Rocky Mountain National Park, Colorado

2001-2005 VEGETATION CLASSIFICATION AND MAPPING

FINAL REPORT -- August, 2005

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

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U.S. Department of the Interior
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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.

USGS-NPS VEGETATION MAPPING PROGRAM

Rocky Mountain National Park, Colorado

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Rock spires along the Continental Divide, near Bear Lake, in Rocky Mountain National Park. Vertical fractures have been enhanced by frost action and weathering during Quaternary ice ages. Horizontal banding shows light-colored granite intruded into metamorphic rocks. This is a popular rock-climbing area. Photo by Jim Cole in 1971
(From http://www.aese.org/a_annual_meetingFieldTrip.html).

Precipitous cliff walls of the east face of Longs Peak, as viewed from Chasm Lake, some 2,400 feet below the summit of the mountain. At 14,255 feet, Longs Peak is the highest peak in Rocky Mountain National Park. It is a prominent landmark visible from Denver and the surrounding Great Plains. Photograph by W.T. Lee on July 22, 1916. U.S. Geological Survey Photographic Library (From http://www.aese.org/a_annual_meetingFieldTrip.html). This view is similar to the cover photograph but taken above Peacock Pool.

Sprague Lake

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A project of this size, complexity, expanse and onerous logistics necessarily required the enthusiasm and energy of many people over several years. The dedication of all involved helped to produce a product that we, the authors, gratefully acknowledge. The combination of ecologists, geographers, botanists and natural resource professionals in all the cooperating agencies and organizations allowed for a phenomenal work environment that greatly reduced the stresses one might imagine for a project of this size.

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cover photograph and some text, the public domain “Colorado Headwater” photograph by Jeff Marmorstone, and the “Rock spires along the Continental Divide” photograph by Jim Cole. All other photographs in the main report courtesy of Rocky Mountain National Park website. Photographs in the appendices are from various members of the field crews.

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David, Joe and Keith

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
CNHP	Colorado Natural Heritage Program
DEM	Digital Elevation Model
DLG	Digital Line Graph
DRG	Digital Raster Graphic
DOQQ	Digital Orthophoto Quarter Quadrangle
FGDC	Federal Geographic Data Committee
GIS	Geographic Information System(s)
GPS	Global Positioning System
IMU	Inertial Measurement Unit
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 - SCS)
NREL	Natural Resource Ecology Lab, Colorado State University, Fort Collins.
NVC	National Vegetation Classification
NVCS	National Vegetation Classification System
NRCS	Natural Resource Conservation Service (Formerly – SCS)
NWI	National Wetland Inventory
PARK	ROMO
RMS	Root Mean square
RSGIG	Remote Sensing and Geographic Information Group
TNC	The Nature Conservancy
USBR	United States Bureau Of Reclamation (also BOR)
USDA-SCS	U.S. Dept. Of Agriculture – Soil Conservation Service
USFS	United States Forest Service
USGS	United States Geological Survey
UTM	Universal Transverse Mercator
ROMO	Rocky Mountain National Park

EXECUTIVE SUMMARY

Rocky Mountain National Park (ROMO) encompasses 417 square miles in north central Colorado, and lies on the eastern slope of the southern Rocky Mountains. This mapping effort is part of the National Park Services' national inventory and monitoring program and will provide core or 'baseline' information that park managers need to effectively manage and protect park resources. This vegetation inventory was conducted in accordance with specified protocols and quality assurance standards. Data obtained through this inventory are compatible, allowing for synthesis and analysis at broader levels (http://www1.nature.nps.gov/protectingrestoring/IM/resourceinventories.cfm).

To effectively classify and map the wide range of vegetation at ROMO required a multi-year approach and consisted of several linked phases: (1) vegetation classification using the National Vegetation Classification (NVC), (2) digital vegetation map production, and (3) map accuracy assessment. To classify the vegetation, we sampled 623 representative plots located throughout the 267,000-acre (108,000 ha) park during the summer of 2003. Analysis of the plot data using ordination and clustering techniques produced 172 distinct plant associations, 19 of which were newly described. These include 14 NVC associations, and 5 local types.

To produce the digital map, we used a combination of 2001 1:12,000-scale true color aerial photography, 2001 1:40,000-scale true color ortho-rectified imagery reproduced at 1:12,000-scale, and 3 years of ground-truthing to interpret the complex patterns of vegetation and landuse at ROMO. In the end, 46 map units were developed and directly cross-walked or matched to corresponding plant associations and land-use classes. All of the interpreted and remotely sensed data were converted to Geographic Information System (GIS) databases using ArcInfo© software. Draft maps created from the vegetation classification were field-tested and revised before independent ecologists conducted an assessment of the map's accuracy during 2004.

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

- A Final Report that includes a vegetation key, accuracy assessment information, and a map unit visual guide;
- A Spatial Database containing digital vegetation map, plots, accuracy assessment, and flight line index layers;
- Digital Photos of each vegetation type along with representative ground photos and miscellaneous Park views;
- Field key for association identification and a list of associations present in the mapping area;
- Federal Geographic Data Committee-compliant metadata for all spatial database coverages and field data.

In addition, ROMO and the USGS CBI both received copies of:

- 9x9 inch Aerial Photos;

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

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

For more information on the NVCS and NVC associations in the U.S. please go to NatureServe's website: http://www.natureserve.org. Colorado Natural Heritage Program and BOR have numerous services and programs and may be visited at http://www.cnhp.colostate.edu and http://www.usbr.gov.

Horseshoe Park

INTRODUCTION

Background

USGS-NPS Park Vegetation Mapping Program

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

Central to fulfilling the goals of this national program is the use of the National Vegetation Classification (NVC) as the standard vegetation classification. This classification:

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

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

The NVC has primarily been developed and implemented by The Nature Conservancy (TNC) and the network of Natural Heritage Programs over the past twenty years (Grossman et al. 1998). Currently the NVC is maintained and updated by NatureServe. Additional support has come from federal agencies, the Federal Geographic Data Committee (FGDC), and the Ecological Society of America. Refinements to the classification occur in the application process, leading to ongoing proposed revisions that are reviewed both locally and nationally. NatureServe has made available a 2-volume publication presenting the standardized classification. This document provides a thorough introduction to the classification, its structure, and the list of vegetation types found across the United States as of April 1997 (Grossman et al. 1998). This publication can be found on the Internet at: http://www.natureserve.org/publications/library.jsp.
NatureServe has since superseded Volume II (the classification listing) with an oline database server that provides regular updates to ecological

communities in the United States and Canada. NatureServe Explorer®, can also be found on the Internet at: http://www.natureserve.org/explorer.

Rocky Mountain National Park Vegetation Mapping Project

The specific decision to map the vegetation at ROMO as part of the U.S. Vegetation Mapping Program was made in response to the NPS Natural Resources Inventory and Monitoring Guidelines issued in 1992. Under these guidelines, ROMO was viewed as a top-priority Park based on its need for the program's vegetation map products. Driving this need was the Park's inability to spatially analyze the vegetation at a fine enough scale to accurately predict various management issues. Central to their concerns were the need for modeling the spread and intensity of fire and the management of a number of native and non-native flora and fauna.

In 2000 the USGS Center for Biological Informatics (CBI) kicked-off this project by asking the U.S. Bureau of Reclamation's Remote Sensing and Geographic Information Group (RSGIG) to undertake the mapping portion of this project. At this time Colorado Natural Heritage Program and NatureServe were also contracted to conduct both stages of fieldwork (initial classification and accuracy assessment) and classification stages.

Colorado Natural Heritage Program, NatureServe, BOR RSGIS, and the Park ultimately formed a four-part vegetation team each responsible for a specific portion of the project as outlined by CBI (Appendix A). Colorado Natural Heritage Program and NatureServe became primarily responsible for collecting standardized field samples and using them to classify ROMO's vegetation types and also to provide data for an accuracy assessment on the final vegetation map. RSGIS took on the role of the mapping team responsible for aerial photo interpretation and creation of a digital vegetation map. Finally, ROMO staff provided logistical and technical support, helped coordinate fieldwork, and reviewed and evaluated draft data.

As a team, our objectives were to produce final products consistent with the national program's mandates. These included the following:

Spatial Data

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

Vegetation Information

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

Previous Vegetation Maps

Only one previous effort has been completed for a vegetation map of the entire Park. The existing vegetation map was developed in the late 1980's. The differences in resolution, both spatially and in the classification for the mapped area within the Park boundary is detailed in Table 1. The current map is considerably more detailed in both polygon size and number of map units. In addition there is considerably more detailed floristic description of the vegetation communities.

The previous vegetation map was a compilation of several maps for the Park and the various State and Federal lands adjacent to the Park. Because this is a digital compilation one does find artifacts such as sliver polygons that are 0.001 hectare in size. Summary statistics were difficult to determine and information about how the map was made could not be found. No attempt was made to develop metadata for this previoius project beyond using it for comparison.

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

Statistic	Old Vegetation Map	Current Vegetation Map
Number of Polygons	7,141	22,065
Mean Polygon size (acres)	37.7	13.1
Range in Polygon Size (acres)	0.001-26,298	0.03-3,254
Number of Map Units	33	46

Scope of Work

Vegetation at ROMO was mapped and classified by a consortium that included the U.S. Bureau of Reclamation, Colorado Natural Heritage Program and Natureserve. The protocols and standards used are described in the NPS/BRD program documents. BOR was contracted by USGS-BRD in 2001 to have 652 square miles in an around ROMO flown and photographed to obtain 1:12,000 true color stereo-pair aerial photographs and 1:12,000 scale true color digital ortho-photography (1 meter pixels) using the USGS DOQQ specifications.

Vegetation mapping for ROMO encompassed both the executive boundary of ROMO, a 1 mile environ radius or buffer to the north, west and south and approximately 4 miles from the eastern most extent of the Park boundary. The 1 mile buffer is standard for most park mapping projects. The extended buffer to the east of the Park was to include data available for broader management concerns that included the extensive urban interface. Wildfire concerns for this area largely drove the decision to include this large buffer (Figure 1).

The project was initiated in the Fall of 2001 with the acquisition of the aerial imagery and completion of scoping meetings. Project planning and logistics were completed during the winter and spring of 2001- 2002, and vegetation data were collected during the summer of 2002. The vegetation classification, field key, and local association descriptions were completed during 2003. Planning for the accuracy assessment was conducted during the spring of 2004 and the AA data were collected over the summer of 2004. The assessment of the map accuracy was completed during the winter of 2004 and spring of 2005.

Vegetation mapping required the close cooperation of the three primary contractors for this project and communication between all three and the co-project managers (Jeff Connor and Ron Thomas - NPS ROMO) was instrumental to this very large effort.

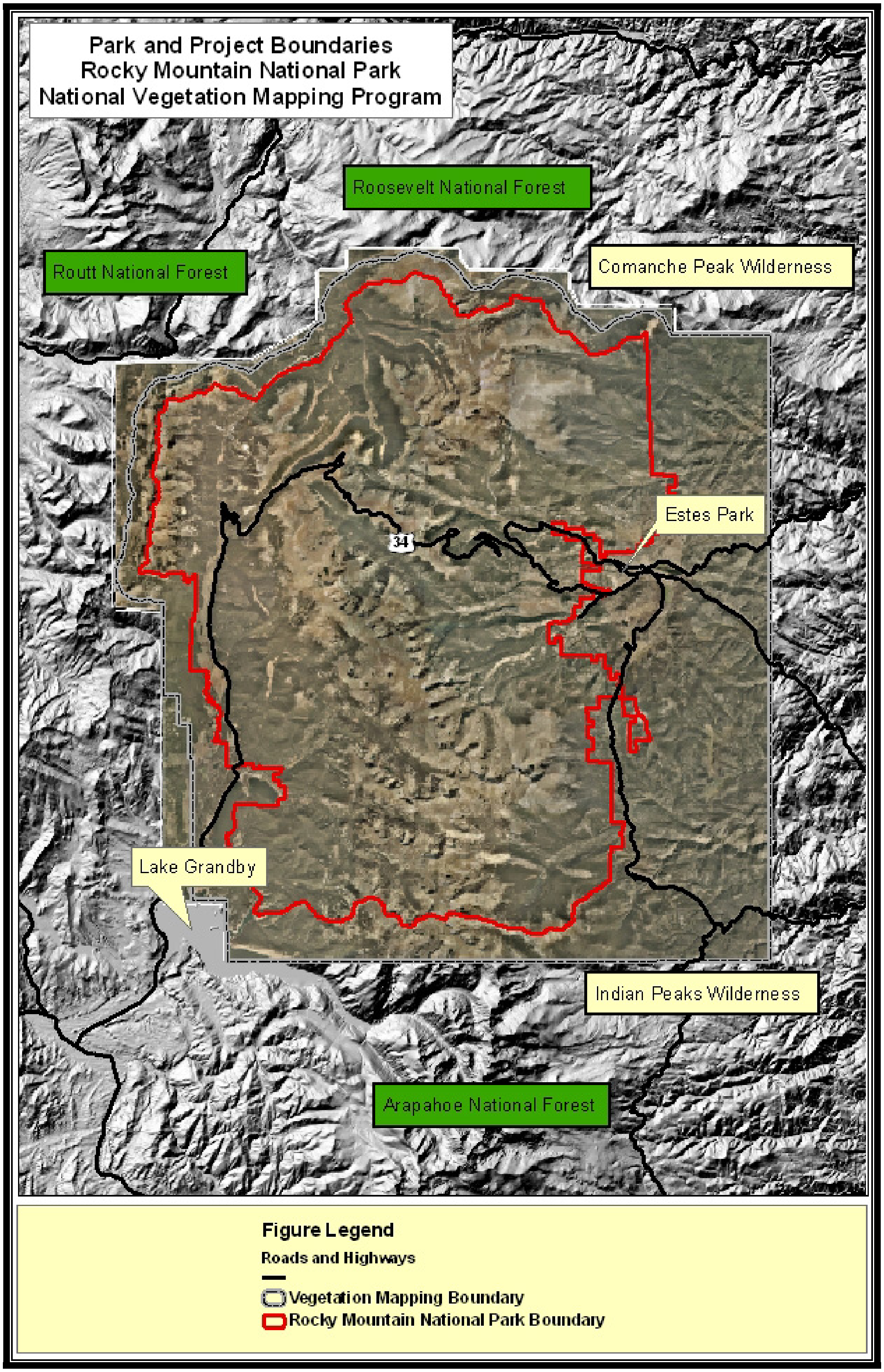


Figure 1. Vegetation mapping – project and map boundaries.

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

The Vegetation Mapping Program uses the US National Vegetation Classification (NVC) as the standard to identify and describe vegetation types within the map boundaries. The National Vegetation Classification (NVC) was begun in the early 1990's by ecologists in the Science Division of The Nature Conservancy and state Natural Heritage Programs and Conservation Data Centers in collaboration with partners from the academic, conservation, and government sectors and is now managed and maintained by NatureServe. This classification was designed to allow description of plant assemblages based on existing vegetation rather than on potential natural vegetation, climax vegetation, or physical habitats. The classification currently includes more than 5000 vegetation associations and 1,800 Alliances, and has been adopted by the Federal Geographic Data Committee for use by all U.S. federal agencies.

The US NVC is part of the International Vegetation Classification System (IVC) which currently includes the USA, Canada, and several Caribbean, Central and South American countries. Its application is rapidly expanding and may soon include other countries as well.

The NVC uses a hierarchical system of 7 levels; the lower levels are nested into the higher levels. The two lowest levels (most specific), Alliance and Association, are based entirely on the floristics, while the upper five levels are based on physiognomy (structural and morphological characteristics of the vegetation type e.g. forest, grassland, evergreen, deciduous, broadleaved , needle-leaved), natural and cultural characteristics, and flood regime. Table 2 identifies the 7 levels of the NVC and depicts their placement in the hierarchical relationship (Maybury 1999).

Table 2. Summary of the National Vegetation Classification System Hierarchal Approach (Maybury 1999).

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

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

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

Examples of alliance names from ROMO:

- *Pseudotsuga menziesii* Forest Alliance
- *Pinus flexilis - Populus tremuloides* Forest Alliance

Examples of association names from ROMO:

- *Abies lasiocarpa / Mertensia ciliata* Forest
- *Artemisia tridentata ssp. vaseyana - (Purshia tridentata) / Muhlenbergia montana - (Hesperostipa comata ssp. comata)* Shrubland
- *Carex rupestris - Trifolium dasyphyllum* Herbaceous Vegetation

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

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

Introduction to Natural Heritage Program Methodology and Element Ranking

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

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

The Natural Heritage Ranking System

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

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

Element imperilment ranks are assigned both in terms of the element's degree of imperilment within Colorado (its State-rank or S-rank) and the element's imperilment over its entire range (its Global-rank or G-rank). Taken together, these two ranks indicate the degree of imperilment of an element. For example, the lynx, which is thought to be secure in northern North America but is known from less than five current locations in Colorado, is ranked G5 S1 (globally-secure, but critically imperiled in this state). The Rocky Mountain Columbine, which is known only in Colorado from about 30 locations, is ranked a G3 S3 (vulnerable both in the state and globally, since it only occurs in Colorado and then in small numbers). Further, a tiger beetle that is only known from one location in the world at the Great Sand Dunes National Park and Preserve is ranked G1 S1 (critically imperiled both in the state and globally, because it exists in a single location). CNHP actively collects, maps, and electronically processes specific occurrence information for animal and plant species considered extremely imperiled to vulnerable in the state (S1 - S3). Certain elements are “watchlisted,” meaning that specific occurrence data are periodically analyzed to determine whether more active tracking is warranted. A complete description of each of the Natural Heritage ranks is provided in Table 3.

This single rank system works readily for all elements except migratory animal species. Those animals that migrate may spend only a portion of their life cycles within the state. In these cases, it is necessary to distinguish between breeding, non-breeding, and resident species. As noted in Table 3, ranks followed by a "B,” for example S1B, indicate that the rank applies only to the status of breeding occurrences. Similarly, ranks followed by an "N” refer to non-breeding status, typically during migration and winter. Elements without this notation are believed to be year-round residents within the state.

Table 3. Definition of Natural Heritage Imperilment Ranks.

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

G/S1	Critically Imperiled globally/state because of rarity (5 or fewer occurrences in the world/state; or 1,000 or fewer individuals), or because some factor of its biology makes it especially vulnerable to extinction.
G/S2	Imperiled globally/state because of rarity (6 to 20 occurrences, or 1,000 to 3,000 individuals), or because other factors demonstrably make it very vulnerable to extinction throughout its range.
G/S3	Vulnerable through its range or found locally in a restricted range (21 to 100 occurrences, or 3,000 to 10,000 individuals).
G/S4	Apparently Secure globally/state, though it may be quite rare in parts of its range, especially at the periphery. Usually more than 100 occurrences and 10,000 individuals.
G/S5	Demonstrably Secure globally/state, though it may be quite rare in parts of its range, especially at the periphery.
G/SX	Presumed Extinct globally, or extirpated within the state.
G#?	Indicates uncertainty about an assigned global rank.
G/SU	Unable to assign rank due to lack of available information.
GQ	Indicates uncertainty about taxonomic status.
G/SH	Historically known, but usually not verified for an extended period of time.
G#T#	Trinomial rank (T) is used for subspecies or varieties. These taxa are ranked on the same criteria as

	G1-G5.
S#B	Refers to the breeding season imperilment of elements that are not residents.
S#N	Refers to the non-breeding season imperilment of elements that are not permanent residents. Where no consistent location can be discerned for migrants or non-breeding populations, a rank of SZN is used.
SZ	Migrant whose occurrences are too irregular, transitory, and/or dispersed to be reliably identified, mapped, and protected.
SA	Accidental in the state.
SR	Reported to occur in the state but unverified.
S?	Unranked. Some evidence that species may be imperiled, but awaiting formal rarity ranking.

Legal Designations for Rare Species

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

Element Occurrences and their Ranking

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

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

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

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

Each of these factors is rated on a scale of A through D, with A representing an excellent rank and D representing a poor rank. These ranks for each factor are then averaged to determine an appropriate EO-Rank for the occurrence. If not enough information is available to rank an element occurrence, an EO-Rank of E is assigned. EO-Ranks and their definitions are summarized in Table 4.

Table 4. Element Occurrence Ranks and their Definitions

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

PROJECT AREA

Location and Regional Setting

ROMO lies in north central Colorado on the Eastern slope (Figure 2). The eastern entrance is situated adjacent to Estes Park and is accessed by either State Highway 36 from Boulder or State Highway 34 from Loveland / Fort Collins. The western entrance is adjacent to Grand Lake and is accessed from State Highway 34. State Highway 34 traverses the Park and is commonly known as “Trail Ridge Road”. It is the highest continually paved highway in the United States and peaks at just over 12,100 feet above sea level. Rocky Mountain is the highest national park in the US, with elevations from 7860' to 14,259' More than one-fourth of the Park is above tree line (11,200-11,500'). State Highway 34 crosses the continental divide at 10,790 ft (3289 m). (http://www.nps.gov/romo/pphtml/naturalfeatures.html). The Park is divided unequally into eastern (~60%) and western portions (~40%) by the continental divide which runs roughly from the southeast to the northwest (Figure 3). The Park also lies within Grand, Larimer and Boulder counties. Surrounding the Park are the Routt, Roosevelt and Arapahoe National Forests, the Colorado State Forest State Park and the Comanche Peak and Indian Peaks Wilderness areas. A populated / urban interface occurs all along the eastern edge of the Park and along the southwest corner in the Grand Lake and Lake Granby area. The Park boundary is contiguous with both U. S. Forest Service lands (67%) and private lands (33%).

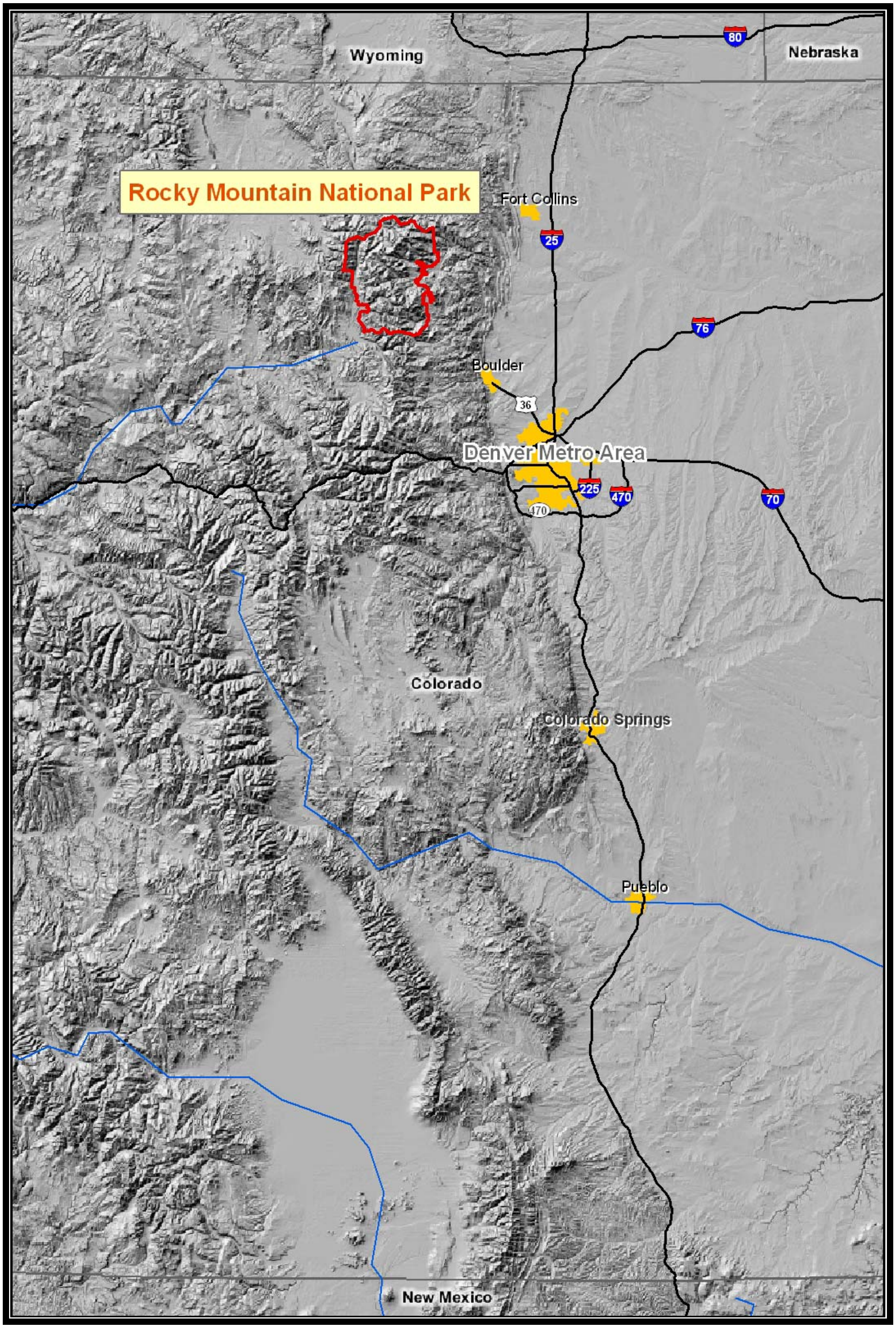


Figure 2. Location map – ROMO.

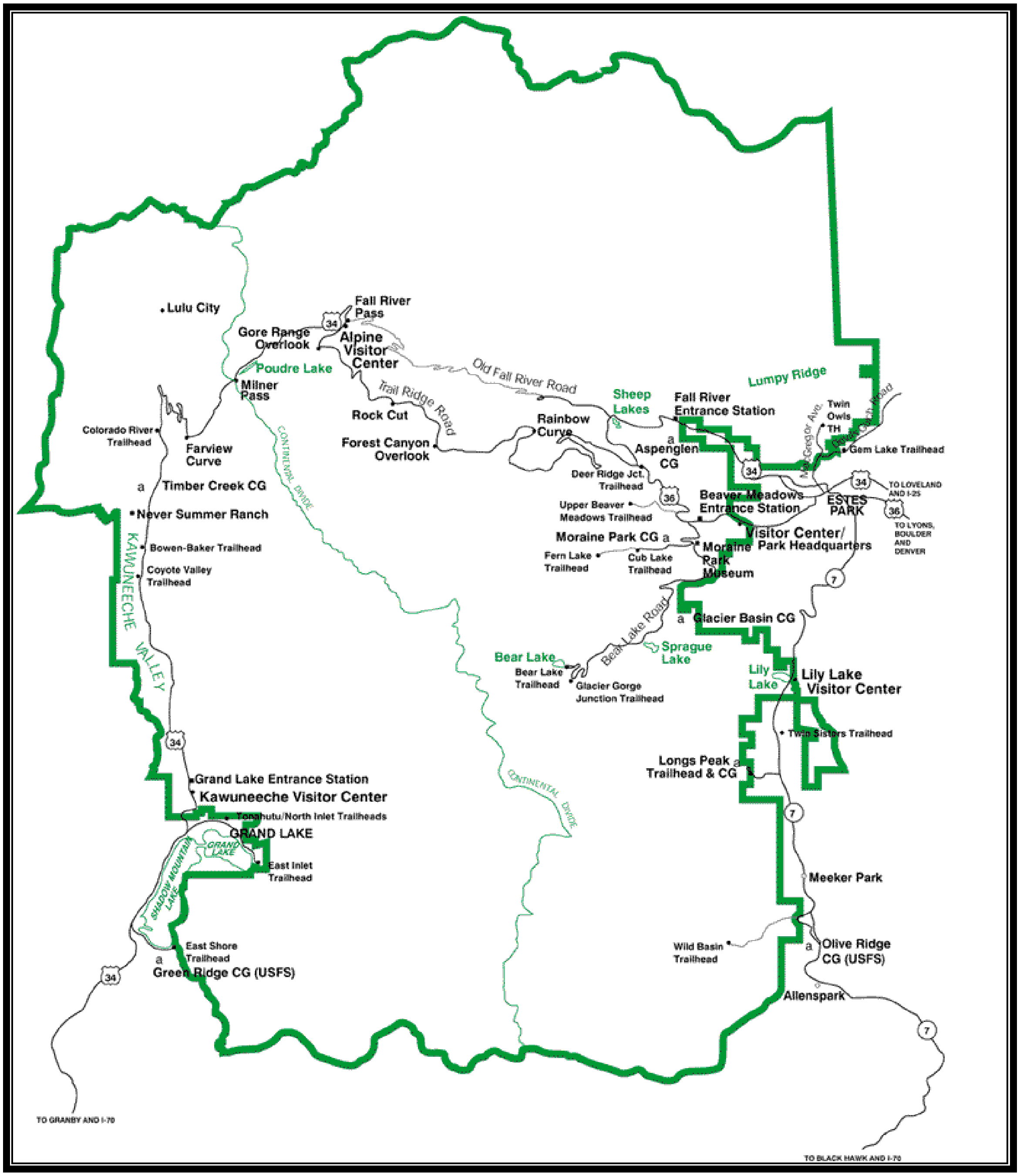


Figure 3. Detail map - ROMO

Climate and Weather

The climate in and around ROMO is described as temperate semi arid steppe (Bailey R.G. 1995). The primary controlling factor to climate is the north – south orientation of the Rocky Mountains and its elevation gradient. Weather arriving from the west tends to leave its moisture on the western slopes; hence the eastern slopes are typically drier and warmer. This rain shadow effect is region wide and is exemplified in the Park by the mean annual precipitation of both the *Pinus contorta* and *Picea engelmannii- Abies lasiocarpa* zones on the east and west sides of the continental divide. In both cases the mean annual precipitation is up to 5 inches more on the west than on the east side. (Haeffner 1971; Marr 1968a, 1968b).

Precipitation varies considerably and is primarily controlled by elevation. Precipitation at higher elevations usually falls as snow. The winter precipitation is typically more predictable than summer as cyclonic storms tend to dominate (Peet 1981). Lower elevations may receive 10 to 20 inches of rainfall while the peaks may receive twice that much. Because of the proximity to the Gulf of Mexico and the Gulf of California, the summer precipitation is monsoonal – that is, it arrives regularly and sometimes violently in the afternoons. The mountains tend to generate thundershowers and thunderstorms, which then move elsewhere. Although precipitation arrives year around, the annual hydrologic cycle is dominated by wintertime accumulation snow and the melting of the snowpack in spring (http://instaar.colorado.edu/research/highlights.html#hydrology).

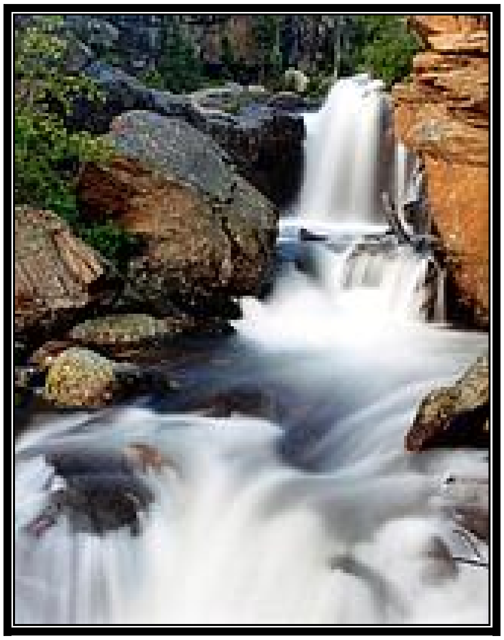
Temperature is also largely controlled by elevation. Temperatures at higher elevations will tend to fluctuate wildly as a result of rapid gain and loss through a thinner atmosphere (Kershaw et al. 1998). Given the topographic variability throughout the Park, any meaningful climatic information for a given locality is difficult (Hess and Alexander 1986). Nonetheless, the Institute of Arctic and Alpine Research (INSTARR) has collected climatological data for four sites in the area dating back to 1952. These data show a gradient in mean annual temperature from 8.3°C at 2195 m to –3.3° C at 3,750 m. The elevational cooling effect equates to 7.5° C per 1,000 m of elevation (Peet 1981).

Winds can often have a severe and lasting impact on the vegetation. The alpine Krummholz owes its very existence not only to the cold but also the persistent winter winds and short growing season found in this zone. These winds can be exceptionally strong during the spring and can alter the landscape by creating large blowdowns in forests (Peet 1981). These winds often exceed hurricane force, with speeds over 74 miles per hour (119 kilometers) in some areas. Anecdotal accounts tell of a wind anemometer self destructing after passing a recorded speed of 200 miles per hour (Jeff Connor– pers. comm.).

Topography

ROMO lies on the eastern edge of the Rocky Mountains and abuts the Great Plains that extends eastward. The Park is located approximately 60 miles north of

Denver, Colorado. The project boundary includes elevations from 2285 m at Estes Park to 4,345 m at Longs Peak. The Park is divided in two by the continental divide. There are a number of cirque glaciers, extensive alpine tundra, a variety of glacial landforms, glacial lakes and moraines, cirques and talus slopes, patterned ground, and permafrost. The mapping area is bounded on the west by the Never Summer Range and on the east by the hogbacks of the Fountain Formation. The range trends north to south with a large valley running north to south on the west side of the Park (Kawuneeche Valley)(Figure 4.) Grand Lake and the area around it are derived from the glacial deposits from this valley.



Colorado River Headwaters

Two prominent drainages exit the Park to the northeast. These are the Fall River and the Thompson River drainages. Both these have large moraine deposits forming Horseshoe Park and Moraine Park respectively. To the southeast is yet another important drainage, the North St. Vrain. Copeland Moraine is formed from this valley's outwash. To the southwest one finds the headwaters of the Colorado River flowing south through the Kawuneeche Valley, into Shadow Mountain Lake, then into Lake Granby and then exiting to the southwest through Granby Dam.

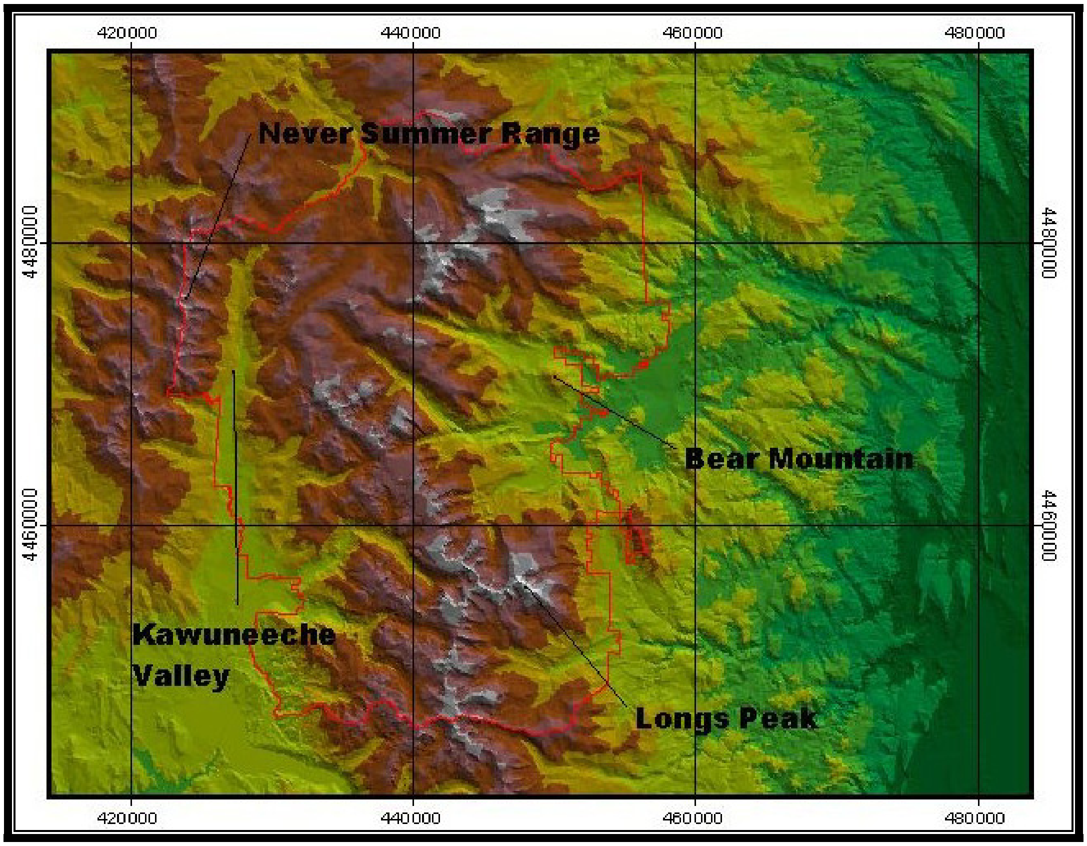


Figure 4. Topography of Rocky National Park end environs.

Geology

The geology of ROMO dates back to the Precambrian and includes several episodes of mountain building and erosion, the evidence of which may be found within the Park. The Quaternary geological history is the most evident feature within the Park.

Precambrian

Some time over two billion years ago the entire Rocky Mountain area was under water. Sediments from surrounding areas formed deposits tens of thousands of feet deep. It is believed that the sediments collected within a geosyncline created by the continental crust riding over oceanic crust. These sediments where then subjected to tremendous pressures from the accumulated weight and buckled and twisted and eventually were transformed into metamorphic rocks. These metamorphics are primarily gneisses with lesser amounts of schist and quartzites interlaced with material from the underlying magma chamber and lava flows. These dark gray contorted bands of rock can be seen today along Trail Ridge Road on the west side of the Park. In fact, the majority of the exposed geology within ROMO is metamorphic and igneous rocks from the Precambrian. Approximately one billion years ago the underlying molten magma chamber began to rise and eventually cooled to form the pink granites seen on the eastern side of the Park (Silver Plume Granite).

Paleozoic

The next 500 million years or so were marked by an extensive period of erosion and the area was again covered by an inland sea. There is no evidence of marine deposits during this period within the Park (Middle Paleozoic). This was then followed by a new mountain building event to form what we know as the ancestral Rockies. These Rockies where thought to be a vast island with 2000 foot peaks about 100 miles to sea. These ancestral Rockies eventually eroded to form the "Fountain Formation" which is a very distinctive red outcrop, steeply tilted and runs along the eastern edge of the present mountain range from Wyoming to South of Colorado Springs.

Mesozoic

The ancestral Rockies eroded during the late Paleozoic to early Mesozoic (325 – 245 mya). The Mesozoic period was a time of extensive marine deposition and is best known as the age of dinosaurs. Mesozoic deposits are poorly represented within the Park with only a few areas of Pierre shale in the North West section of the Park in the Never Summer Range and in the vicinity of Lake of the Clouds.

Cenozoic

As the Mesozoic came to an end the modern day Rocky Mountains began to appear. This episode is known as the Laramide Orogeny and is associated not only with uplift but also volcanic activity and erosion of the marine sediments. At this time, much of the earlier Dakota sandstone and cretaceous sediments where eroded away exposing the Precambrian granites and schists. A secondary uplift beginning in the Oligocene pushed the Rockies back up. The Never Summer Range experienced extensive volcanism about 25 million years ago. Most of these volcanic sediments have been eroded away however there are traces of this event in the northwest corner of the Park at Specimen Mountain, Lava Cliffs and Milner Pass on Trail Ridge Road.

Quaternary

The end of Tertiary period saw the Rocky Mountains with considerable elevation and V-shaped valleys. Then the ice age began. Much of the current topography within ROMO is a direct result of the sculpting and deposition of mountain glaciers. The Rocky Mountains are far enough south to have escaped the continental glaciation experienced in northern North America but still experienced considerable mountain glaciation. There were a number of glaciations in the Rocky Mountains during the Quaternary, however evidence for the earlier episodes is sparse.

It is generally believed that there where at least four glaciations of which only the last two have left any evidence within the Park. Previous glacial deposits (Pre-Bull Lake) were eliminated by the actions of the Pinedale and Bull Lake glaciations. In the high country the mountains were scraped away forming broad U-shaped valleys that are typical of glaciated valleys. Towards the lower elevations are the moraine deposits. "The oldest is represented by a moraine about three miles west of Estes Park where the Big Thompson River traverses a wide U-shaped valley before entering its narrow, unglaciated canyon" (Chronic and Chronic 1972). Others include the Aspen-Gold campground, Horseshoe Park and Moraine Park. A terminal moraine also formed Grand Lake. Most of the lakes within the Park are a result of glacial action, whether by erosion (cirques) or moraine deposition.

Soils

Soils play an important role in determining the types of vegetation that might inhabit a site. The controlling factors in young soils derived from Precambrian granites and schists is often texture and depth. Both of these factors, in turn, will affect water availability (Smith 1985). When the soil develops a significant horizon and the texture is fine, grasses and forbs can form a dense sod that inhibits tree generation (Peet 1988). In other areas that have poor drainage wetland vegetation will appear. These characteristics can aid in the photointerpretive process. The NRCS has produced a soil map for the Park and surrounding areas. The soil types descriptions are as follows:

"The formation of the soils of ROMO has been strongly influenced by landform and climate. There is a wide range in soil properties from the warmer and drier valleys to the high elevation tundra. Soils of the low elevation valleys are generally very deep, loamy, and, particularly on the east side of the Park, have dark-colored surface horizons. In the floodplains they are poorly or very poorly drained with stratified textures. On stream terraces they are well drained. They formed in alluvium from the nearby mountains. Soils of the glacial moraines are very deep, well or somewhat excessively drained, and loamy or sandy with a high content of rock fragments. They formed in till derived mainly from granite, gneiss, and schist. Soils of the Subalpine mountain slopes are generally well or somewhat excessively drained, loamy with a high content of rock fragments, and have light-colored surface horizons. Depth to the underlying bedrock ranges from shallow to very deep. Typically soil reaction becomes more acid with increasing elevation, as the climate becomes cooler and moister. These soils formed mainly in material weathered from granite, gneiss, and schist. Soils of the alpine mountains and ridges are generally well drained, loamy with a high content of rock fragments, strongly acid, and have dark-colored surface horizons. These soils formed mainly in material weathered from granite, gneiss, and schist. Poorly drained soils are common in landscape depressions and drainageways." (Neve, L.A. 2000)

Wildlife

The Rocky Mountains have a wide variety of wildlife although the southern rockies are depauperate in large carnivores such as the North American Wolf (*Canis lupus*) and Grizzly Bear (*Ursus arctos horribilis*). Within the Park, the large carnivores are represented primarily by the Mountain Lion (*Felis concolor*), perhaps the Wolverine (*Gulo gulo)* and occasionally the Lynx (*Lynx canadensis)*(Jeff Conner pers. Comm.). The large omnivores present include the Black Bear (*Ursus americanus*), Coyote (*Canis latrans),* Bobcat *(Lynx rufus)* and the Red and Gray Fox (*Vulpes vulpes* and *Urocyon cinereoargentues*).

The greatest impact on vegetation and vegetation distribution lies with the herbivores. The large herbivores in the Park are the Mule Deer (*Odocoileus hemionus)* the Rocky Mountain Elk (*Cervus elaphus*) and the Big Horn Sheep (*Ovis canadensis*). There are also numerous other small herbivores that play an important role in vegetation patterns with their herbivory and seed dispersal, however the large herbivores are of particular concern due to their impact on aspen groves. Aspen makes up a small percentage of the Park but its importance vastly outweighs its presence. Aspen is a critically important habitat to a number of species including elk. Elk forage heavily in these areas and, given the very high number of Elk in the Park, adversely impact the viability of aspen groves.

Hydrology

The hydrology of ROMO may be considered in two forms: its arrival and its movement. Each of these will impact the soil, vegetation, erosion, and even the release of carbon and other greenhouse gases (Hauer et al. 1997).

Precipitation typically arrives from the Pacific or Gulf of Mexico and falls as winter snow and summer thunderstorms. The winter snowfall normally is regional and widespread while the summer thunderstorms typically are local and violent producing episodic flows in individual drainages.

Winter snow may either accumulate on the existing glaciers and permanent snow fields, sublimate or join the spring melt in either surface or subsurface flow. Winter precipitation may impact the ecosystem with periglacial activities (freezing and thawing of soils leading to frost heave and gelifluction) and mass movement such as avalanches. Within the mapping area are 93 snow fields or glaciers that range in size from 0.04 to 13.3 hectares with a mean of 1.6 hectares. . In this project a total of 145 hectares of snowfields/glaciers weremapped.

The spring snowmelt flows down 29 km of canals (Grand Ditch) and 960 km of tributaries and streams within the Park boundaries into or through numerous lakes and ponds. There are 410 mapped lakes or ponds that range in size from 0.01 hectares to 14 hectares (mean size 1hectare) for a sum of 428 hectares of water surface within Park boundaries. Larger reservoirs exist outside the Park. These are on the northwest boundary of the Park (Long Draw Reservoir), the central-eastern mapping area (Lake Estes) and to the southwest (Shadow Mountain Lake and Lake Granby). Adjacent to Shadow Mountain Lake and Lake Granby is Grand Lake which is the largest natural lake in Colorado.

Anticipated long term hydrologic impacts due to climate change include a “Rise in snow line in winter-spring, possible increases in snowfall, earlier snowmelt, more frequent rain on snow - changes in seasonal streamflow, possible reductions in summer streamflow, reduced summer soil moisture and stream temperature changes affecting species composition; increased isolation of coldwater stream fish (Hofmann et al. 1998. Fyfe and Flato 1999, McCabe and Wolock 1999, Leith and Whitfield 1998, Williams et al. 1996, Hauer et al. 1997).” (From http://www.isse.ucar.edu/water_climate/html_map.html#3”).

Vegetation

Overview

ROMO lies within the Dry Domain, Temperate Steppe Division and Southern Rocky Mountain Steppe – Open Woodland – Coniferous Forest – Alpine Meadow Province as described by Bailey (1995). This ecoregion is characterized by dramatic vertical zonation of vegetation. This zonation is a consequence of abrupt elevational gradients between flatlands and mountains. Topographic relief is quite dramatic and in a short distance one may see various life zones as described by Merriam and Steineger (1890).

ROMO has all but the lower two life zones present (Upper and Lower Sonoran). The Pinyon-Juniper (Upper Sonoran) life zone begins a short distance to the east of the Park and a few foothill communities occur within the study area on warm aspects.

The concept of life zones or landscape units has been addressed by numerous researchers since the late 19th century. These include Merriam (1898), Gregg (1947), Daubenmire (1938) Rydberg (1916) and Marr (1967) amongst others. More recently, Peet (1981, 1988), quite extensively described the vegetation within the Park. All of these researchers recognize three major vegetation zones or regions based upon their easily recognizable major flora although they have often named them differently and or sub-divided them into sub-zones or regions. The three primary vegetation zones described and mapped in this effort are the alpine, Subalpine and montane zones (Table 5). As a matter of local interest we also briefly describe the east-west slope effects and the extensive wetland/riparian systems present within the Park. Within each recognized zone exists a variety of NVC plant alliances, and even more associations (see Appendix I).

The concept of "zones" is complicated and exacerbated by plants refusing to follow the paradigms of previous investigators (Ramaley 1907, 1908, Rydberg 1916, Daubenmire 1938, 1943, Costello 1954 and Moir 1969). Peculiar groupings of soil, aspect, elevation and other controlling factors may allow species associated with a particular zone to appear where they ought not. Indeed, the distribution of vegetation within the Park may be linked to various factors, all of which are interrelated in one form or another. These include dramatic topography and elevation, a variety of soils, moisture, temperature, wind, aspect, and slopes. The primary factors controlling vegetation distribution within the Front Range are elevation, moisture, disturbance (Peet 1981), and soils (Peet 1988).

East/West Slope Effects

One important factor affecting the distribution of vegetation in ROMO is the continental divide, which dissects the Park from north to south into two unequal halves, the larger half (63%) being the eastern side. According to Beidleman et al. (2000), the western slope (everything west of the divide) receives more rain in summer and more snow in winter, than does the windier eastern slope (everything east of the divide). This is due to the mountains blocking weather that comes predominantly from the west. This phenomenon is typically referred to as orographic precipitation on the west slope and the "rain shadow" effect (or more accurately, precipitation shadow) on the eastern slopes. Beidleman also mentions that the divide acts as a "barrier to the spread of some plant species," especially those from lower elevations. Because of these factors, the east and west sides of the Park are floristically different, with the greatest differences occurring in the montane zone.

In very general terms, montane forests on the eastern slope are dominated by *Pinus ponderosa* (Ponderosa pine) on south facing slopes and by *Pseudotsuga menziesii* (Douglas-fir) on north facing slopes. Grasslands are common, and riparian areas are dominated by tall willows. Though the western slope contains many of the same communities as the eastern slope, *Pinus contorta* (lodgepole pine) and *Populus tremuloides* (aspen) are more common. *Artemisia tridentata* (sagebrush) communities, occur mostly on the east side although there do occur patches within the Park in the south west. Outside the Park one finds more sagebrush to the southwest, especially in the Granby Lake area. At higher elevations in the Subalpine and alpine zones, environmental conditions created by the divide affect vegetation, but the barrier to migration is less pronounced since the habitat of these species is continuous across the divide, thus, the east/west slope effect is less apparent the higher one climbs.

Table 5. Life zones as described by Merriam and Steineger (1890) and their modern equivalent.

(from http://www.cpluhna.nau.edu/Biota/merriam.htm) "Elevations given above modified for the latitude at ROMO" (Beidleman et al. 2000) and from estimations from Peet (1981).

Merriam's Life Zones 1891	***Modern Vegetation Zones***	***General Name Used During Project***	***Elevation Range (feet)***
Arctic-Alpine	***Alpine Tundra***	***Alpine***	***10,900-14,255***
Hudsonian	***Spruce-Fir or Subalpine Conifer Forest***	***Subalpine***	***9,000-10,900***
Canadian	***Mixed Conifer Forest***	***Upper Montane***	***8,000-9500***
Transition	***Ponderosa pine Forest***	***Lower Montane***	***6000-8500***
Upper Sonoran	***Pinyon-Juniper Woodland, Semi-Arid Grasslands, Semi-Arid Scrub***	***Foothill***	***n/a***
Lower Sonoran	***Mojave, Sonoran, or Chihuahuan Desert***	***NA***	***n/a***

Alpine Zone

Perhaps the harshest environment within the Park is the Alpine zone. Here one encounters the greatest extremes in temperature and insolation coupled with thin, or very young, soils. The alpine zone in the Rocky Mountains has been extensively studied and factors controlling plant distribution in this zone are fairly well known. The primary controlling factors for alpine vegetation distribution appear to be "topographic exposure and distribution of snow and meltwater superimposed upon geological substratum patterns" (Billings and Mooney 1968). Additional studies report similar results (Isard 1986; Marr 1961; Haase 1987, Willard 1979, Zwinger and Willard 1972); that is, snow cover and soil moisture control the distribution of plant communities.

Categorizing the alpine tundra has taken on numerous shapes and sizes. There are many authors that describe the alpine vegetation and categorize them differently. Daubenmire (1943) breaks this zone into three rough, non-defined edaphic categories that include very young, almost nonexistent soils, an intermediate gravelly and boulder category, and a relatively more mature category of thin soils. Clements (1904), in his study of the Pikes Peak area, identified five formations within the alpine zone which include:

Alpine meadow formation
Alpine bog formation
Alpine lake formation
Alpine mat formation
Alpine rock formation

Rydberg (1914) divides the zone into eight categories:

Alpine mountain crests
Alpine rock slides
Alpine mountain seeps
Alpine meadows
Alpine bogs
Snow drift formations
Alpine lakes

Billings (1988) describes a vegetational gradient that goes from the windward to leeward slope that includes seven very general plant communities along a transect. These include:

Windward slope from –150 m to ridge top at 0 m – open rock fellfield.
Upper lee slope from 0 m to 40 m: modified fellfield
Upper lee slope from 40 m to 60 m: transitional from fellfield to early snowbed community
Middle lee slope from 60 m to 90 m: early snowbed community
Middle lee slope from 90 m to 120 m: late snowbed community
Middle lee slope from 120 m to 150 m: moist meadow
Lower lee slope from 150 m to 260 m: mostly late snowbed community
Bottom of lee slope from 260 m to 300 m: very wet meadow

The youngest of Daubenmire's categories consists of the more stable "boulder fields". Little vegetation is found here with exception of crustose lichens and crevice plants such as *Oxyria digyna*, *Aquilegia* spp., *Polemonium* spp., *Pentstemon fruticosus* and *Sibbaldia procumbens*.

Areas with gravelly soils (fellfields) have very sparse vegetation characterized by mat or cushion plants such as *Silene acaulis*, *Dryas octopetala*, *Arenaria sajanesis*, *Erigeron compositus*, *E. multiflorus*, *Luzula spicata*, *Paronychia* spp., *Phlox caespitosa* and *Selaginella densa* (Daubenmire 1943).

Areas with some soil development, typically lower in the alpine zone, may be covered with dense, low lying vegetation often referred to as "alpine meadow" or "alpine grassland". Species density increases dramatically and includes numerous grasses, forbs and sedges, including *Carex* spp., *Kobresia myosuroides*, *Poa* spp., *Phleum alpinum*, *Deschampsia caespitosa*, *Trisetum subspicatum*, *Agrostis* spp., *Festuca* spp., *Polygonum viviparum*, *Potentilla* spp., *Sieversia turbinate*, *Trifolium* spp. and *Pedicularis parryi* (Daubenmire 1943).

Subalpine Zone

The Subalpine zone is characterized by the two dominant species of *Picea engelmannii* (Engelmann spruce) and *Abies lasiocarpa* (Subalpine fir), though other authors (Rydberg 1915) count Subalpine fir as a secondary species in this zone, and aspen as a primary. *Pinus aristida* (bristlecone pine) is also considered a secondary species within this zone; however, it's known northern most extent is just south of ROMO, and is unlikely to be found within the Park. However, *Pinus flexilis* (limber pine) occurs in similar habitats in the Park and extend to the northern Rocky Mountains. At the upper elevational end of this zone, the trees take on a stunted growth form known as Krummholz due primarily to extreme conditions of a short growing season, low temperatures and desiccating winds. The lower elevation boundary between the montane Douglas-fir zone and the Subalpine zone is somewhat amorphous as Douglas-fir, the primary tree in the montane zone, often extends well into the Subalpine and, conversely, Engelmann spruce often extends well into the montane zone (Rydberg 1915). Engelmann spruce is typically found on northern slopes in either pure stands or mixed with Subalpine fir. Subalpine fir rarely forms homogenous stands and is usually found growing with Engelmann spruce. Aspen will grow interspersed with Engelmann spruce or it may form large groves. In addition, aspen will grow on slopes, but can also be found in moist areas with rich soil. Lodgepole pine and aspen both regenerate rapidly after fire. When fire does invade the Subalpine zone, and the fire is intense enough to create a "stand replacement," it is often colonized by dense, monotypic stands of lodgepole pine, aspen, and sometimes Douglas-fir. The colonizing species will typically not establish themselves near timberline, but rather, spruce and fir regenerate directly (Daubenmire 1943).

Subalpine understory is typically very similar over the entire range and is often composed of continuous cover of either *Vaccinium scoparium* or *V. myrtillus* (Peet 1981, 1988). Few other species are found in the understory, but some species that sometimes occur are *Arnica cordifolia, Carex geyeri, Pyrola secunda, and Polemonium delicatum* (Daubenmire 1943, Peet 1988).

Within each zone, vegetation variation is often a function of moisture; for example, Hess and Alexander (1986) report that the *Abies lasiocarpa/Vaccinium scoparium* habitat type occupies mesic upland positions while *Abies lasiocarpa / Calamagrostis canadensis* is typically found on wetter sites and topographically lower.

The Subalpine vegetation is not restricted to only forest and woodland ecosystems. Rydberg (1915) identifies five grassland - forb types within the Subalpine. These types are as follows; 1) Lakes, Ponds, Brooks and Swamps, 2) Meadows, 3) Dry Valleys and Bench-lands, 4) Mountain slopes, and 5) Hog-backs. Hess and Alexander (1986) also report extensive high elevation grasslands dominated by *Festuca thurberi* on Arapahoe National Forest, adjacent to the west of the Park.

Montane Zones

The montane zones (upper and lower) in ROMO occur mostly on the far east and west sides of the Park at elevations below 3000m (9,800 ft.), and are dominated by mixed to single species woodlands and forests, alternating with shrublands and dry grasslands on hillsides and ridges, and with riparian areas in valleys and gullies.

On the east side of the Park, the montane zone is dominated by open Ponderosa pine forests on south facing slopes, and by mixed conifer forests (generally dominated by Douglas-fir) on the more northern aspects. Understory species in the Ponderosa pine forests generally include shrubs such as *Purshia tridentata* (bitterbrush), and dry grassland species. In the lower elevations of this zone the south facing slopes are often dominated by shrubs and herbaceous species mixed with Ponderosa pine and / or Juniper. The north facing slopes often are dominated by Ponderosa pine, Douglas-fir, Juniper or a combination of these. Ponderosa pine forests in ROMO are sometimes attacked by Rocky Mountain pine beetles and mistletoe. Ponderosa pine can be an early seral species after disturbance. Dry grasslands, dominated by *Muhlenbergia montana*, *Hesperostipa comata*, and other grasses, form a patchwork with the Ponderosa pine forests. Douglas-fir forests tend to be dense, with a sparse understory, and are susceptible to spruce budworm. Other common trees that often grow mixed with Douglas-fir include lodgepole pine and aspen, which are often early seral species (Beidleman 2000).

On the wetter, west side of the Park lodgepole pine stands are more prevalent, and have a more diverse understory of shrubs. Aspen groves are also more common in wet areas. Shrublands dominated by *Artemisia tridentata ssp. vaseyana* (mountain sagebrush) and bitterbrush, which are less common on the eastern slope, occur in abundance on the western slope. *Lupinus spp*. (lupine) and *Balsamorhiza sagittata* (arrowleaf balsamroot), which don't often grow on the east side, are common here (Beidleman 2000).

Peculiar to the montane zone on the east side of the Park is the distribution of Douglas-fir. Typically one finds Douglas-fir on north facing slopes or other protected microclimates. Recently, however, one finds that many Ponderosa pine stands have a rather extensive sub-canopy of Douglas-fir. It has been hypothesized by some (Dickman 1978, Peet 1981, Covington and Moore 1992, Veblen 1998, Brown et al. 1999, Kaufmann et al. 2001) that this is a result of effective fire suppression exercised throughout the region during the later parts of the 20th century.

Wetland and Riparian

Wetlands and riparian areas are abundant throughout the Park at all elevations and vary according to elevation and topography. In the alpine zone, wet meadows and bogs contain a variety of sedges, rushes and forbs, the most common being *Carex scopulorum* and *Caltha leptosepala*. Near treeline, wet areas are usually home to communities of short willows such as *Salix planifolia* and *Salix brachycarpa,* which often grow mixed with *Betula nana* and dwarfed spruce and fir. Wide riparian valleys in the Subalpine zone also contain this mix of shrubs, and often have a diverse understory of forbs and graminoids. Creeks and lakes are abundant in the Subalpine; wet meadows, and long, thin riparian strips, which often contain tall willows and aspens, can be found near these.

In the montane zones, wetlands and riparian areas can include rivers, lakes, reservoirs, and wide glacial valleys. Riparian vegetation along rivers can be dominated by *Picea pungens* (Colorado blue spruce), or by a mixture of tall willows, aspen and alder. Lakes and reservoirs are often surrounded by wet meadows similar to those found in the glacial valleys; these glacial valley and lakeside meadows are dominated by graminoid species such as *Juncus balticus* and *Carex aquatilis*, with *Carex utriculata* in particularly wet areas. Willows are often present in strips along streams in these meadows, and occasionally whole valleys can be filled with mixed willow stands.

METHODS

The methods to produce a vegetation map of this magnitude involve a tremendous amount of interaction and communication between numerous groups and individuals. All of these interactions are summed up in a flow chart that describes the general task assignments and relationships (Appendix A). The general groups of tasks include planning meetings, collecting and analyzing existing data, development of the classification, development of the sampling strategy, field work, data input and analysis, photointerpretation, cartography, and map validation and accuracy assessment. These tasks necessarily interact with one another throughout the entire process.

Planning and Scoping

This project incorporated the combined expertise and oversight of several organizations. Oversight and programmatic considerations were managed by the Center for Biological Informatics (CBI) of the USGS/BRD. NPS and ROMO personnel provided additional guidance on specific Park needs. The technical mapping portion was contracted to the BOR RSGIG in Denver, CO. CNHP was contracted separately to collect, analyze, and write-up the requisite plant association data and conduct fieldwork to support the accuracy assessment (AA). NatureServe was contracted to support the field surveys and data analysis. The specific technical responsibilities and deliverables for the mapping portion included the following:

BOR Responsibilities and Deliverables:

- Interpret aerial photographs;
- Transfer interpreted information to a digital spatial database and produce hard copy (paper) vegetation maps;
- Create digital vegetation coverages including relevant attribute information;
- Produce Arc/Info export file of vegetation plot, observation point, and accuracy assessment locations;
- Provide an annotated list of representative field site photographs/slides;
- Create a contingency table comparing the mapped classes with the AA classes in order to determine map accuracy;
- Provide any ancillary digital files developed during the mapping process;
- Document and record digital FGDC compliant metadata files (*.html) for all created spatial data;
- Produce the final report and CD-ROM describing procedures used in preparing all products;

NatureServe Responsibilities and Deliverables:

- Assist in project scoping and planning activities;
- Develop a preliminary vegetation classification for the study area from secondary sources;
- Design a sampling strategy using Gradsect design;
- Assist in training field crews in standard NPS vegetation sampling methods for classification and accuracy assessment;
- Be available for consultation in data management and vegetation classification;
- Assist in developing mapping units;

- Support photo-interpretation by spending time in field with photo-interpreters and being available of consultation;
- Review and finalize draft classification, local community descriptions, and field key to community types;
- Complete the global descriptions that characterize the vegetation types throughout its distribution;
- Conduct targeted sampling to resolve classification issues and sample undersampled or unsampled vegetation associations;
- Assist in analysis of Accuracy Assessment data;
- Assist in preparation of final report.

CNHP Responsibilities and Deliverables:

Responsibilities

- Research existing vegetation data from ROMO;
- Collect 500+ Vegetation Plots;
- Work closely with BOR photo interpreters to assure a common understanding of the classification of vegetation in the Park;
- Enter and analyze data from Vegetation Plots to produce a final classification for mapping;
- Collect, and enter data for, 1200+ Accuracy Assessment Points;
- Create a Vegetation Field Key;
- Write Local Descriptions for all Vegetation Types;
- Provide information and sections for the Final Report.

Deliverables

- Data in digital form from Vegetation Plots and Accuracy Assessment Points;
- Classification of ROMO vegetation;
- Local vegetation descriptions;
- Key to the Vegetation of ROMO;
- Final Report.

Scoping Meetings

The project participants met on several occasions over the course of the project to discuss project progress and develop the scope of activities that needed to be completed over the near-term. These informally structured “scoping” meetings were held at least once per year, often more frequently. The following is a summary of several of the most pertinent of these.

Initial Planning Meetings:
Several initial planning meetings were held prior to the start of any field work. These were intended to provide the forum for discussing various logistical issues and determining the scope and scale of various project aspects. Questions of whether and how to permanently mark the plots, the availability of crew housing, backcountry camping, land access, the content of the preliminary association list, the content of the map unit list, and other questions were discussed at these initial planning meetings.

Gradsect Meeting:
A logical and systematic method of sampling the vegetation was necessary. The Gradsect Sampling (GRADient-directed tranSECTs) approach was used and required the input of a number of different interested parties with a wide assortment of expertise to design the sampling method.

Field Preparation Meetings:
Prior to beginning field work in 2002 and 2004, the project team met to discuss issues for the approaching field seasons. These included developing an agenda for the orientation and training of the field crews, completion and application of the gradsect analysis, scheduling the plot work, and defining appropriate Park contacts for various issues that might arise.

Interim Status Meeting:
An interim project status meeting was held following the completion of the 2002 summer field season. The purpose of the meeting was for the project participants to summarize their progress on the project and to plan remaining tasks to be completed prior to the start of the 2003 field season. Topics covered during the meeting included progress on defining the Map Units, comparison of the number of plots collected with their from the field and their distribution across the preliminary list of associations, progress of checking the data and entering it into the PLOTS database, and the status of the fuels and photographic data. We also briefly discussed schedules and tasks for the coming months.

Map Unit Meeting:
After a draft classification was developed, representatives from the Park, BOR, CNHP, and NatureServe met at the BOR office in Denver on February 7th 2003 to decide on appropriate map units. The purpose of the meeting was to determine a final mapping classification for vegetation and land use at ROMO. BOR presented a preliminary map unit schema after a review of the final vegetation classification and consideration of prior work. Each map unit was discussed and either lumped or split depending on the opinions of the various ecologists and GIS / remote sensing professionals present. In addition, we reviewed and discussed the field data, aerial photo-interpretation, transfer to digital orthophoto quads (DOQ's), and Park management needs.

Accuracy Assessment Meeting:
Following completion of the vegetation sampling, an accuracy assessment meeting was held on November 19, 2004 to discuss the accuracy assessment and the AA plot data collection. These included topics such as the methodology for defining the appropriate number and distribution (spatial and thematic) of the random plots, development of the cost surface to be used in placing the plots on the map, data to be collected at the plot locations, and logistics for completing the required number of plots in a single season.

Preliminary Data Collection and Review of Existing Information

To minimize duplication of previous work and to aid in the overall mapping project, existing maps and reports were obtained from various sources. The staff at ROMO provided digital and hard copy background material for numerous themes including geology, fire history, soils and previous vegetation maps. Digital elevation models (DEM's), digital line graphics (DLG's), and digital raster graphics (DRG's) were obtained from both ROMO and the USGS. The DEM's were manipulated to create slope and aspect maps.

Before beginning the 2002 field season, CNHP reviewed existing literature and data from previous studies of vegetation in and near ROMO. Of particular interest was plot data presented in Peet (1981) which was collected between 1972 and 1974, and a large dataset collected by various researchers from the Natural Resource

Ecology Laboratory (NREL). Additional plots presented by Carsey et al. (2003) were also evaluated. The locations of all plots evaluated from previous literature are shown in Figure 5.

The Peet (1981) data, although very pertinent, was collected with different assumptions and different methodologies. Instead of cover classes, Peet (1981) calculated stem densities for all trees and shrubs inside the plot. Because stem counts do not equate with cover, it is impossible to quantitatively use that data in the classification. In most instances we were able to cross-walk the types described by Peet (1981) to a recognized NVC type and assign the plots to a map unit. This allowed us to qualitatively use the plots to inform the preliminary classification list and to provide additional control points for the mapping effort.

Several datasets were obtained from the NREL plot database. These were similarly evaluated for their usefulness, and were applied to the classification and mapping in a similar manner to the Peet (1981) data. The NREL database included 180 plots that were mostly collected using multi-scale sampling methods (Stohlgren et al. 1996; Stohlgren et al. 1997; Stohlgren et al. 2000).

The plots from Carsey et al. (2003) were collected as part of a multi-year wetland and riparian vegetation classification project. The 24 plots we used were originally collected by Gwen Kittel in 1993 and 1996 from portions of the project area within Larimer, Grand, and Boulder Counties. These plots were directly applicable to the project methods and were used in the classification as well as the mapping effort.

To establish a "preliminary list" of associations, NatureServe Ecologists queried the NatureServe BIOTICS Database for the types known to occur within the Southern Rocky Mountain Ecoregion. Based on that query the preliminary list contained 242 associations. This list was then reviewed by a number of local experts and refined to indicate the likelihood of a type occurring in the Park; 174 were considered *probable* to occur in the Park, 22 were considered *possible* to occur in the Park, and 46 were considered *not probable* to occur in the Park. Following further discussion and revision at the scoping meetings we ended with a preliminary list of NVC Associations likely to occur in ROMO. Data from previous studies were also used to inform the development of this list, and as indicated above, to inform the final classification. At the start of the 2002 field season, the preliminary classification included between 174-196 existing NVC association types.

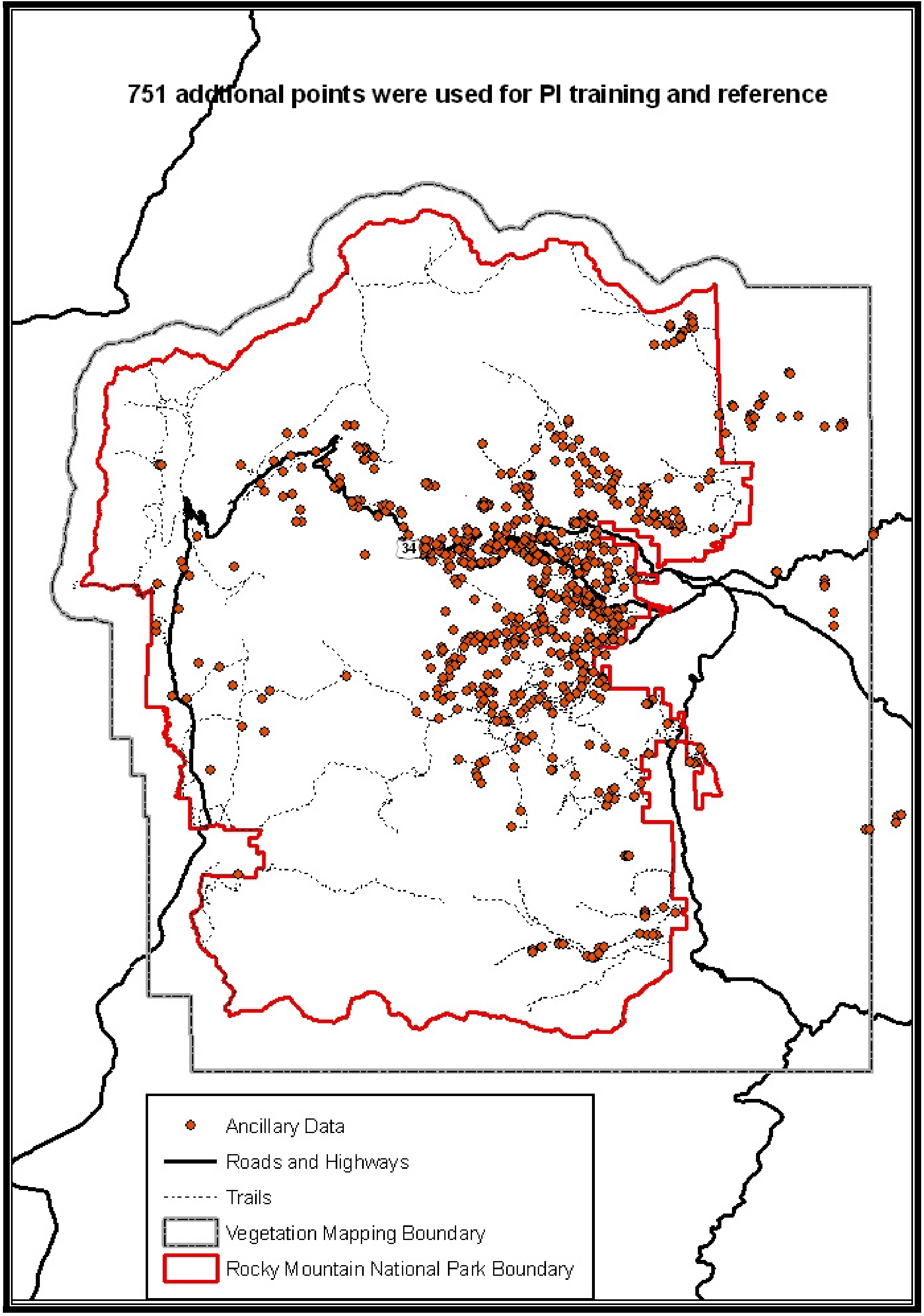


Figure 5. Location of ancillary plots used for photointerpretative training and reference.

Field Survey

Sampling Design: Stratified Random Gradsect

Our ultimate goal at ROMO was to obtain a thorough description for the range of plant communities, both the common/extensive and the rare/unique (Austin and Heyligers 1991). To this end we felt that an unbiased census of all the vegetation (*i.e.* a complete enumeration of the population) would not be achievable or practical for such a large, remote Park. As a result, to cost-effectively capture the full spectrum of vegetation we felt it necessary to optimally locate sampling plots using "Gradsect Sampling" (GRADient-directed tranSECTs) (Gillison and Brewer 1985). Gradsects are a survey method that addresses 1) the need for representative sampling based on environmental stratification, 2) the need for a compromise between statistical sampling, practical logistical problems, and costs, and 3) the value of replicated and randomized sampling (Austin and Heyligers 1991, Gillison and Brewer 1985). We assumed that a modified Gradsect methodology would allow field crews to visit the full spectrum of physical environments and thus most of the vegetation types.

For ROMO, we decided that a spatial-historical model coupled to a 30-meter digital elevation model (DEM) of the Park would be more predictive of vegetative diversity and more efficient than a linear transect approach. A working group of Park, CNHP, NatureServe and BOR ecologists / botanists / geographers familiar with the region selected the model's driving variables; those thought to influence vegetation response. During this process, practical constraints were also considered including the lack of time and money to develop new digital data layers.

For ROMO's modified gradsect, elevation, geology and solar insolation, were chosen as the key abiotic factors (Table 6). We then split each gradsect variable into logical classes to best reflect the vegetation distribution and created digital map layers using ArcView GIS. These GIS layers were then added together to generate a map coverage of all combinations occurring in ROMO, with each unique combination representing a Biophysical Unit (BPU).

At ROMO there were 210 BPU types within the model area that formed a mosaic of 51,242 polygons. The model area extended past the mapping boundary to the north, south and west and fell short to the east due to limited geologic coverage. This model area was subsequently clipped by the mapping boundary and randomly sampled. We selected a subset of these BPUs using a cost-surface analysis, (Appendix D) which favored polygons that were more accessible, of adequate size, and spatially dispersed. This resulted in 2-3 polygons of each type for a total of 925 polygons selected for possible sampling during the initial field season. At ROMO, polygons ranged from 1 -10 ha in size, although the overall range was 0.1-47 ha. This cost-surface process for selecting sampling locations was especially important for ROMO, due to access difficulties caused by the steep and inaccessible areas of the Park.

The crew response to field visits to the selected BPU's was mixed to poor. Often the comment from the crews was that the BPU's really did not provide anything new or interesting and questioned the utility of this approach. One positive note to the use of BPU's is that it provided us a utility to disperse the targets over a very wide range of habitats. Often, once a crew reached the selected target they sampled other areas adjacent or near the modeled target.

Table 6. Environmental variables and classes used in the modified gradsect analysis for ROMO.

(For more detailed information on the ROMO National Park Analysis - Sample Site Selection Methodology see Appendix D.)

ELEVATION (FT)	SOLAR INSOLATION	GEOLOGY
6000 - 7000	10-Full Shade	Granite of Hagues Peak
7000 - 8000	20-Partial Sun	Troublesome Formation
8000 - 9000	30-Partial Shade	Talus
9000 - 10000	40-Full Sun	Alluvium
10000 - 11000		Granitic gneiss
11000 - 12000		Colluvium
		Till of Pinedale-age
		Silver Plume Granite
		Biotite Schist

General Plot Collection Considerations

At the beginning of the 2002 field season, four crews of two people each were hired to collect data in ROMO. The crews were trained in the vegetation and fuels sampling methodology and provided with BPU maps identifying possible plot collection sites. Crews were also given a list of the 180 potential vegetation types to be sampled and instructed to try to collect three plots in each type. Since ROMO is large, diverse, and inaccessible by car in many places, crews were hired both for their botanical and ecological skills, and for their ability to work effectively in variable outdoor conditions, and to work while backpacking. Crews were provided with training in project methods, housing protocols and vehicle use.

The process of collecting vegetation plots is long and complicated, and required several months of planning and preparation. Based on the results of the GRADSECT analysis, proposed plot locations were evaluated for distance from access points and difficulty of travel. Plot locations in areas determined to be more than three or four hours from an access point were considered as backcountry, while those less than that were considered as front country. All front country sites were accessed via day hikes from the nearest road access point. Backcountry sites were accessed via foot trail on multi-night backpacking trips. Crews accessing backcountry sites camped in established campsites and cross-country camping zones. A total of 102 backcountry camp night reservations were required to collect data from all of the backcountry sites. Crews typically stayed in a single established site for 1 to 3 nights, and remained in the backcountry for 3 to 7 nights.

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

Data Collection: Relevé Plots

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

The crews would navigate to the selected area using GPS units as well as maps and compasses. After arriving at the selected BPU, crews would select a specific location to place the plot. They would walk through the polygon to get an idea of the vegetation. If the polygon contained vegetation in a type, or types that crews still needed to collect, they would choose a relatively homogenous and representative area to place a plot. If the polygon was diverse, the crew might select two or more locations in order to capture that variation. If the polygon contained only types that crews did not need to collect they could choose to collect an Observation point or navigate to a different polygon. An observation point is a short version of a plot which uses a dimensionless plot to document the structure, dominant species, and environmental attributes in the area. It can be collected using the same forms and instructions as for full vegetation plots. Observation points are very useful for the photointerpreters as training / reference sites.

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

At each sampling location, plot data were collected using the protocols of the NPS National Vegetation Mapping Program. At the plot center, crews would bury a permanent marker (a small copper tag inscribed with the project acronym, plot code, and date, attached to a galvanized nail) and record the UTM location from the GPS. They would then lay out the plot, using measuring tapes, according to the size specified in the field manual for that vegetation type (most plots were $400m^2$). Crews would begin analyzing vegetation by dividing the vegetation visually into strata, or height classes, and recording the dominant species by cover in each stratum. They would then develop a comprehensive species list for the plot by recording the species name and percent cover for each plant found within the plot. Numerous other data describing the environmental characteristics of the site were collected at each plot including elevation, slope, aspect, soil texture, surficial geology, percent ground cover, and hydrology. A complete set of forest fuels data were also collected from each plot. Before breaking down the plot, crews would attempt to place the vegetation into one of the potential vegetation types. If the plot did not fit into a vegetation type, they would assign a type based on the dominant species in the top two strata. Two pictures showing the plot center and typical vegetation were taken at each plot. When the Plot had been completed, crews would navigate to the next selected BPU and begin the process again.

Data Collection: Forest Fuels Data

Throughout both the 2002 and 2004 field seasons, fire specific data (fuels data) were collected at each site visited. Fuels data collected included information on both live and dead/down fuels. Live fuels data included the density, DBH, height, crown ratio, and height to the base of the crown for all live trees in the stand, as well as the cover of shrubs and herbaceous species. In particularly dense stands, crews were permitted to sub-sample a quarter of the full plot.

For the dead/down fuels, crews recorded depth of litter and duff, shrub cover, herbaceous cover, cover of bare soil, and the cover of wood, litter, and duff. Four photos were taken at each site and photo information was recorded on the fuels datasheet. Fire data collected during 2002 also included a surface fuels characterization, further information on dead and down wood and extensive information, including DBH, on all trees found at the site (Field forms in Appendix C).

Aerial Photography Acquisition and Orthobase Map Development

A contract for aquiring aerial photography was let to Horizons, Incorporated of Rapid City, South Dakota. This contract specified the acquisition of color aerial photography for ROMO and vicinity at two different scales. In addition to the standard 1:12,000 scale photography typically used for photo-interpretation, the project also required 1:40,000 scale photography for the production of orthophotos for the entire area.

Normally for these types of projects photography is acquired at mid-summer however due to the emphasis on mapping aspen the acquisition date was pushed back to September. The aspen leaf color change in the fall made photointerpretation of this important map unit much easier. We did experience long shadows in some areas but this was not a tremendous issue. In fact, in some cases the shadow and subsequent profile from the trees allowed us to determine species.

The project area is covered by 28 flight lines flown south to north for the 1:12,000 scale photography (Figure 6) and 10 flight lines for the 1:40,000 scale photography (Figure 7). Some of the flight lines overlap with repeat flights due to elevation and scale considerations. A total of 1,412 color photographs were taken at 1:12,000 (1"=1,000') scale and 366 color photographs for the 1:40,000 (1" = 3,333') all printed on 9"x 9" paper stock. Overlap for all photographs was approximately 50-60% and sidelap between flight lines was approximately 20-30%. All photography was acquired between September 25 and October 3, 2001. Repeat dates were required due to the large area being acquired in addition to the challenging terrain. Airborne GPS was collected with a base station at the Fort Collins, Colorado Airport (Latitude: 40 26 58.07884; Longitude:-105 00 24.66076; Height:1509.710 m; Antenna ht:0.203 m). GPS points provided for a flight line point shape file and aided with the ortho-rectification process.

The contracting for new digital and hard copy color ortho base maps for this project not only provided new base maps for the Park but also provided for much better transfer of interpreted information to better base data. Technical specifications for the base map photography and subsequent data manipulation can be found in the orthophoto metadata file located in the accompanying DVD. All aerial and ortho-photography received a rigorous examination by BOR prior to being accepted.

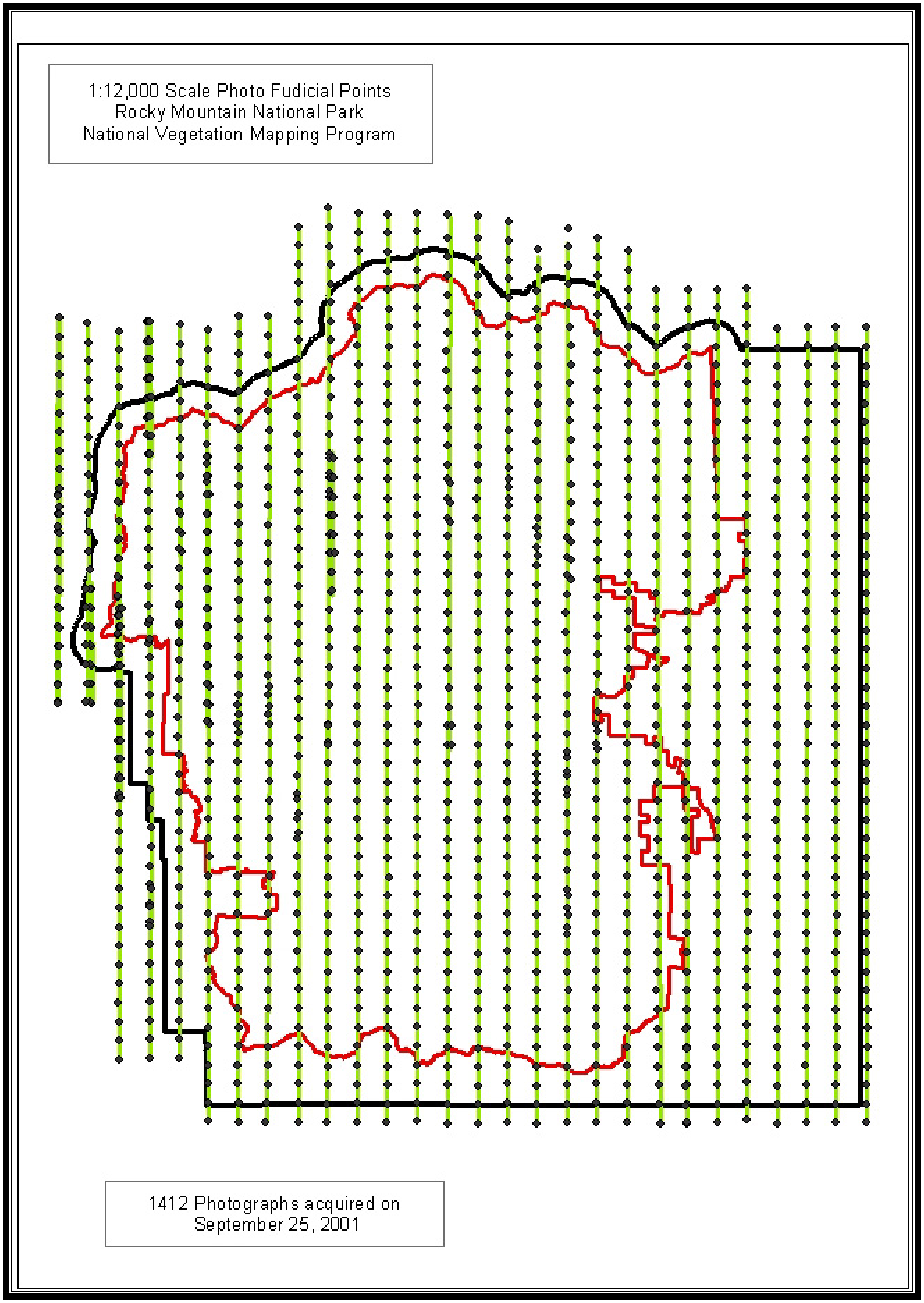


Figure 6. Flight lines and photo centers for 1:12,000 color photography.

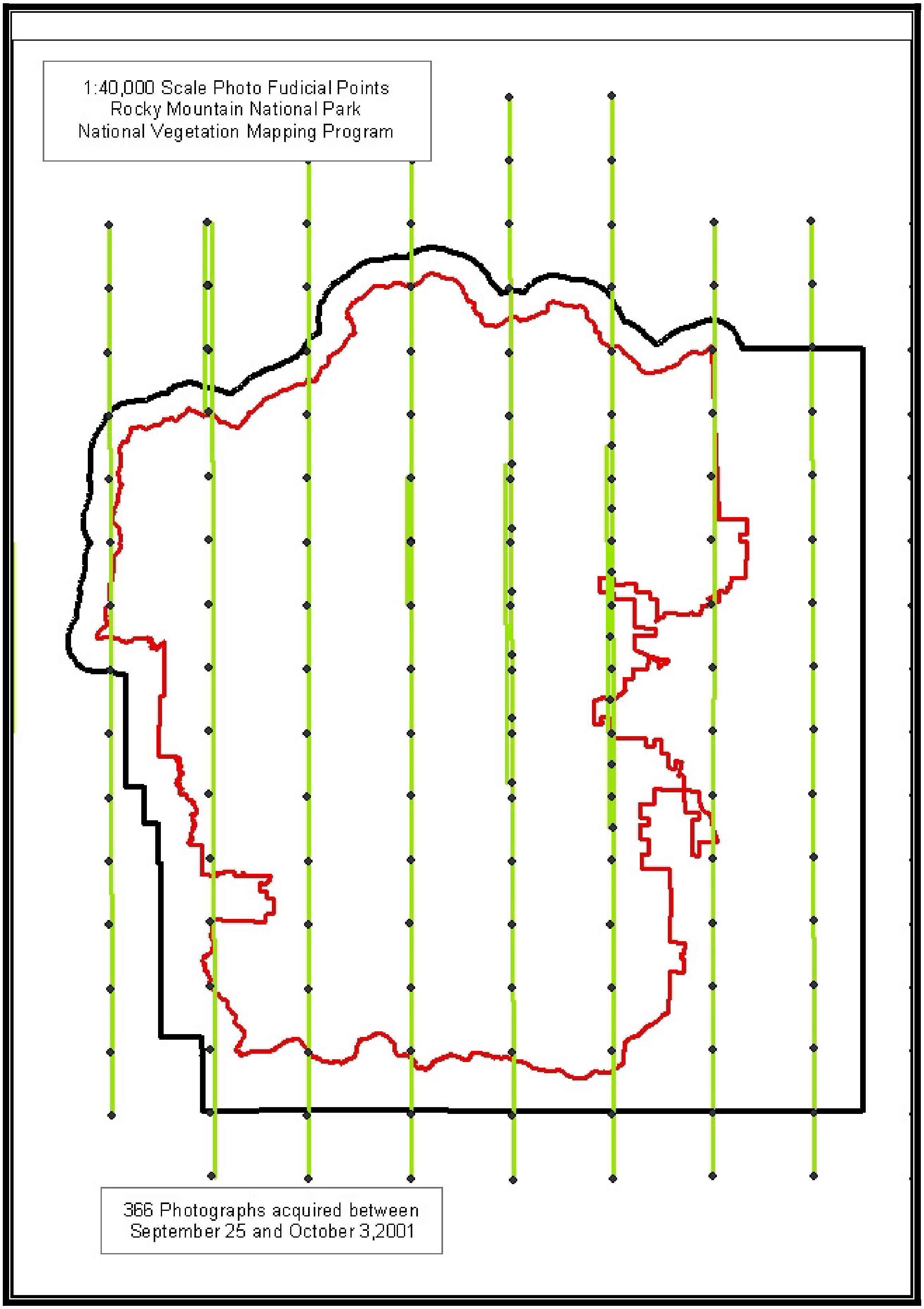


Figure 7. Flight lines and photo centers for 1:40,000 color photography.

Photo Interpretation – Map Units

Photo Interpretation

Photointerpretation was done using the 9 x 9, 1:12,000 scale color photographs in addition to the paper copies of the orthophotos. The interpretation on the aerial photography or the paper copies of the orthophotos depended a lot on the complexity of the landscape. Areas with high heterogeneity were mapped using the aerial photos and the orthophotos as ancillary. Areas of high homogeneity, such as vast areas of young lodgepole, were mapped with less reference to the aerial photography.

We requested that the orthophotos be delivered from the contractor (Horizons Inc) as 48, 1:12,000 scale sheets and printed on photographic paper with a 1,000 meter UTM grid. These were then covered with translucent (semi-frosted) Mylar, fastened together, and backlit on a light table. All UTM grid points were marked on the overlays and the initial polygons were delineated using a 0.5 mm lead pencil. This served as our base for future transfer to the digital realm.

Mylar overlays placed on each aerial photo allowed us to make notes and delineate polygons. At this stage of interpretation we used a stereoscope to help recognize complex photo signatures and three-dimensional features on the 9X9 aerial photos. We then manually transferred these to the orthophotos (Figure 8). Finally, in order to insure completeness and accuracy, digital transfer specialists reviewed all of the interpreted orthophotos for consistency and recommended changes where necessary. Once all the obvious vegetation and land-use classes were delineated we proceeded into the second stage.

Map Units and Polygon Attribution

The map units delineated on the orthophotos were derived from the NVC classification as constrained by the limitations of the photography. After an initial map unit meeting with all parties to this mapping effort, we arrived at an initial list of map units we thought reasonable. In few instances, one NVC association corresponded to one map unit. In most cases, however, many associations were grouped into one map unit. The number and names of map units changed as the project progressed. (see Table 12 in “Results” section) After the initial determination of preliminary map units the photointerpreters started their work. After some PI had been done several additional map units were added as the photointerpreters became more familiar with the project. Some new map units were an attempt to use mental models rather than just signature as a photointerpretive tool. After the accuracy assesment the number of map units was again modified. A map unit key is included in Appendix G.

The photointerpretation included vegetation context and structure. Four attributes are included. These are map unit, height, density and coverage pattern. The structural categories and codes are listed in Table 7. A lookup table for the map unit names is included in the attached dataset and in Appendix J. There is an oldvegcode item that reflects the earlier map unit classification.

Each polygon has a number of attributes that are stored in the associated table within the GIS database. Many of these attributes are derived from the photointerpretation and others are calculated or crosswalked from other classifications. Table 8 shows all the attributes and their sources.

Anderson Level 1 and 2 codes are also included. These codes should allow for a more regional perspective on the vegetation types. A lookup table for the names associated with the codes is included with the attached dataset and in Appendix J.

There is also an ecological system code (El_Code). Look-up tables for these ecological system names are also included with the attached dataset and in Appendix J. There are three El_codes in the database. These reflect the one to many relationships that may exist when cross walking the Map Unit to ecological systems.

Slope (degrees), aspect and elevation are calculated for each polygon label point using a DEM and an ArcView script developed by Jenness enterprises and downloadable from www.jennessent.com. The slope figure will vary if one uses a TIN versus a GRID for the calculation (Jenness 2005). A grid was used for the slope figure in this dataset.

Acres and hectares are calculated using XTools Pro for ArcGis Desktop (www.xtoolspro.com).

Instrumental to the photointerpretive effort was the use of the GPS located vegetation plots collected by the field crew. These plots gave us a good idea of what the signatures of the individual map units should look like. In addition to the tablular data associated with each vegetation plot were the four photographs collected at each plot. These photographs helped not only in identifying the immediate area but also provided us with a "look" at the areas surrounding the vegetation plot which might be a different map unit. In addition to the vegetation plots we made use of a number of different sources that had ground referenced information.

Additional ground information was supplied by a wide range of researchers that have done previous vegetation work in the Park. Many plots were provided by Dr. Tom Stohlgren and the NREL at Colorado State University in Fort Collins. Additional plot data were provided by the Fire program at ROMO. Others included Colorado State Parks and Gwen Kittel (Natureserve). The largest share of previous plot data were provided by Dr. Robert Peet who collected 305 plots for his dissertation (Peet 1981). The distribution of the ancillary plots tended toward that area around the principal roads (Figure 5). The content of each of the plot data sets varied from simple references to the overstory to detailed species list and cover values for each species. These data are not included with the ROMO dataset as the data were loaned to this project to help with the photointerpretation and the specifics remain the intellectual property rights of the individual researchers. Those readers wishing to use the additional data are encouraged to contact the individual researcher directly.

Table 7. Structural categories for vegetation photointerpretation.

Code	HEIGHT	
1	< 1 Meter	
2	1 - 5 Meters	
3	5 - 15 Meters	
4	15 - 30 Meters	
5	> 30 Meters	
	COVERAGE DENSITY	
1	Closed Canopy / Continuous	75 – 100 %
2	Discontinuous	50 – 75 %
3	Dispersed	25 – 50 %
4	Sparse	< 25 %
	COVERAGE PATTERNS	
1	Evenly Dispersed	
2	Clumped / Bunched	
3	Gradational / Transitional	
4	Alternating	

Figure 8. Example of transfer process from aerial 9 x 9 photography to color orthophoto base map.

(Example from Zion National Park – Vegetation Mapping Project (Cogan et al. 2003).

Table 8. Polygon attribute items and descriptions used in the ROMO spatial database (GIS coverage).

Attribute	**Description**
AREA*	Surface area of the polygon in meters squared
PERIMETER*	Perimeter of the polygon in meters
ROMO_VEG#*	Unique internal polygon coding
ROMO_VEG-ID*	Unique internal polygon coding
VEGCODE	Final Map Unit Codes - BOR derived, project specific.
OLDVEGCODE	Initial Map Unit Codes - BOR derived, project specific.
HEIGHT	Height range of the dominant vegetation layer.
	(Height classes: 0-2, 2-5, 5-10, 10-20, >20 meters)
DENSITY	Density of the tallest strata.
	(Density classes:<25%, 25-50%, 50-75%, >75%)
PATTERN	Vegetation pattern within the polygon.
	(Vegetation pattern classes: Evenly dispersed, Clumped/bunched, Gradational, Alternating)
SLOPE	Slope of label point within polygon (degrees).
ASPECT	Aspect of label point within polygon.
AND_LEV1	Land Use and Land Cover Classification System (USGS, Anderson et al. 1976) Level 1.
AND_LEV11	Land Use and Land Cover Classification System (USGS, Anderson et al. 1976) Level 2.
HECTARES	Area in Hectares
ACRES	Area in Acres
ELEV_M	Elevation in meters for label point
ELEV_FT	Elevation in feet for label point
EL_CODE_1	Ecological Systems Classification Code - NatureServe Ecological Classification.
EL_CODE_2	Ecological Systems Classification Code - NatureServe Ecological Classification.
EL_CODE_3	Ecological Systems Classification Code - NatureServe Ecological Classification.
(*ArcInfo© default items)	

Digital Transfer

The transfer process for ROMO involved taking the interpreted line work and rendering it into a comprehensive digital network of attributed polygons. To accomplish this, we created an ArcInfo© GIS database 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. The actual transfer of information from the interpreted orthophotos to a digital, geo-referenced format involved scanning, rasterizing, vectorizing, cleaning, building topology, and labeling each polygon.

The scanning technique 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 was then geo-referenced to the matching digital version of the orthophoto. The essential principle of geo-referencing was to match control points (the UTM grid) as marked on the orthophotos to the same ones in the digital images. In this manner the transfer was 1-to-1.

Once scanned and registered, we removed all erroneous information such as dangling lines. After cleaning, we joined the lines into polygons by building topology in the GIS program. The resulting polygons were then edge matched with those from adjacent orthophotos. Finally, we created labels for each polygon and use these to add the attribute information. Using this process we created one final coverage or spatial database for the entire project.

Attribution for all the polygons at ROMO included information pertaining to map units, NVC associations, Anderson land-use classes, and other relevant data. Attribute items requested by the ROMO fire program included height, density, and pattern. All of the attribute items are listed in Table 8 and are referenced in the ROMO vegetation look-up table included on the accompanying CD-ROM. Attribute data were taken directly from the interpreted photos or were added later using the orthophotos as a guide.

Scanning a ROMO orthophoto sheet

Plot Data Management and Classification Analysis

Plot Data Management

Following the field season and prior to data entry, all plot forms were checked to ensure quality control (QC). Particular attention was paid to making sure that the recorded plot location was correct and that all relevant fields were filled in. When information was missing, an effort was made to find and record that information, often from the associated fuels form, or from other data sheets produced by the same crew on that or an adjacent day. Changes to field form entries were made in red pen and marked with a date and the reviewer's initials.

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

Vegetation Classification

Field crews collected data from 632 sample plots during the summer of 2002 (Figure 9). Of the 632 plots collected, 547 were full vegetation plots and 85 were the shorter observation points (see Appendix C for field forms). Data from these plots were reviewed for accuracy and entered into the PLOTS database during the fall of 2002. From November 2002 to January 2003, the data were statistically analyzed using direct and indirect ordination and a polythetic divisive technique and assigned to vegetation types. The statistical analysis was conducted with the aid of the multi-variate statistical software package PC-ORD version 4.14. An additional 9 plots and 8 observation points were collected in the fall of 2004 to augment sampling of targeted vegetation types, but were not used in the multi-variate analysis.

After subjecting plot data to QC, we began the process of analyzing and interpreting the data. The goal was to classify the plots at the community level based on species composition and environmental characteristics. Our intentions were to finalize the community classification by merging our ecological understanding of the classification system with two multivariate analysis techniques, Two-way Indicator Species Analysis, or TWINSPAN (Hill 1979), and Detrended Correspondence Analysis, or DCA (Hill and Gauch 1980).

A data matrix was created in PC-ORD using data from all 547 plots. We first ran the matrix in TWINSPAN, in the hopes that we would see some initial breaks, which would allow us to further refine our analysis using DCA. We hypothesized that the initial breaks would be based on high coverage indicator species such as *Abies lasiocarpa, Pinus contorta, Pinus ponderosa, Salix planifolia, Caltha leptosepala , Carex aquatilis*, and others. The initial analysis reflected this trend; however, there were other, less indicative species, such as *Achillea millefolium* and *Taraxacum officinale*, which occurred with such regularity that unnecessary breaks were created by the analysis.

After the initial run with TWINSPAN we created a priori breaks in our data set based on the physiognomic classes of the plots. We hoped to decrease the confusion and lack of consistency inherent in an analysis of such a large number of plots and plant species. We created three subsets of data: Herbaceous plots, Shrubland plots, and Forest plots, and ran each subset as a unique data set on DCA with default settings.

Data were interpreted through graphical representation on two axis. Each iteration would display “outlier” plots, or plots which visibly stood apart from the larger congregations of plots on the two way axis. We would manually analyze the data behind outlier plots on the graph, and classify the plots or table them for further discussion, then remove them from the analysis. The judgment of what was and was not an outlier was up to the interpretation of the analyzer. After removing outliers, and, in effect, diminishing noise in the matrix, we would run the analysis again. This iterative process quickly revealed groupings of plots. At this point we would manually analyze the data behind the plots in the groupings. During analysis we took into account environmental characteristics of the plot and species composition. We also looked at the provisional community name given to the plot by the field researchers, as this was a helpful starting point for further analysis, and a useful piece of information for making final tough calls.

The limitations of DCA were apparent, as the groupings often did not easily reflect the final classification of the plots. When possible we would reference previously published materials regarding relevant and similar community types, and make a decision based on this information and on our ecological understanding of these communities. The DCA was helpful as a tool to bring out patterns we would otherwise not discern from the data; however, the final call for classification was based primarily on information regarding previously studied vegetation community types and on our ecological interpretation of the plot data.

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

The field key combines the characteristics indicated by the ROMO plot data with the essence of the NVC concept for each of the associations. It provides the user with a series of dichotomous choices that result in identification of the association. The field key was used during the 2004 Accuracy Assessment to determine the vegetation type for each of the AA Points. Based on the results of its use during AA, the key was edited to include previously omitted types and to clarify the text and simplify its use.

Map Verification and Accuracy Assessment

As we completed the ortho-photo interpretation and digital transfer for sections of the Park, draft 1:12,000-scale hard copy vegetation maps were printed for review. In all cases, we checked these draft maps against the interpreted photographs to ensure that the polygons were labeled properly and to locate any extra or missing lines. We also compared the map labels to the plot data if they fell in the same location. Copies of the revised draft map were then sent into the field on several occasions by the photo interpreters for ground-truthing. During the ground-truthing process, we verified aerial photograph signatures using landmarks and GPS waypoints. The map and map units were then modified to correct any mistakes.

Sample Design

Selection of AA sample points followed that described by the NBS/NPS Vegetation Mapping Program, Accuracy Assessment Procedures manual. The design attempts to adhere to scientific principles that govern sampling and statistical analysis and also be practical. The consideration of map accuracy typically can have two components: thematic map accuracy and positional accuracy. The accuracy assessment that follows reflects only thematic map accuracy. Positional accuracy is not considered. Given that polygon boundaries are only occasionally “hard” and subject to interpretation it makes little sense to spend the effort to quantify a subjective boundary.

Sample Method

The accuracy assessment protocol takes into consideration maximum and minimum sample sizes. Considerations include statistical as well as cost constraints and mapped class abundance and frequency. The sample selection is a stratified random sample, stratified by map units. Five scenarios are based on class abundance and frequency and are defined in Table 9.

Sample Site Selection

These parameters were coded into in-house software programs that allows for repeat sample selection using a variety of sample choices such as cost weighting and distance from polygon boundary. The cost weighting allowed us to eliminate sample points that had extremely arduous access (distance/difficulty = cost) or were in dangerous locations. Being able to choose minimum distance to polygon boundaries helped to eliminate ecotonal boundaries which lead to confusion and loss of effort. A minimum distance of 10 meters was chosen for this effort. The distribution of sample points is shown in Figure 10.

AA Sample points were collected for the entire mapping area as opposed to the original vegetation sampling which was restricted solely to the Park itself.

Field crews were provided with two sets of samples. The primary set included the preferred target for the sample selection. If a target was inaccessible for any reason, the crews were free to substitute from a secondary set of points. The effect of this arbitrary reselection reduces somewhat the stratified random selection of points. The positive effect of this is to take advantage of the cost of sending a crew to a particular location.

Data Collection – AA Points

Field maps were produced that showed the sample point and polygon boundary. The addition of the polygon boundary to the field map aided in navigation to the point and provided the field crews with some contextual information. Field crews navigated to each point using the field maps produced for this effort in addition to a GPS with a known target location.

To help control cost and logistic issues only those map units that had a vegetative component received an accuracy assessment. This resulted in the removal of 5422 polygons from consideration or 15% of the total number of polygons. This translates into 11% of the mapped area not accuracy assessed. Un-assessed map units include areas such as rock outcrops, glaciers, water bodies etc. These areas were assumed to have a very high accuracy, as there is little, if any, ambiguity in their interpretation. The result of this is that the reported overall accuracies are most probably lower than the actual overall map accuracy.

In June of 2004, the CNHP Accuracy Assessment field crews were given printouts of the aerial photographs and topographic maps overlaid with the map unit polygons. These maps contained 1167 randomly selected locations to be used as AA Points. The field crews were instructed to navigate to these points and complete an AA datasheet (Appendix C). Given the time frame of the project, and the rugged nature of the Park, it was assumed that not all of the generated points would be accessible. A secondary set of 1,010 possible AA Points was included on the maps as replacements for those primary points which might be discovered to be inaccessible or otherwise unusable.

Between June 5th and October 15th 2004, the Field Crews collected 1219 AA Points. 811 AA Points were from the primary point list and 408 were from the secondary list. Figure 10 shows the locations of the collected AA points. Each day crews choose points to visit based on logistical factors. Low elevation points were visited early or late in the season, while high elevation sites were only accessible when not covered by snow. Remote sites were visited during backpacking trips, which were planned prior to the start of the field season. Points located around Lake Granby were accessed by pontoon boat, while all other sites were accessed by car and/or on foot. Field days were planned around collecting as many primary points as possible; however, when secondary points occurred along a planned route for the day, they were surveyed in anticipation of future points which might be missed. The tally of which points had been collected in each Map Unit was updated throughout the summer. During the last few weeks of the project, areas for the crews to visit were chosen strategically, to assure point coverage across all of the Map Units.

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

At the end of the field season, all AA point paperwork was subjected to the same quality control (QC) procedures as the vegetation plot data. While all fields on the AA form were checked for accuracy, particular attention was given to checking the UTM's and plot numbers, and to comparing the assigned association name with species data. All AA point data were then entered into the PLOTS database. Following the data entry, the AA data in the database was subjected to another round of QC to catch data entry errors. The Map Unit was not specifically assigned in the field, but was assumed to correlate directly with Association; with one Map Unit encompassing one to several Associations. A Map Unit column was added to the database and filled using a Microsoft Access query. Those points which did not fit well into an existing NVC Association were keyed to Map Unit by hand.

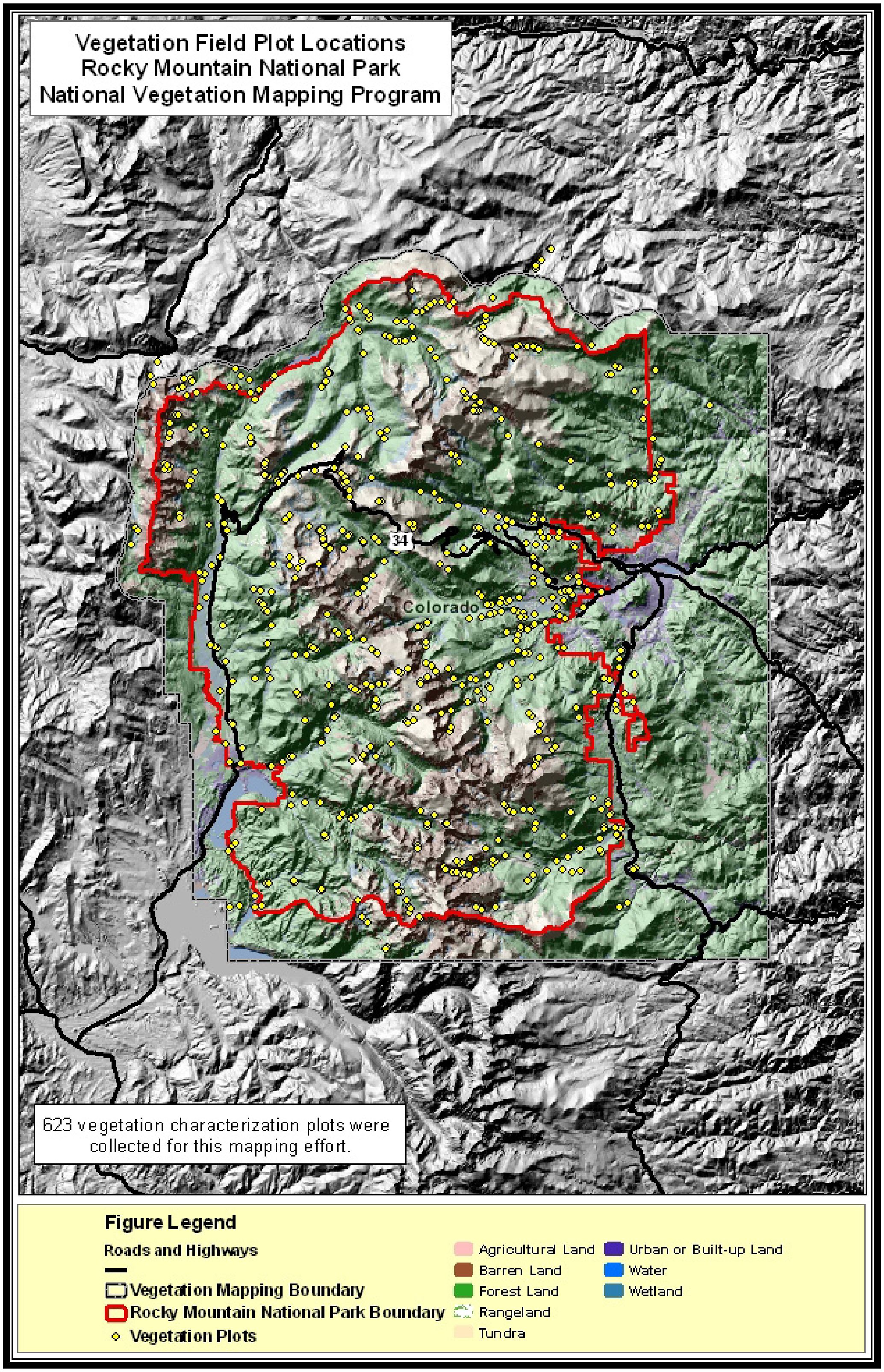


Figure 9. Location of vegetation plots collected at ROMO.

Table 9. Recommended map accuracy sample number per class by frequency and area.

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

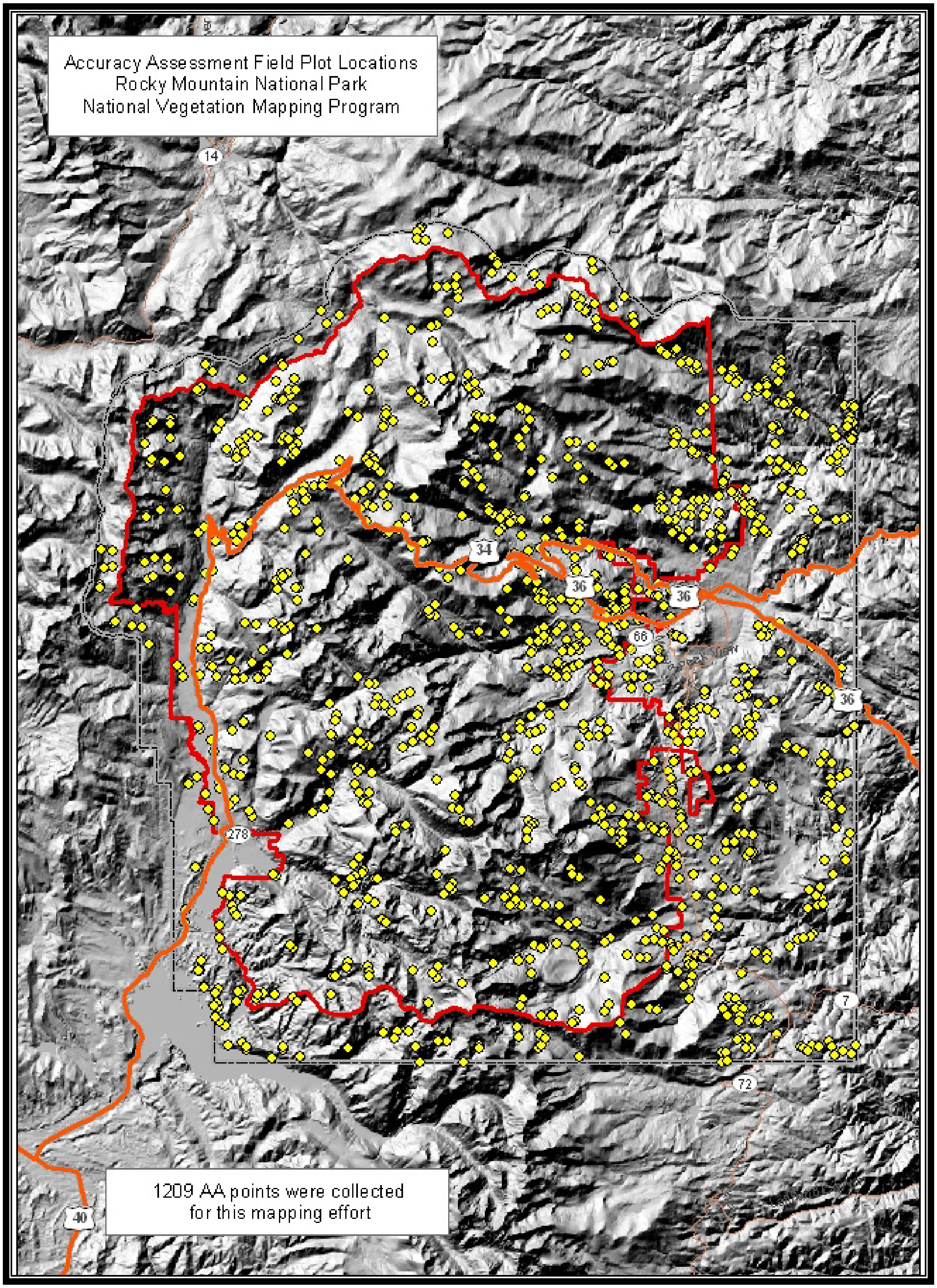


Figure 10. Distribution of accuracy assessment points, ROMO and environs.

AA Metrics

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

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

User's accuracy is calculated as:

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

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

Producer's accuracy was calculated as:

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

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

Overall accuracy for the map was calculated as:

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

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

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

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

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

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

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

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

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

Fuzzy Accuracy Assessment: The need for an alternative to the standard binary approach of accuracy assessment was recognized some time ago. Gopal and Woodcock (1994) described the first fuzzy accuracy assessment approach that is commonly used today. This type of analysis allows for degrees of membership to a particular class. That is, we are allowed to recognize that a particular class may be considered wrong using a strict binary approach but with the fuzzy analysis that class may be mostly correct. This does provide a much better representation of the continuity present in the real world and still allows us to map using discrete classes.

The standard approach to assigning fuzzy membership to a class is to review each of the AA plots and assign a fuzzy level to that plot. Fuzzy level designations are shown in Table 10. The result of this fuzzy designation then allowed us to evaluate each fuzzy level using the standard binary approach. That is, we developed a contingency table for fuzzy levels 5, 4 and 3. Because we are only interested in the fuzzy levels that allow for varying degrees of membership and still be considered correct we ignored fuzzy levels 2 and 1.

To facilitate this analysis it was necessary to create one table that included all the information necessary for a multiple contingency table analysis. A screen shot of this table is shown in Figure 11. The table has several columns. The first column is generated by the GIS software and may be ignored for analysis purposes. The second column is the unique plot id for each AA point. Column three is the map unit assigned to the AA point. After each AA point was collected it was assigned to a vegetation association and subsequently to a map unit. The number in column three is the equivalent of the map unit code. This column becomes the “reference” point when applied to a binary analysis such as described in the binary approach above. Columns four and five are the UTM coordinates for each AA point. Column six is the fuzzy designation applied to each plot. The designation of a fuzzy code is a lengthy process and made more difficult by its subjective nature. To provide some objectivity to the fuzzy membership we developed some on the fly rules for evaluating the plots and the subsequent fuzzy designation. The rules are rough in that they do not evaluate every single possible permutation of species occurrence, density, canopy etc. An example of this process is as follows:

If an AA plot is designated as map unit 7 (alpine meadow) and the vegetation map shows map unit 2 (alpine fellfield) then the initial binary accuracy assessment would indicate that this was wrong. During the fuzzy accuracy assessment and redesignation we applied the following rules:

If there was no herbaceous or rock in the plot then it received a fuzz code of 1 – *Absolutely Wrong: This answer is absolutely unacceptable. Very Wrong.* If the cover was herbaceous but contained no cushion plants or rock cover then it received a fuzz code of 2 – *Understandable but Wrong: Not a good answer. There is something about the site that makes the answer understandable but there is clearly a better answer. This answer would pose a problem for the users of the map.* If the plot had an herbaceous cover, perhaps some cushion plants and had a high amount of surface rock then it received a fuzz code of 3 – *Reasonable or Acceptable Answer: Maybe not the best possible answer but it is acceptable; this answer does not pose a problem to the user if it is seen on the map. Correct.* If there was a high cover of cushion plants but not enough to be called a fellfield as per the association description it received a fuzz code of 4 - *Good Answer**:** Would be happy to find this answer given on the map. Very Right.* If the AA point (reference point) matched the vegetation polygon (predicted value) then the fuzz code was calculated to 5 - *Absolutely Right: No doubt about the match. Perfect.*

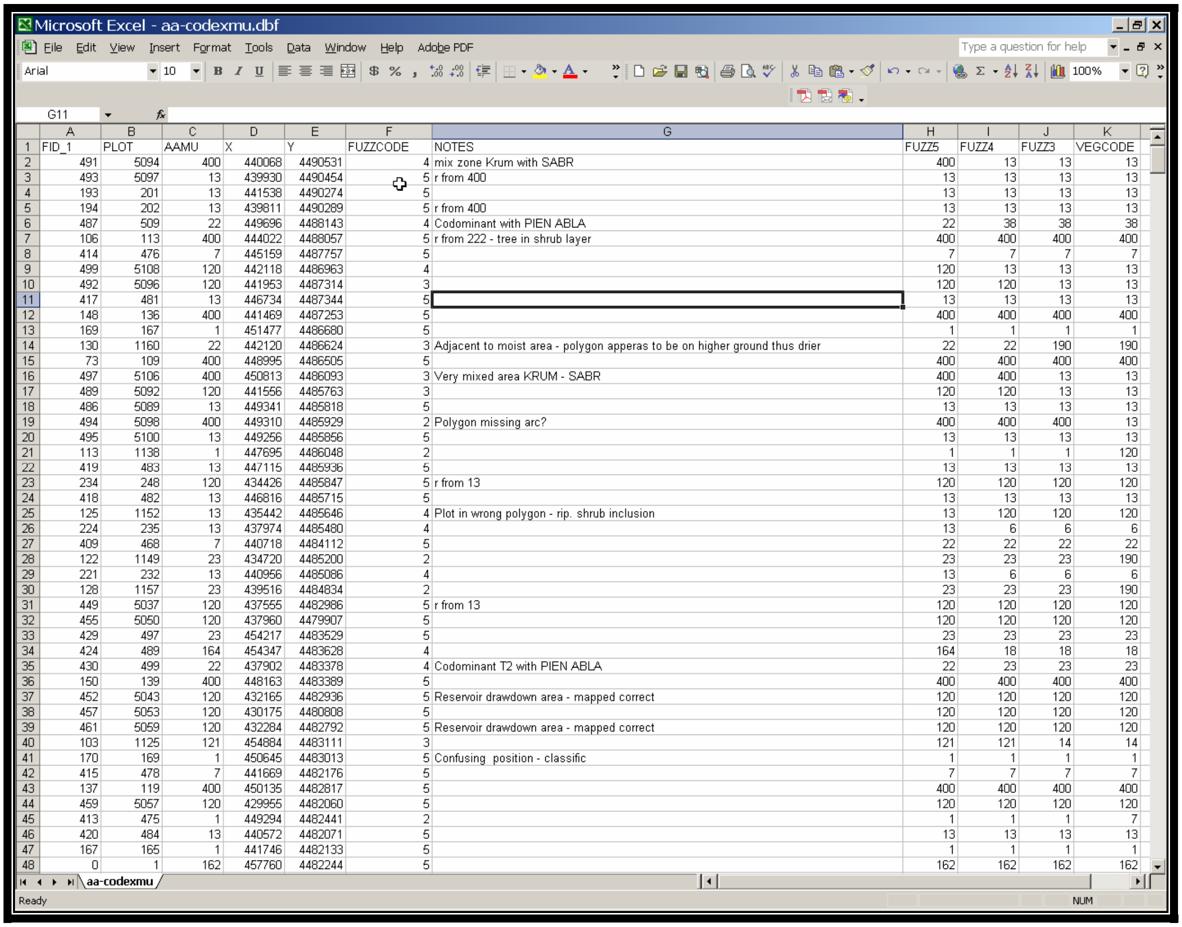
During the evaluation process, all three authors debated the merits of each plot and fuzzy membership. Consensus was reached on each designation before moving on to the next AA plot.

All plots that received a "correct" designation during the initial binary assessment received a fuzzy membership 5. All other plots were then selected for other fuzzy membership designations.

To evaluate fuzzy levels 4 and 3 using a contingency table we recalculated the reference layer (AA Plot) to be equal to the predicted layer (digital polygon map) depending upon the fuzzy level. To do this we created three additional columns in the AA table. These are columns "fuzz5, fuzz4 and fuzz3". Evaluation of fuzzy level 5 is identical to the initial binary accuracy assessment as described above. The designation of values in the fuzz4 and fuzz3 columns is as follows. If a plot received a fuzzy designation of 4 then all levels at and below 4 were calculated to equal the polygon code. This column was then used as the "reference" layer in the contingency table. These would show up as "correct" in the contingency table for fuzzy level 4. However, at fuzz5 this would still show up as wrong which is what we would expect for the very stringent class membership at fuzzy level 5. When we calculate the contingency table for fuzzy level 3 this AA plot would show up as correct because it received a fuzzy code of 4 and therefore it follows logically that it must also be correct at fuzzy level 3. Adjacent to the fuzz5, fuzz4 and fuzz3 columns is the "vegcode" which is the code for the predicted value (polygon layer). Also in this table is a column for the original AA code assigned to each AA plot ("AAMU" – accuracy assessment Map Unit). This column is identical to the fuzz5 column and is duplicated for the sake of clarity. The "fuzzcode" column is the fuzzy designation for each plot arrived at by plot evaluation by the authors. The contingency tables are presented in the "Results" section of this report.

Table 10. Fuzzy set accuracy ranks (Gopal and Woodcock, 1994).

Fuzzy Class	Description
1	**Absolutely Wrong:** This answer is absolutely unacceptable. Very Wrong
2	**Understandable but Wrong:** Not a good answer. There is something about the site that makes the answer understandable but there is clearly a better answer. This answer would pose a problem for the users of the map
3	**Reasonable or Acceptable Answer:** Maybe not the best possible answer but it is acceptable; this answer does not pose a problem to the user if it is seen on the map. Correct
4	**Good Answer:** Would be happy to find this answer given on the map. Very Right
5	**Absolutely Right:** No doubt about the match. Perfect



	A	B	C	D	E	F	G	H	I	J	K
1	FID_1	PLOT	AAMU	X	Y	FUZZCODE	NOTES	FUZZ5	FUZZ4	FUZZ3	VEGCODE
2	491	5094	400	440068	4490531	4	mix zone Krum with SABR	400	13	13	13
3	493	5097	13	439930	4490454	5	r from 400	13	13	13	13
4	193	201	13	441538	4490274	5		13	13	13	13
5	194	202	13	439811	4490289	5	r from 400	13	13	13	13
6	487	509	22	449696	4488143	4	Codominant with PIEN ABLA	22	38	38	38
7	106	113	400	444022	4488057	5	r from 222 - tree in shrub layer	400	400	400	400
8	414	476	7	445159	4487757	5		7	7	7	7
9	499	5108	120	442118	4486963	4		120	13	13	13
10	492	5096	120	441953	4487314	3		120	120	13	13
11	417	481	13	446734	4487344	5		13	13	13	13
12	148	136	400	441469	4487253	5		400	400	400	400
13	169	167	1	451477	4486680	5		1	1	1	1
14	130	1160	22	442120	4486624	3	Adjacent to moist area - polygon apperas to be on higher ground thus drier	22	22	190	190
15	73	109	400	448995	4486505	5		400	400	400	400
16	497	5106	400	450813	4486093	3	Very mixed area KRUM - SABR	400	400	13	13
17	489	5092	120	441556	4485763	3		120	120	13	13
18	486	5089	13	449341	4485818	5		13	13	13	13
19	494	5098	400	449310	4485929	2	Polygon missing arc?	400	400	400	13
20	495	5100	13	449256	4485856	5		13	13	13	13
21	113	1138	1	447695	4486048	2		1	1	1	120
22	419	483	13	447115	4485936	5		13	13	13	13
23	234	248	120	434426	4485847	5	r from 13	120	120	120	120
24	418	482	13	446816	4485715	5		13	13	13	13
25	125	1152	13	435442	4485646	4	Plot in wrong polygon - rip. shrub inclusion	13	120	120	120
26	224	235	13	437974	4485480	4		13	6	6	6
27	409	468	7	440718	4484112	5		22	22	22	22
28	122	1149	23	434720	4485200	2		23	23	23	190
29	221	232	13	440956	4485086	4		13	6	6	6
30	128	1157	23	439516	4484834	2		23	23	23	190
31	449	5037	120	437555	4482986	5	r from 13	120	120	120	120
32	455	5050	120	437960	4479907	5		120	120	120	120
33	429	497	23	454217	4483529	5		23	23	23	23
34	424	489	164	454347	4483628	4		164	18	18	18
35	430	499	22	437902	4483378	4	Codominant T2 with PIEN ABLA	22	23	23	23
36	150	139	400	448163	4483389	5		400	400	400	400
37	452	5043	120	432165	4482936	5	Reservoir drawdown area - mapped correct	120	120	120	120
38	457	5053	120	430175	4480808	5		120	120	120	120
39	461	5059	120	432284	4482792	5	Reservoir drawdown area - mapped correct	120	120	120	120
40	103	1125	121	454884	4483111	3		121	121	14	14
41	170	169	1	450645	4483013	5	Confusing position - classific	1	1	1	1
42	415	478	7	441669	4482176	5		7	7	7	7
43	137	119	400	450135	4482817	5		400	400	400	400
44	459	5057	120	429955	4482060	5		120	120	120	120
45	413	475	1	449294	4482441	2		1	1	1	7
46	420	484	13	440572	4482071	5		13	13	13	13
47	167	165	1	441746	4482133	5		1	1	1	1
48	0	1	162	457760	4482244	5		162	162	162	162

Figure 11. Example of fuzzy re-designation for the creation of contingency tables.

Hypothesis Testing

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

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

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

Error Distribution

The distribution of error over the landscape was produced using ordinary kriging and the following parameters:

Selected Method: Ordinary Kriging
Output: Prediction Map

Number of datasets: 1

Number of Points: 1207

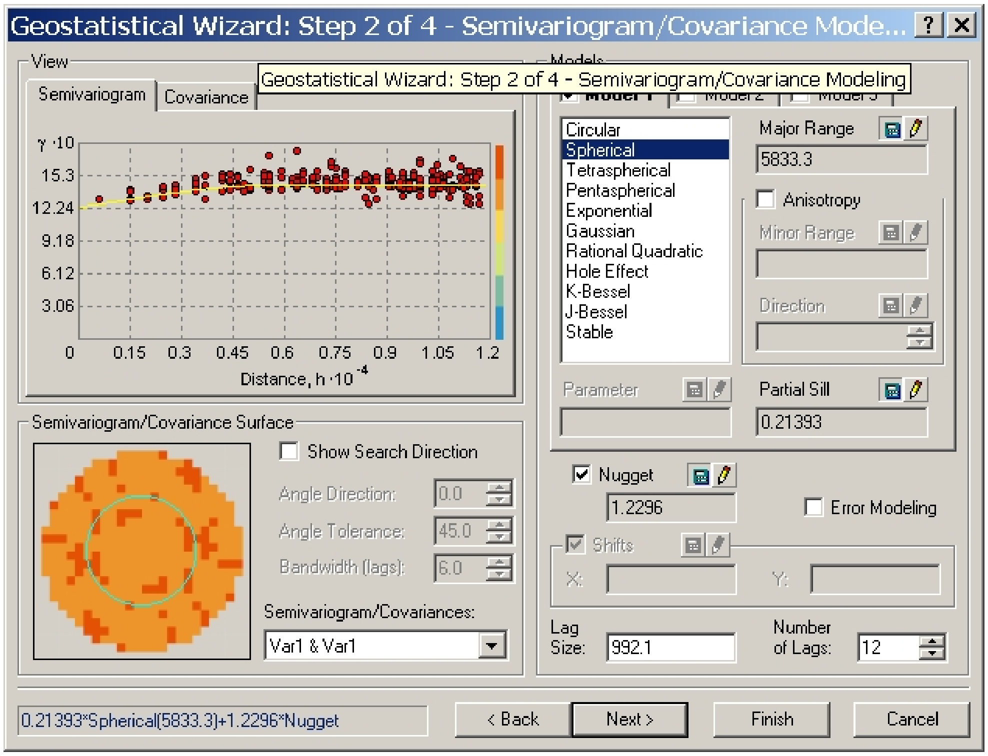
Semivariogram/Covariance:
Model:
0.21393*Spherical(5833.3)+1.2296 * Nugget
Error modeling:
Microstructure: 1.2296 (100%)
Measurement error: 0 (0%)

Searching Neighborhood:
Neighbors to Include: 5 or at least 2 for each angular sector
Searching Ellipse:
Angle: 0
Major Semiaxis: 5833.3
Minor Semiaxis: 5833.3
Angular Sectors: 4

The usefulness of this tool is to be able to infer the accuracy of a map at unsampled locations using randomly selected locations as reference points. In this case, the randomly selected points are the 1207 accuracy assessment points collected for this project. Key to this analysis is the assumption that there exists spatial dependence in the variable to be predicted (Thomas and Jacobs 2000). The following analysis follows that described by Thomas and Jacobs (2000).

The output figure is described in the "Results" section, Figure 13.

"The fuzzy set reference data must be explored and modeled prior to kriging. The spatial autocorrelation of the fuzzy set reference data must be calculated (semivariance) and plotted to understand the extent to which neighboring accuracy ranks influence each other. Positive spatial autocorrelation indicates that similar values are clustered together in space, and is usually evident in geostatistical data, or natural processes (Odland 1988)." (Thomas and Jacobs 2000). The semivariogram and spherical model is shown in Figure 12. The yellow line in the semivariogram represents the model



Geostatistical Wizard: Step 2 of 4 - Semivariogram/Covariance Modeling

Model 1: Spherical

Major Range: 5833.3

☐ Anisotropy

Partial Sill: 0.21393

☑ Nugget: 1.2296

☐ Error Modeling

☑ Shifts

Lag Size: 992.1

Number of Lags: 12

☐ Show Search Direction

Angle Direction: 0.0

Angle Tolerance: 45.0

Bandwidth (lags): 6.0

Semivariogram/Covariances: Var1 & Var1

0.21393*Spherical(5833.3)+1.2296*Nugget

Figure 12. Semivariogram and spherical model for 1207 AA points in ROMO.

RESULTS

Field Data Collection

Field data were collected during the summers of 2002 and 2004. During the summer of 2002, a total of 635 vegetation plots were established in the Park. Of these, 547 were permanent vegetation plots and 85 were observation points. During the summer of 2004, a total of 1219 accuracy assessment points were established. These data were used to develop the classification of the vegetation of ROMO as well as verify the accuracy of the completed map. The accuracy assessment points also served to refine the classification by verifying the presence of additional types that had not been identified during the vegetation plot sampling in 2002. An additional 9 plots and 8 observation points were collected in the fall of 2004 to augment sampling of targeted vegetation types, but were not used in the multi-variate analysis.

Vegetation Classification

The preliminary classification produced in the spring of 2002 prior to any field sampling included 174 -196 vegetation types depending on the probability of occurrence (*probable, possible, or not probable*). These were types existing in the NVC at the time and for which local experts had reasonable certainty would occur in the Park. The analysis of the vegetation plots (and accuracy assessment points) identified some of those types as well as others not on the preliminary list, but failed to identify others that were thought to be *probable* to occur there. Additionally, some of the data collected was sufficient to identify a type only to the Alliance level of classification.

Using the methods described above, the vegetation plot data collected in 2002 were classified into 172 distinct vegetation types based on species composition, structure, and environmental characteristics. Of these, 167 are recognized NVC types, while an additional 5 are “Local” types specific to the Park, but not yet recognized in the NVC. The 172 classified types included 120 of the types that were on the original preliminary list and 47 types that were not. Of the 120 types on the original list, 101 were originally considered *probable*, 11 were considered *possible*, and 8 were originally considered *not probable*. Of the 47 classified types that were not on the preliminary list, 28 were existing NVC Associations, while 19 are new or Local Associations.

Assignment of all the accuracy assessment sampling points to either a classified NVC type, or an “other/unclassified” category identified an additional 35 types (22 Associations, 7 Alliances, and 6 non-vegetated types). These “Other” types have not been included in the classification, because they are based only on AA sample points and were not used to create the classification. With additional sampling and classification work these additional types may represent possible future extensions of the classification, or may be recognized as variants of existing classified types. The list of these other types is included in Appendix L. The Dichotomous Key to the Vegetation Types of ROMO is located in Appendix E. Local and global descriptions for each NVC type can be found in Appendix I.

The vegetation described from Rocky Mountain NP is very diverse and classified types span all of the elevational zones and environmental gradients found in the project area. They range from the foothills zone shrublands and woodlands found on the east side of the park, though the montane and sub-alpine forests of the east and west sides of the divide, to the alpine tundra and cushion plant communities found at the Park's highest elevations. They include upland, wetland, and aquatic communities as well.

Forests and woodlands comprise the greatest number of classified types found within the Park. Together, these two related categories account for 68 of the 172 classified types. The classification presented here includes 48 forest types and 20 woodland types. On an aerial basis, forest and woodland types also occupy the greatest spatial extent of all types described in the project area. Of these, 19 types are dominated by spruce and fir (*Picea engelmannii* and *Abies lasiocarpa*), 13 are dominated by ponderosa pine (*Pinus ponderosa*), 10 types are dominated by lodgepole pine (*Pinus contorta*), 5 are dominated by Douglas fir (*Pseudotsuga menziesii*), 2 of the types are dominated by limber pine (*Pinus flexilis*), and 20 are represented by aspen and cottonwood (*Populus teremuloides, P. balsamifera, and P. angustifolia*). Taken together, these associations represent the largest portion of the Park's vegetation types.

A total of 49 herbaceous community types were classified for the Park. Herbaceous communities include graminoid dominated as well as forb dominated types, and may occur as xeric to mesic foothills types, mesic montane and sub-alpine meadows, on wetter sites dominated by species adapted to saturated and flooded soil conditions, or as alpine tundra. The most diverse group of herbaceous communities is those that occur on wet sites and which are dominated by sedges (*Carex* spp.) and rushes (*Juncus* spp.)

Shrubland types identified in the Park range from xeric foothill communities of bitterbrush (*Purshia tridentata*) and sagebrush (*Artemisia tridentata Nutt.* ssp. *Vaseyana*) to carrs dominated by various species of willow (*Salix* spp.), to sub-alpine and alpine dwarf shrublands dominated by huckleberry (*Vaccinium* spp.) or arctic willow (*Salix arctica*). In total, shrublands account for 49 of the 172 classified types. The most diverse and prevalent group of shrublands are those dominated by species of willows (*Salix* spp.) which total 27 associations.

Photographic database

The photographic dataset collected in documenting the vegetation plots in 2002 and the AA points in 2004 includes a total of 7,979 digital photographs. The photos collected in 2002 at the vegetation plot sites typically include six photos of each plot and total 3,080 different frames. Four were taken on the cardinal directions from the plot center and two additional representative photos were taken with bearings recorded. The photos taken in the 2004 season typically include 4 photos of each plot and total 4,899 different frames. These photos were taken on the cardinal directions only.

The dataset of digital photos has been provided to the Park GIS Manager for integration into a database and map that will allow users to easily query and display the photos.

Table 11. Vegetation classification for ROMO.

NVC ALLIANCE	NVC ASSOCIATION	GLOBAL RANK	STATE RANK*	ASSOCIATION COMMON NAME	ELEMENT CODE	PLOT CODES
Abies lasiocarpa - Picea engelmannii Forest Alliance	Abies lasiocarpa - Picea engelmannii / Acer glabrum Forest	G5	CO, ID:S3, MT, NM:S5, UT:S5, WY:S3	Subalpine Fir - Engelmann Spruce / Rocky Mountain Maple Forest	CEGL000294	ROMO.707, ROMOAA.312
Abies lasiocarpa Seasonally Flooded Forest Alliance	Abies lasiocarpa - Picea engelmannii / Alnus incana Forest	G5	CO:S5	Subalpine Fir - Engelmann Spruce / Speckled Alder Forest	CEGL000296	ROMO.125, ROMO.292, ROMO.604, ROMOAA.739
Abies lasiocarpa Seasonally Flooded Forest Alliance	Abies lasiocarpa - Picea engelmannii / Calamagrostis canadensis Forest	G5	AB, CO:S3, ID:S3, MT:S5, UT:S4?, WA?, WY:S2	Subalpine Fir - Engelmann Spruce / Bluejoint Forest	CEGL000300	ROMO.050, ROMO.120, ROMO.288, ROMO.359, ROMO.732, ROMOAA.1076, ROMOAA.380, ROMOAA.442, ROMOAA.583, ROMOAA.913
Abies lasiocarpa Woodland Alliance	Abies lasiocarpa - Picea engelmannii / Juniperus communis Woodland	G4G5	AZ:S2, CO, ID:S3?, MT:S3, NM?, NV?, OR?, UT:S2?, WA:S3, WY:S2?	Subalpine Fir - Engelmann Spruce / Common Juniper Woodland	CEGL000919	ROMO.397, ROMO.703, ROMOAA.357, ROMOAA.359, ROMOAA.509, ROMOAA.5209, ROMOAA.5216, ROMOAA.5221, ROMOAA.5243, ROMOAA.526, ROMOAA.5265, ROMOAA.5333, ROMOAA.5422, ROMOAA.5750, ROMOAA.5765, ROMOAA.5767, ROMOAA.581, ROMOAA.582, ROMOAA.586, ROMOAA.648, ROMOAA.659, ROMOAA.795, ROMOAA.840, ROMOAA.904, ROMOAA.992
Abies lasiocarpa Temporarily Flooded Forest Alliance	Abies lasiocarpa - Picea engelmannii / Mertensia ciliata Forest	G5	CO:S5, NM:S5, WY?	Subalpine Fir - Engelmann Spruce / Mountain Bluebells Forest	CEGL002663	ROMO.008, ROMO.170, ROMO.711, ROMO.816, ROMOAA.1154
Abies lasiocarpa - Picea engelmannii Forest Alliance	Abies lasiocarpa - Picea engelmannii / Moss Forest	G4	AZ:S2, CO:S2?, NM:S4, WY:S3	Subalpine Fir - Engelmann Spruce / Moss Forest	CEGL000321	ROMO.104, ROMO.118, ROMO.153, ROMO.431, ROMO.526, ROMOAA.1007, ROMOAA.15, ROMOAA.318, ROMOAA.5239, ROMOAA.5282, ROMOAA.5334, ROMOAA.5340, ROMOAA.5359, ROMOAA.5499, ROMOAA.5568, ROMOAA.584, ROMOAA.5901, ROMOAA.5910, ROMOAA.5916, ROMOAA.903, ROMOAA.919, ROMOAA.984

NVC ALLIANCE	NVC ASSOCIATION	GLOBAL RANK	STATE RANK*	ASSOCIATION COMMON NAME	ELEMENT CODE	PLOT CODES
Abies lasiocarpa - Picea engelmannii Forest Alliance	Abies lasiocarpa - Picea engelmannii / Polemonium pulcherrimum Forest	G5	CO:S4, NM:S5	Subalpine Fir - Engelmann Spruce / Beautiful Jacob's-ladder Forest	CEGL000373	ROMO.133, ROMO.702, ROMO.724, ROMOAA.459, ROMOAA.5854
Abies lasiocarpa - Picea engelmannii - Pinus flexilis Krummholz Shrubland Alliance	Abies lasiocarpa - Picea engelmannii / Salix (brachycarpa, glauca) Krummholz Shrubland	GUQ	CO:SU, UT?	Subalpine Fir - Engelmann Spruce / (Short-fruit Willow, Grayleaf Willow) Krummholz Shrubland	CEGL000986	ROMOAA.109, ROMOAA.118, ROMOAA.119, ROMOAA.129, ROMOAA.136, ROMOAA.139, ROMOAA.1128, ROMOAA.1135, ROMOAA.5094, ROMOAA.5106, ROMOAA.539, ROMOAA.5098, ROMOAA.5815, ROMOAA.5817, ROMOAA.5820, ROMOAA.5857
Abies lasiocarpa Seasonally Flooded Forest Alliance	Abies lasiocarpa - Picea engelmannii / Salix drummondiana Forest	G5	CO:S4	Subalpine Fir - Engelmann Spruce / Drummond's Willow Forest	CEGL000327	ROMO.729, ROMO.731, ROMOAA.384, ROMOAA.813, ROMOAA.5177
Abies lasiocarpa - Picea engelmannii Forest Alliance	Abies lasiocarpa - Picea engelmannii / Vaccinium caespitosum Forest	G5	CO:S4, ID:S3, MT:S5, UT:S4S5, WA:S3?	Subalpine Fir - Engelmann Spruce / Dwarf Blueberry Forest	CEGL000340	ROMO.035, ROMO.063, ROMO.193, ROMO.235, ROMO.614, ROMOAA.100, ROMOAA.1160, ROMOAA.135, ROMOAA.5845, ROMOAA.87, ROMOAA.91
Abies lasiocarpa - Picea engelmannii Forest Alliance	Abies lasiocarpa - Picea engelmannii / Vaccinium myrtillus Forest	G5	AZ:S2, CO:S5, NM:S5, UT:S3S4	Subalpine Fir - Engelmann Spruce / Whortleberry Forest	CEGL000343	ROMO.045, ROMO.324, ROMO.415, ROMOAA.1010, ROMOAA.1042, ROMOAA.1051, ROMOAA.1075, ROMOAA.1096, ROMOAA.1107, ROMOAA.1116, ROMOAA.138, ROMOAA.300, ROMOAA.372, ROMOAA.373, ROMOAA.434, ROMOAA.437, ROMOAA.456, ROMOAA.466, ROMOAA.5235, ROMOAA.5247, ROMOAA.5313, ROMOAA.5320, ROMOAA.5322, ROMOAA.5327, ROMOAA.5352, ROMOAA.537, ROMOAA.5462, ROMOAA.5470, ROMOAA.5473, ROMOAA.5487, ROMOAA.5504, ROMOAA.5505, ROMOAA.5510, ROMOAA.5751, ROMOAA.672, ROMOAA.680, ROMOAA.791, ROMOAA.792, ROMOAA.843, ROMOAA.845, ROMOAA.850, ROMOAA.852, ROMOAA.856, ROMOAA.857, ROMOAA.94, ROMOAA.988

NVC ALLIANCE	NVC ASSOCIATION	GLOBAL RANK	STATE RANK*	ASSOCIATION COMMON NAME	ELEMENT CODE	PLOT CODES
Abies lasiocarpa - Picea engelmannii Forest Alliance	Abies lasiocarpa - Picea engelmannii / Vaccinium scoparium Forest	G5	AZ?, CO:S5, ID:S5, MT:S5, NM?, OR:S4, UT:S5, WA:S4, WY:S5	Subalpine Fir - Engelmann Spruce / Grouseberry Forest	CEGL000344	ROMO.005, ROMO.018, ROMO.025, ROMO.027, ROMO.111, ROMO.124, ROMO.126, ROMO.129, ROMO.171, ROMO.225, ROMO.232, ROMO.263, ROMO.309, ROMO.330, ROMO.407, ROMOAA.102, ROMOAA.1038, ROMOAA.1043, ROMOAA.1050, ROMOAA.1052, ROMOAA.1062, ROMOAA.1095, ROMOAA.1108, ROMOAA.1150, ROMOAA.1153, ROMOAA.1159, ROMOAA.126, ROMOAA.133, ROMOAA.285, ROMOAA.286, ROMOAA.289, ROMOAA.462, ROMOAA.463, ROMOAA.499, ROMOAA.5318, ROMOAA.5325, ROMOAA.5328, ROMOAA.5331, ROMOAA.541, ROMOAA.542, ROMOAA.543, ROMOAA.544, ROMOAA.5450, ROMOAA.5451, ROMOAA.5458, ROMOAA.5463, ROMOAA.5468, ROMOAA.5472, ROMOAA.5502, ROMOAA.574, ROMOAA.5822, ROMOAA.5846, ROMOAA.595, ROMOAA.844, ROMOAA.847, ROMOAA.85, ROMOAA.853, ROMOAA.997
Abies lasiocarpa - Picea engelmannii - Pinus flexilis Krummholz Shrubland Alliance	Abies lasiocarpa Krummholz Shrubland	G4	AB, CO, MT:S4, UT?, WY	Subalpine Fir Krummholz Shrubland	CEGL000985	ROMOAA.82, ROMOAA.83, ROMOAA.89, ROMOAA.92, ROMOAA.93, ROMOAA.94, ROMOAA.95, ROMOAA.102, ROMOAA.103, ROMOAA.106, ROMOAA.108, ROMOAA.110, ROMOAA.113, ROMOAA.121, ROMOAA.124, ROMOAA.126, ROMOAA.127, ROMOAA.128, ROMOAA.169, ROMOAA.217, ROMOAA.5818, ROMOAA.5822, ROMOAA.5825, ROMOAA.5829, ROMOAA.5838, ROMOAA.5845, ROMOAA.5847, ROMOAA.5861, ROMOAA.5989,
Acer glabrum Temporarily Flooded Shrubland Alliance	Acer glabrum Drainage Bottom Shrubland	G4?	CO, MT:S4, WY:S3	Rocky Mountain Maple Drainage Bottom Shrubland	CEGL001062	ROMO.188, ROMO.224, ROMOAA.268, ROMOAA.8006
Alnus incana Seasonally Flooded Shrubland Alliance	Alnus incana - Salix (monticola, lucida, ligulifolia) Shrubland	G3	CO:S3, NM:S3?, WY?	Speckled Alder - (Mountain Willow, Whiplash Willow, Strapleaf Willow) Shrubland	CEGL002651	ROMO.084, ROMOAA.859

NVC ALLIANCE	NVC ASSOCIATION	GLOBAL RANK	STATE RANK*	ASSOCIATION COMMON NAME	ELEMENT CODE	PLOT CODES
Alnus incana Temporarily Flooded Shrubland Alliance	Alnus incana - Salix drummondiana Shrubland	G3	CO:S3, NM?, WY	Speckled Alder - Drummond's Willow Shrubland	CEGL002652	ROMO.418
Alnus incana Seasonally Flooded Shrubland Alliance	Alnus incana / Equisetum arvense Shrubland	G3	BC?, CA?, CO:S3, ID:S3, OR:S2, UT:S2S3, WA:S3, WY	Speckled Alder / Field Horsetail Shrubland	CEGL001146	ROMO.064
Alnus incana Temporarily Flooded Shrubland Alliance	Alnus incana / Mesic Graminoids Shrubland	G3	CO:S3, ID, NV, UT:S2S3, WY	Speckled Alder / Mesic Graminoids Shrubland	CEGL001148	ROMO.039, ROMO.119, ROMO.127, ROMO.179, ROMO.223, ROMO.302, ROMO.626, ROMOAA.254, ROMOAA.287, ROMOAA.391, ROMOAA.5077
Aquilegia (caerulea, flavescens) Sparsely Vegetated Alliance	Aquilegia caerulea - Cirsium scopulorum Scree Sparse Vegetation	GU	CO:SU	Colorado Blue Columbine - Alpine Thistle Scree Sparse Vegetation	CEGL001938	ROMO.081, ROMO.169, ROMO.429, ROMOAA.5380
Artemisia arctica Herbaceous Alliance	Artemisia arctica ssp. arctica Herbaceous Vegetation	GU	CO:SU	Boreal Sagebrush Herbaceous Vegetation	CEGL001848	ROMO.391, ROMO.423, ROMO.436, ROMO.709, ROMOAA.767
Artemisia tridentata ssp. vaseyana Shrubland Alliance	Artemisia tridentata ssp. vaseyana - (Purshia tridentata) / Muhlenbergia montana - (Hesperostipa comata ssp. comata) Shrubland	GNR	CO	Mountain Big Sagebrush - (Bitterbrush) / Mountain Muhly - (Needle-and-Thread) Shrubland	CEGL005827	ROMO.107, ROMO.284, ROMO.315, ROMO.341, ROMO.347, ROMO.494, ROMO.632, ROMO.800, ROMO.803, ROMO.813, ROMO.825, ROMO.843, ROMOAA.1068, ROMOAA.1105, ROMOAA.188, ROMOAA.408, ROMOAA.412, ROMOAA.5130, ROMOAA.5142, ROMOAA.5147, ROMOAA.5156, ROMOAA.5157, ROMOAA.5161, ROMOAA.5259, ROMOAA.5791, ROMOAA.716, ROMOAA.718, ROMOAA.726, ROMOAA.814, ROMOAA.816, ROMOAA.817, ROMOAA.818, ROMOAA.819, ROMOAA.821, ROMOAA.822, ROMOAA.824, ROMOAA.825, ROMOAA.944, ROMOAA.953

NVC ALLIANCE	NVC ASSOCIATION	GLOBAL RANK	STATE RANK*	ASSOCIATION COMMON NAME	ELEMENT CODE	PLOT CODES
Betula nana Seasonally Flooded Shrubland Alliance	Betula nana - Salix brachycarpa Shrubland	GNR	CO	Swamp Birch / Short-fruit Willow Shrubland	CEGL005828	ROMO.151, ROMO.427, ROMO.438, ROMO.453, ROMO.476, ROMOAA.1152, ROMOAA.216, ROMOAA.263, ROMOAA.399, ROMOAA.484, ROMOAA.5037, ROMOAA.5089, ROMOAA.5090, ROMOAA.5100
Betula nana Seasonally Flooded Shrubland Alliance	Betula nana / Mesic Forbs - Mesic Graminoids Shrubland	G3G4	CO:S3, WY	Swamp Birch - Mesic Forbs - Mesic Graminoids Shrubland	CEGL002653	ROMO.034, ROMO.155, ROMO.219, ROMO.242, ROMO.310, ROMO.469, ROMO.726, ROMO.741, ROMOAA.1133, ROMOAA.232
Betula occidentalis Seasonally Flooded Shrubland Alliance	Betula occidentalis / Mesic Graminoids Shrubland	G3	CO:S2, NV, UT	Water Birch / Mesic Graminoids Shrubland	CEGL002654	ROMO.074, ROMO.123, ROMO.202, ROMO.486, ROMO.8003, ROMO.8008, ROMO.8010, ROMOAA.420, ROMOAA.5083, ROMOAA.5922, ROMOAA.714, ROMOAA.715, ROMOAA.8009, ROMOAA.8014, ROMOAA.830
Bouteloua gracilis Herbaceous Alliance	Bouteloua gracilis Herbaceous Vegetation	G4Q	AZ, CO, NM?, UT, WY:S4	Blue Grama Herbaceous Vegetation	CEGL001760	ROMO.636, ROMOAA.179, ROMOAA.5134
Bromus inermis Semi-natural Herbaceous Alliance	Bromus inermis - (Pascopyrum smithii) Semi-natural Herbaceous Vegetation	GNA	CO, MT, ND, SD, UT, WY	Smooth Brome - (Western Wheatgrass) Semi-natural Herbaceous Vegetation	CEGL005264	ROMO.061, ROMOAA.159, ROMOAA.174, ROMOAA.195,
Calamagrostis canadensis Seasonally Flooded Herbaceous Alliance	Calamagrostis canadensis Western Herbaceous Vegetation	G4	AB, BC:S3S4, CA, CO:S4, ID:S4, MT:S4, ND, OR:S3S4, SD, UT:S2S3, WA:S3S4, WY:S2	Bluejoint Western Herbaceous Vegetation	CEGL001559	ROMO.049, ROMO.115, ROMO.175, ROMO.267, ROMO.291, ROMO.482, ROMOAA.479, ROMOAA.592, ROMOAA.75
Caltha leptosepala Saturated Herbaceous Alliance	Caltha leptosepala - Rhodiola rhodantha Herbaceous Vegetation	GNRQ	CO:SU	White Marsh-marigold - Queen's Crown Herbaceous Vegetation	CEGL001957	ROMO.231, ROMO.240

NVC ALLIANCE	NVC ASSOCIATION	GLOBAL RANK	STATE RANK*	ASSOCIATION COMMON NAME	ELEMENT CODE	PLOT CODES
Caltha leptosepala Saturated Herbaceous Alliance	Caltha leptosepala Herbaceous Vegetation	G4	CO:S4, ID:S4, MT, UT:S2S3, WY	White Marsh-marigold Herbaceous Vegetation	CEGL001954	ROMO.011, ROMO.037, ROMO.323, ROMO.332, ROMO.433, ROMO.481
Cardamine cordifolia Saturated Herbaceous Alliance	Cardamine cordifolia - Mertensia ciliata - Senecio triangularis Herbaceous Vegetation	G4	CO:S4	Large Mountain Bittercress - Mountain Bluebells - Arrowleaf Ragwort Herbaceous Vegetation	CEGL002662	ROMO.002, ROMO.233, ROMO.237, ROMO.241, ROMO.247, ROMO.252, ROMO.255, ROMO.366, ROMO.399, ROMO.463, ROMO.725, ROMOAA.1136, ROMOAA.5885, ROMOAA.777
Carex aquatilis Seasonally Flooded Herbaceous Alliance	Carex aquatilis - Carex utriculata Herbaceous Vegetation	G4	AB, CO:S4, MT:S3, NB?, WY?	Aquatic Sedge - Beaked Sedge Herbaceous Vegetation	CEGL001803	ROMO.038, ROMO.114, ROMOAA.230
Carex aquatilis Seasonally Flooded Herbaceous Alliance	Carex aquatilis Herbaceous Vegetation	G5	AB, AZ?, CA:S3, CO:S4, ID:S4, MT:S4, NM:S4, NV, OR:S4, UT:S3?, WA:S3, WY:S3	Aquatic Sedge Herbaceous Vegetation	CEGL001802	ROMO.003, ROMO.113, ROMO.147, ROMO.154, ROMO.215, ROMO.226, ROMO.251, ROMO.254, ROMO.265, ROMO.333, ROMO.381, ROMO.419, ROMO.430, ROMO.457, ROMOAA.228, ROMOAA.233, ROMOAA.251, ROMOAA.5930, ROMOAA.607, ROMOAA.645, ROMOAA.69, ROMOAA.80
Carex elynoides Herbaceous Alliance	Carex elynoides - Geum rossii Herbaceous Vegetation	G4	CO, MT:S4	Blackroot Sedge - Ross' Avens Herbaceous Vegetation	CEGL001853	ROMO.456, ROMO.459, ROMOAA.475, ROMOAA.5371, ROMOAA.5379, ROMOAA.5970, ROMOAA.6010
Carex (lachenalii, capillaris, illota) Seasonally Flooded Herbaceous Alliance	Carex illota Herbaceous Vegetation	GUQ	CO:SU, OR:S3, WY	Small-head Sedge Herbaceous Vegetation	CEGL001876	ROMO.141, ROMO.172, ROMO.270, ROMO.480, ROMOAA.1058, ROMOAA.5928, ROMOAA.5951

NVC ALLIANCE	NVC ASSOCIATION	GLOBAL RANK	STATE RANK*	ASSOCIATION COMMON NAME	ELEMENT CODE	PLOT CODES
Carex limosa Seasonally Flooded Herbaceous Alliance	Carex limosa Herbaceous Vegetation	G2	BC?, CA:S1, CO, ID:S1, MT:S2, NM, UT:S1S2, WA:S2?, WY:S2?	Mud Sedge Herbaceous Vegetation	CEGL001811	ROMO.824
Carex microptera Seasonally Flooded Herbaceous Alliance	Carex microptera Herbaceous Vegetation	G4	CO:S2?, ID?, OR?, UT:S2S3, WY:S3	Small-wing Sedge Herbaceous Vegetation	CEGL001792	ROMO.8018
Carex pyrenaica Herbaceous Alliance	Carex pyrenaica Herbaceous Vegetation	GU	CO:SU	Pyrenean Sedge Herbaceous Vegetation	CEGL001860	ROMO.007, ROMO.340, ROMO.390, ROMO.466, ROMO.474, ROMO.600
Carex rupestris Herbaceous Alliance	Carex rupestris - Geum rossii Herbaceous Vegetation	G4	CO:S4, UT, WY:S2	Curly Sedge - Ross' Avens Herbaceous Vegetation	CEGL001861	ROMO.010, ROMO.030, ROMO.132, ROMO.137, ROMO.339, ROMO.355, ROMOAA111, ROMOAA.1047, ROMOAA.471, ROMOAA.5045, ROMOAA.550, ROMOAA.5600, ROMOAA.5602, ROMOAA.5620, ROMOAA.5982, ROMOAA.5997, ROMOAA.771, ROMOAA.979
Carex rupestris Herbaceous Alliance	Carex rupestris - Trifolium dasyphyllum Herbaceous Vegetation	G3G4	CO:S3S4, UT?	Curly Sedge - Uinta Clover Herbaceous Vegetation	CEGL001863	ROMO.165, ROMO.352, ROMO.385, ROMO.387, ROMO.439, ROMO.472, ROMOAA.224, ROMOAA.5028, ROMOAA.5615, ROMOAA.5976
Carex scopulorum Seasonally Flooded Herbaceous Alliance	Carex scopulorum - Caltha leptosepala Herbaceous Vegetation	G4	CO:S4, MT:S3, WY:S2?	Holm's Rocky Mountain Sedge - White Marsh-marigold Herbaceous Vegetation	CEGL001823	ROMO.052, ROMO.298, ROMO.468, ROMO.478, ROMO.612, ROMOAA.1139, ROMOAA.1144, ROMOAA.225, ROMOAA.236, ROMOAA.247, ROMOAA.772
Carex siccata Herbaceous Alliance	Carex siccata - Geum rossii Herbaceous Vegetation	GU	CO:SU	Dry-spike Sedge - Ross' Avens Herbaceous Vegetation	CEGL001808	ROMO.458, ROMO.490, ROMOAA.155

NVC ALLIANCE	NVC ASSOCIATION	GLOBAL RANK	STATE RANK*	ASSOCIATION COMMON NAME	ELEMENT CODE	PLOT CODES
Carex (rostrata, utriculata) Seasonally Flooded Herbaceous Alliance	Carex utriculata Herbaceous Vegetation	G5	AB, AZ?, CA:S4, CO:S4, ID:S4, MT:S5, NM:S3, NV, OR:S4, UT:S3S4, WA:S3S4, WY:S3	Beaked Sedge Herbaceous Vegetation	CEGL001562	ROMO.131, ROMO.152, ROMO.218, ROMO.229, ROMO.342, ROMO.367, ROMOAA.227, ROMOAA.270, ROMOAA.414, ROMOAA.63, ROMOAA.64, ROMOAA.67, ROMOAA.78
Cercocarpus montanus Shrubland Alliance	Cercocarpus montanus / Hesperostipa comata Shrubland	G2	CO:S2	Mountain-mahogany / Needle-and-Thread Shrubland	CEGL001092	ROMOAA.558, ROMOAA.5652, ROMOAA.657
Cercocarpus montanus Shrubland Alliance	Cercocarpus montanus / Muhlenbergia montana Shrubland	GU	CO:S2	Mountain-mahogany / Mountain Muhly Shrubland	CEGL002914	ROMO.8007, ROMO.8017, ROMOAA.1161, ROMOAA.614, ROMOAA.655, ROMOAA.656
Danthonia intermedia Herbaceous Alliance	Danthonia intermedia Herbaceous Vegetation	G2G3	CO, UT:S2S3, WA:S2?	Timber Oatgrass Herbaceous Vegetation	CEGL001794	ROMO.046, ROMO.070, ROMO.173, ROMO.176, ROMO.278, ROMO.283, ROMO.491, ROMOAA.158, ROMOAA.5835, ROMOAA.5926, ROMOAA.869
Danthonia parryi Herbaceous Alliance	Danthonia parryi Herbaceous Vegetation	G3	CO:S3, WY:S2	Parry's Oatgrass Herbaceous Vegetation	CEGL001795	ROMO.489, ROMO.720
Dasiphora fruticosa Temporarily Flooded Shrubland Alliance	Dasiphora fruticosa ssp. floribunda / Deschampsia caespitosa Shrubland	G4	CO:S3S4, ID:S3, MT:S4, OR:S2, UT:S3S4, WY:S3	Shrubby-cinquefoil / Tufted Hairgrass Shrubland	CEGL001107	ROMO.157, ROMO.194, ROMO.277, ROMO.740, ROMO.806, ROMOAA.411
Dasiphora fruticosa Temporarily Flooded Shrubland Alliance	Dasiphora fruticosa ssp. floribunda Shrubland [Provisional]	G5?	CO, NV:S5	Shrubby-cinquefoil Shrubland	CEGL001105	ROMO.117, ROMO.268, ROMO.814, ROMOAA.409, ROMOAA.410, ROMOAA.413, ROMOAA.621, ROMOAA.622, ROMOAA.713, ROMOAA.823
Dasiphora fruticosa Temporarily Flooded Shrubland Alliance	Dasiphora fruticosa ssp. floribunda Subalpine Shrubland	GNR	CO, NM	Shrubby-cinquefoil Subalpine Shrubland	CEGL003499	ROMO.353, ROMO.452, ROMO.831,

NVC ALLIANCE	NVC ASSOCIATION	GLOBAL RANK	STATE RANK*	ASSOCIATION COMMON NAME	ELEMENT CODE	PLOT CODES
Deschampsia caespitosa Saturated Herbaceous Alliance	Deschampsia caespitosa - Caltha leptosepala Herbaceous Vegetation	G4	CO:S4, ID:S2, MT:S3, WY	Tufted Hairgrass - White Marsh-marigold Herbaceous Vegetation	CEGL001882	ROMO.140, ROMO.264, ROMO.272, ROMO.475, ROMOAA.1056, ROMOAA.1057, ROMOAA.1060, ROMOAA.476, ROMOAA.5950
Deschampsia caespitosa Temporarily Flooded Herbaceous Alliance	Deschampsia caespitosa - Geum rossii Herbaceous Vegetation	G5	CO:S5, WY:S3?	Tufted Hairgrass - Ross' Avens Herbaceous Vegetation	CEGL001884	ROMO.023, ROMO.083, ROMO.144, ROMO.248, ROMO.250, ROMO.331, ROMO.358, ROMO.444, ROMOAA.1131, ROMOAA.221, ROMOAA.237, ROMOAA.468, ROMOAA.5012, ROMOAA.547, ROMOAA.5603, ROMOAA.5609, ROMOAA.5984, ROMOAA.6000, ROMOAA.651, ROMOAA.660
Deschampsia caespitosa Seasonally Flooded Herbaceous Alliance	Deschampsia caespitosa Herbaceous Vegetation	G4	AB, AZ:S2?, CA?, CO:S4, ID:S3, MT:S4, NM, NV?, OR:S2, UT:S3S4, WA, WY	Tufted Hairgrass Herbaceous Vegetation	CEGL001599	ROMO.006, ROMO.036, ROMO.055, ROMO.139, ROMO.180, ROMO.190, ROMO.245, ROMO.253, ROMO.349, ROMO.377, ROMO.378, ROMO.447, ROMO.451, ROMO.713, ROMOAA.1049, ROMOAA.1059, ROMOAA.1122, ROMOAA.1134, ROMOAA.1146, ROMOAA.144, ROMOAA.478, ROMOAA.5026, ROMOAA.5035, ROMOAA.591, ROMOAA.594, ROMOAA.5944, ROMOAA.5946, ROMOAA.5964, ROMOAA.5968, ROMOAA.712, ROMOAA.742, ROMOAA.766, ROMOAA.781, ROMOAA.809, ROMOAA.86, ROMOAA.960
Dryas octopetala Dwarf-shrub Herbaceous Alliance	Dryas octopetala - Carex rupestris Dwarf-shrub Herbaceous Vegetation	G4	AB, CO:S4?, ID?, MT:S3	Eight-petal Mountain-avens - Curly Sedge Dwarf-shrub Herbaceous Vegetation	CEGL001892	ROMO.150, ROMO.238, ROMO.246, ROMO.336, ROMO.356, ROMO.428, ROMO.441, ROMO.449, ROMO.506, ROMOAA.1083, ROMOAA.5013, ROMOAA.5605, ROMOAA.5963, ROMOAA.5978
Eleocharis (quinqueflora, rostellata) Saturated Herbaceous Alliance	Eleocharis quinqueflora Herbaceous Vegetation	G4	CA, CO:S3S4, ID:S1, MT:S3, NV?, OR:S4, UT:S2?, WA:S2?, WY:S2	Few-flower Spikerush Herbaceous Vegetation	CEGL001836	ROMO.004, ROMO.020, ROMO.021, ROMO.024, ROMO.048, ROMO.056, ROMO.072, ROMO.156, ROMO.163, ROMO.227, ROMO.234, ROMO.296, ROMO.343, ROMO.375, ROMO.414, ROMO.421, ROMO.479, ROMO.493, ROMOAA.226, ROMOAA.231, ROMOAA.5949
na	Elymus trachycaulus Alliance [Placeholder]	na	CO	Slender Wild Rye Alliance [Placeholder]	Local Type	ROMO.809

NVC ALLIANCE	NVC ASSOCIATION	GLOBAL RANK	STATE RANK*	ASSOCIATION COMMON NAME	ELEMENT CODE	PLOT CODES
Festuca brachyphylla Herbaceous Alliance	Festuca brachyphylla - Geum rossii var. turbinatum Herbaceous Vegetation	GUQ	CO, NM:SU	Shortleaf Fescue - Ross' Avens Herbaceous Vegetation	CEGL001895	ROMO.426, ROMOAA.775
Festuca thurberi Herbaceous Alliance	Festuca thurberi Subalpine Grassland Herbaceous Vegetation	G3	CO, NM:S3	Thurber's Fescue Subalpine Grassland Herbaceous Vegetation	CEGL001631	ROMO.635, ROMO.832
Geum rossii Herbaceous Alliance	Geum rossii - Minuartia obtusiloba Herbaceous Vegetation	G3?	CO, MT:S3	Ross' Avens - Alpine Stitchwort Herbaceous Vegetation	CEGL001965	ROMO.149, ROMO.443, ROMO.504, ROMOAA.206, ROMOAA.215, ROMOAA.5007, ROMOAA.5623, ROMOAA.5990
Geum rossii Herbaceous Alliance	Geum rossii - Polygonum bistortoides Herbaceous Vegetation	G4G5	CO:S4S5, WY	Ross' Avens - American Bistort Herbaceous Vegetation	CEGL001967	ROMO.715, ROMOAA.210, ROMOAA.5029, ROMOAA.708
Geum rossii Herbaceous Alliance	Geum rossii - Sibbaldia procumbens Herbaceous Vegetation	GU	CO:SU	Ross' Avens - Creeping Glow-wort Herbaceous Vegetation	CEGL001969	ROMO.012, ROMO.192, ROMO.392, ROMO.467, ROMO.701, ROMOAA.166, ROMOAA.208, ROMOAA.241, ROMOAA.773
Geum rossii Herbaceous Alliance	Geum rossii - Trifolium spp. Herbaceous Vegetation	G3	CO, WY:S3	Ross' Avens - Clover species Herbaceous Vegetation	CEGL001970	ROMO.009, ROMO.082, ROMO.085, ROMO.189, ROMO.345, ROMO.379, ROMO.384, ROMO.465, ROMO.477, ROMO.492, ROMOAA.220, ROMOAA.5047, ROMOAA.5387, ROMOAA.5613, ROMOAA.5626, ROMOAA.707, ROMOAA.776
Glyceria (grandis, striata) Seasonally Flooded Herbaceous Alliance	Glyceria grandis Herbaceous Vegetation	G2?	CO, ID:S1?, MT, OR:S1S2, WA:S1S2	American Mannagrass Herbaceous Vegetation	CEGL003429	ROMO.637, ROMOAA.79

NVC ALLIANCE	NVC ASSOCIATION	GLOBAL RANK	STATE RANK*	ASSOCIATION COMMON NAME	ELEMENT CODE	PLOT CODES
Juncus balticus Seasonally Flooded Herbaceous Alliance	Juncus balticus Herbaceous Vegetation	G5	BC:S3, CA?, CO:S5, ID:S5, MT:S5, NE, NM:S4, NV, OR:S5, SD, UT:S3S4, WA:S3S4, WY:S3	Baltic Rush Herbaceous Vegetation	CEGL001838	ROMO.100, ROMO.121, ROMO.222, ROMO.314, ROMO.338, ROMO.807, ROMOAA.5067, ROMOAA.578, ROMOAA.5942, ROMOAA.710, ROMOAA.711
Juncus drummondii Herbaceous Alliance	Juncus drummondii - Carex spp. Herbaceous Vegetation	G4	CO:SU, ID:S4	Drummond's Rush - Sedge species Herbaceous Vegetation	CEGL001905	ROMO.043, ROMO.257, ROMO.484, ROMO.601, ROMO.823, ROMOAA.5617, ROMOAA.769, ROMOAA.770
Juncus parryi Herbaceous Alliance	Juncus parryi / Sibbaldia procumbens Herbaceous Vegetation	G3G4	AB, CO, MT:S3?, WY	Parry's Rush / Creeping Glow-wort Herbaceous Vegetation	CEGL005871	ROMO.068, ROMO.164, ROMO.177, ROMO.191, ROMO.294, ROMO.299
Juniperus scopulorum Woodland Alliance	Juniperus scopulorum / Purshia tridentata Woodland	G2	CO:S2, WY?	Rocky Mountain Juniper / Bitterbrush Woodland	CEGL000749	ROMO.402, ROMO.623, ROMO.628, ROMO.631, ROMO.828, ROMOAA.326, ROMOAA.328, ROMOAA.520, ROMOAA.5201, ROMOAA.5638, ROMOAA.5640, ROMOAA.5645, ROMOAA.5647, ROMOAA.5651, ROMOAA.930, ROMOAA.936, ROMOAA.973
Kobresia myosuroides Herbaceous Alliance	Kobresia myosuroides - Carex rupestris var. drummondiana Herbaceous Vegetation	G3	CO:S3	Pacific Bog Sedge - Drummond's Curly Sedge Herbaceous Vegetation	CEGL001907	ROMO.344, ROMO.442, ROMOAA.5004
Kobresia myosuroides Herbaceous Alliance	Kobresia myosuroides - Geum rossii Herbaceous Vegetation	G5	CO:S5, NM:S4, UT:S4S5	Pacific Bog Sedge - Ross' Avens Herbaceous Vegetation	CEGL001908	ROMO.166, ROMO.450, ROMO.460, ROMO.505, ROMOAA.218, ROMOAA.222, ROMOAA.223, ROMOAA.242, ROMOAA.546, ROMOAA.5612
Muhlenbergia montana Herbaceous Alliance	Muhlenbergia montana - Hesperostipa comata Herbaceous Vegetation	G1G2	CO:S2?	Mountain Muhly - Needle-and-Thread Herbaceous Vegetation	CEGL001647	ROMO.487, ROMO.804, ROMO.808, ROMO.834, ROMO.839, ROMOAA.176, ROMOAA.5783, ROMOAA.5785, ROMOAA.719

NVC ALLIANCE	NVC ASSOCIATION	GLOBAL RANK	STATE RANK*	ASSOCIATION COMMON NAME	ELEMENT CODE	PLOT CODES
Muhlenbergia montana Herbaceous Alliance	Muhlenbergia montana Herbaceous Vegetation	G3G4	AZ, CO:S2?, UT:S3S4	Mountain Muhly Herbaceous Vegetation	CEGL001646	ROMO.041, ROMO.835, ROMOAA.178, ROMOAA.5132, ROMOAA.5784, ROMOAA.5800, ROMOAA.674, ROMOAA.731
Nymphaea odorata - Nuphar spp. Permanently Flooded Temperate Herbaceous Alliance	Nuphar lutea ssp. polysepala Herbaceous Vegetation	G5	BC:S5, CA, CO:S3, ID:S4, MT, OR:S5, WA:S4S5	Yellow Pond-lily Herbaceous Vegetation	CEGL002001	ROMO.102, ROMO.322, ROMO.416, ROMO.728, ROMOAA.76
Paronychia pulvinata Dwarf-shrubland Alliance	Paronychia pulvinata - Silene acaulis Dwarf-shrubland	G5	AZ, CO:S5, NM?, UT:S4S5, WY	Rocky Mountain Nailwort - Cushion Pink Dwarf-shrubland	CEGL001976	ROMO.357, ROMO.613, ROMO.716, ROMO.721, ROMOAA.145
Picea engelmannii Saturated Forest Alliance	Picea engelmannii / Calamagrostis canadensis Forest	G4	CO, ID:S4, MT:S4, WY:S3	Engelmann Spruce / Bluejoint Forest	CEGL002678	ROMO.346, ROMO.605, ROMO.607ROMOAA.1074, ROMOAA.5269, ROMOAA.950
Picea engelmannii Seasonally Flooded Forest Alliance	Picea engelmannii / Equisetum arvense Forest	G4	AB, CO:S2, ID:S2, MT:S4, OR:S3, UT:S3?, WA:S3, WY:S2	Engelmann Spruce / Field Horsetail Forest	CEGL005927	ROMO.216, ROMO.325, ROMOAA.448
Picea engelmannii Forest Alliance	Picea engelmannii / Moss Forest	G4	AZ:S1, CO:SU, NM:S4	Engelmann Spruce / Moss Forest	CEGL000371	ROMO.182, ROMO.266, ROMO.326, ROMOAA.849
Picea engelmannii Forest Alliance	Picea engelmannii / Trifolium dasyphyllum Forest	G2?	CO:S2	Engelmann Spruce / Uinta Clover Forest	CEGL000377	ROMO.199, ROMOAA.82, ROMOAA.92, ROMOAA.5844
Picea engelmannii Forest Alliance	Picea engelmannii / Vaccinium myrtillus Forest	G4Q	CO, NM:S4	Engelmann Spruce / Whortleberry Forest	CEGL000379	ROMO.207, ROMO.370, ROMOAA.255, ROMOAA.288, ROMOAA.316, ROMOAA.5326, ROMOAA.5482, ROMOAA.5484, ROMOAA.5491

NVC ALLIANCE	NVC ASSOCIATION	GLOBAL RANK	STATE RANK*	ASSOCIATION COMMON NAME	ELEMENT CODE	PLOT CODES
Picea engelmannii Forest Alliance	Picea engelmannii / Vaccinium scoparium Forest	G3G5	CO, MT?, NM, OR:SU, UT:S4S5, WY:S3	Engelmann Spruce / Grouseberry Forest	CEGL000381	ROMO.815, ROMOAA.1151, ROMOAA.302, ROMOAA.5321, ROMOAA.5323, ROMOAA.5344, ROMOAA.5466, ROMOAA.5475, ROMOAA.5506, ROMOAA.5578, ROMOAA.573, ROMOAA.81, ROMOAA.810, ROMOAA.98
Picea pungens Temporarily Flooded Woodland Alliance	Picea pungens / Alnus incana Woodland	G3	CO:S3, NM?, WY	Blue Spruce / Speckled Alder Woodland	CEGL000894	ROMO.184, ROMO.827, ROMOAA.5913, ROMOAA.5921, ROMOAA.735, ROMOAA.925
Pinus contorta Forest Alliance	Pinus contorta / Arctostaphylos uva-ursi Forest	G5	CO, MT?, OR:S4, UT:S4S5, WA:S4?, WY:S3	Lodgepole Pine / Kinikinnick Forest	CEGL000134	ROMO.174, ROMO.311, ROMO.313, ROMO.818, ROMOAA.1102, ROMOAA.306, ROMOAA.343, ROMOAA.35, ROMOAA.421, ROMOAA.511, ROMOAA.5248, ROMOAA.525, ROMOAA.5262, ROMOAA.5419, ROMOAA.5516, ROMOAA.5554, ROMOAA.658, ROMOAA.875
Pinus contorta Forest Alliance	Pinus contorta / Carex geyeri Forest	G4?	CO:S4, ID:S4, MT?, OR?, WY:S3S4	Lodgepole Pine / Geyer's Sedge Forest	CEGL000141	ROMO.134, ROMO.327, ROMOAA.388, ROMOAA.439
Pinus contorta Forest Alliance	Pinus contorta / Carex rossii Forest	G5	CO, ID, MT?, UT:S4?, WY:S5	Lodgepole Pine / Ross' Sedge Forest	CEGL000144	ROMO.8001, ROMO.812
Pinus contorta Forest Alliance	Pinus contorta / Jamesia americana Forest	GNR	CO	Lodgepole Pine / Waxflower Forest	CEGL005933	ROMO.060, ROMO.210, ROMO.512, ROMO.517, ROMO.743, ROMOAA.291, ROMOAA.5256, ROMOAA.5399, ROMOAA.5541, ROMOAA.5567, ROMOAA.650, ROMOAA.879, ROMOAA.883

NVC ALLIANCE	NVC ASSOCIATION	GLOBAL RANK	STATE RANK*	ASSOCIATION COMMON NAME	ELEMENT CODE	PLOT CODES
Pinus contorta Woodland Alliance	Pinus contorta / Juniperus communis Woodland	G5	CO:S3, ID:S3, MT:S3, NV?, UT:S4?, WY:S3	Lodgepole Pine / Common Juniper Woodland	CEGL000764	ROMO.106, ROMO.204, ROMO.306, ROMOAA.1004, ROMOAA.1026, ROMOAA.1034, ROMOAA.1070, ROMOAA.1086, ROMOAA.1091, ROMOAA.192, ROMOAA.308, ROMOAA.310, ROMOAA.315, ROMOAA.332, ROMOAA.338, ROMOAA.387, ROMOAA.389, ROMOAA.424, ROMOAA.494, ROMOAA.495, ROMOAA.497, ROMOAA.500, ROMOAA.517, ROMOAA.5213, ROMOAA.5233, ROMOAA.5275, ROMOAA.5306, ROMOAA.5418, ROMOAA.5447, ROMOAA.5517, ROMOAA.5544, ROMOAA.5563, ROMOAA.5564, ROMOAA.5574, ROMOAA.5768, ROMOAA.59, ROMOAA.695, ROMOAA.782, ROMOAA.788, ROMOAA.826, ROMOAA.899, ROMOAA.902, ROMOAA.929, ROMOAA.993
Pinus contorta Woodland Alliance	Pinus contorta / Rock Woodland	GNR	CO	Lodgepole Pine / Rock Woodland	CEGL005934	ROMO.128, ROMO.183, ROMO.289, ROMOAA.1001, ROMOAA.1002, ROMOAA.1013, ROMOAA.1033, ROMOAA.1039, ROMOAA.1066, ROMOAA.13, ROMOAA.313, ROMOAA.319, ROMOAA.356, ROMOAA.36, ROMOAA.5224, ROMOAA.524, ROMOAA.5403, ROMOAA.5410, ROMOAA.563, ROMOAA.585, ROMOAA.611, ROMOAA.793, ROMOAA.797, ROMOAA.8, ROMOAA.876, ROMOAA.882, ROMOAA.9, ROMOAA.946
Pinus contorta Forest Alliance	Pinus contorta / Shepherdia canadensis Forest	G3G4	CO:S3S4, ID, MT?, WA:S3?, WY:S3S4	Lodgepole Pine / Russet Buffaloberry Forest	CEGL000163	ROMO.105, ROMO.130, ROMO.348, ROMOAA.311, ROMOAA.789
Pinus contorta Forest Alliance	Pinus contorta / Vaccinium caespitosum Forest	G5	AB, CO, ID:S4?, MT:S5, OR:S3, UT	Lodgepole Pine / Dwarf Blueberry Forest	CEGL000168	ROMO.158, ROMO.196, ROMO.276, ROMOAA.608

NVC ALLIANCE	NVC ASSOCIATION	GLOBAL RANK	STATE RANK*	ASSOCIATION COMMON NAME	ELEMENT CODE	PLOT CODES
Pinus contorta Forest Alliance	Pinus contorta / Vaccinium myrtillus Forest	GNR	CO	Lodgepole Pine / Whortleberry Forest	CEGL005935	ROMO.109, ROMO.205, ROMO.411, ROMO.417, ROMOAA.1064, ROMOAA.1078, ROMOAA.1090, ROMOAA.1094, ROMOAA.1157, ROMOAA.299, ROMOAA.5485, ROMOAA.5534, ROMOAA.5537, ROMOAA.5588, ROMOAA.5594, ROMOAA.796, ROMOAA.798, ROMOAA.966
Pinus contorta Forest Alliance	Pinus contorta / Vaccinium scoparium Forest	G5	CA?, CO:S4, ID:S5, MT:S5, OR:S3, UT:S4S5, WA:S4, WY:S5	Lodgepole Pine / Grouseberry Forest	CEGL000172	ROMO.304, ROMO.305, ROMO.308, ROMOAA.1063, ROMOAA.298, ROMOAA.303, ROMOAA.309, ROMOAA.457, ROMOAA.5461, ROMOAA.5486, ROMOAA.5524, ROMOAA.5535, ROMOAA.600, ROMOAA.703, ROMOAA.848, ROMOAA.918
Pinus flexilis Woodland Alliance	Pinus flexilis / Arctostaphylos uva-ursi Woodland	G4	AB, CO:S2?, MT, NM:S4	Limber Pine / Kinikinnick Woodland	CEGL000802	ROMO.318, ROMO.371, ROMOAA.5253
Pinus flexilis Woodland Alliance	Pinus flexilis / Juniperus communis Woodland	G5	CA?, CO:S3, ID:S3, MT:S4, NV?, OR:S1, UT, WY:S2?	Limber Pine / Common Juniper Woodland	CEGL000807	ROMO.103, ROMO.236, ROMO.303, ROMO.317, ROMO.369, ROMO.507, ROMO.518, ROMO.527, ROMO.617, ROMOAA.11, ROMOAA.342, ROMOAA.358, ROMOAA.465, ROMOAA.508, ROMOAA.540, ROMOAA.5430, ROMOAA.5448, ROMOAA.5460, ROMOAA.5762, ROMOAA.5764, ROMOAA.5770, ROMOAA.5776, ROMOAA.5777, ROMOAA.662, ROMOAA.678, ROMOAA.753, ROMOAA.807
na	Pinus flexilis Krummholz Shrubland	na	CO	Limber Pine Krummholz Shrubland	Local Type	ROMOAA.355, ROMOAA.394, ROMOAA.5851, ROMOAA.5852, ROMOAA.5859
Pinus ponderosa Woodland Alliance	Pinus ponderosa / Arctostaphylos uva-ursi Woodland	G4	CO:S3, MT:S3, NM:S4, SD:S4, UT?, WY:S3	Ponderosa Pine / Kinikinnick Woodland	CEGL000844	ROMO.372, ROMO.412, ROMO.616, ROMO.706, ROMOAA.1071, ROMOAA.204, ROMOAA.345, ROMOAA.368, ROMOAA.453, ROMOAA.5182, ROMOAA.52, ROMOAA.53, ROMOAA.5406, ROMOAA.5437, ROMOAA.5635, ROMOAA.5675, ROMOAA.5677, ROMOAA.5700, ROMOAA.5711, ROMOAA.5714, ROMOAA.641, ROMOAA.701, ROMOAA.803, ROMOAA.890, ROMOAA.975

NVC ALLIANCE	NVC ASSOCIATION	GLOBAL RANK	STATE RANK*	ASSOCIATION COMMON NAME	ELEMENT CODE	PLOT CODES
Pinus ponderosa Woodland Alliance	Pinus ponderosa / Artemisia tridentata ssp. vaseyana Woodland	GNR	CO, UT	Ponderosa Pine / Mountain Big Sagebrush Woodland	CEGL002794	ROMO.186, ROMO.488, ROMOAA.269, ROMOAA.350, ROMOAA.353, ROMOAA.948
Pinus ponderosa Woodland Alliance	Pinus ponderosa / Carex geyeri Woodland	G3G4	CO:S2S3, MT?, OR:S2, UT:S4?, WY:S3	Ponderosa Pine / Geyer's Sedge Woodland	CEGL000182	ROMO.290, ROMO.837, ROMOAA.5205, ROMOAA.5660
Pinus ponderosa Woodland Alliance	Pinus ponderosa / Carex inops ssp. heliophila Woodland	G3G4	CO:S2, MT:S3S4, SD, WY:S2S3	Ponderosa Pine / Sun Sedge Woodland	CEGL000849	ROMOAA.390, ROMOAA.43, ROMOAA.5688, ROMOAA.928
Pinus ponderosa Forest Alliance	Pinus ponderosa / Carex rossii Forest	G4G5	CO:S3S4, SD, WY:S3	Ponderosa Pine / Ross' Sedge Forest	CEGL000183	ROMO.373, ROMO.801, ROMO.805, ROMOAA.1036, ROMOAA.5739, ROMOAA.737
Pinus ponderosa Woodland Alliance	Pinus ponderosa / Cercocarpus montanus Woodland	G4	CO:S4, NM?, WY?	Ponderosa Pine / Mountain-mahogany Woodland	CEGL000851	ROMO.8016
Pinus ponderosa Woodland Alliance	Pinus ponderosa / Juniperus communis Woodland	G4?	CO, MT:S3, SD:S4, WY:S3?	Ponderosa Pine / Common Juniper Woodland	CEGL000859	ROMOAA.1085, ROMOAA.1120, ROMOAA.17, ROMOAA.175, ROMOAA.294, ROMOAA.337, ROMOAA.440, ROMOAA.5241, ROMOAA.5258, ROMOAA.5303, ROMOAA.5401, ROMOAA.5411, ROMOAA.5412, ROMOAA.5428, ROMOAA.5440, ROMOAA.5561, ROMOAA.5712, ROMOAA.6, ROMOAA.666, ROMOAA.736, ROMOAA.746, ROMOAA.786, ROMOAA.832, ROMOAA.892
Pinus ponderosa Woodland Alliance	Pinus ponderosa / Leucopoa kingii Woodland	G3	CO:S3, WY:SU	Ponderosa Pine / Spike Fescue Woodland	CEGL000186	ROMO.845, ROMOAA.5436, ROMOAA.5666, ROMOAA.5678, ROMOAA.633, ROMOAA.638

NVC ALLIANCE	NVC ASSOCIATION	GLOBAL RANK	STATE RANK*	ASSOCIATION COMMON NAME	ELEMENT CODE	PLOT CODES
Pinus ponderosa Woodland Alliance	Pinus ponderosa / Muhlenbergia montana Woodland	G4G5	AZ:S4, CO:S2S3, NM:S4, TX, UT:S4S5	Ponderosa Pine / Mountain Muhly Woodland	CEGL000862	ROMO.300, ROMO.510, ROMO.521, ROMOAA.1077, ROMOAA.1118, ROMOAA.1121, ROMOAA.344, ROMOAA.352, ROMOAA.382, ROMOAA.39, ROMOAA.504, ROMOAA.507, ROMOAA.5187, ROMOAA.5190, ROMOAA.5416, ROMOAA.559, ROMOAA.5649, ROMOAA.5685, ROMOAA.5718, ROMOAA.5728, ROMOAA.5731, ROMOAA.5787, ROMOAA.5807, ROMOAA.675, ROMOAA.748, ROMOAA.871, ROMOAA.889
Pinus ponderosa Forest Alliance	Pinus ponderosa / Physocarpus monogynus Forest	G3	CO, SD:S4, WY:S2?	Ponderosa Pine / Mountain Ninebark Forest	CEGL000190	ROMO.413, ROMO.523, ROMOAA.5661
Pinus ponderosa Woodland Alliance	Pinus ponderosa / Purshia tridentata Woodland	G3G5	CA:S2, CO:S3?, ID:S3, MT:S3, UT:S5	Ponderosa Pine / Bitterbrush Woodland	CEGL000867	ROMO.042, ROMO.075, ROMO.209, ROMO.401, ROMOAA.1109, ROMOAA.2, ROMOAA.320, ROMOAA.321, ROMOAA.354, ROMOAA.363, ROMOAA.419, ROMOAA.5118, ROMOAA.5120, ROMOAA.5124, ROMOAA.5128, ROMOAA.5139, ROMOAA.5169, ROMOAA.5170, ROMOAA.55, ROMOAA.554, ROMOAA.560, ROMOAA.5650, ROMOAA.5655, ROMOAA.5658, ROMOAA.5662, ROMOAA.5667, ROMOAA.5679, ROMOAA.5691, ROMOAA.5694, ROMOAA.5699, ROMOAA.5702, ROMOAA.5727, ROMOAA.5740, ROMOAA.5747, ROMOAA.637, ROMOAA.65, ROMOAA.720, ROMOAA.727, ROMOAA.743, ROMOAA.947, ROMOAA.956
Pinus ponderosa Forest Alliance	Pinus ponderosa / Ribes cereum Forest	GNR	CO:SU	Ponderosa Pine / White Squaw Currant Forest	CEGL000199	ROMO.522, ROMO.610, ROMO.705, ROMOAA.1165, ROMOAA.22, ROMOAA.335, ROMOAA.42, ROMOAA.518, ROMOAA.5341, ROMOAA.5439, ROMOAA.725, ROMOAA.923

NVC ALLIANCE	NVC ASSOCIATION	GLOBAL RANK	STATE RANK*	ASSOCIATION COMMON NAME	ELEMENT CODE	PLOT CODES
Pinus ponderosa Woodland Alliance	Pinus ponderosa / Rockland Woodland	G5?	AZ, CO, NM:S5, UT	Ponderosa Pine / Rockland Woodland	CEGL000877	ROMO.201, ROMO.220, ROMO.319, ROMO.403, ROMOAA.1087, ROMOAA.330, ROMOAA.347, ROMOAA.38, ROMOAA.46, ROMOAA.493, ROMOAA.512, ROMOAA.5203, ROMOAA.5569, ROMOAA.5690, ROMOAA.5701, ROMOAA.605, ROMOAA.634, ROMOAA.636, ROMOAA.868, ROMOAA.878, ROMOAA.893
na	Poa cusickii / Sibbaldia procumbens Herbaceous Vegetation	na	CO	Cusick's Bluegrass - Creeping Glow-wort Herbaceous Vegetation	Local Type	ROMO.293
Populus angustifolia Temporarily Flooded Woodland Alliance	Populus angustifolia / Betula occidentalis Woodland	G3	CO:S2, ID:S1, NV:S2, UT:S3?, WY:S2	Narrowleaf Cottonwood / Water Birch Woodland	CEGL000648	ROMO.8011, ROMO.8015
Populus angustifolia Temporarily Flooded Woodland Alliance	Populus angustifolia / Bromus inermis Semi-natural Woodland	GNR	CO	Narrowleaf Cottonwood / Smooth Brome Semi-natural Woodland	CEGL005847	ROMO.841, ROMOAA.5629
na	Populus balsamifera / Pteridium aquilinum Woodland	na	CO	Balsam Poplar / Northern Bracken Woodland	Local Type	ROMO.633
Abies lasiocarpa - Populus tremuloides Forest Alliance	Populus tremuloides - Abies lasiocarpa / Juniperus communis Forest	G3G4	CO:S4, UT:S3S4	Quaking Aspen - Subalpine Fir / Common Juniper Forest	CEGL000527	ROMO.112, ROMO.838, ROMOAA.3, ROMOAA.4, ROMOAA.489, ROMOAA.5250, ROMOAA.587, ROMOAA.754, ROMOAA.915
Picea pungens - Populus tremuloides Forest Alliance	Populus tremuloides - Picea pungens Forest	G3G4	CO, UT:S3S4	Quaking Aspen - Blue Spruce Forest	CEGL000535	ROMO.833, ROMOAA.1112, ROMOAA.274
Pinus contorta - Populus tremuloides Forest Alliance	Populus tremuloides - Pinus contorta / Juniperus communis Forest	G4G5	UT:S4S5, WY	Quaking Aspen - Lodgepole Pine / Common Juniper Forest	CEGL000537	ROMOAA.1, ROMOAA.258, ROMOAA.431, ROMOAA.438, ROMOAA.447, ROMOAA.5208, ROMOAA.5268, ROMOAA.5287, ROMOAA.794, ROMOAA.836, ROMOAA.1065, ROMOAA.1069, ROMOAA.1099,ROMOAA.1016

NVC ALLIANCE	NVC ASSOCIATION	GLOBAL RANK	STATE RANK*	ASSOCIATION COMMON NAME	ELEMENT CODE	PLOT CODES
Pinus ponderosa - Populus tremuloides Forest Alliance	Populus tremuloides - Pinus ponderosa Rocky Mountain Forest	G3G4	CO:S3S4, UT:S3S4, WY?	Quaking Aspen - Ponderosa Pine Rocky Mountain Forest	CEGL000541	ROMOAA.1012, ROMOAA.1035, ROMOAA.426, ROMOAA.436, ROMOAA.5184, ROMOAA.5189, ROMOAA.5345, ROMOAA.5425, ROMOAA.562, ROMOAA.722, ROMOAA.911, ROMOAA.952, ROMOAA.976
Populus tremuloides - Pseudotsuga menziesii Forest Alliance	Populus tremuloides - Pseudotsuga menziesii / Juniperus communis Forest	G3G4	UT:S3S4	Quaking Aspen - Douglas-fir / Common Juniper Forest	CEGL000545	ROMO.101, ROMOAA.336, ROMOAA.428, ROMOAA.5171, ROMOAA.5231, ROMOAA.5249, ROMOAA.5251, ROMOAA.5875, ROMOAA.690, ROMOAA.835, ROMOAA.877,
Populus tremuloides Forest Alliance	Populus tremuloides / Acer glabrum Forest	G1G2	CO:S1S2	Quaking Aspen / Rocky Mountain Maple Forest	CEGL000563	ROMO.122, ROMO.485, ROMO.708, ROMOAA.1164, ROMOAA.24, ROMOAA.5586, ROMOAA.961
Populus tremuloides Temporarily Flooded Forest Alliance	Populus tremuloides / Alnus incana Forest	G3	CO:S3	Quaking Aspen / Speckled Alder Forest	CEGL001150	ROMO.033, ROMO.076, ROMO.217, ROMOAA.279, ROMOAA.1089, ROMOAA.282, ROMOAA.283, ROMOAA.444, ROMOAA.5172, ROMOAA.618, ROMOAA.686, ROMOAA.942
Populus tremuloides Seasonally Flooded Forest Alliance	Populus tremuloides / Calamagrostis canadensis Forest	G3	AB, CO:S3, ID:S2, MT:S2, OR:S1, WA:S1, WY?	Quaking Aspen / Bluejoint Forest	CEGL000574	ROMO.069, ROMO.520, ROMO.630, ROMO.817, ROMOAA.277, ROMOAA.381, ROMOAA.5308
Populus tremuloides Forest Alliance	Populus tremuloides / Juniperus communis Forest	G4	CO:S4, MT?, UT, WY:S3	Quaking Aspen / Common Juniper Forest	CEGL000587	ROMO.135, ROMO.197, ROMO.704, ROMO.733, ROMO.810, ROMOAA.1061, ROMOAA.1092, ROMOAA.256, ROMOAA.264, ROMOAA.365, ROMOAA.366, ROMOAA.425, ROMOAA.5299, ROMOAA.5725, ROMOAA.5872, ROMOAA.780, ROMOAA.842, ROMOAA.867, ROMOAA.901, ROMOAA.963
Populus tremuloides Temporarily Flooded Forest Alliance	Populus tremuloides / Phleum pratense Semi-natural Forest	GNR	CO	Quaking Aspen/ Timothy Semi-natural Forest	CEGL005829	ROMO.067, ROMO.502, ROMO.503, ROMO.609, ROMO.627, ROMO.744, ROMO.842, ROMOAA.1000, ROMOAA.423, ROMOAA.5175, ROMOAA.5294, ROMOAA.5305, ROMOAA.863

NVC ALLIANCE	NVC ASSOCIATION	GLOBAL RANK	STATE RANK*	ASSOCIATION COMMON NAME	ELEMENT CODE	PLOT CODES
Populus tremuloides Forest Alliance	Populus tremuloides / Physocarpus monogynus Forest	GNR	CO	Quaking Aspen / Mountain Ninebark Forest	CEGL005932	ROMO.509, ROMO.629, ROMOAA.281, ROMOAA.490,
Populus tremuloides Forest Alliance	Populus tremuloides / Poa pratensis Forest	GNR	CA, CO, NV	Quaking Aspen / Kentucky Bluegrass Forest	CEGL003148	ROMO.519, ROMO.528, ROMOAA.193, ROMOAA.272, ROMOAA.276, ROMOAA.5173, ROMOAA.5181, ROMOAA.747
Populus tremuloides Forest Alliance	Populus tremuloides / Prunus virginiana Forest	G3G4	CO, MT?, OR:SU, SD:S3, UT, WY:S2S3	Quaking Aspen / Choke Cherry Forest	CEGL000596	ROMO.621, ROMOAA.698
Populus tremuloides Forest Alliance	Populus tremuloides / Pteridium aquilinum Forest	G4	CO:S3S4, SD, UT:S2S3, WY	Quaking Aspen / Northern Bracken Forest	CEGL000597	ROMO.406
Populus tremuloides Forest Alliance	Populus tremuloides / Shepherdia canadensis Forest	G3G4	CO:S3?, ID:S2S3, WY:S2S3	Quaking Aspen / Russet Buffaloberry Forest	CEGL000606	ROMO.730
Populus tremuloides Forest Alliance	Populus tremuloides / Thalictrum fendleri Forest	G5	CA?, CO:S5, ID:S3, UT:S4S5, WY:S3	Quaking Aspen / Fendler's Meadowrue Forest	CEGL000619	ROMO.110, ROMO.198, ROMO.511
Populus tremuloides Forest Alliance	Populus tremuloides / Vaccinium myrtillus Forest	G3	CO:S3	Quaking Aspen / Whortleberry Forest	CEGL000620	ROMO.066, ROMO.320, ROMO.395, ROMO.410, ROMO.514, ROMOAA.1093, ROMOAA.1114, ROMOAA.5300, ROMOAA.66, ROMOAA.954, ROMOAA.955, ROMOAA.981, ROMOAA.982
Pseudotsuga menziesii Forest Alliance	Pseudotsuga menziesii / Carex geyeri Forest	G4?	CO:S3, ID:S4?, MT:S4, OR:S3, WA:S1, WY	Douglas-fir / Geyer's Sedge Forest	CEGL000430	ROMO.516

NVC ALLIANCE	NVC ASSOCIATION	GLOBAL RANK	STATE RANK*	ASSOCIATION COMMON NAME	ELEMENT CODE	PLOT CODES
Pseudotsuga menziesii Forest Alliance	Pseudotsuga menziesii / Jamesia americana Forest	G3G4	CO:S3, WY	Douglas-fir / Waxflower Forest	CEGL000438	ROMO.077, ROMO.409, ROMO.500, ROMO.622, ROMOAA.1045, ROMOAA.370, ROMOAA.445, ROMOAA.515, ROMOAA.516, ROMOAA.5227, ROMOAA.530, ROMOAA.5408, ROMOAA.5763, ROMOAA.5864, ROMOAA.5876, ROMOAA.630, ROMOAA.673, ROMOAA.881, ROMOAA.885, ROMOAA.965
Pseudotsuga menziesii Forest Alliance	Pseudotsuga menziesii / Juniperus communis Forest	G4	CO:S1S2, ID:S3, MT:S4, WY:S3S4	Douglas-fir / Common Juniper Forest	CEGL000439	ROMO.187, ROMO.200, ROMO.221, ROMO.618, ROMO.619, ROMOAA.29, ROMOAA.290, ROMOAA.293, ROMOAA.331, ROMOAA.416, ROMOAA.473, ROMOAA.5192, ROMOAA.5214, ROMOAA.5261, ROMOAA.527, ROMOAA.5271, ROMOAA.54, ROMOAA.5432, ROMOAA.5734, ROMOAA.631, ROMOAA.696, ROMOAA.709, ROMOAA.741, ROMOAA.758, ROMOAA.804, ROMOAA.870, ROMOAA.884, ROMOAA.933
Pseudotsuga menziesii Woodland Alliance	Pseudotsuga menziesii / Leucopoa kingii Woodland	G3G4	CO, ID:S3, WY:S3S4	Douglas-fir / Spike Fescue Woodland	CEGL000904	ROMO.844
Pseudotsuga menziesii Forest Alliance	Pseudotsuga menziesii / Physocarpus monogynus Forest	G4	CO:S4, MT:S1S2, NM:S4, WY:S2S3	Douglas-fir / Mountain Ninebark Forest	CEGL000449	ROMO.501, ROMO.525, ROMO.760, ROMO.811, ROMOAA.297, ROMOAA.34, ROMOAA.346, ROMOAA.5431, ROMOAA.8005
Purshia tridentata Shrubland Alliance	Purshia tridentata / Artemisia frigida / Hesperostipa comata Shrubland	G1G2	CO:S1S2	Bitterbrush / Fringed Sagebrush / Needle-and-Thread Shrubland	CEGL001055	ROMO.8013, ROMOAA.1067, ROMOAA.5168
Purshia tridentata Shrubland Alliance	Purshia tridentata / Muhlenbergia montana Shrubland	G2	CO:S2	Bitterbrush / Mountain Muhly Shrubland	CEGL001057	ROMO.040, ROMO.108, ROMO.203, ROMO.515, ROMO.524, ROMO.620, ROMO.625, ROMO.829, ROMO.836, ROMO.840, ROMOAA.1097, ROMOAA.1113, ROMOAA.16, ROMOAA.173, ROMOAA.198, ROMOAA.267, ROMOAA.407, ROMOAA.415, ROMOAA.417, ROMOAA.418, ROMOAA.486, ROMOAA.5119, ROMOAA.5133, ROMOAA.5137, ROMOAA.519, ROMOAA.606, ROMOAA.729, ROMOAA.730, ROMOAA.801, ROMOAA.827, ROMOAA.828, ROMOAA.932

NVC ALLIANCE	NVC ASSOCIATION	GLOBAL RANK	STATE RANK*	ASSOCIATION COMMON NAME	ELEMENT CODE	PLOT CODES
Rhus trilobata Shrub Herbaceous Alliance	Rhus trilobata Rocky Mountain Shrub Herbaceous Vegetation	G2	CO:S2	Squawbush Rocky Mountain Shrub Herbaceous Vegetation	CEGL002910	ROMO.624
Ribes montigenum Shrubland Alliance	Ribes montigenum Shrubland	GU	CO:SU	Western Prickly Gooseberry Shrubland	CEGL001133	ROMO.365, ROMO.398, ROMO.712, ROMOAA.567
Rubus idaeus ssp. strigosus Shrubland Alliance	Rubus idaeus Scree Shrubland	GU	CO:SU	Red Raspberry Scree Shrubland	CEGL001134	ROMO.185, ROMO.386, ROMO.393, ROMO.394, ROMOAA.704
Salix arctica Dwarf-shrubland Alliance	Salix arctica - Salix nivalis Dwarf-shrubland	G2Q	CO, NM:S2	Arctic Willow - Snow Willow Dwarf-shrubland	CEGL001432	ROMO.015, ROMO.295, ROMO.473, ROMO.603
Salix arctica Dwarf-shrubland Alliance	Salix arctica / Geum rossii Dwarf-shrubland	G4	CO:S4?	Arctic Willow / Ross' Avens Dwarf-shrubland	CEGL001430	ROMO.022, ROMO.461, ROMO.722, ROMO.723, ROMOAA.165, ROMOAA.219, ROMOAA.5104, ROMOAA.5967, ROMOAA.5992, ROMOAA.670
Salix brachycarpa Seasonally Flooded Shrubland Alliance	Salix brachycarpa / Mesic Forbs Shrubland	G4	CO:S4, WY:S3	Short-fruit Willow / Mesic Forbs Shrubland	CEGL001135	ROMO.044, ROMO.047, ROMO.143, ROMO.244, ROMO.380, ROMO.383, ROMO.498, ROMO.611, ROMO.634, ROMO.714, ROMOAA.201, ROMOAA.202, ROMOAA.481, ROMOAA.482, ROMOAA.483, ROMOAA.5096, ROMOAA.5097, ROMOAA.5107, ROMOAA.5986, ROMOAA.5987, ROMOAA.5995, ROMOAA.609, ROMOAA.646, ROMOAA.778
Salix drummondiana Temporarily Flooded Shrubland Alliance	Salix drummondiana / Calamagrostis canadensis Shrubland	G3	AB?, BC?, CO:S3, ID:S2, MT, WA:S2?	Drummond's Willow / Bluejoint Shrubland	CEGL002667	ROMO.312, ROMO.719, ROMO.737ROMOAA.1166
Salix drummondiana Seasonally Flooded Shrubland Alliance	Salix drummondiana / Carex utriculata Shrubland	G4	BC, CO, ID:S3, MT:S4, UT?, WA:S3, WY	Drummond's Willow / Beaked Sedge Shrubland	CEGL002631	ROMO.513, ROMOAA.945
Salix drummondiana Temporarily Flooded Shrubland Alliance	Salix drummondiana / Mesic Forbs Shrubland	G4	AB, CO:S4, MT, WY	Drummond's Willow / Mesic Forbs Shrubland	CEGL001192	ROMO.710

NVC ALLIANCE	NVC ASSOCIATION	GLOBAL RANK	STATE RANK*	ASSOCIATION COMMON NAME	ELEMENT CODE	PLOT CODES
Salix geyeriana Temporarily Flooded Shrubland Alliance	Salix geyeriana - Salix monticola / Calamagrostis canadensis Shrubland	G3	CO:S3	Geyer's Willow - Mountain Willow / Bluejoint Shrubland	CEGL001247	ROMO.269, ROMO.608, ROMO.738, ROMO.826, ROMOAA.249, ROMOAA.5079
Salix geyeriana Temporarily Flooded Shrubland Alliance	Salix geyeriana - Salix monticola / Mesic Forbs Shrubland	G3	CO:S3	Geyer's Willow - Mountain Willow / Mesic Forbs Shrubland	CEGL001223	ROMO.396, ROMO.736, ROMO.830
Salix geyeriana Seasonally Flooded Shrubland Alliance	Salix geyeriana / Calamagrostis canadensis Shrubland	G5	CO:S3, ID:S4, MT:S4, OR, UT:S2?, WY	Geyer's Willow / Bluejoint Shrubland	CEGL001205	ROMO.316, ROMO.321, ROMO.734
Salix geyeriana Seasonally Flooded Shrubland Alliance	Salix geyeriana / Carex aquatilis Shrubland	G3	CO:S3, ID:S3, MT?, UT:S3?, WY?	Geyer's Willow / Aquatic Sedge Shrubland	CEGL001206	ROMO.116, ROMO.206
Salix geyeriana Seasonally Flooded Shrubland Alliance	Salix geyeriana / Carex utriculata Shrubland	G5	CO:S3, ID:S4, MT:S5, NV, OR:S2, UT:S2S3, WY	Geyer's Willow / Beaked Sedge Shrubland	CEGL001207	ROMO.212, ROMOAA.246, ROMOAA.999
Salix geyeriana Temporarily Flooded Shrubland Alliance	Salix geyeriana / Mesic Graminoids Shrubland	G3?	CO:S3, ID, NV, UT:S2S3, WY	Geyer's Willow / Mesic Graminoids Shrubland	CEGL001210	ROMO.820, ROMO.821, ROMO.822, ROMOAA.5061, ROMOAA.5063, ROMOAA.5066, ROMOAA.5071
Salix monticola Temporarily Flooded Shrubland Alliance	Salix monticola / Calamagrostis canadensis Shrubland	G3	CO:S3, NM?	Mountain Willow / Bluejoint Shrubland	CEGL001222	ROMO.079, ROMO.742, ROMOAA.1030
Salix monticola Temporarily Flooded Shrubland Alliance	Salix monticola / Carex aquatilis Shrubland	G3	CO:S3	Mountain Willow / Aquatic Sedge Shrubland	CEGL002656	ROMO.287, ROMO.368, ROMO.606, ROMOAA.1125, ROMOAA.1126, ROMOAA.998
Salix monticola Temporarily Flooded Shrubland Alliance	Salix monticola / Carex utriculata Shrubland	G3	CO:S3	Mountain Willow / Beaked Sedge Shrubland	CEGL002657	ROMO.261, ROMO.802, ROMO.819, ROMOAA.8004

NVC ALLIANCE	NVC ASSOCIATION	GLOBAL RANK	STATE RANK*	ASSOCIATION COMMON NAME	ELEMENT CODE	PLOT CODES
Salix monticola Temporarily Flooded Shrubland Alliance	Salix monticola / Mesic Graminoids Shrubland	G3	CO:S3, NM?, UT?, WY	Mountain Willow / Mesic Graminoids Shrubland	CEGL002659	ROMO.211, ROMOAA.5180
Salix (reticulata, nivalis) Dwarf-shrubland Alliance	Salix nivalis / Geum rossii Dwarf-shrubland	GNR	CO	Snow Willow / Ross' Avens Dwarf-shrubland	CEGL005936	ROMO.062, ROMO.181, ROMOAA.5085
Salix planifolia Temporarily Flooded Shrubland Alliance	Salix planifolia / Calamagrostis canadensis Shrubland	G4	CO:S3, UT:S2?, WY:S2?	Planeleaf Willow / Bluejoint Shrubland	CEGL001225	ROMO.054, ROMO.073, ROMO.160, ROMO.282, ROMO.354, ROMO.420, ROMOAA.1079, ROMOAA.1084, ROMOAA.5065, ROMOAA.5068, ROMOAA.5072, ROMOAA.5074, ROMOAA.5075, ROMOAA.5076, ROMOAA.5084, ROMOAA.568
Salix planifolia Seasonally Flooded Shrubland Alliance	Salix planifolia / Caltha leptosepala Shrubland	G4	CO:S4, WY	Planeleaf Willow / White Marsh-marigold Shrubland	CEGL002665	ROMO.057, ROMO.161, ROMO.275, ROMO.285, ROMO.496, ROMOAA.164, ROMOAA.485, ROMOAA.5087
Salix planifolia Seasonally Flooded Shrubland Alliance	Salix planifolia / Carex aquatilis Shrubland	G5	CO:S4, ID:S4, MT:S3, NM:S4, UT:S2S3, WY	Planeleaf Willow / Aquatic Sedge Shrubland	CEGL001227	ROMO.001, ROMO.026, ROMO.071, ROMO.136, ROMO.138, ROMO.213, ROMO.214, ROMO.307, ROMO.328, ROMO.440, ROMOAA.1140, ROMOAA.1145, ROMOAA.5054, ROMOAA.5058, ROMOAA.5062, ROMOAA.5092, ROMOAA.5093, ROMOAA.5947, ROMOAA.616, ROMOAA.764
Salix planifolia Seasonally Flooded Shrubland Alliance	Salix planifolia / Carex scopulorum Shrubland	G4	BC?, CO:S4?, ID:S3, WA:S3?, WY	Planeleaf Willow / Holm's Rocky Mountain Sedge Shrubland	CEGL001229	ROMO.168, ROMO.249, ROMO.432, ROMO.470, ROMO.483, ROMOAA.1137, ROMOAA.1143, ROMOAA.261, ROMOAA.5051
Salix planifolia Seasonally Flooded Shrubland Alliance	Salix planifolia / Carex utriculata Shrubland	GNR	CO, MT, UT, WY	Planeleaf Willow / Beaked Sedge Shrubland	CEGL005937	ROMO.228, ROMO.376, ROMO.382, ROMOAA.5053, ROMOAA.5073, ROMOAA.5081, ROMOAA.5933

NVC ALLIANCE	NVC ASSOCIATION	GLOBAL RANK	STATE RANK*	ASSOCIATION COMMON NAME	ELEMENT CODE	PLOT CODES
Salix planifolia Temporarily Flooded Shrubland Alliance	Salix planifolia / Deschampsia caespitosa Shrubland	G2G3	CO, UT:S2S3, WY	Planeleaf Willow / Tufted Hairgrass Shrubland	CEGL001230	ROMO.017, ROMO.031, ROMO.051, ROMO.059, ROMO.162, ROMO.271, ROMO.281, ROMO.286, ROMO.374, ROMO.445, ROMOAA.238, ROMOAA.245, ROMOAA.257, ROMOAA.260, ROMOAA.5033, ROMOAA.5034, ROMOAA.5050, ROMOAA.5057, ROMOAA.5108, ROMOAA.597, ROMOAA.604
Salix planifolia Seasonally Flooded Shrubland Alliance	Salix planifolia / Mesic Forbs Shrubland	G4	CO:S4, WY	Planeleaf Willow / Mesic Forbs Shrubland	CEGL002893	ROMO.146, ROMO.334, ROMOAA.253, ROMOAA.545
Salix wolfii Seasonally Flooded Shrubland Alliance	Salix wolfii / Carex utriculata Shrubland	G4	CO:S3, ID:S4, UT:S2?, WY:S2S3	Wolf Willow / Beaked Sedge Shrubland	CEGL001237	ROMO.735
Salix wolfii Temporarily Flooded Shrubland Alliance	Salix wolfii / Deschampsia caespitosa Shrubland	G3	CO, ID:S2, MT:S3, UT:S2S3, WY:S2S3	Wolf Willow / Tufted Hairgrass Shrubland	CEGL001238	ROMO.195, ROMO.274, ROMO.279, ROMO.280, ROMO.739, ROMOAA.248
Salix wolfii Temporarily Flooded Shrubland Alliance	Salix wolfii / Fragaria virginiana Shrubland	G4?	CO, ID:S3, WY:S3S4	Wolf Willow / Virginia Strawberry Shrubland	CEGL001239	ROMO.159, ROMO.273
na	Sedum lanceolatum ssp. lanceolatum Herbaceous Vegetation	na	CO	Lance-Leaf Stonecrop Herbaceous Vegetation	Local Type	ROMO.448
Sibbaldia procumbens Herbaceous Alliance	Sibbaldia procumbens - Polygonum bistortoides Herbaceous Vegetation	G3?	CO:SU, WY:S3?	Creeping Glow-wort - American Bistort Herbaceous Vegetation	CEGL001933	ROMO.142
Silene acaulis Herbaceous Alliance	Silene acaulis Herbaceous Vegetation	G5?	CO, MT:S5, WY?	Cushion Pink Herbaceous Vegetation	CEGL001934	ROMO.019, ROMO.259, ROMO.435, ROMO.454, ROMO.455, ROMOAA.142, ROMOAA.5018

NVC ALLIANCE	NVC ASSOCIATION	GLOBAL RANK	STATE RANK*	ASSOCIATION COMMON NAME	ELEMENT CODE	PLOT CODES
Sparganium angustifolium Permanently Flooded Herbaceous Alliance	Sparganium angustifolium Herbaceous Vegetation	G4	CA, CO:SU, ID, OR:S4, WA:S3S4	Greenfruit Bur-reed Herbaceous Vegetation	CEGL001990	ROMO.495, ROMO.602, ROMO.718, ROMO.727
Sparse Nonvascular Vegetation (on rock and unconsolidated substrates) Alliance	Sparse Nonvascular Vegetation (on rock and unconsolidated substrates)	GNR	CO	Sparse Nonvascular Vegetation (on rock and unconsolidated substrates)	CEGL002888	ROMO.230, ROMO.329, ROMO.389, ROMO.408, ROMO.499, ROMOAA.1008, ROMOAA.1014, ROMOAA.207, ROMOAA.209, ROMOAA.474, ROMOAA.5020, ROMOAA.5111, ROMOAA.5123, ROMOAA.5291, ROMOAA.5362, ROMOAA.5367, ROMOAA.5369, ROMOAA.5599, ROMOAA.570, ROMOAA.575, ROMOAA.576, ROMOAA.589, ROMOAA.590, ROMOAA.5965, ROMOAA.768
Trifolium (dasyphyllum, nanum) Herbaceous Alliance	Trifolium dasyphyllum Herbaceous Vegetation	G4	CO:S4?, NM:S3S4	Uinta Clover Herbaceous Vegetation	CEGL001935	ROMO.029, ROMO.351, ROMO.437, ROMOAA.1138, ROMOAA.157, ROMOAA.167, ROMOAA.5008, ROMOAA.5030, ROMOAA.752
Trifolium (dasyphyllum, nanum) Herbaceous Alliance	Trifolium nanum Herbaceous Vegetation	GNR	CO	Tundra Clover Herbaceous Vegetation	CEGL005939	ROMO.178, ROMO.260, ROMO.337, ROMO.350, ROMOAA.898
Trifolium parryi Herbaceous Alliance	Trifolium parryi Herbaceous Vegetation	GU	CO:SU, WY?	Parry's Clover Herbaceous Vegetation	CEGL001936	ROMO.258, ROMO.464, ROMO.471
Vaccinium (caespitosum, myrtillus, scoparium) Dwarf-shrubland Alliance	Vaccinium (caespitosum, scoparium) Dwarf-shrubland	G4	AB, CO:S1?, NV, WY	(Dwarf Blueberry, Grouseberry) Dwarf-shrubland	CEGL001140	ROMO.058, ROMO.145, ROMO.243, ROMO.256, ROMO.262, ROMO.297, ROMO.335, ROMO.422, ROMO.434, ROMO.462, ROMOAA.1029, ROMOAA.1048, ROMOAA.1080, ROMOAA.163, ROMOAA.212, ROMOAA.235, ROMOAA.684, ROMOAA.812

Photo-Interpretation and Map Units

We recognized and delineated 46 map units on the true color aerial photographs for ROMO. Of these, 35 are vegetated and received an accuracy assessment. All map units were developed from a combination of an initial NVC vegetation classification provided by NatureServe with input from Park biologists and BOR ecologists, fieldwork, and preliminary photo-interpretation.

Appendix H details the descriptions and representative photos for all vegetation map units. Table 12 details each of the map units and salient associations.

A few map units have a one to one relationship with the vegetation associations, but most have several associations as part of each map unit. This is largely due to the fact that many associations are defined by the understory vegetation which is often not visible from overhead. Some map units may be modeled given known or inferred distribution. An example of this is the *Pinus contorta* map units. There are three *P. contorta* map units. One of these, the *P. contorta* / Rock Woodland is a one to one relationship. There is only one association within this map unit. The high and low elevation *P. contorta* map units are separated by the known distribution of the understory. Plot data shows us that, typically, the three *Vaccinium* species occur as a prominent member of the understory above 9,500 ft. We therefore modeled this distribution with some success (see results – accuracy assessment). This is a one to many relationship (one map unit – many associations). In addition, it should be noted that some associations may occur in more than one map unit. We see this with the *P. contorta / Juniperus communis* Woodland which we find at all elevations within *P. contorta* types. This is a many to one relationship (many map units – one association).

Table 12. Map units and vegetation associations within each map unit.

Notes:
1 – This association occurs in multiple map units
2 – This association is a minor type in this map unit
3 – Local types are not part of the NVC

Veg Code	MAP UNIT NAME	ASSOCIATION	Elcode	Notes
1	Herbaceous Upland - Alpine	*Artemisia arctica* ssp. *arctica* Herbaceous Vegetation	CEGL001848	
		Carex elynoides - Geum rossii Herbaceous Vegetation	CEGL001853	
		Carex pyrenaica Herbaceous Vegetation	CEGL001860	1
		Carex rupestris - Geum rossii Herbaceous Vegetation	CEGL001861	
		Carex rupestris - Trifolium dasyphyllum Herbaceous Vegetation	CEGL001863	
		Carex siccata - Geum rossii Herbaceous Vegetation	CEGL001808	
		Deschampsia caespitosa Herbaceous Vegetation	CEGL001599	1
		Dryas octopetala - Carex rupestris Dwarf-shrub Herbaceous Vegetation	CEGL001892	
		Festuca brachyphylla - Geum rossii var. *turbinatum* Herbaceous Vegetation	CEGL001895	
		Geum rossii - Trifolium spp. Herbaceous Vegetation	CEGL001970	
		Juncus parryi / Sibbaldia procumbens Herbaceous Vegetation	CEGL005871	
		Kobresia myosuroides - Carex rupestris var. *drummondiana* Herbaceous Vegetation	CEGL001907	
		Kobresia myosuroides - Geum rossii Herbaceous Vegetation	CEGL001908	
		Salix arctica - Salix nivalis Dwarf-shrubland	CEGL001432	
		Salix arctica / Geum rossii Dwarf-shrubland	CEGL001430	
		Salix nivalis / Geum rossii Dwarf-shrubland	CEGL005936	
		Sedum lanceolatum ssp. *lanceolatum* Herbaceous Vegetation	Local Type	3
		Sibbaldia procumbens - Polygonum bistortoides Herbaceous Vegetation	CEGL001933	
		*Trifolium dasyph*yllum Herbaceous Vegetation	CEGL001935	1
2	Herbaceous Upland - Alpine Fellfield	*Geum rossii - Minuartia obtusiloba* Herbaceous Vegetation	CEGL001965	
		Paronychia pulvinata - Silene acaulis Dwarf-shrubland	CEGL001976	
		Silene acaulis Herbaceous Vegetation	CEGL001934	
		Trifolium dasyphyllum Herbaceous Vegetation	CEGL001935	1

Veg Code	MAP UNIT NAME	ASSOCIATION	Elcode	Notes
		Trifolium nanum Herbaceous Vegetation	CEGL005939	
		Trifolium parryi Herbaceous Vegetation	CEGL001936	
4	Herbaceous Upland - Montane	*Bouteloua gracilis* Herbaceous Vegetation	CEGL001760	
		Bromus inermis - (Pascopyrum smithii) Semi-natural Herbaceous Vegetation	CEGL005264	
		Danthonia parryi Herbaceous Vegetation	CEGL001795	
		Elymus trachycaulus Alliance [Placeholder]	Local Type	[3]
		Festuca thurberi Subalpine Grassland Herbaceous Vegetation	CEGL001631	
		*Muhlenbergia montana - Hesperostipa c*omata Herbaceous Vegetation	CEGL001647	
		Muhlenbergia montana Herbaceous Vegetation	CEGL001646	
5	Herbaceous Wetland - Cross Zone - Marsh	*Nuphar lutea* ssp. *polysepala* Herbaceous Vegetation	CEGL002001	
		Sparganium angustifolium Herbaceous Vegetation	CEGL001990	
6	Herbaceous Wetland - Cross Zone - Wetland	*Calamagrostis canadensis* Western Herbaceous Vegetation	CEGL001559	
		Caltha leptosepala - Rhodiola rhodantha Herbaceous Vegetation	CEGL001957	
		*Caltha le*ptosepala Herbaceous Vegetation	CEGL001954	
		Cardamine cordifolia - Mertensia ciliata - Senecio triangularis Herbaceous Vegetation	CEGL002662	
		Carex aquatilis - Carex utriculata Herbaceous Vegetation	CEGL001803	
		Carex aquatilis Herbaceous Vegetation	CEGL001802	
		Carex limosa Herbaceous Vegetation	CEGL001811	
		Carex microptera Herbaceous Vegetation	CEGL001792	
		Carex scopulorum - Caltha leptosepala Herbaceous Vegetation	CEGL001823	
		Carex utriculata Herbaceous Vegetation	CEGL001562	
		Eleocharis quinqueflora Herbaceous Vegetation	CEGL001836	
		Glyceria grandis Herbaceous Vegetation	CEGL003429	
		Juncus balticus Herbaceous Vegetation	CEGL001838	
7	Herbaceous Wetland - Subalpine / Alpine - Alpine Meadow	*Carex illota* Herbaceous Vegetation	CEGL001876	
		Carex pyrenaica Herbaceous Vegetation	CEGL001860	
		Danthonia intermedia Herbaceous Vegetation	CEGL001794	
		Dasiphora fruticosa ssp. *floribunda / Deschampsia caespitosa* Shrubland	CEGL001107	
		Dasiphora fruticosa ssp. *floribunda* Subalpine Shrubland	CEGL003499	

Veg Code	MAP UNIT NAME	ASSOCIATION	Elcode	Notes
		Deschampsia caespitosa - Caltha leptosepala Herbaceous Vegetation	CEGL001882	
		Deschampsia caespitosa - Geum rossii Herbaceous Vegetation	CEGL001884	
		Deschampsia caespitosa Herbaceous Vegetation	CEGL001599	1
		Geum rossii - Polygonum bistortoides Herbaceous Vegetation	CEGL001967	
		Geum rossii - Sibbaldia procumbens Herbaceous Vegetation	CEGL001969	
		Geum rossii - Trifolium spp. Herbaceous Vegetation	CEGL001970	1
		Juncus drummondii - Carex spp. Herbaceous Vegetation	CEGL001905	
		Poa cusickii / Sibbaldia procumbens Herbaceous Vegetation	Local Type	3
10	Rock (Alpine - Upper Subalpine)	*Aquilegia caerulea - Cirsium scopulorum* Scree Sparse Vegetation	CEGL001938	1
		Rubus idaeus Scree Shrubland	CEGL001134	1
		Sparse non-vascular vegetation (on rock and unconsolidated substrates)	CEGL002888	1
11	Rock Foothill - Lower Subalpine)	Sparse non-vascular vegetation (on rock and unconsolidated substrates)	CEGL002888	1
120	Shrub - Riparian - Cross Zone > 9600 ft	*Alnus incana / Equisetum arvense* Shrubland	CEGL001146	1,2
		Betula nana / Mesic Forbs - Mesic Graminoids Shrubland	CEGL002653	1
		Salix brachycarpa / Mesic Forbs Shrubland	CEGL001135	1
		Salix drummondiana / Mesic Forbs Shrubland	CEGL001192	
		Salix geyeriana - Salix monticola / Mesic Forbs Shrubland	CEGL001223	1,2
		Salix monticola / Carex aquatilis Shrubland	CEGL002656	1,2
		Salix monticola / Carex utriculata Shrubland	CEGL002657	1,2
		Salix planifolia / Calamagrostis canadensis Shrubland	CEGL001225	1
		Salix planifolia / Caltha leptosepala Shrubland	CEGL002665	
		Salix planifolia / Carex aquatilis Shrubland	CEGL001227	1
		Salix planifolia / Carex scopulorum Shrubland	CEGL001229	
		Salix planifolia / Carex utriculata Shrubland	CEGL005937	1
		Salix planifolia / Deschampsia caespitosa Shrubland	CEGL001230	
		Salix planifolia / Mesic Forbs Shrubland	CEGL002893	1
		Salix planifolia / Mesic Forbs Shrubland	CEGL002893	
		Salix wolfii / Carex utriculata Shrubland	CEGL001237	
		Salix wolfii / Deschampsia caespitosa Shrubland	CEGL001238	
		Salix wolfii / Fragaria virginiana Shrubland	CEGL001239	

Veg Code	MAP UNIT NAME	ASSOCIATION	Elcode	Notes
121	Shrub - Riparian - Cross Zone < 9600 ft	*Acer glabrum* Drainage Bottom Shrubland	CEGL001062	
		Alnus incana - Salix (monticola, lucida, ligulifolia) Shrubland	CEGL002651	
		Alnus incana - Salix drummondiana Shrubland	CEGL002652	
		Alnus incana / Equisetum arvense Shrubland	CEGL001146	1
		Alnus incana / Mesic Graminoids Shrubland	CEGL001148	
		Betula nana / Mesic Forbs - Mesic Graminoids Shrubland	CEGL002653	1
		Betula occidentalis / Mesic Graminoids Shrubland	CEGL002654	
		Dasiphora fruticosa ssp. *floribunda* Shrubland [Provisional]	CEGL001105	
		Salix drummondiana / Calamagrostis canadensis Shrubland	CEGL002667	
		Salix drummondiana / Carex utriculata Shrubland	CEGL002631	
		Salix geyeriana - Salix monticola / Calamagrostis canadensis Shrubland	CEGL001247	
		Salix geyeriana - Salix monticola / Mesic Forbs Shrubland	CEGL001223	1
		Salix geyeriana / Calamagrostis canadensis Shrubland	CEGL001205	
		Salix geyeriana / Carex aquatilis Shrubland	CEGL001206	
		Salix geyeriana / Carex utriculata Shrubland	CEGL001207	
		Salix geyeriana / Mesic Graminoids Shrubland	CEGL001210	
		Salix monticola / Calamagrostis canadensis Shrubland	CEGL001222	1
		Salix monticola / Carex aquatilis Shrubland	CEGL002656	1
		Salix monticola / Carex utriculata Shrubland	CEGL002657	1
		Salix monticola / Mesic Graminoids Shrubland	CEGL002659	
		Salix planifolia / Calamagrostis canadensis Shrubland	CEGL001225	
		Salix planifolia / Carex aquatilis Shrubland	CEGL001227	1
		Salix planifolia / Carex utriculata Shrubland	CEGL005937	1
13	Shrub Upland - Alpine	*Betula nana - Salix brachycarpa* Shrubland	CEGL005828	
		Ribes montigenum Shrubland	CEGL001133	
		Salix brachycarpa / Mesic Forbs Shrubland	CEGL001135	1
		Salix planifolia / Mesic Forbs Shrubland	CEGL002893	1
		Vaccinium (caespitosum, scoparium) Dwarf-shrubland	CEGL001140	
14	Shrub Upland - Lower Montane	*Cercocarpus montanus / Hesperostipa comata* Shrubland	CEGL001092	
		Cercocarpus montanus / Muhlenbergia montana Shrubland	CEGL002914	

Veg Code	MAP UNIT NAME	ASSOCIATION	Elcode	Notes
		Rhus trilobata Rocky Mountain Shrub Herbaceous Vegetation	CEGL002910	
141	Shrub Upland - Lower Montane - Big Sagebrush	*Artemisia tridentata* ssp. *vaseyana - (Purshia tridentata) / Muhlenbergia montana - (Hesperostipa comata* ssp. *comata*) Shrubland	CEGL005827	
142	Shrub Upland - Lower Montane - Bitterbrush	*Purshia tridentata / Artemisia frigida / Hesperostipa comata* Shrubland	CEGL001055	
		Purshia tridentata / Muhlenbergia montana Shrubland	CEGL001057	
15	Riparian Aspen	*Populus tremuloides - Picea pungens* Forest	CEGL000535	
		Populus tremuloides / Acer glabrum Forest	CEGL000563	
		Populus tremuloides / Alnus incana Forest	CEGL001150	
		Populus tremuloides / Calamagrostis canadensis Forest	CEGL000574	
		Populus tremuloides / Phleum pratense Semi-natural Forest	CEGL005829	
18	Upland Aspen	*Populus balsamifera / Pteridium aquilinum* Woodland	Local Type	3
		Populus tremuloides / Juniperus communis Forest	CEGL000587	
		Populus tremuloides / Physocarpus monogynus Forest	CEGL005932	
		Populus tremuloides / Poa pratensis Forest	CEGL003148	
		Populus tremuloides / Prunus virginiana Forest	CEGL000596	
		Populus tremuloides / Pteridium aquilinum Forest	CEGL000597	
		Populus tremuloides / Shepherdia canadensis Forest	CEGL000606	
		Populus tremuloides / Thalictrum fendleri Forest	CEGL000619	
		Populus tremuloides / Vaccinium myrtillus Forest	CEGL000620	
161	Mixed conifer with aspen (Ponderosa Pine)	*Populus tremuloides - Pinus ponderosa* Rocky Mountain Forest	CEGL000541	
162	Mixed conifer with aspen (Lodgepole Pine)	*Populus tremuloides - Pinus contorta / Juniperus communis* Forest	CEGL000537	
163	Mixed conifer with aspen (Douglas-fir)	*Populus tremuloides - Pseudotsuga menziesii / Juniperus communis* Forest	CEGL000545	
164	Mixed conifer with aspen (Spruce - Fir)	*Populus tremuloides - Abies lasiocarpa / Juniperus communis* Forest	CEGL000527	
190	Upper Montane - Mixed Conifer - Riparian > 9600 ft	*Abies lasiocarpa - Picea engelmannii / Acer glabrum* Forest	CEGL000294	
		Abies lasiocarpa - Picea engelmannii / Calamagrostis canadensis Forest	CEGL000300	
		Abies lasiocarpa - Picea engelmannii / Mertensia ciliata Forest	CEGL002663	
		Abies lasiocarpa - Picea engelmannii / Salix drummondiana Forest	CEGL000327	1,2
		Picea engelmannii / Calamagrostis canadensis Forest	CEGL002678	1
191	Upper Montane - Mixed Conifer - Riparian < 9600 ft	*Abies lasiocarpa - Picea engelmannii / Alnus incana* Forest	CEGL000296	

Veg Code	MAP UNIT NAME	ASSOCIATION	Elcode	Notes
		Abies lasiocarpa - Picea engelmannii / Calamagrostis canadensis Forest	CEGL000300	1
		Abies lasiocarpa - Picea engelmannii / Salix drummondiana Forest	CEGL000327	1
		Picea engelmannii / Calamagrostis canadensis Forest	CEGL002678	1
		Picea engelmannii / Equisetum arvense Forest	CEGL005927	
20	Montane Douglas Fir	*Pseudotsuga menziesii / Carex geyeri* Forest	CEGL000430	
		Pseudotsuga menziesii / Jamesia americana Forest	CEGL000438	
		Pseudotsuga menziesii / Juniperus communis Forest	CEGL000439	
		Pseudotsuga menziesii / Leucopoa kingii Woodland	CEGL000904	1
		Pseudotsuga menziesii / Physocarpus monogynus Forest	CEGL000449	
22	Subalpine mixed conifer	*Abies lasiocarpa - Picea engelmannii / Juniperus communis* Woodland	CEGL000919	
		Abies lasiocarpa - Picea engelmannii / Moss Forest	CEGL000321	
		Abies lasiocarpa - Picea engelmannii / Polemonium pulcherrimum Forest	CEGL000373	
		Abies lasiocarpa - Picea engelmannii / Vaccinium caespitosum Forest	CEGL000340	
		Abies lasiocarpa - Picea engelmannii / Vaccinium myrtillus Forest	CEGL000343	
		Abies lasiocarpa - Picea engelmannii / Vaccinium scoparium Forest	CEGL000344	
		Picea engelmannii / Moss Forest	CEGL000371	
		Picea engelmannii / Trifolium dasyphyllum Forest	CEGL000377	
		Picea engelmannii / Vaccinium myrtillus Forest	CEGL000379	
		Picea engelmannii / Vaccinium scoparium Forest	CEGL000381	
23	Lodgepole - high elevation > 9500 ft.	*Pinus contorta / Juniperus communis* Woodland	CEGL000764	1
		Pinus contorta / Vaccinium caespitosum Forest	CEGL000168	
		Pinus contorta / Vaccinium myrtillus Forest	CEGL005935	1
		Pinus contorta / Vaccinium scoparium Forest	CEGL000172	
24	Lodgepole - low elevation < 9500 ft.	*Pinus contorta / Arctostaphylos uva-ursi* Forest	CEGL000134	
		Pinus contorta / Carex geyeri Forest	CEGL000141	
		Pinus contorta / Carex rossii Forest	CEGL000144	
		Pinus contorta / Jamesia americana Forest	CEGL005933	
		Pinus contorta / Juniperus communis Woodland	CEGL000764	1
		Pinus contorta / Shepherdia canadensis Forest	CEGL000163	
		Pinus contorta / Vaccinium myrtillus Forest	CEGL005935	1,2

Veg Code	MAP UNIT NAME	ASSOCIATION	Elcode	Notes
26	Lodgepole pine - Rock	*Pinus contorta* / Rock Woodland	CEGL005934	1
32	Cottonwood	*Populus angustifolia / Betula occidentalis* Woodland	CEGL000648	
		Populus angustifolia / Bromus inermis Semi-natural Woodland	CEGL005847	
33	Juniper Woodland	*Juniperus scopulorum / Purshia tridentata* Woodland	CEGL000749	
34	Ponderosa Pine - Graminoid	*Pinus ponderosa / Carex geyeri* Woodland	CEGL000182	
		Pinus ponderosa / Carex inops ssp. *heliophila* Woodland	CEGL000849	
		Pinus ponderosa / Carex rossii Forest	CEGL000183	
		Pinus ponderosa / Leucopoa kingii Woodland	CEGL000186	
		Pinus ponderosa / Muhlenbergia montana Woodland	CEGL000862	
		Pseudotsuga menziesii / Leucopoa kingii Woodland	CEGL000904	1,2
35	Ponderosa Pine - Rockland	*Pinus ponderosa* / Rockland Woodland	CEGL000877	
36	Ponderosa Pine - Shrubland	*Pinus ponderosa / Arctostaphylos uva-ursi* Woodland	CEGL000844	
		Pinus ponderosa / Artemisia tridentata ssp. *vaseyana* Woodland	CEGL002794	
		Pinus ponderosa / Cercocarpus montanus Woodland	CEGL000851	
		Pinus ponderosa / Juniperus communis Woodland	CEGL000859	
		Pinus ponderosa / Physocarpus monogynus Forest	CEGL000190	
		Pinus ponderosa / Purshia tridentata Woodland	CEGL000867	
		Pinus ponderosa / Ribes cereum Forest	CEGL000199	
38	Limber Pine	*Pinus flexilis / Arctostaphylos uva-ursi* Woodland	CEGL000802	
		Pinus flexilis / Juniperus communis Woodland	CEGL000807	
41	Disturbance – Dead and Down			
43	Blue Spruce	*Picea pungens* Temporarily Flooded Woodland Alliance	A.567	
		Picea pungens / Alnus incana Woodland	CEGL000894	
39	Ribbon Forests	(subset of map unit 400)		
400	Krummholz	*Abies lasiocarpa – Picea engelmannii / Salix (brachycarpa, glauca)* Krummholz Shrubland	CEGL000986	
		Abies lasiocarpa - Picea engelmannii Krummholz Shrubland	CEGL000985	
		Pinus flexilis Krummholz Shrubland	Local Type	3
9	Alpine - Ice Field - Glacier			
46	Talus	*Aquilegia caerulea - Cirsium scopulorum* Scree Sparse Vegetation	CEGL001938	1

Veg Code	MAP UNIT NAME	ASSOCIATION	Elcode	Notes
		Rubus idaeus Scree Shrubland	CEGL001134	1
		Sparse non-vascular vegetation (on rock and unconsolidated substrates)	CEGL002888	1
48	Exposed Soil - Man made			
49	Cliff Face - Bare Soil	Sparse non-vascular vegetation (on rock and unconsolidated substrates)	CEGL002888	
51	Streams - Rivers			
52	Natural Lakes - Ponds			
53	Reservoir - Stock Tanks			
999	Un-vegetated Surfaces			

Vegetation Map

A total of 427,438 acres (172,982 ha) comprising ROMO and its environs was mapped. The area mapped within the Park boundary was 289,469 acres (117,147 ha). Forty-six map units were used to describe the landscape. Of these, twelve were un-vegetated map units. Of all the map units, the most frequently occurring within the entire mapping area was Map Unit 22 Spruce – Fir with 4,521 polygons ranging in size from 0.03 acres (0.01 ha) to 1,400 acres (567 ha). The most abundant map unit in terms of area was also Map Unit 22, Spruce – Fir, covering 103,841 acres or about 24% of the project area. Spatial statistics for each of the map units are listed in Table 13. A reduced statistics table is included for areal coverage of map units within the Park (Table 14). Polygon size ranged from 0.02 acres (0.01 ha) to 3,254 acres (1,317 ha) with the mean polygon size being 12 acres (4.8 ha).

The individual map unit statistics are important in that they reveal so much more than just the mean size. Often the mean area for each map unit is highly skewed. For example, many small polygons will show a higher frequency for the small polygons yet a few large polygons may represent the greatest area. The use of mean as a summary statistic may then be highly misleading.

Particularly useful is the several vegetation codes that describe each polygon. We have the project specific vegetation code developed specifically for this mapping effort that has considerable local detail. We have also cross-walked the project specific vegetation code to several others that will allow for analysis at various other scales and perspectives. These include two Anderson type landcover codes and the ecological system codes. Using these items one can then link to external databases that may contain more information than provided here. For example, if one links the El Code in Table 21 to the El Code in the GIS database one can query for a range of G or S ranked Ecological Systems, the plots in each or, after further linking to the plots database, a query for specific species with specific cover values, heights or any other item recorded as part of this effort.

The utility of this map extends from the very basic to the very involved. Much depends upon the sophistication and imagination of the user or the investigator. For the more advanced investigations one might expect the need for a GIS analyst.

Table 13. Spatial statistics for all map units in the mapping area.

VEG CODE	Map Unit Name	Count	Min ACRES	Max ACRES	Ave ACRES	Sum ACRES	SD ACRES	Var ACRES	Min HECT	Max HECT	Ave HECT	Sum HECT	SD HECT	Var HECT	Min ELEV (Ft)	Max ELEV (Ft)	Ave ELEV (Ft)	SD ELEV (Ft)
1	Herbaceous Upland Alpine > 9600 ft	1243	0.1	447.5	11.6	14407.3	33.1	1093.5	0.0	181.1	4.7	5830.6	13.4	179.1	9603	13146	11196	649
2	Herbaceous Upland Alpine Fellfield		0.1	1682.4	28.8	19712.6	113.3	12829.6	0.0	680.9	11.7	7977.6	45.8	2101.2	9504	13281	11455	597
4	Herbaceous Upland Montane < 9600 ft	1519	0.0	385.5	6.1	9201.6	19.6	382.4	0.0	156.0	2.5	3723.9	7.9	62.6	7005	9593	8402	501
5	Herbaceous Wetland Cross Zone - Marsh	59	0.1	9.3	1.3	76.2	1.7	2.8	0.0	3.8	0.5	30.8	0.7	0.5	7444	11197	9326	999
6	Herbaceous Wetland Cross Zone - Wetland	1935	0.0	273.0	3.8	7355.9	12.3	150.1	0.0	110.5	1.5	2976.9	5.0	24.6	7356	12395	10227	1013
7	Herbaceous Wetland Subalpine / Alpine - Alpine Mead	1374	0.0	928.8	15.6	21454.5	58.5	3424.9	0.0	375.9	6.3	8682.5	23.7	560.9	8376	13333	11182	667
9	Glacier	93	0.1	33.0	3.9	358.5	5.9	34.3	0.0	13.3	1.6	145.1	2.4	5.6	9616	13317	11866	609
10	Rock (Alpine-Upper Subalpine)	559	0.0	274.7	6.0	3366.6	19.3	373.4	0.0	111.2	2.4	1362.4	0.3	61.2	8120	13615	11234	848
11	Rock (Foothill-Lower Subalpine)	2229	0.0	25.9	1.3	2893.2	2.1	4.4	0.0	10.5	0.5	1170.9	0.9	0.7	7159	11525	9380	879
13	Shrub Upland Alpine	729	0.1	443.2	6.3	4622.7	22.8	521.6	0.0	179.4	2.6	1870.8	9.2	85.4	8737	12401	11050	603
14	Shrub Upland Lower Montane - Undifferentiated	490	0.2	166.8	6.7	3300.4	14.7	216.6	0.1	67.5	2.7	1335.6	6.0	35.5	7034	10676	8376	646
15	Riparian Aspen	324	0.1	53.7	2.9	934.5	5.3	27.8	0.0	21.7	1.2	378.2	2.1	4.6	7001	10102	8483	703
18	Upper Montane Aspen	1349	0.1	62.1	1.9	2505.8	3.8	14.7	0.0	25.1	0.8	1014.1	1.6	2.4	7211	10955	8904	623
20	Lower Montane Douglas-fir	2282	0.1	402.7	16.7	38148.7	29.3	858.6	0.0	163.0	6.8	15438.6	11.9	140.6	7083	11312	8581	637
22	Subalpine Mixed Conifer	4521	0.0	1400.9	23.0	103841.6	76.7	5876.3	0.0	566.9	9.3	42024.1	31.0	962.4	8054	11965	10435	696
23	Lodgepole Pine - High Elevation > 9500 ft	1039	0.1	668.3	25.5	26498.6	52.9	2801.3	0.0	270.5	10.3	10723.8	21.4	458.8	9501	11256	10067	408
24	Lodgepole Pine - Low Elevation < 9500 ft	2441	0.1	904.1	18.0	43933.6	46.6	2174.6	0.0	365.9	7.3	17779.7	18.9	356.1	7333	9498	8831	370
26	Lodgepole Pine - Rock	145	0.3	181.4	8.3	1198.7	18.0	324.1	0.1	73.4	3.4	485.1	7.3	53.1	7949	10955	9456	688
32	Cottonwood	29	0.1	11.7	2.7	77.5	3.0	8.8	0.0	4.7	1.1	31.4	1.2	1.4	7014	9698	8052	718
33	Juniper	103	0.2	53.1	8.6	890.0	10.1	101.8	0.1	21.5	3.5	360.2	4.1	16.7	7067	10059	8364	620
34	Ponderosa pine Graminoid	1137	0.0	487.3	12.2	13863.7	24.3	589.6	0.0	197.2	4.9	5610.6	9.8	96.6	7129	9964	8291	463
35	Ponderosa pine Rockland	805	0.2	350.8	14.5	11692.8	30.6	936.5	0.1	142.0	5.9	4732.0	12.4	153.4	7254	10453	8345	501
36	Ponderosa pine Shrubland	797	0.2	208.0	15.7	12530.5	23.9	573.3	0.1	84.2	6.4	5071.0	9.7	93.9	7011	10535	8184	467
38	Subalpine Limber Pine	509	0.1	241.3	12.9	6552.0	22.6	509.4	0.1	97.6	5.2	2651.6	9.1	83.4	8287	11319	10187	605
39	Ribbon Forest - Islands	14	0.3	20.3	7.9	110.7	7.3	53.0	0.1	8.2	3.2	44.8	3.0	8.7	11132	11571	11389	132
41	Disturbance - Dead and Down	108	0.2	299.0	10.3	1111.0	33.6	1126.9	0.1	121.0	4.2	449.6	13.6	184.6	7815	11256	9407	852
43	Blue Spruce	95	0.1	43.0	5.2	495.1	7.2	51.1	0.0	17.4	2.1	200.4	2.9	8.4	7083	10341	8318	604
46	Talus	1561	0.1	2361.7	10.8	16847.4	69.1	4770.0	0.0	955.8	4.4	6818.1	28.0	781.2	7746	14006	10624	760
47	Outwash	5	1.0	110.3	26.5	132.3	47.3	2233.2	0.4	44.6	10.7	53.5	19.1	365.8	8569	11867	10176	1426
48	Exposed Soil Man-made	50	0.1	142.5	10.4	521.6	27.8	772.4	0.1	57.7	4.2	211.1	11.3	126.5	8054	11663	8781	759
49	Cliff face – Bare soil / Rock	162	0.2	3255.0	103.4	16754.6	307.9	94778.9	0.1	1317.3	41.9	6780.5	124.6	15522.7	7067	13510	11282	1162
51	Streams - rivers	38	0.1	20.1	5.2	199.0	5.4	29.5	0.0	8.2	2.1	80.5	2.2	4.8	7096	11417	8731	921
52	Natural Lakes - Ponds	531	0.0	829.4	4.6	2435.6	37.5	1406.6	0.0	335.7	1.9	985.7	15.2	230.4	7093	13192	10304	1242

VEG CODE	Map Unit Name	Count	Min ACRES	Max ACRES	Ave ACRES	Sum ACRES	SD ACRES	Var ACRES	Min HECT	Max HECT	Ave HECT	Sum HECT	SD HECT	Var HECT	Min ELEV (Ft)	Max ELEV (Ft)	Ave ELEV (Ft)	SD ELEV (Ft)
53	Reservoirs – Stock Tanks	51	0.1	1299.8	40.8	2081.5	193.0	37242.5	0.1	526.0	16.5	842.4	78.1	6099.5	7474	10613	8488	616
120	Shrub Riparian Cross Zone > 9600 ft	469	0.1	562.7	8.3	3866.9	35.0	1224.0	0.0	227.7	3.3	1564.9	14.2	200.5	9609	12113	10850	588
121	Shrub Riparian Cross Zone < 9600 ft	506	0.1	291.4	6.5	3284.0	20.6	424.6	0.0	117.9	2.6	1329.0	8.3	69.5	7126	11023	8548	520
141	Shrub Upland Lower Montane - Big Sagebrush	156	0.2	205.8	6.8	1059.7	19.0	361.6	0.1	83.3	2.8	428.8	7.7	59.2	7274	9527	8491	313
142	Shrub Upland Lower Montane - Bitterbrush	63	0.4	28.3	3.4	215.8	4.2	17.6	0.2	11.5	1.4	87.3	1.7	2.9	7050	9239	8302	535
161	Mixed Conifer with Aspen (Ponderosa pine)	403	0.1	70.3	5.1	2065.5	7.9	63.1	0.0	28.5	2.1	835.9	3.2	10.3	7044	9796	8462	448
162	Mixed Conifer with Aspen (Lodgepole Pine)	461	0.1	104.3	4.0	1832.8	8.9	78.7	0.0	42.2	1.6	741.7	3.6	12.9	7851	10702	9006	468
163	Mixed Conifer with Aspen (Douglas-fir)	532	0.1	122.0	5.3	2811.8	11.5	132.7	0.0	49.4	2.1	1137.9	4.7	21.7	7451	10371	8810	494
164	Mixed Conifer with Aspen (Spruce - Fir)	253	0.1	65.0	5.1	1292.6	8.2	67.8	0.0	26.3	2.1	523.1	3.3	11.1	8107	10869	9327	533
190	Riparian Upper Montane Mixed Conifer > 8500 ft	662	0.1	372.9	12.5	8255.4	30.3	915.3	0.0	150.9	5.1	3340.9	12.2	149.9	8517	11699	10143	927
191	Riparian Lower Montane Mixed Conifer < 8500 ft	134	0.5	35.2	7.2	960.4	7.2	52.5	0.2	14.2	2.9	388.7	2.9	8.6	7228	8497	8083	299
400	Krummholz	3358	0.0	94.9	2.7	9121.1	6.6	43.1	0.0	38.4	1.1	3691.3	2.7	7.1	10138	12126	11325	282
999	Un-vegetated surface	144	0.3	721.7	18.4	2645.5	64.9	4208.9	0.1	292.1	7.4	1070.6	26.3	689.3	7431	11824	8403	829

Table 14. Summary area statistics for map units within ROMO.

VEG CODE	COUNT	Sum ACRES	Sum HECTARES
1	1052	13503	5464
2	532	18528	7498
4	396	1939	785
5	25	38	15
6	1518	5759	2331
7	1058	19200	7770
9	74	260	105
10	452	3052	1235
11	1201	1720	696
13	643	4135	1673
14	186	1334	540
15	107	296	120
18	512	1123	454
20	741	10887	4406
22	3547	85736	34697
23	852	22456	9088
24	1232	23852	9653
26	107	952	385
32	17	31	12
33	50	359	145
34	196	1391	563
35	247	3007	1217
36	205	3586	1451
38	401	5392	2182
39	14	111	45
41	89	899	364
43	22	115	46
46	1284	14768	5976
47	5	132	54
48	20	249	101
49	130	15933	6448
51	18	124	50
52	410	2073	839
53	7	1324	536
120	393	3522	1425
121	284	2575	1042
141	46	274	111
142	31	128	52
161	90	499	202
162	212	837	339
163	187	999	404
164	137	629	255
190	535	6721	2720
191	39	199	80
400	2747	7732	3129
999	28	1174	475

Fuzzy Accuracy Assessment

The use of "fuzzy" techniques to describe the accuracy of thematic maps is a useful if somewhat ambiguous tool. Now one is forced to interpret the thematic accuracy of a product from multiple perspectives and a number of caveats. There is no "one" figure to use as an estimate for either overall or individual map unit accuracies. It is now standard to couch the results in statistical parlance of confidence intervals and sample sizes. Its use in many thematic products today originates from the recognition that the binary approach of either "right" or "wrong" belies the true nature of most map units and even the view from the person or persons providing the "reference" data.

The great utility of a fuzzy approach is the acknowledgement of degrees of correctness. Only occasionally do map units have discrete boundaries; more often grading into one another over distances ranging from a few to hundreds of meters. The necessity of drawing discrete lines representing non-discrete entities requires other than a binary approach.

We performed a fuzzy accuracy assessment on the digital thematic map for ROMO. Only vegetated map units were sampled. Table 10 describes the 5 fuzzy classes used during this analysis. This concept and class descriptions was first described by Gopal and Woodcock (1994) using fuzzy set theory described by Zadeh (1965). A fuzzy class was only analyzed using a contingency table for the top three fuzzy classes that are considered "correct. The overall map accuracies for each of the fuzzy classes are outlined in Table 15 and include a 90% confidence interval and Kappa statistic. The contingency table detailed results are shown in Table 16, Table 17 and Table 18 for fuzzy classes 5, 4 and 3 respectively. Each map unit is analyzed in terms of its individual accuracy for omission and commission (producer's error and user's error respectively) for three levels of fuzzy accuracy and includes a 90% confidence interval. A summary table of all map unit accuracies for both omission and commission for all fuzzy levels is shown in Table 19. Mean errors of omission and commission for each fuzzy level are shown in the last row in Table 19 and separately in Table 20. Individual map unit metrics are discussed below.

Comparison of mean overall and omission/commission accuracies between fuzzy levels: Predictably, overall map accuracy increases as one relaxes requirements for individual map unit membership. Table 15 shows the increasing overall accuracy from fuzzy level 5 to fuzzy level 3. We also include a Kappa statistic as a metric of the overall accuracy. This statistic assumes that a certain number of correct classifications will occur by chance. Therefore, the Kappa statistic penalizes the overall map accuracy. The mean error for omission and commission also increase as one relaxes map unit membership requirements.

Table 15. Overall map accuracies for each fuzzy class.

Fuzzy Class	**Overall Map Accuracy**	**Standard Deviation (90% - two tailed)**	**Overall Map Accuracy (Kappa)**
5	50.3	2.4	47.5
4	74.7	2.1	72.4
3	86.7	1.7	80.9

.

Fuzzy 5

Reference (Accuracy Assessment Field Data)

Sample Data (Polygon Map Data)

	1	**2**	**4**	**5**	**6**	**7**	**13**	**14**	**15**	**18**	**20**	**22**	**23**	**24**	**26**	**32**	**33**	**34**	**35**	**36**	**38**	**41**	**43**	**120**	**121**	**141**	**142**	**161**	**162**	**163**	**164**	**190**	**191**	**400**	Sum	Commission Error %Correct	+/ - (90% Conf. Interval)
1	31	8	0	0	0	13	3	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	59.0	52.5%	11.5%
2	3	7	0	0	0	4	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	17.0	41.2%	22.6%
4	0	0	28	0	0	0	0	1	0	0	3	0	0	0	0	0	0	1	0	1	0	0	0	0	0	1	2	0	0	0	0	0	0	0	37.0	75.7%	13.0%
5	0	0	1	7	7	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	18.0	38.9%	21.7%
6	0	0	1	0	24	2	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	33.0	72.7%	14.3%
7	12	1	0	0	4	23	7	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	1	51.0	45.1%	12.4%
13	2	0	0	0	0	1	13	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	12	1	0	0	0	1	0	1	0	0	4	37.0	35.1%	14.3%
14	0	0	3	0	0	0	0	4	0	2	0	0	0	0	0	0	0	0	0	9	0	0	0	0	2	0	8	0	0	0	0	0	0	0	28.0	14.3%	12.7%
15	0	0	0	0	1	0	0	1	12	7	0	0	0	0	0	3	0	0	0	0	0	0	0	0	1	0	0	2	0	1	0	1	1	0	30.0	40.0%	16.4%
18	0	0	0	0	0	0	0	0	7	20	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	1	0	1	0	0	1	0	0	0	32.0	62.5%	15.6%
20	0	0	0	0	0	1	0	0	0	0	15	2	3	8	2	0	0	6	3	14	2	0	0	0	0	0	0	1	0	0	0	0	0	0	57.0	26.3%	10.5%
22	0	0	0	0	0	0	0	0	0	0	0	59	4	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	1	67.0	88.1%	7.3%
23	0	0	0	0	0	0	0	0	0	0	0	6	17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	25.0	68.0%	17.3%
24	0	0	0	0	0	0	0	0	0	0	1	1	0	34	1	0	0	0	1	2	1	0	0	0	0	0	0	0	1	0	0	0	1	0	43.0	79.1%	11.4%
26	0	0	0	0	0	0	0	0	0	1	2	7	5	1	9	0	0	0	2	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	28.0	32.1%	16.3%
32	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4.0	25.0%	48.1%
33	1	0	0	0	0	0	0	2	0	0	3	0	0	0	0	0	13	2	1	7	0	0	0	0	0	0	1	0	0	0	0	0	0	0	30.0	43.3%	16.5%
34	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	14	0	12	0	0	0	0	0	0	1	1	0	1	0	0	0	0	31.0	45.2%	16.3%
35	0	0	0	0	0	0	0	0	0	0	7	0	1	2	0	0	0	2	10	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	31.0	32.3%	15.4%
36	0	0	0	0	0	0	0	1	0	0	2	0	0	1	0	0	0	7	1	19	0	0	0	0	0	1	0	0	0	0	0	0	0	0	32.0	59.4%	15.8%
38	0	1	0	0	0	0	0	0	0	0	3	10	3	2	1	0	0	0	0	0	12	0	0	0	0	1	0	0	0	0	0	0	0	1	34.0	35.3%	15.0%
41	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	3	1	2	1	47	0	0	0	0	0	0	0	0	1	0	0	0	57.0	82.5%	9.2%
43	0	0	0	0	0	0	0	0	0	0	2	6	0	1	0	0	0	1	0	2	0	0	7	0	0	0	0	0	0	0	1	1	1	0	22.0	31.8%	18.6%
120	2	0	0	0	6	6	3	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	22	0	0	0	0	0	0	0	0	0	1	41.0	53.7%	14.0%
121	0	0	0	0	1	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	27	0	0	0	1	1	0	0	0	0	32.0	84.4%	12.1%
141	0	0	2	0	1	0	0	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	19	4	0	0	0	0	0	0	0	33.0	57.6%	15.7%
142	0	0	4	0	0	0	0	6	0	0	1	0	0	0	0	0	2	0	0	3	0	0	0	0	0	0	13	0	0	0	0	0	0	0	29.0	44.8%	16.9%
161	0	0	0	0	0	0	0	0	1	3	1	0	0	1	0	0	1	5	1	5	0	0	0	0	2	0	0	5	1	1	0	0	0	0	27.0	18.5%	14.1%
162	0	0	0	0	0	0	0	0	0	0	2	7	2	0	1	0	0	0	0	0	0	0	1	0	0	0	0	1	15	1	4	0	0	0	34.0	44.1%	15.5%
163	0	0	0	0	0	0	0	0	0	0	1	4	0	4	1	0	0	0	0	2	1	0	0	0	0	0	0	2	4	3	2	1	0	0	25.0	12.0%	12.7%
164	0	0	0	0	0	0	0	0	1	3	2	4	2	2	0	0	0	0	0	1	0	0	0	0	0	0	0	0	4	1	7	0	3	0	30.0	23.3%	14.4%
190	0	0	0	0	0	0	0	0	0	0	0	28	2	4	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	1	6	0	1	44.0	13.6%	9.6%
191	0	0	0	0	0	0	0	0	0	0	3	1	0	0	1	0	0	2	0	6	0	0	4	0	0	0	0	1	1	0	0	0	4	0	23.0	17.4%	15.2%
400	0	0	0	0	0	2	0	0	0	0	0	10	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	47	61.0	77.0%	9.7%
Sum	51	17	39	7	44	52	30	23	22	40	50	149	39	63	16	4	16	43	20	98	22	48	12	40	36	23	29	14	30	9	19	10	10	57	Total Correct = 594 Total Samples = 1182		
% Accurate	60.8%	41.2%	71.8%	100.0%	54.5%	44.2%	43.3%	17.4%	54.5%	50.0%	30.0%	39.6%	43.6%	54.0%	56.3%	25.0%	81.3%	32.6%	50.0%	19.4%	54.5%	97.9%	58.3%	55.0%	75.0%	82.6%	44.8%	35.7%	50.0%	33.3%	36.8%	60.0%	40.0%	82.5%			
+/ - (90% Conf. Interval)	12.2%	22.6%	13.1%	7.1%	13.5%	12.3%	16.5%	15.2%	19.7%	14.3%	11.7%	6.9%	14.3%	11.1%	23.5%	48.1%	19.2%	12.9%	20.9%	7.1%	19.7%	4.4%	27.6%	14.2%	13.3%	15.2%	16.9%	24.6%	16.7%	31.4%	20.8%	30.5%	30.5%	9.2%			

OVERALL TOTAL ACCURACY = 50.3%   OVERALL KAPPA INDEX = 47.5%   OVERALL 90% UPPER AND LOWER CONFIDENCE INTERVAL: 47.9% and 52.7%

Producers Accuracy (Omission Error) Confidence Interval is 90% two-sided limit

Users Accuracy (Commission Error) Confidence Interval is 90% two-sided limit

Table 16. Contingency table for fuzzy accuracy assessment level 5.

Fuzzy 4

Reference (Accuracy Assessment Field Data)

Sample Data (Polygon Map Data)

	1	2	4	5	6	7	13	14	15	18	20	22	23	24	26	32	33	34	35	36	38	41	43	120	121	141	142	161	162	163	164	190	191	400	Sum	Commission Error %Correct	+/- (90% Conf. Interval)
1	38	6	0	0	0	9	2	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	59	64.4%	11.1%
2	1	14	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	20	70.0%	19.4%
4	0	0	35	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	37	94.6%	7.5%
5	0	0	1	15	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	18	83.3%	17.2%
6	0	0	0	0	31	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	33	93.9%	8.3%
7	11	1	0	0	0	32	5	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	51	62.7%	12.1%
13	2	0	0	0	0	1	21	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	7	1	0	0	0	1	0	0	0	0	3	37	56.8%	14.7%
14	0	0	1	0	0	0	0	24	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	28	85.7%	12.7%
15	0	0	0	0	0	0	0	1	17	5	0	0	0	0	0	3	0	0	0	0	0	0	0	0	1	0	0	1	0	1	0	1	0	0	30	56.7%	16.5%
18	0	0	0	0	0	0	0	0	6	24	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	32	75.0%	14.2%
20	0	0	0	0	0	1	0	0	0	0	39	2	3	2	2	0	0	1	1	5	0	0	0	0	0	0	0	1	0	0	0	0	0	0	57	68.4%	11.0%
22	0	0	0	0	0	0	0	0	0	0	0	59	4	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	1	67	88.1%	7.3%
23	0	0	0	0	0	0	0	0	0	0	0	4	21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	25	84.0%	14.1%
24	0	0	0	0	0	0	0	0	0	0	1	0	0	38	0	0	0	0	0	2	1	0	0	0	0	0	0	0	1	0	0	0	0	0	43	88.4%	9.2%
26	0	0	0	0	0	0	0	0	0	1	2	4	0	0	20	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	28	71.4%	15.8%
32	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	25.0%	48.1%
33	1	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	24	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	30	80.0%	13.7%
34	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	28	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	31	90.3%	10.3%
35	0	0	0	0	0	0	0	0	0	0	4	0	1	1	0	0	0	0	25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	31	80.6%	13.3%
36	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	32	0	0	0	0	0	0	0	0	0	0	0	0	0	0	32	100.0%	1.6%
38	0	0	0	0	0	0	0	0	0	0	3	4	1	1	1	0	0	0	0	0	23	0	0	0	0	1	0	0	0	0	0	0	0	0	34	67.6%	14.7%
41	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	3	1	2	1	47	0	0	0	0	0	0	0	0	1	0	0	0	57	82.5%	9.2%
43	0	0	0	0	0	0	0	0	0	0	2	6	0	1	0	0	0	0	0	1	0	0	9	0	0	0	0	0	0	0	1	1	1	0	22	40.9%	19.5%
120	2	0	0	0	0	6	2	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	29	0	0	0	0	0	0	0	0	0	1	41	70.7%	12.9%
121	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	28	0	0	0	1	1	0	0	0	0	32	87.5%	11.2%
141	0	0	1	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	27	0	0	0	0	0	0	0	0	33	81.8%	12.6%
142	0	0	0	0	0	0	0	5	0	0	1	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	21	0	0	0	0	0	0	0	29	72.4%	15.4%
161	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0	1	0	0	4	0	0	0	0	0	0	0	17	1	1	0	0	0	0	27	63.0%	17.1%
162	0	0	0	0	0	0	0	0	0	0	1	2	1	0	1	0	0	0	0	0	0	0	1	0	0	0	0	1	25	1	1	0	0	0	34	73.5%	13.9%
163	0	0	0	0	0	0	0	0	0	0	0	3	0	2	1	0	0	0	0	1	0	0	0	0	0	0	0	0	2	14	1	1	0	0	25	56.0%	18.3%
164	0	0	0	0	0	0	0	0	0	0	1	0	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	24	0	0	0	30	80.0%	13.7%
190	0	0	0	0	0	0	0	0	0	0	0	17	2	3	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	20	0	1	44	45.5%	13.5%
191	0	0	0	0	0	0	0	0	0	0	3	1	0	0	1	0	0	2	0	6	0	0	1	0	0	0	0	0	1	0	0	0	8	0	23	34.8%	18.5%
400	0	0	0	0	0	1	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	55	61	90.2%	7.1%
Sum	55	21	38	15	32	53	31	35	25	37	64	109	35	52	26	4	26	34	28	61	29	48	11	38	32	28	21	20	33	20	28	24	9	63	Total Correct = 885 Total Samples = 1185		
% Accurate	69.1%	66.7%	92.1%	100.0%	96.9%	60.4%	67.7%	68.6%	68.0%	64.9%	60.9%	54.1%	60.0%	73.1%	76.9%	25.0%	92.3%	82.4%	89.3%	52.5%	79.3%	97.9%	81.8%	76.3%	87.5%	96.4%	100.0%	85.0%	75.8%	70.0%	85.7%	83.3%	88.9%	87.3%			
+/ - (90% Conf. Interval)	11.2%	19.3%	8.5%	3.3%	6.6%	12.0%	15.4%	14.3%	17.3%	14.3%	10.8%	8.3%	15.1%	11.1%	15.5%	48.1%	10.5%	12.2%	11.4%	11.3%	14.1%	4.4%	23.7%	12.7%	11.2%	7.6%	2.4%	15.6%	13.8%	19.4%	12.7%	14.6%	22.8%	7.7%			

Users Accuracy (Commission Error) Confidence Interval is 90% two-sided limit

OVERALL TOTAL ACCURACY = 74.7% OVERALL KAPPA INDEX = 72.4% OVERALL 90% UPPER AND LOWER CONFIDENCE INTERVAL: 72.6% and 76.8%

Producers Accuracy (Omission Error) Confidence Interval is 90% two-sided limit

Table 17. Contingency table for fuzzy accuracy assessment level 4.

Fuzzy 3

Reference (Accuracy Assessment Field Data)

Sample Data (Polygon Map Data)

	1	2	4	5	6	7	13	14	15	18	20	22	23	24	26	32	33	34	35	36	38	41	43	120	121	141	142	161	162	163	164	190	191	400	Sum	Commission Error %Correct	+/ - (90% Conf. Interval)
1	49	3	0	0	0	4	1	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	60	81.7%	9.1%
2	0	20	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	23	87.0%	13.7%
4	0	0	35	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	37	94.6%	7.5%
5	0	0	1	15	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	18	83.3%	17.2%
6	0	0	0	0	33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	33	100.0%	1.5%
7	10	1	0	0	0	36	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	51	70.6%	11.5%
13	2	0	0	0	0	1	30	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	2	37	81.1%	11.9%
14	0	0	1	0	0	0	0	26	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	29	89.7%	11.0%
15	0	0	0	0	0	0	0	1	28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	30	93.3%	9.2%
18	0	0	0	0	0	0	0	0	0	30	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	32	93.8%	8.6%
20	0	0	0	0	0	0	0	0	0	0	48	0	3	1	2	0	0	1	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	57	84.2%	8.8%
22	0	0	0	0	0	0	0	0	0	0	0	66	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	67	98.5%	3.2%
23	0	0	0	0	0	0	0	0	0	0	0	3	22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	25	88.0%	12.7%
24	0	0	0	0	0	0	0	0	0	0	1	0	0	41	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	43	95.3%	6.4%
26	0	0	0	0	0	0	0	0	0	1	0	4	0	0	22	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	28	78.6%	14.5%
32	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	25.0%	48.1%
33	1	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	26	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	30	86.7%	11.9%
34	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	31	96.8%	6.8%
35	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	31	93.5%	8.9%
36	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	32	0	0	0	0	0	0	0	0	0	0	0	0	0	0	32	100.0%	1.6%
38	0	0	0	0	0	0	0	0	0	0	1	3	0	1	0	0	0	0	0	0	28	0	0	0	0	1	0	0	0	0	0	0	0	0	34	82.4%	12.2%
41	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	3	1	2	1	47	0	0	0	0	0	0	0	0	1	0	0	0	57	82.5%	9.2%
43	0	0	0	0	0	0	0	0	0	0	2	6	0	1	0	0	0	0	0	1	0	0	9	0	0	0	0	0	0	0	1	1	1	0	22	40.9%	19.5%
120	2	0	0	0	0	6	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	31	0	0	0	0	0	0	0	0	0	1	41	75.6%	12.3%
121	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	30	0	0	0	1	0	0	0	0	0	32	93.8%	8.6%
141	0	0	1	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	29	0	0	0	0	0	0	0	0	33	87.9%	10.9%
142	0	0	0	0	0	0	0	5	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	22	0	0	0	0	0	0	0	29	75.9%	14.8%
161	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	24	0	0	0	0	0	0	27	88.9%	11.8%
162	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	33	0	0	0	0	0	34	97.1%	6.2%
163	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	23	0	0	0	0	25	92.0%	10.9%
164	0	0	0	0	0	0	0	0	0	0	0	0	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	27	0	0	0	30	90.0%	10.7%
190	0	0	0	0	0	0	0	0	0	0	0	4	2	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	34	0	1	44	77.3%	11.5%
191	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	15	0	23	65.2%	18.5%
400	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	61	61	100.0%	0.8%
Sum	64	24	38	15	33	49	35	35	29	36	62	91	31	52	24	1	27	34	31	51	29	48	9	31	31	30	22	24	35	23	29	35	16	66	Total Correct = 885 Total Samples = 1185		
% Accurate	76.6%	83.3%	92.1%	100.0%	100.0%	73.5%	85.7%	74.3%	96.6%	83.3%	77.4%	72.5%	71.0%	78.8%	91.7%	100.0%	96.3%	88.2%	93.5%	62.7%	96.6%	97.9%	100.0%	100.0%	96.8%	96.7%	100.0%	100.0%	94.3%	100.0%	93.1%	97.1%	93.8%	92.4%			
+/ - (90% Conf. Interval)	9.5%	14.6%	8.5%	3.3%	1.5%	11.4%	11.2%	13.6%	7.3%	11.6%	9.5%	8.2%	15.0%	10.3%	11.4%	50.0%	7.8%	10.6%	8.9%	12.1%	7.3%	4.4%	5.6%	1.6%	6.8%	7.1%	2.3%	2.1%	7.9%	2.2%	9.5%	6.1%	13.1%	6.1%			

Users Accuracy (Commission Error) Confidence Interval is 90% two-sided limit

OVERALL TOTAL ACCURACY = 86.7% OVERALL KAPPA INDEX = 80.9% OVERALL 90% UPPER AND LOWER CONFIDENCE INTERVAL: 85% and 88.4%

Producers Accuracy (Omission Error) Confidence Interval is 90% two-sided limit

Table 18. Contingency table for fuzzy accuracy assessment level 3.

Table 19. Map unit accuracies for omission and commission errors for all errors at all fuzzy levels (only vegetated polygons).

VEG CODE	Map Unit Name	Fuzzy 5		Fuzzy 4		Fuzzy 3	
		Users' accuracy	Producers' accuracy	Users' accuracy	Producers' accuracy	Users' accuracy	Producers' accuracy
1	Herbaceous Upland Alpine > 9600 ft	52.5%	60.8%	64.4%	69.1%	81.7%	76.6%
2	Herbaceous Upland Alpine Fellfield	41.2%	41.2%	70.0%	66.7%	87.0%	83.3%
4	Herbaceous Upland Montane < 9600 ft	75.7%	71.8%	94.6%	92.1%	94.6%	92.1%
5	Herbaceous Wetland Cross Zone - Marsh	38.9%	100.0%	83.3%	100.0%	83.3%	100.0%
6	Herbaceous Wetland Cross Zone - Wetland	72.7%	54.5%	93.9%	96.9%	100.0%	100.0%
7	Herbaceous Wetland Subalpine / Alpine - Alpine Mead	45.1%	44.2%	62.7%	60.4%	70.6%	73.5%
13	Shrub Upland Alpine	35.1%	43.3%	56.8%	67.7%	81.1%	85.7%
14	Shrub Upland Lower Montane - Undifferentiated	14.3%	17.4%	85.7%	68.6%	89.7%	74.3%
15	Riparian Aspen	40.0%	54.5%	56.7%	68.0%	93.3%	96.6%
18	Upper Montane Aspen	62.5%	50.0%	75.0%	64.9%	93.8%	83.3%
20	Lower Montane Douglas-fir	26.3%	30.0%	68.4%	60.9%	84.2%	77.4%
22	Subalpine Mixed Conifer	88.1%	39.6%	88.1%	54.1%	98.5%	72.5%
23	Lodgepole Pine - High Elevation > 9500 ft	68.0%	43.6%	84.0%	60.0%	88.0%	71.0%
24	Lodgepole Pine - Low Elevation < 9500 ft	79.1%	54.0%	88.4%	73.1%	95.3%	78.8%
26	Lodgepole Pine - Rock	32.1%	56.3%	71.4%	76.9%	78.6%	91.7%
32	Cottonwood	25.0%	25.0%	25.0%	25.0%	25.0%	100.0%
33	Juniper	43.3%	81.3%	80.0%	92.3%	86.7%	96.3%
34	Ponderosa pine Graminoid	45.2%	32.6%	90.3%	82.4%	96.8%	88.2%
35	Ponderosa pine Rockland	32.3%	50.0%	80.6%	89.3%	93.5%	93.5%
36	Ponderosa pine Shrubland	59.4%	19.4%	100.0%	52.5%	100.0%	62.7%
38	Subalpine Limber Pine	35.3%	54.5%	67.6%	79.3%	82.4%	96.6%
41	Disturbance - Dead and Down	82.5%	97.9%	82.5%	97.9%	82.5%	97.9%
43	Blue Spruce	31.8%	58.3%	40.9%	81.8%	40.9%	100.0%
120	Shrub Riparian Cross Zone > 9600 ft	53.7%	55.0%	70.7%	76.3%	75.6%	100.0%
121	Shrub Riparian Cross Zone < 9600 ft	84.4%	75.0%	87.5%	87.5%	93.8%	96.8%
141	Shrub Upland Lower Montane - Big Sagebrush	57.6%	82.6%	81.8%	96.4%	87.9%	96.7%
142	Shrub Upland Lower Montane - Bitterbrush	44.8%	44.8%	72.4%	100.0%	75.9%	100.0%
161	Mixed Conifer with Aspen (Ponderosa pine)	18.5%	35.7%	63.0%	85.0%	88.9%	100.0%
162	Mixed Conifer with Aspen (Lodgepole Pine)	44.1%	50.0%	73.5%	75.8%	97.1%	94.3%
163	Mixed Conifer with Aspen (Douglas-fir)	12.0%	33.3%	56.0%	70.0%	92.0%	100.0%
164	Mixed Conifer with Aspen (Spruce - Fir)	23.3%	36.8%	80.0%	85.7%	90.0%	93.1%
190	Riparian Upper Montane Mixed Conifer > 8500 ft	13.6%	60.0%	45.5%	83.3%	77.3%	97.1%
191	Riparian Lower Montane Mixed Conifer < 8500 ft	17.4%	40.0%	34.8%	88.9%	65.2%	93.8%
400	Krummholz	77.0%	82.5%	90.2%	87.3%	100.0%	92.4%
Mean		**46.26%**	**52.23%**	**72.52%**	**76.94%**	**84.45%**	**89.89%**

Table 20. Change in mean map unit accuracies by fuzzy level.

	Omission (Producers error)	Commission (Users error)
Fuzzy 5	52.2	46.3
Fuzzy 4	77	72.5
Fuzzy 3	90	84.4

Accuracy Assessment by Map Unit.

Herbaceous Upland Alpine
Map Unit – 1

Most of the errors for both omission and commission in fuzzy class 5 are with map unit 7 – Alpine Meadows. This may be an artifact of the extremely dry year when the photographs were acquired. Secondarily, errors for both omission and commission are with map unit 2 – Alpine Fellfield. Often, the rocks one sees in fell-fields are small and thus fall below the photographic grain making them look like drier upland herbaceous areas. Fuzzy class 4 accuracy for this map unit improves slightly as AA points described fellfield are moved into this map unit. This trend continues for fuzzy class 3. Both errors of omission and commission are roughly the same.

Herbaceous Upland Alpine Fellfield
Map Unit – 2

Most of the errors for both omission and commission in fuzzy class 5 are with map unit 1 – Herbaceous Upland Alpine. Both omission and commission errors are significant yielding only 41.2% for both. Often, the rocks one sees in fellfields are small and thus fall below the photographic grain. This then makes the signature much like drier upland herbaceous areas. In addition, the photographic signature provided by field plots shows a high amount of rock thus confusing the interpretation. Fuzzy class 4 accuracy for this map unit improves slightly as AA points described as alpine meadow are moved into this map unit. This trend continues for fuzzy class 3. Both errors of omission and commission are roughly the same.

Herbaceous Upland Montane > 9600 ft.
Map Unit – 4

Most of the errors for both omission and commission in fuzzy class 5 are with the upland shrub map units 14, 141 and 142. The error appears to be a matter of shrub density, that is, low density shrub areas are often photo-interpreted as herbaceous. Fuzzy class 4 accuracy for this map unit improves significantly, as AA points described as shrub are moved into this map unit. There is no additional increase in accuracy as on looks at fuzzy class 3. Both errors of omission and commission are roughly the same.

Herbaceous Wetland Cross Zone - Marsh
Map Unit – 5

There are no errors in this map unit. This map unit is rare within the mapping area but it does have a distinct signature and is difficult to misinterpret. Some AA points described wetlands or wet meadows, however, when one looks at the imagery one finds the area sampled to be underwater or shoreline. Adjustments were made accordingly and the photo-interpretation was assumed to be absolutely correct – fuzzy class 5.

Herbaceous Wetland Cross Zone - Wetland
Map Unit – 6

The errors in this map unit are almost exclusively with other "wet" map units such as alpine wet meadows – map unit 7, marshes – map unit 5 and riparian cross-zone shrublands – map unit 120. The error associated with map units 5 and 7 are "degrees of wetness" interpretations in the AA plots. In addition, the photography was acquired during a drier than normal year and the AA points were acquired during a wetter than normal year creating a notable point of reference difference. The error associated with the riparian shrubland map unit is a density issue. Low-density riparian shrublands are often interpreted as wetlands. Error of omission is very high (44.2% correct) and reasonable (72.7% correct) for errors of commission in fuzzy class 5. These improve markedly for fuzzy class 4 and are 100% correct for fuzzy class 3.

Herbaceous Wetland Subalpine / Alpine – Alpine Meadow
Map Unit – 7

The errors in this map unit are primarily with Herbaceous Alpine – map unit 1 and wetlands – map unit 6. This is not too surprising as this map unit sits between the two in a wetness scale. Secondarily, there are omission and commission errors with riparian shrublands – map unit 120. The error associated with the riparian shrubland map unit is a density issue. Low-density riparian shrublands are often interpreted as wetlands or in this case, wet meadows. At fuzzy class 5 we have a low accuracy for both omission and commission (44.2% and 45.1% respectively). These both improve markedly for fuzzy class 4 and minimally more for fuzzy class 3 leaving this map unit below the mapping accuracy norm of 80%. The greatest error for this map unit even after the application of fuzzy assessment is with herbaceous upland meadows – map unit 1.

Shrub Upland Alpine
Map Unit – 13

The omission and commission errors in this map unit include alpine meadows and riparian shrublands. The errors appear to be both floristic and physiognomic and are both quite high (43.3% and 35.1% correct for errors of omission and commission respectively). The primary omission error is with wet meadows – map unit 7. This appears to be a density issue as described above with other map units. Mapped (photo-interpreted) low density upland alpine shrublands mapped as herbaceous, in this case wet meadow, are often assigned to an upland shrub community. In addition, many of the shrubs described are either small in stature making them hard to discern on photographs or are heavily browsed. These errors improve somewhat as one moves from fuzzy class 5 to fuzzy class 3. The other source of error is confusion with riparian shrub communities. Much of the error differentiating riparian shrub communities from upland shrub communities is the mental model used by the photo-interpreters. The assumption used was that riparian shrub communities are usually found adjacent to water and this it seems is wrong. Water percolating to the surface from springs or other sources quite distant from water bodies will allow for the development of riparian shrub communities. At fuzzy class 3 this map unit meets program standards.

Shrub Upland Montane – Undifferentiated
Map Unit – 14

Errors for this map unit are very high at fuzzy class 5. Almost all omission and commission errors for this map unit are with the two other shrub classes, Big Sagebrush – map unit 141 and Bitterbrush – map unit 142. It appears that errors of omission are the greatest for this map unit with the both shrub types and error of commission only with Bitterbrush. These errors improve markedly and meet program norms as one moves to fuzzy class 3. This is because many shrub communities share elements of both map unit 141 and 142. The secondary error is that of commission with the Ponderosa pine Shrub map unit – 36. This is a density issue as all of these errors occur in what that AA crews called Ponderosa pine woodland with very low tree density while the photo-interpreters called it shrubland and ignored the few trees in the polygon. This map unit does not meet program standards for error of omission but does for error of commission.

Riparian Aspen
Map Unit – 15

The greatest confusion here is with the other Aspen class (MU 18). At fuzzy level 5 we have 55% and 40% accuracies for omission and commission errors respectively. Errors of commission also included confusion with the mixed conifer – aspen classes (MU's 161 and 164). Accuracies improve to 65% and 75% for omission and commission errors respectively at fuzzy level 4. With increasing relaxation of membership requirements, we have 83% and 94% accuracies at fuzzy level 3.

Montane Aspen
Map Unit – 18

The greatest confusion here is with the other Aspen class (MU 15). At fuzzy level 5 we have 50% and 63% accuracies for omission and commission errors respectively. Errors of commission also included confusion with the mixed conifer – aspen classes (MU's 161 and 163). Accuracies improve to 68% and 57% for omission and commission errors respectively at fuzzy level 4. With increasing relaxation of membership requirements, we have 97% and 93% accuracies at fuzzy level 3.

Douglas-fir
Map Unit – 20

Errors for this map unit at fuzzy level 5 are very high and are spread across all conifer types. The errors of omission and commission are almost equal, 30% and 26.3% accurate respectively. The accuracy improves markedly at fuzzy level 4. Both accuracies more than double. The error trend is the same as errors are distributed across most conifer types. At fuzzy level 3 the accuracy is acceptable for errors of commission and approaches minimum levels for omission errors. The error in this map unit may be attributed to the great mixing found in Douglas-fir types in this area. All vegetation plots and AA plots showed a high cover of other conifers leading to the confusion. In addition, most of the Douglas-fir occurs outside the Park boundary to the east. These areas were not sampled during the initial vegetation survey and therefore had few photointerpretive reference points. A high proportion of the errors in both omission and commission occurred with the Ponderosa pine map units. This is in large part due to the recent encroachment of Douglas-fir into the Ponderosa pine zone. Often there existed areas of Ponderosa pine making up the primary canopy but with a high cover of Douglas-fir as a T2 layer. Although this could be discerned on the photographs, no map unit existed for this occurrence as well as a recognized vegetation description.

Subalpine Mixed conifer
Map Unit – 22

This class shows a marked difference at fuzzy level 5 between omission and commission errors. Errors of commission are minimal showing 88% accuracy while omission errors are high with accuracy of 40%. Most of the omission error lies with misclassification of lodgepole pine, limber pine and the riparian upper montane mixed conifer. The errors in the lodgepole pine area a result of a mixed canopy of spruce, fir and lodgepole. The error with these classes drops notably in fuzzy level 4 and 3. Similar error was found with mixed canopy limber pine. The misclassification with the riparian mixed conifer type seems to be derived from an overestimation of the ecological extent of a riparian corridor. Many riparian polygons were delineated in drainages with a stream and the extent of the riparian influence estimated. There was no visible clue showing how far the riparian influence extended. It now appears that the riparian influence was greatly overestimated. Commission error (high accuracy) is very low at all fuzzy levels.

Lodgepole Pine – High Elevation > 9500 ft
Map Unit – 23

This map unit shows low accuracy at fuzzy level 5 for errors of omission (44%) and reasonable errors for errors of commission (68%). Most of these errors were with like map units such as Lodgepole – Rock (MU 26) and Mixed Lodgepole with Aspen (MU 162) although there are other scattered errors for omission errors. Commission errors occurred almost exclusively with mixed lodgepole – spruce/fir stands. Class accuracy improves in both fuzzy class 4 and 3 for omission error. Accuracy is consistently high for errors of commission. No confusion is noted with MU 24 as these are separated in the model.

Lodgepole Pine – Low Elevation < 9500 ft
Map Unit – 24

Errors in this map unit mimic those in MU 23. Error typically occurs with other like types however, it does occur with many other conifer types. Omission error is fairly high and commission error is fairly low at fuzzy level 5. These both improve at fuzzy levels 4 and 3. However, omission error does not quite meet map standards for errors of omission.

Lodgepole Pine – Rock
Map Unit – 26

This map unit suffers low accuracy for both omission and commission at fuzzy level 5. The omission errors are evenly spread out amongst other conifer types. Commission errors occur mostly with lodgepole pine high elevation (MU 23) and the spruce/fir map unit (MU22). Accuracies improve markedly for fuzzy levels 4 and 3. Accuracies for both omission and commission are in the mid 70% range at fuzzy level 4 and meet map accuracy standards for omission errors at fuzzy level 3.

Cottonwood
Map Unit – 32

The cottonwood map unit suffers from very low occurrence and therefore estimations of map accuracy are suspect. However, these accuracies are low, most of the confusion occurring with riparian Aspen (MU 15).

Juniper
Map Unit – 33

This map unit / association has very high accuracy (81%) for errors of omission and low for errors of commission (43%) at fuzzy level 5. The confusion at this level is generally with other Ponderosa pine types that have a mixed canopy of Ponderosa and Juniper. This is reflected by this map unit achieving map accuracy standards at just fuzzy level 4. At fuzzy level 3 accuracies approach 100%.

Ponderosa pine - Graminoid
Map Unit – 34

This map unit shows very low accuracy at fuzzy level 5 for both errors of omission and commission (33% and 43% respectively). The accuracies both jump to map standard levels at fuzzy level 4 (82% and 90% respectively) and improve slightly at fuzzy level 3 (88% and 97% respectively). Most of the confusion at fuzzy level 5 was with like types such as Ponderosa pine – Rockland (MU 35), Ponderosa pine – Shrub (MU 36), Mixed Ponderosa pine – Aspen (MU 161) and the Douglas-fir type (MU 20) that had a mixed canopy with Ponderosa pine.

Ponderosa pine – Rockland
Map Unit – 35

This map unit shows very low accuracy at fuzzy level 5 for both errors of omission and commission (50% and 32% respectively). The accuracies both jump to map standard levels at fuzzy level 4 (89% and 80% respectively) and improve slightly at fuzzy level 3 (94% for both). Most of the confusion at fuzzy level 5 for errors of omission was with like types such as Ponderosa pine – Shrub (MU 36), Mixed Ponderosa pine – Aspen (MU 161) and the Douglas-fir type (MU 20) that had a mixed canopy with Ponderosa pine. Errors of commission were exclusively with other Ponderosa pine map units (MU 34 and 36) in addition to the Douglas-fir map unit (MU 20).

Ponderosa pine - Shrubland
Map Unit – 36

This map unit shows very low accuracy at fuzzy level 5 for both errors of omission and commission (19% and 54% respectively). The accuracies both jump at fuzzy level 4 to 53% and 100% respectively. Fuzzy level 3 shows a moderate increase in the omission accuracy to 63%. Most of the confusion at fuzzy level 5 for errors of omission was spread amongst most conifer types. In most of these cases, there was a mixed canopy with Ponderosa pine. However, in this case we also see confusion in the undifferentiated shrub class (MU 14). This error is one of density differentiation. That is, the observer on the ground providing the reference data saw shrubland with a few scattered Ponderosas while the interpreter saw a low density Ponderosa stand with shrubs. For this reason we see the accuracy improve dramatically at fuzzy level 4 but still relatively low. Errors continue to occur with other map units such as Douglas-fir (MU 20), Mixed Ponderosa pine – Aspen (MU161) and some lodgepole. Errors of commission were exclusively with other Ponderosa pine map units (MU 34 and 36) in addition to the Douglas-fir map unit (MU 20) at fuzzy level 4 and achieve 100% accuracy at fuzzy level 3.

Map Unit – 38
Subalpine Limber Pine

This map unit shows low accuracy for both errors of omission and commission (55% and 35% respectively) at fuzzy level 5. At this level, errors of omission were spread out with no real marked confusion with another class. The error of commission shows that most confusion occurred with the spruce-fir map unit (MU 22) followed by Douglas-fir (MU 20) and lodgepole (MU's 23 and 24). Most of these confusions were related to mixed canopies. At fuzzy level 4 we see the accuracies jump to 79% and 68% for omission and commission. At fuzzy level three, the accuracies reach 97% and 82% for omission and commission respectively.

Disturbance – dead and down
Map Unit – 41

This map unit has high map standard accuracy at fuzzy level 5 and this does not change as one examines fuzzy levels 4 and 3.

Blue Spruce
Map Unit – 43

At fuzzy level 5 this map unit shows very low accuracy. However, at fuzzy level 5 this jumps considerably to 82% accurate for omission error however commission error still remains low at 41%. Error of omission is reduced further at fuzzy level 3 with a 100% accuracy. Commission error remains poor at 41%. Sample sizes are small for this map unit.

Shrub Riparian – Cross Zone > 9600 ft
Map Unit – 120

This map unit shows low accuracy at fuzzy level 5 with 55% and 54% accuracies for errors of omission and commission respectively. At this level the errors of omission are typically with alpine shrublands (MU 13) and wetlands (MU 6). Errors of commission include alpine shrublands (MU 13), wetlands (MU 6) and alpine wet meadows (MU 7). At fuzzy level 4 the accuracies improve to 76% and 71% for omission and commission respectively. The omission error is primarily with alpine shrublands (MU 13) while commission error is primarily with alpine wet meadows (MU 7). The accuracies improve to 100% and 76% for omission and commission respectively at fuzzy level 3.

Shrub Riparian – Cross Zone < 9600 ft

Map Unit – 121

Accuracies are reasonably high at fuzzy level 5 with 75% and 85% for omission and commission respectively. The confusion for omission error is typically with undifferentiated shrubland (MU 14), mixed Ponderosa pine / Aspen (MU 161) and riparian upper montane mixed conifer. Commission error is scattered with no real trend. At fuzzy level 4 we have 88% accuracy for both errors of omission and commission. This improves to 97% and 94% accurate for omission and commission respectively.

Shrub Upland Lower Montane – Big Sagebrush

Map Unit – 141

Accuracies are reasonably high at fuzzy level 5 with 83% for omission errors. Commission errors are 58%. The confusion for commission error is with the Bitterbrush shrub map unit (MU 142). This is because the bitterbrush is often mixed with big sagebrush (MU 141). A large proportion of this error is with the undifferentiated shrub map unit (MU 14). Many of these errors occur on the eastern portion of the mapping area where there was no vegetation plot collection. In this area we find shrub communities that were not originally described such as *Cercocarpus montanus* shrub types and these were often confused for bitterbrush. Accuracies improve to 96.4% and 82% at fuzzy level 4 for omission and commission respectively. Accuracies continue to improve to 97% and 88% at fuzzy level 3 for omission and commission respectively.

Shrub Upland Lower Montane – Bitterbrush

Map Unit – 142

Accuracies are low for both errors of omission and commission (45% for both) at fuzzy level 5. The omission confusion is primarily with undifferentiated shrublands (MU 14) and big sagebrush (MU 141). Commission confusion is primarily with undifferentiated shrublands (MU 14) but some confusion also exists with herbaceous montane uplands (MU 4) and juniper woodlands (MU 33), both of which may have a shrub component. This is reflected by the increase in accuracy at fuzzy level 4 to 100% and 72% for omission and commission respectively. At fuzzy level three accuracies improve to 76% for errors of commission.

Mixed Conifer with Aspen (Ponderosa pine)

Map Unit – 161

Very low accuracies exist at fuzzy level 5 for this map unit (36% and 19% - omission and commission errors respectively). Omission errors generally occurred with other conifer – aspen map units (MU's 162, 163) but also other map aspen map units (MU's 15 and 18). Commission confusion is primarily with the Ponderosa pine – graminoid map unit (MU 34). The confusion with MU 34 is primarily due to low density aspen in the sampling area within a Ponderosa pine / aspen polygon. This is reflected in fuzzy level 4 as we see accuracies improve dramatically for errors of omission (85%) and 63% for commission errors. Accuracy improves to 100% and 89% at fuzzy level 3 for omission and commission errors respectively.

Mixed Conifer with Aspen (Lodgepole Pine)
Map Unit – 162

Very low accuracies exist at fuzzy level 5 for this map unit (50% and 44% - omission and commission errors respectively). Omission and commission errors are generally found with other conifer – aspen map units (MU's 161, 163,164) that have a considerable amount of mixed canopy. Commission confusion is also found with the spruce – fir map unit (MU 22). At fuzzy level 4 as we see accuracies improve dramatically for errors of omission (76%) and 74% for commission errors. Accuracy improves to 94% and 97% at fuzzy level 3 for omission and commission errors respectively.

Mixed Conifer with Aspen (Douglas-fir)
Map Unit – 163

Very low accuracies exist at fuzzy level 5 for this map unit (33% and 12% - omission and commission errors respectively). Omission and commission errors are generally found with other conifer – aspen map units (MU's 161, 162,164) that have a considerable amount of mixed canopy. Commission confusion is also found with the spruce – fir map unit (MU 22) and the low elevation lodgepole pine map unit (MU 24). This low accuracy reflects the generally poor ability to differentiate Douglas-fir from other conifers. At fuzzy level 4 as we see accuracies improve for errors of omission (70%) and 56% for commission errors. Accuracy improves to 100% and 92% at fuzzy level 3 for omission and commission errors respectively.

Mixed Conifer with Aspen (Spruce - fir)
Map Unit – 164

Very low accuracies exist at fuzzy level 5 for this map unit (37% and 23% - omission and commission errors respectively). Omission and commission errors are generally found with other conifer – aspen map units (MU's 161, 162,163) that have a considerable amount of mixed canopy. Other omission errors are generally scattered with other map units. Commission confusion is also found with the spruce – fir map unit (MU 22), the low elevation lodgepole pine map unit (MU 24) and the Douglas-fir map unit (MU 20). At fuzzy level 4 as we see accuracies improve for errors of omission (86%) and for commission (80%). Accuracy improves to 93% and 90% at fuzzy level 3 for omission and commission errors respectively.

Riparian Upper Montane-Alpine Mixed Conifer > 8500 ft.
Map Unit – 190

Accuracies are low for both errors of omission and commission (60% and 14% for omission and commission respectively) at fuzzy level 5. The omission confusion is spread out amongst several map units showing no particular trend. Commission confusion is occurs hugely with the spruce – fir map unit (MU 22). This error is discussed in more depth under the MU 22 description. Briefly, this error is due to unmet ecological justifications for assuming the occurrence of this class. Accuracies improve moderately at fuzzy level 4 yielding 83% and 46% accuracy for omission and commission errors respectively. At fuzzy level three accuracies improve to 97% and 77% for errors of omission and commission respectively.

Riparian Lower Montane Mixed Conifer < 8500 ft.
Map Unit – 190

Accuracies are low for both errors of omission and commission (40% and 17% for omission and commission respectively) at fuzzy level 5. Most of the error of omission occurs with confusion with the spruce- fir mixed canopy with aspen map unit (MU 164). Commission confusion is occurs with a number of different map units. These include the blue spruce map unit (MU 43), Ponderosa pine – shrubland (MU 36) and the Douglas-fir map unit (MU 20). Accuracies improve markedly for omission error at fuzzy level 4 yielding 89%. Commission error remains marginal at 35% accuracy. At fuzzy level three accuracies improve to 94% and 65% for errors of omission and commission respectively.

Krummholz
Map Unit – 400

The Krummholz map unit shows high accuracy at fuzzy level 5 with 83% and 77% accurate for errors of omission and commission respectively. Most of the omission errors occurred with the alpine shrub map unit (MU 13). Commission errors occurred primarily with the spruce – fir map unit (22). The commission errors were due primarily to interpretations of Krummholz height and the boundary between Krummholz and the spruce – fir forest. Accuracies improve to 87% and 90% for fuzzy level 4 and 92% and 100% for fuzzy level 3.

Comparison of mean accuracies between fuzzy levels: Predictably, overall map accuracy increases as one relaxes requirements for individual map unit membership. Table 15 shows the increasing overall accuracy from fuzzy level 5 to fuzzy level 3.

Comparison of errors between fuzzy levels: As with overall map accuracy, results improve as per class requirements for membership within any particular class are relaxed.

Fuzzy Error Distribution

The distribution of error across the landscape may often provide additional valuable information. Certain zones may be more or less susceptible to error than others. Portions of a vegetation map may be more accurate in some areas than others for any number of different reasons. The error distribution is completely unrelated to individual map unit accuracies. The intent of the error distribution map is to provide additional insight to users. Figure 13 shows the error distribution throughout the mapping area. Areas outside the mapping boundary may be ignored, as these are just calculations that extend to the minimum and maximum x and y for each of the AA points and are based on interpolations from data within the mapping boundary. Low values indicate low accuracy. The values in the legend reflect the fuzzy level designations. The kriging derived distribution map shows that accuracy is high throughout the entire area. There is no concentration of error in any particular area. There is one "hole" in the north central portion of the mapping area in the Mummy Range, west of Fairchild Mountain and east of the Desolation Peaks. These errors are likely various map units being confused for bare rock.

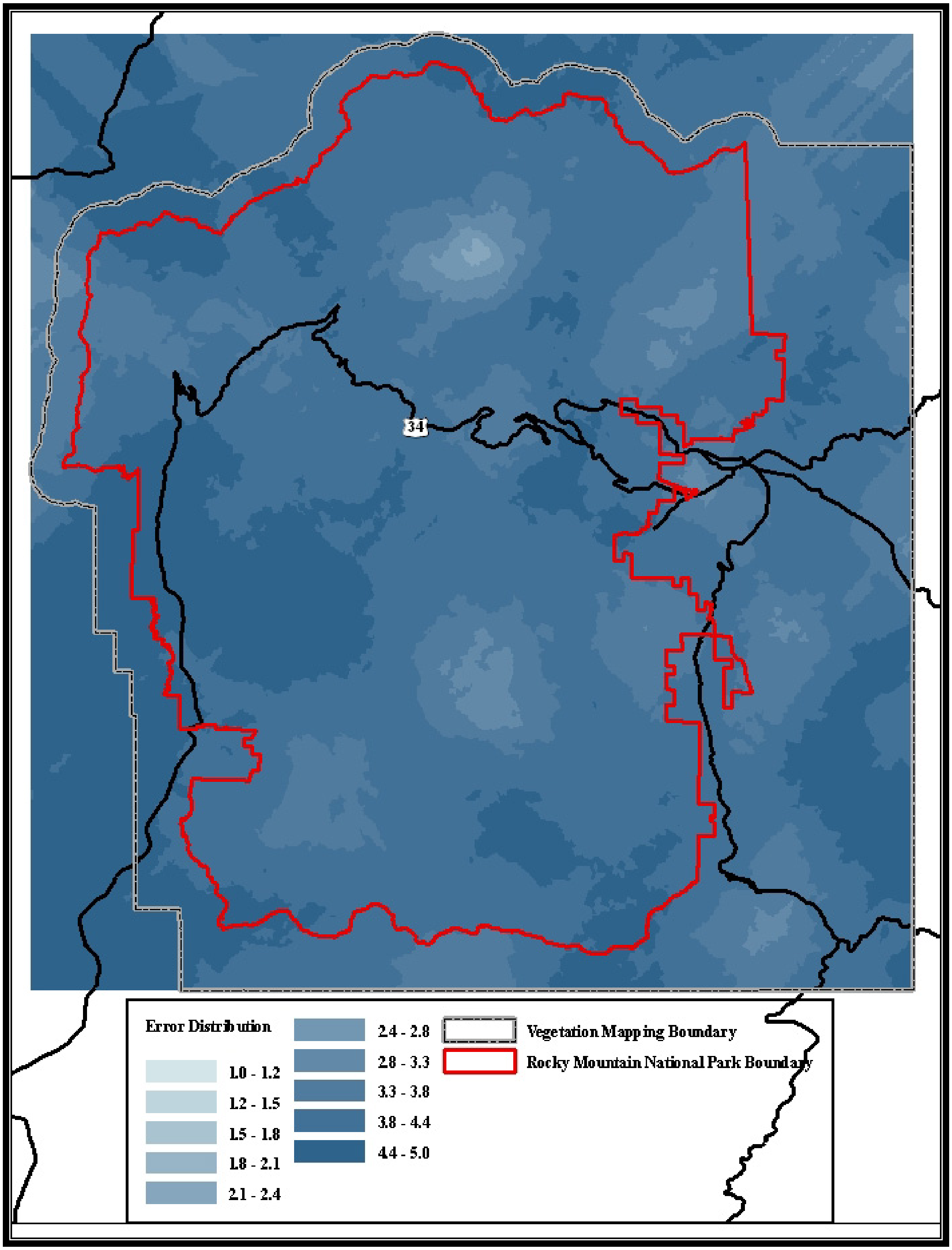


Figure 13. Fuzzy spatial view of accuracy.

Discussion

NVC Classification

As explained above, the vegetation of ROMO vegetation mapping project is very diverse ranging from the foothills to alpine peaks, and although there has been previous local classifications and vegetation research completed in and near the Park e.g., Marr 1977, Komarkova 1979, Willard 1963 [alpine]; Marr 1967, Peet 1981 forest and woodland]; Hess 1981, Hess and Alexander 1986 [USFS Habitat Types]; Carsey et al. 2003, Cooper 1990, Kittel 1994 [wetlands], none were done in this comprehensive and detailed fashion for this large project/planning area. Even with all this previous work, several new NVC alliances and several new associations were described and ranges of several existing types expanded.

Interestingly, there were a relatively high number of NVC associations added to the list of types in ROMO from the AA field work. Reasons for that include: 1) the 2002 vegetation crews focused their effort within the Park boundaries, but the AA was done for the whole project area, which included the 6 mile eastern buffer area. In this lower elevation zone, field crews encountered several foothill associations that likely do not occur within the Park. 2) Additionally, Krummholz and aspen-conifer mixed forests types were not included in the preliminary classification so 2002 field crews did not sample these types. These were later added as map units and consequently, showed up in the AA data. NatureServe and CNHP ecologists did spend time in field during fall 2004 augmenting the classification by targeting sampling of the “new” types in the eastern buffer area and resolving some classification questions. In the future it is recommended to have a second field season after the draft classification from the first field season is completed. That way crews can target sampling of certain types to clarify confusing types, augment under-sampled types and look for un-sampled, but “expected” types. We also recommend that preliminary map units (MU) be developed prior to the first field season and used to help allocate samples to MU not well represented by NVC associations. This will help insure mappers have a minimum number of training site data to begin mapping.

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

The plot data collected during this project was extensive with plots, observation points and AA points combining to total over 1800 new sample sites with vegetation, environmental and fuels data and photos. The data create a new “baseline” from which to evaluate past and future management issues and will be useful for years to come for various planning and resource management activities including fuels and fire management.

In the future, resource management personnel may key habitat for species of concern to association, then locate potential sites by using vegetation map and environmental variables (e.g. North slope Subalpine forest).

Global Rarity

National Parks such as ROMO play an important role in the global effort to conserve biological diversity. It is a goal of ROMO management and planning to protect in perpetuity the natural world with in the Park and to serve as a world leader in wilderness protection, management, and education (ROMO 2005). As an area where management strives to maintain the natural landscape and preserve natural ecological processes, ROMO preserves examples of rare communities and species that outside of Park boundaries are threatened by a wide range of human pressures that diminish biological diversity.

In several ways, the vegetation mapping program contributes to the ability of the Parks to manage their landscapes for conservation of biological diversity. The classification completed for the mapping projects identifies Park vegetation to the association level of the NVC. Associations tracked by the Heritage Program are listed in the classification for the Park. Map units on the completed vegetation map likely to contain the highest priority of these elements can either be specifically surveyed to verify the presence of a rare community type, or these areas can be managed with consideration of the rare type in mind. Also, some occurrences of rare elements have been directly identified from the plot data collected for the classification and the accuracy assessment.

The plot and AA data collected for the vegetation mapping project specifically identified occurrences of some tracked elements within the Park. Plots that are classified to a tracked element have been converted to an element occurrence using a generalized method to assign an element occurrence rank. These interpreted occurrences include both species identified on the plot species lists as well as community elements identified when the plot was classified to a specific plant association.

Several globally and state rare communities and species were located within the ROMO project area. These include 19 different G1G2-G2G3 communities and 3 G2G3 plant species. The rarest community elements identified from the plot data were several G1G2 Ranked associations. These included *Hesperostipa comata* Colorado Front Range Herbaceous Vegetation (G1G2), *Muhlenbergia montana - Hesperostipa comata* Herbaceous Vegetation (G1G2), *Populus tremuloides / Acer glabrum* Forest (G1G2), and *Purshia tridentata / Artemisia frigida / Hesperostipa comata* Shrubland (G1G2). In total, 118 G1G2-G2G3 community element occurrences were identified from the plot data. Table 21 presents all of the Natural Heritage association elements with an element rank of G1G2-G2G3 identified from the ROMO plot data.

The rarest vascular plant species identified from the plot data was the G2 ranked *Delphinium ramosum* var. *alpestre*. Other important vascular plant elements identified in the plot data included *Castilleja puberula* (G2G3) and *Draba crassa* (G3). In total, 37 G2-G3 vascular plant element occurrences were identified from the plot data. Table 21lists the Natural Heritage plant elements identified from the ROMO plot data.

Table 21. Natural Heritage Elements Identified from Plot Data.

ELCODE	SCIENTIFIC NAME	G RANK	S RANK	PLOT CODE
Natural Communities				
CEGL001702	Hesperostipa comata Colorado Front Range Herbaceous Vegetation	G1G2	(blank)	ROMOAA.194
CEGL001647	Muhlenbergia montana - Hesperostipa comata Herbaceous Vegetation	G1G2	(blank)	ROMO.487, ROMO.804, ROMO.808, ROMO.834, ROMO.839, ROMOAA.176, ROMOAA.5783, ROMOAA.5785, ROMOAA.719,
CEGL000563	Populus tremuloides / Acer glabrum Forest	G1G2	(blank)	ROMO.122, ROMO.485, ROMO.708, ROMOAA.1164, ROMOAA.24, ROMOAA.5586, ROMOAA.961,
CEGL001055	Purshia tridentata / Artemisia frigida / Hesperostipa comata Shrubland	G1G2	(blank)	ROMO.8013, ROMOAA.1067, ROMOAA.5168,
CEGL001811	Carex limosa Herbaceous Vegetation	G2	(blank)	ROMO.824
CEGL001092	Cercocarpus montanus / Hesperostipa comata Shrubland	G2	(blank)	ROMOAA.558, ROMOAA.5652, ROMOAA.657
CEGL000745	Juniperus scopulorum / Cercocarpus montanus Woodland	G2	(blank)	ROMOAA.639
CEGL000749	Juniperus scopulorum / Purshia tridentata Woodland	G2	(blank)	ROMO.402, ROMO.623, ROMO.628, ROMO.631, ROMO.828, ROMOAA.326, ROMOAA.328, ROMOAA.520, ROMOAA.5201, ROMOAA.5638, ROMOAA.5640, ROMOAA.5645, ROMOAA.5647, ROMOAA.5651, ROMOAA.930, ROMOAA.936, ROMOAA.973,
CEGL002638	Pinus ponderosa / Alnus incana Woodland	G2	(blank)	ROMOAA.738
CEGL001057	Purshia tridentata / Muhlenbergia montana Shrubland	G2	(blank)	ROMO.040, ROMO.108, ROMO.203, ROMO.515, ROMO.524, ROMO.620, ROMO.625, ROMO.829, ROMO.836, ROMO.840, ROMOAA.1097, ROMOAA.1113, ROMOAA.16, ROMOAA.173, ROMOAA.198, ROMOAA.267, ROMOAA.407, ROMOAA.415, ROMOAA.417, ROMOAA.418, ROMOAA.486, ROMOAA.5119, ROMOAA.5133, ROMOAA.5137, ROMOAA.519, ROMOAA.606, ROMOAA.729, ROMOAA.730, ROMOAA.801, ROMOAA.827, ROMOAA.828, ROMOAA.932
CEGL002910	Rhus trilobata Rocky Mountain Shrub Herbaceous Vegetation	G2	(blank)	ROMO.624
CEGL001124	Ribes cereum / Leymus ambiguus Shrubland	G2	(blank)	ROMOAA.760
CEGL003429	Glyceria grandis Herbaceous	G2?	(blank)	ROMO.637, ROMOAA.79

ELCODE	SCIENTIFIC NAME	G RANK	S RANK	PLOT CODE
	Vegetation			
CEGL000377	Picea engelmannii / Trifolium dasyphyllum Forest	G2?	(blank)	ROMO.199
CEGL000431	Pseudotsuga menziesii / Carex rossii Forest	G2?	(blank)	ROMOAA.349, ROMOAA.5441,
CEGL001794	Danthonia intermedia Herbaceous Vegetation	G2G3	(blank)	ROMO.046, ROMO.070, ROMO.173, ROMO.176, ROMO.278, ROMO.283, ROMO.491, ROMOAA.158, ROMOAA.5835, ROMOAA.5926, ROMOAA.869
CEGL000540	Populus tremuloides - Pinus flexilis Forest	G2G3	(blank)	ROMOAA.301, ROMOAA.994,
CEGL001230	Salix planifolia / Deschampsia caespitosa Shrubland	G2G3	(blank)	ROMO.017, ROMO.031, ROMO.051, ROMO.059, ROMO.162, ROMO.271, ROMO.281, ROMO.286, ROMO.374, ROMO.445, ROMOAA.238, ROMOAA.245, ROMOAA.257, ROMOAA.260, ROMOAA.5033, ROMOAA.5034, ROMOAA.5050, ROMOAA.5057, ROMOAA.5108, ROMOAA.597, ROMOAA.604,
CEGL001432	Salix arctica - Salix nivalis Dwarf-shrubland	G2Q	(blank)	ROMO.015, ROMO.295, ROMO.473, ROMO.603,
Vascular Plants				
PDRAN0B020	Delphinium ramosum var alpestre	G2	S2	ROMO.107, ROMO.108
PDSCR0D2M0	Castilleja puberula	G2G3	SNR	ROMO.238, ROMO.244, ROMO.248, ROMO.250, ROMO.258, ROMO.259, ROMO.384, ROMO.392, ROMO.423, ROMO.424, ROMO.426, ROMO.428, ROMO.429, ROMO.436, ROMO.437, ROMO.439, ROMO.441, ROMO.442, ROMO.443, ROMO.444, ROMO.449, ROMO.452, ROMO.453, ROMO.454, ROMO.455, ROMO.471, ROMO.473, ROMO.475, ROMO.476, ROMO.477, ROMO.492, ROMO.496, ROMO.701
PDBRA110S0	Draba crassa	G3	S3	ROMO.139, ROMO.337

Non-native Species

The vegetation of ROMO includes over 100 species that are considered non-native and that were either intentionally or un-intentionally introduced since before the time the Park was created in 1915 (USDOI 2003). These non-native species may have been planted by early settlers in an attempt to improve pasture forage, or may have arrived in the park accidentally as seed. Non-native species typically occur in and near areas where human development has occurred, in areas that have been recently disturbed, and along roads and trails.

Non-native species have been recognized as a serious threat to Park biodiversity and ecology. Of the 100 non native species known to occur in the Park, 35 have been targeted for control. To assist in the effort to control non-native species in the Park, field crews were instructed to note occurrences of non-native species when observed, and to record their presence when found in a field plot. Although information regarding casual observance of an infestation was typically relayed to Park managers it was not recorded and formally transmitted or filed. Occurrences within plots were documented in the plot data and remain to be evaluated for possible management action.

Aerial Photography and Orthophotos

The acquisition of new orthophotos in addition to the aerial photography was critical to our mapping efforts at ROMO. We found that these not only saved time in the digitizing and transfer stage but also aided tremendously with map verification. The true color orthophotos provided the utility of a map with the functionality of an aerial photo. In other words, we could easily prepare and plot draft maps that contained both our polygon outlines and a true color representation of the vegetation. In the past, we would have had to either plot polygons on less-clear black-and-white orthophotos or use a clumsy combination of non-rectified aerial photos, simple color plots or digital raster graphics of the topographic maps of the area. Furthermore, as a digital product they afforded us the capability of easily reproducing them for multiple users.

We would suggest that future projects strongly consider purchasing new orthophotos in addition to the aerial photography for the following reasons: 1.) Reduces the amount of time needed for digital transfer or digitizing of the line work; 2.) helps minimize shadows and scale distortion in areas with large changes in elevation; 3.) increases the accuracy and thoroughness of the mapping by having recent, true-color basemap imagery; 4.) allows for more useful and easier dissemination of draft products to field crews, mappers, ecologists, etc., and 5.) is a great stand alone product that can be used in many other applications.

Photo-interpretation and Map Units

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

For a highly diverse park such as ROMO we suggest that a completed (or nearly completed) classification be in place before the actual interpretation begins. This is often difficult to do given the constraints of time. Waiting for a complete classification of the vegetation before proceeding with the mapping may add a year or more to the entire process. The benefits include avoiding a revisit or, in the worst case, redoing the interpretation based on classification changes. Ideally, plot sampling should begin early in the project, followed by analysis of the vegetation data to the NVC before the ground-truthing and interpretation of the aerial photographs. With this mapping effort a map unit meeting was held early in the project to try and determine appropriate map units. This was done using only “expected” associations and the input of Park staff and other ecologists. In addition, the lack of sampling to the east of the Park boundary resulted in a reduced vision of the associations that existed there in addition to a lack of photointerpretive training sites. Another problem discerned late in the project was the amount of mixing of conifer types. We included no mixed conifer map units other than the Subalpine Spruce – Fir map unit. Lodgepole mixed quite extensively with all conifer types at high and low elevations. A mixed lodgepole map unit would have been helpful.

Map Accuracy

General Considerations

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

The term ground truth can be misleading as even classification of a location on the ground is subject to interpretation (Foody 2001, Bird et al., 2002. The determination of vegetation association using keys usually has some room for interpretation of vegetative characteristics and even presence of species. The original vegetation classification may have been developed from samples collected during significantly different climatic periods (e.g. wet year vs. dry year) or even seasonal variation (e.g., spring sampling vs. fall sampling). A temporal change in the landscape between photo acquisition / interpretation and field sampling for accuracy assessment is also common (Fire, landslides, avalanches etc.) Vegetation association descriptions also depend heavily on estimations of cover that, in spite of extensive training prior to sampling, may be different enough to produce erroneous site classifications. For example, some AA plots were classified to the Spruce - Fir map unit based upon the cover value for spruce and fir. However, upon examination of the field form we find that the cover type was actually co-dominant with limber pine. If the map unit name assigned to the AA point was taken at face value more than a few interpreted limber pine polygons would have been wrong. This occurred on more than one occasion and emphasizes the need for a fuzzy approach to map accuracy.

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

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

Mis-registration of AA field samples and the actual location to be sampled can cause tremendous problems and invalidate an entire project. At ROMO, we encountered a few points that were miss-registered due to transcription errors. One of the more common problems encountered was the location of plots within extremely small polygons. Many polygons were well below the minimum mapping unit for the project. Small polygons do provide for a higher map precision however, the sampling of these can be very problematic. With very small polygons not only is the location a problem, especially in a forested site, but the edge effect leads to considerable confusion in classifying the area properly. Adjustments for this issue were addressed during assessment of the fuzzy accuracy field data.

Given the detail of the map and the variability of the vegetation, we believe the accuracy assessment for ROMO was successful due to several factors. First we made sure that the overall sampling design followed closely the protocols described for by the National Park Mapping Program. We did make some allowances for practicality and statistical necessities. Boundaries between polygons were minimally avoided but not so much so that only large homogenous areas were sampled. The distribution of the sample points was excellent and most map units received an adequate number of points per type to draw general conclusions at each fuzzy level. In addition the spatial distribution of the AA sample points across the Park was very good and the field crews made every effort to reach many difficult sites. Finally the predicted accuracy at almost all un-sampled sites was high (Figure 13) and this tends to verify our assumption that no mapped area has a disproportionate amount of error.

The overall magnitude of error for this project can be discerned by an examination of the contingency tables. Typically, one will find errors between similar map units. Occasionally one will find errors between such disparate groups such as conifer map units and shrub map units. At face value, this may be a gross error however; a closer look at the image and sample points often clarifies the problem. For example, errors were often recorded when a crew sampled a low density conifer type that may have been classified as either a shrub type with a scattering of conifers or a low density conifer plot with a shrub understory. When the AA crew reports their plot as a low-density conifer and the PI shows a shrub community, the reporting of this type of error is maintained as wrong at fuzzy level 5 but is accepted as correct at fuzzy level 4. This problem is typically one of perspective and is inherent in combining ground information from remotely sensed information.

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

1. Lines are sometimes dropped between adjacent polygons and they may appear closed and separate but in reality are not.
2. The polygon coding may have been incorrectly transcribed from the photo into the digital database.
3. The polygon lines may have been mis-registered to the base map. In other words, the transfer process from lines drawn on mylar to a digital format requires a transformation from a non-rectified raster to a geo-rectified raster, followed by vectorization. The transformation process may introduce some mis-registration into the digital product. This problem is particularly noticeable with very small polygons or in areas with extreme relief.

The Accuracy Standard for the NBS/NPS Vegetation Mapping Program

The program standards for accuracy are 80% for both overall accuracy and individual class accuracy. The program recognizes that these levels of accuracy may be difficult to achieve. Indeed, the Program Accuracy Assessment Procedures states that ***"Given that vegetation mapping is necessarily interpretive, it is recommended that relaxed requirements be used in terms of acceptable levels of error as well as confidence levels in the estimate. Otherwise, regardless how carefully the mapping process is carried out, it is unlikely that accuracy requirements will be met".*** With the advent of fuzzy accuracy procedures we now have the capability to express the accuracy of a thematic map in several ways - very stringent to relaxed. The choice of which standard to use would depend on the subject being mapped. In the case of vegetation mapping, the preferred rigor would be relaxed vs. stringent.

When the vegetation mapping program began, the use of fuzzy accuracy was recognized but considered experimental with little use or publication. At this point, eleven years after the publication of the Accuracy Assessment Procedures, much theory has been published but is remiss in applications. Even in the vegetation mapping program these techniques have not been used to any great extent. In addition to this project we know of three others that have used fuzzy accuracy assessment (Hansen et al 2004, a, b, c) and informally at Zion National Park (Cogan – pers comm.). The overall fuzzy accuracies of these parks are presented in Table 22 for comparative purposes. The trends across this small set are similar. Given the suggestions from the program standards and the results of four fuzzy accuracy assessments within the vegetation mapping program we recommend that the standard for stated and recognized accuracy be fuzzy level 3. The definition for fuzzy level 3 as proposed by Gopal and Woodcock (1994) is "Reasonable or Acceptable Answer: Maybe not the best possible answer but it is acceptable; this answer does not pose a problem to the user if it is seen on the map. Correct" therefore it would seem reasonable to accept this level as a program standard.

Table 22. Comparative fuzzy accuracies for four national parks.

	Fuzzy 5	**Fuzzy 4**	**Fuzzy 3**
Rocky Mountain National Park	50.3%	74.7%	86.7%
Walnut Canyon National Monument	50.0%	69.2%	96.9%
Sunset Crater Volcano National Monument	53.9%	70.3%	86.8%
Wupatki National Monument	59.1%	69.7%	92.2%
Mean	**53.3%**	**71.0%**	**90.7%**

Recommendations

Field Survey

Vegetation mapping is only as good as the fieldwork that backs it up. Since field crews are such an important component of the project we found that making sure that they were well supported, well trained, and motivated was instrumental to the success of the project. The following are some recommendations for ensuring that field crews collect the best data possible.

- Start hiring early. By the end of March most good field botanists have already accepted a job. We started advertising for the positions in early December, and tried to complete the hiring by the end of February.
- Hire crew members for both botanical and outdoor skills. At ROMO crews had to backpack for many days at a time. If they aren't up for this, they have difficulty collecting good data. Make sure your crew members are committed for the whole field season.
- Hire an even number of people and have them work in crews of two. A crew of two is typically more efficient than two solo crews. This is also better from a safety standpoint since no one has to work alone.
- Keep crew members for multiple seasons. This reduces training time and adds consistency to methods over the whole project.
- Support your crews with adequate housing, equipment, and supplies. Many of the crew members come from other areas of the country and often don't yet have a stable living situation. It's hard for the crew's to keep their morale up if they have nowhere to leave their possessions, no where to shower, and nowhere to call home. Housing needs to be available to them for the duration of the summer.
- Provide vehicles to the crews. Often the personal vehicles the crew members own are older and less reliable than is a newer government vehicle or a new rental vehicle. Very few ecologists established in permanent positions would consider using their own vehicle on a daily basis for field work. There is no reason to expect others to do differently.
- Provide the crews with the tools they need to do good work. Measuring tapes, plot markers, GPS units, cameras, dissecting scopes, field guides, and all incidental supplies (batteries, pens, forms, files, folders) are all necessary and reasonable project costs.
- Pay crews per diem for all field days.
- Provide the crews with adequate training and orientation. Spend the first week or two with them in the field to ensure that all the field methods are understood and being followed.
- Meet regularly with your crews and make sure that they have everything that they need and are

following the methodology. Encourage the crews to document anything they encounter or are unsure of by taking extensive notes. These are very valuable in December when you are trying to interpret what they were seeing.

Vegetation Map

The amount of mixed vegetation types at ROMO complicated the interpretation. Lodgepole pine mixed freely at all elevations with all other conifer types. During the initial map unit designation meeting this issue did not come up and therefore was not included as a map unit. Had this been anticipated many mixed type polygons could probably been interpreted with some success.

Field sampling was restricted to those areas within the Park. The result of this was poor characterization of the vegetation in the large buffer area to the east of the Park. For example, there are several more shrub types in the lower elevations that were not described at all, during the first sampling effort. In addition, no sample points to the east of the Park also hurt the photointerpretive effort for lack of training sites. This was ameliorated somewhat by extensive visits to this area.

Map Units

ROMO map units contain varying levels of detail. If more data becomes available about the distribution of certain associations then additional modeling should be attempted in the future. However, modeling associations and the map units that encompass them should be done with caution unless the results are verified by an associated accuracy assessment. General trends in vegetation (map unit) distribution may be expected but not hold up to rigorous testing. For example, we attempted to model map unit 22 – Spruce-Fir, with the assumption that north and south facing slopes should have distinct groups of associations. Therefore, this map unit was divided along ridgelines during the photointerpretation and assigned separate map units with the assumption that the accuracy assessment would validate our mental model. This mental model failed after examination of the accuracy assessment results. The north and south facing Spruce-Fir polygons were then reassigned back to one map unit. Typically, one would then dissolve the lines between adjacent north and south facing Spruce-Fir polygons to produce one polygon representing the one map unit. In this case we maintained the separation of these polygons for two reasons. One is that the mental model is reasonable and that perhaps we just did not have enough information to properly model north and south facing Spruce-Fir map units. The other reason is that maintaining the separation of polygons along the ridgelines may be useful for fire modeling.

Accuracy

There are a number of areas that would benefit from revised protocol. Improvements in sampling and the data evaluation for fuzzy accuracy are two areas that need the most work. The sample selection process allowed a number of unanticipated problems to creep in. Because of the excellent imagery, many polygons went well below the minimum mapping unit size.

The proportion of very small polygons increased which then gave them a disproportionate amount of weight during the sampling process. As discussed before, sampling these small polygons is problematic not only for locating and selecting the site properly but also for edge effect of the surrounding vegetation. Large, more homogenous polygons should have received a greater proportion of the sample points. This effectively provides an overly conservative estimation of overall and individual map unit accuracy.

The review process of each plot in order to provide a fuzzy designation was very time consuming and unanticipated. Each plot had to be looked at and discussed amongst three people. This took a tremendous amount of time. Some ideas on speeding this up include assigning an additional secondary or alternate association to the point. This secondary association, once assigned to its map unit could then automatically receive a fuzzy designation of four. This would be similar to those AA points that exactly matched the polygon designation receiving a fuzzy designation of five. This would greatly reduce the number of plots that had to be reviewed. Similar problems were encountered when Zion National Park went through the same process (Cogan pers. com.). The fuzzy review was necessarily subjective however it is conceivable that a numeric application can be devised that analyzes the dataset and assign fuzzy levels based upon such items as cover, density, wetland indication (FACW, FAC, OBL etc) or other factor.

Map Improvement Suggestions:

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

2. In addition to formal ground truthing we would also like to see more verification done by piggybacking it onto other projects. As opportunities arise, maps should be sent into the field not only to be used but so they can be checked by competent crews. We encourage ROMO and all researchers to continuely ground truth the map as they use it.
3. All new vegetation data including GPS data and other GIS layers should be wisely incorporated into this map. This may involve such things as using new research that more accurately models certain vegetation types or updating the

current vegetation after a fire. Current advances in GIS and GPS technology easily allows for updates to the digital map and allows previous copies to be tracked and archived. Having an archive would allow for temporal analyses such as examining change over time and tracking the effects of climate change. Overall, we feel strongly that this product should not be static but change with new and better information.

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

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