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Bent's Old Fort National Historic Site

Vegetation Classification and Mapping, A Report for the Southern Plains Network

Natural Resource Technical Report NPS/SOPN/NRTR—2007/049

ON THE COVER
Bent's Old Fort sits on the banks of the Arkansas River between upland shortgrass prairie and riparian willow shrublands and cottonwood gallery forests.
Photograph by: Stephanie Neid, CNHP

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Vegetation Classification and Mapping, A Report for the Southern Plains Network

Natural Resource Technical Report NPS/SOPN/NRTR—2007/049

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Executive Summary

Bent's Old Fort National Historic Site (BEOL) was established in 1960 to preserve and commemorate an early trading post site located along the Santa Fe Trail on the banks of the Arkansas River in what is now southeastern Colorado. During the period from 1833 to 1849, Bent's Fort was influential in the westward expansion of European settlers into the American southwest. Since the time of its establishment, the site of Bent's Fort and the surrounding landscapes have undergone many ecological changes. This project is an effort of the National Park Service to map the existing vegetation of the Park using a set of standardized methods.

The BEOL vegetation mapping project was initiated in 2005 by the NPS Southern Plains Network. All stages of the project were carried out by biologists from the Colorado Natural Heritage Program, with some assistance from BEOL park staff. Using U.S. National Vegetation Classification standards, plant communities within the park were identified and sampled in the summer of 2005. Over the following winter, this information was used to define the vegetation types present at BEOL. The vegetation classification includes locally based descriptions of the vegetation types and a dichotomous field key to the types. The documented locations of these types were also used to inform the photo interpretation and mapping process. In the summer of 2006, accuracy assessment plots were collected at BEOL. These randomly selected points were used to give a measure of accuracy to the map. This analysis was completed late in 2006 and was used as a basis for minor revisions to the final map.

A total of 800 acres (324 ha) were mapped. Thirteen map classes were used to describe the landscape. Among these were six plant association, one alliance, two non-natural map classes (Disturbed, Development), three local types, and one un-vegetated natural class (Open Water). The map accuracy exceeded program minimums at 92%.

Final products include the following:

Spatial Data

- Aerial photography
- Map classification
- Map classification description and key
- 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
- Visual guide to photointerpretation conventions

Introduction

Bent's Old Fort National Historic Site (BEOL) was established in 1960 to preserve and commemorate an early trading post site located along the Santa Fe Trail on the banks of the Arkansas River in what is now southeastern Colorado (Figure 1). During the period from 1833 to 1849, Bent's Fort was influential in the westward expansion of the United States into what is now the American southwest. Since the time of its establishment, the site of Bent's Fort and the surrounding landscapes have undergone many ecological changes. This project is an effort of the National Park Service to map the Park's existing vegetation using a set of standardized methods.

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).

Central to fulfilling the goals of this national program is the use of the National Vegetation Classification (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 NVC and mapping protocols facilitates 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 (Grossman et al. 1998). Currently the NVC is maintained and updated by NatureServe. Additional support has come from federal agencies, the Federal Geographic Data Committee (FGDC), and the Ecological Society of America. Refinements to the classification occur in the application process, leading to ongoing proposed revisions that are reviewed both locally and nationally. 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). NatureServe

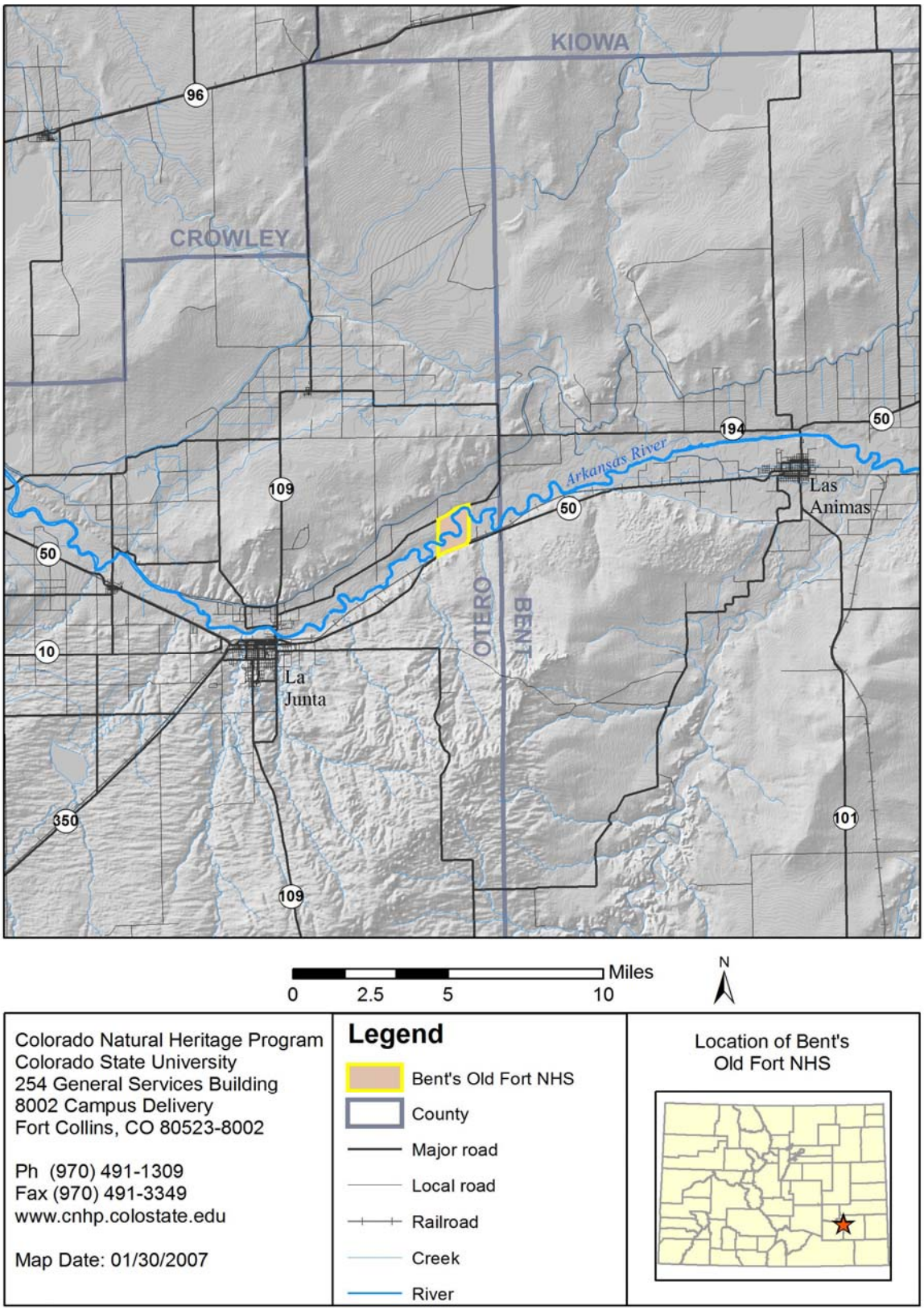

Figure 1. Regional location of the Bent's Old Fort National Historic Site.

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.

Bent's Old Fort National Historic Site Vegetation Mapping Project

The decision to map the vegetation at BEOL as part of the U.S. Vegetation Mapping Program was made under the NPS Natural Resources Inventory and Monitoring Guidelines issued in 1992. Under these guidelines, all Park units within the NPS are to be mapped using a consistent set of vegetation classification and mapping protocols. The status of previous vegetation mapping efforts and recent changes in the vegetation of the site from removal of invasive tamarisk species are factors driving BEOL's need for the program's vegetation map products.

In 2005, the NPS Southern Plains Network (SOPN) initiated this project by requesting the Colorado Natural Heritage Program (CNHP) to undertake both the classification and mapping portions of the project. CNHP biologists conducted both stages of fieldwork (initial classification and accuracy assessment), classification of vegetation types, as well as all mapping.

CNHP collected standardized field samples to classify BEOL's vegetation types and also to provide data for an accuracy assessment (AA) of the final vegetation map. CNHP, in conjunction with biological staff at the park also took on the role of aerial photo interpretation and creation of a digital vegetation map. Finally, BEOL staff provided logistical and technical support, helped coordinate fieldwork, and reviewed and evaluated draft data.

Our objectives were to produce final products consistent with the national program's mandates. These included the following:

Spatial Data
- Aerial photography
- Map classification
- Map classification description and key
- 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
- Visual guide to photo interpretation conventions

Previous Vegetation Maps: Only one previous effort has been completed for a vegetation map of the entire park. The existing vegetation map was created by Kettler (1994). The differences between the two mapping projects in resolution, both spatially and in the classification for the

mapped area within the Park boundary are detailed in Table 1. The current map is more detailed in both size and number of map polygons. The current map provides fewer map units, however, those map units are consistent with national classification standards as opposed to the ad-hoc classes of the previous map. In addition, the current map includes a set of considerably more detailed floristic descriptions for the vegetation communities as well as a field key to identify them.

The previous vegetation map was created from aerial photography and field visits. The classification was subjective and based solely on ocular estimates of dominant species across the landscape. No formal plots were placed and collected data was not statistically analyzed.

Table 1. Summary statistical comparison of current map effort to existing vegetation map.

Statistic	Old Vegetation Map	Current Vegetation Map
Number of Polygons	46	98
Mean Polygon size (acres)	14.5	8.2
Range in Polygon Size (acres)	0.3 – 70.9	0.1 – 107.2
Number of Map Units	26	13

Project Scope of Work: The protocols and standards used to map the vegetation at BEOL are described in the NPS program documents (USGS-NPS 2006). These are modified slightly in consideration of the smaller size of BEOL compared to many other parks in the Service for which the protocols were originally developed. CNHP purchased Otero County 2005 aerial imagery for the project mapping through the USDA's National Agriculture Imagery Program (NAIP). Vegetation mapping for BEOL was confined to the established park boundary. Although a 1 mile buffer surrounding the park boundary is standard for mapping at most parks, the small size of BEOL and the agricultural land uses surrounding the park eliminated the need for mapping a buffer around the Park.

The project began in the spring of 2005 with a project planning meeting between CNHP, BEOL biologists, and the NPS program botanist. Project planning and logistics were completed during the late spring of 2005, and vegetation data were collected during the summer of 2005 and early summer 2006. The vegetation classification, field key, and local association descriptions were completed during the winter of 2005 - 2006. The AA data were collected over the summer of 2006. The assessment of the map accuracy was completed during the winter of 2006.

Introduction to the National Vegetation Classification (NVC)

The Vegetation Mapping Program uses the U.S. NVC as the standard to identify and describe vegetation types within the map boundaries. The NVC was initiated 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 and is now managed and maintained by NatureServe. 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 classification currently includes more than 5600 vegetation associations and more than 1700

Alliances, and has been adopted by the Federal Geographic Data Committee for use by all U.S. federal agencies. The U.S. NVC is part of the International Vegetation Classification System (IVC) which currently includes the United States, Canada, and several Caribbean, Central and South American countries. Its application is rapidly expanding and soon other countries may be using it as well.

The NVC uses a hierarchical system of seven levels; lower levels are nested into 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 2 identifies the seven levels of the NVC and depicts their placement in the hierarchical relationship (Maybury 1999).

Table 2. Summary of the National Vegetation Classification System hierarchal approach (Maybury 1999).

Level	**Primary basis for classification**	**Example**
Class	Structure of vegetation	Shrubland
Subclass	Leaf phenology	Evergreen shrubland
Group	Leaf types, corresponding to climate	Microphyllous evergreen shrubland
Subgroup	Relative human impact (natural/semi-natural, or cultural)	Natural/Semi-natural microphyllous evergreen shrubland
Formation	Additional physiognomic and environmental factors, including hydrology	Lowland microphyllous evergreen shrubland
Alliance	Dominant/diagnostic species of the uppermost or dominant stratum	Sand Sagebrush Shrubland Alliance
Association	Additional dominant/diagnostic species from any strata	Sand Sagebrush / Sand Bluestem Shrubland

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 species consistently found in some vegetation 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. The species nomenclature for all Alliances and Associations follows that of Kartesz (1999). Documentation from Grossman et al. (1998) 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", or "Herbaceous Vegetation"), but are followed by the word "Alliance" to distinguish them from Associations.

Examples of alliance names from BEOL:

- *Artemisia filifolia* Shrubland Alliance
- *Populus deltoides* Temporarily Flooded Woodland Alliance
- *Sporobolus airoides* Intermittently Flooded Herbaceous Alliance

Examples of association names from BEOL:

- *Artemisia filifolia / Bouteloua (curtipendula, gracilis)* Shrubland
- *Populus deltoides / Pascopyrum smithii - Panicum virgatum* Woodland
- *Sporobolus airoides - Distichlis spicata* Herbaceous Vegetation

In addition to the NVC, NatureServe has created standardized Ecological Systems Classification for describing sites based on both the vegetation and the ecological processes that drive them. Ecological systems are mid-scale biological communities that occur in similar physical environments and are influenced by similar dynamic ecological processes, such as fire or flooding. They are not conceptually a unit within the NVC and do not occupy a place in the NVC hierarchy. However, within each Ecological System resides a specific list of NVC associations that are likely to occur. Because the structure of the NVC is hierarchical, each association occurs in only one alliance. An association may occur in any number of Ecological Systems, limited only by the range of ecological settings in which that Association occurs. Ecological Systems are much like the map units used for the map legend; they are a broader scale concept that embodies the concepts of several highly specific Associations that might be found in a particular setting.

Natural Heritage Program Methodology and Element Ranking

The Colorado Natural Heritage Program is a member of the NatureServe Network of Natural Heritage Programs and Conservation Data Centers. The Natural Heritage Programs are located in all the States (and conservation data centers are in all Canadian Provinces as well as in several countries in Central and South America). Each Program serves as that state's (area's) biological diversity data center, gathering information and field observations to help develop national and statewide conservation priorities.

The multi-disciplinary team of scientists, planners, and information managers at the Heritage Programs use a standardized methodology to gather information on the rare, threatened, and endangered species and significant natural plant communities that occur in each state. Each Program maintains data for species and plant communities that are referred to as “elements of natural diversity,” or simply “elements”. Life history, status, and location data are regularly updated in a comprehensive, shared data system. Sources of element data include published and unpublished literature, museums and herbaria labels, and field surveys conducted by knowledgeable naturalists, experts, agency personnel, and our own staff of botanists, ecologists, and zoologists.

As part of the tracking process, elements are assigned two imperilment ranks. A State-rank (S-rank) represents the element's degree of imperilment within Colorado, and a Global-rank (G-rank) represents the element's imperilment over its entire range. Taken together, these two ranks indicate the degree of imperilment of an element. The Heritage ranking system is described in Appendix A

Study Area

Location and Regional Setting

BEOL occupies 800 acres on the north and south facing floodplain terraces of the Arkansas River in southeastern Colorado. It is approximately eight miles east of the Otero County seat of La Junta along Colorado State Route 194. The BEOL site is surrounded by private lands that are used for irrigated and dryland agriculture and rangeland. Figure 2 shows the local setting of the BEOL site along the Arkansas River.

Climate and Weather

Climate data for the BEOL site are available through the Western Regional Climate Center (WRCC 2006) from long-term monitoring of stations at La Junta (1945 to 2005), Las Animas (1930 to 2005), and Rocky Ford (1918 to 2005).

The climate at BEOL is semi-arid and typical for the southern high plains of Colorado. The summers are hot with very low humidity, while the winter season is dry and mild. Annual total precipitation averages about 12 inches per year, with approximately 9 to 10 inches of that being lost to evaporation and transpiration (USGS 1965). The majority of precipitation occurs in late spring and summer as local thunderstorms, often accompanied by hail, lightning, and gusty winds. July and August are the warmest months with average monthly maximum temperatures of 94.1°F and 91.5°F, respectively. During the summer months the maximum daytime temperature can commonly reach 100°F to 110°F.

The average annual total snowfall is 20 to 25 inches and occurs primarily in the winter months from November through April. January is the coldest month when the mean monthly minimum and maximum temperature ranges from a low of 14.9°F to a high of 45.8°F. The average monthly maximum temperature in the winter ranges from 44.6°F to 71.8°F. The mean monthly maximum temperature for the winter months is 55.2°F. The average monthly minimum temperature in the winter ranges from 13.6°F to 37.7°F. The mean monthly minimum temperature for the winter months is 22.9°F.

Topography

The topography of the BEOL site is dominated by the hydro-geomorphic influence of the Arkansas River and nearby tributaries. It is located on the banks of the Arkansas River and includes area of active floodplain and a series of stepped river terraces. The alluvial plain is about a mile wide at the park and is marked by a river bluff to the north, and low hills to the south. The Fort itself is located within the 100-year floodplain on a low terrace north of the river (NPS 2007).

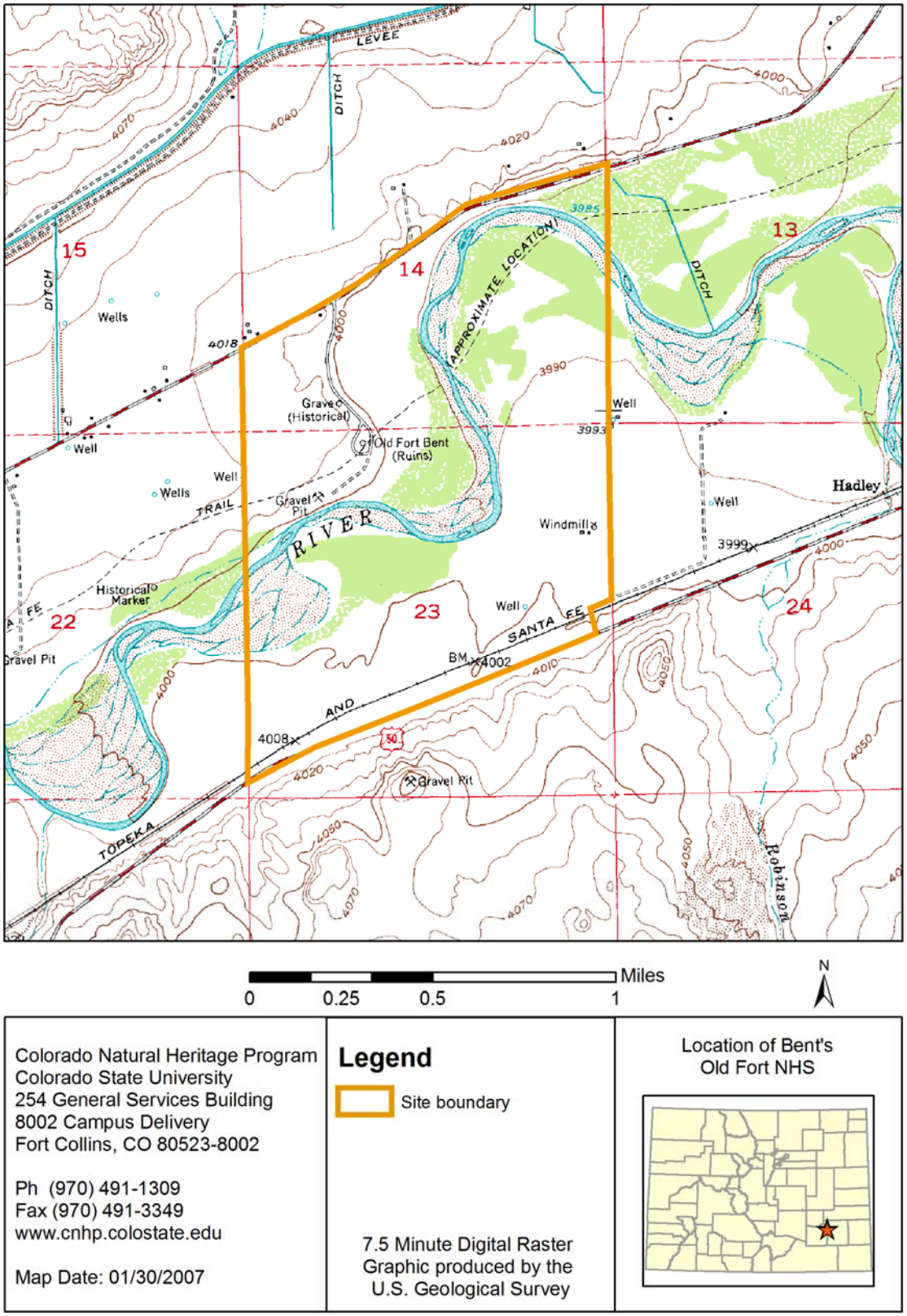

Figure 2. BEOL vegetation mapping project area boundary and local topography.

Geology

BEOL is within the Colorado Piedmont section of the Great Plains Physiographic province (Fenneman and Johnson 1946) (Figure 3). The surficial geology of BEOL consists of sedimentary deposits ranging in age from the Late Jurassic (Morrison Formation) to Recent Quaternary alluvial and aeolian deposits. The Arkansas River channel and alluvial plain are the central geomorphic features at the park. The river meanders widely throughout this stretch, with a grade of 5 feet per mile (NPS 2005). An investigation on the movement of the main channel revealed that the meanders have migrated downstream little since the construction of the Fort (NPS 2005). However, beginning in the late 1930's the river has become more braided in character, with more sandbars and islands. It is believed that this change has taken place due to increased drawdown in the dry summer months for irrigation (NPS 2005). The National Park Service has investigated the geology of the site and produced a detailed study of its characteristics (NPS 2005).

Soils

The soils at BEOL belong to the Rocky Ford – Numa – Kornman soil association, a type which occupies much of the Arkansas River valley in Otero County (SCS 1972) (Figure 4). They originate from a combination of alluvial and aeolian deposition. Bankard Sand occurs nearest to the river, where it has been deposited by flood waters. This sand is excessively drained and has low fertility, supporting cottonwoods, willows and tamarisk. Some areas of the floodplain have salt deposits from intermittent flooding. On the first terrace and to the north of the Fort, the soils include fertile loams which have been utilized for agriculture. The other soils present in the Park include Glenberg-Bankard sandy loam, Rocky Ford silty clay loam, Bloom loam, and Las Animas soils (SCS 1972).

Wildlife

Common mammal species at BEOL include white-tailed deer (*Odocoileus virginianus*), mule deer (*Odocoileus virginianus*), raccoons (*Procyon lotor*), coyotes (*Canis latrans*), black-tailed prairie dogs (*Cynomys ludovicianus*), and many small mammals (Gionfriddo et al. 2002). Also, BEOL is home to numerous reptiles, amphibians and fish.

BEOL's bird list contains 99 documented species, roughly half of which are known to breed at BEOL. Common bird species at BEOL include Red-tailed Hawks, Wild Turkeys, Mallards, Great Blue Herons, and Great Horned Owls, to name a few. The Colorado Field Ornithologists website lists Bent's Old Fort as having the "marsh where Black Rail was first found in the state" (CFO 2007).

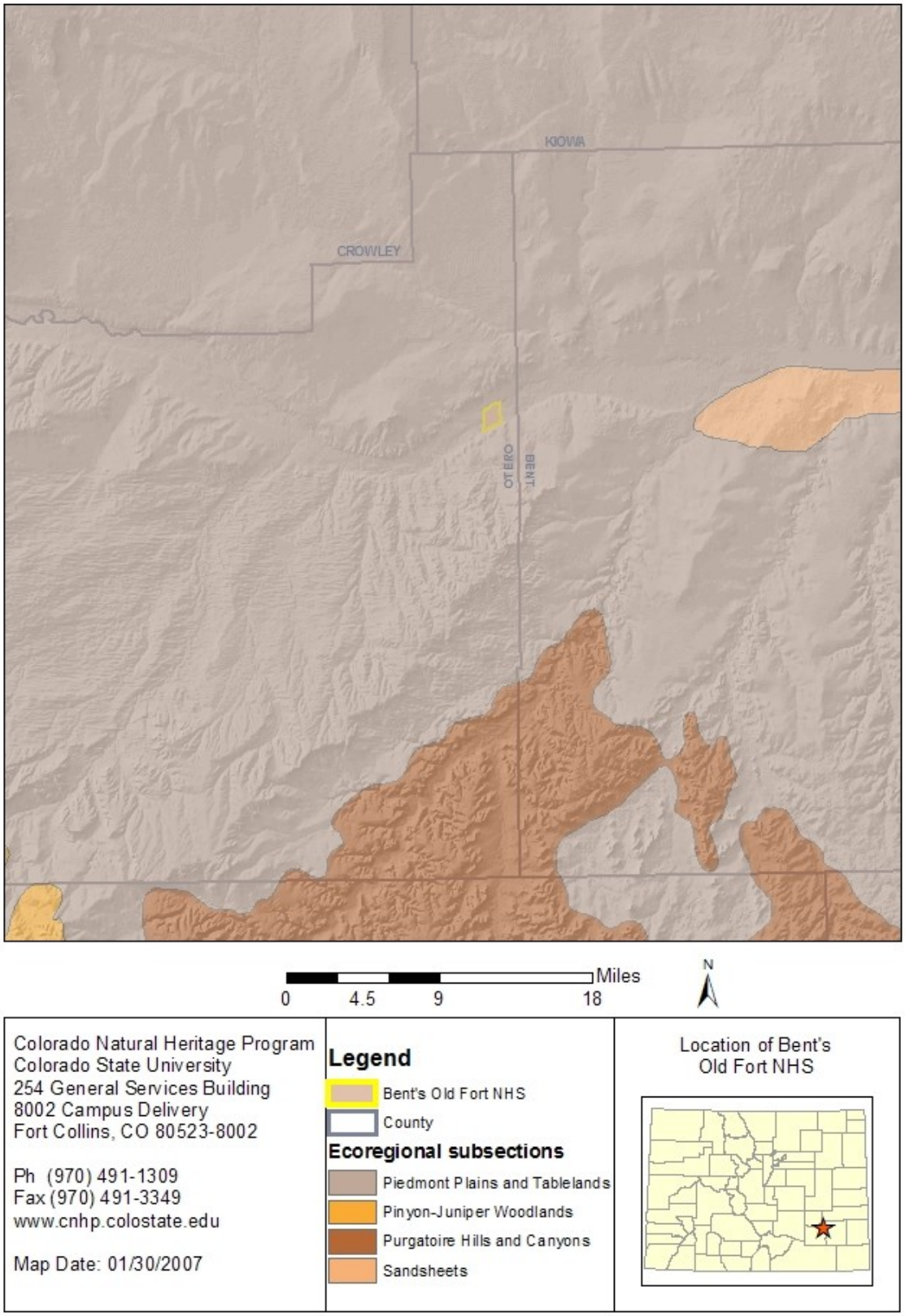

Figure 3. Ecoregional subsections of the Great Plains Physiographic Provinces at BEOL.

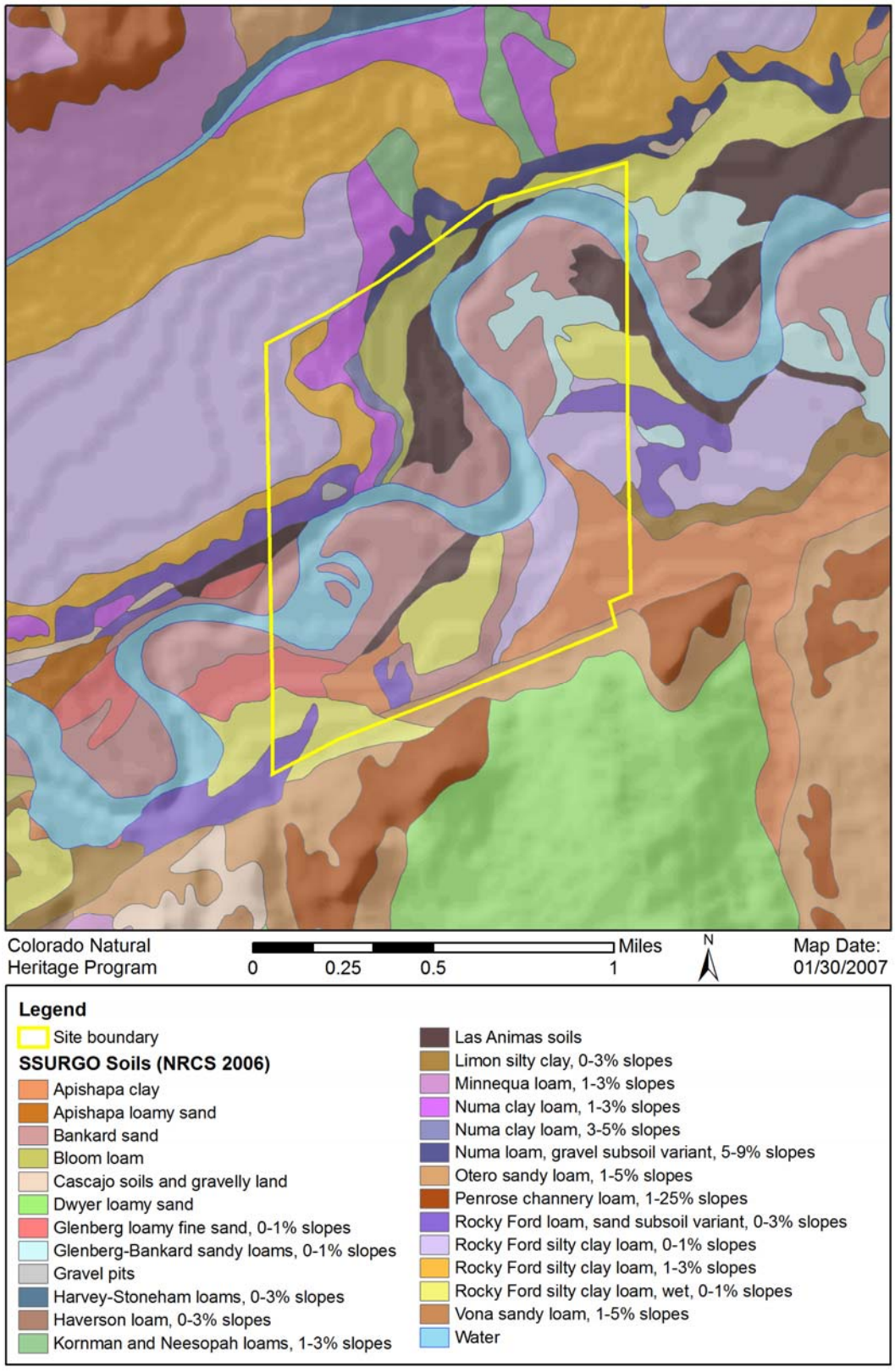

Figure 4. Soils map of the BEOL site Otero County, Colorado.

Hydrology

The Arkansas River has dams and diversions along most of its length, the majority of which are concentrated in Oklahoma. Seventy-five miles upstream from BEOL is the Pueblo dam and reservoir west of Pueblo, Colorado. The John Martin Reservoir begins about 20 miles downstream from BEOL. The Fort Lyon Canal, which is used for irrigation, diverts water near La Junta, and runs parallel to the river in the broad alluvial plain. At BEOL, the canal is roughly a mile north of the river. Fountain Creek, a tributary of the Arkansas River entering downstream from Pueblo, drains south from Colorado Springs. Urban runoff from this area has had high levels of *Escherichia coli* bacteria from untreated sewage. Urban development in a watershed also can affect the hydrograph of a stream by increasing the intensity and speed with which runoff occurs. A concentrated area of impervious surfaces effectively funnels precipitation out of the city as fast as possible. This makes the peak flow of a river both larger in magnitude and shorter in duration.

Floods along this stretch of the Arkansas River often happen due to a combination of snowmelt and spring rainstorms. This was the case in June of 1921, when heavy rains in the upper watershed contributed to the largest flood ever recorded in Pueblo. This flood washed away part of the ruins of the old Fort at BEOL. Other regionally significant flood events occurred in 1935, 1942, 1955 and 1965. Park personnel reported high waters during the summers of 1995 and 1999. During both of these years the water level reached the second bench of the floodplain.

The groundwater along the floodplain of the Arkansas River is commonly within 10 feet of the land surface, and it has been measured at 11 and 13 feet below the surface in the vicinity of the Fort (NPS 2005). It is thought that seepage from the Fort Lyon Canal contributes to the level of the water table in the vicinity of the Fort (NPS 2005). Water diversion into the Canal may also contribute to daily fluctuations in the river level at BEOL.

According to USGS gage data (1974 to 2005), the discharge of the Arkansas River at gage number 07123000 at La Junta (8 miles upstream) has been highest in the early summer months, with peak discharge occurring between May and July. The average monthly discharge from La Junta for June during this time period is 842 cubic feet per second. During the flood of 1921, peak discharge reached 200,000 cubic feet per second (USGS 2007).

Vegetation

The vegetation at BEOL is typical for the lower Arkansas River valley, and is influenced by several natural and anthropogenic processes. The Arkansas River has a direct effect on the vegetation of much of BEOL through the level of the water table, the shape of the channel and floodplain, and periodic flooding. The lower Arkansas River has been impacted by the activities of humans in many ways, and this has probably influenced the ecology of the region. Alterations in hydrology, the introduction of non-native species, and changes in land use, such as grazing and cultivation all have noticeable effects at BEOL. A list of plant species documented during this project can be found in Appendix B.

In BEOL, the banks of the river are lined with narrow bands of coyote willow (*Salix exigua*). The rest of the floodplain supports plains cottonwood (*Populus deltoides*) gallery forests with an understory of inland saltgrass (*Distichlis spicata*) and alkali sacaton (*Sporobolus airoides*). In

some areas, the cottonwoods are sparse and grade into meadows composed of these grasses. Along the terraces, the vegetation transitions to shortgrass prairie. North of the Fort, alfalfa fields have ceased to be irrigated and have been seeded with native grasses with the intention of restoring the fields to native shortgrass prairie. These areas are now dominated by buffalograss (*Buchloe dactyloides*) and grama grass (*Bouteloua gracilis*). Sand sagebrush (*Artemisia filifolia*) shrublands cover the high ground on the south side of the river. The southeast corner of the park supports a large black-tailed prairie dog colony. In this area the vegetation is dominated by bindweed (*Convolvulus arvensis*).

The Arch Wetland is a 55-acre perennial natural wetland dominated by cattails (*Typha latifolia*). It is located to the northeast of the Fort and is likely fed in part by irrigation water seeping from the Fort Lyon Canal (Gionfriddo et al. 2002). Several smaller wetlands exist along the floodplain, and are either old gravel pits or abandoned river sloughs which likely flood during high water events.

The lower Arkansas River basin widely supports tamarisk (*Tamarix ramosissima*), a non-native invasive tree. Efforts have been taken to eradicate this species within the BEOL property boundary. In March of 2002, more than 500 acres of land, including the areas cleared of tamarisk, burned in a fire caused by high winds sparking an agricultural ditch burn that occurred several days earlier. Annual weeds, including Russian thistle (*Salsola* spp.) and kochia (*Kochia scoparia*), form dense patches in these recently disturbed areas. Along the plains cottonwood gallery forest, many of the mature cottonwoods were killed in the fire and are now resprouting.

Historic Setting

The original Fort was built in1833 by Charles and William Bent and Ceran St. Vrain. It served as an important trading post along the Santa Fe Trail, and was a center for commercial and cultural exchange until 1849 (NPS 2007). Bent's Old Fort became a National Historic Site in 1960. The Fort was reconstructed from 1975 to 1976. Today, BEOL is valued for its archeological resources, the reconstructed Fort, and the historic setting. BEOL maintains a small collection of livestock for use in its living history program.

The site of the Fort and much of the surrounding area has undergone many changes since the days when the Fort was first established. Cattle grazing and cattle drives started prior to the establishment of the Fort in 1833. It is estimated that in 1847 as many as 1000 head of cattle, 400 horses, several hundred pack mules and several hundred oxen were located on the Bent ranches in the area (Lavender 1954).

By the 1880's, dryland farming was used extensively in Colorado. Droughts spurred the development of diversion and irrigation programs. The Fort Lyon Canal Company was incorporated as a cooperative nonprofit group owned by farmer-shareholders during that time (Sherow 1989). By 1909, the state of Colorado ranked first in the nation for area of irrigated agricultural land.

Water rights and diversion projects along the Arkansas River have a long history of litigation, with farmers, canal companies and states all contending for water rights. Some of this conflict was mitigated by the construction of the John Martin and Pueblo dams and reservoirs, which

serve as storage for winter runoff and floodwaters, and regulate the flow of the river. Drought and water rights continue to be challenges to area farmers. Presently, there is pressure to divert water to growing urban areas along the Front Range.

Methods

Planning and Scoping

An initial planning and scoping meeting was held at BEOL with the NPS vegetation mapping program botanist, the principal investigator for CNHP, and the BEOL park biologists. The meeting allowed the partners to discuss the available existing data, previous mapping efforts at BEOL, plan the schedule for the project, and discuss the project logistics. A preliminary list of associations that could potentially occur in BEOL was reviewed at that time.

To establish a preliminary list of associations, CNHP ecologists queried the BIOTICS Database for the vegetation types known to occur within the Central Shortgrass Prairie Ecoregion. Based on that query, the preliminary list of associations for BEOL included 62 types. These were all established NVC vegetation associations and did not include any of the common land use types such as “developed”, or “disturbed”.

The previous vegetation map created for BEOL (Kettler 1994) was reviewed prior to initiating the project. That map used non-standard map classes and association names, and was not based on established mapping protocols. Although that effort provided an adequate representation of the existing vegetation on the site at that time, it was completed before the NPS implemented a standardized mapping effort and before the large scale removal of invasive tamarisk from the lower floodplain benches. It was therefore useful for reference, but could not be used to provide a preliminary basis for this effort. An unpublished park map by Hess (1992) was also used as reference.

It was decided at the scoping meeting that aerial imagery produced by the US Department of Agriculture’s Farm Service Agency’s National Agriculture Imagery Program (NAIP) would be used to aid the classification and mapping. Prior to field survey, 2004 NAIP imagery was purchased and used to identify key areas for the field crew to visit. These images, however, provided poor thematic resolution and were not used to make a preliminary map of the site vegetation, but were useful for the field crew to identify and target areas of high contrast for field investigation.

Field Survey

The field survey of vegetation associations at BEOL was conducted by CNHP ecologists during August and September of 2005. CNHP field biologists reviewed the 2004 aerial photos of the site to identify areas of the site with unique vegetation signatures and traveled over all areas of the site to place vegetation sample plots in each observed vegetation type. Plot locations were subjectively located in homogeneous examples of each vegetation type found at BEOL using the NPS National Vegetation Mapping Program protocols. Data collected at each plot location included the composition and structure of the vegetation and environmental data used to produce the community classification and to inform mapping. Fuels data was also collected for fire and fuels management.

General Plot Collection Considerations

Field data collection at BEOL was completed by a single crew of two CNHP biologists. The crew was trained in the vegetation and fuels sampling methodology and provided with maps and aerial photos of the site. The crew was also given a list of the 62 preliminary vegetation types to be sampled and instructed to collect at least one plot in each type, and up to three if the area was significantly large. Because BEOL is a small park, all of the vegetation types are relatively easy to access and identify. Sample plots were therefore systematically placed in each vegetation type as it was encountered. This eliminated the need for the more complicated GRADSECT analysis (Gillison and Brewer 1985, Austin and Heyligers 1989) protocol used to identify potential sample sites in large parks.

The crew was provided with a field manual describing all of the methodology for the plot sampling, as well as supplemental information on sampling techniques, field safety, species lists, and accepted plant species codes. The field manual provided to the crew is provided Appendix C. Examples of the field forms are in Appendix D. The following is a general description of the process.

Crews were instructed to travel by foot over the site looking for examples of the vegetation types in the preliminary list or any other types not listed. Upon encountering a type for which sufficient samples had not been collected, the crews would locate a sample plot in a representative location within the boundaries of the type. When the plot had been completed, crews would navigate to another suitable plot location in the same or another vegetation type and begin the process again.

Data Collection: Relevé Plots

At each selected sampling location, plot data were collected using the protocols of the NPS National Vegetation Mapping Program. Crew members selected the plot center and buried a permanent marker (a small copper tag inscribed with the project acronym, plot code, and date, attached to a galvanized nail). Locations were recorded as UTMs using a Garmin GPSMap 76CS GPS unit. The crews would then lay out the plot, using 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. Species nomenclature follows that of USDA PLANTS database (USDA-NRCS 2006).

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. Crews would attempt to identify the plot with one of the potential vegetation type names. If the plot did not fit into an existing vegetation type, crew members were required to assign a new type name based on the dominant species in the top two strata. Four photographs were taken from the plot center of each plot oriented to the cardinal directions. An example of the field forms used for data collection is provided in Appendix D.

A total of 24 sample plots were collected; there were 23 relevé plots and an additional observation point. Only the 23 relevé plots were used in the vegetation classification due to their full species lists. The additional observation point was used to define and describe vegetation types. The distribution of the relevé plots can be seen in Figure 5.

Data Collection: Forest Fuels Data

Fire management data (fuels data) were collected at each site visited. Fuels data collected included information on both live and dead/down fuels. Live fuels data included the surface cover of shrubs and herbaceous species. For the dead/down fuels, crews recorded cover of coniferous and deciduous leaf litter, woody debris, and unburnables (rock, mineral soil, open water). At plot center and at 10 m from plot center on the cardinal directions, crews also measured the depth of litter and duff. Four photos were taken at each site and photo information was recorded on the fuels datasheet. Field forms are included in Appendix D.

Plot Data Management

Following data collection and prior to data entry, duplicates of the field forms were made and stored off site to ensure a duplicate set would always be available. The original plot forms were then checked to ensure quality control (QC) of the collected data. 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 the associated fuels form, or from other data sheets produced by the same crew on that or an adjacent day. Changes to field form entries were made in red pen and marked with a date and the reviewer's initials.

Following the QC of the datasheets, the data were entered into the vegetation mapping program PLOTS 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 typographic errors. The species lists were carefully examined to make sure that only USDA PLANTS names and acronyms (USDA-NRCS 2006) were used, and that species names and assignments to strata were consistent and logical. Plant lists were compared to the assigned association name to assure correlation.

Vegetation Classification

Plot data were analyzed and interpreted with the goal of classifying plots at the association level using species composition and environmental characteristics/parameters. Plot data were exported from PLOTS and formatted as matrices for import into PC-ORD version 5, a multivariate statistical software package (McCune and Mefford 1999). Data were explored using summary statistics, outlier analysis, cluster analysis, multi-response permutation procedures (MRPP), indicator species analysis (ISA), and non-metric multidimensional scaling (NMS) ordination. Our intentions were to finalize the community classification by incorporating the type concepts that emerged from BEOL into the NVC, not to create a stand-alone, site-specific classification. Thus these analyses guided the assignment of plots to associations in combination with our ecological understanding of the landscape as well as the additional observation point data collected at the site.

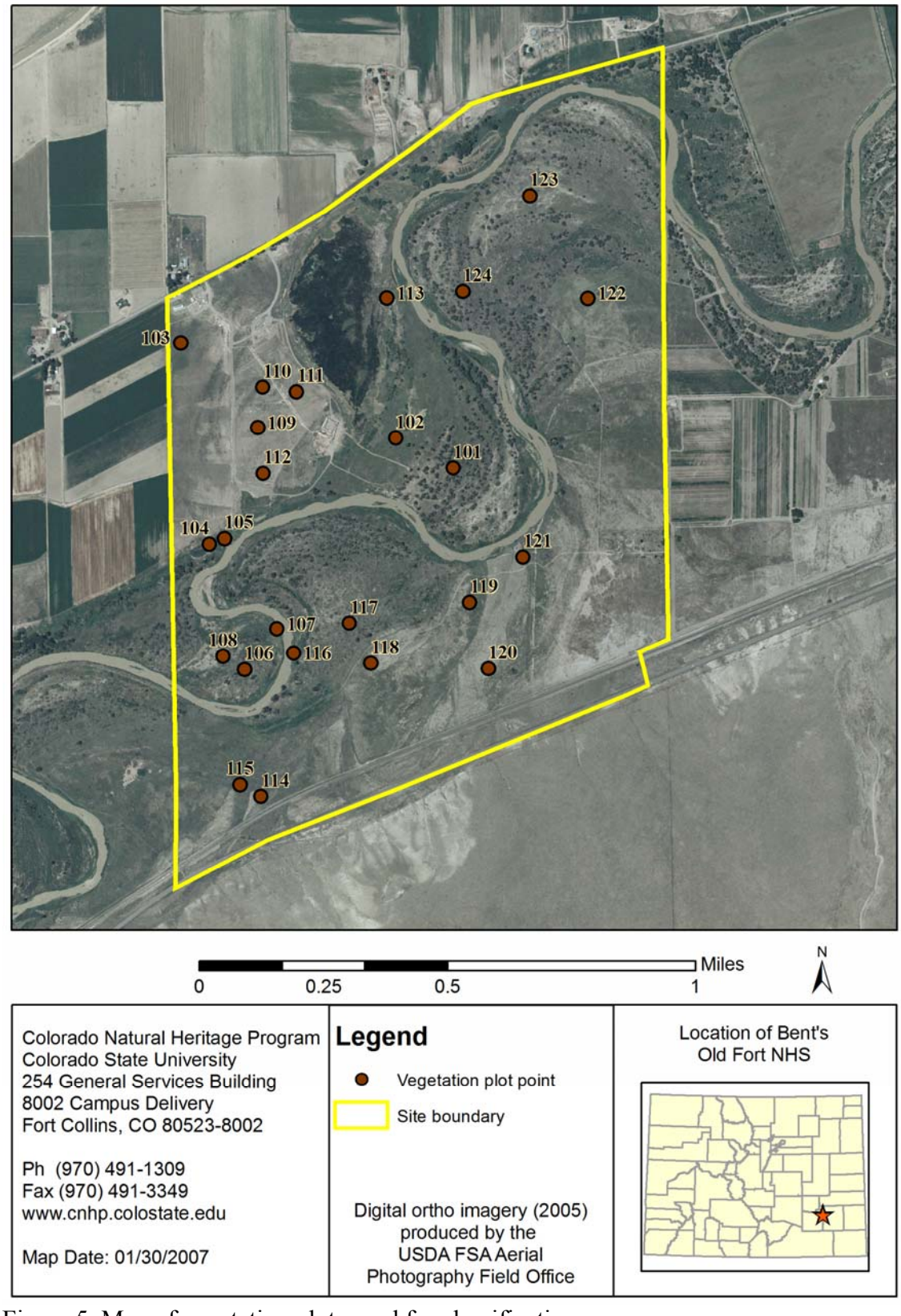

Figure 5. Map of vegetation plots used for classification.

For the classification analyses, mid-points of each cover class were used as the absolute cover for the plot data. Because of the small size of the dataset, all entities (species and those only identified to genus) that occurred within the plots were retained. Summary statistics were generated to inform underlying assumptions for the analyses (assessing heterogeneity, skewness, etc.). Outlier analysis was performed to identify any plots that may have disproportionate effects on the analyses. The analysis identified any plots having greater than two standard deviations from the average distance. Cluster analysis using Sorensen distance and the flexible beta linkage method (ß=¯0.25) was performed to identify similar groups within the dataset. Pruning of the resulting cluster dendrogram of plots was directed by ISA (Dufrêne and Legendre 1997) and significant differences between groups were identified using MRPP (McCune and Grace 2002). MRPP tests the hypothesis of no differences between groups without requiring normality or homogeneity of variance and was run using Sorenson distance on cluster groups (McCune and Grace 2002, Zimmerman et al. 1985). NMS was run using random starting configuration, Sorenson distance, and forty runs with real data (Mather 1976, Kruskal 1964). Low stress (stress is the inverse measure of the fit of the data according to the environmental parameters analyzed) was sought in the results (McCune and Grace 2002).

Photo Interpretation, Map Units, and Polygon Attribution

After fieldwork was completed, ecologists used field data (plot data, observation points, photographs, and field notes) and digital aerial imagery (NAIP 2005) to map draft vegetation polygons for BEOL within an ESRI personal geodatabase. In most cases, the map units are equivalent to vegetation associations, although one is represented at the alliance level. Table relationships were used to create a drop-down list of plant associations and map unit categories in the attribute table to ensure consistent data entry. A CNHP GIS Specialist then cleaned the layer topology, removing overlaps, gaps, slivers, and any data inconsistencies. FGDC compliant metadata was created for the vegetation layers and the layers were exported from the geodatabase as ESRI shapefiles. The layers are all in the coordinate system UTM Zone 13, North American Datum 1983.

Map Verification and Accuracy Assessment

After completing interpretation of the aerial photography, the polygon line work was reviewed for accuracy. We checked the line work to identify errors in the topology, ensure that polygon attributes were correctly labeled, and to locate any extra or dropped lines. The map and map unit labels were then modified as needed to correct any identified errors.

Sample Method and Design

The protocol used to select the AA sample points is that described by the NPS Vegetation Mapping Program, Accuracy Assessment Procedures manual (USGS-NPS 2006). That protocol's design employs accepted sampling and statistical analysis methods, yet is also intended to be economically and logistically practical.

Map accuracy as discussed here, and as prescribed by the above protocol, is concerned strictly with thematic map accuracy. Positional map accuracy, describing the accuracy with which map features are located, is not considered. Because polygon boundaries are rarely explicitly delimited in the field, and therefore subject to interpretation, it is unnecessary and impractical to estimate their accuracy.

The AA protocol uses mapped class abundance and frequency and defines maximum and minimum sample sizes needed to ensure statistical validity. The sample selection method is a stratified random design, stratified by map units. Based on map class abundance and frequency, five different sample sizes were possible (Table 3).

Sample Site Selection: AA Points

Using the above parameters, we used ESRI ArcMap version 9.0 GIS software (ESRI 2006) in conjunction with the Hawth's tools extension (Beyer 2005) to randomly locate the correct number of sample points within the map polygons. A minimum separation distance between points of 100 m was chosen for this effort. We also evaluated minimum separation distances of 50 m and 150 m. It was determined that 100 m was the largest separation distance we could use and still be able to place all of the needed points within some of the smaller polygons. The distribution of AA sample points is shown in Figure 6. This method does not allow the user to specify a minimum distance from the polygon edge and therefore results in some plots being located on or near to the polygon boundary

We used this method to create two sets of potential AA samples; a primary set and a secondary replacement set. Each set of points was stratified by map class. The primary set was the preferred target for the sample; however, if a target was inaccessible or if the primary sample was too close to the polygon boundary, the crews were instructed to use the first available sample from the secondary set of points. This systematic reselection process maintains the stratified random design for the selection of points and was designed to allow crews to collect a complete set of AA points.

Table 3. Recommended map accuracy sample number per class by frequency and area (USGS-NPS 2006).

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

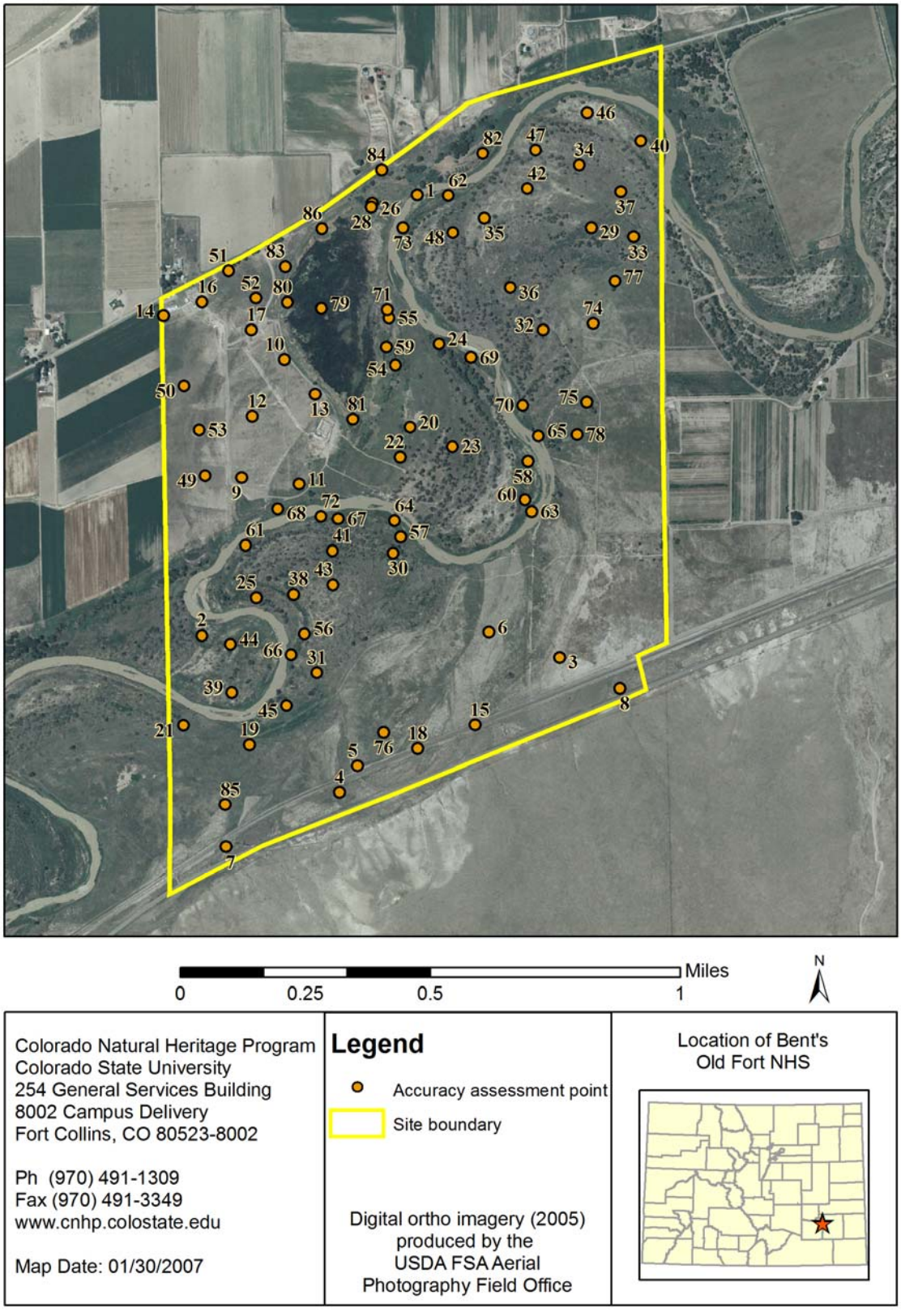

Figure 6. Map of sampled accuracy assessment points.

Data Collection: AA Points

Field maps were produced that showed the primary sample point and polygon boundary. 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 GPS with a known target location.

In July of 2006, the CNHP biologist visited BEOL and conducted a half day training of the BEOL biologist in conducting the AA. The BEOL and SOPN biologists were given field forms, two sample frames representing the primary and secondary points, and maps of the site overlaid with the map unit polygons and primary sample points. In total, the primary sample frame included 86 randomly selected locations to be used as AA points. The BEOL and SOPN biologists were instructed to navigate to these points and complete an AA field form (Appendix D).

Upon arrival at a point, the crew 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 polygon (to identify ecotones or inclusions). If vegetation was not representative, or if the point was to close to the polygon boundary, the crew would select a replacement point from the secondary frame. The crew would then visually determine the boundaries of the point to be sampled. The minimum mapping unit is 0.5 ha and this was used as the sample plot. The crew would then begin collecting data on species composition, vegetation structure, and geology and topography of the area. After filling out the AA Point form, the crew would use the draft field key and local descriptions 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). If more than one name seemed to fit, the crews were instructed to provide a primary and a secondary name. At each plot, four pictures were taken in each of the cardinal directions from the plot center. Crews were instructed to document what they observed at the plots by recording extensive field notes. The pictures and the notes that crews collected in the field proved very useful in resolving classification questions later during the AA.

Data Entry and QC: AA Points

At the end of the field season, all AA point paperwork was 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 PLOTS database. Following the data entry, the AA data in the database was subjected to another round of QC to catch data entry errors.

Thematic Accuracy Assessment Analysis

Following data entry and QC procedures, accuracy assessment analysis was conducted using both standard accuracy assessment analysis (USGS-NPS 2006) and modified fuzzy set analysis as performed by other NPS vegetation mapping efforts (Hansen et al. 2004; Salas et al. 2005; Cogan et al. 2005).

Accuracy Assessment Statistics: The statistical methods used in this analysis are described in detail in the document Accuracy Assessment Procedures (USGS-NPS 2006). To begin the accuracy assessment, the map classes in the reference data (from the sampled AA plots) were compared to the predicted map classes at the locations on the map. Contingency matrices were generated showing reference map classes in columns, predicted map classes in rows, and the number of points assigned to each in the body of the matrix. The matching pairs show up as values along the diagonal.

The overall accuracy of the map was calculated by dividing the number of matching pairs by the total number of pairs in the matrix. Kappa values were calculated to adjust for the chance occurrence of matching pairs. Two forms of accuracy were then computed for each individual map class: user's accuracy and producer's accuracy.

User's accuracy describes the probability of actually finding, for example, a cattail marsh on the ground where one is marked on the map. It is defined as the number of matches between the map and the reference data for a given class divided by the total number of samples that fell into the map class on the map. The difference between these two numbers is due to errors of omission.

Producer's accuracy describes the probability that, for example, when standing in a cattail marsh, the map will agree. It is defined as the number of matches between the map and the reference data for a given class divided by the total number of samples of the class in the reference data. The difference between these two numbers is due to errors of commission.

Fuzzy Set Accuracy Assessment: The program standards are seldom met with a strict binary 'right/wrong' approach. More importantly, binary classification does not capture the shades of variation across landscapes. Communities rarely have discrete boundaries or homogenous representation. Often, a point on the ground can represent multiple map classes to varying degrees, these names being somewhat open to the interpretation of the AA field crews. Also, where communities tend to have transitions zones or ecotones along their boundaries, photo interpreters must draw concise lines. Fuzzy set accuracy assessment takes these and other limitations into account by defining degrees of 'rightness' and allowing points to be seen as correct based on predefined levels of error, as shown in Table 4.

Table 4. Fuzzy level ranking criteria for AA plots (Adapted from Hansen et al. 2004).

Level	Description
5	Exact match: The reference data is an exact match to the map class.
4	Acceptable Error: If any of the following criteria were met, the case was considered acceptable error: 1) The reference data are the same as a map class in the nearest adjacent polygon and is within 12m of that polygon (distance chosen based on project specific considerations); 2) The reference data has an alternative correct reference label that was described in the field, which was correct for the map class; or 3) The reference data classify an inclusion smaller than the minimum mapping unit, (a sampling error on the part of the field crew).
3	Reasonable error: The map class has similar structural composition and species dominance.
2	Vague Similarity: The map class has a similar formation type, but not similar species composition.
1	Complete error: No similarity in the species or structural composition.

Each AA plot was reviewed and assigned to a fuzzy level of correctness based on its primary and secondary association names, vegetation description, plot photos, and position relative to polygon boundaries.

Fuzzy level 5, or Binary Accuracy, included plots in which the primary association name matched the mapped map class and is equivalent to absolutely accurate. Fuzzy level 4, or Acceptable Accuracy, included plots that met any of the requirements listed in Table 4. An example of a point correct at the fuzzy 4 level would be AA point number 23, located in an Inland Saltgrass polygon two meters from the edge of a Plains Cottonwood – Inland Saltgrass polygon, where either because of positional (GPS) error or sampling error, trees were included in the sampling and the point was labeled by field crews as a treed plot.

Fuzzy level 3, or Reasonable Accuracy, included plots that were similar in structural composition and species dominance to the mapped class, but did not meet any of the strict requirements for the fuzzy 4 level. An example of a plot correct at the fuzzy 3 level is AA point 43. This plot was located in a Plains Cottonwood polygon, but the location had been burned in the 2003 fire and had a high cover of annual weeds at the time of sampling. The field crew identified it as Disturbed, but the vegetation description on the data sheet listed significant cover of Plains Cottonwood. Additionally, some characteristic understory species were present at the site. Therefore, the vegetation and structure were similar to the predicted map class, and the plot was counted as correct at the fuzzy 3 level (Reasonable Accuracy). Fuzzy levels two and one were not considered to be correct, and were not analyzed.

Contingency matrices were generated for Level 5 (Binary Accuracy), Level 4 (Acceptable Accuracy), and Level 3 (Reasonable Accuracy). The map classes were weighted by the proportion of the area that they represent on the map, and overall accuracy, kappa values, and user's and producer's accuracy with 90% confidence intervals were computed at the Acceptable and Reasonable Accuracy levels. Weighted accuracies and the corresponding Kappa value were not calculated at the Binary Accuracy level due to null values in the contingency matrix. These statistics were computed with the use of Kappa analysis extension for ArcView (Jenness and Wynne, 2006).

Classes with only one or two plots were excluded from the above statistics at the Acceptable and Reasonable Accuracy levels. The polygons of these classes were too small and infrequent to be sampled with statistical accuracy. The total area excluded from the AA statistics is 136.2 acres (55.1 hectares), and constitutes 17% of the study area.

Program Standards: The kappa values, as well as user's and producer's accuracy for each individual map class, are used as the final measures of map accuracy. Vegetation Mapping Program thematic accuracy standards call for 80% accuracy with a 90% confidence interval for overall accuracy and user's and producer's accuracy for each map class.

Element Occurrence Records

Element Occurrence Records (EOR's) for animal and natural community elements of biodiversity tracked by CNHP were written from plot data collected at the site. EOR's were written using the Heritage Methodology as described in Appendix A and include elements with a CNHP tracking status of "yes".

Results

Field Data Collection: Relevé Plots

A CNHP field crew collected data from 24 sample plots during August and September of 2005. Of these, 23 were full vegetation plots and one was an observation point. Plots were distributed throughout BEOL in all of the community types found there (Figure 5).

Photographic Database

The classification plot and AA point photos can be found in the final GIS project, as part of the geodatabase. These are hyperlinked in the GIS project to the plot locations and are viewable by selecting the desired plot using the hyperlink tool. As such, they can be easily queried or selected by location. In most cases four photos, one taken in each of the cardinal directions from the plot center, are linked to each point. There are 94 frames associated with the classification plots from 2005, and 224 frames associated with the AA points gathered in 2006.

Vegetation Classification

The BEOL plot dataset had 24 samples and 81 species. No outliers were identified within the plot dataset. Average total plant cover for all species in all plots was 61.4% with a range of 30.1% to 110.3%. Species richness, or the average number of species per plot, was 10.1 with a range of 3 to 23. Beta diversity, a measure of heterogeneity within the dataset, was 8.02 across the analysis dataset. Simpson's (1949) index of diversity, a measure of relative abundance of species within a plot or the probability of two randomly selected individuals in a plot or site being different species, was 0.778 across all classification plots with a range of 0.406 to 0.935.

Cluster Analysis

ISA informed pruning of the resulting cluster dendrogram at six groups with distance measured by objective function (Figure 7). The resulting dendrogram shows very low chaining at 5.33% with approximately 65% of the information in the original data retained at this level of clustering as measured using objective function. MRPP tests suggested significant differences between groups at this level of clustering ($A = 0.27$, $P = 0.009$).

NMS

NMS revealed that ground cover data elucidated the primary axes in ordination space. A three-dimensional solution was recommended by the analysis with a final stress of 10.8 in 110 iterations. The ordination represented 88% of the variation in the dataset, with 33% loaded on axis 1, 25.8% on axis 2, and 30% on axis 3 (Figure 8). Axes were defined by the amount of downed wood, bare soil, and litter. Bare soil showed strong relationship with upland plots (sand sagebrush and shortgrass prairie), whereas litter and downed wood were high in the floodplain (although not along the river banks).

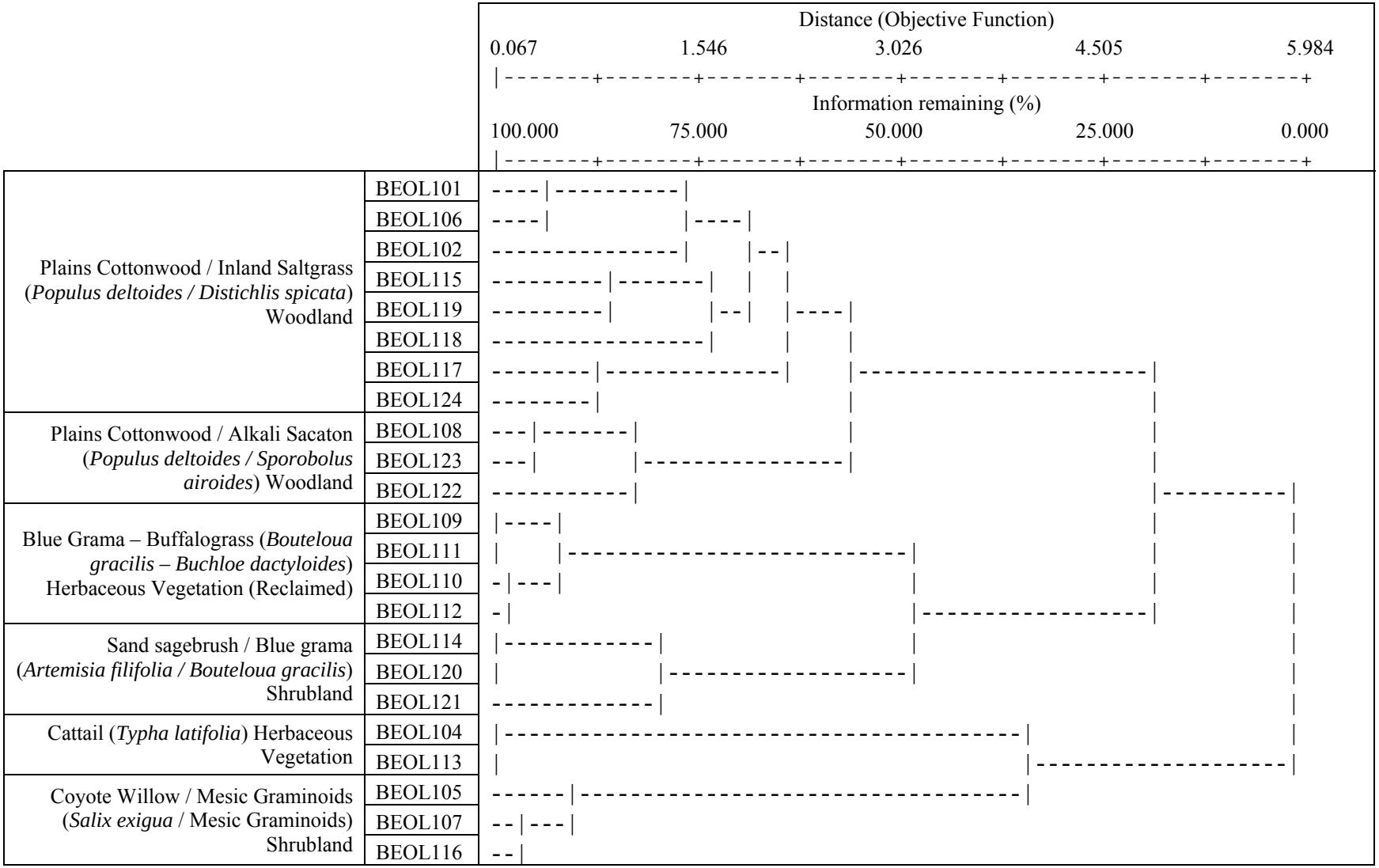

Figure 7. Hierarchical cluster analysis dendrogram (Sorenson distance, flexible beta linkage, ß = -0.25) for the classification plots of the BEOL dataset. Left column displays the plant association attributed to the BEOL plot.

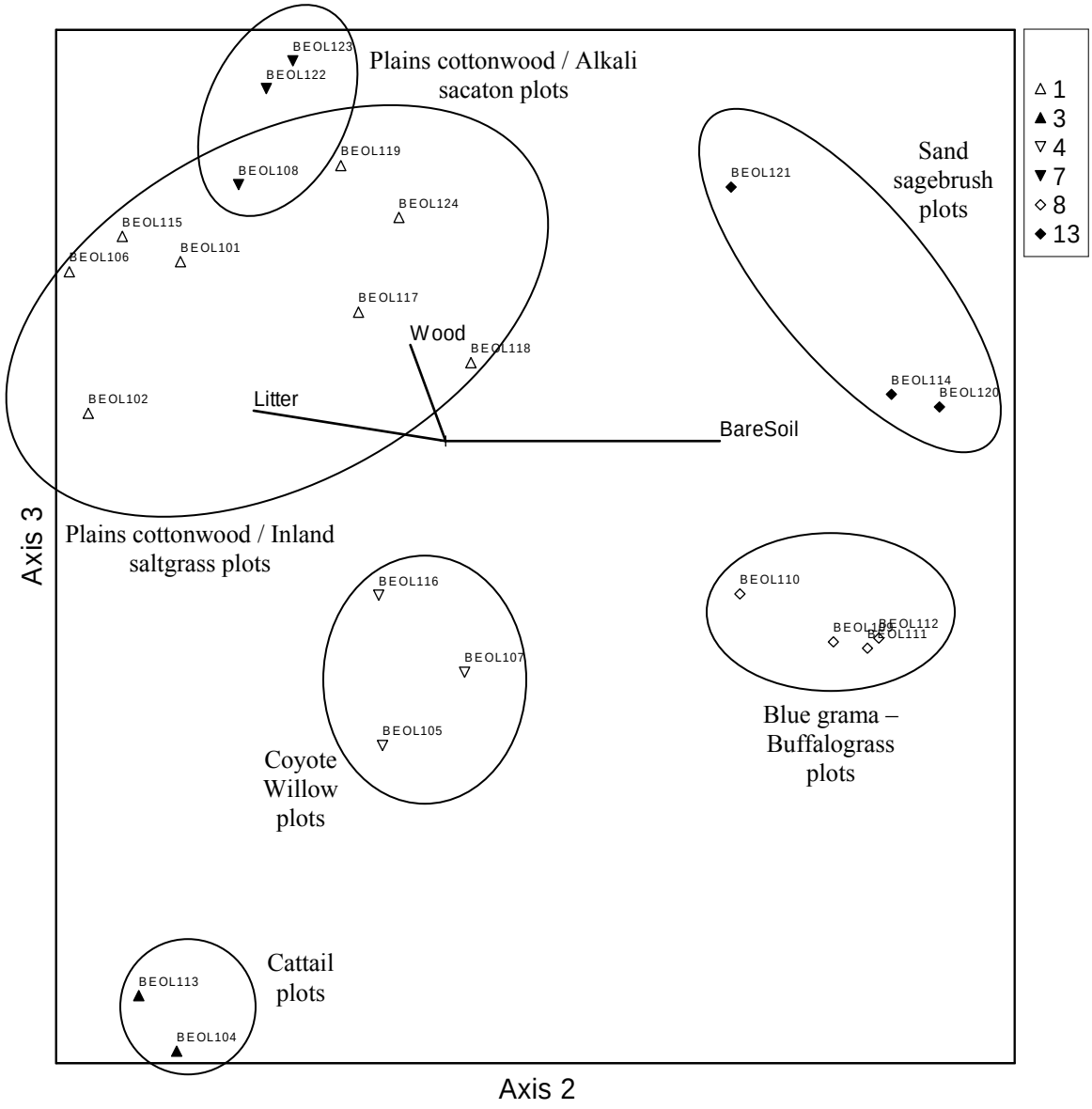

Figure 8. Three-dimensional solution of NMS ordination (random starting configuration, Sorenson distance, forty runs with real data) of BEOL classification dataset.

Summary of Physiognomic Types

Cluster analysis and NMS were used to identify and describe two woodland associations belonging to one alliance, two shrubland associations and two herbaceous associations. Cluster analysis revealed two distinct woodland associations, both of which are characterized by plains cottonwood tree canopy and graminoid understory and are components of the Plains Cottonwood Temporarily Flooded Woodland Alliance. The two associations are Plains Cottonwood / Alkali Sacaton Woodland and Plains Cottonwood / Inland Saltgrass Woodland, with three and eight plots respectively. The associations differ in the overall graminoid composition, with the nominal species being dominant. However, both alkali sacaton and inland saltgrass were generally found throughout the area with cottonwood canopy. The Plains Cottonwood / Alkali Sacaton Woodland plots all had silty clay or silty clay loam soil texture and less species richness, whereas Plains

Cottonwood / Inland Saltgrass Woodland had some plots with rapidly drained sands, although the majority of plots were silty clay, and had greater species richness.

Two shrubland associations were defined. Coyote Willow / Mesic Graminoids Shrubland lines the banks of the Arkansas River in the riparian corridor. Sand Sagebrush / Blue Grama Shrubland occurs on sandy berms on the south side of BEOL.

The remaining two types are herbaceous associations. The Broadleaf Cattail Marsh occurs in wetland soils in the Arch Wetland and two other smaller wetlands. Blue Grama – Buffalograss Shortgrass Prairie occurs in natural stands south of the river and in restored upland areas between the Fort and park headquarters structures on the north side of the river. These restored areas are mapped as Reclaimed Agricultural Land.

Preliminary Vegetation Map

A total of 800 acres (324 ha) were mapped (Figure 9). Fifteen map classes were used to describe the landscape. Among these were eight plant associations, one alliance, two non-natural map classes (Disturbed, Development), three local types, and one un-vegetated natural class (Open Water). From the classification analysis, six associations and the alliance were used as map classes. The two other associations were Alkali Sacaton – Inland Saltgrass Herbaceous Vegetation and Inland Saltgrass Herbaceous Vegetation. These associations exist in large areas of the floodplain. Local types defined as map classes included Reclaimed Agricultural Land, Black-tailed Prairie Dog Town, and Plains Cottonwood Semi-Natural Woodland, all previously known from specific areas at BEOL. The accuracy assessment was based on this preliminary map and classification scheme.

Accuracy Assessment

AA points were sampled by the BEOL biologist and assistants between July and October of 2006. A total of 85 AA points were sampled at BEOL (Figure 6). A number of replacement sample points were utilized due to proximity of the primary point to the polygon boundary.

Overall Accuracy

Overall map accuracy was achieved at fuzzy Level 4 (Acceptable Accuracy), and increased at Level 3 (Reasonable Accuracy), as summarized in Table 5. Contingency tables showing the distribution of errors across map classes can be found in Appendix G.

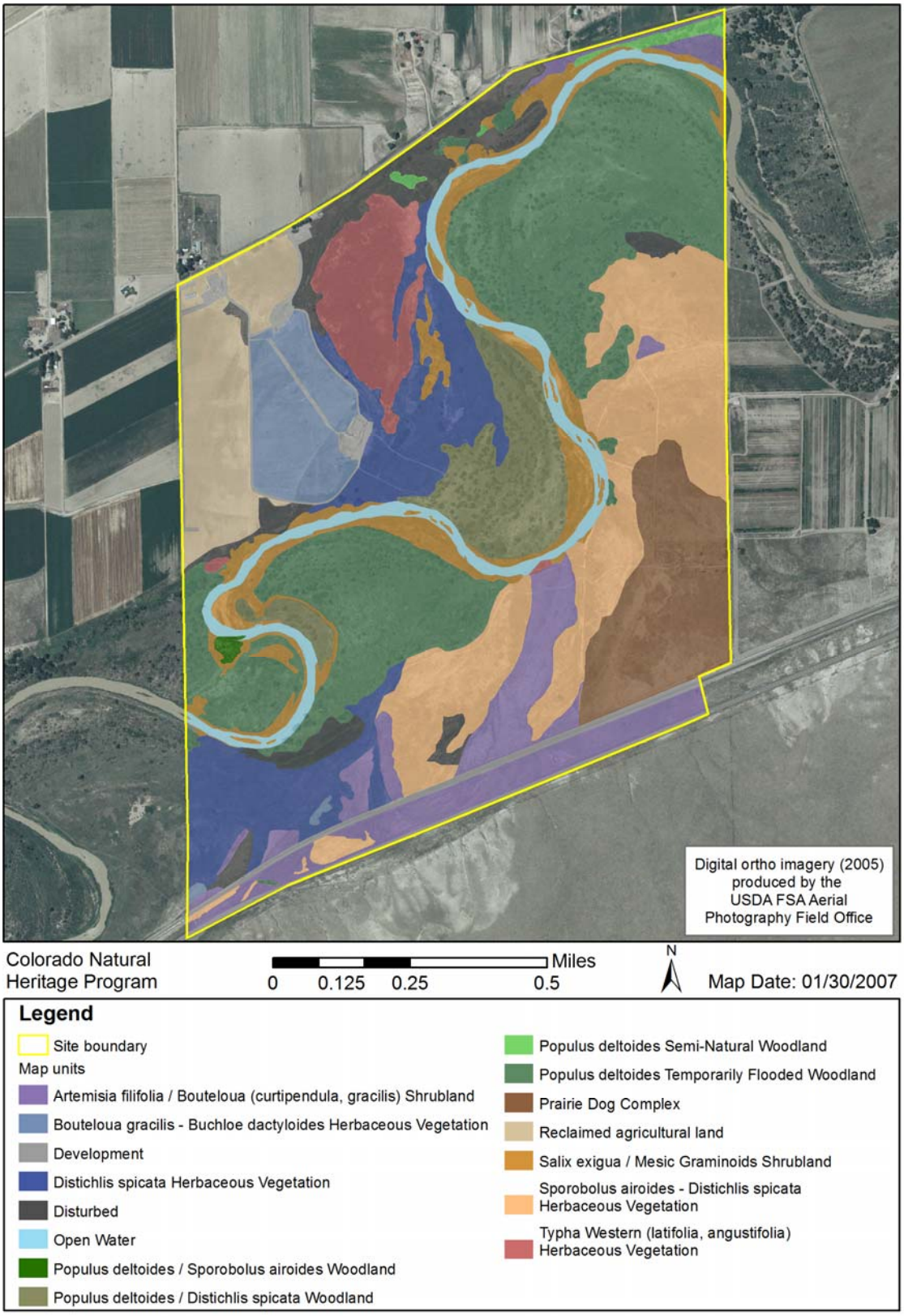

Figure 9. BEOL preliminary vegetation map.

Table 5. Weighted overall map accuracy and kappa values (with 90% confidence intervals) at each fuzzy set level.

Fuzzy level	Overall accuracy	Kappa value
5 - Binary Accuracy	47%*	41%*
4 - Acceptable Accuracy	87% (81% - 92%)	85%
3 - Reasonable Accuracy	93% (89% - 98%)	92%

* These values are not weighted by area.

Accuracy Assessment by Map Class

1. Development: The only confusion in this class occurred where vegetation was growing on the railroad bank. AA crews called the plot Disturbed because of the vegetation while the photo interpreter mapped the railroad as Development. At Level 5, this resulted in a user's accuracy of 80%. This was corrected to 100% at Level 4.

2. Reclaimed Agricultural Land: All AA plots in this map class were initially called Blue Grama – Buffalograss Shortgrass Prairie, giving producer's accuracy a null value at Level 5. The mapped Reclaimed Agricultural Land has been reseeded and may be easily confused with natural types. The plots listed a secondary association, or one was assigned from the notes and vegetation descriptions, so they were correct at Level 4. Both user's and producer's accuracy were 100% at Level 4.

3. Black-tailed Prairie Dog Town: This map class was not included in the AA statistics. Initially, this class had low producer's accuracy because one of two AA plots found prairie dogs outside of their mapped range. Producer and user accuracy of 100% was reached at Level 4.

4. Blue Grama – Buffalograss Shortgrass Prairie: At Level 5, this map class had low producer's accuracy due to confusion with Reclaimed Agricultural Land. These errors were corrected at Level 4, bringing the producer's accuracy to 76% (and within the confidence interval). User's accuracy was 80% at Level 4. This class was also confused with the Disturbed map class for both user's and producer's accuracy. One plot placed into a polygon mapped to this class was newly colonized by prairie dogs and recorded as prairie dog town complex by the AA crews.

5. Inland Saltgrass Herbaceous Vegetation: This map class was not included in the preliminary field key for AA field crews, and so had 0% user's accuracy at Level 5. Plots were evaluated based on their vegetation descriptions, and received a secondary association if they matched this type. They were then correct at Level 4, where both user's and producer's accuracy reached 100%. This type was confused with Alkali Sacaton – Inland Saltgrass Herbaceous Vegetation (the closest alternative given to AA crews) and plains cottonwood types with very low cover of plains cottonwood. This class was combined with class 6, Alkali Sacaton – Inland Saltgrass Herbaceous Vegetation on the final version of the map.

6. Alkali Sacaton – Inland Saltgrass Herbaceous Vegetation: This map class initially had low producer's accuracy because of confusion with the Disturbed, Coyote Willow / Mesic Graminoids Shrubland, and Inland Saltgrass Herbaceous Vegetation map classes. Producer's accuracy reached 93% and user's accuracy reached 100% at Level 4.

7. Sand Sagebrush / Blue Grama Shrubland: Errors affecting user's accuracy in this map class came from confusion with the Disturbed map class. They were corrected at the Level 4, where user's accuracy came to 100%.

8. Coyote Willow / Mesic Graminoids Shrubland: User's accuracy for this class was 60% at Level 5 and climbed to 80% at Levels 4 and 3. Errors affecting user's accuracy came from four AA plots located in a mislabeled polygon. The polygon was mapped as Coyote Willow / Mesic Graminoids Shrubland, but the plots documented short stature plains cottonwood (tall shrub growth form) with inland saltgrass understory. There were minor positional errors and confusion with the Disturbance map class at Level 5. Producer's accuracy was 86% at Level 5.

9. Plains Cottonwood Temporarily Flooded Woodland Alliance: This map class includes all other plains cottonwood map classes. It represents areas where the understory grasses were unknown and could not be mapped to association. Plots that were labeled with one of these associations were considered correct at Level 5. Many plots were labeled Disturbed, and this was corrected at Level 4 if the plot sampled an inclusion smaller than the minimum mapping unit of 0.5 ha (estimated from imagery). Both producer's and user's accuracy met program standards at Level 4. Disturbance misidentifications were corrected at Level 3 if plains cottonwood was listed in the vegetation description. The remaining error comes from Disturbed inclusions at the level of the minimum mapping unit.

10. Plains Cottonwood / Alkali Sacaton Woodland: This map class was not included in the AA statistics. One plot was sampled in the map area of this class, and it was called Plains Cottonwood Semi-Natural Woodland. This was corrected at Level 3. This class is not included on the final version of the map, but does represent an association present at BEOL.

11. Plains Cottonwood / Inland Saltgrass Woodland: This map class was not included in the AA statistics. Errors in producer's accuracy in this map class come from three out of four points located in a mislabeled polygon. Errors in user's accuracy were from confusion with the Disturbance map class and Coyote Willow / Mesic Graminoids Shrubland.

12. Plains Cottonwood Semi-Natural Woodland: This map class was not included in the AA statistics. The only two plots located in this map class were in the same mislabeled polygon, giving 0% producer's accuracy and a null value for user's accuracy.

13. Disturbed: This class has low producer's accuracy due to the occurrence of large inclusions within plains cottonwood types. Disturbance is widespread throughout the park, and AA crews applied the label liberally to any plot with a high abundance of annual weeds, evidence of tamarisk removal or close proximity to Development. Many of these mistakes were corrected at Level 4 if the vegetation description matched the mapped map class, adding a secondary association. Errors in user's accuracy stemmed from sampling in areas where natural vegetation was dominant despite there being a history of disturbance or ongoing maintenance (mowing). At Level 3, user's accuracy was 80% and producer's accuracy was 52%.

14. Open Water: This map class was not included in the AA statistics. Only two plots were located in this map class. One was located on the edge of a Coyote Willow / Mesic Graminoids

Shrubland polygon mistakenly called Open Water due to positional accuracy. This was corrected (for the Willow map class) to 100% at Level 4.

15. Broadleaf Cattail Marsh: This class had no errors and is considered accurate as mapped.

Element Occurrence Records

EORs were written for several community elements located at the site. These have been added to the CNHP BIOTICS database. Community element EORs generated through this project are listed in Table 6.

Table 6. Community element occurrence records at BEOL.

Element code (Elcode)	Global name	G Rank	S Rank	Tracking status
CEGL000939	*Populus deltoides* / *Distichlis spicata* Woodland	G2	S2	Y
CEGL005977	*Populus deltoides* / *Sporobolus airoides* Woodland	G3	S2	Y
CEGL001687	*Sporobolus airoides - Distichlis spicata* Herbaceous Vegetation	G4?	S4?	Y
AMAFB06010	*Cynomys ludovicianus* Black-tailed Prairie Dog	G4	S3	Y

Vegetation Map

A total of 800 acres (324 ha) were mapped (Figure 10). Thirteen map classes were used to describe the landscape. Among these were six plant association, one alliance, two non-natural map classes (Disturbed, Development), three local types, and one un-vegetated natural class (Open Water). The most frequently occurring within the entire mapping area was Coyote Willow / Mesic Graminoids Shrubland with 33 polygons ranging in size from 0.02 acres (0.01 ha) to 12.5 acres (5.06 ha). The most abundant map class in terms of area was Alkali Sacaton – Inland Saltgrass Herbaceous Vegetation covering 205.72 acres (83.25 ha) or about 25.7% of the project area. Spatial statistics for each of the map classes are listed in Table 7. Polygon size ranged from 0.01 acres (0.05 ha) to 107.2 acres (43.4 ha) with the mean polygon size being 15.8 acres (6.4 ha).

Two associations from the preliminary map were not included as map classes on the final map. Stands of Plains Cottonwood / Alkali Sacaton Woodland could not be accurately delineated from other plains cottonwood stands and were instead included in the Plains Cottonwood Temporarily Flooded Woodland Alliance map class. However, this association is present at BEOL, and it is included in the field key. Inland Saltgrass Herbaceous Vegetation was grouped with Alkali Sacaton – Inland Saltgrass Herbaceous Vegetation to better represent the vegetation at the site. It is not included in the key or descriptions. In addition to the vegetation descriptions (Appendix F), a visual guide to the map classes is included in Appendix H.

Table 7. Area totals for final map classes.

Map class name	Total number of polygons	Minimum area acres (ha)	Maximum area acres (ha)	Mean area acres (ha)	Total area acres (ha)
Sand Sagebrush / Blue Grama Shrubland	11	0.59 (0.24)	20.84 (8.43)	4.00 (1.62)	43.99 (17.80)
Blue Grama – Buffalograss Shortgrass Prairie	3	0.07 (0.03)	0.58 (0.23)	0.39 (0.16)	1.16 (0.47)
Development	7	0.01 (0.00)	12.23 (4.95)	3.56 (1.44)	24.91 (10.08)
Disturbed	9	0.60 (0.24)	24.18 (9.78)	4.66 (1.88)	41.90 (16.96)
Open Water	1	32.06 (12.97)	32.06 (12.97)	32.06 (12.97)	32.06 (12.97)
Plains Cottonwood / Inland Saltgrass Woodland	1	39.52 (15.99)	39.52 (15.99)	39.52 (15.99)	39.52 (15.99)
Plains Cottonwood Semi-Natural Woodland	3	0.15 (0.06)	3.28 (1.33)	1.39 (0.56)	4.16 (1.68)
Plains Cottonwood Temporarily Flooded Woodland Alliance	12	0.18 (0.07)	107.21 (43.39)	16.17 (6.54)	193.99 (78.55)
Black-tailed Prairie Dog Town	1	54.12 (21.90)	54.12 (21.90)	54.12 (21.90)	54.12 (21.90)
Reclaimed Agricultural Land	6	0.20 (0.08)	34.20 (13.84)	12.89 (5.22)	77.37 (31.31)
Coyote Willow / Mesic Graminoids Shrubland	32	0.02 (0.01)	12.50 (5.06)	1.49 (0.60)	47.77 (19.33)
Alkali Sacaton – Inland Saltgrass Herbaceous Vegetation	9	0.08 (0.03)	78.01 (31.57)	22.86 (9.25)	205.72 (83.25)
Broadleaf Cattail Marsh	3	0.34 (0.14)	32.40 (13.11)	11.09 (4.49)	33.27 (13.46)

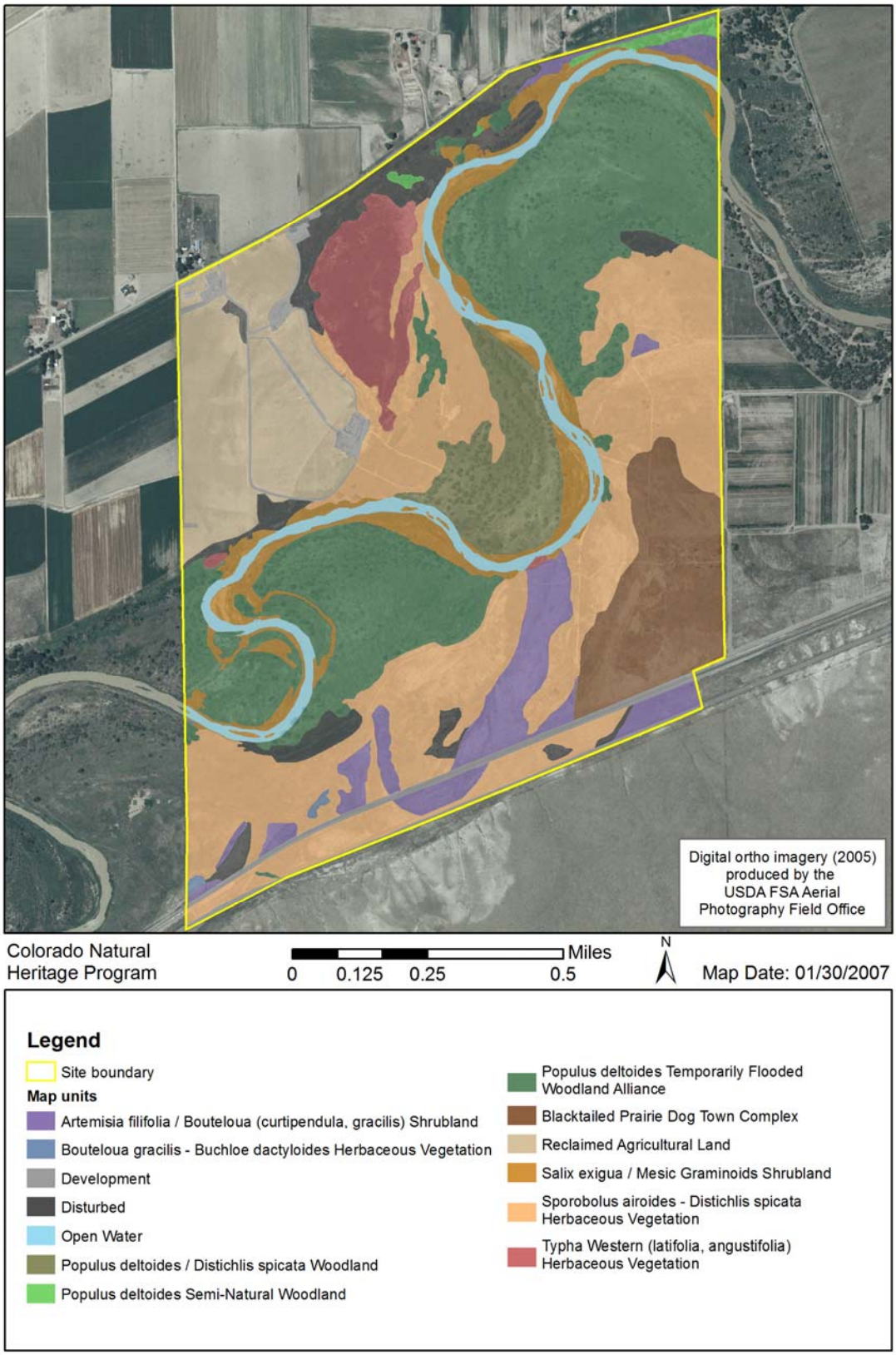

Figure 10. BEOL final vegetation map.

Discussion

The vegetation of BEOL is a complex mosaic of natural, semi natural, disturbed, and cultural types. The long history of intensive use at the site has resulted in many changes to what would have been the natural vegetation of the area. Areas of the upper river terrace near the Fort have been plowed and planted to row crops in the past. These areas have now been reseeded to a native grass mix and are moving toward a reclaimed state. Large scale disturbances that have occurred more recently on the lower floodplain terraces (e.g. floods, large fires, tamarisk removal) have established (or reestablished) large weed infested areas. Every year park resource managers work very hard to ameliorate the extensive weed infestations that are present on the site. Although future implementations of the NVC are projected to address cultural and other non-natural vegetation types, the current implementation does not. We attempted to create simple yet meaningful map classes to define areas dominated by non-native species or areas that are actively managed for weed control, restoration, or as landscaping. In applying the vegetation map to the site management it is important to keep in mind the influence disturbance and weeds can have on the vegetation of a site as well as the influence it has on an observer's perspective of the vegetation.

Accuracy Assessment

Upon direct comparison of the AA plots to the map polygons, the thematic accuracy was much lower than expected. This was due to a number of compounding errors that occurred at each step of the AA process. At the beginning of the accuracy assessment stage, the map contained two polygons attributed to a residual map class not intended to be included by the mapper. Despite map verification efforts, these map classes remained in the AA map, received randomly distributed sample points, but were not listed in the field key. The AA points distributed to these polygons were therefore wrong at Level 5 (binary accuracy). Additionally, the Hawth's tools extension (Beyer 2006) used to randomly distribute the sample points in ArcMap (ESRI 2006) did not allow us to specify a minimum distance from the polygon border. In some cases, AA points were distributed right at the polygon edges. Although AA crews were instructed to use replacement points when this occurred, it eventually resulted in the sampling of wrong polygons and sampling of ecotones. Classes with few small polygons did not get points in each separate polygon. As a result, these classes were not thoroughly sampled, and did not have large enough sample sizes from which to draw statistical conclusions. During AA field sampling, the crews were given a key to associations that did not match the classes present on the map. They were instructed to move points away from polygon boundaries, and to replace non-representative points with alternate AA points. This happened to some extent, but plots still ended up on the edge of both associations and polygons.

Fortunately, these errors were able to be interpreted and accounted for during the AA analysis. Each sample point that was not correct at Level 5 (binary accuracy) received an in-depth evaluation to correct for any possible sampling errors. Using plot photos, aerial photos, plot coordinates, plot location on the map, and the vegetation data on the field forms, the plots were evaluated as to their actual location and what was sampled, and how that fit the whole list of possible communities. Secondary associations were used where plot data, notes, or AA plot photo evidence supported it. Some plots were deemed location errors based on plot coordinates,

proximity to polygon boundaries, adjacent polygon attributes, and plot and aerial photos. The fuzzy set approach to AA allowed these errors to be viewed as correct to a degree. Most errors were viewed as correct by Level 4, and by Level 3, the map had the very high thematic accuracy one would expect for a small park. The reported accuracy is most likely an understatement of the final thematic accuracy of the map, as information gained from the accuracy assessment has been incorporated into the final map.

Specifically, the Disturbance map class proved the most difficult to map and assess. AA field crews documented disturbed areas throughout BEOL, and across many map classes. This reflects the highly disturbed nature of the park, but confounded the key's application of alliance and association names intended to describe natural community types. The draft FGDC standard revisions are proposed to incorporate an "up-front" split of natural and cultural vegetation, which in the future may ameliorate this difficulty (FGDC 2006). Examples of factors that confounded the accuracy of the disturbance map class include those associated with the long-term intensive human use of the site, as well as off-site modifications that have occurred in the upper and lower watershed. Land within and surrounding the BEOL boundaries has been intensively used for livestock grazing and transit since before the Fort was established in 1833 (Lavender 1954). The park boundaries encompass formerly cultivated and recently reseeded land, and neighboring land is still under cultivation. The site of BEOL is located on the floodplain of the Arkansas River which has been hydrologically altered due by dams, diversions, return flow from irrigation, and runoff from upstream urban areas. The ecology of the floodplain has been impacted by the invasion and subsequent removal of tamarisk and invasion by other noxious weeds. Finally, a large section of the park burned in 2003. As a result of these disturbances, summer rainfall led to an abundance of annual weeds, (mostly *Kochia scoparia*), during the AA sampling window. This growth obscured the vegetation on which most of the map classes were based. All of the things listed above contributed to the Disturbed map class being difficult to define and map accurately.

Another source of error in the overall level five accuracy (binary accuracy) results from the conversion of the reclaimed agricultural fields that have been reseeded with native prairie grasses. AA crews called all the polygons attributed to Reclaimed Agricultural Land as Blue Grama – Buffalograss Shortgrass Prairie. This indicates that reseeding and restoration efforts are having a positive effect on moving the old alfalfa fields toward a more natural state.

One area mapped as Blue Grama – Buffalograss Shortgrass Prairie has recently been colonized by black-tailed prairie dogs. At the time of the AA field work this recently colonized polygon retained a representative cover of the native species that were present prior to arrival of the prairie dogs. Other areas at the site mapped as Black-tailed Prairie Dog Town have been largely denuded of the native species and support a dominant cover of non-native species, notably bindweed.

Final Vegetation Map

The final vegetation map was corrected following the AA to incorporate any changes needed to fix errors discovered during the process. Similarly, minor changes were made to the field key as well, since many of the errors that were discovered had to do with interpretation of the key. Changes made to the final vegetation map following the AA included adding polygons to the area south of the railroad to more accurately represent the vegetation patterns there.

The Plains Cottonwood Temporarily Flooded Woodland Alliance map unit represents a mosaic of two plant associations, Plains Cottonwood / Alkali Sacaton Woodland and Plains Cottonwood / Inland Saltgrass Woodland. These associations form an intricate mosaic on the floodplain, and although they are distinct classification units based on plant composition, they undergo identical ecological processes at BEOL and can be considered a single management unit.

The final vegetation map of BEOL is a representation of the vegetation of the Park at this point in time. However, it should be a dynamic tool that the Park can and should update as the vegetation changes naturally through time and as a result of specific management actions. It is only through regular updating and maintenance in response to natural and anthropogenic change that the map will continue to be a valuable tool for park management.

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Appendix A. Natural Heritage Program methodology.

The Natural Heritage Ranking System

The cornerstone of Natural Heritage methodology is the use of a standardized element imperilment ranking system. Ranking species and ecological communities according to their imperilment status provides guidance for where Natural Heritage Programs should focus their information-gathering activities and provides data users with a concise and meaningful tool for decision-making.

To determine the status of an element within Colorado, CNHP gathers information on plants, animals, and plant communities that occur in the state. Based on this information, each of these elements of natural diversity is assigned a rank that indicates its relative degree of imperilment on a five-point scale (1 = critically imperiled, 5 = demonstrably secure). The criteria used to define the element imperilment rank are number of occurrences, size of population, and quality of population. The primary criterion is the number of occurrences (in other words, the number of known distinct localities or populations). This factor is weighted more heavily than other factors because an element found in one place is more imperiled than something found in twenty-one places. Also of importance are the size of the geographic range, the number of individuals, the trends in both population and distribution, identifiable threats, and the number of protected occurrences.

Element imperilment ranks are assigned a State-rank (S-rank) to represent the element's degree of imperilment within Colorado, and a Global-rank (G-rank) to represent the element's imperilment over its entire range. Taken together, these two ranks indicate the degree of imperilment of an element. For example, the lynx, which is thought to be secure in northern North America but is known from less than five current locations in Colorado, is ranked G5 S1 (globally-secure, but critically imperiled in this state). The Rocky Mountain Columbine, which is known only in Colorado from small populations in about 30 locations, is ranked a G3 S3 (vulnerable both in the state and globally, since it only occurs in Colorado and then in small numbers). Further, a tiger beetle that is only known from one location in the world at the Great Sand Dunes National Park and Preserve is ranked G1 S1 (critically imperiled both in the state and globally, because it exists in a single location). CNHP actively collects, maps, and electronically processes specific occurrence information for animal and plant species considered extremely imperiled to vulnerable in the state (S1 - S3). Certain elements are “watchlisted,” meaning that specific occurrence data are periodically analyzed to determine whether more active tracking is warranted. A complete description of each of the Natural Heritage ranks is provided in Table 8.

This single-rank system works readily for all elements except migratory animal species. Those animals that migrate may spend only a portion of their life cycles within the state. In these cases, it is necessary to distinguish between breeding, non-breeding, and resident species. Ranks followed by a "B,” for example S1B, indicate that the rank applies only to the status of breeding occurrences (Table 8. Definition of Natural Heritage Imperilment Ranks.). Similarly, ranks followed by an "N” refer to non-breeding status, typically during migration and winter. Elements without this notation are believed to be year-round residents within the state.

Table 8. Definition of Natural Heritage Imperilment Ranks.

Rank	Definition
G/S1	Critically Imperiled globally/state because of rarity (5 or fewer occurrences in the world/state; or 1,000 or fewer individuals), or because some factor of its biology makes it especially vulnerable to extinction.
G/S2	Imperiled globally/state because of rarity (6 to 20 occurrences, or 1,000 to 3,000 individuals), or because other factors demonstrably make it very vulnerable to extinction throughout its range.
G/S3	Vulnerable through its range or found locally in a restricted range (21 to 100 occurrences, or 3,000 to 10,000 individuals).
G/S4	Apparently Secure globally/state, though it may be quite rare in parts of its range, especially at the periphery. Usually more than 100 occurrences and 10,000 individuals.
G/S5	Demonstrably Secure globally/state, though it may be quite rare in parts of its range, especially at the periphery.
G/SX	Presumed Extinct globally, or extirpated within the state.
G#?	Indicates uncertainty about an assigned global rank.
G/SU	Unable to assign rank due to lack of available information.
GQ	Indicates uncertainty about taxonomic status.
G/SH	Historically known, but usually not verified for an extended period of time.
G#T#	Trinomial rank (T) is used for subspecies or varieties. These taxa are ranked on the same criteria as G1-G5.
S#B	Refers to the breeding season imperilment of elements that are not residents.
S#N	Refers to the non-breeding season imperilment of elements that are not permanent residents. Where no consistent location can be discerned for migrants or non-breeding populations, a rank of SZN is used.
SZ	Migrant whose occurrences are too irregular, transitory, and/or dispersed to be reliably identified, mapped, and protected.
SA	Accidental in the state.
SR	Reported to occur in the state but unverified.
S?	Unranked. Some evidence that species may be imperiled, but awaiting formal rarity ranking.

Note: Where two numbers appear in a state or global rank (for example, S2S3), the actual rank of the element is uncertain, but falls within the stated range.

Legal Designations for Rare Species

Natural Heritage imperilment ranks should not be interpreted as legal designations. Although most species protected under state or federal endangered species laws are rare, not all rare species receive legal protection. Legal status is designated either by the U.S. Fish and Wildlife Service under the Endangered Species Act at the federal level, or state-wide by the Colorado Division of Wildlife under Colorado Statutes 33-2-105 Article 2. In addition, the U.S. Forest Service and the Bureau of Land Management recognize some species as "Sensitive."

Element Occurrences and their Ranking

Actual locations of elements, whether they are single organisms, populations, or plant communities, are referred to as element occurrences. The element occurrence is considered the most fundamental unit of conservation interest and is at the heart of the Natural Heritage Methodology. To prioritize element occurrences for a given species, an element occurrence rank (EO-Rank) is assigned according to the size, ecological quality and landscape context of the occurrences whenever sufficient information is available. This ranking system is designed to indicate which occurrences are the healthiest and ecologically the most viable, thus focusing conservation efforts where they will be most successful. The EO-Rank is based on three factors:

Size – a measure of the area or abundance of the element's occurrence. This ranking factor takes into account factors such as area of occupancy, population abundance, population density, population fluctuation, and minimum dynamic area (which is the area needed to ensure survival or re-establishment of an element after natural disturbance). This factor for an occurrence is evaluated relative to other known, and/or presumed viable, examples.

Condition/Quality – an integrated measure of the composition, structure, and biotic interactions that characterize the occurrence. This includes measures such as reproduction, age structure, biological composition (such as the presence of exotic versus native species), structure (for example, canopy, understory, and ground cover in a forest community), and biotic interactions (such as levels of competition, predation, and disease).

Landscape Context – an integrated measure of two factors: the dominant environmental regimes and processes that establish and maintain the element, and connectivity. Dominant environmental regimes and processes include herbivory, hydrologic and water chemistry regimes (surface and groundwater), geomorphic processes, climatic regimes (temperature and precipitation), fire regimes, and many kinds of natural disturbances. Connectivity includes such factors as a species having access to habitats and resources needed for life cycle completion, fragmentation of ecological communities and systems, and the ability of the species to respond to environmental change through dispersal, migration, or re-colonization.

Each of these factors is rated on a scale of A through D, with A representing an excellent rank and D representing a poor rank. These ranks for each factor are then averaged to determine an appropriate EO-Rank for the occurrence. If not enough information is available to rank an element occurrence, an EO-Rank of E is assigned. EO-Ranks and their definitions are summarized in Table 9.

Table 9. Element occurrence ranks and their definitions.

Rank	Definition
A	Excellent viability.
B	Good viability
C	Fair viability.
D	Poor viability.
H	Historic: known from historical record, but not verified for an extended period of time.
X	Extirpated (extinct within the state).
E	Extant: the occurrence does exist but not enough information is available to rank.
F	Failed to find: the occurrence could not be relocated.

Appendix B. Plants documented at BEOL during the vegetation mapping project.

Family	Species	Common Name
Amaranthaceae	Amaranthus	pigweed
	Amaranthus retroflexus	redroot amaranth
Apocynaceae	Apocynum	dogbane
	Apocynum cannabinum	Indianhemp
Asclepiadaceae	Asclepias	milkweed
	Asclepias speciosa	showy milkweed
	Asclepias subverticillata	horsetail milkweed
Asteraceae	Ambrosia psilostachya	Cuman ragweed
	Artemisia	sagebrush
	Artemisia filifolia	sand sagebrush
	Aster	aster
	Baccharis	baccharis
	Baccharis salicifolia	mule's fat
	Baccharis salicina	Great Plains false willow
	Cirsium arvense	Canada thistle
	Cirsium undulatum	wavyleaf thistle
	Conyza canadensis	Canadian horseweed
	Ericameria nauseosa	rubber rabbitbrush
	Eupatorium maculatum	spotted joepyeweed
	Euthamia	goldentop
	Gutierrezia sarothrae	broom snakeweed
	Helianthus	sunflower
	Helianthus annuus	common sunflower
	Helianthus petiolaris	prairie sunflower
	Iva axillaris	povertyweed
	Lactuca serriola	prickly lettuce
	Lygodesmia juncea	rush skeletonplant
	Machaeranthera	tansyaster
	Machaeranthera canescens	hoary tansyaster
	Machaeranthera pinnatifida	lacy tansyaster
	Machaeranthera tanacetifolia	tanseyleaf tansyaster
	Ratibida	prairie coneflower
	Ratibida columnifera	upright prairie coneflower
	Ratibida tagetes	green prairie coneflower
	Rayjacksonia phyllocephala	camphor daisy
	Solidago	goldenrod
	Solidago canadensis	Canada goldenrod
	Solidago missouriensis	Missouri goldenrod
	Symphyotrichum	aster
	Symphyotrichum ericoides	white heath aster
	Symphyotrichum ericoides var. ericoides	white heath aster
	Symphyotrichum falcatum var.	white prairie aster

	falcatum	
Boraginaceae	Cryptantha minima	little cryptantha
Family	**Species**	**Common Name**
Brassicaceae	Cardaria chalapensis	lenspod whitetop
	Descurainia	tansymustard
	Lepidium latifolium	broadleaved pepperweed
Cactaceae	Opuntia phaeacantha	tulip pricklypear
Caprifoliaceae	Symphoricarpos occidentalis	western snowberry
Chenopodiaceae	Bassia	smotherweed
	Chenopodium	goosefoot
	Chenopodium berlandieri	pitseed goosefoot
	Kochia	molly
	Salsola	Russian thistle
	Salsola tragus	prickly Russian thistle
Convolvulaceae	Convolvulus arvensis	field bindweed
	Ipomoea leptophylla	bush morning-glory
Cucurbitaceae	Cucurbita foetidissima	Missouri gourd
Cyperaceae	Carex	sedge
	Schoenoplectus acutus	hardstem bulrush
	Scirpus	bulrush
Dipsacaceae	Dipsacus fullonum	Fuller's teasel
Euphorbiaceae	Chamaesyce missurica	prairie sandmat
	Croton texensis	Texas croton
Fabaceae	Astragalus bisulcatus	twogrooved milkvetch
	Glycyrrhiza lepidota	American licorice
	Sophora nuttalliana	silky sophora
Lamiaceae	Scutellaria galericulata	marsh skullcap
Liliaceae	Asparagus	asparagus
Malvaceae	Sphaeralcea angustifolia	copper globemallow
	Sphaeralcea coccinea	scarlet globemallow
Nyctaginaceae	Mirabilis glabra	smooth four o'clock
	Mirabilis nyctaginea	heartleaf four o'clock
Onagraceae	Gaura mollis	velvetweed
Poaceae	Achnatherum hymenoides	Indian ricegrass
	Aristida purpurea	purple threeawn
	Bothriochloa laguroides	silver beardgrass
	Bouteloua curtipendula	sideoats grama
	Bouteloua gracilis	blue grama
	Bromus tectorum	cheatgrass
	Buchloe dactyloides	buffalograss
	Cynodon dactylon	Bermudagrass
	Distichlis spicata	inland saltgrass
	Elymus canadensis	Canada wildrye
	Hesperostipa comata	needle and thread
	Leersia oryzoides	rice cutgrass
	Muhlenbergia asperifolia	scratchgrass
	Panicum	panicgrass

	Panicum capillare	witchgrass
	Panicum obtusum	vine mesquite
Family	**Species**	**Common Name**
Poaceae, cont.	Panicum virgatum	switchgrass
	Pascopyrum smithii	western wheatgrass
	Phragmites australis	common reed
	Pleuraphis jamesii	James' galleta
	Schizachyrium scoparium	little bluestem
	Setaria	bristlegrass
	Spartina pectinata	prairie cordgrass
	Sporobolus	dropseed
	Sporobolus airoides	alkali sacaton
	Sporobolus cryptandrus	sand dropseed
	Thinopyrum	wheatgrass
Polygonaceae	Eriogonum effusum	spreading buckwheat
	Rumex	dock
Ranunculaceae	Clematis ligusticifolia	western white clematis
Salicaceae	Populus deltoides	eastern cottonwood
	Salix	willow
	Salix amygdaloides	peachleaf willow
	Salix exigua	narrowleaf willow
Scrophulariaceae	Verbascum thapsus	common mullein
Solanaceae	Physalis virginiana	Virginia groundcherry
	Solanum rostratum	buffalobur nightshade
Tamaricaceae	Tamarix	tamarisk
	Tamarix ramosissima	saltcedar
Typhaceae	Typha	cattail
	Typha latifolia	broadleaf cattail
Ulmaceae	Ulmus pumila	Siberian elm
Vitaceae	Parthenocissus quinquefolia	Virginia creeper
	Parthenocissus vitacea	woodbine

Appendix C. BEOL / SAND Field Manual: Vegetation Sampling Survey Form Instructions.

VEGETATION SURVEY FORM

Plot Code
Code indicating the specific plot within the vegetation polygon. For Bents Old Fort, the codes will be "BEOL.VMP..###". Each crew will be assigned a range of plot numbers. Begin with BEOL.VMP.001 and increment up from there. Opportunistic and Random plots will use slightly different systems. Be certain you are not using the same range as another team or numbers you have already used. If someone switches to another team, it is important they know what plot numbers the team will use to identify the data they gather. Before you leave for the field, be sure you know what number range the crew will use and that these are not being used by another team!

Survey Date
Date the survey was taken; month, day, year

Surveyors
Record the three initials of the surveyors present.

Provisional Map Unit
Using the preliminary classification you were provided for the Park, assign the name of the vegetation type that most closely resembles the type you are surveying.

Provisional Association Name
Enter the finest level of the classification possible. If in fact, *none* of the names may be a good fit; you may have found a new type, although this should be the exception and not the rule. If you have a new type, create a provisional name with the dominant and diagnostic species. You must make sure to appropriately mark the field log that you have chosen a new association and not one that was previously on the list given. The 'provisional community name' that is assigned will be used to update the tally of plots needed for each vegetation type.

UTM X
Use GPS if at all possible. If you can't get a GPS reading, estimate coordinates from a topo map and note on the form that this method was used.

UTM Y
Use GPS if at all possible. If you can't get a GPS reading, estimate coordinates from a topo map and note on the form that this method was used.

GPS Accuracy
Note the error in the GPS reading off your unit (PDOP).

Location comments
Enter a simple monument to help someone find the plot again. Put comments on the plot marker here, for instance if you had to place the plot marker in a corner instead of the center of the plot. Record here if you moved a DPL to be more representative.

Plot Length and Plot Width
Enter diameter for circular plots and width and length dimensions for square or rectangular plots. Choose the appropriate plot size based on the following:

Vegetation Class	Standard Plot Dimensions	PLOT AREA
Forest	11.3 m radius or 20 m x 20 m	**400 m^2**
Woodland	11.3 m radius or 20 m x 20 m	**400 m^2**
Shrubland	11.3 m radius or 20 m x 20 m	**400 m^2**
Dwarf-shrubland	5.65 m radius or 10 m x 10 m	**100 m^2**
Herbaceous	5.65 m radius or 10 m x 10 m	**100 m^2**
Nonvascular	2.82 m radius or 5 m x 5 m	**25 m^2**

Camera and Photographs
We are taking digital pictures of the plots on "flashcard" memory cards. Note the flashcard number and frame numbers of each photo. Be sure to have taken a photo of the GPS screen everyday or at least every other day.

Plot Representativeness
Does this plot represent the full variability of the polygon/stand? Note additional species not seen in the plot in the space provided below.We distinguish in this section the plot's ability to represent the stand or polygon you are sampling as one component and the ability of this sample to represent the range of variability of the association in the entire mapping area. The former comment may be ascertained by reconnaissance of the stand. The latter comment comes only after some familiarity with the vegetation type throughout the mapping area and may be left blank if you have no opinion at this time.

ENVIRONMENTAL DESCRIPTION
Elevation
Elevation of the plot. Specify whether in feet of meters (this will depend on the units used on the GPS or on the topographic map being used). In general, we have determined that the reading you get from a topo map, provided you are certain where you are, is more accurate than the average reading from the GPS unit. Thus, please attempt to estimate your elevation with the topo map.

Slope
Measure the slope in **degrees** using a clinometer at the plot, not the general slope.

Aspect
Measure the slope aspect using a compass (be sure to correct for the magnetic declination). Note: all compasses should be pre-set to an average declination for the park and thus, readings from the compasses carried by the field crews may be directly noted.
Topographic Position

Topographic position of the plot. Choose one:

INTERFLUVE (crest, summit, ridge). Linear top of ridge, hill, or mountain; the elevated area between two fluves (drainageways) that sheds water to the drainageways.

HIGH SLOPE (shoulder slope, upper slope, convex creep slope). Geomorphic component that forms the uppermost inclined surface at the top of a slope. Includes the transition zone from backslope to summit. Surface is dominantly convex in profile and erosional in origin.

HIGHLEVEL (mesa). Level top of a plateau.

MIDSLOPE (transportational midslope, middle slope). Intermediate slope position.

BACKSLOPE (dipslope). Subset of midslopes that are steep, linear, and may include cliff segments (fall faces).

STEP IN SLOPE (ledge, terracette). Nearly level shelf interrupting a steep slope, rock wall, or cliff face.

LOWSLOPE (lower slope, foot slope, colluvial footslope). Inner gently inclined surface at the base of a slope. Surface profile is generally concave and a transition between midslope or backslope, and toeslope.

TOESLOPE (alluvial toeslope). Outermost gently inclined surface at base of a slope. In profile, commonly gentle and linear and characterized by alluvial deposition.

LOW LEVEL (terrace). Valley floor or shoreline representing the former position of an alluvial plain, lake, or shore.

CHANNEL WALL (bank). Sloping side of a channel.

CHANNEL BED (narrow valley bottom, gully, arroyo, wash). Bed of single or braided watercourse commonly barren of vegetation and formed of modern alluvium.

BASIN FLOOR (depression). Nearly level to gently sloping, bottom surface of a basin.

Landform

Choose one (the best representative if more than one type) landform that describes the site where the plot was taken. Note on the code sheet the landform choices are listed at different scales. Thus, one can select more than one for plot if appropriate (e.g., mountain could be macro and ridge could be meso scale). You can add to the list for Bents Old Fort and Sand Creek areas. Just be consistent so we can analyze by landform so be simple and not wordy.

LANDFORM (from Glacier)	Levee
Alluvial fan	Meander belt
Bench	Meander scar
Bottomland	Moraine (undifferentiated)
Canyon	Mound
Channel	Mountain valley
Cirque floor	Mountain (s)
Cliff	Mountain-valley fan
Colluvial slope	Mud flat
Dome	Patterned ground (undifferentiated)
Drainage channel	Periglacial boulderfield
Draw	Pinnacle
Earth flow	Plateau
Eroded bench	Ravine
Eroding stream channel system,	Ridge
Erosional stream terrace	Ridge and valley
Escarpment	Ridgetop bedrock outcrop
Flood plain	Rim
Fluvial	Riverbed
Glaciated uplands	Rock fall avalanche
Gorge	Saddle
Ground moraine	Scour
Hanging valley	Seep
Hills	Upper 1/3 of slope
Hillslope bedrock outcrop	Middle 1/3 of slope
Island	Lower 1.3 of slope
Knob	Slump pond
Knoll	Soil creep slope
Lake/pond	Stream terrace (undifferentiated)
Lake bed	Streambed
Lake plain	Swale
Lake terrace	Talus
Lateral moraine	Tarn
Lava flow (undifferentiated)	Toe slope
Ledge	Valley floor

Surficial Geology

Note the geologic substrate influencing the plant community (bedrock or surficial materials). Accurately recording the geology at the plot is especially important if the plot is on an inclusion in the type on the geology map. Choose the best one that describes the plot, try to only choose one if possible.

IGNEOUS ROCKS
Granite *Light*
Diorite *50/50*
Gabbro *Dark*

SEDIMENTARY ROCKS
Conglomerate
Breccia
Sandstone
Siltstone

METAMORPHIC ROCKS
Gneiss

GLACIAL DEPOSITS
Lacustrine (lake) and fluvial (river) deposits (glacio-fluvial, fluvio-lacustrine, freshwater sandy beaches, stony/gravelly shoreline)

ORGANIC DEPOSITS
Peat (with clear fibric structure)
Muck
Marsh, regularly flooded by lake or river (high mineral content)

SLOPE AND MODIFIED DEPOSITS
Colluvial (deposition by mass movement (direct gravitational action) and local, unconcentrated runoff (overland flow)
Alluvial (deposition by concentrated running water)
Aeolean (wind deposition)
Solifluction, landslide

Cowardin System / Hydrology

If the system is a wetland, check off the name of the USFWS system which best describes its hydrology and landform. Choose one: Upland, Palustrine, Riverine, or Lacustrine. Indicate "upland" if the system is not a wetland.

Next, assess the hydrologic regime of the plot using the descriptions below (adapted from Cowardin et al. 1979).

PERMANENTLY FLOODED - Water covers the land surface at all times of the year in all years. Equivalent to Cowardin's "permanently flooded."

SEASONALLY FLOODED - Surface water is present for extended periods during the growing season, but is absent by the end of the growing season in most years. The water table after flooding ceases is very variable, extending

from saturated to a water table well below the ground surface. Includes Cowardin's Seasonal, Seasonal-Saturated, and Seasonal-Well Drained modifiers.

SEMIPERMANENTLY FLOODED - Surface water persists throughout growing season in most years except during periods of drought. Land surface is normally saturated when water level drops below soil surface. Includes Cowardin's Intermittently Exposed and Semipermanently Flooded modifiers.

TEMPORARILY FLOODED - Surface water present for brief periods during growing season, but water table usually lies well below soil surface. Often characterizes flood-plain wetlands. Equivalent to Cowardin's Temporary modifier.

INTERMITTENTLY FLOODED - Substrate is usually exposed, but surface water can be present for variable periods without detectable seasonal periodicity. Inundation is not predictable to a given season and is dependent upon highly localized rain storms. This modifier was developed for use in the arid West for water regimes of Playa lakes, intermittent streams, and dry washes but can be used in other parts of the U.S. where appropriate. This modifier can be applied to both wetland and non-wetland situations. Equivalent to Cowardin's Intermittently Flooded modifier.

SATURATED - Surface water is seldom present, but substrate is saturated to surface for extended periods during the growing season. Equivalent to Cowardin's Saturated modifier.

UNKNOWN - The water regime of the area is not known. The unit is simply described as a non-tidal wetland.

Environmental Comments
Enter any additional noteworthy comments on the environmental setting. This field can be used to describe site history such as fire events (date since last fire or evidence of severity) as well as other disturbance or reproduction factors including animal disturbance.

Ground Cover
Estimate ground cover to the nearest percentage by each category, excluding plant basal area. Total should sum to 100%.

Soil Texture
Using the following key, assess average soil texture. In addition to this key you can choose Peat, Muck or Loam.

Simplified Key to Soil Texture (Brewer and McCann 1982)

A1 Soil does not remain in a ball when squeezed.....sand
A2 Soil remains in a ball when squeezed.....B

B Squeeze the ball between your thumb and forefinger, attempting to make a ribbon that you push up over your finger.
B1 Soil makes no ribbon.....loamy sand
B2 Soil makes a ribbon; may be very short.....C

C1 Ribbon extends less than 1 inch before breaking.....D
C2 Ribbon extends 1 inch or more before breaking.....E

D Add excess water to small amount of soil.
D1 Soil feels at least slightly gritty.....loam *or* sandy loam
D2 Soil feels smooth.....silt loam

E1 Soil makes a ribbon that breaks when 1 2 inches long; cracks if bent into a ring.....F
E2 Soil makes a ribbon 2+ inches long; does not crack when bent into a ring.....G

F Add excess water to small amount of soil.
F1 Soil feels at least slightly gritty.....sandy clay loam *or* clay loam
F2 Soil feels smooth.....silty clay loam *or* silt

G Add excess water to a small amount of soil.
G1 soil feels at least slightly gritty.....sandy clay *or* clay
G2 Soil feels smooth.....silty clay

Soil Drainage
The soil drainage classes are defined in terms of (1) actual moisture content (in excess of field moisture capacity) and (2) the extent of the period during which excess water is present in the plant-root zone. It is recognized that permeability, level of groundwater, and seepage are factors affecting moisture status. However, because these are not easily observed or measured in the field, they cannot generally be used as criteria of moisture status. It is further recognized that soil profile morphology, for example mottling, normally, but not always, reflects soil moisture status. Although soil morphology may be a valuable field indication of moisture status, it should not be the overriding criterion. Soil drainage classes cannot be based solely on the presence or absence of mottling. Topographic position and vegetation as well as soil morphology are useful field criteria for assessing soil moisture status.

RAPIDLY DRAINED - The soil moisture content seldom exceeds field capacity in any horizon except immediately after water addition. Soils are free from any evidence of gleying throughout the profile. Rapidly drained soils are commonly coarse textured or soils on steep slopes.

WELL DRAINED - The soil moisture content does not normally exceed field capacity in any horizon (except possibly the C) for a significant part of the year. Soils are usually free from mottling in the upper 3 feet, but may be mottled below this depth. B horizons, if present, are reddish, brownish, or yellowish.

MODERATELY WELL DRAINED - The soil moisture in excess of field capacity remains for a small but significant period of the year. Soils are commonly mottled (chroma < 2) in the lower B and C horizons or below a depth of 2 feet. The Ae horizon, if present, may be faintly mottled in fine-textured soils and in medium-textured soils that have a slowly permeable layer below the solum. In grassland soils the B and C horizons may be only faintly mottled and the A horizon may be relatively thick and dark.

SOMEWHAT POORLY DRAINED - The soil moisture in excess of field capacity remains in subsurface horizons for moderately long periods during the year. Soils are commonly mottled in the B and C horizons; the Ae horizon, if present, may be mottled. The matrix generally has a lower chroma than in the well-drained soil on similar parent material.

POORLY DRAINED - The soil moisture in excess of field capacity remains in all horizons for a large part of the year. The soils are usually very strongly gleyed. Except in high-chroma parent materials the B, if present, and upper C horizons usually have matrix colors of low chroma. Faint mottling may occur throughout.

VERY POORLY DRAINED - Free water remains at or within 12 inches of the surface most of the year. The soils are usually very strongly gleyed. Subsurface horizons usually are of low chroma and yellowish to bluish hues. Mottling may be present but at the depth in the profile. Very poorly drained soils usually have a mucky or peaty surface horizon.

VEGETATION DESCRIPTION

Leaf Phenology

Select <u>one</u> value which best describes the leaf phenology of the dominant stratum. The dominant stratum is the uppermost stratum that contains at least 10% cover.

EVERGREEN - Greater than 75% of the total woody cover is never without green foliage.

COLD DECIDUOUS – More than 75% of the total woody cover sheds its foliage in connection with an unfavorable season mainly characterized by winter frost.

MIXED EVERGREEN - COLD DECIDUOUS - Evergreen and deciduous species generally contribute 25-75% of the total woody cover. Evergreen and cold-deciduous species admixed.

PERENNIAL - Herbaceous vegetation composed of more than 50% perennial species.

ANNUAL - Herbaceous vegetation composed of more than 50% annual species.

Leaf Type
Select one value which best describes the leaf form of the dominant stratum. The dominant stratum is the uppermost stratum that contains at least 10% cover.

BROAD-LEAVED - Woody vegetation primarily broad-leaved (generally contributes greater than 50 percent of the total woody cover).

NEEDLE-LEAVED - Woody vegetation primarily needle-leaved (generally contributes greater than 50 percent cover).

MICROPHYLLOUS - Woody cover primarily microphyllous.

GRAMINOID - Herbaceous vegetation composed of more than 50 percent graminoid/stipe leaf species.

FORB (BROAD-LEAF-HERBACEOUS) - Herbaceous vegetation composed of more than 50% broad-leaf forb species.

PTERIDOPHYTE - Herbaceous vegetation composed of more than 50 percent species with frond or frond-like leaves.

Physiognomic Class
Choose one:

Forest: Trees with their crowns overlapping (generally forming 60-100% cover).

Woodland: Open stands of trees with crowns not usually touching (generally forming 25-60% cover). Canopy tree cover may be less than 25% in cases where it exceeds shrub, dwarf-shrub, herb, and nonvascular cover, respectively.

Shrubland: Shrubs generally greater than 0.5 m tall with individuals or clumps overlapping to not touching (generally forming more than 25% cover, trees generally less than 25% cover). Shrub cover may be less than 25% where it exceeds tree, dwarf-shrub, herb, and nonvascular cover, respectively. Vegetation dominated by woody vines is generally treated in this class.

Dwarf-Shrubland: Low-growing shrubs usually under 0.5 m tall. Individuals or clumps overlapping to not touching (generally forming more than 25% cover, trees and tall shrubs generally less than 25% cover). Dwarf-shrub cover may be less than 25% where it exceeds tree, shrub, herb, and nonvascular cover, respectively

Herbaceous: Herbs (graminoids, forbs, and ferns) dominant (generally forming at least 25% cover; trees, shrubs, and dwarf-shrubs generally with less than 25% cover). Herb cover may be less than 25% where it exceeds tree, shrub, dwarf-shrub, and nonvascular cover, respectively.

Nonvascular: Nonvascular cover (bryophytes, non-crustose lichens, and algae) dominant (generally forming at least 25% cover). Nonvascular cover may be less than 25% where it exceeds tree, shrub, dwarf-shrub, and herb cover, respectively.

Sparse Vegetation: Abiotic substrate features dominant. Vegetation is scattered to nearly absent and generally restricted to areas of concentrated resources (total vegetation cover is typically less than 10% and greater than 0%).

Strata/Lifeform, Height, Cover, Diagnostic Species

Visually divide the community into vegetation layers (strata). Indicate the average height class of the stratum in the first column, using the Height Scale on the form. Enter the average percent cover class of the whole stratum in the second column, using the Cover Scale on the form. Many plots will have only a few of the possible layers. Height and Cover classes are also listed below. Then list a few of the most common species in each stratum.

Trees are defined as single- or few-stemmed woody plants, generally greater than 5 m in height and 10 cm DBH at maturity and under optimal growing conditions. Individuals can be determined relatively easily. Shrubs are defined as multiple-stemmed woody plants generally less than 5 m in height at maturity and under optimal growing conditions, and determining individuals can sometimes be difficult.

Herbaceous layers are Ht = total, H1 = Graminoids (grass, sedge, rush), H2 = Forbs (non-graminoid flowering herbaceous), H3 = Ferns and Fern allies, and H4 = tree seedlings. List the dominant species in each stratum. If species known to be diagnostic of a particular vegetation type are present, list these as well, marking them with an asterisk.

Cover Scale for Strata		Height Scale for Strata	
T	0-1%	01	<0.5 m
P	>1-5%	02	0.5-1m
1 +/-	>5-15%	03	1-2 m
2	>15-25%	04	2-5 m
3	>25-35%	05	5-10 m
4	>35-45%	06	10-15 m
5	>45-55%	07	15-20 m
6	>55-65%	08	20-35 m
7	>65-75%	09	35-50 m
8	>75-85%	10	>50 m
9	>85-95%		
10	>95%		

Vegetation Comments
Record comments on the vegetation. If there is damage to certain spcies etc. Record any thoughts about the make up of the stratums. This is a good place to add any other basic comments as well.

Species/ Percent Cover Table
Starting with the uppermost stratum, list all the species present (record the latin name and not a code) and cover class (using the 12 point scale) and percent cover of each species in that particular stratum. Indicate strata in the left-hand columns. If in the tree layer (single-stemmed woody plants, generally 5 m in height or greater at maturity), note in the "T" column if T1 (emergent tree), T2 (tree canopy), or T3 (tree sub-canopy). If in the shrub layer, note in the "S" column if S1 (tall shrub, > 2m), S2 (short shrub, < 2m), or S3 (dwarf shrub. < 0.5m). If in the ground layer, note in the "G" column if H1 (herbaceous - graminoid), H2 (Herbaceous Forb), H3 (Herbaceous Fern), H4 (Tree Seedlings), N (nonvascular other than ferns), V (vine/liana), or E (epiphyte).

Make sure to double check with the dominant strata list and make sure all species that you said were part of the dominant strata are present in the species list.

*For plots with trees, estimate cover of seedlings, saplings, mature (all others), and total cover for **each** tree species. Use a separate line for each and assign the most appropriate strata class (by height). Seedlings are generally less than 1.5 m, but that may vary by species.

BEOL / SAND Code List - Cheatsheet

LANDFORM

Alluvial fan
Bench
Bottomland
Canyon
Channel
Cirque floor
Cliff
Colluvial slope
Dome
Drainage channel
Draw
Earth flow
Eroded bench
Eroding stream channel system
Erosional stream terrace
Escarpment
Flood plain
Fluvial
Glaciated uplands
Gorge
Ground moraine
Hanging valley
Hills
Hillslope bedrock outcrop
Island
Knob
Knoll
Lake/pond
Lake bed
Lake plain
Lake terrace
Lateral moraine
Lava flow (undifferentiated)
Ledge
Levee
Meander belt
Meander scar
Moraine (undifferentiated)
Mound
Mountain valley
Mountain (s)
Mountain-valley fan
Mud flat
Patterned ground (undifferentiated)
Periglacial boulderfield
Pinnacle
Plateau
Ravine
Ridge
Ridge and valley
Ridgetop bedrock outcrop
Rim
Riverbed
Rock fall avalanche
Saddle
Scour
Seep
Upper 1/3 of slope
Middle 1/3 of slope
Lower 1.3 of slope
Slump pond
Soil creep slope
Stream terrace (undifferentiated)
Streambed
Swale
Talus
Tarn
Toe slope
Valley floor

ASPECT

Flat (n/a)
Variable
N 338-22
NE 23-67
E 68-112
SE 113-157
S 158-202
SW 203-247
W 248-292
NW 293-337

SOIL TEXTURE

sand
loamy sand
sandy loam
silt loam
sandy clay loam
clay loam
silty clay loam
silt
sandy clay
clay
silty clay
peat
muck
loam

DRAINAGE

Rapidly drained
Well drained
Moderately well drained
Somewhat poorly drained
Poorly drained
Very poorly drained

TOPOGRAPHIC POSITION

Interfluve
High Slope
Highlevel
Midslope
Backslope
Step In Slope
Lowslope
Toeslope
Low Level
Channel Wall
Channel Bed
Basin Floor

SURFICIAL GEOLOGY
descriptive terms

IGNEOUS ROCKS
Granite *Light*
Diorite *50/50*
Gabbro *Dark*

SEDIMENTARY ROCKS
Conglomerate
Breccia
Sandstone
Siltstone

METAMORPHIC ROCKS
Gneiss

GLACIAL DEPOSITS
Lacustrine (lake) and fluvial (river) deposits (glacio-fluvial, fluvio-lacustrine, freshwater sandy beaches, stony/gravelly shoreline)

ORGANIC DEPOSITS
Peat (with clear fibric structure)
Muck
Marsh, regularly flooded by lake or river (high mineral content)

SLOPE AND MODIFIED DEPOSITS
Colluvial (deposition by mass movement (direct gravitational action) and local, unconcentrated runoff (overland flow)
Alluvial (deposition by concentrated running water)
Aeolean (wind deposition)
Solifluction, landslide

Appendix D. Examples of vegetation plot and AA field forms.

Vegetation and AA Plot form:

IDENTIFIERS/LOCATORS

Plot Code: BEOL.VMP._____ ☐ Observation Plot Survey Date: _____/_____/ 2005 Surveyors: _____
SAND.VMP._____

Provisional Map Unit Name: _____

Provisional Association Name: _____

UTM Zone: 13 UTM X: ___ ___ ___ ___ ___ ___ (m E) UTM Y: ___ ___ ___ ___ ___ ___ ___ (m N) Accuracy _____m

Location Comments:

Plot length(m):_____ Plot width(m):_____

Azimuth: _____° Radius(m):_____

Camera #: _____ CF Card #: _____

Photo #: N_____ E_____ S_____ W_____

Plot representativeness (discuss decisions for placement and/or reasons for non-representativeness)

a. Representativeness of association (if known):

b. Representativeness of plot in stand:

ENVIRONMENTAL DESCRIPTION

Elevation _____m Slope _____° Aspect_____°

Topographic Position (see cheat sheet)_____ Landform (see cheat sheet)_____

Surficial Geology (see cheat sheet)_____

Cowardan System:
___ Upland
___ Palustrine
___ Riverine
___ Lacustrine

Hydrology:
___Permanently Flooded
___Seasonally Flooded
___Semi-permanently Flooded
___Temporarily Flooded
___Intermittently Flooded
___Saturated
___Unknown

Soil Texture:
___ sand
___ loamy sand
___ sandy loam
___ silt loam
___ sandy clay loam
___ clay loam
___ silty clay loam
___ silt
___ sandy clay
___ clay
___ silty clay
___ peat
___ muck
___ loam

Soil Drainage:
___ Rapidly drained
___ Well drained
___ Moderately well drained
___ Somewhat poorly drained
___ Poorly drained
___ Very poorly drained

% Ground Cover: *(Sum = 100%)*
___ Litter / duff
___ Wood (> 1 cm)
___ Bare soil
___ Sand (0.1-2 mm)
___ Small rocks (0.2-10 cm)
___ Large rocks (> 10 cm)
___ Bedrock
___ Water
___ Moss
___ Lichen
___ Cryptogam
___ Basal area
___ Other: _____

Environmental Comments (dynamic stage, fire history, insect damage, animal use evidence, natural or anthropogenic disturbance):

VEGETATION DESCRIPTION

Leaf phenology (of dominant stratum)	Leaf Type (of dominant stratum)	Physiognomic class	Height Scale for Strata	Cover Scale for Strata
Trees and Shrubs ____Evergreen ____Cold-deciduous ____Mixed evergreen-cold-deciduous Herbs ___Annual ___Perennial	___Broad-leaved ___Needle-leaved ___Microphyllous ___Graminoid ___Forb ___Pteridophyte	___Forest ___Woodland ___Shrubland ___Dwarf Shrubland ___Herbaceous ___Nonvascular ___Sparsely Vegetated	01 <0.5 m 02 0.5-1m 03 1-2 m 04 2-5 m 05 5-10 m 06 10-15 m 07 15-20 m 08 20-35 m 09 35 – 50 m 10 >50 m	T 0-1% P >1-5% 1 >5-15% +/- 2 >15-25% 3 >25-35% 4 >35-45% 5 >45-55% 6 >55-65% 7 >65-75% 8 >75-85% 9 >85-95% 10 > 95%

	Height Class	Cover Class	Dominant Species (mark Diagnostics with *)
T1 Emergent	_____	_____	_____
T2 Canopy	_____	_____	_____
T3 Sub-canopy	_____	_____	_____
S1 Tall shrub	_____	_____	_____
S2 Short Shrub	_____	_____	_____
S3 Dwarf-shrub	_____	_____	_____
Ht Herbaceous	_____	_____	_____
H1 Graminoids	_____	_____	_____
H2 Forbs	_____	_____	_____
H3 Ferns	_____	_____	_____
H4 Seedlings	_____	_____	_____
N Non-vascular	_____	_____	_____
V Vine/liana	_____	_____	_____
E Epiphyte	_____	_____	_____

Vegetation Comments:

Species list for vegetation plot only:

PlotCode BEOL.VMP. SAND.VMP._____

Species/percent cover: Starting with the uppermost stratum, list all species with % cover for each species in the stratum. For each tree species estimate seedling, sapling, mature, and total cover indicating stratum . Also list any additional species outside the plot at the end of the table or designate with a 0 in Cover Class column.

Cover Scale for Strata			
T	0-1%	5	>45-55%
P	>1-5%	6	>55-65%
1	>5-15% +/-	7	>65-75%
2	>15-25%	8	>75-85%
3	>25-35%	9	>85-95%
		10	> 95%

Stratum	Species Name	Cover Class	Stratum	Species Name	Cover Class
				Species outside plot	

Bents Old Fort and Sand Creek Massacre Vegetation Mapping Fuels Data Sheet

BEOL / SAND **Plot #**	**Date** ____/____/2005	**Surveyors**
UTM X: __ __ __ __ __ __ (mE) UTM Y: __ __ __ __ __ __ __ (mN) Accuracy _____(m)		

SURFACE COVER	**% COVER (absolute)**
Shrubs > 1 m	
Shrubs 0.3 - 1 m	
Shrubs <= 0.3m	
Grass or forbs > 0.6 m	
Grass or forbs 0.3 – 0.6 m	
Grass or forbs <= 0.3 m	
Long needle conifer litter (PIPO only)	
Short needle conifer litter	
Deciduous litter	
Woody debris (>1 cm; within 2m of ground)	
Un burnable (rock, sand, etc.)	
Other	
	100%

LITTER AND DUFF LOADING: 5 measurements, to be taken at plot center and 10 m from origin to the North, East, South, &West

Location	**Litter Depth (cm)**	**Duff Depth (cm)**
Plot Center		
10 m North		
10 m East		
10 m South		
10 m West		

Notes:

Plot # VMP.BEOL. VMP.SAND.	**Date/Time** ____/_____/2005	**Surveyors**	DBH Sheet ___ of ___

Plot Dimensions: _____M x_____M_____ Sub-sampled portion:_____M_____M_____

CANOPY FUEL LOAD:

Tree #	**DBH (~ 3 cm)**	**DAB (~ 3 cm)**	**Species**	**Tree Height (nearest 2 m)**	**Live (y or n)**	**Crown Ratio**	**Tree Structure Stage ***	**COMMENTS (fire scar, charred logs, etc.)**

* Tree Structure Stage = one of the following for live trees : 1 Dominant, 2 Co-dominant, 3 Intermediate, 4 Sub-canopy, or 5 Open Growth

Appendix E. Key to natural vegetation types at BEOL.

Key to Natural Vegetation Types at Bent's Fort National Historic Site
January 2007

1. Prairie dog burrows active or recently active .....**Black-tailed Prairie Dog Town**
1. Prairie dog burrows absent or inactive.....2

2. *Populus deltoides* present, often forming tree canopy (also can occur as saplings or stump sprouts).....3
2. *Populus deltoides* absent.....6

3. *Populus deltoides* occurring with *Salix exigua* in isolated low areas such as ditches or along roads.....4
3. *Populus deltoides* occurs as a tree canopy or shrub layer with a graminoid understory on alluvial terraces of the Arkansas River ....(***Populus deltoides*** **Temporarily Flooded Woodland Alliance**) 5

4. *Populus deltoides* occurring with *Salix exigua*..... ***Salix exigua*** **/ Mesic Graminoids Shrubland**
4. *Populus deltoides* dominant in tree canopy with a variable herbaceous understory not dominated by *Distichlis spicata* and/or *Sporobolus airoides* ....***Populus deltoides*** **Semi-Natural Vegetation**

5. *Populus deltoides* present; *Distichlis spicata* strongly dominant in the understory; *Sporobolus airoides* may or may not be present .....***Populus deltoides* / *Distichlis spicata* Woodland**
5. *Populus deltoides* present; *Sporobolus airoides* strongly dominant in the understory; *Distichlis spicata* may or may not be present .....***Populus deltoides* / *Sporobolus airoides* Woodland**

6. *Salix exigua* dominant often with herbaceous understory, or bare soil or litter .... ***Salix exigua*** **/ Mesic Graminoids Shrubland**
6. *Salix exigua* absent or occurs as isolated individuals 7

7. *Typha latifolia* dominant..... ***Typha (latifolia, angustifolia)*** **Western Herbaceous Vegetation**
7. *Typha latifolia* absent or not dominant.....8

8. *Artemisia filifolia* present with greater than 5% cover and understory is not a mix of *Panicum obtusum* and/or *Sporobolus airoides* .....***Artemisia filifolia / Bouteloua gracilis*** **Shrubland**
8. *Artemisia filifolia* absent or occurring as isolated individuals (<5% cover).....9

9. Vegetation dominated by native grasses.....10
9. Vegetation not dominated by native grasses. Area may be dominated by non-native species and/or mechanically disturbed (mowing, clearing, burning), or with evidence of *Tamarix ramosissima* stumps.....13

10. Vegetation sparse, native species may be dominant, but there is approximately >60% bare ground AND evidence of *Tamarix ramosissima* stumps.....**Disturbed**

10. Not as above, native grasses with >40% cover.....11

11. Grassland dominated by *Sporobolus airoides* and/or *Distichlis spicata* .....
.....***Sporobolus airoides – Distichlis spicata*** **Herbaceous Vegetation**
11. Grassland not dominated by *Distichlis spicata* and/or *Sporobolus airoides*; *Bouteloua gracilis* generally dominant or abundant; often co-occurring with *Buchloe dactyloides, Pascopyrum smithii*, or *Hilaria jamesii*.....12

12. Vegetation dominated by native species; *Buchloe dactyloides* present.....
.....***Bouteloua gracilis – Buchloe dactyloides*** **Herbaceous Vegetation**
12. Vegetation dominated by native species, but has been previously seeded; *Buchloe dactyloides* not present..... .....**Reclaimed Agricultural Land**

13. Area with buildings, roads or railroad .....**Development**
13. Area vegetated and buildings, roads or railroad not present.....**Disturbed**

Appendix F. Local descriptions of the plant associations at BEOL.

Local Descriptions for Bent's Fort National Historic Site
January 2007

ENVIRONMENTAL DESCRIPTION

This shrubland occurs on small rises in the gently undulating ground surface between river terraces and the railroad on the south side of the Arkansas River. Some rises are naturally occurring from successive alluvial and aeolian deposition, while others are anthropogenic berms and spoil piles from historic agricultural activity. Soils are rapidly drained sands and loamy sands with pockets of sandy loam. Bare ground generally predominates with greater than 50% exposed in most places, often up to 80-90%. Some litter is generally present at 10-20% (up to 50% depending on the degree of localized wind protection. Minor amounts of small woody debris occasionally occurs, generally *Artemisia filifolia* dieback.

VEGETATION DESCRIPTION

This sand sage shrubland is characterized by *Artemisia filifolia*. The shrubs are generally robust, growing to 0.5 to 1 meter tall and with an average cover of 25% (ranging from 15-35%). *Atriplex canescens* is an occasional associate in the shrub layer. The herbaceous layer is characterized by graminoids, especially *Bouteloua gracilis*, which occurs at 5-25% cover. *Sporobolus cryptandrus* and *Oryzopsis hymenoides* are common associates. *Sporobolus cryptandrus* can have up to 15% cover while *Oryzopsis hymenoides* generally occurs in trace amounts (<1%). Forbs are generally sparse, although *Eriogonum effusum* can have up to 15% cover. Additional forb species that can occur at the site include *Helianthus petiolaris, Ratibida tagetes*, and *Asclepias subverticillatus*. *Salsola australis* is a common weedy species in these areas.

MOST ABUNDANT SPECIES

Stratum	Species
SHRUB	*Artemisia filifolia*
HERBACEOUS	*Bouteloua gracilis*

CHARACTERISTIC SPECIES

Stratum	Species
SHRUB	*Artemisia filifolia*
HERBACEOUS	*Bouteloua gracilis, Sporobolus cryptandrus*

CLASSIFICATION COMMENTS

These plots are fairly species-poor relative to sand sage systems. Certain areas with *Artemisia filifolia* do not have a grama grass understory; in these areas *Artemisia filifolia* appears to have invaded *Distichlis spicata*-dominated grasslands.

ELEMENT DISTRIBUTION

This shrubland occurs on small rises in the gently undulating ground surface between river terraces and the railroad on the south side of the Arkansas River forming a mosaic with grassland swards. It also occurs on road and railroad rights-of-way and between the railroad and highway 50.

ELEMENT SOURCES

Bent's Fort National Historic Site Inventory Notes: BEOL: 114, 120, 121
Authors: S. Neid

ENVIRONMENTAL DESCRIPTION

This association occupies high terraces above the fort, well above the current floodplain of the Arkansas River. It occurs on poorly-drained silty clay soils. Litter generally covers approximately 40-60% of the ground surface, the remainder exhibiting bare soil. There is frequent evidence of animal activity including burrows, ant mounds, and livestock grazing.

VEGETATION DESCRIPTION

This variable association has been augmented by seeding activities at the site. *Bouteloua gracilis, Buchloe dactyloides*, and *Sporobolus cryptandrus* form a mixed mosaic where any one of the species is dominant in a given patch. *Bouteloua gracilis* is constant and abundant throughout, ranging from 5-35% cover. *Buchloe dactyloides* is codominant and can form large swards where it is dominant; its cover ranges from 1-50%. Common associated species include *Aristida purpurea, Pascopyrum smithii,* and *Hilaria jamesii*; these are less frequent and have variable cover throughout. Forbs are sparse to absent. Where present, trace amounts of *Opuntia phaeacantha* and *Cryptantha minima* occur sporadically. Weedy species are ubiquitously present, sometimes forming relatively large patches, including *Convolvulus arvensis, Salsola australis, Kochia scoparia*, and *Bromus tectorum*. Occasional individuals of *Atriplex canescens* or *Chrysothamnus nauseosus* dot the area.

MOST ABUNDANT SPECIES

Stratum	Species
HERBACEOUS	*Bouteloua gracilis, Buchloe dactyloides, Sporobolus cryptandrus*

CHARACTERISTIC SPECIES

Stratum	Species
HERBACEOUS	*Bouteloua gracilis, Buchloe dactyloides, Sporobolus cryptandrus*

CLASSIFICATION COMMENTS

These plots and adjacent areas have been seeded with graminoids in restoration activities, reclaiming the land from agriculture; they are possibly non-natural vegetation.

Internal Comments: The area within the park north of the Arkansas River and near the building infrastructure has the characteristics of shortgrass prairie as the potential natural vegetation. However, it has seen a long history of anthropogenic use since establishment of the fort and has recently been subject to series of seeding operations with various seed mixes.

ELEMENT DISTRIBUTION

This association occupies high terraces between the fort and the administration and recreation buildings, well above the current floodplain of the Arkansas River. It also forms small patches on the south side of the river in a mosaic with other grasslands and *Artemisia filifolia* shrublands.

Bent's Fort National Historic Site Inventory Notes: BEOL: 109, 110, 111, 112
Authors: S. Neid

CEGL000939—*Populus deltoides / Distichlis spicata* Woodland

Plains Cottonwood / Inland Saltgrass Woodland

ENVIRONMENTAL DESCRIPTION

This association occurs on alluvial terraces above the seasonal deposition zone along the immediate riverbanks. Soil textures on these terraces are a mosaic of silty clay and loamy sand, often in alternating bands that reflect the depositional environment. Leaf litter is common and abundant, usually exceeding 75% ground cover. Coarse woody debris is also present at 5-10% cover. There is generally about 5-10% bare soil.

VEGETATION DESCRIPTION

This cottonwood woodland is characterized by *Populus deltoides*. Cover of *Populus deltoides* is variable but is generally between 5-15% although the canopy cover is denser in places as well as absent in certain plots. The woodland at the site has variable maturity of individuals due to recent disturbances (fire, flooding); some areas have an intact canopy, whereas mature canopy trees are dying back or dead in other areas. Where dieback is present, regeneration is occurring with vigorous stump sprouts and sapling copses. The graminoid understory is strongly dominated by *Distichlis spicata*, ranging from 35-85% cover. Common graminoid associates include *Sporobolus airoides* (1-15%), *Panicum obtusum* (1-5%), *Pascopyrum smithii* (1-5%), *Elymus canadensis* (<1-5%), and *Sporobolus cryptandrus* (<1-5%); these can occur in locally dense patches, although *Distichlis spicata* is generally present and dominant in the vicinity. Forbs are generally sparse and have low abundance. Species that commonly occur include *Physalis virginiana, Ambrosia psilostachya, Asclepias subverticillata, Ratibida tagetes, Glycyrrhiza lepidota*, and *Helianthus petiolaris* among others. Invasive weedy species are prevalent in the surrounding area in this woodland, including *Tamarix ramosissima, Kochia scoparia, Cardaria chalapensis, Salsola australis,* and *Descurainia spp.* Weed management activities and subsequent natural disturbances have left disturbed patches often dominated by *Kochia scoparia* or by bare ground.

MOST ABUNDANT SPECIES

Stratum	Species
TREE CANOPY	*Populus deltoides*
SHRUB	*Populus deltoides*
HERBACEOUS	*Distichlis spicata*

CHARACTERISTIC SPECIES

Stratum	Species
TREE CANOPY	*Populus deltoides*
HERBACEOUS	*Distichlis spicata, Sporobolus airoides, Panicum obtusum, Muhlenbergia asperifolia*

OTHER NOTEWORTHY SPECIES

Stratum	Species
SHRUB	*Baccharis salicina*

CLASSIFICATION COMMENTS

Species composition of the understory is identical to that of *Populus deltoides / Sporobolus airoides* plots; the difference being which grass species is dominant.

ELEMENT DISTRIBUTION

This cottonwood woodland occurs on terraces on the inside bends of the Arkansas River within the site, forming a mosaic with *Populus deltoides / Sporobolus airoides* Woodland.

ELEMENT SOURCES

Bent's Fort National Historic Site Inventory Notes: BEOL: 101, 106, 117, 124, [102]
Authors: S. Neid

ENVIRONMENTAL DESCRIPTION

This association occurs on alluvial terraces above the seasonal deposition area along the immediate riverbanks. Soil textures on these terraces are a mosaic of silty clay, silty clay loam, and sand, often in alternating bands that reflect the depositional environment. Leaf litter is common and abundant, generally comprising 50-60% of the ground cover. Coarse woody debris is also present at 1-10% cover. There is generally about 40-50% bare soil.

VEGETATION DESCRIPTION

This cottonwood woodland is characterized by *Populus deltoides*. Cover of *Populus deltoides* is variable but is generally between 5-15% although the canopy cover is denser in places and absent in some plots. The woodland at the site has variable maturity of individuals due to recent disturbances (fire, flooding); some areas have an intact canopy, whereas mature canopy trees are dying back or dead in other areas. Where dieback is present, regeneration is occurring with vigorous stump sprouts and sapling copses. In addition to *Populus deltoides* saplings, additional shrubs occasionally occur, including *Salix exigua* and *Baccharis salicina*. The graminoid understory is strongly dominated by *Sporobolus airoides*, ranging from 35-45% cover. Common graminoid associates include *Distichlis spicata* (1-5%), *Panicum obtusum* (1-5%), *Pascopyrum smithii* (1-5%) and *Buchloe dactyloides* (<1-5%). Forbs are generally sparse and have low abundance. Species that commonly occur include *Ambrosia psilostachya, Asclepias subverticillata, Ratibida tagetes, Glycyrrhiza lepidota*, and *Gaura parvifolia* among others. Invasive weedy species are prevalent in the surrounding area in this woodland, including *Tamarix ramosissima, Kochia scoparia, Cardaria chalapensis, Salsola australis,* and *Descurainia spp.* Weed management activities and subsequent natural disturbances have left disturbed patches often dominated by *Kochia scoparia* or by bare ground.

MOST ABUNDANT SPECIES

Stratum	Species
TREE CANOPY	*Populus deltoides*
SHRUB	*Populus deltoides*
HERBACEOUS	*Sporobolus airoides*

CHARACTERISTIC SPECIES

Stratum	Species
TREE CANOPY	*Populus deltoides*
HERBACEOUS	*Sporobolus airoides, Distichlis spicata*

OTHER NOTEWORTHY SPECIES

Stratum	Species
SHRUB	*Tamarix ramosissima*

CLASSIFICATION COMMENTS

Species composition of the understory is identical to that of *Populus deltoides / Distichlis spicata* plots; the difference being which grass species is dominant.

ELEMENT DISTRIBUTION

This cottonwood woodland occurs on terraces on the inside bends of the Arkansas River within the site, forming a mosaic with *Populus deltoides / Distichlis spicata* Woodland.

ELEMENT SOURCES

Bent's Fort National Historic Site Inventory Notes: BEOL: 108, 122, 123
Authors: S. Neid

ENVIRONMENTAL DESCRIPTION

This association lines the majority of the banks of the Arkansas River through the site. It occurs in wider swaths on intermittently and seasonally flooded sand bars, point bars, and the inside bends of the river. Soil texture are generally sandy clay loams or silty clay loams, but the association also occurs on sand. Litter is generally prevalent, covering 70-90% of the ground surface, although it is nearly absent in some areas depending on recent flood events.

VEGETATION DESCRIPTION

Salix exigua strongly dominates this association forming dense stands that are 1.5-2 m in height. The dense shrub layer often shades out the understory, which tends to be sparse and variable. Where present, the understory can contain *Apocynum cannibinum, Glycyrrhiza lepidota, Euthamia* spp., *Ambrosia psilostachya*, and *Carex* spp. Along the river edge, emergent vegetation tends to occur, like *Typha angustifolia, Phragmites australis, Phalaris arundinacea*, and *Carex praegracilis*. Weedy species occur sporadically in the association, often in locally dense patches, including *Cardaria chalapensis, Dipsacus fullonum*, and *Kochia scoparia*. *Salsola australis* tumbleweeds can form dense tangles depending on recent flood events.

MOST ABUNDANT SPECIES

Stratum	Species
SHRUB	*Salix exigua*

CHARACTERISTIC SPECIES

Stratum	Species
SHRUB	*Salix exigua*

OTHER NOTEWORTHY SPECIES

Stratum	Species
SHRUB	*Baccharis salicina, Tamarix ramosissima*
HERBACEOUS	*Phragmites australis*

CLASSIFICATION COMMENTS

Some areas within the site tend toward *Salix exigua* / Bare Ground Shrubland, especially on newly forming sand bars.

Internal Comments: There is a small area with *Salix exigua* on the high terrace on the north side of the Arkansas River between the *Populus deltoides* woodland and the *Typha* marsh. It occurs with *Populus deltoides* saplings in the midst of an expanse of *Distichlis spicata* grassland.

ELEMENT DISTRIBUTION

This willow shrubland occurs along the banks of the Arkansas River and in old oxbow channels.

ELEMENT SOURCES

Bent's Fort National Historic Site Inventory Notes: BEOL: 105, 107, 116
Authors: S. Neid

ENVIRONMENTAL DESCRIPTION

This association occurs on high alluvial terraces above the *Populus deltoides* woodland adjacent to the river; they are removed from seasonal flooding. It occurs on somewhat poorly drained silty clay soils. The ground surface is 70-95% covered by litter with the remainder showing bare soil.

VEGETATION DESCRIPTION

This association is strongly dominated by D*istichlis spicata* and/or *Sporobolus airoides* in monotypic or codominant swards. These grasses form dense hummocks. *Distichlis spicata* is generally the predominant species at the site with cover ranging from 25-45%. *Sporobolus airoides* is usually present and often codominant, ranging from 5-25%; it often has greater cover at the ecotone with other plant associations. Associated species that are characteristic of this grassland include *Muhlenbergia asperifolia* and *Panicum obtusum*, the latter of which can be locally dominant at the site, forming dense swards with up to 50% cover. Additional grasses tend to occur more incidentally and include *Elymus canadensis, Pascopyrum smithii*, and *Bouteloua gracilis*. Forbs are generally not characteristic of this type and tend to be absent or sparse, usually occurring in only trace (<1%) amounts, but can form local patches, especially *Asclepias subverticillata, Helianthus petiolaris, Ambrosia psilostachya*, and *Astragalus bisulcatus*. Additional forbs that may incidentally occur include *Bassia sieversiana, Physalis virginiana, Sphaeralcea coccinea, Ratibida tagetes, Sophora nuttalliana, Symphyotrichum* spp., and *Machaeranthera phytocephala*. Local wet spots within the grassland support inclusions of *Spartina pectinata* or *Bothriochloa laguroides*.

MOST ABUNDANT SPECIES

Stratum	Species
HERBACEOUS	*Distichlis spicata*

CHARACTERISTIC SPECIES

Stratum	Species
HERBACEOUS	*Distichlis spicata, Sporobolus airoides, Muhlenbergia asperifolia, Panicum obtusum*

CLASSIFICATION COMMENTS

Many of these plots clustered with *Populus deltoides / Sporobolus airoides* or *Populus deltoides / Distichlis spicata* plots at higher levels.

ELEMENT DISTRIBUTION

This association occurs on high terraces above the *Populus deltoides* woodland adjacent to the river.

ELEMENT SOURCES

Bent's Fort National Historic Site Inventory Notes: BEOL: 115, 118, 119
Authors: S. Neid

ENVIRONMENTAL DESCRIPTION

This association occurs in saturated to permanently flooded depressions in the landscape on the site. The largest depression is naturally occurring and occupies the north-central area of the site. A small, anthropogenically ponded area occurs within the floodplain southwest of the fort on the north side of the river. Otherwise, small localized stands of emergent vegetation occasionally occur along the river banks. Soil texture is clay in the anthropogenic pond and muck in the naturally occurring marsh areas. Cattail litter is present and abundant. Open water occurs, but varies in depth and extent during the growing season.

VEGETATION DESCRIPTION

This freshwater marsh is strongly dominated by *Typha latifolia*, which typically exhibits 40-65% cover. Infrequent associates include *Schoenoplectus acutus, Schoenoplectus pungens*, and *Schoenoplectus lacustris*. On drier edges of the wetlands, native species like *Gaura parvifolia, Solidago giganetea, Asclepias subverticillata*, and *Glycyrrhiza lepidota* are often abundant as well as weedy species like *Cirsium canadensis, Asclepias speciosa, Dipsacus fullonum, Cardaria chalapensis,* and *Salsola australis*.

MOST ABUNDANT SPECIES

Stratum	Species
HERBACEOUS	*Typha latifolia*

CHARACTERISTIC SPECIES

Stratum	Species
HERBACEOUS	*Typha latifolia, Schoenoplectus acutus*

ELEMENT DISTRIBUTION

This association occurs in saturated to permanently flooded depressions on the site, the largest of which is naturally occurring and occupies the north-central area of the site near the entrance to the park. A small, anthropogenically ponded area occurs within the floodplain southwest of the fort on the north side of the river. Otherwise, small localized stands of emergent vegetation occasionally occur along the river banks.

ELEMENT SOURCES

Bent's Fort National Historic Site Inventory Notes: BEOL: 104, 113
Authors: S. Neid

PARK SPECIALS

Black-tailed Prairie Dog Town
The prairie dog town at Bent's Old Fort occupies an abandoned agricultural field adjacent to the railroad tracks and the road on the east boundary of the site. It is level ground with clay loam soils. The majority of the prairie dog town is strongly dominated by *Convolvulus arvensis*. The town is expanding northward and extends past the road at the gate. In this area there is more diverse vegetation including *Buchloe dactyloides, Sporobolus cryptandrus*, and limited *Sporobolus airoides*. In 2005, there was one prairie dog town in the southeast corner of the site north of the railroad tracks; this colony is expanding north- and westward.

Development
This map unit reflects anthropogenic infrastructure and includes roads, the railroad, powerline corridors, parking areas, park buildings and associated infrastructure, and the historic fort.

Disturbed
This map unit reflects anthropogenic activity outside of development areas. These are often spoil piles of unknown origin and areas dominated by non-native weedy species like *Bassia (=Kochia) scoparia, Cardaria draba, Dipsacus fullonum*, and *Salsola australis*, among others. Many of these areas occur where *Tamarix ramossissimum* reduction and removal efforts occurred.

***Populus deltoides* Semi-Natural Woodland**
Plains Cottonwood Semi-Natural Woodland
This map unit occurs along or near the right-of-way of Highway 194 on the north side of BEOL. *Populus deltoides* and *Salix amygdaloides* form the tree canopy with little understory composition. The history of these stands is unknown, but they have a distinct aerial photo signature that differs from their surroundings.

Reclaimed Agricultural Land
This map unit reflects formerly plowed fields that have been reseeded (drilled) with native grasses (*Buchloe dactyloides, Bouteloua gracilis, Bouteloua curtipendula, Pascopyrum smithii*). It currently occurs between the modern park buildings and the historic fort. The current vegetation composition on the level surface is dominated by *Bouteloua gracilis* with *Pascopyrum smithii, Asclepias subverticillata, Convolvulus arvensis*, and *Physalis* sp. as associated species. *Pascopyrum smithii* drops out toward the south end, which has less vegetation establishment in general and exhibits approximately 50% bare ground.

Appendix G. Accuracy assessment contingency tables for each fuzzy set level of accuracy.

Key to Map Class Codes used in the contingency tables.

Map Class Code	Map Class
1	Development
2	Reclaimed Agriculture Land
3*	Blacktailed Prairie Dog Town Complex
4	*Bouteloua gracilis – Buchloe dactyloides* Herbaceous Vegetation
5	*Distichlis spicata* Herbaceous Vegetation
6	*Sporobolus airoides – Distichlis spicata* Herbaceous Vegetation
7	*Artemisia filifolia / Bouteloua gracilis* Shrubland
8	*Salix exigua* / Mesic Graminoids Shrubland
9	*Populus deltoides* Temporarily Flooded Woodland Alliance
10*	*Populus deltoides / Sporobolus airoides* Woodland
11*	*Populus deltoides / Distichlis spicata* Woodland
12*	*Populus deltoides* Semi-natural Woodland
13	Disturbed
14*	Development
15	*Typha (latifolia, angustifolia)* Western Herbaceous Vegetation

* These classes are not included in fuzzy levels 3 and 4.

Fuzzy Level 5 – Binary Accuracy
Reference data (from AA plots) in columns, Classification data (from map polygons) in rows.

Map Class Code	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	SUM	User's Accuracy
1	4	0	0	0	0	0	0	0	0	0	0	0	1	0	0	5	80%
2	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	5	0%
3	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	100%
4	0	0	1	1	0	0	0	0	0	0	0	0	3	0	0	5	20%
5	0	0	0	0	0	1	0	0	0	0	2	0	2	0	0	5	0%
6	0	0	0	1	0	4	0	0	0	0	0	0	0	0	0	5	80%
7	0	0	0	0	0	0	2	0	0	0	0	0	3	0	0	5	40%
8	0	0	0	0	0	1	0	12	0	1	3	0	2	1	0	20	60%
9	0	0	0	0	0	0	0	0	10	0	1	0	9	0	0	20	50%
10	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0%
11	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	2	0%
12	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	2	0%
13	0	0	0	1	0	1	0	1	0	0	0	0	2	0	0	5	40%
14	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	100%
15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	3	100%
SUM	4	0	2	8	0	7	2	14	10	1	6	1	25	2	3	85	
Producer's Accuracy	100%	Null	50%	13%	Null	57%	100%	86%	100%	0%	0%	0%	8%	50%	100%	Overall Accuracy = 47% Kappa Value = 41%	

Fuzzy Level 4 – Acceptable Accuracy

Reference data (from AA plots) in columns, Classification data (from map polygons) in rows.

Map Class Code	1	2	4	5	6	7	8	9	13	15	SUM	User's Accuracy	+/- 90% Confidence Interval	Map Proportion
1	5	0	0	0	0	0	0	0	0	0	5	100%	0%	0.036
2	0	5	0	0	0	0	0	0	0	0	5	100%	0%	0.069
4	0	0	4	0	0	0	0	0	1	0	5	80%	29%	0.049
5	0	0	0	5	0	0	0	0	0	0	5	100%	0%	0.117
6	0	0	0	0	5	0	0	0	0	0	5	100%	0%	0.168
7	0	0	0	0	0	5	0	0	0	0	5	100%	0%	0.094
8	0	0	0	0	0	0	16	3	1	0	20	80%	15%	0.077
9	0	0	0	0	0	0	0	14	6	0	20	70%	17%	0.278
13	0	0	1	0	1	0	0	0	3	0	5	60%	36%	0.061
15	0	0	0	0	0	0	0	0	0	3	3	100%	0%	0.05
SUM	5	5	5	5	6	5	16	17	11	3	78			
Producer's Accuracy	100%	100%	76%	100%	93%	100%	100%	94%	27%	100%				
+/- 90% Confidence Interval	0%	0%	28%	0%	10%	0%	0%	9%	13%	0%				

Overall Accuracy = 87% (81% - 92%)
Kappa Value = 85%

Fuzzy level 3 – Reasonable Accuracy

Reference data (from AA plots) in columns, Classification data (from map polygons) in rows.

Map Class Code	1	2	4	5	6	7	8	9	13	15	SUM	User's Accuracy	+/- 90% Confidence Interval	Map Proportion
1	5	0	0	0	0	0	0	0	0	0	5	100%	0%	0.036
2	0	5	0	0	0	0	0	0	0	0	5	100%	0%	0.069
4	0	0	5	0	0	0	0	0	0	0	5	100%	0%	0.049
5	0	0	0	5	0	0	0	0	0	0	5	100%	0%	0.117
6	0	0	0	0	5	0	0	0	0	0	5	100%	0%	0.168
7	0	0	0	0	0	5	0	0	0	0	5	100%	0%	0.094
8	0	0	0	0	0	0	16	3	1	0	20	80%	15%	0.077
9	0	0	0	0	0	0	0	17	3	0	20	85%	13%	0.278
13	0	0	1	0	0	0	0	0	4	0	5	80%	29%	0.061
15	0	0	0	0	0	0	0	0	0	3	3	100%	0%	0.05
SUM	5	5	6	5	5	5	16	20	8	3	78			
Producer's Accuracy	100%	100%	80%	100%	100%	100%	100%	95%	52%	100%				
+/- 90% Confidence Interval	0%	0%	24%	0%	0%	0%	0%	7%	21%	0%				

Overall Accuracy = 93% (89%-98%)
Kappa Value = 92%

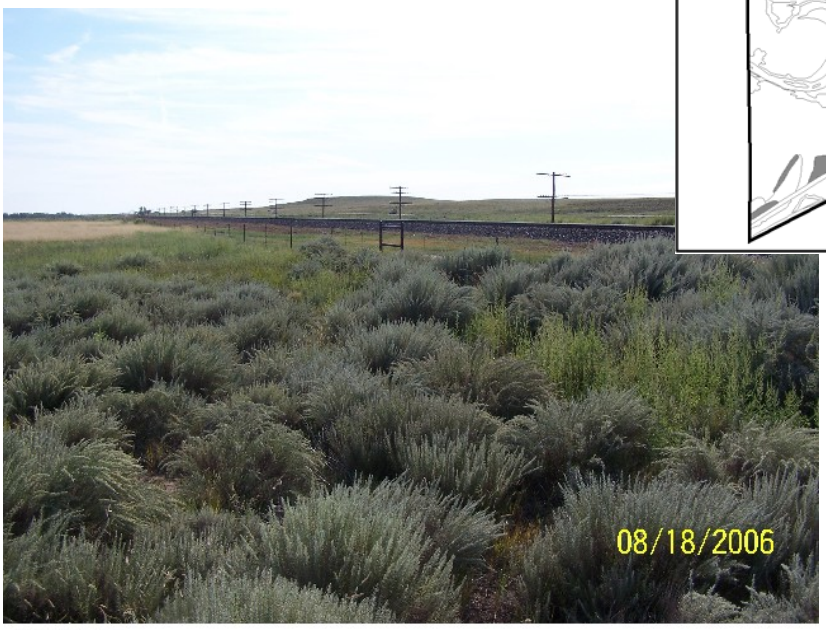
Appendix H. Photo interpretation mapping conventions and visual guide to the map classes.

Description : This type occurs in small, isolated areas on the south side of the Arkansas River. It was mapped from GPS tracks around the small patches. The aerial photo signature is a relatively rough grayish green. The small size of the polygons obscure the signature in some areas where the polygons were mapped from field observations.

Total number of polygons	Minimum area acres (ha)	Maximum area acres (ha)	Mean area acres (ha)	Total area acres (ha)
11	0.59 (0.24)	20.84 (8.43)	4.00 (1.62)	43.99 (17.80)

Common Species:

Artemisia filifolia
Bouteloua gracilis
Sporobolus cryptandrus

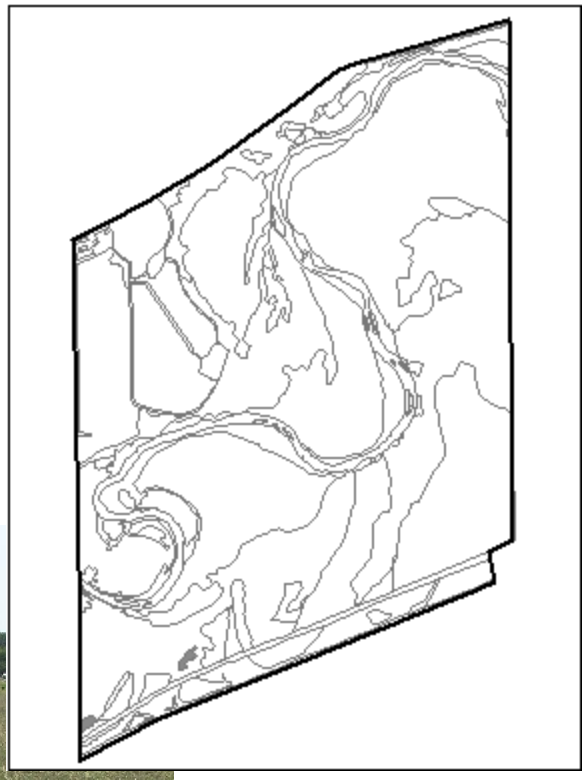


Description : This shortgrass grassland type occurs in small patches on the south side of the Arkansas River. It was mapped using GPS tracks and appears as light tan and light brown on aerial photos.

Total number of polygons	Minimum area acres (ha)	Maximum area acres (ha)	Mean area acres (ha)	Total area acres (ha)
3	0.07 (0.03)	0.58 (0.23)	0.39 (0.16)	1.16 (0.47)

CommonSpecies:

Bouteloua gracilis
Buchloe dactyloides
Sporobolus cryptandrus



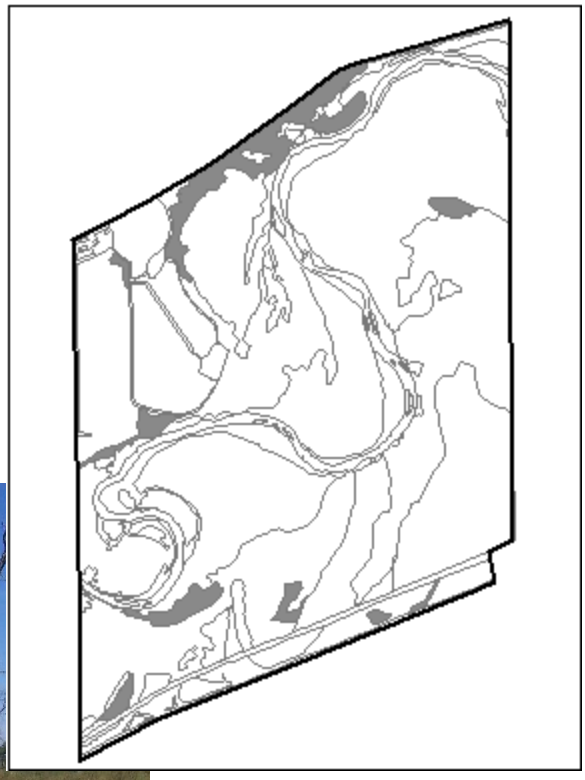
	Disturbed
Park Special	Disturbed

Description : This map class is variable in composition and aerial photo signature, but comprises areas dominated by various proportions of non-native species. Aerial photo signature ranges from dark green where there is more dense stands of *Bassia (=Kochia) scoparia, Cardaria draba,* or *Salsola australis* to tan signatures where there is bare ground following tamarisk removal treatment.

Total number of polygons	Minimum area acres (ha)	Maximum area acres (ha)	Mean area acres (ha)	Total area acres (ha)
9	0.60 (0.24)	24.18 (9.78)	4.66 (1.88)	41.90 (16.96)

Common Species:

Bassia scoparia
Cardaria draba
Dipsacus fullonum
Salsola australis

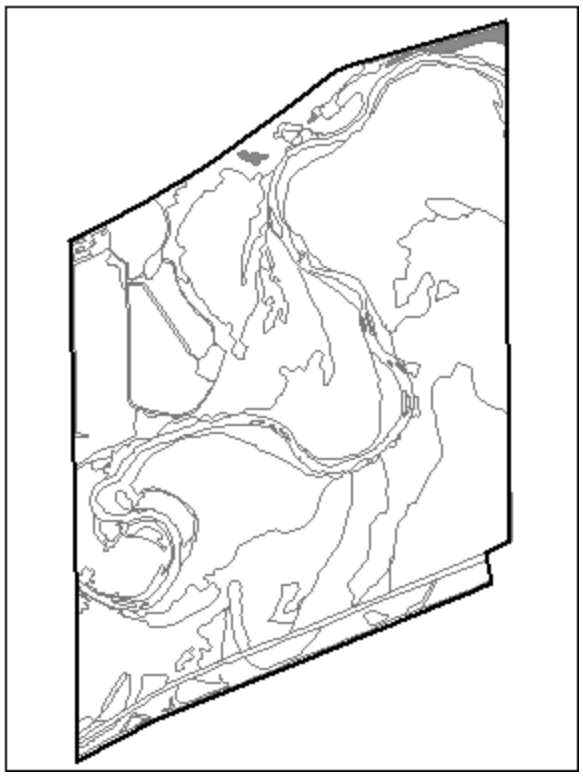


Description : This type occurs along roads on the north side of the Arkansas River. The aerial photo signature is that of dense tree canopy of *Populus deltoides* or *Salix amygdaloides*.

Total number of polygons	Minimum area acres (ha)	Maximum area acres (ha)	Mean area acres (ha)	Total area acres (ha)
3	0.15 (0.06)	3.28 (1.33)	1.39 (0.56)	4.16 (1.68)

Common Species:

Populus deltoides
Salix amygdaloides



A636	*Populus deltoides* Temporarily Flooded Woodland Alliance
NVC Alliance	Plains Cottonwood Temporarily Flooded Woodland Alliance

Including associations:

CEGL005977	*Populus deltoides / Sporobolus airoides* Woodland
NVC Association	Plains Cottonwood / Alkali Sacaton Woodland
CEGL000939	*Populus deltoides / Distichlis spicata* Woodland
NVC Association	Plains Cottonwood / Inland Saltgrass Woodland

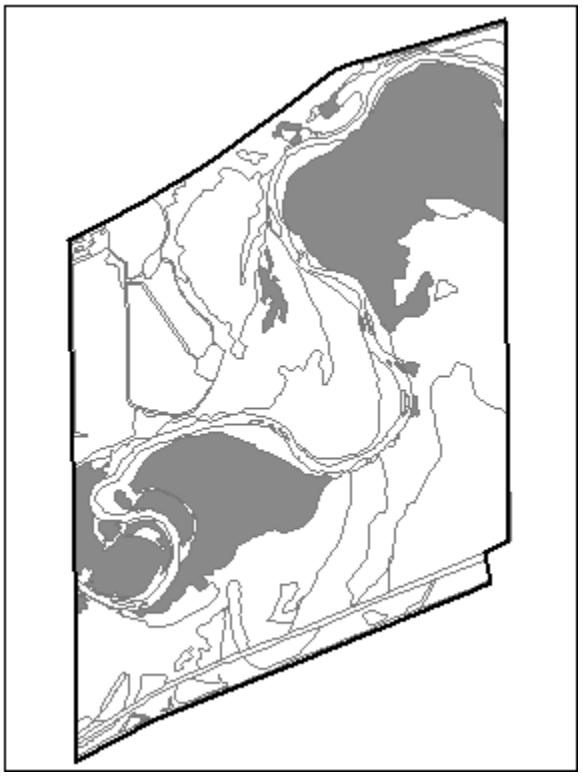
Description : This type is a riparian woodland alliance that occurs along the Arkansas River. The aerial photo signature shows dark green trees (*Populus deltoides*). Polygons were identified as areas with minimally 25% cover of *P. deltoides* in any strata. Following the multiple disturbances experienced at the site, root-suckering is prevalent in many areas, which is not visible on aerial photographs. Small- to moderate-sized areas of dark green are present throughout this type and largely reflect small patches of non-native species.

Total number of polygons	Minimum area acres (ha)	Maximum area acres (ha)	Mean area acres (ha)	Total area acres (ha)
Populus deltoides Temporarily Flooded Woodland Alliance				
12	0.18 (0.07)	107.21 (43.39)	13.17 (6.54)	193.99 (78.55)
Populus deltoides / Distichlis spicata Woodland				
1	39.52 (15.99)	39.52 (15.99)	39.52 (15.99)	39.52 (15.99)

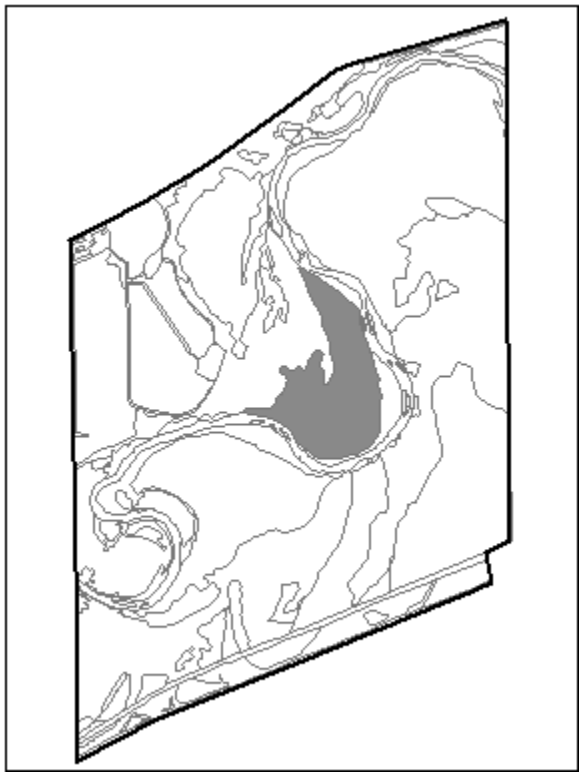
Common Species:

Populus deltoides
Sporobolus airoides
Distichlis spicata
Panicum obtusum
Muhlenbergia asperifolia
Kochia scoparia

Populus deltoides Temporarily Woodland Flooded Woodland Alliance



Populus deltoides / Distichlis spicata Woodland

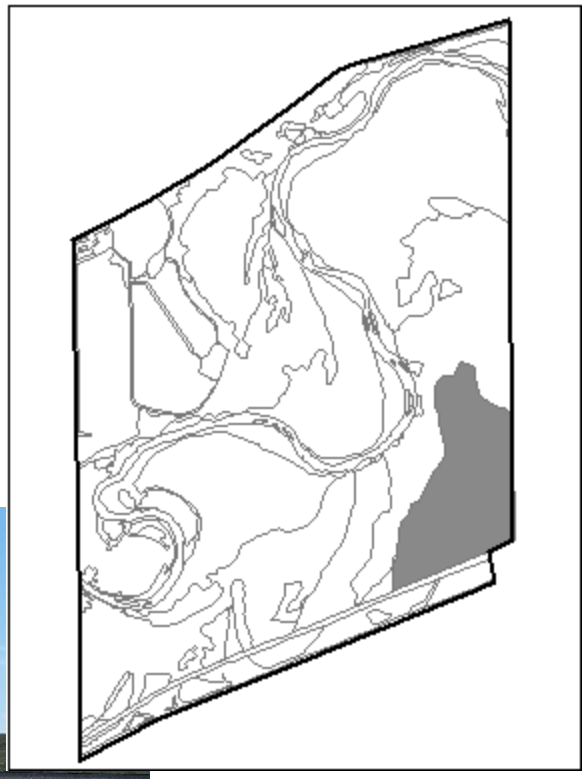


Description : This type occurs in the southeast corner of the site on level ground and was mapped from field observations. The aerial photo signature is a mix of brownish green of *Convolvulus arvensis* and light tan where there is a high proportion of bare ground. White dots of burrows are visible on aerial photographs.

Total number of polygons	Minimum area acres (ha)	Maximum area acres (ha)	Mean area acres (ha)	Total area acres (ha)
1	54.12 (21.90)	54.12 (21.90)	54.12 (21.90)	54.12 (21.90)

Common Species:

Convulvulus arvensis
Buchloe dactyloides
Sporobolus cryptandrus
Sporobolus airoides



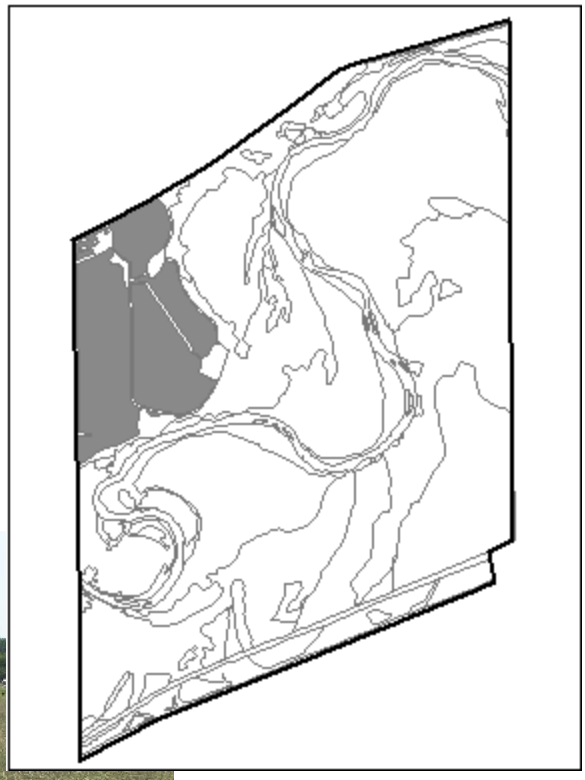
BEOL AA 03 E
13 N 0638566 4210745 08/18/2006 10:09:55 AM

Description : This type occurs primarily in the northwest corner near the park headquarters buildings. It was mapped from park staff descriptions of management activities. The aerial photo signature is grayish tan to brownish green (where the soils are more mesic).

Total number of polygons	Minimum area acres (ha)	Maximum area acres (ha)	Mean area acres (ha)	Total area acres (ha)
6	0.20 (0.08)	34.20 (13.84)	12.89 (5.22)	77.37 (31.31)

Common Species:

Bouteloua gracilis
Buchloe dactyloides
Sporobolus cryptandrus

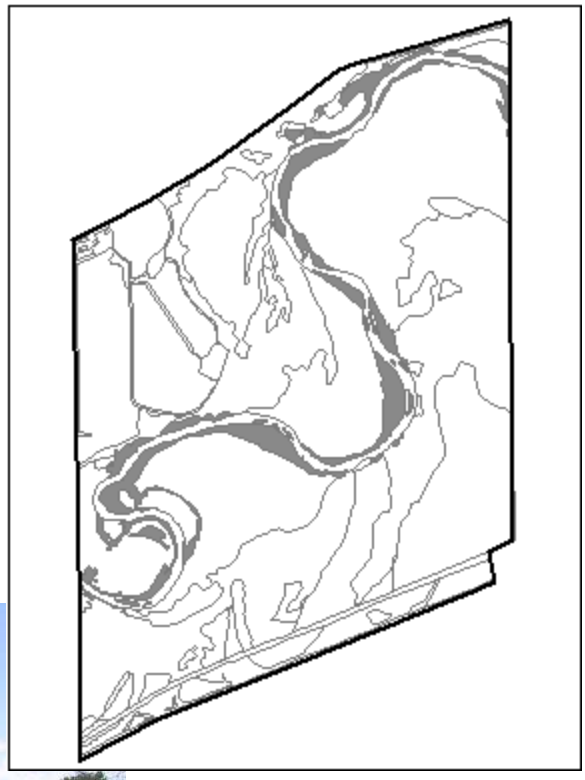


Description : This riparian shrubland primarily occurs along the Arkansas River on the riverbanks and on sand bars. The aerial photo signature is a smooth, vibrant green.

Total number of polygons	Minimum area acres (ha)	Maximum area acres (ha)	Mean area acres (ha)	Total area acres (ha)
32	0.02 (0.01)	12.50 (5.06)	1.49 (0.60)	47.77 (19.33)

Common Species:

Artemisia filifolia
Bouteloua gracilis
Sporobolus cryptandrus



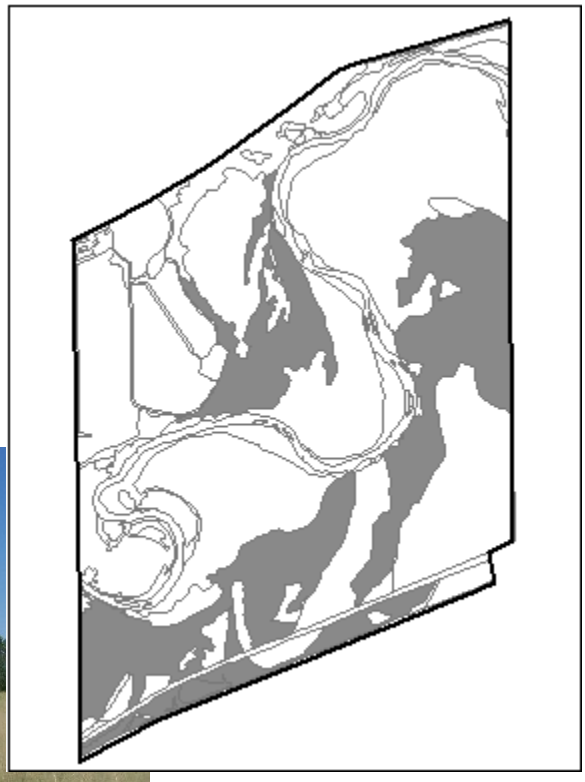
BEOL 107 S
13 N 0637642 4210825 08/18/2005

Description : This type occurs behind the cottonwood gallery on the floodplain as you proceed away from the river. It is a mosaic of the nominal graminoid species. The aerial photo signature is treeless and ranges in color between light grayish tan (where there is more *Sporobolus airoides*) to mottled grayish green and green (where there is more *Distichlis spicata*). Small areas of dark green are present throughout this type and largely reflect small patches of non-native species.

Total number of polygons	Minimum area acres (ha)	Maximum area acres (ha)	Mean area acres (ha)	Total area acres (ha)
9	0.08 (0.03)	78.01 (31.57)	22.86 (9.25)	205.72 (83.25)

Common Species:

Distichlis spicata
Sporobolus airoides
Muhlenbergia asperifolia
Panicum obtusum

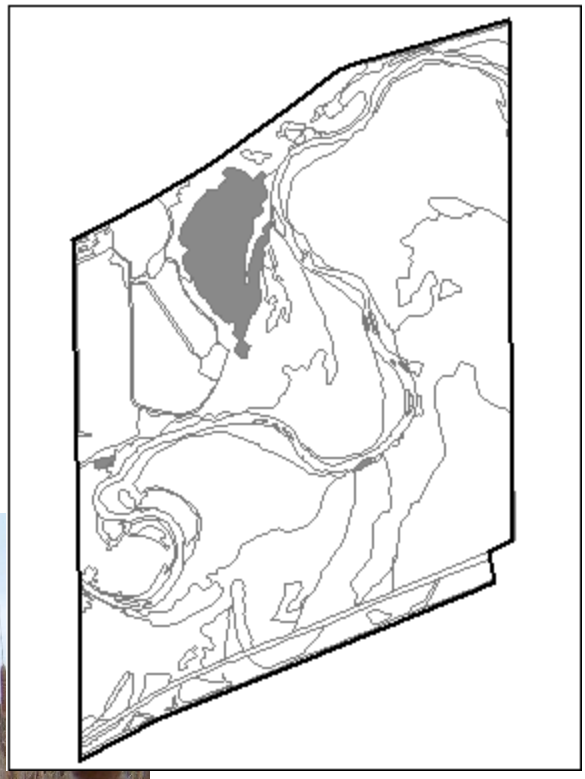


Description : This type occurs in jurisdictional wetlands on the site and was mapped from aerial photo signatures and field observations. The large marsh in the north-central portion of the site has a greenish black aerial photo signature. The smaller, man-made pool on the north side of the river is dark green on aerial photos.

Total number of polygons	Minimum area acres (ha)	Maximum area acres (ha)	Mean area acres (ha)	Total area acres (ha)
3	0.34 (0.14)	32.40 (13.11)	11.09 (4.49)	33.27 (13.46)

Common Species:

Typha latifolia



The Department of the Interior protects and manages the nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its special responsibilities to American Indians, Alaska Natives, and affiliated Island Communities.

NPS D-81, March 2007

National Park Service
U.S. Department of the Interior

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