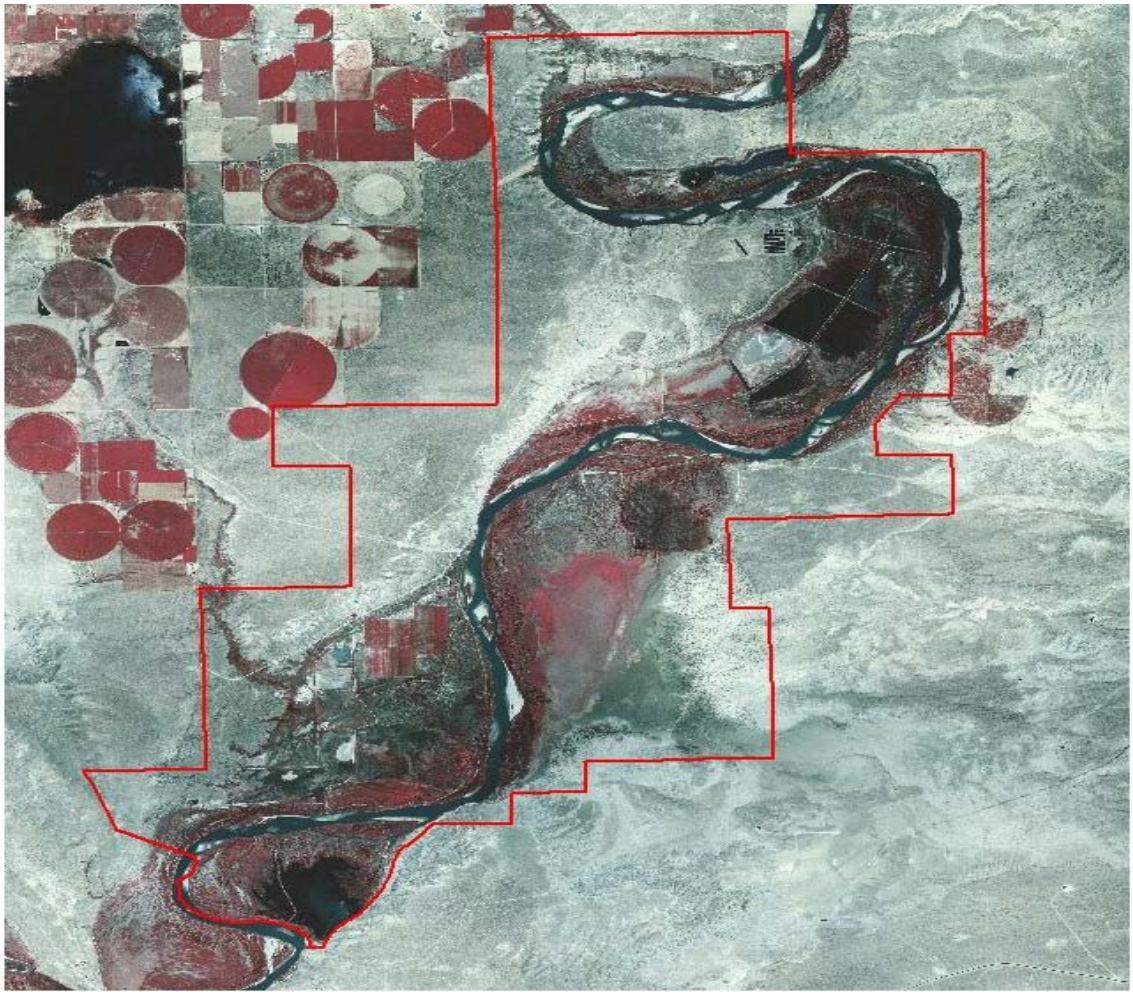
Ouray National Wildlife Refuge, Utah
2000-2001 VEGETATION MAPPING PROJECT



FINAL REPORT MARCH 31, 2002

Technical Memorandum 8260-02-03
Remote Sensing and GIS Group
Technical Service Center
Bureau of Reclamation
Denver, CO

RECLAMATION'S MISSION

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

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The Remote Sensing and Geographic Information Group, organized in 1975, provides assistance and advice regarding the application of remote sensing and geographic information systems (GIS) technologies to meet the spatial information needs of the Bureau of Reclamation and other governmental clients.

This report was prepared for the U.S. Fish and Wildlife Service's Mountain-Prairie Region (Region 6) and the U.S. Geological Survey's Center for Biological Informatics by the Remote Sensing and GIS Group of the Bureau of Reclamation's Technical Service Center, Denver, CO as Technical Memorandum No. 8260-02-03.

USGS-USFWS VEGETATION MAPPING PROGRAM

Ouray National Wildlife Refuge, Utah

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Adapting the USGS-NPS Vegetation Mapping Standards to the needs of National Wildlife Refuges required the dedicated and ingenious efforts of many individuals. The staff at ONWR contributed in many ways to the completion of the project and this report. They helped with the initial organization and provided experts for fieldwork. They also reviewed the draft vegetation maps and vegetation classification, their valuable comments improving the consistency and usefulness of both. NatureServe helped complete the vegetation descriptions, while the USGS Center for Biological Informatics and the Region 6 office of USFWS provided overall program coordination. Special thanks goes to Jim Von Loh who started and performed most of the work on this project (and took the ground photographs) but who has since moved on to other endeavors. After departure, he continued to support the project by reviewing this report.

A heartfelt thank you goes to these dedicated individuals for helping to make this project a success:

- Wayne King and Jaymee Fojtik of USFWS Region 6 for having the foresight to get this project started and the patience and perseverance to see it through
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- Tom Owens of the USGS Center for Biological Informatics for helping to coordinate all aspects of the project and lending expertise at many stages
- The entire staff of BOR RSGIS (both past and present) for so many things.

LIST OF ABBREVIATIONS AND ACRONYMS

AA Accuracy Assessment
AML Arc Macro Language
BOR Bureau of Reclamation (also USBR)
BRD Biological Resource Division (of the USGS)
CBI Center for Biological Informatics (of the USGS/BRD)
CIR Color Infrared Photography
DEM Digital Elevation Model
DLG Digital Line Graph
DRG Digital Raster Graphic
DOP Digital Orthophoto
FGDC Federal Geographic Data Committee
USFWS Fish And Wildlife Service
GIS Geographic Information System(s)
GPS Global Positioning System
MMU Minimum Mapping Unit
NPS U.S. National Park Service
NAD North American Datum
NBII National Biological Information Infrastructure
NRCS Natural Resources Conservation Service (formerly the Soil Conservation Service)
NVCS National Vegetation Classification System
ONWR Ouray National Wildlife Refuge
PLGR Precision Light-Weight GPS Receiver
RSGIS Remote Sensing And Geographic Information Group
TNC The Nature Conservancy
USBR United States Bureau Of Reclamation (also BOR)
USDA-SCS U.S. Dept. Of Agriculture – Soil Conservation Service
USFS United States Forest Service
USGS United States Geological Survey
UTM Universal Transverse Mercator

EXECUTIVE SUMMARY

The Ouray National Wildlife Refuge (ONWR) was established in 1960 as an inviolate sanctuary for migratory birds and any other management purpose. In 2000, the Refuge published a Comprehensive Conservation Plan in accordance with the 1997 National Wildlife Refuge Improvement Act. The plan shifted the Refuge's emphasis toward ecosystem-based management of all resident and migratory species. Refuge and Regional staff asked that a detailed and accurate vegetation map be developed for planning and for managing the Refuge effectively. The Bureau of Reclamation's Remote Sensing and Geographic Information Group (RSGIS) was contracted by US Fish and Wildlife Service to map vegetation and land-use classes at ONWR using remote sensing and GIS technologies originally developed for the National Park Service's Vegetation Mapping Program.

The diverse vegetation and complicated land-use history of Ouray National Wildlife Refuge presented a unique challenge to mapping vegetation at the plant association level of the US National Vegetation Classification. To meet this challenge, the project consisted of two linked phases: (1) vegetation classification and (2) digital vegetation map production. To classify the vegetation, we sampled representative plots located throughout the 14,025-acre (5676 ha) project area. Analysis of the plot data using ordination and clustering techniques yielded 58 distinct plant associations. To produce the digital map, we used a combination of new color-infrared aerial photography and fieldwork to interpret the complex patterns of vegetation and land-use at ONWR. Eighty-one map units were developed and the vegetation units matched to the corresponding plant associations. The interpreted map data were converted to a GIS database using ArcInfo©. Draft maps created from the vegetation classification were field-tested and revised before an independent ecologist conducted an assessment of the map's accuracy. The accuracy assessment revealed an overall database accuracy of 75.2%.

Products developed for the Ouray National Wildlife Refuge Vegetation Mapping Project include

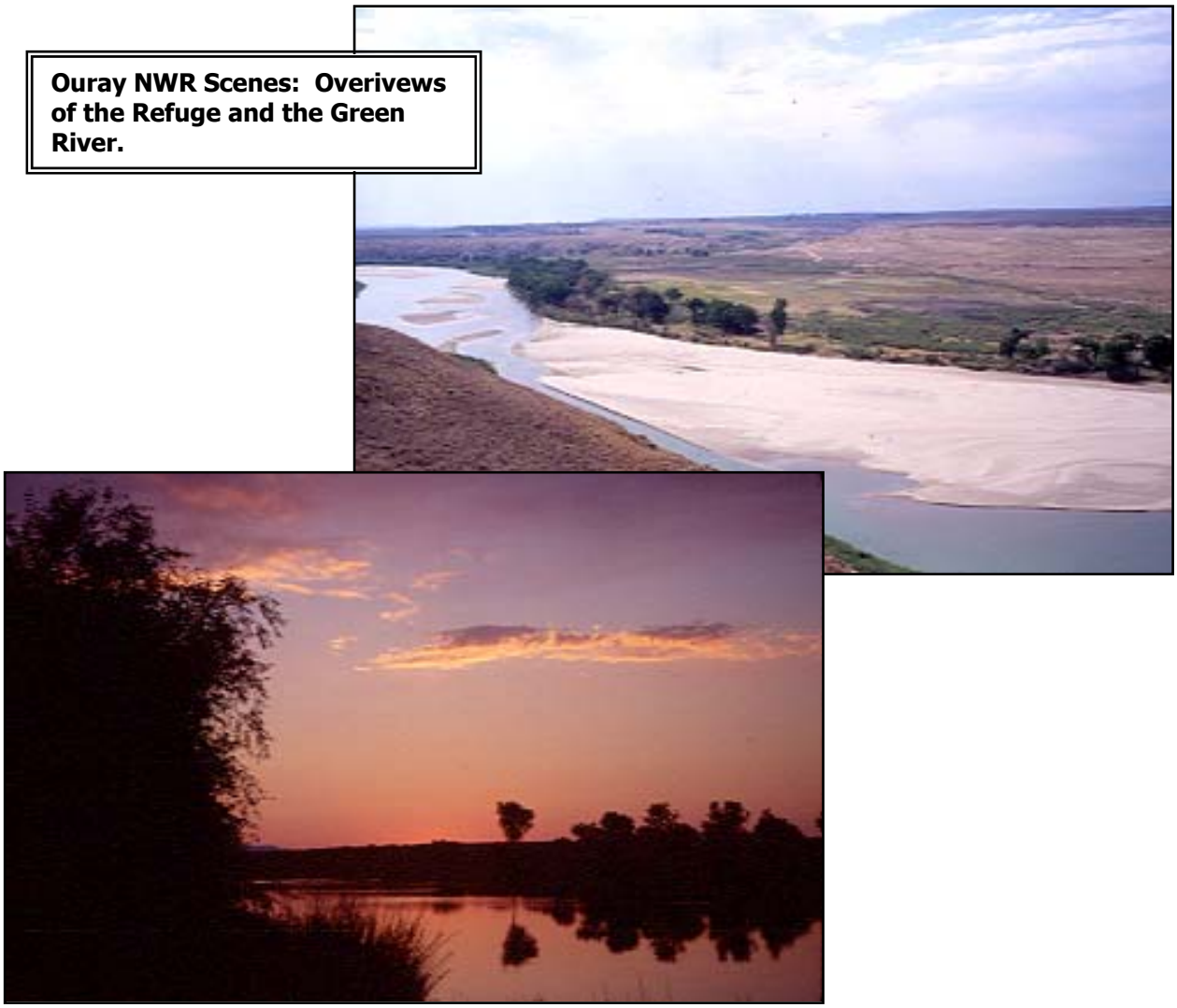
- the final report, vegetation key, map accuracy assessment results and contingency table, and photo interpretation key;
- spatial database coverages of the vegetation map, vegetation plots, accuracy assessment sites, and flight line index;
- digital photos (scanned from 35mm slides) of each vegetation type;
- graphics of all spatial database coverages;
- Federal Geographic Data Committee-compliant metadata for all spatial database coverages and field data.

In addition, the Refuge and USFWS copies of this report contain

- original aerial photographs of the project area;
- digital data files and hard copy data sheets of the observation points, vegetation field plots, and accuracy assessment sites;
- original slides of each vegetation type.

A CD-ROM attached to this report contains text and metadata files, keys, lists, field data, spatial data, the vegetation map, graphics, and ground photos. The USGS will post this project on its website: http://biology.usgs.gov/cbi/bio-char/fws_veg.html. For information on other projects completed by the RSGIS, visit http://www.usbr.gov/pmts/rsgis/.

Ouray NWR Scenes: Overivews of the Refuge and the Green River.



1. INTRODUCTION

This report describes the creation of a vegetation classification and a spatial vegetation database for Ouray National Wildlife Refuge (ONWR) by the Remote Sensing and GIS Group of the Bureau of Reclamation (RSGIS). The objectives of this project were to:

- collect and analyze vegetation data;
- create vegetation and map unit classifications based on the National Vegetation Classification System (NVCS) and Refuge-specific requirements;
- develop a spatial database of ONWR's vegetation, using remote sensing and Geographic Information System (GIS) techniques;
- produce digital and hard copy vegetation maps with a minimum 80% accuracy

1.1 BACKGROUND

The Prairie-Mountain Region of the USFWS has made a priority of obtaining accurate vegetation data in order to improve Refuge capacity for inventory, planning and management. The USGS-NPS Vegetation Mapping Program (URL: http://biology.usgs.gov/npsveg) was selected as the operating model and ONWR was one of two refuges chosen to test the applicability of the model. The USGS-NPS Vegetation Mapping Program uses standard methods and protocols to classify, describe, and map vegetation, but they were developed for use at relatively pristine National Parks. At the beginning of this project no one knew how well USGS-NPS methods would work on the modified and managed vegetation of a National Wildlife Refuge.

In March 2000, the U.S. Fish and Wildlife Service (USFWS) asked the U.S. Bureau of Reclamation's Remote Sensing and Geographic Information Group (RSGIS) to undertake the classification and mapping of vegetation at Ouray National Wildlife Refuge. The USFWS requested that the U.S. Geological Survey's Biological Resources Division, Center for Biological Informatics (CBI) be responsible for overall project coordination and ensuring that the mapping was performed in accordance with USGS-NPS Vegetation Mapping Program protocols and standards (**Appendix A**). The RSGIS submitted a work proposal (**Appendix B**) to CBI and in June 2000, an Interagency Agreement was established between the USFWS, CBI, and RSGIS for this project.

1.2 SCOPE OF WORK

The goal of this project was to describe the vegetation within the executive boundary for Ouray National Wildlife Refuge, including leased lands owned by other entities. Project goals centered around the following products: digital files of the vegetation map and field data, descriptions of and keys to the plant associations, metadata, map accuracy summaries, and aerial photographs. The RSGIS created most of the products and provided day-to-day project coordination. CBI was responsible for general oversight and adherence to the standards and protocols of the USGS-NPS Vegetation Mapping Program. NatureServe was responsible for producing a preliminary vegetation classification and providing global descriptions for the final plant associations.

1.3 OURAY NATIONAL WILDLIFE REFUGE

ONWR executive boundary occupies 14,029 acres (5678 ha) in northeastern Utah, approximately 30 miles south-southwest of Vernal in Uintah County. To access the Refuge, travel west 14 miles (23 km) from Vernal on US Highway 40, then turn south on State Highway 88 and go 17 miles (**Figure 1**). The Refuge includes State and leased Tribal lands as well as private inholdings. Other Federal agencies have minor holdings within the Refuge (**Figure 2**). (U.S. Dept. of Interior 1999)

Climate: ONWR's semiarid climate is characteristic of a cold desert steppe; annual precipitation is 7.09 inches at the Refuge and 8.5 inches (22 cm) in the surrounding Uinta Basin (USDA 1997). The average relative humidity is likewise low. Peak precipitation events typically occur in April-May and September-October, while February is the driest month. Strong winds can occur in the late spring and early summer, while temperature extremes range from a low of -45° F in January to 110° F in July. The growing season extends from May to September for an average of 113 frost-free days (USDA 1959).

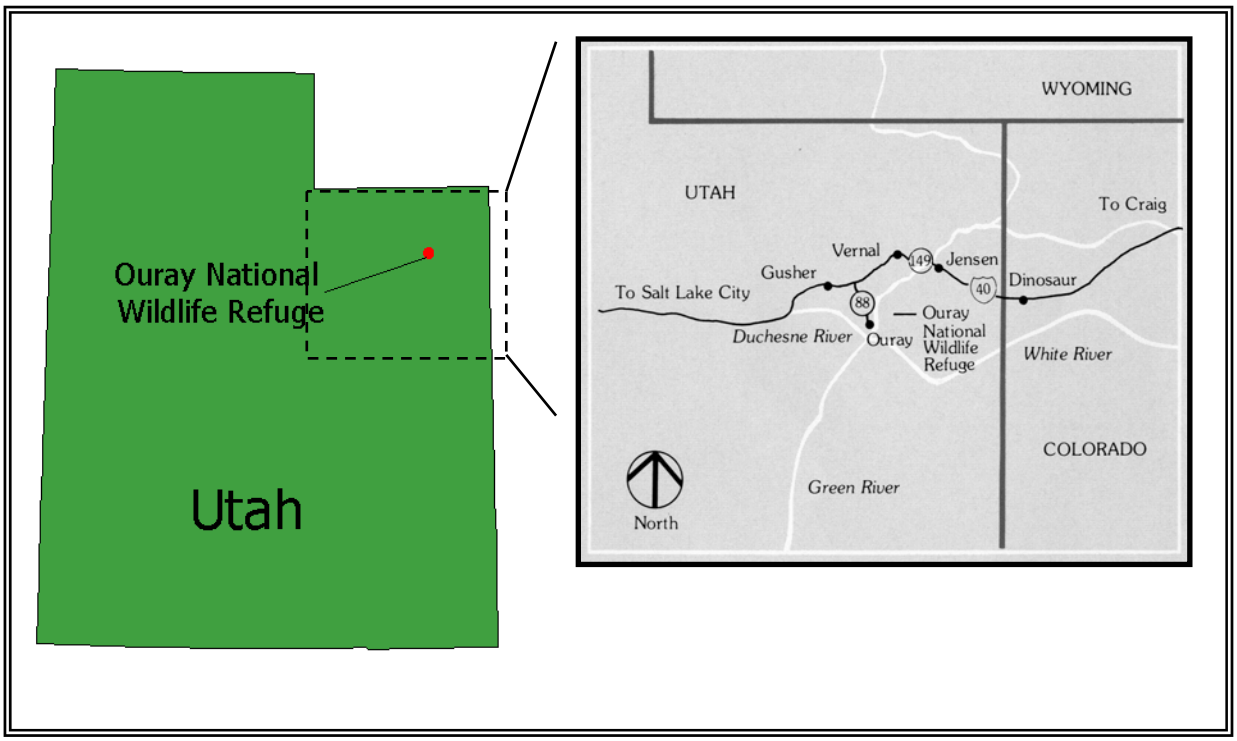


Figure 1. Location of Ouray National Wildlife Refuge in Northeastern Utah.

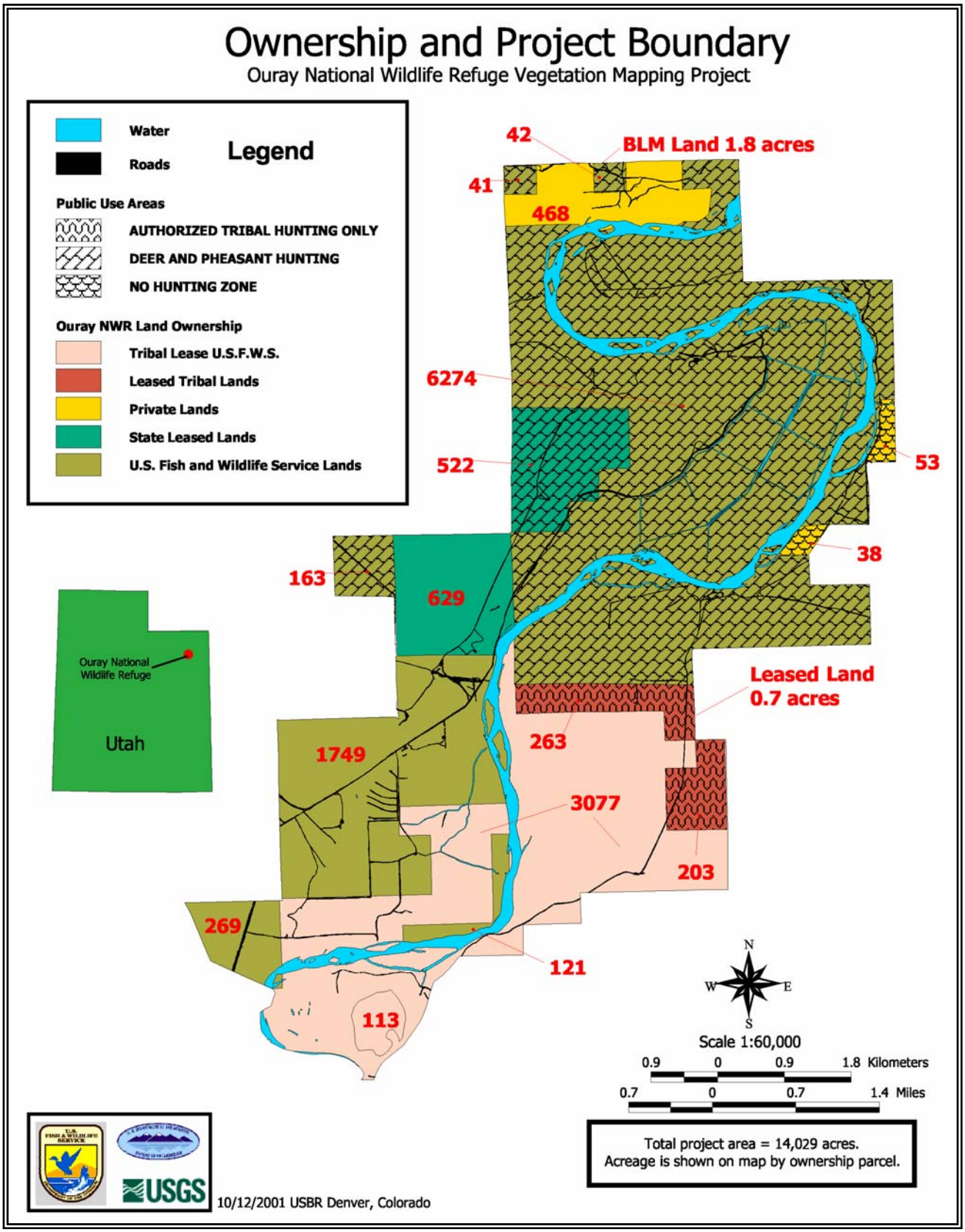


Figure 2. Land Ownership Map for the Ouray National Wildlife Refuge Project Area.

Topography: Ouray National Wildlife Refuge is in the Uinta Basin, which is situated at the northern extreme of the Colorado Plateau physiographic province. To the north lie the Uinta Mountains, the longest east west oriented mountain chain in the Western Hemisphere. To the south lie the bluffs of the East and West Tavaputs plateaus. The Refuge is situated in a broad valley and is bounded by shale bluffs and hills that are the highest points in the Refuge. These high points rise 200 to 300 feet above the surrounding Green River floodplain. The highest point within the Refuge is Leota Bluff (5072 ft/1546 m). The lowest points in the Refuge are associated with the Green River (4670 ft/1423 m at the northern boundary and 4650 ft/1420 m at the southern boundary) (U.S. Dept. of Interior 2000). ONWR topography can be visualized using the shaded relief map in **Figure 3**.

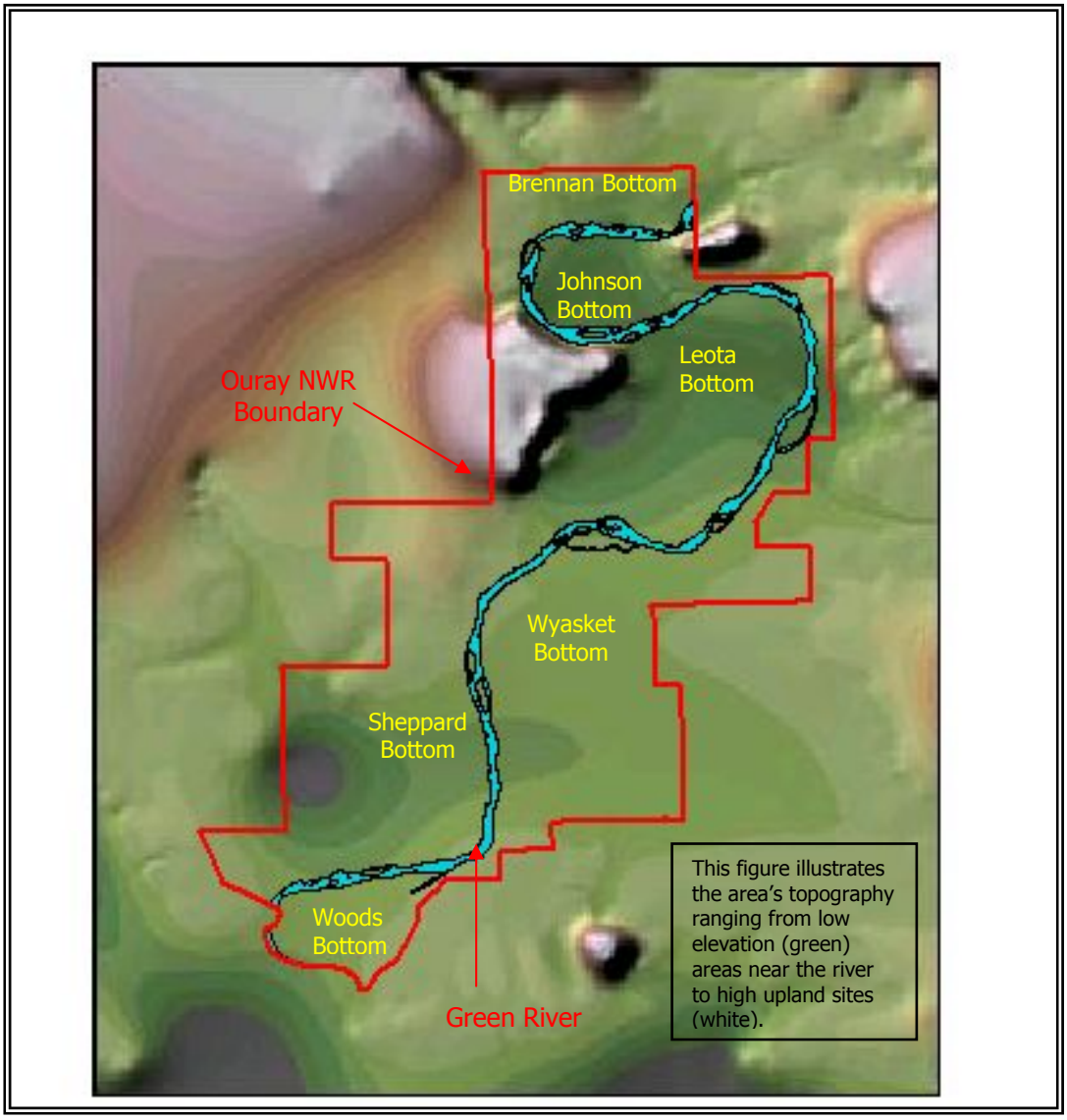


Figure 3. Shaded Relief Map of the Ouray National Wildlife Refuge Project Area.

Hydrology: Ouray National Wildlife Refuge includes 16 miles of the Green River and lies approximately 120 river miles below Flaming Gorge Dam. The river meanders through the Refuge (six 'bottoms' are situated along the river in the Refuge - see **Figure 3**) and runs in a generally southerly direction. The floodplain through the Refuge is more than one mile wide. The Refuge has no natural surface tributaries or groundwater inputs (David Cooper *et al.* 1994).

Vegetation: Much botanical work has been done in the area in and around ONWR yielding a thorough understanding of species composition (Cronquist *et al*. 1972, Folks 1963, and Goodrich and Neese 1986). Based on this knowledge, ONWR's vegetation can ecologically be divided based on plant species common to wetland, riparian, and upland habitats in the Uinta Basin subdivision of the Colorado Plateau physiographic province. The wetlands can further be separated into lacustrine and palustrine systems and uplands split into semi-desert shrubland, grassland, and clay bluff categories. (U.S. Dept. of Interior 2000)

Lacustrine wetlands at ONWR typically contain annual forbs resulting from dam operation or seasonal drawdowns of backwater pools along the Green River. Species composition varies greatly and stands typically have low diversity. Representative species include smartweeds (*Polygonum* spp.), pondweeds (*Potamogeton* spp.), dock (*Rumex* spp.), beggarticks (*Bidens* spp.), red orache (*Atriplex rosea*), and kochia (*Kochia scoparia*).

Palustrine wetlands contain greater species diversity and range from small potholes to oxbow lakes. Emergent species in saturated areas include cattails (*Typha* spp.), spikerushes (*Eleocharis* spp.), bulrushes (*Schoenoplectus* spp.), and rushes (*Juncus* spp.). Herbaceous species occupying adjacent floodplains include witchgrass (*Panicum capillare*), dogbane (*Apocynum cannabinum*), and inland saltgrass (*Distichlis spicata*).

Riparian areas support shrubs and trees as well as rich and diverse herbaceous communities. Shrubland species vary with soil moisture, ranging from willows (*Salix* spp.) and skunkbush sumac (*Rhus trilobata*) on mesic floodplains and point bars to sagebrush (*Artemisia* spp.) and greasewood (*Sarcobatus vermiculatus*) on drier terraces. Riparian trees include Fremont cottonwood (*Populus fremontii*) and peach-leaf willow (*Salix amygdaloides*).

Semi-desert uplands are scattered throughout the Refuge and total approximately 2669 acres (1080 ha). Common species include greasewood, rubber rabbitbrush (*Ericameria nauseosa*), yellow rabbitbrush (*Chrysothamnus viscidiflorus*), spiny hopsage (*Grayia spinosa*), shadscale (*Atriplex confertifolia*), fourwing saltbush (*Atriplex canescens*), winterfat (*Krascheninnikovia lanata*), and sagebrush. Graminoids are usually present and include Indian ricegrass (*Achnatherum hymenoides*), needle-and-thread (*Hesperostipa comata*), sand dropseed (*Sporobolus cryptandrus*), and cheatgrass (*Bromus tectorum*).

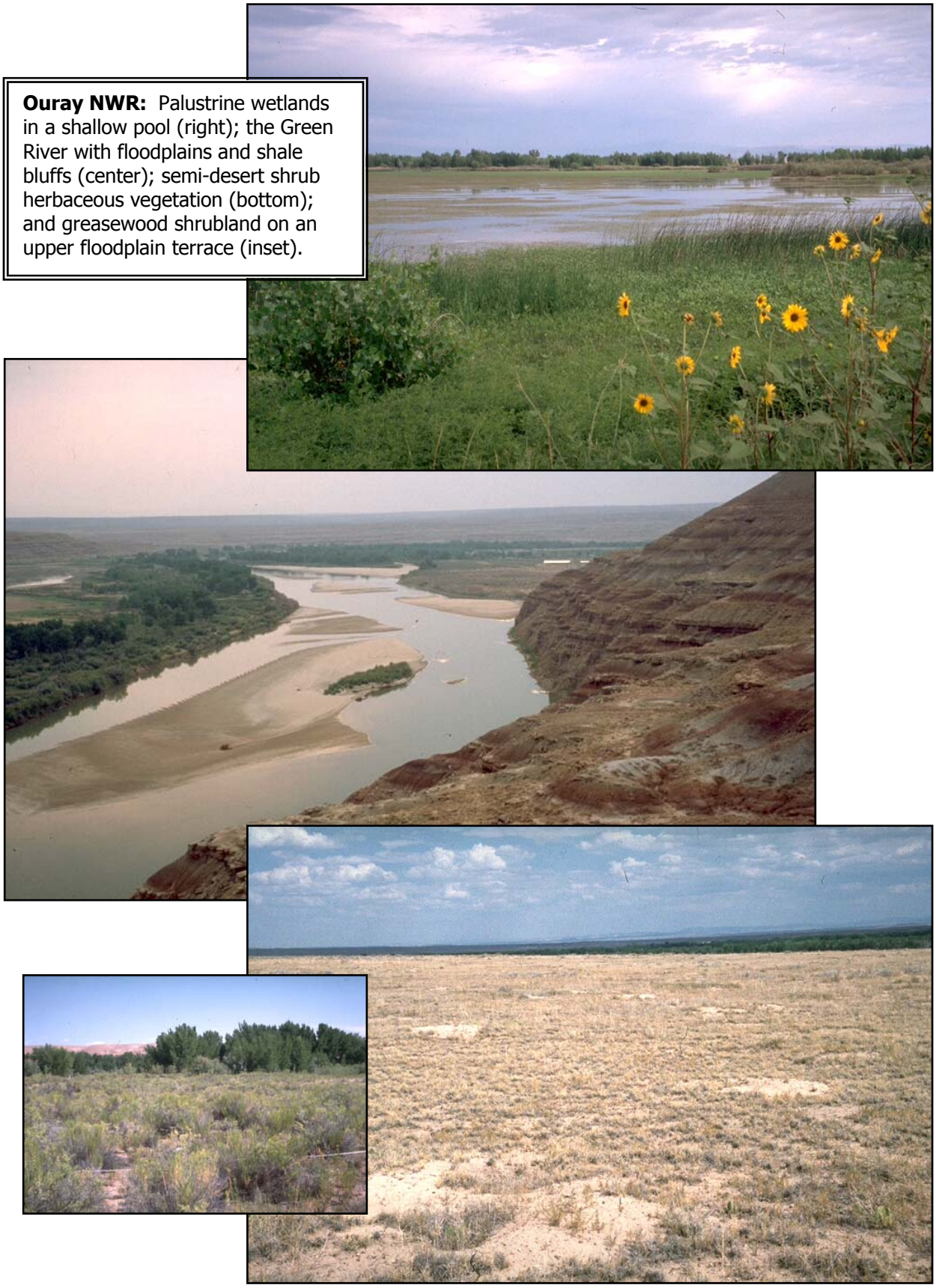
Grasslands are widely distributed throughout he project area and total about 1520 acres (615 ha). Typical grasses are alkali sacaton (*Sporobolus airoides*), western wheatgrass (*Pascopyrum smithii*), wildryes (*Elymus* spp.), and galleta (*Pleuraphis jamesii*). Grasslands typically occur on benches above clay bluffs. Clay bluffs define the outer limits of the Green River floodplain and consist of about 1935 acres (783 ha) of barren slopes. Few plants grow on this harsh terrain; however, scattered individuals of broom snakeweed (*Gutierrezia sarothrae*) and shadscale (*Atriplex confertifolia*) can be found.

Several problematic non-native and invasive plant species are found within the Refuge. These include salt cedar (*Tamarix* spp.), giant whitetop (*Lepidium latifolium*), Russian-olive (*Elaeagnus angustifolia*), and Russian knapweed (*Acroptilon repens*).

Agricultural or semi-natural lands total about 150 acres (61 ha) at ONWR. A cooperative agreement with an adjacent landowner allows for limited production of alfalfa and small grains. These lands provide additional forage for migratory birds and other resident wildlife.

Wildlife: Located along the Green River, Ouray National Wildlife Refuge provides habitat for migrating water birds, and resident fish, mammal, amphibian, and reptile populations. During different times of the year Canada geese, snow geese, mallard, gadwall, northern pintail, American widgeon, green-winged teal, and common merganser all use OWNR as a primary roost. Shorebirds also benefit from the large areas of shallow water along the Green River. These include yellowlegs, willet, and killdeer. Elk, mule deer, moose, and black bear all use the Refuge as a watering site. Common smaller mammals include beaver, river otter, and muskrat. Threatened and endangered fish resident in the Green River include Colorado pikeminnow, razorback sucker, and humpback chub. Non-native fish found in the river include smallmouth bass, channel catfish, and black bullhead (U.S. Dept. of Interior 1999).

Pronghorn antelope at Ouray National Wildlife Refuge.



Ouray NWR: Palustrine wetlands in a shallow pool (right); the Green River with floodplains and shale bluffs (center); semi-desert shrub herbaceous vegetation (bottom); and greasewood shrubland on an upper floodplain terrace (inset).

2. MATERIALS AND METHODS

Based on the overall project scope and the assignment of responsibilities the project was divided into six major steps following the USGS flowchart (**Appendix A**):

1. Plan, gather data and coordinate tasks
2. Conduct a field survey of ONWR to understand and sample the vegetation
3. Classify the vegetation using field data to NVCS standards and crosswalk it to recognizable map units
4. Acquire aerial photography and interpret the photographs using the classification scheme and crosswalk
5. Transfer the interpreted data to a digital form
6. Ground-truth and assess the accuracy of the final map product.

All protocols for this project as outlined in the following sections can be found in documents produced by The Nature Conservancy (1994a, 1994b, and 1994c) for the USGS-NPS Vegetation Mapping Program and found at this website: http://biology.usgs.gov/npsveg.

2.1 Planning, Data Gathering and Coordination

A scoping meeting was held in July 2000 and attended by RSGIS, USFWS (Region 6 and ONWR), NatureServe, and CBI staff. The goals of this meeting were to (1) determine the project boundary, (2) assess the availability of aerial photography, base maps and other data, (3) plan the logistics of doing fieldwork at ONWR, and (4) assign specific tasks to the organizations involved.

The meeting resulted in two guiding decisions:

1. The project extent was defined as the 'executive' boundary of the Refuge (approximately 14,029 acres).

2. New aerial photography would be required as well as a new orthophoto base map since USGS DOQQ base maps for ONWR were not yet available.

Work responsibilities were assigned to the participants:

USBR Responsibilities

- Provide overall project facilitation and coordination.
- Acquire new 1:12,000 scale color infrared aerial photography and ortho-rectified imagery.
- Verify vegetation and land use/land cover signatures on the aerial photographs.
- Collect data for the vegetation classification and local NVCS descriptions.
- Develop map units linked to the NVCS.
- Provide NatureServe with information regarding the distribution and characteristics of vegetation types within ONWR.

- Interpret and delineate vegetation and land use types using aerial photographs.
- Transfer and automate interpreted photographs to produce a digital spatial database and hard copy vegetation maps.
- Produce spatial coverages of plot and accuracy assessment site locations.
- Provide an analysis of the accuracy assessment.
- Provide a final report describing all aspects of the project.
- Provide a visual guide to the photo signatures of each map unit.
- Document FGDC-compliant metadata for all vegetation data.
- Create a CD-ROM with reports, metadata, guides, vegetation classification, plot data, spatial data, the vegetation database (map), graphics, and ground photos.

USFWS Responsibilities

- Provide program oversight in conjunction with CBI.
- Supply RSGIS with the ONWR boundary in digital format.

NatureServe Responsibilities

- Develop a vegetation classification for the study area based on the NVCS, using field data provided by RSGIS.
- Provide guidance to the photo interpreters regarding the ecology and floristic composition of each vegetation type.
- Provide global vegetation descriptions and assist with keys to the vegetation.

RSGIS obtained copies of maps, soil surveys, reports, and other documents describing the Refuge and its environmental setting. ONWR provided species lists, annual reports, and their draft comprehensive conservation plan. Two documents were obtained from the Upper Colorado Endangered Fish Recovery Program (Cooper *et al.* 1994, and Hansen 1994) regarding studies done at ONWR as well a report from the USGS regarding USFWS refuges along the Green River (Laubhan 1997). The Region 6 office of the USFWS provided a digital copy of the project area boundary. NatureServe provided a list of potential plant associations (Reid *et al.* 2000).

2.2 Field Survey

RSGIS conducted a field survey during the summer of 2000, during which both observation point data and plot data were collected. Observation points allowed the field team to become generally familiar with the vegetation while field checking NatureServe's list of potential plant associations. Data collected at each observation point included a general description of the vegetation, UTM coordinates, estimates of foliar cover for the dominant species, and a brief description of the environmental characteristics (**Appendix C**). We collected data at 129 observation points during the September field survey (**Figure 4**).

We also sampled 130 vegetation plots during the August 2000 field survey (**Figure 5**). These plots differed from the observation points in two important ways. First, plot boundaries were formally defined, and second, the data we collected were quantitative

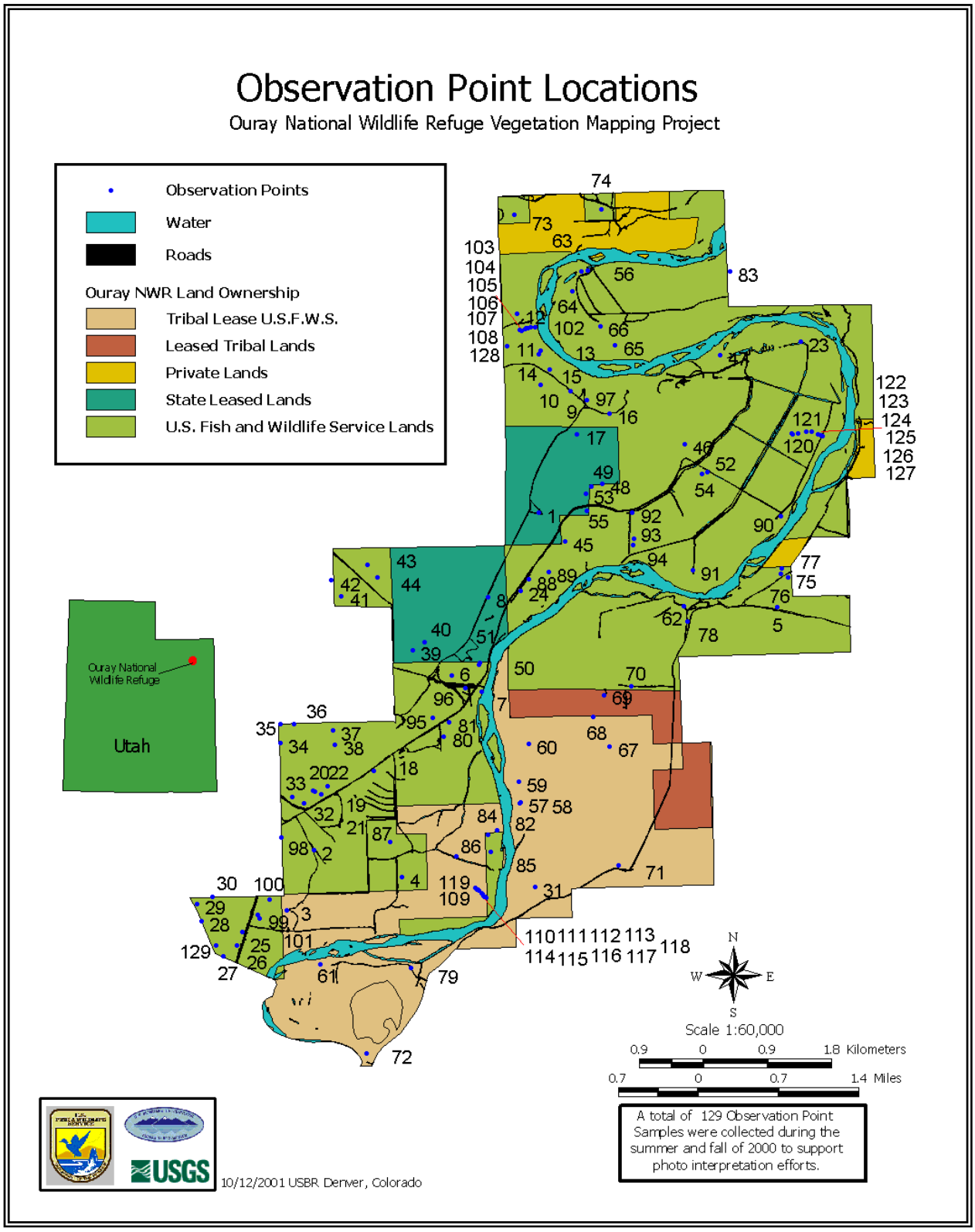


Figure 4. Location of Observation Points at Ouray National Wildlife Refuge.

and much more detailed. The plots were placed subjectively in vegetation that was judged to be "representative" and relatively homogeneous over at least 0.5 ha (the size of the minimum mapping unit). Ecotones were not sampled, and smaller areas were only sampled if they represented unique or distinctive vegetation types. We used 20 x 20 m square plots to sample forest and woodland communities, while shrubland and herbaceous communities were sampled using 10 x 10 m plots. We made an effort to sample three plots per vegetation type with more plots in types not previously documented by the NVCS. The plots were spread across the Refuge to capture the full range of variation.

The descriptive information we collected in each plot included slope, aspect, elevation, soil characteristics, and evidence of wildlife and human disturbance (**Appendix C**). To characterize the vegetation in a plot, we estimated the cover of all vascular plant species (Daubenmire 1959) by layer (herb, shrub, tall shrub, subcanopy, canopy, etc.). The UTM coordinates and elevation of all plots were logged using a Garmin™ 12XL GPS receiver. We took photographs (35 mm format) of each plot and scanned them as digital images. Representative slides for all plots are included in **Appendix G** and all scanned images can be found on the CD_ROM attached to this report. Data collected for each plot was entered into TNC's PLOTS (MS Access©) database and analyzed by NatureServe ecologists using the procedures described in **Section 2.3**.

2.3 NVCS Classification at Ouray NWR

The National Vegetation Classification System (NVCS) for the United States was selected as the vegetation classification standard for this project for several reasons. First, the NVCS is the system mandated by the USGS-NPS Vegetation Mapping Program model we adopted for this project. Second, the Federal Geographic Data Committee (FGDC) (FGDC 1997) has adopted the NVCS to the formation level as a standard for federal agencies. Finally, a national (as opposed to regional, state, or local) vegetation classification system facilitates resource stewardship by ensuring that the same plant associations get the same names throughout the National Refuge System. The strengths of the NVCS are that it:

- is vegetation based
- 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.

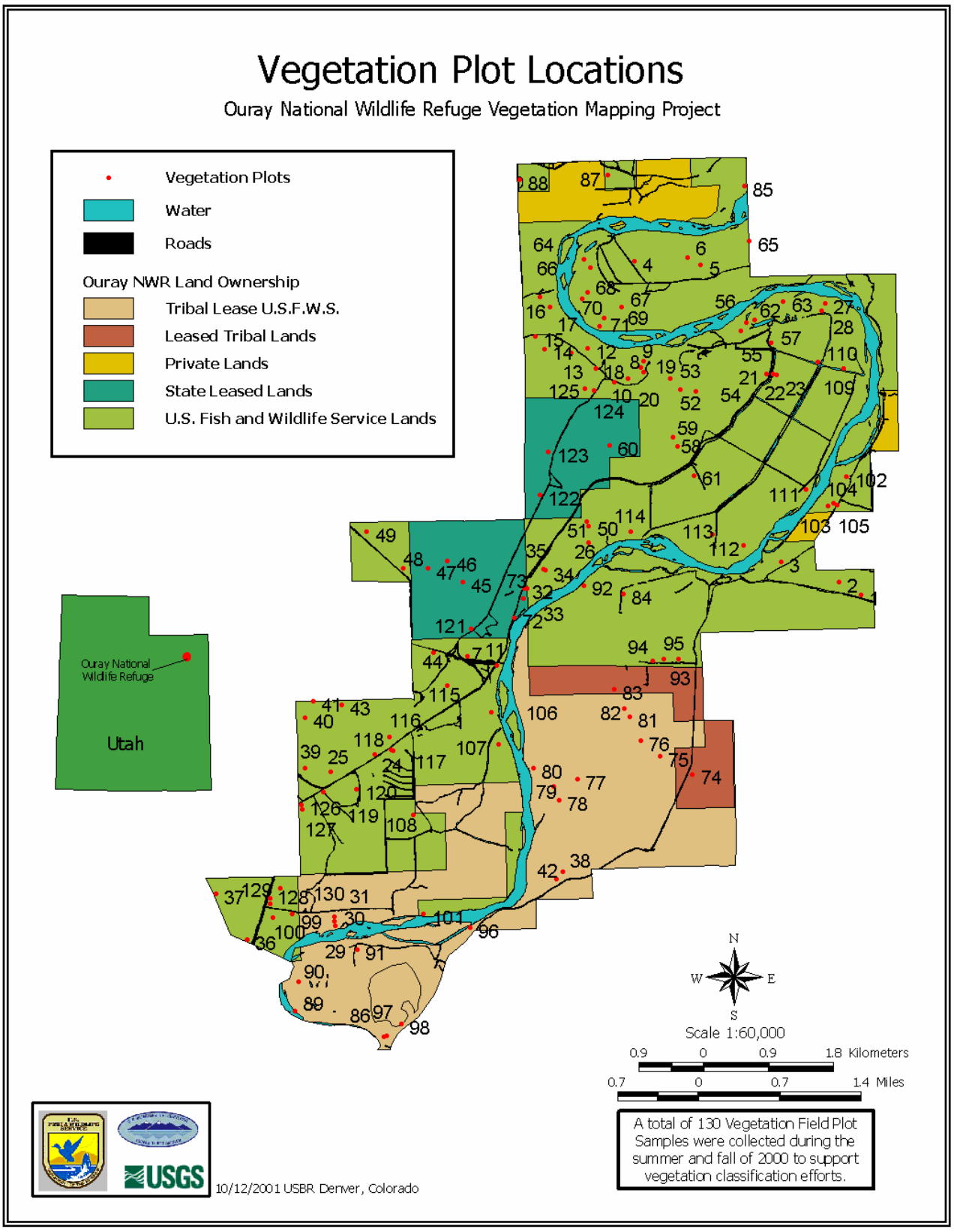


Figure 5. Location of Vegetation Sample Plots at Ouray National Wildlife Refuge.

The NVCS was established primarily by The Nature Conservancy (TNC) and is being implemented and updated by NatureServe in support of the network of Natural Heritage Programs (Grossman *et al.* 1998). Development and refinement of the classification is an ongoing process, and proposed revisions are reviewed both locally and nationally. TNC published two volumes describing the classification of US vegetation as of April 1997 (Grossman *et al.* 1998). This publication can be found on the Internet (URL: http://www.natureserve.org/publications/library.jsp#nspubs). NatureServe also posts regular updates to the list of plant associations in the United States and Canada on their online database server: http://www.natureserve.org).

The procedure for classifying vegetation followed guidelines described in the Vegetation Classification Standard (FGDC 1997), which was derived from the NVCS. The NVCS is a species-based, hierarchical system with seven levels (Grossman *et al.* 1998). The highest (i.e., coarse) levels of the hierarchy have a broad geographic perspective and use physiognomic features to distinguish among groups of plant communities. The lower levels (i.e., finest) have a local and site-specific perspective and are based on floristics (**Table 1**). The two lowest levels (alliance and association) were used in the ONWR project.

Table 1. An example of the NVCS's physiognomic-floristic classification hierarchy.

Level	Primary Basis For Classification	Example
Class	Growth form and structure of vegetation	Woodland
Subclass	Growth form characteristics, e.g., leaf phenology	Deciduous Woodland
Group	Leaf types, corresponding to climate	Cold-deciduous Woodland
Subgroup	Relative human impact (natural/semi-natural or cultural)	Natural/Semi-natural
Formation	Additional physiognomic and environmental factors, including hydrology	Temporarily Flooded Cold-deciduous Woodland
Alliance	Dominant/diagnostic species of uppermost or dominant stratum	*Salix amygdaloides* Temporarily Flooded Woodland Alliance
Association	Additional dominant/diagnostic species from any stratum	*Salix amygdaloides/Salix exigua* Woodland

The NVCS defines an association as "a plant community of definite floristic composition, uniform habitat conditions, and uniform physiognomy" (see Flahault and Schroter 1910 in Moravec 1993). Associations are separated from alliances through the use of total floristic composition and are named by the most dominant and/or indicator species. If two or more dominant species occur in the same stratum a dash symbol is used between the names. If the species occur in different strata then a slash is used. Parentheses indicate that a diagnostic species is not always present. Alliances are physiognomically uniform groups of plant associations that share dominant or diagnostic species, usually found in the uppermost stratum of the vegetation. For forested types, the alliance is roughly equivalent to the "cover type" of the Society of American Foresters. NVCS alliances also include non-forested types.

Unlike classifications based on habitat types or potential vegetation, the NVCS strives to describe existing vegetation. This includes both natural and cultural vegetation. However, due in part to the conservation focus of TNC and NatureServe, the classification of natural vegetation types is often better developed than that of cultural or modified types. The NVCS is also unique in that the association is the basic unit, with broader levels of the hierarchy representing aggregations of lower units (*i.e.*, from the bottom up). This differs from other classifications that recognize plant communities as refinements of broader units (*i.e.*, from the top down).

Preparing the Data for Analysis

The vegetation classification for ONWR began with RSGIS and NatureServe ecologists manually sorting observation point and plot data into groups based on vegetation structure and composition. Most of the plots could be evaluated qualitatively and assigned to an existing NVCS alliance or association. In a few instances, new NVCS units were defined from quantitative analysis of the plot data using ordination techniques described below. The results of the numerical analyses were compared to the subjective classification so that discrepancies between the two could be reconciled.

Data from the 130 ONWR vegetation plots were entered into the PLOTS database following procedures outlined by the NVCS (Grossman *et al.* 1998). The cover values for species in each plot were used to create a plots-by-species data matrix. Prior to analysis, all species with total cover values (summed over all plots) of 1% or less were removed from the data matrix. This prevented minor species from influencing the classification. The resulting matrix was then run through a number of computer analyses to organize and summarize the compositional and structural characteristics of the vegetation and assess patterns related to environmental gradients.

Classification and ordination procedures work best on relatively uniform data sets. Therefore before the data matrix was analyzed, plots with exceptionally low similarity to the remaining plots (outliers) were identified and removed. Outliers are common in large data sets and occur because of disturbed, heterogeneous, or otherwise unusual sites, or because of gaps in sampling (Gauch 1982). Plots sampled within prairie dog towns were the first outlier group to be identified and removed from the data matrix. The remaining plots were then placed subjectively into a floodplain or upland group to further reduce heterogeneity. Floodplain plots were on active and abandoned terraces of the Green River containing wetland or riparian species. Upland plots were on badlands, bluffs, ridges and erosional fans, as well as the driest floodplain soils.

Data Analysis

Following procedures described by Grossman *et al.* (1998) and McCune and Mefford (1999), the floodplain and upland groups were analyzed separately using TWINSPAN (a classification program) and DECORANA (an ordination program). The TWINSPAN analyses were conducted using relative cover values, while raw cover values were used in the DECORANA ordination procedures. TWINSPAN recognizes distinct ecological

groups of plots such as wetlands, riparian woodlands, shrublands, and grasslands. DECORANA clarifies these patterns of classification and places the plots along a two-dimensional gradient that can be related inferentially to environmental gradients.

TWINSPAN analysis of the floodplain plots identified two additional groups of outliers. The larger group was characterized by exotic and/or early successional species, the smaller by aquatic species. These groups were removed from the data matrix. Another group of plots with very similar composition were combined into one composite plot. The refined floodplain data matrix was then analyzed using DECORANA, which identified a third group of outliers that was removed prior to the final ordination. Removing the outliers had the effect of spreading out the remaining plots in a two-dimensional space that represents significant environmental gradients.

Classification and ordination of the upland plots was simpler than the floodplain group. After removing outlier plots (cheatgrass and some greasewood types) and after combining similar plots into composite samples, the upland plots were run through the same series of classification and ordination analyses as the floodplain plots.

A classification of ONWR's vegetation was the end product of this process. RSGIS ecologists, photo interpreters, and Refuge staff field-reviewed the classification. RSGIS and NatureServe prepared a dichotomous map unit key for ONWR (**Appendix F**). The key was tested during the accuracy assessment process. An illustrated guide to the map units **(Appendix G)** was also developed to assist managers and field researchers in identifying plant associations in the field.

2.4 Aerial Photograph Acquisition and Photo-interpretation

Horizons, Inc. (Rapid City, SD) flew color-infrared (CIR) aerial photography for ONWR at scales of 1:12,000 and 1:40,000 on July 5, 2000. We chose CIR film because of its ability to highlight subtle differences in vegetation, especially among wetland types. Frame overlap on the 1:12,000-scale photography was between 50% and 60% along the flight lines and 20% to 30% between the flight lines (**Figure 6**). The 1:40,000-scale photography was draped over a 30m digital elevation model (DEM) to produce a color digital orthophoto base map (see **Title Page**) while RSGIS photo interpreters used 9" X 9" prints of the 1:12,000-scale photography (**Figure 7**) to map the Refuge's vegetation.

RSGIS interpreted the aerial photographs twice. The first interpretation identified patches of homogenous vegetation (areas on the photos with similar tone, texture, color and landscape position) to identify the best sites to place sample plots. The final interpretation used NVCS-derived map units, field notes, observation point and vegetation plot data to prepare the GIS vegetation database.

Stereoscopic photo interpretation

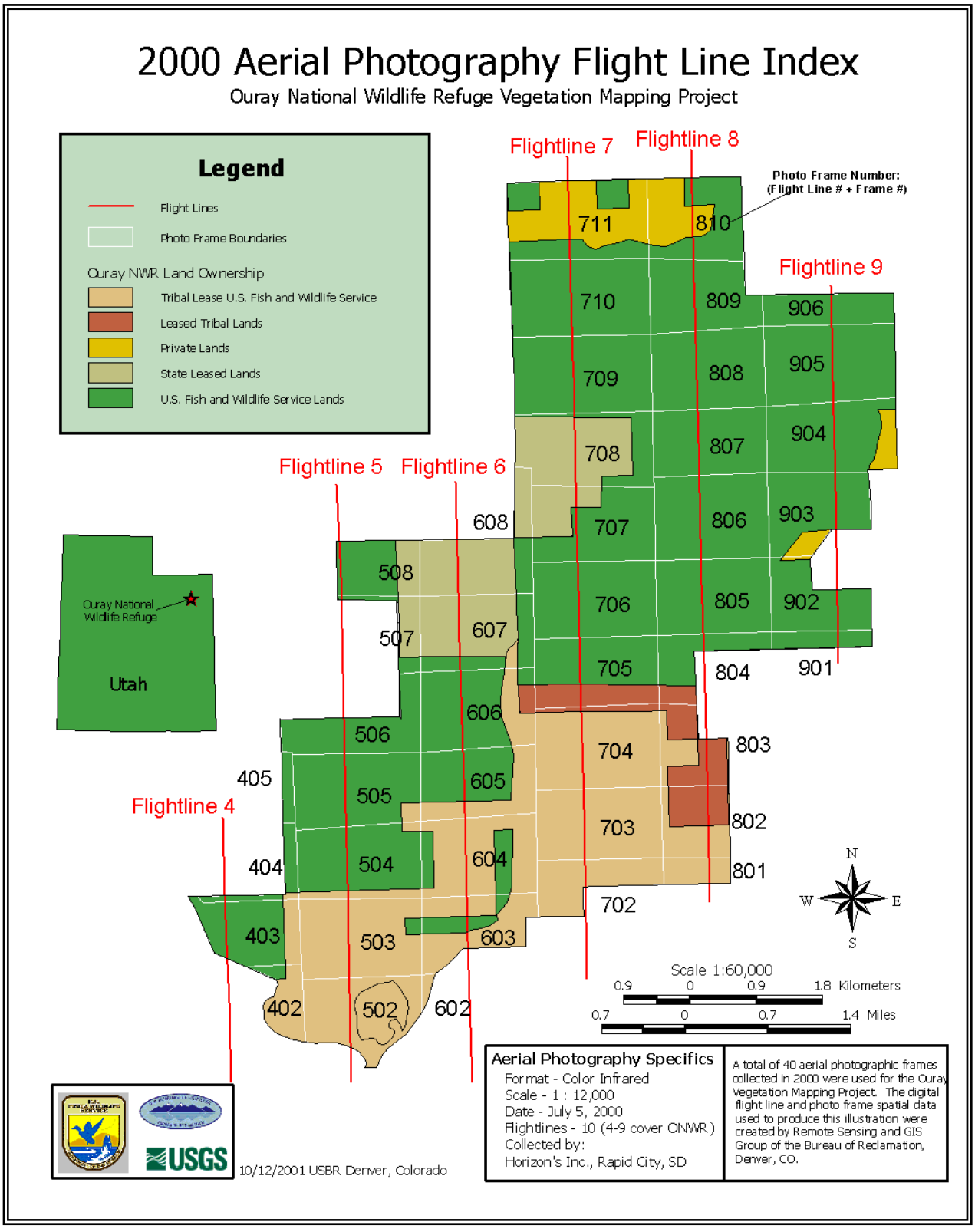


Figure 6. 2000 Aerial Photo Flight Line Index Map for Ouray National Wildlife Refuge.

For both levels of interpretation, we covered each 9"x 9" aerial photograph with sheets of translucent (semi-frosted) Mylar. The aerial photos and their overlays were backlit on a light table and a stereoscope was used to help recognize photo signatures and three-dimensional features. Corner and side tics, photograph and flight line numbers were marked on each Mylar sheet. Polygons were delineated using a 0.5 mm lead pencil. Only the center portion of each aerial photograph was interpreted to minimize the effects of edge distortion. In order to insure completeness and accuracy, digital transfer specialists reviewed all of the interpreted photos for consistency and recommended changes where necessary.

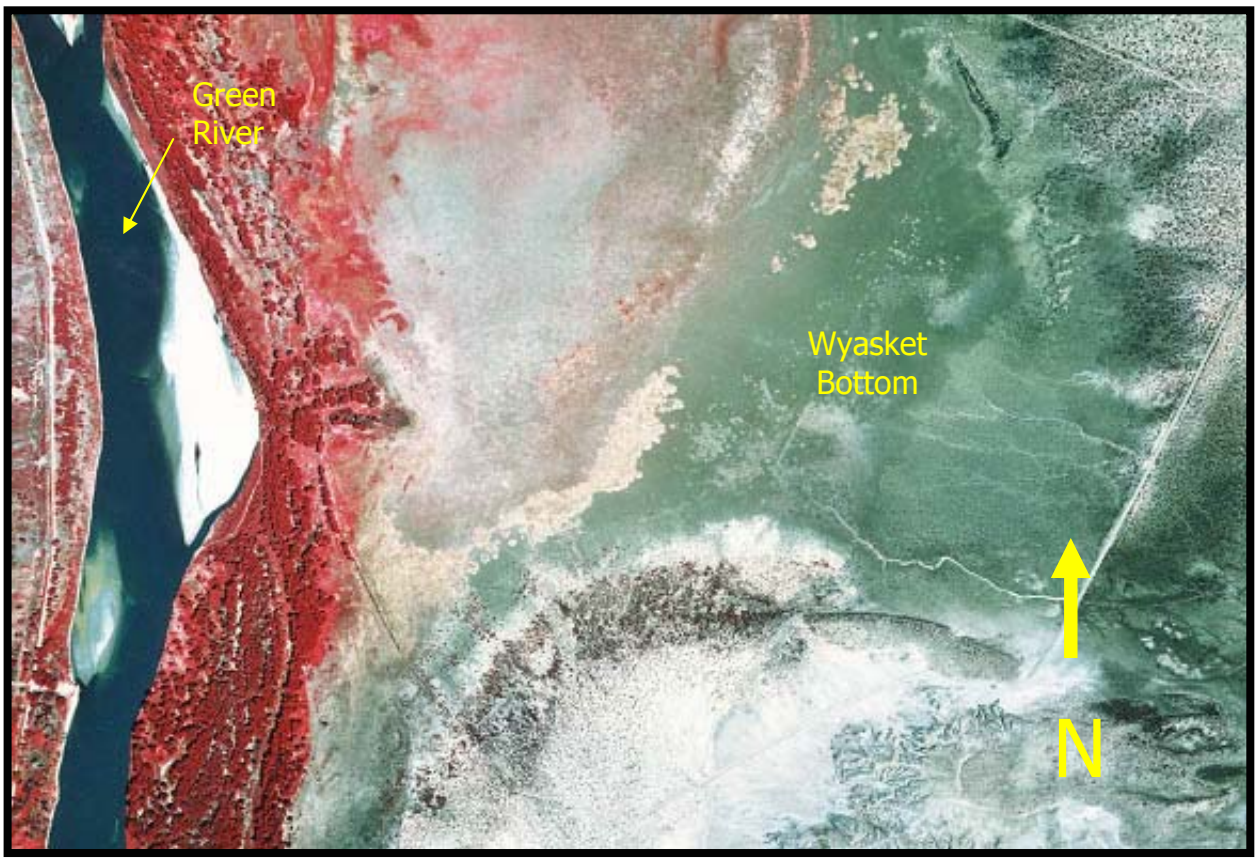


Figure 7. Example of an Aerial Photograph from the ONWR Vegetation Mapping Project (example is not to scale).

The map units delineated on the photos were derived from the NVCS classification as constrained by the limitations of the photography. Photo interpreters applied the preliminary NVCS classification to aerial photo signatures to see how many plant associations could be recognized on the photos. In most instances, one NVCS association corresponded to one map unit. However, sometimes a plant association could not be recognized consistently on the photos or the photo interpreter could see more detail than was recognized by the vegetation classification. These problems were overcome by using two separate but related classifications: (1) a NVCS classification for the plot data and (2) a map unit classification for the GIS database.

The two were related or "crosswalked" by noting where plant associations were lumped into single map units and where other associations were split into multiple map units.

We created map units for land-use types based on the system developed by Anderson (1976) to classify remotely sensed cover types. This includes unvegetated lands not included in the NVCS, such as roads, facilities, and agricultural fields. A third class of map units was defined especially for ONWR to cover vegetation types that were easily mapped but were not included in either the NVCS or Anderson, such as white-tailed priaire dog towns. A list of the final map units appears in **Table 3**.

2.5 Digital Transfer of Photo Interpreted Data

The transfer process removes much of an aerial photograph's inherent distortion and ties the interpreted data to real-world coordinates so it can be digitally automated. To accomplish this for ONWR, an ArcInfo© GIS database was created using in-house protocols. The protocols consist of a shell (master file) of Arc Macro Language (AML) scripts and menus (nearly 100 files) that automate the transfer process, thus insuring that all spatial and attribute data are consistent and stored properly (**Figure 8**). The actual transfer of information from the interpreted aerial photographs to a digital, geo-referenced format involves two basic techniques: (1) scanning the interpreted line work and (2) on-screen digitizing. Both techniques require a background image or basemap. For ONWR, we used nine digital orthophoto sheets created under contract by Horizons, Inc. as the base maps for this project (**Figure 9**).

The scanning technique used for ONWR involved a multi-step process whereby the Mylar overlay sheets produced by the photo interpreters were scanned into a digital form. The digital image file (tagged image format .tif) created from the scanned sheet was then converted from a raster image to a vector file using RSGIS-developed AMLs in ArcInfo©. The vector file or 'line coverage' was then geo-referenced to the orthophoto base map. The essential principle of geo-referencing is to match the scale and position of features on the photographs with the scale and position of the same features on the orthophotos. Technicians accomplished this by adjusting the scale of the scanned Mylar between known control points using computer program routines until the adjustment was considered a good fit.

Large Format Scanning

Any remaining land use classes not already scanned (such as roads) were transferred by means of on-screen digitizing. This process entered data into GIS format by manually tracing digital lines (using a mouse) on a computer monitor screen with the orthophoto as a background image. The completed line work for each photo was then edge matched. Finally, polygon topology was built and attribute information added to produce digital vector or polygon coverages (one per photo) that were combined into a final coverage for the entire Refuge.

On-screen Digitizing

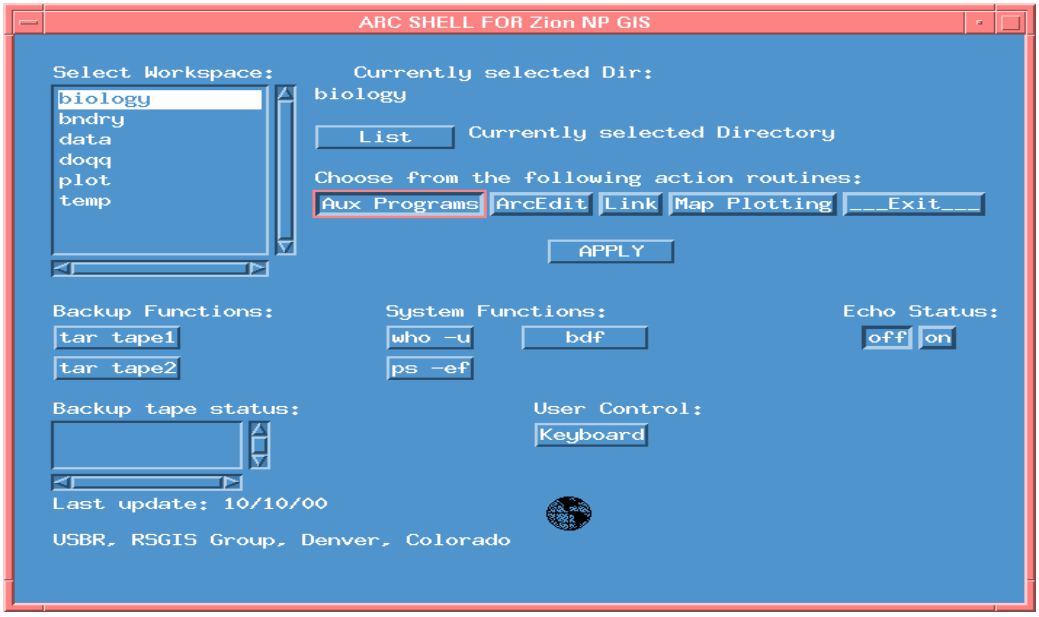


Figure 8. Example of UNIX ArcInfo© Shell Menu Interface.

We attributed, or labeled, each vegetation polygon for ONWR with information pertaining to map units, NVCS units, Anderson land-use classes, Refuge-special units, and other relevant data. The attribute items are listed in **Table 2** and are referenced in the ONWR vegetation look-up table included on the accompanying CD-ROM. Attribute items include standard GIS categories (area, perimeter), NVCS types mandated by the program (Association, Alliance), and USFWS specific modifiers (mod and eco).

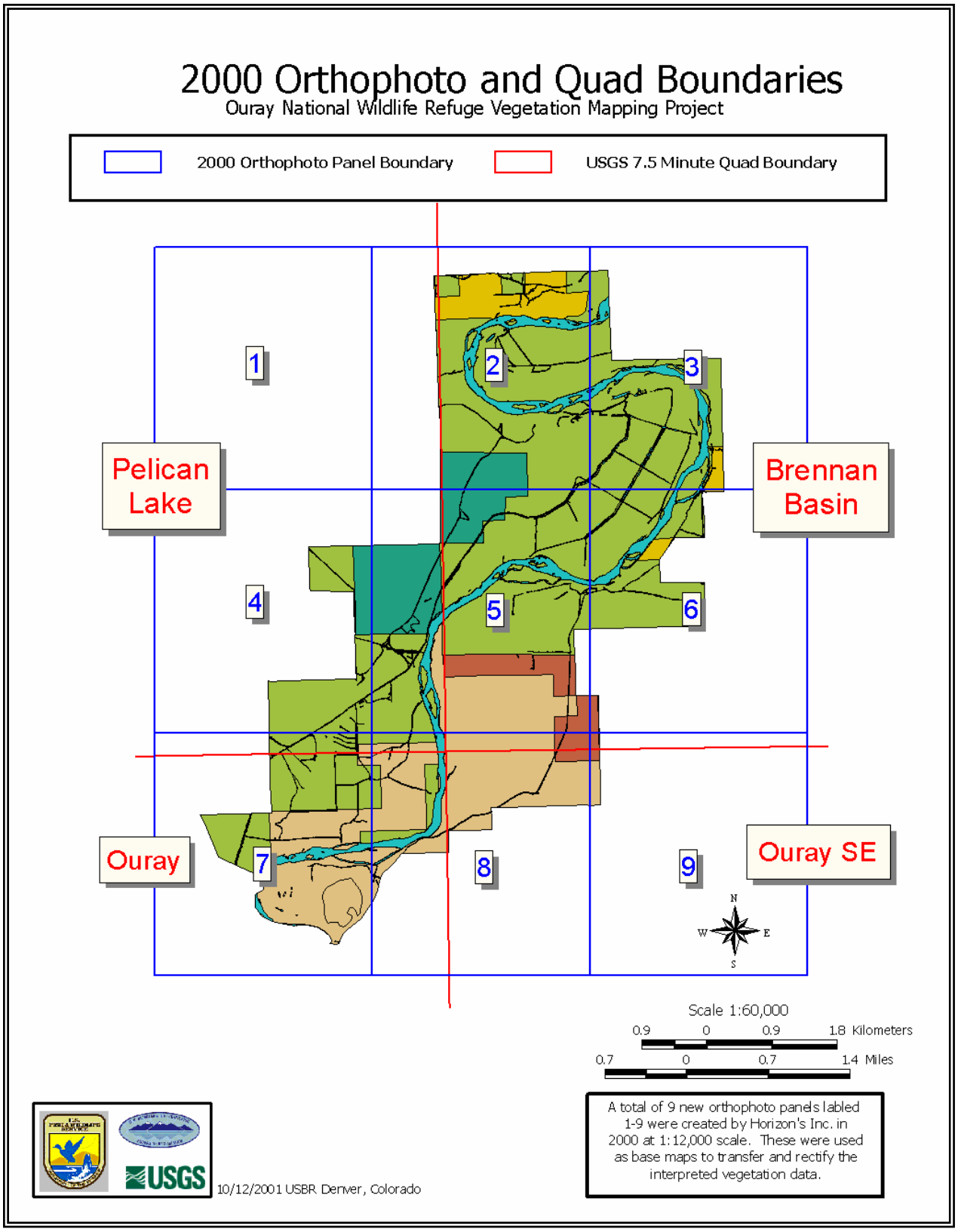


Figure 9. Color Orthophoto and USGS Quadrangle Reference Map for ONWR.

Table 2. Polygon attribute items and descriptions used in the ONWR spatial database (GIS coverage).

ATTRIBUTE	DESCRIPTION
AREA*	Surface area of the polygon in meters squared
PERIMETER*	Perimeter of the polygon in meters
ONWR_VEG#*	Unique internal polygon coding
ONWR_VEG-ID*	Unique internal polygon coding
VEG_CODE	Map unit code - project derived, project specific
VEG_NAME	Map unit name - project derived, project specific
ECO	Ecological description of the polygon
PHYS	Physiographic description of the polygon
ASSN_NAME	Community name - NVCS plant association used by the project
ASSN_CNAME	Community common name used by the project
SYNONYM	Other common name of plant association
ASSN_CEGL	Community element global code - TNC element code link to NVCS plant association
ALL_NAME	NVCS alliance name
ALL_CNAME	Translated common name of the NVCS alliance
NVCS_CODE	NVCS code (formation level)
CLASS	NVCS class name (code)
SUBCLASS	NVCS subclass name (code)
GROUP	NVCS group name (code)
SUBGROUP	NVCS subgroup name (code)
FORMATION	NVCS formation name
LUC_II	Land use and land cover classification system (USGS, Anderson *et al.*. 1976)
COMMENT1	General description of the map unit
COMMENT2	General comment describing how the map unit relates to other map units
PDOG	Evidence of prairie dog activity in the polygon (1=yes or 0=no)
(*ArcInfo© default items)	

2.6 MAP VERIFICATION AND ACCURACY ASSESSMENT

Once the aerial photo interpretation transfer and digitization was complete, we printed draft 1:12,000-scale hard copy vegetation maps. Photo interpreters checked the map against the interpreted aerial photographs to ensure that the polygons were labeled properly and to locate any extra or missing lines. They also compared the map labels to the observation and plot data. Copies of the revised draft map were then sent to the Refuge for review and taken into field by the photo interpreters for ground-truthing. During the ground-truthing process, we collected additional observation points and verified aerial photograph signatures using landmarks and GPS waypoints. The map and map units were then modified to correct any mistakes.

RSGIS conducted an assessment of the vegetation map's thematic accuracy in the summer of 2001. Accuracy assessment (AA) sample sites were selected by following the protocols defined by the USGS-NPS Vegetation Mapping Program (TNC 1994a). AA points were selected using a 100-meter grid overlaid on the ONWR vegetation coverage in ArcInfo©. The origin of the grid was selected using a random number

table and the intersections of the gridlines became the pool of potential sample points. Sample points were removed from the pool if they fell within 10 meters of a vegetation polygon line or fell on a non-vegetated site. The remaining points were attributed by vegetation type. Between five and 30 points were randomly selected for each vegetation type using a random number generator in ArcInfo©. More AA sample points were selected for common map units and fewer selected for rare map units. Some extremely rare map units had fewer than five AA sample points due to their small size (all potential AA points fell within 10m of a polygon boundary). A total of 421 sample points were selected for the ONWR accuracy assessment (**Figure 10**).

AA logistics involved plotting AA points and polygon boundaries on hard copy 1:12,000-scale topographic quadrangle maps. Each point's UTM coordinates were uploaded into a Garmin GPS unit to help find the field location of the AA points. Armed with the vegetation key, the digital AA point coordinates, and the map, an RSGIS ecologist (who had not previously been involved with the project) collected AA data at ONWR. The ecologist walked to each AA point and used the vegetation key (**Appendix D**) to identify the plant association within a 40m radius. Data recorded for each point included the community name(s), dominant species, environmental conditions, and rationale for the identification (**Appendix C**).

Upon completion of the fieldwork, the AA data were entered into the PLOTS database and reviewed for data entry errors. Incomplete data on the field sheets, including missing GPS coordinates, were corrected if possible. Final AA points were viewed in ArcView in relation to the vegetation map coverage. Actual assessment consisted of comparing the determination made in the field for each AA point to the polygon map label. These comparisons were made at an AA meeting held in September 2001 by a panel of USFWS and BOR staff. Each point was reviewed for accuracy and for errors made by the AA ecologist. In this manner, "false" errors or mismatches between a polygon and an accuracy assessment were separated from true errors. False errors were generally recognized as resulting from one of three problems:

- **GPS errors:** The point was located incorrectly (wrong polygon) due to GPS limitations (+/- error). Usually the point was too close to a polygon boundary.
- **Ecotone errors:** A point occurred in a zone of transition between two types.
- **Intuitive errors:** A point was classified differently than the polygon label but was overruled by USFWS staff. These errors probably resulted either from assessing areas too small to map or assessing too small an area around the point. Some of these points were removed from the assessment entirely.

The assessments for each point was recorded in an error matrix (*i.e.*, contingency table) after final approval by the ONWR biologist and USFWS regional planner.

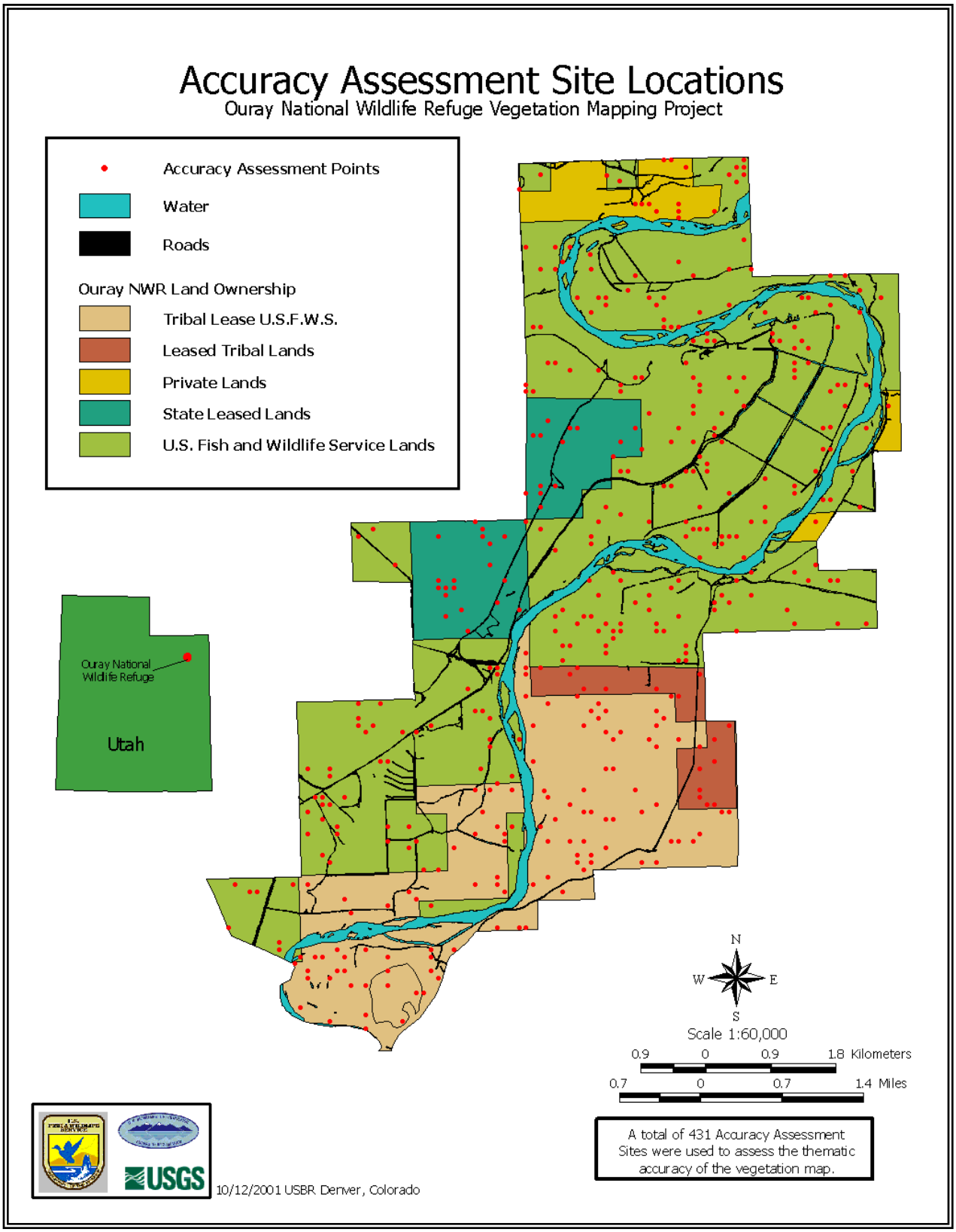


Figure 10. Locations of Accuracy Assessment Points Sampled at ONWR.

3. RESULTS AND DISCUSSION

3.1 NVCS CLASSIFICATION AT OURAY NWR

Visual inspection, classification and ordination of the 130 plots sampled at ONWR resulted in 58 plant associations (**Figures 11-15)**. The floodplain plant associations appeared to segregate primarily on the basis of soil moisture and/or depth to water table. For example, willow-dominated and annual forb (*e.g.* smartweed) plots adjacent to the Green River occurred at the mesic end of the environmental gradient (**Figure 14**) and big sagebrush and greasewood plots (found on the higher (drier) alluvial terraces) at the dry end. The middle of the gradient contained an intricate mixture of riparian woodland, shrubland, and herbaceous plant associations such as Russian-olive, salt cedar, and cattail types. Spread throughout the middle of the gradient were grassland sites dominated by western wheatgrass, alkali sacaton and inland saltgrass occurring on a variety of upper terraces, shallow draws, and tributary drainages.

The upland plant associations appeared to segregate on the basis of soil texture and depth, and to a lesser extent, on fire and grazing history (**Figure 15**). Classification revealed three major subgroups of upland plots: Dwarf-shrubland, Shrubland and Grassland. Plots dominated by snakeweed were unique in that they were often grouped with other kinds of shrublands and grasslands. Plots dominated by sand dropseed, Indian ricegrass and rubber rabbitbrush occur at one end of the gradient, representing somewhat disturbed, deep sandy soils. The one plot representing the black sagebrush plant association (Plot 10) occurs on coarse cobble soils at the other extreme. Finally, the plots located toward the bottom of the ordination space represent plant associations found on fine textured, silty clay soils.

The final NVCS classification summary and detailed plant association descriptions appear in **Appendix E**.

3.2 PHOTO-INTERPRETATION AND MAP UNITS

We recognized and delineated 82 map units on the color infrared aerial photographs for ONWR. This included 59 vegetation units and 22 Anderson Level II (1976) and sub-level II (more detailed units than Level II) land-use units (Table 4). All map units were developed from a combination of an initial NVCS vegetation classification provided by the NatureServe with input from Refuge biologists and BOR ecologists, fieldwork, and preliminary photo-interpretation.

Please reference **Appendix G**. for detailed descriptions and representative photos for all vegetation map units.

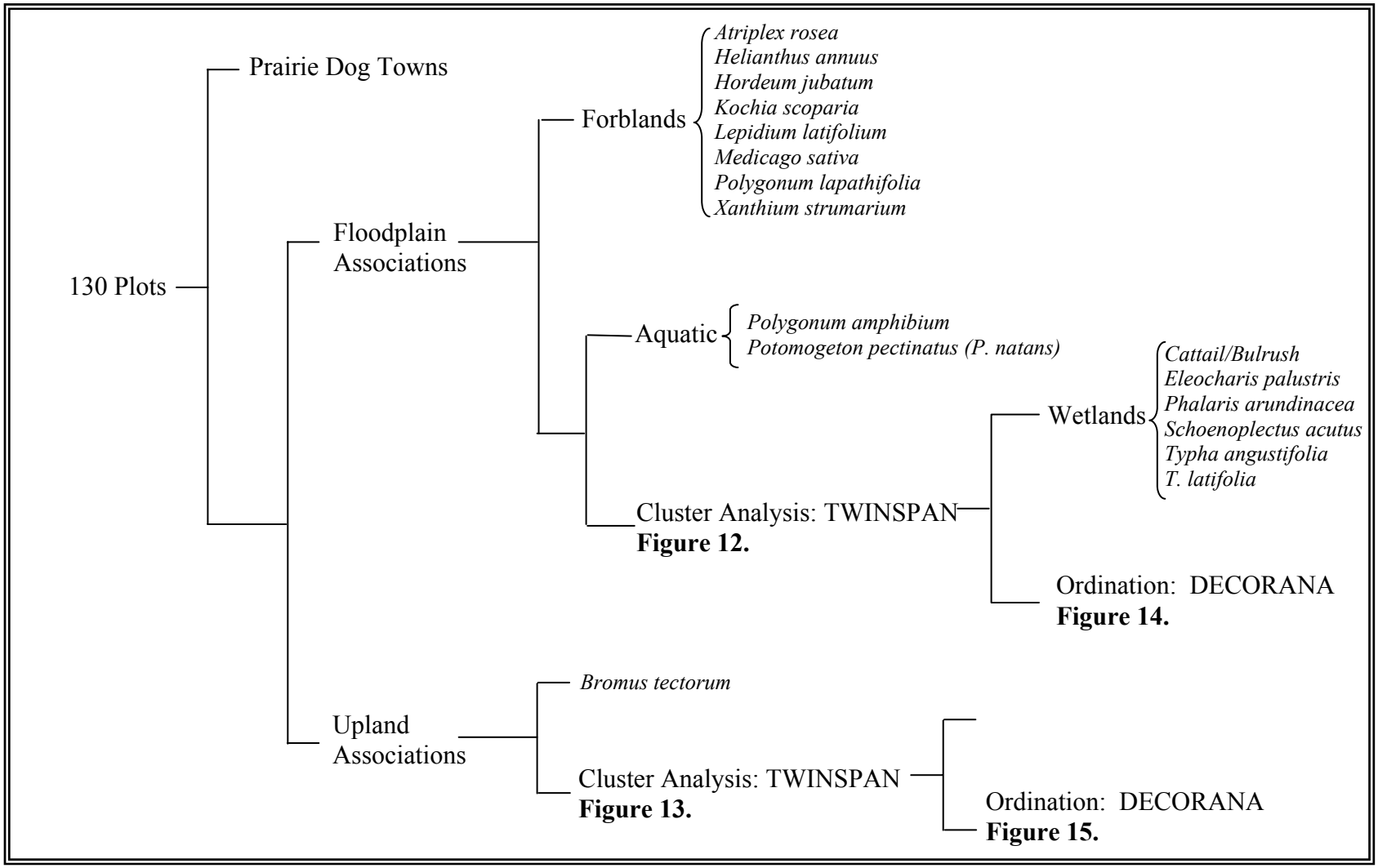


Figure 11. Dendrogram illustrating subjective classification of all 130 plots.
-Illustration represents subjective groupings prior to multivariate analysis using TWINSPAN and DECORANA (McCune and Mefford 1999).
-Dominant species for each outlier association are indicated in italics.

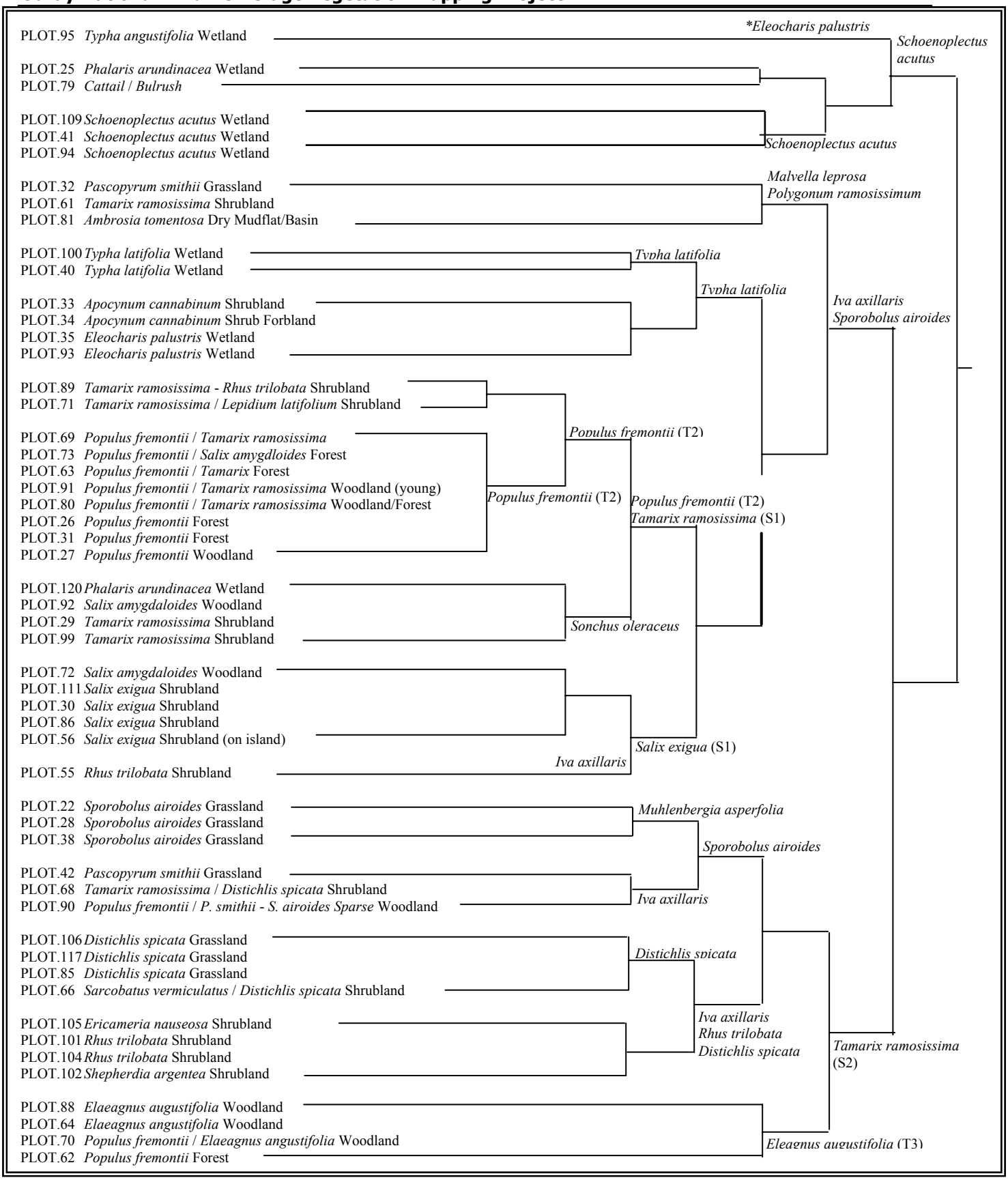


Figure 12. TWINSPAN Dendrogram of 53 Floodplain Plots Sampled at ONWR.
*=Indicator species. Strata:**T2**=canopy layer, **T3**=sub-canopy, **S1**=shrub layer 1, **S2**=shrub layer 2, **S3**=shrub layer 3.

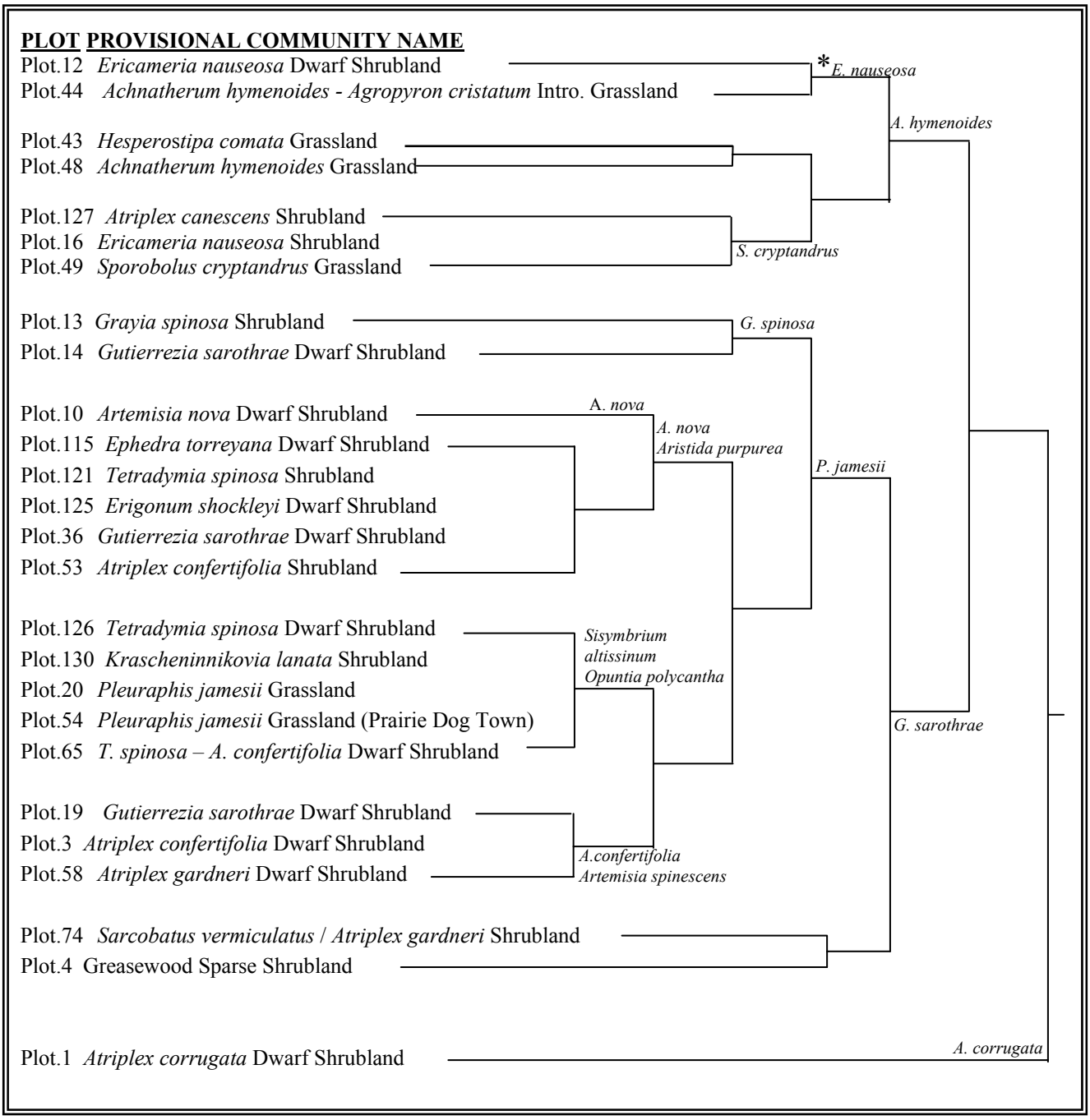


Figure 13. TWINSPAN Dendrogram of 26 Upland Plots Sampled at ONWR.

* = Indicator species

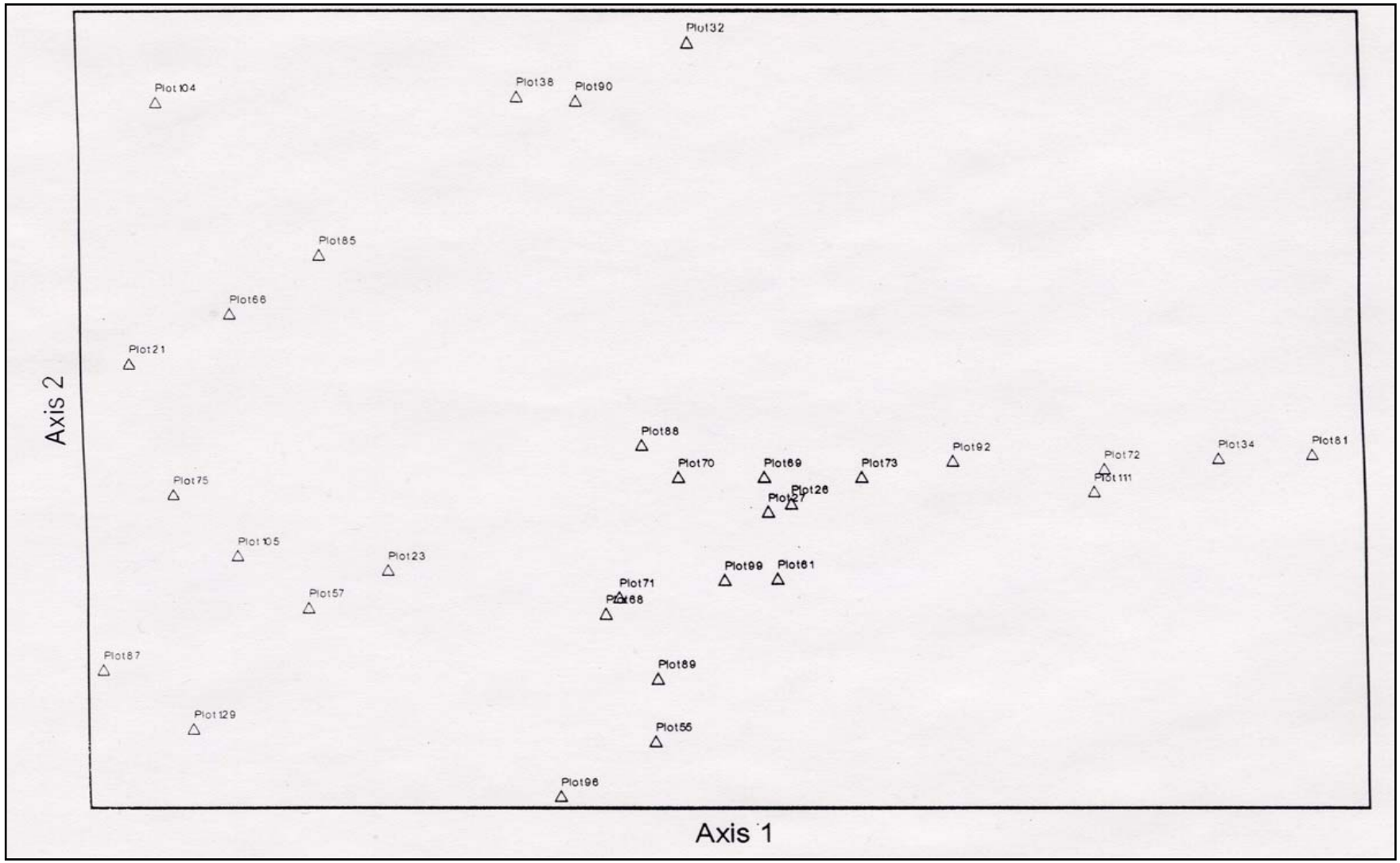


Figure 14. DECORANA Ordination of 34 Floodplain Vegetation Plots.

-See **Figure 10** for provisional community names for each plot.

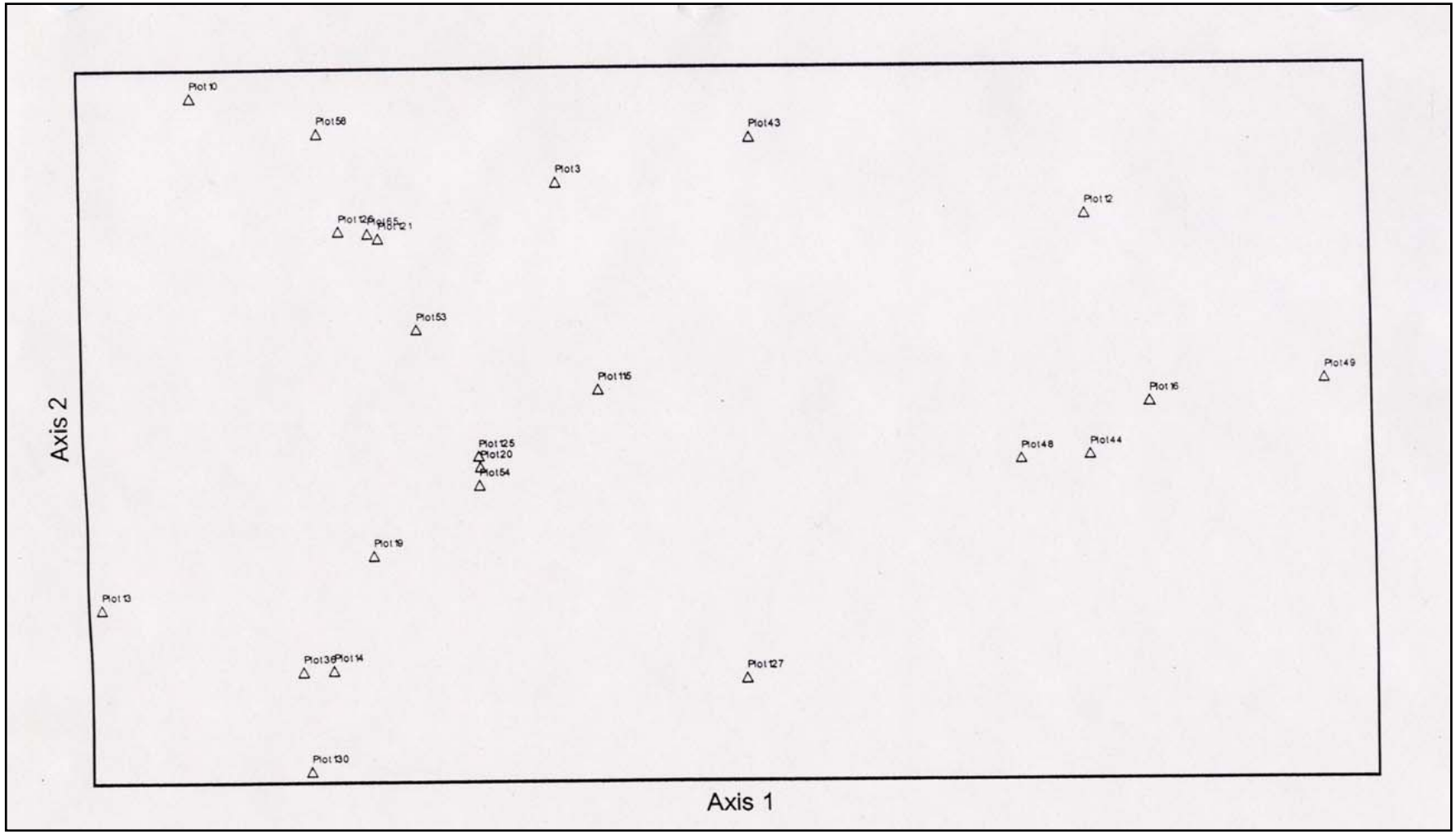


Figure 15. DECORANA Ordination of 23 Upland Plots Sampled at ONWR.

-See **Figure 11** for provisional community names for each plot.

Table 3. Established and provisional NVCS plant associations and alliances at Ouray NWR.

Plant Association Name	Common Name	Elcode*
Floodplain Plant Associations – Forests and Woodlands		
Elaeagnus angustifolia Semi-natural Woodland	Russian-olive Semi-natural Woodland	CEGL005269
Populus fremontii Temporarily Flooded Forest	Fremont Cottonwood Temporarily Flooded Forest	A.313
Populus fremontii Temporarily Flooded Woodland	Fremont Cottonwood Temporarily Flooded Woodland	A.644
Salix amygdaloides / Salix exigua Woodland	Peachleaf Willow / Coyote Willow Woodland	CEGL000948
Floodplain Plant Associations - Shrublands		
Ericameria parryi-Sarcobatus vermiculatus Shrubland [Provisional]	Parry rabbitbrush-Black Greasewood Shrubland [Provisional]	Local Community
Rhus trilobata - Salix exigua Shrubland	Ill-scented Sumac - Coyote Willow Shrubland	CEGL001121
Salix exigua / Barren Shrubland	Coyote Willow / Barren Shrubland	CEGL001200
Sarcobatus vermiculatus / Atriplex gardneri Shrubland	Black Greasewood / Gardner's Saltbush Shrubland	CEGL001360
Sarcobatus vermiculatus / Distichlis spicata Shrubland	Black Greasewood / Saltgrass Shrubland	CEGL001363
Sherpherdia argentea Great Basin Shrubland	Silver Buffaloberry Great Basin Shrubland	New NVCS Association
Tamarix spp. Temporarily Flooded Shrubland	Tamarisk species Temporarily Flooded Shrubland	CEGL003114
Floodplain Plant Associations – Forblands and Grasslands		
Annual Weedy Forbs Mudflat Complex	Annual Weedy Forbs Mudflat Complex	CECX Mudflat Complex
Distichlis spicata Herbaceous Vegetation	Saltgrass Herbaceous Vegetation	CEGL001770
Eleocharis palustris Herbaceous Vegetation	Marsh Spikerush Herbaceous Vegetation	CEGL001833
Hordeum jubatum Herbaceous Vegetation	Foxtail Barley Herbaceous Vegetation	CEGL001798
Juncus balticus Herbaceous Vegetation	Baltic Rush Herbaceous Vegetation	CEGL001838
Pascopyrum smithii Herbaceous Vegetation	Western Wheatgrass Herbaceous Vegetation	CEGL001577
Phalaris arundinacea Western Herbaceous Vegetation	Reed Canary Grass Western Herbaceous Vegetation	CEGL001474

Phragmites australis Western North America Temperate Semi-natural Herbaceous Vegetation	Common Reed Western North America Temperate Semi-natural Herbaceous Vegetation	CEGL001475
Polygonum amphibium Permanently Flooded Herbaceous Alliance	Water Smartweed Permanently Flooded Herbaceous Alliance	CEGL002002
Potamogeton natans Herbaceous Vegetation	Floating Pondweed Herbaceous Vegetation	New NVCS Association
Schoenoplectus acutus Herbaceous Vegetation	Hardstem Bulrush Herbaceous Vegetation	CEGL001840
Schoenoplectus pungens Herbaceous Vegetation	Threesquare Herbaceous Vegetation	CEGL001587
Sporobolus airoides Southern Plains Herbaceous Vegetation	Alkali Sacaton Southern Plains Herbaceous Vegetation	CEGL001685
Typha domingensis Western Herbaceous Vegetation	Southern Cattail Western Herbaceous Vegetation	CEGL001845
Typha latifolia Western Herbaceous Vegetation	Broadleaf Cattail Western Herbaceous Vegetation	CEGL002010
Upland Plant Associations - Shrublands		
Artemisia nova Dwarf-shrubland	Black Sagebrush Dwarf-shrubland	CEGL001417
Artemisia tridentata Shrubland	Big Sagebrush Shrubland	CEGL000991
Atriplex canescens / Pleuraphis jamesii Shrubland	Fourwing Saltbush / James' Galleta Shrubland	CEGL001288
Atriplex confertifolia / Pleuraphis jamesii Shrubland	Shadscale / James' Galleta Shrubland	CEGL001304
Atriplex corrugata Dwarf-shrubland	Mat Saltbush Dwarf-shrubland	CEGL001437
Atriplex gardneri Dwarf-shrubland	Gardner's Saltbush Dwarf-shrubland	CEGL001438
Ephedra torreyana – (Atriplex canescens, confertifolia) Sparse Vegetation [Provisional]	Torrey's Joint-fir – (Fourwing Saltbush, Shadscale) Sparse Vegetation [Provisional]	Local Community
Ericameria nauseosa Sand Deposit Sparse Vegetation	Rubber Rabbitbrush Sand Deposit Sparse Vegetation	New NVCS Association
Ericameria parryi – Sarcobatus vermiculatus Shrubland [Provisional]	Parry Rabbitbrush – Black Greasewood Shrubland [Provisional]	Local Community
Eriogonum schockleyi Badlands Sparse Vegetation [Provisional]	Schockley's Buckwheat Badlands Sparse Vegetation [Provisional]	Local Community
Grayia spinosa / Pleuraphis jamesii Shrubland	Spiny Hopsage / James' Galleta Shrubland	New NVCS Association
Gutierrezia sarothrae - (Opuntia spp.) / Pleuraphis jamesii Dwarf-shrubland	Snakeweed - (Prickly-pear species) / James' Galleta Dwarf Shrubland	CEGL002690
Krascheninnikovia lanata / Pleuraphis jamesii Dwarf-shrubland	Winter-fat / James' Galleta Dwarf Shrubland	CEGL001322

Tetradymia spinosa / Pleuraphis jamesii Dwarf-shrubland	Short-spine Horsebrush / James' Galleta Dwarf Shrubland	New NVCS Association
Upland Plant Associations – Forblands and Grasslands		
Achnatherum hymenoides Herbaceous Alliance	Indian Ricegrass Herbaceous Alliance	A.1262
Bromus tectorum Semi-natural Herbaceous Alliance	Cheatgrass Herbaceous Semi-natural Alliance	CEGL003019
Hesperostipa comata Great Basin Herbaceous Vegetation	Needle-and-Thread Great Basin Herbaceous Vegetation	CEGL001705
Lepidium latifolium Semi-natural Herbaceous Vegetation [Provisional]	Broadleaved Pepperweed Semi-natural Herbaceous Vegetation [Provisional]	Local Community
Pleuraphis jamesii Herbaceous Vegetation	James' Galleta Herbaceous Vegetation	CEGL001777
Sporobolus cryptandrus Great Basin Herbaceous Vegetation	Sand Dropseed Great Basin Herbaceous Vegetation	CEGL002691

*ELCODE represents NatureServe's internal database tracking code for each recognized plant association. Local communities have not been described outside of ONWR by NatureServe but have been recognized as provisional NVCS associations by NatureServe. New NVCS associations have not yet been assigned an Elcode number.

Table 4. Map units used for Ouray National Wildlife Refuge.
The units are organized into ecological groups. "Level" refers to whether the map unit represents a NVCS plant association or alliance (NVCS unless otherwise noted), local plant community/plant population, or a land use class. Anderson Land Use Classes are identified by Roman numerals.

Map Code	Map Unit Name	Map Unit Common Name	Level
Floodplain Units – Forests and Woodlands			
1	*Populus fremontii* Temporarily Flooded Forest Alliance	Fremont Cottonwood Temporarily Flooded Forest Alliance	Alliance
2	*Populus fremontii* Temporarily Flooded Woodland Alliance	Fremont Cottonwood Temporarily Flooded Woodland Alliance	Alliance
3	*Salix amygdaloides / Salix exigua* Woodland	Peachleaf Willow / Coyote Willow Woodland	Association
4	*Elaeagnus angustifolia* Semi-Natural Woodland	Russian-olive Semi-natural Woodland	Association
Floodplain Units – Shrublands			
5	*Salix exigua /* Barren Shrubland	Coyote Willow / Barren Shrubland	Association
6	*Tamarix* spp. Temporarily Flooded Shrubland	Tamarisk spp. Temporarily Flooded Shrubland	Association
7	*Tamarix* spp./ *Sporobolus airoides* Shrubland	Tamarisk spp. / Alkali Sacaton Shrubland	Local Plant Community
8	*Rhus trilobata – Salix exigua* Shrubland	Ill-scented Sumac – Coyote Willow Shrubland	Association
9	*Shepherdia argentea* Great Basin Shrubland	Silver Buffaloberry Great Basin Shrubland	New NVCS Association
10	**Symphoricarpos occidentalis* Shrubland	Snowberry Shrubland	Local Plant Population
11	*Sarcobatus vermiculatus / Distichlis spicata* Shrubland	Black Greasewood / Saltgrass Shrubland	Association
12	*Sarcobatus vermiculatus / Atriplex gardneri* Shrubland	Black Greasewood / Gardner's Saltbush Shrubland	Association
14	*Ericameria parryi - Sarcobatus vermiculatus* Shrubland [Provisional]	Parryi Rabbitbrush – Black Greasewood Shrubland [Provisional]	Association (NVCS Provisional)
Floodplain Units – Herbaceous Wetland			
27	*Potamogeton natans* Herbaceous Vegetation	Floating Pondweed Herbaceous Vegetation	New NVCS Association
28	*Polygonum amphibium* Permanently Flooded Herbaceous Alliance	Water Smartweed Permanently Flooded Herbaceous Alliance	Alliance
29	*Polygonum lapathifolium* Permanently Flooded Herbaceous Vegetation	Pale Smartweed Permanently Flooded Herbaceous Vegetation	Local Plant Community

30	*Schoenoplectus acutus* Herbaceous Vegetation	Hardstem Bulrush Herbaceous Vegetation	Association
31	*Typha domingensis (Typha angustifolia, latifolia)* Herbaceous Vegetation	Southern (Broad-leaved, Narrow-leaved) Cattail Herbaceous Vegetation	Complex[1]
32	***Schoenoplectus pungens* Herbaceous Vegetation**	Threesquare Herbaceous Vegetation	Association
33	*Juncus balticus* Herbaceous Vegetation	Baltic Rush Herbaceous Vegetation	Association
34	*Eleocharis palustris* Herbaceous Vegetation	Common Spikerush Herbaceous Vegetation	Association
35	*Phragmites australis* Western North America Temperate Semi-natural Herbaceous Vegetation	Common Reed Western North America Temperate Semi-natural Herbaceous Vegetation	Association
36	*Phalaris arundinacea* Western Herbaceous Vegetation	Reed Canary Grass Western Herbaceous Vegetation	Association
Floodplain Units – Herbaceous Non-wetland			
37	*Hordeum jubatum* Herbaceous Vegetation	Foxtail Barley Herbaceous Vegetation	Association
40	*Distichlis spicata* Herbaceous Vegetation	Saltgrass Herbaceous Vegetation	Association
41	*Sporobolus airoides* Southern Plains Herbaceous Vegetation	Alkali Sacaton Southern Plains Herbaceous Vegetation	Association
42	*Pascopyrum smithii* Herbaceous Vegetation	Western Wheatgrass Herbaceous Vegetation	Association
50	*Apocynum cannabinum* Herbaceous Vegetation	Hemp Dogbane Herbaceous Vegetation	Local Plant Community
60	*Ambrosia tomentosa - Helianthus annuus* Herbaceous Vegetation	Bur Ragweed - Wild Sunflower Herbaceous Vegetation	Floristic Sub-association
61	*Atriplex rosea* Semi-natural Herbaceous Vegetation	Red Orache Semi-natural Herbaceous Vegetation	Floristic Sub-association
62	*Xanthium strumarium* Herbaceous Vegetation	Cocklebur Herbaceous Vegetation	Floristic Sub-association
63	*Iva axillaris* Herbaceous Vegetation	Poverty Sumpweed Herbaceous Vegetation	Local Plant Community
64	*Kochia scoparia* Semi-natural Herbaceous Vegetation	Kochia Semi-natural Herbaceous Vegetation	Floristic Sub-association
66	*Lepidium latifolium* Semi-natural Herbaceous Vegetation [Provisional]	Pepperweed Semi-natural Herbaceous Vegetation [Provisional]	Association (NVCS Provisional)
68	*Glycyrrhiza lepidota* Herbaceous Vegetation	Wild Licorice Herbaceous Vegetation	Local Plant Community

Upland Units - Shrubland			
13	*Artemisia tridentata* Shrubland	Big Sagebrush Shrubland	Association
15	*Ericameria nauseosa* Sand Deposit Sparse Vegetation	Rubber Rabbitbrush Sand Deposit Sparse Vegetation	New NVCS Association
16	*Atriplex canescens / Pleuraphis jamesii* Shrubland	Fourwing Saltbush / James' Galleta Shrubland	Association
17	*Grayia spinosa / Pleuraphis jamesii* Shrubland	Spiny Hopsage / James' Galleta Shrubland	New NVCS Association
18	*Tetradymia spinosa / Pleuraphis jamesii* Dwarf-shrubland	Short-spine Horsebrush / James' Galleta Dwarf-shrubland	New NVCS Association
19	*Gutierrezia sarothrae* – (*Opunita* spp.) */ Pleuraphis jamesii* Dwarf-shrubland	Snakeweed - (Prickly-pear spp.) / James' Galleta Dwarf Shrubland	Association
20	*Artemisia dracunculus* Dwarf-shrubland	Tarragon Dwarf-shrubland	Local Plant Community
21	*Ephedra torreyana – (Atriplex canescens, confertifolia)* Sparse Vegetation [Provisional]	Torrey's Joint-fir – (Fourwing Saltbush, Shadscale) Sparse Vegetation [Provisional]	Local Plant Community
22	*Artemisia nova* Dwarf-shrubland	Black Sagebrush Dwarf-shrubland	Association
23	*Atriplex confertifolia / Pleuraphis jamesii* Shrubland	Shadscale / James' Galleta Shrubland	Association
24	*Atriplex corrugata* Dwarf-shrubland	Mat Saltbush Dwarf-shrubland	Association
25	*Atriplex gardneri* Dwarf-shrubland	Gardner's Saltbush Dwarf-shrubland	Association
26	*Eriogonum schockleyi* Badlands Sparse Vegetation [Provisional]	Schockley's Buckwheat Badlands Sparse Vegetation [Provisional]	Association (NVCS Provisional)
51	*Krascheninnikovia lanata / Pleuraphis jamesii* Dwarf-shrubland	Winter-fat / James' Galleta Dwarf-shrubland	Association
Upland Units - Herbaceous			
43	*Achnatherum hymenoides* Herbaceous Alliance	Indian Ricegrass Herbaceous Alliance	Alliance
44	*Achnatherum hymenoides - Agropyron cristatum* Herbaceous Vegetation	Indian Ricegrass - Crested Wheatgrass Herbaceous Vegetation	Local Plant Community
45	*Sporobolus cryptandrus* Great Basin Herbaceous Vegetation	Sand Dropseed Great Basin Herbaceous Vegetation	Association
46	*Hesperostipa comata* Great Basin Herbaceous Vegetation	Needle-and-Thread Great Basin Herbaceous Vegetation	Association
47	*Pleuraphis jamesii* Herbaceous Vegetation	James' Galleta Herbaceous Vegetation	Association
48	*Bromus tectorum* Semi-natural Herbaceous Alliance	Cheatgrass Semi-natural Herbaceous Alliance	Alliance

Modified Vegetation			
49	*Bouteloua gracilis* Introduced Grassland	Blue Grama Introduced Grassland	Local Plant Community
65	*Medicago sativa / Populus fremontii* Herbaceous Vegetation	Alfalfa / Fremont Cottonwood Herbaceous Vegetation	Local Plant Community
67	*Opuntia polyacantha - Gutierrezia sarothrae / Halogeton glomeratus - Bromus tectorum* Disturbed Vegetation	Prairie Dog Town Disturbed Vegetation	Local Plant Community
101	*Schoenoplectus acutus* Herbaceous Vegetation - Burned	Hardstem Bulrush Herbaceous Vegetation - Burned	Management Association
103	*Typha domingensis (Typha angustifolia, latifolia)* Herbaceous Vegetation - Burned	Southern (Broad-leaved, Narrow-leaved) Cattail Herbaceous Vegetation – Burned	Management Complex[1]
104	*Typha domingensis (Typha angustifolia, latifolia)* Herbaceous Vegetation - Disked	Southern (Broad-leaved, Narrow-leaved) Cattail Herbaceous Vegetation - Disked	Management Complex[1]
Barren Units			
73	Clay Bluffs - Barren	Clay Bluffs - Barren	II
74	Mud Flats - Barren	Mud Flats - Barren	II
76	Point Bars - Dry Sand	Point Bars - Dry Sand	Sub-Level II
77	Point Bars - Wet Sand	Point Bars - Wet Sand	Sub-Level II
78	Islands - Dry Sand	Islands - Dry Sand	Sub-Level II
79	Islands - Wet Sand	Islands - Wet Sand	Sub-Level II
Land Use Units			
70	Agricultural Crop - Alfalfa	Agricultural Crop - Alfalfa	Sub-Level II
71	Agricultural Crop - Barley	Agricultural Crop - Barley	Sub-Level II
72	Agricultural Crop - Fallow Land	Agricultural Crop - Fallow Land	Sub-Level II
75	Constructed Waterfowl Nesting Islands	Constructed Waterfowl Nesting Islands	Sub-Level II
80	Utah Highway 88 ROW	Utah Highway 88 ROW	Sub-Level II
81	Uintah County Road	Uintah County Road	Sub-Level II
82	Hatchery Road	Hatchery Road	Sub-Level II

83	Auto Tour Route	Auto Tour Route	Sub-Level II
84	Service Roads and Trails	Service Roads and Trails	II
85	Levee (Flood Control)	Levee (Flood Control)	Sub-Level II
86	Dike (Separate Impoundment)	Dike (Separate Impoundment)	Sub-Level II
89	Refuge Facility	Refuge Facility	Sub-Level II
90	Oil and Gas Facility	Oil and Gas Facility	Sub-Level II
91	Green River - Main Channel	Green River - Main Channel	Sub-Level II
92	Green River - Backwater	Green River - Backwater	Sub-Level II
93	Canal	Canal	II
95	Pond - Fish Hatchery	Pond - Fish Hatchery	Sub-Level II
96	Pond - Impoundment	Pond - Impoundment	Sub-Level II
97	Pond - Moist Soil	Pond - Moist Soil	Sub-Level II
98	Pond - Pot hole, Dugout, Livestock	Pond - Pot hole, Dugout, Livestock	Sub-Level II
99	Gravel Pit	Gravel Pit	II
100	Levee Removal Site	Levee Removal Site	Sub-Level II

[1] **COMPLEX:** A group of plant associations that cannot be mapped individually on the aerial photographs but occur together predictably on the landscape**.** Complexes typically are composed of communities with similar physiognomies, thus are more difficult to tell apart on the photos.

*****These associations and map units occurred in the Refuge but were not of sufficient size to map.

3.3 Relationship Between Map Units and Plant Associations

The ONWR map units represent a compromise among the detail of the NVCS classification, the needs of the Refuge and the limitations of the photography. As a result, the ONWR mapping scheme does not exactly match the NVCS. The vegetation map units are linked ("crosswalked") to the NVCS plant associations. When a plant association has a unique photo signature, the map unit and the plant association are the same. When plant associations occur in complexes of stands too small to map or when related plant associations share the same signature, several plant associations are lumped into a single map unit. When more than one phase of a single plant association could be recognized on the photos, a plant association is split among several map classes. Finally, non-vegetated areas and vegetation types not recognized by the NVCS receive special map unit designations. The crosswalking of the NVCS associations to the map units for ONWR are listed below.

Map Units Representing Single NVCS Units (either existing or new)

The following map units were created from the NVCS and represent established or provisional plant associations or alliances that could be discerned and delineated on the aerial photography.

Map Code	Map Unit NVCS Plant Association
1	*Populus fremontii* Temporarily Flooded Forest Alliance *Populus fremontii* Temporarily Flooded Forest Alliance
2	*Populus fremontii* Temporarily Flooded Woodland Alliance *Populus fremontii* Temporarily Flooded Woodland Alliance
3	*Salix amygdaloides/Salix exigua* Woodland *Salix amygdaloides/Salix exigua* Woodland
4	*Elaeagnus angustifolia* Semi-natural Woodland *Elaeagnus angustifolia* Semi-natural Woodland
5	*Salix exigua*/Barren Shrubland *Salix exigua*/Barren Shrubland
6	*Tamarix* spp. Temporarily Flooded Shrubland *Tamarix* spp. Temporarily Flooded Shrubland
8	*Rhus trilobata* - Coyote Willow Shrubland *Rhus trilobata-Salix exigua* Shrubland
9	*Shepherdia argentea* Great Basin Shrubland *Shepherdia argentea* Great Basin Shrubland
11	*Sarcobatus vermiculatus / Distichlis spicata* Shrubland *Sarcobatus vermiculatus / Distichlis spicata* Shrubland

12 *Sarcobatus vermiculatus / Atriplex gardneri* Shrubland
Sarcobatus vermiculatus / Atriplex gardneri Shrubland

13 *Artemisia tridentata* Shrubland
Artemisia tridentata Shrubland

14 *Ericameria parryi – Sarcobatus vermiculatus* Shrubland [Provisional]
Ericameria parryi-Sarcobatus vermiculatus Shrubland [Provisional]

15 *Ericameria nauseosa* Sand Deposit Sparse Vegetation
Ericameria nauseosa Sand Deposit Sparse Vegetation

16 *Atriplex canescens / Pleuraphis jamesii* Shrubland
Atriplex canescens / Pleuraphis jamesii Shrubland

17 *Grayia spinosa / Pleuraphis jamesii* Shrubland
Grayia spinosa / Pleuraphis jamesii Shrubland

18 *Tetradymia spinosa / Pleuraphis jamesii* Dwarf-shrubland
Tetradymia spinosa / Pleuraphis jamesii Dwarf-shrubland

19 *Gutierrezia sarothrae - (Opuntia spp.) / Pleuraphis jamesii* Dwarf-shrubland
Gutierrezia sarothrae - (Opuntia spp.) / Pleuraphis jamesii Dwarf-shrubland

21 *Ephedra torreyana – (Atriplex canescens, confertifolia)* Sparse Vegetation [Provisional]
Ephedra torreyana –(Atriplex canescens, confertifolia) Sparse Vegetation [Provisional]

22 *Artemisia nova* Dwarf-shrubland
Artemisia nova Dwarf-shrubland

23 *Atriplex confertifolia / Pleuraphis jamesii* Shrubland
Atriplex confertifolia / Pleuraphis jamesii Shrubland

24 *Atriplex corrugata* Dwarf-shrubland
Atriplex corrugata Dwarf-shrubland

25 *Atriplex gardneri* Dwarf-shrubland
Atriplex gardneri Dwarf-shrubland

26 *Eriogonum schockleyi* Badlands Sparse Vegetation [Provisional]
Eriogonum schockleyi Badlands Sparse Vegetation [Provisional]

27 *Potamogeton natans* Herbaceous Vegetation
Potamogeton natans Herbaceous Vegetation

28 *Polygonum amphibium* Permanently Flooded Herbaceous Alliance
Polygonum amphibium Permanently Flooded Herbaceous Alliance

30 *Schoenoplectus acutus* Herbaceous Vegetation
Schoenoplectus acutus Herbaceous Vegetation

32. *Schoenoplectus pungens* Herbaceous Vegetation
Schoenoplectus pungens Herbaceous Vegetation

33 *Juncus balticus* Herbaceous Vegetation
Juncus balticus Herbaceous Vegetation

34 *Eleocharis palustris* Herbaceous Vegetation
Eleocharis palustris Herbaceous Vegetation

35 *Phragmites australis* Western North America Temperate Semi-natural Herbaceous Vegetation
Phragmites australis Western North America Temperate Semi-natural Herbaceous Vegetation

36 *Phalaris arundinacea* Western Herbaceous Vegetation
Phalaris arundinacea Western Herbaceous Vegetation

37 *Hordeum jubatum* Herbaceous Vegetation
Hordeum jubatum Herbaceous Vegetation

40. *Distichlis spicata* Herbaceous Vegetation
Distichlis spicata Herbaceous Vegetation

41 *Sporobolus airoides* Southern Plains Herbaceous Vegetation
Sporobolus airoides Southern Plains Herbaceous Vegetation

42 *Pascopyrum smithii* Herbaceous Vegetation
Pascopyrum smithii Herbaceous Vegetation

43 *Achnatherum hymenoides* Herbaceous Alliance
Achnatherum hymenoides Herbaceous Alliance

45 *Sporobolus cryptandrus* Great Basin Herbaceous Vegetation
Sporobolus cryptandrus Great Basin Herbaceous Vegetation

46 *Hesperostipa comata* Great Basin Herbaceous Vegetation
Hesperostipa comata Great Basin Herbaceous Vegetation

47 *Pleuraphis jamesii* Herbaceous Vegetation
Pleuraphis jamesii Herbaceous Vegetation

48 *Bromus tectorum* Semi-natural Herbaceous Alliance
Bromus tectorum Semi-natural Herbaceous Alliance

51 *Krascheninnikovia lanata / Pleuraphis jamesii* Dwarf-shrubland
Krascheninnikovia lanata / Pleuraphis jamesii Dwarf-shrubland

66 *Lepidium latifolium* Semi-natural Herbaceous Alliance [Provisional]
Lepidium latifolium Semi-natural Herbaceous Alliance [Provisional]

Map Units Representing Multiple Phases of a Plant Association Complex

The following map units represent plant associations that are divided into multiple map units because of floristic differences easily discerned on the aerial photographs. The floristic differences result from a combination of management, substrate, or moisture differences. Map units used to delineate these types can be considered local plant communities or plant populations.

Map Code	Map Unit NVCS Plant Association
29	*Polygonum lapathifolium* Permanently Flooded Herbaceous Vegetation Annual Weedy Forbs Mudflat Complex
60	*Ambrosia tomentosa-Helianthus annuus* Herbaceous Vegetation Annual Weedy Forbs Mudflat Complex
61	*Atriplex rosea* Semi-natural Herbaceous Vegetation Annual Weedy Forbs Mudflat Complex
62	*Xanthium strumarium* Herbaceous Vegetation Annual Weedy Forbs Mudflat Complex
64	*Kochia scoparia* Semi-natural Herbaceous Vegetation Annual Weedy Forbs Mudflat Complex

Map Units Representing Aggregations of Plant Associations (Complex)

In cases where closely related plant associations could not be distinguished on the photos, they were combined into a single map unit.

Map Code	Map Unit NVCS Plant Associations
31	*Typha domingensis (Typha angustifolia, latifolia)* Herbaceous Vegetation *Typha domingensis* Western Herbaceous Vegetation *Typha latifolia* Western Herbaceous Vegetation

Map Units Representing No Association (Refuge specials)

These map units were created for ONWR to describe vegetation for which no NVCS association exists, or for one of the following reasons:

- To represent important wildlife habitat types not known outside ONWR;
- To represent important wildlife habitat types occurring in patches smaller than the minimum mapping unit of 0.5 ha;
- To represent vegetation that was manipulated in the recent past, such as old fields, areas planted to native grasses and burned and disked cattail stands.

Map Code	Map Unit (Explanation)
7	*Tamarix* spp. */ Sporobolus airoides* Shrubland (Map unit not known or described outside of ONWR.)
10	*Symphoricarpos occidentalis* Shrubland (Map unit represents areas that are below the MMU but have been observed at ONWR)
20	*Artemisia dracunculus* Dwarf-shrubland (Map unit not known or described outside of ONWR.)
44	*Achnatherum hymenoides - Agropyron cristatum* Herbaceous Vegetation (Map unit represents an area that was reseeded along a reclaimed pipeline corridor.)
49	*Bouteloua gracilis* Introduced Grassland (Map unit represents a re-seeded area)
50	*Apocynum cannabinum* Herbaceous Vegetation (Map unit represents areas that are often below the MMU. Type closely compares with NVCS Dogbane association CEGL006537 but more dense.)
63	*Iva axillaris* Herbaceous Vegetation (Map unit represents areas that are often below the MMU.)
65	*Medicago sativa / Populus fremontii* Herbaceous Vegetation (Map unit represents an area that was seeded or adjacent to an old field.)
67	*Opuntia polyacantha - Gutierrezia sarothrae / Halogeton glomeratus - Bromus tectorum* Disturbed Vegetation (Map unit represents an old prairie dog town. Map unit is not known or described outside of ONWR.)
68	*Glycyrrhiza lepidota* Herbaceous Vegetation (Map unit represents individual stands that are not known or described outside of ONWR. Type is likely not a true community but rather a monotypic stand resulting from disturbance.)

101 *Schoenoplectus acutus* Herbaceous Vegetation - Burned
(Map unit represents *Schoenoplectus acutus* Herbaceous Vegetation (see Map Unit 30) stands that have been burned in the recent past)

103 *Typha domingensis (Typha angustifolia, latifolia)* Herbaceous Vegetation - Burned
(Map unit represents *Typha* spp. (see Map Unit 31) stands that have been burned for control purposes in the recent past.)

104 *Typha domingensis (Typha angustifolia, latifolia)* Herbaceous Vegetation - Disked
Map unit represents *Typha* spp. (see Map Unit 31) stands that have been disked for control purposes in the recent past.)

3.4 Vegetation Map

A total of 14,029 acres (5678 ha) comprising Ouray National Wildlife Refuge was mapped, including acreage leased by FWS from other agencies, tribes, and private individuals. Of this total, NVCS-related vegetation map units covered 10,714 acres (4286 ha). The remaining acreage was mapped using land cover and Refuge special map units. Of all the map units, the most frequent was #2 Fremont Cottonwood Temporarily Flooded Woodland with 902 polygons. However these were typically quite small (0.6 acres). The most abundant map unit in terms of area was #15 Rubber Rabbitbrush Dwarf-shrubland (sparse) type covering 1196 acres. Frequencies of map units (*i.e.*, number of polygons) along with acreage per map unit are listed in **Table 5**.

3.5 Accuracy Assessment

Of the 421 sampling points generated for the accuracy assessment (see **Figure 10**), 42 could not be sampled because they were in impenetrable tamarisk thickets or in deep water or mud. The remainders were evaluated for accuracy in August 2001. By comparing these points back to the vegetation map we were able to calculate an overall thematic accuracy of 75.2%. **Table 6** presents the accuracy assessment scores and confidence intervals for each map unit assessed along with the values for the entire map.

Table 5. Total acreage and frequency of map units for Ouray National Wildlife Refuge.

Map Code	Map Unit Common Name	Polygons	Hectares	Ave (h)	Acres	Ave (a)
1	Fremont Cottonwood Temporarily Flooded Forest	38	153.1	4.0	378.3	10.0
2	Fremont Cottonwood Temporarily Flooded Woodland	902	213.8	0.2	528.3	0.6
3	Peachleaf Willow / Coyote Willow Woodland	22	4.4	0.2	10.8	0.5
4	Russian-olive Semi-natural Woodland	113	15.6	0.1	38.5	0.3
5	Coyote Willow / Barren Shrubland	92	54.1	0.6	133.6	1.5
6	Tamarisk spp. Temporarily Flooded Shrubland	95	61.6	0.6	152.1	1.6
7	Tamarisk spp. / Alkali Sacaton Shrubland	456	273.1	0.6	674.7	1.5
8	Ill-scented Sumac – Coyote Willow Shrubland	115	62.2	0.5	153.7	1.3
9	Silver Buffaloberry Great Basin Shrubland	11	1.3	0.1	3.2	0.3
10	Snowberry Shrubland	0	0	0	0	0
11	Black Greasewood / Saltgrass Shrubland	326	446.2	1.4	1102.6	3.4
12	Black Greasewood / Gardner's Saltbush Shrubland	70	267.3	3.8	660.5	9.4
13	Big Sagebrush Shrubland	8	8.6	1.1	21.2	2.7
14	Parryi Rabbitbrush – Black Greasewood Shrubland [Provisional]	18	10.4	0.6	25.8	1.4
15	Rubber Rabbitbrush Sand Deposit Sparse Vegetation	208	483.9	2.3	1195.6	5.7
16	Fourwing Saltbush / James' Galleta Shrubland	16	20.3	1.3	50.2	3.1
17	Spiny Hopsage / James' Galleta Shrubland	41	145.7	3.6	360.0	8.8
18	Short-spine Horsebrush / James' Galleta Dwarf-shrubland	23	64.4	2.8	159.1	6.9
19	Snakeweed – (Prickly-pear spp.) / James' Galleta Dwarf-shrubland	35	24.5	0.7	60.5	1.7
20	Tarragon Dwarf-shrubland	1	0.1	0.1	0.2	0.2
21	Torrey's Joint-fir – (Fourwing Saltbush, Shadscale) Sparse Vegetation [Provisional]	61	18.2	0.3	45.0	0.7
22	Black Sagebrush Dwarf-shrubland	9	6.1	0.7	15.1	1.7
23	Shadscale / James' Galleta Dwarf-shrubland	54	25.7	0.5	63.6	1.2
24	Mat Saltbush Dwarf-shrubland	4	0.5	0.1	1.2	0.3
25	Gardner's Saltbush Dwarf-shrubland	9	32.9	3.7	81.4	9.0
26	Schockley's Buckwheat Badlands Sparse Vegetation [Provisional]	6	2.4	0.4	5.9	1.0
27	Floating Pondweed Herbaceous Vegetation	8	52.8	6.6	130.5	16.3
28	Water Smartweed Permanently Flooded Herbaceous Alliance	59	43.0	0.7	106.2	1.8
29	Pale Smartweed Permanently Flooded Herbaceous Vegetation	13	44.0	3.4	108.8	8.4
30	Hardstem Bulrush Herbaceous Vegetation	68	61.8	0.9	152.8	2.2
31	Southern (Broad-leaved, Narrow-leaved) Cattail Herbaceous Vegetation	243	306.9	1.3	758.3	3.1
32	Threesquare Herbaceous Vegetation	0	0	0	0	0
33	Baltic Rush Herbaceous Vegetation	2	0.2	0.1	0.5	0.3
34	Common Spikerush Herbaceous Vegetation	38	14.1	0.4	34.8	0.9
35	Common Reed Western North America Temperate Semi-natural Herbaceous Vegetation	3	0.3	0.1	0.8	0.3
36	Reed Canary Grass Western Herbaceous Vegetation	12	4.7	0.4	11.6	1.0
37	Foxtail Barley Herbaceous Vegetation	5	14.2	2.8	35.2	7.0

Map Code	Map Unit Common Name	Polygons	Hectares	Ave (h)	Acres	Ave (a)
40	Saltgrass Herbaceous Vegetation	259	143.5	0.6	354.5	1.4
41	Alkali Sacaton Southern Plains Herbaceous Vegetation	50	19.5	0.4	48.2	1.0
42	Western Wheatgrass Herbaceous Vegetation	101	132.7	1.3	327.9	3.2
43	Indian Ricegrass Herbaceous Alliance	93	62.1	0.7	153.5	1.7
44	Indian Ricegrass - Crested Wheatgrass Herbaceous Vegetation	1	0.7	0.7	1.8	1.8
45	Sand Dropseed Great Basin Herbaceous Vegetation	2	6.7	3.4	16.6	8.3
46	Needle-and-Thread Great Basin Herbaceous Vegetation	116	75.6	0.7	186.9	1.6
47	James' Galleta Herbaceous Vegetation	152	216.6	1.4	535.3	3.5
48	Cheatgrass Semi-natural Herbaceous Alliance	44	24.3	0.6	60.1	1.4
49		2	0.7	0.4	1.8	0.9
50	Hemp Dogbane Herbaceous Vegetation	66	40.3	0.6	99.6	1.5
51	Winter-fat / James' Galleta Dwarf-shrubland	2	0.2	0.1	0.5	0.3
60	Bur Ragweed - Wild Sunflower Herbaceous Vegetation	13	46.0	3.5	113.6	8.7
61	Red Orache Semi-natural Herbaceous Vegetation	33	91.1	2.8	225.0	6.8
62	Cocklebur Herbaceous Vegetation	23	6.2	0.3	15.4	0.7
63	Poverty Sumpweed Herbaceous Vegetation	6	1.0	0.2	2.4	0.4
64	Kochia Semi-natural Herbaceous Vegetation	23	25.7	1.1	63.5	2.8
65	Alfalfa / Fremont Cottonwood Herbaceous Vegetation	12	4.9	0.4	12.0	1.0
66	Pepperweed Semi-natural Herbaceous Vegetation [Provisional]	389	218.1	0.6	538.9	1.4
67	Prairie Dog Town Disturbed Vegetation	42	109.4	2.6	270.3	6.4
68	Wild Licorice Herbaceous Vegetation	42	18.3	0.4	45.2	1.1
70	Agricultural Crop - Alfalfa	5	19.3	3.9	47.8	9.6
71	Agricultural Crop - Barley	1	57.0	57.0	140.8	140.8
72	Agricultural Crop - Fallow Land	6	21.7	3.6	53.7	9.0
73	Clay Bluffs - Barren	79	363.2	4.6	897.5	11.4
74	Mud Flats - Barren	80	121.2	1.5	299.5	3.7
75	Constructed Waterfowl Nesting Islands	23	0.3	0.0	0.8	0.0
76	Point Bars - Dry Sand	92	52.2	0.6	128.9	1.4
77	Point Bars - Wet Sand	65	31.8	0.5	78.5	1.2
78	Islands - Dry Sand	43	21.2	0.5	52.5	1.2
79	Islands - Wet Sand	86	24.8	0.3	61.2	0.7
80	Utah Highway 88 ROW	1	3.0	3.0	7.3	7.3
81	Uintah County Road	10	22.2	2.2	54.9	5.5
82	Hatchery Road	1	18.4	18.4	45.4	45.4
83	Auto Tour Route	1	5.5	5.5	13.5	13.5
84	Service Roads and Trails	40	40.1	1.0	99.0	2.5
85	Levee (Flood Control)	5	9.1	1.8	22.6	4.5
86	Dike (Separate Impoundment)	7	23.4	3.3	57.9	8.3
89	Refuge Facility	17	32.7	1.9	80.9	4.8
90	Oil and Gas Facility	4	1.7	0.4	4.1	1.0

Map Code	Map Unit Common Name	Polygons	Hectares	Ave (h)	Acres	Ave (a)
91	Green River - Main Channel	4	324.4	81.1	801.5	200.4
92	Green River - Backwater	46	11.0	0.2	27.2	0.6
93	Canal	9	4.2	0.5	10.3	1.1
95	Pond - Fish Hatchery	38	6.6	0.2	16.2	0.4
96	Pond - Impoundment	59	114.9	1.9	283.8	4.8
97	Pond - Moist Soil	1	0.0	0.0	0.1	0.1
98	Pond - Pot hole, Dugout, Livestock	2	0.0	0.0	0.1	0.1
99	Gravel Pit	18	8.5	0.5	21.0	1.2
100	Levee Removal Site	4	3.4	0.9	8.5	2.1
101	Hardstem Bulrush Herbaceous Vegetation - Burned	5	15.5	3.1	38.2	7.6
103	Southern (Broad-leaved, Narrow-leaved) Cattail Herbaceous Vegetation - Burned	32	95.3	3.0	235.4	7.4
104	Southern (Broad-leaved, Narrow-leaved) Cattail Herbaceous Vegetation - Disked	6	43.2	7.2	106.7	17.8
Totals						
All Map Units		**5445**	**5677.7**	**278.1**	**14,029.4**	**687.2**
Natural/Semi-natural Vegetation Map Units (1-68, 101, 103, 104)		**4698.0**	**4335.9**	**82.8**	**10,713.9**	**204.7**
Planted/Cultivated, Land Use/Land Cover and Refuge Specific Map Units (70-100)		**747.0**	**1341.8**	**195.3**	**3315.5**	**482.5**

Using the Accuracy Assessment Contingency Table (**Table 6**)*:* The contingency table or error matrix is an array of numbers set out in rows and columns corresponding to a particular vegetation map unit relative to the actual vegetation type as verified on the ground. The column headings represent the vegetation associations as determined in the field and the row headings represent the map unit codes taken from the vegetation map (see **Table 5**). The highlighted diagonal indicates the number of points assessed in the field that agree with the map label. Conversely, the inaccuracies of each map unit are described as both errors of inclusion (user's or commission errors) and errors of exclusion (producer's or omission errors). By reading across this table (*i.e.*, rows) one can calculate the percent error of commission, or how many polygons for each map unit were incorrectly labeled according to the field ecologist. By reading down the table (*i.e.*, columns) one can calculate the percent error of omission, or how many polygons for that type were left off the map. Numbers "on the diagonal" tell the user how well the map unit was interpreted and how confident they can be in using it. Numbers "off the diagonal" yield important information about the deficiencies of the map including which types were often confused and which types were under- or over-represented.

Table 6. Contingency table (error matrix) for vegetation mapping at Ouray National Wildlife Refuge.

Reference Data (Accuracy Assessment Field Classification)

Sample Data (Map Unit) Map Code	1	2	3	4	5	6	7	8	11	12	13	14, 15	16	17	18	19	21	22	23	25	27	28	29	30	31	34	36	37	40	41	42	43	45	46	47	48	50	60	61	62	64	65	66	67	68	104	Total Samples (N)	Commission Error % Correct	90% Confidence Interval -	90% Confidence Interval +
1	11																																														11	100%	80%	100%
2	1	17					2																																								20	85%	67%	94%
3		1	2																																												3	67%	20%	97%
4				2			1																																								3	67%	20%	97%
5					4																																										4	100%	50%	100%
6						2	2																																								4	50%	14%	86%
7					1		14																							1																	16	88%	70%	97%
8								4																																							4	100%	50%	100%
11									20	3		1																1																			25	80%	64%	90%
12									1	21																																					22	95%	82%	100%
13											4																																				4	100%	50%	100%
14,15									1			18		1																		1		4	3												28	64%	47%	
16													5																																		5	100%	62%	100%
17														15																																	15	100%	85%	100%
18														1	4																																5	80%	38%	98%
19												2			1	2																															5	40%	11%	75%
21												1					4																														5	80%	38%	98%
22																		2																													2	100%	32%	100%
23									1			1							2															1													5	40%	11%	75%
25																				5																											5	100%	62%	100%
27																					3																										3	100%	46%	100%
28																						5																									5	100%	62%	100%
29																							2																								2	100%	32%	100%
30							1																	2	2																						5	40%	11%	75%
31																									15															3	1						19	79%	61%	91%
34																										3			1																		4	75%	32%	97%
36																											2																				2	100%	32%	100%
37																												0			3																3	0%	0%	54%
40		1																											16		2										1						20	80%	63%	91%
41																														4																	4	100%	50%	100%
42																												4		1	7							1							1		14	50%	26%	74%
43												2																			1	1												1			5	20%	2%	62%
45												1																					1														2	50%	5%	95%
46																																		4													4	100%	50%	100%
47												1																				2		3	19												25	76%	61%	90%
48																				2																2											4	50%	14%	86%
50																									1						1						2										4	50%	14%	86%
60																															1							4									5	80%	38%	98%
61																																							2								2	100%	32%	100%
62																																								1							1	100%	10%	100%
64																													2												2		1				5	40%	11%	75%
65																																						2				0	1				3	0%	0%	54%
66																								1				3		4								1					15				24	63%	45%	78%
67										1				1		2																			1	1								7			13	54%	28%	75%
68							1																																						4		5	80%	38%	98%
104																								1																						4	5	80%	38%	98%
Total Samples:	12	19	2	2	5	2	21	4	23	25	4	27	5	18	5	4	4	2	2	7	3	5	2	4	18	3	2	8	19	10	15	4	1	12	23	3	2	8	2	4	4	0	17	8	5	4	Total Correct:			285
Omission Error	92%	90%	100%	100%	80%	100%	67%	100%	87%	84%	100%	67%	100%	83%	80%	50%	100%	100%	100%	71%	100%	100%	100%	50%	83%	100%	100%	0%	84%	40%	47%	25%	100%	33%	83%	67%	100%	50%	100%	25%	50%	0%	88%	88%	80%	100%	Total Samples:			379
90% Confidence -	71%	74%	32%	32%	38%	32%	46%	50%	73%	69%	50%	50%	62%	65%	38%	14%	50%	32%	32%	32%	46%	62%	32%	14%	65%	46%	32%	0%	66%	19%	25%	3%	10%	15%	67%	20%	32%	24%	32%	3%	14%	0%	71%	58%	38%	50%				
90% Confidence +	99%	97%	100%	100%	98%	100%	100%	81%	100%	95%	93%	100%	95%	93%	100%	80%	100%	100%	100%	92%	100%	100%	100%	86%	94%	100%	100%	26%	94%	66%	68%	68%	100%	60%	92%	97%	100%	76%	100%	68%	86%	0%	97%	99%	98%	100%				

OVERALL TOTAL ACCURACY = 75.2 % **OVERALL KAPPA INDEX = 74.2 %** [Pchance = 0.0388] **OVERALL TOTAL ACCURACY 90% UPPER AND LOWER CONFIDENCE INTERVAL: + 79%** and **- 71.4%**

Map units 14 and 15 were combined for the AA and map units 9,20,24,26,33,35,44,49,51, 63,101,and 103 were not assessed (see below). The total sample size (N) is used to calculate Overall Total Accuracy. (Omission and Commission errors were calculated using total accuracy)

Twelve map units were not assessed for accuracy due to their limited distribution and small size (usually below the minimum mapping unit):

(Map Unit# Map Unit Name)

9. Silver Buffaloberry Great Basin Shrubland,
10. Snowberry Shrubland,
20. Taragon Dwarf-shrubland,
24. Mat Saltbush Dwarf-shrubland,
26. Schockley's Buckwheat Badlands Sparse Vegetation [Provisional],
32. Threesquare Herbaceous Vegetation,
33. Baltic Rush Herbaceous Vegetation,
35. Common Reed Western North America Temperate Semi-natural Herbaceous Vegetation,
44. Indian Ricegrass - Crested Wheatgrass Herbaceous Vegetation,
49. Blue grama Introduced Grassland,
51. Winter-fat / James' Galleta Dwarf-shrubland,
63. Poverty Sumpweed Herbaceous Vegetation.

In most cases these units represented very rare types that were already documented in their entirety by plot or observation data. Further, the small nature of these types made it impossible to place and buffer accuracy assessment points within their polygons. Map units 101 and 103 were also not assessed since it was impossible to determine a "burned" cattail or bulrush situation a year after the fire occurred (*i.e.*, difference between 2000 photography and 2001 accuracy assessment sampling). Map units 13 and 14 were combined for assessment purposes due to difficulty in distinguishing between rabbitbrush species in the field.

Of the assessed map units, some had lower then expected levels of accuracy. By carefully examining these discrepancies we found seven common issues that seem to explain most of the errors.

1. Many of the errors occurred when a polygon was mapped as an association very similar, but different to the one identified by the field ecologist. This can happen because the photo interpreter and the field ecologist see the vegetation differently. For example, the photo interpreter sees the cover of shrubs and herbaceous vegetation over a large area, while the field ecologist assesses the cover in a much smaller area. This frequently leads to different estimates of cover and differing conclusions as to the correct plant association or map unit.

    - *Example:* Rabbitbrush map units (14,15) were confused with both Galleta (47) and Needle-and-thread (46) grass types 7 times causing commission error. This is likely a result of a limited perspective of the field ecologist relative to the photo interpreter. Subtle shifts in cover estimation may have caused sites recognized as shrubland on the photos to be assessed as grasslands on the ground. Review of the data does indicate that rabbitbrush was present.

2. Discrepancies with some map units arose from the NVCS, which depends on an arbitrary cutoff of shrub cover to separate herbaceous communities from shrublands. At ONWR, the cutoff between grasslands and shrublands was 25% shrub cover, which was very difficult for the photo interpreters to see.

- *Example:* Errors of commission associated with the Cheatgrass Herbaceous Alliance type (48) are likely explained by the difficulty in seeing the cutoff in shrub cover on the aerial photography. This resulted in having it confused with the Gardner's Saltbush Dwarf-shrubland, which forms a sparse shrubland.

3. Some plant associations are separated from each other based on the percent cover of species in the lower strata that the photo interpreter usually can't see.

   - *Example:* Tamarisk spp./ Temporarily Flooded Shrubland (6) was twice confused with Tamarisk spp./ Alkali Sacaton Shrubland (7) because the understory is obscured by the canopy on the photos. If combined, these types would improve to 90% commission and 78% omission accuracy.

4. Changes in land use and flooding regimes between 2000 and 2001 within the Refuge helped create inconsistencies between classification fieldwork (2000) and the accuracy assessment (2001). Areas bordering the Green River and the ponds might be covered by annual forbs (or different forb communities in different years) or might be completely bare, depending on the timing, height, and duration of flooding. This change from year to year was called "annual variation" by the accuracy assessment panel and explains most of the map errors in the annual forb and grassland types. This highly dynamic situation may be better categorized and mapped as a 'mixed annual forb mudflat" community.

   - *Example 1:* Alfalfa / Fremont Cottonwood Herbaceous Vegetation map unit (65) was used to describe disturbed areas in the floodplain with only two species, alfalfa and seeding cottonwoods. These areas are likely influenced by annual variation in flooding, which may explain why this map unit was often confused with the Bur Ragweed - Wild Sunflower Herbaceous Vegetation (60). This type should probably be grouped with the other mixed annual forb mudflat communities.

   - *Example 2:* Kochia Semi-natural Herbaceous Vegetation (64), Cocklebur Herbaceous Vegetation (62), and Bur Ragweed - Wild Sunflower Herbaceous Vegetation (60), would all be good candidates for grouping into a mixed annual forb mudflat type.

5. White-tailed prairie dogs at ONWR presented challenges to the photo interpreters and the accuracy assessment ecologists, due to their highly dynamic nature and life history. Because white-tailed prairie dogs migrate large distances and more frequently than black-tailed prairie dogs, they have less impact on the vegetation and it is more difficult to detect a prairie dog colony on the ground and determine if it is occupied or abandoned. This resulted in AA points in some prairie dog polygons being classified in the field as native undisturbed vegetation with "probably an old prairie dog town" noted in the comments.

- *Example:* Prairie Dog Town Disturbed Vegetation (67) had a high error of commission but an acceptable error of omission. All commission errors occurred with types that are common to disturbed sites and prairie dog towns (*e.g.* Snakeweed (Prickly-pear spp.) James' Galleta Dwarf-shrubland 19). The error is likely a result of the difficulty in distinguishing a prairie dog town from a natural community on the ground. On these grounds, we would recommend that either the error associated with map unit 67 be accepted or this type be dropped from the assessment.

6. The vegetation map was based on the photo interpretation of CIR aerial photography flown in 2000, while the accuracy assessment took place in 2001. Some map errors can be ascribed to changes in plant expression and phenology due to the severe drought in 2000 contrasted with normal precipitation in 2001. For example, upland bunchgrasses were much more evident in 2001 than they were in 2000, in some cases covering the dominant dwarf shrubs. Thus areas that would have appeared to be shrublands in 2000 may have been classified as grasslands in 2001.

   - *Example 1:* Relatively high levels of omission error for Foxtail Barley (37), Alkali Sacaton (41), Western Wheatgrass (42), Indian Ricegrass Sparse Dune (43), and Needle-and-thread Grass (46) Herbaceous Vegetation map units are all likely a result of higher moisture levels in 2001. In mesic 2001 these species were present and identified by the field biologist, however in 2000 they dried-up and simply were not visible on the 2000 aerial photography.

   - *Example 2:* Mapping Pepperweed Semi-natural Herbaceous Vegetation (66) is of great importance to Refuge management. In this project we obtained an 88% producers accuracy (indicating that we didn't miss many sites) however our user's accuracy was lower than expected at 63%. The largest source of confusion came between this type and Foxtail Barley Herbaceous Vegetation (37) and Alkali Sacaton Southern Plains Herbaceous Vegetation (41) both types that occur in similar habitat. We feel that this error is likely a function of either a change in species composition from the timing of the photography to the AA work (due to control of pepperweed or flooding) or these types were inclusions within the larger pepperweed polygons. Future work should concentrate on verifying and recording change of pepperweed sites on a yearly basis, especially those polygons that were assessed differently in this project.

7. The white, clayey soils common throughout the barren slopes and surrounding uplands of ONWR produced a high reflectance on the CIR photographs. This reflectance effectively masked some patches of vegetation, causing confusion when assessed. This is especially likely with the cheatgrass map unit (#48).

3.6 Recommendations for Future Projects

Several ideas for improving the mapping process resulted from the ONWR project. Implementing these suggestions could improve the quality and increase the efficiency of the process, and result in more accurate and useful products.

Vegetation Classification and Characterization

It is highly recommended that a completed (or nearly completed) classification be in place before the actual interpretation begins. Plot sampling should begin early in the project, followed by analysis of the vegetation data to the NVCS before the ground-truthing and interpretation of the aerial photographs. It is important to have written descriptions of the associations, approval of the types by the refuge, and a vegetation key during ground-truthing so that vegetation types can be related to the photo signatures. Also critical is deciding how to characterize and describe vegetation that has been manipulated in the past. This includes dealing with areas inherent to Refuges that have been reclaimed or reseeded and are not necessarily covered by the NVCS.

Vegetation Mapping

The objectives of the vegetation mapping process include classifying the vegetation into a system of plant associations and a system of map units. Typically the systems are similar; however, in many cases there is not a strict one-to-one correspondence between the two. Photographic interpretation centers around the ability to accurately and consistently delineate map classes based on complex photographic signatures. Vegetation characteristics that can be seen on aerial photography are not necessarily the same as those that are apparent on the ground. The reverse is also true. Due in part to the manipulated and sometimes altered vegetation on wildlife refuges, lengthy explanations are needed to describe disparities between map units and associations. Having two classification systems that use different approaches to describe the vegetation also creates a need for links or crosswalks between the two systems. No matter how clearly the linkages are described, the potential for confusion remains.

The reason for using the NVCS is to promote increased sharing, exchanging, and comparing of vegetation-related data among federal government agencies and other partners. This is greatly hindered when map units deviate from the NVCS. By creating the NVCS classification for a site before the photo interpretation is started the mapping classification and the entire project will more closely resemble the NVCS types. Further, detailed and effective follow-up fieldwork and map verification can substantially contribute to improving the entire process by discerning the inherent variability of the landscape.

The acquisition of new aerial photography and generating an orthophoto base map from that photography greatly added to the value and quality of this project. In

addition, there is no ground condition difference between the photos used for interpretation and the base map, therefore, this database, at time of completion is only one year old in terms of the 'ground condition'.

Editing and quality checking of the digital polygons created borders that tightly bounded corresponding features on the DOP base map. Automation of the scanning and transfer process (via in-house AMLS) using a 'shell' system greatly aided speed and consistency. Also, to accommodate several technicians working on the transfer work, the work was subdivided. Once all the transfer work was complete, all the individual vegetation coverages were combined into an overall vegetation coverage. This speeded up the digital transfer process without an increase in transfer errors.

Summary

Recognizing the logistical and technical issues inherent to the vegetation mapping process, there are a number of factors that are critical to the success of any vegetation-mapping project. The amount of time needed to develop map units, create mapping conventions, make photo interpretation decisions, and produce the final digital map is inversely proportional to the degree that the parties involved communicate. Consensus building and good communication among the ecologists, photo interpreters, and Refuge staff greatly increases the quality and efficiency of the project. Future projects should strive to involve USFWS staff (both at the region and local levels), NatureServe ecologists, and BOR ecologists/photo-interpreters at all stages of the project. Prompt and constructive feedback from Refuge personnel throughout, but especially during the initial interpretation and classification can substantially reduce many of the problems that might otherwise surface late in the process.

In particular, the ONWR mapping process was among the smoothest ever experienced by the RSGIS staff. Although the project lead changed in the middle of the process, there was little overall delay. This was due in part to the hard work and high degree of organization of the original project lead, but also in large part to the high degree of involvement by Refuge staff. Refuge staff reviewed every draft product and made helpful suggestions at every major step of the process. Prompt review and substantial response should be the norm for these projects and not the exception.

It was also noted by USFWS staff that 80% accuracy for every map unit might not be realistic nor desirable for vegetation mapping projects in refuges. Having less than 80% accuracy for some classes is likely a result of either land manipulation and/or seasonal/annual variations in precipitation, flooding, draw-down timing etc. Instead of grouping similar types together to increase the overall accuracy it was deemed more important to retain the detail for future studies. This detail will allow the refuge staff to focus their validation/ground-truthing efforts along with their long-term monitoring and inventory studies on types that are subject to anthropogenic or natural environmental change.

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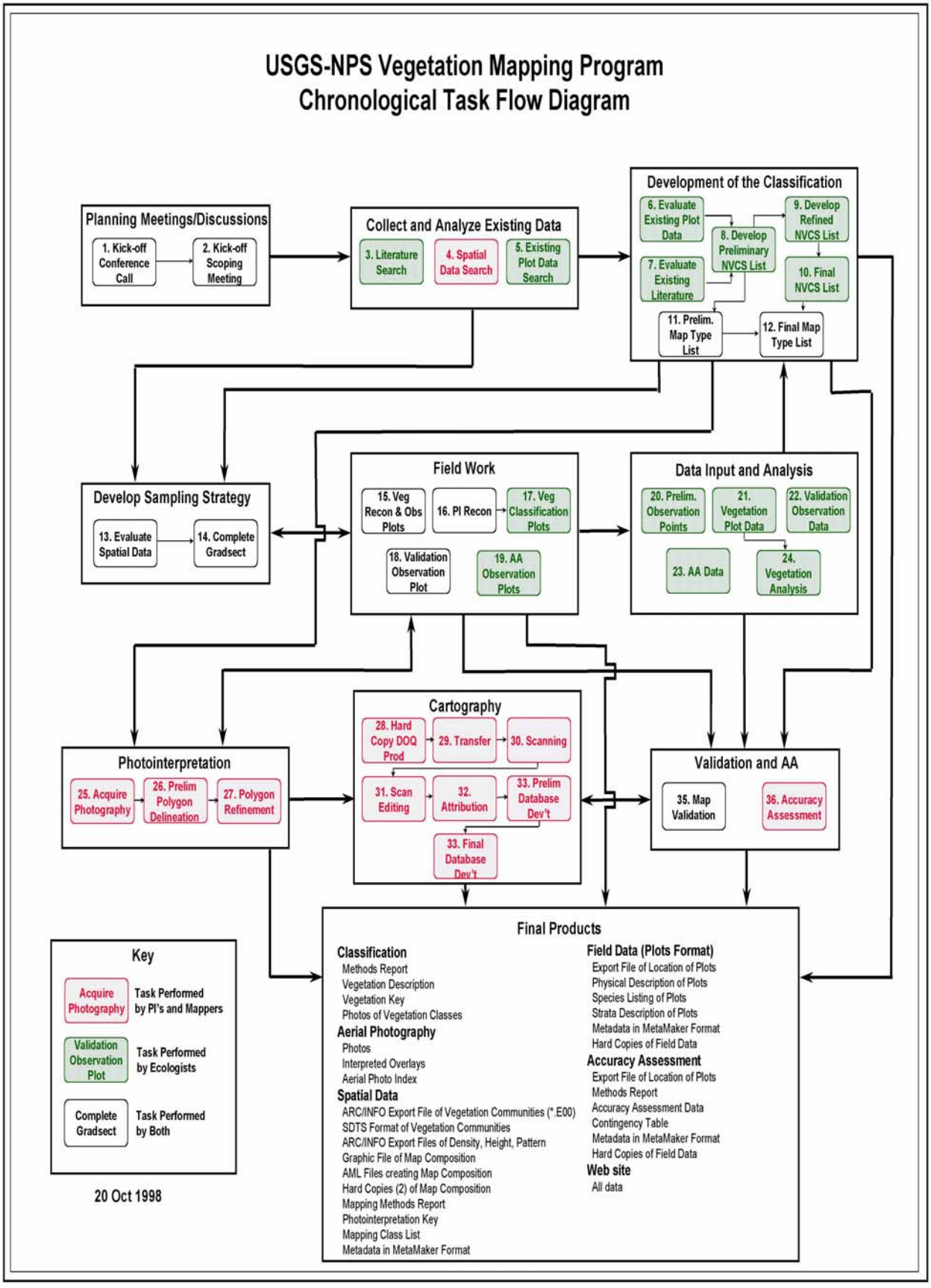
APPENDIX A. FLOWCHART FOR THE USGS-NPS VEGETATION MAPPING PROGRAM

(Tom Owens, USGS-BRD)


USGS-NPS Vegetation Mapping Program
Chronological Task Flow Diagram
Planning Meetings/Discussions
1. Kick-off Conference Call
2. Kick-off Scoping Meeting
Collect and Analyze Existing Data
3. Literature Search
4. Spatial Data Search
5. Existing Plot Data Search
Development of the Classification
6. Evaluate Existing Plot Data
7. Evaluate Existing Literature
8. Develop Preliminary NVCS List
9. Develop Refined NVCS List
10. Final NVCS List
11. Prelim. Map Type List
12. Final Map Type List
Develop Sampling Strategy
13. Evaluate Spatial Data
14. Complete Gradsect
Field Work
15. Veg Recon & Obs Plots
16. PI Recon
17. Veg Classification Plots
18. Validation Observation Plot
19. AA Observation Plots
Data Input and Analysis
20. Prelim. Observation Points
21. Vegetation Plot Data
22. Validation Observation Data
23. AA Data
24. Vegetation Analysis
Cartography
28. Hard Copy DOQ Prod
29. Transfer
30. Scanning
31. Scan Editing
32. Attribution
33. Prelim Database Dev't
33. Final Database Dev't
Photointerpretation
25. Acquire Photography
26. Prelim Polygon Delineation
27. Polygon Refinement
Validation and AA
35. Map Validation
36. Accuracy Assessment
Key
Acquire Photography
Task Performed by PI's and Mappers
Validation Observation Plot
Task Performed by Ecologists
Complete Gradsect
Task Performed by Both
20 Oct 1998
Final Products
Classification
Methods Report
Vegetation Description
Vegetation Key
Photos of Vegetation Classes
Aerial Photography
Photos
Interpreted Overlays
Aerial Photo Index
Spatial Data
ARC/INFO Export File of Vegetation Communities (*.E00)
SDTS Format of Vegetation Communities
ARC/INFO Export Files of Density, Height, Pattern
Graphic File of Map Composition
AML Files creating Map Composition
Hard Copies (2) of Map Composition
Mapping Methods Report
Photointerpretation Key
Mapping Class List
Metadata in MetaMaker Format
Field Data (Plots Format)
Export File of Location of Plots
Physical Description of Plots
Species Listing of Plots
Strata Description of Plots
Metadata in MetaMaker Format
Hard Copies of Field Data
Accuracy Assessment
Export File of Location of Plots
Methods Report
Accuracy Assessment Data
Contingency Table
Metadata in MetaMaker Format
Hard Copies of Field Data
Web site
All data

APPENDIX B: USBR-RSGIS WORK PROPOSAL

Proposal for Classifying and Mapping Vegetation Communities
Ouray National Wildlife Refuge - Utah

U.S. Bureau of Reclamation, Remote Sensing and Geographic Information Group
Technical Service Center, Denver, Colorado

1. Overview

This document presents our proposed methods and estimated costs associated with classifying and mapping vegetation communities at Ouray National Wildlife Refuge (ONWR), Utah to the standards developed under the USGS-NPS Vegetation Mapping Program. This discussion is based on telephone conversations with Tom Owens of the Center for Biological Informatics, Biological Resources Division, USGS. The mapping effort will cover approximately 12,000 acres inside the ONWR. Note, refer to Section 5. below for abbreviations used in this proposal.

2. Aerial Photograph Acquisition.

It is anticipated that existing aerial photographs will not suffice for this mapping effort and it is proposed that new aerial photography be acquired. The latest NAPP photos (1:40,000) are 1997 and they are B/W film. The latest NAPP CIR photos are 1987 and they are also 1:40,000 scale. In addition, there are no DOQQ's available from USGS for the 4 quads covering ONWR for use as a basemap. The aerial photos will be ortho-rectified and an orthophoto basemap will be produced. This will greatly aid in GIS database creation as it will decrease the amount of time required to transfer interpreted data into the database as compared to using un-rectified photos.

1:12,000 scale, CIR, stereo-pair to be used for photo-interpretation.
1:40,000 scale for 1:12,000 scale, CIR, orthophoto basemap production.

The BOR will cover the cost of the aerial photo acquisition and orthophoto basemap production.

3. Project Tasks.

3.1 Scoping / Kick-off Meeting.

A preliminary meeting would be required with Refuge and Regional FWS personnel to discuss the project, present examples of similar projects the BOR has performed, and acquire available information from the FWS (ex: digital files of the Refuge boundary, roads, hydrology, etc). This meeting would allow FWS to address any special mapping needs and vegetation classification. Our proposal is based on this meeting taking place in Denver, therefore, no field time or travel expenses are anticipated:

2 BOR Staff Personnel.

3.2. Field Data Collection.

Vegetation field data will be collected at two levels of intensity: 1) Approximately 50 observation points will be visited and data collected to determine the range of aerial photograph signatures to guide interpretation for potential map classes or units, collect preliminary vegetation data relative to species dominance and habitat structure, and to determine the distribution of plant associations within ONWR; and 2) More detailed plot data (vegetation, soils, hydrology, environmental, etc.) will be collected for each plant association present to determine the NVCS classification. A set of representative color slides or digital photographs for each plant association and a comprehensive species list will be produced.

Detailed vegetation data and photo-documentation will be collected from 1-3 plots per association (approximately 45-60 vegetation plots), depending on stand dominance and variability within the landscape. Likely plant associations will include stand dominants such as Rio Grande cottonwood, willow (Gooding and sandbar/coyote), boxelder, tamarisk, Russian-olive, seep-willow, greasewood, saltbush (four-wing and shadscale), sagebrush (black and big), rabbitbrush, snakeweed, western wheatgrass, needle-and-thread grass, cattail, bulrush, spikerush, sedge, common reed, reed canary grass, smooth brome, Kentucky bluegrass, and cheatgrass, among others. Plots will be established in representative vegetation stands that meet or exceed the minimum mapping unit (MMU) of 0.5 hectares. If determined to be important to Refuge staff, some smaller units of vegetation or land use may be considered as "Refuge Specials", to be determined during scoping meetings. Unless otherwise directed by FWS-ONWR ecologists/staff, the plots will be 10m x 10m for herbaceous and shrub associations

and 20m x 20m for woodlands. During the Observation data collection field trip, a PI reconnaissance will also take place (see item 3.4 below).

Observation Point/Photo Signature Data Collection.
2 Researchers/2 Travel days/4 data collection/recon days.
Plot/NVCS Classification Data Collection.
2 Researchers/2 Travel Days/8 data collection days.
1 Researcher/ 1 day per trip planning.

3.3. Vegetation Classification.

Plot data collected in ONWR will be evaluated using the NVCS (Standardized National Vegetation Classification System); this system contains seven classification levels with the two finest being the alliance and association (community) levels. These data are quantitatively analyzed using ordination techniques (Detrended Correspondence Analysis and Non-Metric Multidimensional Scales), a clustering algorithm, Unweighted Pair-Group Method Using Arithmetic Means, and Two-Way Indicator Species Analysis.

Following analysis, plant associations are described as they occur in ONWR (local description), and nationally or world-wide (global descriptions)('global' by others). Further, a dichotomous key to the plant associations is prepared and illustrated with photos taken during the vegetation data gathering phase of the study. This key is valuable both to researchers conducting the accuracy assessment for this project, but also as an educational guide for other researchers or visitors to ONWR. Another product of this analysis is a comprehensive species list.

Vegetation Data Analysis/Descriptions/Species List.

3.4. Photo-interpretation.

A reconnaissance trip to establish photo-signatures and take ground photographs will be conducted before photo-interpretation starts. This trip will be combined with the Field Data Collection trip (see 3.2 above) and will add one day to that trip. Interpretation of the aerial photos will be performed using a combination of stereo pairs and on-screen orthophoto use. Data will be interpreted on drafting film (Mylar) overlays on the hardcopy orthophoto prints.

Photo-interpretation: 1 Researcher.

3.5. GIS Database.

Mylar overlays from the photo-interpretation will be scanned, rectified, and converted to ArcInfo coverages. The coverages will be edited, attributed according to the markings on the mylar overlays, and combined into one final coverage. One overall hard-copy map will be produced. An FGDC-compliant metadata* file will be produced for the coverage and the field data points.

Transfer data into GIS database: 1 Technician
Produce Map Product: 1 Technician.
Metadata*: 1 Technician.

3.6. Accuracy Assessment.

An accuracy assessment (AA) of the vegetation map will be performed during the second field season, Summer 2001. Eighty to 100 points will be randomly selected and field ecologists will navigate to their coordinates using a hand-held GPS receiver and determine the vegetation type present. The vegetation type will be determined by using an Illustrated Field Key to the NVCS Vegetation Associations at ONWR, prepared for this purpose. Also recorded will be other vegetation types occurring within 50m of the selected point. This data will be entered into a digital overlay (also export file for AA plot locations) for the vegetation map and each point will be evaluated for accuracy or error of omission or commission; an AA matrix or contingency table will be prepared to summarize results.

Typical guidelines for the AA procedure include:

·Observations of vegetation types are ground-based,
·Ground sampling techniques are similar to the Observation Points collected during initial classification,
·The number of samples per vegetation mapping unit will vary depending on abundance of the class upon the landscape,
·Logistical planning for the AA will revolve around access to work areas within ONWR and will be based on completed vegetation maps, and AA points will be randomly selected.

Following the AA, a decision analysis will be undertaken which examines the accuracy of each vegetation-mapping unit. The analysis will determine if the vegetation mapping unit, with its inherent variability: 1) meets the minimum standard of 80% accurate at the 90% confidence interval and is considered

acceptable, or 2) two or more vegetation mapping units must be combined into an alliance, complex, or mosaic in order to meet the minimum accuracy standard.

2 Researchers/2 Travel days/3 data collection days.
2 Researchers/3 Office days.

3.7. Final Report

All study methods, results, and appendices will be presented in a comprehensive final report. At a minimum, the final report will contain: list of contacts and contributors, list of tables and figures, executive summary and introduction, project area description, materials and methods, results, discussion, bibliography, appendices, CD-ROM (containing report and digital point and vegetation coverages in ArcView 3.1 format), and a vegetation map. Along with the final report, all aerial photography, orthophotos, and original observation point/plot/accuracy assessment data, will become the property of FWS-ONWR, as will any plant materials collected and preserved for identification purposes. In addition, a hardcopy orthophoto print of the entire Refuge will be produced to be used by the Refuge for display and other visual uses.

Final Report: 2 Researchers/10 office days.

APPENDIX C: OBSERVATION, PLOT, AND AA FIELD FORMS

NATIONAL WILDLIFE REFUGE VEGETATION MAPPING PROGRAM: OBSERVATION POINT FORM (1997)

IDENTIFIERS/LOCATORS

Plot Code_____ Polygon Code_____

Provisional Community Name___ _____

State ___ Refuge Name _____ Refuge Site Name _____

Quad Name_____ Quad Code_____

GPS file name_____ Field UTM X___ ___ ___ ___ ___ ___ m E Field UTM Y___ ___ ___ ___ ___ ___ ___ m N

please do not complete the following information when in the field
Corrected UTM X___ ___ ___ ___ ___ ___ m E Corrected UTM Y___ ___ ___ ___ ___ ___ ___ m N UTM Zone_____

Survey Date_____ Surveyors_____

ENVIRONMENTAL DESCRIPTION

Elevation _____ Slope _____ Aspect_____

Topographic Position

Landform

Cowardian System	Hydrologic Regime		Salinity Modifiers
___Upland	Non-Tidal		___Saltwater
___Riverine	___Permanently Flooded	___Saturated	___Brackish
___Palustrine	___Semipermanetly Flooded	___Temporarily Flooded/Saturated	___Freshwater
___Lacustrine	___Seasonally Flooded	___Intermittently Flooded	

Environmental Comments:	Unvegetated Surface: (please use the cover scale below)
	___ Bedrock ___ Litter, duff ___ Wood (> 1 cm) ___ Large rocks (cobbles, boulders > 10 cm) ___ Small rocks (gravel, 0.2-10 cm) ___ Sand (0.1-2 mm) ___ Bare soil ___ Other:_____

VEGETATION DESCRIPTION

Leaf phenology (of dominant stratum)	Leaf Type (of dominant stratum)	Physiognomic class	Cover Scale for Strata & Unvegetated Surface	Height Scale for Strata
Trees and Shrubs ___Evergreen ___Cold-deciduous ___Drought-deciduous ___Mixed evergreen - cold-deciduous ___Mixed evergreen - drought-deciduous Herbs ___Annual ___Perennial	___Broad-leaved ___Needle-leaved ___Mixed broad-leaved/Needle leaved ___Microphyllous ___Graminoid ___Forb ___Pteridophyte	___Forest ___Woodland ___Shrubland ___Dwarf Shrubland ___Herbaceous ___Nonvascular ___Sparsely Vegetated	01 5% 02 10% 03 20% 04 30% 05 40% 06 50% 07 60% 08 70% 09 80% 10 90% 11 100%	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

Strata	Height	Cover Class	Dominant species (mark any known diagnostic species with a *)	Cover Class
T1 Emergent	_____	_____	_____	
T2 Canopy	_____	_____	_____	
T3 Sub-canopy	_____	_____	_____	
S1 Tall shrub	_____	_____	_____	
S2 Short Shrub	_____	_____	_____	
S3 Dwarf-shrub H Herbaceous	_____	_____	_____	
N Non-vascular	_____	_____	_____	
V Vine/liana	_____	_____	_____	
E Epiphyte	_____	_____	_____	

please see the table on the previous page for height and cover scales for strata

Other Comments

Cover Scale for Species
- 01 <1%
- 02 1-5%
- 03 5-25%
- 04 25-50%
- 05 50-75%
- 06 75-100%

NATIONAL PARK VEGETATION MAPPING PROGRAM: PLOT SURVEY FORM

IDENTIFIERS/LOCATORS

Plot Code____ONWR_____ Habitat/BPU Code_____

Provisional Community Name_____

State _UT__ Park Name__Ouray NWR_____ Refuge Site Name_____

Quad Name_____ Quad Code_____

GPS file name_____ Field UTM X___ ___ ___ ___ ___ ___ m E Field UTM Y___ ___ ___ ___ ___ ___ ___ m N

Comments: _____ Error +/- ___ ____ m

Please do not complete the following information when in the field

Corrected UTM X___ ___ ___ ___ ___ ___ m E Corrected UTM Y___ ___ ___ ___ ___ ___ ___ m N UTM Zone _____

Survey Date_____ Surveyors_____

Directions to Plot

Plot length(m)_____ Azimuth _____ Plot width(m)_____ If circle (diam)_____ Plot Photos (y/n) __ Roll # _____ Frame # _____

Plot Permanent (y/n) ____ Comments on photos or marker

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 _____ Slope _____ Aspect_____

Topographic Position (see cheat sheet)

Landform (see cheat sheet)

Surficial Geology (see cheat sheet)

Cowardian System

___ Upland ____ Palustrine

___ Riverine ____ Lacustrine

Hydrology

___Permanently Flooded ___Seasonally Flooded ___Temporarily Flooded

___Semipermanetly Flooded ___Saturated ___Intermittently Flooded

___Unknown

Environmental Comments (dynamic stage, fire history, insect damage, etc):

Ground Cover: *(please estimate to the nearest percentage. Sum = 100%)*

___ Bare soil ___ Litter / duff ___ Wood (> 1 cm)

___ Bedrock ___Large rocks (cobbles, boulders > 10 cm)

___ Small rocks (gravel, 0.2-10 cm) ___ Sand (0.1-2 mm) dune /alluvium

___ Moss ___ Lichen ___ Cryptogam ___ Water ___ Other (name):

Soil Texture:

___ sand ___ loamy sand ___ sandy loam ___ loam

___ silt loam ___ silt ___ clay loam ___ silty clay

___ sandy clay ___ clay ___ peat ___ muck

Soil Drainage

___ Rapidly drained ___ Well drained

___ Moderately well drained ___ Somewhat poorly drained

___ Poorly drained ___ Very poorly drained

VEGETATION DESCRIPTION

Leaf phenology (of dominant stratum)	Leaf Type (of dominant stratum)	Physiognomic class	Cover Scale for Strata	Height 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	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%	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

	Height/Strata 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 Tree seedlings	_____	_____	_____
N Non-vascular	_____	_____	_____
V Vine/liana	_____	_____	_____
E Epiphyte	_____	_____	_____

Animal Use Evidence (including scat, browse, graze, burrows, bedding sites, etc)

Natural and Anthropogenic Disturbance Comments (please see cheat sheet for impact codes, list intensity as High, Med, or Low)

Other Comments (locations of photos and permanent plot marker)

Plot Code__Ouray._____

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 for forests and woodlands, on a separate page **or** line below each tree species, list the DBH of all trees above 5 cm diameter. Separate measurements with a comma (note if measurements are from multi-stemmed tree). Put an asterisk next to any species that are known diagnostics for a particular community in the classification. **Also list species outside the plot at the end of the table or designate with a 0 in Cover Class column.**

Stratum	Species Name	Cover Class	Stratum	Species Name	Cover Class	Stratum	Species Name	Cover Class

Cover Class Scale
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%
4 = >35-45% 10 = >95%

Ouray National Wildlife Refuge Vegetation Mapping Project

Tree D.B.H Form

Plot Code: Ouray Units in cm or inches (circle one)

Record tree diameter over 5 cm at 4.5 feet (1.37 m) height for species that contribute to tree canopy.

Separate measurements of multi-stemmed trees with commas. Can estimate by 5 cm dia. classes

Species	D.B.H.(s) for multi-stems trees

Species	D.B.H.(s) for multi-stems trees

Accuracy assessment Form (1998)
USGS-USFWS Vegetation Mapping Program

1. Plot Number _____ 2. Refuge Code _____ 3. Date _____

4. Observer(s)_____5. Datum _____ 6. Accuracy _____

7. UTM Coordinates: Easting __ __ __, __ __ __Northing __, __ __ __, __ __ __

8. UTM Zone _____ 9. Offset from Point: Easting _____m Northing _____m

10. Topographic Description _____

11. Elevation _____m 12. Aspect _____

13. Veg Assoc. at Site _____

14. Veg Assoc 2 within 50m of Site _____

15. Veg Assoc 3 within 50m of Site _____

16. Major Species Present (by strata)_____

_____

_____

17. Canopy Closure of Top Layer _____

18. Rationale for Classification_____

_____

_____

_____

19. Comments _____

_____

_____

APPENDIX F: A LIST OF VASCULAR PLANT SPECIES FOUND AT ONWR

SPECIES LIST - SORTED by FAMILY

AGAVACEA — Common: Agave Family

Genus - Species - Authority	Common Name	Reference
Yucca spp.	Yucca (Soapweed)	

AIZOACEAE — Common: Carpetweed Family

Genus - Species - Authority	Common Name	Reference
Sesuvium sessile Pers.	Lowland purslane	2,3
Sesuvium verrucosum Raf.	Sea purslane	1,4

ALISMATACEAE — Common: Water Plantain Family

Genus - Species - Authority	Common Name	Reference
Alisma gramineum Lej. (A. geyeri Torr.)	Narrowleaf water plantain	1,2,4
Echinodorus bertoroi (Spreng.) Fass.	Burhead	2,3
Echinodorus rostratus (Nutt.) Engelm.	Burhead	1,2
Sagittaria cuneata Sheldon	Wapato	1,2,3,4

AMARANTHACEAE — Common: Amaranth Family

Genus - Species - Authority	Common Name	Reference
Amaranthus retroflexus L.	Redroot pigweed	1,2

ANACARDIACEAE — Common: Sumac Family

Genus - Species - Authority	Common Name	Reference
Rhus (R. aromatica Aiton ssp.) trilobata Nutt. Weber	Skunkbush, Three-leaved	1,2,3,4

APIACEAE — Common: Carrot Family

Genus - Species - Authority	Common Name	Reference
Cymopterus acaulis (Pursh) Raf.	Spring-parsley	1,2
Cymopterus bulbosus A. Nels.	Onion spring-parsley	1,2
Cymopterus duchenensis Jones	Uinta Basin spring-parsley	1,2
Cymopterus purpurascens (Gray) Jones	Purple spring-parsley	1,2

APOCYNACEAE — Common: Dogbane Family

Genus - Species - Authority	Common Name	Reference
Apocynum cannabinum L.	Hemp dogbane	1,2,4

ASCLEPIADACEAE — Common: Milkweed Family

Genus - Species - Authority	Common Name	Reference
Asclepias cryptoceras Wats.	Pallid milkweed	1,2,4
Asclepias labriformis Jones	Milkweed	1,2,3
Asclepias speciosa Torr.	Showy milkweed	1,2,3,4

ASTERACEAE — Common: Sunflower Family

Genus - Species - Authority	Common Name	Reference
Ambrosia acanthicarpa Hook.	Annual burweed	1,4
Ambrosia tomentosa (Franseria discolor) Nutt.	Bur ragweed	1,2,4
Ambrosia trifida L.	Giant ragweed	4
Artemisia biennis Willd.	Biennial wormwood	1,2
Artemisia dracunculus L.	Tarragon	1,2,4
Artemisia ludoviciana Nutt.	Western mugwort	1,2,3,4
Artemisia nova A. Nels.	Black sagebrush	1,2,4
Artemisia spinescens D.C. Eaton in Wats.	Bud sagebrush	1,2,4
Artemisia tridentata Nutt. ssp. tridentata	Big sagebrush	1,2,3,4
Aster frondosus (Nutt.) T. & G.	Leafy aster	1,2
Aster sp.	Aster	1,4
Bahia dissecta (Gray) Britt.	Ragleaf bahia	1,3
Bidens cernua L.	Nodding beggartick	1,2
Brickellia oblongifolia Nutt.	Mohave brickellbush	1,2
Centaurea repens L.	Russian knapweed	1,2,4
Chaenactis douglassii (Hook.) H. & A.	Douglas chaenactis	1,2,4
Chaenactis stevioides H. & A.	Chaenactis	1,2,3

Chrysothamnus viscidiflorus (Hook.) Nutt.	Low rabbitbrush	1,2,4
Cirsium arvense (L.) Scop.	Canada thistle	1,2,4
Cirsium vulgare (Savi) Ten.	Bull thistle	1,2
Conyza canadensis (L.) Cronq.	Horseweed	1,4
Crepis runcinata (James) T. & G. var. glauca (Nutt.) Welsh	Dandelion hawksbeard	1,2
Enceliopsis nutans (Eastw.) A. Nels.	Enceliopsis	1,2
Ericameria nauseosa (Pallas) Britt.	Rubber rabbitbrush	1,2,3,4
Ericameria parryi (Gray) Greene	Parry rabbitbrush	1,4
Erigeron bellidiastrum Nutt. var. typicus Cronq.	Fleabane	3
Erigeron pumilus Nutt.	Low fleabane	1,2
Gnaphalium palustre Nutt.	Lowland cudweed	1,2,3,4
Grindelia squarrosa (Pursh) Dunal.	Curlycup gumweed	1,2,3,4
Gutierrezia sarothrae (Pursh) Britt. & Rusby	Broom snakeweed	1,2,3,4
Helenium autumnale L.	Orange sneezeweed	1,2
Helianthus annuus L.	Common sunflower	1,2,4
Helianthus petiolaris Nutt.	Sunflower	1,2,3
Heliomeris multiflora Nutt.	Showy goldeneye	1,2
Heterotheca villosa (Pursh) Shinners	Hairy goldaster	1,4
Hymenopappus filifolius Hook. var. luteus (Nutt.) Turner	Fineleaf hymenopappus	1,2,3,4
Iva axillaris Pursh	Poverty sumpweed	1,2,3,4
Lactuca serriola L.	Prickly lettuce	1,4
Lactuca tatarica (L.) C. A. Mey	Chicory lettuce	1,2
Leucelene ericoides (Torr.) Greene (Aster leucelene Blake)	Heath aster	1,2,3
Lygodesmia grandiflora (Nutt.) T. & G.	Skeleton plant	1,2,3
Machaeranthera canescens (Pursh) Gray	Purple tansyaster	1,2
Machaeranthera grindelioides (Nutt.) Shinners	Discoid tansyaster	1,2
Malacothrix sonchoides (Nutt.) T. & G.	Desert dandelion	1,2,3
Onopordum acanthum L.	Scotch thistle	1,4
Platyschkuhria integrifolia (Gray) Rydbg. (Bahia nudicaulis Gray)	Platyschkuhria	1,2,3
Prenanthella exigua (Gray) Rydbg.	Skeletonweed	1,2
Euthamia canadensis L.	Canada goldenrod	1,2,3
Euthamia missouriensis Nutt.	Missouri goldenrod	1,2,3
Euthamia occidentalis (Nutt.) T. & G.	Western goldenrod	1,2,4
Sonchus arvensis L.	Field sowthistle	1,2
Sonchus asper (L.) Hill	Prickly sowthistle	1,2
Sonchus oleraceous L.	Common sowthistle	1,4
Stephanomeria pauciflora (Torr.) Hall	Wire lettuce	3
Stephanomeria runcinata Nutt.	Wire lettuce	1,2
Tetradymia nuttallii T. & G.	Nuttall horsebrush	1,2,3
Tetradymia spinosa T. & G.	Cottonthorn horsebrush	1,2,4
Townsendia grandiflora Nutt.	Townsendia	3
Townsendia incana Nutt.	Townsendia	1,2
Tragopogon dubius Scop.	Yellow salsify	1,2,3,4
Xanthium strumarium L. (X. italicum Moretti)	Cocklebur	1,2,3,4
Xylorhiza venusta (Jones) Heller	Desert daisy	1,2,4

BORAGINACEAE **Common:** Borage Family

Genus - Species - Authority	Common Name	Reference
Cryptantha ambigua (Gray) Greene	Catseye	1,2,3
Cryptantha flava (A. Nels.) Payson	Yellow catseye	1,2,3
Cryptantha paradoxa (A. Nels.) Payson	Catseye	1,2
Heliotropium curassavicum L.	Salt heliotrope	1,4
Lappula redowskii (Hornem.) Greene	Desert stickseed	1,2,3
Tiquilia nuttallii (Hook.) A. Richardson	Nuttall's crinklemat	1,2

BRASSICACEAE **Common:** Mustard Family

Genus - Species - Authority	Common Name	Reference
Arabis pulchra Jones	Beauty rockcress	1,2
Descurainia pinnata (Walt.) Britt.	Blue tansy mustard	1,4
Descurainia sophia (L.) Webb ex Prantl.	Flixweed	1,4
Erysimum asperum (Nutt.) DC.	Rough wallflower	1,2,3,4
Lepidium densiflorum Schrad.	Prairie pepperweed	1,2,3

Lepidium latifolium L.	Giant whitetop	1,2,4
Lepidium montanum Nutt. in T. & G.	Mountain pepperweed	1,2
Malcolmia africana R. Br. in Ait.	African mustard	1,2
Physaria acutifolia Rydb.	Common twinpod	1,4
Rorippa curvipes Greene	Yellowcress	1,2
Rorippa islandica (Oeder) Borbas	Marsh yellowcress	1,2
Rorippa lyrata (Nutt.) Rydbg.	Yellowcress	3
Rorippa tenerrima Greene	Yellowcress	1
Schoenocrambe linifolia (Nutt.) Greene	Flaxleafed plains mustard	1,2
Sisymbrium altissimum L.	Jim Hill mustard	1,2,3,4
Stanleya pinnata (Pursh) Britt.	Bushy stanleya	1,4
Thelipodiopsis elegans (Jones) Rydbg.	Thelypodiopsis	1,2

CACTACEAE **Common:** Cactus Family

Genus - Species - Authority	Common Name	Reference
Coryphantha vivipara (Nutt.) Britt. & Rose	Pincushion cactus	1,2
Opuntia polyacantha (Haw.) (O. rutila Nutt.)	Plains pricklypear	1,2,3,4
Sclerocactus whipplei (Engelm.) Britt. & Rose var. glaucus (J. A. Purpus)	Uinta Basin hookless cactus	1,2,4

CAPPARIDACEAE **Common:** Caper Family

Genus - Species - Authority	Common Name	Reference
Cleome lutea Hook.	Yellow spiderflower	1,2,3
Cleome serrulata Pursh	Rocky Mountain bee-plant	1,2,3,4
Polanisia dodecandra (L.) DC.	Roughseed clammyweed	1,4

CAPRIFOLIACEAE: **Common:** Honeysuckle Family

Genus - Species - Authority	Common Name	Reference
Symphoricarpos occidentalis Hook	Western snowberry	1,4

CARYOPHYLLACEAE **Common:** Pink Family

Genus - Species - Authority	Common Name	Reference
Arenaria fendleri Gray	Fendler sandwort	1,2

CHENOPODIACEAE **Common:** Goosefoot Family

Genus - Species - Authority	Common Name	Reference
Atriplex argentea Nutt.	Silverscale	1,2,4
Atriplex canescens (Pursh) Nutt.	Four-wing saltbush	1,2,3,4
Atriplex confertifolia (Torr. & Frem.) Wats.	Shadscale	1,2,3,4
Atriplex corrugata Wats.	Mat saltbush	1,2,4
Atriplex gardneri (Moq.) Dietr. var. cuneata A. Nels.	Gardner's saltbush	1,2,3,4
Atriplex heterosperma Bunge	Orache	1,2
Atriplex patula L.	Spearscale	1,4
Atriplex rosea L.	Red orache	1,4
Bassia hyssopifolium (Pall.) Kuntze	Fivehook bassia	1,2,3,4
Ceratoides lanata (Pursh) J. T. Howell	Winterfat	1,2,3,4
Chenopodium album L.	Lambsquarters	1,4
Chenopodium atrovirens Rydb.	Goosefoot	1,2
Chenopodium glaucum L.	Oakleaf goosefoot	1,3
Grayia spinosa (Hook.) Moq. In DC.	Spiny hopsage	1,2,4
Halogeton glomeratus (Bieb.) C. A. Mey. in Ledeb.	Halogeton	1,4
Kochia americana Wats.	Green molly	1,3,4
Kochia scoparia (L.) Schrad.	Kochia	1,4
Monolepis nuttalliana (Schult.) Greene	Nuttall povertyweed	1,3
Salicornia europaea L.	Marshfire glasswort	1,4
Salsola iberica Sennen & Pau (S. kali L.)	Russian-thistle	1,2,3,4
Sarcobatus vermiculatus (Hook.) Torr.	Black greasewood	1,2,3,4
Suaeda torreyana Wats.	Bush seepweed	1,4

CONVOLVULACEAE **Common:** Morning-glory Family

Genus - Species - Authority	Common Name	Reference
Convolvulus arvensis L.	Field bindweed	1,2,3,4
Cuscuta sp.	Dodder	1,2,3

CYPERACEAE — Common: Sedge Family

Genus - Species - Authority	Common Name	Reference
Carex sp.	Sedge	1,4
Cyperus aristatus Rottb.	Awned flatsedge	1,2,3
Eleocharis acicularis (L.) R. & S.	Needle spikerush	1,2,3,4
Eleocharis palustris (L.) R. & S.	Common spikerush	1,2,3,4
Eleocharis parvula (R. & S.) Link	Dwarf spikerush	1,2
Schoenoplectus acutus Muhl.	Hardstem bulrush	1,2,4
Schoenoplectus maritimus L.	Alkali bulrush	1,2,3,4
Schoenoplectus pungens Vahl.	Common threesquare	1,4
Schoenoplectus saximontanus Fernald	Bulrush	2,3
Schoenoplectus surpinus L.	Bulrush	1
Schoenoplectus validus Vahl.	Softstem bulrush	1,4

ELAEAGNACEAE — Common: Oleaster Family

Genus - Species - Authority	Common Name	Reference
Elaeagnus angustifolia L.	Russian-olive	1,2,4
Shepherdia argentea (Pursh) Nutt.	Silver buffaloberry	1,2,3,4

EPHEDRACEAE: — Common: Ephedra Family

Genus - Species - Authority	Common Name	Reference
Ephedra torreyana S. Wats.	Torrey Mormon-tea	1,2,3,4

EQUISETACEAE — Common: Horsetail Family

Genus - Species - Authority	Common Name	Reference
Equisetum arvense L.	Field horsetail	1,4
Equisetum laevigatum A. Br. (E. kansanum Schaffn.)	Smooth scouring-rush	1,2,3,4

EUPHORBIACEAE — Common: Spurge Family

Genus - Species - Authority	Common Name	Reference
Euphorbia albomarginata T. & G.	Snow-on-the-mountain	1,2,3
Euphorbia fendleri T. & G.	Fendler spurge	1,2
Euphorbia glyptosperma Engelm. in Torr.	Ridgeseed spurge	1,4

FABACEAE — Common: Pea Family

Genus - Species - Authority	Common Name	Reference
Astragalus chamaeleuce Gray in Ives (A. amphioxys Gray)	Cicada milkvetch	1,2,3
Astragalus convallarius Greene	Lesser rushy milkvetch	1,2
Astragalus duchesnensis Jones	Duchesne milkvetch	1,2
Astragalus flavus Nutt. in T. & G.	Yellow milkvetch	1,2
Astragalus geyeri Gray	Geyer milkvetch	1,2
Astragalus hamiltonii C. L. Porter	Hamilton milkvetch	1,2
Astragalus mollissimus Torr.	Woolly milkvetch	1,2
Astragalus spatulatus Sheld.	Draba milkvetch	1,2
Glycyrrhiza lepidota Pursh	Wild licorice	1,2,3,4
Lupinus pusillus Pursh	Dwarf lupine	1,2,3
Medicago lupulina L.	Black medic	1,4
Medicago sativa L.	Alfalfa	1,4
Melilotus alba Medicus	White sweetclover	1,4
Melilotus officinalis (L.) Pallas	Yellow sweetclover	1,2,3,4
Oxytropis sp.	Locoweed	1,4
Sophora stenophylla Gray in Ives	Silvery sophora	1,2,4
Sphaerophysa salsula (Pallas) DC.	Salt globepea	1,4

GENTIANACEAE — Common: Gentian Family

Genus - Species - Authority	Common Name	Reference
Centaurium exaltatum (Griseb.) Wight.	Exalted centaury	1,2

HYDROPHYLLACEAE **Common:** Waterleaf Family

Genus - Species - Authority	Common Name	Reference
Nama densum Lemmon	Nama	1,2
Phacelia crenulata Torr. in Wats. (P. corrugata A. Nels.)	Scorpionweed	1,2,3
Phacelia ivesiana Torr. in Ives	Scorpionweed	1,2

JUNCACEAE **Common:** Rush Family

Genus - Species - Authority	Common Name	Reference
Juncus alpinus Vill.	Alpine rush	1,2
Juncus arcticus Willd.	Baltic rush	1,2,4
Juncus bufonius L.	Toad rush	1,2
Juncus torreyi Cov.	Torrey rush	1,2

LAMIACEAE **Common:** Mint Family

Genus - Species - Authority	Common Name	Reference
Mentha arvensis L.	Field mint	1,4
Stachys palustris L. var. pilosa (Nutt.) Fernald	Marsh hedge nettle	1,2,3

LEMNACEAE **Common:** Duckweed Family

Genus - Species - Authority	Common Name	Reference
Lemna miniscula Herter	Duckweed	1,4

LILIACEAE **Common:** Lily Family

Genus - Species - Authority	Common Name	Reference
Allium geyeri Wats.	Geyer onion	1,2
Allium textile Nels. & Macbr.	Textile onion	1,2
Asparagus officinalis L.	Asparagus	1,2,3,4
Calochortus nuttallii T. & G. in Beckwith	Sego lily	1,2,3
Smilacina stellata (L.) Desf.	False (Starry) Solomon's seal	1,2,3,4

LOASACEAE **Common:** Loasa Family

Genus - Species - Authority	Common Name	Reference
Mentzelia albicaulis Dougl. In Hook.	Whitestem mentzelia	1,2
Mentzelia dispersa Wats.	Brushy mentzelia	1,2,3
Mentzelia pterosperma Eastw.	Wingseed mentzelia	1,2

LYTHRACEAE **Common:** Loosestrife Family

Genus - Species - Authority	Common Name	Reference
Ammannia robusta Heer & Regel	Purple ammannia	1,2,3,4

MALVACEAE **Common:** Cotton Family

Genus - Species - Authority	Common Name	Reference
Malvella leprosa (Ortega) Krapov.	Alkali-mallow	1,2,4
Sphaeralcea coccinea (Nutt.) Rydb.	Scarlet globemallow	1,2,3
Sphaeralcea parvifolia A. Nels.	Nelson globemallow	1,2,3,4

NYCTAGINACEAE **Common:** Four-o'clock Family

Genus - Species - Authority	Common Name	Reference
Abronia elliptica A. Nels.	Sandverbena	1,2,3
Mirabilis linearis (Pursh) Heimerl.	Narrowleaf umbrellawort	1,2,3,4
Tripterocalyx micranthus (Torr.) Hook.	Sandverbena	1,2

ONAGRACEAE: **Common:** Evening Primrose Family

Genus - Species - Authority	Common Name	Reference
Camissonia scapoidea (T. & G.) Raven	Barestem camissonia	1,2
Epilobium ciliatum Raf.	Common willowherb	1,4
Gaura parviflora Dougl. In Hook.	Small-flowered gaura	1,2,3,4
Oenothera biennis L.	Common evening-primrose	1,4
Oenothera caespitosa Nutt.	Tufted evening-primrose	1,2
Oenothera elata H. B. K..	Evening-primrose	1,2
Oenothera pallida Lindl.	Pale evening-primrose	1,2,3

OROBANCHACEAE — Common: Broomrape Family

Genus - Species - Authority	Common Name	Reference
Orobanche ludoviciana Nutt.	Louisiana broomrape	1,4

PLANTAGINACEAE — Common: Plantain Family

Genus - Species - Authority	Common Name	Reference
Plantago asiatica	Plantain	2,3
Plantago major L.	Common plantain	1,2,4
Plantago patagonica Jacq. (P. purshii R. & S.)	Woolly plantain	1,2,3,4

POACEAE — Common: Grass Family

Genus - Species - Authority	Common Name	Reference
Agropyron cristatum (L.) Gaertn.	Crested wheatgrass	1,2,4
Agropyron smithii Rydbg. (Pascopyrum smithii (Rydbg.) Love)	Western wheatgrass	1,2,3,4
Agrostis stolonifera L.	Creeping bentgrass	1,2,4
Aristida purpurea Nutt.	Purple threeawn	1,2,3,4
Beckmannia syzigachne (Steud.) Fern.	American sloughgrass	1,2,3,4
Bouteloua gracilis (H. B. K.) Lag.	Blue grama	1,4
Bromus inermis Leyss.	Smooth brome	1,4
Bromus tectorum L.	Cheatgrass	1,2,3,4
Crypsis schoenoides (L.) Lam.	Annual timothy	4
Distichlis spicata (L.) Greene	Saltgrass	1,2,3,4
Echinochloa crus-galli (L.) Beauv.	Barnyard grass	1,2,3,4
Elymus canadensis L.	Canada wildrye	1,2,4
Elymus simplex (Scribn. & Williams) D. R. Dewey	Low creeping wildrye	1,2,3
Elymus trachycaulus (Link) Gould ex. Shinners	Slender wheatgrass	1,2,3
Festuca octoflora Walter	Six-weeks fescue	1,2,3,4
Hesperostipa comata Trin. & Rupr.	Needle-and-thread	1,2,3,4
Pleuraphis jamesii (Torr.) Benth.	Galleta	1,2,3,4
Hordeum jubatum L.	Foxtail barley	1,2,3,4
Leptochloa fascicularis (Lam.) Gray	Sprangletop	1,4
Muhlenbergia asperifolia (Nes & Mey.) Parodi	Alkali muhly	1,2,3,4
Muhlenbergia pungens Thurb. in Gray	Sandhill muhly	1,4
Achnatherum hymenoides (R. & S.) Ricker	Indian ricegrass	1,2,3,4
Panicum capillare L.	Witchgrass	1,2,3,4
Phalaris arundinacea L.	Reed Canary grass	1,4
Phragmites australis (Cav.) Trin.	Common reed	1,2,4
Poa annua L.	Annual bluegrass	1,4
Poa secunda Presl.	Sandberg bluegrass	1,2,3
Polypogon monspeliensis (L.) Desf.	Rabbit-foot grass	1,2,3,4
Sitanion hystrix (Nutt.) J. G. Smith (Elymus elymoides (Raf.) Swezey)	Squirreltail	1,2,3,4
Sporobolus airoides (Torr.) Torr.	Alkali sacaton	1,2,3,4
Sporobolus cryptandrus (Torr.) Gray	Sand dropseed	1,2,4

POLEMONIACEAE — Common: Phlox Family

Genus - Species - Authority	Common Name	Reference
Gilia congesta Hook.	Ballhead gilia	1,2
Gilia leptomeria Gray	Gilia	1,2
Gilia polycladon Torr. in Emory	Gilia	1,2
Gilia pumila Nutt.	Dwarf gilia	1,2,3
Leptodactylon pungens (Torr.) Nutt.	Common prickly phlox	1,2,3,4
Phlox hoodii Rich.	Hood phlox	1,2,3,4
Phlox longifolia Nutt.	Longleaf phlox	1,2

POLYGONACEAE — Common: Buckwheat Family

Genus - Species - Authority	Common Name	Reference
Eriogonum batemanii Jones	Wild buckwheat	1,2
Eriogonum cernuum Nutt.	Nodding wild buckwheat	1,2
Eriogonum corymbosum Benth. in DC.	Big wild buckwheat	1,2
Eriogonum flexum Jones	Wild buckwheat	1,2
Eriogonum gordonii Benth. in DC.	Gordon wild buckwheat	1,2
Eriogonum hookeri Wats.	Hooker wild buckwheat	1,2

Eriogonum inflatum Torr. & Frem. in Frem.	Desert trumpet	1,2,3,4
Eriogonum microthecum Nutt.	Slenderbush eriogonum	1,2,4
Eriogonum salsuginosum (Nutt.) Hook.	Wild buckwheat	1,2
Eriogonum schockleyi Wats.	Schockley's buckwheat	1,2,3,4
Eriogonum viridulum Reveal	Green eriogonum	1,2
Polygonum amphibium L.	Water smartweed	1,2,3,4
Polygonum aviculare L.	Prostrate knotweed	1,2,3,4
Polygonum lapathifolium L.	Pale smartweed	1,2,3,4
Polygonum ramosissimum Michx.	Bushy knotweed	1,4
Rumex crispus L.	Curly dock	1,2,3,4
Rumex hymenosepalus Torr.	Canaigre	1,2,3
Rumex maritimus L.	Golden dock	1,2,3,4
Rumex obtusifolius L.	Bitter dock	1,2
Rumex occidentalis Wats.	Western dock	1,2
Rumex stenophyllus Ledeb.	Dock	1,4

POTAMOGETONACEAE **Common:** Pondweed Family

Genus - Species - Authority	Common Name	Reference
Potamogeton natans L.	Floatingleaf pondweed	1,4
Potamogeton nodosus Poir.	Longleaf pondweed	1,2,3
Potamogeton pectinatus L.	Sago pondweed	1,2,3,4

RANUNCULACEAE **Common:** Buttercup Family

Genus - Species - Authority	Common Name	Reference
Clematis ligusticifolia Nutt. in T. & G.	Western virgin's bower	1,2,4
Delphinium nuttallianum Pritz. ex Walp.	Nuttall larkspur	1,2
Ranunculus aquatilis L.	Hairleaf water buttercup	1,2
Ranunculus cymbalaria Pursh	Shore buttercup	1,2,3,4
Thalictrum sp.	Meadowrue	1,2,3

ROSACEAE **Common:** Rose Family

Genus - Species - Authority	Common Name	Reference
Amelanchier alnifolia Nutt.	Saskatoon serviceberry	1,4
Potentilla biennis Greene	Biennial cinquefoil	1,2,3
Potentilla rivalis Nutt.	River cinquefoil	1,2
Rosa woodsii Lindl.	Woods' rose	1,2,3,4

SALICACEAE **Common:** Willow Family

Genus - Species - Authority	Common Name	Reference
Populus fremontii Wats.	Fremont cottonwood	1,2,3,4
Salix amygdaloides Andress.	Peachleaf willow	1,2,3,4
Salix exigua Nutt.	Coyote or Sandbar willow	1,2,3,4
Salix lasiandra Benth.	Whiplash willow	1,2
Salix lutea Nutt.	Yellow willow	1,4

SCROPHULARIACEAE **Common:** Figwort Family

Genus - Species - Authority	Common Name	Reference
Castilleja chromosa A. Nels.	Desert paintbrush	1,2,3
Castilleja exilis A. Nels.	Marsh paintbrush	1,2,4
Gratiola neglecta Torr.	Hedge hyssop	1,2,3
Limosella aquatica L.	Mudwort	1,2
Veronica anagallis-aquatica L.	Water speedwell	1,2
Verbascum thapsis	Mullein	

SOLANACEAE **Common:** Potato Family

Genus - Species - Authority	Common Name	Reference
Solanum nigrum L.	Black nightshade	1,2

TAMARICACEAE **Common:** Tamarisk Family

Genus - Species - Authority	Common Name	Reference
Tamarix ramosissima Ledeb.	Tamarisk or Saltcedar	1,2,3,4

TYPHACEAE	Common:	Cattail Family		
Genus - Species - Authority			**Common Name**	**Reference**
Typha domingensis Pers. (T. angustifolia L.)			Narrow-leaved cattail	1,4
Typha latifolia L.			Broad-leaved cattail	1,2,3,4
ULMACEAE	**Common:**	Elm Family		
Genus - Species - Authority			**Common Name**	**Reference**
Ulmus pumila L.			Siberian elm	1,4
VERBENACEAE	**Common:**	Verbena Family		
Genus - Species - Authority			**Common Name**	**Reference**
Phyla cuneifolia (Torr.) Greene			Fogfruit	1,2,3,4
Verbena bracteata Lag. & Rodr.			Prostrate verbena	1,2,3,4

References: (1) Uinta Basin Flora, 1986; (2) ONWR CCP, 2000; (3) ONWR Species List, 1963; (4) USBR-ONWR Veg. Study, 2000