bare Land		

General Plot Collection: Considerations

At the beginning of the 2004 field season, two crews of two people each were selected to collect classification plot data in LAMR. The purpose of the collection of plot data is the characterize the composition and structure of the vegetation of the Park and environs and associated environmental conditions. In April 2004, NatureServe personnel provided on-site training for the field crews in standardized NVC vegetation sampling methodology. The field teams were provided with BPU maps identifying the full range of plot collection sites. They were also given a list of the potential vegetation types to be sampled and instructed to try to collect three plots in each existing type and up to five in the new potential vegetation types that had been identified for the area. The crews were provided with a field manual describing all of the methodology for the plot sampling. The following is a general description of the process.

Data Collection: Relevé Plots

Before leaving for the field each day, crews would plan a strategy for efficiently collecting plots data. They would take into consideration the proximity of selected BPUs to roads, trails, and to each other, as well as topography and vegetation in the area to be surveyed, and would plan routes to collect the most plots in the most different potential vegetation types without excessive travel time. Crews would then gather all field equipment and personal gear needed for the duration of the trip.

The crews would navigate to the selected area using GPS units as well as maps and compasses. After arriving at the selected BPU, crews would select a specific location to place the plot. They would walk through the polygon to determine what plant associations were present. The field investigators were instructed to select homogenous and representative areas to sample. If the polygon was diverse, the crew might select two or more locations in order to capture that variation. Ecotones or areas of mixed vegetation between two or more plant communities were avoided. Disturbed areas were also avoided.

Along the way to and from the selected polygons, crew members would pay attention to vegetation types they were passing through. If they observed other needed vegetation types (especially rare types) or found possible new vegetation types (undocumented vegetation composition which repeated on the landscape) that might help define the classification of LAMR, they would stop and collect either a full vegetation plot, or an observation point. If crews noticed exotics or rare plants, they would stop and record those as well.

At each sampling location, plot data were collected using the protocols of the NPS National Vegetation Mapping Program. At the plot center, crews would record the UTM location from the GPS. They would then lay out the plot with measuring tapes, according to the size specified in the field manual for that vegetation type (most plots were $400m^2$). Crews would begin analyzing vegetation by dividing the vegetation visually into strata, or height classes, and recording the dominant species by cover in each stratum. They would then develop a comprehensive species list for the plot by recording the species name and percent cover for each plant found within the plot. Numerous other data describing the environmental characteristics of the site were collected at each plot including elevation, slope, aspect, soil texture, surficial geology, percent ground cover, and hydrology. A very limited set of fuels data were also collected from each plot (see Appendix 2, Fuel Models for details of the methodology). Before leaving the plot, crews would attempt to classify the vegetation into one of the potential plant communities. If the plot did not fit into an existing plant community, they would assign a type based on the dominant species in the top two strata. Two digital photographs documenting the typical vegetation of each sample plot were taken. As requested by LAMR personnel, guidelines for the ground photos were that one photo showed detail of the plot vegetation and the other photo showed the overall vegetation along with the surrounding plant communities. If possible, one of the photos would include some kind of identifying landmark such as a ridge in the background or on the horizon.

Data Collection: Fuels Data

After consulting with LAMR fire specialists, a simplified fuel data collection protocol was suggested that would allow the vegetation crews to record a fuel model for each plot. A fuel model number was entered into the PLOTS database. The fuel data collection protocol can be found in Appendix 2, LAMR Fuel Models.

3 - Aerial Photography Acquisition and Orthobase Map Development

A 2-tiered contract for acquiring aerial photography was established with Horizons, Incorporated of Rapid City, South Dakota. This contract specified the acquisition of color infrared (CIR) aerial photography for LAMR and vicinity at two different scales. In addition to the standard 1:12,000 scale photography typically used for photo-interpretation, the project also required 1:40,000 scale photography for the production of orthophotos for the entire area.

The project area is covered by 16 flight lines flown southwest to northeast for the 1:12,000 scale photography (Figure 7.) and 4 flight lines for the 1:40,000 scale photography (Figure 8.). A total of 364 CIR photographs were taken at 1:12,000 (1"=1,000') scale and 58 CIR photographs for the 1:40,000 (1" = 3,333') all printed on 9"x 9" paper stock. Forward overlap for all photographs was approximately 55-65% and sidelap between flight lines was approximately 25-35%. All photography was acquired on July 14-16, 2002.

The contracting for new digital and hard copy color infrared ortho base maps for LAMR was originally undertaken for an unrelated Bureau of Reclamation project. At the time, negotiations were underway to map LAMR as part of the U.S. National Vegetation Mapping Program. The decision to proceed with LAMR was aided by the existence of this photography and basemap. Technical specifications for the base map photography and subsequent data manipulation can be found in the orthophoto metadata file located on the accompanying DVD. All aerial and ortho-photography received a rigorous examination by BOR staff familiar with the needed technical specifications prior to being accepted.

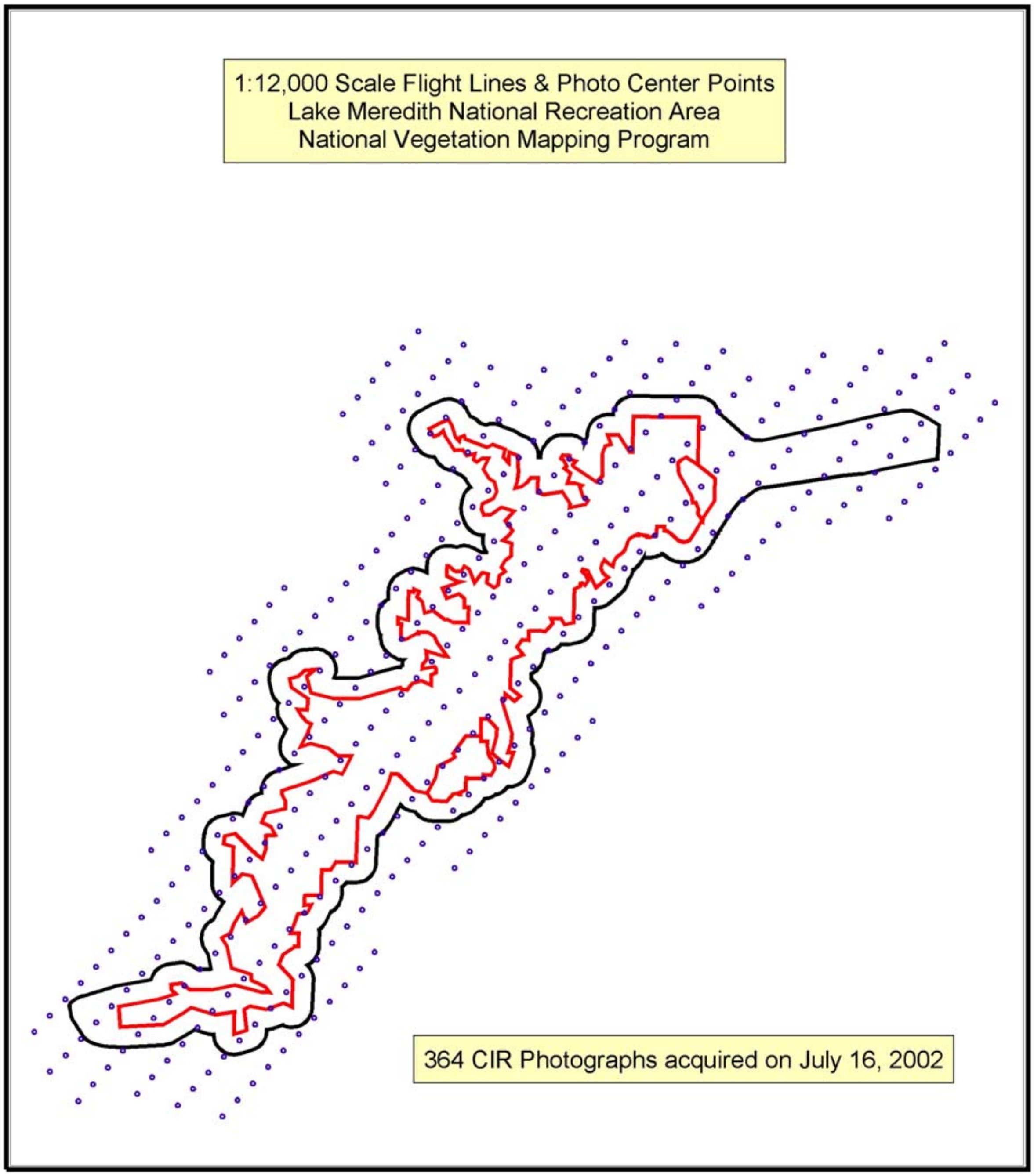


Figure 7. Flight lines and photo centers for 1:12,000 CIR photography.

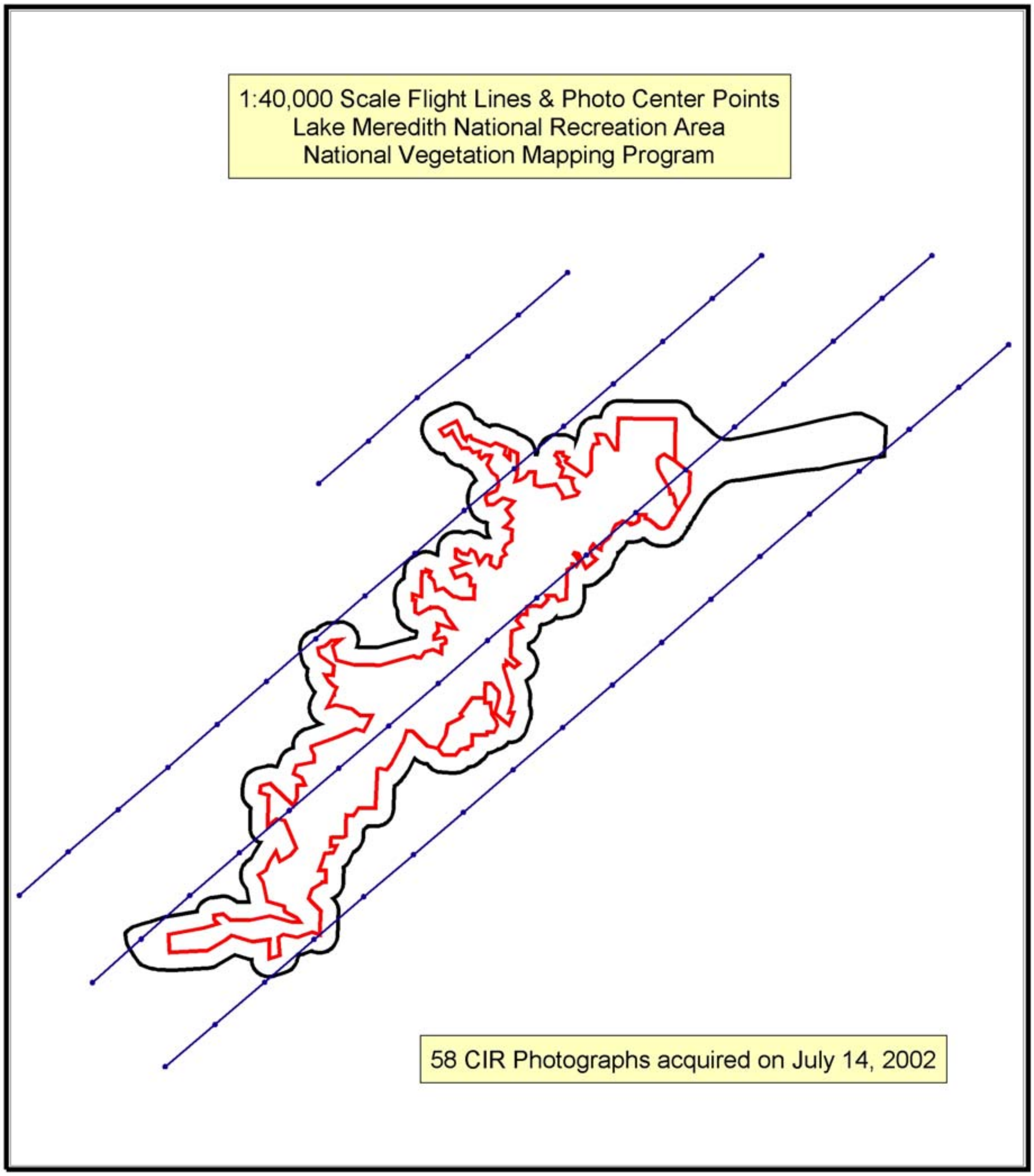


Figure 8. Flight lines and photo centers for 1:40,000 CIR photography

4 - Photo Interpretation – Map Units

Photo Interpretation

Photointerpretation was accomplished using the 9 x 9, 1:12,000 scale color infrared photographs in addition to the digital orthophoto basemap imagery. This 1:12,000 scale product was used as the basemap or background image for the creation of the geo-spatial database. Photo-interpretation used the standard identification features such as tone, texture, color, pattern, topographic location, and shadow.

The data were entered into the GIS using the "heads-up" technique in which the scientist digitizes the vegetation polygons on the computer screen using a mouse with the orthophoto as a background image. For this step, both Arc View version 3.3 and TNT MIPS version 6.8 mapping software were used. In deciding where to draw the vegetation polygons, stereo pairs of the 9"x9" aerial photographs were viewed, especially in areas with high heterogeneity. This allowed the photo-interpreter to see the vegetation in three dimensions. A more accurate mapping was therefore possible. Areas of high homogeneity, such as vast areas of mesquite shrubland, were mapped with less reference to the aerial photography.

Map Units and Polygon Attribution

The map units delineated on the orthophotos were derived from the NVC classification as constrained by the limitations of the photography. Based on the input from all parties involved in the mapping effort, we arrived at an initial list of reasonable map units. In some instances, one NVC association corresponded to one map unit, a one-to-one relationship. In other cases, however, several to many associations were grouped into one map unit, referred to as a map unit complex. See Table 3 for a complete list of map units and map unit complexes with corresponding NVC classes. In Table 3, each map unit is shown in bold text. Map unit complexes that are composed of more than one NVC association are defined by the indented list of individual NVC associations below the unit name. Each NVC type is shown with the scientific name, common name, and the applicable elcode or NVC unique 10-digit identifier. "Veg. Code" is a unique number or attribute assigned to each map class in the GIS data base.

Some map units were an attempt to use mental models rather than just signature as a photointerpretive tool. In other words, map units are based on such criteria as vegetation structure and position in the landscape since photo signature alone does not always allow for accurate mapping to the association level. The goal of the map unit is to maximize as much of the detail of the NVC classification as possible while still achieving an acceptable map accuracy.

GPS-located vegetation plot data collected by the field crew were instrumental to the photointerpretive effort These plots gave us a good idea of what the signatures of the individual map units should look like since they represented measured vegetation types on the ground. Ground photos were also collected along with the tabular data at each vegetation plot. These photographs helped not only in identifying the immediate area but also provided us with a "look" at the adjacent areas which might be a different map unit.

Table 3. Map Units and associated NVC Vegetation Associations

Veg. Code	Map Classes / Classified Community Name	Common Name - NVC Alliance or Association	NVC ELCODE
1	***Juniperus monosperma / Bouteloua curtipendula Woodland***	One-seed Juniper / Sideoats Grama Woodland	CEGL000708
2	***Cottonwood / Mesic Grass Complex:***		
	Populus deltoides / Panicum virgatum - Schizachyrium scoparium Woodland	Cottonwood / Switchgrass - Little Bluestem Woodland	CEGL001454
	Populus deltoides / Pascopyrum smithii - Panicum virgatum Woodland	Cottonwood / Western Wheatgrass - Switchgrass Woodland	NEW
3	***Populus deltoides-Celtis laevigata/Sapindus saponaria Woodland***	Cottonwood - Hackberry / Soapberry Woodland	NEW
4	***Artemisia filifolia/Bouteloua (curtipendula, gracilis) Shrubland***	Sand Sagebrush / (Sideoats Grama, Hairy Grama) Shrubland	CEGL002176
5	***Artemisia filifolia - Rhus trilobata Shrubland***	Sand Sagebrush - Skunkbush Shrubland	NEW
6	***Baccharis salicina Shrubland***	Willow Baccharis Shrubland	NEW
8	***Honey Mesquite Shrubland Complex:***		
	Prosopis glandulosa/Bouteloua curtipendula Shrubland	Mesquite / Sideoats Grama Shrubland	CEGL002194
	Prosopis glandulosa/Bouteloua gracilis Shrubland	Mesquite / Blue Grama - Buffalograss Shrubland	CEGL003877
10	***Salix exigua Temporarily Flooded Shrubland***	Sandbar Willow Temporarily Flooded Shrubland	CEGL001197
11	***Tamarisk spp. Temporarily Flooded Shrubland***	Tamarisk spp. Temporarily Flooded Shrubland	CEGL003114
12	***Gypsum Outcrops***	Little Bluestem - Sideoats Grama Western Great Plains HV	CEGL001594
13	***Bouteloua gracilis-Buchloe dactyloides HV***	Blue Grama - Buffalograss Herbaceous Vegetation	CEGL001756
14	***Perennial Bottomland Grassland Complex:***		
	Andropogon hallii-Calamovilfa gigantea HV	Sand Bluestem - Giant Sandreed Herbaceous Vegetation	CEGL004016
	Andropogon hallii/Sorghastrum nutans/Panicum virgatum HV	Sand Bluestem - Indian Grass - Switchgrass HV	NEW
	Panicum virgatum – Pascopyrum smithii Souothern HV	Switchgrass - Western Wheatgrass Southern HV	NEW
	Phragmites australis Western North America Temperate Semi-Natural HV	Common Reed Herbaceous Vegetation	CEGL001475
15	***Perennial Bottomland/Upper Terrace/Valley Floor HV Complex:***		
	Andropogon hallii-Schizachyrium scoparium-Hesperostipa comata HV	Sand Bluestem - Little Bluestem - Needle-and-Thread HV	NEW
	Bouteloua curtipendula - Bouteloua (gracilis, eriopoda) HV	Sideoats Grama - (Blue, Black) Grama Herbaceous Vegetation	CEGL002250
	Panicum obtusum Herbaceous Vegetaion	Vine Mesquite Herbaceous Vegetation	CEGL002708
	Pascopyrum smithii Herbaceous Vegetation	Western Wheatgrass - Blue Grama Herbaceous Vegetation	CEGL001578
	Sporobolus airoides Southern Plains HV	Alkali Sacaton Southern Plains Herbaceous Vegetation	CEGL001685
	Phragmites australis Western North America Temperate Semi-Natural HV	Common Reed Western N. A. Temp. Semi-Natural HV	CEGL001475
16	***Semipermanently Flooded HV Complex:***		
	Phragmites australis Western North America Temperate Semi-Natural HV	Common Reed Western N. A. Temp. Semi-Natural HV	CEGL001475
	Typha (angustifolia, domingensis, latifolia) - Schoenoplectus americanus HV	(Narrowleaf, Southern, Broadleaf Cattail) - Chairmaker's Bulrush HV	CEGL002032
17	***Upland Slopes/Rolling Hills Vegetation Complex:***		
	Bouteloua curtipendula - Bouteloua (gracilis, eriopoda) HV	Sideoats Grama - (Blue, Black) Grama Herbaceous Vegetation	CEGL002250
	Cercocarpus montanus Shrubland	Mountain Mahogany Shrubland	CEGL001086
	Dalea formosa - Mimosa borealis Shrubland	Feather Dalea - Catclaw Mimosa Dwarf-shrubland	NEW
	Gutierrezia sarothrae - Yucca glauca Dwarf-shrubland	Broom Snakeweed - Soapweed Yucca Dwarf-shrubland	NEW
	Krascheninnikovia lanata Dwarf-Shrubland	Winterfat Dwarf-shrubland	NEW
	Schizachyrium scoparium-Bouteloua curtipendula HV	Little Bluestem - Sideoats Grama Western Great Plains HV	CEGL001594
18	***Steep Slope Vegetation Complex:***		
	Rhus trilobata/Bouteloua curtipendula-Schizachyrium scoparium Shrubland	Skunkbush / Sideoats Grama - Little Bluestem Shrubland	NEW
	Schizachyrium scoparium-Bouteloua curtipendula HV	Little Bluestem - Sideoats Grama Western Great Plains HV	CEGL001594

5 - Plot Data Management and Classification Analysis

Plot Data Management

Following the first field season and prior to data entry, all plot forms were checked to ensure quality control (QC). Particular attention was paid to making sure that the recorded plot location was correct and that all relevant fields were filled in. When information was missing, an effort was made to find and record that information often from other data sheets produced by the same crew on that or an adjacent day.

Following the QC of the datasheets, the data were entered into the PLOTS2 database, and all plots were subjected to a second QC to eliminate any data entry errors. During this second QC, the database was examined, sorted, and queried to find missing data, misspellings, duplicate entries, and typos. The species lists were carefully examined to make sure that only USDA PLANTS (USDA, NRCS 2005) names and acronyms were used and were consistent and logical.

Vegetation Classification

Field crews collected data from 182 sample plots during the summer of 2004 (Figure 9. Distribution of 182 vegetation characterization plots collected at LAMR.). Data from these plots were reviewed for accuracy and entered into the PLOTS2 database during the fall of 2004. From November 2004 to January 2005, the data were statistically analyzed using direct and indirect ordination and assigned to vegetation types. The statistical analysis was conducted by NatureServe. See Appendix 1 for details of the methodology.

After all plots had been classified to NVC vegetation types (28 at the Association level and 1 at the Alliance level), local descriptions were written for each type, and a dichotomous key to the vegetation types of LAMR was written (Appendix 1B). The local descriptions are based on the plot data from LAMR only and describe the structure, composition, and environmental characteristics for the type as it occurs at LAMR. Because the descriptions are based only on the LAMR field data, their completeness and accuracy is solely a function of the number of plots and observation points collected for each particular type. Additional plots in any given type can further inform the classification of the type and its description.

The field key combines the characteristics indicated by the LAMR plot data with the essence of the NVC concept for each of the associations. It provides the user with a series of dichotomous choices that result in identification of the association. The field key was used during the 2005 Accuracy Assessment to determine the vegetation type for each of the AA Points. Based on the results of its use during AA, the key was edited to include one previously omitted type and to clarify the text and simplify its use. A mixed tallgrass herbaceous vegetation, *Andropogon hallii-Sorghastrum nutuns-Panicum virgatum* Herbaceous Vegetation was added to the key during the acquisition of AA points.

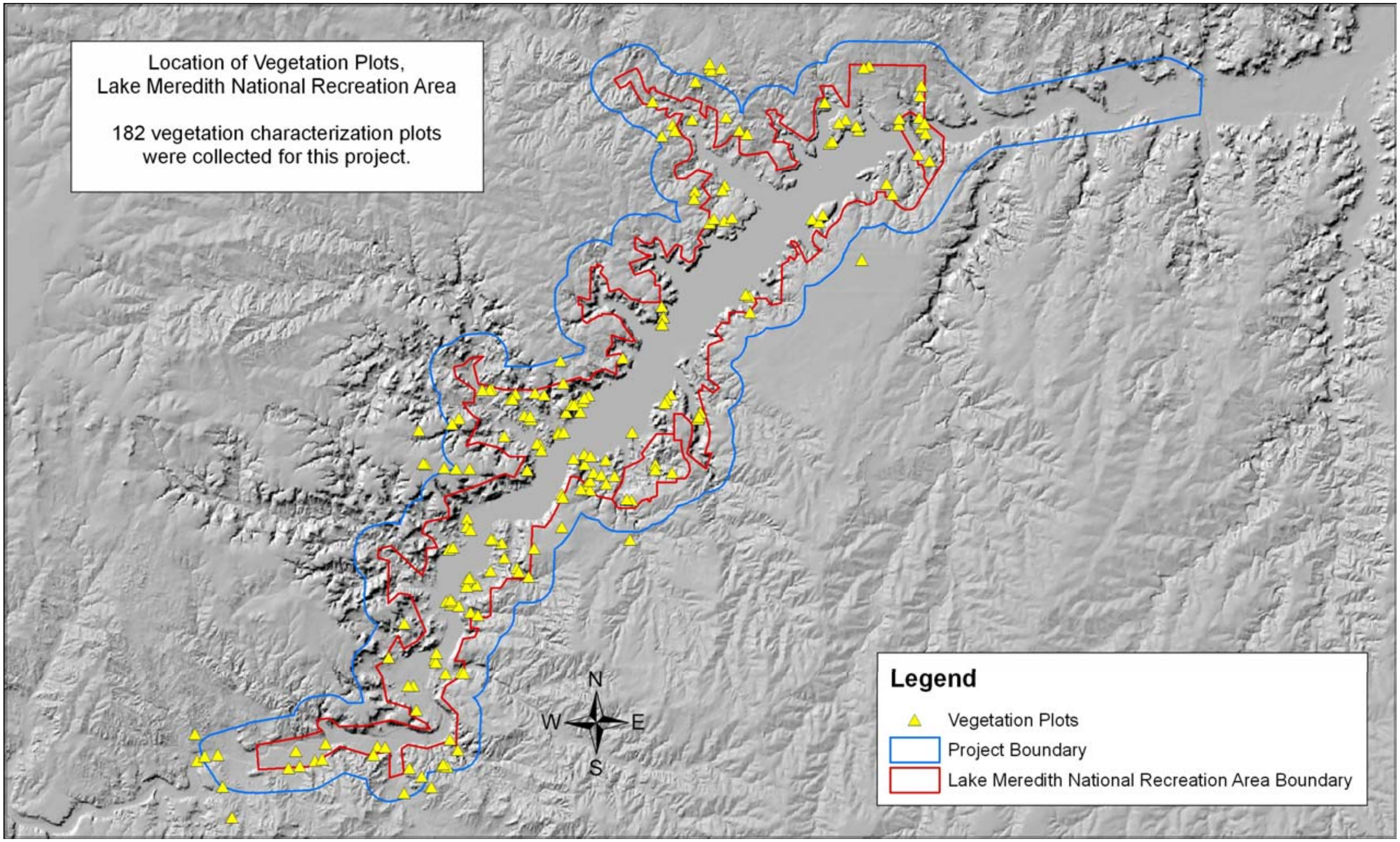


Figure 9. Distribution of 182 vegetation characterization plots collected at LAMR

6 - Map Verification and Accuracy Assessment

Introduction

Following the standards and guidelines of the USGS/NPS Vegetation Mapping Program, Accuracy Assessment Procedures manual, an accuracy assessment is conducted that tests to what degree the map polygon attributes reflect the actual vegetation. The statistics that are calculated give end-users the ability to determine the suitability of the vegetation data for specific applications.

Sample Design

Selection of AA sample points followed that described by the USGS/NPS Vegetation Mapping Program, Accuracy Assessment Procedures manual. The design attempts to adhere to scientific principles that govern sampling and statistical analysis in a practical fashion. The consideration of map accuracy typically can have two components: thematic map accuracy and positional accuracy. The accuracy assessment that follows reflects only thematic map accuracy. Positional accuracy of the polygon edges are not considered due to the fact that there are rarely discreet boundaries between vegetation map classes that can be positively identified in the field.

Sample Method

The accuracy assessment protocol takes into consideration maximum and minimum sample sizes. Considerations include statistical as well as mapped class abundance and frequency. The sample selection is a stratified random sample, stratified by map units. Five scenarios are based on class abundance and frequency and are defined in Table 4. (USGS/NPS Vegetation Mapping Program)

Sample Site Selection

These parameters were coded into in-house software programs that allows for repeat sample selection using a variety of sample choices such as cost weighting and distance from polygon boundary. Being able to choose minimum distance to polygon boundaries helped to eliminate ecotonal boundaries which lead to confusion and loss of effort. A minimum distance of 10 meters was chosen for this effort. The distribution of 283 sample points is shown in Figure 10.

Field crews were provided with two sets of samples. The primary set included the preferred target for the sample selection. If a target was inaccessible for any reason, the crews were free to substitute from the secondary set of points. The effect of this arbitrary reselection reduces somewhat the stratified random selection of points. However, on the plus side, having the flexibility to choose from a second list enabled the field crew to work more efficiently.

Table 4. Recommended map accuracy sample number per class by frequency and area.

Scenario	Description	Polygons in class	Area occupied by class	Recommended number of samples in class
Scenario A:	The class is abundant. It covers more than 50 hectares of the total area and consists of at least 30 polygons. In this case, the recommended sample size is 30.	>30	> 50 ha	30
Scenario B:	The class is relatively abundant. It covers more than 50 hectares of the total area but consists of fewer than 30 polygons. In this case, the recommended sample size is 20. The rationale for reducing the sample size for this type of class is that sample sites are more difficult to find because of the lower frequency of the class.	< 30	> 50 ha	20
Scenario C:	The class is relatively rare. It covers less than 50 hectares of the total area but consists of more than 30 polygons. In this case, the recommended sample size is 20. The rationale for reducing the sample size is that the class occupies a small area. At the same time, however, the class consists of a considerable number of distinct polygons that are possibly widely distributed. The number of samples therefore remains relatively high because of the high frequency of the class.	> 30	< 50 ha	20
Scenario D:	The class is rare. It has more than 5 but fewer than 30 polygons and covers less than 50 hectares of the area. In this case, the recommended number of samples is 5. The rationale for reducing the sample size is that the class consists of small polygons and the frequency of the polygons is low. Specifying more than 5 sample sites will therefore probably result in multiple sample sites within the same (small) polygon. Collecting 5 sample sites will allow an accuracy estimate to be computed, although it will not be very precise.	.5, 30	<50 ha	5
Scenario E:	The class is very rare. It has fewer than 5 polygons and occupies less than 50 hectares of the total area. In this case, it is recommended that the existence of the class be confirmed by a visit to each sample site. The rationale for the recommendation is that with fewer than 5 sample sites (assuming 1 site per polygon), no estimate of level of confidence can be established for the sample (the existence of the class can only be confirmed through field checking).	< 5	< 50 ha	Visit all and confirm

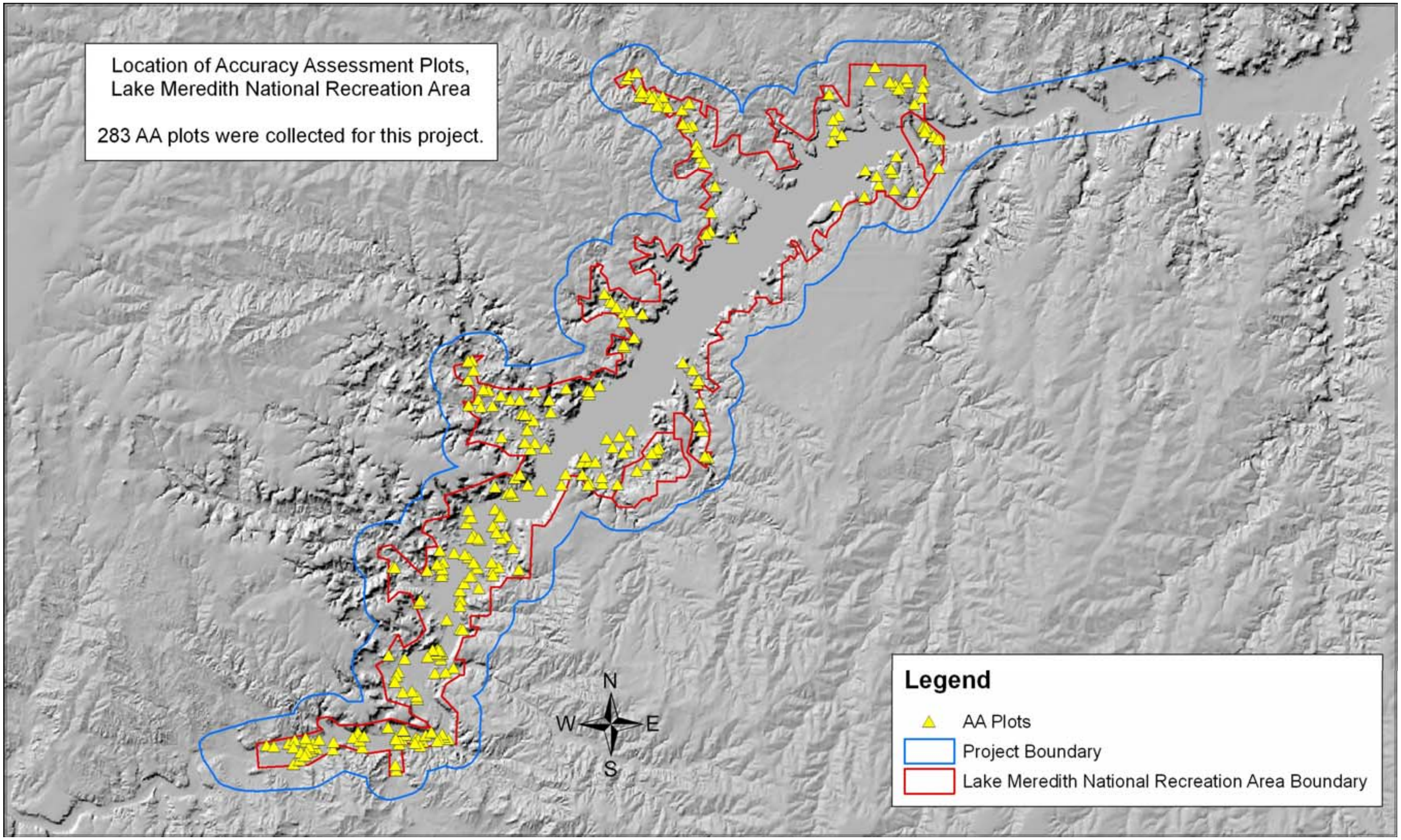


Figure 10. Distribution of 283 accuracy assessment plots within LAMR.

Data Collection – AA Points

Field maps were produced that showed the sample points and polygon boundaries. The addition of the polygon boundary to the field map aided in navigation to the point and provided the field crews with some contextual information. Field crews navigated to each point using the field maps produced for this effort in addition to a hand-held GPS unit loaded with the complete set of primary and secondary GPS points. To help control cost and logistic issues, only those map units that had a vegetative component recognized by the NVC received an accuracy assessment. Five vegetated map classes were not assessed for accuracy. The reservoir drawdown map class was not assessed for accuracy due to the fluctuating nature of its vegetation. The cottonwood alliance map class was not assessed for accuracy because at the time of the AA, it was considered rare although more of it was found during the course of AA data collection. The mountain mahogany map class was found in only one location and therefore was not assessed for accuracy. The weedy forbs were not assessed for accuracy since they are relatively transient and not addressed by the NVC. Finally, a park specific map class, small clonal mattes of Western Soapberry were mapped but not assessed for accuracy. It would be possible to aggregate these polygons into the eastern cottonwood-sugarberry/soapberry woodland map class.

In June of 2005, the AA field crew was given printouts of the vegetation map, an orthophoto image, overlaid with the map unit polygons. These maps contained 325 randomly selected locations to be used as AA Points. The field crews were instructed to navigate to these points and complete an AA datasheet. Given the time frame of the project, and the rugged nature of the Park, it was assumed that not all of the generated points would be accessible. A secondary set of 325 possible AA Points was included on the maps as replacements for those primary points which might be discovered to be inaccessible or otherwise unusable.

Between August 15 and November 15, 2005, the Field Crews collected 283 AA Points (Figure 10). Of these, 255 points were taken from the primary list and 28 sample points were taken from the alternate list. Each day crews chose points to visit based on logistical factors. Floodplain points were visited late in the season, while upland sites were visited earlier. Field days were planned around collecting as many primary points as possible; however, when secondary points occurred along a planned route for the day, they were surveyed in anticipation of future points which might be missed. The tally of which points had been collected in each Map Unit was updated throughout the summer and fall. During the last few weeks of the accuracy assessment, areas for the crews to visit were chosen strategically, to assure point coverage across all of the Map Units.

Upon arrival at a point, crews would begin with a broad visual survey of the area. This was done to determine whether vegetation at the point was representative of the Map Unit polygon (ecotone or inclusions). If vegetation was not representative, the crew would move the point to a more representative location within the polygon and record the distance and bearing to the new point. They recorded the new GPS location and that became the point of record. The crew would then visually determine the boundaries of the point to be sampled. The MMU is ½ Ha and this was used as the sample plot. Crews would then begin collecting data on species composition, vegetation structure, geology and topography of the area. After filling out the AA Point form, the crew would use the Field Key (Appendix 1) to assign an NVC Association to the plot. If no Association seemed to fit, the crew would assign an association name to the plot based on the NVC naming conventions for Associations (dominant species of the primary strata). At each plot two digital photographs were taken. Crews were instructed to document what they observed at the plots by recording extensive field notes. The pictures and field notes that crews collected during the AA data collection phase proved very useful in resolving classification questions later during the AA data analysis.

At the end of the field season, all AA point data sheets were subjected to the same quality control (QC) procedures as the vegetation plot data. While all fields on the AA form were checked for accuracy, particular attention was given to checking the UTM's and plot numbers, and to comparing the assigned association name with species data. All AA point data were then entered into the PLOTS2 database.

Accuracy Assessment Analysis

Once all the AA data had been entered and compiled the accuracy analysis portion of the project was started. This involved a number of steps including an initial binary accuracy assessment, calculation of confidence intervals, a fuzzy evaluation of the AA data, and hypotheses testing.

Binary accuracy assessment: All AA plots and their respective map unit classification (reference layer) were compared to the digital vegetation polygon data (predictive layer). This provides an initial overall accuracy assessment and omission and commission errors (User's and producer's accuracy respectively). (Unless otherwise noted all subsequent formulas are described from *Accuracy Assessment Procedures*, 1994)

User's accuracy is calculated as:

$$\frac{n_{ii}}{n_{i+}}$$

where i is the land cover type, n_{ii} is the number of matches between map and reference data and n_{i+} is the total number of samples of i in the map. This formula is the number of "correct" observations divided by the sum of the column.

Producer's accuracy was calculated as:

$$\frac{n_{ii}}{n_{+i}}$$

where n_{+i} = total number of sample of i in the reference data. This formula is the number of "correct" observations divided by the sum of the row.

Overall accuracy for the map was calculated as:

$$\frac{\sum_{i=1}^{k} n_{ii}}{n}$$

where k is the number of land cover types and n is the total number of reference points. This formula is simply the sum of the diagonal entries divided by the total number of AA points.

Confidence Interval: The 90% confidence interval for a binomial distribution is obtained from the following equation:

$$\hat{p} \pm \left\{ z_\alpha \sqrt{\frac{\hat{p}(1 - \hat{p})}{n}} + \frac{1}{(2n)} \right\}$$

where z_α = 1.645 (this comes from a table of the z-distribution at the significance level for a two-sided limit with a 90% confidence interval), $\hat{p}$ is the sample accuracy (0 to 1.0) and n is the number of sites sampled. The term 1/(2n) is the correction for continuity. The correction should be applied to account for the fact the binomial distribution describes discrete populations.

A kappa statistic is calculated for overall accuracy for each fuzzy level evaluated as follows:

Kappa can be used as a measure of agreement between model predictions and reality (Congalton1991) or to determine if the values contained in an error matrix represent a result significantly better than random (Jensen 1996). Kappa is computed as

$$k = \frac{N\sum_{i=1}^{r} x_{ii} - \sum_{i=1}^{r}(x_{i+} \text{ x } x_{+i})}{N^2 - \sum(x_{i+} \text{x } x_{+i})}$$

where N is the total number of sites in the matrix, r is the number of rows in the matrix, x_{ii} is the number in row i and column i, x_{+i} is the total for row i, and x_{i+} is the total for column I (Jensen1996). Existing Arcview scripts made this onerous process easy and repeatable (kappa_stats.avx by Jenness and Wynne (2004) or kappa.avx developed by the RS/GIS Laboratories at Utah State University (2003) and available at http://www.gis.usu.edu/~chrisg/avext/.

Alternative Map Accuracy Analysis: The need for an alternative to the standard binary approach of accuracy assessment was recognized some time ago. Gopal and Woodcock (1994) described the first fuzzy accuracy assessment approach that is commonly used by some analysts today. Indeed, references to weighting of accuracy results are discussed in the NBS/NPS Vegetation Mapping Program "Accuracy Assessment Procedures" (1994, sections 6.3 and 7.4). This alternate type of analysis allows for degrees of membership to a particular class and establishes guidelines for categorizing the binary mismatches in a standardized fashion. That is, we are allowed to recognize that a particular class may be considered wrong using a strict binary approach but with the fuzzy analysis that class may be mostly correct. This does provide a much better representation of the continuity present in the real world and still allows us to map using discrete classes. All details of the fuzzy accuracy assessment that were calculated for LAMR are found in Appendix 3, Map Accuracy Assessment Using the Fuzzy Accuracy Technique.

Unique Cottonwood Alliance at mouth of Bonita Creek.

Hypothesis Testing

The purpose of the hypothesis test for this accuracy assessment is to determine whether or not the accuracy estimate exceeds 80% (program standard). For the purposes of this accuracy assessment we use the following hypotheses:

"The hypothesis that 80% accuracy has been met will be accepted unless the sample map accuracy is low enough so that the conclusion that rejection is appropriate can be drawn with some predetermined degree of certainty."

In order to accept or reject this hypothesis we use the confidence interval. There is an extremely close relationship between confidence intervals and hypothesis testing. When a 90% confidence interval is constructed, all values in the interval are considered plausible values for the parameter being estimated. Values outside the interval are rejected as implausible. If the value of the parameter specified by the null hypothesis is contained in the 90% interval then the null hypothesis cannot be rejected at the .01 level. If the value specified by the null hypothesis is not in the interval then the null hypothesis can be rejected at the .01 level.

RESULTS

Field Data Collection

Field data were collected during the summers of 2004 and 2005. During the summer of 2004, a total of 182 vegetation plots were established in the Park. During the summer of 2005, a total of 283 accuracy assessment points were established. These data were used to develop the classification of the vegetation of LAMR as well as verify the accuracy of the completed map. The accuracy assessment points also served to refine the classification by verifying the presence of additional types that had not been identified during the vegetation plot sampling in 2004.

Vegetation Classification

The preliminary classification produced by NatureServe in the spring of 2004 prior to any field sampling included approximately 70 vegetation types depending on the probability of occurrence (*probable, possible, or not probable*). These were types existing in the NVC at the time and for which local experts had reasonable certainty would occur in the Park. The analysis of the vegetation plots (and accuracy assessment points) identified some of those types as well as others not on the preliminary list, but failed to identify others that were thought to be *probable* to occur there. Additionally, some of the data collected was sufficient to identify a type only to the Alliance level of classification.

Using the methods described above, the vegetation plot data collected in 2004 were classified into 29 distinct vegetation types based on species composition, structure, and environmental characteristics. Of these, 19 are recognized NVC types, while an additional 10 are “Local” types specific to the Park, but not yet recognized in the NVC. Table 5 contains the complete list of NVC communities found at Lake Meredith NRA. In Table 5, the 28 NVC associations and 1 alliance are organized by the physiognomic classes of floodplain woodlands, floodplain shrublands, wetland herbaceous communities, floodplain grasslands, mesic grasslands, upland woodlands and shrublands, and upland grasslands. Those classified communities that are newly described for the LAMR project are noted as NEW in the NVC ELCODE column.

The Dichotomous Key to the Vegetation Types of LAMR is located in Appendix 1-B. Local descriptions for each NVC type can also be found in Appendix 1-C.

Table 5. List of NVC Communities at Lake Meredith NRA and Alibates NM.

Classified Community Name	Common Name	NVC ELCODE
	Floodplain Woodlands	
Populus deltoides - Celtis laevigata / Sapindus saponaria Woodland	Eastern Cottonwood - Sugarberry / Soapberry Woodland	NEW
Populus deltoides / Panicum virgatum - Schizachyrium scoparium Woodland	Eastern Cottonwood / Switchgrass - Little Bluestem Woodland	CEGL001454
Populus deltoides / Pascopyrum smithii - Panicum virgatum Woodland	Eastern Cottonwood / Western Wheatgrass - Switchgrass Woodland	NEW
Populus deltoides Woodland Alliance	Eastern Cottonwood Woodland Alliance	A.636
	Floodplain Shrublands	
Baccharis salicina Shrubland	Great Plains False Willow Shrubland	NEW
Salix exigua Temporarily Flooded Shrubland	Coyote Willow Temporarily Flooded Shrubland	CEGL001197
Tamarisk spp. Temporarily Flooded Shrubland	Tamarisk spp. Temporarily Flooded Shrubland	CEGL003114
	Wetland Herbaceous Communities	
Phragmites australis Western North America Temperate Semi-Natural Herbaceous Vegetation	Common Reed Western North America Temperate Semi-Natural Herbaceous Vegetation	CEGL001475
Schoenoplectus pungens - Distichlis spicata Herbaceous Vegetation	Threesquare - Saltgrass Herbaceous Vegetation	CEGL005988
Typha (angustifolia, domingensis, latifolia) - Schoenoplectus americanus Herbaceous Vegetation	(Narrowleaf Cattail, Southern Cattail, Broadleaf Cattail) - Chairmaker's Bulrush Herbaceous Vegetation	CEGL002032
	Floodplain Grasslands	
Andropogon hallii - Calamovilfa gigantea Herbaceous Vegetation	Sand Bluestem - Giant Sandreed Herbaceous Vegetation	CEGL004016
Pascopyrum smithii - Bouteloua gracilis Herbaceous Vegetation	Western Wheatgrass - Hairy Grama Herbaceous Vegetation	CEGL001578
Sporobolus airoides Southern Plains Herbaceous Vegetation	Alkali Sacaton Southern Plains Herbaceous Vegetation	CEGL001685
Classified Community Name	**Common Name**	**NVC ELCODE**

	Mesic Grasslands	
Panicum obtusum Herbaceous Vegetation	Vine Mesquite Herbaceous Vegetation	CEGL002708
Panicum virgatum - Pascopyrum smithii Southern Herbaceous Vegetation	Switchgrass - Western Wheatgrass Southern Herbaceous Vegetation	NEW
	Upland Woodlands and Shrublands	
Juniperus monosperma / Bouteloua curtipendula Woodland	One-seed Juniper / Sideoats Grama Woodland	CEGL000708
Artemisia filifolia – Rhus trilobata Shrubland	Sand Sagebrush - Squawbush Shrubland	NEW
Artemisia filifolia / Bouteloua (curtipendula, gracilis) Shrubland	Sand Sagebrush / (Sideoats Grama, Hairy Grama) Shrubland	CEGL002176
Cercocarpus montanus Shrubland	Mountain Mahogany Shrubland	CEGL001086
Dalea formosa - Mimosa borealis Dwarf-shrubland	Feather Dalea - Catclaw Mimosa Dwarf-shrubland	NEW
Gutierriezia sarothrae - Yucca glauca Dwarf-shrubland	Broom Snakeweed - Soapweed Yucca Dwarf-shrubland	NEW
Krascheninnikovia lanata Dwarf-Shrubland	Winterfat Dwarf-shrubland	NEW
Prosopis glandulosa / Bouteloua curtipendula Shrubland	Mesquite / Sideoats Grama Shrubland	CEGL002194
Prosopis glandulosa var. glandulosa / Bouteloua gracilis – Buchloe dactyloides Shrubland	Mesquite / Hairy Grama - Buffalograss Shrubland	CEGL003877
Rhus trilobata / Bouteloua curtipendula - Schizachyrium scoparium Shrubland	Squawbush / Sideoats Grama - Little Bluestem Shrubland	NEW
	Upland Grasslands	
Bouteloua curtipendula - Bouteloua (gracilis, eriopoda) Herbaceous Vegetation	Sideoats Grama - (Sideoats Grama, Black Grama) Herbaceous Vegetation	CEGL002250
Bouteloua gracilis - Buchloe dactyloides Herbaceous Vegetation	Hairy Grama - Buffalograss Herbaceous Vegetation	CEGL001756
Schizachyrium scoparium - Bouteloua curtipendula Western Great Plains Herbaceous Vegetation	Little Bluestem - Sideoats Grama Western Great Plains Herbaceous Vegetation	CEGL001594
Sporobolus cryptandrus – Schizachyrium scoparium – Bouteloua curtipendula Herbaceous Vegetation	Sand Dropseed - Little Bluestem - Sideoats Grama Herbaceous Vegetation	NEW

Photo-Interpretation and Map Units

We recognized and delineated 34 map units (see Table 6. Vegetation Code and Map Unit) using the color infrared aerial photographs for LAMR. Of these, 16 are natural or semi-natural vegetation and received an accuracy assessment and twelve were un-vegetated map units based on Anderson (1976) or vegetated map units that are not part of the NVC. All map units were developed from a combination of the initial NVC vegetation classification provided by NatureServe with input from Park biologists and BOR ecologists, fieldwork, and preliminary photo-interpretation. Appendix 4 provides detailed descriptions and includes representative photos for all vegetation map units. A few map units have a one to one relationship with the vegetation associations, but most have several associations as part of each map unit. This is a one to many relationship (one map unit – many associations). In addition, it should be noted that some associations may occur in more than one map unit. This is a many to one relationship (many map units – one association).

Vegetation Map

A total of 88,479 acres (35,806 ha) comprising LAMR, ALFL and its environ was mapped. The area mapped within the Park boundary was 43,037 acres (17, 417 ha). Thirty-four map units were developed to describe the landscape. Of all the map units, the most frequently occurring within the entire mapping area was Map Unit 8, Honey Mesquite Shrubland with 825 polygons ranging in size from under 0.01 acres to over 285 acres. The most abundant map unit in terms of area was Map Unit 17, Upland Slopes/Rolling Hills Vegetation Complex at 27,128 acres or about 31% of the total mapped area but 18% of the Park. All of the frequencies for each map unit (*i.e.,* number of polygons) along with acreage and hectares per map unit in Table 7 and Table 8.

Normally the standard minimum mapping unit for NPS vegetation mapping projects is defined as 0.5 hectares. However, this definition was used as a guideline and the actual minimum threshold defined by the high resolution of the aerial photography was more in the range of 1/4 acre. This ability to recognize small patches of vegetation is reflected in the high number of polygons. The particular vegetation associations that occur in the Park, especially those that occur in stands smaller than 0.5 hectares are what drive the need to map below the MMU. For example, sandbar willow frequently occupies areas smaller in size than 0.5 hectares. In the photointerpretation, we try to minimize going below the minimum mapping size while still maintaining the level of detail required to map at the vegetation association level. The trade-off would be to map less detail or to characterize these associations with point rather than polygon data. It should also be noted that polygons that occur on the boundary of the Park or project boundaries are likely to be smaller than normal since they are artificially cut off by the conditions.

Table 6. Vegetation Code and Map Unit Name

VEG_CODE	MAP_UNIT_NAME
1	One-seed Juniper / Sideoats Grama Woodland
2	Cottonwood / Mesic Grass Complex
3	Cottonwood - Hackberry / Soapberry Woodland
4	Sand Sagebrush / (Sideoats Grama, Hairy Grama) Shrubland
5	Sand Sagebrush - Skunkbush Shrubland
6	Willow Baccharis Shrubland
7	Mountain Mahogany Shrubland
8	Honey Mesquite Shrubland Complex
10	Sandbar Willow Temporarily Flooded Shrubland
11	Tamarisk spp. Temporarily Flooded Shrubland
12	Gypsum Outcrop Grassland
13	Blue Grama - Buffalograss Herbaceous Vegetation
14	Perennial Bottomland Grassland Complex
15	Perennial Bottomland/Upper Terrace/Valley Floor HV Complex
16	Semipermanently Flooded HV Complex
17	Upland Slopes/Rolling Hills Vegetation Complex
18	Steep Slope Vegetation Complex
20	Drawdown Areas
21	Kochia-Salsola Weedy Forb Herbaceous Vegetation
22	Miscellaneous Cottonwood Woodland
24	Western Soapberry Woodland
25	Transportation
26	Oil/Gas Development Sites
27	Mixed Urban-Built-up Land
28	Croplands and Pastures
30	Perennial Streams
31	Intermittent Streams
32	Reservoirs
33	Stock Ponds
34	Strip Mines, Quarries, and Borrow Areas
35	Sandy Areas/River Sandbars
36	Open Water
37	Disturbed-Off Road Vehicle
38	Dolomite Outcrops

Table 7. Summary area statistics for map units within LAMR.

VEG_CODE	COUNT	Sum Acres	Sum Hectares
1	8	54	22
2	56	302	122
3	58	499	202
4	71	947	383
5	11	383	155
6	28	912	369
7	2	2	1
8	433	4467	1808
10	21	36	15
11	171	1919	776
12	61	42	17
13	68	842	341
14	73	1996	808
15	198	3575	1447
16	34	150	61
17	400	7777	3147
18	130	6017	2435
20	30	4213	1705
21	7	93	38
22	31	115	47
24	9	20	8
25	34	222	90
26	23	21	8
27	39	245	99
28	2	1	0
30	1	150	61
31	4	18	7
32	5	7056	2856
33	2	1	1
34	2	536	217
35	71	325	131
36	7	10	4
37	4	88	35
38	4	2	1
TOTALS	**2098**	**43037**	**17417**

Table 8. Summary area statistics for map units within Project Area (Park buffer)

VEG_CODE	Count	Sum Acres	Sum Hectares
1	23	510	206
2	69	382	155
3	135	886	359
4	115	3401	1376
5	39	672	272
6	48	1233	499
7	2	2	1
8	825	13576	5494
10	25	49	20
11	213	3238	1310
12	91	103	42
13	96	2226	901
14	107	2468	999
15	335	6421	2598
16	65	721	292
17	719	27128	10979
18	303	9319	3771
20	30	4213	1705
21	9	127	51
22	31	115	47
24	13	36	15
25	59	425	172
26	116	124	50
27	135	2170	878
28	19	203	82
30	2	166	67
31	7	29	12
32	26	7083	2866
33	10	4	2
34	35	707	286
35	106	535	217
36	27	36	15
37	10	168	68
38	4	2	1
TOTALS	**3850**	**88479**	**35806**

Map Accuracy Assessment

The assessment of map accuracy is the comparison of the map class that was observed and recorded in the field during the AA effort to the map class that was predicted on the vegetation map by the photo-interpreter. In the field, the vegetation specialists key out the vegetation to a particular NVC association or alliance. These NVC plant communities are crosswalked to the map classes during the data analysis (Table 3). When the field call matched the map polygon class, that particular AA point was considered correct. If the vegetation association determined in the field did not match the cross-walked map class, the AA point was considered incorrect.

After initial calculation of accuracy, an AA meeting was convened to review the initial results. Each mis-matched AA point was evaluated to determine if the error was a true error or one that could reasonably be adjusted. Common reasons for correcting an AA point were GPS position error due to data transcription errors or questionable field assessments. After consensus was reached, a final AA analysis was calculated. In addition to this informal review, further analysis of the LAMR AA data was conducted using the protocols of a fuzzy accuracy assessment (see Appendix 3, Map Accuracy Assessment using Fuzzy Accuracy Analysis).

The results of the data analysis using the standard accuracy assessment are shown in Table 9. Contingency table for map accuracy assessment.

Instructions on Using the Accuracy Assessment Contingency Table:

The contingency table or error matrix presents an array of numbers set out in rows and columns corresponding to a particular vegetation map unit relative to the actual vegetation type as verified on the ground. The column headings represent the vegetation classification as determined in the field and the row headings represent the vegetation classification taken from the vegetation map. The highlighted diagonal indicates the
number of points assessed in the field that agree with the map label. Conversely, the inaccuracies of each map unit are described as both errors of inclusion (user's or commission errors) and errors of exclusion (producer's or omission errors). By reading across this table (i.e., rows) one can calculate the percent error of Commission, or how many polygons for each map unit were incorrectly labeled when compared to the field data. By reading down the table (i.e., columns) one can calculate the percent error of omission, or how many polygons for that type were left off the map. Numbers "on the diagonal" tell the user how well the map unit was interpreted and how confident they can be in using it. Numbers "off the diagonal" yield important information about the deficiencies of the map including which types were: 1) over- mapped - commission errors on the right or 2) under-mapped - omission errors on the bottom.

Definitions:

Producer's accuracy – the probability that an AA point has been mapped correctly (also referred to as "errors of omission" and "errors of exclusion")

User's accuracy – the probability that the map actually represents what was found on the ground (also referred to as "errors of commission" and "errors of inclusion") (Hop et al. 2005)

High producer's accuracy combined with low user's accuracy indicates that the map class is under-mapped. Conversely, low producer's accuracy combined with high user's accuracy indicates that a type is over-mapped.

The AA process relies on matching field observations based on the vegetation classification (through the use of the key) system with mapping results based on photo interpretation. Errors occur when map classes differ from the classes observed in the field.

Table 10 lists the Producer's and User's accuracy for each map unit.

Table 9. Contingency table for map accuracy assessment.

		Reference (Accuracy Assessment Field Data)																		
		1	2	3	4	5	6	8	10	11	12	13	14	15	16	17	18	Sum	Commission Error %Correct	+/ - (90% Conf. Interval)
Predictive Data (Polygon Map Data)	1	0	0	0	0	0	0	2	0	0	0	0	0	0	0	2	1	5.0	0.0%	10.0%
	2	0	18	0	0	0	1	0	0	0	0	0	4	0	0	0	0	23.0	78.3%	16.3%
	3	0	7	11	0	0	0	0	0	1	0	0	1	0	0	0	0	20.0	55.0%	20.8%
	4	0	0	0	5	0	0	1	0	0	0	0	0	0	0	9	1	16.0	31.3%	22.2%
	5	0	0	2	0	3	0	1	0	0	0	0	0	1	0	1	0	8.0	37.5%	34.4%
	6	0	0	0	0	0	6	0	0	0	0	0	11	0	0	0	0	17.0	35.3%	22.0%
	8	0	0	0	0	0	0	9	0	0	0	0	0	1	0	3	0	13.0	69.2%	24.9%
	10	0	0	0	0	0	1	0	2	0	0	0	1	0	0	0	0	4.0	50.0%	53.6%
	11	0	0	0	0	1	1	0	0	17	0	0	2	1	0	0	0	22.0	77.3%	17.0%
	12	0	0	0	0	0	0	0	0	0	11	0	0	0	0	3	0	14.0	78.6%	21.6%
	13	0	0	0	0	0	0	2	0	0	0	5	0	0	0	17	0	24.0	20.8%	15.7%
	14	0	0	0	0	0	1	0	1	0	0	0	22	0	0	0	0	24.0	91.7%	11.4%
	15	0	0	0	0	0	0	0	0	0	0	2	2	25	0	1	0	30.0	83.3%	12.9%
	16	0	1	0	0	0	1	0	6	6	0	0	0	0	11	0	0	25.0	44.0%	18.3%
	17	0	0	1	1	0	0	0	0	0	0	0	0	0	0	20	0	22.0	90.9%	12.4%
	18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	13	16.0	81.3%	19.2%
Sum		0	26	14	6	4	11	15	9	24	11	7	43	28	11	59	15	Total Correct = 178		
% Accurate		0.0%	69.2%	78.6%	83.3%	75.0%	54.5%	60.0%	22.2%	70.8%	100.0%	71.4%	51.2%	89.3%	100.0%	33.9%	86.7%	Total Samples = 283		
+/ - (90% Conf. Interval)		0.0%	16.8%	21.6%	33.4%	48.1%	29.2%	24.1%	28.4%	17.3%	4.5%	35.2%	13.7%	11.4%	4.5%	11.0%	17.8%			

Users Accuracy (Commission Error)

OVERALL TOTAL ACCURACY = 62.9% **OVERALL KAPPA INDEX = 59.9%** **OVERALL 90% UPPER AND LOWER CONFIDENCE INTERVAL: 58.0**% and **67.8**%

Producers Accuracy (Omission Error)

Confidence Interval is 90% two-sided limit

Table 10. Map unit accuracies for omission and commission errors.

VEG CODE	Map Unit Name		
		Users' accuracy	Producers' accuracy
1	One-Seed Juniper	n/a	n/a
2	Cottonwood / Mesic Grass	78.3	69.2
3	Cottonwood / Hackberry / Soapberry	55.0	78.5
4	Sand Sage / Sideoats-Blue Grama Shrubland	31.3	43.8
5	Sand Sage / Skunkbush Sumac Shrubland	37.5	75.0
6	Willow Baccharis Shrubland	35.3	54.5
8	Honey Mesquite Shrubland	69.2	69.2
10	Sandbar Willow Shrubland	50.0	22.2
11	Tamarisk Shrubland	77.3	70.8
12	Gypsum Outcrops Sparse Herbaceous Vegetation	78.6	100.0
13	Blue Grama-Buffalograss Herbaceous Vegetation	20.8	71.4
14	Perennial Bottomland Herbaceous Vegetation Complex	91.7	51.2
15	Perennial Bottomland/Upper Terrace/Valley Floor HV Complex	83.3	89.3
16	Semipermanently Flooded herbaceous Vegetation Complex	40.0	100.0
17	Upland Slopes/Rolling Hills Herbaceous Vegetation Complex	90.9	35.1
18	Steep Slope Vegetation Complex	81.2	92.9
MEAN		57.8%	66.4%

Accuracy Assessment by Map Unit

Common Trends and Map Errors

While the total area of Lake Meredith is relatively small compared to other Parks, the vegetation is complex and the landscape is highly dissected. Even with the plant species overlap between the different map classes, we achieved a successful outcome. We were able to reliably distinguish most of the map classes. One of the keys to this success was the association of map classes with their location in the landscape. While the vegetation associations might blend with each other, map units were rarely found outside of where they typically occurred. A discussion of the pitfalls and points of confusion follows. The purpose of discussing the common sources of error is to help refine the classification and aid future updates of the database. Of the assessed map units, some had lower than expected levels of accuracy. These discrepancies were examined and some common issues were found to explain most of these errors. These four common types of error are (1) perspective, (2) rare types, (3) physiognomic and growth similarities, and (4) species overlap.

One-Seed Juniper
Map Unit – 1

After a thorough discussion of this map class, it was determined that although there are junipers present in the park, they probably do not constitute a woodland association type but would most likely fit into one of the existing shrubland types. For the photointerpreter, in many cases these junipers are not visible because they occur in the shadows of the steep slopes or they occur in such a scattered pattern as to be called a grassland or shrubland type by the field ecologists. Some areas of juniper woodland do occur outside of the park on private ranch land although even these areas have a sparse cover of juniper and could again be mapped into a shrubland type in the field. This map class and its NVC association need further review as it relates to Lake Meredith. This example fits into the common error associated with rare types. Only a few polygons of this type were mapped in the park. This small sample size produced an error that may or may not be indicative of the actual ability of the photo interpreter. It may be more indicative of an error in classification.

Cottonwood with Mesic Grass
Map Unit – 2 confused with Perennial Bottomland Herbaceous Complex
Map Unit – 14 and Cottonwood with Hackbery and Soapberry
Map Unit – 3

Most of the errors for these map classes were based on perspective or physiognomic and growth similarities. The photointerpreter is looking at the vegetation pattern over a larger area than the field ecologist. The cottonwoods/mesic grass class at Lake Meredith is part of the bottomland grassland community. It can be very subjective when to call an area a cottonwood stand versus a grassland with cottonwood.

This map class (Map Unit 2) and the other cottonwood map class (Map Unit 3) were sometimes confused by the photointerpreter. The two map classes are differentiated by location in the landscape and the presence of hackberry and soapberry as well as different understory grasses. Sometimes map unit 3 was found without all of the major components of the type and in a location more commonly occupied by the cottonwood with mesic grass.

Sand Sage with Sideoats-Blue Grama
Map Unit – 4

In some cases, this map unit was mistaken for the grasslands of the rolling hills map class. The photo signature of the sand sage is generally distinctive but the typical stippling can be faint. This signature was sometimes confused with the dark color and texture of some of the rolling hills signatures which occupy a similar position in the landscape.

Sand Sage with Skunkbush Sumac Shrubland
Map Unit – 5

This map class turned out to be less plentiful than originally estimated. It is more common on the private land surrounding the park. It is quite distinctive in photo signatures.

Willow Baccharis Shrubland
Map Unit – 6

The errors associated with the mapping of willow baccharis related to physiognomic and growth similarities with both tamarisk and with the bottomland grasslands. In areas near the Canadian River prone to flooding or that has been burned, there is a succession that can occur in which willow baccharis colonizes the sandy areas. When the baccharis is young and mixed with grasses, the signature is difficult to distinguish from the grasses. Young tamarisk and willow baccharis can be difficult to distinguish by the photo interpreter. In general, willow baccharis and tamarisk do mix frequently.

Honey Mesquite Shrubland
Map Unit – 8

In general, map unit 8 was one of the easiest to map accurately. This map class has a distinctive photo signature and is reliably located where expected in the landscape. The errors associated with Honey Mesquite were generally a matter of perspective. The density of this shrub varies considerably and it is easy to understand how the field ecologists might call an area of low density mesquite a grassland while the photo-interpreter is looking at a much larger polygon.

Sandbar Willow Shrubland
Map Unit – 10

Large stands of pure sandbar willow are rare at LAMR. Typically it occurs in very small patches or mixed with other species and map classes. The larger stands of sandbar willow are distinctive but at the same time they can be confused with stands of tamarisk of uniform age in that both have a particular smooth texture.

Tamarisk Shrubland
Map Unit – 11

Overall, this map class was successfully mapped. This map class was confused with other shrubland classes, sandbar willow and willow baccharis. The error in mapping tamarisk is likely associated with its many different growth forms. Although there is a classic photo signature associated with dense mature tamarisk, the many other growth and physiognomic forms can present confusion with the photo signatures of willow baccharis and sand bar willow. The presense of ground water also tends to add confusion to the separation of tamarisk, willow and emergent wetlands. The Canadian River bottomland between Bonita Creek and Chicken Creek is the prime example of this situation This area appears to have additional ground water which causes the photosignature to resemble that of emergent wetland. Numerous AA points fell in this area and several of these polygons mapped as emergent wetland were in fact tamarisk.

Gypsum Outcrops
Map Unit – 12

This map unit was fairly easy to map accurately. The only errors were associated with the small size of these polygons. The points could easily be placed in the surrounding rolling hills vegetation and a distinct boundary was not always easily discernable.

Blue Grama-Buffalograss
Map Unit – 13

Errors for this map unit were based on a poor mental model by the photointerpreter. There simply was not enough plot data to emphasize that this map class was restricted to the flat tops of the mesas. Fairly level uplands that exhibited a smooth texture on the aerial photographs were frequently mistaken for Map Unit 13. Also, there is more of this map unit outside of the park on private ranch land. Once this error was discovered it was easily corrected.

Semipermanently Flooded Herbaceous Vegetation Complex
Map Unit – 16

In general, this map class occurs as small polygons. A source of error occurred at the river bottom between Bonita Creek and Chicken Creek. Several polygons of sandbar willow were mapped as Semipermanently Flooded Herbaceous Vegetation Complex, map unit 16. After discussion at the AA meeting, it was decided that this area is unique in that it appears to have a subsurface source of water. All of the map classes that occur there are wetter than ordinary. So while the photointerpreter mapped many of these incorrectly, the photo signature clearly indicates high water table. Despite this anomalous area, it is likely that map unit 16 is discernable from tamarisk, willow and willow baccharis in other areas of the park. However, this area did contribute significantly to the error for this map unit.

Species Overlap

One of the most challenging issues at LAMR and a constant issue across all of the map units was the overlap in common species among different map classes. The vegetation at LAMR was diverse and a majority of species occurred across multiple landscapes. The overall variability in the terrain also created many transition areas containing different mixes of vegetation. This overlap in common species caused some confusion in keying the vegetation on the ground and delineating discreet units on the aerial photography. This is especially apparent among the grassland communities. Typically, shrubland communities are easy to discern and delineate on aerial photography. There is commonly a stippling pattern associated with any shrubland community. At Lake Meredith there are several xeromorphic shrub communities that are also dwarf shrublands. In most cases, these communities display more of a grassland photo signature. The result is that the overlap in both grass species and dwarf shrub species among vegetation communities contributed to the challenge of mapping Lake Meredith to the level of detail that was ultimately achieved.

DISCUSSION

NVC Classification

The vegetation of LAMR vegetation mapping project is diverse. Even with several previous vegetation studies, quite a number of new NVC associations were described.

Although budgets and time constraints often preclude In the future it is recommended to conduct a second field season after the draft classification based on the first field season is completed. That way crews can target sampling of certain types to clarify confusing types, augment under-sampled types and look for un-sampled, but "expected" types. We also recommend that preliminary map units (MU) be developed prior to the first field season and used to help allocate samples to MU not well represented by NVC associations. This will help insure mappers have a minimum number of training site data points to begin mapping. In practical terms, it is difficult to fast track a park of this size because the map classes which drive the eventual accuracy of the park end up being determined by a fairly small number of plot data points. It is only after all of the plot data and AA data are collected that the map classes begin to have enough information to best describe the vegetation.

There are some unresolved classification issues that will need additional survey work to further define, such as clarifying some remaining sparse vegetation types and classifying possible vegetation types identified in the AA point data. Anthropogenic disturbance of many of the lowland riparian vegetation types created challenges in classifying them.

The site specific data collected during this project was extensive with plots and AA points combining to total over 450 new sample sites, each with vegetation, environmental and fuels data and photos. The data create a new "baseline" from which to evaluate past and future management issues and will be useful for years to come for various planning and resource management activities including fuels and fire management.

In the future, resource management personnel may key habitat for species of concern to association, then locate potential sites by using the vegetation map and environmental variables.

Non-native Species

The vegetation of LAMR includes numerous non-native species, including , as well as many annual weeds. The park manages some of these species with various techniques, including burning, mechanical removal and chemical treatment. It was noted that often the removal of tamarisk resulted in a stimulation of annual weeds. It is recommended that the benefits of tamarisk removal need to be weighed against this stimulation of introduced annuals.

Photo-interpretation and Map Units

Inherent to vegetation mapping projects is the need to produce both a consistent vegetation classification and a set of map units. Typically, the systems are very similar if not identical, but when using a national classification such as the NVCS there is typically not a strict one-to-one correspondence. This is due to the remote sensing nature of photographic interpretation and its ability to only delineate map units based on complex photo signatures. Subtle vegetation characteristics that can be seen on the ground are not necessarily the same as those apparent on the photos. Canopy closure, shadows, and timing of the photography can also distort or obscure photo signatures.

For a diverse park such as LAMR we suggest that a completed (or nearly completed) classification be in place before the actual interpretation begins. This is often difficult to do given the constraints of time. Waiting for a complete classification of the vegetation before proceeding with the mapping may add a year or more to the entire process. The benefits include avoiding a revisit or, in the worst case, redoing the interpretation based on classification changes. Ideally, plot sampling should begin early in the project, followed by analysis of the vegetation data to the NVC before the ground-truthing and interpretation of the aerial photographs. Another problem discerned late in the project was the amount of mixing of associations. Rather than being attributable to an error in classification, it just appeared that in some areas of the park, two or more associations blended into each other. This was apparent both in the field and in the photo interpretation.

Map Accuracy

General Considerations

Judging the accuracy of a thematic map has become as important as the actual creation of that map, yet the methods for collecting and interpreting accuracy assessment data remains problematic. The concept of accuracy assessment is straightforward however; the practicality (measurement and expression) can be tricky (Foody 2001). Foody (2001, 2002) and even the Park mapping protocols (Accuracy Assessment Procedures – 1994) discuss the many sources of thematic error that may lead to misinterpretations of accuracy assessments. The improper use or reporting of accuracy data may lead to over or under estimation of map or map unit accuracy. Problems may arise from inaccurate reference data, data set mis-registration, poor or inappropriate sampling design, spatial variation of accuracy, error magnitude and procedural errors during the creation of the digital products. This project has attempted to address these many pitfalls and these problem areas are discussed below.

The term ground truth can be misleading as even classification of a location on the ground is subject to interpretation (Foody 2001, Bird et al., 2000). The determination of vegetation association using keys usually has some room for interpretation of vegetative characteristics and even presence of species. The original vegetation classification may have been developed from samples collected during significantly different climatic periods (e.g. wet year vs. dry year) or even seasonal variation (e.g. spring sampling vs. fall sampling). A temporal change in the landscape between photo acquisition / interpretation and field sampling for accuracy assessment is also common (Fire, landslides, avalanches etc.) Vegetation association descriptions also depend heavily on estimations of cover that, in spite of extensive training prior to sampling, may be different enough to produce erroneous site classifications.

Exacerbating all of these potential problems is the underlying but false assumption that the vegetation classes are discrete rather than continuous. We know that rarely are vegetation types distinguished by sharp boundaries but rather grade into one another (Gleason 1917, 1926, Whittaker 1956, 1962, Curtis 1959). The degree of gradation often will relate to the steepness of the environmental gradient. "Steep environmental gradients tend to produce distinct vegetation boundaries where gradual environmental gradients tend to produce wider transition zones between vegetation types." (Standardized National Vegetation Classification System, 1994). Environmental gradients within LAMR vary from gradual to steep. Thus, the membership of a location or sample to a single discrete vegetation type or description is suspect. The field key also assumes that any accuracy samples described in a plot have already been described when in reality a new association may be confounding the classification in the field. Implicit is that the vegetation classification is complete and correct. Because the emphasis for this project is the vegetation map rather than the vegetation classification, no testing of the classification has been conducted, although the field key is tested in the AA. In a statistically perfect world, another round of samples would have been collected to test the vegetation classification prior to any mapping. Although it may be cost prohibitive, the program is making plans to test classifications before mapping.

Given that source data may be rife with problems, Foody (2001) suggests that "…the typical accuracy assessment is rather a measurement of the degree of agreement or correspondence between the two data sets, rather than an evaluation of the closeness of the thematic map to reality." This is probably the case with this project.

Mis-registration of AA field samples and the actual location to be sampled can cause problems. At LAMR, we encountered a few points that were mis-registered due to transcription errors. All errors of transcription were corrected. One of the more common problems encountered was the location of plots within small polygons. Many polygons were below the MMU for the project. Small polygons do provide for a higher map precision however, the sampling of these can be very problematic. With very small polygons not only is the location a problem, but the edge effect leads to considerable confusion in classifying the area properly. More adjustments to ensure that random points are not placed at the edge of polygons would be useful to avoid the confusion created by sampling of ecotones.

Given the detail of the map and the variability of the vegetation, we believe the accuracy assessment for LAMR was successful due to several factors. First we made sure that the overall sampling design followed closely the protocols described for by the National Park Mapping Program. Boundaries between polygons were minimally avoided but not so much so as to only sample large homogenous areas. The distribution of the sample points was good and most map units received an adequate number of points per type to draw general conclusions at each fuzzy level. In addition the spatial distribution of the AA sample points across the Park was very good.

Very rarely did we find gross errors of classification without some explanation. In these rare cases we speculate that the error is likely a result of inaccuracies introduced during the digitizing process. These include:

1. Lines are sometimes dropped between adjacent polygons and they may appear closed and separate but in reality are not.
2. The polygon coding may have been incorrectly transcribed from the photo into the digital database.

The Accuracy Standard for the USGS/NPS Vegetation Mapping Program

The program standards for accuracy are 80% for both overall accuracy and individual class accuracy. The program recognizes that these levels of accuracy may be difficult to achieve. Indeed, the Program Accuracy Assessment Procedures states that ***"Given that vegetation mapping is necessarily interpretive, it is recommended that relaxed requirements be used in terms of acceptable levels of error as well as confidence levels in the estimate. Otherwise, regardless how carefully the mapping process is carried out, it is unlikely that accuracy requirements will be met".***

The final results for the AA assessment of 16 vegetation classes mapped within LAMR and ALFL are found in Table 14. Overall map accuracy for the evaluated area is 63%. When the AA data is analyzed with relaxed requirements, the overall map accuracy of the evaluated area is 86% (see Appendix 3. Map Accuracy Assessment using Fuzzy Accuracy Analysis).

Recommendations

Field Survey

The field data were collected by a small number of individuals. This worked well with the exception that it would have gone more quickly if the teams could have dedicated more continuous blocks of time to the project. The availability of experienced field surveyors is an ongoing problem given the seasonal nature of this work. Having the expertise of Mr. J.R. Bell worked particularly well for the project. His knowledge of the parks based on years of experience as a representative of the NRCS was invaluable in knowing the particular plants, the vegetation types that occur there, as well as the lay of the land and the ability to gain permission from private landowners to enter and sample their properties in the course of the project. In addition, his ability to train the rest of the field crew made the whole project more consistent and thorough in the end. In many cases, the Park may have an expert or experts but with some of the smaller, more remote parks, this is not always the case. So, the use of a local expert barring the availability of park personnel is highly recommended.

In addition, it is highly recommended that data collection be entered into a field computer or data logger rather than on paper as is usually the case. The data logger could be set up with an electronic version of the field forms, both plot and AA, which would save a great deal of effort in the data entry side of things back in the lab. Much time is spent entering the data and tracking down missing information or interpreting incomplete information. The data logger would be set up to force that all required data be entered before the field ecologist could move on to the next data entry section.

During the collection of AA data, time would be saved in that the field ecologists would be able to select from a pick list of potential vegetation classes. Any discussion or confusion over the existing vegetation would occur in the field at the source. They would have less to write and there would be less need to interpret the results on the part of the data analyst. It is worthy of time and effort to establish and support the transition to collection of field data in a digital format.

Vegetation Map

The mixing of vegetation types at LAMR complicated the interpretation as it does at all of the parks. During the map unit designation meeting this issue was not discussed and therefore these mixed types were not included as map units. Had this been anticipated many mixed type polygons could probably have been interpreted with greater success. While it might seem like a good plan to reconvene and change course, the time frame for a project often does not have enough flexibility.

If field sampling were spread over 3 growing seasons as opposed to 2, a more complete and fine-tuned classification and map unit development would result.

Accuracy

There are a number of areas that would benefit from revised protocol. Improvements in sampling and the data evaluation for fuzzy accuracy are two areas that need the most work. The sample selection process allowed a number of unanticipated problems to creep in. Because of the excellent imagery, many polygons went well below the MMU size. The proportion of very small polygons increased which then gave them a disproportionate amount of weight during the AA sampling process. As discussed before, sampling these small polygons is problematic not only for locating and selecting the site properly but also for edge effect of the surrounding vegetation. Large, more homogenous polygons should have received a greater proportion of the sample points. This effectively provides an overly conservative estimation of overall and individual map unit accuracy. It should be emphasized that every attempt be made to honor the MMU size and only go below it when some special situation requires it for reasons of detail. It may be counterproductive to map to this level of detail especially if it results in lower map accuracies.

The review process of each plot in order to provide a fuzzy designation was very time consuming and unanticipated. Each plot had to be looked at and discussed among several people. This took a tremendous amount of time. Some ideas on speeding this up include assigning an additional secondary or alternate association to the point. Rather than making this a suggestion, the selection of secondary, tertiary and other should be emphasized and the importance of this should be part of the training of field ecologists. This secondary association, once assigned to its map unit could then automatically receive a fuzzy designation of four. This would be similar to those AA points that exactly matched the polygon designation receiving a fuzzy designation of five. This would greatly reduce the number of plots that had to be reviewed. However time-consuming this fuzzy designation was, the meeting generated a great deal of understanding of the nature of the vegetation.

Map Improvement Suggestions:

1. We would like to see the map periodically and formally refined and updated. This could be as simple as having field crews GPS record the locations of unique vegetation not already on the map or as involved as a new photo interpretation effort. On the low-cost side, the current vegetation map could help target likely stands within certain map classes and an efficient ground truthing of just these types could follow. Through smaller scale accuracy assessment and verification efforts important types such as rare and threatened communities and plant species could be further defined. More costly efforts such as re-mapping the entire Park are probably more appropriate on a 10-25 year timeframe.

2. In addition to formal ground truthing we would also like to see more verification done by piggybacking onto other projects. As opportunities arise, maps should be sent into the field not only to be used but so they can be checked by competent crews. We encourage LAMR and all researchers to continually ground truth the map as they use it.

3. All new vegetation data including GPS data and other GIS layers should be wisely incorporated into this map. This may involve such things as using new research that more accurately models certain vegetation types or updating the current vegetation after a fire. Current advances in GIS and GPS technology easily allows for updates to the digital map and allows previous copies to be tracked and archived. Having an archive would allow for temporal analyses such as examining change over time and tracking the effects of climate change. Overall, we feel strongly that this product should not be static but change with new and better information.

The most straightforward method of improving this map would be to incorporate the results of the accuracy assessment. This can be accomplished by recoding the inaccurate polygons to the appropriate map class as recorded on the field form. Also general trends observed on the contingency tables could be included in the GIS layer. This may involve combining similar types or scaling the map classes up into broader categories.

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Appendix 1

Vegetation Classification

Lake Meredith NRA and Alibates Flint Quarries NM (report by NatureServe)

Data Management
Data Analysis
Classification Results
Discussion
References

Appendix A: List of Plant Taxa Identified During Field Sampling

Appendix B: Vegetation Key for Plant Communities

Appendix C: Descriptions of the Vegetation Associations

Appendix D: Ecological Systems Descriptions

Appendix 2

Fuel Models

Lake Meredith NRA and Alibates Flint Quarries NM

Appendix 3

Map Accuracy Assessment Using Fuzzy Accuracy Analysis

Lake Meredith NRA and Alibates Flint Quarries NM

Appendix 4

Map Unit Descriptions

Lake Meredith NRA and Alibates Flint Quarries NM